HIGHWAY DESIGN DIVISION

OPERATIONS AND PROCEDURES MANUAL

PART IV

&

APPENDIXES A - H

1976 EDITION

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION

PART IV

DESIGN

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PART IV - DESIGN

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PART IV-DESIGN
GENERAL (4-100)

4-101 APPLICATION OF DESIGN STANDARDS

(a) Minimum Standards

The Standards contained herein generally represent minimum values and should be considered by the Engineer as the lowest acceptable limits in design. It is expected that designs will embody the highest values possible, commensurate with conditions, and that minimum values will be utilized only in those cases where inordinately high costs would otherwise result.

(b) Departures from Standards

These design policies and standards are intended to serve as a basic Departmental guide in design work; however, they are not to be considered as inflexible. They are not intended as a substitute for engineering knowledge, experience or judgment. When it is deemed necessary or desirable to deviate from these design policies and standards, approval will be secured from proper Departmental authorities.

(c) Policy on Use of AASHTO Standards.

The American Association of State Highway and Transportation Officials (AASHTO) has established various standards, policies, guides, etc., relating to highway practice. These are approved references to be used in conjunction with this manual; however, since AASHTO policies and guidelines represent nationwide standards which do not always satisfy Texas conditions, the instructions in this manual shall take precedence over AASHTO standards.

4-102 PREPARATION AND SUBMISSION OF GEOMETRIC LAYOUTS

Prior to initiating detailed plan preparation for a proposed project, a preliminary plan should be prepared which indicates the general geometric features and location requirements peculiar to the project. Five (5) copies of geometric layouts should be submitted to File D-8 for approval and subsequent coordination with the Federal Highway Administration where applicable. Layouts should be submitted for two-lane highway projects on new location and for all multi-lane highway projects.

The geometric layout should include basic information which is necessary for the proper review and evaluation of the proposed improvement such as the following:

(1) The location of interchanges, main lanes, grade separations, frontage roads and ramps.

(2) Main lane, ramp, frontage road, and necessary cross road profiles at proposed interchanges or grade separations.

(3) A complete explanation of the sequence and methods of stage construction, if proposed, which would include the initial and ultimate proposed treatment of crossovers and ramps.

(4) The tentative right-of-way limits.

(5) The geometrics of the typical sections of proposed highway (roadway, ramps and structures).

(6) The projected traffic volumes.

(7) The control of access lines if Interstate or designated under H.B. 179.

(8) Direction of traffic flow on all roadways.

(9) Location of median openings for highways without access control.

(10) The location of speed change lanes.

For projects involving freeway-to-freeway or other types of directional interchanges, and projects including left hand ramps or connections, an additional schematic showing signing should be submitted directly to D-18T in accordance with Chapter 2, Section 2 of the D-18T Procedures Manual.

Upon approval of the geometric layout by File D-8 (Federal Highway Administration on Federal-aid projects), it should be the basis for an exhibit at any required public hearing prior to final development of the project. If there are any changes to the schematic after File D-8 and FHWA approval and before the public hearing, five copies of the revised schematic, as displayed at the hearing, should be submitted either prior to or accompanying the public hearing data. If there are no changes in the schematic as displayed at the hearing, only photographs of the schematic and other displays should be submitted with the public hearing data.

4-103 PAVEMENT DESIGN

Prior to initiating detailed plan preparation for a project a preliminary investigation should be made to determine the approximate section and pavement type to be used for the pavement structure. The Flexible Pavement Designer's Manual for flexible pavement and Appendix F for rigid pavement may be used for this purpose. If FHWA approval of the pavement structure is required, a typical section of the proposed design together with documentation of the design should be furnished to the Highway Design Division prior to detailed preparation of the P.S. & E. The Roadway Design Section is available for consultation and assistance for pavement design problems.

PART IV-DESIGN
BASIC DESIGN CRITERIA (4-200)

4-201 TRAFFIC VOLUME

(a) General

The volume of traffic is an important basics for determining what improvements, if any, are required on a highway or street facility. Traffic volumes may be expressed in terms of average daily traffic or design hourly volumes.

(b) Average Daily Traffic (ADT)

Average daily traffic, commonly abbreviated ADT, represents the total traffic for a year divided by 365, or the average traffic volume per day. Due to seasonal, weekly, daily, or hourly variations, ADT is generally undesirable as a basis for design, particularly for high volume facilities. ADT should only be used as a design basis for low and moderate volume facilities, where additional lanes unquestionably are not justified.

(c) Design Hourly Volumes (DHV)

The design hourly volume (abbreviated DHV) is the thirtieth highest hourly volume for the design year, commonly twenty years from the time of construction. DHV is the traffic parameter most commonly used in level of service evaluations and for geometric design. In particular situations involving high seasonal fluctuations in ADT, some adjustment of DHV may be appropriate. DHV is determined by application of conversion factors to ADT as discussed in Paragraph 4-201 (e).

(d) Factors Affecting Design Hourly Volume Determination

Traffic composition, directional distribution, and the percent of ADT occurring in the design hour are factors considered in converting ADT to DHV.

1. The percent of ADT occurring in the design hour is commonly referred to as the "K" factor, or sometimes called the DHV factor. "K" factor is the percentage of ADT representing the thirtieth highest hourly volume in the design year. For typical main rural highways, "K" factors generally range from twelve to eighteen percent. For urban facilities, "K" factors are typically somewhat lower, ranging from eight to twelve percent.

2. The percentage of the design hourly volume that is in the predominant direction of travel is known as the directional distribution factor, or "D". As a general rule, traffic tends to be more equally divided by direction near the center of an urban area or on loop facilities. For other facilities, "D" factors of sixty to seventy percent frequently occur.

3. Composition of traffic is normally expressed as the percentage of trucks during the design hour and is referred to by the letter "T". For geometric design and capacity studies, the truck traffic is usually converted to passenger cars through application of

equivalency factors. Truck traffic volume is equivalent to a larger volume of passenger cars since trucks occupy a greater road space, travel at lower speeds, and exhibit restricted operating characteristics. For design purposes, light delivery trucks, such as panels and pickups, operate similarly to passenger cars and are included as such. Combination truck-trailers, buses, and single unit trucks with dual rear tires are included in "T".

(e) Conversion of ADT to DHV

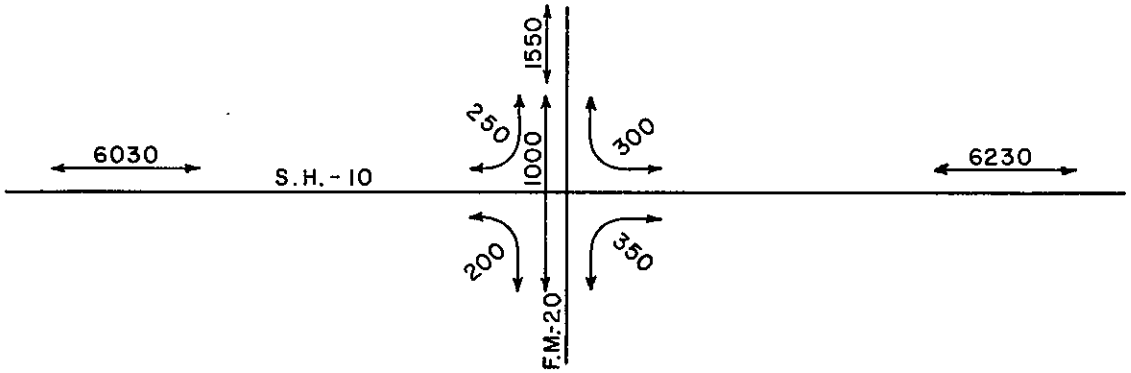
Projected traffic volumes are provided by the Transportation Planning Division, File D-10, upon request and serve as a basis for design of proposed improvements. For high volume facilities, a tabulation showing traffic converted to DHV will be provided by D-10 if specifically requested. Generally, however, projected traffic volume is expressed as ADT, with K, D, and T factors provided. The user then must convert ADT to DHV.

The first step in converting ADT to DHV is selecting an appropriate truck equivalency factor, E_t. For approximate analysis of operations on a given highway section it is usually sufficient to apply an overall approximate E_t as selected from Figure 4-1 to the entire section. In more refined spot analysis, however, truck operations on each of the more significant grades should receive individual attention. Appropriate truck equivalencies for spot analysis are shown in Figure 4-1A and 4-1B.

The value of E_t depends on the type of highway facility and its grades. In level terrain where trucks can maintain speeds that are equal to or approach the speed of passenger cars, trucks are equivalent, in a capacity sense, to two passenger cars on multilane highways and two to three passenger cars on two-lane highways. For rolling or mountainous terrain, however, E_t increases as shown in Figure 4-1. Particular care should be exercised in selecting an appropriate E_t for urban freeways on level terrain, since design mainlane profile may, in effect, induce rolling terrain characteristics.

Once an E_t has been selected, the ADT to DHV conversion may be accomplished through application of E_t and the factors furnished by File D-10 (K, D, T). ADT may be furnished as directional (one-way) or non-directional (two-way), and the conversion procedures for these two cases are as follows:

Case I: Non-directional ADT given as shown on sketch, K = 14%, D = 60%, and T = 10%. A multilane highway is being considered on level terrain, hence select E_t = 2 from Figure 4-1.



TWO-LANE HIGHWAYS
PASSENGER CAR EQUIVALENTS FOR TRUCKS
(INCLUDING UPGRADES, DOWNGRADES, AND LEVEL SUBSECTIONS)

	LEVEL OF SERVICE	EQUIVALENT, FOR:		
		LEVEL TERRAIN	ROLLING TERRAIN	MOUNTAINOUS TERRAIN
E_T For Trucks	A	3	4	7
	B and C	2.5	5	10
	D and E	2	5	12

FREEWAYS AND MULTILANE HIGHWAYS
PASSENGER CAR EQUIVALENTS FOR TRUCKS
(INCLUDING UPGRADES, DOWNGRADES, AND LEVEL SUBSECTIONS)

LEVEL OF SERVICE	EQUIVALENT, E, FOR:		
	LEVEL TERRAIN	ROLLING TERRAIN	MOUNTAINOUS TERRAIN
A	Widely variable; one or more trucks have same total effect, causing other traffic to shift to other lanes, use equivalent for remaining levels in problems.		
B Through E E_T For Trucks	2	4	8

FIG. 4-1 Refers to Paragraph 4-20(e)

PASSENGER CAR EQUIVALENTS OF TRUCKS ON TWO-LANE HIGHWAYS, ON SPECIFIC INDIVIDUAL SUBSECTIONS OR GRADES

GRADE (%)	LENGTH OF GRADE (MI)	PASSENGER CAR EQUIVALENT, E_T (FOR ALL PERCENTAGES OF TRUCKS)		
		LEVEL OF SERVICE A AND B	LEVEL OF SERVICE C	LEVELS OF SERVICE D AND E (CAPACITY)
0-2	All	2	2	2
3	1/4	5	3	2
	1/2	10	10	7
	3/4	14	16	14
	1	17	21	20
	1 1/2	19	25	26
	2	21	27	29
	3	22	29	31
	4	23	31	32
4	1/4	7	6	3
	1/2	16	20	20
	3/4	22	30	32
	1	26	35	39
	1 1/2	28	39	44
	2	30	42	47
	3	31	44	50
	4	32	46	52
5	1/4	10	10	7
	1/2	24	33	37
	3/4	29	42	47
	1	33	47	54
	1 1/2	35	51	59
	2	37	54	63
	3	39	56	66
	4	40	57	68
6	1/4	14	17	16
	1/2	33	47	54
	3/4	39	56	65
	1	41	59	70
	1 1/2	44	62	75
	2	46	65	80
	3	48	68	84
	4	50	71	87
7	1/4	24	32	35
	1/2	44	63	75
	3/4	50	71	84
	1	53	74	90
	1 1/2	56	79	95
	2	58	82	100
	3	60	85	104
	4	62	87	108

FIG. 4-1A Refers to Paragraph 4-201 (e)

PASSENGER CAR EQUIVALENTS OF TRUCKS ON ORDINARY MULTI-LANE HIGHWAYS, FREEWAYS AND EXPRESSWAYS ON SPECIFIC INDIVIDUAL SUBSECTIONS OR GRADES

Grade (%)	Length of Grade (Mi)	Passenger Car Equivalent, E_T									
		Levels of Service A through C for:					Levels of Service D and E (Capacity) for:				
		3% Trucks	5% Trucks	10% Trucks	15% Trucks	20% Trucks	3% Trucks	5% Trucks	10% Trucks	15% Trucks	20% Trucks
0-1	All	2	2	2	2	2	2	2	2	2	2
2	1/4-1/2	5	4	4	3	3	5	4	4	3	3
	3/4-1	7	5	5	4	4	7	5	5	4	4
	1 1/2-2	7	6	6	6	6	7	6	6	6	6
	3-4	7	7	8	8	8	7	7	8	8	8
3	1/4	10	8	5	4	3	10	8	5	4	3
	1/2	10	8	5	4	4	10	8	5	4	4
	3/4	10	8	6	5	5	10	8	5	4	5
	1	10	8	6	5	6	10	8	6	5	6
	1 1/2	10	9	7	7	7	10	9	7	7	7
	2	10	9	8	8	8	10	9	8	8	8
	3	10	10	10	10	10	10	10	10	10	10
	4	10	10	11	11	11	10	10	11	11	11
4	1/4	12	9	5	4	3	13	9	5	4	3
	1/2	12	9	5	5	5	13	9	5	5	5
	3/4	12	9	7	7	7	13	9	7	7	7
	1	12	10	8	8	8	13	10	8	8	8
	1 1/2	12	11	10	10	10	13	11	10	10	10
	2	12	11	11	11	11	13	12	11	11	11
	3	12	12	13	13	13	13	13	14	14	14
	4	12	13	15	15	14	13	14	16	16	15
5	1/4	13	10	6	4	3	14	10	6	4	3
	1/2	13	11	7	7	7	14	11	7	7	7
	3/4	13	11	9	8	8	14	11	9	8	8
	1	13	12	10	10	10	14	13	10	10	10
	1 1/2	13	13	12	12	12	14	14	13	13	13
	2	13	14	14	14	14	14	15	15	15	15
	3	13	15	16	16	15	14	17	17	17	17
	4	15	17	19	19	17	16	19	22	21	19
6	1/4	14	10	6	4	3	15	10	6	4	3
	1/2	14	11	8	8	8	15	11	8	8	8
	3/4	14	12	10	10	10	15	12	10	10	10
	1	14	13	12	12	11	15	14	13	13	11
	1 1/2	14	14	14	14	13	15	16	15	15	14
	2	14	15	16	16	15	15	18	18	18	16
	3	14	16	18	18	17	15	20	20	20	19
	4	19	19	20	20	20	20	23	23	23	23

FIG. 4-IB Refers to Paragraph 4-201 (e)

The conversion formula for non-directional ADT to DHV is as follows:

$$DHV = (ADT)\ (K)\ (D)\ (1 + T\ (E_t - 1))$$

Therefore, for the example problem

$$DHV = (ADT)\ (0.14)\ (0.60)\ (1 + 0.10\ (2-1))$$

$$= (ADT)\ (0.14)\ (0.60)\ (1.1)$$

$$DHV = (ADT)\ (0.092)$$

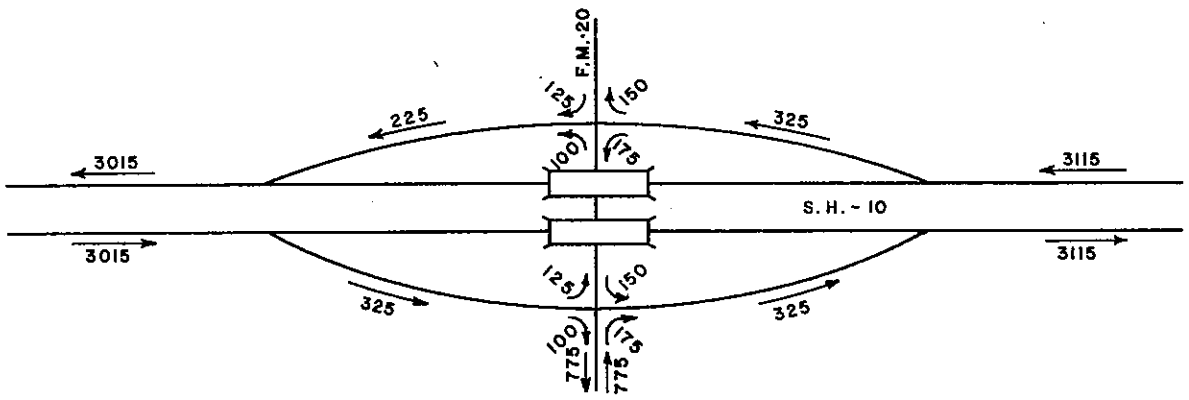
The value 0.092 becomes the computed conversion factor, accounting for the combined effects of trucks, directional flow, and rush hour peaking. This factor may be multiplied by the given non-directional ADT, either turning or non-turning, to determine DHV in passenger cars per hour in the predominant direction of flow.

Therefore, for a non-directional ADT = 6030 vehicles per day,

$$DHV = (6030)\ (0.092)$$

DHV = 557 passenger cars per hour in the predominant direction (i.e., one way).

Case II: Directional ADT given as shown on the sketch, K = 14%, D = 60%, T = 10%, and an E_t



of 2 has been selected. The conversion formula for directional ADT to DHV is as follows:

$$DHV = 2\ (ADT)\ (K)\ (D)\ (1 + T(E_t - 1))$$

Therefore, for the example problem,

$$DHV = 2\ (ADT)\ (0.14)\ (0.60)\ (1 + 0.10(2-1)$$

$$= 2\ (ADT)\ (0.14)\ (0.60)\ (1.1)$$

$$= 2\ (ADT)\ (0.092)$$

$$DHV = (ADT)\ (0.184)$$

The value of 0.184 becomes the computed conversion factor, accounting for the combined effects of trucks, directional flow and peaking. Application of this factor to directional ADT values, either turning or non-turning, yields DHV in passenger cars per hour. Therefore, for a directional ADT of 3015 vehicles per day,

$$DHV = 3015\ (0.184)$$

$$DHV = 557 \text{ pcph.}$$

Traffic volumes are usually converted from ADT to DHV for an entire length of a proposed project. In DHV form, traffic volumes are readily usable for geometric design of intersections, for determining the type of facility which is appropriate and the number of lanes warranted, ramp merge-diverge analysis, and weaving analysis.

(f) Traffic Volumes As A Design Control

The term "capacity" pertains to the maximum number of vehicles reasonably expected to pass over a given section of lane or roadway during a given time period under prevailing roadway and traffic conditions. A knowledge of highway capacity is essential to the proper fitting of a planned highway to the requirements of traffic, both in the selection of highway type and in determining dimensional needs such as number of lanes and minimum lengths for weaving sections. Appendix D, entitled Capacity and Level of Service, contains sufficient detail for use in most traffic analysis. Additional information may be found in the *Highway Capacity* Manual, Highway Research Board, Special Report 87, dated 1965.

(g) Traffic Speed

Traffic speed is influenced by volume, capacity, design, weather, traffic control devices including legal limits and, of course, by individual driver preference. In the wake of national energy shortages, maximum legal speeds have been reduced to 55 mph, interrupting a long term annual increase in average speed on rural highways for all vehicle types. Due to the uncertainties involved regarding future energy supplies, the permanence of the nationwide 55 mph speed limit cannot be predicted.

(h) Design Speed

Design speed is the maximum safe speed that can be maintained over a specified section of highway when the design features of the highway govern. All facilities should be designed with all elements in balance, consistent with an appropriate design speed. Design elements such as sight distance, vertical and horizontal alignment, lane and shoulder widths, roadside clearances, superelevation, etc., are influenced by design speed. It is therefore important that an appropriate design speed be selected.

Selection of design speed is influenced primarily by the character of terrain, economic considerations, extent of roadside development (i.e., urban or rural), and highway type. For example, the design speed chosen would usually be somewhat less for rough terrain, or for an urban facility with frequent points of access, as opposed to a rural highway on level terrain. Choice should be influenced by the expectations of drivers, which, in turn, are closely related to traffic volume conditions, potential traffic conflicts, and topographic features.

Appropriate design speed values for the various highway classes are presented in subsequent Sections.

4-202 DESIGN ELEMENTS

(a) General

Common to all types of highways and streets are several principal elements of design, such as sight distance, alignment, and pavement and shoulder cross slope.

(b) Sight Distance

Of utmost importance in highway design is the arrangement of geometric elements so that there is adequate sight distance for safe and efficient traffic operation assuming adequate light, clear atmospheric conditions, and drivers' visual acuity. For design, two types of sight distance are considered: that for overtaking vehicles, and that required for stopping. Passing sight distance is applicable only in the design of two lane rural highways and therefore is presented in Section 4-502(d).

(c) Stopping Sight Distance

Minimum stopping sight distance is length of roadway required to enable a vehicle traveling at or near design speed to safely stop before reaching an object in its path. Based on drivers' eye height of 3.75 feet and 0.5 feet height of object criteria, minimum and desirable stopping sight distance values for various design speeds are tabulated in Figure 4-1C. These values are also recommended by AASHTO.

STOPPING SIGHT DISTANCE VALUES

DESIGN SPEED (mph)	STOPPING SIGHT DISTANCE (ft.)	
	Minimum	Desirable
30	200	200
40	275	300
50	350	450
60	475	650
70	600	850
80	750	1050

Figure 4-1C Refers to Paragraph 4-202(c)

After selection of design speed, stopping sight distance values become a controlling element for several basic design features such as roadway alignment and non-signalized intersection design.

(d) Horizontal Alignment

1. Maximum curvature.

Maximum degree of curve, or minimum radius, is an important control value in designing for safe operation. Standards for curvature are shown in Figure 4-2.

Usual maximum values or flatter curves should be used for design, with absolute maximum values used only in exceptional cases where cost of providing a higher standard is inconsistent with benefits.

2. Superelevation

As a vehicle traverses a horizontal curve, centrifugal force is counter-balanced by the vehicle weight component due to roadway superelevation and by the side friction between tires and surfacing as shown in the following equation:

$$e + f = V^2/15R$$

Where e = rate of superelevation, foot per foot

f = side friction factor

V = vehicle speed, mph

R = radius of curve, feet.

There are practical limits to the rate of superelevation since high rates create steering problems for drivers traveling at lower speeds, particularly during ice or snow conditions. Additionally, on urban facilities lower maximum superelevation rates may be employed than on rural highways since adjacent buildings, lower design speeds, and frequent intersections are limiting factors. Maximum superelevation rates of 0.04 to 0.06 foot per foot are commonly used on urban streets without full access control. For urban freeways and all types of rural highways, rates of 0.06 to 0.08 are generally used, and rates of 0.10 and 0.12 may be used for those instances where snow and ice are not factors.

STANDARDS FOR CURVATURE WITH SUPERELEVATION

Design Speed (mph)	Usual Max. Degree of Curve[1]	Absolute Max. Degree of Curve[2]
30	12°00'	19°00'
40	8°00'	10°00'
50	5°00'	6°00'
60	3°00'	4°00'
70	2°00'	3°00'
80	1°00'	2°00'

1. Generally used as design maximum.
2. Used in exceptional cases when cost of providing the usual maximum degree of curve or flatter is inconsistent with benefits; based on max. e = 0.04 for design speeds of 30 and 40 mph and max. e = 0.06 for design speeds of 50, 60, 70 and 80 mph.

STANDARDS FOR CURVATURE OF HIGH SPEED HIGHWAYS WITHOUT SUPERELEVATION[3]

Design Speed (mph)	Maximum Degree of Curve
50	0°30'
60	0°20'
70	0°15'
80	0°15'

3. Normal crown maintained.

Figure 4-2 Refers to Paragraph 4-202(d)1

Figures 4-3, 4-4, and 4-5 show minimum length of runoff for various rates (0.04, 0.06, and 0.08 respectively) of superelevation, design speeds, and degrees of curvature.

Superelevation transition is the general term denoting the change in cross section from a normal crown section to the full superelevated section or vice versa. To meet the requirements of comfort and safety, the superelevation transition should be effected uniformly over a length adequate for the usual travel speeds. In general, the location of the transition in respect to the end of the curve should be such that two-thirds of the transition is on the tangent and one-third within the limits of the curve. This results in two-thirds of the full superelevation at the beginning of the curve. On curves which are spiraled, the transition shall be distributed over the length of the spiral curve. Care must be exercised in the transition, especially in curbed sections, to avoid drainage problems.

Profiles of both gutters should be plotted to insure a smooth transition and proper drainage throughout the transition section. Three specific methods in attaining superelevation are used in common practice, as shown under Cases 1, 2 and 3 of Figure 4-6. The criteria for the development of the superelevation transition lengths are (1) that the maximum relative slope between the profiles of the edge of a two-lane pavement and the centerline (axis of rotation about the centerline) based on design speed be 1:175 for 40 mph, 1:200 for 50 mph, 1:225 for 60 mph, 1:250 for 70 mph, and 1:275 for 80 mph; (2) the minimum length of superelevation transition for four lane, six lane and eight lane highways to be respectively 1.5, 2.0 and 2.5 times the length for a two lane highway. Pavement superelevation will be accomplished in accordance with Figure 4-6.

More detailed information regarding superelevation may be found in AASHTO's *A Policy on Geometric Design of Rural Highways,* 1965, and *A Policy on Design of Urban Highways and Arterial Streets,* 1973.

3. Sight Distance on Horizontal Curves

Where an object off the pavement, such as a bridge pier, bridge railing, building, cut slope or natural growth restricts sight distance, the minimum radius of curvature is determined by the stopping sight distance.

Stopping sight distance on horizontal curves is obtained from Figure 4-7. It is assumed that the driver's eye is 3.75 feet above the center of the inside lane (inside with respect to curve) and the object is 0.5 foot high. The line of sight is assumed to intercept the view obstruction at the midpoint of the sight line and 2 feet above the center of the inside lane. The clear distance (m) is measured from the center of the inside lane to the obstruction.

4. General Considerations for Horizontal Alignment

In addition to the specific elements discussed previously, there are a number of general considerations which are important in attaining safe, smooth flowing, and aesthetically pleasing facilities. These practices as outlined below are particularly applicable to high speed facilities.

a. Flatter than maximum curvature for a certain design speed should be used where possible, retaining the maximum standards for the most critical conditions.

b. Compound curves should be used with caution and should be avoided where conditions permit the use of a simple curve. Where compound curves are used, the radius of the flatter curve should not be more than 50 percent greater than the radius of the sharper curve for rural and urban conditions.

VALUES FOR DESIGN ELEMENTS RELATED TO DESIGN SPEED AND HORIZONTAL CURVATURE

D	R	V = 30 mph			V = 40 mph			V = 50 mph		
		e	L-Feet		e	L-Feet		e	L-Feet	
			2-lane	4-lane		2-lane	4-lane		2-lane	4-lane
0°15'	22918'	NC	0	0	NC	0	0	NC	0	0
0°30'	11459'	NC	0	0	NC	0	0	NC	0	0
0°45'	7639'	NC	0	0	NC	0	0	RC	150	225
1°00'	5730'	NC	0	0	RC	125	190	.016	150	225
1°30'	3820'	RC	100	150	.015	125	190	.020	150	225
2°00'	2865'	RC	100	150	.018	125	190	.023	150	225
2°30'	2292'	.015	100	150	.020	125	190	.026	150	225
3°00'	1910'	.016	100	150	.022	125	190	.028	150	225
3°30'	1637'	.017	100	150	.024	125	190	.030	150	225
4°00'	1432'	.018	100	150	.025	125	190	.033	150	225
5°00'	1146'	.021	100	150	.028	125	190	.036	150	225
6°00'	955'	.023	100	150	.031	125	190	.040	150	225
7°00'	819'	.024	100	150	.033	125	190	.040	150	225
8°00'	716'	.026	100	150	.036	125	190	D max. = 6.0°		
9°00'	637'	.028	100	150	.038	125	190			
10°00'	573'	.029	100	150	.040	125	190			
11°00'	521'	.031	100	150	.040	125	190			
12°00'	477'	.032	100	150	D max. = 10.0°					
13°00'	441'	.033	100	150						
14°00'	409'	.035	100	150						
16°00'	358'	.037	100	150						
18°00'	318'	.039	100	150						
		.040	100	150						
		D max. = 19.0°								

e max. = 0.04*

D - Degree of curve
R - Radius of curve
V - Assumed design speed
e - Rate of superelevation
L - Minimum length of runoff or spiral curve
NC - Normal crown section
RC - Remove adverse crown, superelevate at normal crown slope
Spirals are desirable

Lengths rounded in multiples of 25 or 50 feet permit simpler calculations.
*Applicable only to urban streets without full control of access.

FIG. 4-3 Refers to Paragraph 4-202(d)2.

VALUES FOR DESIGN ELEMENTS RELATED TO DESIGN SPEED AND HORIZONTAL CURVATURE

D	R	V = 30 mph			V = 40 mph			V = 50 mph			V = 60 mph			V = 70 mph		
		e	L-Feet		e	L-Feet		e	L-Feet		e	L-Feet		e	L-Feet	
			2-lane	4-lane		2-lane	4-lane		2-lane	4-lane		2-lane	4-lane		2-lane	4-lane
0°15'	22918'	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
0°30'	11459'	NC	0	0	NC	0	0	NC	0	0	RC	175	175	RC	200	200
0°45'	7639'	NC	0	0	NC	0	0	RC	0	0	.021	175	175	.026	200	200
1°00'	5730'	NC	0	0	RC	125	125	.020	150	150	.027	175	175	.033	200	200
1°30'	3820'	RC	100	100	.020	125	125	.028	150	150	.036	175	175	.044	200	200
2°00'	2865'	RC	100	100	.026	125	125	.035	150	150	.044	175	180	.052	200	230
2°30'	2292'	.020	100	100	.031	125	125	.040	150	150	.050	175	200	.057	200	260
3°00'	1910'	.023	100	100	.035	125	125	.044	150	160	.054	175	220	.060	200	270
3°30'	1637'	.026	100	100	.038	125	125	.048	150	170	.057	175	230	D max. = 3.0°		
4°00'	1432'	.029	100	100	.041	125	130	.051	150	180	.059	175	240			
5°00'	1146'	.034	100	100	.046	125	140	.056	150	200	D max. = 4.0°					
6°00'	955'	.038	100	100	.050	125	160	.059	150	210						
7°00'	819'	.041	100	110	.054	125	170	D max. = 6.0°								
8°00'	716'	.043	100	120	.056	125	180									
9°00'	637'	.046	100	120	.058	125	180									
10°00'	573'	.048	100	130	.060	125	190									
11°00'	521'	.050	100	140	D max. = 10.0°											
12°00'	477'	.052	100	140												
13°00'	441	.053	100	140												
14°00'	409'	.055	100	150												
16°00'	358'	.058	100	160												
18°00'	318'	.059	110	160												
19°00'	303'	.060	110	160												
		D max. = 19.0°														

e max. = 0.06

D - Degree of curve
R - Radius of curve
V - Assumed design speed
e - Rate of superelevation
L - Minimum length of runoff or spiral curve
NC - Normal crown section
RC - Remove adverse crown, superelevate at normal crown slope
Spirals desirable
Lengths rounded in multiples of 25 or 50 feet permit simpler calculations.

FIG. 4-4 Refers to Paragraph 4-202(d)2.

VALUES FOR DESIGN ELEMENTS RELATED TO DESIGN SPEED AND HORIZONTAL CURVATURE

D	R	V = 40 mph			V = 50 mph			V = 60 mph			V = 70 mph		
		e	L-Feet		e	L-Feet		e	L-Feet		e	L-Feet	
			2-lane	4-lane		2-lane	4-lane		2-lane	4-lane		2-lane	4-lane
0°15'	22918'	NC	0	0	NC	0	0	NC	0	0	NC	0	0
0°30'	11459'	NC	0	0	NC	0	0	RC	175	175	RC	200	200
0°45'	7639'	NC	0	0	RC	150	150	.022	175	175	.029	200	200
1°00'	5730'	RC	125	125	.021	150	150	.029	175	175	.038	200	200
1°30'	3820'	.021	125	125	.030	150	150	.040	175	175	.053	200	240
2°00'	2865'	.027	125	125	.038	150	150	.051	175	210	.065	200	290
2°30'	2292'	.033	125	125	.046	150	170	.060	175	240	.073	220	330
3°00'	1910'	.038	125	125	.053	150	190	.067	180	270	.078	230	350
3°30'	1637'	.043	125	140	.058	150	210	.073	200	300	D max. = 3.0°		
4°00'	1432'	.047	125	150	.063	150	230	.077	210	310			
5°00'	1146'	.055	125	170	.071	170	260	D max. = 4.0°					
6°00'	955'	.061	130	190	.077	180	280						
7°00'	819'	.067	140	210	D max. = 6.0°								
8°00'	716'	.071	150	220									
9°00'	637'	.075	160	240									
10°00'	573'	.077	160	240									
		D max. = 10.0°											

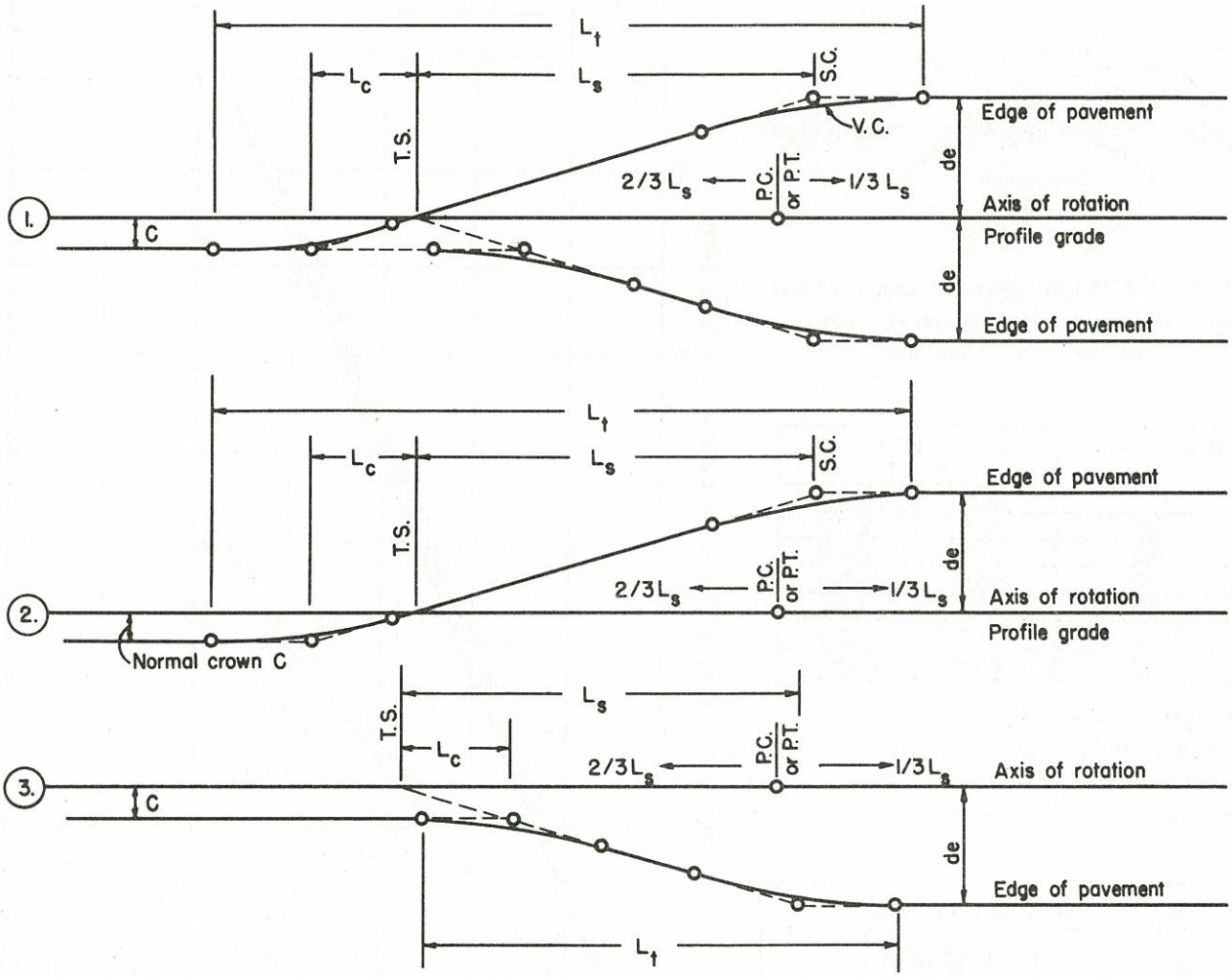
e max. = 0.08*

D - Degree of curve
R - Radius of curve
V - Assumed design speed
e - Rate of superelevation
L - Minimum length of runoff or spiral curve
NC - Normal crown section
RC - Remove adverse crown, superelevate at normal crown slope
Spirals desirable
Lengths rounded in multiples of 25 or 50 feet permit simpler calculations.
*Applicable only to rural highways of all types and urban freeways.

FIG. 4-5 Refers to Paragraph 4-202(d)2.

SUPERELEVATION TRANSITIONS

L_s = Length of superelevation runoff in feet (See figures 4-3, 4-4, or 4-5)
L_c = Length of crown runoff in feet = $L_s C/de$.
C = Normal vertical crown in feet.
d = Distance from axis of rotation to edge of pavement in feet.
e = Maximum superelevation rate in ft./ft.
L_t = Total length superelevation transition.
V.C. = Vertical curve; VC length = Approx. ½ minimum Ls



CASE (1.) - Rotation of pavement about centerline. Usually used on divided highways with narrow medians, divided highways with wide medians where the axis of rotation is the centerline of each pavement and on two lane roads.

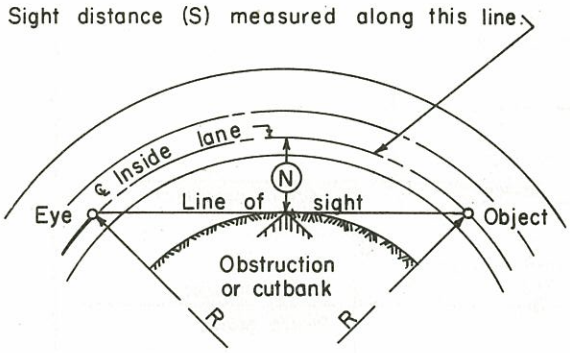
CASE (2.) - Rotation about pavement edge. Used when the superelevation is in the opposite direction to the crown slope.

CASE (3.) - Rotation about pavement edge. Used when the superelevation is in the same direction as the crown slope.

Case I is combination of cases 2 and 3.

FIG. 4-6 Refers to Paragraph 4-202(d)2.

STOPPING SIGHT DISTANCE ON HORIZONTAL CURVES



Height of eye 3.75 feet. Height of object 0.5 feet. At obstruction, line of sight is 2.0 feet above center of inside lane.

DESIGN SPEED M.P.H.	SIGHT DISTANCE FEET	
	MIN.	DES.
30	200	200
40	275	300
50	350	450
60	475	650
70	600	850
80	750	1050

S = Sight distance in feet.
R = Radius of ℄ inside lane in feet.
N = Distance from inside lane in feet.
V = Design speed for S in M.P.H.

ANGLE IS EXPRESSED IN DEGREES

$$N = R\left[\text{vers}\left(\frac{28.65\ S}{R}\right)\right]$$

$$S = \frac{R}{28.65}\left[\cos^{-1}\left(\frac{R-N}{R}\right)\right]$$

Formula applies only when S is equal to or less than length of curve.

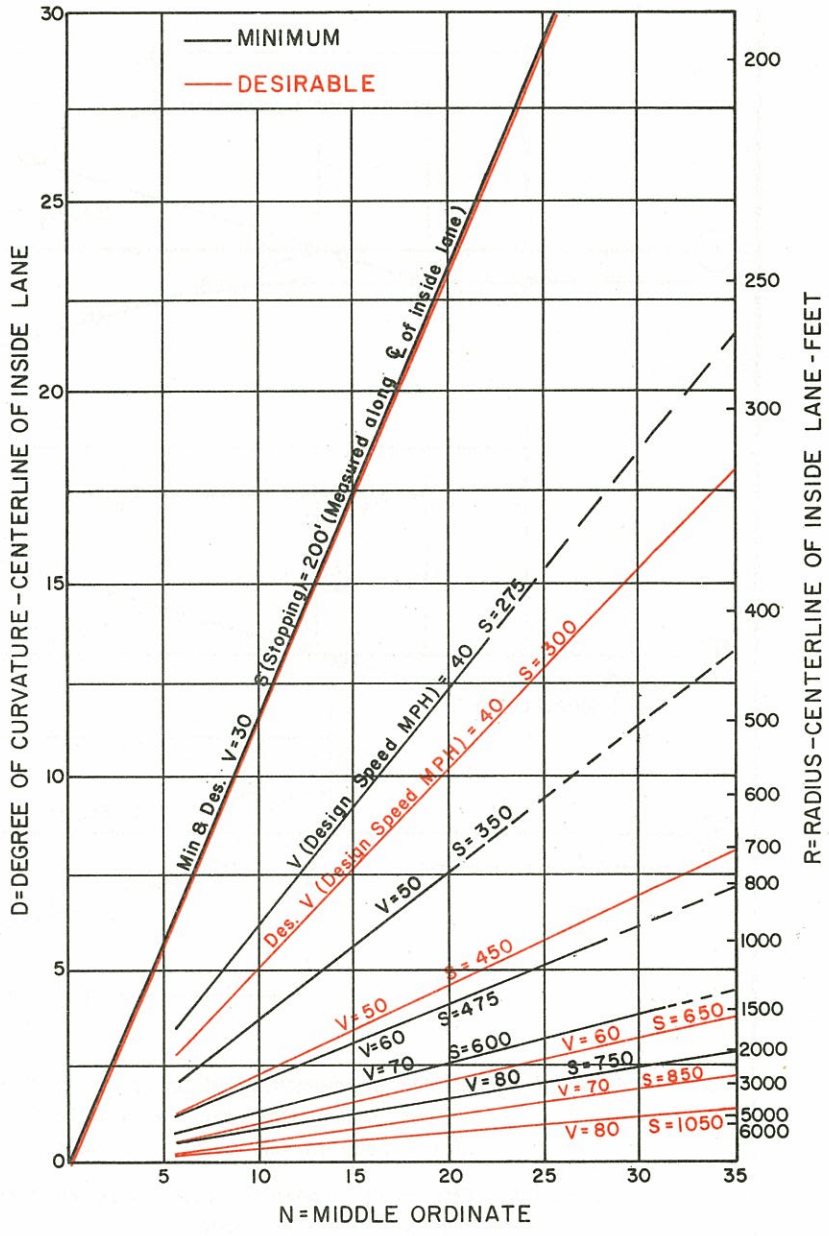


FIG. 4-7 Refers to Paragraph 4-202(d)3.

c. Reverse curves on high speed facilities should include an intervening tangent section of sufficient length to provide adequate superelevation runoff between the curves.

d. Broken-back curves consist of two curves in the same direction connected with a short tangent and should not be used. This type of curve is unexpected by drivers and is not pleasing in appearance.

e. Horizontal alignment and its associated design speed should be consistent with other design features and topography. Coordination with vertical alignment is discussed in Paragraph 4-202(f).

(e) Vertical Alignment

The two basic elements of vertical alignment are the tangents (grades) and vertical curves.

1. Grades

The effects of rate and length of grades are more pronounced on the operating characteristics of trucks than on passenger cars and thus may introduce hazardous speed differentials between the vehicle types. The term "critical length of grade" is used to indicate the maximum length of a specified ascending gradient upon which a loaded truck can operate without an unreasonable reduction (commonly 10 or 15 mph) in speed. Figure 4-8 shows the relationship of percent upgrade, length of grade, and truck speed reduction; where critical length of grade is exceeded for two lane highways, climbing lanes should be considered as discussed in Section 4-502(e) and Appendix D.

a. Maximum Grades

Figure 4-9 summarizes the maximum grade controls in terms of design speed. For low volume (less than 750 v.p.d. in the current year) rural highways, maximum grades may be two percent steeper. Since traffic on arterial streets operates at lower speeds with relatively few heavy trucks, maximum design grades for arterial streets are steeper than the corresponding values for freeways and rural highways. Maximum design grade should be used infrequently rather than as a value to be used in most cases.

b. Minimum Grades

Flat or level grades on uncurbed pavements are satisfactory when the pavement is adequately crowned to drain the surface water laterally. When side ditches are required, the grade should seldom be less than 0.5 percent for unpaved ditches and 0.25 percent for lined channels. With curbed pavements, desirable minimum grades of 0.35 percent should be provided to facilitate surface drainage. Joint analysis of rainfall frequency and duration, the longitudinal grade, cross slope, curb, inlet type and spacing of inlets or discharge points usually is required so that the width of water on the pavement surface during likely storms does not unduly interfere with traffic.

2. Vertical Curves

The simple parabola, as shown in Figure 4-10, is used in highway profile design.

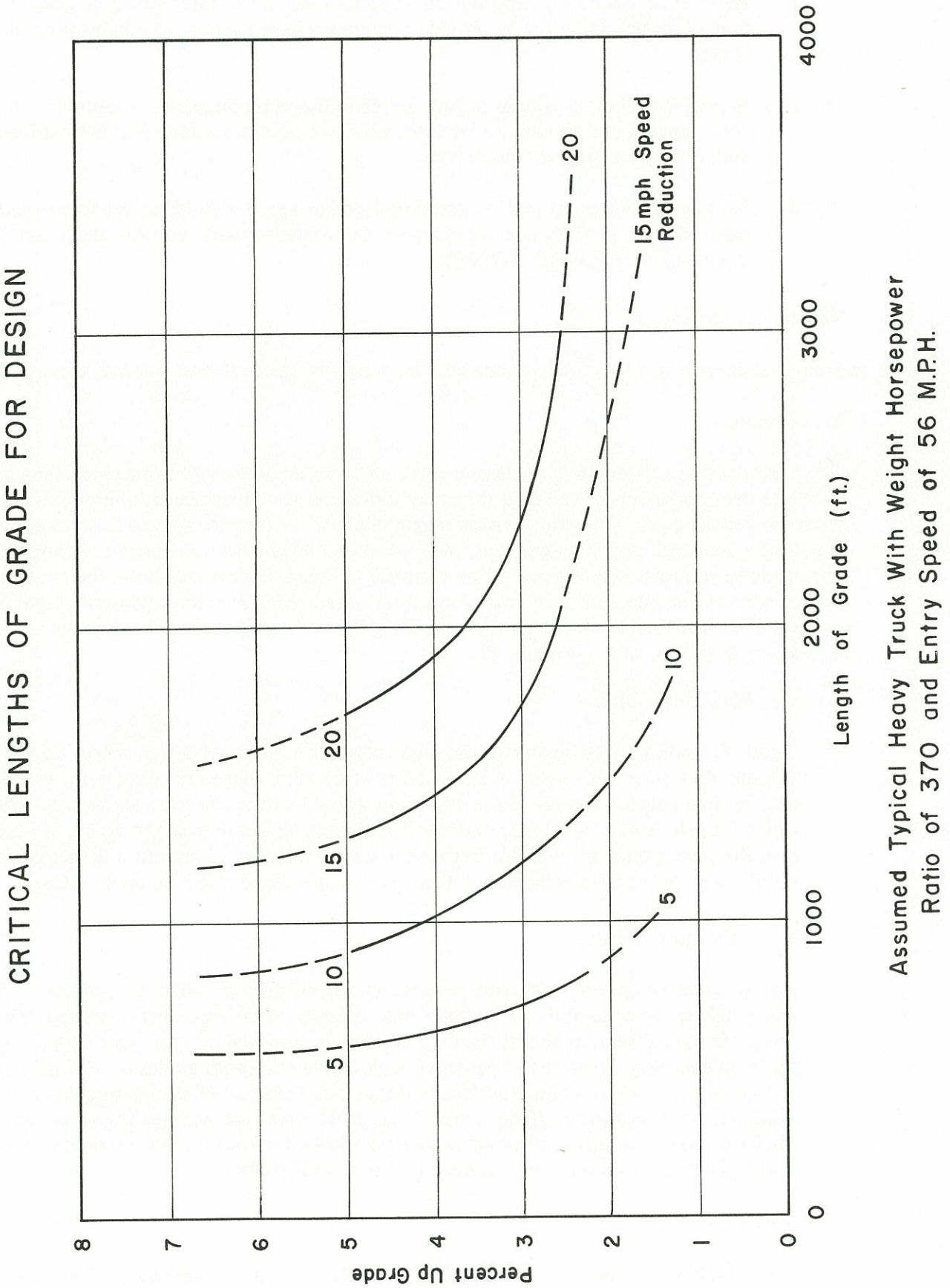


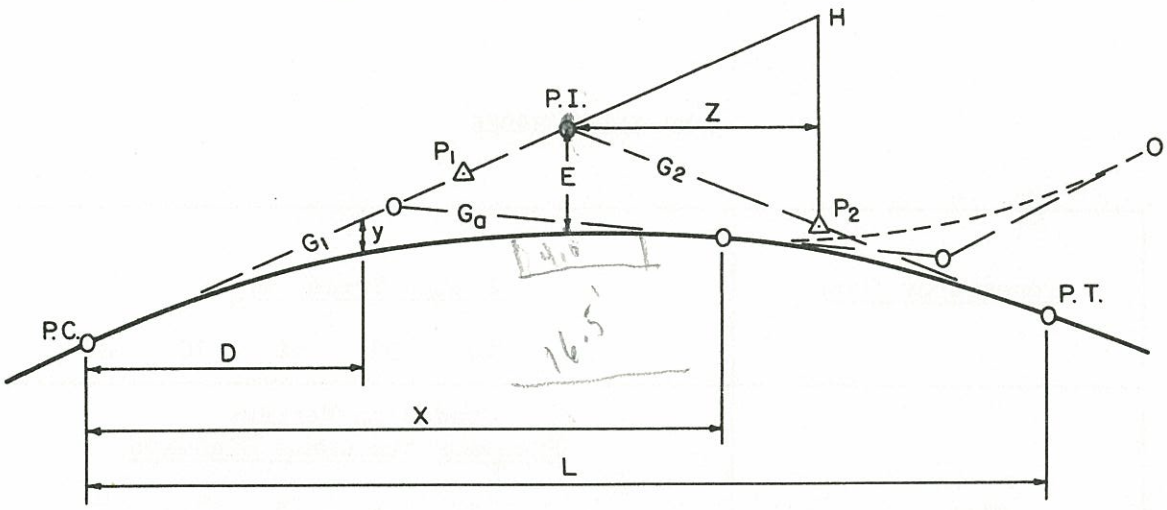
FIG. 4-8 Refers to Paragraph 4-202(e)1.

MAXIMUM GRADES

Topography Type	Design Speed, mph					
	30	40	50	60	70	80
	Grades in Percent Freeways and Rural Highways					
Flat	-	5	4	3	2.5	2
Rolling	-	6	5	4	3	2.5
	Arterial Streets Without Full Access Control					
Flat	8	7	6	5	-	-
Rolling	9	8	7	6	-	-

Figure 4-9 (Refers to Paragraph 4-202(e)1)

VERTICAL CURVE



Given: Grades G_1 and G_2, Elevation P_1 and P_2 on respective grades.
To Find P.I. Let H = elevation of G_1 extended to Station of P_2

$$\text{Then } Z = \frac{100(H-P_2)}{A}$$

In any vertical curve:

1. $E = \frac{AL}{8}$

2. $C = \frac{A}{2L}$

3. $y = (D)^2 \frac{E}{(1/2L)^2}$

   $y = D^2C$

4. $G_a = G_1 - A\frac{X}{L}$

5. $X' = L\frac{G_1}{A}$

Where:

G_1, G_2 = tangent grades, in percent.

E = ordinate from P.I. to curve, in feet.

A = $G_1 - G_2$, the algebraic difference in grade.

L = length of curve, in stations.

y = ordinate from tangent to curve in feet.

D = distance from nearest P.C. or P.T. to any point on curve.

X = any distance from P.C., in stations

X' = distance from P.C. to lowest or highest point on the vertical curve.

G_a = tangent grade at any point, in per cent

FIG. 4-10 Refers to Paragraph 4-202(e)2.

a. Crest Vertical Curves

Minimum lengths of crest vertical curves, as controlled by stopping sight distance requirements, generally are satisfactory from the standpoint of safety, comfort, and appearance. The minimum and desirable lengths (L) of crest vertical curves for various algebraic differences in grade (A) to provide minimum and desirable stopping sight distances for various design speeds are shown in Figure 4-11.

The K (or L/A) value indicates the rate of vertical curvature, and particular K values correspond with specific design speeds. Vertical curves on curbed facilities with 50 mph or greater design speed exceed a K value of 143 (drainage maximum) indicating that drainage near the apex needs to be carefully considered.

b. Sag Vertical Curves

Design criteria for sag vertical curves is based on headlight sight distance, or, comfort control where fixed source lighting is installed. In the absence of continuous lighting, a sag vertical curve should be long enough so that the automobile light beam distance is nearly the same as stopping sight distance. Figure 4-12 shows minimum and desirable lengths for sag curves for various design speeds and algebraic differences in grade. Desirable values are also shown for sag curves where continuous fixed source illumination is involved.

Care should be exercised in sag vertical curve design to insure that overhead sight obstructions such as structures for overpassing roadways, overhead sign bridges, tree crowns, etc., do not reduce stopping sight distance below the appropriate minimum value.

(f) Combination of Vertical and Horizontal Alignment

Due to the near permanent nature of roadway alignment once constructed, it is important that the proper alignment be selected consistent with design speed, existing and future roadside development, subsurface conditions, topography, etc. The following factors are general considerations in obtaining a proper combination of horizontal and vertical alignment:

1. The design speed of both vertical and horizontal alignment should be compatible, with longer vertical curves and flatter horizontal curves than dictated by minimum values used where practical. Design speed should be compatible with topography, with the roadway fitting the terrain where feasible.

2. A more attractive and safer facility results where horizontal and vertical alignment are superimposed. Ideally, the P.I. of each curve coincides, communicating the alignment to the driver free of distortions and deceptions and producing a pleasing appearance.

3. Alignment should be as flat as possible near intersections where sight distance is of extreme importance.

4. Sharp horizontal curvature should not be introduced at or near pronounced vertical curves to avoid distorted appearance and foreshortened sight distance (at night for sags).

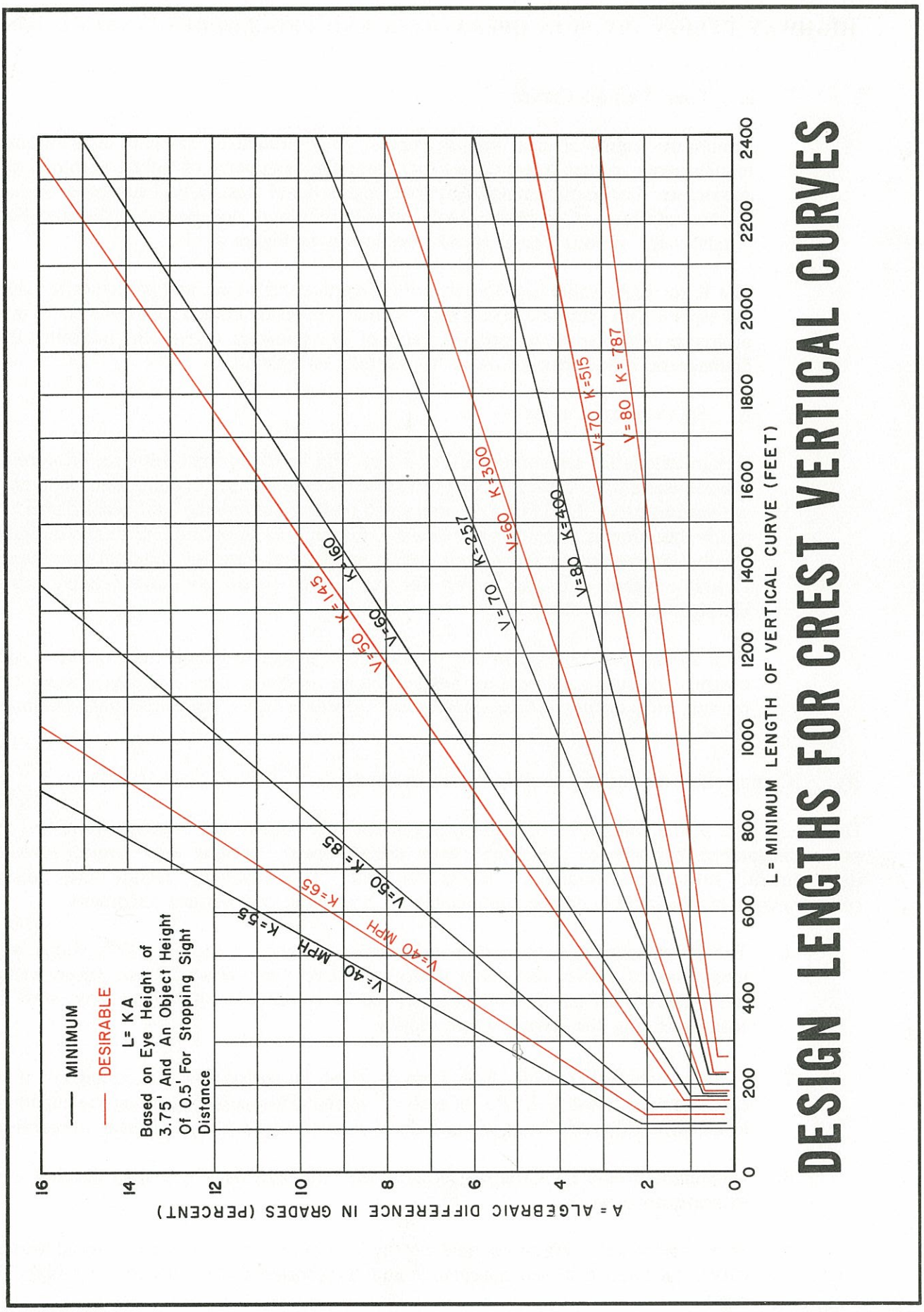


FIG. 4-11 Refers to Paragraph 4-202(e)2.

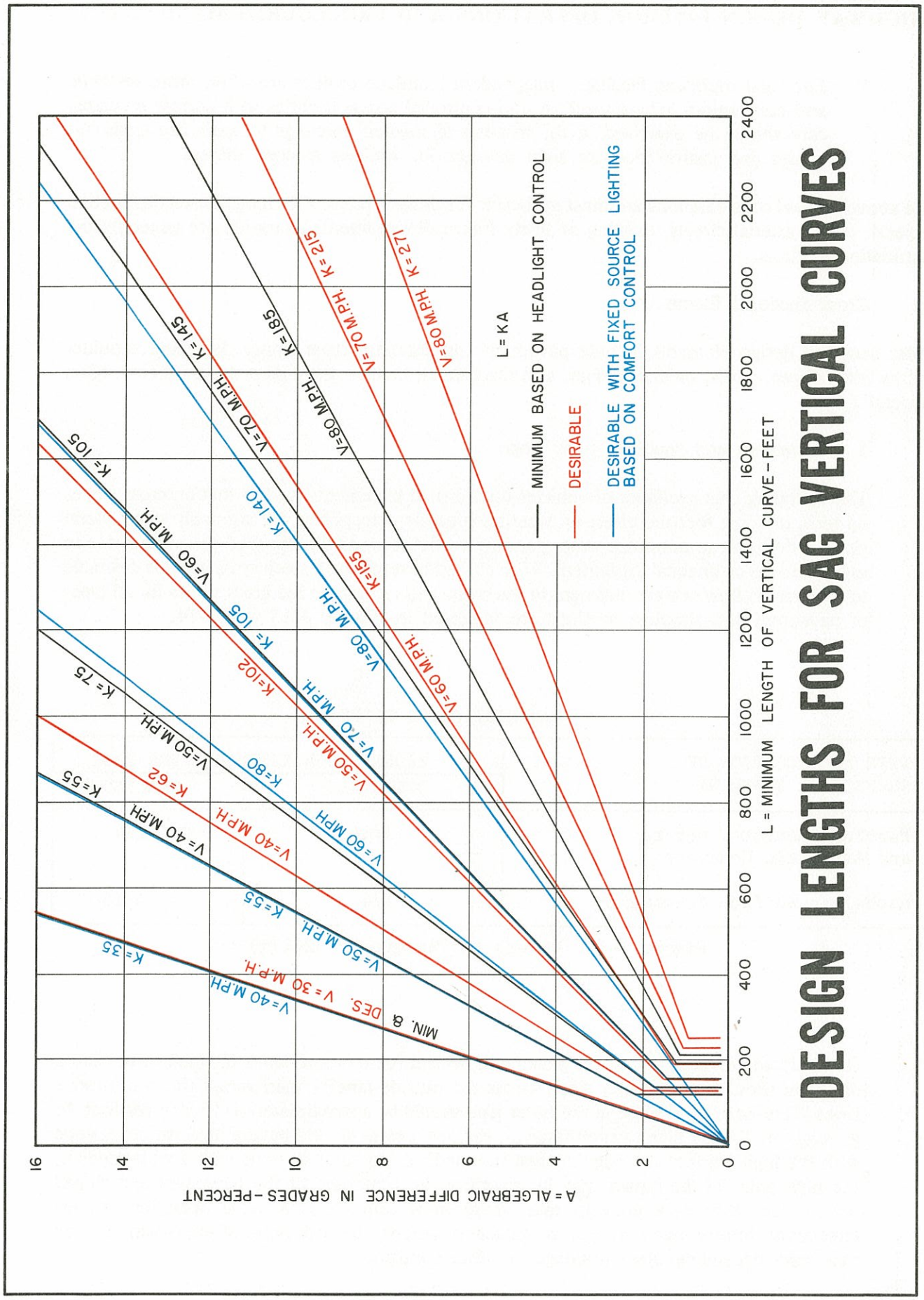


FIG. 4-12 Refers to Paragraph 4-202(e)2.

5. For rural multilane facilities, independent mainlane profiles are often more aesthetic and economical. Where used on non-controlled access facilities with narrow medians, care should be exercised in the location of median openings to minimize crossover grades and insure adequate sight distance for vehicles stopped therein.

The above general considerations are most applicable for designs on new location; for reconstruction projects, or for arterial streets, existing or likely future developments alongside are generally the dominating controls.

(g) Cross Sectional Elements

Cross sectional design elements include pavement and shoulder cross slopes, lane and shoulder widths, side slopes, curbs, median design, and roadside clearances. Pavement design is covered in Appendix F.

1. Pavement and shoulder cross slope.

The operating characteristics of vehicles on crowned pavements is such that on cross slopes up to ¼ inch per foot the effect on steering is barely perceptible. A reasonably steep lateral slope is desirable to minimize water ponding on flat sections of uncurbed pavements due to imperfections or unequal settlement. With curbed pavements, a steep cross slope is desirable to contain the flow of water adjacent to the curb. The recommended cross slopes for all types of pavement and shoulder sections are indicated in Figures 4-13 and 4-14.

PAVEMENT CROSS SLOPE

TYPE AND LOCATION OF SURFACE OR PAVEMENT	CROWN SLOPE IN INCHES PER FOOT	
	DESIRABLE	MAXIMUM
Portland Cement Concrete and Asphaltic Concrete	3/16	1/4
Asphaltic Surface Treatment	1/4	5/16

Figure 4-13 Refers to Paragraph 4-202(g)1

On multilane divided highways, pavements with three or more lanes inclined in the same direction should have greater slope across the outside lane(s) than across the two interior lanes. This increase in slope in the outer lane should be approximately 1/16 inch per foot. In general, on divided highways on tangent, each pavement should have a uniform cross slope with the high point at the edge nearest the median. On rural sections with a wide median, the high point of the crown may be placed at the centerline of the pavement and sloped toward the edges at a uniform rate where snow removal is a usual operation. At intersections, interchange ramps or in unusual situations, the high point of the crown position may vary depending upon drainage or other controls.

RECOMMENDED SHOULDER SLOPES

TYPE OF SHOULDER	SLOPE IN INCHES PER FOOT OF WIDTH	
	DESIRABLE	MAXIMUM
Asphaltic Concrete	1/2	5/8
Asphaltic Surface Treatment	1/2	5/8
Gravel or Crushed Stone	5/8	3/4
Turf or Sod	3/4	1

Figure 4-14 Refers to Paragraph 4-202(g)1

2. Slopes and Ditches

Flat slopes are safer than steep slopes. Rates of 6:1 or flatter on embankments can be negotiated by an errant vehicle with a good chance of recovery and should, where feasible, be provided. Steeper fill slopes, up to 4:1, are traversable without vehicle roll-over but the chances of recovery are substantially lessened. In this regard, guardrail should not be used solely for slope protection for rates of 4:1 or flatter since the barrier would be more hazardous than the slope.

The intersections of slope planes in the highway cross section should be well rounded for added safety, increased stability, and aesthetics. Side slopes, back slopes, and ditches should be sodded and/or seeded where feasible to promote stability and reduce erosion. In arid regions, concrete or rock retards may be necessary to prevent ditch erosion.

Where guardrail is placed on side slopes, the area between the roadway and barrier should be sloped at 10:1 or flatter.

For steeper slopes protected by barriers, slope rates of 3:1 facilitate efficient operation of construction and maintenance equipment. Difficulty in operation of such equipment is experienced at 2:1, and is virtually impossible for steeper slopes.

Roadside drainage ditches should have a minimum depth of two feet, as measured from the centerline profile grade, and generally should be at least six inches below the subgrade crown to insure stability of the base course.

3. Median Design

A median (i.e., the area between opposing travel lane edges) is provided primarily to separate opposing traffic streams. The general range of median widths is from 4 to 76 feet, with design width dependent on the type and location of the highway or street facility.

In rural areas, median sections are normally wider than in urban areas. For multilane rural highways without access control, a median width of 76 feet is desirable to provide complete shelter for trucks at median openings (crossovers). These wide, depressed medians are also effective in reducing headlight glare and providing a safety zone for run-off-the-road vehicle encroachments.

Where economically feasible, freeways in rural areas should desirably include a 76-foot median to minimize headlight glare and provide a wide safety zone. Since freeways by design do not allow at-grade crossings, median widths need not be sufficient to shelter crossing trucks. In this regard, where right of way costs are prohibitive, reduced (less than 76 feet) median widths may be appropriate for certain rural freeways. Statistical studies have shown that over 90 per cent of median encroachments involve lateral distances traveled of 48 feet or less. In this regard, depressed medians on rural freeways sections should always be 48 feet or more in width.

Urban freeways generally include narrower, flush medians with continuous longitudinal barriers. For urban freeways with six or more travel lanes, full (10') inside shoulders should be provided to provide space for emergency parking. Median widths vary up to 30 feet, with 24 feet commonly used. For projects involving the rehabilitation and expansion of existing urban freeways, the provision of wide inside shoulders may not be feasible.

For lower speed urban arterial streets, flush or curbed medians are used. A width of 14 feet will effectively accommodate left turning traffic for either raised or flush medians. The two way (continuous) left turn lane design is appropriate where there exists (or is expected to exist) a high frequency of mid-block left turns. Median types for urban arterials without access control are further discussed in Section 4-302(b).

4. Lane Widths

For high speed facilities such as all freeways and rural highways, lane widths should be twelve feet minimum. For lower speed urban streets, eleven or twelve foot lanes are generally used. Subsequent sections of this publication identify appropriate lane widths for the various classes of highway and street facilities.

5. Shoulder Widths

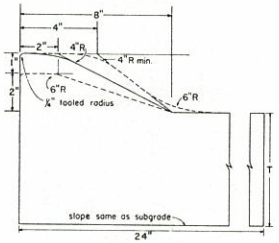
Wide, surfaced shoulders provide a suitable, all weather area for stopped vehicles to stand clear of the travel lanes. Shoulders are of considerable value on high speed facilities such as freeways and rural highways; however, on arterial streets, parking lanes are generally provided instead of shoulders. Shoulders, in addition to serving as emergency parking areas, lend lateral support to travel lane pavement structure, provide a maneuvering area, increase sight distance on horizontal curves, and give drivers a sense of safe, open roadway. Design shoulder widths for the various classes of highways are shown in the appropriate subsequent portions of this manual.

6. Curb and Curb and Gutters

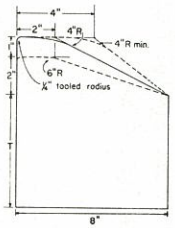
As shown in Figure 4-15, the two general types of curbs are "mountable" and "deterrent." Either type may be constructed as an integral part of a concrete pavement (Type I and II Mono Curb), placed adjacent to the pavement (Type I and II Curb), or constructed with gutter to form a combination curb and gutter section (Type I and II Curb and Gutter).

a. Mountable Curbs

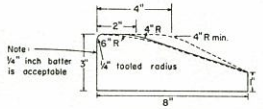
Mountable curbs are designed so that vehicles can cross them without a severe jolt. They are low curbs, three inches in height or less, with flat sloped faces. Type I curbs as shown in Figure 4-15 are mountable.



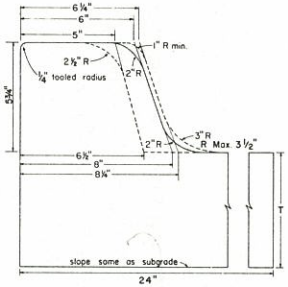
TYPE I CURB AND GUTTER



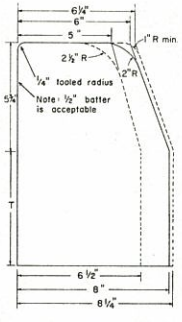
TYPE I CURB



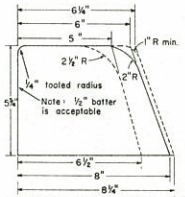
TYPE I MONO CURB OR CURB PLACED ON PAVEMENT



TYPE II CURB AND GUTTER



TYPE II CURB



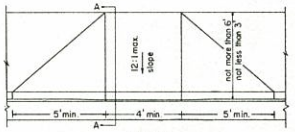
TYPE II MONO CURB OR CURB PLACED ON PAVEMENT

GENERAL NOTES

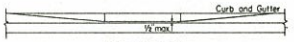
1. CONTRACTOR MAY USE EXISTING FORMS IF THE CROSS SECTION LIES WITHIN THE BAND SHOWN BY DOTTED LINES. IF NEW FORMS ARE TO BE PURCHASED, LEASED, OR CONSTRUCTED THEY SHALL CONFORM TO THE SOLID LINE.
2. WHEN REINFORCING STEEL IS REQUIRED OR PLACED AT CONTRACTOR'S OPTION, ONE OF THE FOLLOWING SCHEMES OF REINFORCEMENT SHALL BE REQUIRED. THE MANNER OF PLACEMENT AND LOCATION SHALL BE TO THE SATISFACTION OF THE ENGINEER.
   a. TYPE I CURB AND GUTTER (REINF.) OR TYPE II CURB AND GUTTER (REINF.) SHALL HAVE LONGITUDINAL REINFORCING BARS AS FOLLOWS; THREE #3, TWO #4, TWO #5, OR ONE #6.
   b. ALL TYPES OF CURB (REINF.) SHALL HAVE ONE #3 OR #4 BAR FOR LONGITUDINAL REINFORCEMENT.
3. REINFORCING BARS SHALL BE LAPPED A MINIMUM OF 15".
4. WHEN CURB OR CURB AND GUTTER IS PLACED BY A SEPARATE POUR ADJACENT TO OR ATOP CONCRETE PAVEMENT, CURB OR CURB AND GUTTER SHALL BE TIED TO PAVEMENT IN A MANNER SATISFACTORY TO THE ENGINEER WITH 8-INCH LONG #3 OR #4 BARS SPACED AT 5 FEET AND EXPANSION AND/OR CONTRACTION JOINTS OF CURB OR CURB AND GUTTER SHALL MATCH THOSE OF PAVEMENT.

   WHEN CURB OR CURB AND GUTTER IS NOT CONSTRUCTED ADJACENT TO CONCRETE PAVEMENT, THE FOLLOWING SHALL GOVERN:

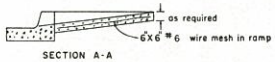
   a. REINFORCED CURB OR CURB AND GUTTER SHALL HAVE NO CONTRACTION JOINTS.
   b. NON-REINFORCED CURB OR CURB AND GUTTER SHALL HAVE FORMED, TOOLED OR SAWED CONTRACTION JOINTS AT 10'±. THE DEPTH OF THESE JOINTS SHALL BE SUFFICIENT TO INSURE CRACKING AT THE JOINTS.
   c. REINFORCED CURB OR CURB AND GUTTER SHALL HAVE EXPANSION JOINTS AT POINTS OF CURVATURE AND AT INTERVALS NO GREATER THAN 120' IN ALL CURVES AND AT STRUCTURES SUCH AS BRIDGES, BOX CULVERTS, CURB INLETS, ETC.
   d. NON-REINFORCED CURB OR CURB AND GUTTER SHALL HAVE EXPANSION JOINTS AT POINTS OF CURVATURE ON CURVES OF RADIUS LESS THAN 25' AND AT STRUCTURES SUCH AS BRIDGES, BOX CULVERTS, CURB INLETS, ETC.
5. ONE-HALF INCH EXPANSION JOINT MATERIAL SHALL BE PROVIDED WHERE CURB OR CURB AND GUTTER IS ADJACENT TO SIDEWALK OR RIPRAP.
6. TRANSITIONS BETWEEN CURBS OR CURBS AND GUTTERS OF DIFFERING CROSS SECTION SHALL BE ACCOMPLISHED OVER A 20 FT. LENGTH AS APPROVED BY THE ENGINEER.
7. AT CONTRACTOR'S OPTION, DIMENSION "T" MAY BE THICKNESS OF PAVEMENT STRUCTURE. IN NO CASE SHALL IT BE LESS THAN 6".



PLAN

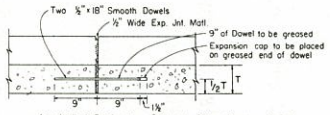


ELEVATION



SECTION A-A

WHEELCHAIR & BICYCLE RAMP



Longitudinal Section thru Curb and Gutter Showing Typical Expansion Joint Details.
Reinforcing steel (when used) shall not cross expansion joints. Steel shall be terminated 3" ± |" from face of the joint.

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

CONCRETE CURB AND CURB AND GUTTER

CCCG-75

DN.	CK. DN.	DW.	CK. DW.	TR.	CK. TR.	DRAWING	ORIGINAL	REVISED	REVISED	DATE	FED. RD. DIV. NO.	STATE & STATE DIST. NO.	FEDERAL PROJECT NO.	COUNTY	CONT.	SECT.	JOB	SHEET NO.	HIGHWAY NO.
												TEXAS							

FIG. 4-15 Refers to Paragraph 4-202 (g) 6.

b. Deterrent Curbs

Deterrent curbs are relatively high, steep faced curbs and are designed to discourage motorists from leaving the pavement, yet permit such a movement in an emergency. Deterrent curbs should be a maximum of 5-3/4 inches in height. Face batter for Type II (deterrent) curbs should be 1-3/4 inches per 3 inches of height, or steeper. These curbs are not adequate to prevent an out of control vehicle from leaving the pavement at speeds greater than about 35 mph and encroachment angles greater than 10 degrees. If redirection capabilities are required at these speeds and angles, use of the concrete median barrier or guard fence should be considered.

c. Structural Design

Experience has shown that nonreinforced curb gives satisfactory performance, at least when not placed directly on swelling subgrades. Therefore, the basic structural design of curbs should provide for non-reinforced curb and curb and gutter built on an extension of the base courses of adjacent pavement structure. Contraction joints should be spaced at approximately 10 feet to prevent wide cracks from forming. Expansion joints are unnecessary except when the curb abuts an immovable object and at the points of curvature for small radius curves.

For those situations (i.e., swelling subgrades) that may require reinforced curb or curb and gutter, the reinforcement should be continuous to eliminate the need for contraction joints. "See Figure 4-15 for discussion of reinforcement."

d. Curb Location

Curbs will be used primarily on frontage roads, cross roads, and low speed streets in urban areas. They should not be used in connection with the through, high speed traffic lanes or ramp areas except at the outer edge of the shoulder where needed for drainage, in which case they shall be of the mountable type. For Federal-Aid Projects, documentation to justify exceptions should be submitted with the P.S. and E.

e. Wheelchair Ramps

In order to provide adequate and reasonable access for the safe and convenient movement of handicapped persons, including those in wheelchairs, curb ramps should be included at all pedestrian crosswalks. Curb ramps should be at least four feet in width, desirably sloped at the rate of one inch per foot, and located on the pedestrian side of the curb face.

7. Roadside Design

Of particular concern to the design engineer is the number of single-vehicle, run-off-the-road accidents which occur even on the safest facilities yet devised. In recent years, about one-third of all highway fatalities were associated with accidents of this nature. The configuration and condition of the roadside greatly affect the extent of damages and injuries for these accidents.

Increased safety may be realized through application of the following principles, particularly on high speed (greater than 50 mph) facilities:

a. A "forgiving" roadside should be provided, free of unyielding obstacles including landscaping, hazardous drainage facilities, steep slopes, utility poles, etc. For adequate safety, it is desirable to provide an unencumbered roadside recovery area that is as wide as practicable for the specific highway and traffic conditions.

b. For existing highways, treatment of obstacles should be considered in the following order: (a) elimination of the hazard; (b) relocation of the hazard to a point where it is less likely to be struck; (c) reduction of the hazard severity through use of breakaway devices, and (d) application of a cost-effective device to provide for redirection (longitudinal barrier) or severity reduction (impact attenuators). A decision to use guard fence should be reached only if the guard fence is less a danger than the hazard it would protect.

c. Use of higher than minimum design standards result in a driver environment which is fundamentally safer because it is more likely to compensate for driver errors. Frequently, a more liberal design, including sight distances greater than minimum, flattened slopes, etc., costs little more over the life of a project and increases its safety and usefulness substantially.

d. For improved safety performance, highway geometry and traffic control devices should merely confirm drivers' expectations. Unexpected situations, such as left side ramps on freeways, sharp horizontal curvature introduced within a series of flat curves, etc., have demonstrated adverse effects on traffic operations and safety.

These principles have been incorporated as appropriate into the design standards included herein. It is the responsibility of the designer that these principles be carefully examined for their applicability at each particular site based on its particular circumstances, including the aspects of social impact, environmental impact, economy, and safety.

8. Horizontal Clearances to Obstructions

A clear recovery area should be provided along high speed rural highways. Such a recovery area should be clear of unyielding objects where practical or shielded by crash cushions or guardrail.

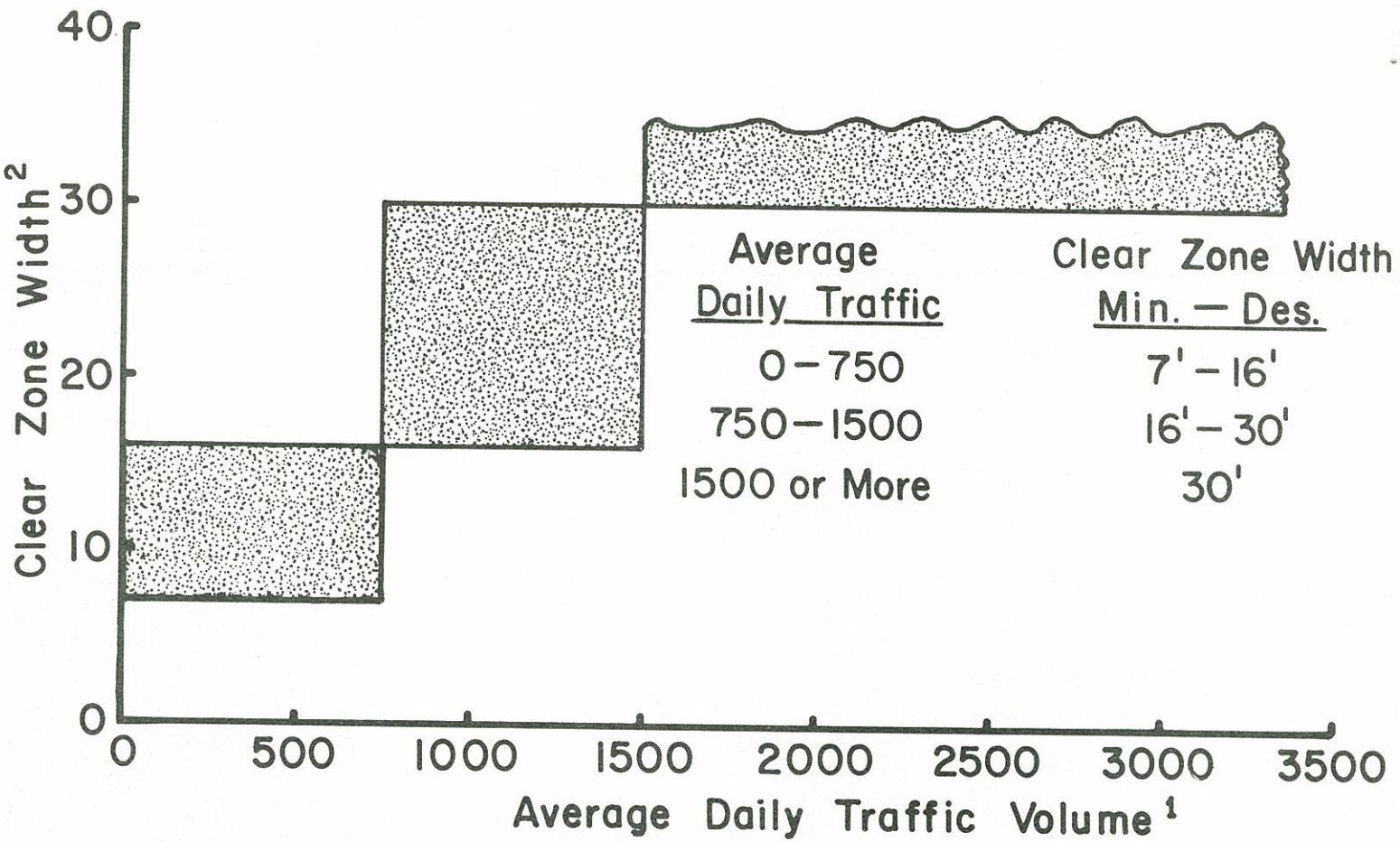
Figure 4-15A shows criteria for horizontal clearances to obstructions on new location projects for highways without full access control and "major" reconstruction projects on existing routes. "Major" reconstruction projects are those which involve extensive vertical or horizontal re-alignment, and/or extensive alteration of side slopes.

Figure 4-15B shows criteria for horizontal clearances to culvert ends and is applicable for certain improvement projects on existing highways. The scope of applicable projects is less than

that described above for "major" reconstruction projects; appropriate projects are those which retain existing vertical and horizontal alignment and existing slopes. These projects may provide for pavement structure reconstruction, including minor crown widening, as long as existing alignment is fundamentally retained.

Figure 4-15B suggests "engineering judgment" be applied for certain combinations of ADT and existing lateral offset to culvert end. Factors which should be considered in reaching a design decision for these circumstances include availability or right-of-way, size and severity (i.e., potential for producing serious injury during accidental impact) of culvert end, the presence or absence of a flat-sloped recovery area between the culvert end and the travel lane edge, and the cost of a suitable improvement. Where an improvement is warranted, culvert end grates are cost effective for small and moderate size pipe and box culverts. In situations where culvert extension is selected to accomplish an improvement, the extension should be to an offset distance meeting the criteria in Figure 4-15A. Guard fence protection is generally the least desirable treatment and should be used only where other methods of improvement are not feasible.

The information shown in Figures 4-15A and 4-15B does not apply to projects which involve only resurfacing work.

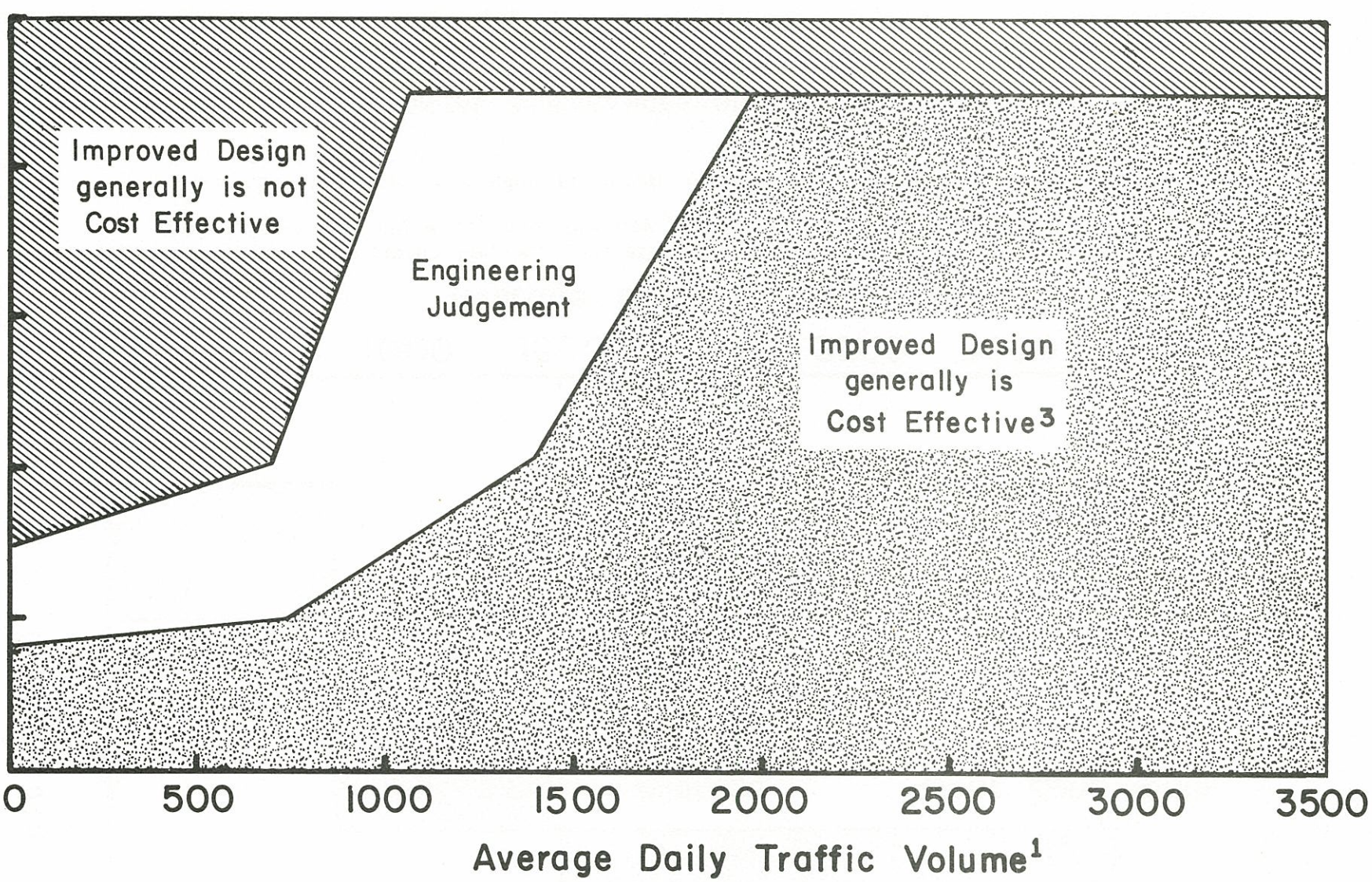


[1] Average ADT over project life, i.e., 0.5 (present ADT + design year ADT). Use two-way ADT for two-lane highways, and one-way ADT for four-lane highways.

[2] Clear zone measured from edge of travel lane.

HORIZONTAL CLEARANCES ON NEW LOCATION
AND MAJOR RECONSTRUCTION PROJECTS

Figure 4-15A Refers to Paragraph 4-202(g)8



1 Average ADT over project life, i.e., 0.5 (present ADT + design year ADT). Use two-way ADT for two-lane highways, and one-way ADT for four-lane highways.

2 Lateral offset measured from edge of travel lane.

3 Where the design treatment selected is culvert extension, the minimum and desirable design offsets are shown in Figure 4-15A.

HORIZONTAL CLEARANCES TO CULVERT ENDS, MINOR RECONSTRUCTION PROJECTS

Figure 4-15B Refers to Paragraph 4-202(g)8

DESIGN - URBAN STREETS (4-300)

4-301 GENERAL

The term "urban street" as used in this publication refers to roadways in developed areas which provide access to abutting property as well as movement of vehicular traffic. Access for these facilities is controlled only through driveway locations, pavement markings, and the possible use of curbed medians where more positive medial access control is needed. Freeways, both urban and rural, are treated in a subsequent section.

4-302 BASIC DESIGN FEATURES

Figures 4-16 and 4-17 show tabulated basic geometric design criteria for urban arterial, collector and local streets. Figure 4-18 shows typical cross sections for curbed urban streets (all classifications) without parking. Cross sections for curbed urban *arterial* streets with parking are shown in Figure 4-19; curbed urban *collector* and *local* streets with parking are shown in Figure 4-20.

The basic design criteria shown in Figures 4-16, 4-17, 4-18, 4-19 and 4-20 reflect minimum and desirable values which are applicable to projects on new location or major improvement projects such as widening to provide additional lanes. For minor rehabilitation projects where no additional lanes are proposed, existing curbed cross sections should be compared with the standard designs shown herein to determine the practicality and economic feasibility of minor widening to meet the prescribed standards. Where only minimal widening is required to conform with a standard design, it is often cost-effective to retain the existing street section thereby sparing the cost of removing and replacing concrete curb and gutter.

(a) Access Control

Frontage roads used in combination with urban streets introduce a hazard where the frontage road and arterial intersect a crossroad at-grade. The added hazard results in part from the increase in the number of conflicting movements and from the confusing pattern of roadways and separations which may lead to wrong-way entry. The multiple (usually three), closely spaced at-grade intersections inevitably introduce design and control problems which are far more complex than when the street is a single (i.e., not flanked by frontage roads) roadway intersecting a cross street. In this regard, frontage roads are generally inappropriate for use in urban areas except for application in freeway design.

Access driveways shall be installed in accordance with the Departmental publication "Regulations for Access Driveways to State Highways."

(b) Medians

Medians are desirable for urban streets with four or more traffic lanes primarily to provide storage space for left turning vehicles. Medians may be curbed or flush.

1. Curbed Medians

A raised median with curbing is used on urban arterial (non-freeway) streets where it is desirable to prevent mid-block turns. Where the demand for mid-block turns is high, this design may be inappropriate since operational problems may result due to the heavy concentration of left turns at intersections. Curbed medians are more appropriate where driveways are infrequent and/or low volume, such as through residential areas, parks, etc.

GEOMETRIC DESIGN STANDARDS

Urban Arterial Streets Without Access Control		
	Desirable	Minimum
Design Speed (mph)	50	30
Max. Horiz. Curvature (degrees)	5	--
Intersection Curb Radii (feet)	30 - 50	15 - 25
Max. Gradient (percent)	6	See Fig. 4-9
Stopping Sight Distance (feet)	450	200
Width of Travel Lanes (feet)	12	11
Width of Refuge Lanes (feet)	12	10
Median Width (feet)	14 (usual) or more	11
Curb Offset (feet)	2	1
R.O.W. Width	Determined by local conditions	
Structure Widths	Curb-to-curb and sidewalk(s)	
Vertical Clearance (feet)	16.5	*
Clear Recovery Zone Width (feet)	Border Width	2
Superelevation	yes	none
Parallel Parking Lane Width (feet)	12	10 **
Border Width (feet)	12 or more	8
Walkway Width (feet)	6 ***	4
Bicycle Facility Widths (feet)		
a. Reserved Lane On-Street		
1. One way	4	3.5
2. Two way	8	7
b. Separate Trail (two way)	8	7

* 16.5' usual minimum, exceptional cases near as practical to 16.5' but never less than 14.5'.

** Minimum parking lane width is twelve (12) feet where adjacent travel lane is eleven (11) feet in width.

*** Applicable for commercial areas or major school route.

Fig. 4-16

Urban Collector and Local Streets		
	Desirable	Minimum
Design Speed (mph)		
Local	30	30
Collector	40	30
Max. Horiz. Curve (radius, feet)		
Local	400	200*
Collector	700	400*
Intersection Curb Radii (feet)	30	15
Maximum Gradient (%)		
Local	8	12
Collector	7	8
Stopping Sight Distance (feet)		
Local	200	200
Collector	275	200
Width of Travel Lanes (feet)	12	11 **
Width of Refuge Lanes (feet)	12	10
Median Width (feet)	14 (usual) or more	11
Curb Offset (feet)	2	1
R.O.W. Width	Determined by local conditions	
Structure Width		
Curbed Streets	Curb-to-curb and sidewalk(s)	
Uncurbed Streets		
ADT = 400 vpd or greater	Pavement & Shoulders	Pavement + 6'
ADT = Less than 400 vpd	Pavement & Shoulders	Pavement + 4'
Vertical Clearance (feet)	16.5	14.5
Clear Recovery Zone (feet)	Border Width	2
Superelevation	Yes	None
Parallel Parking Lane Width (feet)	10	8 ***
Border Width (feet)	Sidewalk + 8	Sidewalk + 4
Walkway Width (feet)	-	4
Bicycle Facility Widths	See Fig. 4-16	

* Absolute minimum with superelevation is R = 115' for Local, and R = 275' for Collector.

** Ten-foot lanes may be used in residential areas where available or attainable width of right of way imposes severe limitations.

*** Eight-foot minimum width applicable in residential areas; ten-foot minimum width appropriate in commercial and industrial areas.

Fig. 4-17

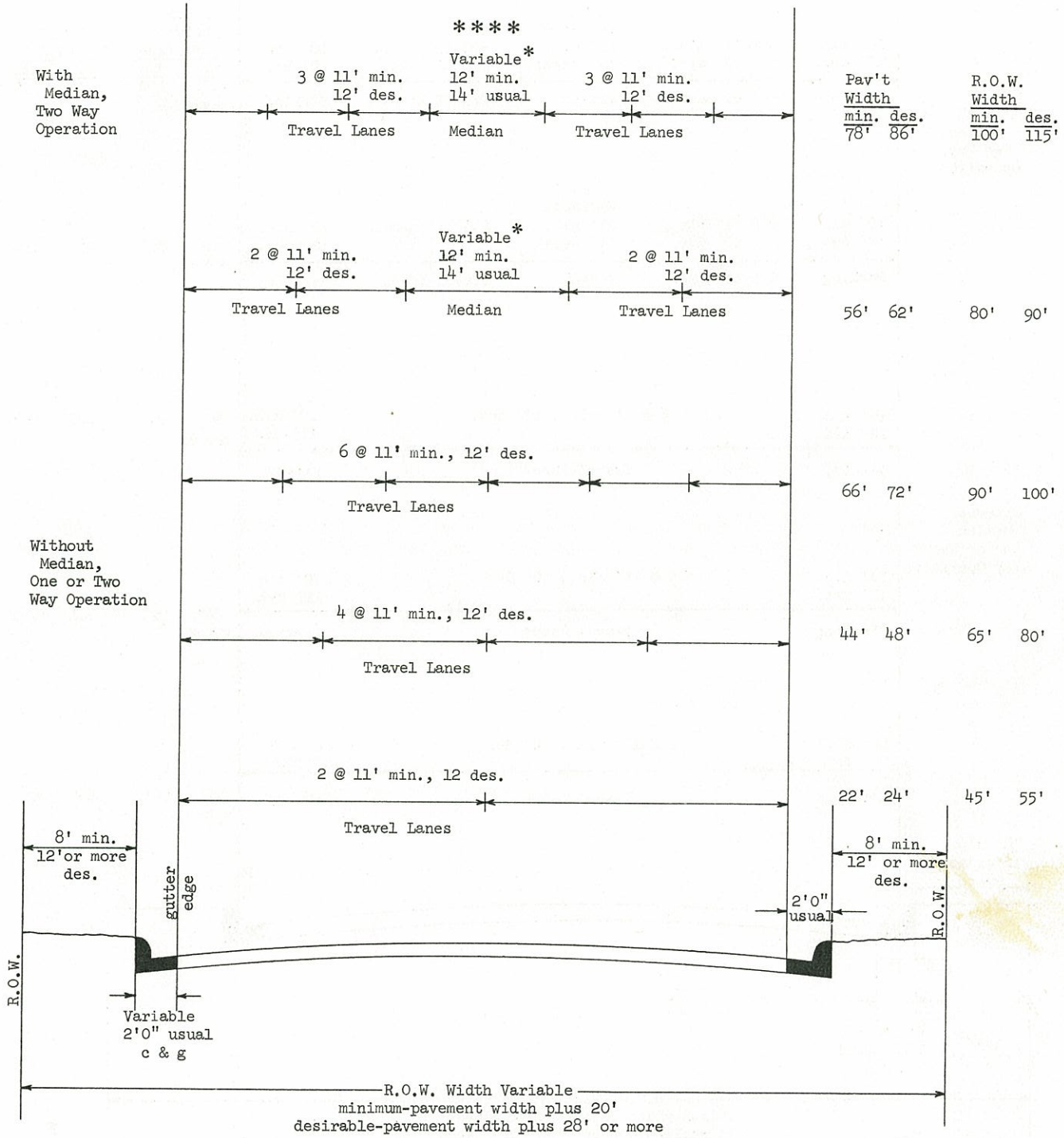


FIG. 4-18 STANDARD CURBED CROSS SECTIONS - URBAN STREETS WITHOUT PARKING (Arterial, Collector, and Local Streets)

* Median width of 11' may be used for streets with maximum legal speed of 30 mph with two way left turn lane operation.

**** For six lane facilities with medians, refuge area for pedestrains may be required in the median depending on signalization phasing. Where required, a medial divider of six (6) feet in width is necessary for pedestrian storage, resulting in a sixteen (16) feet minimum and eighteen (18) feet desirable median width.

Note: In industrial areas, minimum lane width 12'.

(Refers to Paragraph 4-302)

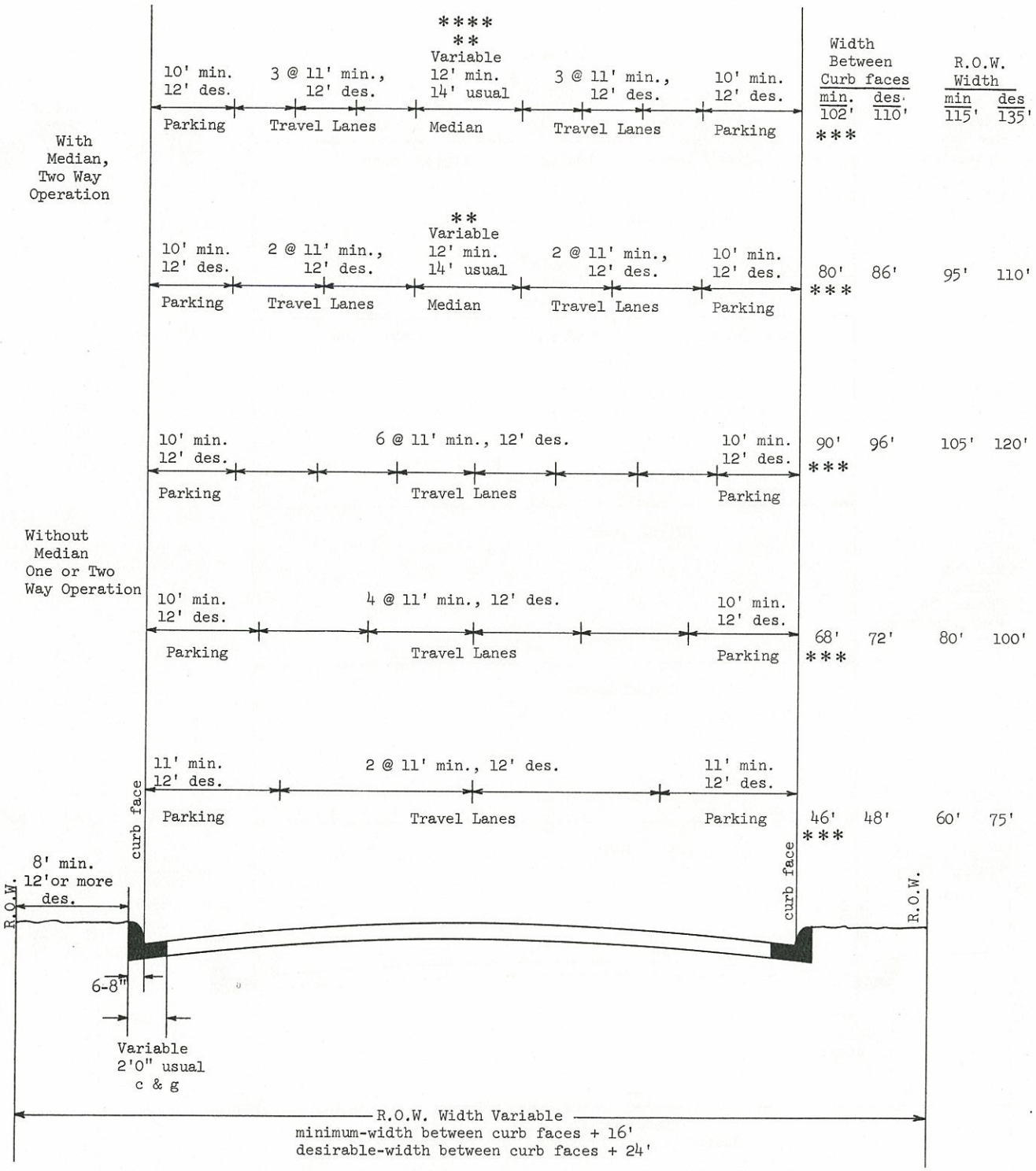


FIG. 4-19 STANDARD CURBED CROSS SECTIONS - URBAN ARTERIAL STREETS WITH PARKING

Note: In industrial areas, minimum lane width 12'.

** Two way left turn medians 11' wide may be used where maximum legal speed is 30 mph.

*** Where minimum (11') travel lane widths are used, parking lanes twelve (12) feet in width should be provided.

**** For six lane facilities with medians, refuge area for pedestrians may be required in the median depending on signalization phasing. Where required, a medial divider of six (6) feet in width is necessary for pedestrian storage, resulting in a sixteen (16) feet minimum and eighteen (18) feet desirable median width.

(Refers to Paragraph 4-302)

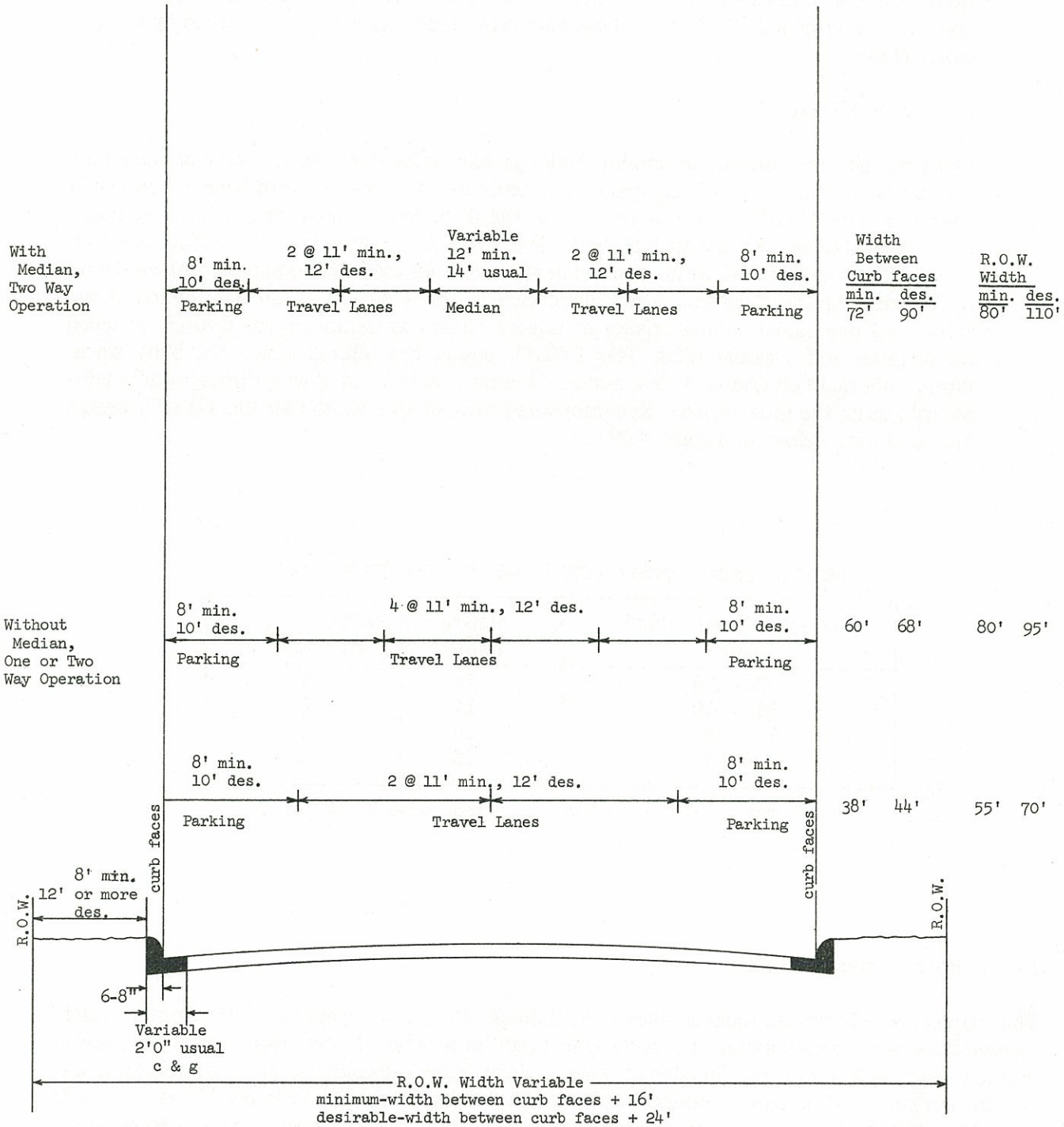


FIG. 4-20 STANDARD CURBED CROSS SECTIONS - URBAN LOCAL & COLLECTOR STREETS WITH PARKING

(Refers to Paragraph 4-302)

Note: In commercial or industrial areas, minimum lane width 12' and parking lane width 10' minimum, 12' desirable. In residential areas, parking lane width 8' minimum.

Curbed medians should be minimally 12 feet (10' storage lane plus 2' divider) and desirably 14 feet (10-12' storage lane and 4' and 2', respectively, divider) in width. Wider medians are receptive to landscaping, but with widths exceeding 20 feet cross street left turning traffic may cause intersection "lock-up" where both cross street approaches are served by a single signal phase.

2. Flush Medians

Flush medians may include pavement markings delineating directional turning bays, or they may be used where appropriately marked as continuous two-way left turn lanes (abbreviated TWLTL). The TWLTL design allows use of the flush median area for left turns by traffic from either direction on the arterial street. The TWLTL is appropriate where there is a high demand for mid-block left turns, such as in areas with (or expected to experience) moderate or intense strip development. Used appropriately, the TWLTL design has improved the safety and operational characteristics of arterial streets as demonstrated through reduced travel times and accident rates. The TWLTL design has offered added flexibility since, during spot maintenance activities, a travel lane may be barricaded with through traffic temporarily using the median lane. Recommended median lane widths for the TWLTL design are as shown below in Figure 4-21:

MEDIAN LANE WIDTHS FOR TWO-WAY LEFT TURN LANES

MAXIMUM LEGAL SPEED (mph)	WIDTH OF TWLTL (Ft.)	
	Usual	Minimum
0 - 30	14	11
35 - 40	14	11
45 - 50	14	12
over 50	16	16

Figure 4-21 Refers to Paragraph 4-302(b)2

(c) Borders and Sidewalks

The border, which accommodates sidewalks, utilities, etc., and separates traffic from privately owned areas, is the area between the roadway and right of way line. Every effort should be made to provide wide borders to serve functional needs, reduce traffic nuisances to adjacent development, and for aesthetics. Minimally, borders should be about 8 feet wide and desirably 12 feet or more. Sidewalks should be 4 feet in width minimum with increased widths applicable near schools, commercial areas, or other areas with high pedestrian volumes.

(d) Bicycle Facilities

Bicycle facilities, both on-street and independently aligned, are discussed in Appendix G entitled "Bikeways."

(e) Grade Separations and Interchanges

Although grade separations and interchanges are not often provided on urban streets, they may be the only means available for providing sufficient capacity at critical intersections. Normally, a grade separation is part of an interchange (except grade separations with railroads), usually the diamond type where there are four legs. Locations considered include high volume intersections and where terrain conditions favor separation of grades.

The entire roadway width of the approach, including parking lanes or shoulders if applicable, should be carried across or under the separation. Interchange design elements may have lower dimensional values as compared to freeways due to the lower speeds involved. For example, diamond ramps may have lengths controlled by the minimum distance to overcome the elevation difference at suitable gradients.

In some instances, it may be feasible to provide grade separations or interchanges at all major crossings for a lengthy section of arterial street. In these cases, the street assumes the operating characteristics and appearance of a freeway. In this regard, where right of way availability permits, it may be appropriate to eliminate the relatively few crossings at-grade and control access by design (i.e., provide continuous frontage roads) in the interest of safety. It is not desirable, however, to intermix facility types by providing intermittent sections of fully controlled and non-controlled access facilities.

(f) Right of Way Width

The width of right of way for urban streets is influenced by traffic volume requirements, land use, cost, extent of ultimate expansion, and its availability. The minimum and desirable widths are the summation of the various minimum and desirable cross sectional elements, including widths of travel lanes, shoulders or parking lanes, median, borders, and the area necessary to accommodate slopes and provide ramps or connecting roadways where interchanges are involved.

(g) Intersections

The number, design, and spacing of intersections influence the capacity, speed, and safety on urban streets. Capacity analysis of signalized intersections, as discussed in Appendix D, is one of the most important considerations in intersection design. Dimensional layout or geometric design considerations are closely influenced by traffic volumes and operational characteristics and the type of traffic control measures used.

Because of space limitations and lower operating speeds on urban streets, curve radii for turning movements are less than for rural highway intersections. Curb radii of 15 to 25 feet permit passenger cars to negotiate right turns with little or no encroachment on other lanes. Where heavy volumes of trucks or buses are present, increased curb radii of 30 to 50 feet expedite turns to and from through lanes.

In general, intersection design should be rather simple, free of complicated channelization, to minimize driver confusion. Sight distance is an important consideration even in the design of signalized intersections since, during the low volume hours, flashing operation may be used.

(h) Speed Change Lanes

On urban arterial streets, speed change lanes generally provide space for the deceleration and possibly storage of turning vehicles. Acceleration lanes are not usually provided on low speed urban streets.

Figure 4-22 shows taper and storage lengths for urban streets. A short curve is desirable on each end of the taper, but may be omitted for construction ease. Where reverse curves are used, the intervening tangent should be one-third to one-half of the total taper length, and the turnoff curve should be about twice the radius of the second curve.

(i) Parking

Where permitted, parking should be parallel on urban arterial streets. Where feasible, parking should be restricted at least during the peak hours and preferably at all times. Parking should be restricted in the vicinity of bus stops and at least 20 feet from intersection crosswalks.

4-303 BUS FACILITIES

Urban areas benefit from the effective bus utilization of downtown and radial arterial streets, and from the effective coordination of transit and traffic improvements. To maintain and increase bus patronage, bus priority treatments on arterial streets may be used to underscore the importance of transit use. Possible bus priority treatments on non-controlled access facilities include measures designed to separate car and bus movements and general traffic engineering improvements designed to expedite overall traffic flow.

(a) Bus Lanes

Bus lanes are usually used exclusively by buses; however, in some instances carpools, taxis, or turning vehicles may share the lane. They may be located along curbs or in street medians and may operate with or counter to automobile flow.

1. Curb Bus Lanes (normal flow)

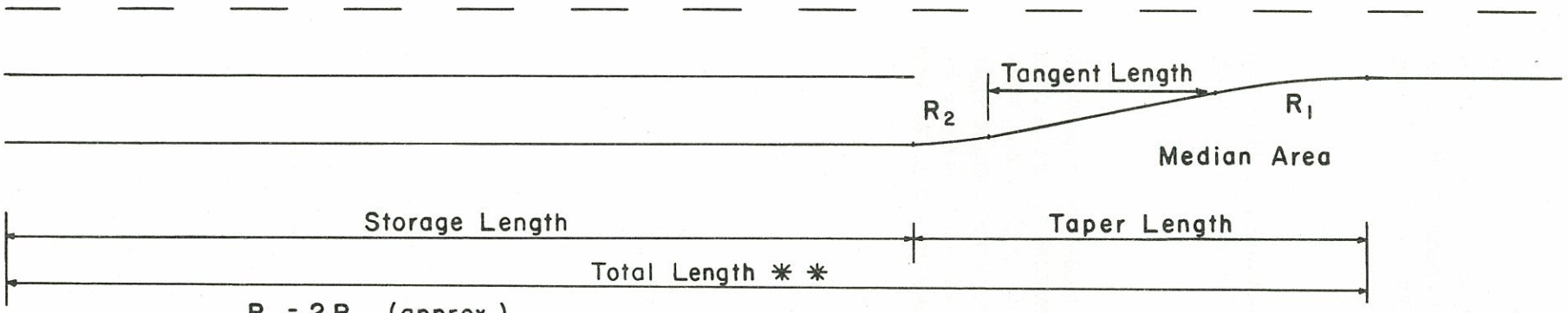
Curb bus lanes in the normal direction flow are usually in effect only during the peak periods. They are usually implemented in conjunction with removal of curb parking so that there is little adverse effect on existing street capacity. This type of operation may be difficult to enforce and may produce only marginal benefits to bus flow. In operation, right turning vehicles conflict with buses.

2. Median Bus Lanes

Median bus lanes generally are in effect throughout the day. Wide medians are required to provide refuge for bus patrons, and passengers are required to cross active street lanes to reach bus stops. Additionally, left turn traffic must be prohibited or controlled to minimize interference between transportation modes.

3. Contraflow Bus Lanes

Contraflow bus lanes, in which buses operate opposite to normal traffic flow, should be used



$R_1 = 2R_2$ (approx.)
Tangent Length = (1/3 To 1/2) (taper length)
Taper length and storage length from table.

FIG. 4-22 Refers to Paragraph 4-302(h)

LENGTHS OF SPEED CHANGE LANES - URBAN STREETS * * *

Design Speed (mph)	Taper Length (feet) minimum	Storage Length (feet) * * * *			
		Signalized		Non - Signalized	
		min.	des.	min.	des.
30	80	*See	170	50	170
40	125	note	245	75	245
50	180	below	320	100	320

* Based on design hour volume, Storage Length = (2) (average no. of vehicles stored per signal cycle)

* * Total length of speed change lane = Storage Length + Taper Length

* * * Applicable to speed change lanes to accommodate left or U-turns at median openings or intersections; applies also to speed change lanes for right turns where desired.

* * * * Block spacing may dictate lesser values

only on one-way streets without parking. They are "self enforcing" with heavy transit traffic although a left turn conflict is introduced with opposing traffic. In central business districts or other areas with closely spaced signalized intersections, buses may operate against signal progression. In certain instances, the lanes may complicate loading and access to adjoining properties.

(b) Bus Streets

Reserving entire streets for the exclusive use of buses represents a major commitment to transit and generally is not feasible due to adverse effects on abutting properties and businesses, including parking garages or lots, drive-in banks, etc.

(c) Traffic Engineering Improvements

Coordination of street improvement projects with bus service needs increases overall street efficiency. Street improvements that relieve bottlenecks improve transit operations as well as other traffic operations. The range of traffic engineering projects that enhance bus service include: street extensions or widening to improve bus routing continuity or increase traffic capacity; traffic signal improvements such as system coordination, modernization, and preemptions or overrides for buses; intersection improvements; provision of bus turnouts for loading and unloading, bus stop lengthening or relocation; and extension of parking regulations.

DESIGN-MULTILANE RURAL HIGHWAYS (4-400)

4-401 GENERAL

The general geometric features for multilane rural highways without access control are outlined in Figures 4-23, 4-24 and 4-25 and discussed in subsequent paragraphs.

4-402 BASIC DESIGN FEATURES

(a) Access Control

The installation of all access driveways along multilane facilities from adjacent property connecting to the mainlanes shall be in accordance with the Departmental publication entitled "Regulations for Access Driveways to State Highways."

For multilane highways constructed in developed (or expected to be developed) areas, such as by-passes in close proximity to urban areas, it may be desirable to control access to the mainlanes by design (i.e., provision of frontage roads). Where desired, control of access by design may be provided only in the interchange areas or continuously, depending on traffic volumes, the degree of roadside development, availability of right-of-way, economic conditions, etc.

(b) Medians

Insofar as practical, wide (desirably 76 feet) medians should be used to provide sufficient storage space for tractor-trailer combination vehicles at median openings, reduce headlight glare, provide a pleasing appearance, and reduce the chances of head-on collisions.

1. Four Lane Undivided Highways

Improvement of an existing two lane highway to a four lane highway facility preferably should include a median. Undivided highways may be constructed as betterment projects for existing two lane highways to improve passing opportunities and traffic operation. Undivided highways are thus typically provided in rolling terrain, or where restricted right-of-way conditions and moderate traffic volumes (up to ADT of 7500 in design year) dictate. Figures 4-23 and 4-24 include the general geometric features for four lane undivided highways.

2. Narrow Medians

Medians of 4' to 16' are classified as narrow medians and are used in restricted conditions. Medians 4' wide provide little separation of opposing traffic and a minimal refuge area for pedestrians. Narrow medians of 12' to 16' offer space for a median lane for use by exiting traffic turning left, but do not offer protection for crossing vehicles. Narrow median designs are most appropriate in areas with roadside development.

3. Wide Medians

Medians 76' in width significantly reduce headlight glare, are pleasing in appearance, reduce the chances of head-on collisions, and provide a sheltered storage area for crossing vehicles, including tractor-trailer combinations. Wide medians should be used whenever feasible.

STANDARDS OF DESIGN FOR MULTI-LANE RURAL HIGHWAYS
(NON-CONTROLLED ACCESS)

HIGHWAY CLASS		CLASS 6L		CLASS 4L		CLASS 4L UNDIVIDED[7]	
Average Daily Traffic (ADT)[1]		20,000 or more		5000 to 20,000		Up to 7500	
Design Hourly Volume (DHV)[2]		1600 to 2400		400 to 1600		Up to 600	
Design Speed		Des.	Min.	Des.	Min.	Des.	Min.
Flat		80	60[3]	80	60[3]	80	60[3]
Rolling		70	60[4]	70	60[4]	70	60[4]
Mountainous (Use AASHO Standards)							
Lane Width (Ft.)		← 12 →					
Median Width (Ft.)	Narrow	16	4	16	4	0	
	Depressed	76	48	76	48		
Shoulder Outside (Ft.)		10	8	10	8	10	8[8]
Shoulder Inside (Ft.)		4	2[5]	4	2[5]	Not Applicable	
Bridge Width (Ft.)	Narrow Med.	108	92	84	68	68	64[9]
	Depressed Med.	50	42[6]	38	30[6]		

1 ADT at design year (equivalent passenger vehicles per day, flat terrain, ideal conditions, 20 years from date of construction).

2 One-way DHV (equivalent passenger vehicles per hour, flat terrain, ideal conditions, 20 years from date of construction).

3 55 mph acceptable for heavy betterment under unusual circumstances. Otherwise, 60 mph should be minimum.

4 50 mph acceptable for heavy betterment under unusual circumstances. Otherwise, 60 mph should be minimum for rural design.

5 Applicable only to four lane divided with 4 ft. flush median.

6 Pertains only to existing bridges to be retained. All new or widened bridges to be width of approach roadway, including shoulders.

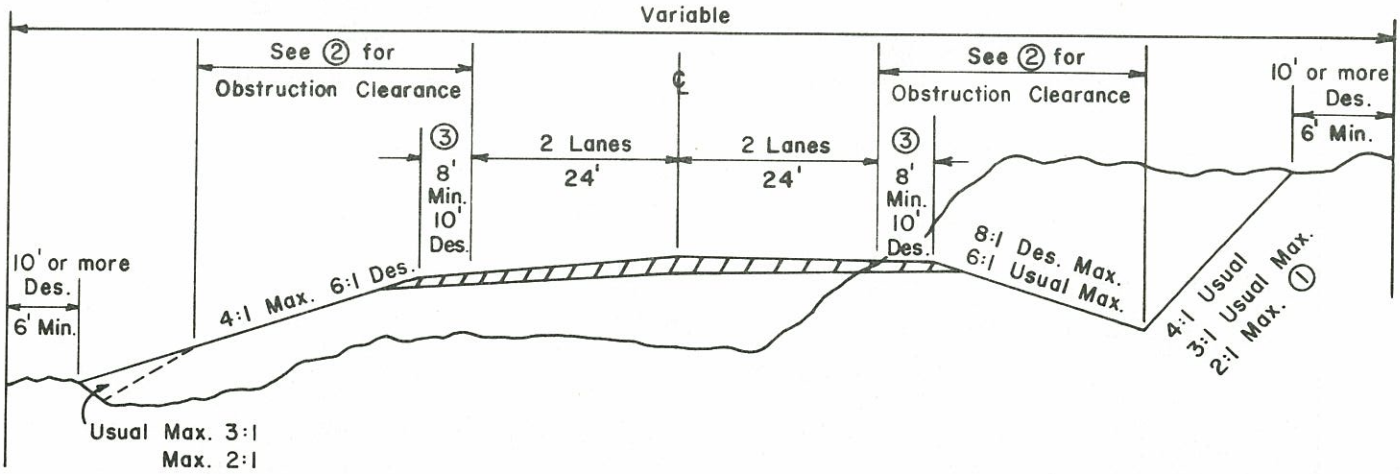
7 Undivided section may be used on betterment projects of two lane highways to improve passing opportunities. Most appropriate for use for rolling terrain and/or restrictive right of way conditions.

8 Outside surfaced shoulder width may be decreased to 4 feet where flat (10:1 desirable, 8:1 minimum), sodded front slopes are provided for a minimum distance of 4 feet from the shoulder edge.

9 Bridge width of 56 feet may be retained; all new or widened bridges to be width of approach roadway, including shoulders.

Figure 4-23 Refers to Paragraph 4-401

CROSS SECTIONS FOR MULTILANE RURAL HIGHWAYS
(ADT 7500 OR LESS)



TYPICAL MULTILANE SECTION
UNDIVIDED HIGHWAY

(1) Slope may be exceeded in rock cuts.

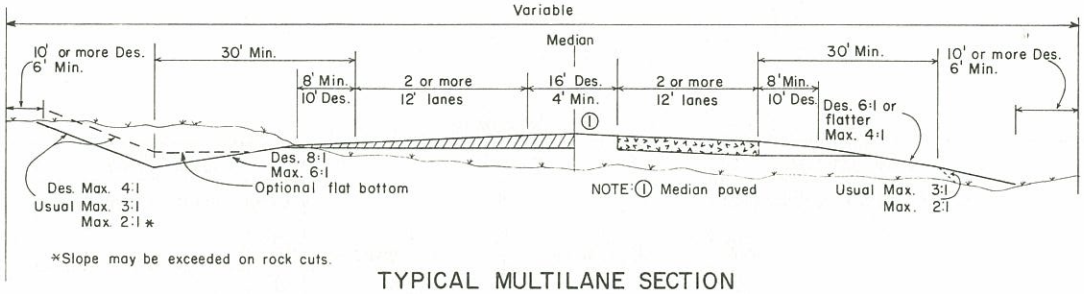
(2) Thirty (30) feet usual minimum, except for low volume facilities (See Paragraph 4-202 (g) 8 and related Figures 4-15A and 4-15B).

(3) Shoulders desirably and usually fully surfaced. Partial shoulder surfacing four (4) feet in width permissible where remaining shoulder width is sloped at 8:1 (desirably 10:1) and sodded.

NOTE: All existing structures to be retained shall be fifty-six (56) feet or wider. New or widened structures minimally shall be width of approach roadway including shoulders.

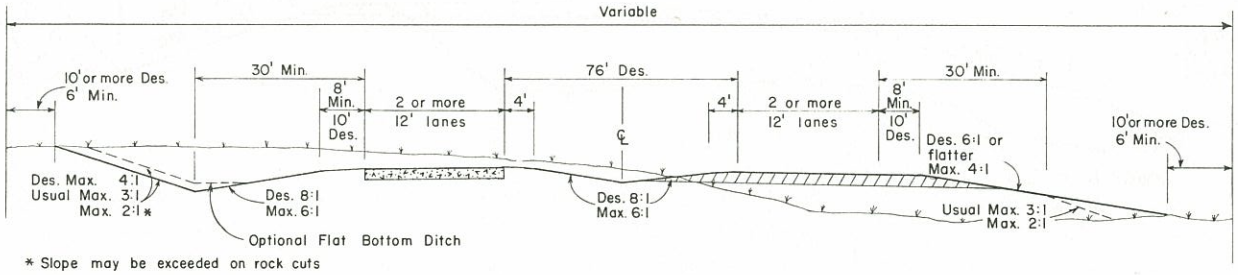
FIG. 4-24 Refers to Paragraph 4-401

CROSS - SECTIONS FOR MULTI-LANE RURAL HIGHWAYS
(ADT 5000 OR MORE)



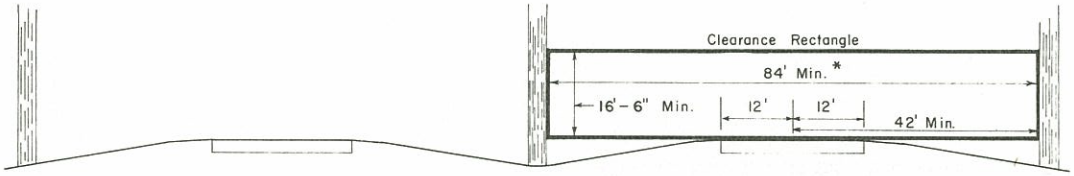
*Slope may be exceeded on rock cuts.

TYPICAL MULTILANE SECTION
Narrow Median



* Slope may be exceeded on rock cuts

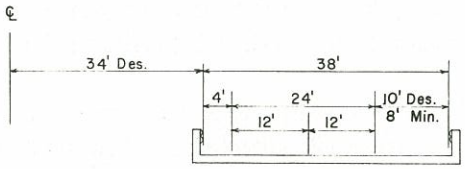
TYPICAL MULTILANE SECTION
Depressed Median



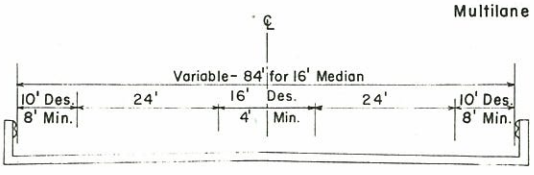
* Where future lanes are anticipated, add 12' to width of clearance rectangle for each added lane.

CLEARANCE REQUIREMENTS
MULTILANE HIGHWAY

NOTE: To determine ROW required, determine Appropriate R_L and R_R from Figure 4-32 and add width of median plus number of lanes above two.



STRUCTURE SECTION
Multilane Depressed Median



STRUCTURE SECTION
Multilane Narrow Median

FIGURE 4-25 Refers to Paragraph 4-401

(c) Median Openings

Median openings at close intervals on divided highways create undue hazard and interference with high speed through traffic. The frequency of median openings varies with topographic restrictions and local requirements; however, as a general rule the minimum spacing should not be less than one-fourth mile in rural areas. Spacing often is selected so as to provide openings at all public roads and at major traffic generators such as industrial sites or shopping centers, with additional openings provided so as not to surpass a maximum one-half mile spacing. Left turn bays should be provided at all median openings. At intersections with highways or other major public roads, speed change lanes for right turning vehicles entering and exiting the highway desirably should be provided. For divided highways with independent mainlane alignment, particular care should be exercised at median openings to provide a satisfactory profile along the cross-over with flat, platform approaches to the mainlanes.

Median opening width should in no case be less than 40' nor less than cross-road pavement width plus 8'. Turning templates for a selected control radius and design vehicle are often used as the basis for minimum design of median openings, particularly for multilane cross-roads and skewed intersections.

(d) Speed Change Lanes

1. Median Speed Change Lanes

Median speed change lanes provide deceleration and storage area for vehicles making left turns to leave a divided highway. Storage and taper lengths for design are summarized in Figure 4-26.

LENGTHS OF MEDIAN SPEED CHANGE LANES - MULTILANE RURAL HIGHWAYS

Turning DHV, vph	30	60	100	200	300
Minimum Storage length, feet	25	50	100	175	250
Design Speed	50	60	70		
Taper length, feet	180	245	320		

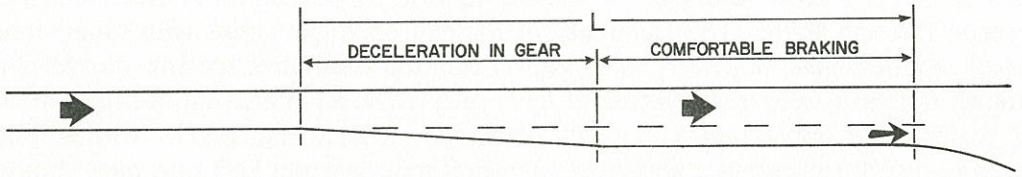
Note: For low volume median openings, such as those serving private drives or U-turns, taper length of 180' may be used regardless of main lane design speed.

Figure 4-26 Refers to Paragraph 4-402(d)

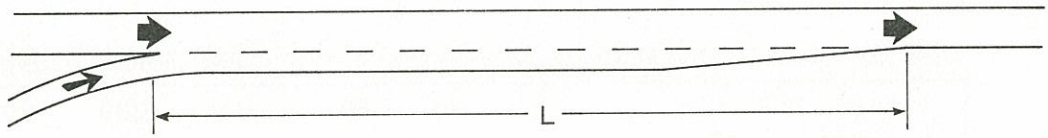
2. Right Speed Change Lane

Right side speed change lanes provide deceleration or acceleration area for right turning vehicles. Design criteria for right side speed change lanes are shown in Figure 4-27.

LENGTHS OF RIGHT TURN SPEED CHANGE LANES FOR NON-CONTROLLED ACCESS HIGHWAYS



HIGHWAY DESIGN SPEED MPH	MINIMUM LENGTH OF TAPER (FEET)	L-LENGTH OF DECELERATION LANE-FEET FOR DESIGN SPEED OF EXIT CURVE-MPH								
		STOP CONDITION	15	20	25	30	35	40	45	50
		FOR AVERAGE RUNNING SPEED ON EXIT CURVE-MPH								
		0	14	18	22	26	30	36	40	44
30	150	235	185	160	140	——	——	——	——	——
40	190	315	295	265	235	185	155	——	——	——
50	230	435	405	385	355	315	285	225	175	——
60	270	530	500	490	460	430	410	340	300	240
65	290	570	540	530	490	480	430	380	330	280
70	300	615	590	570	550	510	490	430	390	340
75	315	660	630	610	590	560	530	470	440	390
80	330	700	680	660	640	610	580	530	490	450



HIGHWAY DESIGN SPEED MPH	MINIMUM LENGTH OF TAPER (FEET)	L-LENGTH OF ACCELERATION LANE-FEET FOR ENTRANCE CURVE DESIGN SPEED, MPH								
		STOP CONDITION	15	20	25	30	35	40	45	50
		AND INITIAL SPEED, MPH								
		0	14	13	22	26	30	36	40	44
30	150	190	——	——	——	——	——	——	——	——
40	190	380	320	250	220	140	——	——	——	——
50	230	760	700	630	680	500	380	160	——	——
60	270	1,170	1,120	1,070	1,000	910	800	590	400	170
70	290	1,590	1,540	1,500	1,410	1,330	1,230	1,010	830	580

NOTE: Where lengths exceed 1,300 feet, or design speeds exceed 70 mph, uniform 50:1 tapers are recommended.

FIGURE 4-27 Refers to paragraph 4-402 (d) 2.

(e) Transition from Two-Lane to Four-Lane Divided

Typical transitions from two lane to four lane divided are shown in Figure 4-28. The transition should be visible to the driver approaching from either direction and median openings should not be permitted within 1300' of the transition area. Transition areas should be located so that obstructions such as restrictive width bridges or underpasses or other fixed objects are not within the no-passing zone or the two lane highway approach.

(f) Pavements and Shoulders

1. Pavements

Travel lanes should be twelve feet minimum width on rural multilane highways. For narrow, depressed median sections, it may be necessary to effect superelevation across the entire cross section to provide for safer operation at median openings.

2. Shoulders

Stabilized (usually and desirably surfaced) shoulders should always be provided with widths as shown in Figures 4-23, 4-24 and 4-25.

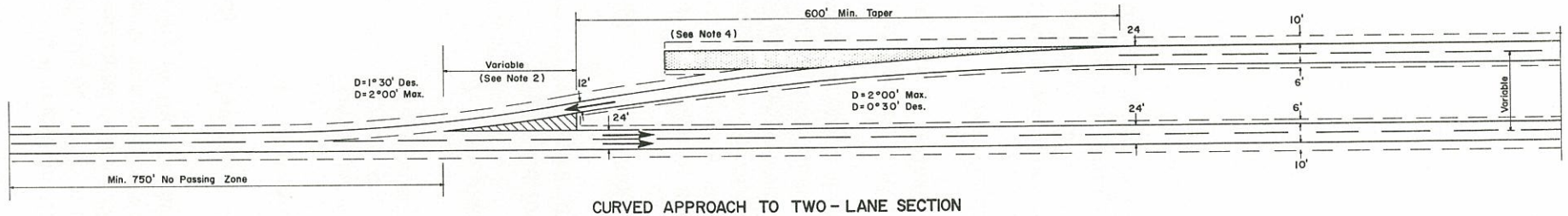
(g) Intersections

In the design of intersections, careful consideration should be given to the appearance of the intersection to the driver. In this regard, design should be rather simple to avoid driver confusion, and adequate sight distance should be provided throughout, especially in maneuver or conflict areas. Right angle crossings are preferred to skewed crossings, and where skew angles exceed 60° alignment modifications are generally necessary. Speed change lanes should be provided in accordance with Paragraph 4-402(d).

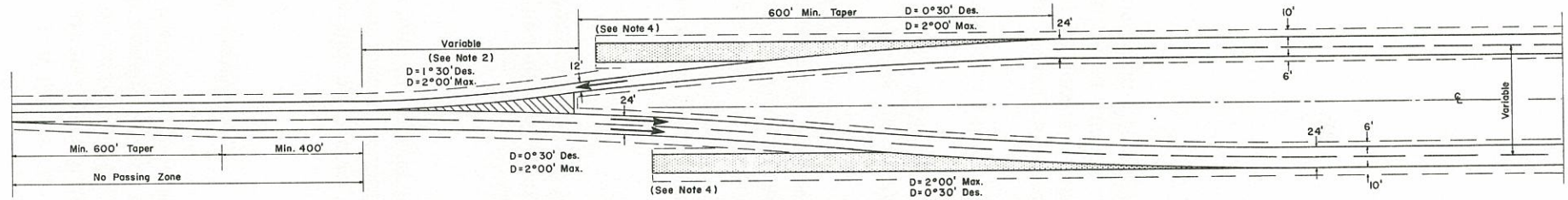
Intersections formed at by-pass and existing route junctions should be designed so as not to mislead drivers as typified in Figure 4-29.

(h) Grade Separations and Interchanges

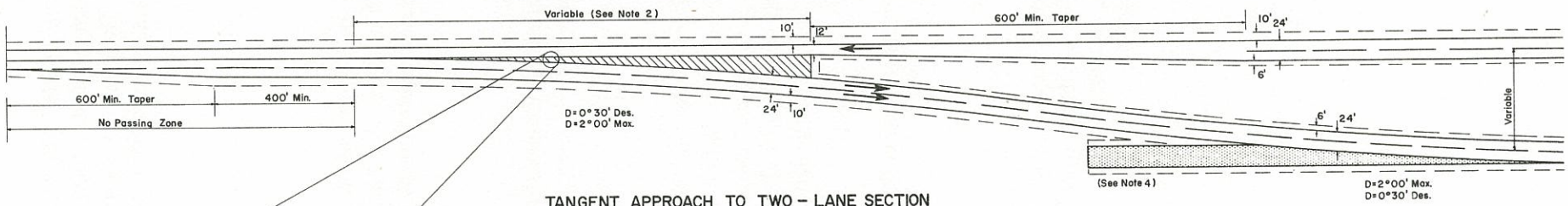
Grade separations or interchanges on multilane rural highways may be provided at high volume highways, railroads, or to increase safety at accident-prone crossings. Where interchanges are provided in urban area fringes such as along by-pass routes, frontage roads may be appropriate to control access as discussed in Paragraph 4-402(a).



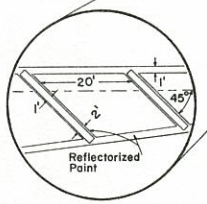
CURVED APPROACH TO TWO - LANE SECTION



EXPANDED SYMETRICALLY ABOUT CENTERLINE OF TWO - LANE HIGHWAY



TANGENT APPROACH TO TWO - LANE SECTION



GENERAL NOTES

1. DRAWINGS ARE NOT TO SCALE.
2. THE LATERAL MARKINGS WILL BE CONTINUED UNTIL A MEDIAN WIDTH OF AT LEAST 12 FEET IS REACHED. IF THE WIDTH OF THE MEDIAN DOES NOT REACH 12 FEET, THEN THE MARKINGS WILL BE DISCONTINUED AFTER A LONGITUDINAL DISTANCE OF 500 FEET IS OBTAINED.
3. PAVEMENT MARKINGS WILL CONFORM TO THE TEXAS MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES.
4. WHERE THE FOUR-LANE PAVEMENT IS TO BE EXTENDED IN THE NEAR FUTURE THE FOUR-LANE PERMANENT PAVEMENT SHOULD BE EXTENDED BEYOND THE TRANSITION TO FACILITATE MOVEMENT OF TRAFFIC WHEN THE CONNECTION IS MADE.

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

TYPICAL TRANSITIONS FROM TWO-LANE TO FOUR-LANE DIVIDED HIGHWAY

FIGURE 4-28 Refers to Paragraph 4-402(e)

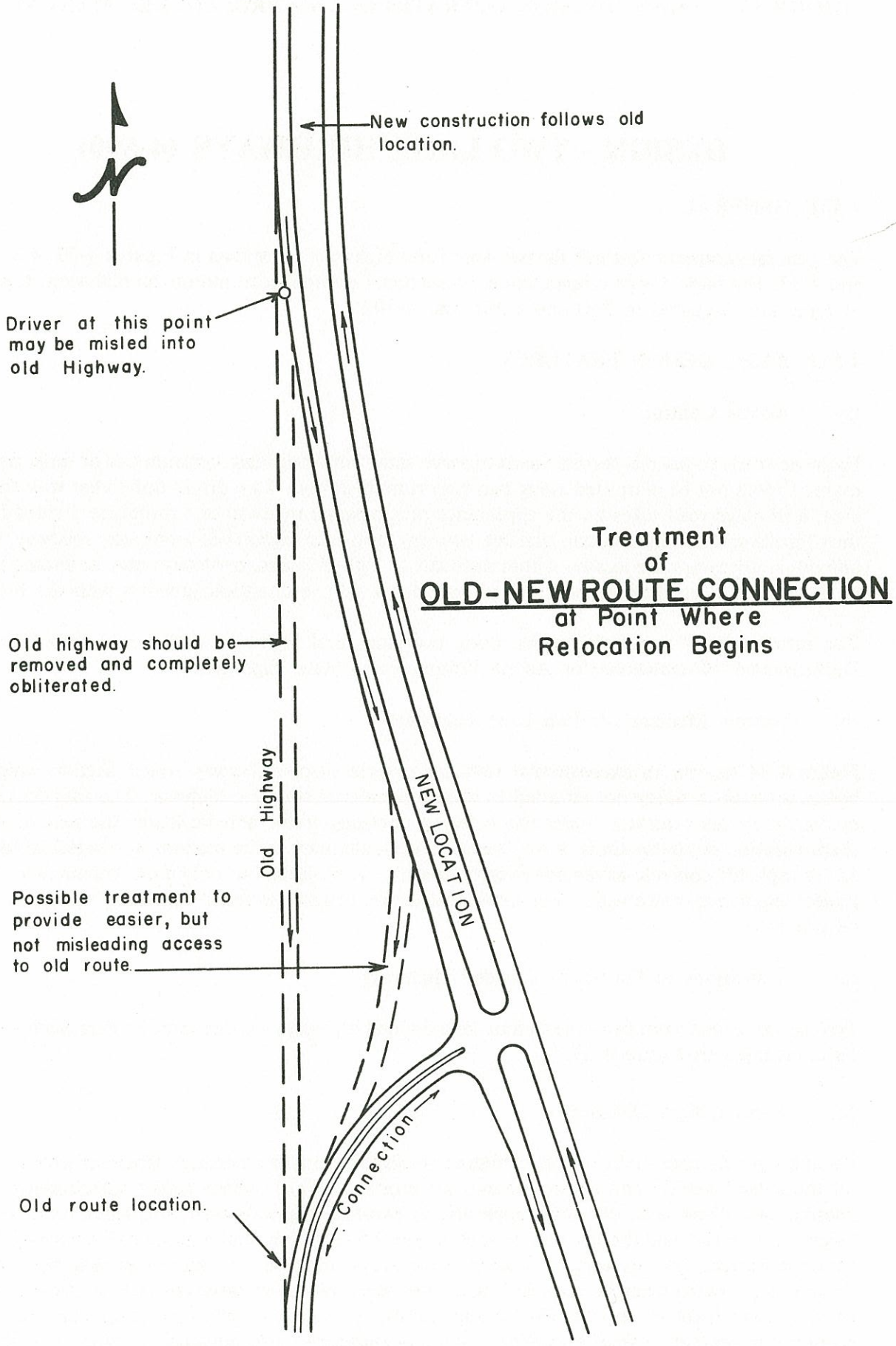


FIGURE 4-29 Refers to Paragraph 4-402(g)

DESIGN - TWO LANE HIGHWAYS (4-500)

4-501 GENERAL

The general geometric features for two-lane rural highways are shown in Figures 4-30, 4-31, 4-32 and 4-33. The basic design criteria and cross sectional elements common to all highways, regardless of type, are discussed in Sections 4-201 and 4-202.

4-502 BASIC DESIGN FEATURES

(a) Access Control

Frontage roads or parallel service roads to serve small rural business communities or other developments should not be permitted along two-lane rural highways. To a driver unfamiliar with the local area, a frontage road takes on the appearance of a separate roadway of a multilane divided facility, thus resulting in the assumption that the two-way, two-lane highway is a one-way roadway. Where individual driveways are located within deep cut or high fill areas, driveways may be routed parallel to the highway for short distances to provide for a safe, economical junction with the highway.

The installation of access driveways along two-lane rural highways shall be in accordance with Departmental "Regulations for Access Driveways to State Highways."

(b) Narrow Medians on Two Lane Highways

Figure 4-34 depicts an experimental two-lane double striped highway typical section which embodies a factor of safety not afforded by the conventional two-lane highway. The four-foot striped median provides a greater separation between opposing traffic and facilitates the introduction of channelization at intersections. It may be used as an alternate to the sections illustrated in Figure 4-32 for asphaltic concrete pavement overlay or seal coat projects, but only if all structures within the project length are crown width. For new construction or reconstruction full width shoulders should be provided.

(c) Transitions to Four-Lane Divided Highways

Typical transitions from two-lane to four-lane divided highways are discussed in Paragraph 4-402(e) and illustrated in Figure 4-29.

(d) Passing Sight Distance

Passing sight distance is the length of highway required to make a passing maneuver without cutting off the passed vehicle and before meeting an opposing vehicle which might subsequently appear. Passing sight distance is, therefore, applicable to two-lane highways only. It is based on driver's eye height of 3.75 feet and the perception of an object 4.5 feet high, and a speed differential of 10 mph between vehicles. In the design of two-lane highways, minimum or greater passing sight distance should be provided wherever practical, since less than minimum distances reduce capacity and adversely affect level of service. For rolling terrain, provision of climbing lanes may be a more economical alternative than achieving a vertical alignment with adequate passing sight distance.

STANDARDS OF DESIGN FOR MODERATE AND HIGH VOLUME

TWO-LANE RURAL HIGHWAYS

HIGHWAY CLASS	HIGH VOLUME (HV)		MODERATE VOLUME (MV)	
Design Year ADT[1] (vpd)	4400 - 7500		2200 - 4400	
Design Year DHV[1] (pcph)	750 - 1400		475 - 750	
Current Year ADT[2] (vpd)				
Design Speed[3] (mph)	Des.	Min.	Des.	Min.
Flat	80	60	80	60
Rolling	70	60[4]	70	50[5]
Structure Widths (ft.)	44	30[6]	44	30[6]
Lane Widths (ft.)	12	12	12	12
Usable Shoulder Width[7] (ft.)	10	8	10	8
Usual Surf.Shoulder Wd.(ft.)	10	8	10	8
Usual Min. Rdside Cl. (ft.)	30		30	
Right-of-Way	See Figures 3-31 and 4-32			

1 Traffic volume in equivalent passenger cars twenty years from the anticipated date of construction.

2 Where average ADT over project life, i.e., 0.5 (present ADT + design year ADT) is 1500 or more, MV or HV standards apply.

3 For mountainous terrain, use AASHTO standards for design speed.

4 50 mph acceptable for heavy betterment of existing highways.

5 40 mph acceptable for heavy betterment of existing highways.

6 Pertains only to existing bridges to be retained. All new or widened bridges shall be width of approach roadway, including usable shoulders (no offset to bridge rail required).

7 "Usable" shoulder width is the actual width that can be used for an emergency or parking stop. Where front slopes are 4:1 or flatter, "usable" shoulder width is the same as "graded" shoulder width. For steeper front slopes, "usable" width should be increased by 2 or 3 feet so that rounding at the intersection of the shoulder and front slope planes does not lessen useful width appreciably.

Figure 4-30 (Refers to Paragraph 4-501)

STANDARDS FOR DESIGN FOR LOW-VOLUME

TWO-LANE RURAL HIGHWAYS

Design Speed (mph)	Traveled Way Widths, Ft.[1]			
	Current ADT[1]			
	0 - 250	250 - 400	400 - 750	750 - 1500
50 or less	20	20	22	24
over 50	20	22	22	24
	Usable Shoulder Widths, Ft.[2]			
All	4	4	6	8
	New Bridge Widths, Ft.			
50 or less	28	28	34	40
over 50	28	34	34	40

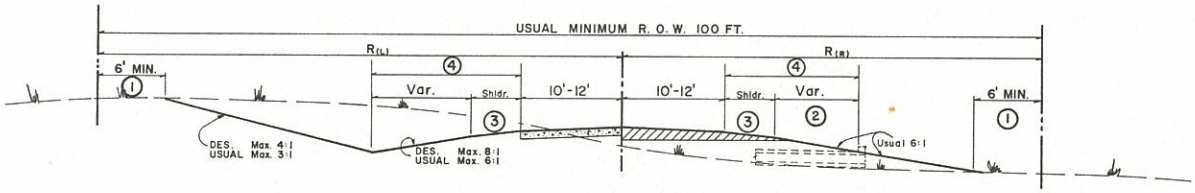
[1] Traffic volume in terms of mixed traffic. For design speeds of 50 mph or less, traveled way widths that are two feet narrower may be used on minor roads with few trucks. Federal-aid projects shall not have the two-foot reduction without prior approval from the FHWA.

[2] Two-foot width of each shoulder may be surfaced.

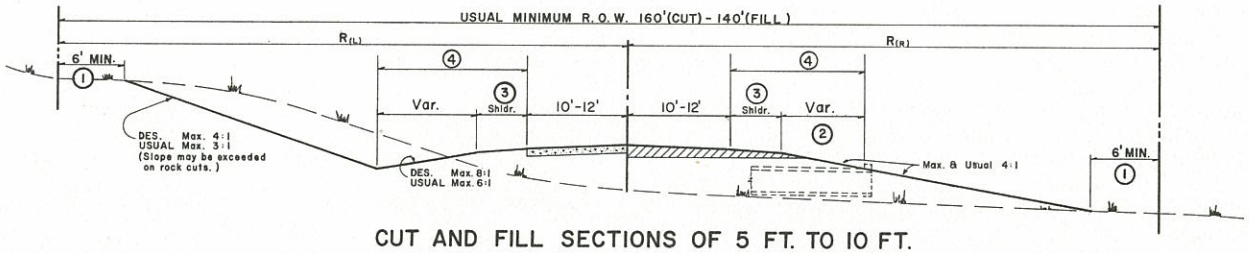
Figure 4-30A (Refers to Paragraph 4-501)

CROSS-SECTIONS FOR LOW VOLUME TWO-LANE RURAL HIGHWAYS

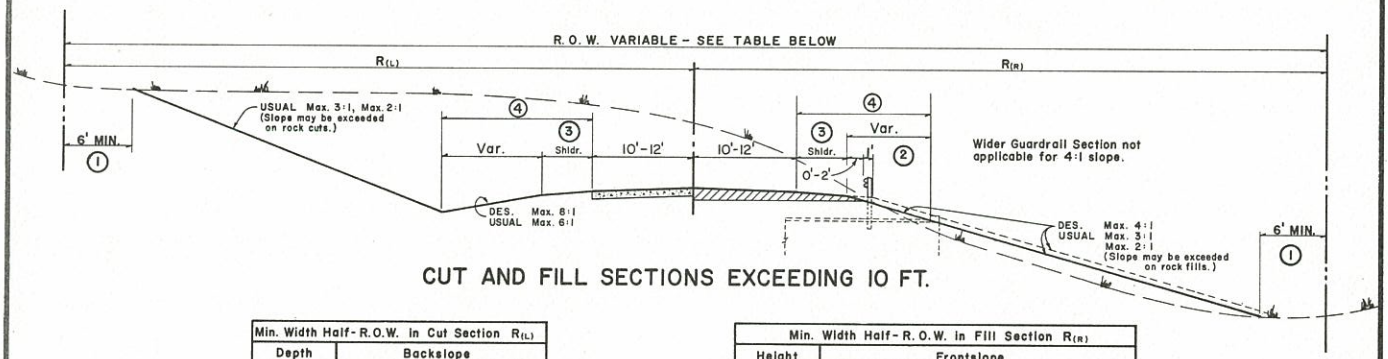
LV LESS THAN 1500 CURRENT YEAR ADT



CUT AND FILL SECTIONS OF 5 FT. OR LESS



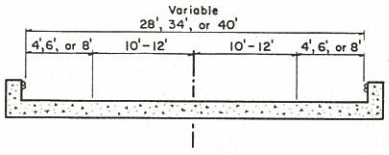
CUT AND FILL SECTIONS OF 5 FT. TO 10 FT.



CUT AND FILL SECTIONS EXCEEDING 10 FT.

Min. Width Half-R.O.W. in Cut Section $R_{(L)}$		
Depth of Cut	Backslope	
	3:1	2:1
15'	95'	80'
20'	110'	90'
30'	140'	110'
40'	170'	130'

Min. Width Half-R.O.W. in Fill Section $R_{(R)}$			
Height of Fill	Frontslope		
	4:1	3:1	2:1
15'	90'	75'	60'
20'	110'	90'	70'
30'	150'	120'	90'
40'	190'	150'	110'



TWO LANE STRUCTURE SECTION

NOTES:

(1) 10 FT. or more desirable.

(2) Clear Roadway Area to Obstruction. (Face of Culvert Headwall, etc.) Applicable to both Cut and Fill Sections. On fills, where guard fence is required, Culvert Headwalls may be placed at crown line, behind guard fence.

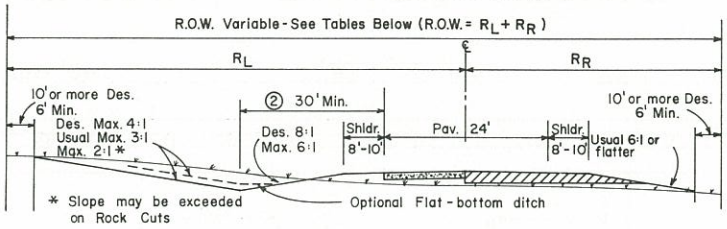
(3) For shoulder and pavement widths, see Standards of Designs for Two Lane Highways, Figure 4-30A. Minimum effective shoulder width for Primary Federal Projects to be 8 ft. Slopes 8:1 or flatter will be considered shoulders.

(4) See paragraph 4-202(g) 8 and Figures 4-15A and 4-15B.

FIGURE 4-31 Refers to Paragraph 4-501

CROSS - SECTIONS FOR MODERATE AND HIGH VOLUME TWO-LANE RURAL HIGHWAYS①

HV & MV over 1500 Current Year ADT



CUT AND FILL SECTIONS OF 5 FT. OR LESS

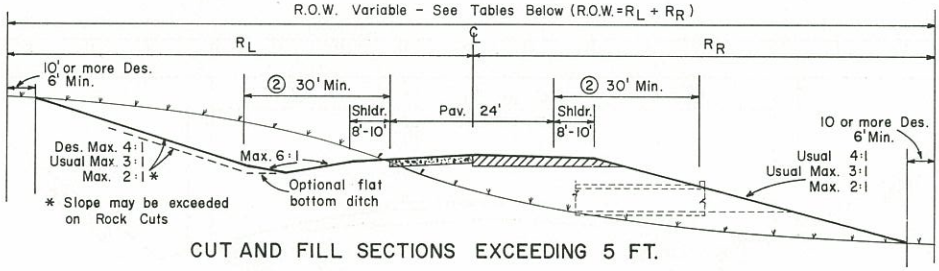
Min. Width of Half - ROW in Cut Section (R_L)				
Depth of Cut	8:1 Front Slope		6:1 Front Slope	
	Backslope Beyond 30' Clearance			
	3:1	2:1	3:1	2:1
5'	75'	65'	75'	65'

Min. Width of Half - ROW in Fill Section (R_R)			
Height of Fill	Slope		
	8:1	6:1	4:1
5'	70'	60'	50'

NOTE

① : For standards of design for two lane rural highways, see Figure 4-30.

② For minor reconstruction projects, see Figure 4-15B and related paragraph 4-202(g)8.

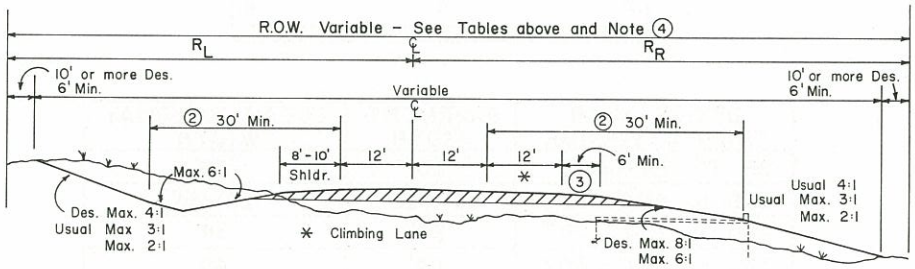


CUT AND FILL SECTIONS EXCEEDING 5 FT.

Min. Width of Half - ROW in Cut Section (R_L)		
Depth of Cut	Backslope Beyond 30' Clearance	
	3:1 *	2:1 *
10'	80'	70'
15'	95'	80'
20'	110'	90'
30'	140'	110'
40'	170'	130'

Min. Width of Half - ROW in Fill Section (R_R)			
Height of Fill	Slope Beyond 30' Clearance		
	4:1	3:1	2:1
10'	70'	60'	50'
15'	90'	75'	60'
20'	110'	90'	70'
30'	150'	120'	90'
40'	190'	150'	110'

* Computations based on 12 ft. of 6:1 front slope



NOTE : ③ Surfaced shoulder - Variable width as needed for edge support and parking of disabled vehicles

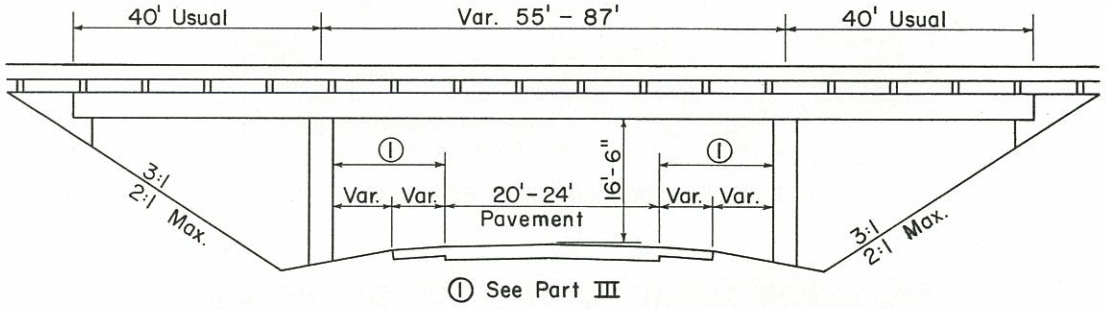
NOTE : ④ To determine minimum R.O.W. width add 10' per side where climbing lane occurs

CLIMBING LANE SECTION

NOTE : All table depths computed from finished Crown. Right of Way diminsions rounded up to nearest five feet.

FIGURE 4-32 Refers to Paragraph 4-501

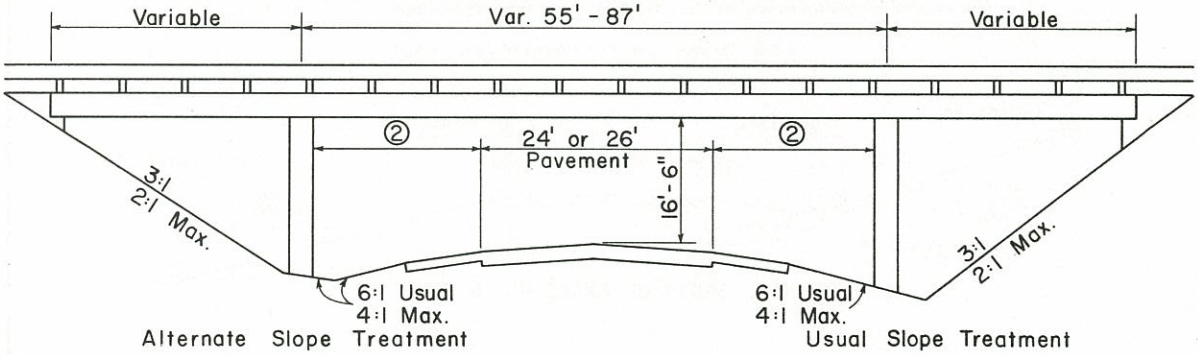
CLEARANCE REQUIREMENTS
TWO-LANE RURAL HIGHWAYS



① See Part III

TWO-LANE FM ROADS

② Project Life Avg. ADT ≥ 1500 - Provide 30' Min. } See Paragraph 4-202(g)8
② Project Life Avg. ADT < 1500 } and Figure 4-15A.

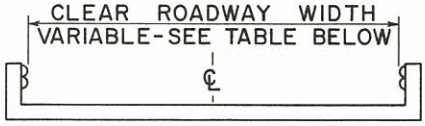


Alternate Slope Treatment

Usual Slope Treatment

TWO-LANE U.S. & STATE HIGHWAYS

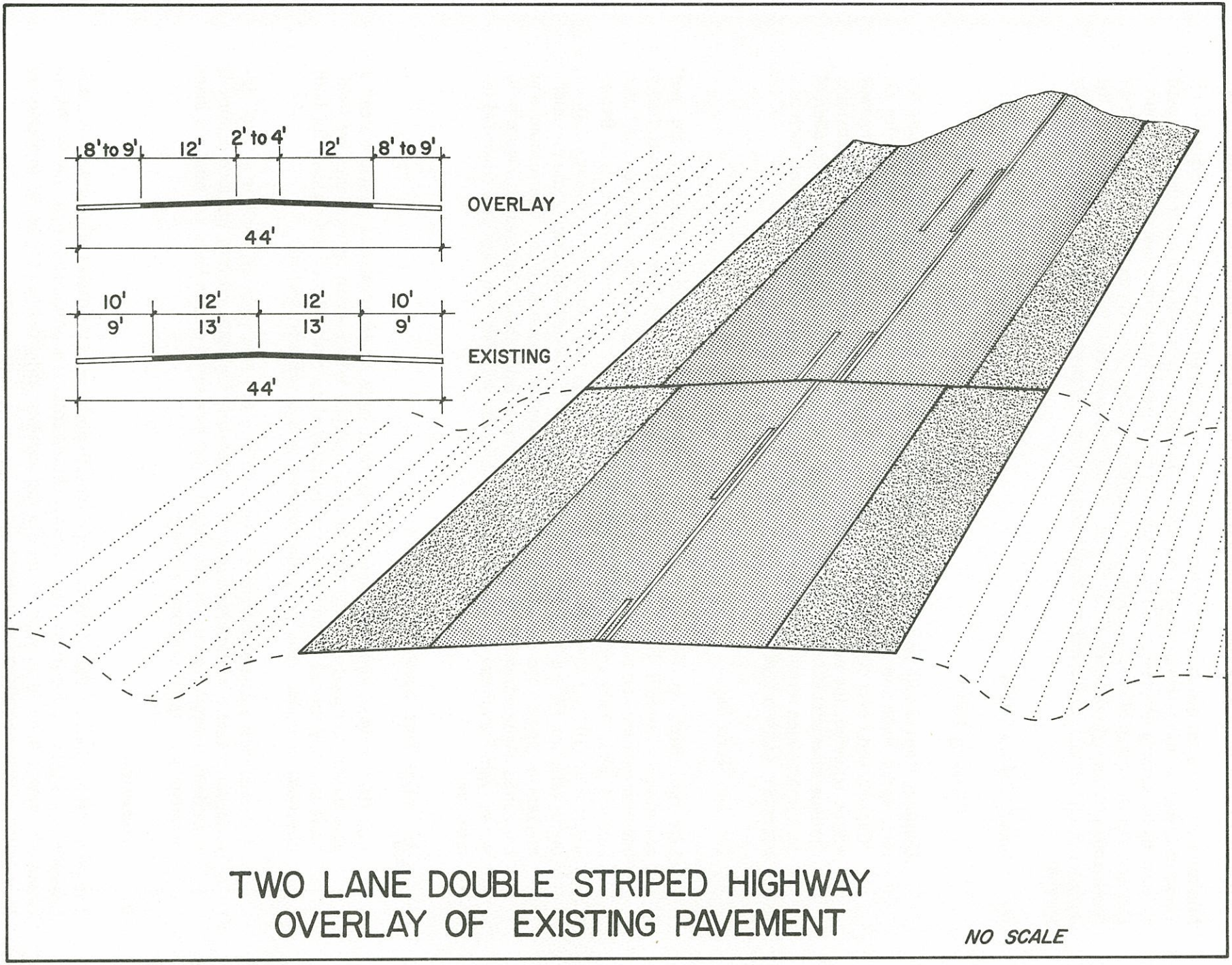
NOTE: WITHIN THE CONFINES OF THE MAJOR HIGHWAY ROW, DESIGN YEAR FOR CROSSROAD TRAFFIC SHALL BE THE SAME AS FOR THE MAJOR FACILITY.



DESIGN YEAR TRAFFIC VOLUME	PAVEMENT WIDTH	CLEAR ROADWAY WIDTH
UP TO 250 ADT	20'	28'
250 to 400 ADT	20'-22'	28'-34'
400 to 750 ADT	22'	34'
750 to 1500 ADT	24'	40'
1500 ADT & >	24' or 26'	40'-44'

TWO-LANE STRUCTURE SECTIONS

FIGURE 4-33 Refers to Paragraph 4-501



TWO LANE DOUBLE STRIPED HIGHWAY
OVERLAY OF EXISTING PAVEMENT

NO SCALE

FIGURE 4-34 REFERS TO PARAGRAPH 4-502 (b)

Minimum passing sight distance values for design of two-lane highways are shown in Figure 4-35. These distances are for design purposes only and should not be confused with other distances used as warrants for striping no-passing zones as shown in the Texas Manual on Uniform Traffic Control Devices. For the design of typical two-lane rural highways, except for level terrain, provision of near continuous passing sight distance (2500 feet at 70 mph design speed) is impractical. However, the designer should attempt to increase the length and frequency of passing sections where economically feasible.

(e) Speed Change Lanes

1. Climbing Lanes

Climbing lanes should be provided on two-lane highways when they meet the warrants (10 mph speed reduction and inadequate level of service) as described in Appendix D, "Capacity and Level of Service." For projects on new location or where an existing highway will be regraded, the economics of providing an improved grade line in lieu of providing climbing lanes should be investigated. In design, attention should be given to the location of the climbing lane terminal. Such lanes should not end just prior to an obstruction such as a restrictive width bridge.

2. Left Turn Bays

Left turn bays on two-lane highways at intersecting crossroads generally are not economically justified. For certain moderate or high volume two-lane highways with heavy left-turn movements, however, left turn bays may be justified in view of reduced road user accident costs. Delay and acceleration-deceleration costs are not significant economic factors where wide (10 feet) shoulders would permit nonturning traffic to by-pass a queue stored on the travel lanes. Where used, left-turn bays should be delineated with striping and pavement markers or jiggle bars. Passing should be restricted in advance of the intersection, and horizontal alignment shifts of the approaching travel lanes should be gradual. Figure 4-36 shows typical geometry for a rural two-lane highway with left-turn bays at a crossroad intersection.

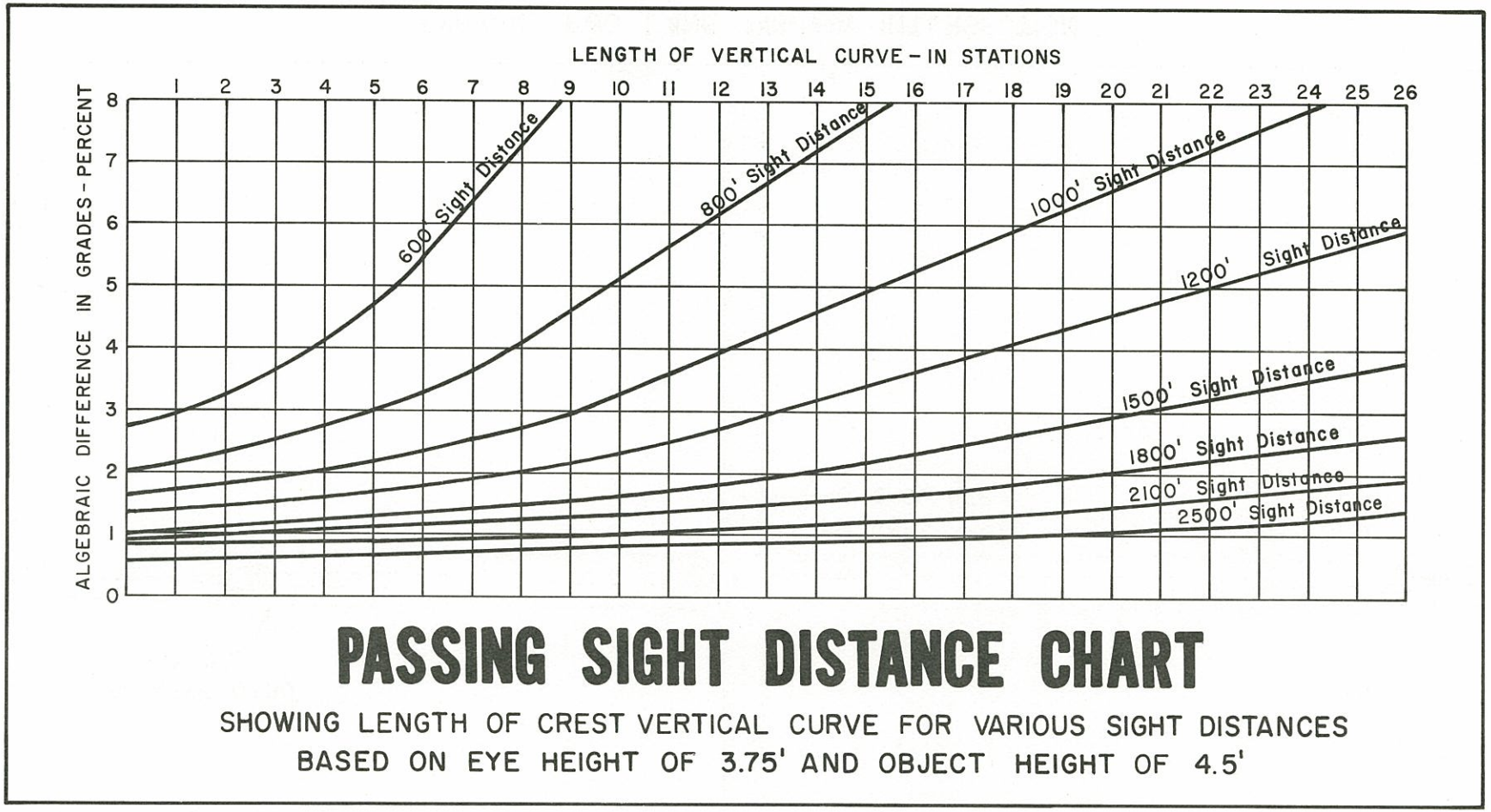
3. Right Turn Speed Change Lanes

Full (10 feet wide) shoulders alongside the traffic lanes generally provide sufficient area for acceleration or deceleration of right-turning vehicles. Where speed change lanes are used, however, they should be provided symmetrically along both sides of the highway for both directions of traffic, thus presenting drivers with a balanced section.

A deceleration-acceleration lane on one side of a two-lane highway, such as a "tee" intersection, results in the appearance of a three-lane highway and may produce confused, hazardous driving practices. In this regard, right turn speed change lanes are generally inappropriate for "tee" intersection design.

(f) Intersections

The provision of adequate sight distance is of utmost importance in the design of intersections along two-lane rural highways. Desirably, the roadways should cross at approximately right angles. Where crossroads skew is flatter than sixty degrees to the highway, the crossroad should be re-aligned to provide for a near perpendicular crossing.

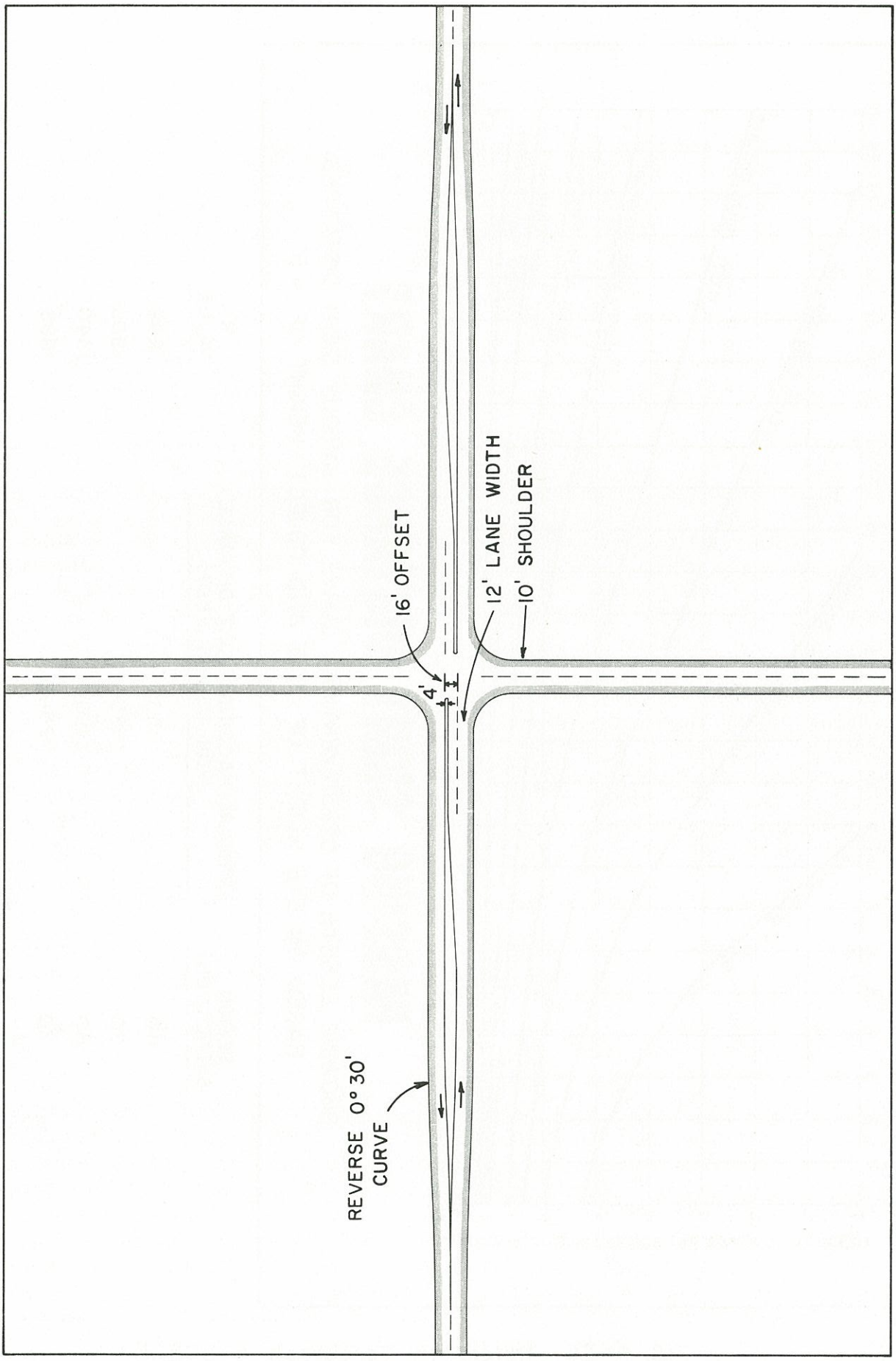


PASSING SIGHT DISTANCE CHART

SHOWING LENGTH OF CREST VERTICAL CURVE FOR VARIOUS SIGHT DISTANCES
BASED ON EYE HEIGHT OF 3.75' AND OBJECT HEIGHT OF 4.5'

DESIGN SPEED (MPH)	MINIMUM PASSING SIGHT DISTANCE FOR DESIGN (FEET)	K VALUE
40	1500	686
50	1800	985
60	2100	1340
70	2500	1895

FIG. 4-35 Refers to Paragraph 4-502(d)



TYPICAL TWO LANE HIGHWAY INTERSECTION
WITH LEFT TURN BAYS

FIGURE 4-36 Refers to Paragraph 4-502 (e)2

DESIGN-FREEWAYS (4-600)

4-601 GENERAL

A controlled access facility will generally be considered in a rural area when design year traffic volumes approach 15,000 vpd. In an urban area, the general warrants for freeways are not so clearly indicated since traffic operations and the capacity of the signal system control the volume of traffic that can be acceptably served on a more conventional facility. However, when design year volumes approach 18,000 vph on a four lane arterial or 30,000 vpd on a six-lane arterial, a freeway should be considered. For capacity and level of service evaluation, see Appendix D, Paragraph D-104.

4-602 BASIC DESIGN FEATURES

(a) Frontage Roads and Control Access

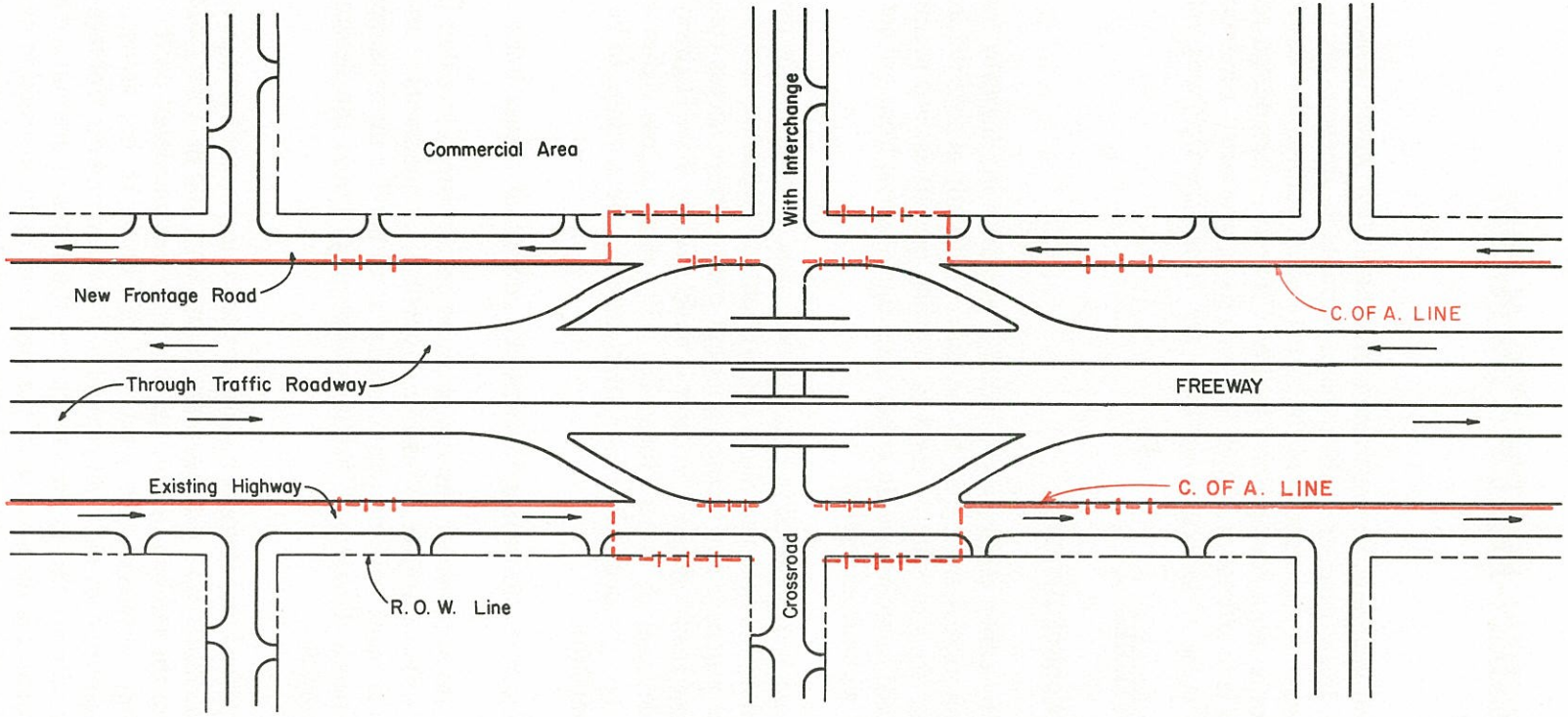
Control of access is achieved by either (a) acquiring rights of access to the highway from abutting property owners and permitting ingress and egress to the main lanes only at selected interchanges; or (b) construction of frontage roads to restore access to abutting properties, but permitting access to the main lanes only at selected interchanges. In either case, direct access from private property to the main lanes is prohibited without exception.

A controlled access highway may be developed in either of two ways, by design or by designation. If a highway is to be developed by design, the State Department of Highways and Public Transportation is not empowered to purchase any access rights but must achieve access control by construction of continuous frontage roads. When a freeway is developed by State Highway and Public Transportation Commission designation under House Bill 179, either access rights may be purchased or frontage roads may be provided, whichever arrangement is determined to be appropriate as discussed in Paragraph 4-602(b).

Figures 4-37 through 4-42 indicate the proper location for control of access lines.

In establishing access control along freeways, the design must be consistent in either providing or restricting access to like areas within a project. Where at all possible, all quadrants of an interchange should be provided similar treatment and, desirably, access at all similar interchanges should be identical. Only where traffic needs dictate a different arrangement should the designer establish dissimilar access control restrictions.

Where a freeway parallels a railroad and there is insufficient space to place a frontage road between an existing road and the adjacent railroad - highway right of way line, and necessary additional right of way cannot be secured from the railroad, a frontage road may be considered on the off-side of a railroad paralleling the freeway. However, the legal staff of File D-15 has advised that where through lanes are superimposed upon an old road parallel to a railroad and the frontage road is constructed on the off-side of the railroad, this in no way changes the status of the railroad as the owner of property abutting the old road. It is the opinion of the legal staff that construction of the frontage road on the offside of the railroad will not extinguish the company's rights of access to the through lanes. It will, therefore, be necessary that the railroad exercise a relinquishment of access rights to the through lanes in order to insure complete control of access.



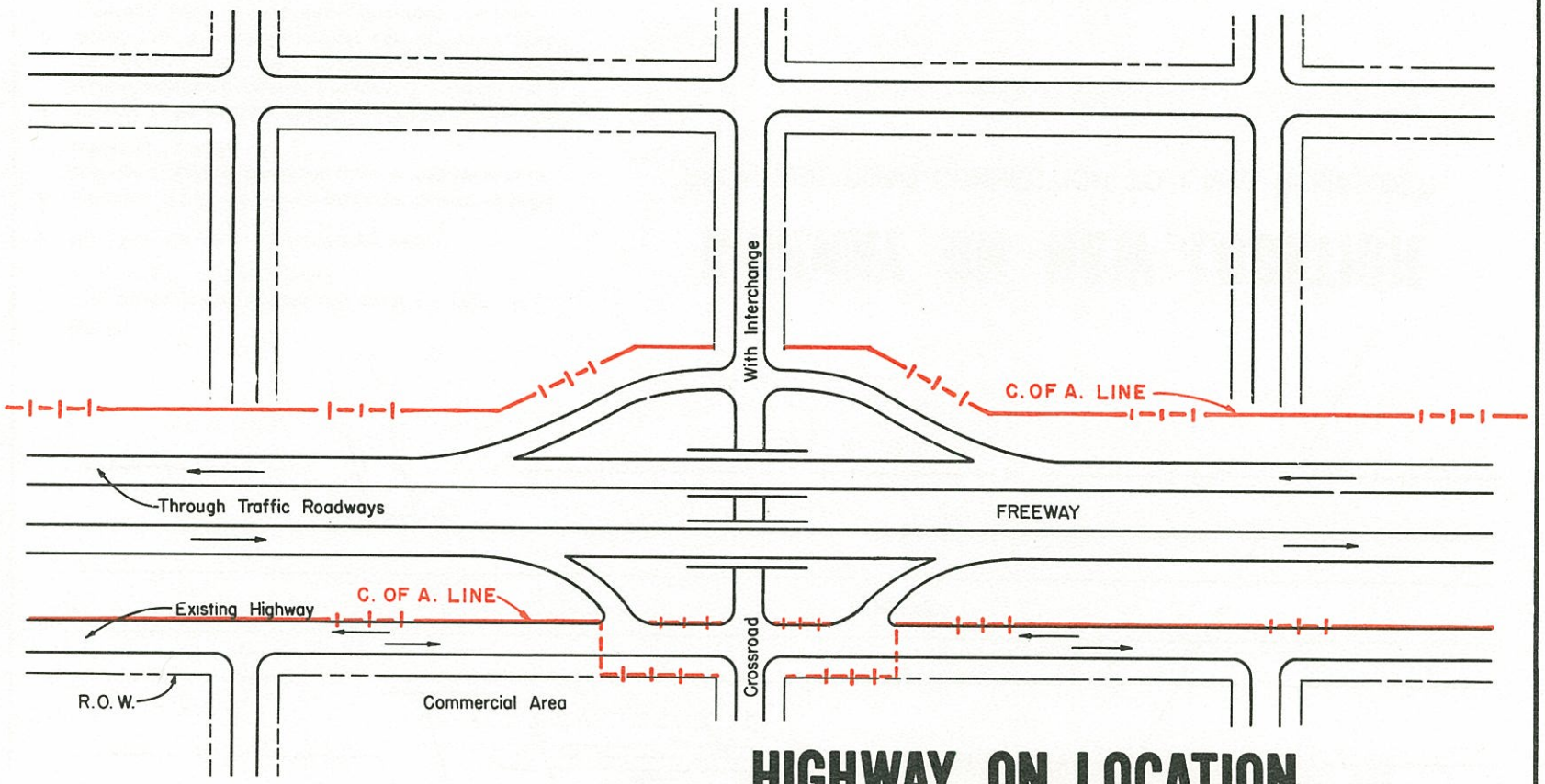
HIGHWAY ON LOCATION OF EXISTING ROAD

EXISTING HIGHWAY CONVERTED TO A ONE-WAY FRONTAGE ROAD AND NEW FRONTAGE ROAD ADDED

NOTE:

1. This drawing is diagrammatic only and is not to be used as a basis for geometric layout.
2. Alternate 1 - Two-way frontage roads, ramps adjusted.
3. Commercial areas might be along crossroads and frontage roads.
4. Control of access from ramp to crossroad may be required on Interstate projects or where high volumes of exiting-entering traffic would be subjected to hazards due to side road entrances.

FIGURE 4-37 Refers to Paragraph 4-601



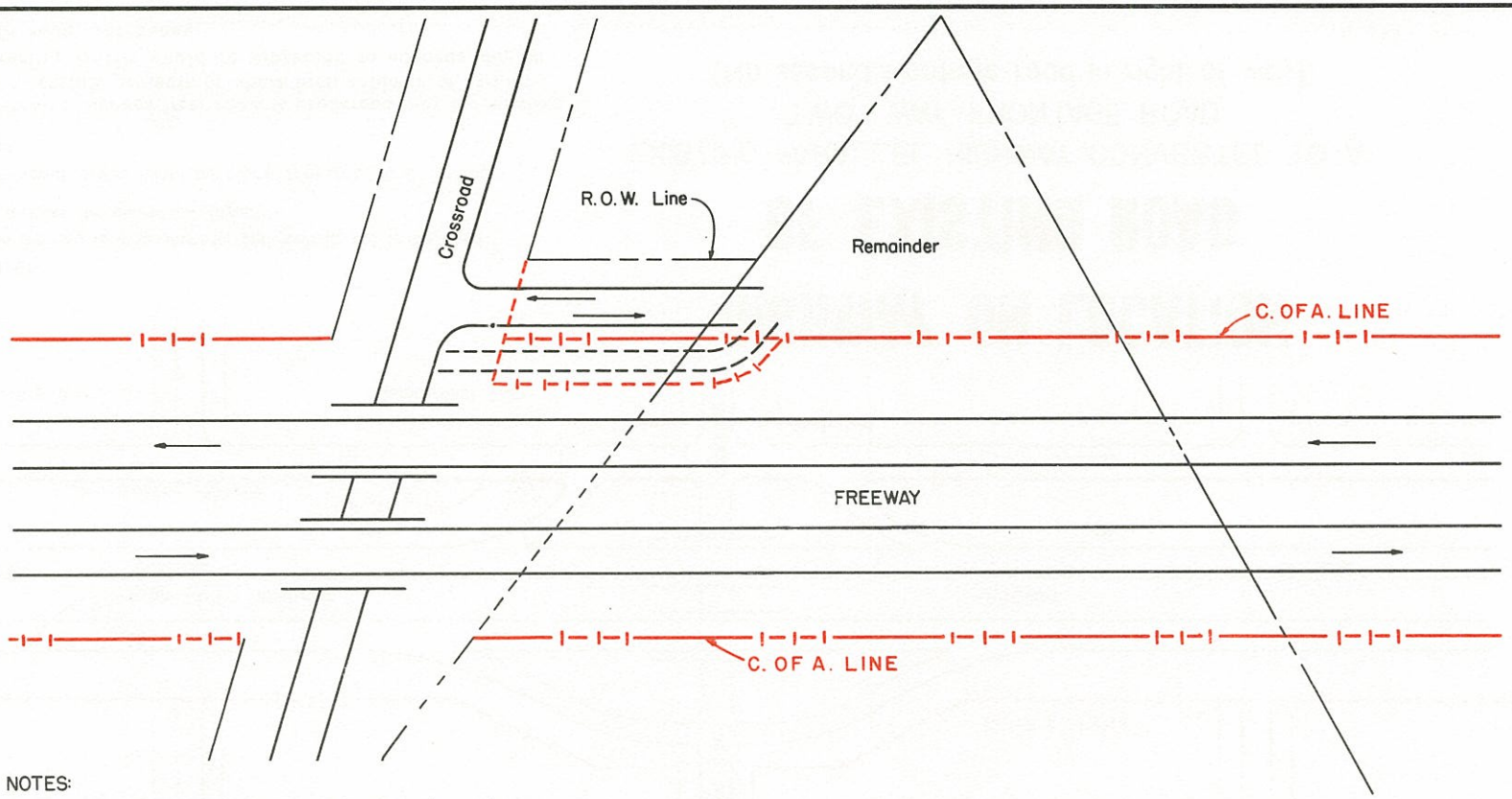
HIGHWAY ON LOCATION OF EXISTING ROAD

EXISTING PARALLEL HIGHWAY CONVERTED TO A TWO - WAY FRONTAGE ROAD
(No second frontage road in right of way)

NOTES:

1. This drawing is diagrammatic only and is not to be used as a basis for geometric layout.
2. Commerial areas might be along crossroad and frontage road.
3. Control of access from ramp to crossroad may be required on Interstate projects or where high volumes of exiting-entering traffic would be subjected to hazards due to side road entrances.

FIGURE 4-38 Refers to Paragraph 4-601



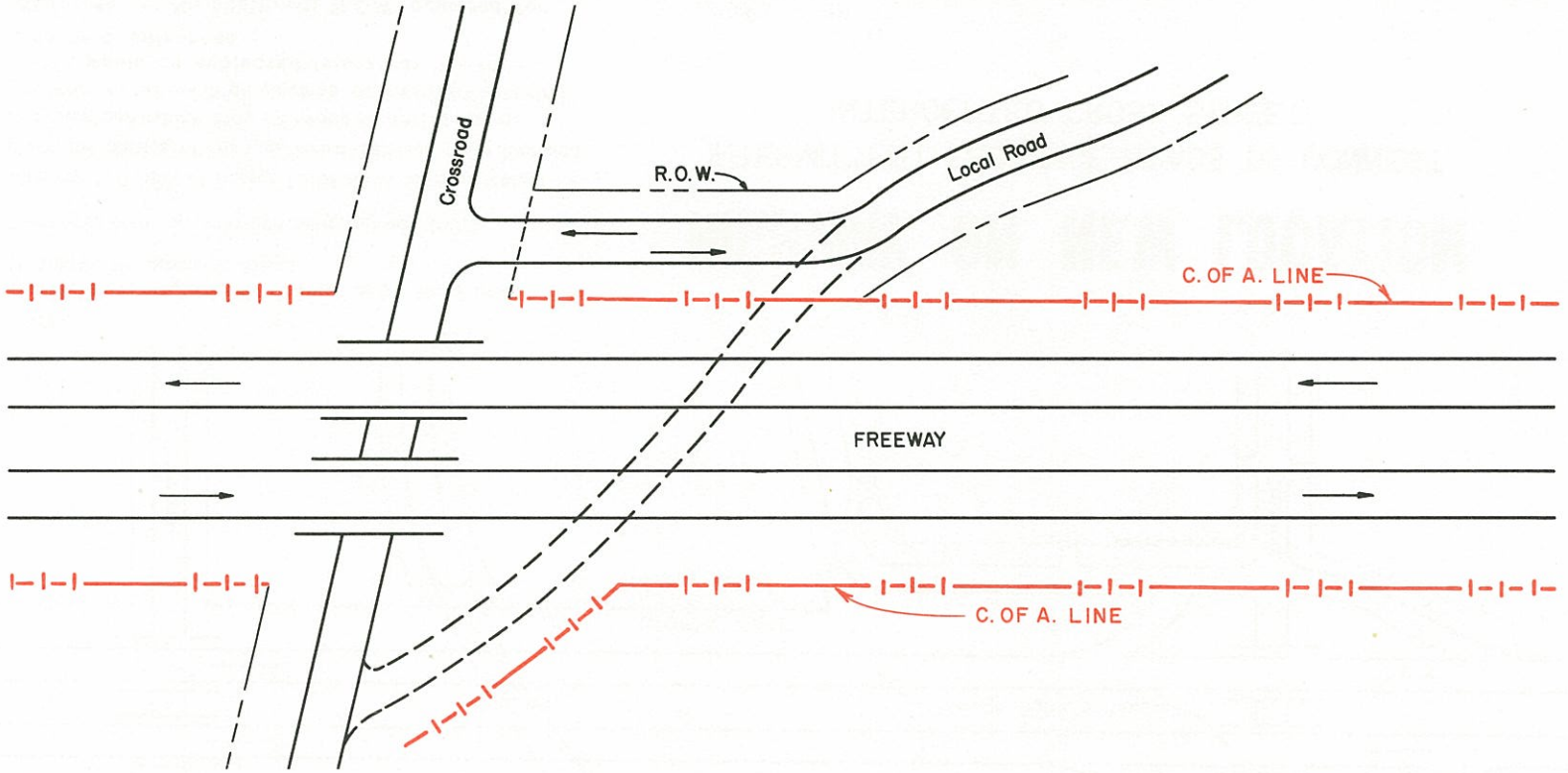
NOTES:

1. This drawing is diagrammatic only and is not to be used as a basis for geometric layout.
2. No commercial areas to serve highway traffic.
3. Alternate 1-R.O.W. occupied by connection to land remainder conveyed to political subdivision and then considered to be outside of freeway.
4. Alternate 2-No additional R.O.W. acquired for frontage road which is constructed inside of freeway R.O.W. line but C of A line considered to be inside of frontage road as shown dashed.
5. Alternate 3-provide neither connection or stub frontage road if severance damages are less than cost of frontage road.
6. Grade separation only.

HIGHWAY ON NEW LOCATION

FRONTAGE ROAD CONNECTION TO LAND REMAINDER

FIGURE 4-39 Refers to Paragraph 4-601



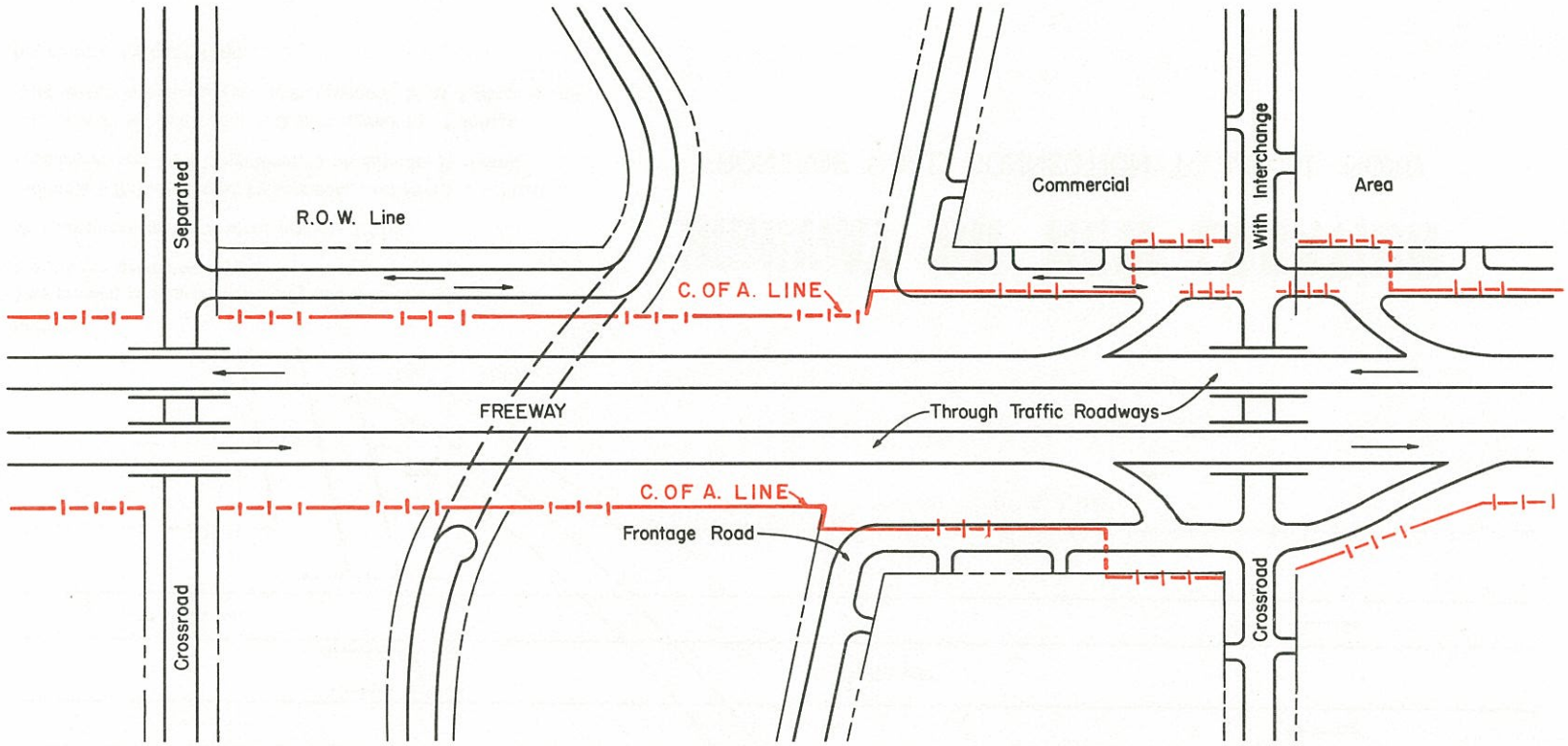
NOTES:

1. This drawing is diagrammatic only and is not to be used as a basis for geometric layout.
2. No commercial areas to serve highway traffic.
3. Alternate 1 - R.O.W. occupied by connection conveyed to political subdivision and then considered to be outside of freeway.
4. Alternate 2 - No additional R.O.W. acquired for frontage road which is constructed as in alternate 2 of Figure 4-64.
5. No ramps to crossroad.

HIGHWAY ON NEW LOCATION

FRONTAGE ROAD CONNECTION TO LOCAL ROAD

FIGURE 4-40 Refers to Paragraph 4-601



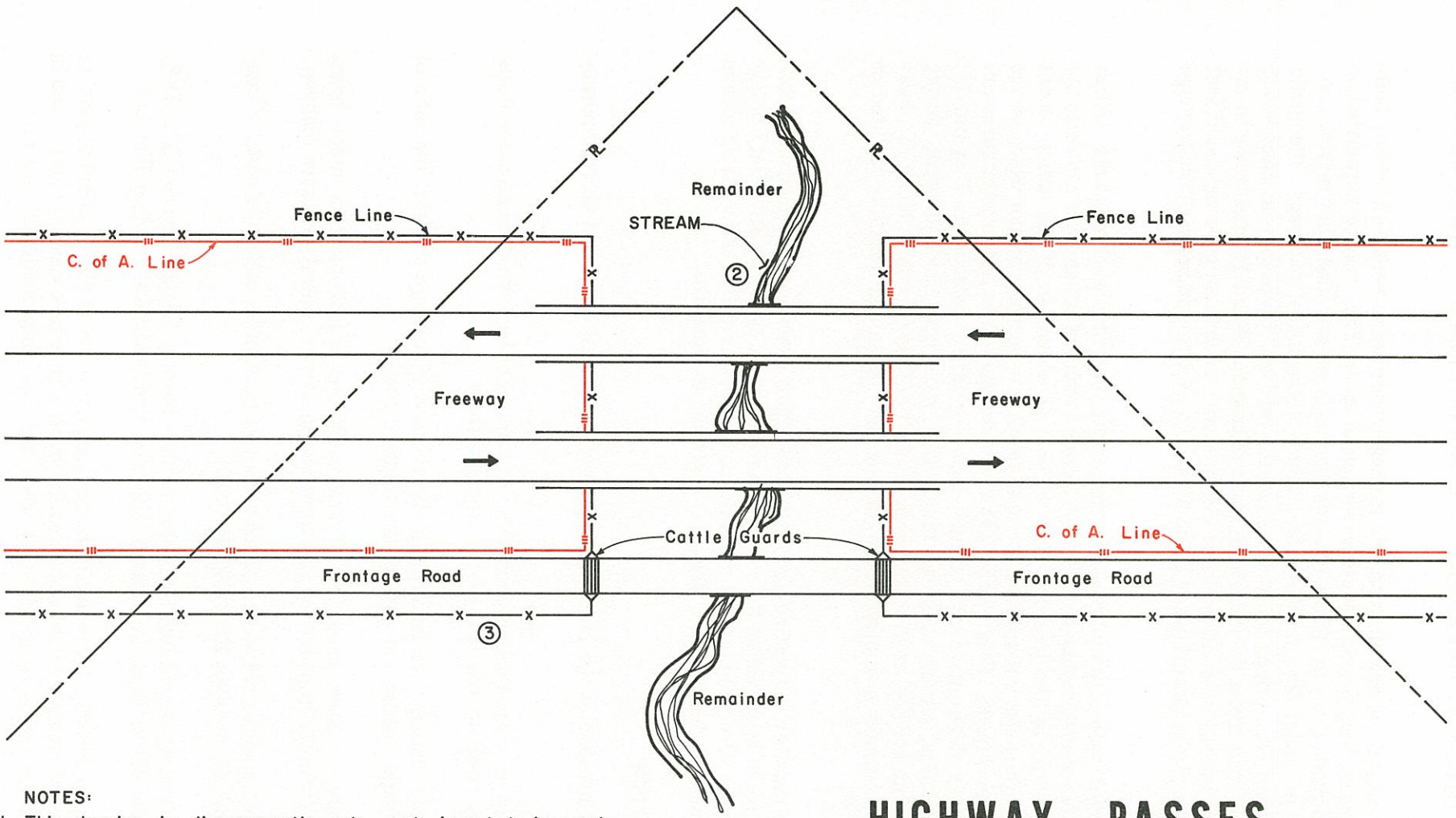
NOTES:

1. This drawing is diagrammatic only and is not to be used as a basis for geometric layout.
2. Commercial areas on crossroad serve highway traffic.
3. Alternate 1 - Control of Access (C. of A.) is as shown except along the outside of frontage roads between ramp terminals and crossroad which may be required on Interstate projects or where high volumes of exiting-entering traffic would be subjected to hazards due to side road entrances.
4. Alternate 2 - No additional R.O.W. acquired for frontage roads.

HIGHWAY ON NEW LOCATION

INTERMITTENT FRONTAGE ROADS TO CONNECT INTERCEPTED CROSS STREETS

FIGURE 4-41 Refers to Paragraph 4-601



NOTES:

1. This drawing is diagrammatic only and is not to be used as a basis for geometric layout.
2. A narrow pass corridor may be reserved where future multiple-use of right of way under the structure is a possibility.
3. Frontage Road - Cattle Guard arrangement is illustrative only. Different designs may be required, dependent upon drainage requirements or other considerations.

HIGHWAY PASSES

HIGHWAY SEVERS PROPERTY RESULTING IN LAND REMAINDERS ON EACH SIDE OF HIGHWAY

FIGURE 4-42 Refers to Paragraph 4-60l

Where the freeway is developed on new location and frontage roads are provided on one or both sides of the through roadways, they should not cross railroads at grade. They may be terminated or dead ended at the railroad right of way or, where two frontage roads are provided, they may be connected by crossing over or under the through traffic lanes, enlarging, if necessary, the grade separation structures between the through traffic lanes and the railroad. There may be cases which justify carrying the frontage road across the railroad by grade separation. Where frontage roads in urban or suburban areas are initially constructed to be discontinuous at railroad crossings, sufficient right of way should be acquired to permit future grade separations and continuation of the frontage roads across the railroad.

Frontage roads serve a multitude of purposes other than controlling or providing access. Urban frontage roads are multi-functional as they reduce the "barrier" effect of urban freeways since the local street grid is not severed by the freeway. They become an extension of the surface street system, providing for continuity and traffic circulation, and result in a freeway corridor which serves local, as well as intracity travel needs. They also serve as separate bus routes and express buses can exit from the freeway and use the frontage road to safely load or discharge passengers. They provide invaluable operational flexibility, serving as detour routes when main lane accidents occur, during major main lane maintenance activity, or for over-height loads. For freeways which include freeway surveillance and control, continuous frontage roads provide the operational flexibility required to manage saturation.

In addition to the above-described purposes of frontage roads, many times they prove advantageous when used as the first stage of construction for a complete freeway facility. By constructing frontage roads prior to the main lanes very often interim traffic demands can be satisfied and a usable section of highway can be opened to the traveling public at a greatly reduced cost.

(b) Frontage Road Policy

Frontage roads may be included in the planning stage of a designated controlled access highway when:

1. It is necessary to unlandlock the remainder of a parcel of land which has a value equal to or nearly equal to the cost of the frontage road.

2. The appraised damages, resulting from the absence of frontage roads at the time of planning, would exceed the cost of the frontage roads.

3. It is necessary to restore circulation of local traffic due to local roads or streets being severed or seriously impaired by the construction of the controlled access highway.

4. An economic analysis shows the benefits derived more than offset the costs of constructing and maintaining the frontage roads.

All such frontage road planning should first be cleared by the Highway Design Division (File D-8) and any exception to the above must be cleared with the Administration through File D-8.

In those instances where requests for additional frontage roads are received during or subsequent to the planning stage or after the freeway has been constructed, they may be considered and placed in order of priority of highway needs in the District when the following conditions are met:

1. A usable section of frontage road shall be developed. The intent of a usable section would be a facility from a separation to a separation or connecting public roadway.

2. The construction of frontage roads shall not adversely affect the movement of traffic at the ramp terminals and crossroads.

3. The frontage road shall be constructed to Departmental specifications and standards.

4. The Department shall receive from the requesting agency or individual the actual construction cost, including all preliminary and construction engineering costs.

5. Any additional right of way shall be furnished free of cost and clear of utilities, and the requesting agency shall be responsible for any Relocation Assistance payments involved in the acquisition. The Department shall handle all relocation actions exclusive of monetary payments to insure compliance with Departmental policies and procedures.

For additional frontage roads requested subsequent to the planning stage or after the freeway has been constructed, control of access as originally conceived for the facility may be modified to allow access to the proposed frontage road only to the extent as may be permitted by safety considerations and in keeping with Departmental policies and procedures. Access control will be similar to precedents as far as traffic volumes, safety and design policy permit.

(c) Frontage Road Standards

The standard typical sections for rural and urban type frontage roads are shown in Figure 4-43.

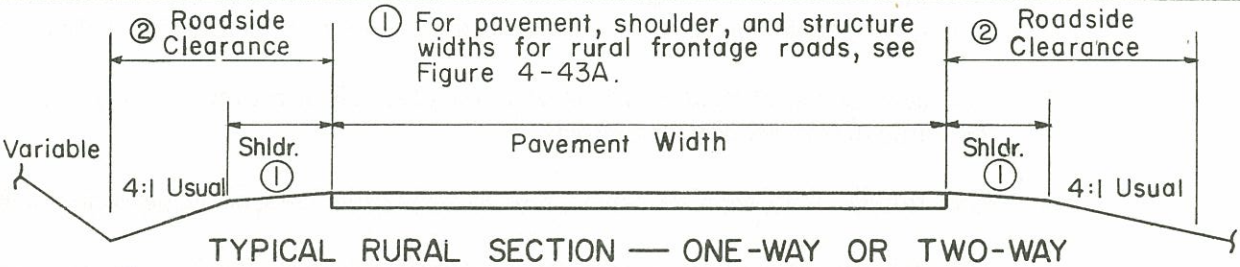
Any frontage road constructed within an area which is expected to be either urban or suburban in nature by the design year will be so designed as to provide one-way operation initially. There may be exceptions to this policy in certain isolated instances; however, such exceptions will be considered only where, due to extraordinary circumstances, a one-way pattern would impose severe restrictions on circulation within an area. In those cases where such exceptions are considered, they will be cleared with the Administration through the Highway Design Division.

(d) Lanes, Width and Number

The minimum and usual main lane width shall be 12 feet. The number of lanes required is determined by the level of service evaluation as discussed in Appendix D, "Capacity and Level of Service."

(e) Shoulders

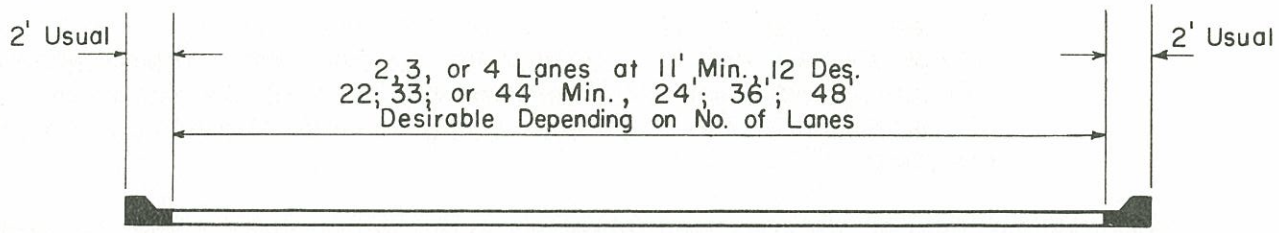
Continuous surfaced shoulders should be provided on each side of the main-lane roadways, both rural and urban, as shown in Figure 4-44. The minimum widths should be 10 feet on the outside and 4 feet on the median side of the pavement for four lane freeways. On freeways of six lanes or more, 10 foot inside shoulders for emergency parking should be provided where flush medians are used. Where a six lane freeway includes a depressed median design, 4-foot shoulders may be used on the median side of the travel lanes. A 10-foot shoulder should be maintained along all speed change lanes with a 6-foot shoulder considered in those instances where light weaving movements take place. All shoulders should be separated from the through traffic lanes by edge striping.



TYPICAL RURAL SECTION — ONE-WAY OR TWO-WAY

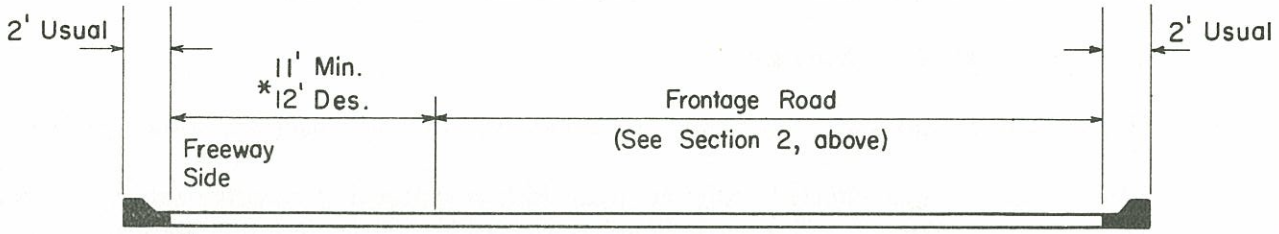
② For obstruction clearance, see paragraph 4-202 (g)8 and Figures 4-15A & 4-15B.

SECTION 1



TYPICAL URBAN OR SUBURBAN SECTION — USUALLY ONE-WAY

SECTION 2



*Added width between Ramp Terminals

WIDENING BETWEEN RAMP TERMINALS

SECTION 3

NOTE: In suburban areas it may be desirable to curb property side of frontage road without corresponding curb on freeway side.

TYPICAL SECTIONS FRONTAGE ROADS

FIGURE 4-43 Refers to Paragraph 4-601 (c)

STANDARDS OF DESIGN FOR RURAL FRONTAGE ROADS

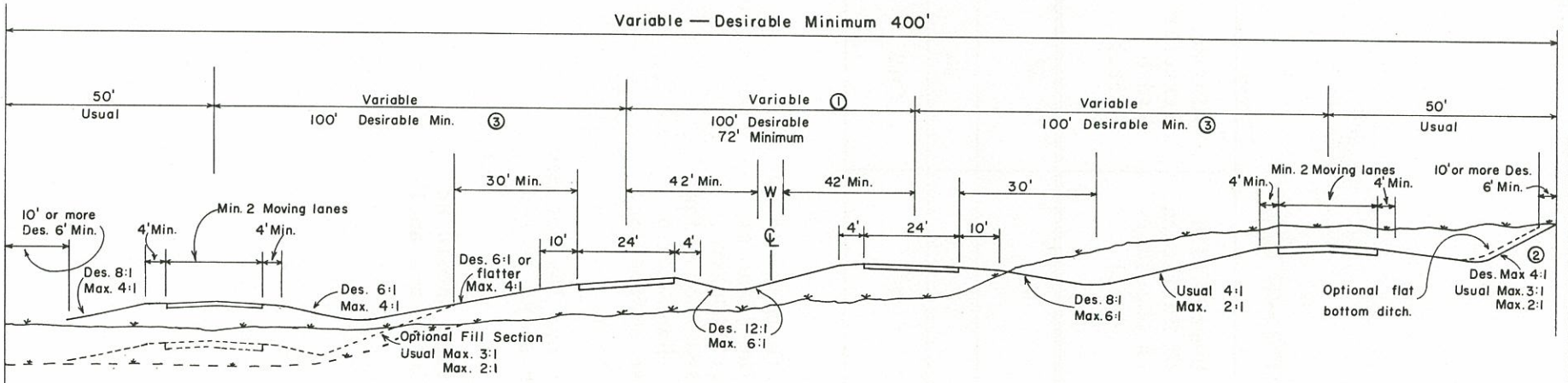
Current Year ADT (Veh/Day)	Minimum Pavement Width (ft.)	Minimum Usable[1] Shoulder Width (ft.)	Usual Width of Surfacing on Shoulders (ft.)	Minimum Structure Width (ft.)
Less than 400[2]	20	4	4	28
400 - 750	22	6	4	34
More than 750	24	8	4[3]	40

[1] "Usable" shoulder width is the actual width that can be used for an emergency or parking stop. The plane of usable shoulders shall be sloped at 8:1 or flatter. "Usable" shoulder width should be increased 2 or 3 feet where embankment side slopes are steeper than 4:1 so that rounding at the intersection of these slopes does not reduce useful shoulder width appreciably.

[2] For 250-400 current ADT, 22-foot pavement and 34-foot new bridge width should be provided if design speed exceeds 50 mph.

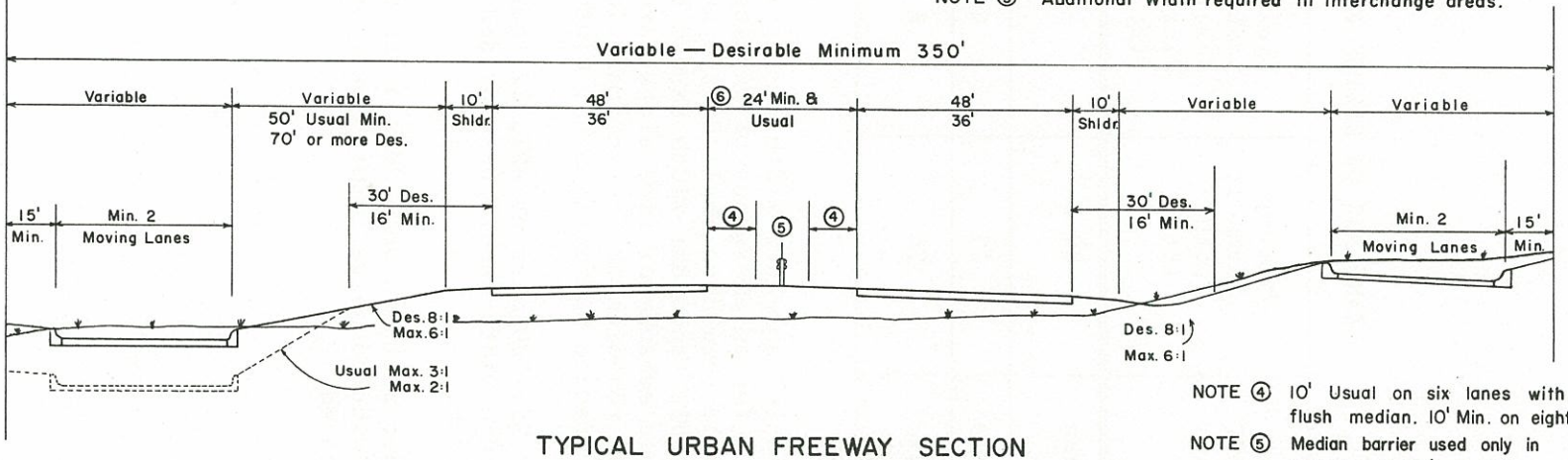
[3] Wider surfaced shoulders or an urban section should be considered where future heavy traffic volumes are anticipated.

Figure 4-43A (Refers to Paragraph 4-601(c))



TYPICAL RURAL FREEWAY SECTION
WITH FRONTAGE ROADS

NOTE ① For min. 30' Clearance to obstruction in median, Width ℄ to ℄ of 84' + W* is required.
*"W" is width of obstruction.
NOTE ② Backslope in cuts may be exceeded in rock.
NOTE ③ Additional Width required in interchange areas.



TYPICAL URBAN FREEWAY SECTION

NOTE ④ 10' Usual on six lanes with flush median. 10' Min. on eight lanes.
NOTE ⑤ Median barrier used only in medians of 30' or less.
NOTE ⑥ A 48' median is appropriate where a future additional lane in each direction is planned.

TYPICAL FREEWAY SECTIONS

FIGURE 4-44 Refers to Paragraph 4-601(e)
4-72

All shoulders should be separated from the through traffic lanes by edge striping.

STANDARDS OF DESIGN FOR CONTROLLED ACCESS FACILITIES

Average Daily Traffic (ADT)[1]	Over 15,000	
Design Hourly Volume (DHV)[2]	Over 1,200	
Design Speed (mph)	Des.	Min.
Mainlanes - Urban	70	50
Frontage Roads - Urban	50	30
Mainlanes - Rural		
Flat	80	70
Rolling	70	60
Mountainous	60	50
Frontage Roads - Rural	50	30
Lane Width (Ft.)	12	
Median Width (Ft.)		
Urban	--	24 (usual)[3]
Rural	76	48
Shoulder Outside (Ft.)	10	
Inside Shoulder (Ft.)	4[4]	
Structure Widths	See Figure 4-45	

[1]ADT at design year in equivalent passenger cars per day.

[2]One-way DHV in equivalent passenger cars per hour.

[3]Applicable to urban freeways with flush medians and six or more mainlanes.

[4]Minimum 10-foot inside shoulders shall be provided on urban freeways with flush medians and six or more lanes.

Figure 4-44A Refers to Paragraph 4-601(e)

(f) Medians

The width of the median is the distance between the inside edges of the travel lanes. For rural freeway sections, generally depressed medians 76 feet in width are used. Where topography, right of way, or other special considerations dictate, rural freeway medians may be reduced in width to less than 76 feet to a minimum of 48 feet. The typical urban freeway includes six or more travel lanes and a flush 24-foot median, resulting in a section providing 10-foot inside shoulders and a usual 2-foot offset to barrier centerline.

Due to the presence of high speed and volume traffic on urban freeways and the resulting adverse environment for accomplishing construction improvements thereon, it is the usual practice to construct the ultimate freeway section initially. Under those unusual circumstances where future additional lanes will be provided in the median area, the usual median width of 24 feet should be increased by the appropriate multiple of 12 feet in anticipation of need for additional lanes.

On elevated urban freeway sections, a single structure rather than twin main lane structures should be used where median width is 30 feet or less.

At horizontal curves on freeways with narrow medians, a check should be made to insure that the median barrier does not restrict stopping sight distance to less than minimum values.

(g) Outer Separation

The portion of the freeway between the main lanes and frontage road, or right-of-way line where frontage roads are not provided, should be wide enough to accommodate shoulders, speed change lanes, side slopes, retaining walls and ramps, as well as the necessary signs and other appurtenances necessary for traffic control. Because of right-of-way limitations in urban areas, the outer separation may oftentimes be narrower than desired; however, in rural areas, where opposing headlights along a two-way frontage road tend to reduce a driver's comfort and perception on the freeway, the outer separation should be as wide as possible.

(h) Structures

Figures 4-16, 4-17, 4-23 and 4-45 show the appropriate roadway and structure widths for various types of roadways. For a more detailed discussion refer to the "Bridge Division Operation and Planning Manual".

The crown slope on structures shall be the same as the approach pavement.

(i) Horizontal and Vertical Clearance at Structures

Vertical

All new highway grade separation structures, including railroad underpasses, shall provide 16'-6" minimum vertical clearance over the usable roadway.

No exception shall be made to this policy for structures over main lanes of Interstate or controlled access highways except within cities where the 16'-6" vertical clearance is provided on an Interstate Loop around the particular city. On all other systems of highways with separations involving interchange facilities, other highways, public roads, city streets or railroads, where this minimum clearance is impractical or excessively expensive to provide, exceptions may be made. In such cases, the vertical clearance shall be held as near as practicable to the 16'-6" minimum, but in no case shall it be less than 14'-6".

Vertical clearances for pedestrian crossover structures shall be approximately 1'-0" greater than that provided for other grade separation structures. This is due to the increased risk of personal injury upon impact by over-height loads and the relative weakness of such structures to resist lateral loads from vehicular impact.

ROADWAY AND STRUCTURE WIDTHS

CONTROLLED ACCESS FACILITIES

Type of Roadway	Inside Shoulder Width	Outside Shoulder Width[1]		Traffic Lanes	Structure Width	
Main Lanes:						
4-lane divided	4'	10'		24'	38' min.	
6-lane divided	10'[2]	10'		36'	56' min.[2]	
8 lanes or more	10'	10'		48[3]	68' min.[3]	
1 Lane Direct Conn.	2' Rdwy) See 4' Str.) Note 4	8'		14'	26 min.	
2-Lane Direct Conn.	2' Rdwy) See 4' Str.) Note 4	8'		24'	36 min.	
Ramps	2' Rdwy) See 4' Str.) Note 4	Min.	Des.		Min.	Des.
		6'	8'[5]	14'	24'	26[5]

[1] For auxiliary (speed change) lanes, see Paragraph 4-602(e) for outside shoulder width.

[2] Ten-foot shoulders appropriate for six-lane freeways with flush median. Six-lane freeways with depressed median may include four-foot shoulders with 50' minimum structure width.

[3] For more than eight lanes, add 12-foot width per lane.

[4] Minimum inside shoulder width is two feet (2') on roadway sections and four feet (4') on bridges. All longitudinal traffic barriers, including bridge rail, wall, and guard fence, should be located a minimum of four feet (4') from the travel lane edge.

[5] Desirable values should be used where there are sufficient combination type vehicles to govern design. Where ramp ADT includes greater than 10% five-axle (3S2) tractor-trailer vehicles, desirable values are appropriate for use.

FIGURE 4-45 Refers to Paragraph 4-601(h)

The above-specified clearances apply over the entire width of roadway including usable shoulders and include an allowance of six inches for future pavement overlays. It is recognized that it is impractical to arrive at the exact clearance dimensions on the structure plans. However, the above clearances should not be exceeded by more than approximately three inches.

Horizontal

The minimum horizontal clearance to bridge parapets and piers will be as shown on Figures 4-46 through 4-48.

(j) Ramps and Direct Connections

1. General

All ramps and direct connections should be designed for one-lane operation with provision for emergency parking; however, if the anticipated volume exceeds the capacity of one freeway lane, two-lane operation may be provided. Several examples of ramps and connecting roadway arrangements are shown in Figure 4-49.

Once ramps have been located on a schematic layout and the same has been exhibited at a public hearing or the design has otherwise become a matter of public record, extreme caution should be exercised in making any subsequent changes in ramp location to better serve areas which may have developed after the original design was determined. In all cases, proposed changes should be submitted to the Highway Design Division, and another public hearing may be required.

Right-hand ramps are markedly superior in their operational characteristics and safety to those that leave or enter on the left. With right-hand ramps, merging and diverging maneuvers are accomplished into or from the slower moving right travel lane. Since a high majority of ramps are right-hand, there is an inherent expectancy by drivers that all ramps will be right-hand, and violations of this expectancy may adversely affect operation and safety characteristics.

2. Design Speed

There should be a definite relationship between the design speed on a ramp or direct connection and the design speed on the intersecting highway. All ramps and connections shall be designed to enable vehicles to leave and enter the traveled way of the freeway at no less than 0.7 of the freeway's design speed. Figure 4-50 shows guide values for ramp design speed.

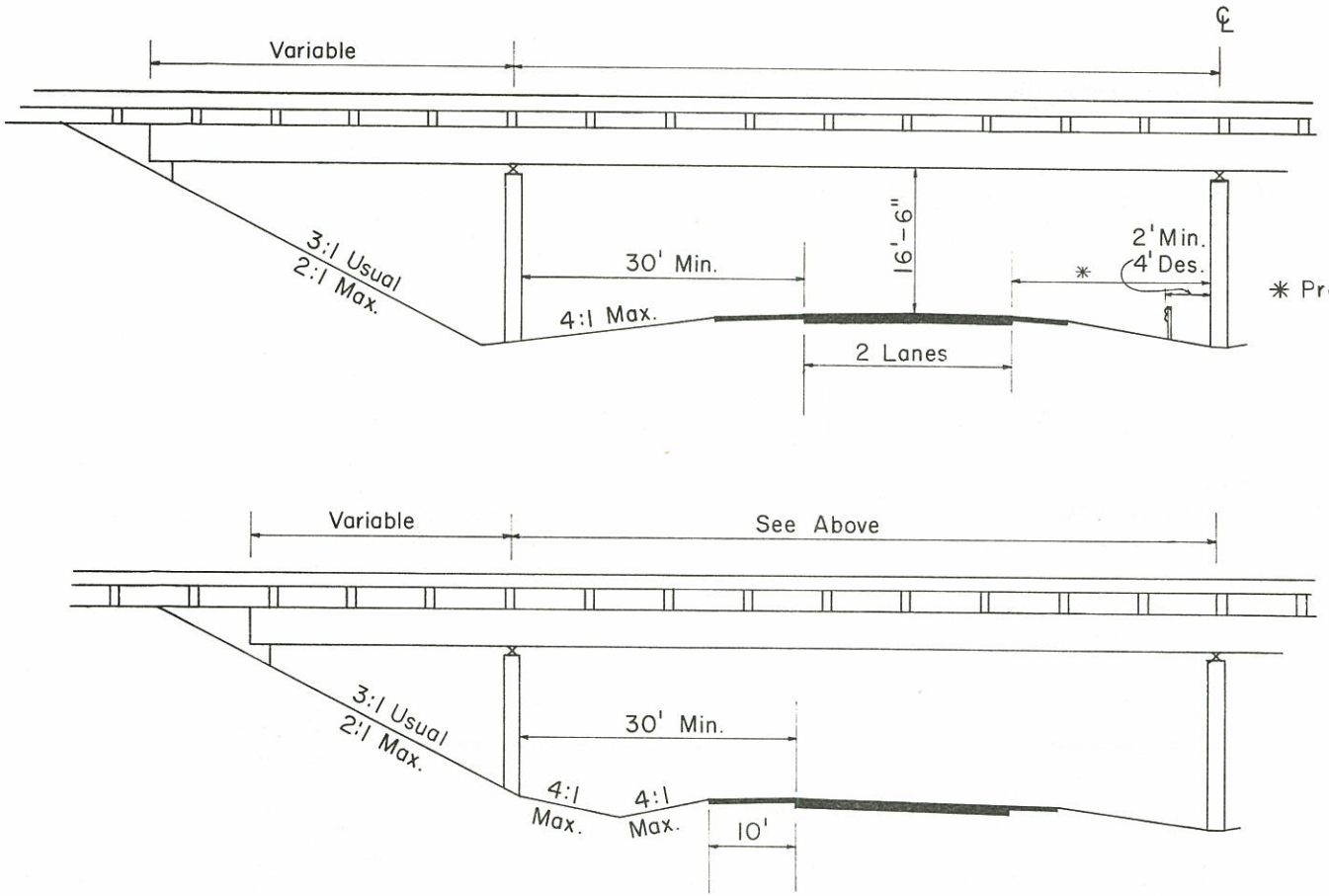
GUIDE VALUES FOR RAMP DESIGN SPEED AS RELATED TO HIGHWAY DESIGN SPEED*

(DESIRABLE BASED ON MAX. "e" = 0.06 FT./FT.)

Highway Design Speed, mph	50	60	70	80
Desirable Ramp Design Speed, mph	40	45	50	55
Corresponding Radius, feet	500	660	830	1040

* Loops: Desirable values of design speed generally do not apply. The design speed on a loop is usually 25 mph (150 ft. radius). Particular attention should be given to controlling superelevation on loops due to the tight turning radii and speed limitations.

Figure 4-50 Refers to Paragraph 4-601(j)2

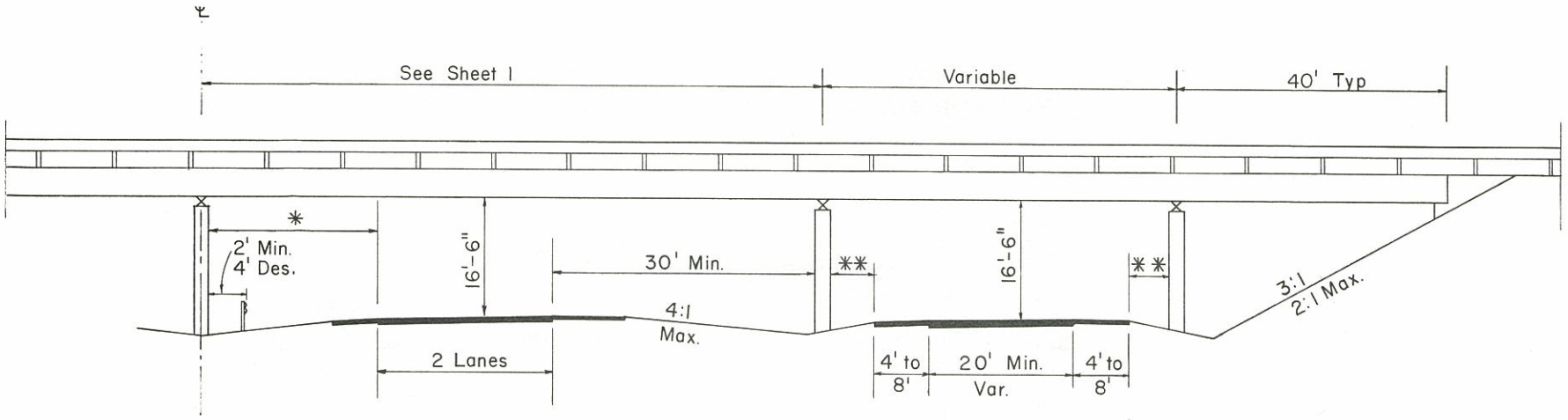


Alternate Bent Location – Under Certain Conditions End Span May Be Omitted – Ditch Line or Top of 4:1 Back Slope Must Be 30' Min. off Pavement

TYPICAL FREEWAY UNDERPASSES

HALF-SECTION WITHOUT FRONTAGE ROADS

FIGURE 4-46 Refers to Paragraph 4-601(1)



*Provide Protection Where Clearance < 30'

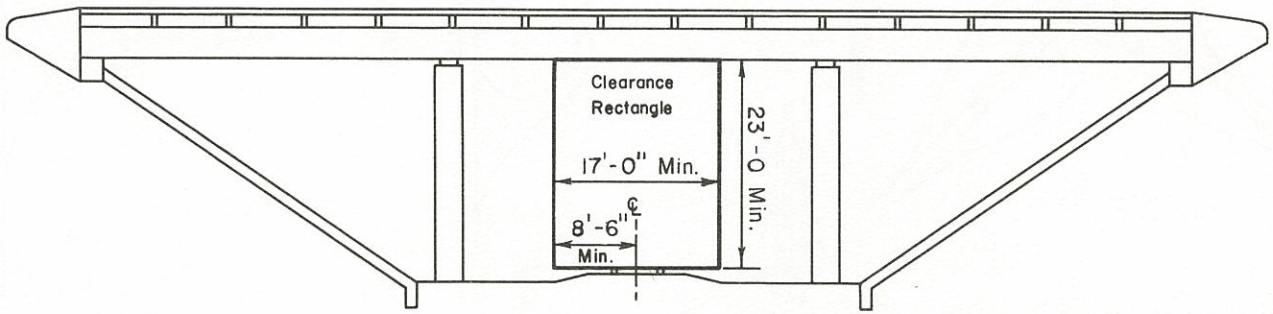
Note: Minimum and desirable clearances indicated for frontage road above also apply to headwalls.

** For design speed of 50 mph or greater, see paragraph 4-202(g)8 and Figure 4-15A. For lower design speeds 6' minimum, 10' to 15' preferred.

TYPICAL FREEWAY UNDERPASSES

HALF-SECTION WITH FRONTAGE ROADS

FIGURE 4-47 Refers to Paragraph 4-601 (i)



REQUIRED CLEARANCES

HORIZONTAL CLEARANCE
(℄ Track to Face of Pier)
8'-6" - Req'd Minimum
12'-0" - Des. Minimum
20'-0" or less - Crash Wall
May be Req'd.

TYPICAL HIGHWAY RAILROAD OVERPASS

Use 17'-0" width rectangle for determination of vertical clearance. 23'-0" vertical clearance may be increased for Electric Power Trains.

FIGURE 4-48 Refers to Paragraph 4-60I (i)

TYPICAL INTERCHANGES SHOWING RAMPS AND CONNECTING ROADWAYS

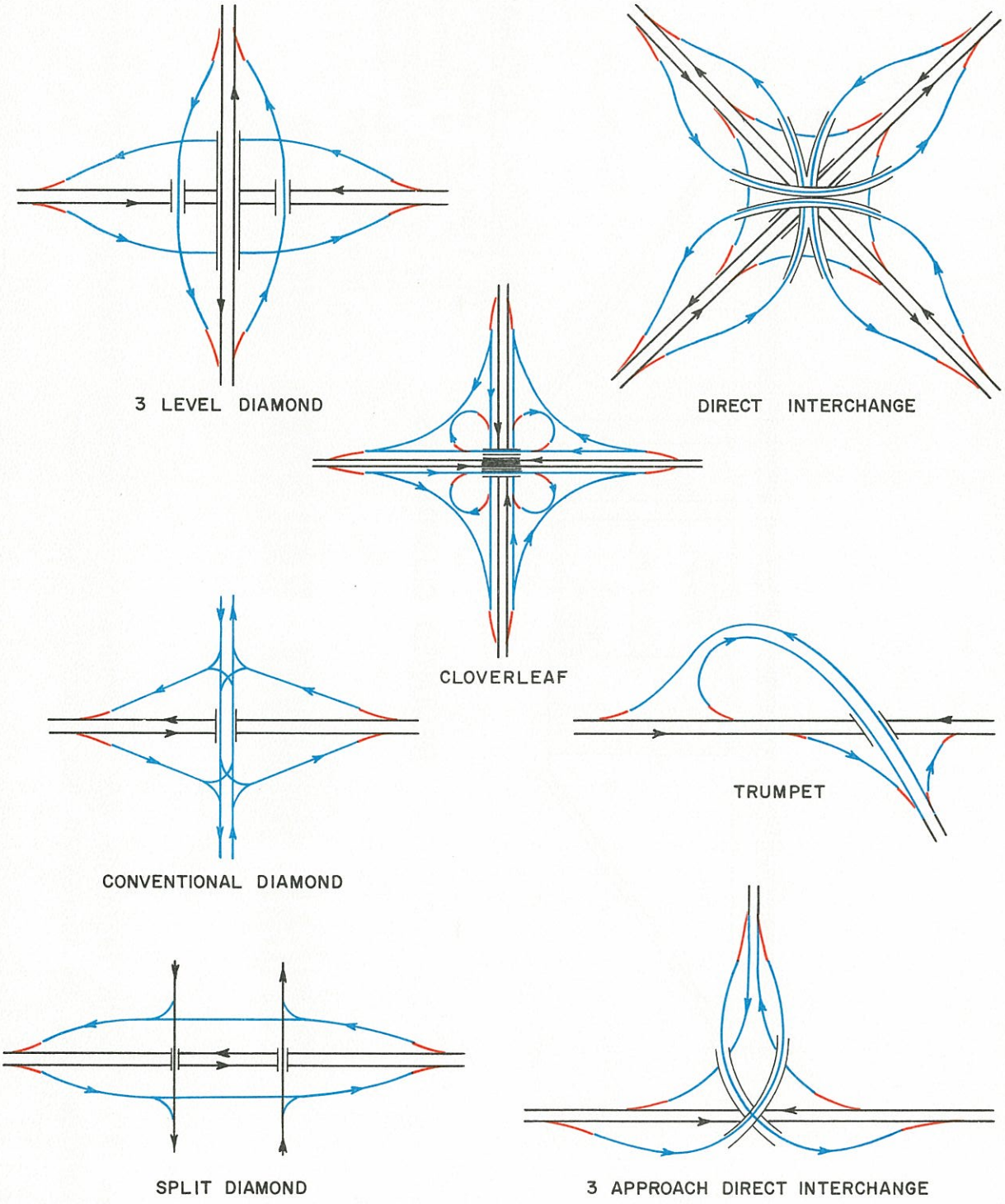


FIGURE 4-49

3. Sight Distance

On all ramps and direct connections, the combination of grade, vertical curves, alignments and clearance of lateral and corner obstructions to vision shall be such as to provide sight distance along such ramps and connections from terminal junctions along the freeway, consistent with the probable speeds of vehicle operation.

MINIMUM STOPPING SIGHT DISTANCE RAMPS AND DIRECT CONNECTIONS

Design Speed, mph	25	30	35	40	45	50	55
Minimum Stopping Sight Distance, feet	150	200	250	300	375	450	525

Figure 4-51 Refers to Paragraph 4-601(j)3

4. Grades and Profiles

Minimum lengths of crest and sag vertical curves on ramps may be obtained from Figure 4-52. Longer vertical curves with increased stopping sight distances should be provided wherever possible.

Ramp profiles generally consist of a section of tangent grade between two vertical curves. The tangent or controlling grade on ramps should be as flat as possible, and preferably should be limited to 4 percent or less.

5. Typical Sections

Typical exit and entrance ramp details are shown in Figures 4-53 through 4-59.

Channelized (braided) entrance and exit ramps, as typified in Figure 4-58, should be used only where ramp volumes are considerably greater than frontage road traffic such as where stub frontage roads occur. Where used, the exit ramp shall cross the frontage road at approximately ninety degrees to minimize wrong way entry. Passing should be restricted between the crossroad and the channelized area.

6. Distance Between Successive Ramps and/or Connections

The minimum acceptable distance between ramps is dependent upon the merge, diverge and weaving operations which take place between ramps and distances required for signing. For analysis of these requirements, see Appendix D, "Capacity and Level of Service."

7. Cross Section and Cross Slopes

Superelevation rates, as related to curvature and design speed of the ramp or connecting roadway, are given in Figure 4-61. As high a rate as practicable should be used, preferably in the upper half or third of the indicated range, particularly on descending grades.

The cross slope on portions of connecting roadways or ramps on tangent normally is sloped one way at a practical minimum rate of 0.015.

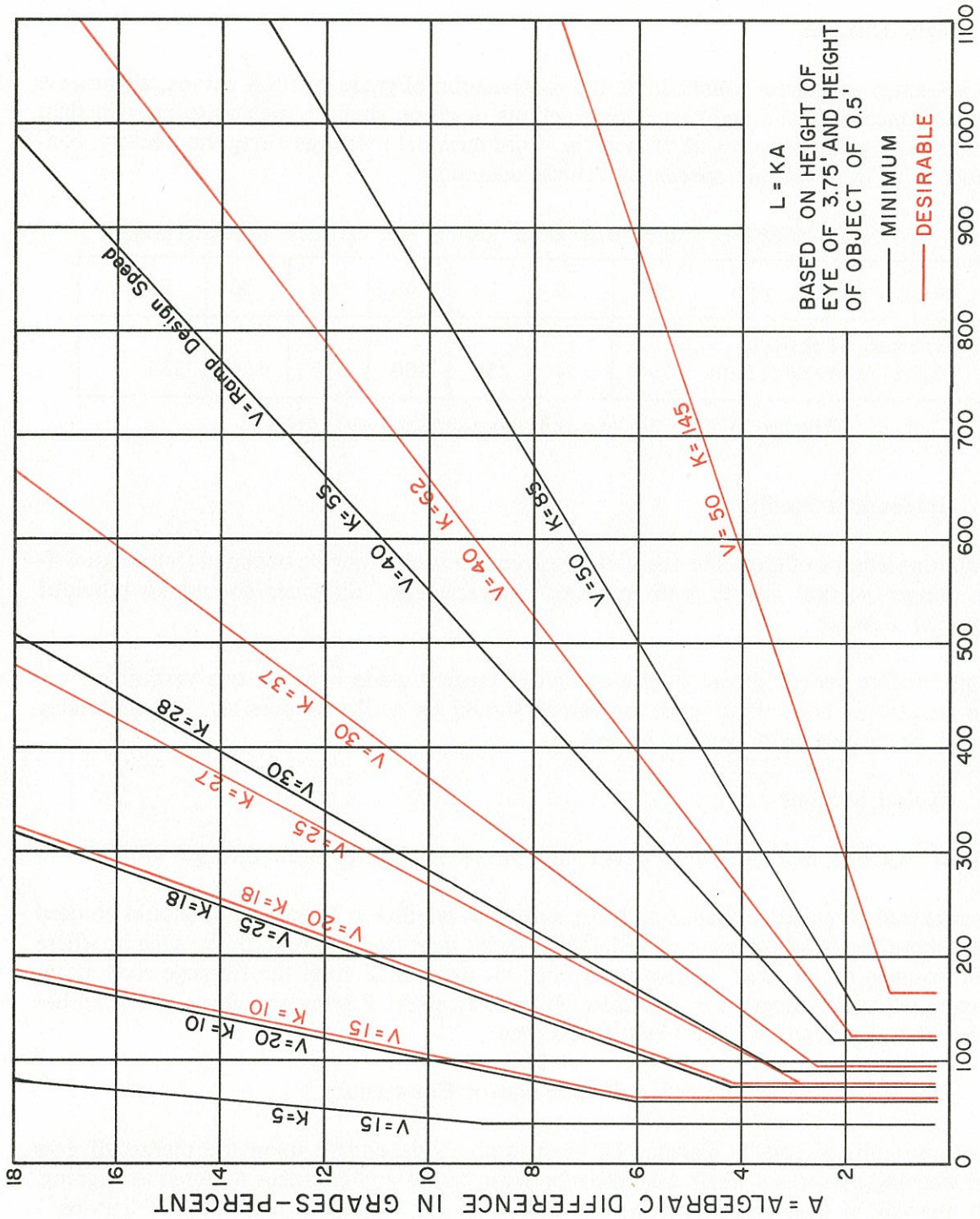
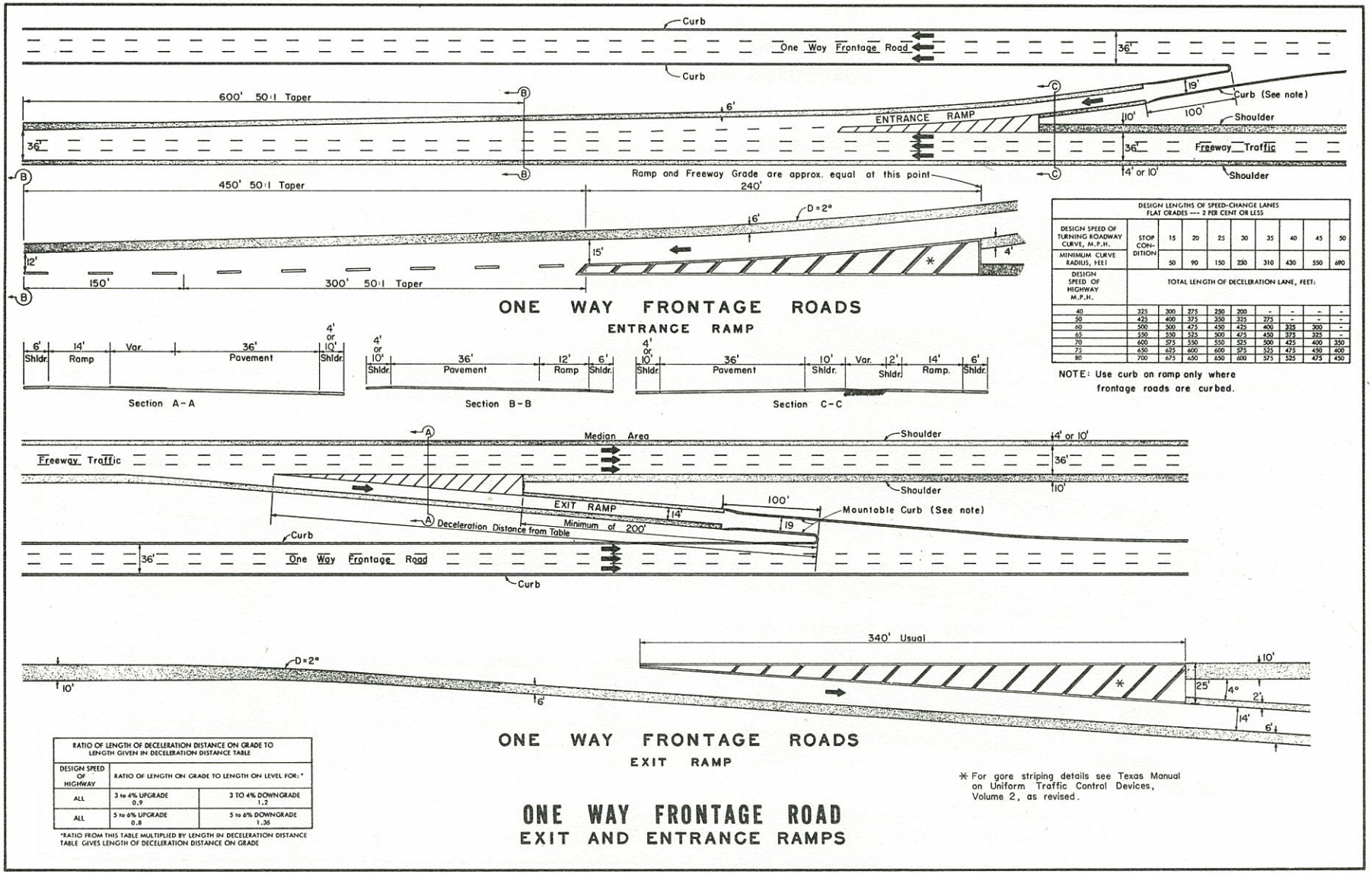


FIGURE 4-52 Refers to Paragraph 4-601(j)4.



DESIGN LENGTHS OF SPEED-CHANGE LANES
FLAT GRADES --- 2 PER CENT OR LESS

DESIGN SPEED OF TURNING ROADWAY CURVE, M.P.H.	STOP CONDITION	15	20	25	30	35	40	45	50
MINIMUM CURVE RADIUS, FEET		50	90	150	230	310	430	550	690
DESIGN SPEED OF HIGHWAY M.P.H.	TOTAL LENGTH OF DECELERATION LANE, FEET:								
40	325	300	275	250	200	-	-	-	-
50	425	400	375	350	325	275	-	-	-
60	500	500	475	450	425	400	325	300	-
65	550	550	525	500	475	450	375	325	-
70	600	575	550	550	525	500	425	400	350
75	650	625	600	600	575	525	475	450	400
80	700	675	650	650	600	575	525	475	450

NOTE: Use curb on ramp only where frontage roads are curbed.

RATIO OF LENGTH OF DECELERATION DISTANCE ON GRADE TO LENGTH GIVEN IN DECELERATION DISTANCE TABLE

DESIGN SPEED OF HIGHWAY	RATIO OF LENGTH ON GRADE TO LENGTH ON LEVEL FOR:*	
ALL	3 to 4% UPGRADE 0.9	3 TO 4% DOWNGRADE 1.2
ALL	5 to 6% UPGRADE 0.8	5 to 6% DOWNGRADE 1.35

*RATIO FROM THIS TABLE MULTIPLIED BY LENGTH IN DECELERATION DISTANCE TABLE GIVES LENGTH OF DECELERATION DISTANCE ON GRADE

* For gore striping details see Texas Manual on Uniform Traffic Control Devices, Volume 2, as revised.

FIGURE 4-53 (Refers to Paragraph 4-6D(1).5)

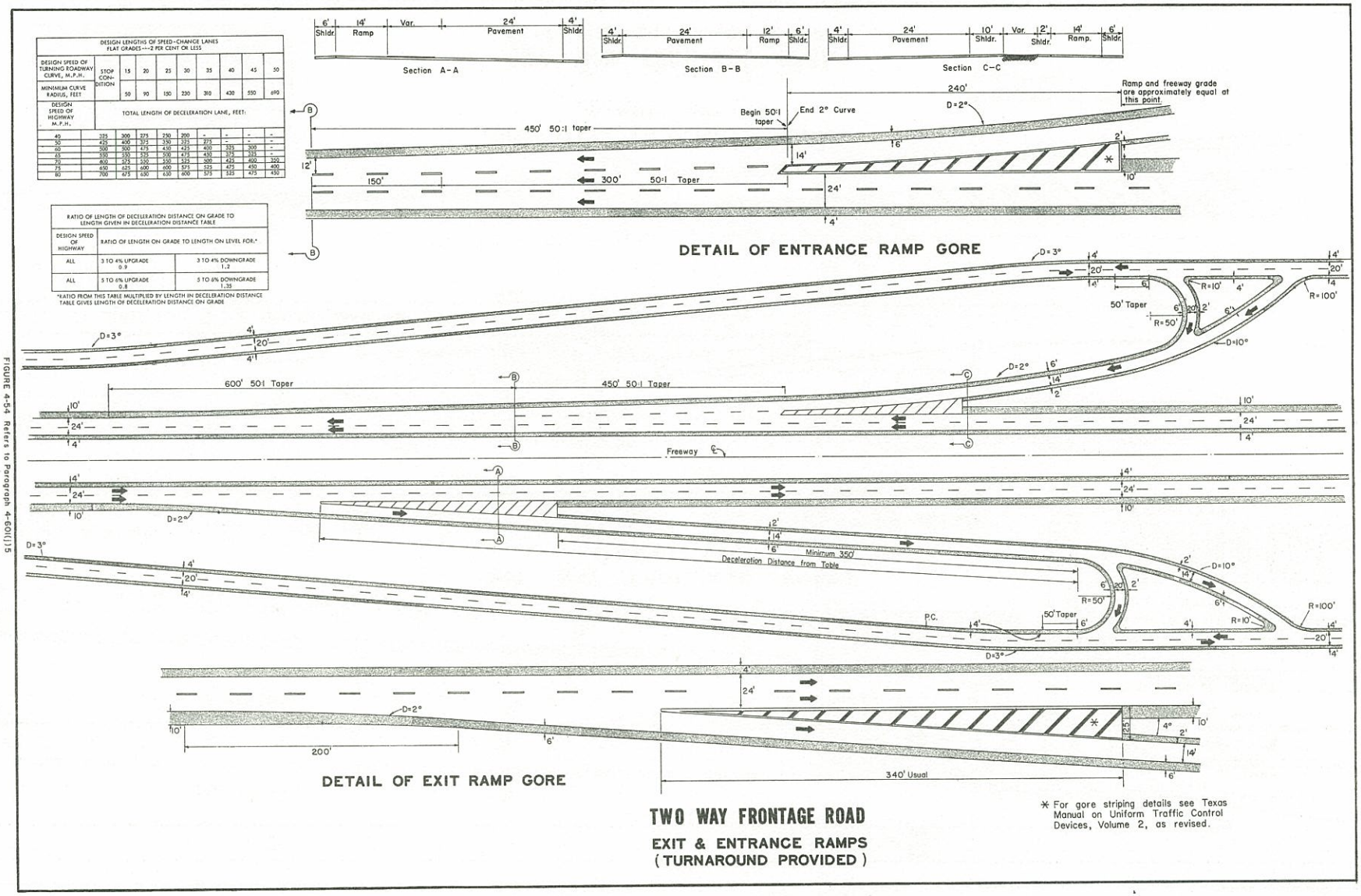
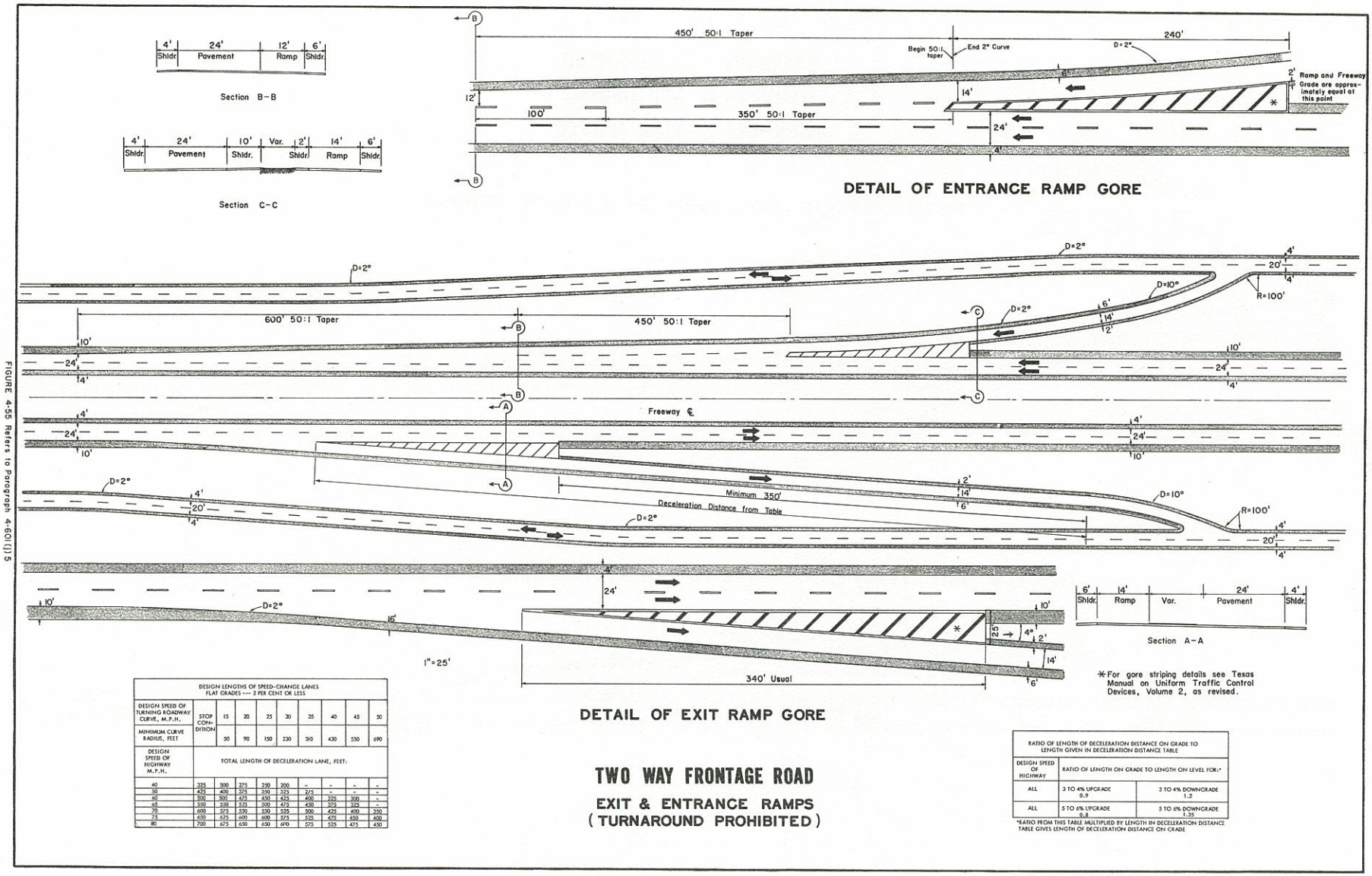


FIGURE 4-54 Refers to Paragraph 4-60(1)5

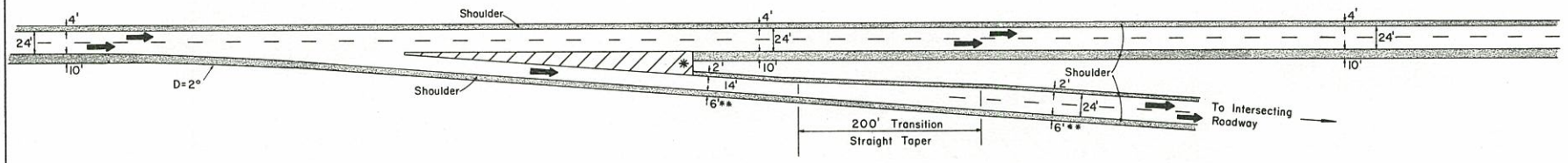


DESIGN LENGTHS OF SPEED-CHANGE LANES FLAT GRADES --- 2 PER CENT OR LESS									
DESIGN SPEED OF TURNING ROADWAY CURVE, M.P.H.	STOP CONDITION	15	20	25	30	35	40	45	50
MINIMUM CURVE RADIUS, FEET		50	90	150	230	310	430	550	690
DESIGN SPEED OF HIGHWAY M.P.H.	TOTAL LENGTH OF DECELERATION LANE, FEET:								
40	325	300	275	250	200	-	-	-	-
50	425	400	375	350	325	275	-	-	-
60	500	500	475	450	425	400	325	300	-
65	550	550	525	500	475	450	375	325	-
70	600	575	550	550	525	500	425	400	350
75	650	625	600	600	575	525	475	450	400
80	700	675	650	650	600	575	525	475	450

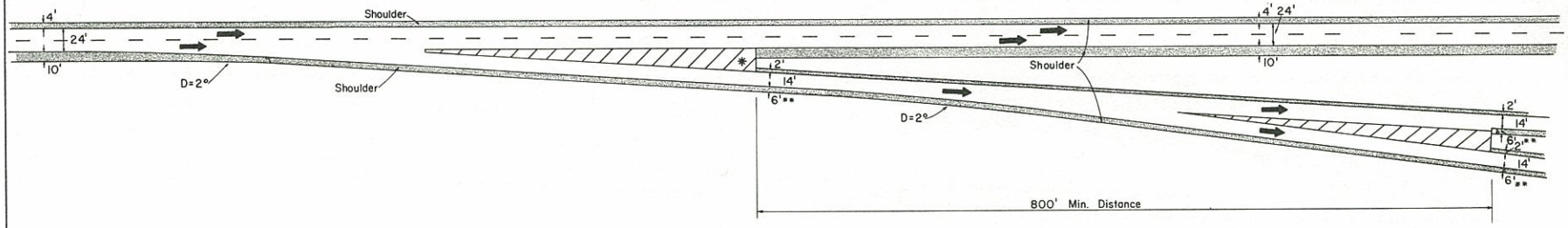
RATIO OF LENGTH OF DECELERATION DISTANCE ON GRADE TO LENGTH GIVEN IN DECELERATION DISTANCE TABLE		
DESIGN SPEED OF HIGHWAY	RATIO OF LENGTH ON GRADE TO LENGTH ON LEVEL FOR:*	
ALL	3 TO 4% UPGRADE 0.9	3 TO 4% DOWNGRADE 1.2
ALL	5 TO 6% UPGRADE 0.8	5 TO 6% DOWNGRADE 1.35

*RATIO FROM THIS TABLE MULTIPLIED BY LENGTH IN DECELERATION DISTANCE TABLE GIVES LENGTH OF DECELERATION DISTANCE ON GRADE

FIGURE 4-55 Refers to Paragraph 4-601(j) 5



ONE LANE EXIT TRANSITION TO TWO LANE CONNECTING ROADWAY



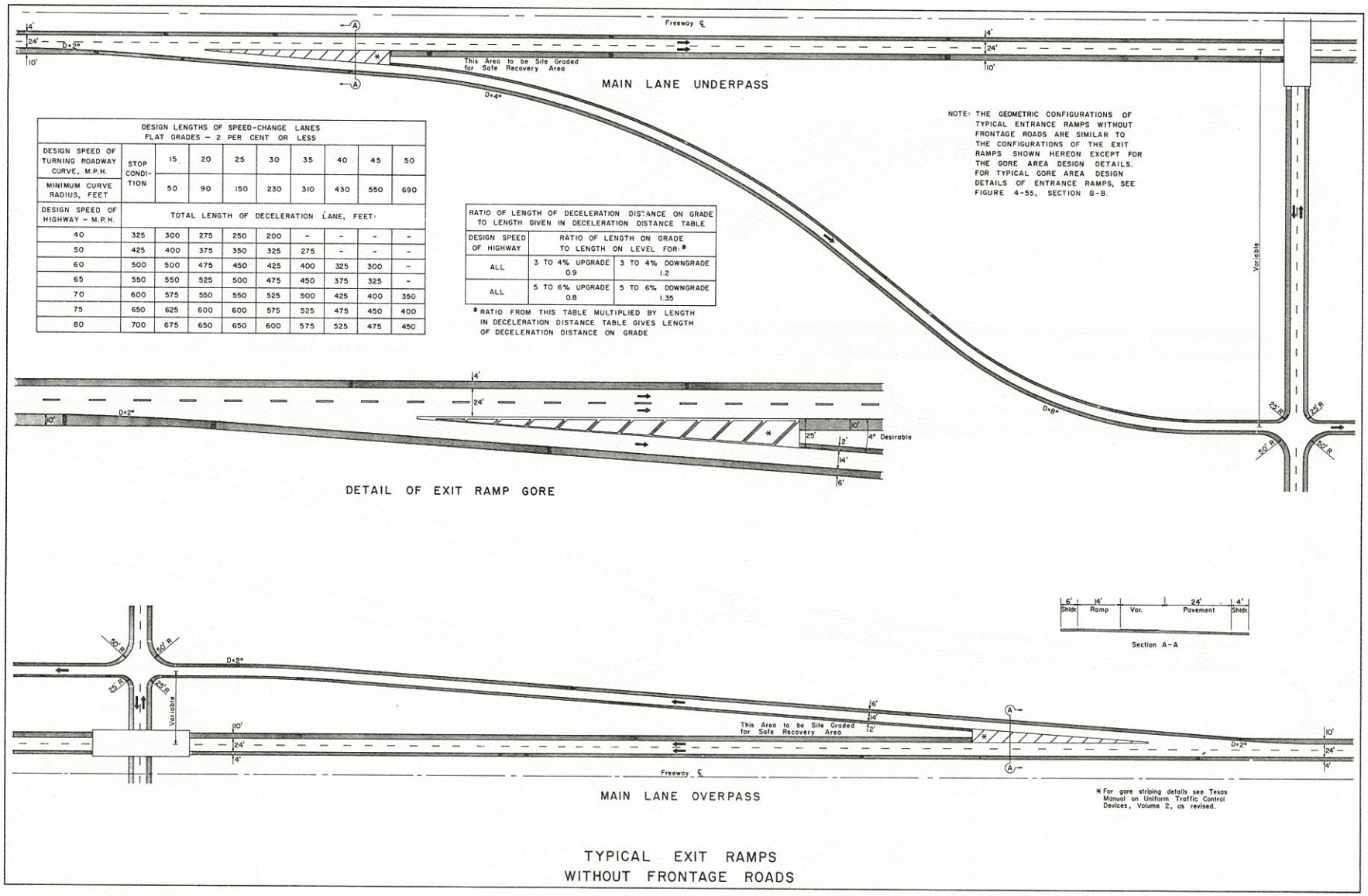
MINIMUM DISTANCE BETWEEN RAMP INTERSECTIONS

* For gore striping details see Texas Manual on Uniform Traffic Control Devices, Volume 2, as revised.

** For direct connecting roadways in directional interchanges, use outside (right) 8' shoulder width.

DESIGN DETAILS FOR RAMP TRANSITIONS INTO SINGLE OR MULTIPLE ROADWAYS

FIGURE 4-56 Refers to Paragraph 4-601(1)5



DESIGN LENGTHS OF SPEED-CHANGE LANES
FLAT GRADES – 2 PER CENT OR LESS

DESIGN SPEED OF TURNING ROADWAY CURVE, M.P.H.	STOP CONDITION	15	20	25	30	35	40	45	50
MINIMUM CURVE RADIUS, FEET		50	90	150	230	310	430	550	690
DESIGN SPEED OF HIGHWAY – M.P.H.	TOTAL LENGTH OF DECELERATION LANE, FEET*								
40	325	300	275	250	200	–	–	–	–
50	425	400	375	350	325	275	–	–	–
60	500	500	475	450	425	400	325	300	–
65	550	550	525	500	475	450	375	325	–
70	600	575	550	550	525	500	425	400	350
75	650	625	600	600	575	525	475	450	400
80	700	675	650	650	600	575	525	475	450

RATIO OF LENGTH OF DECELERATION DISTANCE ON GRADE TO LENGTH GIVEN IN DECELERATION DISTANCE TABLE

DESIGN SPEED OF HIGHWAY	RATIO OF LENGTH ON GRADE TO LENGTH ON LEVEL FOR*	
ALL	3 TO 4% UPGRADE 0.9	3 TO 4% DOWNGRADE 1.2
ALL	5 TO 6% UPGRADE 0.8	5 TO 6% DOWNGRADE 1.35

*RATIO FROM THIS TABLE MULTIPLIED BY LENGTH IN DECELERATION DISTANCE TABLE GIVES LENGTH OF DECELERATION DISTANCE ON GRADE

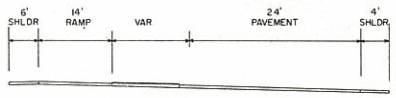
TYPICAL EXIT RAMPS
WITHOUT FRONTAGE ROADS

FIGURE 4-57 Refers to Paragraph 4-601(j)5

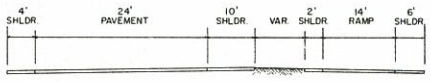
DESIGN LENGTHS OF SPEED-CHANGE LANES FLAT GRADES---2 PER CENT OR LESS									
DESIGN SPEED OF TURNING ROADWAY CURVE, M.P.H.	STOP CONDITION	15	20	25	30	35	40	45	50
MINIMUM CURVE RADIUS, FEET		50	90	150	230	310	430	550	690
DESIGN SPEED OF HIGHWAY M.P.H.	TOTAL LENGTH OF DECELERATION LANE, FEET:*								
40	325	300	275	250	200	-	-	-	-
50	425	400	375	350	325	275	-	-	-
60	500	500	475	450	425	400	325	300	-
65	550	550	525	500	475	450	375	325	-
70	600	575	550	550	525	500	425	400	350
75	650	625	600	600	575	525	475	450	400
80	700	675	650	650	600	575	525	475	450

RATIO OF LENGTH OF DECELERATION DISTANCE ON GRADE TO LENGTH GIVEN IN DECELERATION DISTANCE TABLE		
DESIGN SPEED OF HIGHWAY	RATIO OF LENGTH ON GRADE TO LENGTH ON LEVEL FOR:*	
ALL	3 TO 4% UPGRADE * 0.9	3 TO 4% DOWNGRADE 1.2
ALL	5 TO 6% UPGRADE 0.8	5 TO 6% DOWNGRADE 1.35

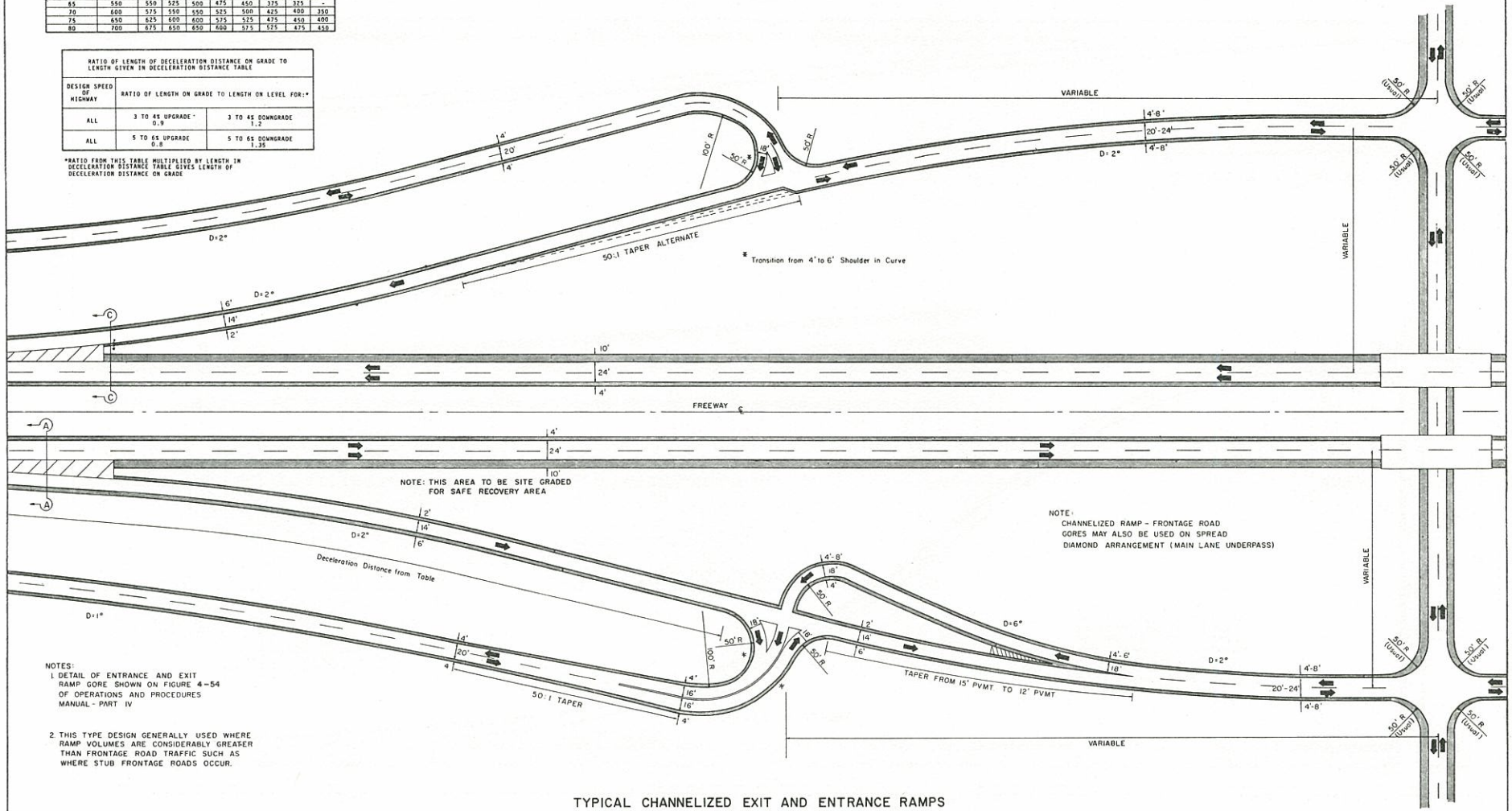
*RATIO FROM THIS TABLE MULTIPLIED BY LENGTH IN DECELERATION DISTANCE TABLE GIVES LENGTH OF DECELERATION DISTANCE ON GRADE



SECTION A-A



SECTION C-C

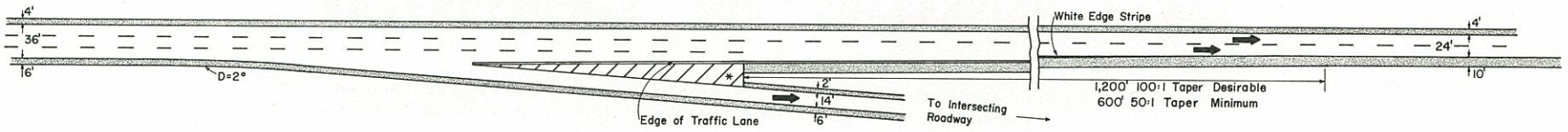


NOTES:
1. DETAIL OF ENTRANCE AND EXIT RAMP GORE SHOWN ON FIGURE 4-54 OF OPERATIONS AND PROCEDURES MANUAL - PART IV

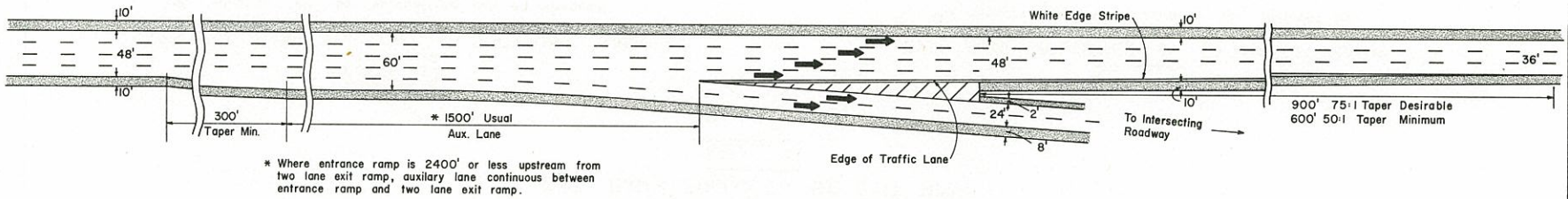
2. THIS TYPE DESIGN GENERALLY USED WHERE RAMP VOLUMES ARE CONSIDERABLY GREATER THAN FRONTAGE ROAD TRAFFIC SUCH AS WHERE STUB FRONTAGE ROADS OCCUR.

TYPICAL CHANNELIZED EXIT AND ENTRANCE RAMPS
(TWO WAY FRONTAGE ROAD)

FIGURE 4-58 Refers to Paragraph 4-601(1)5

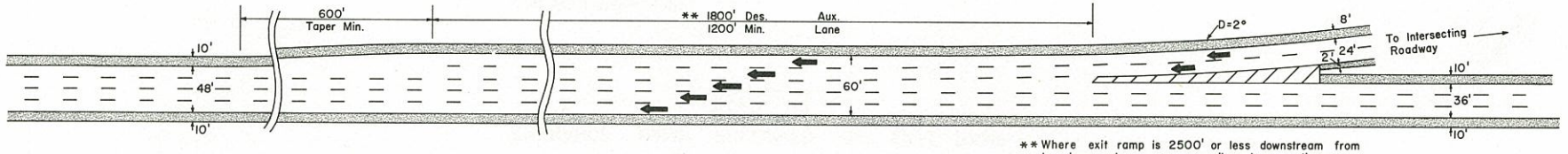


AUXILIARY LANE TERMINATION



* Where entrance ramp is 2400' or less upstream from two lane exit ramp, auxilary lane continuous between entrance ramp and two lane exit ramp.

MULTILANE DIVERGE



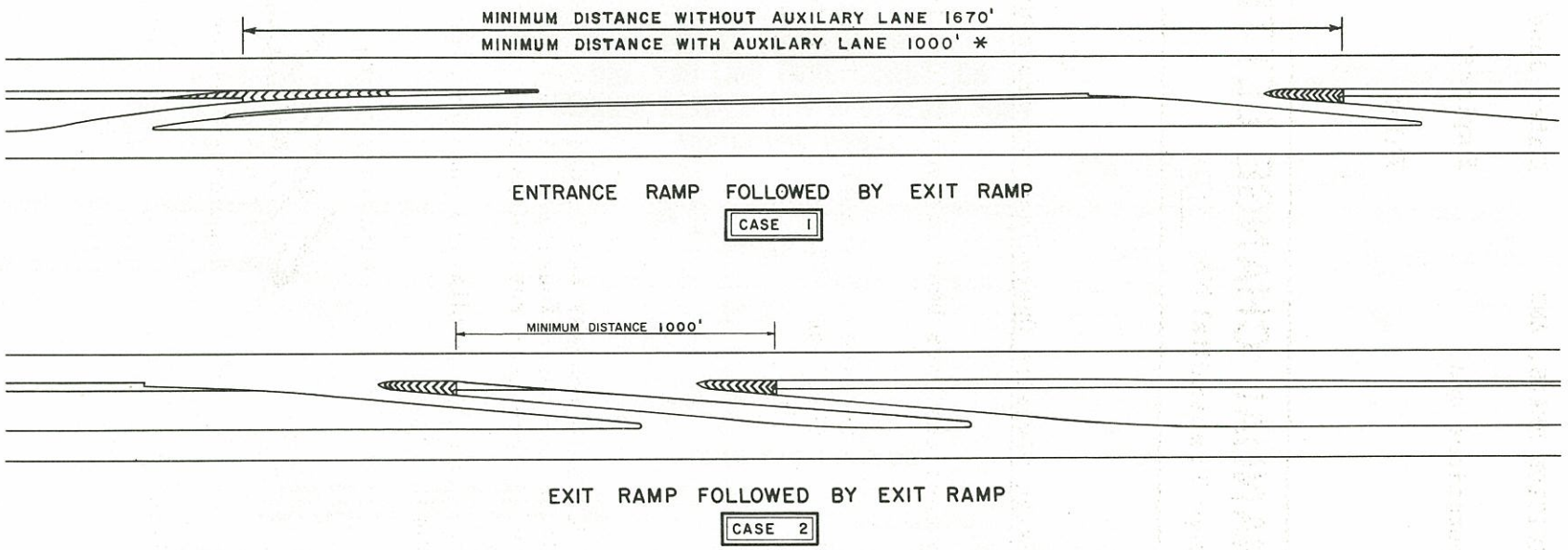
** Where exit ramp is 2500' or less downstream from two lane entrance ramp, auxilary lane continuous between two lane entrance ramp and exit ramp.

MULTILANE MERGE

DESIGN DETAILS FOR RECOVERY AREA ONE AND TWO LANE RAMPS OR DIRECT CONNECTIONS

Note: For gore striping details see Texas Manual on Uniform Traffic Control Devices, Volume 2 as revised.

FIGURE 4-59 Refers to Paragraph 4-601(j)5



CASE 3

ENTRANCE RAMP FOLLOWED BY ENTRANCE RAMP

This situation will be encountered only on infrequent occasions and special design treatment will be required. It will usually require an added freeway lane.

CASE 4

EXIT RAMP FOLLOWED BY ENTRANCE RAMP

The distance between an entrance ramp followed by an exit ramp will be governed by the geometrics of the connections to the adjacent roadway or connecting roadway.

* MINIMUM DISTANCE WITH AUXILARY LANE USUALLY GOVERNED BY TRAFFIC WEAVING REQUIREMENTS. SEE APPENDIX D "CAPACITY AND LEVEL OF SERVICE."

ARRANGEMENTS FOR SUCCESSIVE RAMPS

FIGURE 4-60 Refers to Paragraph 4-601(j)6

Superelevation run-off, or the change in superelevation rate per given length of connecting roadway or ramp, should be that in Figure 4-61. The maximum algebraic difference in pavement cross slope at connecting roadways or ramps should not exceed that set forth in Figure 4-63.

Connecting roadways or ramps of appreciable length should provide width for two moving lanes plus shoulders. The lanes provide freedom and flexibility of movement and prevent the accumulation of queues of vehicles which will probably have difficulty entering the facility to which the connecting roadway is joined. Where transitions from the two lanes to one occur, the right lane should be continuous.

SUPERELEVATION RATES FOR CURVES ON CONNECTING ROADWAYS
RANGE IN DESIGN VALUES

Radius Feet	Degree of Curve	Range in Superelevation Rate (ft. per ft.) For Connecting Roadways With Design Speed, MPH, of:			
		25	30	35	40
150	38.2	.04-.12			
230	24.8	.03-.12	.06-.12		
310	18.5	.03-.06	.05-.09	.08-.12	
430	13.3	.03-.05	.04-.05	.04-.07	.09-.12
600	9.6	.02-.04	.03-.05	.05-.07	.07-.09
1000	5.7	.02-.03	.03-.04	.04-.05	.05-.06
1500	3.8	.02	.02-.03	.03-.04	.04-.05
2000	2.9	.02	.02	.02-.03	.03-.04
3000	1.9		.02	.02	.02-.03

Figure 4-61 (Refers to Paragraph 4-601(j)7)

DESIGN RATE OF CROSS SLOPE CHANGE FOR CONNECTING ROADWAYS

Design, Speed MPH	25	30	35 or more
Change in Superelevation Rate:			
Per Station	.07	.06	.05
Per 25-foot length	.017	.015	.012

Figure 4-62 (Refers to Paragraph 4-601(j)7)

MAXIMUM ALGEBRAIC DIFFERENCES IN PAVEMENT CROSS SLOPE
AT CONNECTING ROADWAY TERMINALS

Design Speed of Exit or Entrance Curve, mph	Maximum Algebraic Difference in Cross Slope at Crossover Crown Line, foot per foot
25 and 30	0.05 to 0.06
35 and over	0.04 to 0.05

Figure 4-63 Refers to Paragraph 4-602(j)7

(k) Collector-Distributor Roads

A collector-distributor road may be warranted within an interchange, through two adjacent interchanges or continuous for some distance along the freeway through several interchanges. Collector-distributor roads should be provided at all cloverleaf interchanges and particularly on such interchanges on controlled access facilities. A collector-distributor road is a valuable addition within interchanges which involve weaving. Where there is considerable demand for frequent ingress and egress, as in and near the business district of large cities, a collector-distributor road, continuous for some distance, should be provided.

(l) Turnarounds

Turnaround lanes shall be provided at all interchanges with major arterials, in urban and suburban areas, where the freeway lanes are flanked by one-way frontage roads. Turnaround lanes will not be provided where two-way frontage roads are used. In all cases, the end spans of overpasses or grade line at underpasses should be so arranged that turnarounds may be added in the future, when warranted. Figure 4-64 shows a typical turnaround at a diamond interchange.

(m) Types of Interchanges

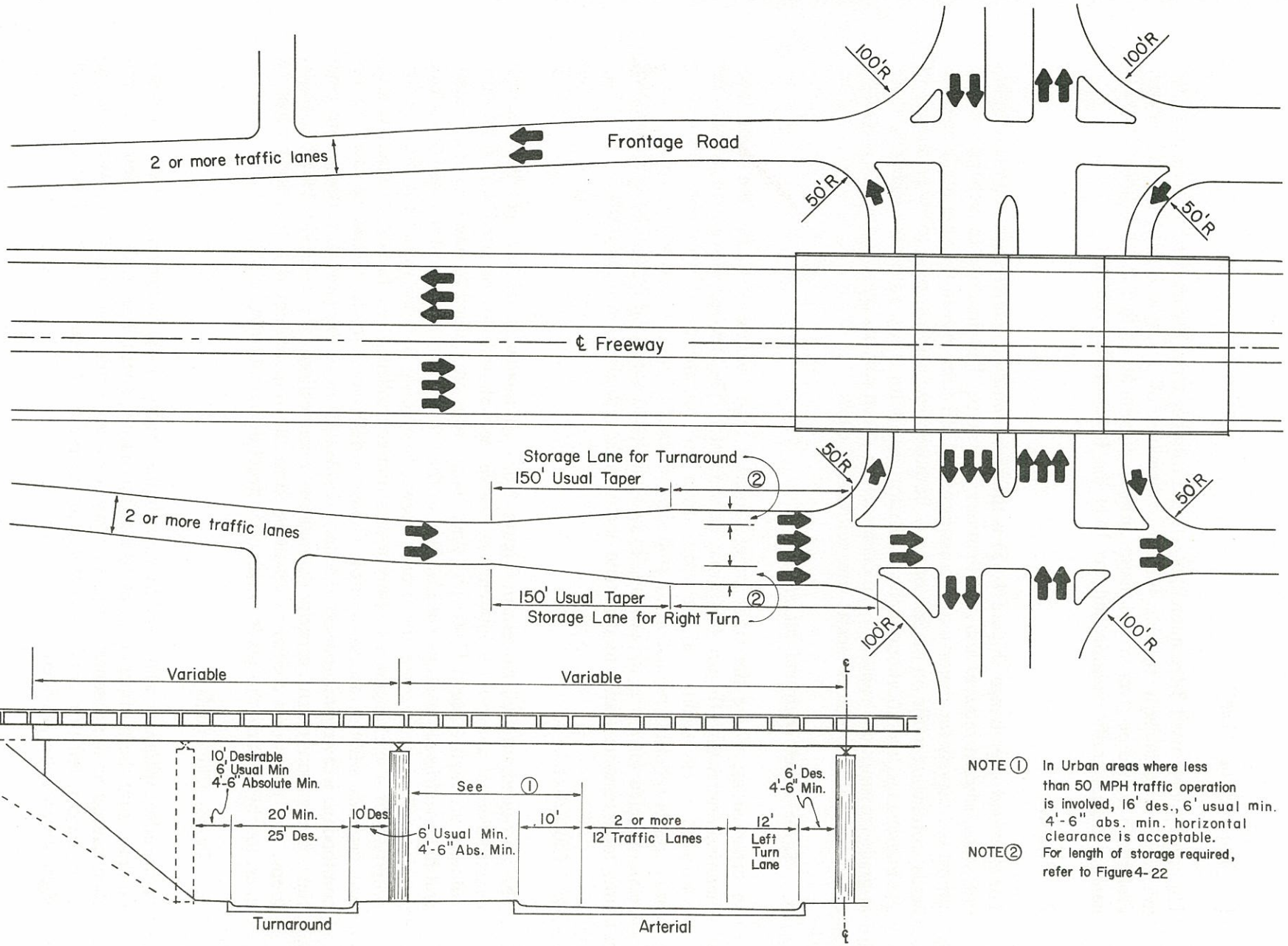
The decision to develop a facility to freeway standards becomes the warrant for providing highway grade separations or interchanges at the most important intersecting streets, roads, railroads and highways.

An interchange or series of interchanges on a freeway through a community may affect large continuous areas or even the entire community. For this reason, interchanges must be located and designed so that they will provide the best possible traffic service.

Drivers who have exited from a freeway expect to be able to re-enter in the same vicinity; therefore, partial interchanges which do not serve all desired traffic movements should be avoided.

Interchanges are classified in a general way, according to the number of approach roadways or intersection legs, as 3-leg, 4-leg and multi-leg interchanges. Through common usage, interchanges are descriptively called "Tee" (or Trumpet) for 3-leg design; Cloverleaf (full or partial) and Diamond for 4-leg and Directional for three or more legs.

A brief description and some of the advantages and disadvantages of each type and variety are given in the following discussion.



TYPICAL DIAMOND INTERCHANGE WITH TURNAROUNDS

FIGURE 4-64 REFERS TO PARAGRAPH 4-601(e)

1. Trumpet or "Tee"

The most widely used 3-leg interchange is the trumpet type, Figure 4-65. This type of interchange is particularly suitable for the connection of a major facility and a freeway. Preference should be given to the major turning movements so that the directional roadway handles higher traffic volume and the loop the lower traffic volume.

2. Diamond

The diamond interchange (Figure 4-65) is the most common interchange, especially in urban areas, since it requires less area than any other type. The diamond interchange is used almost exclusively for major-minor crossings since left-turn movements are made at-grade across conflicting traffic on the minor road. Because these conflicts tend to lower capacity of the interchange, modifications such as collector-distributor roads, pavement widening at the at-grade crossings or "splitting" the diamond (i.e., each pair of ramps connect to a separate cross-street about a block apart) are sometimes used.

3. Three Level Diamond Interchange

In urban areas, where the cross street carries a high volume of traffic, the three level diamond interchange (Figure 4-66) may be warranted. The through movements of both the controlled access facility and the cross street flow uninterrupted with only the turning movements requiring regulation by stop signs or traffic lights. This type interchange is not recommended for use at the crossing of two controlled access facilities since it requires left turn interchanging traffic to negotiate three traffic signals or stop controls.

4. Cloverleaf

The four-quadrant, full cloverleaf (Figure 4-67) eliminates all left-turn conflicts through construction of a two-level interchange. Cloverleafs should not be used where left-turn volumes are high (exceed 1200 vph) since loop ramps are limited to one lane of operation and have restricted operating speeds. Due to their inherent capacity restrictions, cloverleafs are generally inappropriate for urban freeway-to-freeway interchanges, but may be appropriate for interchanging a freeway with a non-controlled access facility, or interchanging two facilities without access control. Collector-distributor roads should be used to accommodate weaving maneuvers. Primary disadvantages of the cloverleaf design are large right of way requirement, capacity restrictions of connections, short weaving length between loops, and the driver confusion resulting from the requirement that left turns must be executed by passing the grade separation structure and turning right.

5. Partial Cloverleafs

A cloverleaf without ramps in all four quadrants (Figure 4-68) is sometimes used when site controls limit the number of loops and/or the traffic pattern is such that the left turn conflicts caused by the absence of one or more loops are within tolerable limits. With such an arrangement, left turn conflicts at the ramp intersections require that satisfactory approach sight distance be provided.

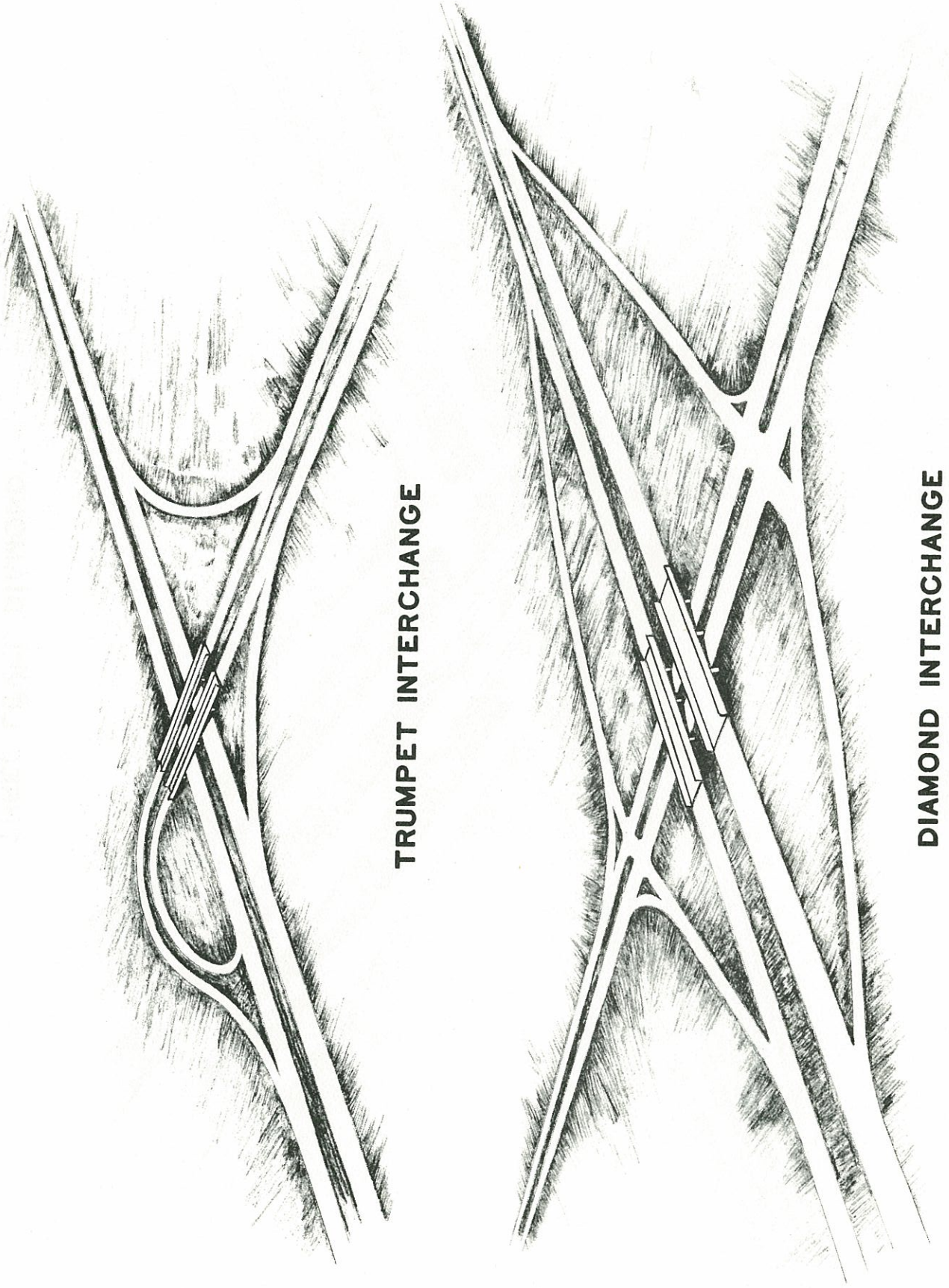
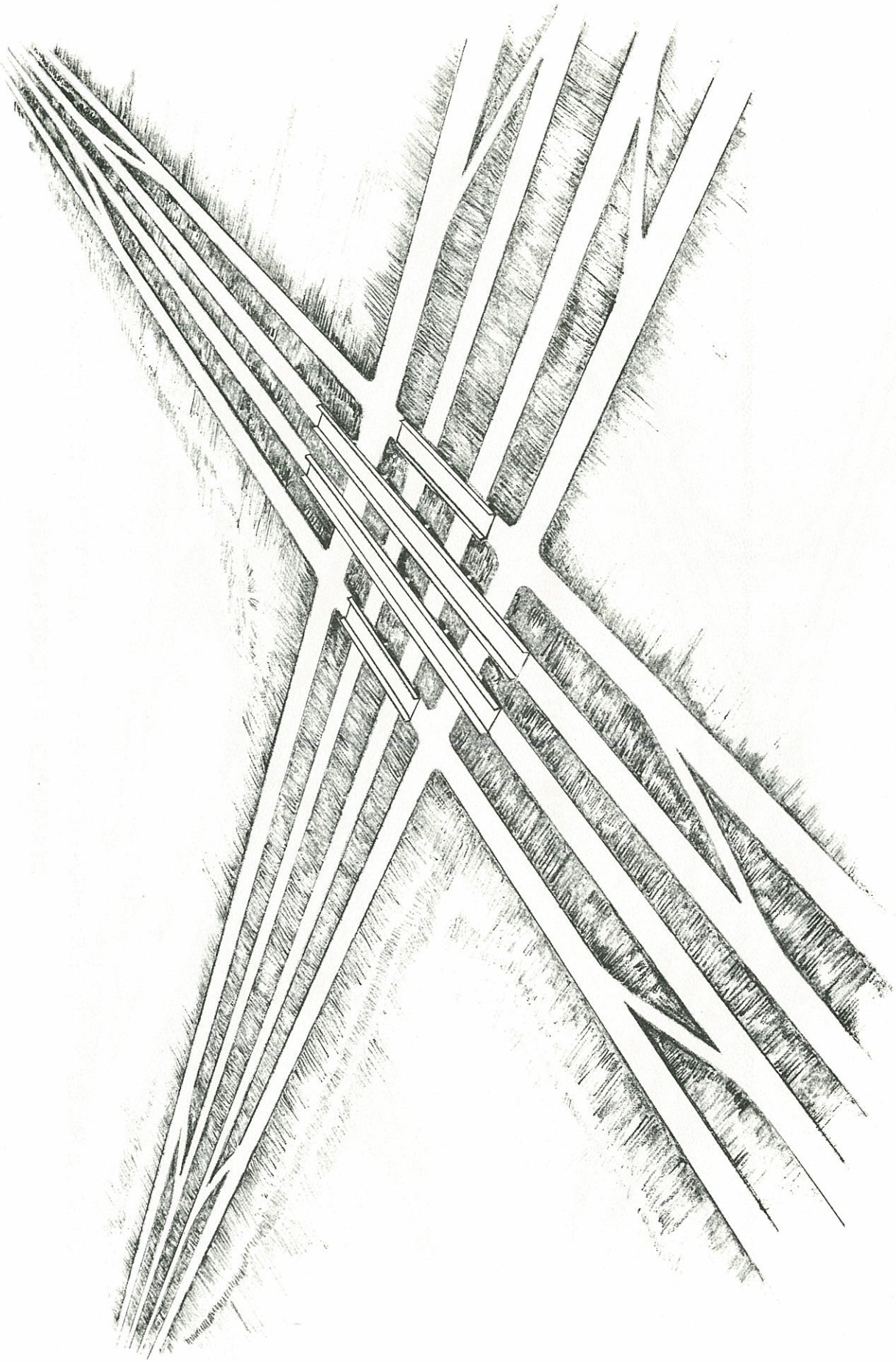
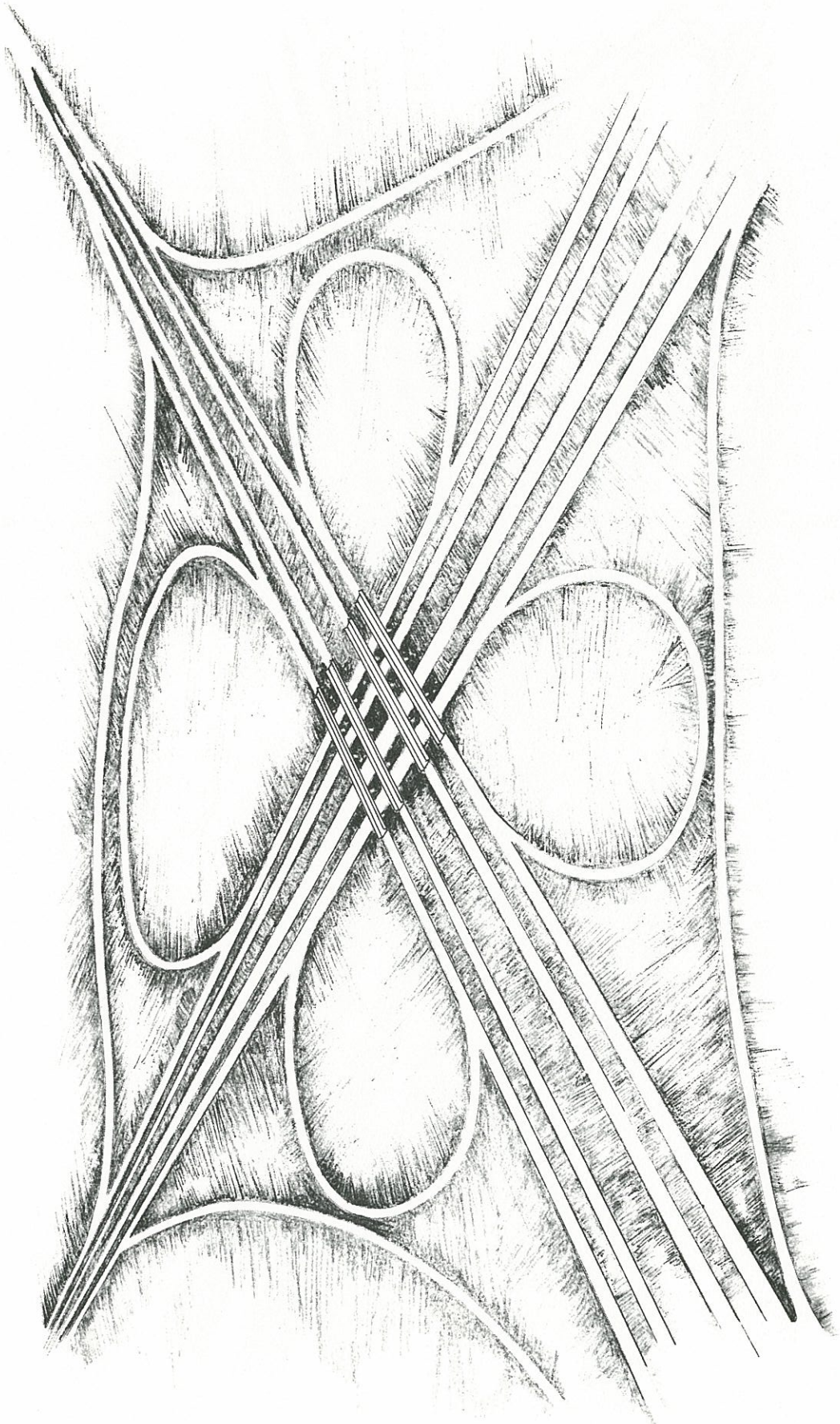


FIGURE 4-65 Refers to Paragraph 4-601(m)1



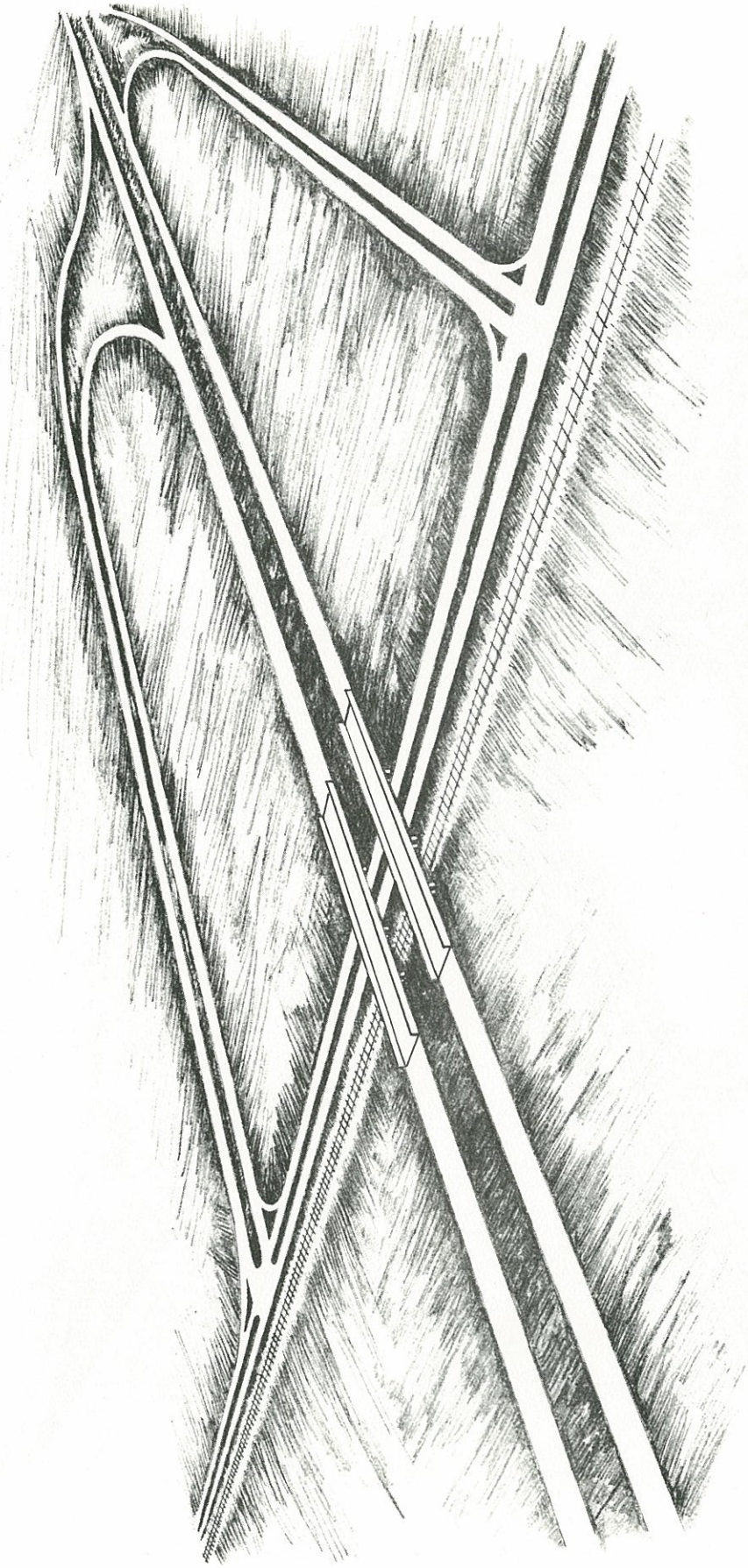
THREE LEVEL DIAMOND

FIGURE 4-66 Refers to Paragraph 4-601(m)1



CLOVERLEAF INTERCHANGE WITH COLLECTOR-DISTRIBUTOR ROADS

FIGURE 4-67 Refers to Paragraph 4-601(m)1



PARTIAL CLOVERLEAF INTERCHANGE

FIGURE 4-68 Refers to Paragraph 4-601(m)1

6. Directional

Interchanges which use direct or semi-direct connections for one or more left-turn movements are called "directional" interchanges (Figure 4-69). When all turning movements travel on direct or semi-direct ramps or direct connections, the interchange is referred to as "all directional." These direct or semi-direct connections are used for important turning movements instead of loops to reduce travel distance, increase speed and capacity, reduce weaving and avoid loss of direction in traversing a loop. "All-directional" interchanges are usually justified at the intersection of freeways.

The four-level directional interchange as depicted in Figure 4-69 includes direct connections for all freeway-to-freeway movements. In some instances, it may be desirable to continue the frontage roads through the interchange at the first or second level, producing a five-level directional interchange. Where frontage roads are made continuous through the interchange, the lower three levels are a three-level diamond configuration. Where stage construction is desired, the three-level diamond will adequately serve moderate traffic volumes until the upper two levels of direct connections are constructed to complete the five-level interchange.

(n) Requests for Additional Interchanges on Interstate Highways

Requests for additional interchanges on completed Interstate highways must be approved by the Federal Highway Administrator. In the interest of expediting the processing of requests, documentation for justification of an additional interchange should normally include the following information (as appropriate) and any other data demonstrating public benefits or needs:

1. A statement of the type and condition of the crossroad including:

   a. The system or regional plan of which it is a part.

   b. ADT, current and design year; through and turning.

   c. Number of existing traffic lanes and type of highway.

   d. Probable number of traffic lanes for the design year.

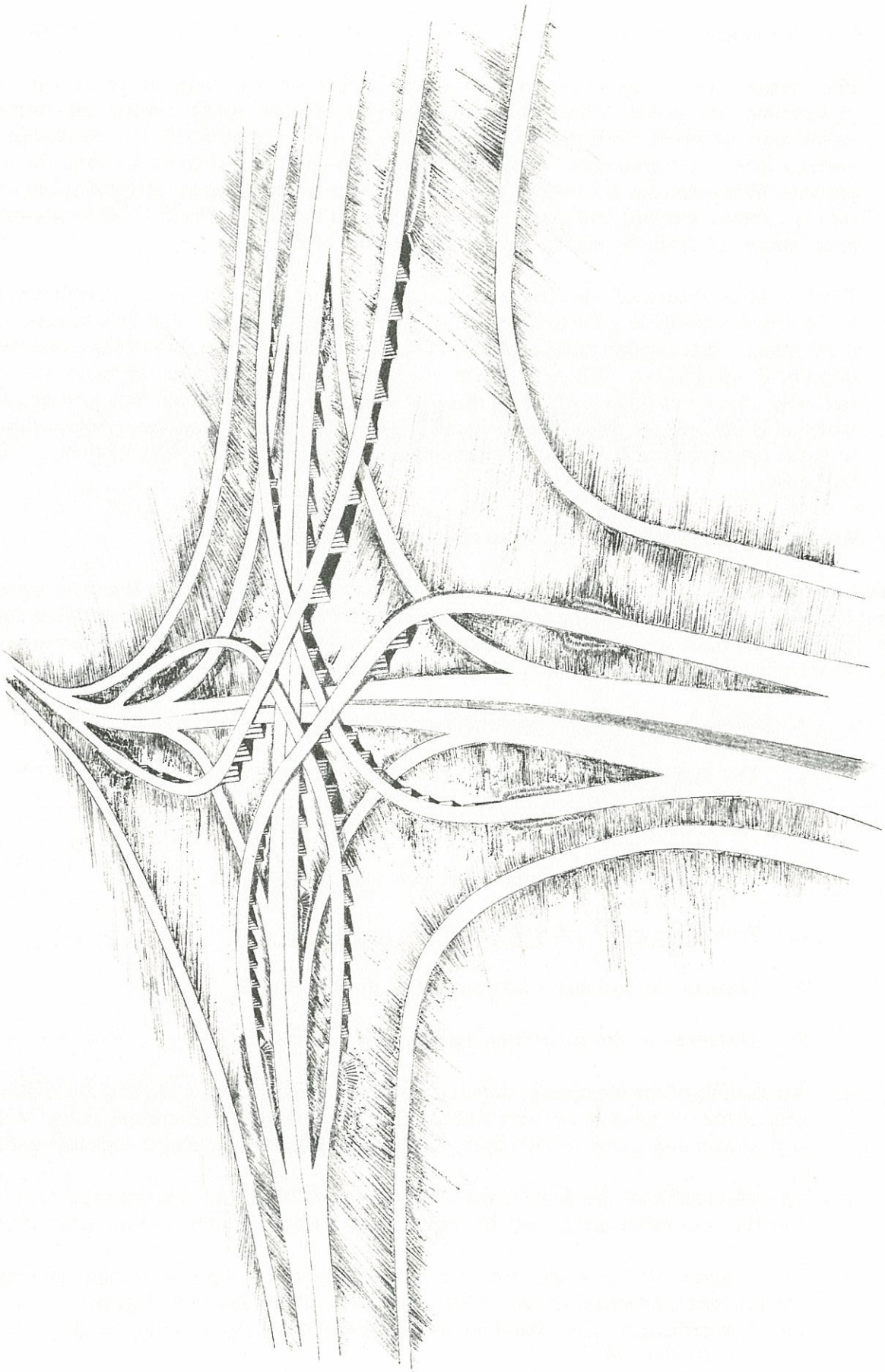
   e. Distance to and size of communities directly served.

   f. Distances to the next interchange in each direction.

2. An analysis of the crossroads, the other roads and streets in the area, and the relationship of the interchange to them and to other interchanges to assure the ability of the said streets and roads to effectively collect and distribute interstate highway traffic.

3. The relationship of the interchange to adjacent interchanges of the Interstate highway and the acceptable merge and diverge lengths, and the ability to sign adequately.

4. The existence of other roads or streets, or the probability of developing them, generally parallel to the interstate system, which could be used by interstate highway traffic by way of interchanges other than the one under consideration in traveling to and from its origin or destination.



MULTI-LEVEL DIRECTIONAL INTERCHANGE

FIGURE 4-69 (Refers to Paragraph 4-601(m) 1

5. A statement of the cost resulting from construction of the interchange, together with the estimated benefit-cost ratio for the additional work involved.

6. If appropriate, a statement that the interchange is a special case where it is clearly necessary to serve a compelling public need.

BUSWAY GEOMETRIC DESIGN STANDARDS

Traveled Way:	Desirable	Minimum
Design Speed (mph)	50-70	30-50
Lane Widths (ft.)[1]	13	12
Shoulder Widths (ft.)		
a. Carpool Users	8-10	6-8
b. Professional Drivers Only	8-10	2-4
Total Pavement Width (ft.)[2]	44	28[3]
Vertical Clearance (ft.)	14.5	12.5
Maximum Gradients (%)	3	6
Lateral Distance to Fixed Obstruction (ft.)[4]		
Left	3.5	2
Right	6	3

Pavement cross slope, vertical curvature, horizontal curvature, and super-elevation should conform to Departmental highway design practice.

Busway Ramps:		
Design Speed (mph)	30-35	15-25
Lane Width (ft.)		
With paved shoulders	12	12
Without paved shoulders	14	13
Paved shoulder width (ft.)	8	8
Total paved width (ft.)	14-20	13-20

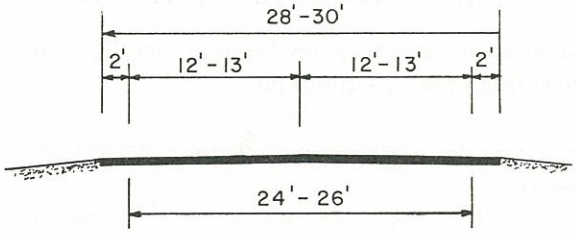
1 Increase lane widths one (1) foot when longitudinal barriers are used adjacent to busway travel lane.

2 Total pavement width between stations. At stations, single parallel platforms should be at least 6 feet and preferably 10 feet or more in width.

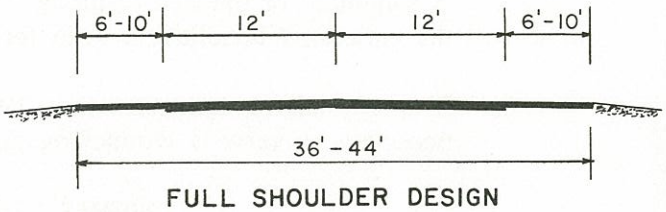
3 Elevated sections also 28 feet in width; tunnel widths minimally 31 feet.

4 Distance from edge of busway travel lane to face of noncontinuous obstruction such as a bridge pier.

Figure 4-69A (Refers to Paragraphs 4-603(a)1 and 2)

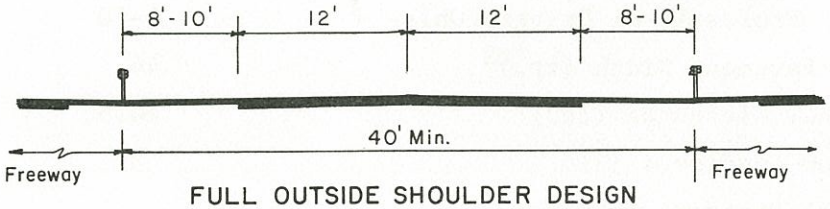


MINIMUM DESIGN

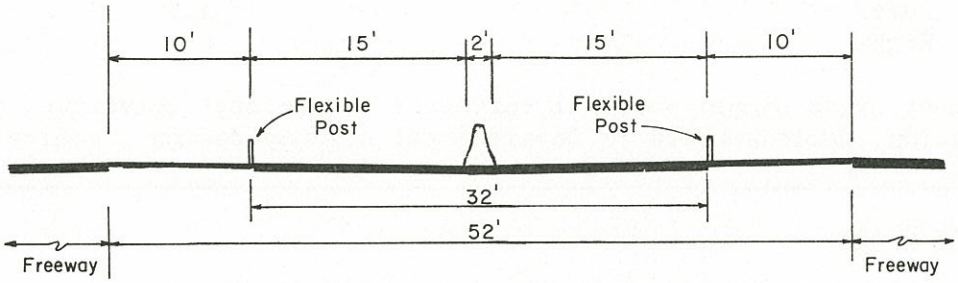


FULL SHOULDER DESIGN

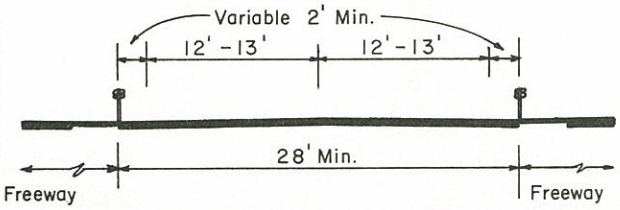
EXCLUSIVE BUSWAY ON SEPARATE RIGHT-OF-WAY



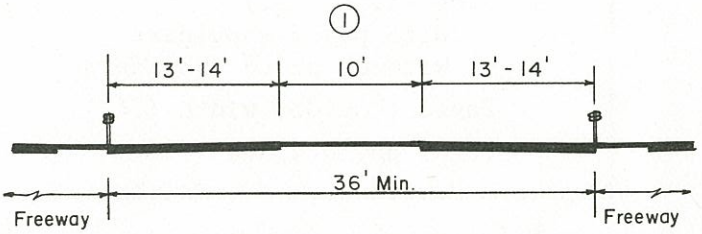
FULL OUTSIDE SHOULDER DESIGN



COMMON FREEWAY-BUSWAY SHOULDER



MINIMUM OUTSIDE SHOULDER DESIGN



FULL INTERIOR SHOULDER DESIGN

BUSWAYS IN FREEWAY MEDIANS

1. May operate as normal or contra-flow, interior lane for breakdown or passing.

BUSWAY TYPICAL SECTION (Refers to Paragraphs 4-603(a) 1 and 2)

FIGURE 4-69B

4-603 FREEWAY RELATED BUS PRIORITY TREATMENTS

(a) General

Buses operate rapidly and efficiently on uncongested urban freeways. Many freeways, particularly radial routes leading to downtown areas, become routinely congested during peak hours, delaying buses as well as other freeway users. To improve bus travel, several general techniques may be considered, including busways on separate rights-of-way, busways on freeway rights-of-way, ramp metering and special bus ramps.

1. Busways on Separate Rights-of-Way

Exclusive busways on their own rights-of-way with complete access control provide the highest type of service. Abandoned or little used railroad rights-of-way are potential locations for these exclusive busways.

2. Busways on Freeway Rights-of-Way

a. Use of Median Area

Lengthy, flush medians may provide space for exclusive bus lanes on freeways. Most existing freeways with flush medians are deficient in width, or include only a few miles of length with adequate median characteristics. These areas may be used, however, for short, exclusive bus lanes to give buses priority treatment through bottleneck areas. In the design of new urban freeways, it may be desirable to reserve a portion of the median area for exclusive use by buses or other transit modes. Thirty to fifty feet of width should normally be provided with wider areas at pickup and discharge points.

b. Reserved Freeway Lanes, Normal Flow

Reservation of a freeway lane in the peak direction for exclusive use by buses (and possibly carpools) generally is not given serious consideration. There are weaving problems associated with this type of operation, regardless of which lane is selected for restricted use, and enforcement is difficult.

c. Reserved Freeway Lanes, Contraflow

Application of the contraflow concept has greater possibilities on existing freeways. Candidate sites should have a minimum of six freeway main lanes, and the contraflow lane should have a logical beginning and ending point. Left hand ramps or connections introduce traffic conflicts with the contraflow lane. However, when located at the beginning or ending point of the contraflow lane, conversion of left hand ramps to two-way operation may be a convenient way to initiate or terminate the contraflow lane. Directional split of traffic should be considered. Volume on the remaining off-peak direction traffic lanes should not exceed 1500 vehicles per hour per lane to insure that congestion will not be caused in the off-peak direction. Also, traffic in the peak direction should be near capacity (congested) say, over 1800 vehicles per hour per lane, so that the advantages in using transit are evident. Special markings, cones, and overhead signals are required for contraflow operation.

3. Ramp Metering and Special Bus Ramps

Provision of special bus ramps to and from freeways and metering of other ramps with special priority for buses can expedite bus flow with minimum construction costs and minimum user delay. Special bus ramps can bypass queues, reduce bus travel time, and promote continuity between terminals and freeways. Metering of other entrance ramps controls the rate of main lane egress and preserves main lane operating speeds; where in effect and also serving bus traffic, it is often possible to provide a bypass lane (or use ramp shoulder) to remove buses from the queue and reduce travel time.

(b) Non-Freeways

Bus priority treatments on urban streets without access control are discussed in Section 4-303.

MISCELLANEOUS DESIGN ELEMENTS (4-700)

4-701 GENERAL

Included in this section is information regarding fencing (ght of way, control of access, median barriers, headlight barrier fence, and guard fence), pedestrian separations, roadside vegetation, signing, signals, pavement markings, and emergency median openings on freeways.

4-702 FENCING

(a) Right of Way

The procedures for fencing highway right of way are set forth in Section 66 of Right of Way Manual I. Where additional right of way is not required for construction of improvements to existing highways, right of way (property) fencing shall be the entire responsibility of the land owner.

(b) Control of Access Fencing on Freeways

Control of access fence shall be erected whenever it is necessary to prohibit unrestricted access to the through lanes by pedestrians, animals and/or vehicles. The prohibition of access to the through lanes shall be from private property, intercepted local roads and unauthorized crossings from frontage roads to the through lanes.

Where frontage roads are provided, control of access fence, when used, will be placed in the outer separation, approximately equidistant between the main lanes and frontage roads, at least 30 feet from edge of main lane pavement. Where the control of access line is at the right of way line, the control of access fence will be located at the right of way line and will serve a dual function as a right of way fence.

The following types of fence shall be used for the condition indicated:

1. Urban and Suburban Areas

   Chain link fence of four feet usual height or six feet height where necessary for control of pedestrians.

2. Rural Conditions Where Both Large and Small Animals Exist

   The control of access fence, when used, will be located at the right-of-way line. A wire mesh fence with one or more strands of barbed wire.

3. Where Only Large Animals Exist

   A four-foot or five-foot barbed wire fence.

4. Where Control is for Vehicles Only

   A post and cable fence of closely spaced guard posts.

Department standard designs will be used where applicable. Specially designed fences may be necessary in certain areas where sand storms and snow storms occur and for other special conditions.

(c) Median Barriers

1. Median barriers are necessary to prevent unlawful turns, to prevent out of control vehicles from entering the opposing traffic lanes and, in some cases, to prevent unlawful crossing of medians by pedestrians.

2. On controlled access highways, median barriers will generally be provided in medians of 30 ft. or less. On non-controlled access highways, median barriers may be used on medians of thirty feet or less; however, care should be exercised in their use in order to avoid the creation of a hazard or restriction in sight distance at median openings. Generally, the use of median barriers on non-controlled access facilities should be restricted to areas of potential hazard such as at railroad separations or through areas where a median constriction occurs.

3. Median barriers are generally comprised of fabricated steel rail, double-deep beam guard fence, chain link fence, concrete or shrubbery. A post and cable fence serves the purpose of a median barrier on wide medians by controlling unauthorized crossings of the median; however, it falls more into the class of a control of access fence. Its use is not generally recommended since it constitutes a hazard to high speed traffic.

4. Median barriers should be included in the P.S. & E. as a contract item and installed as part of the contract.

5. Medians for urban freeway sections generally are non-depressed and relatively narrow. For new construction, an urban freeway usually includes a 24-foot flush median (see Section 4-602 (f)) with either slope faced concrete or double steel beam median barrier.

In determining the type of barrier to be used for any project, the primary consideration is safety, both for vehicular impacts and during any subsequent maintenance activities. In this regard, extensive live and simulated crash testing of the two most prominently used median barriers have been conducted, and measurements were made at accident sites to establish frequencies of various angles of encroachment. Analysis of this information indicates that accident severity levels probably will not result in serious injury for unrestrained occupants for the following conditions:

a. For concrete barriers, when installed in median widths of 24 feet (i.e., lateral distance from travel lane edge to centerline of barrier of 12 feet) or less.

b. For double steel beam barriers, when installed in median widths of 30 feet (i.e., lateral distance from travel lane edge to centerline of barrier of 15 feet) or less.

Field experience with concrete median barriers indicates that, unlike the double steel beam system, maintenance operations are not normally required following accidental vehicular encroachment. Accordingly, on new urban freeway sections with narrow medians (18 feet or less), a flexible median barrier system should not normally be

used, since resulting maintenance activites would (a) create unduly hazardous exposure of maintenance crews to high speed and volume traffic, (b) usually necessitate blocking a travel lane thereby significantly disrupting traffic, causing delay, congestion, and a hazardous driving environment, and (c) result in high costs. Therefore, for projects involving new construction or complete reconstruction of a highway section, the determination of median barrier type should be in accordance with the guidelines shown in Figure 4-70.

MEDIAN WIDTH	BARRIER TYPE
Up to 18 ft.	Concrete
18 to 24 ft.	Concrete or double steel beam
24 to 30 ft.	Double steel beam

FIGURE 4-70

Where there is a frequent presence of fixed objects such as continuous illumination systems in 18 to 24 foot medians the concrete barrier system offers advantages over double steel beam and should be used. Where the double steel beam barrier system is used, consideration should be given to special design treatments to increase barrier stiffness at fixed object locations. Special circumstances, such as the presence of blowing sand, may dictate deviation from the guidelines shown in Figure 4-70.

Reconstruction projects with median barriers should be considered on a project by project basis. Often the structural capability of existing bridges may make infeasible the use of concrete median barrier due to increased dead load.

(d) Headlight Barrier Fence

Headlight barrier fence serves a dual prupose of controlling headlight glare from opposing traffic and is a positive deterrent to pedestrian crossings. On wide medians, a fence of continuous shrubbery provides a means of reducing headlight glare as well as beautifying the highway.

(e) Guard Fence

1. General

Guard fence is considered a protective device for the traveling public and is used at points on the highway where vehicles inadvertently leaving the facility would be subjected to considerable hazard. It is designed to resist impact by deflecting the vehicle so that it continues to move at a reduced velocity along the rail in the original direction of traffic. The limits of rail to be installed are shown on the plans; however, they should be adjusted in the field after the grading is completed. Guard fence is required only where the result of striking a fixed object or leaving the roadway would be more severe than the consequences resulting from hitting the rail.

2. Location

Guard fence should be installed in areas where the consequence of an errant vehicle leaving the roadway is judged to be more hazardous than impact with the guard fence (See "Roadside Design Guidelines", Appendix A). It should be offset at least two feet and desirably four feet from the nearest edge of fixed objects.

At overpasses, guardrail should be anchored securely to the structure and carried continuously across the structure.

3. Standard Installations

Guard fence will be installed in accordance with the current Departmental standards. See "Roadside Design Guidelines" in Appendix A.

4-703 PEDESTRIAN SEPARATIONS AND RAMPS

(a) Pedestrian separations are generally limited to controlled access facilities since it is necessary that all at-grade pedestrian crossings be eliminated. Control of access fences and other means will be used to encourage pedestrians to cross at traffic separations. On highways other than freeways, pedestrian separations will be considered only in unusual circumstances.

Pedestrain structures may be warranted to provide for heavy pedestrian movements adjacent to factories, schools, parks, athletic fields, etc. If the location of traffic separations is such that their use would add an unreasonable pedestrian distance, a pedestrian structure may be considered for lower pedestrian volumes.

(b) A pedestrian structure should be made as natural and convenient as possible. Either an overcrossing or undercrossing may be provided. All separations must be accessible to the handicapped unless alternate safe means are provided to enable mobility-limited persons to cross the roadway at that location, or unless it would be infeasible for mobility-limited persons to reach the structure because of unusual topographical or architectural obstacles unrelated to the roadway facility.

1. Overcrossings

All pedestrian overcrossings should be enclosed with wire fabric to discourage pedestrians from throwing debris on vehicles below the structure. Ramp gradients should not exceed 8.33%.

2. Undercrossings

Pedestrians avoid the use of undercrossings unless the underpass is in line with the approach sidewalk and continuous vision through the underpass from the approaching sidewalk is provided. Ample lighting, both day and night, is essential. Undercrossings should be located only where ample police protection is available.

(c) Pedestrian separation plans will be prepared by the State Department of Highways and Public Transportation, working in close cooperation with the city in which the structure is located. All construction work will be performed by the State.

(d) It will be the city's responsibility to bear the cost of power for operating lighting and for police protection.

(e) Pedestrian ramps associated with roadway facilities such as pedestrian separations, parking lots, rest areas, curb cuts at cross walks, etc. must be accessible to handicapped persons and ramp gradients must not exceed 8.33%.

4-704 FRINGE PARKING LOTS

Fringe parking lots are generally located along express bus routes. These facilities are simply designed and usually charge a minimal or no fee. Based on present knowledge, it is difficult to predict the success or failure of park-and-ride lots. It is, therefore, often beneficial to use shopping center, stadium, drive-in theater, etc., lots if available or lease a site to establish the success or failure of a system before spending a relatively large amount on right of way, surfacing, etc., on a permanent lot.

Several items should be given careful consideration regarding fringe parking areas:

(a) It is important that a fringe parking lot be located to serve a rather homogeneous socio-economic neighborhood.

(b) The neighborhood served must have a high level of attraction for the destination (usually central business district). Conditions vary among different cities, but generally white collar, clerical, etc., workers will have a higher level of attraction than blue collar workers.

(c) The quality of service must be attractive. More specifically, the time required to reach the destination point by bus must be comparable to or better than driving one's own car. In this regard, bus headways are an important factor, as well as delay and congestion to vehicular traffic in the corridor, access characteristics and aesthetics of the lot, etc. Location generally needs to be far enough out so that the time required to park one's car, board the bus, and travel in is incidental to the time required merely to travel the total distance by automobile. Good access roads to the parking area to provide quick ingress and egress are important, and the parking arrangement should be designed to provide for maneuvering ease and a short walk to the bus boarding area.

For fringe parking areas within highway right of way, projects are generally developed as any other multiple use project. Where parking lots are proposed which are located outside of existing or proposed highway right of way, Commission approval is required.

Fringe parking lot projects are eligible for Federal aid participation (Interstate, Urban System, Primary and Secondary). Projects will usually be located within or adjacent to highway right of way, outside the c.b.d., but inside the urbanized area, and consistent with the urban transportation (3C) planning process. Operation and maintenance responsibilities should be assigned to local governmental agencies by agreement.

4-705 PARKING ALONG HIGHWAYS

(a) This section deals with parking as it pertains to the main lanes of a controlled access highway, the frontage roads for such a facility and parking along urban and sub-urban arterials. Offstreet parking facilities provided within highway right of way are discussed in Paragraph 4-704 and Appendix G, "Multiple Use of Highway Right of Way". Safety rest areas as parking facilities are not considered in this section.

(b) Parking on and adjacent to the main lanes of a highway will not be permitted except for emergency situations. It is of paramount importance, however, that provision be made for emergency parking. Shoulders of adequate design provide for this required parking space.

Street parking can be provided for only by the provision of parking lanes on frontage roads or urban/suburban arterials. The design requirements for such lanes vary according to the characteristics of the abutting property, the area served and the type of facility. In any instance, only parallel parking lanes shall be provided. Parking lanes ten feet wide are sufficient to provide space for parking on frontage roads and urban/suburban arterials. Parking shall be confined to the outer side of the arterial or frontage road. Where the need for street parking is localized, sections of parking lanes or parking inserts may be provided at that particular location.

Parking lanes in the vicinity of crossroad intersections, ramp terminals and on sections of channelized roadway require special consideration. Parking lanes should be continued their full width to an intersecting street but parking should be restricted a sufficient distance back from the intersection to allow for turning clearance and added capacity that might be required at the intersection.

4-706 ROADSIDE VEGETATION

(a) Erosion Control

All construction slopes, 3:1 or flatter, should be adequately protected with vegetation to prevent erosion and downstream pollution. The most satisfactory form of vegetation is grass or turf for erosion control. This can be established where the average annual rainfall is approximately fifteen inches or greater.

Consideration should be given to preserving topsoil within construction limits to replace clay, caliche, shale, rock, and other similar slopes not capable of supporting vegetation.

On urban freeways, where possible, a neat, well trimmed turf should be provided on the right of way. Where irrigation systems are necessary to sustain a turf, the water shall be furnished at no cost to the State.

(b) Preservation of Native Growth

Consideration should be given to preservation of existing trees and shrubs to provide an interesting and pleasing highway whose safety is improved by proper plant groupings and the aesthetic appearance is enhanced. It is desirable to obtain right of way in excess of that needed for construction of cuts and fills to preserve some native growth. A variation in the profile grade along with a variable width median also permits the preservation of much desirable growth. The proper consideration for preservation of native growth will eliminate the need for future planting projects.

Generally, all growth is removed within the limits of cuts and fills which normally provides the desired thirty foot recovery area. However, good judgment should be used in preserving trees within these limits that have scenic, historic or aesthetic value especially when they are located in the vicinity of homes. Tree wells in fills and retaining walls in cuts may be used to preserve outstanding specimens. Those trees located within the recovery area should be protected.

(c) Planting Projects

Those sections of highway devoid of native growth should be considered for a planting project to provide for the comfort, safety and convenience of the traveling public. The design should be primarily functional in nature keeping ground covers and ornamental plantings to a minimum. Consideration should be given to screening of junkyards and unsightly areas where feasible. Assistance

in the preparation of P.S.&E. of this and other phases of landscape work will be furnished by the Landscape Section, File D-18.

4-707 SIGNING AND PAVEMENT MARKINGS

(a) Texas highways are designed to provide rapid, convenient and safe travel between and through traffic generating centers. To achieve this design goal, it is necessary to provide a high type system of highway signing that will be fully adequate for this high density, high speed, motor vehicle traffic.

(b) All signing and pavement markings will be in accordance with the Texas Manual on Uniform Traffic Control Devices for Streets and Highways, Volume I, Signs, Markings and Barricades, as amended.

(c) Rumble Strips

Recommendations relative to use of rumble strips and jiggle bars are as follows:

1. That they be used only across areas which are not intended for vehicular travel, such as emergency parking lanes on bridges, the triangular areas formed by pavement markings at the beginning of freeway off-ramps and on-ramps, paved shoulders on the approach to bridges not having full crown width, flush medians on four-lane divided highways, and the areas within the limits of pavement markings placed on the approach end treatments of median and channelizing islands.

2. That they never be used across the main traveled lanes of an Interstate Highway or any other freeway not designated as an Interstate Highway which is constructed to full control of access standards.

3. That they not be used, except as a last resort, across the traveled lanes of a conventional type highway such as those having two or three lanes or across a four-lane divided highway which has intersections at-grade.

4-708 EMERGENCY MEDIAN OPENINGS ON FREEWAYS

(a) Introduction

Median crossings between the main lanes are sometimes necessary for proper law enforcement or for performance of highway maintenance on rural freeways. The construction of such median crossings is not encouraged since the necessary U-turns by such vehicles should be accomplished by using ramps at interchanges to the maximum extent feasible.

(b) Warrants

Median crossings as turnarounds create undue hazard and interference with through traffic and should be avoided. Normally the spacing of interchanges and layout of the highway provides for all necessary traffic movements, including those of emergency vehicles.

In unusual situations, where the distances between interchanges are great, emergency crossings may be provided with Administrative approval.

(c) Spacing of Openings

Due to the close spacing of interchanges on urban freeways, emergency median openings are not needed for the operation of official vehicles and, in general, they should not be provided. In rural areas where the spacing of interchanges are greater than approximately three miles, a U-turn median opening may be considered at a favorable location about halfway between interchanges. In no case shall emergency median openings be spaced at less than one mile intervals. All emergency median openings should be at least one-half mile from any structure that over-crosses a freeway and at least one mile from any ramp terminal or other access connection, such as those serving safety rest areas. They should be located where adequate stopping sight distance is available and where the median is sufficiently wide to permit an official vehicle to turn between the inner freeway lanes. The emergency median crossings should be as inconspicuous to the traveling public as possible.

(d) Construction

Location and type of emergency median openings shall be made a part of the P.S.&E. as a contract item and shall be installed as such.

4-709 SIGNALS

All traffic signals will be in accordance with the Texas Manual on Uniform Traffic Control Devices for Streets and Highways, Volume II, Signals.

E DEPARTMENT OF HIGHWAYS
PUBLIC TRANSPORTATION

Kovar

ADMINISTRATIVE CIRCULAR NO. 81-79

To: DISTRICT ENGINEERS, ENGINEER-MANAGER AND DIVISION HEADS

Date: December 12, 1979

Subject: Highway Design Division Operations And Procedures Manual

Expires: Upon Receipt

Reference:

File: D-8

HIGHWAY DESIGN MANUAL CHANGE LETTER

Manual Change Transmittal No. 37

Gentlemen:

Part V of the subject manual has been revised to update the material to conform with current procedures and Federal regulations. The material presently occupying Part V should be entirely removed from the Manual and replaced with the new material.

This revision should be posted in the Manual immediately upon receipt and the record of revisions sheet properly completed.

Sincerely yours,

B. L. DeBerry
Engineer-Director

Attachment

DISTRIBUTION:

District Engineers
Engineer-Manager
Division Heads

PLANS, SPECIFICATIONS AND ESTIMATE SUBMISSIONS

PART V - PLANS, SPECIFICATIONS AND ESTIMATE SUBMISSIONS

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5-101 SUPPORTING PAPERS

5-101.1 GENERAL

The supporting papers for a construction project are an integral part of the project submission. Omission of some of the papers or incomplete or improperly prepared papers may delay processing of the project to the desired letting. The P.S.&E. and supporting papers should be submitted together.

The purpose of this section is to present instructions regarding the preparation of the required supporting papers.

5-101.2 THE P.S.&E. SUBMISSION DATA SHEET

The P.S.&E. Submission Data Sheet is essentially a supporting papers check list to be used by the District in preparing the P.S.&E. and to provide the Austin Office with a record of all papers contained in the submission. This form should be completed and carefully checked when preparing the submission to avoid overlooking any of the supporting papers. Information as to the status of the missing papers should be on the form and in the letter of transmittal.

5-101.3 LETTER OF TRANSMITTAL

All P.S.&E. proposed for contracting should be submitted to File D-8. An informative, well-prepared letter of transmittal should be addressed to File D-8. Under the lines of responsibility established by the Administration there are several items for which responsibility must be acknowledged by the District. Unusual design features or innovations should also be discussed in the letter of transmittal. A letter of three or more pages will not be uncommon. A carefully prepared letter aids in project review and is beneficial in eliminating "second guessing".

In preparing the letter of transmittal, consideration should be given to the following items:

(a) Preliminary Approval: During preliminary planning for most projects, schematic layouts, typical sections, basic design-value sheets and/or preliminary bridge layouts and hydraulic data, if any, have been submitted to the Austin Office for concurrence by the responsible Division. Further study during plan preparation often leads to changes in major design features which should be reviewed by all concerned. However, if prior approval of revisions has not been obtained, the conditions warranting the changes should be fully explained in the letter of transmittal. A thorough review of all past correspondence should be made prior to P.S.&E. submission to ascertain that all design questions have been settled and project authorization is assured.

(b) Special Provisions and Special Specifications: In order to expedite handling and approval of specifications, it is requested that special provisions and special specifications be submitted to the Austin Office for consideration of the Specification Committee prior to submission of P.S.&E. where possible. This is necessary to provide the affected design division and the Specification Committee with sufficient time to evaluate and consider the specification.

Special specifications and special provisions transmitted to the appropriate design division for approval should be listed in a transmittal letter or on the P.S.&E. Submission Data Sheet. They should be submitted immediately after the final draft is prepared. In order to facilitate action on these special specifications, the letter should contain a condensed statement setting out the condition or conditions that created the need for the new specification and a brief summary of their content. A brief statement giving the need for, and the benefit to be derived from special provisions which may be construed as special specifications, or are a major variation from the original specifications will also aid in obtaining approval and should be included in the transmittal letter.

For unusual job conditions, a special provision or a special specification may be necessary for use only on that project. This should so be noted in the transmittal letter. If this item is approved, it will not be valid for subsequent projects. In order to expedite processing a P.S.&E. containing items without prior approval, the new items may be approved for use on that project only, pending a more in-depth review by the Specifications Committee.

(c) Relocation Assistance, Right of Way Certification and Utility Adjustments: Where relocation assistance is involved it will be necessary that a certification, signed by the District Engineer, be included with the letter of transmittal for the P.S.&E. This certification should be in accordance with the requirements of the Federal-Aid Highway Program Manual, Volume 6, Chapter 4, Section 2, Subsection 1, Paragraph 5c.

In those cases where the relocation assistance program is not involved, a statement should be included in the P.S.&E. letter of transmittal that "Relocation Advisory Assistance is not required".

No project will be advertised for bids where persons are still living on the right of way except where very unusual circumstances prevail. Where businesses are involved, this authorization will not be given until specific dates for termination of operations of businesses have been established so as not to interfere in any way with the construction operations. Should there be unusual circumstances where persons may be on the right of way, or businesses in operation, then necessary certification in accordance with FHPM Volume 6, Chapter 4, Section 3, Subsection 1, Paragraph 5c(3) should be submitted to the Highway Design Division for clearance prior to processing of the project.

Complete information regarding the status of right of way must be furnished. In accordance with federal regulations the following applicable statement, signed by the District Engineer, must be attached to the P.S.&E. letter of transmittal.

1. All right of way acquired at the time of P.S.&E. submission.

   "This is to verify that right of way has been acquired in accordance with the current FHWA directive(s) covering the acquisition of real property".

2. All right of way acquired, except one or more parcels, at the time of P.S.&E. submission.

"This is to certify that right of way has been acquired or will be acquired in accordance with the current FHWA directive(s) covering the acquisition of real property".

3. No right of way acquired at the time of P.S.&E. submission.

"This is to certify that right of way will be acquired in accordance with the current FHWA directive(s) covering the acquisition of real property".

4. No right of way required.

"This is to certify that no additional right of way is required for this project".

A statement should be included in the letter of transmittal advising that all utility adjustments that will interfere with construction or maintenance are either complete or incomplete. In the event that all right of way has not be acquired or necessary utility adjustments not completed, a special provision must accompany the letter of transmittal listing each parcel and/or description of improvements and utilities, approximate station numbers and whether the Contractor or others are to remove improvements. In order to receive Federal Highway Administration approval, the letter of transmittal must state the reasons for going to contract before all right of way is available.

Proceeding to contract without all right of way clear is to be done only in unusual cases. For Federal-aid projects a statement should be included outlining the reason why all of the right of way has not been acquired.

If all utilities have not been completely adjusted, a Utility Adjustment Status Form (included in the attachments), should be attached to the P.S.&E. letter of transmittal including the following information:

(a) Owner

(b) Description of the utility that has not been adjusted (type, including whether overhead, underground, crossing, etc. Size, location, etc.)

(c) Indicate if work has started on the adjustment or when work is expected to start.

(d) Amount of work completed.

(e) Amount of work remaining.

(f) Estimated date of completion.

(g) Indicate whether work will be by contract, utility's own forces or state forces. If by contract list contractor and whether work has been let.

This form must be updated prior to P.S.&E. submission to the FHWA. If utility adjustments are to be made by others, it is recommended that documentation by letter be furnished by those responsible for the adjustment. The letter should include dates adjustments will commence and be completed.

5-101.4 LIST OF GOVERNING SPECIFICATIONS AND SPECIAL PROVISIONS

Each standard specification item, special provision and special specification proposed for the project should be listed. When more than one project is combined for contracting purposes only one list should be prepared with particular care taken to insure that all items are included. This list is used in contract preparation and becomes a part of the contract.

The list of specifications is divided into three sections and should be prepared as follows:

(a) Standard Specifications: The list of standard specification items includes Items 1 through 9 and the number and title of each standard specification item for which payment is to be made under the construction contract. The title of each item as indicated in the Specifications Book should be used.

Reference items should be given the proper attention in preparation of the list of specifications. In order for a nonpay item to be included in the executed contract, it must be shown as a reference to one of the items listed. This is shown by adding the number of the referenced specification in parenthesis after the pay item.

Each pay item should be examined carefully to insure that not only those items referred to directly are included but also those items which are referred to in the reference item itself. For example Item 364 refers to Item 421 for concrete and concrete ingredients; however, it is also necessary to list Item 437 for admixtures and Item 502 for ready-mix concrete plants, etc.

It is not necessary to include reference items which are also listed as one of the pay items. Also, the reference item should be indicated only once and should appear after the first applicable pay item.

There are other instances where it is necessary to show items as reference items although they are not referred to in any of the other specifications. This frequently occurs when minor work is required by a note on the plans and a specification is referred to for materials or construction requirements. An example is requiring backfill of a conduit trench in accordance with Item 401. In order to have the specification governing this work in the contract it will be necessary to list it as a reference item and cover it by a note on the plans.

(b) Special Provisions: Each required contract provision and special provision to a standard pay item, a standard reference item or to a special specification should be listed under "Special Provisions". Under the present system for computer tabulation of bids, only one special provison to any one bid item description can be used, with the following exception. An alternate bid item description may have different special provisions from its base bid item.

(c) Special Specifications: All special specifications under which payment is to be made or which are used as reference items should be listed by number and title as required for standard specifications. Particular attention should be given to insure that any standard items referred to in the special specifications are indicated as reference items.

(d) Structure for Field Office and Laboratory: If these are desired, Item 580 must be shown in the Specifications List and a plan note stating type must be shown.

5-101.5 SPECIAL PROVISIONS AND SPECIAL SPECIFICATIONS

A Specifications Committee composed of the Highway Design, Bridge, Maintenance, Materials and Tests and Construction Division Heads considers proposed special provisions and special specifications. One purpose of the Committee is to carefully screen all special provisions and special specifications for conformance with Departmental policies and construction practices and to approve only those deemed essential. The Committee also recommends special provisions and special specifications affecting Departmental policy to the Engineer-Director for his approval. The Committee also has liaison with legitimate highway-industry associations and representatives for the purpose of discussing and/or clarifying specifications affecting those institutions.

The following general guides regarding the preparation of special provisions and special specifications have been established by the Committee.

Special provisions and special specifications should be submitted only when it has been determined that construction under the standard specifications will not achieve the desired results or will prove to be uneconomical.

Special provisions should modify the standard specification only to the extent necessary to accomplish the desired results. When voiding portions of an article the remainder should be reinserted exactly as it appears in the standard specification. While condensation and simplification may result in a more concise special provision, this practice has too often resulted in misinterpretation and important standard specification requirements being unintentionally omitted.

The same general format and wording used in the standard specifications should be followed in preparing special specifications. This can most readily be accomplished by using a similar standard item as a guide and substituting the desired wording where appropriate. The measurement and payment paragraphs in particular should be essentially the same as similar standard items. This is necessary since conflicts or vagueness in these paragraphs are often the basis for claims against the Department.

During the preparation of both special provisions and special specifications, considerable thought should be given toward requirements and wording which will permit the use of the special provisions or special specifications on other projects having slightly different conditions. By relegating certain features such as density and gradation requirements to the plans and exercising foresight in preparing the measurement and payment paragraphs this end can be achieved. The repeated use of desirable special provisions and special specifications is most beneficial in that it results in progress in construction methods and materials and uniform interpretation of specification requirements.

5-101.6 MATERIAL OPTION AGREEMENTS

Two forms for securing material option agreements to purchase local materials for construction projects are in current use: "Agreement for Purchase of Road Material", for material intended for use in the roadway pavement structure and "Agreement for Purchase of Road Material (Borrow)" for materials going into the road embankments. Material option agreements should be obtained when possible on the appropriate form and six copies should be submitted with the P.S.&E. or, under some circumstances in advance of P.S.&E. The forms are largely self-explanatory; however, some of the more important features are discussed below:

(a) Name of Owner: If the owner is a married individual, the spouse's name should also appear and both should sign the instrument. If only a woman signs the instrument, the letter of transmittal should contain a statement indicating that she is a "femme sole".

Material option agreements for material on land lying in an estate should bear the estate name and administrator's name. Each individual having an interest in the estate or someone empowered to sign for each must sign the instrument. Corporation-owned lands should be optioned in the corporate name and signed by officials properly authorized to execute agreements for the corporation.

Signatures of individuals must be identical to their name as it appears as the Party of the First Part.

(b) Term: Careful consideration should be given the term of the material option agreement to anticipate delays in acquisition of right of way, completion of P.S.&E. and letting of the contract.

(c) Royalty Price: The unit royalty price established should generally be comparable to royalty for other similar materials in the same geographical area. Should a higher price be proposed, justifying information is to be submitted with the material option agreement. Surface damage payments are not eligible for deduction from a Monthly Estimate.

(d) Method of Measurement: The unit of measure and method of measurement for borrow, flexible base, admixtures, etc., shall be the same as will be used in the construction contract. Long-term material option agreements secured for use on several projects should contain provisions for different units of measure and methods of measurement if it is apparent that project conditions will warrant such action. The wording "by the ton of 2000 pounds dry weight" should be used for measurement by the ton.

(e) Special Conditions: The material option agreement form should ordinarily be executed without variations or additional conditions; however, it is sometimes necessary to insert special clauses in order to secure the owner's signature. Minor requirements pertaining to watchmen, cattleguards, fences, etc., are permissible though undesirable. Unusual conditions should receive advance Administrative approval as legal statutes or Departmental policy may dictate that other material sources be obtained. Since the construction contract does not require the Contractor to operate a listed or designated source, care should be taken in wording special clauses to avoid obligating the State if the option is not exercised.

(f) Certification of Value for Borrow Materials: The form "Agreement for Purchase of Road Material (Borrow)", includes a statement for the District Engineer's signature which certifies that the cost of the borrow materials does not exceed the normal land value of the source. This certification is required except for unusual conditions which will be considered on an individual basis, and exceptions must receive Administrative approval. If the cost of borrow exceeds 75 percent of the estimated value of the land, appraisals by staff appraisers may be made to substantiate the estimated value. This appraisal may be charged to I.P.E. authorizations.

Consideration should be given to damages to the remaining property as well as severance damages in determining the land value.

It is not the intent of this policy to provide for the actual purchase of land to obtain borrow sources. This policy does not pertain to materials going into the pavement, such as select borrow, roadbed treatment, admixtures, etc., as the value of these materials is not considered in relation to the value of the land. The policy is applicable to borrow sources obtained under the "Easement for Purpose of Producing and Hauling Materials" and submission of this easement should be accompanied by a separate certification of value.

Where overburden of a flexible base source is to be used as embankment material rather than be disposed of as stripping, certification of value is not necessary and the form "Agreement for Purchase of Road Materials", may be used to option both materials.

(g) General: In accordance with Attorney General Opinion No. M-625 the State may not lawfully issue a warrant, in payment for material from material sources, to a member of the Legislature or to a firm or partnership of which a member of the Legislature is a member, when the warrant is to be charged to funds appropriated by the Legislature during the term for which said member was elected to office. Administrative approval of sources on land owned by State, County or City officials is necessary.

5-101.7 EASEMENT FOR PURPOSE OF PRODUCING AND HAULING MATERIALS

Local material deposits may be secured by obtaining an easement in the name of the State ("Easement for the Purpose of Producing and Hauling Materials" form) but this procedure should be resorted to only in those areas where a genuine shortage of acceptable materials exists or is anticipated. Where easements are being considered it should be borne in mind that the Federal Highway Administration will not necessarily approve of the use of an easement as a required source.

The easement, when properly executed and recorded, constitutes a binding legal document. The same care should be given the preparation of the easement as any other right of way instrument as outlined in the Right of Way Manual.

The consideration for the easement must be a fixed sum based on the current royalty price in the area and a specified quantity of material and a unit price for additional quantities. The fixed sum should be determined only after thorough investigation has revealed the quantity of acceptable material available and deductions for loss have been made. Results of this investigation should be submitted with the easement to enable the appropriate Division to concur in the purchase.

If the material to be secured consists of borrow, certification of value is required as described for material option agreements.

5-101.8 MATERIAL SOURCES, LAND CONTRACT WITH VETERANS' LAND BOARD

Where investigation indicates that a proposed material option agreement or easement is on land under purchase contract with the Veterans' Land Board, the following procedure is to be followed:

Material option agreements sought under the subject circumstances should be prepared to reflect the Veteran as the Party of the First Part and the Veterans' Land Board as approving the option but not as a Party of the First Part. The material option agreement should provide that payment of one-half of the amount due for the material purchased be paid directly to the Veterans' Land Board and the other one-half royalty be paid directly to the Veteran. Where the Veteran is delinquent in his loan repayment, the full royalty payment will be made to the Veterans' Land Board. Any delinquency notice will be forwarded to the District Office by the Austin Office. These payment requirements are as covered by Article 5421m, Section 18 and other provisions of the Veterans' Land Act.

Approval of the material option agreement by the Veterans' Land Board will be obtained by the Austin Office when the material option agreements are forwarded to Austin.

Monthly Statements and requisitions should be prepared to accomplish the objectives outlined above. The Veterans' Land Board will require that the source be described by metes-and-bounds description and that sketches of the pit accompany the agreement.

5-101.9 MATERIAL SOURCES ON PROPERTIES OWNED BY OTHER STATE AGENCIES

Material option agreements permitting the Department to take material from properties belonging to other State agencies should be prepared in the same manner as described above for private owners except that metes-and-bounds descriptions should be used in all cases and a sketch should be submitted. If the State agency concerned wants payment for materials taken from their land the Department shall pay them the same price as would be paid any other property owner. If they do not want payment, the Department should secure a material option agreement, or other agreement acceptable to both parties, permitting the Department to use the material without cost.

The following procedure should be followed:

(a) The standard material option agreement, or other agreement acceptable to both parties, should be used to buy material or to permit its use without cost to the Department. In either case the material should be obtained under the provisions of Art. 6674w-3 (which is the same as Sec. 4-2 of HB 179, Acts 55th Legislature, 1957). Only one payment should be made after all material used on the project has been taken from the pit. The language, "Authorized by Art. 6674w-3, does not require approval by the State Board of Control", should be shown on the face of the material option agreement, or other agreement, and on the form "Monthly Statement", when it is submitted for payment on a District Payroll. A copy of the material option agreement should be attached to the Finance Division's copy of the "Monthly Statement" form. This language will give notice to the Comptroller that the approval of the Board of Control is not required on such purchase of material.

(b) If the agency does not have area agents or representatives authorized to secure approval of the material option agreement, such as the General Land Office, the required number of copies should be forwarded by the District to the appropriate design division of the Austin Office, which will secure approval from the agency concerned, approve it and return the required number of copies to the District.

(c) After all material used on the project has been taken from the pit, the Resident Engineer should prepare the form, "Monthly Statement". The form should show correct quantities for which payment is to be made. He should sign it as to receipt of goods, and forward it to the agency concerned with the letter requesting that the affidavit be executed and statement be returned to the District office. The Monthly Statement should then be included on a material and supply voucher.

5-101.10 SPECIAL PROVISION FOR LOCAL MATERIAL SOURCES

Three forms are provided to facilitate submission of an adequate provision to control the use of materials from sources on which the Department holds material option agreements or easements.

(a) Designated Sources: The form, "Special Provision Local Material Sources (Designated Sources)", should be used for Designated Sources, which are defined as those covered by approved material option agreements from which adequate quantities of material meeting the specifications can be produced.

When Designated Material Sources are shown on the plans and in the special provisions, the State guarantees the quantity of acceptable material in the pit and will be responsible for providing another pit if it develops that the pit as designated does not contain a sufficient quantity of satisfactory material.

Therefore, it is incumbent upon the State to perform adequate preliminary testing so as to keep the probability of an investigation for another pit, and consequent moving of the Contractor's equipment to a minimum. The State will compensate the Contractor for additional cost in producing the material from the new source. This additional compensation may include the cost of equipment moves and setups, additional haul and additional cost in producing the material. The change in pits and the determination of additional cost involved shall be in accordance with an agreement acceptable to the State and the Contractor. Work may be performed on a force-account basis if unit prices cannot be agreed upon. Since the Engineer has the responsibility for controlling the areas of operation in the pit, extreme care should be taken to insure that all available suitable material is secured before the Contractor is authorized to move to a new source involving additional cost to the State. Changes in formations in the pits and other factors affecting production should not be used as the reasons for abandoning the pit so long as acceptable material can be produced within the original concept of the item as bid.

(b) Listed Sources: The form "Special Provision Local Material Sources (Listed Sources)", should be used for Listed Sources, which are the same as designated sources with one exception, i.e., a paragraph is added thereto indicating such sources are available if the Contractor elects to use them and can produce material meeting the requirements of the

specifications. This form should be used in conjunction with the "delivered-material" specification if and when their use is considered desirable. When this type of material source is shown on the plans and the special provisions, the State assumes no responsibility whatever as to the quantity of acceptable material in the pit. It is the Contractor's sole responsibility to make any investigation to satisfy himself as to the availability of acceptable material. When showing a prospective bidder over the project, it should be made clear that these pits are shown for information purposes only; that they are available for use under the terms of the material-option agreements; that the State only assumes responsibility for right of entry and the right to move material from the pit in accordance with the terms of the material option agreement and should the quantity of acceptable material in any listed pit prove inadequate, the Contractor must provide material meeting the specifications from another source at no additional cost to the State regardless of the cost to the Contractor.

If preliminary tests have been made on materials secured from local material sources, such tests may be made available to prospective bidders with the understanding that such information does not void or change any part of the applicable special provision for local material sources, nor does such information void or change any part or requirement of any other specification item.

(c) Required Sources: The form, "Special Provision Local Material Sources (Required Sources)", should be used for Required Sources which are to be used only when it is desired to require the Contractor to produce material from a particular source as would be the case when an easement is held. Where more than one type of source is involved on an individual project, separate special provisions must be prepared for each type of source.

On Federal-aid projects, if the form "Special Provision Local Material Sources (Required Sources)", is used requiring the Contractor to operate a particular source or use State-owned stockpiled base, justifying information must be submitted for transmittal to the Federal Highway Administration for prior approval. It is necessary that the justifying information indicates that use of the source is in the public interest.

The Federal Highway Administration will generally approve the use of required borrow sources where it is necessary to replace the storage capacity lost by construction of embankment, in wet weather lakes; however, that agency will not consistently approve the use of State-owned stockpiled base material as a required source. The Federal Highway Administration will sometimes approve the use of required sources where unusual circumstances exist, such as a need to increase ponding capacity to satisfy hydraulics requirements, etc. When easements for the purpose of producing local materials are being considered it should be borne in mind that the Federal Highway Administration will not necessarily approve of the use of an easement as a required source.

(d) General: All material sources are to be indicated on the special provision including those which are royalty free. The special provision should be checked against the material option agreements or easements to insure that the owner's name is exactly as it appears on the instrument and that the unit of measurement and royalty price are the same as those on the

instrument. Special conditions regarding operation of the source contained in the material option agreement should be indicated in the special provision and, if more than one source is being used, referenced to the correct source.

(e) Archaeological - Historical Clearances Required for Material Sources, Borrow Pits and Waste Sites: Certification is required that all material sources have been investigated and determined to be clear of cultural resources. (In addition to material sources this also includes borrow pits, waste areas, haul roads, storage areas or other disturbances to the natural ground that will be necessary to develop a specific project.) Certification of this investigation should be submitted with other project documents on the appropriate forms furnished to the Districts by D-8. Archaeological-Historical investigations of these locations are to be conducted by District personnel that have been trained for this work by professional archaeologists of the Highway Design Division. District personnel should only certify that cultural resources are not present. If evidence of cultural resources is discovered, the Archaeology Section of the Highway Design Division should be notified. A staff member from the Archaeology Section of the Highway Design Division will determine the significance of cultural materials and will also determine measures necessary to mitigate damage to these resources. When cultural resources are involved, the Highway Design Division will coordinate with the State Historic Preservation Officer and obtain clearance on Federal-aid projects from the FHWA.

5-101.11 REQUEST FOR CONSTRUCTION SPEED ZONING

If construction speed zoning is desired for projects or portions of a project outside the limits of incorporated cities, the "Request for Construction Speed Zone" form should be prepared and submitted for Commission action. The form is self-explanatory with instructions contained on the reverse side. Cities have the authority to establish construction speed zones within their corporate limits and this should be encouraged since the city will likely be responsible for enforcement. If, however, a city desires the Commission to establish the zones then a written statement from the city is required.

5-101.12 PROJECT AGREEMENT ESTIMATE

The project agreement estimate is to be prepared in accordance with the requirements listed below for State and Federal-aid projects. Cooperation in following this procedure will eliminate the time consuming operation of revising the estimate in the Austin Office.

Estimated prices should be based on recent comparable projects of approximately the same magnitude with study given to the factors peculiar to each individual project. Particular attention should be given projects that require complicated sequences of work, projects that are to be done under large volumes of traffic, projects involving specialty work, projects in commercial areas, etc. When more than one project number is included with the proposed work, a separate estimate must be prepared for each individual project. Each of these estimates must be further separated into roadway and bridge quantities with each structure of bridge classification listed individually. However, certain bridges may be combined in the estimate as follows:

1. Quantities for MBC's of bridge classification on freeway-type projects should be combined in two groups; those under the main lanes in one group and those under frontage roads in another. The name of stream, location, description and length should be listed for each structure in the group. Also, quantities for all MBC's of bridge classification on other projects should be combined with the above data given for each structure.

2. Parallel twin structures on the main lanes or frontage roads should have their quantities combined, preceded by a description of each structure. Do not combine main lane and frontage road structures.

In addition to the foregoing general requirements, the project agreement estimate should be prepared as follows:

(a) If the Federal project number covers more than one State control, quantities for each control must be shown separately. In addition to the entire length and limits of the project, it will be necessary to include the physical limits and length of each separate control.

(b) Contract items to be financed by a city, county or any other agency must be shown separately unless fixed-sum participation is involved, in which case the participating items should be included in the main body of the estimate. Administrative approval must be obtained before any agreement is made with the city, county or other agency.

(c) For Federal-aid projects, contract items that are non-participating in Federal-aid should be listed spearately and noted on the estimate quantity sheet as such. These include such items as cleaning culvert barrels and materials to be stockpiled for future use.

(d) Railroad force account work and work to be done by State forces should not be included in the main body of the estimate. These items should be shown separately under their appropriate control or project.

(e) Metal series railroad crossing signs on Federal-aid projects must be separated from the roadway portion of the estimate and be shown as a railroad crossing protective device participating in Federal-aid. It will not be necessary to separate this item on State projects.

(f) Material to be furnished by the State must be shown on the estimate so that funds will be made available to pay for the initial cost of the material.

If base materials are to be obtained from a stockpile, the materials should be listed on a cubic yard or ton basis and the unit price derived from the actual stockpiling costs plus allowances for loss during stockpiling, loading and hauling and including charges for engineering and contingencies. For Federal-aid projects this price must be approved by the Federal Highway Administration.

To be eligible for Federal participation, any materials, other than local natural materials, to be purchased by the Department and furnished to the Contractor for mandatory use, must have been acquired on the basis of competitive bidding, except when there is a finding of public interest justifying the use of another method of acquisition.

Pay item code numbers, description and unit of measurement, item numbers and alternates should be identical to those on the estimate quantity sheet of the plans and preferably in the same order of appearance.

Engineering and contingency charges should be approximately ten percent of the subtotal, but not over 10 percent and adjusted downward to reflect a total to the nearest 100 dollars.

(g) State law requires that materials salvaged cannot be given to contractors. Therefore, when the salvaged material is to be sold to the Contractor a credit bid item is to be included in the contract. This applies to all projects.

(h) For all projects (State and Federal-aid) on which work is necessary for water pollution control, it must be worded in the Project Agreement Estimate and on the Estimate and Quantity Sheet as follows:

Contractor Force Account or

Agreed Unit Price (Part) or (Non-Part)

(Federal Participation Based on Actual Cost Basis)

Temp. Erosion, Sediment and Water Pollution Control

(i) The amounts should be prorated over the applicable projects if more than one project is included.

For Federal-aid projects on which job training is to be provided, it must be worded in the Project Agreement Estimate and on the Estimate and Quantity Sheet as follows:

Force Account by Contractor (Part)

(Federal Participation Based on Actual Cost Basis)

Job Training (_____Trainees)

All Job Training should be charged to the Federal-aid project having the largest estimated cost.

(j) Other force account work must be worded as follows either as participating or non-participating in Federal-aid.

State Force Account Work

(Non-Part)

State Force Acct. Work (Part)

(Federal Participation Based on Actual Cost Basis)

5-101.13 PROGRAMMING DATA FOR FEDERAL-AID PROJECTS AT THE CONSTRUCTION STAGE

Under the new program procedures recently introduced by the Federal Highway Administration, no program approval will be required at the construction stage on certain projects. Accordingly, it will not be necessary to submit Forms 1088 and 1089R with P.S.&E. for Interstate, Primary, Urban System, Bridge Replacement on the Primary System, safety related projects and similar type projects where a formal submission of P.S.&E. is made to the FHWA for their review and approval. The above forms (an original and one copy) together with a sketch map will still be required on Rural Secondary, Safer Off System, Bridge Replacement on the Secondary System and similar type projects where P.S.&E. are not submitted to the FHWA.

The following information is provided regarding completion of these forms:

(a) Request for Programming of Federal-Aid Project (Form 1089R): This form and the form, "Programming Supporting Data Federal-Aid _____ Funds", must be submitted for each Federal-aid project. Should more than one Federal-aid project number be involved, separate forms must be submitted with each showing the notation that the projects are to be combined for contracting. Most of the required data is self-explanatory and may be inserted by referring to the example forms; however, the following information may be useful.

1. Traffic: The actual average daily traffic from the latest count should be inserted. For projects on new location zero should be used. Twenty-year projected ADT should be used for the future traffic except for Federal-aid secondary projects, developed under the FM and RM design standards, where 2 year traffic projections or traffic upon completion is sufficient.

2. Bridges: The total number of structures of bridge classification, other than grade separations, and their combined length should be indicated. List each grade separation structure and its length separately. Twin structures would be counted as two structures with two separate lengths.

3. Estimated Cost: Participating funds such as city, county or railroad are to be shown. The cost of any items which are to be non-participating in Federal-aid should not be included.

(b) Program Supporting Data Federal-aid Funds (Form 1088): This form is to be submitted for each project. Additional information to aid in its completion is listed below.

1. Road Connections: Roadway features and conditions at each end of the project should be inserted. If the project ends at a "T" intersection or an interchange, conditions on the crossroad should be used.

2. Bridge Data: Data on existing bridges only is necessary.

3. Remarks: In addition to data necessary to explain answers to other questions, information regarding public hearings should be inserted. When applicable a statement should be included affirming notification of area-wide review agencies.

5-101.14 HYDRAULICS COMPUTATIONS

Pertinent hydrologic and hydraulics design data for bridges, culverts and storm sewers shall be shown in the plans rather than on separate calculation sheets submitted with the P.S.&E. This not only facilitates review of the P.S.&E. but assures a permanent record. See Bridge Division Operation and Planning Manual and Hydraulic Manual for minimum requirements.

5-101.15 LOAD ZONING IN CONJUNCTION WITH CONSTRUCTION WORK

The Department has reserved the right to load zone highways in accordance with the law whenever and wherever a highway is about to be subjected to loads which will destroy it. The need for load zoning that will affect the contractor on proposed construction work should be determined during the time the P.S.&E. are being prepared. Requests for load zoning where possible should be submitted to the Maintenance Operations Division in sufficient time for official action to be taken thereon prior to advertising projects that will be affected.

5-101.16 LEAD TIME FOR ACCUMULATION OF MATERIALS FOR ILLUMINATION, TRAFFIC SIGNAL AND FOR INTERSTATE SIGNING AND DELINEATION PROJECTS

To provide realistically for securing materials that are critical, there is a need to provide for considerable lead time for traffic signal, signing and delineation projects that are let independently of other work such as grading, structures and/or surfacing. Providing a realistic lead time tends to establish a uniform practice in time charges.

The P.S.&E. for Interstate signing and delineation projects that are to be contracted independently of other work such as grading, structures and/or surfacing should provide a minimum lead time of 120 days unless there is some reason that would make it imperative to not do so. A lead time of 180 days should be considered for traffic signal projects if specialized equipment and/or steel poles are required.

Adequate lead time for illumination projects (usually 60 or 90 days) should be provided.

5-101.17 MUNICIPAL CONSTRUCTION AND MAINTENANCE AGREEMENTS

The following regulations governing municipal construction and maintenance agreements are in force.

(a) For controlled access highways designated under the provisions of House Bill 179, no agreements are required.

(b) For all projects which consist of maintenance type work or heavy betterment, no agreements are required.

(c) For all projects where the responsibilities of the Department and the affected municipalities have been outlined in a Minute Order tendered by the Department and accepted by the municipality, no agreements are required. (Offer to accept terms of maintenance agreement included in the Minute Order.)

(d) Agreements will be required for projects not included under either (a) or (b) above and on which it is not practicable to outline the responsibilities of the Department and the affected municipalities in the Minute Order tendered by the Department with acceptance by the municipality.

(e) Special agreements will be required for the installation of illumination systems, irrigation systems, parking facilities, traffic signals and any other items of work in which the municipality participates in the maintenance operations.

5-102 GENERAL ASPECTS OF P.S.&E. PREPARATION

5-102.1 GENERAL

The purpose of this section is to discuss plans requirements of the Department or the Federal Highway Administration.

5-102.2 P.S.&E. SUBMISSION SCHEDULE

Each year a P.S.&E. Submission and Processing Schedule will be furnished the Districts. In accordance with this schedule, two weeks prior to the P.S.&E. submission deadline, Districts will notify the Highway Design Division by computergram of all projects that will be ready for letting. If no projects are ready for letting, the District should report accordingly. Computergram notification for projects ready to be let can be accomplished by two methods; first, if the information on the PHAST File is current and fully describes the proposed project, all that is needed on the computergram is the county and I.P.E. number; second, if the project is not listed in the PHAST File, or if PHAST data is not current, the information listed below should be furnished by computergram.

DISTRICT COMPUTERGRAM

ATTENTION: D8-0 FILE D-48

DISTRICT (NUMBER)

CONTROL-SECTION (NUMBER)

PROJECT (NUMBER, IF AVAILABLE)

COUNTY

HIGHWAY (NUMBER)

PROJECT LENGTH (MILES)

LIMITS: FROM.....

TO.....

TYPE OF WORK

WORKING DAYS

IPE OR PD (NUMBER)

TOTAL ESTIMATED COST (DOLLARS) (INDICATE ANY CITY, COUNTY OR OTHER AGENCY FUNDS)

AUTHORIZED BY (MINUTE NUMBER, 20 YEAR PROJ. DEVEL. AND CONTROL PLAN, PROGRAM, ETC.)

AUTHORIZED FUNDS (DOLLARS)

ROW STATUS (NUMBER OF PARCELS REQUIRED _____

NUMBER OF PARCELS ACQUIRED _____

ROW NOT REQ

CLEAR

WILL BE CLEAR BY _____DATE)

UTILITY ADJUSTMENTS (NUMBER TO BE ADJUSTED _____

NUMBER ADJUSTED _____

CLEAR

WILL BE CLEAR BY _____DATE)

NEEDED AGREEMENTS (RAILROAD, MUNICIPAL, ETC. INDICATE STATUS)

Districts will be advised by computergram in approximately one week which projects are approved for letting.

P.S.&E. with estimate computer card deck, tracings, review prints, and supporting papers for all contract projects should be received by the respective Engineer of Field Coordination or the Engineer of Secondary Roads on or before the date specified for receipt of plans. Farm to Market projects and Highway Safety projects should be received by the Engineer of Secondary Roads.

The number of copies of review prints, supporting papers and estimate printouts will be furnished as follows:

Usual Federal-Aid Projects:		
Without signing, traffic control devices, etc.	- 3	(FAS - 2)
With Signing, traffic control devices, etc.	- 4	(FAS - 3)
Highway Safety Projects:	- 3	
Usual State Projects:		
Without signing, traffic control devices, etc.	- 2	
With signing, traffic control devices, etc.	- 3	
Usual Farm to Market Projects:	- 2	
Usual Farm to Market and State Projects Combined:	- 2	

The method of transporting P.S.&E. to Austin continues to be optional with the Districts. However, when appropriate, delivery by District personnel or other messengers is encouraged. Where it is necessary to use mail or other public carrier services, the District should notify their respective D-8 Sections by telephone to advise the method of transportation.

Only P.S.&E. for projects approved for monthly letting should be sent to Austin. These P.S.&E. should be complete and should contain all structural details and all standards except those standards that are routinely added in Austin. The project should be ready to let from the standpoint of public hearing and environmental requirements, right of way and utilities clearance, railroad agreements, 404 permits and Coast Guard permits.

In the event the reproduction requirements for review prints or the recommended delivery process creates an extreme hardship, please contact the Highway Design Division.

The submission of preliminary design data well in advance of P.S.&E. submissions should enable the Design Division to concur in basic designs in accordance with established design criteria and policy. Therefore, it is requested that the Districts submit typical sections, preliminary structure layouts, storm sewer layouts, hydraulics calculations and other basic design data as early as possible after work is authorized for review by the affected design division. This data should in all cases be submitted far enough in advance of P.S.&E. submission to give sufficient time for its study and review without delay to the development of the P.S.&E. in the districts.

5-102.3 MEASUREMENT AND PAYMENT FOR CONTRACT WORK

(a) Use of Subsidiary Items: As a general rule, direct payment should be made for all work covered by the standard specifications. However, showing estimated rates or quantities for non-pay items is desirable provided these rates and quantities are accurate and are shown to be for the Contractor's information only.

(b) Plan Quantity for Roadway Excavation: Payment based on plan quantity will not be permitted for roadway excavation; measurement for payment shall be subsequent to completion of the work. Exceptions to this policy require Administrative approval and will only be considered on individual projects for unusual conditions.

5-102.4 CONTROL OF ACCESS

Control of access lines must be indicated on all turnkey or Unit I (Grading and Structures) Interstate projects and other turnkey or Unit I projects which have been designated controlled access by law and either labeled as such or identified by symbol. The lines may be eliminated from Unit II (Base, Pavement, Signing, etc.) projects if a note is added to the title sheet referring to the previous project or projects where control of access was indicated.

The control of access should be exactly as indicated on the right of way map and in the conveyances. Should deviations be warranted, full documentation must be furnished, preferably prior to P.S.&E. submission.

5-102.5 HAUL ROADS AND DUST NUISANCES

It is the policy to eliminate all plan notes or specifications penalizing the Contractor for hauling legal loads over public roads or streets. Plans and specifications should not limit loads on public streets and highways since legal load restrictions should be enforced by police authority. Maintenance on public roads by the terms of the contract should be limited to sprinkling to settle dust. Contract restrictions on private roads used for haul roads should be the minimum required to satisfy the agreements authorizing their use.

5-102.6 TRAFFIC SAFETY IN HIGHWAY AND STREET WORK ZONES

A Traffic Control Plan (TCP) is a plan for the handling of traffic through a construction project. These plans may range in scope from a very detailed TCP for a specific project, to a reference to standard plans and/or a reference to a section of the Texas Manual on Uniform Traffic Control Devices (TMUTCD). The TCP should be developed during the planning and design phases of the project. On major projects, where complicated movement of traffic is required, a layout of detours and a sequence of work along with a signing layout should be included in the P.S.&E. On minor projects, the TCP can usually be handled by a Special Provision or shown on the Specification Data Sheets.

In addition to the necessary barricades, pavement markings, warning signs and other traffic control devices, the TCP should include temporary barriers and illumination where applicable.

The Department will develop the TCP; however, the Contractor may propose his own TCP and use it after approval by the Department. On Federal-aid projects, approval of any major revision to the TCP will also require approval of the Federal Highway Administration (FHWA).

When conditions warrant, minor or emergency changes to the TCP may be authorized immediately by the Department's responsible person. If substantial changes are made, the changes should be documented and submitted for review.

The Engineer will designate a qualified Departmental person to observe implementation of the Traffic Control Plan with authority to assure compliance on each project. This person shall make frequent inspections of the traffic control devices including night inspections which include a check of reflectivity of the traffic control devices. In addition, the District Safety Review Team and the District Traffic Control Coordinator will periodically review the project for compliance with the TCP.

Contractors will be required to designate a competent employee on each contract to be readily available to assure compliance with the approved TCP.

Provisions for temporary pavement markings should be included in all projects where pavement markings will be required to be placed during construction such as on detours or in pavement overlays, level-up and seal coat projects. The temporary pavement markings should be placed on a daily basis on the sections where traffic is allowed and where standard markings are not in place. This is intended to prevent traffic being required to utilize unmarked pavements and to also allow more efficient scheduling of standard marking placement by striping crews. On Federal-aid projects this is a requirement and is eligible for Federal reimbursement.

5-102.7 COUNTY PARTICIPATION IN CONSTRUCTION COSTS

Occasionally a county desires to participate in cost of curb and gutter, storm sewers, etc., usually as an economical substitute for wider right of way on which to develop a rural section.

Passage of a Minute Order for county acceptance is not required. County participation in cost must receive Administrative approval and an escrow agreement is necessary. Fixed-sum participation must also receive Administrative approval.

5-102.8 MUNICIPAL CONSTRUCTION

(a) Non-Controlled Access Highways

Where it is desired to construct an urban section with curb and gutter, the Department will provide for the construction or widening of pavement and its support, including support of curb and gutter.

The construction of curb and gutter, driveways, sidewalks (except where these are existing) and storm sewers on most projects, other than freeway facilities, is the responsibility of the city or town involved. Usually there are optional methods by which the city may discharge its obligations. The most generally used method is the inclusion of such work in the State's contract. This method has several advantages over the other methods and its use is to be encouraged.

For projects on which the municipality decides to construct the curb and gutter and/or storm sewer with its own forces or by separate contract, a special provision to Item 8 should clearly set out the Contractor's responsibility for cooperating with the city forces or the city's Contractor and for accepting the responsibility of repairing or replacing any of the city's construction work which is damaged or destroyed by the Contractor's operations or neglect, as well as provisions for adequate handling of traffic during construction and any other special conditions on the project. Either by the timing of the letting or by a statement in this special provision, the bidders should be given reasonable assurance that the Contractor will not be unduly delayed due to lack of progress of the city's work.

In all cases where this type of work is proposed, it is required that the work be authorized by Minute Order. The Minute Order will be in the form of a proposal to the City outlining its responsibilities and requiring the City's acceptance.

The time of passage of the Minute Order by the Commission and its acceptance by the City is important and should be when the project first appears on a program or authority for its development is requested by the District. When the project appears in a construction program, the Minute Order should be tendered to the City after the construction program is approved by the Commission. In the event a Minute Order is not tendered to the City at the time the construction program is approved and it is later found desirable to provide a street section, complete details of the proposed work should be forwarded to the program Engineer as soon as possible for Commission passage of a Minute Order. Data must be furnished in sufficient time for passage of the Minute Order, acceptance by the City, execution of the escrow agreement and receipt of escrow before bids are received.

When the municipality desires inclusion of curb and gutter, storm sewers, etc., in the State's contract, an escrow agreement is required. When fixed-sum participation in cost is desired, Administrative approval must be secured. The District should not assure the city of this type of payment or the exact amount or extent of the city's obligation, prior to receiving this approval. These funds shall be placed in escrow prior to receiving bids on the project.

Where city, county or other agencies desire to make their construction responsibilities a part of our construction contract on a unit cost basis, it is deemed desirable that they be made aware that their costs may be greater than originally estimated. Particularly in the case where their obligation is to be satisfied on a fixed-sum basis of participation, it should be made explicitly clear their cost will be based upon up-to-date, realistic estimated prices that may prevail at the time of letting.

(b) Controlled Access Highways

The Department will provide on freeways, both Interstate and Non-Interstate, within areas which are expected to be either urban or suburban in nature by the design year, the cost of all necessary storm sewers and appurtenances, including curb and gutter, to be constructed within the highway right of way as well as all outfall costs for all natural drainage that reaches the project.

In the event the local government unit involved expresses a desire to join the Department in the drainage system in order to divert drainage into the storm sewer system, the local government unit shall pay for the entire cost of collecting and carrying the diverted water to the State's system and shall contribute its proportional share of the cost of the storm sewer and outfall based on the cubic feet per second of additional water diverted to the sewer when compared to the total cubic feet per second of water to be carried by the sewer and outfall. The local unit of government requesting the drainage diversion shall indemnify the State against damages or claims for damages resulting from such diversion. Indemnification may also be required when design criteria is compromised to reduce cost of the project.

The local government shall contribute the cost of diverted drainage on the basis outlined above prior to receiving bids on the project. The Engineer-Director has been authorized to enter into agreement with the local government unit for such work and its cost as may be agreed upon.

Inquiries regarding municipal construction relative to curb and gutter, sidewalks, driveways, etc. should be directed to File D-8, and those concerning storm sewers and drainage to File D-5.

5-102.9 CROSS SECTION DATA

On some construction projects the nature of the work cannot be clearly depicted by the typical cross sections in the plans. In such cases design cross section data should be made available to the field forces and the contractor during construction. This will ordinarily apply to all multi-lane projects and others involving complex interchanges or intersections. Plans for these projects should contain a note that one copy of the design cross section data will be furnished the contractor free of charge. If he should desire additional copies, they will be at his own expense. This information will be required for all projects for which the contractor is to furnish field engineering.

On projects using original cross section data developed photogrammetrically where cross sectioning by conventional field methods will not be performed before beginning excavation work, a note similar to the following advising the contractor of this shall be included on the Specification Data Sheet of the plans.

"Original cross section data used in estimating quantities for roadway excavation has been developed photogrammetrically and will be used in determining final pay quantities."

Where final cross section data will be developed photogrammetrically, an appropriate note advising the contractor of this shall also be included.

5-102.10 ASPHALTIC CONCRETE PAVEMENT

The base course under the wearing surface should be designed for adequacy for the type, volume and weight of the traffic involved. Materials for such base course should be selected from any and all materials available to provide base adequacy at minimum costs. If the base course is two inches in thickness or less, a minimum of a base bid and two alternate bids of asphaltic concrete material shall be provided in the P.S.&E.

The wearing surface to be applied to such base course as indicated above should not exceed one and one-half inches in thickness. When asphaltic concrete is specified in the design for the wearing surface, a minimum of a base bid and two alternate bids of asphaltic concrete material shall be provided in the P.S.&E.

Exceptions to this policy may be authorized, where unusual merit is indicated, by the authority of the Assistant State Engineer-Director.

5-102.11 POLISH VALUE

In order to provide a desirable skid resistance performance, minimum polish values should be specified for asphaltic concrete, seal coat and surface treatment aggregates as follows:

Present ADT or Type of Highway	Minimum Required Polish Value of Aggregate for Flexible Pavements
Below 750	No Requirements
750 - 2000	30
2000 - 5000	33
5000 - and above	35
Interstate	35 or Specify Aggregate Type
Special and High Volume Highways	Specify Aggregate Type

In cases where the District elects to deviate from the above requirements, special justification based on performance history of similar mix designs should be furnished for approval in advance of P.S.&E. submission.

5-102.12 FIELD ENGINEERING (CONSTRUCTION STAKING)

Except for unusual conditions, which will be considered on an individual basis, field engineering will be performed by Departmental personnel. It is permissible, with the use of a special provision, for the contractor to perform construction staking on complicated urban projects in Dallas, Fort Worth, Houston and San Antonio. Special provisions requiring the contractor to do this work in other areas must receive Administrative approval.

5-102.13 PLANS

Plan sheets have been divided into nine categories: title sheet, typical sections, specification data sheets, estimate and quantity sheet, plan profile, roadway details, bridge and culvert details, hydraulic data and standards. Each of these sheets is discussed below in regard to Departmental and Federal Highway Administration requirements.

(a) Title Sheet

The purpose of the title sheet is to establish the location of the project and to describe the nature of the work proposed by the plans. The former is easily accomplished by selecting a layout scale commensurate with the length of the project and nature of the surroundings. The I.P.E. number should be shown to facilitate processing in the Austin Office.

The description of the work should list the basic units of work proposed. Where flexible base is to be stabilized it should be indicated as such with the type of stabilization also shown. The type of surfacing, e.g., one or two course surface treatment, asphaltic concrete pavement or concrete pavement, must be shown rather than such terms as asphaltic surfacing. When rest area driveway construction is proposed and Federal-aid is to be used, the title sheet description of work should reflect this work.

In addition to index of sheets and other data contained on the standard title sheet tracings, the following information must be indicated.

1. The adoption date of the governing specifications and if a Federal-aid project, the title and date of the appropriate required contract provisions must be shown. On State projects indicate: "Special Labor Provisions for State Projects".

2. If a project enters an incorporated city with a population of 5,000 or more (latest official census) or enters one of the designated urban boundaries, the station number of the urban limit should be shown on the title sheet and the total length (mileage) broken to indicate the rural length and urban length.

3. If city, county, irrigation or water district, Corps of Engineers or other participation is involved, the signature of the appropriate official is required.

4. The net length of the project for roadway and bridges further separated by State control and Federal-aid projects must be shown.

5. The limits of the project, preferably as contained in the program authorization are required. It is desirable to reference the beginning (or end) of project by the distance from a town, county line, highway, stream, etc., rather than from end of previously completed project.

6. Barricades and warning signs should be shown as outlined in 5-102.6

7. A signature block entitled "For Chief Engineer of Highway Design" should be provided on the title sheet of the plans for all projects submitted. A signature block for "Bridge Engineer" should also be provided when the project involves bridge classification structures on Federal-aid projects.

8. A signature block for "Engineer of Traffic" should be provided when only a part of the project involves traffic signals or signing and delineation.

9. A signature block for "Chief Engineer, Maintenance Operations" should be provided when the project involves only traffic signals, signing and delineation, comfort stations, etc.

(b) Typical Sections

The typical sections should be as simple as possible and still provide the necessary construction data. A general representation of the nature of construction in each portion of the project is necessary, but a multitude of details are confusing and may best be relegated to roadway detail sheets. Particular emphasis should be placed on the following items:

1. The approximate depth, in inches, of each layer in the pavement structure.

2. Each material should be clearly identified and if stabilization is proposed, indicated as such.

3. The dimensions of the subgrade crown, base crown, pavement width, payment width for stabilized material, etc.

4. The station limits of each typical section should be checked to insure that a section has been shown for all of the project roadway and that roadway widths correspond with those shown on the plan profile.

5. The approximate quantities of base material per station for each section should be shown.

6. A section is necessary for such features as ramps, detours, cross roads, etc.

(c) Specification Data Sheets

The purpose of specification data sheets is to provide, in one section of the plans, the various supplemental data required by the specifications. This consists of base material, grading requirements, density requirements and surface treatment data. The sheets are also intended for general design notes such as variations in slopes, superelevation of curves, concrete surface finish, paint price list, protection system for structures and type of bedding for concrete pipe. (The type of bedding for concrete pipe should be shown in the Culvert Summary where different structures require different bedding.) Specification data sheets have consistently been included in bidding proposals for ready reference of contractors, materials suppliers, etc. This use of specification data sheets has successfully provided for the recording of such data as closed season dates for the application of asphaltic materials and minor modification of grading requirements which are available in acceptable usage.

The use of notes furnishing information regarding quantities that are subject to change because of sequence of construction operations, such as designating portions of unclassified road excavation as rock excavation or foundation course, has resulted in confusion in interpretation and in some cases litigation in which the Department has been suc-

cessfully contested. Where quantities for subsidiary items are available and are accurate, they should be shown, but should be labeled as for the contractor's information only.

All acceptable notes proposed to be placed in the plans should be so worded that they are clear, concise and can have only one meaning.

Minor modifications of specifications such as the closed season on asphaltic materials, curing required for base materials, etc., may be placed on the specification data sheets; however, special provisions are necessary for major specification revisions. The use of specification data sheets to modify methods of measurement or basis of payment is not permissible. All notes should be referred to the specification to which they apply.

Special provisions take precedence over specification data sheet notes, in case of a conflict, in accordance with Article 5.5 of the Standard Specifications.

Specification data sheet notes prepared on plan size sheets should be of a quality and size to permit their clear and legible reproduction at a reduced scale for insertion in the proposal. This reduction in scale can best be accomplished by dividing the plan sheet in half. Preferably, the specification data sheets should be computer run or typed on 8-1/2 x 11 inch specification data sheet forms with reproduction and enlarging done in the Austin Office. After the forms have been reproduced for insertion in the proposal, a tracing of plan sheet size can be reproduced and included in the construction plans.

Specification data sheets should never be used to reiterate that which is already covered in the standard specification, special provision and/or special specification. The use of these sheets should be kept to an absolute minimum.

(d) Basis of Estimate Sheet, Summary Sheets and Estimate and Quantity Sheets

The basis of estimate sheet is necessary for plans preparation and review, for basis of bid preparation and for control of construction. This sheet should show the basis for estimating each of the pay quantities of the contract which cannot be directly measured from the plans. These include such items as sprinkling, rolling, blading, lime, fertilizer, asphalt, aggregate, etc., and should include compaction factors and unit weight for flexible base and embankment items when this information is needed for estimating purposes. When the basis of estimate contains data that will significantly affect the contractor's bid preparation it is desirable to prepare this information in the manner prescribed in 5-102.13(c) "Specification Data Sheets". This will allow this data to become a part of the proposal which means the contractor will have ready reference to this information.

Summary sheets are used to indicate type, quantity and/or location of work for individual items of the proposed project. Properly drawn, they summarize the work to be done and simplify the plans. The number of summary sheets developed will depend on the type of work. Summary sheets are often employed in lieu of Plan Profile Sheet totals. Other specialized usages of summary sheets are for location and quantity of such items as "Blading", "Road Grader Work", "Scraper Work", "Guard Fence", "Removing Old Concrete", "Conduit", etc. Conduit and structure summary sheets should be provided as

outlined in the Bridge Division Manual. When the work includes more than one control, more than one project, City or County participation, non-participation in Federal-aid or other sub-divisions, the summary sheets should so indicate.

The estimate and quantity sheets are to be used to provide a list of all the pay items and estimated quantities under the contract. Such other information as force account work by the Contractor, work to be done by railroads, cities, counties, state forces and for others to be charged to the construction appropriation must be shown. In addition to separation of roadway and bridge quantities, the quantities must be further separated by controls and projects.

The item number, descriptive code and any special provision number should be listed followed by the item description, the unit of measure and the estimated quantity. The item description must be limited to 39 space bars and should be abbreviated in accordance with the Department Manual, "Index and Code to Specification Bid Items". It is desirable, but not necessary to list bid items in numerical sequence. It is suggested that additional lines be available for the addition of bid items. The item description must agree with the measurement and payment articles of the applicable specification.

Alternate numbers should be shown to the left of the item number in the base bid and must appear in the same sequence as the alternate bid. Base bid items involved in alternates do not necessarily have to be grouped together.

For highway illumination, schedules of various types, sizes, etc., for each item should be contained in the body of the plans, along with estimated quantities; but only one pay unit should be provided for each item.

(e) Plan Profile Sheets

Clarity and completeness should be the rule to follow in the preparation of plan profile sheets. On all projects it is desirable to show sheet totals for clearing and grubbing, preparation of right of way, earthwork, curb and gutter, erosion control items and other items which are difficult or impossible to compute from information contained in the plans.

Areas to be measured for payment for clearing and grubbing or preparing right of way must be indicated as should concrete to be removed.

On all Federal-aid projects where existing bridges located adjacent to or within the project limits are to remain in place without change, the following data should be indicated on the plan profile sheet adjacent to each structure: location (stationing), type, span lengths, overall length of structure, roadway width, vertical clearance on through-truss spans, rail-to-rail horizontal clearance and estimated design capacity.

(f) Roadway Details

Roadway detail sheets should contain the numerous design details necessary to complement the typical sections and plan profiles.

Details of concrete pavement, each type of curb or curb and gutter proposed, sidewalk details, geometric details of intersections and ramps and sideroad or driveway design are but a few of the multitude of details necessary for expressway type contracts. A careful check should be made prior to P.S.&E. submission to determine that all necessary details have been included and clearly referenced on the plan profile sheets or on the title sheet index.

(g) Bridge and Culvert Details

These items should conform to the requirements set forth in the Bridge Division Operation and Planning Manual. Bridge layouts should conform closely to those previously approved by the Federal Highway Administration. Slopes at the abutments and thickness and limits of riprap should be shown. For grade separations this thickness should usually be four inches and for stream crossings, five inches. Actual calculated minimum vertical clearances for grade separations and maximum highwater elevations for stream crossings (bridge and bridge-classification culverts) should be shown. Soil data and penetrometer test data should be indicated on the profile at the location of the test holes. Bridge details should be sufficient to clearly indicate the work to be done. The pertinent AASHTO design specifications and loading should be noted on the details.

Calculated pile load (shaft load) or footing pressure (for spread footings) should be shown on substructure details. The length of all large skewed MBC's should be checked for bridge length.

(h) Hydraulic Data

Hydraulic information should be presented in the construction plans as outlined in the Bridge Division Operation and Planning Manual.

(i) Standard Sheets

The title sheet index should be checked carefully to insure that all standard tracings to be inserted by the Austin Office have been listed. The bridge approach slab, right of way marker, railroad crossing sign, riprap and piling standards are frequently overlooked. Current standard sheets should be used and modifications should be minimized in the interest of economy in construction. The barricades and construction sign standards must be included in each set of plans let to contract.

5-102.14 CHANGES IN PLANS AND SPECIFICATIONS

On occasion for various reasons it is necessary that changes be made in plans or specifications after proposals have been released to prospective bidders. On occasion the Austin Office has had requests from the Districts to advise prospective bidders of circumstances not reflected in the P.S.&E. that would affect bidding. Prospective bidders looking at work should never be told that they could do certain things not strictly in accordance with the plans and specifications.

If it becomes absolutely necessary to make a revision to the P.S.&E. for a Federal-aid project during the advertising period, such change must be forwarded to the appropriate Austin division in order to secure approval of the FHWA Division Administrator. Additionally, before bid opening, the Construction Division must assure the FHWA Division Administrator, in writing, that all bidders have acknowledged receipt of the change. Failure to comply will require that the project be removed from that month's letting and readvertised. As a definition of advertising period, this shall be the period after issuance of a letter of authority to advertise for construction by the FHWA. For State projects, this shall be after the proposals are released.

5-102.15 FEDERAL-AID PARTICIPATION IN FUTURE INTERSTATE CONSTRUCTION

Federal-aid Interstate participation on future improvements and/or additions to a completed Interstate highway can be approved by the Federal Highway Administration only if these future additions were approved by their office prior to the time the initial construction project was authorized.

In order that Federal-aid Interstate participation on contemplated additions can be assured, it is imperative that all such additional features be indicated on the P.S.&E. for the initial construction contract. This matter should receive most careful consideration during the planning stage on all Interstate projects.

5-102.16 STATE FORCE ACCOUNT WORK IN CONJUNCTION WITH FEDERAL-AID CONTRACT WORK

It is sometimes desirable to utilize State forces in conjunction with contract work. Temporary and permanent signing, temporary and permanent pavement markings, furnishing and erecting temporary barricades, temporary illumination and traffic handling are only some of the items of work that have been found to be economical for State forces work.

(a) Signing, Delineation and Pavement Markings

All signing, delineation and pavement markings, temporary and/or permanent, required as a result of a construction project, should be considered as construction items. This work will usually be included in the P.S.&E. with other construction items, either by bid item or State force account. However, this work may be handled as a separate project if the size is sufficient to be attractive for contracting. On Federal-aid projects, federal participation should be requested in either case.

When requesting construction authorization, financing or programming, the work items for signing, delineation and pavement markings will generally be considered incidental to roadway construction projects and would not be indicated. However, if any of these items would be considered a major item as defined in Standard Specification Item 4, it should be indicated in program submissions and requests for authorization and finance.

Justification for the use of State forces should be furnished and a public interest letter is to be forwarded to the FHWA for approval, when a State force account item is utilized for the construction of freeway and expressway signs, signs other than conventional signs (Texas MUTCD, Sections B, C & D) or items considered a major item as defined in Standard

Specification Item 4. The use of State force account for all other signing and pavement marking has been approved by the FHWA to be in the public interest.

(b) Miscellaneous Items of Work

All items of work, temporary and/or permanent, required as a result of a construction project should be considered as construction items and Federal participation may be requested. When it is planned to perform miscellaneous items of work by State force account, justification for use of State forces should be furnished and a public interest letter is to be forwarded to the FHWA for approval. Exceptions which have received prior FHWA approval are temporary pipes on detours and temporary guard fence for Interstate projects; minor work such as guard fence, embankment material, conduit installation, etc. on Grade Crossing Protection and Planking Projects; and all work on Safety projects.

Any work to be performed by State force account should be listed in the plans estimate to show the general types of work proposed, with an actual cost estimate for each type of work. Cost for the work will be charged to funds authorized for the project.

5-102.17 CONTRACTOR LIABILITY TO THIRD PARTIES

Plan notes, special specifications or special provisions which make the contractor liable to utility companies or others for damages as third parties to contracts should not be used. In order to avoid discrepancies that might be brought about by variable plan notes or special specification or special provision requirements on this subject, Article 7.11 of the Standard Specifications should be relied upon for this purpose.

5-102.18 TEMPORARY EROSION, SEDIMENT AND WATER-POLLUTION CONTROL

P.S.&E. should include provisions and details for temporary erosion, sediment and water-pollution control. When applicable, specially coded bid items for this work should be used. Examples of these bid items are: blading, bulldozer work, baled hay-placement, pipe, etc. These bid items should be separated from other bid items in the plans and estimate by adding the suffix: "(Erosion Control)". It is also recommended that an item be included in the P.S.&E. for providing for unforeseen temporary controls, where applicable.

5-102.19 LOCAL LETTINGS

A contract may be let locally if the work is authorized and the estimated cost without E & C is less than $100,000. Advertising for local lettings may be limited to two successive issues of any newspaper published in the county in which the work is to be done, and if there is no newspaper in the county in which the work is to be done then said advertising shall be for publication in some newspaper in some county nearest the county seat of the county in which the work is done. Approval by the appropriate Austin division and the Administration will be required prior to the preparation of P.S.&E. Upon completion, P.S.&E. should be submitted to File D-8 and/or D-18 for review and further handling.

The number of sets and size of plans and the number of proposals needed for the letting must be specified in the letter of transmittal. Upon receipt of bids, a list of bidders accompanied by the low bid-

der's proposal should be forwarded to the Finance Division. Since action by the Commission in the award of the contract or rejection of the bid is necessary, sufficient time for processing the low bid, etc., should be allowed between the time of the receipt of bids and the subsequent meeting of the Commission. Low bids of $100,000 or more will be rejected.

5-102.20 DATA REQUIREMENTS TO BE SUBMITTED WITH P.S.&E.

1. P.S.&E. Submission Data Sheet
2. Governing Specifications and Special Provisions
3. Material - Option Agreement - If Applicable
4. Request for Construction Speed Zoning - If Applicable
5. Request for Programming of Federal-Aid Project (Needed for Secondary and Off System Projects Only)
6. Right of Way and Relocation Certification

5-102.21 SPECIFICATION DATA REQUIREMENTS OF STANDARD SPECIFICATION ITEMS

ITEM NO.	TITLE & REQUIREMENTS
100	PREPARING RIGHT OF WAY Limits must be shown on plans.
102	CLEARING AND GRUBBING (1) Limits must be shown on plans. (2) Clearing and Grubbing (Palm) and Clearing and Grubbing (Tree) size must be specified.
104	REMOVING OLD CONCRETE (1) Limits of removal must be shown on plans. (2) Type must be specified.
110	ROADWAY EXCAVATION (1) Classification of excavation must be indicated on plans. (2) Waste must be indicated on plans. (3) Show limits and depth of select materials on plans. (4) When hauling of material is subsidiary, it must be specified on plans.
120	CHANNEL EXCAVATION Same as Item 110

ITEM NO.	TITLE & REQUIREMENTS
130	BORROW (1) Special treatment of sides or ends of borrow sources must be shown on plans. (2) Location for use of select material must be shown on plans. (3) When special material is desired, soil requirements must be shown on plans. (4) When hauling of material is subsidiary, it must be specified on plans.
131	BORROW (DELIVERED) Type and class must be shown on plans.
132	EMBANKMENT Under ordinary compaction, type and rate of rolling and rate of sprinkling must be shown on plans.
140	OVERHAUL No special requirements.
150	BLADING No special requirements.
152	ROAD GRADER WORK (1) Limits of work shall be shown on plans. (2) Minimum length of road grader work section is five (5) stations.
154	SCRAPER WORK No special requirements.
156	BULLDOZER WORK No special requirements.
160	SALVAGING AND PLACING TOPSOIL (1) Location of salvaging must be shown on plans. (2) Location and depth of topsoil to be placed must be shown on plans.
162	SODDING FOR EROSION CONTROL Dimensions for grass retards must be shown on plans.
164	SEEDING FOR EROSION CONTROL Asphalt type and grade must be shown on plans.

ITEM NO.	TITLE & REQUIREMENTS
166	FERTILIZER No special requirements.
170	OBLITERATING ABANDONED ROAD Sections to be obliterated must be shown on plans.
180	FINISHING ROADWAY Limits of work must be shown on plans.
190	ROADSIDE PLANTING (1) Size of plants must be shown on plans. (2) Size of special plants like roses, vines and ground covers will be measured as specified in the plans. (3) Size of ball shall be shown on plans. (4) Bracing trees larger than 4-inch diameter to be done as noted on the plans.
200	STRIPPING No special requirements.
204	SPRINKLING Rate and use must be shown on plans.
210	ROLLING (FLAT WHEEL) Rate and use must be shown on plans.
211	ROLLING (TAMPING) Rate and use must be shown on plans.
212	ROLLING (HEAVY TAMPING) Rate and use must be shown on plans.
213	ROLLING (PNEUMATIC TIRE) Rate and use must be shown on plans.
214	ROLLING (HEAVY PNEUMATIC TIRE) Rate and use must be shown on plans.
215	ROLLING (GRID) Rate and use must be shown on plans.
216	ROLLING (PROOF) No special requirements.

ITEM NO.	TITLE & REQUIREMENTS
230	ROADBED TREATMENT (1) Type must be shown on plans. (2) Type C material must have specification requirements shown on plans. (3) For Density Control, percent density must be shown on plans. (4) When stripping is subsidiary, it must be shown on plans. (5) For Ordinary Compaction, type and rate of rolling and rate of sprinkling must be shown on plans.
232	FLEXIBLE BASE (CALICHE) (1) Number of courses must be shown on typical section. (2) For stockpiled material, stockpile area must be shown on plans. (3) Type and grade must be specified. (4) Grade 2 material requirements must be shown on plans. (5) If stockpiling is required, height, depth of layers, size of stockpile must be shown on plans. (6) When haul is subsidiary, it must be shown on plans. (7) For Density Control, percent density must be shown on plans. (8) For Ordinary Compaction, type and rate of rolling and rate of sprinkling must be shown on plans.
234	FLEXIBLE BASE (SHELL WITH SAND ADMIXTURE) (1) Number of courses must be shown on typical sections. (2) Type and grade must be specified on plans. (3) Grade 2 material requirements must be shown on plans. (4) For Density Control, percent density must be shown on plans. (5) For Ordinary Compaction, type and rate of rolling and rate of sprinkling must be shown on plans.
236	FLEXIBLE BASE (BANK-RUN GRAVEL) (1) Number of courses must be shown on typical sections. (2) For stockpiled material, stockpile site must be shown on plans. (3) Type and grade of material must be specified on plans. (4) Grade 2 material requirements must be shown on plans. (5) If stockpiling is required, height, depth of layers and size must be shown on plans. (6) For Density Control, percent density must be shown on plans.

ITEM NO.	TITLE & REQUIREMENTS
	(7) For Ordinary Compaction, type and rate of rolling and rate of sprinkling must be shown on plans. (8) When haul is subsidiary, it must be shown on plans.
238	FLEXIBLE BASE (PROCESSED GRAVEL) Same as for Item 236
240	FLEXIBLE BASE (IRON ORE) Same as for Item 236
242	FLEXIBLE BASE (CRUSHED STONE) (1) Number of courses must be shown on typical sections. (2) For stockpiled material, stockpile area must be shown on plans. (3) Type and grade of material must be specified on plans. (4) Grade 3 material requirements must be shown on plans. (5) If stockpiling is required, height, depth of layers and size of stockpile, must be shown on plans. (6) For Density Control, percent density must be shown on plans. (7) For Ordinary Compaction, type and rate of rolling and rate of sprinkling must be shown on plans. (8) When haul is subsidiary, it must be shown on plans.
244	FLEXIBLE BASE (CLASS 1) (1) Number of courses must be shown on typical sections. (2) Grade 2 material requirements must be shown on plans. (3) When stockpiling is required on plans, height, depth of layers and size of stockpile must be shown on plans. (4) Percent density shall be as shown on plans. (5) If haul is to be subsidiary, it must be shown on plans.
246	FOUNDATION COURSE (1) When stockpiling is required on plans, the location, height, depth of layers and size of stockpile must be shown on plans. (2) For Ordinary Compaction, type and rate of rolling and rate of sprinkling must be shown on plans. (3) For Density Control, the percent density must be shown on plans. (4) When haul is to be subsidiary, it must be shown on plans. (5) Material requirements must be shown on plans.

ITEM NO.	TITLE & REQUIREMENTS
248	FLEXIBLE BASE (1) Number of courses must be shown on typical sections. (2) Physical requirements for Grade 4 must be shown on plans. (3) Ordinary Compaction, type and rate of rolling and rate of sprinkling must be shown on plans. (4) For Density Control, percent density must be shown on plans. (5) If stockpiling is required, it must be shown on plans with height, depth of layers and minimum quantity.
249	FLEXIBLE BASE (DELIVERED) Same as Item 248
250	SCARIFYING AND RESHAPING BASE COURSES (1) For Ordinary Compaction, type and rate of rolling and rate of sprinkling must be shown on plans. (2) For Density Control, percent density must be shown on plans.
252	SALVAGING AND REPLACING BASE (1) Amount of material to be salvaged per station must be shown on plans. (2) If Ordinary Compaction is indicated on the plans, type and rate of rolling and rate of sprinkling must be shown on plans. (3) If Density Control is indicated, percent density must be shown on plans.
254	SCARIFYING EXISTING PAVEMENT No special requirements.
260	LIME TREATMENT FOR MATERIALS IN PLACE (1) Type of lime must be specified on plans. (2) If Ordinary Compaction is indicated, type and rate of rolling and rate of sprinkling must be shown on plans. (3) If Density Control is indicated and percent densities changed from that shown in specification, the new rate of compaction must be shown on plans. (4) Lateral limits of treated area must be shown on plans. (5) Rate of application of lime should be shown on plans.
262	LIME TREATMENT FOR BASE COURSES Same as for Item 260

ITEM NO.	TITLE & REQUIREMENTS
264	HYDRATED LIME AND LIME SLURRY No special requirements.
270	PORTLAND CEMENT TREATMENT FOR MATERIALS IN PLACE (1) Percent density must be shown on plans. (2) Length of curing must be shown on plans.
272	PORTLAND CEMENT TREATMENT FOR BASE COURSES Same as Item 270
274	CEMENT STABILIZED BASE (1) Gradation for Type H base material must be shown on plans. (2) Under Ordinary Compaction, type and rate of rolling must be shown on plans. (3) If asphalt curing is required, type, grade and rate must be shown on plans.
280	SOIL ASPHALT BASE (1) Processed soil shall meet requirements shown on plans before asphalt is added. (2) Asphalt material shall be of the type and grade shown on plans. (3) Depth of soil asphalt base must be shown on plans. (4) Desired moisture content for density tests should be shown on plans.
290	SHELL CONCRETE BASE (WATER CEMENT RATIO) (1) Same as Item 360, where applicable, and requirements shown below. (2) Reinforcement required as shown on plans. (3) Thickness and typical cross section must be shown on plans.
292	ASPHALT STABILIZED BASE (PLANT MIX) (1) Grade 4 requirements must be shown on plans. (2) When placing the mixture by spreading and finishing machine is required, the plans must so state. (3) When it is desired that the spreading and finishing machine be equipped with automatic screed control device, the plans must so indicate.
300	ASPHALTS, OILS AND EMULSIONS No special requirements.

ITEM NO.	TITLE & REQUIREMENTS
301	AGGREGATE FOR SURFACE TREATMENTS (CLASS A) No special requirements.
302	AGGREGATE FOR SURFACE TREATMENTS (CLASS B) No special requirements.
303	AGGREGATE FOR SURFACE TREATMENTS (LIGHTWEIGHT) No special requirements.
304	AGGREGATE FOR SURFACE TREATMENTS (PRECOATED) (CLASS B) No special requirements.
305	AGGREGATE FOR SURFACE TREATMENTS (PRECOATED) (CLASS A) No special requirements.
310	PRIME COAT (ASPHALTIC MATERIAL ONLY) Type, grade and rate must be shown on plans.
312	PRIME COAT (ASPHALTIC MATERIAL AND SAND) Type, grade and rate of asphaltic material must be shown on plans.
314	EMULSIFIED ASPHALT TREATMENT (1) Type of emulsified asphalt must be shown on plans. (2) Percent of emulsified asphalt in mix must be shown on plans. (3) Rate of application must be shown on plans.
316	SEAL COAT (1) Type of asphalt material and rate of application must be shown on plans. (2) Type, grade and rate of application of aggregate must be shown on plans. (3) Type and rate of rolling must be shown on plans. (4) When aggregate is furnished by the State, the plans must show location of stockpiles and designate areas where it is to be placed.
320	ONE COURSE SURFACE TREATMENT (1) Type of asphalt material and rate of application must be shown on plans. (2) Type, grade and rate of application of aggregate must be shown on plans. (3) Type and rate of rolling must be shown on plans.

ITEM NO.	TITLE & REQUIREMENTS
322	TWO COURSE SURFACE TREATMENT Same as for Item 320
324	THREE COURSE SURFACE TREATMENT Same as for Item 320
330	COLD MIX LIMESTONE ROCK ASPHALT PAVEMENT (CLASS A) (1) Courses and details must be shown on plans. (2) Type and amount of mixture used shall be specified on the plans. (3) If automatic screed control is required, Item 501 must be shown in the specification list. (4) If in-place percent compaction requirement is required, the plans shall indicate minimum value.
340	HOT MIX ASPHALTIC CONCRETE PAVEMENT (CLASS A) (1) Courses and details must be shown on plans. (2) Special types of coarse aggregate, other than those shown under 340.2(a), must be shown on plans. (3) Point of sampling coarse aggregate for Test Method Tex-217-F (Part I and Part II) must be shown on plans. (4) Gravel shall have the percentage of material of more than one crushed face shown on plans. (5) If fine aggregate other than sand, screenings or shell is permitted, they must be shown on plans. (6) Type G mixture shall have grading requirements and asphalt content as shown on plans. (7) When automatic screed controls are required, Item 501 must be shown in specification list. (8) When in-place density is required, the percent density and test method must be shown.
350	HOT MIX-COLD LAID ASPHALTIC CONCRETE PAVEMENT (CLASS A) (1) Courses and area to receive mix must be shown on plans. (2) If coarse aggregate material is other than that shown in 350.2(a), the material must be so specified on the plans. (3) Point of sampling for Test Method Tex-217-F (Part I and II) will be as shown on plans. (4) If fine aggregate other than types shown in the specification is required, the plans must show new types.

ITEM NO.	TITLE & REQUIREMENTS
	(5) For Type G mixture, grading requirements and asphalt content must be shown on plans. (6) If automatic screed control is required on the spreading and finishing machine, Item 501 must be shown in specification list. (7) When in-place density is required, the percent density and test method must be shown on plans. (8) Gravel shall have the percentage of material of more than one crushed face shown on plans.
360	CONCRETE PAVEMENT (WATER CEMENT RATIO) (1) Type of concrete pavement or base of portland cement concrete must be shown on plans. (2) Thickness and typical sections must be shown on plans. (3) Bituminous material, when required, for sealing joints shall be the type and grade shown on plans. (4) Boards for joint filler shall be the size, shape and type shown on plans. (5) Size and type of dowel bars must be shown on plans. (6) Metal installing devices for joint assembly will be as shown on plans. (7) Reinforcing steel shall be placed, spaced and secured as shown on plans. (8) When emulsified asphalt is used for curing concrete base, the type and grade must be shown on plans. (9) Transverse and longitudinal joints shall be of the type and at location as shown on the plans.
364	CONCRETE PAVEMENT (CLASS A CONCRETE) (1) Typical cross section must be shown on plans. (2) Reinforcing requirements must be shown on plans. (3) Joint requirements must be shown on plans. (4) Check reference sections of Item 421 and Item 360 for additional required notes.
366	CONCRETE PAVEMENT (CONTINUOUSLY REINFORCED) (1) Same notes as Item 360. (2) Transverse wires in prefabricated deformed wire mats shall project beyond centerline of edge longitudinal wire as specified on plans. (3) Where deformed wire mats are specified, wire splicing shall conform to requirements set forth in plans.

ITEM NO.	TITLE & REQUIREMENTS
370	ASPHALT UNDERSEAL FOR CONCRETE PAVEMENT Type and grade of asphalt must be shown on plans.
372	ASPHALT SUBGRADE MEMBRANE (1) Type and grade of asphalt must be shown on plans. (2) Rate of application of asphalt must be shown on plans.
500	WEIGHING AND MEASURING EQUIPMENT Automatic proportioning devices shall be equipped with printout attachment when specified on the plans.
501	AUTOMATIC SCREED CONTROLS FOR ASPHALTIC CONCRETE SPREADING AND FINISHING MACHINE Item 501 must be shown in specifications list if desired.
502	READY-MIX PLANTS No special requirements.
510	PIPE UNDERDRAINS (1) Type and size must be shown on the plans and in the proposal. (2) If headwalls are required on drain outlets, the plans must show details.
520	CONCRETE CURB (1) Details must be shown on plans for curb and expansion material. (2) Length of section between expansion joints must be shown on plans.
521	MACHINE LAID CURB (1) Details must be shown on plans for curb and expansion joints. (2) Required type of membrane curing must be shown on plans.
522	CONCRETE CURB AND GUTTER Same as for Item 520
524	CONCRETE SIDEWALKS AND DRIVEWAYS (1) Details must be shown on plans for sidewalks and driveways. (2) Reinforcing, if required, must be shown on plans. (3) Expansion joints must be shown on plans. (4) In urbanized areas details for ramps for the handicapped must be included.

ITEM NO.	TITLE & REQUIREMENTS
530	CEMENT STABILIZED RIPRAP Details of the riprap must be shown on plans.
531	MEMBRANE CURING No special requirements.
540	ROCK RETARDS Details for retards must be shown on plans.
542	GROUTED ROCK RETARDS Same as for Item 540
544	CONCRETE RETARDS Details for retards must be shown on plans.
546	CONCRETE FOR STRUCTURE APPROACH SLABS Details for approach slabs will be shown on plans.
550	RIGHT OF WAY MARKERS (1) Details and type of markers will be as shown on plans. (2) Location of markers must be shown on plans. (3) When State furnishes markers, the location of the source shall be shown on plans.
560	METAL BEAM GUARD FENCE (1) Details of guard fence must be shown on plans. (2) If specific type of rail element is required, the plans must so state. (3) Type of posts must be indicated on the plans. (4) Blockout requirements must be indicated on the plans. (5) Length of posts shall be as shown on plans. (6) When posts are furnished the Contractor by the State, the location of the source must be shown on the plans. (7) The end of structural railing and the beginning point for guard fence must be as shown on plans.
561	REMOVING METAL BEAM GUARD FENCE Location of the guard fence to be removed must be shown on the plans.
562	REMOVING AND REPLACING METAL BEAM GUARD FENCE (1) Location of guard fence must be shown on plans. (2) Details of guard fence must be shown on plans.

ITEM NO.	TITLE & REQUIREMENTS
565	REMOVING TIMBER POST GUARD FENCE No special requirements.
566	REMOVING AND REPLACING TIMBER POST GUARD FENCE (1) Location must be shown on plans. (2) Details must be shown on plans.
567	WIRE FENCE (1) Location must be shown on plans. (2) Details must be shown on plans. (3) Weight and length of metal posts must be shown on plans. (4) Diameter and length of wooden posts must be shown on plans. (5) Gates shall be the size shown on plans. (6) Deadmen at grade depressions shall be as shown on plans. (7) Barbed wire and wire fabric shall be fastened to posts as shown on plans.
568	CHAIN LINK BARRIER FENCE (1) Location must be shown on plans. (2) Details must be shown on plans. (3) Width of fabric shall be as shown on plans. (4) Tie wire gauge and spacing must be shown on plans. (5) Weight and length of posts must be shown on plans. (6) Fabric bands gauge and spacing must be shown on plans. (7) Fittings must be shown on plans. (8) Stretcher bars and bands shall be of the size and spaced as shown on plans. (9) Gate frames shall be the size and weight specified on the plans. (10) Braces shall be the size, weight and length shown on the plans. (11) Minimum size of concrete footings will be as shown on the plans.
570	METAL SERIES RAILROAD CROSSINGS SIGNS (1) Metal for sign blanks will be the type shown on the plans. (2) Location of signs will be as shown on plans.
575	EPOXY ADHESIVE No special requirements.
580	STRUCTURE FOR FIELD OFFICE AND LABORATORY Requirements for Type "F" must be shown on plans.

ITEM NO.	TITLE & REQUIREMENTS
590	CONCRETE MEDIANS AND DIRECTIONAL ISLANDS (1) Dimensions must be shown on plans. (2) Expansion and construction joints must be shown on plans. (3) Reinforcing and dowels must be shown on plans. (4) Typical sections must be shown on plans. (5) Class of concrete must be shown on plans.
591	VEHICULAR IMPACT ATTENUATOR ASSEMBLY (STEEL BARREL) (1) Location must be shown on plans. (2) Details of assembly must be shown on plans.
592	CONSTRUCTING DETOURS (1) Typical sections and class must be shown on plans. (2) Location must be shown on plans. (3) Line and grade must be shown on plans.
610	ROADWAY ILLUMINATION ASSEMBLIES (1) Details must be shown on plans. (2) Location must be shown on plans. (3) Type of assemblies must be shown on plans.
613	HIGH-MAST ILLUMINATION POLES (1) Details must be shown on plans. (2) Location must be shown on plans.
614	HIGH-MAST ILLUMINATION ASSEMBLIES Details must be shown on plans.
630	ROADWAY ILLUMINATION ASSEMBLY FOUNDATIONS Details must be shown on plans.
640	CONDUIT (1) Type and size must be shown on plans. (2) Location must be shown on plans.
650	ELECTRIC CONDUCTOR ASTM Specification governing material must be indicated on the plans.
651	DUCT CABLE (1) Type and size of duct cable must be indicated on plans. (2) Depth of installation in open trench must be shown on plans, except when in conduit.

ITEM NO.	TITLE & REQUIREMENTS
660	CIRCUIT PROTECTOR ASSEMBLY Details must be shown on plans.
670	SERVICE POLES (1) Location must be shown on plans. (2) Hardware and size of pole must be shown on plans.
680	TRANSFORMER STATIONS Details must be shown on plans.
704	ALUMINUM SIGNS (TYPE A) (1) Size and shape must be shown on plans. (2) Reflective face shall be the color shown on plans. (3) Sign message and border shall be the size and color shown on plans. (4) Sign post connections must be as shown in SMD (3).
706	ALUMINUM SIGNS (TYPE B) (1) Size and shape must be shown on plans. (2) Sign message and borders shall be of the size, type and color shown on the plans.
716	FLAT SURFACE FLEXIBLE REFLECTIVE SHEETING No special requirements.
724	REMOVABLE REFLECTORIZED CUTOUT LETTERS, NUMERALS, ARROWS, SYMBOLS, CORNER RADII FOR SIGN BORDERS, BORDERS AND REFLECTORIZED OUTLINES FOR U.S. AND STATE ROUTE MARKERS No special requirements.
728	ROADSIDE TRAFFIC SIGN SUPPORTS (STEEL PIPE) (1) Size and specifications for pipe shall be as shown on plans. (2) Sign height must be shown on plans. (3) Sign supports shall be located as shown on plans.
730	ROADSIDE TRAFFIC SIGN SUPPORTS (STRUCTURAL STEEL) (1) Size of I-Beam and Wide Flange Beam Posts must be shown on plans. (2) Sign height must be shown on plans. (3) Sign supports shall be located as shown on plans. (4) Details of sign supports with stub posts must be shown on plans.

ITEM NO.	TITLE & REQUIREMENTS
732	OVERHEAD TRAFFIC SIGN SUPPORTS (COMMERCIAL ALUMINUM) (1) Standard designs for overhead sign supports must be incorporated in plans. (2) Sign support height and span must be shown on plans. (3) Location of sign support must be shown on plans. (4) Thickness of grout between top of concrete foundation and bottom of tower base plate must be shown on plans.
734	OVERHEAD TRAFFIC SIGN SUPPORTS (COMMERCIAL ALUMINUM) Same as for Item 732
736	OVERHEAD TRAFFIC SIGN SUPPORTS (1) Standard designs for overhead sign supports must be shown on the plans. (2) Sign support height and span must be shown on plans. (3) Location of sign support must be shown on plans. (4) Thickness of grout between top of concrete foundation and bottom of tower base plate must be shown on plans.
738	FOUNDATIONS FOR TRAFFIC SIGNS (1) Dimensions of footings must be shown on plans. (2) Reinforcing, when required, must be shown on plans. (3) Electrical details, when required, must be shown on plans. (4) When required, the size, length and number of anchor bolts must be shown on the plans.
746	HIGHWAY SIGN LIGHTING FIXTURES (1) Details must be shown on plans. (2) Type and location must be shown on plans.
748	SIGN WALKWAYS (1) Material shall be as shown on plans. (2) Location must be shown on plans.
752	PAVEMENT MARKERS (REFLECTORIZED) Location must be shown on plans.
754	TRAFFIC BUTTONS (NON-REFLECTORIZED) Location must be shown on plans.

5-102.22 LIST OF CURRENT FORMS FOR P.S.&E. SUBMISSIONS

FORM NO.	TITLE
1002	P.S.&E. Submission Data
567R	Agreement for Purchase of Road Material
1080R	Agreement for Purchase of Road Material (Borrow)
271	Easement for the Purpose of Producing and Hauling Material
8.92	Special Provision Local Material Sources (Required Sources)
8.93	Special Provision Local Material Sources (Listed Sources)
8.94	Special Provision Local Material Sources (Designated Sources)
1088	Program Supporting Data Federal-aid_____Funds
1089R	Request for Programming of Federal-Aid Projects
1204-1&2	Request for Construction Speed Zone
----	Utility Adjustment Status Form
----	Project Specific Archaeological Survey Form

P.S. & E. SUBMISSION DATA

(This form should be completed and submitted with supporting papers; complete this form for each individual project in contract)

County_____ Project _____ Date _____

Highway_____ Control _____ I.P.E._____

Limits:_____

If one or more projects, for which separate plans are prepared, are to be combined with this project for contracting, list data for other projects below.

PROJECT	CONTROL	HIGHWAY	COUNTY

1. CHECK LIST:

	DESCRIPTION	NO. COPIES REQUIRED	NO. COPIES ATTACHED
(1)	Letter of Transmittal	*	
(2)	Plans Estimate (If Card Deck, Check Here___)	*	
(3)	List of Governing Specifications and Special Provisions	*	
(4)	Request for Construction Speed Zone	3	
(5)	Request for Programming of Federal-aid Projects. (Required for secondary and safer off system projects only.)	2	
(6)	Relocation Advisory	3	
(7)	Right of Way Certification		
(8)	Material Sources and Archaeological Certification		

The number of copies of review prints will be furnished as follows (the number of supporting papers and estimate printouts will be one more than the number of review prints):

Usual Federal-aid Projects:
- Without signing, traffic control devices, etc. - 3 (FAS -2)
- With signing, traffic control devices, etc. - 4 (FAS -3)

Highway Safety Projects - 3

Usual State Projects:
- Without signing, traffic control devices, etc. - 2
- With signing, traffic control devices, etc. - 3

Usual Farm to Market Projects - 2

Usual Farm to Market and State Projects Combined - 2

2. Authorized by following Minute No. or Program _____

_____

3. FINANCING:
(a) Auth. Funds $_____(b) Est. Cost (Excluding Special Funds)$_____
(c) Amount & percent of Overrun or Underrun $_____(%)
(d) Reasons for overrun & suggested method of financing_____
_____
_____
(e) Special Funds:

	Amount	Fixed-Sum or Actual Cost	Type of Work	Authorization Minute No.
County	$_____	_____	_____	_____
City	$_____	_____	_____	_____
Others ( )	$_____	_____	_____	_____

(f) Force-Account Work

	Amount	Type of Work
State	$_____	_____
_____	$_____	_____
Contractor	$_____	Temp, Eros., Sediment and Water Pollution Control

4. TRAFFIC: Present ADT_____Projected ADT_____, 19_____
Upon Completion ADT_____(For FM and Rm Roads Only)

5. Type of ENVIRONMENTAL STATEMENT:_____Date Approved_____

6. PUBLIC HEARING: Required:_____; Held:_____; Opportunity Afforded?_____

7. PRELIMINARY APPROVAL: (yes & Date or No)

Schematics_____, Typical Section_____, Bridge Layouts_____
Basic Design Values (FM and RM Roads Only): Approved_____Date_____

8. MATERIAL-SOURCE OPTION AGREEMENTS:

Previously Submitted_____, for Project_____; with P.S.& E._____
To Be Submitted_____Female Property owners femme soles?_____

9. RIGHT OF WAY
R/W Clear_____R/W Not Clear_____; Utilities Adjusted_____;
Special Provision with P.S.& E._____. If not Clear, reason for contracting with unclear R/W:
(FHPM Vol. 6, Ch. 4, Sec. 2, Subsec. 1, Par.5b)_____
_____
_____

10. NEW SPECIAL PROVISIONS AND SPECIAL SPECIFICATIONS: (If modification is made to an existing spec. please furnish reference)
Reason for Need & Changes from Standard Spec:_____

11. RAILROAD AGREEMENTS: Required?_____Status of Agreement:_____

Name of RR:_____Type of Work:_____

If not executed, date request sent to D-5_____

12. AIRWAY-HIGHWAY CLEARANCE: Not Required_____Required_____Approved_____
Date_____

13. OTHER AGREEMENTS REQUIRED: Yes____No_____ Name of Agency_____
_____Purpose:_____
Status: Executed Yes (Date)_____No, Handled by D-_____

14. WORK TIME FOR TOTAL CONTRACT:_____Days.

Prospective Bidder may see plans at office of_____
Engineer, at_____, Texas_____,_____
(Complete Mailing Address) (Zip) (Area Code-Phone)

15. SECTION 404 OF WATER POLLUTION CONTROL ACT, AMENDMENTS OF 1972:
Permit necessary:_____Application for permit made through D-5?_____
_____ Application been approved:_____Date of Approval___
_____

16. REMARKS (Expansion of above items. Use additional sheet when necessary):_____

Form 567 R
Rev. 8-77

AGREEMENT

for purchase of

ROAD MATERIAL

by and between

the

STATE OF TEXAS
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

and

_____
(Name)

_____
(Mailing Address)

* * * * * * *

Control _____

Project _____

Highway No. _____

_____ County

Type of Material:

_____

Type of Proposed Work:

_____

_____

_____

This material or lesser amounts will be used only when haul makes it most economical source and may be secured on basis of lesser amounts or none.

Form 567 R
Rev. 8-77

STATE OF TEXAS, COUNTY OF _____

This agreement is made this _____Day of _____, 19 __, by and between_____ his/their executors, administrators, heirs, successors or assigns, hereinafter referred to as the Party of the First Part, and the State of Texas, State Department of Highways and Public Transportation, acting through its Engineer-Director, hereinafter referred to as the Party of the Second Part.

Whereas, preliminary investigations have indicated that acceptable material is available from lands hereinafter described, owned/controlled by the Party of the First Part, and

Whereas, the Party of the First Part desires to sell any or all of this acceptable material.

Witnesseth: The Party of the First Part for, and in consideration of one dollar ($1.00) and other valuable considerations, receipt of which is hereby acknowledged, does hereby agree to hold for the exclusive use of the Party of the Second Part, its agent or Contractor, all _____ material occuring on said lands, hereinafter described, and to sell any or all of this material that may prove acceptable to the Party of the Second Part at the unit royalty price of _____ per _____. The Party of the First Part hereby further agrees to indemnify and save harmless the Party of the Second Part from any and all damage, or loss, that may develop from existing mortgages or liens on the lands hereinafter described.

The Party of the Second Part agrees to pay for all accepted material at the unit royalty rate designated above by the Party of the First Part. Royalty payment(s) will be made (1) monthly as material is removed, (2) only once for each contract involved, such payment to be made after all material needed from this quarry for such contract has been removed, (3) as follows: _____

_____

_____

No royalty payment will be made for strippings of quarry or other unsuitable material, whether at quarry or delivered on the road.

It is mutually agreed that payment will be made only for acceptable material, measured as provided for in the governing specification, and delivered at points designated by the duly authorized representative of the Party of the Second Part. The governing specification requires that the material be measured

_____

_____

It is further mutually agreed and understood that the agents of Contractors for the Party of the Second Part are to have free ingress to and egress from said lands, hereinafter described, for the purpose of excavating and removing said material. All fences, gates and other existing improvements on the said lands, hereinafter described, after removal of all material desired by the Party of the Second Part, shall be placed in a condition comparable in repair to their former state by the Party of the Second Part, its agent or Contractor. All equipment placed on said lands by the Party of the Second Part, its agent or Contractor, to assist in the removal of said material, shall be removed by the Party of the Second Part, its agent or Contractor, upon the abandonment of the quarry.

It is further mutually agreed and understood that should the Party of the First Part at any time consider the maintenance of watchmen or the erection of additional fences, cattle guards, etc., against possible damage or loss during quarry operations, all arrangements and costs incident thereto shall be the entire responsibility of the Party of the First Part. Any such safeguards considered necessary by the Party of the Second Part shall be the entire responsibility of the Party of the Second Part.

This agreement shall expire _____ year(s) from the date of execution unless the Party of the Second Part at that time has under contract or has issued work order for construction of the project or projects hereinbefore described, in which event this agreement shall remain in effect until all such material desired by the Party of the Second Part for construction of said project or projects has been removed and the conditions hereinbefore stated have been fulfilled.

Location and description of lands hereinbefore mentioned (Give such information as is necessary to establish the location and limits of the source of material in a manner satisfactory and understandable to both parties):

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IN WITNESS WHEREOF, the Parties concerned hereto have set their hands the date herein named.

Party of the First Part

_____

_____

_____

_____

(If married, both husband and wife should sign)

Witness:

_____

_____

STATE OF TEXAS

Party of the Second Part

Certified as being executed for the purpose and effect of activating and/or carrying out the orders, established policies, or work programs heretofore approved and authorized by the State Highway and Public Transportation Commission:

BY _____
Assistant Engineer-Director

Recommended for approval:

_____
Resident Engineer

_____
District Engineer

_____
Chief Engineer of Highway Design

AGREEMENT

for purchase of

ROAD MATERIAL (BORROW)

by and between

the

STATE OF TEXAS
STATE DEPARTMENT OF HIGHWAYS AND
PUBLIC TRANSPORTATION

and

_____
(Name)

_____
(Mailing Address)

Control _____

Project _____

Highway No. _____

_____ County

Type of Material:

_____

Type of Proposed Work:

_____

_____

_____

This material or lesser amounts will be used only when haul makes it most economical source and may be secured on basis of lesser amounts or none.

STATE OF TEXAS, COUNTY OF _____

This agreement is made this _____Day of _____, 19 __, by and between_____ his/their executors, administrators, heirs, successors or assigns, hereinafter referred to as the Party of the First Part, and the State of Texas, State Department of Highways and Public Transportation, acting through its Engineer-Director, hereinafter referred to as the Party of the Second Part.

Whereas, preliminary investigations have indicated that acceptable material is available from lands hereinafter described, owned controlled by the Party of the First Part, and

Whereas, the Party of the First Part desires to sell any or all of this acceptable material.

Witnesseth: The Party of the First Part for, and in consideration of one dollar ($1.00) and other valuable considerations, receipt of which is hereby acknowledged, does hereby agree to hold for the exclusive use of the Party of the Second Part, its agent or Contractor, all borrow material occuring on said lands, hereinafter described, and to sell any or all of this material that may prove acceptable to the Party of the Second Part at the unit royalty price of _____ per _____. The Party of the First Part hereby further agrees to indemnify and save harmless the Party of the Second Part from any and all damage, or loss, that may develop from existing mortgages, leases, or liens on the lands hereinafter described.

The Party of the Second Part agrees to pay for all accepted material at the unit royalty rate designated above by the Party of the First Part. Royalty payment(s) will be made (1) monthly as material is removed, (2) only once for each contract involved, such payment to be made after all material needed from this pit for such contract has been removed, (3) as follows:_____

_____

_____

No royalty payment will be made for strippings of pit or other unsuitable material, whether at pit or delivered on the road.

It is mutually agreed that payment will be made only for acceptable material, measured as provided for in the governing specification, and delivered at points designated by the duly authorized representative of the Party of the Second Part. The governing specification requires that the material be measured in its original position and the volume computed in cubic yards by the method of average end areas.

Form 1080 R
Rev. Sept. 1975

It is further mutually agreed and understood that the agents of Contractors for the Party of the Second Part are to have free ingress to and egress from said lands, hereinafter described, for the purpose of excavating and removing said material. All fences, gates and other existing improvements on the said lands, hereinafter described, after removal of all material desired by the Party of the Second Part, shall be placed in a condition comparable in repair to their former state by the Party of the Second Part, its agent or Contractor. All equipment placed on said lands by the Party of the Second Part, its agent or Contractor, to assist in the removal of said material, shall be removed by the Party of the Second Part, its agent or Contractor, upon the abandonment of the pit.

It is further mutually agreed and understood that should the Party of the First Part at any time consider the maintenance of watchmen or the erection of additional fences, cattle guards, etc., against possible damage or loss during pit operations, all arrangements and costs incident thereto shall be the entire responsibility of the Party of the First Part. Any such safeguards considered necessary by the Party of the Second Part shall be the entire responsibility of the Party of the Second Part.

This agreement shall expire _____ year(s) from the date of execution unless the Party of the Second Part at that time has under contract or has issued work order for construction of the project or projects hereinbefore described, in which event this agreement shall remain in affect until all such material desired by the Party of the Second Part for construction of said project or projects has been removed and the conditions hereinbefore stated have been fulfilled.

Location and description of lands hereinbefore mentioned (Give such information as is necessary to establish the location and limits of the source of material in a manner satisfactory and understandable to both parties):

IN WITNESS WHEREOF, the Parties concerned hereto have set their hands the date herein named.

STATE OF TEXAS

Party of the First Part

Party of the Second Part

(If married, both husband and wife should sign)

Certified as being executed for the purpose and effect of activating and/or carrying out the orders, established policies, or work programs heretofore approved and authorized by the State Highway and Public Transportation Commission:

BY _____
Assistant Engineer-Director

Witness:

Recommended for approval:

_____
Resident Engineer

_____
District Engineer

_____
Chief Engineer of Highway Design

_____
Engineer, Secondary Roads

CERTIFICATION OF VALUE, after having made necessary investigation of the land I certify that the total royalty cost for the material to be used from this pit will not exceed the normal value of the land.

_____
District Engineer, State Department of Highways and Public Transportation

Form 1080 R
Rev. Sept. 1975

State Department of Highways
and Public Transportation
Form 271
Page 1 of 4
Rev. 7-75

EASEMENT FOR PURPOSE OF PRODUCING AND HAULING MATERIALS

STATE OF TEXAS §
§
COUNTY OF _____ § KNOW ALL MEN BY THESE PRESENTS:

That _____

_____

_____

of _____, in consideration of the sum of _____
_____ ($_____)
Dollars, and other good and valuable consideration in hand paid by the State of Texas, acting through the State Highway and Public Transportation Commission, receipt of which is hereby acknowledged, do by these presents, Grant, Bargain, Sell and Convey unto the State of Texas, the free and uninterrupted use, liberty and privilege of the passage in, along, upon and across the following described premises in _____ County, Texas, more particularly described as follows, to wit:

For the purpose of removing and processing materials therefrom either upon or under the surface, with the right and privilege at all times of the State, its agents, employees, workmen, contractors, and representatives having ingress to and egress from, along, upon and across said premises and adjoining property of the grantor. It is specifically understood that the State and its assigns shall be vested with the title to and the right to take and use, without additional compensation, any stone, earth, gravel, caliche, iron ore gravel, or any materials or minerals upon, in and under said land, except oil, gas and sulphur, for the construction and maintenance of the Highway System of Texas.

It is understood that all fences, gates and other existing improvements on the herein described lands, after removal of all material desired by the State, its agents or contractors, as disturbed by the removal of said materials, shall be placed in a condition comparable in repair to their former state by the State, its agents or contractors. All equipment placed on said lands by the State, its agents or contractors, to assist in the removal of said material, shall remain the property of the State, its agents or contractors, and shall be removed on or prior to the expiration date of this easement as herein specified.

It is further understood that should the Grantor herein at any time consider the maintenance of watchmen or the erection of additional fences, cattleguards, etc., necessary to safeguard his-their lands, improvements, livestock, etc., against possible damage during quarry operations and removal of said materials, all arrangements and cost incident thereto shall be the entire responsibility of the grantor herein. Any such safeguards required by the State, its agents or contractors, shall be the entire responsibility of the State, its agents or contractors. The grantor shall permit the State to erect a sign on the herein described property giving notice of the State's ownership of the materials herein.

The grantor agrees to indemnify and save harmles the State of Texas, its agents or contractors, from any and all damage, or loss, that may develop from the grantor's non-ownership of the land, or existing mortgages, liens or easements on the land therein described.

This easement shall expire_____year(s) from the date of execution unless the State, its agents or contractor, is actually engaged in removing materials, in which event it shall remain in effect until all such material desired by the State has been removed and the conditions hereinbefore stated have been fulfilled.

TO HAVE AND TO HOLD unto the said State of Texas as aforesaid for the purposes aforesaid the premises above described.

IN WITNESS WHEREOF, this instrument is executed on this the _____ day of _____, 19 _____.

_____ _____

_____ _____

_____ _____

_____

SINGLE ACKNOWLEDGMENT

THE STATE OF TEXAS
County of _____

Before me, _____, a notary public in and for said County and State, on this day personally appeared _____

_____, known to me (or proved to me on the oath of _____, a credible witness) to be the person ____ whose name ____ _____subscribed to the foregoing instrument and acknowledged to me that ____he____ executed the same for the purposes and consideration therein expressed.

Given under my hand and seal of office, this the _____ day of _____ 19 ____

_____

Notary Public in and for _____ County, Texas.

SINGLE ACKNOWLEDGMENT

THE STATE OF TEXAS
County of _____

Before me, _____, a notary public in and for said County and State, on this day personally appeared _____

_____, known to me (or proved to me on the oath of _____, a credible witness) to be the person ____ whose name ____ _____subscribed to the foregoing instrument and acknowledged to me that ____he____ executed the same for the purposes and consideration therein expressed.

Given under my hand and seal of office, this the _____ day of _____ 19 ____

_____

Notary Public in and for _____ County, Texas.

CORPORATION ACKNOWLEDGMENT

STATE OF TEXAS }
County of _____ }

BEFORE ME, the undersigned authority, a notary public in and for _____ County, Texas, on this day personally appeared _____, _____, of _____, known to me to be the person and officer whose name is subscribed to the foregoing instrument and acknowledged to me that the same was the act of the said _____, a corporation and that he executed the same as the act of such corporation for the purposes and consideration therein expressed, and in the capacity therein stated.

Given under my hand and seal of office, this the _____ day of _____, 19____.

_____

Notary Public in and for _____ County, Texas.

Tract No. _____

County _____
Highway No. _____
Control _____ Sec. _____ Job _____
Federal No. _____
Between _____
and _____

EASEMENT FOR PURPOSE OF PRODUCING & HAULING MATERIALS

TO

THE STATE OF TEXAS

Filed for Record
This _____ day of _____
A. D. 19____, at _____ o'clock _____ M.

Recorded
This _____ day of _____
A. D. 19____, in _____
County, Texas, Records of Deeds,
Book _____ Page _____

_____ Clerk.
_____ Deputy.

ENDORSEMENTS

THE STATE OF TEXAS, }
County of _____ }

I, _____, Clerk of the County Court of said County, do hereby certify that the foregoing instrument of writing, dated the _____ day of _____ A. D. 19____ with its authentication, was filed for record in my office on the _____ day of _____, A. D. 19____ at _____ o'clock _____ M., and duly recorded this the _____ day of _____, A. D. 19____ at _____ o'clock _____ M., in the Deed Records of said County, in Volume _____ on Page _____.

Witness my hand and the seal of the County Court of said County, at office in _____, Texas, the day and year last above written.

_____

Clerk of Court, _____ County, Texas.

By _____ Deputy.

SPECIAL PROVISION

LOCAL MATERIAL SOURCES
(Required Sources)

The Department holds options or easements on or owns the following local material sources. The Contractor shall secure the materials from these sources, and he shall comply with those provisions of the option as outlined below.

Owner's Name	Approximate Location of Optioned Material Source	Item Number, Type and Grade	Option Price Per

Acceptable material will be measured as provided for in the governing specifications.

The Department will make payments to the lessors and the Contractor shall reimburse the State at the option price as indicated above for each separate material source. Reimbursements will be made to the State by making deductions from the Contractor's estimates as material is placed based upon the amount shown in the estimates and the option-agreement prices shown above.

Overburden and other unsatisfactory material shall be placed in designated spoil banks or shall otherwise be disposed of as directed, in such manner as not to create an unsightly or objectionable condition.

All fences, gates and other existing improvements shall be placed in a condition comparable to their condition at the time of inaugurating work.

All equipment used in the removal of the material shall be removed from the property upon the abandonment of the quarry or pit.

COMPENSATION: All royalty costs and work required by these provisions will not be paid for directly, but shall be considered as subsidiary work pertaining to the various bid items of this contract.

Form 8.92
Rev. 4-79

SPECIAL PROVISION

LOCAL MATERIAL SOURCES
(Listed Sources)

The Department holds options or easements on the following local material sources. The Contractor may, if he elects and providing in his mining operation he can produce material meeting the specification requirements for the items listed below, operate these material sources, after the material requirements for other items for which the sources may be designated have been met. If the Contractor elects to use these sources he shall comply with those provisions of the option as outlined below. It is specifically understood that the State assumes no responsibility for either the quality or the quantity of material in these sources.

Owner's Name	Approximate Location of Optioned Material Source	Item Number, Type and Grade	Option Price Per

Acceptable material will be measured as provided for in the governing specifications.

The Department will make payments to the lessors and the Contractor shall reimburse the State at the option price as indicated above for each separate material source. Reimbursements will be made to the State by making deductions from the Contractor's estimates as material is placed based upon the amount shown in the estimates and the option-agreement prices shown above.

Overburden and other unsatisfactory material shall be placed in designated spoil banks or shall otherwise be disposed of as directed in such manner as not to create an unsightly or objectionable condition.

All fences, gates and other existing improvements shall be placed in a condition comparable to their condition at the time of inaugurating work.

All equipment used in the removal of the material shall be removed from the property upon the abandonment of the quarry or pit.

COMPENSATION: All royalty costs and work required by these provisions will not be paid for directly, but shall be considered as subsidiary work pertaining to the various bid items of this contract.

SPECIAL PROVISION

LOCAL MATERIAL SOURCES
(Designated Sources)

The Department holds options or easements on the following local material sources. If the Contractor elects to operate these material sources, he shall comply with those provisions of the option as outlined below.

Owner's Name	Approximate Location of Optioned Material Source	Item Number, Type and Grade	Option Price Per

Acceptable material will be measured as provided for in the governing specifications.

The Department will make payments to the lessors and the Contractor shall reimburse the State at the option price as indicated above for each separate material source. Reimbursements will be made to the State by making deductions from the Contractor's estimates as material is placed based upon the amount shown in the estimates and the option-agreement prices shown above.

Overburden and other unsatisfactory material shall be placed in designated spoil banks or shall otherwise be disposed of as directed in such manner as not to create an unsightly or objectionable condition.

All fences, gates and other existing improvements shall be placed in a condition comparable to their condition at the time of inaugurating work.

All equipment used in the removal of the material shall be removed from the property upon the abandonment of the quarry or pit.

Should the Contractor elect to operate sources other than those shown on the plans and set forth herein, he will notify the Engineer sufficiently far in advance to permit performance of required quality tests and will secure the approval of the Engineer in writing for use of said sources. He will be responsible for any royalty payments and other agreements made with the property owner. If these sources result in alteration of the plans or specifications, necessary negotiations will be made with the Contractor prior to the Engineer's approval of the proposed new source. In no case will approval of a source be given which would result in material of inferior quality to the designated source or which would result in an increased cost to the State.

COMPENSATION: All royalty costs and work required by these provisions will not be paid for directly, but shall be considered as subsidiary work pertaining to the various bid items of this contract.

Form 1088

PROGRAM SUPPORTING DATA — FEDERAL-AID _____ FUNDS

State _____ Texas _____ Proposed Letting Date _____ Date _____
Item No. _____ Project No. _____ County _____
Traffic: Pres. ADT _____ % Comm. _____ Est. Fut. _____

EXISTING FACILITY:

Present Surface Type _____ Pav't Width _____ Base Cr. Width _____
Deficiencies in Alignment and Grade _____

Road Connections at each end of Project:

	Surface	Surface	Base Cr.	
_____ End, Type	_____	Width _____	Width _____	Condition _____
	Surface	Surface	Base Cr.	
_____ End, Type	_____	Width _____	Width _____	Condition _____

Exist. Bridge Data:

Location (Miles from S. or W. Terminus)	Overall Length	Curb-to-Curb Roadway Width	Overhead Clearance	Type	Condition	Estimated Safe Load

Proposed Treatment of Deficient Bridges _____

Railroad Grade Crossing Data:
Name of Railroad: _____
Number of tracks: Main _____ Passing _____ Industrial _____
Number of trains and maximum speed: Passenger _____
Freight _____ Mixed _____
To determine whether sight distances are restricted, refer to page 308 of Blue Book and comment under Remarks. For quadrant with shortest sight distance show the sight distance along the railroad and the distance from the track in determining this sight distance: _____ feet at _____ feet.
Existing Protection: Gates ☐ Flagman ☐ Bells ☐ Flashing Lights ☐
Other Devices _____
Proposed Protection: _____
(If separation is proposed, state whether principle existing grade crossing will be closed.)
Will new crossing be: at present crossing _____ on essentially a relocation of existing road _____ or on a new highway _____
Is system revision involved _____ (If answer is yes, explain under Remarks)
Is airway-highway clearance involved _____ (If answer is yes, explain under Remarks)
Is water development project involved _____ (If answer is yes, explain under Remarks)
Is public hearing required _____ Has public hearing been held _____
Are incorporated cities involved in location _____
Date of execution of Municipal Maintenance Agreement (Form 1038) _____
Is relocation assistance involved _____ Has it been provided _____

REMARKS: _____

Form 1089R

REQUEST FOR PROGRAMMING OF FEDERAL-AID PROJECT

_____
Date

Please program the following project for _____

_____ County, Project No. _____ Route No. _____

Hwy. _____ Traffic: Pres. ADT _____ Future ADT _____ Year _____

Limits _____

_____

Proposed Work _____

_____

No. Lanes _____ Travel Surf : _____ Base Crown: _____

Type Pvt: _____

Front. Roads: No. _____ Travel Surf : _____ Base Crown: _____

Type Pvt: _____

Bridge: (Drainage Str.) No. _____ Total Length _____

No. _____ Overpasses at _____ Combined Length _____

_____

_____ Underpasses at _____ Combined Length _____

_____

Project Length _____ Miles ROW _____ Access Control _____

	Total Funds	Federal Funds	State Funds
Est. Cost:			
P.E.	_____	_____	_____
Construction (Incl. E&C)	_____	_____	_____
Total	_____	_____	_____

Project No._____

County_____

Additional Data Required for Projects having Urban Characteristics

Furnish large scale project sketch map

Typical proposed cross section should be furnished when available - if not, give following:

Right of way width_____

Pavement width_____

Number of lanes_____

Number of parking lanes_____ Parking Control_____

_____

Width of median_____

Turning lanes_____

Frontage roads_____

Volume of cross traffic at critical intersections_____

Grade separations located at_____

Describe plan for control of access_____

_____

_____

Give reference to Preliminary Engineering Report_____

Explain utility adjustments involved_____

_____

_____

Give breakdown of participating and non-participating portions_____

_____

_____

Explain extra utility work such as storm sewer extensions, etc._____

_____

_____

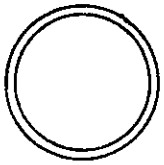
REQUEST FOR CONSTRUCTION SPEED ZONE

1. District_____
2. County_____
3. Highway Number_____
4. Direction_____ (Show direction as Northerly or Southerly, etc., from beginning Station No. to End Station No.)
5. Speed_____
6. Net Length of each Section outside of Incorporated Cities
   Section 1_____
   Section 2_____
   Section 3_____
   Section 4_____
7. Control and Section Number at both beginning and end of each Section to be zoned

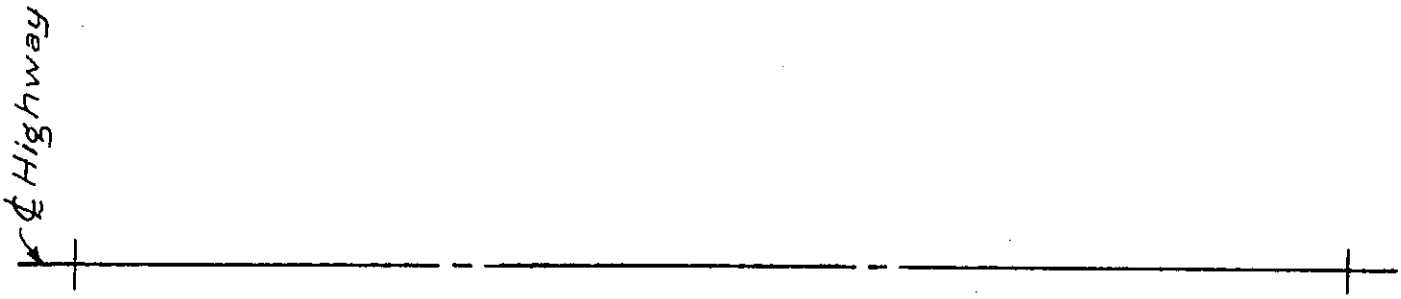
	Beginning				End			
	Station No.	Cont.	Sec.	Job	Station No.	Cont.	Sec.	Job
Section 1								
Section 2								
Section 3								
Section 4								

8. Project Number_____

Draw Sketch Below



Indicate North



3-59-768
D-18

FORM 1204-1

For instructions see reverse side of sheet

UTILITY ADJUSTMENT STATUS

Project:
Control:
Highway:
County:

Utility Adjustment Status as of _____

Owner	Utility	Location	Work Started	Work Completed	Work Remaining	Estimated Completion	Remarks

Project Specific Archaeological Survey Form

1. District _____.
2. County _____.
3. Associated Highway _____.
4. I.P.E. or P.D. No. _____.
5. Location (U.S.G.S. Map) _____.
6. Type of locality: ☐ Borrow pit, ☐ Aggregate source, ☐ Sand source, ☐ Top soil, ☐ Waste pit, ☐ Storage area, ☐ Utility area, ☐ Haul Road, other _____.
7. Owner of locality (Name and address) _____
_____.
8. Size of locality _____.
9. Presence of Archaeological evidence? ☐ yes ☐ no
10. If yes, what type of evidence? ☐ flint flakes, ☐ pottery, ☐ burned rock, ☐ stone artifacts, ☐ prehistoric architectural remains, ☐ historic artifacts, ☐ historic architectural remains, ☐ man-made earth remains, other _____.
11. Describe the evidence _____
_____
_____.
12. Is the locality disturbed? ☐ yes ☐ no
13. If yes, how? ☐ Erosion, ☐ Cultivation, ☐ Vandalism, other _____.
14. Is a professional opinion necessary? ☐ yes ☐ no
15. D-8A notified. ☐ yes ☐ no
16. Recorder _____. Date _____.
17. Signature _____.
18. Comments: _____
_____
_____
_____
_____
_____.

APPENDIX
HIGHWAY DESIGN DIVISION
OPERATIONS AND PROCEDURES MANUAL

1976 EDITION

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION

HIGHWAY DESIGN DIVISION

OPERATIONS AND PROCEDURES MANUAL

APPENDIX

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VALUES FOR DESIGN ELEMENTS RELATED TO DESIGN SPEED AND HORIZONTAL CURVATURE

D	R	V = 30 mph			V = 40 mph			V = 50 mph			V = 60 mph			V = 70 mph		
		e	L-Feet		e	L-Feet		e	L-Feet		e	L-Feet		e	L-Feet	
			2-lane	4-lane		2-lane	4-lane		2-lane	4-lane		2-lane	4-lane		2-lane	4-lane
0°15'	22918'	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
0°30'	11459'	NC	0	0	NC	0	0	NC	0	0	NC	175	175	NC	200	200
0°45'	7639'	NC	0	0	NC	0	0	NC	0	0	.021	175	175	.026	200	200
1°00'	5730'	NC	0	0	NC	125	125	.020	150	150	.027	175	175	.033	200	200
1°30'	3820'	NC	100	100	.020	125	125	.028	150	150	.036	175	175	.044	200	200
2°00'	2865'	NC	100	100	.026	125	125	.033	150	150	.044	175	180	.052	200	230
2°30'	2292'	.020	100	100	.031	125	125	.040	150	150	.050	175	200	.057	200	250
3°00'	1910'	.023	100	100	.035	125	125	.044	150	160	.054	175	220	.060	200	270
3°30'	1637'	.026	100	100	.038	125	125	.048	150	170	.057	175	230	D max. = 5.0°		
4°00'	1432'	.029	100	100	.041	125	130	.051	150	180	.059	175	245			
5°00'	1146'	.034	100	100	.046	125	140	.056	150	200	D max. = 6.0°					
6°00'	955'	.039	100	100	.050	125	160	.059	150	210						
7°00'	819'	.041	100	110	.054	125	170	D max. = 8.0°								
8°00'	716'	.043	100	120	.056	125	180									
9°00'	637'	.046	100	120	.058	125	180									
10°00'	573'	.046	100	130	.060	125	190									
11°00'	521'	.050	100	140	D max. = 10.0°											
12°00'	477'	.052	100	140												
13°00'	441'	.053	100	140												
14°00'	409'	.055	100	150												
16°00'	358'	.056	100	160												
18°00'	318'	.059	110	160												
19°00'	303'	.060	110	160												
		D max. = 19.0°														

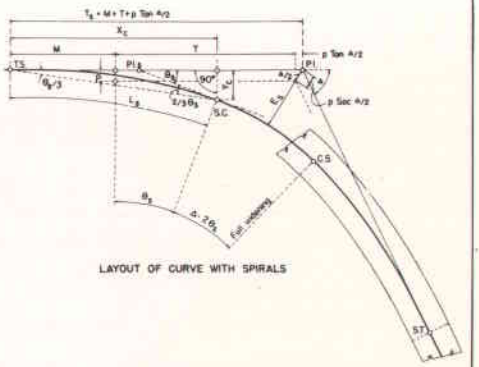
e max. = 8.0%

D = Degree of curve
R = Radius of curve
V = Assumed design speed
e = Rate of superelevation
L = Minimum length of runoff or spiral curve
NC = Normal crown section
RC = Remove adverse crown, superelevate at normal crown slope
Spirals desirable
Lengths rounded to multiples of 25 or 50 feet permit simpler calculations.

WHERE IT IS NOT FEASIBLE TO EXTEND THE SUPERELEVATION RATE THE FULL WIDTH OF THE SHOULDERS, THE SHOULDER SHALL BE ROUNDED WITH THE GRADE OF THE PAVEMENT CROSS SLOPE AND THE GRADE OF THE SHOULDER CROSS SLOPE NOT TO EXCEED 7% AS SHOWN IN SKETCH.

SYMBOLS & FORMULAE

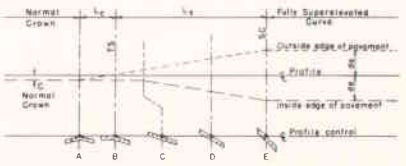
- Δ = INTERSECTION ANGLE BETWEEN MAIN TANGENTS FOR ENTIRE CURVE.
- D = DEGREE OF THE CIRCULAR CURVE
- R = RADIUS OF THE CIRCULAR CURVE.
- X_s = $L_s - .00003\ L_s\ (\theta_s)^2$
- L_s = LENGTH OF SPIRAL.
- T = M + T + (p TAN $1/2\ \Delta$).
- Y_s = X_s TAN. $(\theta_s/3)$.
- θ_s = THE SPIRAL ANGLE = $L_s\ D/200$.
- T = TANGENT OF CIRCULAR CURVE.
- M = $X_c - R\ SIN\ \theta_s$.
- P = .00000727 (L_s) D OR APPROX. $1/4\ Y_s$.
- E_s = E + p SEC $\Delta/2$.
- l = LENGTH OF SPIRAL FROM T.S. TO ANY POINT
- ϕ = SPIRAL DEFLECTION ANGLE FROM T.S. (OR S. T.)
- ϕ = $1/3\ \theta_s\ (l/L_s)^2$
- C = NORMAL VERTICAL CROWN IN FEET.
- d = DISTANCE FROM AXIS OF ROTATION TO EDGE OF PAVEMENT.
- e = FULL SUPERELEVATION PER FOOT OF WIDTH.
- L_x = LENGTH OF CROWN RUNOFF = $L_s\ C/e$.
- f = SAFE SIDE FRICTION FACTOR.
- TS & ST = TANGENT TO SPIRAL AND SPIRAL TO TANGENT.
- SC & CS = SPIRAL TO CURVE AND CURVE TO SPIRAL.



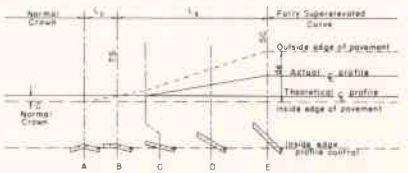
LAYOUT OF CURVE WITH SPIRALS

DETAILS FOR ATTAINING SUPERELEVATION

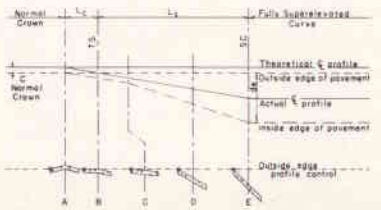
SUPERELEVATION VALUES (e) SHOWN IN THE TABLES ARE SUPERELEVATIONS PER FOOT OF PAVEMENT WIDTH TO BE OBTAINED AT THE S. C. AND C. S., AND THROUGHOUT THE CIRCULAR CURVE. SUPERELEVATION FOR ANY POINT ON THE SPIRAL IS TO BE OBTAINED IN ACCORDANCE WITH THE DIAGRAMS SHOWN ABOVE EXCEPT IN CASES WHERE CENTER LINES OF CURVES ARE NOT ON UNIFORM GRADE, IN WHICH CASE A PROFILE OF THE OUTER AND INNER CROWN LINES ARE TO BE PLOTTED AND THE GRADES ADJUSTED TO SECURE A SATISFACTORY RIDING SURFACE AND APPEARANCE.



A-PAVEMENT REVOLVED ABOUT CENTER LINE



B-PAVEMENT REVOLVED ABOUT INSIDE EDGE



C-PAVEMENT REVOLVED ABOUT OUTSIDE EDGE

GENERAL NOTES

1. MAIN LANE CURVES SHALL BE ESTABLISHED AS SHOWN HERE OR AS SHOWN ON PLAN PROFILE OR TYPICAL SECTION SHEETS. LENGTH OF SPIRAL (L_s) SHALL BE AS SHOWN IN TABLE.

   EXAMPLE: 2-LANE HIGHWAY ON 9°00' CURVE, DESIGN SPEED 70 M.P.H., SUPERELEVATION TO BE REVOLVED ABOUT C_L. NORMAL CROWN 1/4" PER FT. OR .02. L_s = 220, e = .060 $L_x = L_s\ C/e$ = 200 (.130)/.060 = 433'.

2. CURVES WITHOUT SPIRALS SHALL HAVE THE SUPERELEVATION DISTRIBUTED IN THE SAME MANNER AND OVER THE SAME CALCULATED LENGTH AS FOR SPIRALED CURVES. CURVES WITHOUT SPIRALS SHALL HAVE 2/3 THE TRANSITION LENGTH (L_s) DISTRIBUTED ON THE TANGENT AND 1/3 ON THE CURVE.

3. VERTICAL CURVES MAY BE INTRODUCED AT THE BEGINNING AND END OF THE SUPERELEVATION IF DESIRED.

4. THE FULL CROWN WIDTH SHALL BE MAINTAINED EXCEPT UNDER THE NORMAL SHOULDER SLOPE IN LENGTHS LESS THAN THE SUPERELEVATION IN WHICH CASE THE NORMAL SHOULDER SLOPE SHALL BE MAINTAINED.

5. WHERE ICING CONDITIONS ARE PREVALENT A MAXIMUM e OF 0.06 FT./FT. SHOULD BE USED.

6. COMPOUND CURVES APPROXIMATING A SPIRAL MAY BE USED WHERE THE USE OF A SPIRAL VARIES STRUCTURAL DESIGN UNNECESSARILY COMPLICATED.

7. MAXIMUM e OF 0.06 FT./FT. APPLICABLE ONLY TO FACILITIES WITH DESIGN SPEED OF 50 MPH OR LESS, SUCH AS CURBED URBAN STREETS. MAXIMUM e OF 0.04 FT./FT. APPLICABLE TO FACILITIES WITH DESIGN SPEED GREATER THAN 50 MPH, SUCH AS FREEWAYS OR RURAL HIGHWAYS. MAXIMUM e OF 0.06 FT./FT. MAY BE USED REGARDLESS OF DESIGN SPEED OR FACILITY TYPE.

VALUES FOR DESIGN ELEMENTS RELATED TO DESIGN SPEED AND HORIZONTAL CURVATURE

D	R	V = 40 mph			V = 50 mph			V = 60 mph			V = 70 mph		
		e	L-Feet		e	L-Feet		e	L-Feet		e	L-Feet	
			2-lane	4-lane		2-lane	4-lane		2-lane	4-lane		2-lane	4-lane
0°15'	22918'	NC	0	0	NC	0	0	NC	0	0	NC	0	0
0°30'	11459'	NC	0	0	NC	0	0	NC	175	175	NC	200	200
0°45'	7639'	NC	0	0	RC	150	150	.022	175	175	.029	200	200
1°00'	5730'	RC	125	125	.021	150	150	.029	175	175	.038	200	200
1°30'	3820'	.021	125	125	.030	150	150	.040	175	175	.053	200	200
2°00'	2865'	.027	125	125	.038	150	150	.053	175	210	.066	200	250
2°30'	2292'	.033	125	125	.046	150	170	.060	175	240	.075	220	330
3°00'	1910'	.038	125	125	.053	150	190	.067	180	270	.079	230	350
3°30'	1637'	.043	125	140	.058	150	210	.073	200	300	D max. = 5.0°		
4°00'	1432'	.047	125	150	.063	150	230	.077	210	310			
5°00'	1146'	.055	125	170	.071	170	260	D max. = 6.0°					
6°00'	955'	.061	130	190	.077	180	280						
7°00'	819'	.067	140	210	D max. = 6.0°								
8°00'	716'	.071	150	220									
9°00'	637'	.075	160	240									
10°00'	573'	.077	160	240									
		D max. = 10.0°											

e max. = 0.06

VALUES FOR DESIGN ELEMENTS RELATED TO DESIGN SPEED AND HORIZONTAL CURVATURE

D	R	V = 30 mph			V = 40 mph			V = 50 mph		
		e	L-Feet		e	L-Feet		e	L-Feet	
			2-lane	4-lane		2-lane	4-lane		2-lane	4-lane
0°15'	22918'	NC	0	0	NC	0	0	NC	0	0
0°30'	11459'	NC	0	0	NC	0	0	NC	0	0
0°45'	7639'	NC	0	0	NC	0	0	RC	150	225
1°00'	5730'	NC	0	0	RC	125	190	.016	150	225
1°30'	3820'	NC	100	150	.015	125	190	.020	150	225
2°00'	2865'	NC	100	150	.018	125	190	.023	150	225
2°30'	2292'	.015	100	150	.020	125	190	.026	150	225
3°00'	1910'	.016	100	150	.022	125	190	.028	150	225
3°30'	1637'	.017	100	150	.024	125	190	.030	165	225
4°00'	1432'	.018	100	150	.025	125	190	.033	190	225
5°00'	1146'	.021	100	150	.028	125	190	.036	150	225
6°00'	955'	.023	100	150	.031	125	190	.040	150	225
7°00'	819'	.024	100	150	.033	125	190	.040	150	225
8°00'	716'	.026	100	150	.036	125	190	D max. = 6.0°		
9°00'	637'	.028	100	150	.038	125	190			
10°00'	573'	.029	100	150	.040	125	190			
11°00'	521'	.031	100	150	.040	125	190			
12°00'	477'	.032	100	150	D max. = 10.0°					
13°00'	441'	.033	100	150						
14°00'	409'	.035	100	150						
16°00'	358'	.037	100	150						
18°00'	318'	.038	100	150						
		.040	100	150						
		D max. = 19.0°								

e max. = 0.04

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

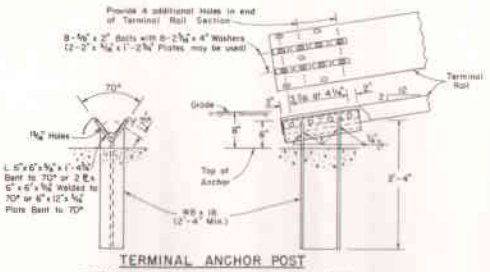
CURVE SUPERELEVATION AND TRANSITION STANDARD

CST-75

DN	CHECKING	DATE	FED. AID PROJ. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
Ck. DN.	ORIGINAL	8-1-75				
DW	REVISED			TEXAS		
Ck. DW	REVISED			STATE DISTRICT	COUNTY	CONT. SECT. JOB HIGHWAY NO.
TR						
Ck. TR						

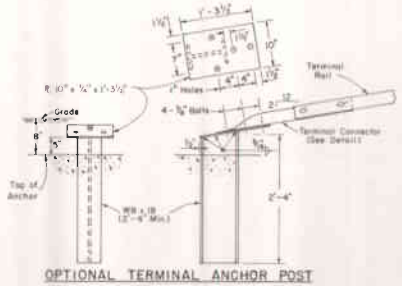
ELEVATION

*NOTE: This dimension measured to center of splice when Terminal Connector is used.



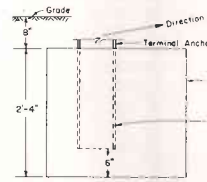
TERMINAL ANCHOR POST

NOTE: This Post requires 4 additional Holes (Shop or Field) in the Terminal Rail member with 8-⅝" Bolts and Washer Plates as shown for attachment.



OPTIONAL TERMINAL ANCHOR POST

NOTE: This Optional Post requires the use of the 10 Ga Terminal Connector with 4-⅝" Bolts for attachment to the Anchor Post

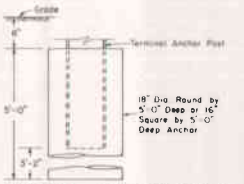


TERMINAL CONCRETE ANCHOR

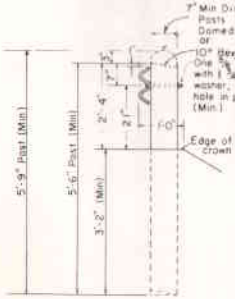
NOTE: Either Post may be used with either Anchor. No Construction Joint is allowed in the Concrete Anchor.

Terminal Rail may be bolted to Post and in twist position prior to placing Concrete Anchor.

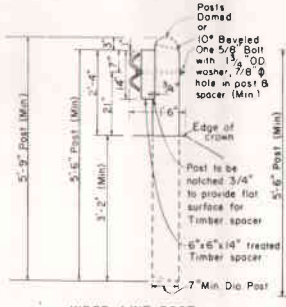
Upper 10" (Min.) of Anchor Post must be Galvanized



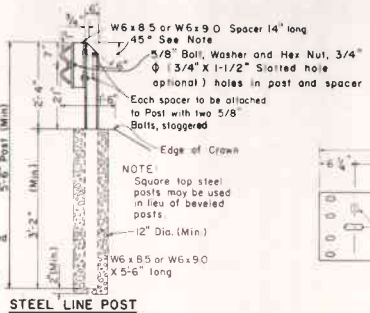
OPTIONAL TERMINAL CONCRETE ANCHOR



WOOD LINE POST



WOOD LINE POST (Blockout)

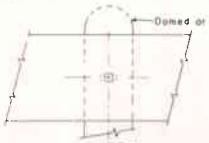


STEEL LINE POST (Blockout)

NOTE:
When undisturbed solid rock is encountered the minimum depth of the hole shall be 1'-6"

ANCHOR OR SPLICE BOLT ⅝" NUT
POST BOLT: Similar except length
(1⅞ Hex bolts required for Terminal Connector)

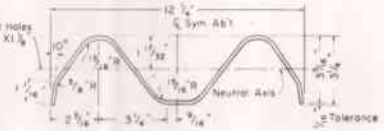
RAIL SPLICE



POST CONNECTION WOOD POST

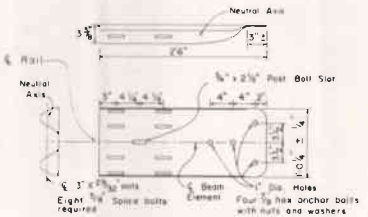
Wood Post May Be Domed, or Beveled

POST CONNECTION STEEL POST

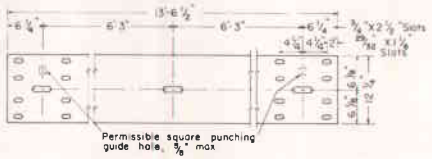


NOTE: Actual Section may be slightly different depending upon the manufacturer

SECTION THRU GUARD RAIL



TERMINAL CONNECTOR
(10 GAGE MINIMUM)



ELEVATION OF NOMINAL
12½ FOOT GUARD RAIL
(25 Foot sections may also be supplied)

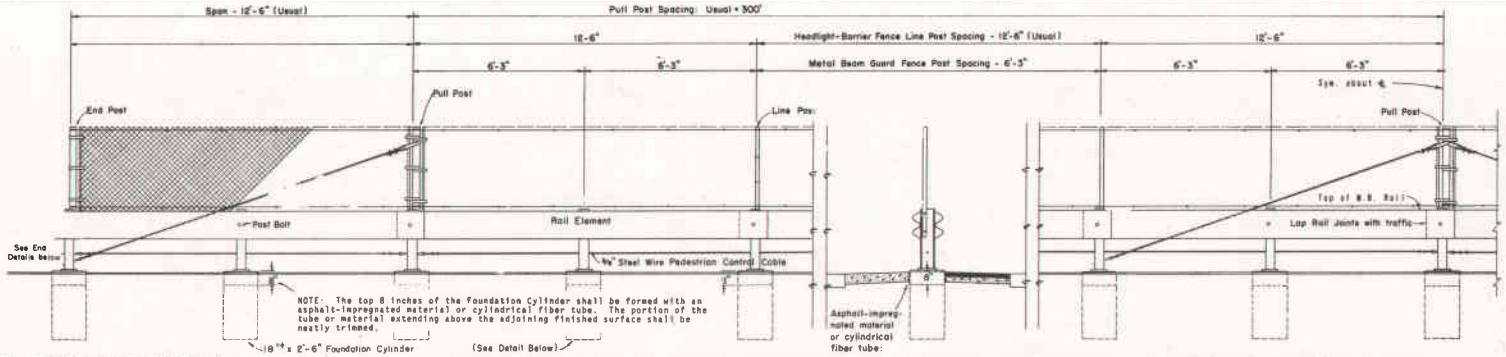
GENERAL NOTES

1. THE EXACT POSITION OF GUARD FENCE SHALL BE AS SHOWN ELSEWHERE ON THE PLANS OR AS DIRECTED BY THE ENGINEER. GUARD FENCE SHALL BE TRANSITIONED TO A SMOOTH CONNECTION WITH OTHER GUARD FENCE OR STRUCTURE RAILING AS SHOWN ELSEWHERE ON PLANS.
2. AT THE OPTION OF THE CONTRACTOR THE RAIL ELEMENTS FOR THE GUARD FENCE MAY BE FURNISHED IN EITHER 12½ OR 25 FOOT NOMINAL LENGTHS WITH POST BOLT SLOTS FOR CONNECTION TO POSTS.
3. BOLTS SHALL BE OF SUFFICIENT LENGTH TO EXTEND THROUGH THE FULL THICKNESS OF THE NUT AND NO MORE THAN ¾" BEYOND IT.
4. THE TOP OF THE TERMINAL ANCHOR POST AND ALL STEEL FITTINGS THEREON SHALL BE GALVANIZED A MINIMUM OF 10" AS SHOWN.
5. WHERE ROCK IS ENCOUNTERED OR WHERE SHOWN ON THE PLANS, THE DIAMETER OF THE HOLES AND THE MATERIAL FOR BACKFILLING SHALL BE AS DIRECTED BY THE ENGINEER. TIMBER POSTS SHALL NOT BE SET IN CONCRETE.
6. THE TERMINAL ANCHOR POST SHALL BE SET IN CLASS "A", "B" OR "C" CONCRETE IN ACCORDANCE WITH ITEM "CONCRETE FOR STRUCTURES", OR SET IN GROUTED IN ACCORDANCE WITH ITEM "CONCRETE PAVEMENT". CONCRETE SHALL BE SUBSIDIARY TO THE BID ITEM REQUIRING CONSTRUCTION OF THE TERMINAL RAIL SECTION AND ANCHORAGE SYSTEM.
7. TIMBER POSTS MAY BE BEVELED AT APPROXIMATELY 10 DEGREES ON THE TOP ON BOTH SIDES WITH WIDE SIDE OF TOP OF POST PLACED TOWARD THE ROADWAY OR THEY MAY BE DOMED. WHEN "BEVELED CUT", THE UPPER PORTION OF THE POST SHALL BE NOTCHED 3/4" TO PROVIDE FLAT SURFACE FOR TIMBER SPACER. A TOLERANCE OF ± 1/8" WILL BE PERMITTED ON THE NOTCHED PORTION OF THE POST.
8. AN ANCHOR OTHER THAN TO A TERMINAL ANCHOR POST SHALL CONSIST OF A CONNECTION SIMILAR TO THE RAIL SPLICE OR SIMILAR TO THE TERMINAL CONNECTOR.
9. SPECIAL FABRICATION WILL BE REQUIRED IN INSTALLATIONS HAVING A CURVATURE OF LESS THAN 150' RADIUS.
10. POST SPACING WILL BE 6'-3" EXCEPT THAT THE FIRST POST WILL BE 21' FROM THE TERMINAL ANCHOR POST AND THE NEXT TWO POSTS SPACED AT 12'-6" WITH A MINIMUM OF 6 POSTS ADJACENT TO STRUCTURES SPACED AT 3'-1½".
11. THE STEEL TERMINAL CONNECTOR MUST BE USED WITH THE OPTIONAL TERMINAL ANCHOR POST. EITHER ANCHOR POST MAY BE USED WITH EITHER CONCRETE ANCHOR.
12. CROWN WILL BE WORKED TO ACCOMODATE GUARD FENCE.
13. STEEL POSTS SHALL BE SET IN CONCRETE AND BLOCKED OUT. A W6x8.5 OR W6x9.0 STEEL SPACER SHALL BE USED WITH STEEL POSTS. CONCRETE FOR LINE POST FOOTINGS SHALL BE SUBSIDIARY TO THE BID ITEM "METAL BEAM GUARD FENCE".
14. WHEN BLOCKOUT GUARD FENCE IS SPECIFIED ELSEWHERE IN THE PLANS, A 6" x 6" x 14" TREATED TIMBER SPACER OF YELLOW PINE SHALL BE USED WITH WOOD POSTS.
15. UNLESS OTHERWISE SHOWN IN THE PLANS, GUARD FENCE PLACED IN THE VICINITY OF CURBS SHALL BE BLOCKED OUT SO THAT THE FACE OF CURB IS LOCATED DIRECTLY BELOW OR BEHIND THE FACE OF RAIL. RAIL PLACED OVER CURBS SHALL BE INSTALLED SO THAT THE POST BOLT IS LOCATED APPROXIMATELY 21-INCHES ABOVE THE GUTTER PAN OR ROADWAY SURFACE.

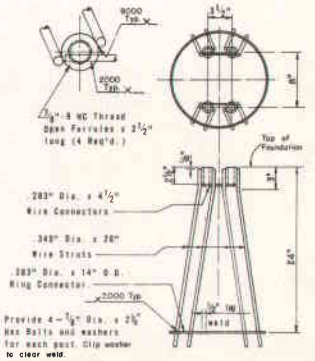
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

METAL BEAM GUARD FENCE
GF(TD) - 80

DN	CHECK	DATE	FED. AID PROJ. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK DW	ORIGINAL			TEXAS		
DW	REVISED					
CK DW	REVISED		STATE DISTRICT	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
PW						
CK TR						



METAL BEAM GUARD FENCE (BARRIER) & CONTROL-OF-ACCESS HEADLIGHT-BARRIER FENCE



OPTIONAL PRESET ANCHORAGE SYSTEM

PRESET ANCHORAGE SYSTEM

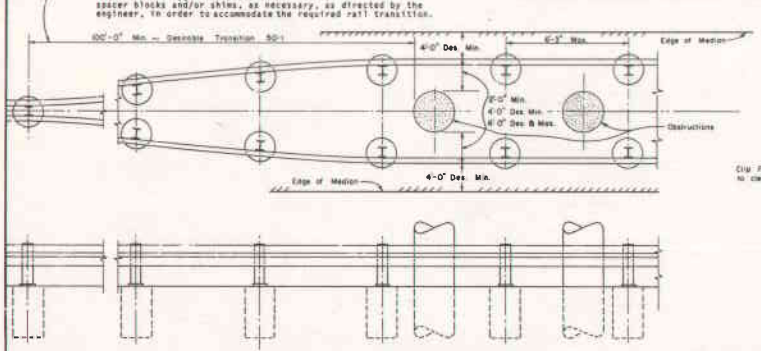
At the option of the Contractor, the preset anchorage system shown above may be used in lieu of conventional anchor bolts and reinforcing steel for rail posts mounted on foundation cylinders.

Material for the preset anchorage shall be as follows:
Ferrules: Steel A.S.T.M. A108 Grade 12 L 14
Wire Connectors: Steel A.S.T.M. A510 Grade 1008
Struts: Steel A.S.T.M. A510 Grade 1022 or 1033
Contractor shall furnish certification that the material furnished meets the requirements of the A.S.T.M. designations.

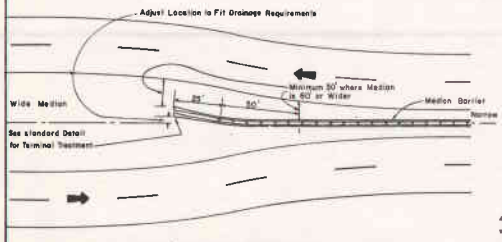
Other systems of similar design may be submitted to the Bridge Engineer for approval. Such proposed systems must be submitted and approved prior to their incorporation on shop drawings for any project. Approval shall be based on certified test results from an approved testing laboratory, that the proposed anchorage satisfies the following requirements:
Minimum pull-out strength: 48,000 Lb. tension on 2 bolts
Minimum shear strength: 40,000 Lb. shear on 4 bolts
Values based on 28 day comp. strength of Conc. = 3000 p.s.i.
An accurate description of the test set-ups shall be included with test results. Test set-ups shall be such that the forces exerted on the test specimen shall simulate those acting on a post-mounted on a concrete foundation cylinder.

GENERAL NOTES

1. If "Metal Beam Guard Fence (Barrier) Block Out" is required by bid item, the requirements for the block outs shall conform to the requirements shown on standard Metal Beam Guard Fence (Block Out Rail Element).
2. At the option of the Contractor, the rail element for the guard fence may be furnished in 25 foot lengths with post bolt slots for 5/8" diameter bolt anchorage to intermediate posts.
3. All steel fittings shall be galvanized.
4. For control of access headlight barrier fence details see standard for control of access headlight barrier fence.
5. Unless otherwise specified elsewhere on the plans, a 3/8" pedestrian control cable shall be placed through the posts as indicated.
6. Metal beam guard fence should maintain continuity of strength at all times. No special provisions for expansion at or near structures or at any other location is needed due to the ability of the rail to distribute such movement over considerable lengths of rail.



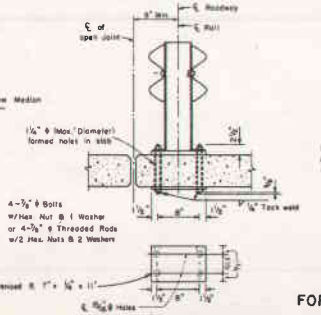
TREATMENT AT MEDIAN OBSTRUCTIONS



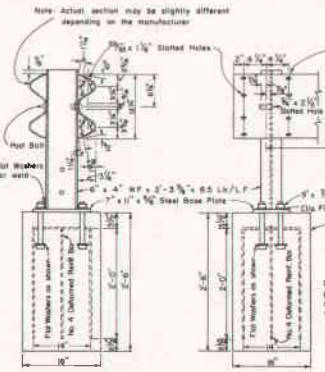
TYPICAL END TREATMENT

NOTE: IF MEDIAN IS 60' OR LESS IN WIDTH THE DOUBLE MEDIAN RAIL SHOULD BE ENDED NEAR THE CENTER LINE. CARE SHALL BE TAKEN TO NOT INTERFERE WITH DRAINAGE REQUIREMENTS.

NOTE: ON NEW STRUCTURES OR STRUCTURES TO BE WIDENED LOCATE OPEN JOINT 9" OFF ℄ OF ROADWAY. ON EXISTING STRUCTURES WHERE OPEN JOINT IS ON ℄ OF STRUCTURE LOCATE BARRIER 9" OFF CENTER WITH 2° REVERSE CURVE TRANSITION OFF END OF STRUCTURE.

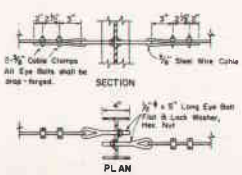


STRUCTURE MOUNTING DETAILS



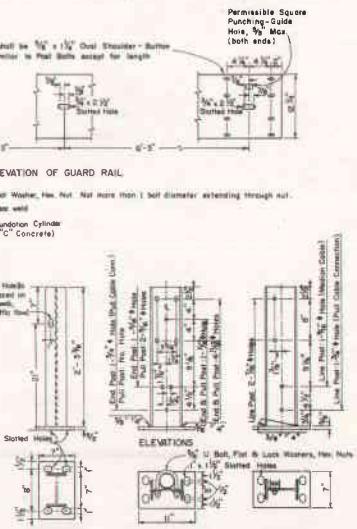
POST BOLT NUT

NOTE: Bolts used in attaching rail to post shall be of sufficient length to extend through the full thickness of the nut and no more than ¼" beyond it.



MEDIAN CABLE CONNECTION AT PULL POST

FOR PEDESTRIAN CONTROL CABLE



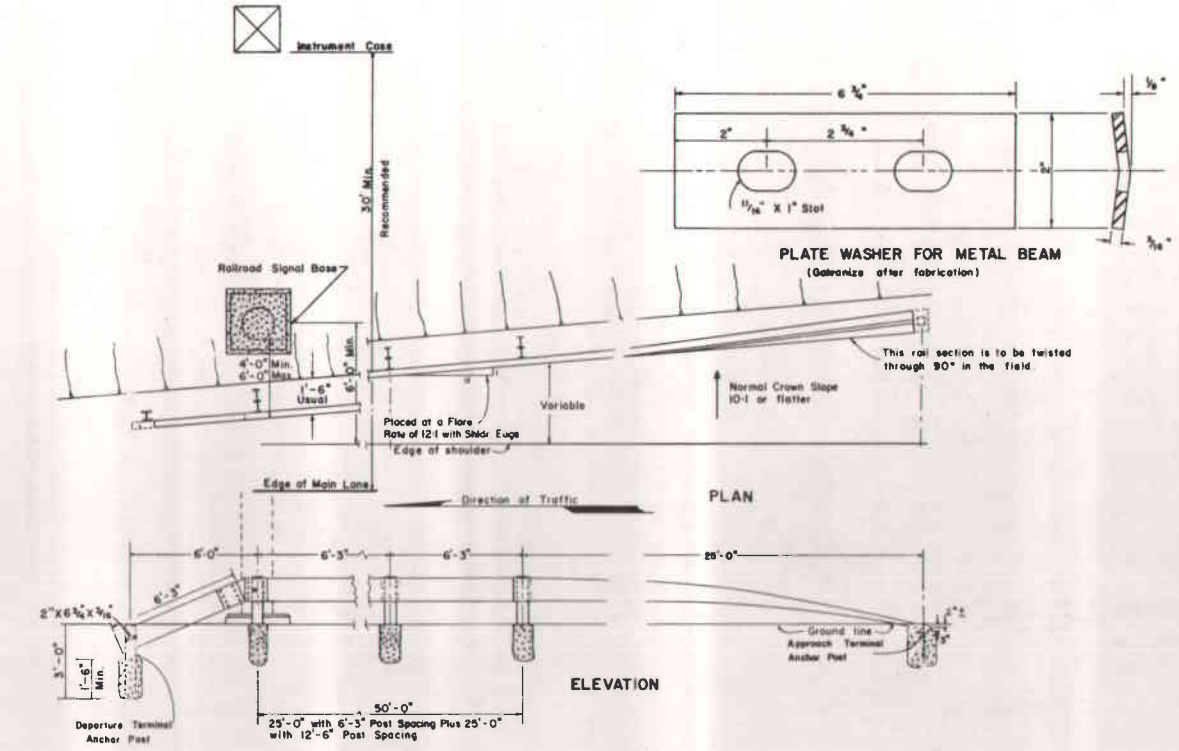
BASE PLATE & POST DETAILS

GUARD RAIL POST - 6" x 4" WF x 2'-3 ⅜" x 8.5 Lb./L.F.
STEEL BASE PLATE - 7" x 11" x ⅝"

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

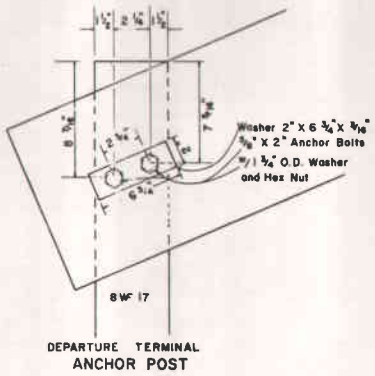
METAL BEAM GUARD FENCE (BARRIER) MBGF (B)-74

DN.	CK. DW.	DW.	CK. QW.	TR.	CK. TR.	DRAWING ORIGINAL	DATE	Rev. 4-'75 Preset Anchor	FED. ROAD DIV. NO. 6	STATE TEXAS	STATE DIST. NO.	FEDERAL PROJECT NO.	COUNTY	SHEET NO.	SHEET NO.	HIGHWAY NO.

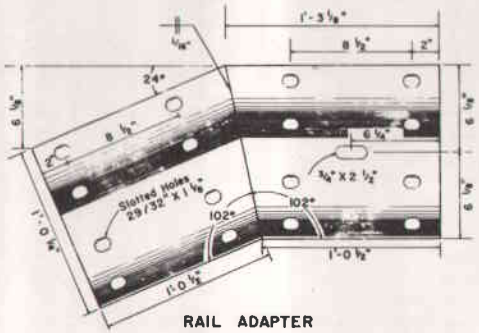


GENERAL NOTES

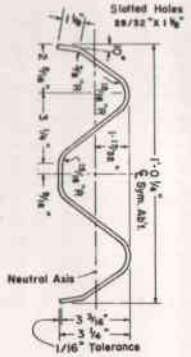
1. FOR METAL BEAM GUARD FENCE DETAILS, CLOCK OUT REQUIREMENTS AND METHOD OF ELIMINATION, SEE LATEST METAL BEAM GUARD FENCE DETAILS.
2. TIMBER POSTS MAY BE USED EXCEPT FOR TERMINAL INSTALLATIONS WHERE STEEL WILL BE REQUIRED.
3. THE TERMINAL ANCHOR POST AND RAIL ADAPTER THEREON SHALL BE GALVANIZED AS SHOWN.
4. FOR URBAN, LOW SPEED (LESS THAN 50 MPH SPEED ZONE) FACILITIES, LENGTH OF GUARD FENCE MAY BE REDUCED AS DIRECTED BY THE ENGINEER TO FIT STREET SPEED AND DRIVEWAY LOCATION CONDITIONS.



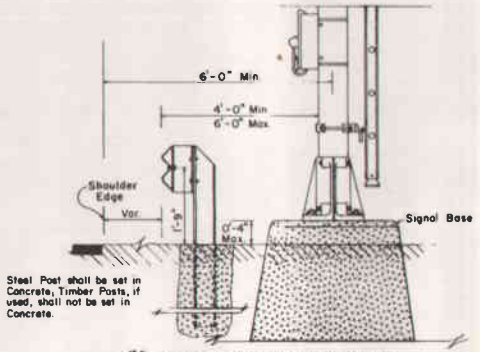
DEPARTURE TERMINAL ANCHOR POST



RAIL ADAPTER
Class A Rail - 10 Gauge
(Galvanize after fabrication)



RAIL ADAPTER END VIEW



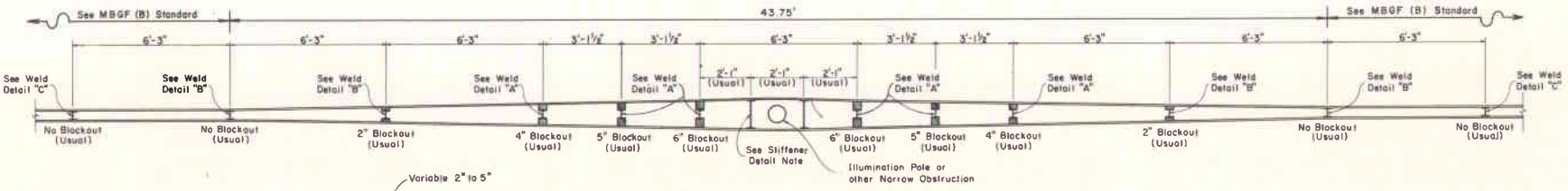
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

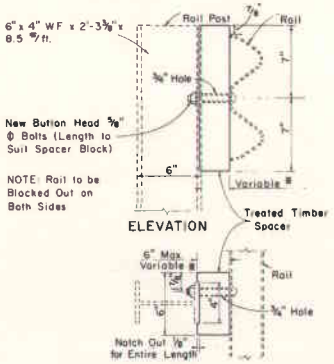
METAL BEAM GUARD FENCE

RAILROAD-SIGNAL PROTECTION

GF(RRSP)-77

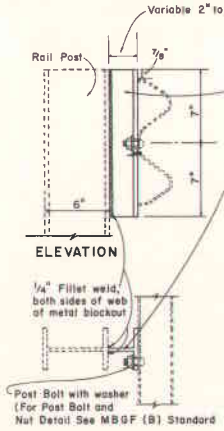
DIST.	STATE	FEDERAL PROJECT NO.	SHEET NO.
	TEXAS		
STATE DIST. NO.	COUNTY	CONT.	SECT.	HIGHWAY NO.





MEDIAN RAIL BLOCKOUT DETAIL
(TIMBER)
All Spacer Sizes

* NOTE: Steel Posts adjacent to obstruction shall be fitted with 6" Timber Block Spacers on each side. The maximum blockout of 6" shall be introduced in not more than 2" increments.



STEEL BLOCKOUT DETAIL
(2" to 5" Spacers)

Tee section cut from 6"X4" WF X 1'-2" X 8.5 #/ft. so that web depth is 2" to 5" as desired.

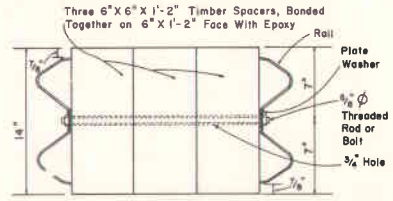
Weld 1'-2" in length along each side between outer flange edges.

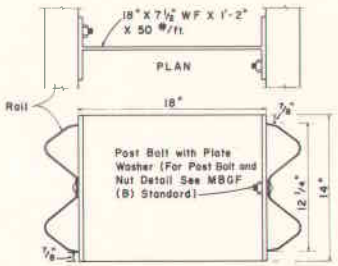
Two ⅝" bolts staggered

For 6" blockout, a 6"X4" WF X 1'-2" X 8.5 #/ft may be used with bolted (two ⅝" bolts, staggered) or seam welded (1'-2" in length along each side between outer flange edges) connections.

STEEL PLAN BLOCKOUT
Detail (6" Spacers)

OPTIONAL MEDIAN RAIL BLOCKOUT DETAIL
(STEEL)



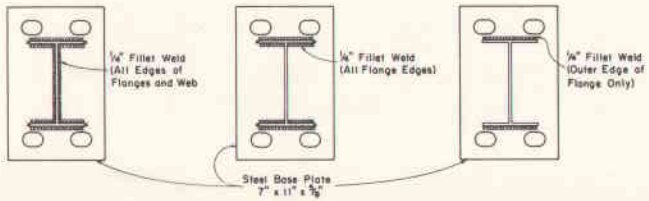


STIFFENER DETAIL

NOTE: Stiffeners shall usually be located 2'-1" from posts nearest obstruction. Where obstruction location prohibits the usual stiffener location, adjustments shall be as directed by the Engineer.

GENERAL NOTES

1. RAIL ELEMENT SHALL BE CLASS A.
2. WHERE OBSTRUCTION LOCATION PROHIBITS USUAL LOCATION OF STIFFENER, ADJUSTMENTS IN LOCATION SHALL BE AS DIRECTED BY THE ENGINEER.
3. TIMBER OR STEEL BLOCKOUTS MAY BE USED. FOR 6" METAL BLOCKOUTS, A 6"x4" WF x 1'-2" x 8.5 #/FT. MAY BE USED WITH BOLTED (TWO 5/8" BOLTS, STAGGERED) OR SEAM WELDED CONNECTION BETWEEN POST AND BLOCKOUT. FOR 2" TO 5" STEEL BLOCKOUTS, A 6" x 4" WFx1'-2"x8.5 #/FT. MAY BE CUT INTO A TEE SECTION OF THE APPROPRIATE WEB DEPTH AND WELDED TO THE POST AS SHOWN ON THE STEEL BLOCKOUT DETAIL.
4. FOR THOSE STANDARD DETAILS (FOUNDATION CYLINDER, ANCHOR BOLTS, POST BOLT AND NUT, ETC.) FOR METAL BEAM GUARD FENCE MEDIAN BARRIER WHICH ARE NOT SHOWN HEREON, SEE MBGF (B) STANDARD.
5. TREATMENT AT OBSTRUCTION AS SHOWN ON MBGF (B) STANDARD TO BE USED IN LIEU OF MBGF (B) OBS WHERE OBSTRUCTION WIDTH EXCEEDS TWELVE (12) INCHES.
6. THREE 6" x 6" x -1'-2" TIMBER BLOCKS MAY BE USED IN LIEU OF THE 18" x 7½" WF x 1'-2"x 50 #/FT. FOR STIFFENERS. WHERE USED, THE THREE TIMBER BLOCKS SHALL BE BONDED TOGETHER WITH EPOXY ADHESIVE ON 6" x 1'-2" FACES AND AFFIXED BETWEEN RAIL ELEMENTS AS SHOWN ON THE OPTIONAL STIFFENER DETAIL.
7. ALL WORK PERFORMED AND MATERIALS FURNISHED AS PRESCRIBED HEREON, WILL BE PAID FOR AT THE UNIT PRICE BID FOR THE ITEM "METAL BEAM GUARD FENCE".



WELD DETAIL "A" WELD DETAIL "B" WELD DETAIL "C"

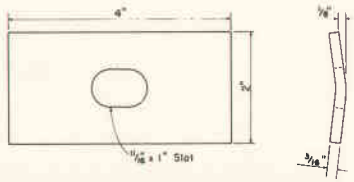


PLATE WASHER FOR METAL BEAM AT STIFFENERS
(Galvanize After Fabrication)

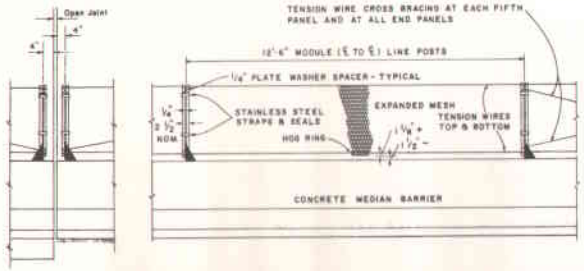
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

METAL BEAM GUARD FENCE
(BARRIER OBSTRUCTION)
MBGF (B) OBS - 74

TREATMENT AT NARROW OBSTRUCTIONS IN MEDIAN

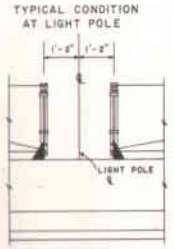
DN	DRAWING	DATE	FED. ROAD DIV. NO.	STATE	FEDERAL PROJECT NO.				SHEET NO.
CK BH	ORIGINAL		6	TEXAS					
DW	REVISED								
CK DW	REVISED		STATE DISTRICT	COUNTY		CONT.	SECT.	JOB	HIGHWAY NO.
TK									
CK TK									

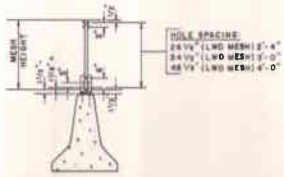
A-7



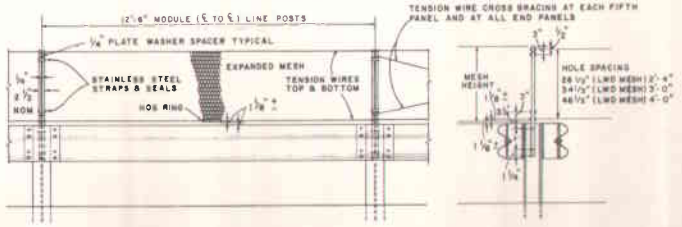
TYPICAL CONDITION AT BRIDGE EXPANSION JOINTS

TYPE A HEADLIGHT BARRIER FOR MOUNTING ON CONCRETE MEDIAN BARRIER

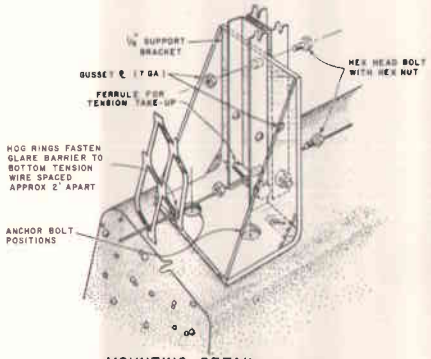




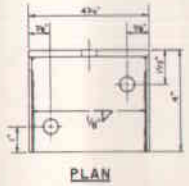
SECTION
(THRU MEDIAN)



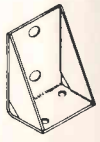
TYPE B HEADLIGHT BARRIER FOR MOUNTING ON METAL BEAM GUARD FENCE



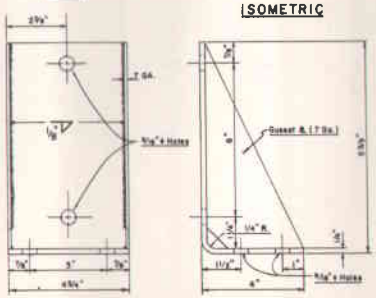
MOUNTING DETAIL
TYPE A HEADLIGHT BARRIER



PLAN



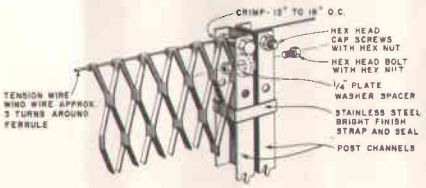
ISOMETRIC



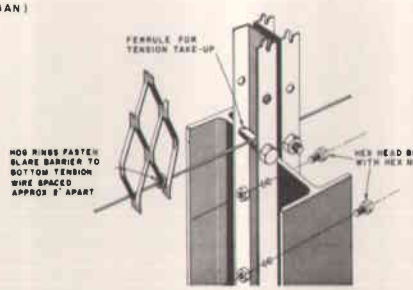
FRONT ELEV.

SIDE ELEV.

POST UNIT SUPPORT BRACKET



TOP-OF-FENCE MOUNTING DETAIL
COMMON TO BOTH TYPE A AND TYPE B HEADLIGHT BARRIER



MOUNTING DETAIL
TYPE B HEADLIGHT BARRIER

MATERIALS REQUIRED

ITEM	AASHTO DESIGNATION	AASHTO GALVANIZED CLASS
EXPANDED METAL MESH PANEL 12'-3" END x 2'-6", 3'-0", 4'-0" LWD, 18 gage, 0.250" strand width, 1.33" x 4.00" center-to-center of bridges. Expanded from Hot Dip Galvanized Sheet. Top edge to be shop curled. Painted in accordance with Specifications.	A-526	A-525 Class G 210
POST UNIT Two-piece back-to-back channels, 1 7/16" x 1 1/8" x 11 gage. Plate Washer (1/4" thick). Painted in accordance with Specifications.	A-569	A-153 Class B-2 A-153 Class C
TENSION WIRE Top and bottom, American Wire Gage No. 9 (0.148" diameter) low carbon Industrial Grade - Hard	A-641	A-641 Class 2
HOG-RING FASTENERS American Wire Gage Fastener No. 12 (0.105" diameter).		A-116 Class 2
BOLTS AND NUTS FOR TENSION TAKE-UP ASS'Y Hex head cap screws 1/2" diameter x 2", with hex nut, 3/16" hole drilled through stem.	A-307	A-153 Class C
FERRULES FOR TENSION TAKE-UP 9/16" I.D. x 1 3/16" long x 14 gage, with 3/16" notch on each end.	A-569	A-153 Class B-3
BOLTS AND NUTS FOR POST UNIT CONNECTIONS Hex head machine bolt 1/2" diameter x 1", with hex nut.	A-307	A-153 Class C
STAINLESS STEEL STRAPS AND SEALS Straps 0.020" x 0.625" coiled strip No. 1 or 2 Finish Seals 0.020" x 1.25" (single crimp).	A-176 T 409	
POST UNIT SUPPORT BRACKET L-Shaped Support Bracket (1/4" thick) with 7 gage gusset plates. Painted in accordance with Specifications.	A-635	A-153 Class B-2
ANCHOR BOLTS 1/2" diameter x 8" with hex nut & lockwasher	A-307	A-153 Class C

GENERAL NOTES

1. DIMENSIONS OF CUTOUT ON POST UNIT SUPPORT BRACKET GUSSET TO BE AS DIRECTED BY THE ENGINEER.
2. EXPANSION TYPE ANCHOR BOLTS OR EPOXIED IN ANCHOR BOLTS MAY BE USED IN LIEU OF CAST IN PLACE ANCHOR BOLTS IF THEIR PULL-OUT STRENGTH IS ACCEPTABLE TO THE ENGINEER.
3. ROUTING OF FENCING AROUND LIGHT POLES, BRIDGE PIERS, ETC. WHEN MOUNTED ON METAL BEAM GUARD FENCE SHALL BE AS DIRECTED BY THE ENGINEER.
4. POST UNIT SUPPORT BRACKETS SHALL BE GALVANIZED AFTER FABRICATION.
5. TENSION WIRE CROSS BRACING AT END PANELS SHALL CONSIST OF ONE WIRE FROM THE BOTTOM FERRULE OF END POST UNIT TO THE TOP FERRULE OF ADJACENT POST UNIT.

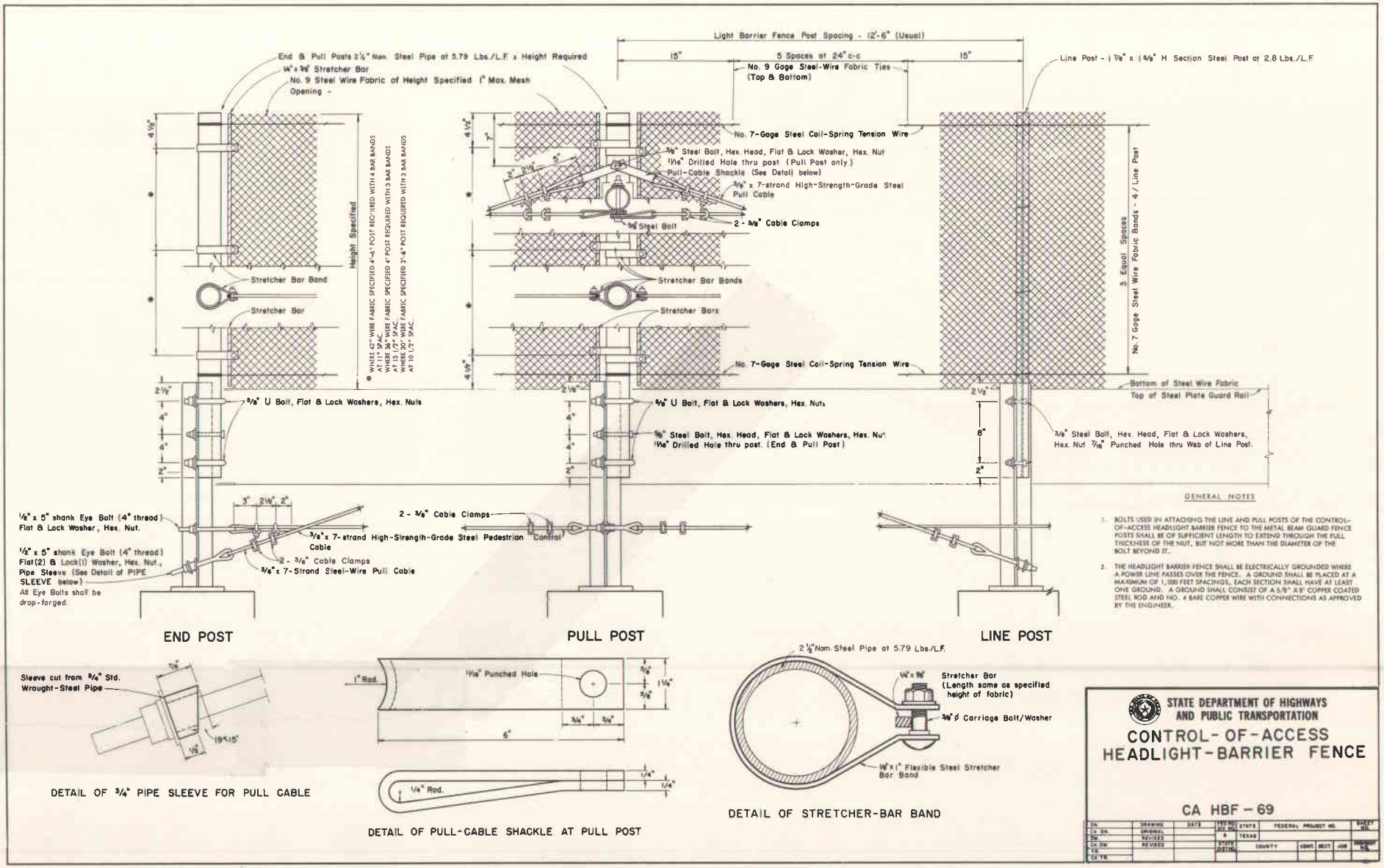
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

EXPANDED METAL MESH HEADLIGHT BARRIER FENCE

EMM HBF - 74

DN	CK	DW	CK	DRAWING	DATE	FED. ROAD DIV. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
				ORIGINAL		6	TEXAS		
				REVISED					
				REVISED		STATE DIST. NO.	COUNTY	CONT. SECT. JOB	HIGHWAY NO.

A-8



GENERAL NOTES

1. BOLTS USED IN ATTACHING THE LINE AND PULL POSTS OF THE CONTROL-OF-ACCESS HEADLIGHT BARRIER FENCE TO THE METAL BEAM GUARD FENCE POSTS SHALL BE OF SUFFICIENT LENGTH TO EXTEND THROUGH THE FULL THICKNESS OF THE NUT, BUT NOT MORE THAN THE DIAMETER OF THE BOLT BEYOND IT.
2. THE HEADLIGHT BARRIER FENCE SHALL BE ELECTRICALLY GROUNDED WHERE A POWER LINE PASSES OVER THE FENCE. A GROUND SHALL BE PLACED AT A MAXIMUM OF 1,000 FEET SPACINGS, EACH SECTION SHALL HAVE AT LEAST ONE GROUND. A GROUND SHALL CONSIST OF A 5/8" X 8' COPPER COATED STEEL ROD AND NO. 4 BARE COPPER WIRE WITH CONNECTIONS AS APPROVED BY THE ENGINEER.

DETAIL OF 3/4" PIPE SLEEVE FOR PULL CABLE

DETAIL OF PULL-CABLE SHACKLE AT PULL POST

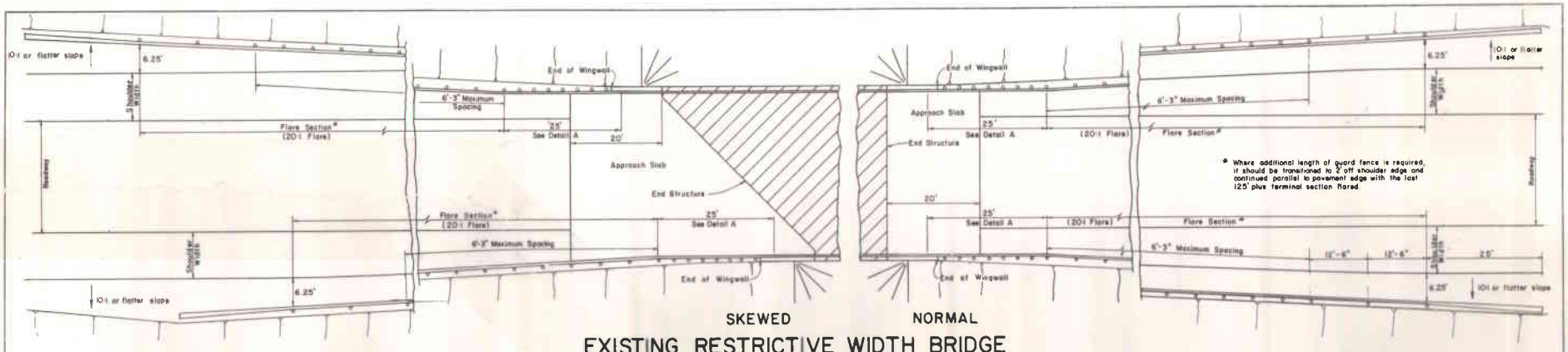
DETAIL OF STRETCHER-BAR BAND

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

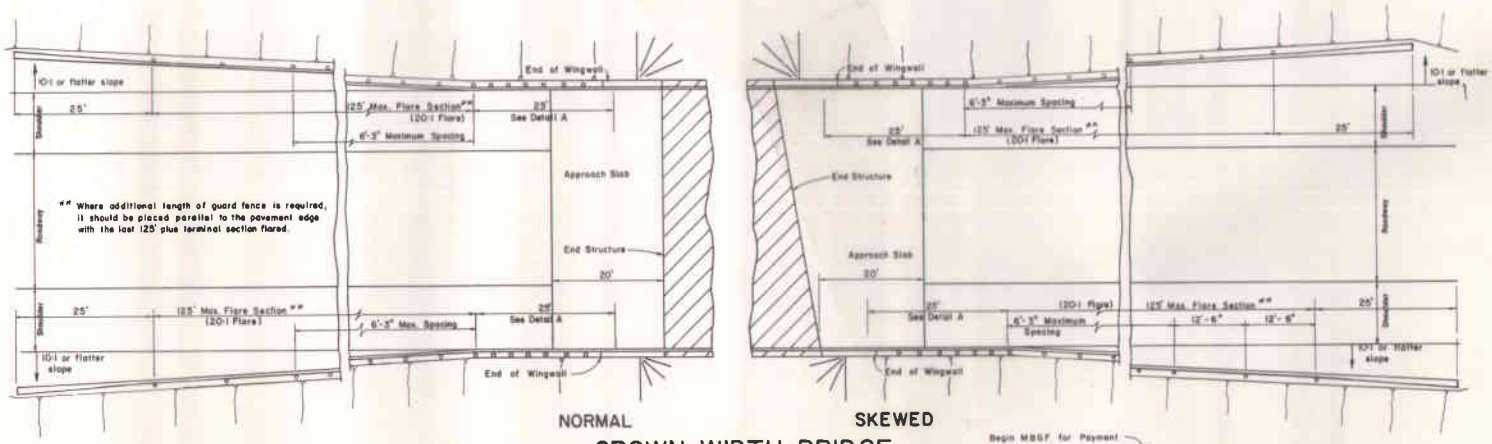
CONTROL-OF-ACCESS HEADLIGHT-BARRIER FENCE

CA HBF - 69

DN	DRAWING	DATE	FED. ROAD DIV. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK. DR.	ORIGINAL					
DW.	REVISED		6	TEXAS		
CK. DW.	REVISED		STATE DISTRICT	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
TR.						
CK TR.						



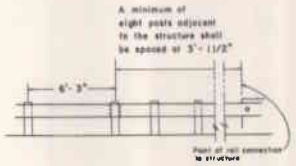
EXISTING RESTRICTIVE WIDTH BRIDGE



CROWN WIDTH BRIDGE

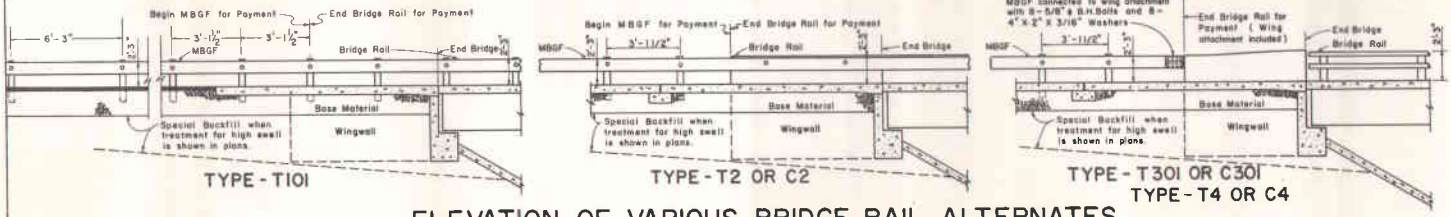
GENERAL NOTES

1. REFER TO LATEST BAS DESIGN DETAIL FOR STRUCTURAL AND JOINT DETAILS OF APPROACH SLAB.
2. FOR METAL BEAM GUARD FENCE DETAILS AND METHOD OF TERMINATION, SEE LATEST METAL BEAM GUARD FENCE DETAIL SHEET.
3. THE FIRST RAIL POST OUTSIDE THE LIMITS OF THE STRUCTURE SHALL BE LOCATED SO THAT THE SPACING BETWEEN THE LAST POINT OF CONNECTION ON THE STRUCTURE AND THIS POST SHALL BE 2'-1 1/2" OR LESS.
4. FOR INFORMATION PERTAINING TO SPECIFIC STRUCTURAL DETAILS REFER TO THE APPROPRIATE STRUCTURAL DETAIL SHEET.
5. POST SPACING WILL BE 6'-3" EXCEPT THAT THE FIRST POST WILL BE 25' FROM THE TERMINAL ANCHOR POST AND THE NEXT TWO POSTS SPACED AT 12'-6" WITH A MINIMUM OF 8 POSTS ADJACENT TO THE STRUCTURE SPACED AT 2'-1 1/2".
6. VARIATIONS IN POST SPACINGS AND/OR THE USE OF SPACER BLOCKS OR SHIMS MAY BE REQUIRED BY THE ENGINEER IN ORDER TO ACCOMMODATE THE REQUIRED RAIL CONNECTION TO STRUCTURES.



POST TREATMENT AT STRUCTURES

DETAIL A



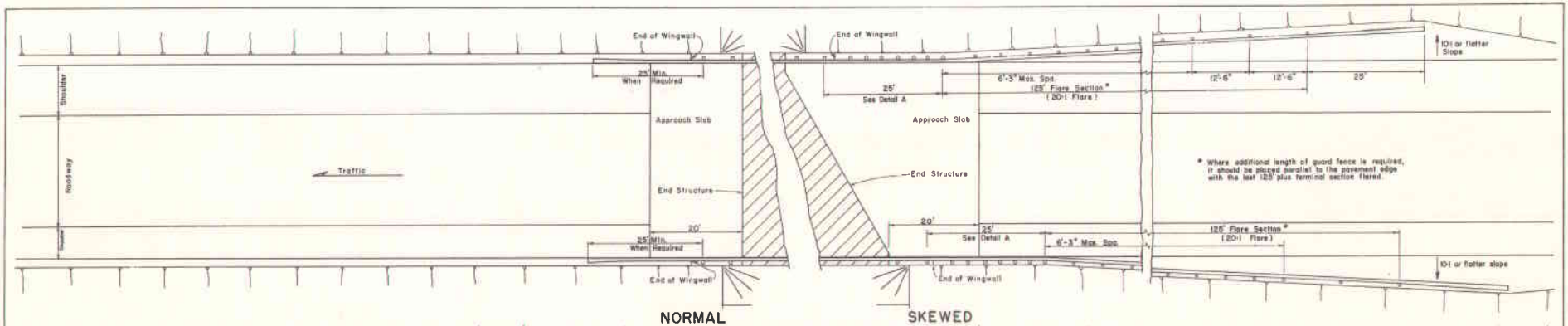
ELEVATION OF VARIOUS BRIDGE RAIL ALTERNATES

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

BRIDGE END DETAILS TWO LANE HIGHWAY

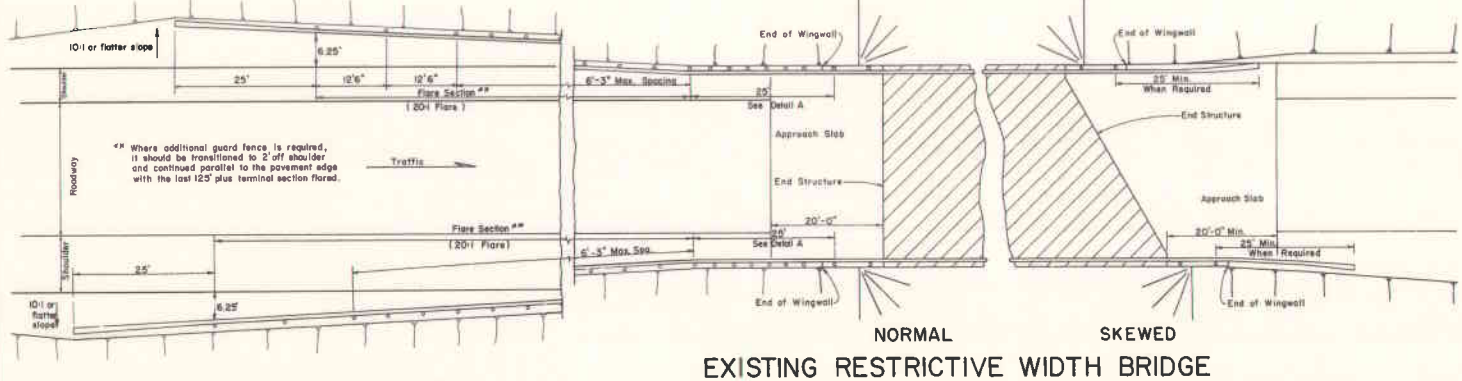
BED-(TH)-75

DN	DRAWN	DATE	FED. ROAD DIV. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK. DN.	ORIGINAL		6	TEXAS		
DW	REVISED					
CK. DW	REVISED		STATE DISTRICT	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
TR						
CK. TR						



NORMAL SKEWED

CROWN WIDTH BRIDGE



NORMAL SKEWED

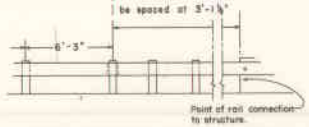
EXISTING RESTRICTIVE WIDTH BRIDGE

GENERAL NOTES

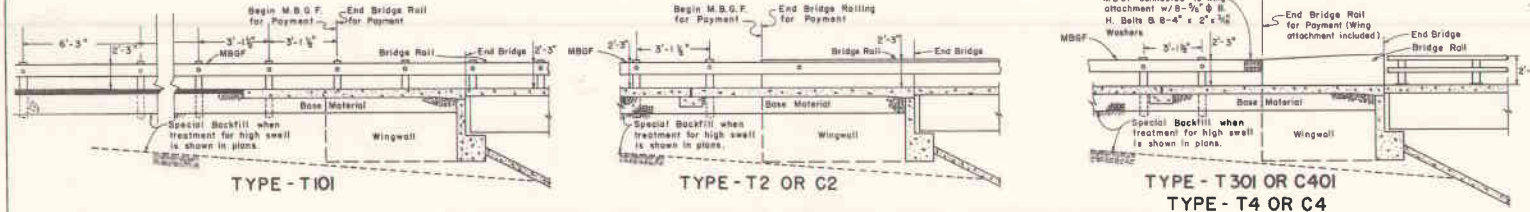
1. REFER TO LATEST BAS DESIGN DETAIL FOR STRUCTURAL AND JOINT DETAILS OF APPROACH SLAB.
2. FOR METAL BEAM GUARD FENCE DETAILS AND METHOD OF TERMINATION, SEE LATEST METAL BEAM GUARD FENCE DETAIL SHEET.
3. THE FIRST RAIL POST OUTSIDE THE LIMITS OF THE STRUCTURE SHALL BE LOCATED SO THAT THE SPACING BETWEEN THE LAST POINT OF CONNECTION ON THE STRUCTURE AND THIS POST SHALL BE 3'-1 1/2" OR LESS.
4. FOR INFORMATION PERTAINING TO SPECIFIC STRUCTURAL DETAILS REFER TO THE APPROPRIATE STRUCTURAL DETAIL SHEET.
5. POST SPACING WILL BE 6'-3" EXCEPT THAT THE FIRST POST WILL BE 25' FROM THE TERMINAL ANCHOR POST AND THE NEXT TWO POSTS SPACED AT 12'-6" WITH A MINIMUM OF 8 POSTS ADJACENT TO THE STRUCTURE SPACED AT 3'-1 1/2".
6. VARIATIONS IN POST SPACINGS AND/OR THE USE OF SPACER BLOCKS OR SHIMS MAY BE REQUIRED BY THE ENGINEER IN ORDER TO ACCOMMODATE THE REQUIRED RAIL CONNECTION TO STRUCTURES.

DETAIL A

A minimum of eight posts adjacent to the structure shall be spaced at 3'-1 1/2"



POST TREATMENT AT STRUCTURES
(Not required at the departure end)



TYPE - T101 TYPE - T2 OR C2 TYPE - T301 OR C401
TYPE - T4 OR C4

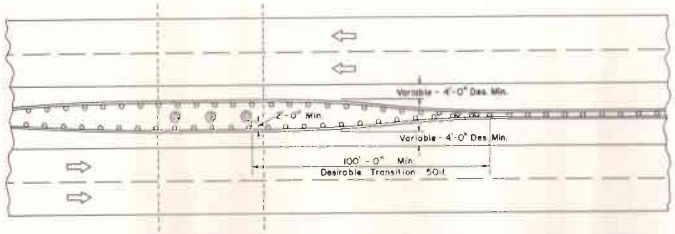
ELEVATION OF VARIOUS BRIDGE RAIL ALTERNATES

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

BRIDGE END DETAILS (DIVIDED HIGHWAY)

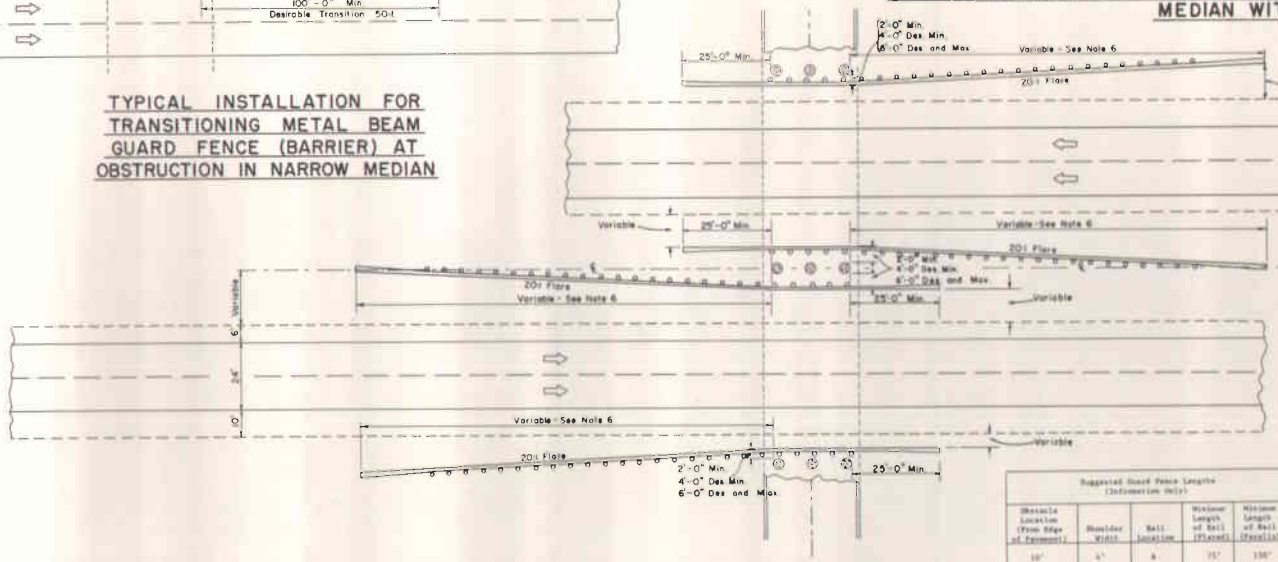
BED - (DH) - 75

DN	CHECKED	DATE	FED. AID PROJ. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK. DW.	ORIGINAL					
DW.	REVISED			TEXAS		
CK. DW.	REVISED		STATE DISTRICT	COUNTY	SHEET NO. / JOB / HIGHWAY NO.	
CK. TR.						

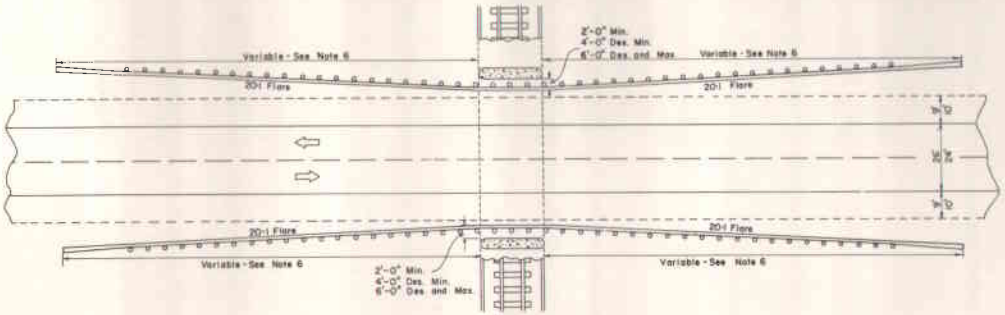


TYPICAL INSTALLATION FOR TRANSITIONING METAL BEAM GUARD FENCE (BARRIER) AT OBSTRUCTION IN NARROW MEDIAN

TYPICAL INSTALLATION FOR METAL BEAM GUARD FENCE AT OBSTRUCTION IN MEDIAN WITH RAIL ELEMENT IN BACK



DIVIDED HIGHWAY

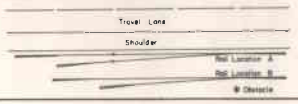


TWO LANE HIGHWAY

Suggested Guard Fence Lengths
(Information Only)

Obstacle Location (From Edge of Pavement)	Shoulder Width	Rail Location	Minimum Length of Rail (Flared)	Minimum Length of Rail (Parallel)
10'	4'	A	75'	150'
13'	4' 6' 8' 10'	A A A A	125' 100' 75' 50'	250' 200' 150' 100'
20'	4' 6' 8' 10' All	A A A A B*	150' 125' 100' 100' 50'	275' 250' 200' 175' 100'
25'	4' 6' 8' 10' All	A A A A B*	175' 150' 150' 125' 50'	300' 275' 250' 225' 75'
30'	4' 6' 8' 10' All	A A A A B*	200' 175' 175' 150' 50'	325' 300' 275' 250' 75'

Legend:
A - 2 feet off shoulder
B - 4 feet from obstacle
* - Slopes 8:1 maximum; 10:1 desired between rail and shoulder



GENERAL NOTES

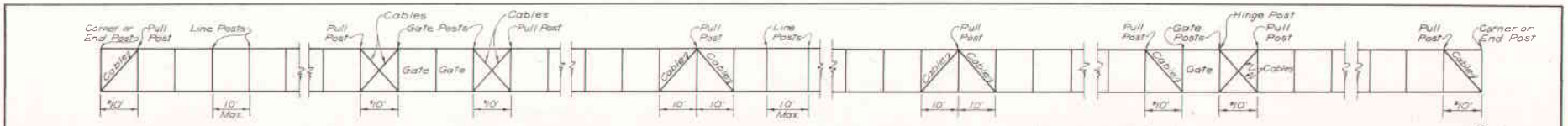
1. FOR METAL BEAM GUARD FENCE DETAILS AND METHOD OF TERMINATION, SEE LATEST METAL BEAM GUARD FENCE DETAILS.
2. WHERE MEDIAN BARRIER GUARD FENCE IS USED IN NARROW MEDIANS, THE TRANSITION AT OBSTRUCTIONS MAY BE PERFORMED ON ONE SIDE WITH THE OTHER SIDE OF THE FENCE BEING CARRIED STRAIGHT, PROVIDED ALL OTHER REQUIREMENTS CAN BE MET.
3. THE DETAILS AND CLEARANCES SHOWN HEREON WILL GOVERN FOR ALL ROADSIDE OBSTRUCTIONS.
4. METAL BEAM GUARD FENCE WITH RAIL ELEMENT IN BACK IS RECOMMENDED FOR USE ON MEDIANS WHERE IT IS NECESSARY THAT THE FENCE INSTALLATION BE 30' OR LESS FROM THE OPPOSING LANE OF TRAFFIC.
5. POST SPACING ON SINGLE RAIL INSTALLATIONS WILL BE 2'-0" EXCEPT THAT ON THE FIRST 50 FEET OF THE APPROACH END THE SPACING WILL BE 12'-6". POST SPACING ON DOUBLE RAIL INSTALLATIONS WHERE USED IN SHORT INCREMENTS WITH ANCHORED ENDS AT OBSTRUCTIONS WILL BE 12'-6" THROUGHOUT. WHERE DOUBLE RAIL IS USED IN LONG SECTIONS AS A MEDIAN BARRIER, THE POST SPACING WILL BE 6'-3".
6. WHEN AN OBSTRUCTION IS LESS THAN 4' BEHIND THE RAIL, A MINIMUM OF 100' OF RAIL WILL BE REQUIRED.
7. THE SLOPE BETWEEN SHOULDER AND GUARD FENCE SHALL BE 10:1 OR FLATTER.

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

ROADSIDE CLEARANCE DETAILS

RCD-75

Ck.	DRAWING	DATE	FED. AID PROJ. NO.	STATE	FEDERAL PROJECT NO.			SHEET NO.
Ck. Dft.	ORIGINAL	7-1-65		TEXAS				
Dft.	REVISED							
Ck. Des.	REVISED		STATE DIST. NO.	COUNTY		CONT.	SECT.	JOB
Des.								
Ck. Des.								



TYPICAL CABLE AND POST ARRANGEMENT DIAGRAM

*Slack Span for Fabric

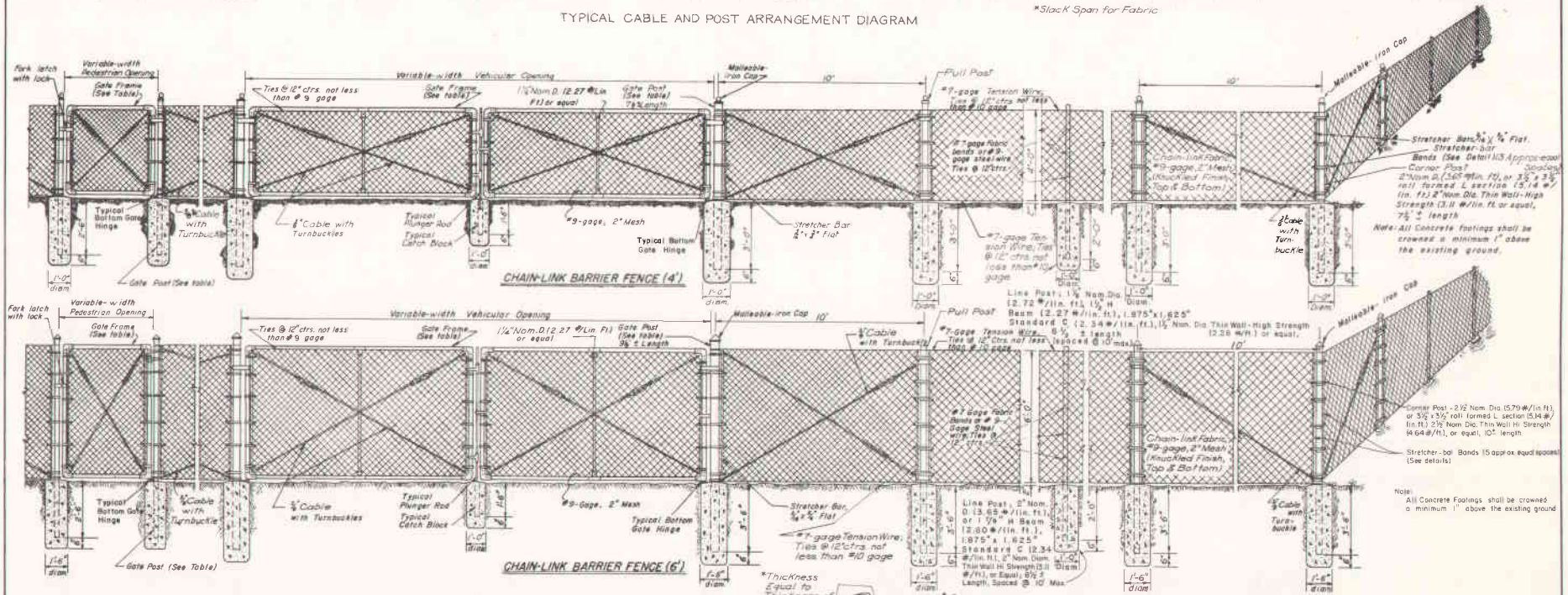


TABLE OF MINIMUM SIZES & WEIGHTS

GATE OPENING TYPE		GATE FRAME		GATE POSTS	
SINGLE, INCLUSIVE	DOUBLE, INCLUSIVE	SIZE	WT/LIN. FT.	SIZE	WT/LIN. FT.
Up to 6'	Up to 12'	1⅝ Nom. O. or Equal	2.72 Lbs.	2½" Nom. O. or equal	5.79 Lbs.
Over 6' to 12'	Over 12' to 26'		2.72 Lbs.	3½" Nom. O. or equal	9.11 Lbs.
Over 12' to 18'	Over 26' to 36'		2.72 Lbs.	6" Nom. O.	18.97 Lbs.
Over 18'	Over 36'		2.72 Lbs.	8" Nom. O.	24.70 Lbs.

GENERAL NOTES

1. TYPICAL INSTALLATION PLAN MAY VARY AS SHOWN ELSEWHERE ON THE PLANS OR AS DIRECTED BY THE ENGINEER. LOCATION OF GATES SHOWN ELSEWHERE ON PLANS.
2. GATE-FRAME MEMBERS SHALL BE BOLTED. AT FRAME CORNERS, TO JOINT FITTINGS WITH FOUR 1/2" BOLTS PER JOINT.
3. ALL CABLE CONNECTIONS ARE TO BE MADE WITH TWO 3/8" CABLE CLAMPS.
4. ALL PULL POSTS AND END POSTS AND THEIR FOUNDATIONS SHALL HAVE THE SAME RESPECTIVE DIMENSIONS AS THOSE SHOWN FOR CORNER POSTS.
5. ALL PULL POSTS SHALL BE FURNISHED WITH TWO STRETCHER BARS.
6. ONE END OF EACH TURNBUCKLE MAY BE ATTACHED DIRECTLY TO FITTINGS WITH A CLEVIS.

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

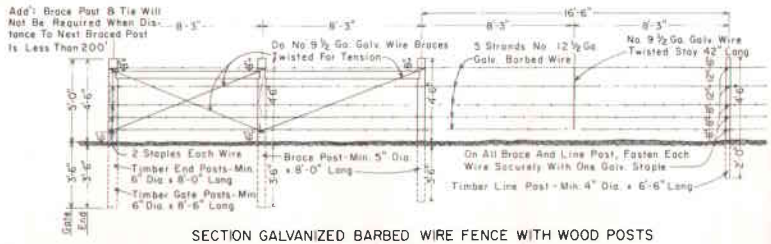
CHAIN-LINK BARRIER FENCE

4 AND 6 FOOT HEIGHT

CLF-80

DN:	DRAWING	DATE	FED. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK. DN:	ORIGINAL		80 NO.			
DW:	REVISED		6	TEXAS		
CK. DW:	REVISED		TYPE	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
TR:			DISTRICT			
CK. TR:						

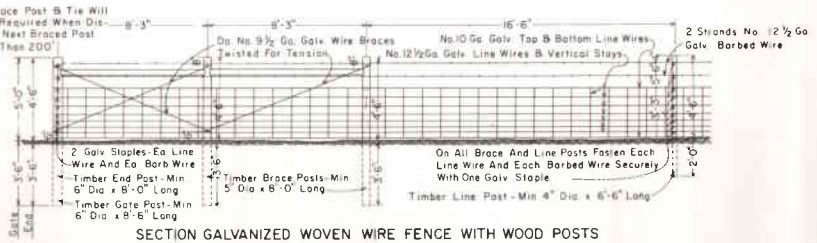
A-13



SECTION GALVANIZED BARBED WIRE FENCE WITH WOOD POSTS

Bracing Detail Used At Ends And Gates

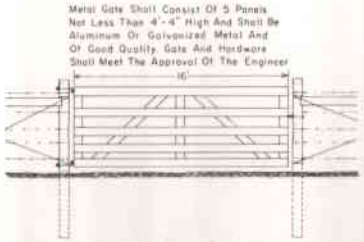
TYPE "A" FENCE



SECTION GALVANIZED WOVEN WIRE FENCE WITH WOOD POSTS

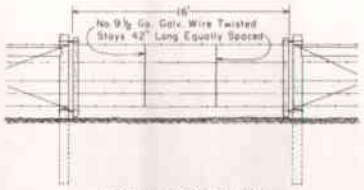
Bracing Detail Used At Ends And Gates

TYPE "B" FENCE



DETAIL TYPE 1 GATE

DETAIL TYPE 2 GATE



DETAIL TYPE 3 GATE

GENERAL NOTES

ANY HIGH POINT WHICH INTERFERES WITH THE PLACING OF WIRE MESH SHALL BE EXCAVATED TO PROVIDE 2" CLEARANCE.

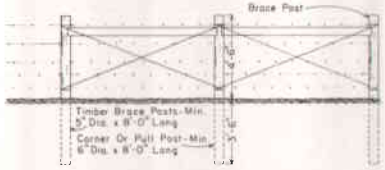
LATCHES FOR TYPE 1 AND TYPE 2 GATES SHALL BE GOOD COMMERCIAL QUALITY AND DESIGN LATCHES OF THE SPRING, FORK OR CHAIN TYPE. ALL LATCHES SHALL BE SUITABLE FOR THE GATE AND SHALL BE APPROVED BY THE ENGINEER.

HINGES FOR TYPE 2 GATES SHALL BE A COMMERCIAL DESIGN APPROVED BY THE ENGINEER SUITABLE FOR POST AND GATE.

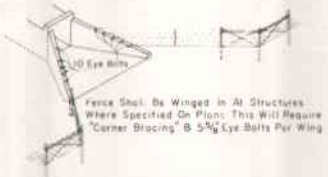
CONCRETE SHALL BE OF THE DESIGN AND CONSISTENCY APPROVED BY THE ENGINEER AND SHALL CONTAIN NOT LESS THAN 4 SACKS OF CEMENT PER CUBIC YARD.

IF ROCK IS ENCOUNTERED AT A DEPTH LESS THAN THE EMBEDDED DEPTH REQUIRED, A 15 INCH OR LARGER DIAMETER HOLE SHALL BE DRILLED FOR THE POST AND THE POST SHALL BE SET IN CONCRETE. IF ROCK IS ENCOUNTERED AT A DEPTH OF 1'-6" OR MORE BELOW THE GROUND SURFACE, THE HOLE SHALL BE DRILLED TO THE REQUIRED DEPTH. IF ROCK IS ENCOUNTERED AT A DEPTH LESS THAN 1'-6" BELOW THE GROUND SURFACE, THE HOLES SHALL BE DRILLED A MINIMUM OF 3" INTO THE ROCK OR TO THE REQUIRED DEPTH WHICHEVER IS THE LESSER DEPTH.

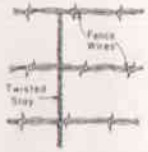
THE LOCATION OF GATES AND CORNER POSTS WILL BE AS INDICATED ELSEWHERE ON THESE PLANS.



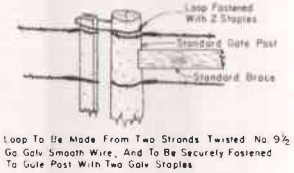
CORNER OR PULL POST ASSEMBLY



DETAIL OF FENCE TREATMENT AT STRUCTURES

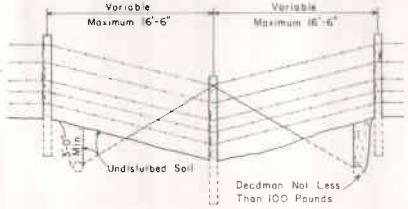


DETAIL OF STAY

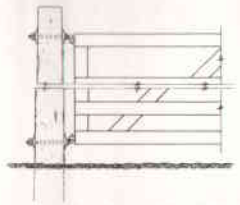


Loop To Be Made From Two Strands Twisted No. 9½ Ga. Galv. Smooth Wire, And To Be Securely Fastened To Gate Post With Two Galv. Staples

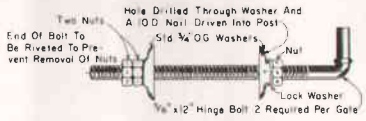
DETAIL FASTENER TYPE 3 GATE



DETAIL OF FENCE SAG



DETAIL SHOWING INSTALLATION OF HINGES OF TYPE 1&2 GATE



DETAIL OF GATE HINGE BOLT ASSEMBLY

DETAIL OF EYE BOLT

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

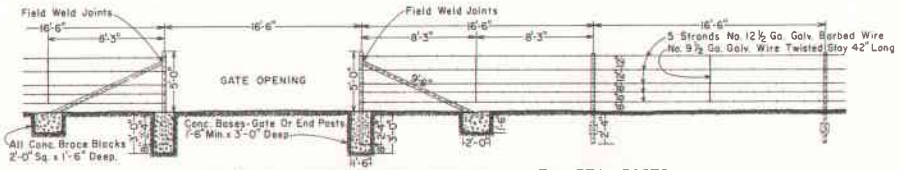
BARBED WIRE FENCE AND WOVEN WIRE FENCE

TIMBER POSTS

WF-69(1)

DN	DRAWING	DATE	FED. AID PROJ. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK. DN.	ORIGINAL					
DN.	REVISED			TEXAS		
CK. DW.	REVISED					
TR.			STATE (DISTRICT)	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
CK. TR.						

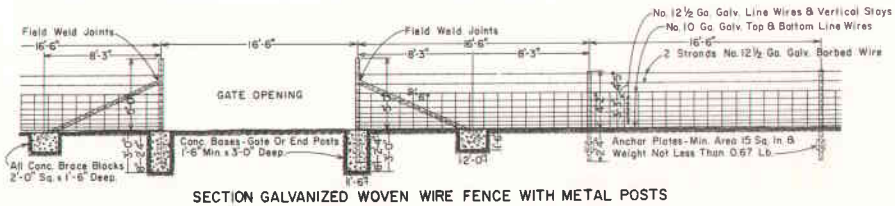
A-14



SECTION GALVANIZED BARBED WIRE FENCE WITH METAL POSTS

Bracing Detail Used At Ends And Gates

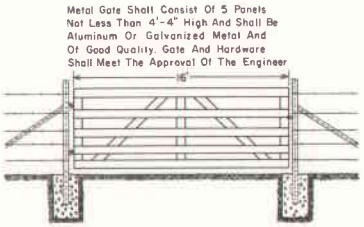
TYPE "C" FENCE



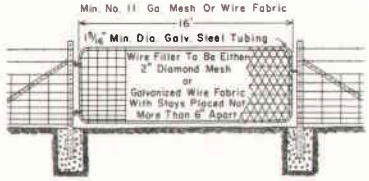
SECTION GALVANIZED WOVEN WIRE FENCE WITH METAL POSTS

Bracing Detail Used At Ends And Gates

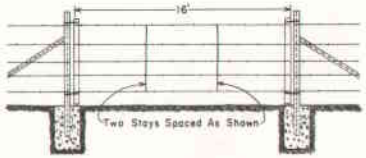
TYPE "D" FENCE



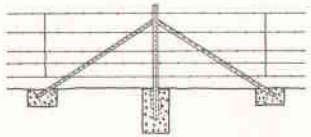
DETAIL TYPE 1 GATE



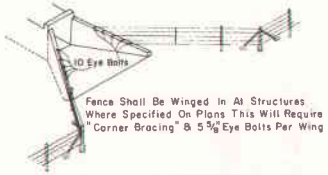
DETAIL TYPE 2 GATE



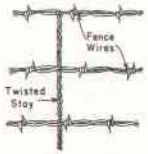
DETAIL TYPE 3 GATE



CORNER OR PULL POST ASSEMBLY



DETAIL OF FENCE TREATMENT AT STRUCTURES



DETAIL OF STAY

GENERAL NOTES

ANY HIGH POINT WHICH INTERFERES WITH THE PLACING OF WIRE MESH SHALL BE EXCAVATED TO PROVIDE 3" CLEARANCE.

LATCHES FOR TYPE 1 AND TYPE 2 GATES SHALL BE A GOOD COMMERCIAL QUALITY AND DESIGN LATCH OF THE SPRING, PORK OR CHAIN TYPE. ALL LATCHES SHALL BE SUITABLE TO THE GATE AND SHALL BE APPROVED BY THE ENGINEER.

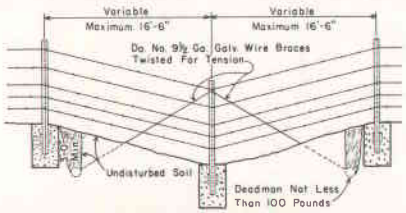
CONCRETE SHALL BE OF THE DESIGN AND CONSISTENCY APPROVED BY THE ENGINEER AND SHALL CONTAIN NOT LESS THAN 4 SACKS OF CEMENT PER CUBIC YARD.

HINGES FOR TYPE 2 GATES SHALL BE A COMMERCIAL DESIGN APPROVED BY THE ENGI ..ER SUITABLE FOR POST AND GATE.

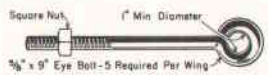
ANCHOR PLATES SHALL BE OF A DESIGN AND THICKNESS SUFFICIENT TO PREVENT TURNING OF THE POST IN FIRM SOIL. METAL END, CORNER AND PULL POST SHALL BE A MINIMUM OF 2" INSIDE DIAMETER PIPE MINIMUM (5.65 LBS./ LIN. FT.) WITH MINIMUM 1 1/4" INSIDE DIAMETER PIPE BRACE MINIMUM (2.27 LBS./ LIN. FT.), MINIMUM 2 1/2 " x 2 1/2" x 1/4" ANGLE (4.1 LBS./LIN. FT.) WITH MINIMUM 2" x 2" x 1/4" ANGLE BRACE (3.19 LBS./LIN. FT.) OR OTHER SECTION APPROVED BY THE ENGINEER. FASTENERS FOR SECURING BARBED WIRE OR WIRE MESH TO METAL POSTS SHALL BE A MINIMUM OF 11 GAGE GALVANIZED STEEL WIRE. TUBULAR POSTS SHALL BE FITTED WITH WATER TIGHT MALLEABLE IRON CAPS.

METAL LINE POST SHALL BE NOT LESS THAN 6 FT. 6 IN. IN LENGTH AND SHALL WEIGH NOT LESS THAN 1.33 LBS. PER LIN. FT.

THE LOCATION OF GATES AND CORNER POSTS WILL BE AS INDICATED ELSEWHERE IN THESE PLANS.



DETAIL OF FENCE SAG



DETAIL OF EYE BOLT

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

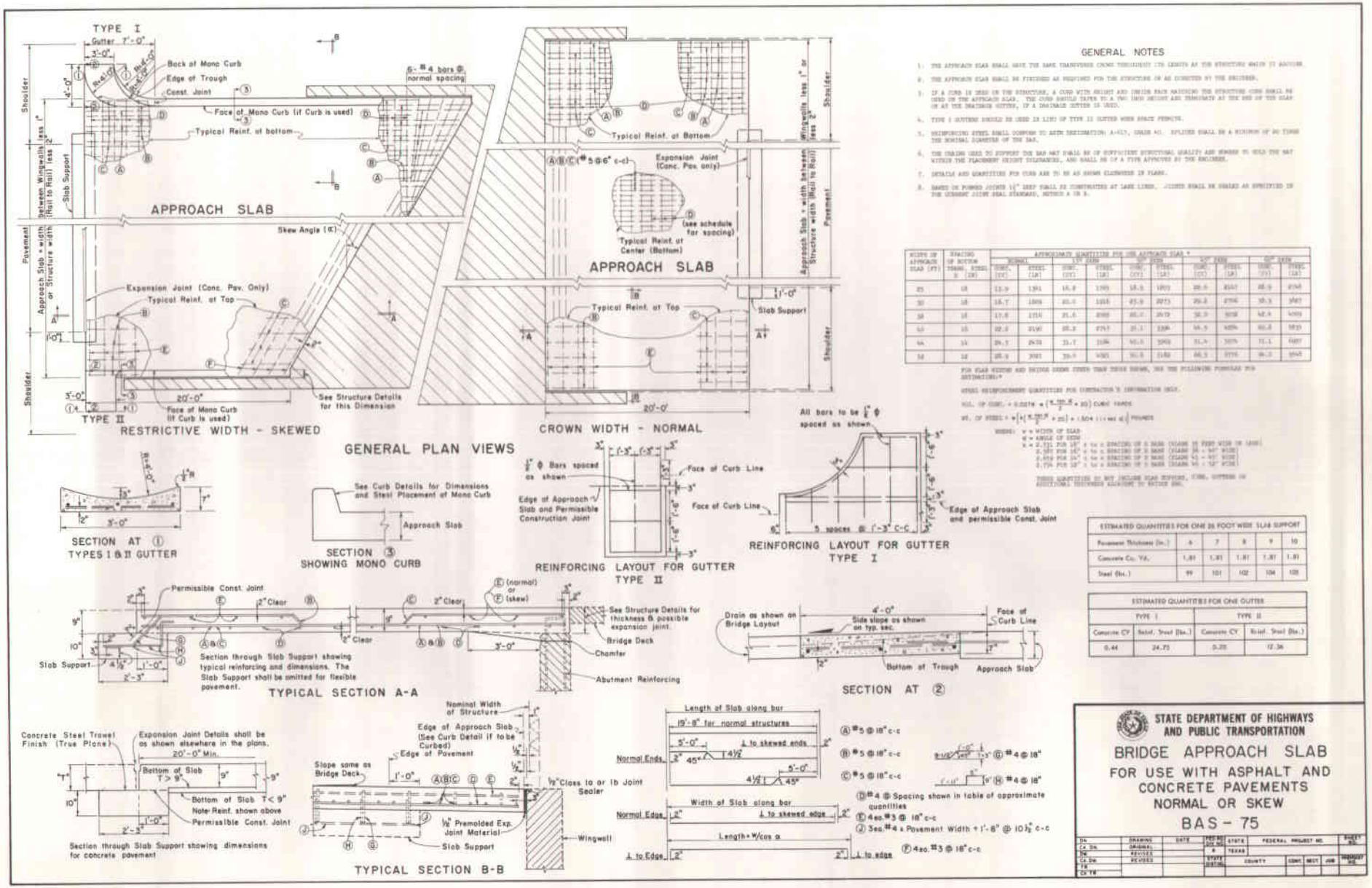
BARBED WIRE FENCE AND WOVEN WIRE FENCE

STEEL POSTS

WF - 69(2)

CO.	DRAWING	DATE	FED. AID PROJ. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CO. ENG.	ORIGINAL					
DIST.	REVISED			TEXAS		
CO. DIR.	REVISED			STATE DIST. NO.	COUNTY	CONT. SECT. JOB HIGHWAY NO.
TR.						
CO. TR.						

A-15



GENERAL NOTES

1. THE APPROACH SLAB SHALL HAVE THE SAME CROSSWISE CROWN THROUGHOUT ITS LENGTH AS THE STRUCTURE WHICH IT ADJOINS.
2. THE APPROACH SLAB SHALL BE FINISHED AS REQUIRED FOR THE STRUCTURE OR AS DIRECTED BY THE ENGINEER.
3. IF A CURB IS USED ON THE STRUCTURE, A CURB WITH HEIGHT AND CROSS PACE MATCHING THE STRUCTURE CURB SHALL BE USED ON THE APPROACH SLAB. THE CURB SHOULD TAPER TO A TWO INCH HEIGHT AND TERMINATE AT THE END OF THE SLAB OR AT THE DRAINAGE GUTTER, IF A DRAINAGE GUTTER IS USED.
4. TYPE I GUTTERS SHOULD BE USED IN LIEU OF TYPE II GUTTER WHEN SPACE PERMITS.
5. REINFORCING STEEL SHALL CONFORM TO ASTM DESIGNATION: A-615, GRADE 40. BENDS SHALL BE A MINIMUM OF SIX TIMES THE NOMINAL DIAMETER OF THE BAR.
6. THE CHAIRS USED TO SUPPORT THE BAR MAT SHALL BE OF SUFFICIENT STRUCTURAL QUALITY AND NUMBER TO HOLD THE MAT WITHIN THE PLACEMENT HEIGHT TOLERANCES, AND SHALL BE OF A TYPE APPROVED BY THE ENGINEER.
7. DETAILS AND QUANTITIES FOR CURB ARE TO BE AS SHOWN ELSEWHERE IN PLANS.
8. SAWED OR FORMED JOINTS 1½" DEEP SHALL BE CONSTRUCTED AT SAME LINES. JOINTS SHALL BE SEALED AS SPECIFIED IN THE CURRENT JOINT SEAL STANDARDS, METHOD A OR B.

WIDTH OF APPROACH SLAB (FT)	SPACING OF BOTTOM TRANS. STEEL S (IN)	APPROXIMATE QUANTITIES FOR ONE APPROACH SLAB *									
		NORMAL		15° SKEW		30° SKEW		45° SKEW		60° SKEW	
		CONC. (CY)	STEEL (LB)	CONC. (CY)	STEEL (LB)	CONC. (CY)	STEEL (LB)	CONC. (CY)	STEEL (LB)	CONC. (CY)	STEEL (LB)
25	18	13.9	1391	14.8	1395	15.5	1393	16.0	1357	16.5	1265
30	18	16.7	1606	17.7	1615	18.6	1613	19.2	1566	19.8	1467
38	18	21.2	1924	22.5	1940	23.6	1939	24.4	1888	25.1	1777
40	18	22.3	2030	23.7	2048	24.9	2048	25.7	1995	26.5	1879
44	18	24.5	2242	26.1	2264	27.4	2264	28.3	2207	29.2	2080
48	18	26.8	2461	28.5	2485	29.9	2485	30.9	2423	31.8	2284

FOR SLAB WIDTHS AND SKEWS SOME WHAT THESE GIVEN, SEE THE FOLLOWING FORMULAS FOR ESTIMATES:*

STEEL REINFORCEMENT QUANTITIES FOR CONTRACTOR'S INFORMATION ONLY.

VOL. OF CONC. = $0.0278 \times \left(\frac{T \cdot 75}{2} + 20\right) \times W$ CUBIC YARDS

WT. OF STEEL = $W\left[\left(\frac{T \cdot 75}{2} + 20\right) + 1.504 \left(\frac{T \cdot 75}{2}\right) \tan \alpha\right]$ POUNDS

WHERE: W = WIDTH OF SLAB
α = ANGLE OF SKEW
T = 2.731 FOR 18" S ⊥ to α SPACING OF 3 BAR (SLABS 25 FEET WIDE OR LESS)
2.587 FOR 18" S ⊥ to α SPACING OF 3 BAR (SLABS 26 > 40' WIDE)
2.519 FOR 24" S ⊥ to α SPACING OF 3 BAR (SLABS 40 > 48' WIDE)
2.774 FOR 18" S ⊥ to α SPACING OF 4 BAR (SLABS 40 > 48' WIDE)

THESE QUANTITIES DO NOT INCLUDE SLAB SUPPORT, CURB, GUTTERS OR ADDITIONAL THICKNESS ADJACENT TO BRIDGE END.

ESTIMATED QUANTITIES FOR ONE 26 FOOT WIDE SLAB SUPPORT					
Pavement Thickness (In.)	6	7	8	9	10
Concrete Cu. Yd.	1.80	1.81	1.81	1.81	1.81
Steel (lbs.)	99	101	102	104	105

ESTIMATED QUANTITIES FOR ONE GUTTER			
TYPE I		TYPE II	
Concrete CY	Reinf. Steel (lbs.)	Concrete CY	Reinf. Steel (lbs.)
0.44	24.75	0.28	12.36

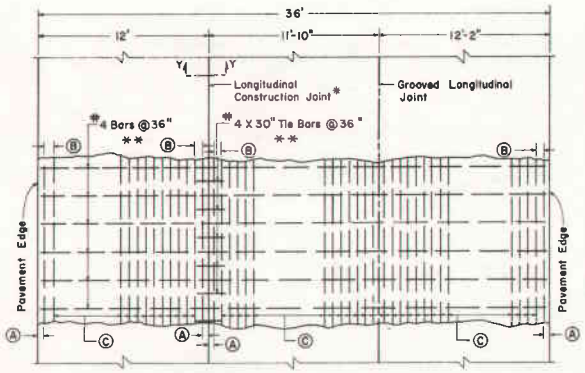
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

BRIDGE APPROACH SLAB

FOR USE WITH ASPHALT AND CONCRETE PAVEMENTS NORMAL OR SKEW

BAS - 75

DN	DRAWING	DATE	FED RD DIV NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
Ck. DN.	ORIGINAL		6	TEXAS		
DW	REVISED					
Ck. DW	REVISED		STATE DIST. NO.	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
FB						
CK FB						



THREE LANE PAVEMENT PLAN
(12ft. and 24ft. Placement)

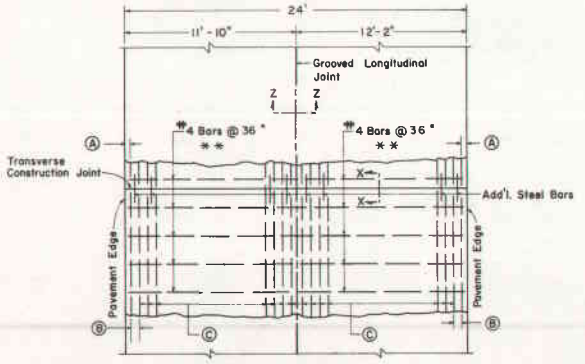
* WITH THE APPROVAL OF THE ENGINEER, THE CONTRACTOR MAY PLACE THE PAVEMENT THE FULL ROADWAY WIDTH AS ONE PLACEMENT. IF SO PLACED, THE LONGITUDINAL CONSTRUCTION JOINT SHOWN SHALL BE REPLACED BY THE GROOVED LONGITUDINAL JOINT.

Per Cent Long Steel	Pavement Thickness "T" in.	Bar Size	24 ft. Placement Width: Spacing c-c A in	B in	C in	No. of Bars	Steel f/sy ①	12 ft. Placement Width: Spacing c-c A in	B in	C in	No. of Bars	Steel f/sy ①	Add'l Steel @ Trans. Const. Jt.: Size	② No. per 24' place. width	③ No. per 12' place. width	Weight f/ft. based on 12' placement
0.5	10	No.6	3	5	8.5	35	21.72	3	5.25	8.5	18	22.28	3/4"ø x36"	18	9	3.38
	9	No.5	3	4.5	6.5	45	19.60	3	4	6.5	23	20.00	5/8"ø x36"	22	11	2.87
	8	No.5	3	6	7.5	39	17.26	3	5.25	7.5	20	17.65	5/8"ø x36"	20	10	2.61
	7	No.5	3	5	8.5	35	15.69	4	8.5	8.5	17	15.30	5/8"ø x36"	18	9	2.35
	6	No.4	3	4.5	7	42	12.53	3	6	7	21	12.53	1/2"ø x36"	20	11	1.84
0.6	10	No.6	3	7	7.25	40	24.53	3	7.25	7.25	20	24.53	3/4"ø x36"	20	10	3.76
	9	No.6	3	5	8	37	22.84	3	5	8	19	23.41	3/4"ø x36"	19	10	3.76
	8	No.5	3	6.25	6.25	46	20.00	3	3.5	6.25	24	20.78	5/8"ø x36"	23	11	2.61
	7	No.5	3	7	7.25	40	17.65	3	7.25	7.25	20	17.65	5/8"ø x36"	20	10	2.87
	6	No.5	3	5	8.5	35	15.69	3	5.25	8.5	18	16.08	5/8"ø x36"	18	9	2.38

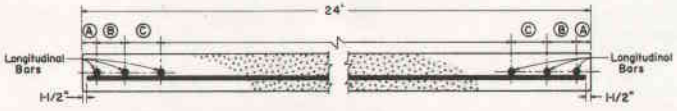
** AT LOCATIONS WHERE THE SLAB WIDTHS ARE GREATER THAN 40' THE TRANSVERSE REINFORCING BARS AND TIE BARS SHALL BE NO. 5 BARS AND THE TIE BARS SHALL BE 36" LONG.

GENERAL NOTES

1. NO EXPANSION JOINTS WILL BE USED EXCEPT AT STRUCTURE ENDS OR FIXED OBJECTS AS SHOWN ELSEWHERE IN THE PLANS.
2. FOR FURTHER INFORMATION REGARDING THE PLACEMENT OF CONCRETE AND REINFORCEMENT REFER TO THE GOVERNING SPECIFICATIONS FOR "CONCRETE PAVEMENT".
3. DETAILS AS TO PAVEMENT WIDTH, PAVEMENT THICKNESS AND THE CROWN CROSS-SLOPE SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
4. WITHIN ANY AREA BOUNDED BY TWO FEET OF PAVEMENT LENGTH MEASURED PARALLEL TO THE CENTERLINE AND TWELVE FEET OF PAVEMENT WIDTH MEASURED PERPENDICULAR TO THE PAVEMENT CENTERLINE, NOT OVER 33% OF THE REGULAR LONGITUDINAL STEEL SHALL BE SPLICED.
5. LONGITUDINAL AND TRANSVERSE BARS SHALL BE STEEL CONFORMING TO ASTM A-615 OR ASTM A-616 (GRADE 60) AS NOTED IN THE SPECIFICATIONS.
6. SPLICES SHALL BE A MINIMUM OF 24 TIMES THE NOMINAL DIAMETER OF THE BAR.
7. BARS OF ASTM DESIGNATIONS: A-615 OR A-616, GRADE 60 STEEL SHALL NOT BE BENT. IF THE CONTRACTOR ELECTS TO BEND THE TIEBARS, THEY SHALL BE STEEL CONFORMING TO ASTM DESIGNATION: A-615, GRADE 40, AND SPACED AT 24" C-C.
8. AT TRANSVERSE CONSTRUCTION JOINTS THE REGULAR LONGITUDINAL BARS SHALL EXTEND BEYOND THE JOINT SO THAT THE BAR SPLICES FOR THE REGULAR LONGITUDINAL BARS SHALL BE A MINIMUM OF FOUR FEET FROM THE CONSTRUCTION JOINT. AT LONGITUDINAL CONSTRUCTION JOINTS IF THE CONTRACTOR ELECTS TO CONTINUE THE REGULAR TRANSVERSE STEEL THROUGH THE JOINT- THE #4 ØTIEBARS SHOWN HEREON MAY BE DELETED. VIBRATION WITH HAND MANIPULATED MECHANICAL VIBRATORS WILL BE REQUIRED ADJACENT TO ALL TRANSVERSE CONSTRUCTION JOINTS..
9. WITH THE APPROVAL OF THE ENGINEER, MULTIPLE PIECE TIEBARS (THREADED COUPLING OR OTHER ADEQUATE DEVICE) MAY BE USED TO FACILITATE CONSTRUCTION PROVIDED THE SYSTEM DEVELOPS A FORCE EQUAL TO 1 1/2 TIMES THE MINIMUM YIELD FORCE OF THE TIEBAR SHOWN. THE SPACINGS FOR THE SYSTEM SHALL BE LESS THAN OR EQUAL TO THE SPACING ALLOWED FOR BARS OF SIMILAR YIELD STRENGTH.
10. THE CHAIRS USED TO SUPPORT THE BAR MAT SHALL BE OF SUFFICIENT STRUCTURAL QUALITY AND NUMBER TO HOLD THE MAT WITHIN THE PLACEMENT HEIGHT TOLERANCES, AND SHALL BE OF A TYPE APPROVED BY THE ENGINEER.
11. IN THE NORMAL 36" PLACEMENT FOR THE TRANSVERSE BARS, CHAIRS SHALL BE PLACED UNDER EVERY TRANSVERSE BAR. THE TRANSVERSE SPACING SHALL BE A 48" MAXIMUM. PLACEMENT MAY BE STAGGERED SO THAT CHAIRS IN ALTERNATE ROWS ARE CENTERED BETWEEN THE CHAIRS IN ADJACENT ROWS.
12. JOINT GROOVE AND SEAL DETAILS SHALL BE AS SHOWN ELSEWHERE IN THE PLANS
13. LONGITUDINAL AND TRANSVERSE STEEL SPACING SHALL NOT VARY MORE THAN ONE-TWELFTH OF THE SPACING SHOWN HEREON.
14. WHEN MACHINE PLACING OF STEEL REINFORCEMENT IS USED, THE USE OF CHAIRS SHALL NOT BE REQUIRED, AND THE TRANSVERSE STEEL MAY BE PLACED EITHER ABOVE OR BELOW THE LONGITUDINAL STEEL.

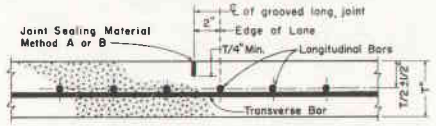


TWO LANE PAVEMENT PLAN
(24ft. Placement) *

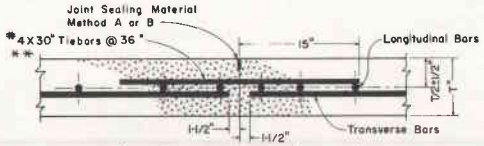


TYPICAL SECTION
(24ft. Placement)

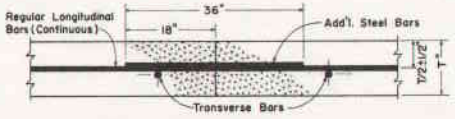
*LANE WIDTHS ARE FOR ILLUSTRATIVE PURPOSES ONLY AND SHOULD NOT BE USED IF IN CONFLICT WITH TYPICAL CROSS SECTIONS SHOWN ELSEWHERE IN THE PLANS.



GROOVED LONGITUDINAL JOINT
Section Z-Z



LONGITUDINAL CONSTRUCTION JOINT
Section Y-Y



TRANSVERSE CONSTRUCTION JOINT
Section X-X

NOTE: THE SPACINGS (B) SHOWN IN THE ABOVE PLACEMENT TABLE ARE THE MAXIMUM ALLOWABLE SPACINGS. WHERE THE PROPOSED PLACEMENT WIDTHS VARY FROM THE BASIC DESIGN WIDTH SHOWN, THE SPACING (B) AND THE ADJACENT SPACING (C) SHALL BE ADJUSTED TO ACCOMMODATE A REINFORCEMENT ARRANGEMENT EQUAL TO OR SLIGHTLY HEAVIER THAN THAT SHOWN AS DIRECTED BY THE ENGINEER.

① INCLUDES BOTH REGULAR LONGITUDINAL AND TRANSVERSE BARS BASED UPON 1 FOOT PAVEMENT LENGTHS FOR THE WIDTH INDICATED. ALL TRANSVERSE STEEL IS #4 BARS AT 36" CENTERS. **

② THIS SHALL BE THE MINIMUM NUMBER OF ADDITIONAL STEEL BARS TO BE PLACED PER LANE. THE SPACING OF THE ADDITIONAL STEEL BARS SHALL BE VARIED AS DIRECTED IN ORDER TO PROVIDE A MINIMUM CLEARANCE OF 1-3/4" FROM EACH REGULAR LONGITUDINAL REINFORCING BAR.

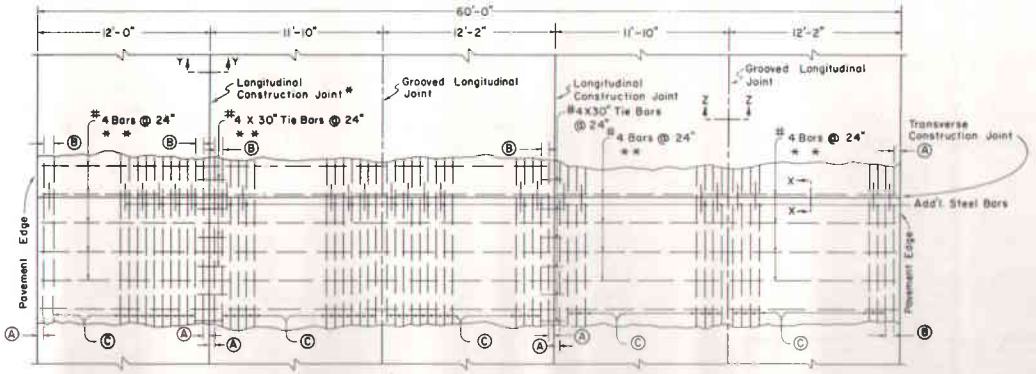
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

CONCRETE PAVEMENT DETAILS CONTINUOUSLY REINFORCED STEEL BARS

CPCR (8)-78 (1)

FILE:	DRAWING: ORIGINAL	DATE: 2-1-77	FED. ROAD DIV. NO. 6	STATE: TEXAS	FEDERAL PROJECT NO.		SHEET NO.
CK. DW.	REVISED		STATE DIST. NO.	COUNTY	CONT.	SECT.	JOB
CK. TR.	REVISED						HIGHWAY NO.

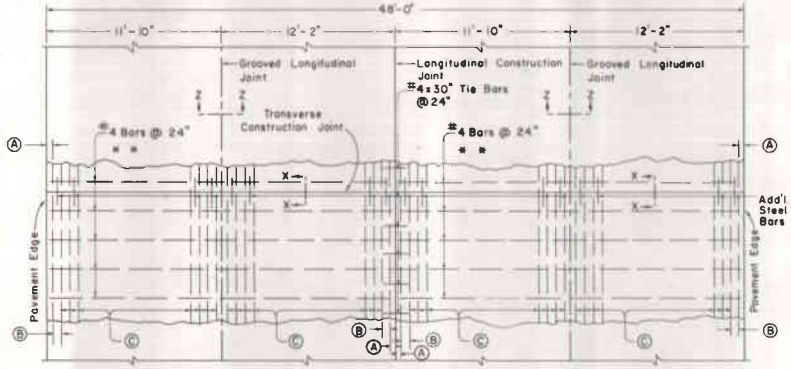
A-17



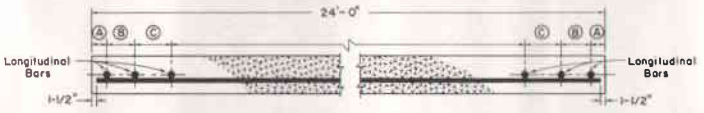
FIVE LANE PAVEMENT PLAN
(12 ft. and 24 ft. Placement)

* WITH THE APPROVAL OF THE ENGINEER, THE CONTRACTOR MAY PLACE THE PAVEMENT THE FULL ROADWAY WIDTH AS ONE PLACEMENT. IF SO PLACED, THE LONGITUDINAL CONSTRUCTION JOINT SHOWN SHALL BE REPLACED BY THE GROOVED LONGITUDINAL JOINT.

** AT LOCATIONS WHERE THE SLAB WIDTHS ARE GREATER THAN 60' THE TRANVERSE REINFORCING BARS AND TIE BARS SHALL BE NO. 5 BARS AND THE TIE BARS SHALL BE 36" LONG.

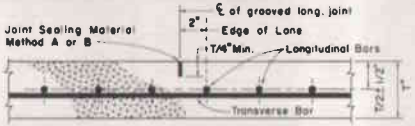


FOUR LANE PAVEMENT PLAN
(24 ft. Placement)

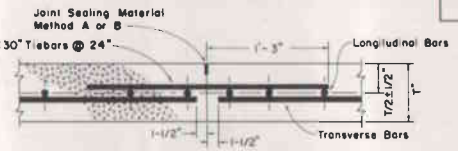


TYPICAL SECTION
(24 ft. Placement)

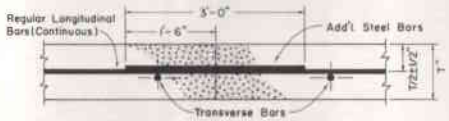
* LANE WIDTHS ARE FOR ILLUSTRATIVE PURPOSES ONLY AND SHOULD NOT BE USED IF IN CONFLICT WITH TYPICAL CROSS SECTIONS SHOWN ELSEWHERE IN THE PLANS.



GROOVED LONGITUDINAL JOINT
Section Z – Z



LONGITUDINAL CONSTRUCTION JOINT
Section Y–Y



TRANSVERSE CONSTRUCTION JOINT
Section X–X

GENERAL NOTES

1. NO EXPANSION JOINTS WILL BE USED EXCEPT AT STRUCTURE ENDS OR FIXED OBJECTS AS SHOWN ELSEWHERE IN THE PLANS.
2. FOR FURTHER INFORMATION REGARDING THE PLACEMENT OF CONCRETE AND REINFORCEMENT, REFER TO THE GOVERNING SPECIFICATIONS FOR "CONCRETE PAVEMENT".
3. DETAILS AS TO PAVEMENT WIDTH, PAVEMENT THICKNESS AND THE CROWN CROSS-SLOPE SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
4. WITHIN ANY AREA BOUNDED BY TWO FEET OF PAVEMENT LENGTH MEASURED PARALLEL TO THE CENTERLINE AND TWELVE FEET OF PAVEMENT WIDTH MEASURED PERPENDICULAR TO THE PAVEMENT CENTERLINE, NOT OVER 33⅓ OF THE REGULAR LONGITUDINAL STEEL SHALL BE SPLICED.
5. LONGITUDINAL AND TRANSVERSE BARS SHALL BE STEEL CONFORMING TO ASTM A-615 OR ASTM A-616 (GRADE 60) AS NOTED IN THE SPECIFICATIONS.
6. SPLICES SHALL BE A MINIMUM OF 24 TIMES THE NOMINAL DIAMETER OF THE BAR.
7. BARS OF ASTM DESIGNATIONS; A-615 OR A-616, GRADE 60 STEEL SHALL NOT BE BENT. IF THE CONTRACTOR ELECTS TO BEND THE TIEBARS, THEY SHALL BE STEEL CONFORMING TO ASTM DESIGNATIONS: A-615, GRADE 40 AND SPACED 20" C-C, FOR 11' TO 60' PAVEMENT WIDTHS.
8. AT TRANSVERSE CONSTRUCTION JOINTS THE REGULAR LONGITUDINAL BARS SHALL EXTEND BEYOND THE JOINT SO THAT THE BAR SPLICES FOR THE REGULAR LONGITUDINAL BARS SHALL BE A MINIMUM OF FOUR FEET FROM THE CONSTRUCTION JOINT. AT LONGITUDINAL CONSTRUCTION JOINTS IF THE CONTRACTOR ELECTS TO CONTINUE THE REGULAR TRANSVERSE STEEL THROUGH THE JOINT, THE #5 TIEBARS SHOWN HEREON MAY BE DELETED. VIBRATION WITH HAND MANIPULATED MECHANICAL VIBRATORS WILL BE REQUIRED ADJACENT TO ALL TRANSVERSE CONSTRUCTION JOINTS.
9. WITH THE APPROVAL OF THE ENGINEER, MULTIPLE PIECE TIEBARS (THREADED COUPLING OR OTHER ADEQUATE DEVICE) MAY BE USED TO FACILITATE CONSTRUCTION PROVIDED THE SYSTEM DEVELOPS A FORCE EQUAL TO 1 1/2 TIMES THE MINIMUM YIELD FORCE OF THE TIEBAR SHOWN. THE SPACINGS FOR THE SYSTEM SHALL BE LESS THAN OR EQUAL TO THE SPACING ALLOWED FOR BARS OF SIMILAR YIELD STRENGTH.
10. THE CHAIRS USED TO SUPPORT THE BAR MAT SHALL BE OF SUFFICIENT STRUCTURAL QUALITY AND NUMBER TO HOLD THE MAT WITHIN THE PLACEMENT HEIGHT TOLERANCES, AND SHALL BE OF A TYPE APPROVED BY THE ENGINEER.
11. IN THE NORMAL 24" PALCEMENT FOR THE TRANSVERSE BARS, CHAIRS SHALL BE PLACED UNDER EVERY TRANSVERSE BAR. THE TRANSVERSE SPACING SHALL BE A 48" MAXIMUM. PLACEMENT MAY BE STAGGERED SO THAT CHAIRS IN ALTERNATE ROWS ARE CENTERED BETWEEN THE CHAIRS IN ADJACENT ROWS.
12. JOINT GROOVE AND SEAL DETAILS SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
13. LONGITUDINAL AND TRANSVERSE STEEL SPACING SHALL NOT VARY MORE THAN ONE-TWELFTH OF THE SPACING SHOWN HEREON.
14. WHEN MACHINE PLACING OF STEEL REINFORCEMENT IS USED, THE USE OF CHAIRS WILL NOT BE REQUIRED, AND THE TRANSVERSE STEEL MAY BE PLACED EITHER ABOVE OR BELOW THE LONGITUDINAL STEEL.

*Per Cent Long Steel	Pavement Thickness "T" in.	Bar Size	24 ft. Placement Width: Spacing of Bars in. S	S	C	No. of Bars	Steel #/sy ①	12 ft. Placement Width: Spacing of Bars in. S	S	C	No. of Bars	Steel #/sy ①	Add'l Steel @ Trans. Const. J.: Size	@ No. per 24' place. width	@ No. per 12' place. width	Weight #/ft. based on 12' place.
0.5	10	No. 6	3	5	8.5	35	22.72	3	5.25	8.5	18	23.38	3/4"ø x36"	18	9	3.38
	9	No. 5	3	4.5	6.5	45	20.61	3	4	6.5	23	21.00	5/8"ø x36"	22	11	2.67
	8	No. 5	3	4	7.5	39	18.36	3	3.75	7.5	20	18.66	5/8"ø x36"	20	10	2.61
	7	No. 5	3	5	8.5	35	16.70	4	8.5	8.5	17	16.30	5/8"ø x36"	18	9	2.35
	6	No. 4	3	4.5	7	42	13.53	3	6	7	21	13.53	1/2"ø x36"	20	11	1.84
0.6	10	No. 6	3	7	7.25	40	25.52	3	7.25	7.25	20	25.52	3/4"ø x36"	20	10	3.76
	9	No. 6	3	5	6	37	23.85	3	5	6	19	24.41	3/4"ø x36"	19	10	3.76
	8	No. 5	3	6.25	6.25	46	21.00	3	3.5	6.25	24	21.79	5/8"ø x36"	23	11	2.87
	7	No. 5	3	7	7.25	40	18.65	3	7.25	7.25	20	18.65	5/8"ø x36"	20	10	2.61
	6	No. 5	3	5	8.5	35	16.70	3	5.25	8.5	18	17.09	5/8"ø x36"	18	9	2.35

NOTE: THE SPACINGS (B) SHOWN IN THE ABOVE PLACEMENT TABLE ARE THE MAXIMUM ALLOWABLE SPACINGS. WHERE THE PROPOSED PLACEMENT WIDTHS VARY FROM THE BASIC DESIGN WIDTH SHOWN, THE SPACING (B) AND THE ADJACENT SPACING (C) SHALL BE ADJUSTED TO ACCOMMODATE A REINFORCEMENT ARRANGEMENT EQUAL TO OR SLIGHTLY HEAVIER THAN THAT SHOWN AS DIRECTED BY THE ENGINEER.

1. INCLUDES BOTH REGULAR LONGITUDINAL AND TRANSVERSE BARS BASED UPON 1 FOOT PAVEMENT LENGTHS FOR THE WIDTH INDICATED. ALL TRANSVERSE STEEL IS #4 BARS AT 24" CENTERS.**
2. THIS SHALL BE THE MINIMUM NUMBER OF ADDITIONAL STEEL BARS TO BE PLACED PER LANE. THE SPACING OF THE ADDITIONAL STEEL BARS SHALL BE VARIED AS DIRECTED IN ORDER TO PROVIDE A MINIMUM CLEARANCE OF 1-3/4" FROM EACH REGULAR LONGITUDINAL REINFORCING BAR.

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

CONCRETE PAVEMENT DETAILS CONTINUOUSLY REINFORCED STEEL BARS

CPCR (B)-75 (2)

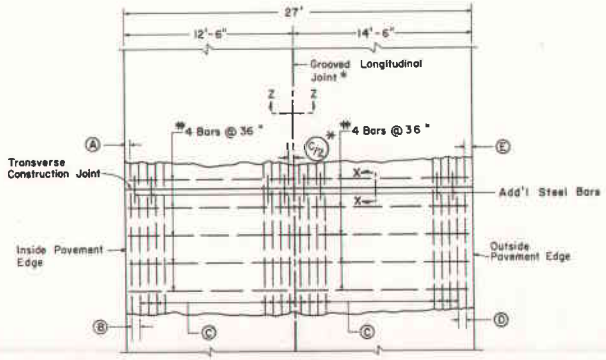
Ck.	DRAWING	DATE	FED. AID PROJ. NO.	STATE	FEDERAL PROJECT NO.			SHEET NO.
Ck. DW.	ORIGINAL			TEXAS				
Dw.	REVISED		STATE DIST. NO.	COUNTY		CONT.	SECT.	JOB
Ck. Dw.	REVISED							HIGHWAY NO.
PR.								
Ck. TR.								

* WITH THE APPROVAL OF THE ENGINEER, THE CONTRACTOR MAY CONSTRUCT IN PLACEMENT WIDTHS OF 12'-6" AND 14'-6". IF SO PLACED THE GROOVED LONGITUDINAL JOINT SHOWN SHALL BE REPLACED BY A LONGITUDINAL CONSTRUCTION JOINT. IN THIS CASE THE SPACE BETWEEN THE LAST REINFORCEMENT BAR AND THE JOINT SHALL BE HALF THE VALUE SHOWN FOR C.

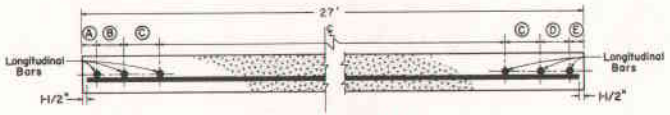
PER CENT LONG STEEL	PAVEMENT THICKNESS "T" IN.	BAR SIZE	27 FT. PLACEMENT WIDTH SPACING C-C							ADDITIONAL STEEL AT TRANSVERSE CONSTRUCTION				
			Ⓐ IN	Ⓑ IN	Ⓒ IN	Ⓓ IN	Ⓔ IN	NO. OF BARS	STEEL #/SY ①	SIZE	② NO. PER 27' PLACEMENT WIDTH	NO PER 12'-6" PLACEMENT WIDTH	NO PER 14'-6" PLACEMENT WIDTH	WEIGHT #/SY ON 27' PLACEMENT
0.5	6	4	3 3/4	6 1/2	6 1/2	5 1/2	3	50	15.1	5/8" x 36"	25	12	13	1.86
	7	5	3	7 1/2	9	9	7 1/2	36	14.5	5/8" x 36"	18	8	10	2.09
	8	5	3 3/4	7 1/2	7 1/2	7 1/2	5 1/2	43	17.0	5/8" x 36"	21	10	11	2.43
	9	5	3 3/4	6 1/2	6 1/2	5½	3	50	18.4	5/8" x 36"	25	12	13	2.90
	10	5	5 5/8	8 3/4	8 3/4	8 3/4	3 3/8	37	20.3	3/4" x 36"	18	8	10	3.00
	11	6	3	7	8	7	3	41	22.5	3/4" x 36"	20	9	11	3.34
	12	6	3	3 1/2	7	6 1/2	3	47	25.5	3/4" x 36"	23	11	12	3.84
0.6	6	5	5 5/8	8 3/4	8 3/4	8 3/4	3 3/8	37	14.9	5/8" x 36"	18	8	10	2.09
	7	5	3	5 5/8	5 5/8	7 1/2	3 5/8	45	17.7	5/8" x 36"	22	10	12	2.55
	8	5	3 3/4	6 1/2	6 1/2	5½	3	50	19.4	5/8" x 36"	25	12	13	2.90
	9	6	3	7	7	7	3	41	22.5	3/4" x 36"	20	9	11	3.34
	10	6	3	5 5/8	5 5/8	7 1/2	3 5/8	45	24.5	3/4" x 36"	22	10	12	3.69
	11	6	3 3/4	6 1/2	6 1/2	5½	3	50	27.0	3/4" x 36"	25	12	13	4.17
	12	6	3	6	6	6	3	54	29.0	3/4" x 36"	27	13	14	4.51

GENERAL NOTES

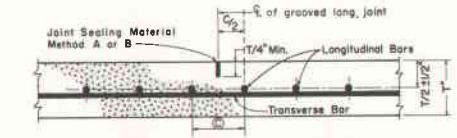
1. NO EXPANSION JOINTS WILL BE USED EXCEPT AT STRUCTURE ENDS OR FIXED OBJECTS AS SHOWN ELSEWHERE IN THE PLANS.
2. FOR FURTHER INFORMATION REGARDING THE PLACEMENT OF CONCRETE AND REINFORCEMENT REFER TO THE GOVERNING SPECIFICATIONS FOR "CONCRETE PAVEMENT".
3. DETAILS AS TO PAVEMENT WIDTH, PAVEMENT THICKNESS AND THE CROWN CROSS-SLOPE SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
4. WITHIN ANY AREA BOUNDED BY TWO FEET OF PAVEMENT LENGTH MEASURED PARALLEL TO THE CENTERLINE AND TWELVE FEET OF PAVEMENT WIDTH MEASURED PERPENDICULAR TO THE PAVEMENT CENTERLINE, NOT OVER 33% OF THE REGULAR LONGITUDINAL STEEL SHALL BE SPLICED.
5. LONGITUDINAL AND TRANSVERSE BARS SHALL BE STEEL CONFORMING TO ASTM A-615 OR ASTM A-616 (GRADE 60) AS NOTED IN THE SPECIFICATIONS.
6. SPLICES SHALL BE A MINIMUM OF 24 TIMES THE NOMINAL DIAMETER OF THE BAR.
7. BARS OF ASTM DESIGNATIONS: A-615 OR A-616, GRADE 60 STEEL SHALL NOT BE BENT. IF THE CONTRACTOR ELECTS TO BEND THE TIEBARS, THEY SHALL BE STEEL CONFORMING TO ASTM DESIGNATION: A-615, GRADE 40, AND SPACED AT 24" C-C.
8. AT TRANSVERSE CONSTRUCTION JOINTS THE REGULAR LONGITUDINAL BARS SHALL EXTEND BEYOND THE JOINT SO THAT THE BAR SPLICES FOR THE REGULAR LONGITUDINAL BARS SHALL BE A MINIMUM OF FOUR FEET FROM THE CONSTRUCTION JOINT. AT LONGITUDINAL CONSTRUCTION JOINTS IF THE CONTRACTOR ELECTS TO CONTINUE THE REGULAR TRANSVERSE STEEL THROUGH THE JOINT- THE #5 @TIEBARS SHOWN HEREON MAY BE DELETED. VIBRATION WITH HAND MANIPULATED MECHANICAL VIBRATORS WILL BE REQUIRED ADJACENT TO ALL TRANSVERSE CONSTRUCTION JOINTS..
9. WITH THE APPROVAL OF THE ENGINEER, MULTIPLE PIECE TIEBARS (THREADED COUPLING OR OTHER ADEQUATE DEVICE) MAY BE USED TO FACILITATE CONSTRUCTION PROVIDED THE SYSTEM DEVELOPS A FORCE EQUAL TO 1 1/2 TIMES THE MINIMUM YIELD FORCE OF THE TIEBAR SHOWN. THE SPACINGS FOR THE SYSTEM SHALL BE LESS THAN OR EQUAL TO THE SPACING ALLOWED FOR BARS OF SIMILAR YIELD STRENGTH.
10. THE CHAIRS USED TO SUPPORT THE BAR MAT SHALL BE OF SUFFICIENT STRUCTURAL QUALITY AND NUMBER TO HOLD THE MAT WITHIN THE PLACEMENT HEIGHT TOLERANCES, AND SHALL BE OF A TYPE APPROVED BY THE ENGINEER.
11. IN THE NORMAL 16" PLACEMENT FOR THE TRANSVERSE BARS, CHAIRS SHALL BE PLACED UNDER EVERY TRANSVERSE BAR. THE TRANSVERSE SPACING SHALL BE A 48" MAXIMUM. PLACEMENT MAY BE STAGGERED SO THAT CHAIRS IN ALTERNATE ROWS ARE CENTERED BETWEEN THE CHAIRS IN ADJACENT ROWS.
12. JOINT GROOVE AND SEAL DETAILS SHALL BE AS SHOWN ELSEWHERE IN THE PLANS
13. LONGITUDINAL AND TRANSVERSE STEEL SPACING SHALL NOT VARY MORE THAN ONE-TWELFTH OF THE SPACING SHOWN HEREON.
14. WHEN MACHINE PLACING OF STEEL REINFORCEMENT IS USED, THE USE OF CHAIRS SHALL NOT BE REQUIRED, AND THE TRANSVERSE STEEL MAY BE PLACED EITHER ABOVE OR BELOW THE LONGITUDINAL STEEL.



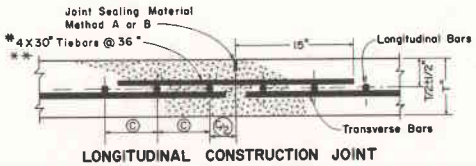
TWO LANE PAVEMENT PLAN
(27ft. Placement) *



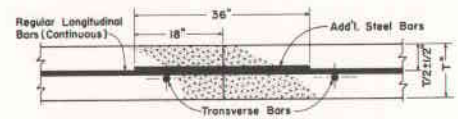
TYPICAL SECTION
(27 ft. Placement)



GROOVED LONGITUDINAL JOINT
Section Z-Z



LONGITUDINAL CONSTRUCTION JOINT
Section Z-Z
(for two separate pours)



TRANSVERSE CONSTRUCTION JOINT
Section X-X

NOTE: THE SPACINGS Ⓒ SHOWN IN THE ABOVE PLACEMENT TABLE ARE THE MAXIMUM ALLOWABLE SPACINGS. WHERE THE PROPOSED PLACEMENT WIDTHS VARY FROM THE BASIC DESIGN WIDTH SHOWN, THE SPACING Ⓒ AND THE ADJACENT SPACING SHALL BE ADJUSTED TO ACCOMMODATE A REINFORCEMENT ARRANGEMENT EQUAL TO OR SLIGHTLY HEAVIER THAN THAT SHOWN AS DIRECTED BY THE ENGINEER.

① INCLUDES BOTH REGULAR LONGITUDINAL AND TRANSVERSE BARS BASED UPON 1 FOOT PAVEMENT LENGTHS FOR THE WIDTH INDICATED. ALL TRANSVERSE STEEL IS #4 BARS AT 36" CENTERS.

② THIS SHALL BE THE MINIMUM NUMBER OF ADDITIONAL STEEL BARS TO BE PLACED PER LANE. THE SPACING OF THE ADDITIONAL STEEL BARS SHALL BE VARIED AS DIRECTED IN ORDER TO PROVIDE A MINIMUM CLEARANCE OF 1-3/4" FROM EACH REGULAR LONGITUDINAL REINFORCING BAR.

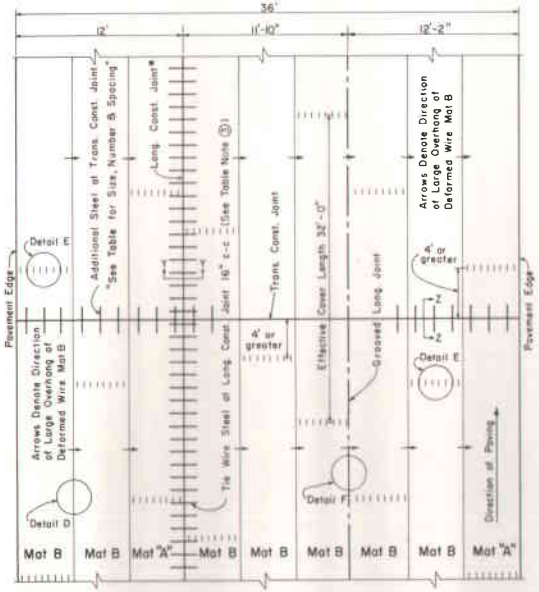
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

CONCRETE PAVEMENT DETAILS CONTINUOUSLY REINFORCED

STEEL BARS

CPCR (8)- 75 (3)

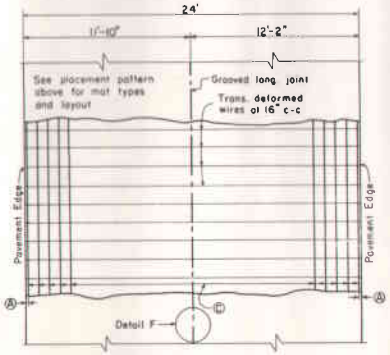
DN	DRAWING	DATE	FED. ROAD DIV. NO.	STATE	FEDERAL PROJECT NO.				SHEET NO.
CK. DN.	ORIGINAL	6-75	6	TEXAS					
DW	REVISED								
CK. DW	REVISED		STATE DISTRICT	COUNTY		CONT.	SECT.	JOB	HIGHWAY NO.
TR									
CK. TR									



THREE LANE PAVEMENT PLAN

(12 foot and 24 foot Placement)*

* WITH THE APPROVAL OF THE ENGINEER, THE CONTRACTOR MAY PLACE THE PAVEMENT THE FULL ROADWAY WIDTH AS ONE PLACEMENT. IF SO PLACED, THE LONGITUDINAL CONSTRUCTION JOINT SHOWN SHALL BE REPLACED BY THE GROOVED LONGITUDINAL JOINT.

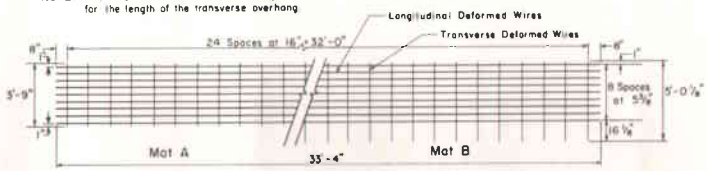


TWO LANE PAVEMENT PLAN

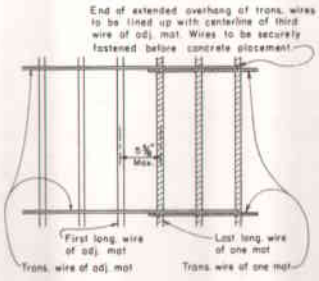
(24 ft. Placement) *

*LANE WIDTHS ARE FOR ILLUSTRATIVE PURPOSES ONLY AND SHOULD NOT BE USED IF IN CONFLICT WITH TYPICAL CROSS SECTIONS SHOWN ELSEWHERE IN THE PLANS.

NOTE: Mat A & Mat B are the same except for the length of the transverse overhang.

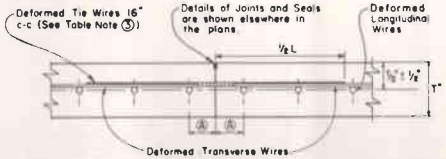


PREFABRICATED DEFORMED WIRE MATS



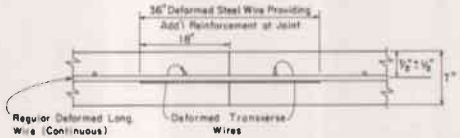
DETAIL D

TYPICAL LAP OF TRANSVERSE WIRES



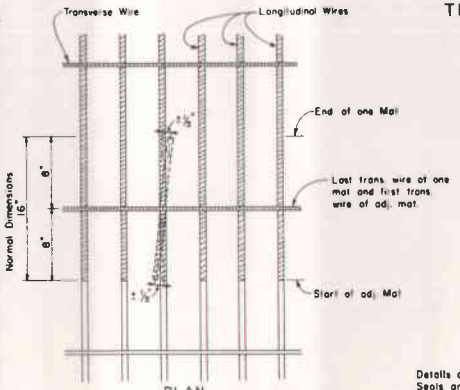
LONGITUDINAL CONSTRUCTION JOINT

SECTION Y-Y



TRANSVERSE CONSTRUCTION JOINT

SECTION Z-Z

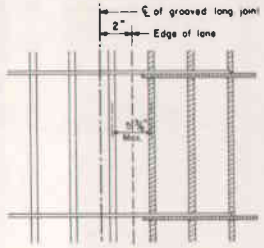


PLAN

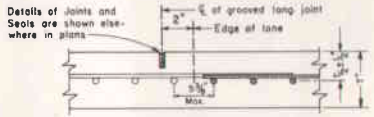
* Note: At long. laps of mats the centerline of the bottom layer of long. steel shall be located within 1/2" of the slab center. The centerline of the upper layer of long. steel shall be within 1-1/2" of the slab center.

SECTION - DETAIL E

TYPICAL LAP OF LONGITUDINAL WIRES



PLAN



SECTION

DETAIL F

TRANSVERSE LAP AT GROOVED LONGITUDINAL JOINT

GENERAL NOTES

1. NO EXPANSION JOINTS WILL BE USED EXCEPT AT STRUCTURE ENDS OR FIXED OBJECTS AS SHOWN ELSEWHERE IN THE PLANS.
2. JOINT GROOVE AND SEAL DETAILS SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
3. CONSTRUCTION JOINTS MAY BE FORMED BY THE USE OF METAL OR WOOD FORMS EQUAL IN DEPTH TO THE NOMINAL DEPTH OF THE PAVEMENT, OR BY OTHER MEANS WHICH HAVE BEEN APPROVED BY THE ENGINEER PRIOR TO THEIR USE.
4. DETAILS AS TO PAVEMENT WIDTH, PAVEMENT THICKNESS, AND THE CROWN CROSS-SLOPE SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
5. IT IS THE INTENT OF THIS DESIGN THAT THE LONGITUDINAL STEEL BE AT THE CENTER OF THE SLAB. IT SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR TO TAKE ALL NECESSARY PRECAUTIONS TO INSURE THAT THE FINAL POSITION OF THE STEEL IS WITHIN 1/2 INCH OF THE SLAB CENTER EXCEPT THAT THE TOLERANCE SHOWN IN THE LONGITUDINAL LAP DETAIL SHALL GOVERN AT THAT POINT. TRANSVERSE WIRES MAY BE PLACED ON TOP OR BOTTOM.
6. THE DEFORMED WIRE MATS SHALL BE PREASSEMBLED AND PLACED AT THE SPECIFIED HEIGHT PRIOR TO THE CONCRETE PLACEMENT OPERATIONS. THE ENTIRE DEPTH OF CONCRETE SHALL BE PLACED IN ONE OPERATION.
7. ADJACENT DEFORMED WIRE MATS SHALL BE SECURELY FASTENED TOGETHER IN A MANNER TO PRECLUDE SEPARATION OF THE STEEL DURING CONCRETE PLACEMENT AND FINISHING OPERATIONS.
8. THE CHAIRS USED TO SUPPORT THE PREFABRICATED MATS SHALL BE PLACED UNDER THE LONGITUDINAL WIRES AND SHALL BE OF A TYPE APPROVED BY THE ENGINEER. A MINIMUM OF TEN CHAIRS PER MAT WILL BE USED TO MEET THE STEEL PLACEMENT REQUIREMENTS.
9. WITHIN ANY AREA BOUNDED BY TWO FEET OF PAVEMENT LENGTH MEASURED PARALLEL TO THE CENTERLINE, AND TWELVE FEET OF PAVEMENT WIDTH MEASURED PERPENDICULAR TO THE PAVEMENT CENTERLINE, NOT OVER 33% OF THE REGULAR LONGITUDINAL STEEL SHALL BE SPLICED.
10. ALL SPLICES SHALL BE A MINIMUM OF 31 TIMES THE NOMINAL DIAMETER OF THE WIRE.
11. AT TRANSVERSE CONSTRUCTION JOINTS THE REGULAR LONGITUDINAL STEEL SHALL EXTEND A MINIMUM OF FOUR FEET ON EITHER SIDE OF THE JOINT.
12. IF WIDTHS GREATER THAN TYPICAL WIDTHS OCCUR, INDIVIDUAL WIRES MAY BE ADDED TO OBTAIN ADDITIONAL WIDTH, PROVIDED THE ℄ TO ℄ SPACING IS NOT EXCEEDED AND LAP REQUIREMENTS ARE MET.
13. THE EDGE SPACING DIMENSION, Ⓑ, SHALL BE THE MINIMUM DIMENSION ALLOWED. THE SPACING, Ⓒ, SHALL BE THE MAXIMUM DIMENSION ALLOWED BETWEEN MATS. SLIGHT VARIATIONS IN MAT DIMENSIONS MAY BE ABSORBED WITHIN THESE SPACINGS.
14. IN THE PLANE OF STEEL PARALLEL TO THE NEAREST SURFACE OF CONCRETE, TEARS OR TEWIRES SHALL NOT VARY FROM PLAN PLACEMENT BY MORE THAN ONE-TWELFTH OF THE SPECIFIED SPACING.

Pavement Thickness (T) in.	LONGITUDINAL REINFORCEMENT: Wire Size	36' Placement Width: Spacing c-c Ⓑ in.	36' Placement Width: Ⓒ in.	36' Placement Width: ① Steel lb/SY	12' Placement Width: Spacing c-c Ⓑ in.	12' Placement Width: Ⓒ in.	12' Placement Width: ① Steel lb/SY	Add'l Steel Trans. Const. Jt.: Wire Size	Length in.	② No. Per Lane	Weight lb/ft.	TRANS. REINF.: Wire Size	Tie Wires ③: Size Length(L) & Spacing	Weight lb/ft.
6	D 18.8	1 9/16	5 3/8	16.5	2 1/8	5 3/8	16.40	D 19.5	36"	14	2.65	D8.8	D8.8x24" @ 16" cc	0.480
7	D 17.0	1 9/16	5 3/8	14.40	2 1/8	5 3/8	14.30	D17.0	36"	18	2.60	D7.7	2" x22" @ 16" cc	0.361
8	D 14.8	1 9/16	5 3/8	12.36	2 1/8	5 3/8	12.28	D14.6	36"	21	2.61	D6.6	D6.6x20" @ 16" cc	0.342

TABLE NOTE: ① INCLUDES BOTH LONGITUDINAL AND TRANSVERSE WIRES BASED ON THE WIDTH INDICATED AND AN EFFECTIVE COVER LENGTH OF 32 FEET. (ESTIMATING QUANTITIES INCLUDE SPLICES)

② THIS SHALL BE THE MINIMUM NUMBER OF ADDITIONAL STEEL WIRES TO BE PLACED PER LANE. THE ADDITIONAL STEEL WIRES SHALL BE PLACED EQUIDISTANT BETWEEN TWO REGULAR LONGITUDINAL REINFORCING WIRES AT AS NEAR A UNIFORM SPACING ACROSS THE LANE AS POSSIBLE.

③ AT THE OPTION OF THE CONTRACTOR, #4 BARS x 30 IN. AT 20 IN. C-C MAY BE USED IN LIEU OF THE DEFORMED TIE WIRES AT 16 IN. C-C SHOWN, PROVIDED WRITTEN APPROVAL HAS BEEN RECEIVED FROM THE ENGINEER.

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

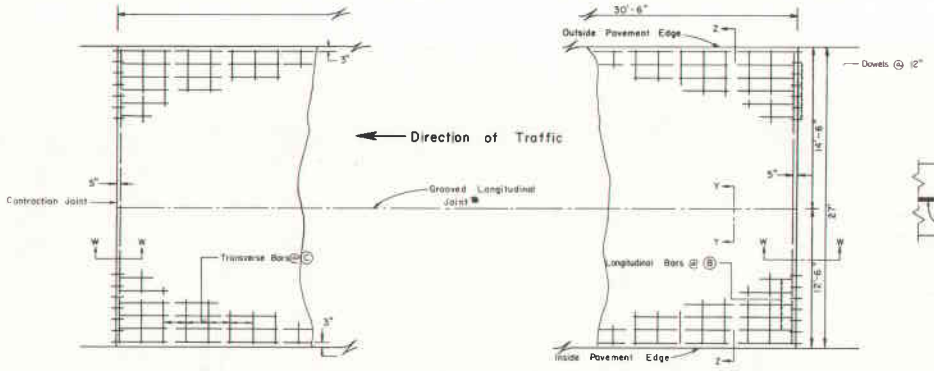
CONCRETE PAVEMENT DETAILS CONTINUOUSLY REINFORCED

DEFORMED WIRE MAT

CPCR (DW) — 69

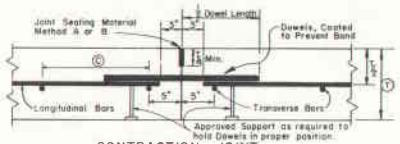
DN.	CK.	DW.	CK.	TR.	CK.	DRAWING	ORIGINAL	DATE	FEB 1969	FED. RD. DIV. NO.	6	STATE	TEXAS	FEDERAL PROJECT NO.	SHEET NO.
										STATE DIST. NO.		COUNTY		CONT.	SECT.	JOB	HIGHWAY NO.

A-20

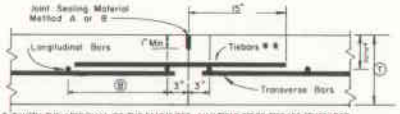


TWO LANE PAVEMENT PLAN
(27ft Placement)

* WITH THE APPROVAL OF THE ENGINEER, THE CONTRACTOR MAY CONSTRUCT IN PLACEMENT WIDTHS OF 12'-6" AND 14'-6". IF SO PLACED THE GROOVED LONGITUDINAL JOINT SHOWN SHALL BE REPLACED BY A LONGITUDINAL CONSTRUCTION JOINT.

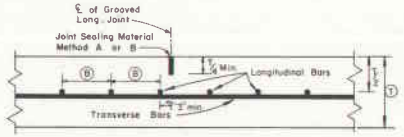


CONTRACTION JOINT
Section W—W



* WITH THE APPROVAL OF THE ENGINEER, MULTIPLE PIECE TIEBARS (THREADED COUPLING OR OTHER ADEQUATE DEVICE) MAY BE USED TO FACILITATE CONSTRUCTION PROVIDED THE SYSTEM DEVELOPS A FORCE EQUAL TO 1-1/2 TIMES THE MINIMUM YIELD FORCE OF THE TIEBAR SHOWN. THE SPACINGS FOR THE SYSTEM SHALL BE LESS THAN OR EQUAL TO THE SPACING ALLOWED FOR BARS OF SIMILAR YIELD STRENGTH.

LONGITUDINAL CONSTRUCTION JOINT
Section Y—Y

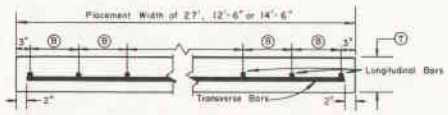


GROOVED LONGITUDINAL JOINT
Section Y—Y

TABLE FOR TRANSVERSE AND LONGITUDINAL REINFORCEMENTS AND DOWEL BARS

PAVEMENT THICKNESS T (INCHES)	SPACINGS FOR #3 BARS 27' PLACEMENT WIDTH					SPACINGS FOR #3 BARS 12'-6" PLACEMENT WIDTH					SPACINGS FOR #3 BARS 14'-6" PLACEMENT WIDTH					DOWELS (SMOOTH BARS)			TIEBARS (DEFORMED)		
	LONGITUDINAL		TRANSVERSE		② STEEL	LONGITUDINAL		TRANSVERSE		③ STEEL	LONGITUDINAL		TRANSVERSE		④ STEEL						
	NO. OF BARS	⑤ SPACE B (IN)	NO. OF BARS	⑤ SPACE C (IN)	#/SY	NO. OF BARS	⑤ SPACE B (IN)	NO. OF BARS	⑤ SPACE C (IN)	#/SY	NO. OF BARS	⑤ SPACE B (IN)	NO. OF BARS	⑤ SPACE C (IN)	#/SY	SIZE	AVG. SPAC. (IN)	WT. #/FT. OF JT	SIZE	AVG. SPAC (IN)	WT. #/FT. OF JT
8	15	22 5/8	16	24	3.67	8	20 1/2	16	24	3.86	9	21	16	24	3.80	1" x 18"	12	4.01	# 4 x 30"	36	.56
9	17	19 3/4	16	24	3.92	9	18	16	24	4.13	10	18 3/4	16	24	4.03	1 1/8" x 20"	12	5.63	# 4 x 30"	36	.56
10	18	18 5/8	19	20	4.36	9	18	19	20	4.45	11	16 3/4	19	20	4.39	1 1/4" x 22"	12	7.63	# 4 x 30"	36	.56
11	20	16 3/4	19	20	4.63	10	16	19	20	4.71	11	16 3/4	19	20	4.59	1 1/4" x 22"	12	7.63	# 4 x 30"	36	.56
12	22	15 1/8	21	18	5.18	11	14 1/2	21	18	5.20	12	13 1/2	21	18	5.03	1 1/4" x 22"	12	7.63	# 4 x 30"	30	.67
13	23	14 3/8	25	15	5.68	11	14 1/2	25	15	5.63	13	14	25	15	5.69	1 1/4" x 22"	12	7.63	# 4 x 30"	30	.67
14	25	13 1/2	25	15	5.92	12	13	25	15	5.90	14	13	25	15	5.92	1 1/2" x 22"	12	7.63	# 4 x 30"	24	.84

1. THE CONTRACTOR MAY USE # 3, # 4, OR # 5 BARS FOR TRANSVERSE OR LONGITUDINAL STEEL. SPACINGS B AND C SHOWN IN THIS TABLE ARE FOR # 3 BARS. EQUIVALENT SPACINGS OF # 4 OR # 5 BARS THAT MAINTAIN AN EQUIVALENT OR GREATER AREA OF STEEL WILL BE ACCEPTED IN ANY CROSS SECTION, PROVIDED NO SPACINGS ARE GREATER THAN 36".
2. STEEL WEIGHTS ARE FOR CONTRACTOR'S INFORMATION ONLY AND INCLUDE WEIGHT OF LONGITUDINAL AND TRANSVERSE BARS.
3. SPACINGS SHOWN ARE FOR ASTM DESIGNATION A-615 OR A-616, GRADE 60 TIEBARS. IF ASTM A-615, GRADE 40 TIEBARS ARE USED, THE AVERAGE SPACING SHALL BE TWO-THIRDS OF THE SPACINGS SHOWN IN THE TABLE.
4. THE B SPACINGS ADJACENT TO THE LONGITUDINAL BAR NEAREST THE EDGE OF PLACEMENT SHALL BE ADJUSTED IN WIDTH TO MAINTAIN THE 3" EDGE SPACING SHOWN IN DETAILS OF LONGITUDINAL CONSTRUCTION JOINT, SECTION Y-Y AND TYPICAL SECTION, SECTION Z-Z. IN A LIKE MANNER THE C SPACING ADJACENT TO THE TRANSVERSE BARS NEAREST THE CONTRACTION JOINT SHALL BE ADJUSTED IN WIDTH TO MAINTAIN THE 3" SPACING FROM THE VERTICAL PLANE OF THE JOINT.



TYPICAL SECTION
Section Z—Z

GENERAL NOTES

1. JOINT GROOVE AND SEAL DETAILS SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
2. CONSTRUCTION JOINTS MAY BE FORMED BY THE USE OF METAL OR WOOD FORMS EQUAL IN DEPTH TO THE NOMINAL DEPTH OF THE PAVEMENT, OR BY OTHER MEANS WHICH HAVE BEEN APPROVED BY THE ENGINEER PRIOR TO THEIR USE.
3. TREATMENT OF PAVEMENT ENDS AT STRUCTURES OR AT FIXED OBJECTS WILL BE SHOWN ELSEWHERE IN THE PLANS.
4. FOR FURTHER INFORMATION REGARDING THE PLACEMENT OF CONCRETE AND REINFORCEMENT REFER TO THE GOVERNING SPECIFICATIONS FOR "CONCRETE PAVEMENT".
5. DETAILS AS TO PAVEMENT WIDTH, PAVEMENT THICKNESS, AND THE CROWN CROSS-SLOPE SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
6. LONGITUDINAL AND TRANSVERSE BARS SHALL BE OF STEEL CONFORMING TO ASTM DESIGNATIONS; A-615 OR ASTM A-616 (GRADE 60) AS NOTED IN THE SPECIFICATIONS. THE SIZE AND SPACING SHALL BE IN ACCORDANCE WITH TABLE SHOWN BELOW.
7. BARS OF ASTM DESIGNATION: A-615 OR A-616, GRADE 60, SHALL NOT BE BENT. IF THE CONTRACTOR ELECTS TO BEND THE TIE BARS, THEY SHALL BE STEEL CONFORMING TO ASTM DESIGNATION; A-615, GRADE 40.
8. IT IS THE INTENT OF THIS DESIGN THAT THE LONGITUDINAL STEEL BE AT THE CENTER OF THE SLAB. IT SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR TO TAKE ALL NECESSARY PRECAUTIONS TO INSURE THAT THE FINAL POSITION OF THE STEEL IS WITHIN 1/2 INCH OF THE SLAB CENTER.
9. CONCRETE SHALL NOT BE DISCHARGED FROM THE MIXER DIRECTLY ON TOP OF OR ON THE SIDES OF THE JOINT ASSEMBLY.
10. ANY APPROVED CHAIR TYPE OR DESIGN, WHICH WILL SATISFY THE REQUIREMENTS NOTED HEREON WILL BE PERMITTED. CHAIR SPACINGS SHALL NOT BE GREATER THAN 60" C-C MEASURED PARALLEL TO THE PAVEMENT CENTER LINE AND 30" C-C MEASURED PERPENDICULAR TO THE PAVEMENT CENTER LINE ADDITIONAL CHAIRS SHALL BE USED IF NECESSARY TO MEET THE STEEL PLACEMENT REQUIREMENT.
11. LONGITUDINAL AND TRANSVERSE STEEL SPACING SHALL NOT VARY MORE THAN ONE TWELFTH OF THE SPACING SHOWN HEREON.

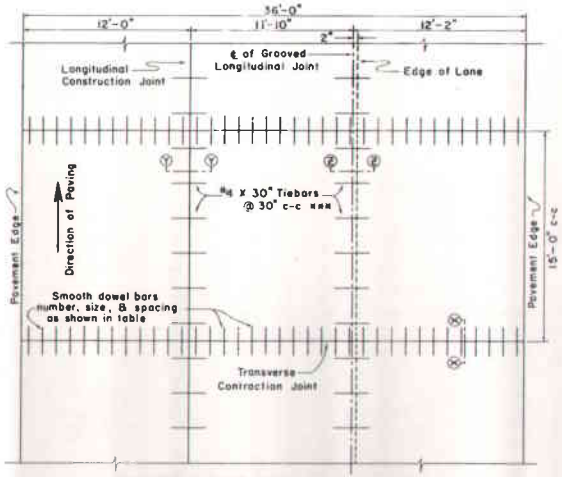
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

CONCRETE PAVEMENT DETAILS
JOINTED REINFORCED STEEL BARS

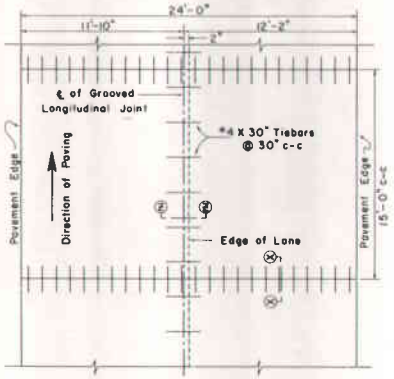
CPJR(30B)-75

DN	CHANGING	DATE	SHEET NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK DN	ORIGINAL	FEB. 1965				
DW	REVISED			TEXAS		
CK			STATE DIST. NO.	COUNTY	CONT.	SECT.	JOB	HIGHWAY NO.
TR								
CK TR								

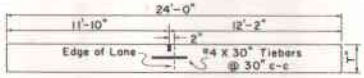
A-21



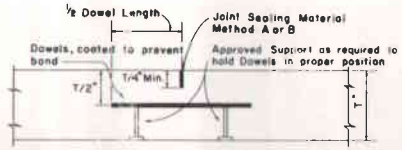
THREE LANE PAVEMENT PLAN
(12 ft. & 24 ft. Placement) **



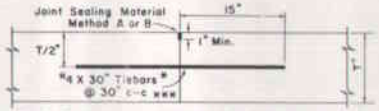
TWO LANE PAVEMENT PLAN



TYPICAL SECTION
(24 ft. Placement) **

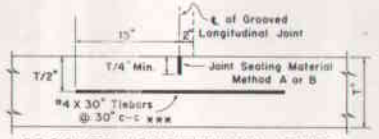


TRANSVERSE CONTRACTION JOINT
Section X-X



LONGITUDINAL CONSTRUCTION JOINT
Section Y-Y

* WITH THE APPROVAL OF THE ENGINEER, MULTIPLE PIECE TIEBARS (THREADED COUPLING OR OTHER ADEQUATE DEVICE) MAY BE USED TO FACILITATE CONSTRUCTION PROVIDED THE SYSTEM DEVELOPS A FORCE EQUAL TO 1 1/2 TIMES THE MINIMUM FORCE OF THE TIEBAR SHOWN. THE SPACINGS FOR THE SYSTEM SHALL BE LESS THAN OR EQUAL TO THE SPACING ALLOWED FOR BARS OF SIMILAR YIELD STRENGTH.



GROOVED LONGITUDINAL JOINT
Section Z-Z

*** At locations where the pavement width is greater than 40 feet but less than 60 feet the tie bar spacing shall be 24" center to center. At locations where pavement width is greater than 60 feet #5 tie bars 36" long shall be 24" center to center.

** Lane widths are for illustrative purposes only and should not be used if in conflict with typical cross sections shown elsewhere in the plans.

GENERAL NOTES

1. NO EXPANSION JOINTS WILL BE USED EXCEPT AT STRUCTURE ENDS OR FIXED OBJECTS AS SHOWN ELSEWHERE IN THE PLANS.
2. FOR FURTHER INFORMATION REGARDING THE PLACEMENT OF CONCRETE AND LOAD TRANSFER DEVICES REFER TO THE GOVERNING SPECIFICATIONS FOR "CONCRETE PAVEMENT".
3. DETAILS AS TO PAVEMENT WIDTH, PAVEMENT THICKNESS, AND THE CROWN CROSS-SLOPE SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
4. JOINT GROOVE AND SEAL DETAILS SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
5. TIEBARS SHALL BE SECURED PARALLEL TO THE PAVEMENT SURFACE AND PERPENDICULAR TO THE CENTERLINE BY:
   (a) USE OF BAR CHAIRS
   (b) ACCURATELY PLACED IN POSITION ON THE SCREEDED CONCRETE BY MEANS OF AN APPROVED TEMPLATE AND FORCED TO THE PROPER POSITION WITH A SUITABLE TOOL; OR
   (c) BY ANY OTHER MEANS WHICH, PRIOR TO ITS USE, HAS BEEN APPROVED BY THE ENGINEER.
6. DOWEL BARS SHALL BE SECURED PARALLEL TO THE PAVEMENT SURFACE AND CENTERLINE BY A DOWEL BAR CHAIR.
7. WHEN WORK IS STOPPED DUE TO BREAKDOWN OR OTHER CAUSE, CONCRETE SHALL BE REMOVED BEYOND LAST CONTRACTION JOINT IN PLACE AND A HEADER INSTALLED.
8. WHERE A MONOLITHIC CURB IS SPECIFIED, THE JOINT IN THE CURB SHALL COINCIDE WITH PAVEMENT JOINTS AND MAY BE FORMED BY ANY MEANS WHICH, PRIOR TO ITS USE, HAS BEEN APPROVED BY THE ENGINEER.
9. CONSTRUCTION JOINTS MAY BE FORMED BY USE OF METAL OR WOOD FORMS EQUAL IN DEPTH TO THE NOMINAL DEPTH OF THE PAVEMENT, OR BY OTHER MEANS WHICH HAVE BEEN APPROVED BY THE ENGINEER PRIOR TO THEIR USE.
10. LONGITUDINAL AND TRANSVERSE STEEL SPACING SHALL NOT VARY MORE THAN ONE TWELFTH OF THE SPACING SHOWN HEREON.
11. THE TIEBAR SPACINGS SHOWN ARE FOR ASTM DESIGNATIONS A-615, OR A-616, GRADE 60, TIEBARS, WHICH SHALL NOT BE BENT. IF TIEBARS ARE TO BE BENT, THEY SHALL BE STEEL CONFORMING TO ASTM DESIGNATION A-615, GRADE 40, WITH A CENTER TO CENTER SPACING OF 24 INCHES.

DEPTH OF PAVEMENT (INCHES)	DOWELS (SMOOTH BARS)		
	SIZE AND LENGTH	AVERAGE SPACING (INCHES)	WEIGHT PER FOOT OF JOINT (LBS.)
8	1" X 18"	12	4.01
9	1¼" X 20"	12	5.63
10	1¼" X 22"	12	7.65
11	1½" X 24"	12	10.10

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

CONCRETE PAVEMENT DETAILS

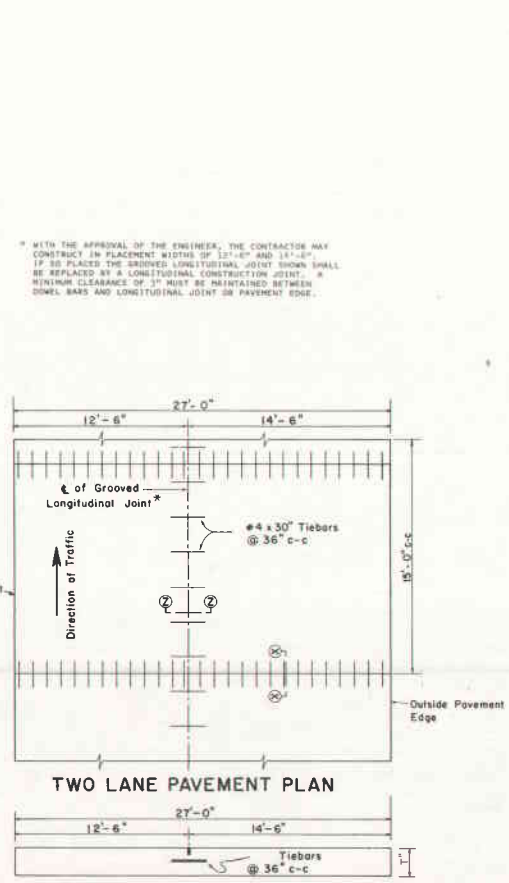
CONTRACTION DESIGN

CPCD - 80 (1)

CH.	DRAWING	DATE	FED. AID PROJ. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CH. ENG.	ORIGINAL					
ENG.	REVISED			TEXAS		
CH. DRF.	REVISED		STATE PROJECT NO.	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
DR.						
CK. DR.						

A-22

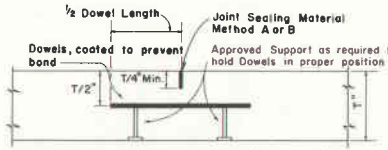
A-23



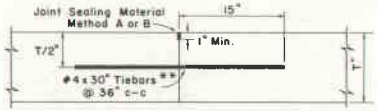
TWO LANE PAVEMENT PLAN

TYPICAL SECTION
(27 ft. Placement)

* WITH THE APPROVAL OF THE ENGINEER, THE CONTRACTOR MAY CONSTRUCT IN PLACEMENT WIDTHS OF 12'-6" AND 14'-6". IF SO PLACED THE GROOVED LONGITUDINAL JOINT SHOWN SHALL BE REPLACED BY A LONGITUDINAL CONSTRUCTION JOINT. A MINIMUM CLEARANCE OF 3" MUST BE MAINTAINED BETWEEN DOWEL BARS AND LONGITUDINAL JOINT OR PAVEMENT EDGE.

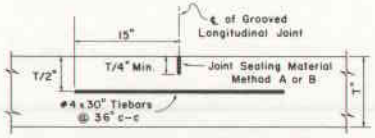


TRANSVERSE CONTRACTION JOINT
Section X-X



LONGITUDINAL CONSTRUCTION JOINT
Section Z-Z

** WITH THE APPROVAL OF THE ENGINEER, MULTIPLE PIECE TIEBARS (THREADED COUPLING OR OTHER ADEQUATE DEVICE) MAY BE USED TO FACILITATE CONSTRUCTION PROVIDED THE SYSTEM DEVELOPS A FORCE EQUAL TO 1 1/2 TIMES THE MINIMUM FORCE OF THE TIEBAR SHOWN. THE SPACINGS FOR THE SYSTEM SHALL BE LESS THAN OR EQUAL TO THE SPACING ALLOWED FOR BARS OF SIMILAR YIELD STRENGTH.



GROOVED LONGITUDINAL JOINT
Section Z-Z

GENERAL NOTES

1. NO EXPANSION JOINTS WILL BE USED EXCEPT AT STRUCTURE ENDS OR FIXED OBJECTS AS SHOWN ELSEWHERE IN THE PLANS.
2. FOR FURTHER INFORMATION REGARDING THE PLACEMENT OF CONCRETE AND LOAD TRANSFER DEVICES REFER TO THE GOVERNING SPECIFICATIONS FOR "CONCRETE PAVEMENT".
3. DETAILS AS TO PAVEMENT WIDTH, PAVEMENT THICKNESS, AND THE CROWN CROSS-SLOPE SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
4. JOINT GROOVE AND SEAL DETAILS SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
5. TIEBARS SHALL BE SECURED PARALLEL TO THE PAVEMENT SURFACE AND PERPENDICULAR TO THE CENTERLINE BY:
   (a) USE OF BAR CHAIRS
   (b) ACCURATELY PLACED IN POSITION ON THE SCREEDED CONCRETE BY MEANS OF AN APPROVED TEMPLATE AND FORCED TO THE PROPER POSITION WITH A SUITABLE TOOL; OR
   (c) BY ANY OTHER MEANS WHICH, PRIOR TO ITS USE, HAS BEEN APPROVED BY THE ENGINEER.
6. DOWEL BARS SHALL BE SECURED PARALLEL TO THE PAVEMENT SURFACE AND CENTERLINE BY A DOWEL BAR CHAIR OR CHAIR ASSEMBLEY.
7. WHEN WORK IS STOPPED DUE TO BREAKDOWN OR OTHER CAUSE, CONCRETE SHALL BE REMOVED BEYOND LAST CONTRACTION JOINT IN PLACE AND A HEADER INSTALLED.
8. WHERE A MONOLITHIC CURB IS SPECIFIED, THE JOINT IN THE CURB SHALL COINCIDE WITH PAVEMENT JOINTS AND MAY BE FORMED BY ANY MEANS WHICH, PRIOR TO ITS USE, HAS BEEN APPROVED BY THE ENGINEER.
9. CONSTRUCTION JOINTS MAY BE FORMED BY USE OF METAL OR WOOD FORMS EQUAL IN DEPTH TO THE NOMINAL DEPTH OF THE PAVEMENT, OR BY OTHER MEANS WHICH HAVE BEEN APPROVED BY THE ENGINEER PRIOR TO THEIR USE.
10. STEEL SPACING SHALL NOT VARY MORE THAN ONE TWELFTH OF THE SPACING SHOWN HEREON.
11. THE TIEBAR SPACINGS SHOWN ARE FOR ASTM DESIGNATIONS: A-615, OR A-616, GRADE 60, TIEBARS, WHICH SHALL NOT BE BENT. IF TIEBARS ARE TO BE BENT, THEY SHALL BE STEEL CONFORMING TO ASTM DESIGNATION: A-615, GRADE 40, WITH A CENTER TO CENTER SPACING OF 34 INCHES.

DEPTH OF PAVEMENT (INCHES)	DOWELS (SMOOTH BARS)			TIE BARS
	SIZE AND LENGTH	AVERAGE SPACING (INCHES)	WEIGHT PER FOOT OF JOINT (LBS.)	SPACE AND SIZE
8	1" X 18"	12	4.01	#4X30" @36" C-C
9	1¼" X 20"	12	5.63	" "
10	1¼" X 22"	12	7.65	" "
11	1¼" X 22"	12	7.65	" "
12-14	1¼" X 22"	12	7.65	#5X36" @36" C-C

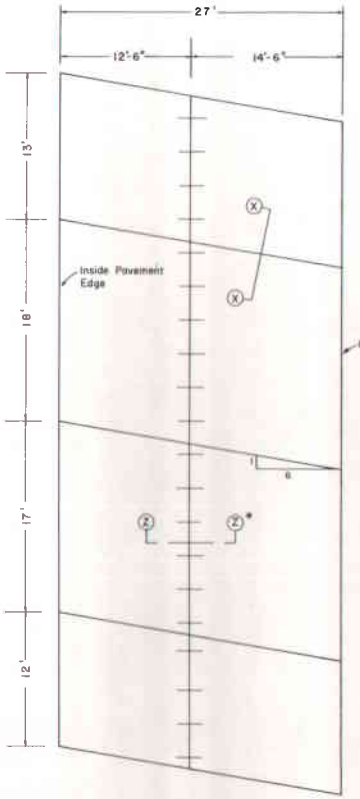
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

CONCRETE PAVEMENT DETAILS
CONTRACTION DESIGN
CPCD-80 (2)

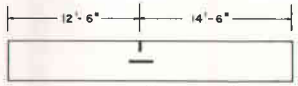
CK.	DRAWING	DATE	FED. ROAD DIV. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK. DN.	ORIGINAL		6	TEXAS		
DN.	REVISED					
CK. DW.	REVISED		STATE DIST. NO.	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
DW.						
CK. TR.						

A-24

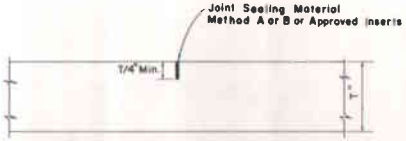
PAVEMENT PLAN



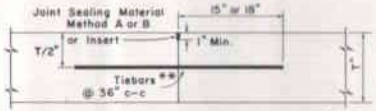
* WITH THE APPROVAL OF THE ENGINEER, THE CONTRACTOR MAY CONSTRUCT IN PLACEMENT WIDTHS OF 12'-6" AND 14'-6". IF SO PLACED THE CHOSEN LONGITUDINAL JOINT SHOWN SHALL BE REPLACED BY A LONGITUDINAL CONSTRUCTION JOINT.



TWO LANE TYPICAL SECTION

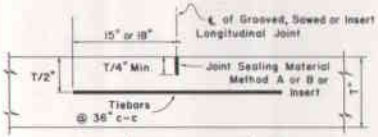


TRANSVERSE CONTRACTION JOINT
Section X-X



LONGITUDINAL CONSTRUCTION JOINT
Section Z-Z

** WITH THE APPROVAL OF THE ENGINEER, MULTIPLE PIECE TIEBARS (THREADED COUPLING OR OTHER ADEQUATE DEVICE) MAY BE USED TO FACILITATE CONSTRUCTION PROVIDED THE SYSTEM DEVELOPS A FORCE EQUAL TO 1 1/2 TIMES THE MINIMUM FORCE OF THE TEBAR SHOWN. THE SPACINGS FOR THE SYSTEM SHALL BE LESS THAN OR EQUAL TO THE SPACING ALLOWED FOR BARS OF SIMILAR YIELD STRENGTH.



LONGITUDINAL JOINT
Section Z-Z

GENERAL NOTES

1. NO EXPANSION JOINTS WILL BE USED EXCEPT AT STRUCTURE ENDS OF FIXED OBJECTS AS SHOWN ELSEWHERE IN THE PLANS.
2. FOR FURTHER INFORMATION REGARDING THE PLACEMENT OF CONCRETE REFER TO THE GOVERNING SPECIFICATIONS FOR "CONCRETE PAVEMENT".
3. DETAILS AS TO PAVEMENT WIDTH, PAVEMENT THICKNESS, AND THE CROWN CROSS-SLOPE SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
4. JOINT GROOVE AND SEAL DETAILS SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
5. TIEBARS SHALL BE SECURED PARALLEL TO THE PAVEMENT SURFACE AND PERPENDICULAR TO THE CENTERLINE BY:
   (a) USE OF BAR CHAIRS
   (b) ACCURATELY PLACED IN POSITION ON THE SCREEDED CONCRETE BY MEANS OF AN APPROVED TEMPLATE AND FORCED TO THE PROPER POSITION WITH A SUITABLE TOOL; OR
   (c) BY ANY OTHER MEANS WHICH, PRIOR TO ITS USE, HAS BEEN APPROVED BY THE ENGINEER.
6. TIEBAR SHALL NEVER CROSS SKEWED TRANSVERSE JOINTS. TO INSURE THIS THE CONTRACTOR MAY VARY THE SPACING OF TIEBARS NEAR THESE JOINTS ± 6 INCHES.
7. WHEN WORK IS STOPPED DUE TO BREAKDOWN OR OTHER CAUSE, CONCRETE SHALL BE REMOVED BEYOND LAST CONTRACTION JOINT IN PLACE AND A HEADER INSTALLED.
8. WHERE A MONOLITHIC CURB IS SPECIFIED, THE JOINT IN THE CURB SHALL COINCIDE WITH PAVEMENT JOINTS AND MAY BE FORMED BY ANY MEANS WHICH, PRIOR TO ITS USE, HAS BEEN APPROVED BY THE ENGINEER.
9. CONSTRUCTION JOINTS MAY BE FORMED BY USE OF METAL OR WOOD FORMS EQUAL IN DEPTH TO THE NOMINAL DEPTH OF THE PAVEMENT, OR BY OTHER MEANS WHICH HAVE BEEN APPROVED BY THE ENGINEER PRIOR TO THEIR USE.
10. STEEL SPACING SHALL NOT VARY MORE THAN ONE TWELFTH OF THE SPACING SHOWN HEREON.
11. THE TIEBAR SPACINGS SHOWN ARE FOR ASTM DESIGNATIONS: A-615, OR A-616, GRADE 60, TIEBARS, WHICH SHALL NOT BE BENT. IF TIEBARS ARE TO BE BENT, THEY SHALL BE STEEL CONFORMING TO ASTM DESIGNATION: A-615, GRADE 40, WITH A CENTER TO CENTER SPACING OF 24 INCHES.
12. JOINT SPACING OF 13'-18'-17'-12' SHALL BE A REPEATED PATTERN. WHERE THE SKEWED CONCRETE PAVEMENT IS TERMINATED THE END OF THE LAST SLAB SHALL BE PERPENDICULAR TO THE CENTERLINE OF THE ROADWAY. THE SPACING OF THE TRANSVERSE JOINTS WILL BE ADJUSTED SO THAT THE MINIMUM SLAB LENGTH WILL BE 8 FT.
13. THE LONGITUDINAL AND TRANSVERSE JOINT SHALL BE SAWED, GROOVED OR FORMED BY APPROVED INSERT. IF THE JOINT IS SAWED OR GROOVED JOINT SEALING MATERIAL METHOD "A" OR "B" SHALL BE USED.

THICKNESS (T) OF PAVEMENT (INCHES)	TIE BARS			
	SIZE	LENGTH	GRADE	SPACING
6"- 11"	#4	30"	60	36"
12"- 16"	#5	36"	60	36"

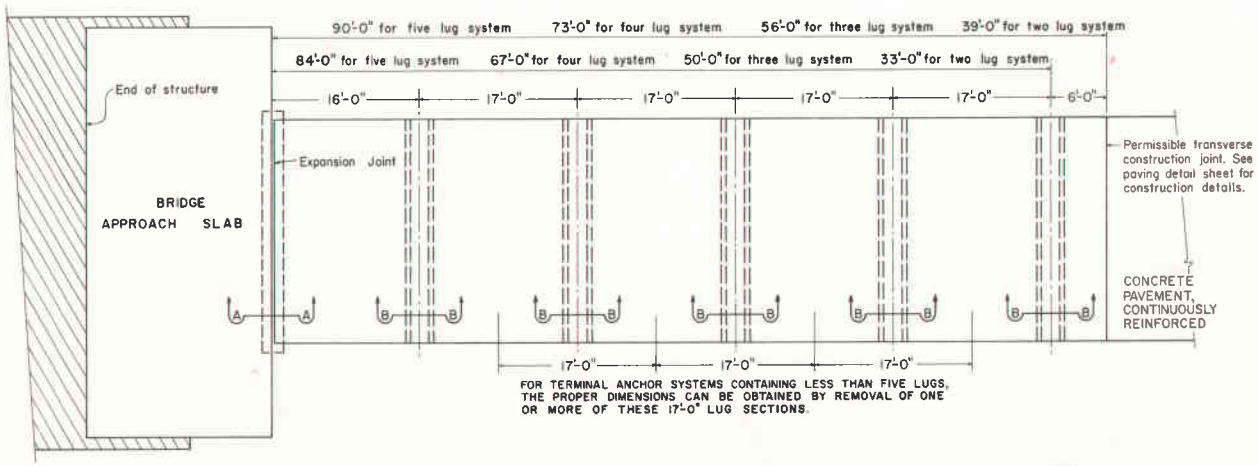
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

CONCRETE PAVEMENT DETAILS

SKEWED TRANSVERSE JOINTS (NO DOWELS)

CPSJ-75

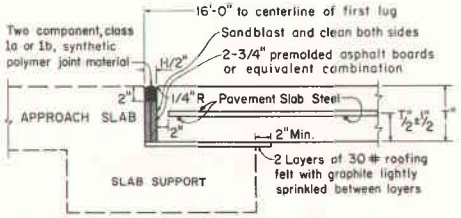
CK	DRAWING	DATE	FED. AID PROJ. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
DN	ORIGINAL			TEXAS		
CK DW	REVISED		STATE DIST. NO.	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
TR						
CK TR						



FOR TERMINAL ANCHOR SYSTEMS CONTAINING LESS THAN FIVE LUGS, THE PROPER DIMENSIONS CAN BE OBTAINED BY REMOVAL OF ONE OR MORE OF THESE 17'-0" LUG SECTIONS.

GENERAL NOTES

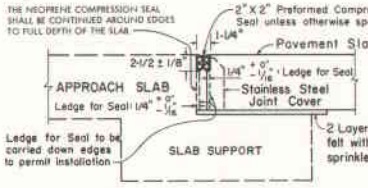
1. THE DETAILS OF THE BRIDGE APPROACH SLAB ARE SHOWN ELSEWHERE IN THE PLANS.
2. THE LOCATIONS OF THE TERMINAL ANCHORAGE SYSTEMS AND NUMBER OF LUGS PER SYSTEM SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
3. DETAILS AS TO PAVEMENT SLAB WIDTH, THICKNESS, AND CROWN CROSS-SLOPE SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
4. THE CONCRETE PAVEMENT SLAB SHALL CONTINUE ACROSS THE ANCHOR LUGS AS SHOWN. ALL REQUIREMENTS AS TO CONSTRUCTION, MEASUREMENT, AND PAYMENT FOR THE PAVEMENT SLABS SHALL BE MADE UNDER THE ITEM "CONCRETE PAVEMENT (CONTINUOUSLY REINFORCED)".
5. REINFORCING STEEL THAT IS NOT A PART OF THE STANDARD PAVEMENT SLAB REINFORCEMENT SHALL BE OF THE SIZE AND SPACING NOTED HEREON AND SHALL BE PAID FOR UNDER THE ITEM "TERMINAL ANCHORAGE (CONCRETE PAVEMENT)". STEEL CONFORMING TO ASTM DESIGNATION: A-615, GRADE 40, OR ANY GRADE OF REINFORCING STEEL APPROVED UNDER THIS ITEM WILL BE PERMITTED EXCEPT THAT STEEL THAT REQUIRES BENDING SHALL BE STEEL CONFORMING TO ASTM DESIGNATION: A-615, GRADE 40.
6. SPLICES IN STEEL CONFORMING TO ASTM DESIGNATION: A-615, GRADE 40, SHALL BE A MINIMUM OF 20 TIMES THE DIAMETER OF THE BAR. SPLICES IN OTHER GRADES OF STEEL SHALL BE AS NOTED ON THE PAVING DETAIL THAT PERMITS ITS USE.
7. DETAILS OF LONGITUDINAL JOINTS (TRANSVERSE JOINTS, IF NECESSARY) AND REQUIRED JOINT SEALS ARE SHOWN ON THE APPROPRIATE PAVING DETAIL SHEET.
8. TRANSVERSE CONSTRUCTION JOINTS WILL NOT BE PERMITTED WITHIN THE LIMITS OF THE ANCHOR LUGS EXCEPT IN AN EMERGENCY STOPPAGE OF THE CONCRETE PLACEMENT AND WITH THE APPROVAL OF THE ENGINEER.
9. THE PERMISSIBLE TRANSVERSE CONSTRUCTION JOINT SHALL BE AS DETAILED ON THE PAVEMENT DETAIL SHEET, BUT MAY BE DELETED IF THE CONTRACTOR ELECTS TO PLACE THE ENTIRE PAVEMENT SLAB IN A SINGLE OPERATION.
10. EXCAVATION FOR, AND CONCRETE USED IN THE ANCHOR LUG SHALL BE PAID FOR UNDER THE ITEM "TERMINAL ANCHORAGE (CONCRETE PAVEMENT)".
11. FOR FURTHER INFORMATION REGARDING THE PLACEMENT OF CONCRETE AND REINFORCING STEEL, REFER TO THE ITEM "TERMINAL ANCHORAGE (CONCRETE PAVEMENT)".
12. DIMENSIONS SHOWN FOR THE SEAT OF THE PREFORMED COMPRESSION SEAL MAY BE MODIFIED TO MORE EFFECTIVELY ACCOMMODATE THE SEAL APPROVED BY THE ENGINEER AND FURNISHED BY THE CONTRACTOR PROVIDED PRIOR APPROVAL IS OBTAINED FROM THE ENGINEER FOR THIS MODIFICATION.
13. IN THE PLANE OF THE STEEL PARALLEL TO THE NEAREST SURFACE OF CONCRETE, BARS SHALL NOT VARY FROM PLAN PLACEMENT BY MORE THAN ONE-TWELFTH OF THE SPACING BETWEEN BARS.



EXPANSION JOINT, METHOD B
THIS OPTION NOT PERMITTED WHEN LUGS ARE NOT USED UNLESS SHOWN ELSEWHERE ON THE PLANS.

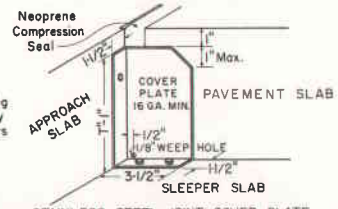
SECTION A-A

NOTE:
THE NEOPRENE COMPRESSION SEAL SHALL BE CONTINUED AROUND EDGES TO FULL DEPTH OF THE SLAB.



EXPANSION JOINT, METHOD A

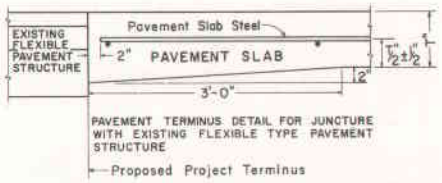
NOTE:
THE STAINLESS STEEL COVER PLATE SHALL BE FASTENED TO THE APPROACH AND SLAB SUPPORT BY MEANS OF BOLTS OR STUDS FIRED INTO THE SLAB OR BY OTHER MEANS APPROVED BY THE ENGINEER. THE PAVEMENT SLAB SHALL BE FREE TO MOVE.



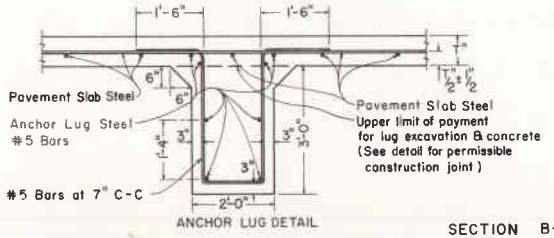
STAINLESS STEEL JOINT COVER PLATE

MATERIAL	ESTIMATING QUANTITIES FOR ANCHOR LUG	
	24 FOOT LENGTH	PER FOOT OF LENGTH
EXCAVATION AND CONCRETE (CU. YD.)	5.56	0.23148
STEEL (LBS)	653	27.369*

* SUBTRACT FOUR LBS. FROM TOTAL TO ALLOW FOR EDGE COVER

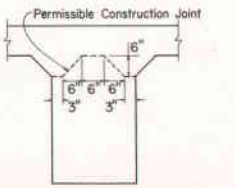


PAVEMENT TERMINUS DETAIL FOR JUNCTURE WITH EXISTING FLEXIBLE TYPE PAVEMENT STRUCTURE

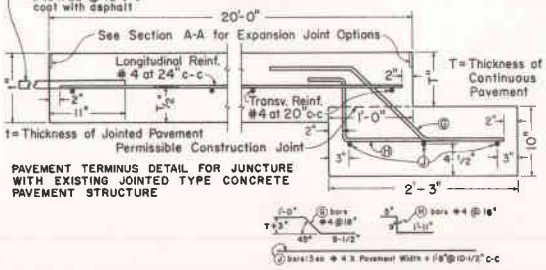


ANCHOR LUG DETAIL

SECTION B-B



ANCHOR LUG DETAIL SHOWING PERMISSIBLE CONSTRUCTION JOINT



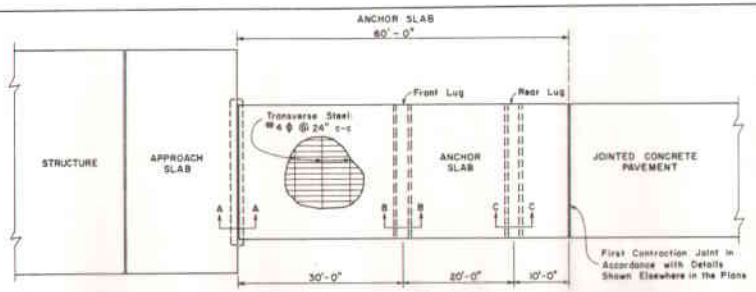
PAVEMENT TERMINUS DETAIL FOR JUNCTURE WITH EXISTING JOINTED TYPE CONCRETE PAVEMENT STRUCTURE

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

TERMINAL ANCHORAGE FOR CONCRETE PAVEMENT CONTINUOUSLY REINFORCED TA(CPCR)-69

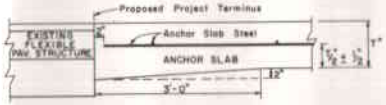
CH.	DRAWING	DATE	FED. AID PROJ. NO.	STATE	FEDERAL PROJECT NO.				SHEET NO.
LA. DIV.	ORIGINAL		6	TEXAS					
DIR.	REVISED								
CH. ENG.	REVISED		STATE CONTROL	COUNTY		CONT.	SECT.	JOB	HIGHWAY NO.
TA									
CH. TYP.									

A-25

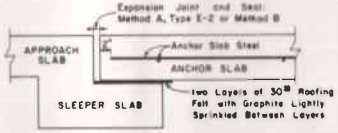


PLAN VIEW

SECTION

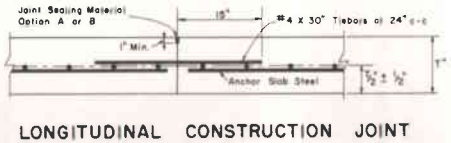


PAVEMENT TERMINUS DETAIL FOR JUNCTURE WITH EXISTING FLEXIBLE TYPE PAVEMENT STRUCTURE

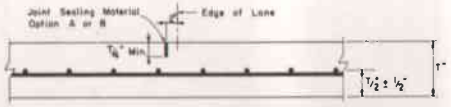


PAVEMENT TERMINUS DETAIL FOR JUNCTURE WITH APPROACH SLAB AND STRUCTURE

SECTION A-A

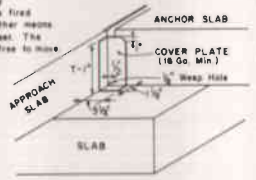


LONGITUDINAL CONSTRUCTION JOINT



GROOVED LONGITUDINAL JOINT

NOTE: The Stainless Steel Cover Plate shall be fastened to the Approach and Slab by means of Bolts or Studs fired into the Slab or by other means approved by the Engineer. The Anchor Slab shall be free to move



STAINLESS STEEL JOINT COVER PLATE
(Required for use with Compression Seal)

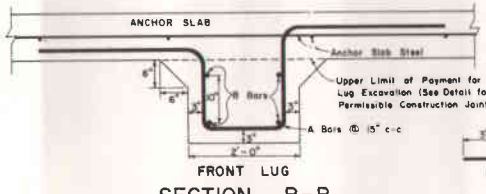
GENERAL NOTES

1. THE DETAILS OF THE BRIDGE APPROACH SLAB ARE SHOWN ELSEWHERE IN THE PLANS.
2. THE LOCATIONS OF THE TERMINAL ANCHORAGE SYSTEMS AND NUMBER OF LUGS PER SYSTEM SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
3. DETAILS AS TO PAVEMENT SLAB WIDTH, THICKNESS, AND CROWN CROSS-SLOPE SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
4. THE CONCRETE PAVEMENT SLAB SHALL CONTINUE ACROSS THE ANCHOR LUGS AS SHOWN. ALL REQUIREMENTS AS TO CONSTRUCTION, MEASUREMENT, AND PAYMENT FOR THE PAVEMENT SLABS SHALL BE MADE UNDER THE ITEM "CONCRETE PAVEMENT (CONTINUOUSLY REINFORCED)".
5. REINFORCING STEEL THAT IS NOT A PART OF THE STANDARD PAVEMENT SLAB REINFORCEMENT SHALL BE OF THE SIZE AND SPACING NOTED HEREON AND SHALL BE PAID FOR UNDER THE ITEM "TERMINAL ANCHORAGE (CONCRETE PAVEMENT)". STEEL CONFORMING TO ASTM DESIGNATION: A-615, GRADE 40 OR ANY OTHER GRADE OF REINFORCING STEEL APPROVED UNDER THIS ITEM WILL BE PERMITTED EXCEPT THAT STEEL THAT REQUIRES BENDING SHALL BE STEEL CONFORMING TO ASTM DESIGNATION: A-615, GRADE 40.
6. SPLICES IN STEEL CONFORMING TO ASTM DESIGNATION: A-615, GRADE 40, SHALL BE A MINIMUM OF 20 TIMES THE DIAMETER OF THE BAR. SPLICES IN OTHER GRADES OF STEEL SHALL BE AS NOTED ON THE PAVING DETAIL THAT PERMITS ITS USE.
7. DETAILS OF LONGITUDINAL JOINTS (TRANSVERSE JOINTS, IF NECESSARY) AND REQUIRED JOINT SEALS ARE SHOWN ON THE APPROPRIATE PAVING DETAIL SHEET.
8. TRANSVERSE CONSTRUCTION JOINTS WILL NOT BE PERMITTED WITHIN THE LIMITS OF THE ANCHOR LUGS EXCEPT IN AN EMERGENCY STOPPAGE OF THE CONCRETE PLACEMENT AND WITH THE APPROVAL OF THE ENGINEER.
9. THE PERMISSIBLE TRANSVERSE CONSTRUCTION JOINT SHALL BE AS DETAILED ON THE PAVEMENT DETAIL SHEET, BUT MAY BE DELETED IF THE CONTRACTOR ELECTS TO PLACE THE ENTIRE PAVEMENT SLAB IN A SINGLE OPERATION.
10. EXCAVATION FOR, AND CONCRETE USED IN, THE ANCHOR LUG SHALL BE PAID FOR UNDER THE ITEM "TERMINAL ANCHORAGE (CONCRETE PAVEMENT)".
11. FOR FURTHER INFORMATION REGARDING THE PLACEMENT OF CONCRETE AND REINFORCING STEEL, REFER TO THE ITEM "TERMINAL ANCHORAGE (CONCRETE PAVEMENT)".
12. DIMENSIONS SHOWN FOR THE SEAT OF THE PREFORMED COMPRESSION SEAL MAY BE MODIFIED TO MORE EFFECTIVELY ACCOMMODATE THE SEAL APPROVED BY THE ENGINEER AND FURNISHED BY THE CONTRACTOR PROVIDED PRIOR APPROVAL IS OBTAINED FROM THE ENGINEER FOR THIS MODIFICATION.
13. IN THE PLANE OF THE STEEL PARALLEL TO THE NEAREST SURFACE OF CONCRETE, BARS SHALL NOT VARY FROM PLAN PLACEMENT BY MORE THAN ONE-TWELFTH OF THE SPACING BETWEEN BARS.

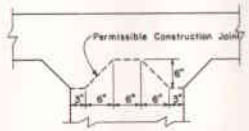
ESTIMATED QUANTITIES FOR ONE 24 FOOT WIDE TERMINAL ANCHORAGE

ITEM	PAVEMENT THICKNESS T(IN.)	CONCRETE (CU. YD.)	STEEL (LBS.)	EXCAVATION (CU. YD.)
FRONT ANCHOR LUG	ALL	2.67		2.67
REAR ANCHOR LUG	ALL	6.22		6.22
ANCHOR SLAB	8	35.6 *		0
	9	40.0 *		0
	10	44.4 *		0

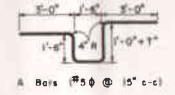
* For pavement terminus with existing flexible pavement structure, the concrete quantity should be increased by 0.2 C.Y. to include the thickened end detail.

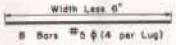


FRONT LUG
SECTION B-B

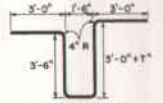


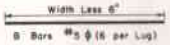
LUG ANCHOR DETAIL SHOWING PERMISSIBLE CONSTRUCTION JOINT





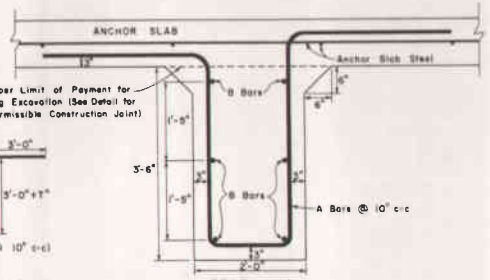
FRONT LUG





REAR LUG

REINFORCING STEEL DETAIL



REAR LUG
SECTION C-C

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

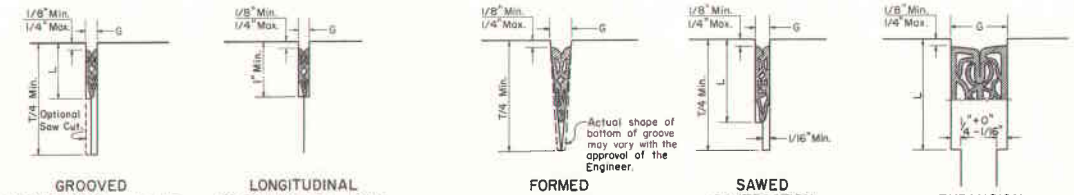
TEXAS HIGHWAY DEPARTMENT
TERMINAL ANCHORAGE
FOR
CONCRETE PAVEMENT
JOINTED
TA(CPJ) - 69

DN.	CK.	DW.	CK.	TR.	CK.

DRAWING	DATE
Original	FEB. 1969

FED. ROAD DIV. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
6	TEXAS		
STATE DIST. NO.	COUNTY	SHEET NO.	HIGHWAY NO.

A-26



GROOVED LONGITUDINAL JOINT (TYPES L-1 or L-2)

LONGITUDINAL CONSTRUCTION JOINT (TYPE L-2)

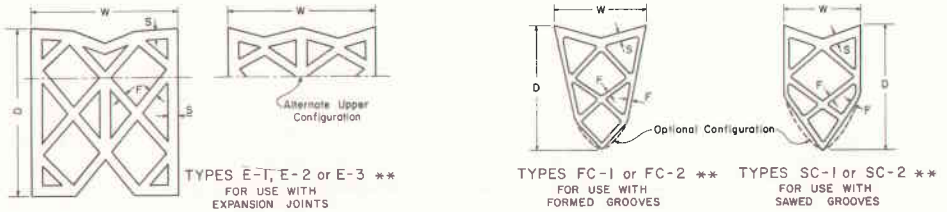
LONGITUDINAL JOINT SEALS

FORMED CONTRACTION JOINT (TYPES FC-1 or FC-2)

SAWED CONTRACTION JOINT (TYPES SC-1 or SC-2)

EXPANSION JOINT (TYPES E-1, E-2 or E-3)

TRANSVERSE JOINT SEALS



TYPES E-1, E-2 or E-3 ** FOR USE WITH EXPANSION JOINTS

TYPES FC-1 or FC-2 ** FOR USE WITH FORMED GROOVES

TYPES SC-1 or SC-2 ** FOR USE WITH SAWED GROOVES

PREFORMED COMPRESSION SEAL TYPES

** See General Note No. 6

METHOD A: PREFORMED COMPRESSION SEALS

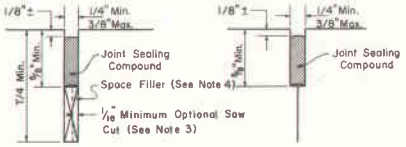
JOINT TYPE	JOINT GROOVE		MINIMUM JOINT SEAL SIZE TO BE USED [2]							SEAL DESIGNATION TYPE
	WIDTH G (In.)	DEPTH L (In.)	WIDTH W (In.)	DEPTH D (In.)	MAX WID AT COMP	THICK. S (In.)	TOLER [3] S (In.)	THICK. F (In.)	TOLER [3] F (In.)	
LONGITUDINAL JOINT	1/8 +1/16 -0	7/8	5/16	5/8	1/8	0.040	-0.005	0.040	-0.005	L-1
	1/4 +1/32 -0	1	7/16	23/32	7/32	0.062	-0.005	0.040	-0.005	L-2
SAWED TRANSVERSE CONTRACTION JOINT	1/4 +1/16 -0	1-1/2	11/16	1-1/8	1/4	0.080	-0.012	0.040	-0.009	SC-1
	3/8 +1/16 -0	1-3/4	13/16	1-1/8	5/16	0.080	-0.012	0.040	-0.009	SC-2
FORMED TRANSVERSE CONTRACTION JOINT	3/8	N/A	13/16	1-1/8	5/16	0.080	-0.012	0.040	-0.009	FC-1
	5/8	N/A	1-1/4	1-1/2	5/8	0.080	-0.012	0.080	-0.012	FC-2
EXPANSION JOINTS	1 *	2-1/8	1-5/8	1-5/8	7/8	0.094	-0.016	0.080	-0.012	E-1
	1-1/4 *	2-3/4	2	2	1	0.125	-0.016	0.110	-0.016	E-2
	1-5/8 *	3-3/8	2-1/2	2-3/4	1-1/4	0.187	-0.016	0.125	-0.016	E-3

* THIS GROOVE WIDTH IS FOR SUMMER CONCRETE PLACEMENT. WHEN CONCRETE IS PLACED DURING THE WINTER SEASON, THIS GROOVE SHALL BE INCREASED 1/8".

1. DUE TO SMALL VARIATIONS IN SEAL SIZES, THIS DIMENSION MAY HAVE TO BE MODIFIED SLIGHTLY TO INSURE PROPER INSTALLATION. THIS DIMENSION IS APPLICABLE ONLY WHEN A STEPPED GROOVE IS USED. N/A: NOT APPLICABLE.
2. THESE DIMENSIONS ARE MINIMUM DIMENSIONS. DIMENSIONS GREATER THAN THOSE SHOWN MAY BE USED IF APPROVED BY THE ENGINEER AND IF THEY PERMIT INSTALLATION IN A WORKMANLIKE MANNER AT NO EXTRA EXPENSE TO THE STATE.
3. ONLY MINIMUM TOLERANCES ARE SHOWN. ANY REASONABLE OVERSIZE WILL BE ACCEPTED PROVIDED PROPER INSTALLATION IS POSSIBLE.

GENERAL NOTES FOR METHOD "A"

1. A SAMPLE OF EACH SIZE AND TYPE OF SEAL PROPOSED FOR USE SHALL BE APPROVED BY THE ENGINEER PRIOR TO INSTALLATION.
2. THE SEALS SHOWN AS METHOD "A" OR METHOD "B" MAY BE USED AT ANY JOINT REQUIRING A SEAL, HOWEVER, THE SAME SEAL SHALL BE USED THROUGHOUT THE PROJECT UNLESS OTHERWISE AUTHORIZED BY THE ENGINEER.
3. LONGITUDINAL JOINTS SHALL BE SAWED STRAIGHT AND TRUE TO LINE AS DETAILED IN THE STANDARD SPECIFICATIONS.
4. TRANSVERSE JOINTS MAY BE SAWED OR FORMED AND SHALL BE PLACED AS SHOWN ELSEWHERE IN THE PLANS.
5. THE SEALS DESIGNATED L-1 AND L-2 SHALL HAVE A CONFIGURATION SIMILAR TO THE TYPE FC OR SC.
** 6. OTHER INTERIOR CONFIGURATIONS MAY BE USED PROVIDED THE MATERIAL MEETS ALL OF THE REQUIREMENTS OF THE SPECIFICATIONS AND AS OTHERWISE SHOWN HEREON OR ELSEWHERE IN THE PLANS. THE NUMBER OF INTERIOR CELLS AND/OR THE THICKNESS OF THE EXTERIOR AND INTERIOR WALLS SHALL BE SUCH AS TO PROVIDE AN ADEQUATE COMPRESSIVE FORCE TO MAINTAIN A POSITIVE SEAL.
7. UNLESS OTHERWISE SPECIFIED, THE SIDES OF THE FORMED CONTRACTION JOINT MAY BE FORMED PARALLEL, BUT IF SO FORMED, THE SEAL SHALL BE AN APPROPRIATE TYPE SC SEAL APPROVED BY THE ENGINEER.
8. UNLESS THE GROOVE AND SEAL COMBINATION IS SPECIFICALLY DESIGNATED ELSEWHERE IN THE PLANS, ANY GROOVE AND SEAL COMBINATION SHOWN IN THE TABLE FOR A PARTICULAR TYPE JOINT MAY BE USED, BUT MUST BE APPROVED BY THE ENGINEER.

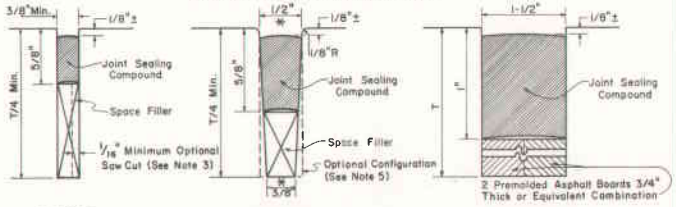


GROOVED LONGITUDINAL JOINT

LONGITUDINAL CONSTRUCTION JOINT

LONGITUDINAL JOINT SEALS

* For Joint Spacing Less Than 20' The Top and Bottom Dimension Shall Be Reduced 1/8".



SAWED CONTRACTION JOINT

FORMED CONTRACTION JOINT (Joint Spacing Greater Than 20')

EXPANSION JOINT

TRANSVERSE JOINT SEALS

METHOD B: JOINT SEALING COMPOUND

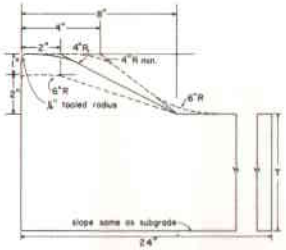
GENERAL NOTES FOR METHOD "B"

1. LONGITUDINAL JOINTS MAY BE SAWED OR FORMED AS DETAILED IN THE STANDARD SPECIFICATIONS.
2. TRANSVERSE JOINTS MAY BE SAWED OR FORMED AND SHALL BE PLACED AS SHOWN ELSEWHERE IN THE PLANS.
3. A SUITABLE SPACE FILLER SHALL BE USED WHERE SHOWN AND THE JOINT SEAL COMPOUND POURED TO THE DEPTH INDICATED EXCEPT THAT IF THE MINIMUM SAW CUT IS USED, THE SPACE FILLER MAY BE DELETED.
4. AT THE OPTION OF THE CONTRACTOR, THE SPACE FILLER MAY BE OMITTED IN THE LONGITUDINAL JOINT ONLY AND THE JOINT SEALING COMPOUND POURED FULL DEPTH.
5. UNLESS OTHERWISE SPECIFIED, THE SIDES OF THE FORMED CONTRACTION JOINT MAY BE FORMED PARALLEL AT THE OPTION OF THE CONTRACTOR.
6. UNLESS OTHERWISE SHOWN IN THE PLANS, EITHER METHOD "A" OR METHOD "B" MAY BE USED.

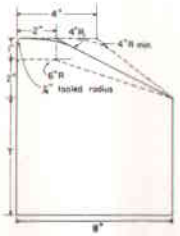
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

CONCRETE PAVING DETAILS
JOINT SEALS
JS-75

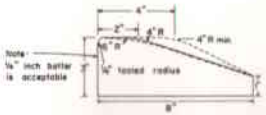
CH.	DRAWING	DATE	FED. RD. DIV. NO.	STATE	FEDERAL PROJECT NO.		SHEET NO.	
CK. CH.	ORIGINAL		6	TEXAS				
DR.	REVISED							
CK. DR.	REVISED		STATE DIST. NO.	COUNTY		CONT.	SECT.	JOB	HIGHWAY NO.
CK.								
CK. TR.								



TYPE I CURB AND GUTTER



TYPE I CURB



TYPE I MONO CURB OR
CURB PLACED ON PAVEMENT

GENERAL NOTES

1. CONTRACTOR MAY USE EXISTING FORMS IF THE CROSS SECTION LIES WITHIN THE BAND SHOWN BY DOTTED LINES. IF NEW FORMS ARE TO BE FABRICATED, LAYED, OR CONSTRUCTED THEY SHALL CONFORM TO THE SOLID LINE.

2. WHEN REINFORCING STEEL IS REQUIRED OR PLACED AT CONTRACTOR'S OPTION, ONE OF THE FOLLOWING SCHEMES OF REINFORCEMENT SHALL BE REQUIRED. THE MANNER OF PLACEMENT AND LOCATION SHALL BE TO THE SATISFACTION OF THE ENGINEER.

   a. TYPE I CURB AND GUTTER (REINF.) OR TYPE II CURB AND GUTTER (REINF.) SHALL HAVE LONGITUDINAL REINFORCING BARS AS FOLLOWS: THREE #3, TWO #4, TWO #5, OR ONE #6.

   b. ALL TYPES OF CURB (REINF.) SHALL HAVE ONE #3 OR #4 BAR FOR LONGITUDINAL REINFORCEMENT.

3. REINFORCING BARS SHALL BE LAPPED A MINIMUM OF 15".

4. WHEN CURB OR CURB AND GUTTER IS PLACED BY A SEPARATE POUR ADJACENT TO OR ATOP CONCRETE PAVEMENT, CURB OR CURB AND GUTTER SHALL BE TIED TO PAVEMENT IN A MANNER SATISFACTORY TO THE ENGINEER WITH 8-INCH LONG #3 OR #4 BARS SPACED AT 5 FEET AND EXPANSION AND/OR CONTRACTION JOINTS OF CURB OR CURB AND GUTTER SHALL MATCH THOSE IN PAVEMENT.

   WHEN CURB OR CURB AND GUTTER IS NOT CONSTRUCTED ADJACENT TO CONCRETE PAVEMENT, THE FOLLOWING SHALL APPLY:

   a. REINFORCED CURB OR CURB AND GUTTER SHALL HAVE NO CONTRACTION JOINTS.

   b. NON-REINFORCED CURB OR CURB AND GUTTER SHALL HAVE FORMED, TOOLED OR SAWED CONTRACTION JOINTS AT 10'±. THE DEPTH OF THESE JOINTS SHALL BE SUFFICIENT TO ENSURE CRACKING AT THE JOINTS.

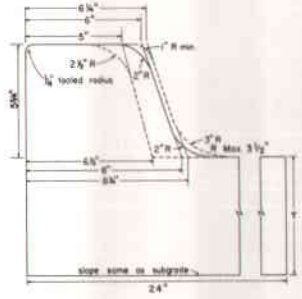
   c. REINFORCED CURB OR CURB AND GUTTER SHALL HAVE EXPANSION JOINTS AT POINTS OF CURVATURE AND AT INTERVALS NO GREATER THAN 120' IN ALL CURVES AND AT STRUCTURES SUCH AS BRIDGES, BOX CULVERTS, CURB INLETS, ETC.

   d. NON-REINFORCED CURB OR CURB AND GUTTER SHALL HAVE EXPANSION JOINTS AT POINTS OF CURVATURE IN CURVES OF RADIUS LESS THAN 25' AND AT STRUCTURES SUCH AS BRIDGES, BOX CULVERTS, CURB INLETS, ETC.

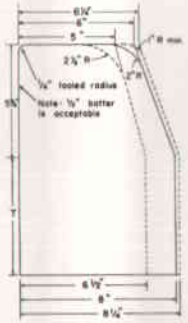
5. ONE-HALF INCH EXPANSION JOINT MATERIAL SHALL BE PROVIDED WHERE CURB OR CURB AND GUTTER IS ADJACENT TO SIDEWALK OR HEADER.

6. TRANSITIONS BETWEEN CURBS OR CURBS AND GUTTERS OF DIFFERING CROSS SECTION SHALL BE ACCOMPLISHED OVER A 20 FT. LENGTH AS APPROVED BY THE ENGINEER.

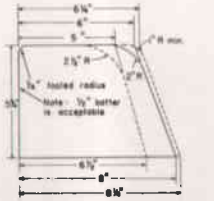
7. AT CONTRACTOR'S OPTION, DIMENSION "T" MAY BE THICKENING OF PAVEMENT STRUCTURE. IN NO CASE SHALL IT BE LESS THAN 6".



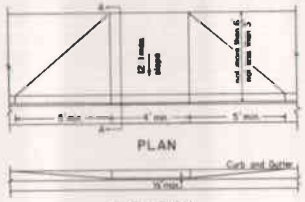
TYPE II CURB AND GUTTER



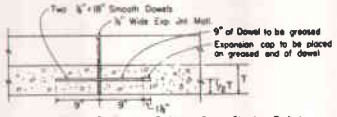
TYPE II CURB



TYPE II MONO CURB OR
CURB PLACED ON PAVEMENT



WHEELCHAIR & BICYCLE RAMP



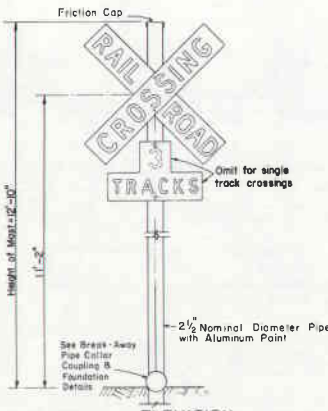
Longitudinal Section thru Curb and Gutter Showing Typical Expansion Joint Details.
Reinforcing steel (when used) shall not cross expansion joints. Steel shall be terminated 3" ± ½" from face of the joint.

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

CONCRETE CURB AND CURB AND GUTTER

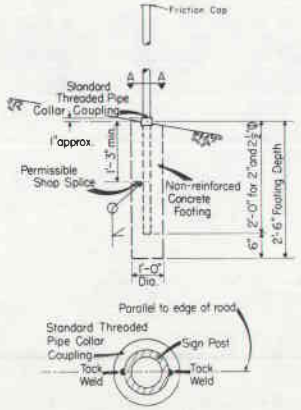
CCCG-75

DN	DRAWING	DATE	FED. AID PROJ. NO.	STATE	FEDERAL PROJECT NO.			SHEET NO.
CK. DN.	ORIGINAL							
DN	REVISED			TEXAS				
CK. DW	REVISED			STATE DISTRICT	COUNTY	CONT.	SECT.	JOB	HIGHWAY NO.
TR								
CK TR								



ELEVATION

REFLECTOR CROSSBUCK SIGN



Tack Welds to be approx. 180° apart

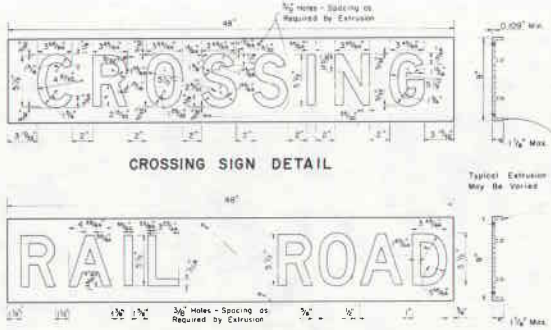
Section A-A

BREAKAWAY PIPE COLLAR COUPLING AND FOUNDATION DETAILS

NOTE

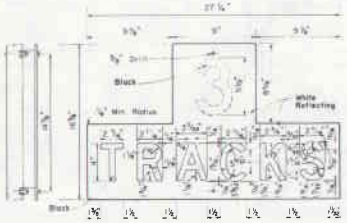
THE CONTRACTOR AT HIS OPTION MAY FURNISH STANDARD WEIGHT PIPE CONFORMING TO ASTM SPECIFICATION A-53B, A-501 OR ANY OTHER STANDARD WEIGHT STEEL PIPE, EITHER OF ELECTRIC RESISTANCE WELDED OR SEAMLESS TYPE, WITH A MINIMUM YIELD STRENGTH OF 35,000 PSI AND A MINIMUM ELONGATION OF 15 PERCENT IN 2 INCHES, AND SHALL HAVE OUTSIDE DIAMETERS AND WALL THICKNESSES WHICH ARE EQUIVALENT TO OR BETTER THAN THOSE SPECIFIED HEREON.

ALL PIPES TO BE WELDED SHALL BE OF WELDABLE QUALITY.



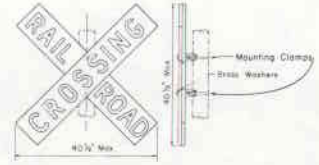
CROSSING SIGN DETAIL

RAILROAD SIGN DETAIL

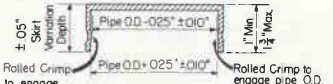


TRACK NUMBER SIGN DETAIL

DETAIL OF NUMBERS



RAILROAD CROSSING SIGN

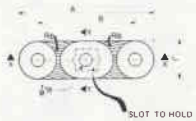


Friction Cap Details

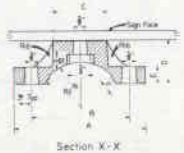
NOTES:
FRICTION CAPS MAY BE MANUFACTURED FROM EITHER HOT ROLLED OR COLD ROLLED STEEL SHEETS. FOR ALL PIPE SIZES THE MINIMUM SHEET METAL THICKNESS SHALL BE 24 GAUGE.

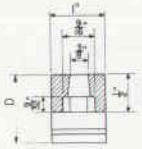
THE RIM EDGES SHALL BE REASONABLY STRAIGHT AND SMOOTH. CAPS SHALL BE SIZED AND FORMED IN SUCH A MANNER AS TO PRODUCE A DRIVE OR FRICTION FIT AND HAVE NO TENDENCY TO ROCK WHEN SEATED ON THE PIPE. THE DEPTH SHALL BE SUFFICIENT TO GIVE POSITIVE PROTECTION AGAINST ENTRANCE OF RAINWATER. THEY SHALL BE FREE OF SHARP CREASES OR INDENTATIONS AND SHOW NO EVIDENCE OF METAL FRACTURE.

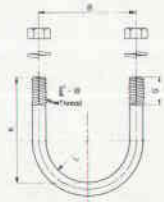
CAPS SHALL HAVE AN ELECTRODEPOSITED COATING OF ZINC IN ACCORDANCE WITH THE REQUIREMENTS OF A.S.T.M. SPECIFICATION A-164, TYPE QS.



SLOT TO HOLD HEAD OF 5/16" SQ. HEAD BOLT. THE BOLT SHALL BE 1" LONG FOR METAL SIGNS AND 1¼" LONG FOR PLYWOOD SIGNS WITH FULL THREAD AND A MEDIUM WASHER. THE HEAD MUST NOT TURN IN SLOT.





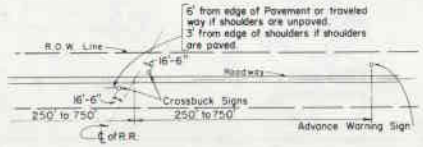


U-BOLT TO BE MADE IN ACCORDANCE WITH STANDARD MANUFACTURING PROCEDURE. 9/32" DIA. STOCK IS PERMISSIBLE. AMERICAN STANDARD REGULAR SEMI-FINISHED HEX. NUTS & SPRING LOCKWASHERS.

Pipe Clamp Casting

PIPE CLAMP CASTING SHALL BE ALUMINIM ALLOY A344-T4 OR 356-F.

ALL SIGN MOUNTING CLAMP PARTS NOT MADE FROM ALUMINUM SHALL BE STAINLESS STEEL OR GALVANIZED STEEL IN CONFORMANCE WITH ITEM 442 OF THE STANDARD SPECIFICATIONS.

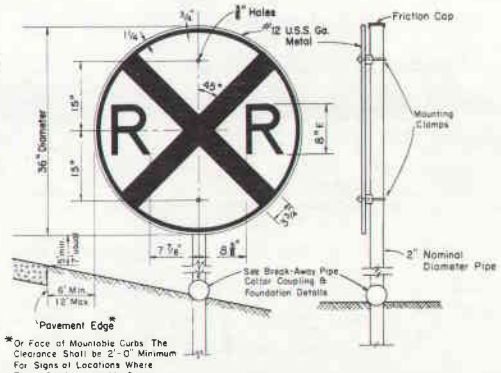


TYPICAL LOCATION SKETCH
METAL SERIES RAILROAD CROSSING SIGNS

Dimensions for Mounting Clamp

Standard Pipe Size	A	B	C	D	E	F	G	K	L	R1	R2
2"	3¾"	2¾"	1½"	1⅛"	½"	3/16"	1"	2 11/16"	1 7/32"	1¼"	1⅜"
2½"	4¼"	3¼"	2"	1¼"	½"	¼"	1"	3⅜"	1 15/32"	1½"	1 7/16"

MOUNTING CLAMP DETAILS



*Or Face of Mountable Curbs. The Clearance Shall be 2'-0" Minimum For Signs at Locations Where There Are Unmountable Curbs

ELEVATION SECTION

The letters, symbol and border shall be black, and the background shall be of yellow reflective material.

ADVANCE WARNING RAILROAD CROSSING SIGN

GENERAL NOTES

CROSSBUCK SIGNS TO BE USED AT LOCATIONS INDICATED ON THE PLANS. CROSSBUCK SIGNS SHALL DISPLAY THE WORDS "RAILROAD CROSSING" IN BLACK LETTERS WITH WHITE BACKGROUND. THE SIGN SHALL FACE TRAFFIC APPROACHING THE NEAR SIDE OF THE CROSSING. ONE SIGN SHALL BE PLACED ON EACH SIDE OF THE RAILROAD CROSSING AS SHOWN BELOW OR ON THE "TYPICAL LOCATION SHEET".

THE TYPICAL LOCATION SKETCH SHOWN HEREON IS INTENDED TO INDICATE MINIMUM ACCEPTABLE CLEARANCES TO RAILROAD AND HIGHWAY. THE EXACT LOCATION SHALL BE AS SHOWN ELSEWHERE ON THESE PLANS OR AS DIRECTED BY THE ENGINEER.

ADVANCE WARNING RAILROAD CROSSING SIGNS TO BE USED AT LOCATIONS INDICATED ON THE PLANS. ADVANCE WARNING SIGNS SHALL NORMALLY BE LOCATED FROM 250' TO 750'. FROM THE RAILROAD CROSSING, THE LOCATION BEING GOVERNED BY THE ANTICIPATED MAXIMUM VEHICULAR SPEED, PROXIMITY OF OTHER SIGNS AND HAZARDS AND VISIBILITY. ADVANCE WARNING SIGNS TO BE LOCATED A MINIMUM OF 6' AND A MAXIMUM OF 12' FROM THE EDGE OF PAVEMENT UNLESS OTHERWISE SPECIFIED ON THE PLANS.

"METAL SERIES RAILROAD CROSSING SIGNS" WILL CONSIST OF TWO CROSSBUCK SIGNS AND MULTIPLE-TRACK SIGNS, IF SUCH MULTIPLE SIGNS ARE REQUIRED.

REFLEX-REFLECTING SHEET MATERIAL SHALL BE USED ON ALL CROSSBUCK SIGN BLANKS. MATERIAL SHALL CONFORM TO THE ITEM "METAL SERIES RAILROAD CROSSING SIGNS" AND ANY SPECIAL PROVISIONS ISSUED.

ADVANCE WARNING SIGN WILL BE FURNISHED AND INSTALLED BY DEPARTMENT MAINTENANCE FORCES.

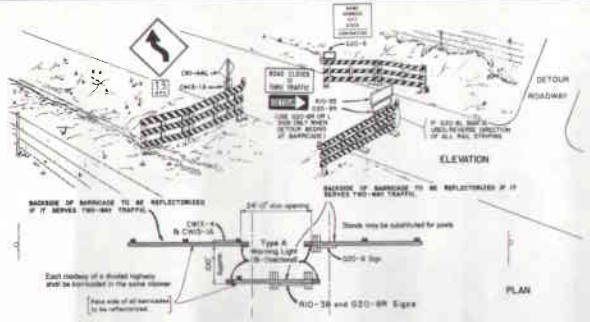
MATERIAL AND FABRICATION SHALL CONFORM TO THE REQUIREMENTS OF DEPARTMENT SPECIFICATIONS AND AMERICAN RAILROAD SIGNAL SPECIFICATIONS.

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

METAL SERIES RAILROAD CROSSING SIGNS (REFLECTORIZED)

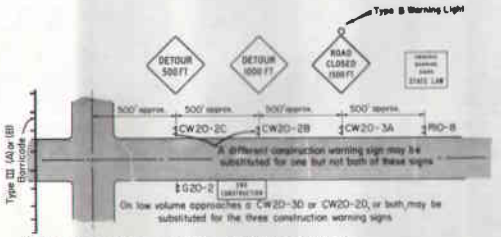
MXS 76

CK	DRAWN	DATE	FED. AID PROJ. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK ON	ORIGINAL			TEXAS		
CK	REVISED	8-1-78				
CK ON	REVISED			COUNTY	CONT. SECT. JOB	HIGHWAY NO.
CK						
CK TR						

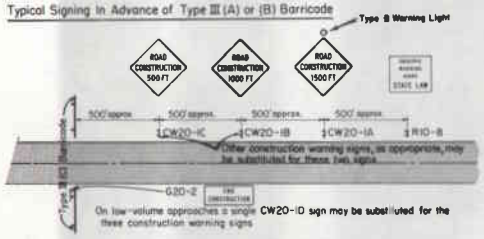


TYPE III(A) BARRICADE

1. The plan shown above is to be used when local traffic is permitted inside project or permitted to use the road beyond the intersection with the temporary route. Other signs and barricades (Type I, II or III) may be required inside the project limits based upon the contractor's sequence of work and other conditions.
2. Where conditions will permit, minimum length of barricade on each side of roadway should be 12 feet
3. First barricade panel on each side of roadway should be approximately level. Additional panels, if needed, may follow contour of right-of-way



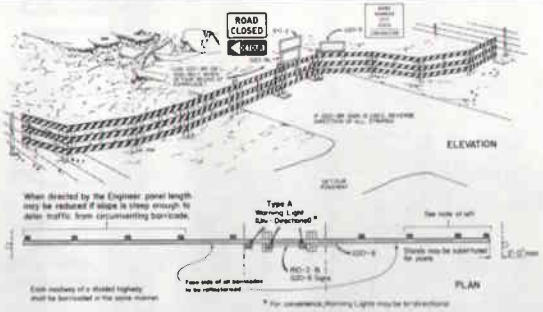
Typical Signing In Advance of Type III (A) or (B) Barricade



Typical Signing In Advance of Type III (C) Barricades

ADVANCE SIGNING--TYPE III BARRICADES

1. Only construction approach signs are shown which are normally erected on fixed supports as defined and illustrated on sheet BC(4)
2. Dimensions shown for location of signs are subject to local conditions.
3. On divided highways where median width will permit and traffic density justifies the advance signing shown above, except for the R10-8, should also be erected on the median side.

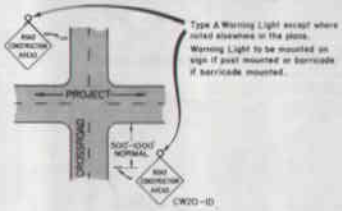


TYPE III(B) BARRICADE

The plan shown above is to be used when no local traffic is permitted inside the project Contractor may locate his access gate anywhere in barricade except at corner of roadway where R10-2 and G20-8 signs must be mounted on fixed barricade section.

GENERAL NOTES FOR TYPE III (A), (B) AND (C) BARRICADES

1. Warning Lights placed on Type III (A), (B), (C) barricades should be Type A Low Intensity Electric Flashers. The color of the light emitted shall be yellow. Flashers should be mounted at a minimum height of 36 inches to the bottom of the lens and may be attached to the barricade or mounted on a separate channelizing device.
2. For dimensions of barricade panels see Construction Details Type III Barricades on Sheet BC (2)

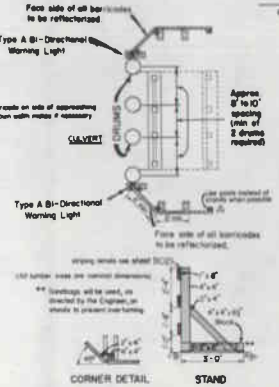


CROSSROAD SIGNING AND BARRICADING

Except as noted below, the minimum signing on a crossroad approach should be one CW20-1D ROAD CONSTRUCTION AHEAD post or barricade mounted sign with a Type B Warning Light except where noted elsewhere in the plans. In rural areas, the sign should be erected a minimum of 500 feet from the intersection. In urban areas, the sign may be closer depending upon the conditions. When work is being performed in the vicinity of the intersection, additional signs such as FLAGMAN AHEAD, LOOSE GRAVEL, or other appropriate signs may be required, and when required, such signs will be considered a part of the minimum requirements.

EXCEPTIONS - TO BE NOTED ELSEWHERE IN THE PLANS

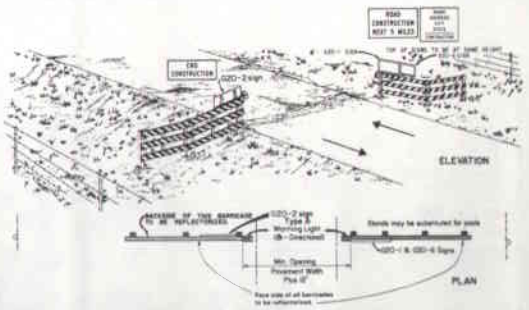
1. On certain types of projects such as Signing and Delineation projects, the CW20-1D sign and warning light will be required, only when work is being performed in the vicinity of the intersection. However, unless such exception is noted elsewhere in the plans, the minimum requirements specified above will prevail.
2. On higher volume roadways or where major construction in the intersection area may require more than normal warning, more signing and barricading than the minimum specified above may be required. In some cases the Type III (c) Barricade plan along with the advance signing may be required during all or certain sequences of the work. However, unless the need for additional signs and/or barricades is noted elsewhere in the plans, the minimum requirements specified above will prevail.



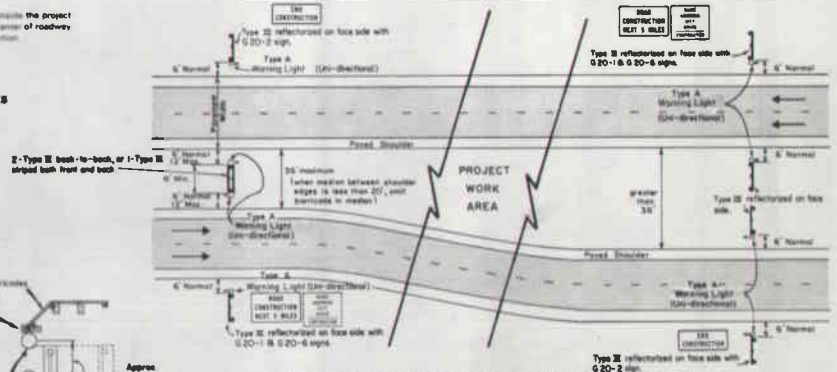
TYPE III(D) BARRICADE
FOR CULVERT WIDENING SITE WITHIN THE PROJECT LIMITS

NOTES

1. Where positive directional capability is provided, drums and barricades may be omitted
2. On streets or roads with posted speeds of 35 MPH or less, Type III Barricades may be used in lieu of barrels where necessary for pedestrian safety.



TYPE III(C) BARRICADE FOR TWO WAY UNDIVIDED ROADWAY



TYPE III(C) BARRICADE FOR DIVIDED HIGHWAYS

NOTES FOR TYPE III (C) BARRICADES

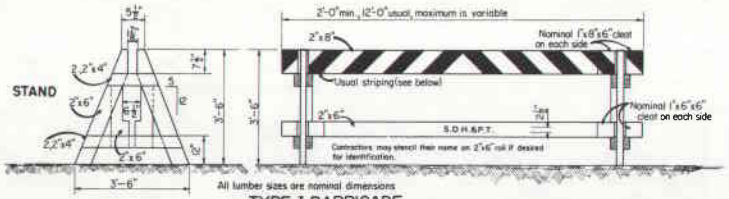
1. The plans shown above are to be used when all traffic is maintained through the project. The signs shown apply to the first and last barricades of a project. Other signs and barricades (Types I, II or III) will be required inside the project limits based upon the contractor's sequence of work and other conditions.
2. Where conditions will permit, minimum length of barricade on each side of roadway should be 12 feet except as noted
3. First barricade panel on each side of roadway should be approximate level. Additional panels, if needed, may follow contour of right-of-way

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

BARRICADE AND CONSTRUCTION STANDARDS

BARRICADE PLACEMENT
BC(1)-79

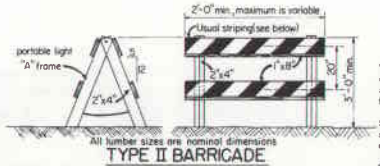
ORIGINAL DRAWING DATE: (-) 70	STATE DISTRICT	FEDERAL AID PROJECT				SHEET
DR.: REVISIONS						
CK.:	COUNTY	CONTROL	SECTION	JOB	HIGHWAY	
DR.:						
CK.:						



TYPE I BARRICADE

For Type I Barricades, both sides of the top rail shall have reflective orange and reflective white striping.

When orange and white stripes are required on the backside, a 2" x 8" rail may be used in lieu of the 1" x 8" rail and 2" x 4" stiffener. Otherwise the rail shall be fabricated as detailed.



TYPE II BARRICADE

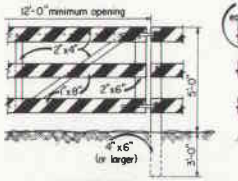
For Type II Barricades, all four (4) rail faces shall have reflective orange and reflective white striping.

STRIPING FOR BARRICADES

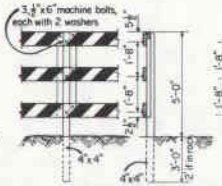
Where a barricade extends entirely across a roadway, it is desirable that the stripes slope downward in the direction toward which traffic must turn in detouring. When both right and left turns are provided for, the chevron striping may slope downward in both directions from the center of the barricade.

Striping shall cover the full width of the rail. Striping of rails, panels and gates for the right side of the roadway is shown above. For the left side of the roadway, striping should slope downward to the right.

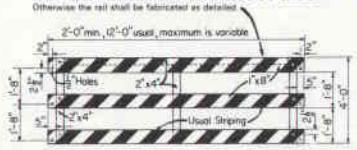
For all types of barricades with rails less than 3'-0" long, stripes 4" wide shall be used.



GATE FOR TYPE III BARRICADE

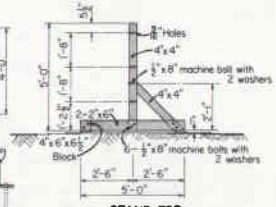


POST FOR TYPE III BARRICADE

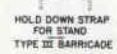


All lumber sizes are nominal dimensions
Fabrication Details ± 1/2"

PANEL FOR TYPE III BARRICADE

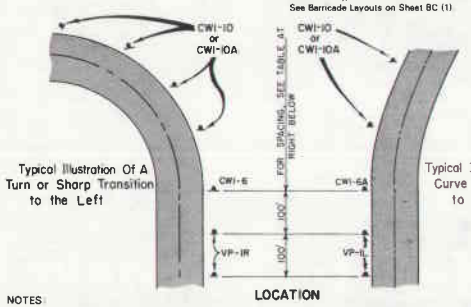


STAND FOR TYPE III BARRICADE



HOLD DOWN STRAP FOR STAND TYPE III BARRICADE

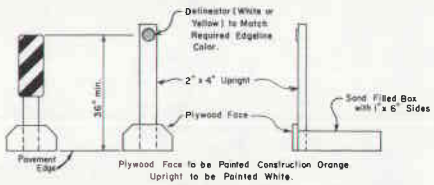
For Type III Barricades, the three (3) rails shall be reflective orange and reflective white stripes on one side if it is facing traffic in one direction only, and on both sides if it serves traffic in two directions. See Barricade Layouts on Sheet BC (1).



LOCATION

NOTES:

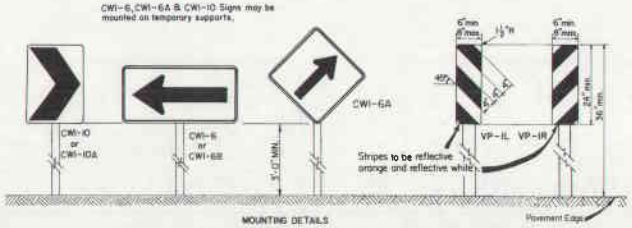
1. For two-way traffic, use same arrangement of signs on outside of curve for each direction of travel.
2. Appropriate Advance Warning Turn or Curve sign with Advisory Speed plaque should be used when needed.
3. For low volume roads (less than 750 V.P.D.) the CW1-10 sign may be used; for other roads, the CW1-10A sign should be used.



Plywood Face to be Painted Construction Orange
Upright to be Painted White.

TYPICAL PORTABLE VERTICAL PANEL OR DELINEATOR MOUNTING

Other similar supports may be used when approved or directed by the Engineer.



MOUNTING DETAILS

CW1-6, CW1-6A & CW1-10 Signs, VP Vertical Panels

CHEVRON ALIGNMENT SIGNS (CW1-10)

The Chevron Alignment sign is intended to provide additional emphasis and guidance for vehicle operators as to changes in horizontal alignment of the roadway.

Chevron Alignment signs, when used, are erected on the outside of a curve, sharp turn on the far side of an intersection, in line with and at right angles to approaching traffic. Spacing of the signs should be as shown in the table below.

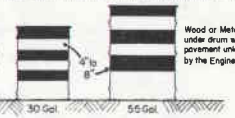
SPACING OF CHEVRON SIGNS AND DELINEATORS

Spacing of chevron signs and Delineators on curves should be according to the Table below. Spacing of delineators on tangent sections should normally be between 100 and 200 feet with the closer spacing for lower speeds and greater spacing for higher speeds.

SPACING FOR CHEVRON SIGNS AND DELINEATORS ON CURVES

Radius of Curve in Feet	Approximate Spacing on Curve in Feet
50	20
150	30
200	35
250	40
300	50
400	55
500	65
600	70
700	75
800	80
900	85
1000	90

DRUMS



Drums, set on end, and used for traffic warning or channelization are normally made of metal and are usually of 30 to 55 gallon capacity. The markings on drums shall be horizontal, circumferential, reflectorized orange and reflectorized white stripes, 4 to 8 inches wide. There shall be at least three orange and two white stripes on each drum. If there are non-reflectorized spaces between the horizontal orange and white stripes, they shall be no more than 2 inches wide and may be painted black or another suitable color. When drums are placed in the roadway, appropriate warning signs should be used. During hours of darkness, a flashing warning light should be placed on drums used singly as a warning device. Steady burn electric lights or delineators should be placed on drums used in series for traffic channelization. Drums should not be weighted with sand, water or other material to the extent that would make them dangerous to motorists.

CW1-10 CHEVRON signs, CW1-6A or CW1-6B ARROW signs or VP-1 Vertical Panels mounted above drums may be used as supplements to drum delineation.

VERTICAL PANELS (VP-1)

Vertical Panels are normally used as channelizing devices to indicate tangent or nearly tangent roadway alignment where good target value of a device is needed in daytime as well as the nighttime. In addition, vertical panels should be used at the edge of shoulder dropoffs and other areas where positive day and night delineation may be required. Vertical panels should be mounted back to back if used at the edge of cuts adjacent to two-way two lane roadways.

PAVEMENT MARKINGS

When required elsewhere in the plans, the Contractor will be responsible for maintaining pavement markings on all roadways that are open to traffic within the limits of the project. On projects involving roadway surfacing which will require pavement marking for control of traffic both during and after construction, the markings may include both standard and temporary markings as defined below:

1. Standard Pavement Markings - Markings placed in conformance with the requirements of the Texas MUTCD. Such markings should be placed on all roadways open to traffic during construction, including new pavement, resurfacing, detours or other roadways where construction activities may have covered or obliterated existing markings. Standard markings should be placed as soon as possible and practical. When it is not practical or possible to place standard markings at the end of each day's work, temporary markings in accordance with the item TEMPORARY PAVEMENT MARKINGS may be utilized for short periods until standard markings can be placed.
2. Temporary Pavement Markings - Abbreviated pavement markings placed to delineate lane continuity until such time as standard pavement markings can be placed. These markings provide lane delineation only and normally are not intended to substitute for standard markings for periods greater than two (2) weeks. To separate traffic flows in opposing directions, the temporary pavement markings shall be yellow. White temporary pavement markings shall be used to delineate the separation of traffic flows in the same direction. Temporary pavement markings shall be in accordance with the item TEMPORARY PAVEMENT MARKINGS.

When temporary pavement markings are used, a DO NOT PASS sign shall be used to mark the beginning of the section where passing is to be prohibited and a PASS WITH CARE sign shall be used to mark the beginning of a section where passing is permitted.

WARNING LIGHTS

Type A Low Intensity Flashing Warning Lights are commonly mounted on barricades, or on other channelization devices, and are intended to warn the driver that he is proceeding in a hazardous area. Their use shall be as specified elsewhere in the plans, on BC(1), or as directed by the Engineer.

Type B High Intensity Flashing Warning Lights are normally mounted on the first Advance Warning Signs at each end of the project. Also extremely hazardous site conditions within the construction area may require that the lights be mounted on barricades, signs, or other supports. As these lights are effective in daylight as well as dark, they are designed to operate 24 hours per day. Their use shall be as specified elsewhere in the plans or as directed by the Engineer.

Type C Steady Burn Lights are intended to supplement other traffic control devices used to delineate the edge of the traveled way on detour curves, on lane changes, on lane closures shoulder drop-offs and on other similar conditions. Delineators may be substituted for steady burn lights.

GENERAL NOTES

REFLECTORIZATION

The reflectorized white and reflectorized orange stripes for barricades, drums and vertical panels shall be constructed of retroreflective sheeting and shall be maintained to meet the requirements for appearance, color and retroreflectivity of the item FLAT SURFACE FLEXIBLE REFLECTIVE SHEETING in the Department's specifications.

BARRICADES

Type I or II Barricades are for temporary use to control traffic within the limits of a project whenever it is necessary to confine traffic to a specific area because of some particular construction operation.

Type I or II Barricades are to be used on city streets which are closed to traffic and as advance warning on streets approaching closed areas. When this barricade is used to close a street, a sufficient number of units shall be used to block the entire street. This barricade may also be used to confine traffic to one side of the street for the protection of workmen, maintenance repairs, open trenches, etc.

Type III(A) Barricades and accompanying signs are to be used at each end of construction projects closed to all but local traffic. The plan on Sheet BC(1) is to be used when local traffic is permitted inside the project or permitted to use the road beyond the intersection with the temporary route.

Type III(B) Barricades and accompanying signs are to be used at each end of construction projects closed to all traffic. The plan on Sheet BC(1) is to be used.

Type III(C) Barricades and accompanying signs are to be used at each end of construction projects where traffic is maintained through the project. The plan on Sheet BC(1) is to be used. In the case of several short sections, which are separated by intervals of considerable distance, each individual section should be barricaded with Type III(C) Barricades. Type III(C) Barricades may also be used where traffic from other highways, county roads or city streets is permitted to enter the project area.

Type III(D) Barricades are to be used on culvert widening projects where traffic is routed over the structure. They shall be erected so as to provide the maximum roadway width for traffic and to allow sufficient space for construction operations behind the barricades.

In all cases the barricades should be as located as to most advantageously warn and direct traffic, and should be within 1,000 feet of the terminus of each section, unless specified otherwise in the plans or by the Engineer.

Barricades used at each end of the project shall be supplemented with warning lights as detailed on BC-(1). For all other barricades, used at night, it is desirable to add flashing warning lights when the barricades are used singly and steady burn lights when the barricades are used in a series. Channelizing devices other than barricades should normally be used for channelization purposes.

Barricades are to be constructed of clean, surfaced, sound lumber cut to the nominal dimensions shown on Sheets BC(1) and BC(2). Barricades shall be of first-class workmanship. All surfaces above ground, which are not striped, shall be painted with an approved brand of white paint to secure thorough coverage and a uniform white color. In no case shall less than two coats be used. Type III Barricades designed for moving or reuse should be erected with bolts. In the construction of legs for Type I or II Barricades, steel may be substituted for lumber, provided that the width of the base is not less than that shown on Sheet BC(2).

The Contractor shall maintain each barricade in a clean and good condition.

Barricades shall be removed upon completion of the work and the elimination of the hazard on any section.

DELINEATORS

Delineators are normally used to indicate roadway alignment where improved nighttime visibility is needed but other roadway features are sufficient for daytime alignment. They should generally be used on high fills and horizontal and vertical curves where only nighttime delineation is needed. Delineators, when required for temporary use to control traffic through construction areas, will be paid for under the item BARRICADE SIGNS AND TRAFFIC HANDLING. Delineators shall meet the material requirements of the item DELINEATORS in the Department's specifications.

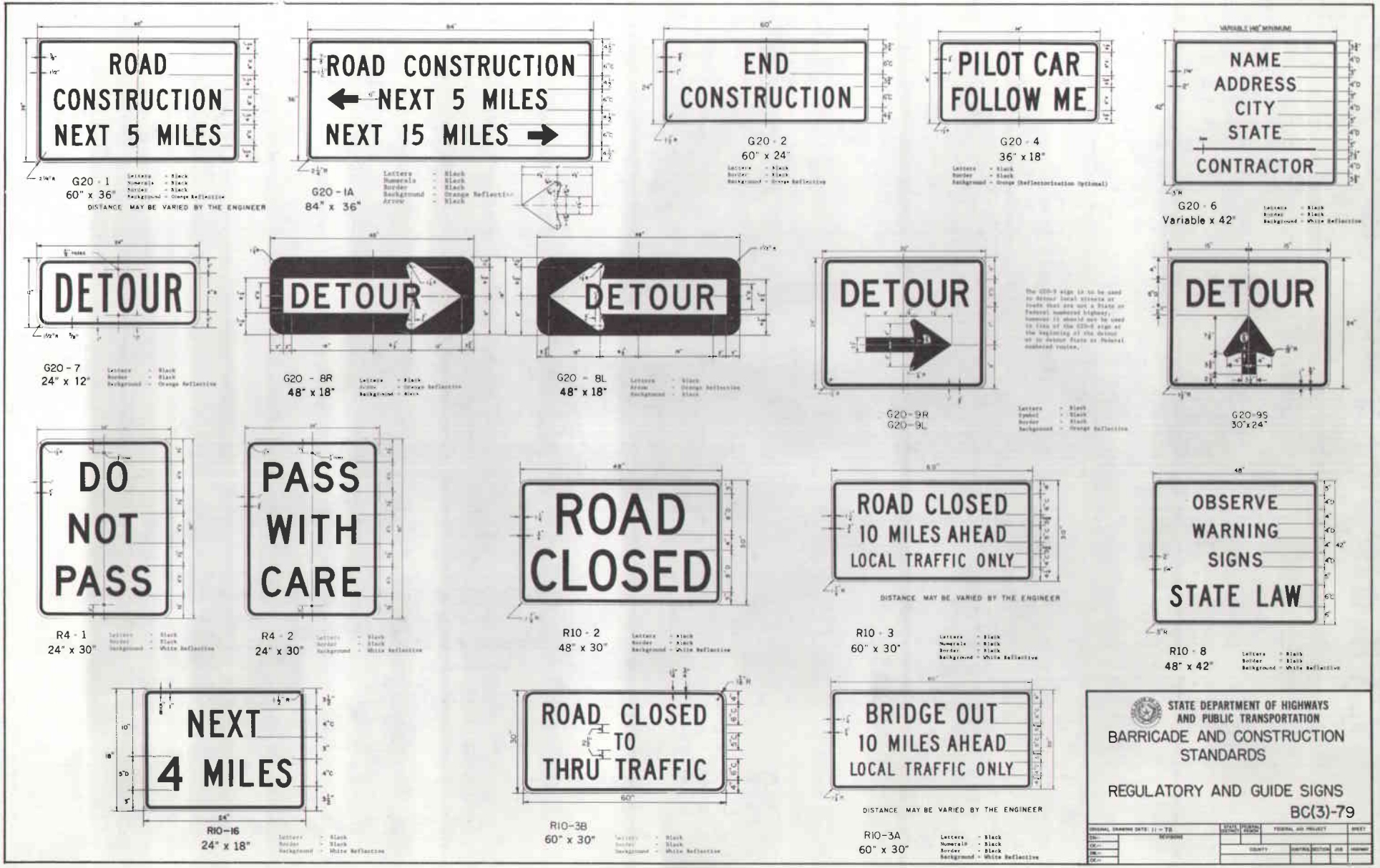
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

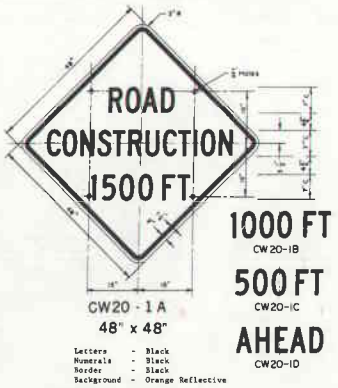
BARRICADE AND CONSTRUCTION STANDARDS

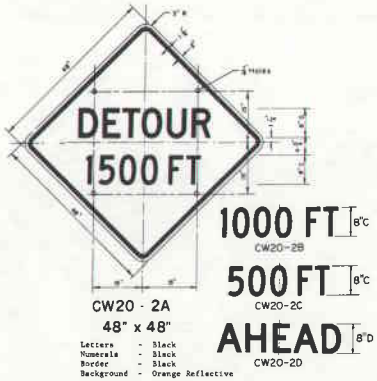
BARRICADE AND CHANNELIZING DEVICES

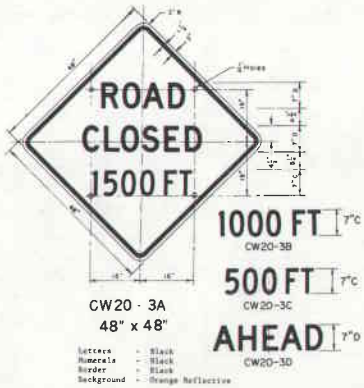
BC(2)-79

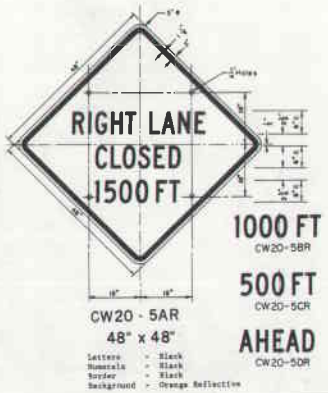
ORIGINAL DRAWING DATE: II-78	STATE DISTRICT	STATE DIVISION	FEDERAL AID PROJECT	SHEET
REVISIONS				
	COUNTY	CONTROL	SECTION	JOB	HIGHWAY

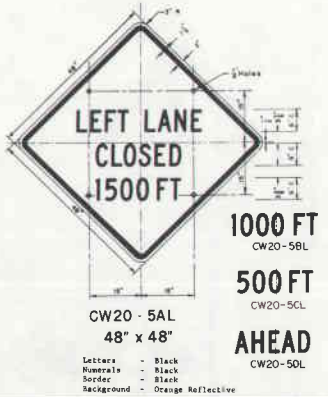

ROAD CONSTRUCTION NEXT 5 MILES
G20 - 1
60" x 36"
DISTANCE MAY BE VARIED BY THE ENGINEER
ROAD CONSTRUCTION
NEXT 5 MILES
NEXT 15 MILES
G20 - 1A
84" x 36"
END CONSTRUCTION
G20 - 2
60" x 24"
PILOT CAR FOLLOW ME
G20 - 4
36" x 18"
NAME
ADDRESS
CITY
STATE
CONTRACTOR
G20 - 6
Variable x 42"
DETOUR
G20 - 7
24" x 12"
DETOUR
G20 - 8R
48" x 18"
DETOUR
G20 - 8L
48" x 18"
DETOUR
G20-9R
G20-9L
DETOUR
G20-9S
30"x24"
DO NOT PASS
R4 - 1
24" x 30"
PASS WITH CARE
R4 - 2
24" x 30"
ROAD CLOSED
R10 - 2
48" x 30"
ROAD CLOSED
10 MILES AHEAD
LOCAL TRAFFIC ONLY
DISTANCE MAY BE VARIED BY THE ENGINEER
R10 - 3
60" x 30"
OBSERVE
WARNING
SIGNS
STATE LAW
R10 - 8
48" x 42"
NEXT
4 MILES
R10-1B
24" x 18"
ROAD CLOSED
TO
THRU TRAFFIC
R10-3B
60" x 30"
BRIDGE OUT
10 MILES AHEAD
LOCAL TRAFFIC ONLY
DISTANCE MAY BE VARIED BY THE ENGINEER
R10-3A
60" x 30"
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
BARRICADE AND CONSTRUCTION STANDARDS
REGULATORY AND GUIDE SIGNS
BC(3)-79

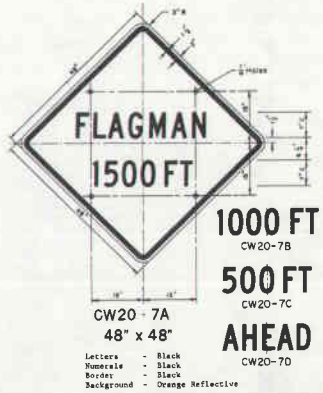












CONSTRUCTION SIGN NOTES

Construction signs shall be made from wood or metal. The designation of metal and wood as primary materials for signs shall not be interpreted to exclude other suitable rigid materials now or hereafter available.

Wood for signs shall be waterproof resinbonded exterior grade plywood, Douglas Fir Plywood Association, or equal, of minimum 1/2 inch thickness. All wood signs made up of 2 or more pieces shall have one or more cleats, 1-2 inch by 6 inch plywood fastened to the back of the sign and extending fully across the sign. On plywood signs cleats shall be used as splice plates running the length of the joints. In localities where untreated wood rots rapidly, it is recommended that wood used for signs be treated either with chromated zinc chloride, Wolman salts, or pentachlorophenol.

Aluminum sign blanks shall have a minimum thickness of 0.080" Steel sign blanks shall have a minimum thickness of 14 gauge.

Reflectorized signs shall be constructed of retro-reflective sheeting and shall be maintained to meet the requirements for appearance, color and retro-reflectivity of the Item FLAT SURFACE FLEXIBLE REFLECTIVE SHEETING in the Department's specifications. Paints and coloration of signs shall be equal to the Department's standards. Signs shall comply with the general requirements specified in the "Standard Specifications for Construction of Highways, Streets and Bridges" in effect at the time of contract award.

All sign lettering shall be clear, open rounded type capital letters as approved by the National Advisory Committee on Uniform Traffic Control Devices and its sponsoring agencies, and as published by the Federal Highway Administration. Signs and lettering shall be of first class workmanship equivalent to that of the Department's standard signs.

Standard signs shall be used as required by Sheets BC(1) and BC(2), the plans, or as directed by the Engineer to regulate, warn, and guide traffic. All sign erection and usage shall be in strict accordance with the "Texas Manual on Uniform Traffic Control Devices for Streets and Highways." The Contractor shall maintain each sign in a clean and good condition.

Signs shall be removed upon completion of the work. Individual warning signs shall be removed, turned away from the view of traffic, or covered whenever the specific danger of which the particular sign warns has ceased to exist, either permanently or temporarily. The sign must be promptly replaced, turned into view, or uncovered when the situation again becomes a potential danger.

Signs erected on portable supports for use on construction projects normally mean signs which are used during the day to warn or guide traffic through and/or around the actual construction area, but at the end of the workday such signs are either removed or turned away from the view of traffic. Portable supports shall be as shown on this sheet or as approved by the Engineer. The bottom of the sign shall be a minimum of one (1) foot above the pavement edge. Signs required for nighttime usage should not normally be mounted on portable supports, except when approved by the Engineer.

Signs erected on fixed supports for use on construction projects normally mean signs that are to remain in place for both day and night usage to regulate, warn and guide traffic in advance of and within the limits of the project including the crossroad approaches. However, under certain conditions, such as where a sign may be required for a few days duration and then is no longer needed or where a sign is moved from location to location every few days or where it is not practical or desirable to provide a fixed mounting, such signs may be erected on a temporary type of support. Temporary supports shall be as shown on this sheet or as approved by the Engineer. Signs erected on temporary supports should be at a minimum height of 2 feet. Signs erected on fixed supports should be at a minimum height of five (5) feet in rural areas and seven (7) feet in urban areas and other rural locations where sight distance obstructions are present. Regardless of the type of support used, regulatory signs should not be erected at height less than the 5 or 7 foot minimum specified above unless a lower height is approved by the Engineer. Posts for fixed supports should be set in the ground without concrete footings.

Where portable or temporary supports require the use of weights to keep a sign or barricade from turning over, the use of some type of sandbag is recommended. The use of pieces of concrete, rocks, iron, steel or other solid objects will not be permitted.

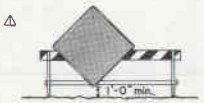
All traffic control devices shall conform with the "Texas Manual on Uniform Traffic Control Devices for Streets and Highways". Contractors shall furnish a copy of a certification from the manufacturer of the lights that the warning lights meet the requirements of the ITE Standard for Flashing and Steady Burn Warning Lights as contained in the latest edition of the "Texas Manual on Uniform Traffic Control Devices for Streets and Highways".

Contractors may use either the sign designs shown on sheets BC-(3), BC-(4), BC-(5) and BC-(6) or those sign designs shown in the U.S. Department of Transportation's latest edition of "Standard Highway Signs" when the required sign is illustrated in the "Standard Highway Signs" book. All construction type signs provided for in "The Construction & Maintenance Operations Section" of the Texas MUTCD, but not detailed in the plans, may be used when so directed by the Engineer.

TYPICAL SIGN SUPPORTS

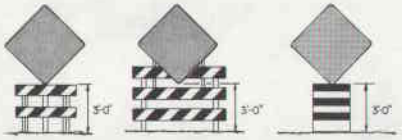
⚠ Other type of portable or temporary sign supports may be used with approval of the ENGINEER.

PORTABLE SUPPORTS ⚠



TYPE I BARRICADE SIGN SUPPORT
Barricade Types I, II or III may be used.

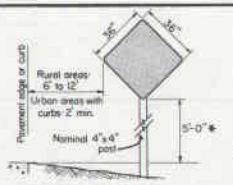
TEMPORARY SUPPORTS ⚠



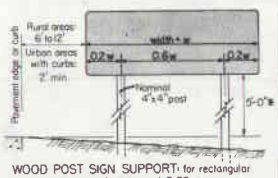
TYPE II BARRICADE SIGN SUPPORT
TYPE III BARRICADE SIGN SUPPORT
DRUM SIGN SUPPORT

FIXED SUPPORTS

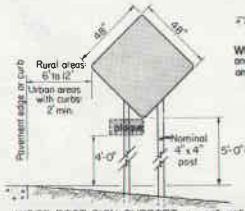
* Where sight distance obstructions are present, or where signs are erected in urban areas, the 5'-0" height should be increased to 7'-0".



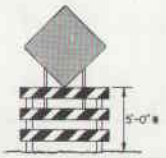
WOOD POST SIGN SUPPORT for 36"x36" and smaller warning signs, and other signs having an area not exceeding 9 sq. ft.



WOOD POST SIGN SUPPORT for rectangular regulatory signs, guide signs, and D 20 signs.



WOOD POST SIGN SUPPORT for 48"x48" warning signs.



TYPE III BARRICADE SIGN SUPPORT for warning or guide signs.

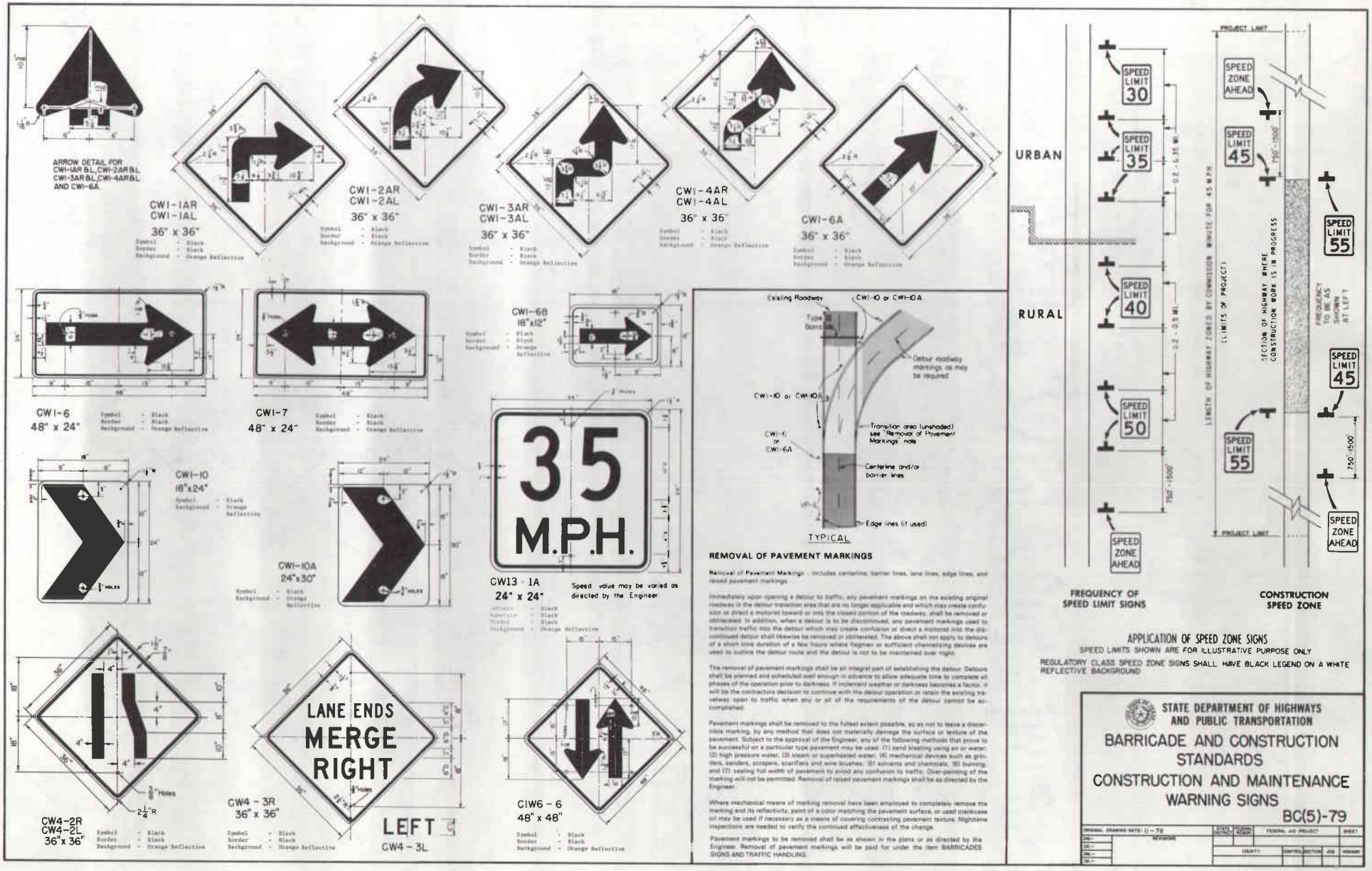
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

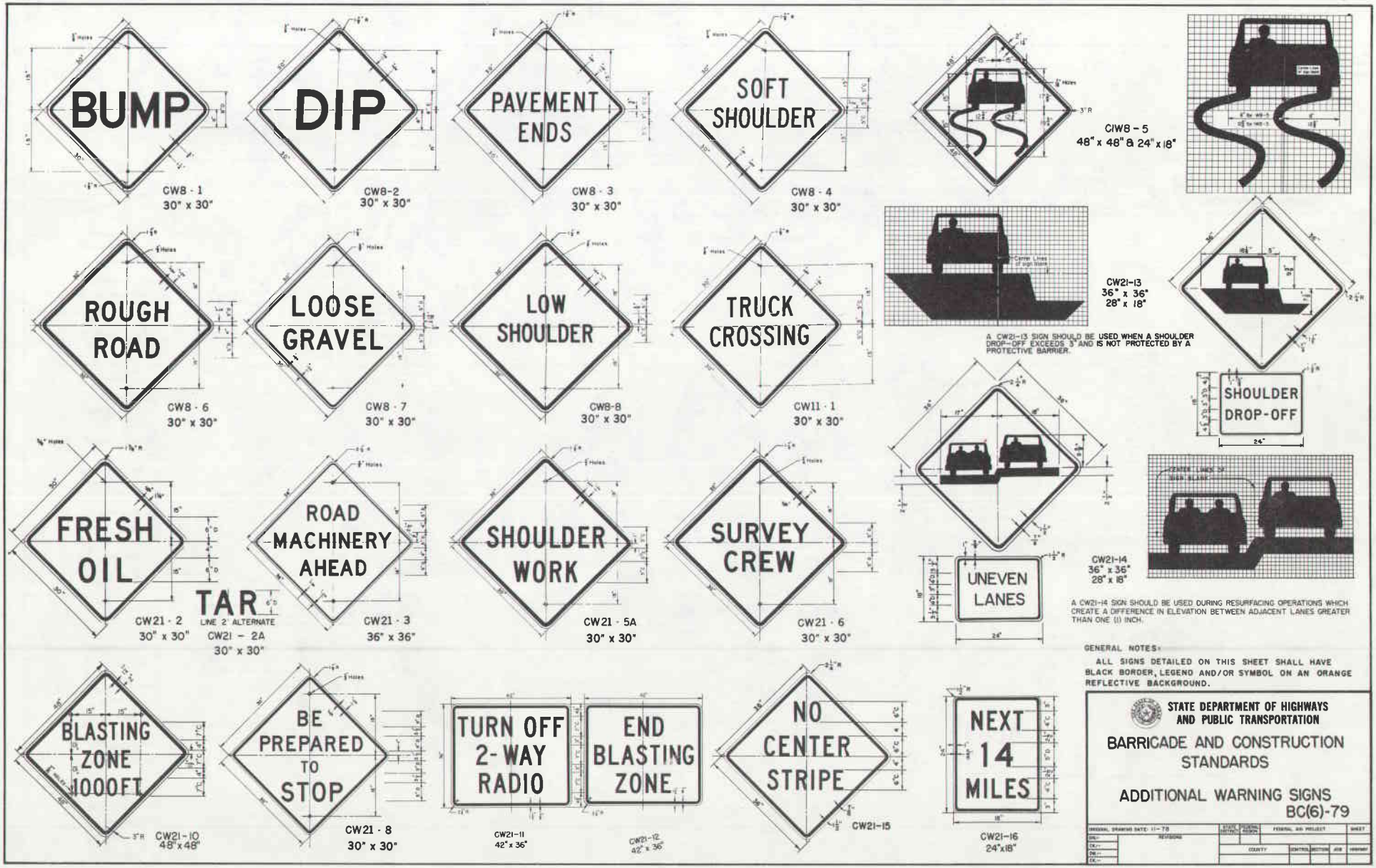
BARRICADE AND CONSTRUCTION STANDARDS

APPROACH WARNING SIGNS

BC(4)-79

ORIGINAL DRAWING DATE: 1-78	STATE DISTRICT	FEDERAL REGION	FEDERAL AID PROJECT	SHEET
REVISIONS				
COUNTY	CONTROL	SECTION	JOB	HIGHWAY

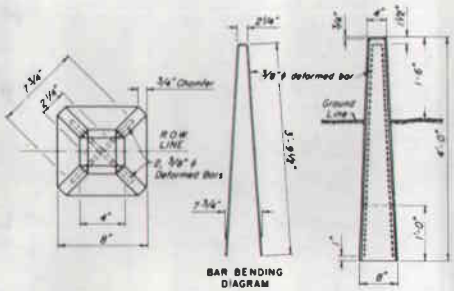

ARROW DETAIL FOR CW1-1AR &L, CW1-2AR &L CW1-3AR &L, CW1-4AR &L AND CW1-6A.
CW1-1AR
CW1-1AL
36" x 36"
CW1-2AR
CW1-2AL
36" x 36"
CW1-3AR
CW1-3AL
36" x 36"
CW1-4AR
CW1-4AL
36" x 36"
CW1-6A
36" x 36"
CW1-6
48" x 24"
CW1-7
48" x 24"
CW1-6B
18"x12"
CW1-10
18"x24"
CW1-10A
24"x30"
35
M.P.H.
CW13 - 1A
24" x 24"
Speed value may be varied as directed by the Engineer
Existing Roadway
CW1-10 or CW1-10A
Type III Barricade
Detour roadway markings as may be required
Transition area (unshaded) see "Removal of Pavement Markings" note
CW1-6 or CW1-6A
Centerline and/or barrier lines
Edge lines (if used)
TYPICAL
REMOVAL OF PAVEMENT MARKINGS
Removal of Pavement Markings - includes centerline, barrier lines, lane lines, edge lines, and raised pavement markings.
Immediately upon opening a detour to traffic, any pavement markings on the existing original roadway in the detour transition area that are no longer applicable and which may create confusion or direct a motorist toward or into the closed portion of the roadway, shall be removed or obliterated. In addition, when a detour is to be discontinued, any pavement markings used to transition traffic into the detour which may create confusion or direct a motorist into the discontinued detour shall likewise be removed or obliterated. The above shall not apply to detours of a short time duration of a few hours where flagmen or sufficient channelizing devices are used to outline the detour route and the detour is not to be maintained over night.
The removal of pavement markings shall be an integral part of establishing the detour. Detours shall be planned and scheduled well enough in advance to allow adequate time to complete all phases of the operation prior to darkness. If inclement weather or darkness becomes a factor, it will be the contractors decision to continue with the detour operation or retain the existing roadway open to traffic when any or all of the requirements of the detour cannot be accomplished.
Pavement markings shall be removed to the fullest extent possible, so as not to leave a discernible marking, by any method that does not materially damage the surface or texture of the pavement. Subject to the approval of the Engineer, any of the following methods that prove to be successful on a particular type pavement may be used: (1) sand blasting using air or water; (2) high pressure water, (3) steam or superheated water; (4) mechanical devices such as grinders, sanders, scrapers, scarifiers and wire brushes; (5) solvents and chemicals; (6) burning; and (7) sealing full width of pavement to avoid any confusion to traffic. Over-painting of the marking will not be permitted. Removal of raised pavement markings shall be as directed by the Engineer.
Where mechanical means of marking removal have been employed to completely remove the marking and its reflectivity, paint of a color matching the pavement surface, or used crankcase oil may be used if necessary as a means of covering contrasting pavement texture. Nighttime inspections are needed to verify the continued effectiveness of the change.
Pavement markings to be removed shall be as shown in the plans or as directed by the Engineer. Removal of pavement markings will be paid for under the item BARRICADES SIGNS AND TRAFFIC HANDLING.
URBAN
RURAL
SPEED LIMIT 30
SPEED LIMIT 35
SPEED LIMIT 40
SPEED LIMIT 50
SPEED ZONE AHEAD
0.2 - 0.35 MI.
0.2 - 0.5 MI.
750' -1500'
PROJECT LIMIT
SPEED ZONE AHEAD
SPEED LIMIT 45
SPEED LIMIT 55
LENGTH OF HIGHWAY ZONED BY COMMISSION MINUTE FOR 45 M.P.H. (LIMITS OF PROJECT)
SECTION OF HIGHWAY WHERE CONSTRUCTION WORK IS IN PROGRESS
FREQUENCY TO BE AS SHOWN AT LEFT
SPEED LIMIT 55
SPEED LIMIT 45
750' -1500'
SPEED ZONE AHEAD
PROJECT LIMIT
FREQUENCY OF SPEED LIMIT SIGNS
CONSTRUCTION SPEED ZONE
APPLICATION OF SPEED ZONE SIGNS
SPEED LIMITS SHOWN ARE FOR ILLUSTRATIVE PURPOSE ONLY
REGULATORY CLASS SPEED ZONE SIGNS SHALL HAVE BLACK LEGEND ON A WHITE REFLECTIVE BACKGROUND
CW4-2R
CW4-2L
36"x 36"
CW4 - 3R
36" x 36"
LANE ENDS
MERGE
RIGHT
LEFT
CW4 - 3L
CIW6 - 6
48" x 48"
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
BARRICADE AND CONSTRUCTION STANDARDS
CONSTRUCTION AND MAINTENANCE
WARNING SIGNS
BC(5)-79


BUMP
CW8 - 1
30" x 30"
DIP
CW8-2
30" x 30"
PAVEMENT ENDS
CW8 - 3
30" x 30"
SOFT SHOULDER
CW8 - 4
30" x 30"
CIW8 - 5
48" x 48" & 24" x 18"
ROUGH ROAD
CW8 - 6
30" x 30"
LOOSE GRAVEL
CW8 - 7
30" x 30"
LOW SHOULDER
CW8-8
30" x 30"
TRUCK CROSSING
CW11 - 1
30" x 30"
CW21-13
36" x 36"
28" x 18"
A CW21-13 SIGN SHOULD BE USED WHEN A SHOULDER DROP-OFF EXCEEDS 3" AND IS NOT PROTECTED BY A PROTECTIVE BARRIER.
SHOULDER DROP-OFF
24"
FRESH OIL
TAR
CW21 - 2
30" x 30"
LINE 2" ALTERNATE
CW21 - 2A
30" x 30"
ROAD MACHINERY AHEAD
CW21 - 3
36" x 36"
SHOULDER WORK
CW21 - 5A
30" x 30"
SURVEY CREW
CW21 - 6
30" x 30"
UNEVEN LANES
24"
CW21-14
36" x 36"
28" x 18"
A CW21-14 SIGN SHOULD BE USED DURING RESURFACING OPERATIONS WHICH CREATE A DIFFERENCE IN ELEVATION BETWEEN ADJACENT LANES GREATER THAN ONE (1) INCH.
GENERAL NOTES:
ALL SIGNS DETAILED ON THIS SHEET SHALL HAVE BLACK BORDER, LEGEND AND/OR SYMBOL ON AN ORANGE REFLECTIVE BACKGROUND.
BLASTING ZONE 1000 FT
CW21-10
48" x 48"
BE PREPARED TO STOP
CW21 - 8
30" x 30"
TURN OFF 2-WAY RADIO
CW21-11
42" x 36"
END BLASTING ZONE
CW21-12
42" x 36"
NO CENTER STRIPE
CW21-15
NEXT 14 MILES
CW21-16
24" x 18"
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
BARRICADE AND CONSTRUCTION STANDARDS
ADDITIONAL WARNING SIGNS
BC(6)-79

GENERAL NOTES

THE REQUIREMENTS FOR THE ABSOLUTE VOLUME MIX DESIGN AND THE WEIGHING OF THE INGREDIENTS FOR THE CONCRETE IN ALL MARKERS WILL BE WAIVED. MIXING OF CONCRETE MAY BE ACCOMPLISHED IN ANY MANNER SATISFACTORY TO THE ENGINEER.

THE WORK PERFORMED AND MATERIALS FURNISHED IN CONSTRUCTING RIGHT-OF-WAY MARKERS MEASURED AS PROVIDED IN ITEM 550 OF THE STANDARD SPECIFICATIONS SHALL BE PAID FOR AT CONTRACT UNIT PRICE BID FOR "RIGHT-OF-WAY MARKERS (TYPE I), " OR "RIGHT-OF-WAY MARKERS (TYPE II)."

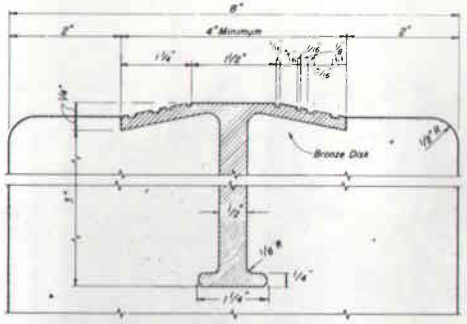


BAR BENDING DIAGRAM

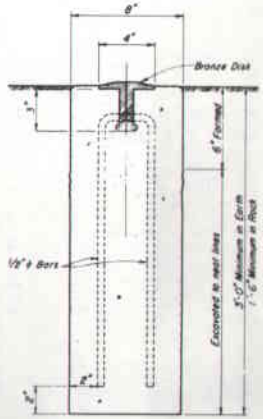
RIGHT-OF-WAY MARKER - TYPE I

Type I Right-of-Way Markers shall be precast concrete, and shall be installed at designated points to the depth, lines, and grades established by the Engineer.

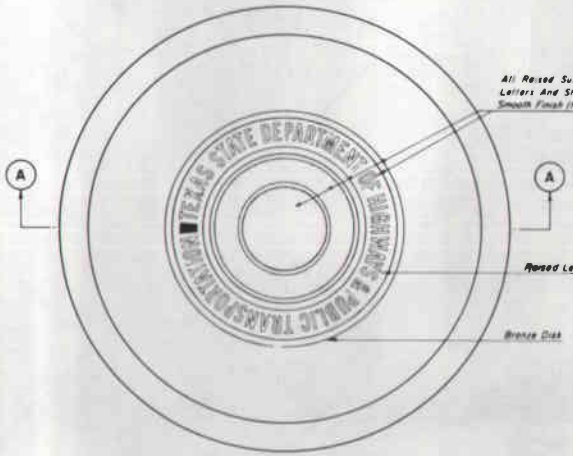
In case the material to be excavated consists of rock or hard clay, this Marker may be shortened 12" if so directed by the Engineer.



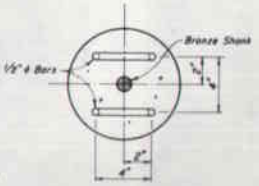
SECTION THRU TOP OF MARKER



SECTION AA



TOP VIEW OF MARKER



CROSS SECTION THRU MARKER

RIGHT-OF-WAY MARKER - TYPE II

TYPE II RIGHT-OF-WAY MARKERS SHALL BE POURED IN PLACE CONCRETE, AND BRONZE DISKS SHALL BE SET TO CORRECT LINE AND GRADE AS DIRECTED BY THE ENGINEER.

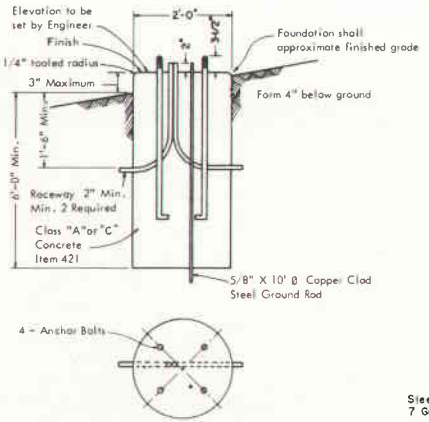
BRONZE DISKS SHALL BE OF ARCHITECTURAL BRONZE HAVING THE FOLLOWING COMPOSITION: COPPER 85%, TIN 5%, LEAD 5%, ZINC 5%. EXCAVATION FOR MARKERS SHALL BE MADE TO NEAT LINES EXCEPT FOR THE TOP 6" OF THE MARKER WHICH SHALL BE FORMED WITH REMOVABLE FORMS OF SHEET METAL OR OTHER SUITABLE MATERIAL. THE TOP PART OF THE MARKER AROUND THE BRONZE DISK SHALL RECEIVE A STEEL TROWEL FINISH. THE BRONZE DISKS WILL BE PURCHASED FROM THE DEPARTMENT AND CHARGED TO THE CONTRACTOR AT A PRICE IN ACCORDANCE WITH THE SPECIAL PROVISION TO ITEM 6 WHICH FORMS A PORTION OF THIS CONTRACT. REIMBURSEMENT TO THE STATE MAY BE ACCOMPLISHED BY MAKING DEDUCTIONS FROM THE CONTRACTOR'S ESTIMATES FOR THE ACTUAL COST OF THE BRONZE DISKS PURCHASED.

AFTER THE CONCRETE HAS TAKEN ITS FINAL SET, THE ENGINEER WILL STENCIL REQUIRED SURVEY DATA AND, WITH CHISEL OR CENTER PUNCH, CUT CROSS MARKING EXACT LOCATION OF RIGHT-OF-WAY LINE IN THE BRONZE DISK.

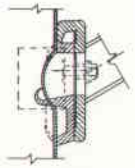
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

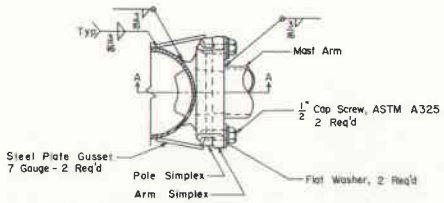
RIGHT-OF-WAY MARKERS M-77

CK	DRAWING	DATE	REVISION NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK DW	ORIGINAL		1	TEXAS		
DW	REVISED					
CK DW	REVISED			STATE DISTRICT	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
TR						
CK TR						

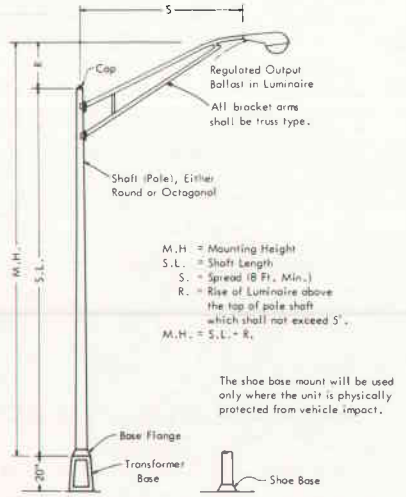


FOUNDATION DETAIL (TYPE A)





MAST ARM TO POLE SHAFT CONNECTION



ROADWAY ILLUMINATION ASSEMBLY

EXPLANATION OF ROADWAY ILLUMINATION ASSEMBLY DESIGNATIONS

Type ST 30 T - 15 - 12 1KW S

First two letters denote material from which pole is fabricated (AL - Aluminum, ST- Steel)

Two numerical digits denote mounting height in feet

Next letter denotes type of base mounting (S - Shoe Base, T - Transformer Base).

First dashed number denotes length of arm in feet. The letter "E" following the dashed number would indicate use of external ballast. No letter indicates ballast located in luminaire.

Use of second mast arm is indicated by second dashed number which denotes length in feet and when followed by the letter "E" would indicate external ballast. No letter indicates ballast located in luminaire.

Size of luminaire is indicated by last figure. (1 KW= 1000 Watts, .4 KW = 400 Watts, etc.)

S - Sodium Vapor
M - Mercury Vapor

GENERAL NOTES:

I SCOPE

Details herein apply to roadway lighting installations bid under the following Specification Items: Roadway Illumination Assemblies, Roadway Illumination Assembly Foundations, Electrical Conductor, Duct Cable, Circuit Protector Assembly, Service Poles, Transformer Stations and Special Specifications relating to lighting and electrical items. All work, materials and services not shown on the plans which may be necessary for complete and proper construction shall be performed, furnished and installed by the Contractor. Faulty fabrication or poor workmanship in any material, equipment and installation will be considered justification for rejection. Materials and installation shall comply with the applicable provisions of the National Electrical Code and National Electrical Manufacturers Association standards.

II MATERIALS

A. General. All materials shall be new and unused and shall be of the latest design.

B. Roadway Illumination Assembly

1. Structural Support Design for Mast-Arm Mounted Luminaires

   a. The complete lighting assembly shall sustain a vertical load of 200 pounds applied at the point of luminaire attachment without failure or permanent deformation of any portion of the assembly. Deflection of the shaft center line shall be not more than 5% of the shaft length when a horizontal load of 500 pounds is applied in any direction 18 inches from the top of the pole. The Engineer may, at any time prior to final acceptance, subject the lighting standards to test loading. Failure of lighting standards to meet the structural requirements herein shall constitute cause for rejection.

   b. Alternately, lighting standards may be designed in accordance with the latest issue of AASHTO's "Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals," using wind loads based on a 50-year mean recurrence interval. The Engineer may require design calculations to be submitted.

2. Slip Joint Poles. Poles having a shaft length in excess of 40 feet may be fabricated in two sections and field-assembled by the lap-joint method. The two sections shall telescope together with a lap length of not less than 1½ times the shaft diameter at the lap joint. The longitudinal seam weld within 13 inches of the slip joint shall be a full penetration weld.

3. Bracket Arm Attachments. All poles shall be fabricated in such a manner that each pole will accommodate any of the various length mast arms. All bracket arms shall be designed for a 66-pound luminaire having a projected area of 2.7 square feet.

4. Minor Damage Repair. The finished pole shall have a smooth, uniform finish free of pits, blisters or other defects. Scratched, chipped, or damaged areas on galvanized poles and mast arms shall be thoroughly cleaned by wire brushing. The cleaned area shall be painted with two coats of zinc dust-zinc oxide paint conforming to the requirements of Federal Specifications TT-P-641b, or repaired by the application of repair compounds meeting Federal Specification O-G93 (stick only) in accordance with the manufacturer's recommendations.

5. Straightness of Shaft. At any time prior to erection the pole shaft may be inspected for straightness. A deviation in excess of 1/4 inch in ten feet shall be considered cause for rejection.

6. Pole Bonding Means. A grounding lug with 1/2 - 13 NC female threads shall be provided inside the pole near the base flange.

7. Hand Holes. All poles for shoe base mounting shall have hand holes with reinforcing frames and covers. The openings on all poles, except poles on CMB, shall be approximately 4" x 6½" located approximately 10 inches from the bottom of the pole and placed 90° to bracket arm unless otherwise noted in plans.

8. CMB Poles. Poles installed on concrete median barrier shall also meet the requirements of CMB details.

9. Steel Poles

   a. Steel poles shall be fabricated in accordance with the Item "Steel Structures." Complete-penetration welds shall be used for pole sections joined by circumferential welds. Longitudinal seam welds for pole sections shall have 60% minimum penetration, except that longitudinal seam welds within six inches of circumferential welds which are complete-penetration welds shall be complete-penetration welds. The pole shaft to base flange connection shall be open-ended to allow proper draining during galvanizing. All welding shall be in accordance with Departmental Construction Bulletin C-5.

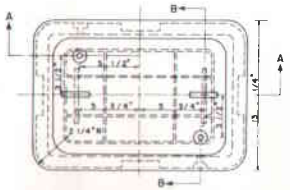
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

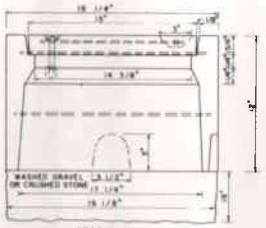
ROADWAY ILLUMINATION DETAILS RID (1)-80

DIST.	DRAWING NO.	DATE	FED. ROAD DIV. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
14 CRP	ORIGINAL					
DIST.			6	TEXAS		
CONTROL			STATE DIST. NO.	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
FILE	REVISED					
CK. BY:						

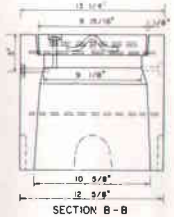
NOTES

1. Concrete shall be class A
2. Body reinforcing - 2 welded frames-No. 3 wire
3. Cover reinforcing - Welded grid - No. 3 wire
4. Cover lift eyes - 3/8" galv. steel - Cast in place
5. Cover hold downs - 3/8" brass rods and nuts
6. Cover lettering - 1" incised letters " ILLUMINATION HIGH VOLTAGE "
7. Use Type I pull box for junctions of up to 8 conductors and/or 4 conduit runs. Use Type II for greater numbers of conductors and conduit runs.



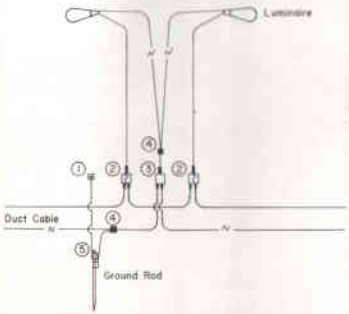


SECTION A - A



SECTION B - B

GROUND BOX (PRECAST CONCRETE)
Type I (13" x 19" x 12")
Type II Similar Except (15" x 25" x 12")

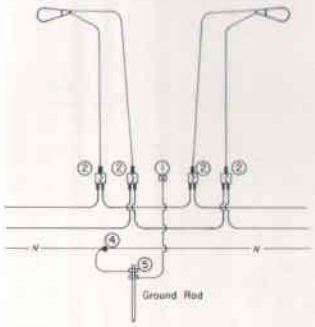


FOR TWO-WIRE GROUNDED CIRCUITS

NOTES:

1. Pole Bonding Connector - Blackburn *TTC3 or Weaver *TGC3 or equal.
2. Fused Connector - Elastimold 825, Joy X8919 or equal.
3. Un-fused Connector - Elastimold 835, Joy X8920 or equal.
4. Split Bolt Connector.
5. Ground Rod Clamp - 2 Required - Blackburn GG5/8H, Burndy GKP635 or equal.

*For Transformer Base Poles. On Shoe Base Poles, connect Luminaire neutral to Pole Bonding Connector.



FOR THREE-WIRE CIRCUIT - CENTER GROUNDED

TYPICAL WIRING - ROADWAY ILLUMINATION ASSEMBLY
Twin Luminaire Shown - Single Luminaire Similar

GENERAL NOTES

b. Pole components shall be constructed using the following material:

Shaft: ASTM A-570 Grade C, ASTM A-607 Grade 45, or ASTM A-595 - galvanized in accordance with ASTM A-123.

Base Flange: ASTM A-181, ASTM A-27 Grade 65-35, or ASTM A-36 - galvanized in accordance with ASTM A-123.

Bracket Attachments: ASTM A-27 Grade 65-35 - galvanized in accordance with ASTM A-153.

Bracket Arms: 2" Pipe ASTM A-53 Grade A or B galvanized in accordance with ASTM A-123.

Cap: ASTM A-27 or ASTM A-48, galvanized in accordance with ASTM A-153; or aluminum alloy ASTM B-26 or B-108 B-443.0 secured by three machine screws.

Pole Hardware: All fasteners, except bracket arm connection bolts, shall be stainless steel or standard steel machine bolts, nuts and washers galvanized ASTM A-153. Bracket Arm attachment bolts shall be ASTM A-325, ASTM A-321, or ASTM A-193 Grade B-7, galvanized ASTM A-153. Screws for attaching hand hole covers shall be treated with anti-seize compound: Never-Seez Compound or Permatex 133K or equal.

Alternate material equal to or better than those specified may be substituted with the approval of the Engineer.

10. Aluminum Poles

a. Aluminum poles shall be fabricated in accordance with AASHTO's "Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals."

b. Pole components shall be constructed using the following material:

Shaft: ASTM B-221 or B-241 6063-T6,ASTM B-209 5086-H34; ASTM B-221 6005-T5.

Base Flange: ASTM B-108 or B-26 356.0-T6; ASTM B-108 A356.0-T6.

Bracket Attachments: ASTM B-209 6061-T6; ASTM B-221 6005-T5.

Bracket Arms: ASTM B-241 6061-T6 or 6063-T6.

Cap: ASTM B-209 5086-H32; ASTM B-108 or B-26 356.0-T6.

Bolts: Stainless Steel AISI 300. Bolts threading into aluminum threads shall be treated with anti-seize compound: Never-Seez Compound or Permatex 133K or equal.

C. Foundations

1. Concrete for foundations will be included for payment under Item "Roadway Illumination Assembly Foundations" only.

2. Anchor bolts shall be steel, ASTM A-36 or ASTM A-576 modified to Grade 50, top and galvanized not less than eight inches. Alternate material equal to or better than those specified may be substituted with the approval of the Engineer.

3. Anchor bolts shall be 1½" x 48" with top threaded not less than 4 inches and furnished with galvanized hexagon nuts, flat and lock washers. The lower end of the bolt shall be bent at a right angle or threaded and furnished with nut and washer. When bolts with rolled threads are furnished, bolt body need not be full size.

4. The bolt circle in foundations for shafts 36 feet and less shall be 15 inches in diameter. The bolt circle in foundations for shafts in excess of 36 feet shall be 17½ inches in diameter if a transformer base is used and 15 inches if a shoe base mounting is used. Poles placed on existing bridge brackets or foundations shall be coordinated with anchor bolts in place.

D. Transformer Base

1. Transformer base shall be cast from aluminum alloy ASTM B-108 or B-26 356.0T6 and shall be furnished with four galvanized anchor lugs ½ inch thick (minimum) and shaped to conform with the transformer base flange. Transformer base shall have a bolt circle at the bottom to match bolt circle of the foundation and a bolt circle at the top to match bolt circle of the pole. The transformer base shall be approximately 20 inches high and shall have a door approximately 13" x 8" x 9¼". Screws or bolts for attachment of door to base shall be treated with anti-seize compound: Never-Seez Compound, Permatex 133K or equal. Four machine bolts with four nuts, eight flat washers and four lock washers, galvanized ASTM A-153, shall be provided with each transformer base.

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

ROADWAY ILLUMINATION DETAILS
RID (2)-80

DRAWING	DATE	FED. AID PROJ. NO.	STATE	FEDERAL PROJECT NO.				SHEET NO.
ORIGINAL			TEXAS					
REVISED								
REVISED		STATE DIST. NO.	COUNTY		CONT.	SECT.	JOB	HIGHWAY NO.
REVISED								

GENERAL NOTES:

2. Transformer bases shall meet the breakaway requirements of AASHTO's "Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals," 1975 edition. Bases that have been modified mechanically (e.g., slotted, notched) shall have been tested to carry the design load for a 90-mph wind. Certification of tests shall be submitted with the shop drawings.

E. All Luminaires

1. The luminaire housing shall be cast or drawn from a non-ferrous alloy and shall be free of cracks and excessive porosity. All nuts, screws, clips, washers and attaching hardware shall be made of stainless steel or steel electro-zinc-plated, minimum thickness 0.0002 inch with olive drab or yellow chromate conversion coating, except that brackets may be made from pre-galvanized steel. All threaded surfaces used in the housing shall be lubricated with a silicone grease.

2. The slipfitter shall securely clamp the luminaire to the mast arm. A positive means of vertical adjustment shall be provided. The refractor shall be crystal-clear pressed glass. The optic assembly shall be provided with resilient gaskets and so constructed that a positive seal against weather and other contaminants will be maintained. The luminaire shall be designed to permit ready removal of the refractor from the luminaire but shall provide a positive means of preventing an unintentional separation. The latch shall provide a positive means of maintaining closure of the luminaire. The socket shell shall be rigidly attached to a high grade porcelain base which shall extend and completely enclose the metal shell. A locking means shall be incorporated in the shell of the socket to positively resist the removal of the lamp.

3. Mast-arm mounted luminaires shall be provided with a leveling device which is clearly visible from the ground. Unless otherwise directed by the Engineer, mast-arm mounted luminaires will be tested and installed in the level position.

4. The underpass luminaire shall have mounting provisions to attach the luminaire directly to the wall or to an outlet box. Wiring entries into the luminaire shall be made through threaded holes or water-tight hubs. Luminaire housing, raceway fittings and attaching hardware shall be installed in such a manner as to prevent water entry into the luminaire or ballast housing. A protective guard shall be provided for the refractor.

F. High Pressure Sodium Vapor Luminaires

1. Photometrics

a. The 250-watt luminaire, when mounted 40 feet above the midpoint of either long side of a rectangular area 200 feet by 50 feet, shall provide a measured minimum intensity of 0.1 footcandle at any point on the surface of this area. Light intensities measured in footcandles along a line parallel to and 20 feet in from the long side of the previously defined rectangular area above which the luminaire is mounted shall decrease at a rate not to exceed 0.8 footcandle in any ten-foot interval along the aforementioned line from 10 to 70 feet on both sides of the luminaire.

The uniformity factor "F" shall be not less than 7.0 when calculated from the equation:

$$F = \frac{L\ (I\ Min.)}{I\ Max.}$$

Where: F = the uniformity factor
L = 200
I Min. = minimum measured intensity within the rectangle
I Max. = maximum measured intensity within the rectangle

b. The 400-watt luminaire, when mounted 50 feet above the midpoint of either long side of a rectangular area 250 feet by 80 feet, shall provide a measured minimum intensity of 0.1 footcandle at any point on the surface of this area. Light intensities measured in footcandles along a line parallel to and 30 feet in from the long side of the previously defined rectangle above which the luminaire is mounted shall decrease at a rate not to exceed 0.8 footcandle in any ten-foot interval along the aforementioned line from 10 to 70 feet on both sides of the luminaire.

The uniformity factor "F" shall be not less than 7.0 when calculated from the equation:

$$F = \frac{L\ (I\ Min.)}{I\ Max.}$$

Where: F = the uniformity factor
L = 250
I Min. = minimum measured intensity within the rectangle
I Max. = maximum measured intensity within the rectangle

c. The luminaires shall meet the photometric requirements of paragraphs F.1a or F.1b when energized at 90 percent of rated line voltage.

2. Ballasts

a. The ballast shall be regulated-type with isolated windings and shall be designed to operate high pressure sodium lamps.

b. When the circuit voltage indicated in the plans is applied, the ballast input wattage during fluctuations of the test voltage of +5 and -10 percent shall not exceed the following:

Nominal Lamp Rating, Watts	Maximum Wattage Input
150	220
250	400
400	552

c. During fluctuation of the test voltage of +5 and -10 percent, the lamp wattage fluctuation shall not exceed a total of 20 percent and ballast shall maintain lamp wattage within the following limits:

Nominal Lamp Watts	Minimum Lamp Watts	Maximum Lamp Watts
150	110	180
250	175	370
400	280	475

d. The power factor of any ballast when tested at circuit voltage indicated in the plans shall be not less than 90 percent.

e. The electronic starting aid shall provide a starting pulse with an amplitude of 2500 volts minimum, 4000 volts maximum. The pulse width shall be a minimum of 0.8 microseconds at 2250 volts. The pulse shall occur when the open-circuit voltage is equal to or greater than 90 percent of peak open-circuit voltage. Pulse repetition rate shall be a minimum of one per cycle and pulse current shall be a minimum of 0.18 amperes. Electronic starting aids for mast-arm mounted poles shall be replaceable without the use of tools.

f. Ballasts shall permanently and clearly indicate the following: lamp type, catalog number, voltage rating, connection diagram, and manufacturer.

3. Lamps

a. All lamps shall be new and shall have been manufactured within six months of the date the project is awarded.

b. High Pressure Sodium vapor lamps in the wattage range of 200 to 400 watts inclusive shall have a lamp voltage not greater than 108 volts when tested after thirty minutes' burn-in.

4. Testing

a. Ballasts and luminaires will be tested using a lamp furnished for the same project.

b. Luminaires, ballasts, and lamps will be sampled and tested in accordance with the Texas Highway Department Manual of Testing Procedures.

G. Wood Poles. For projects requiring more than 10 transformer and/or service poles, poles shall be creosote-treated to eight pounds per cubic foot-retention, or pentacholorophenol-treated to 0.4 pounds per cubic foot-retention in accordance with Item "Timber Preservative and Treatment."

For projects requiring ten or fewer poles, treatment shall be as stated above and Contractor may purchase poles locally if source and treatment are documented. Poles shall meet the requirements of ANSI 05.1-1972.

H. Electrical Conductors

1. All conductors shall be of annealed copper meeting the requirements of ASTM B-3 or B-33, and shall be Class B stranded in accordance with ASTM B-8, except that conductors No. 10 and smaller may be solid.

2. Insulated conductors shall be NEC Types TW, THW, THWN or XHHW. Where project plans specify Type TW or THW, any of the other types may be substituted. Conductors in circuits containing two or more insulated conductors shall be color-coded throughout the entire circuit. Color-coding will be required on pre-conduitised duct cable containing two or more insulated conductors.

3. Insulated conductors shall be marked in accordance with Article 310 of the NEC, and shall meet the requirements of Underwriters Laboratories' Standards.

I. Conduit and Fittings

1. Conduit must be UL Approved for the intended use shown on plan sheets. Aluminum conduit will not be permitted. Where project plans call for rigid metal conduit, NEC Type IMC conduit may be substituted, unless prohibited by plan note.

2. Fittings for Steel conduit shall be steel or malleable iron, threaded or threadless, rain-tight. Die cast, set screw, indenter or push-on (socks) fittings will not be permitted.

3. Insulating-type fittings shall be used on all metallic conduit entries into sheet metal boxes or enclosures.

4. Expansion joints for metallic conduit shall be provided with a grounding strap. Expansion joints shall be Appleton UNYL 50 Series, OZ AX Series or equal, with expansion capacity as shown in plans.

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

ROADWAY ILLUMINATION DETAILS

RID (3) - 80

CK.	DRAWING	DATE	FED.RD. DIV.NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK. DW.	ORIGINAL		6	TEXAS		
DW	REVISED					
CK. DW	REVISED		STATE DIST.NO.	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
DW						
CK. TR						

GENERAL NOTES:

J. Ground Boxes

1. Precast concrete ground boxes shall have minimum inside dimensions of approximately 10" x 17" and at least 10 inches deep. The cover shall be of reinforced concrete or cast iron. The box and cover shall have sufficient strength to support vehicles using the adjacent roadway. A minimum gravel fill of 18 inches shall be provided under each ground box.

2. A plastic ground box meeting the following requirements may be used if permitted by plan note:

   a. It shall be manufactured from Reinforced Plastic Mortar (RPM) composed of borosilicate glass fiber, a catalyzed polyester resin and an aggregate.

   b. Minimum inside dimensions (LxWxH) for Type I: 21" x 12" x 18"; for Type II: 29" x 16" x 26".

   c. RPM ground box shall be designed for a 5000-pound single-wheel load over a 10" x 10" area in accordance with AASHTO specifications.

   d. Cover shall be bolt-down with "ELECTRIC" imprint.

   e. A minimum gravel fill of 18 inches shall be placed under each ground box.

   f. Unless otherwise stateed, ground boxes will not be paid for directly but will be subsidiary to the various bid items.

K. Junction Boxes

1. Junction boxes for use above grade in or on structures shall be cast iron with hot-dipped galvanized finish.

2. Boxes for metallic conduit 1¼" or larger shall be minimum size 6" x 6" x 4", Crouse Hinds Type WAB, O-Z Type YS or equal. For metallic conduit 1" or smaller and conductor size #10 or smaller, boxes shall be 4½" OD round, approximately 2 inches deep, Crouse Hinds Type GRFX, Appleton Type JBDX or equal. For PVC conduit, PVC boxes shall not be used within 8 feet of grade or where exposed to accidental impact. Threaded adapters shall be used to connect PVC conduit to metal boxes. Where protected from accidental impact, PVC boxes of approximately same size as metal boxes may be used.

L. Ground Rods

1. Ground rods shall be steel with a copper-clad surface applied to the steel by the molten-weld process.

2. Ground rod clamps for attaching conductor to rod shall be Blackburn GG5/8H, Weaver W5/8 or equal.

M. Connectors and Splices

1. Quick-disconnect connectors for connecting lighting pole conductors to line shall be Elastimold, Joy or equal.

2. Connector for connecting bonding wire to pole shall be stud-type, Blackburn TTC3, Weaver TGC3 or equal.

3. Connections to neutral or grounded line conductor shall be made with split-bolt or compression connectors. Only two conductors will be allowed per connector.

4. Splices, where permitted by the Engineer, will be made with compression-type sleeves and insulated with thermosetting-compound kit. The neutral or ground wire splice need not be insulated.

III CONSTRUCTION METHODS

A. General. The location of poles, conductors, conduits, junction boxes, transformer stations and service poles is diagrammatic only and may be shifted by the Engineer to accommodate local conditions.

B. Roadway Illumination Assemblies

1. Roadway illumination assembly poles shall be erected plumb and true. Top of foundation shall be struck level and shims used to plumb pole, except that for shoe base poles leveling nuts may be used. Grout will not be placed between base flange and the foundation unless noted on plans. If grout is required by plan note, two 3/8" drain holes will be provided in the grouting.

2. In each pole, continuous, color-coded stranded No. 12 AWG Copper Type TW conductors in accordance with paragraph H.2. shall be connected to the line side of each ballast.

3. A fused connector assembly or fuse-holder as specified shall be connected in each hot wire on the line side of each ballast. Luminaires on poles will be fused using quick-disconnect fuse-holders as shown in details. Underpass luminaires shall be fused internally.

4. For median-mounted poles placed on concrete median barrier, all access plates (hand holes) shall be on same side of the median.

5. Acorn nuts will not be allowed for attaching pole to transformer base or foundation.

C. Duct Cable

1. Duct cable shall be placed by the open trench method, except where otherwise noted, at a depth of approximately 18 inches unless otherwise indicated.

2. All ducts entering ground boxes shall be securely lashed together in a vertical position.

D. Conduit

1. Continuous runs of conduit in excess of 150 feet attached to structures shall have expansion joints at mid-span or 150-foot intervals and at structure expansion joints or as shown in plans.

2. Spacing of conduit hangers shall be as specified in the current issue of the NEC. Hangers shall be Unistrut Series J1200, Globe Series 450 or equal unless otherwise indicated in the plans.

3. Conduit hangers shall not be attached directly to prestressed concrete girders.

4. Conduit placement beneath existing paved surfaces shall be accomplished by jacking or boring in accordance with the pertinent provisions of Article 476.3 "Construction" of the Item "Jacking, Boring or Tunneling Pipe," unless otherwise noted on plans. Jacking, boring, or trenching will not be paid for directly but will be subsidiary to the Item "Conduit." Duct cable shall be extended through the conduit in one continuous length or conductors shall be encased in a continuous length of conduit where passing under an existing roadway. Direct burial of conductor will not be allowed.

E. Circuits and Connections

1. After installation and prior to connecting ends, each continuous length of insulated conductor shall exhitit the following minimum D.C. insulation resistance to ground when tested at 500 volts D.C.:

AWG Size	Megohm Resistance (60°F)
1	336,000 divided by length in feet
2	310,000 " " " " "
4	374,000 " " " " "
6	450,000 " " " " "
8	592,000 " " " " "
10	566,000 " " " " "
12	668,000 " " " " "
14	784,000 " " " " "

All or part of conductors may be tested at the Engineer's direction. The Contractor will not be required to furnish megger for testing. Conductors exhibiting a value less than the above values shall be rejected and shall be replaced by the Contractor at his own expense.

2. Any connection to be taped shall be taped with three half-lapped layers of rubber tape of minimum thickness of 0.030 inch, covered with two half-lapped layers of friction tape or plastic tape.

F. Bonding and Grounding

1. Contractor shall insure that all exposed metal containing electrical conductors is bonded and grounded, using ground rods, grounding bushings and locknuts and other fittings as necessary.

2. Conduit and luminaires on structures shall be grounded by installing a 5/8" by 10-foot ground rod near the point at which the circuit enters the structure and connecting a No. 10 AWG solid grounding conductor to the conduit if conduit is metal. For non-metallic conduit in or on structure, a No. 10 AWG solid conductor shall be installed from the ground rod to each underpass luminaire or structure-mounted lighting pole. Ground rods, connectors and other items necessary for grounding will not be paid for directly but will be subsidiary to the Item "Conduit."

3. Lightning arrester grounding conductor shall be tied directly to the pole-grounding conductor.

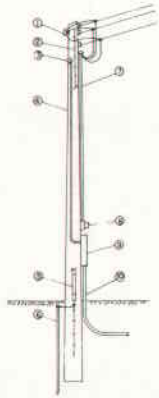
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

ROADWAY ILLUMINATION DETAILS

RID (4)-80

CK	DRAWING	DATE	FED. ROAD DIV. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
Ck Dw	ORIGINAL		6	TEXAS		
DW	REVISED		STATE DIST. NO.	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
Ck DW	REVISED					
TR						
Ck TR						

A-39A



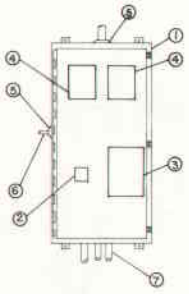
Service Drop from Utility
Three Wire Service Shown -
Omit One Conductor for
Two Wire Service

① - Lightning Arrester
② - No. 6 Bare Ground Wire
③ - Photo Cell and 3/4" RMC
④ - * 30' Class 5 Pole
⑤ - 8' Wood Grnd. Wire Molding
⑥ - 5/8"X 8' Copper Clad Grnd. Rod
⑦ - 1-1/2" RM Conduit - Conductor Size as Shown Elsewhere
⑧ - Meter (If Required)
⑨ - Service Assembly - See Detail
⑩ - Rigid Metal Conduit - Min. Size 2"

NOTES
1. Install Photo Cell on North Side of Pole
2. Attach Service Assembly with 1-1/2" X 1-1/2" Galvanized Channel

* Or As Required By NESC and Utility Company.

TYPICAL SERVICE POLE
See Service Pole Schematic For Types



① - Enclosure with vertical piano hinge
② - Control Unit
③ - Lighting Contactor
④ - Circuit Breakers
⑤ - Conduit Hub
⑥ - Conduit to Photo Cell
⑦ - Conduit as required

NOTE: If Utility provides controlled service, omit photo-cell, control unit and contactor.

SERVICE ASSEMBLY DETAIL

GENERAL NOTES:

SERVICE POLE AND CIRCUIT PROTECTOR ASSEMBLY

1. Service Assembly Enclosure. NEMA 3 enclosure consisting of NEMA 12 enclosure with drip shield and conversion hardware, constructed of 14-gauge steel, with piano hinge and resilient gasket. Door held with clamps with provisions for padlocking. Equipment-mounting panel 12-gauge steel, primed and painted white. Enclosure shall be galvanized outside and primed and painted white inside.

2. Lighting Contactor. Electrically-held, of type designed to control tungsten, mercury vapor and other lighting loads. Rated for 480-volt load, number of poles and ampere rating to meet circuit requirements, with silver alloy double-break contacts. Ampere rating shall be a minimum of 1.25 times circuit load or as shown elsewhere.

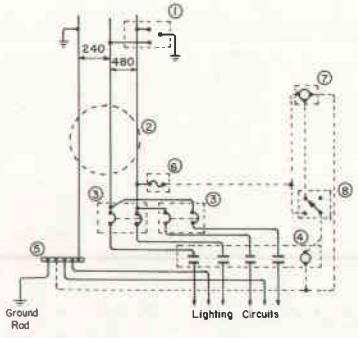
3. Control Unit. Standard duty 3-position (Auto-Manual-Off) control station in NEMA 1 enclosure.

4. Photo-Cell Control. Dry-type hermetically sealed cadmium sulfide cell, expulsion arrester and electro-mechanical relay, mounted in weatherproof plastic housing having twist-lock base. Turn-on range of 0.5 to 5 footcandles, factory-set at 1 ± ½ footcandle. Turn-off 2 footcandles higher than turn-on. Voltage range 100 to 285. Control circuit to be fused with enclosed in-line fuseholder and 5 ampere fuse.

5. Lightning Arrester. Valve-type, 0-650 volt with bracket for pole mounting.

6. Circuit breakers and fuses shall conform to current NEMA and UL Standards and shall be minimum size equal to load in amperes times 125 percent or as shown elsewhere. Circuit breakers shall be rated 480 volts for 240/480 volt or 480-volt circuit and 240 volt for 240-volt circuit. Fuses shall be rated 600 volts for any 480-volt circuit and 250 volts for 240-volt circuit. Renewable link fuses will not be permitted.

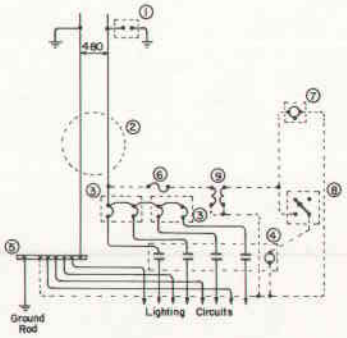
7. Circuit Protector Assemblies shall be similar except that wood poles shall be furnished and installed by others.



SERVICE POLE A
240/480 VOLTS - THREE WIRE

1. Lightning Arrester
2. Meter
3. Circuit Breaker
4. Lighting Contactor
5. Factory-made Ground Bus
6. In-Line Fuse, 5 Amp
7. Photo-Electric Control
8. Control Unit - "Manual-Off-Automatic"
9. Control Transformer

——— Power Wiring
- - - - - Control Wiring



SERVICE POLE B
480 VOLTS - TWO WIRE

SERVICE POLE SCHEMATIC

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

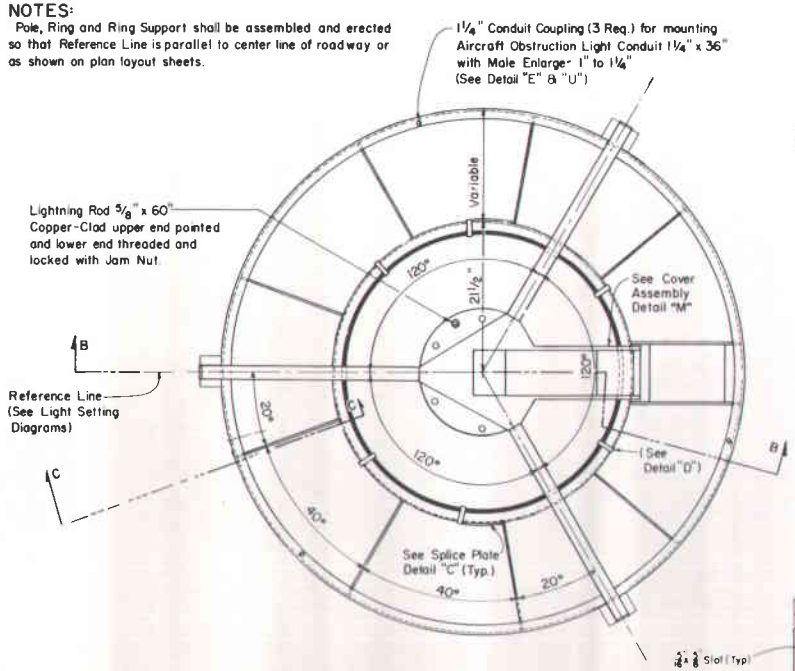
ROADWAY ILLUMINATION DETAILS

RID (5) - 80

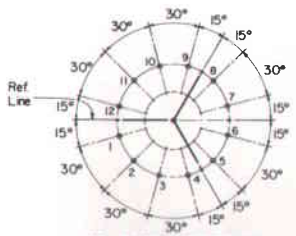
DN	DRAWING	DATE	FED. AID PROJ. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK DN	ORIGINAL			TEXAS		
DW	REVISED		STATE DISTRICT	COUNTY	CONT.	SECT.	JOB	HIGHWAY NO.
CK DW	REVISED							
TR								
CK TR								

A-39B

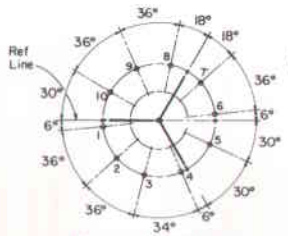
NOTES:
Pole, Ring and Ring Support shall be assembled and erected so that Reference Line is parallel to center line of roadway or as shown on plan layout sheets.



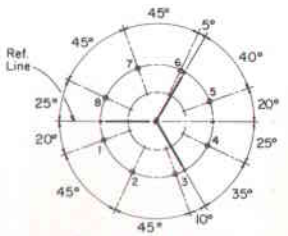
LIGHT MOUNTING RING & SUPPORT ASSEMBLY



12-LIGHT SETTING



10-LIGHT SETTING



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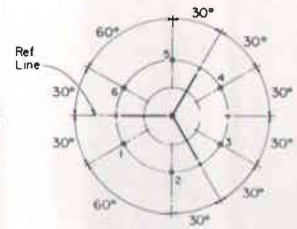

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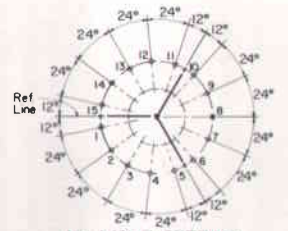

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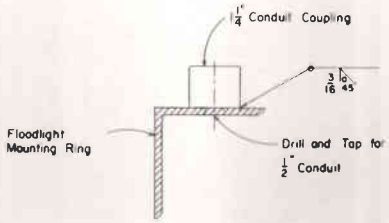
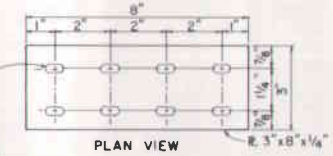
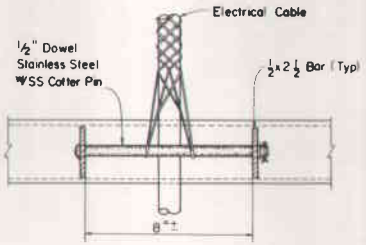


DETAIL "E"
(CONDUIT ATTACHMENT FOR OBSTRUCTION LIGHT)

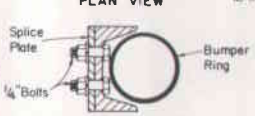


PLAN VIEW

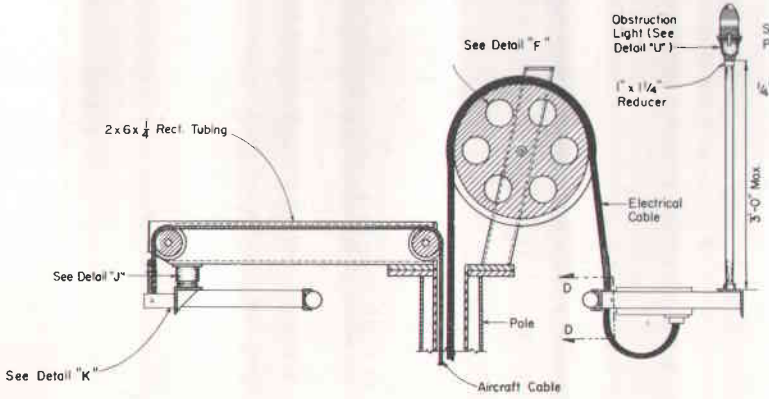
DETAIL "D"
BUMPER RING ATTACHMENT



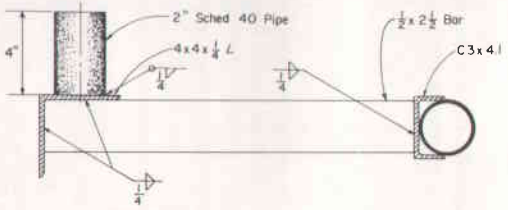
SECTION D-D



DETAIL "C"
SPLICE PLATE



SECTION B-B

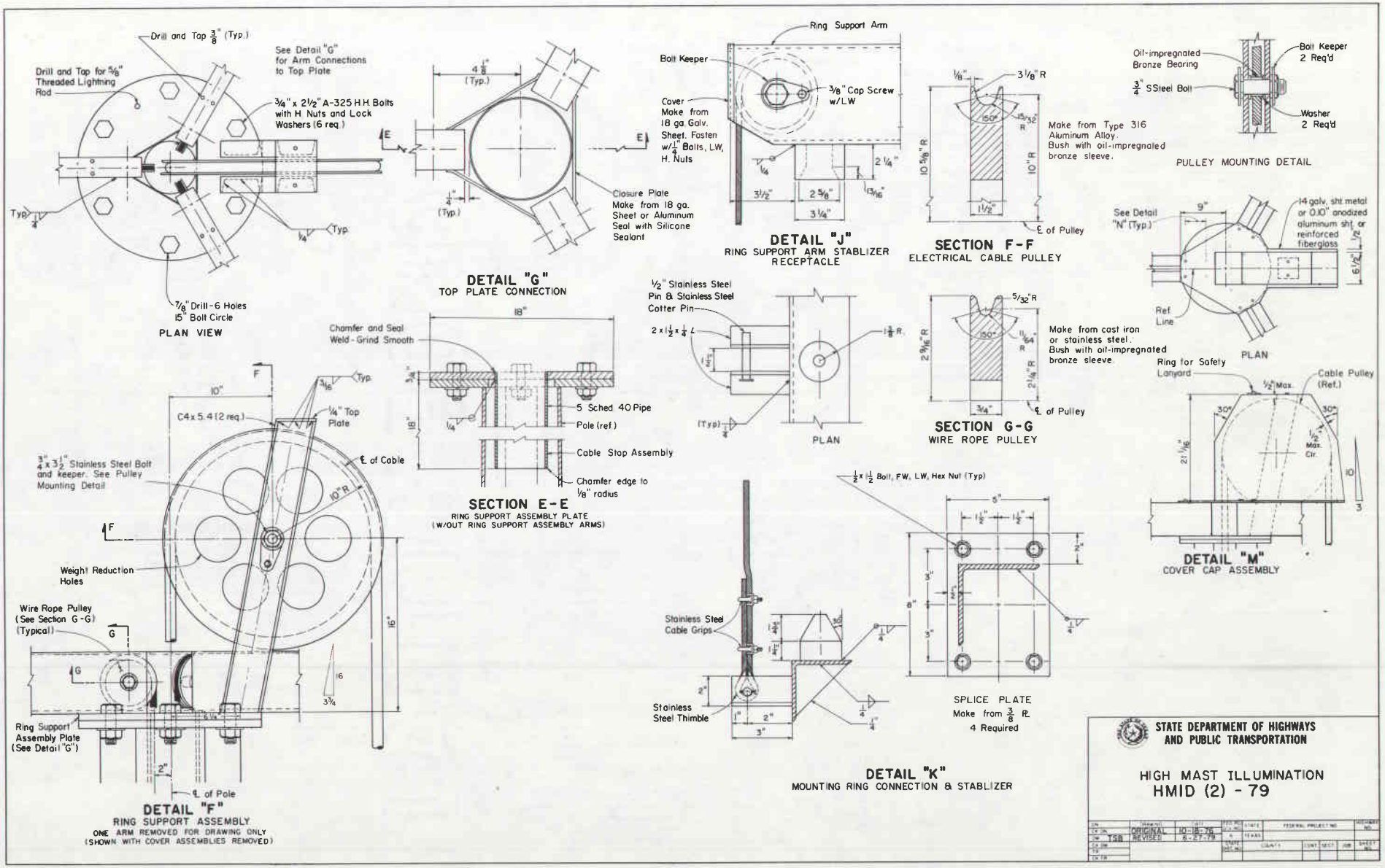


SECTION C-C

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

HIGH MAST ILLUMINATION
HMID (I) - 79

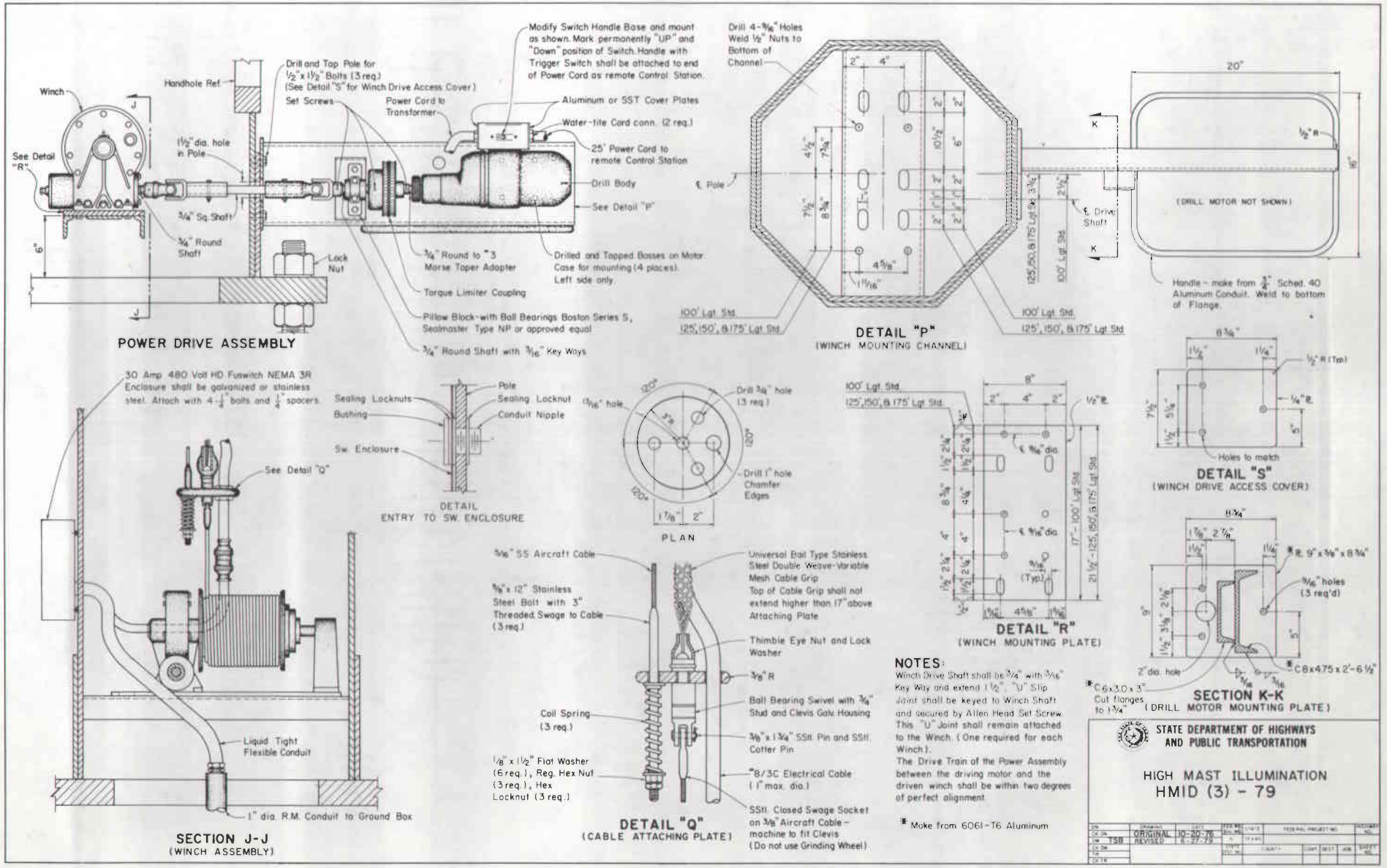
	ORIGINAL	10-13-76		STATE	FEDERAL PROJECT NO.			
	REVISED	6-27-79		TEXAS				
TSB	REVISED	9-28-79		STATE DIST. NO.		COUNT	SECT	JOB



STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

HIGH MAST ILLUMINATION
HMID (2) - 79

DN		TRANS. NO.	DATE	STATE PROJECT NO.		FEDERAL PROJECT NO.				SHEET NO.
CK BY		ORIGINAL	10-18-76							
DR TSB		REVISED	6-27-79							
CK DR				DIST.	COUNTY			UNIT NO.	JOB NO.	SHEET NO.
CK										
DATE										



NOTES:

Winch Drive Shaft shall be ¾" with 3/16" Key Way and extend 1½". "U" Slip Joint shall be keyed to Winch Shaft and secured by Allen Head Set Screw. This "U" Joint shall remain attached to the Winch. (One required for each Winch).

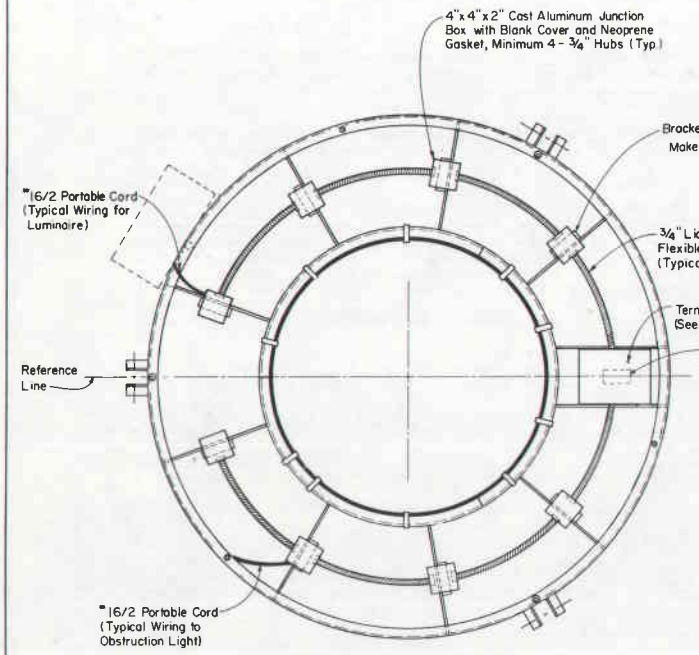
The Drive Train of the Power Assembly between the driving motor and the driven winch shall be within two degrees of perfect alignment.

* Make from 6061-T6 Aluminum

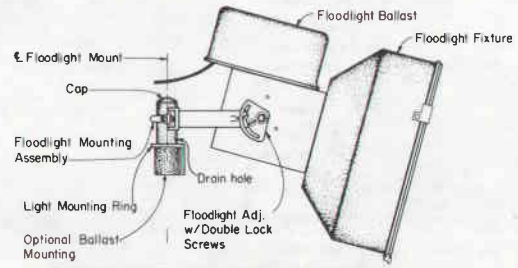
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

HIGH MAST ILLUMINATION
HMID (3) - 79

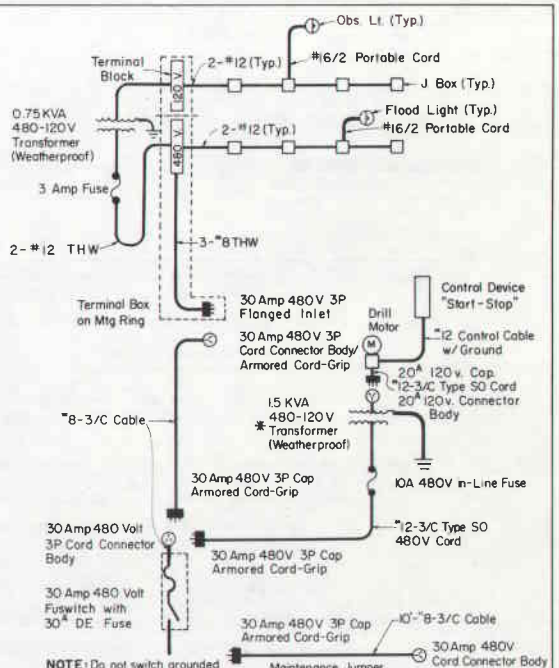
DR.	DRAWING	DATE	FED. AID PROJ. NO.	FEDERAL PROJECT NO.	DOCUMENT NO.
CK. DR.	ORIGINAL	10-20-78			
DR. TSB	REVISED	8-27-79			
CK. DR.			STATE PROJECT NO.		
DR.					
CK. DR.					



LIGHT MOUNTING RING



FLOODLIGHT MOUNTING ASSEMBLY

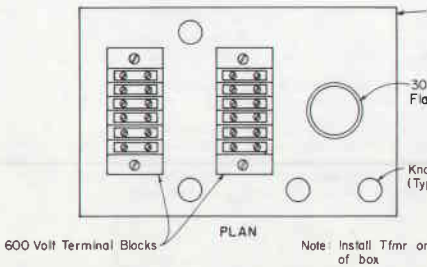


NOTE: Do not switch grounded Conductor Single Phase Service 480 Volt Phase to Ground-Tie neutral and 3rd wire to ground wire.

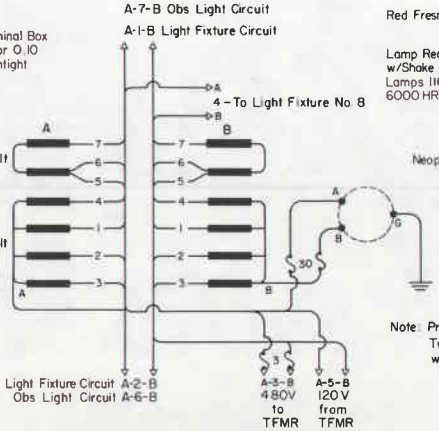
ONE-LINE SCHEMATIC

NOTES: 1. All Caps, Connector Bodies and Flanged Inlet shall be "Twist-Lock" Type, NEMA L8-30 & L8-20

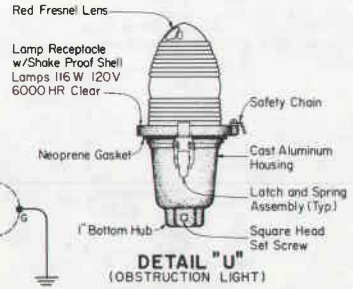
*2. Provide a Handle on 1.5 KVA Transformer for portability.



DETAIL "T" (TERMINAL BOX)



TERMINAL BOX SCHEMATIC



DETAIL "U" (OBSTRUCTION LIGHT)

Note: Provide fuse blocks on Terminal Block - Two for two wire service, four for three wire service.

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

HIGH MAST ILLUMINATION
HMID (4) - 79

DN	DESIGN	CHK	FED. ROAD DIV. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK DW: TSB	ORIGINAL 10-25-76					
CK DW:	REVISED 6-27-79					
CK TW:						

1. FLOODLIGHTS

A. The number of units per pole shall be as shown on the lighting layouts.

B. The photometric efficiency and beam spread of the floodlights will be sufficient to provide a minimum initial intensity of 0.3 horizontal footcandles on all main lanes and direct connections within the floodlighted area shown on the plans, excluding any area shaded by bridge structures or other appurtenances. Prior to installation of the floodlights, the manufacturer, through the Contractor, shall submit to the Department complete fixture-aiming diagrams and aiming instructions. Floodlights shall have aiming devices complete with vertical and horizontal degrees scales. After aiming is completed and resulting illumination is approved by the Engineer, the Contractor will permanently mark the aiming angles for each floodlight.

C. Floodlights shall have cast aluminum housing and 2-inch slipfitter. Housing, slipfitter and door shall be constructed of Type 360 aluminum alloy. Lens retainers, slipfitter bolts, and all machine screws exterior and interior, shall be stainless steel. All bolts and screws threaded into aluminum shall be treated with anti-seize compound. Floodlights shall be so constructed and sealed to prevent entrance of dirt, insects, and other contaminants.

D. Floodlights shall have silicone rubber or elastomer gasket between door and housing. Lens shall be fully gasketed with high temperature, non-hardening, pressure-applied mastic to insure a positive seal.

E. Lens shall be plain, flat, clear, heat- and impact-resistance tempered glass. Reflector shall be removable.

F. Socket shall be mogul with shake-proof shell and spring-loaded center contact.

G. Floodlight housing shall include compartment for ballast and capacitor. Housing shall also have threaded hub or knock-out for installation of water-tight cord connector.

H. Floodlight shall include internal fusing. Insulated fuse-holders, panel-mounted or in-line, shall be provided.

I. Floodlight assembly shall have an effective projected area not to exceed 3.3 square feet and weight shall not exceed 60 pounds.

2. BALLASTS

A. Ballasts shall be regulated type and shall be designed to operate 400-watt high pressure sodium lamps.

B. When the circuit voltage indicated on the plans is applied, the ballast input wattage during fluctuations of the test voltage of plus 5% and minus 10% shall not exceed 552 watts.

C. During fluctuation of the line voltage of plus 5% or minus 10%, the lamp wattage fluctuation shall not exceed a total of 20% and lamp input wattage shall not exceed 475 watts nor be less than 280 watts.

D. The power factor for all ballasts when tested at nominal line voltage shall be not less than 90%.

E. The electronic starting aid shall provide a starting pulse with an amplitude of 2500 volts minimum, 4000 volts maximum. The pulse width shall be a minimum of 0.8 microseconds at 2250 volts. The pulse shall occur when the open-circuit voltage is equal to or greater than 90% of peak open-circuit voltage. Pulse repetition rate shall be a minimum of one per cycle and pulse current shall be a minimum of 0.18 amperes. The pulse shall occur when the open-circuit voltage is equal to or greater than 90% of peak open-circuit voltage.

3. LAMPS

Lamps shall be high pressure sodium, 400-watt with rated life of 24,000 hours. The lamps may be base up to horizontal or base down to horizontal or as required by fixtures as supplied.

4. TESTING

A. Fixtures, lamps, and ballasts will be sampled and tested in accordance with the Departmental Manual of Testing Procedures except as noted in these specifications.

B. Ballasts and fixtures will be tested using lamps furnished for the same project.

C. The Department will bear the cost of all testing of equipment that complies with the specification requirements.

D. All other equipment will be tested in accordance with Item 614 of the Standard Specifications.

5. MOUNTING RING AND SUPPORT ASSEMBLY

A. Ring and support assembly shall be fabricated from steel having a minimum yield strength of 36 KSI.

B. Cover assemblies, fittings and miscellaneous parts shall be as outlined on the plans.

C. Plastic Pulley Cover
(1) Fiberglass reinforced pulley cover shall consist of polyester thermo-setting resin reinforced with chopped strand fiberglass roving with gel coat inside and out.
(2) Resin and gel coat shall contain fire-retardant and ultraviolet inhibiting additives as recommended by the manufacturer. Chopped strand for roving shall be nominally 1-1/2" long.
(3) Nominal thickness of cover shall be 3/8" for vertical portion and 1/2" for horizontal portion with additional thickness at bolt holes. Edges of horizontal portion shall be trimmed or formed neatly with no voids. Horizontal to vertical juncture shall have a minimum radius of 3/8".

6. WINCH

A. Housing shall be high tensile strength die-cast silicone aluminum. Cable drum shall be fabricated from seamless steel tubing with stamped steel flanges and shall be hot-dip galvanized. Drum capacity shall be sufficient to receive a cable equal to the height of the pole it serves plus the first layer of cable. Drum shaft shall be ground from stainless steel and mounted on lubricated bronze bearings with seals. Worm gear shall be made of nickel-bronze and worm shaft shall be high-strength stress-proof steel, ground and polished and supported by tapered roller bearings.

B. Gear ratio shall be 36:1 with safe hoisting capacity of not less than 4000 pounds.

C. Winch shall incorporate adjustable automatic brake to assure positive load suspension. Brake shall be multiple disc with friction plates running in oil bath and one-direction clutch which operates only when load is suspended or lowered. Winch shall not have throw-out clutch .

7. WIRE ROPE

A. Wire rope shall be 7x9 Type 304 or 302 stainless steel aircraft cable of the sizes indicated on the plans.

B. Four factory-swaged stainless steel bolt-end terminals as shown on plans shall be provided. Terminals for hoisting rope shall be 12 inches long with 3 inches of thread, and with wrench flats at cable ends.

C. A Test Sample shall be furnished for each size of wire rope used on this project. Sample shall be swaged at each end with the same bolt-end terminals as furnished with the corresponding size cable for the project. Length of sample shall not exceed 5 feet nor be less than 4 feet including the 12-inch terminal at each end. Samples shall withstand loading equal to minimum breaking strength of cable indicated in catalog without fracture or failure of either component.

D. Winch line shall be of sufficient length to leave one layer remaining on the drum when ring is in down position.

E. Swivel shall be rated for a working load of 1.5 tons with a safety factor of 5:1. Swivel shall have three rows of ball bearings. Contractor shall make brochure submittal of swivel to Engineer for approval.

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

HIGH MAST ILLUMINATION
HMID (5) - 79

	DRAWING	DATE	FED. AID NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
DW TSB	Revised	6-27-79		YEAR		
CK DW			STATE DIST. NO.	COUNTY	CONT. SECT. SUB	HIGHWAY NO.
TR						
CK TR						

8. SPRINGS

A. Provide three steel springs as shown on plans.

B. Springs shall have an uncompressed length of approximately 8 inches and will compress 3 inches under 700-pound load.

C. Springs shall contain approximately 19 total coils with ID of 0.875 and OD of 1.375 inches. Ends shall be closed and ground.

D. Springs shall be made from 1/4-inch diameter oil-tempered MB Steel treated for overstress. Springs shall not develop permanent set from 3-inch compression.

9. ELECTRICAL POWER CABLE

Power cable shall be No. 8AWG three-conductor round Type W, rated 90°C, and 600 volts. Each conductor shall be copper and shall consist of 133 strands. Insulation shall consist of 0.062" of cross-linked reinforced modified DCP tripolymer compound. Jacket shall consist of 0.141" of cross-linked PTR elastomer reinforced with glass fiber cord. Nominal diameter shall be 0.91". Filler shall be rubber compound.

10. LUMINAIRE ELECTRICAL CORD

A. Portable cord for connecting luminaire to junction boxes shall be No. 16 AWG two-conductor portable cord rated 90°C and 600 volts.

B. Each conductor shall be copper and shall consist of 65 No. 34 strands.

C. Insulation shall consist of 2/64" of cross-linked reinforced modified DCP tripolymer compound. Jacket shall consist of 0.063" of cross-linked PTR elastomer. Nominal diameter of the cable shall be 0.405".

11. POWER DRIVE ASSEMBLY (one only this contract)

A. Drive Motor
(1) Drive motor shall be 1-1/4" heavy-duty reversible portable electric drill modified as shown on plans.
(2) Shall have 6 radial ball bearings, one ball-thrust bearing and one lubricant-impregnated bearing.
(3) Shall have No. 3 Morse Taper socket.
(4) Shall be designed for 115 volt 60 Hertz single phase operation 250 RPM at no load.
(5) Shall be designed for continuous rated duty at 160 RPM and 12 amperes at 115 volts with delivery of 33 foot-pounds of torque.
(6) Shall develop 325 foot-pounds of torque at stalled rotor condition.

B. Torque Limiter Coupling
(1) Torque limiter coupling shall consist of standard torque limiter with Type A sprocket center member coupled to a Type B sprocket by an ASA double strand roller chain. Type A sprocket shall be chrome-plated.
(2) Coupling shall have torque capacity minimum of 15 pound-feet and a maximum of 55 pound-feet.
(3) Limiter section of coupling shall consist of intergral hub and pressure plate, two friction facings, sintered iron bushing, pressure plate, disk spring, lock washer and hex adjustment nut. All major components except spring and friction shall be cadmium-plated with dichromate treatment.
(4) Type A center sprocket shall have ground face (63 micro-inch) and shall be run-in for 4 minutes at approximately 60 RPM at a torque setting of 70% to 80% of spring rating. Contractor shall provide written certification that run-in has been accomplished.
(5) The torque limiter coupling shall, after run-in, be set to a torque limit of 35 pound-feet or as directed by the Engineer. The proper setting of the coupling shall be demonstrated to the Engineer.

C. Universal Joints
(1) Shall be slip-type with 4-inch barrel. A grease fitting shall be so located in the spider that all caps and needle bearings will be adequately serviced. The assembly shall be disassembled and zinc-plated, then reassembled and properly lubricated.
(2) Shall have a minimum torque rating of 1270 inch-pounds at 200 RPM.
(3) Shall have set-screw and keyed coupling as shown on plans.

12. CONSTRUCTION METHODS

A. Fabrication
(1) Fabrication and welding shall be in accordance with the Item "Steel Structures," and Department Bulletin C-5.
(2) All holes supporting pulley shafts shall be drilled (not punched) and reamed prior to galvanizing.
(3) All component parts shall be galvanized, where galvanizing is applicable, after fabrication.
(4) All galvanized parts which have become scratched, chipped or otherwise damaged shall be thoroughly cleaned and the cleaned area painted with two coats of zinc dust-zinc oxide paint conforming to the requirements of repair compounds meeting Federal Specification TT-P-64-1b.

B. Installing Wire Rope (Aircraft Cable)
(1) Extreme care shall be used to prevent wire rope from kinking, nicking, or from sustaining other damage during installation. Rope shall not be installed by pulling from flat coil, but shall be carefully unrolled its full length or placed on a horizontal axis and unreeled according to wire rope industry standards.
(2) For right lay rope, the rope shall be attached to the drum on the end opposite the winch gear train, and wound on drum so that the free end of the rope comes off the back side of the drum during normal operation of the winch. Rope must be unreeled carefully as stated above. Care must be taken to insure that the first layer lies full and tight on drum.

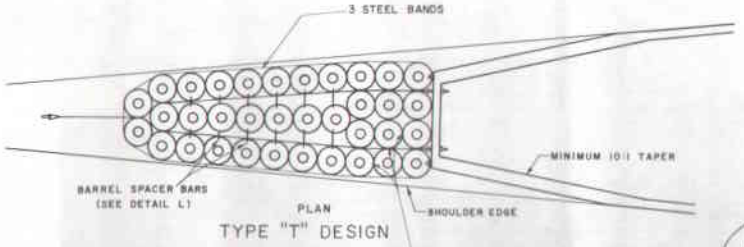
C. Installing Wire Rope Clips
(1) Turn back 5-1/4" of rope, measured from the thimble. Apply first clip one base width from the dead end of the wire rope with U-bolt over dead end and live end in clip saddle. Tighten nuts evenly to 30 pound-feet of torque or as recommended by manufacturer.
(2) Install second clip as near loop as possible, take out slack and torque nuts evenly to 30 pound-feet or as recommended by manufacturer.
(3) After initial load is applied to the rope, re-tighten nuts to required torque.

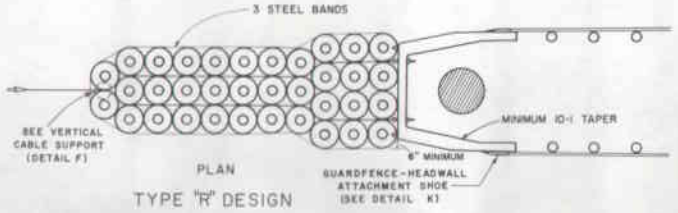
D. Wiring
(1) Wiring of the mounting ring will be in accordance with the NEC and industry standard practices.
(2) Wiring shall be color-coded throughout pole wiring system. Conductor colors for 480-volt system shall be as follows: Phase A, black; Phase B (for 3-wire service), red; and grounded neutral, green or white. For portable cord not containing the required colors, the conductor ends shall be identified with tape of proper color. The 120-volt system for the obstruction lights shall be coded one conductor black and one white. The white conductor shall be grounded to the ring near the transformer secondary.

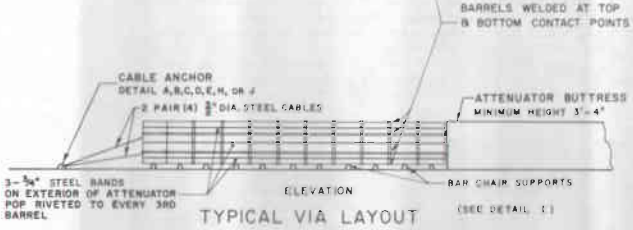
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

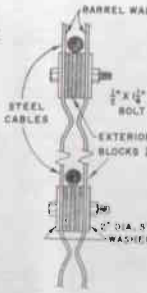
HIGH MAST ILLUMINATION
HMID (6) - 79

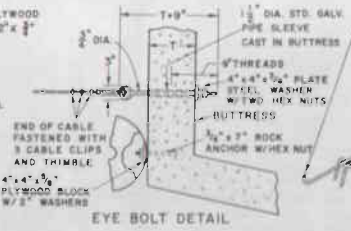
DN	CHECKED	DATE	FED. AID SOL. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CP DN						
CW TSB	Revised	6-27-79	9	TEXAS		
CK CW			STATE DIST. NO.	COUNTY	CONT.	SECT.	JOB	HIGHWAY NO.
TR								
CK TR								

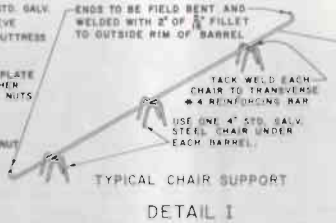


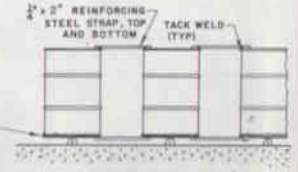


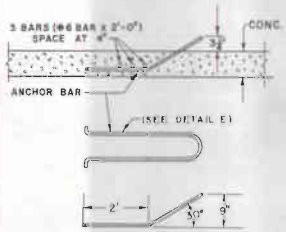


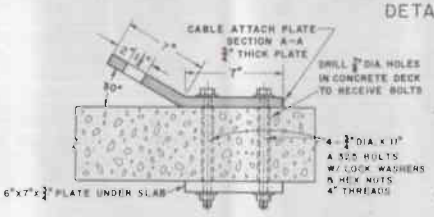


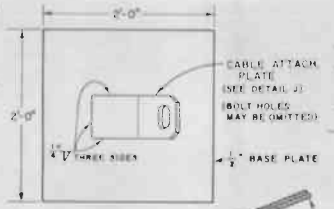


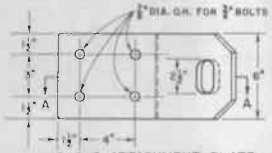


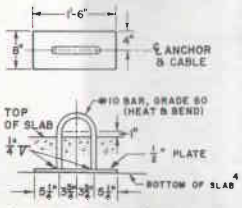


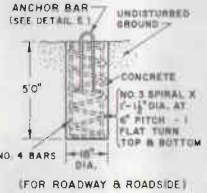


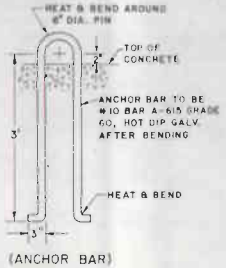


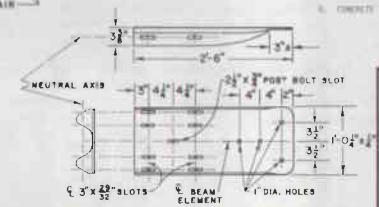












CABLE ANCHORS

GENERAL NOTES

1. ALL CABLE FITTINGS, ANCHOR BARS, BOLTS, NUTS, WASHERS AND MISCELLANEOUS HARDWARE SHALL BE GALVANIZED. STEEL CABLES MAY BE FURNISHED BLACK, UNLESS OTHERWISE SPECIFIED. NUTS AND BOLTS SHALL BE IN ACCORD WITH ASTM - A325.
2. STEEL CABLE FURNISHED SHALL BE OF LEAST 5/8 INCH IN DIAMETER AND SHALL HAVE A MINIMUM BREAKING STRENGTH OF 20 TONS. CABLE SHALL BE TENSIONED AS DIRECTED BY THE ENGINEER.
3. STEEL BARRELS WILL BE INTERCONNECTED AT THE TOP AND BOTTOM AT ALL POINTS OF CONTACT BY SPLICING OR WELDING AS DIRECTED BY THE ENGINEER. WHERE ADJACENT BARRELS ARE NOT IN CONTACT, SPACER BARS SHALL BE PROVIDED AND ATTACHED TO THE TOPS AND BOTTOMS OF THE BARRELS.
4. BARREL CRUSH STRENGTH IS DETERMINED BY HOLE CUT-OUTS SIZE IN TOP AND BOTTOM OF EACH BARREL. BARRELS WITH 28 GAUGE TOPS AND BOTTOMS SHALL BE SUPPLIED WITH 7 INCH DIAMETER HOLES ON TOP AND BOTTOM. WHERE STEEL PAINT BARRELS ARE PROVIDED, HOLE SIZE SHALL BE 13 1/2 INCHES IN TOP AND BOTTOM FOR BOTH TIGHT AND LOOSE NESTED DRUMS. WITH CLAMPS ON LOOSE NESTED DRUMS, SHALL BE DISCARDED AND LESS HOLES TO BE USED WITH EIGHT EQUALLY SPACED 3-INCH SLOTS. UNLESS OTHERWISE SPECIFIED, BARRELS NEED NOT BE GALVANIZED AND THEIR LAYERS OF PAINT MEETING 10 MILS BARRELS NEED NOT BE REMOVED. WHERE SPECIFIED BARREL EXTERIORS SHALL BE PAINTED WITH TWO COATS OF EXTERIOR GRADE REFLECTORIZED PAINT OF THE COLOR SPECIFIED BY THE ENGINEER.
5. CONCRETE FOR THE INSTALLATION SHALL BE CLASS A OR CLASS C CONCRETE.

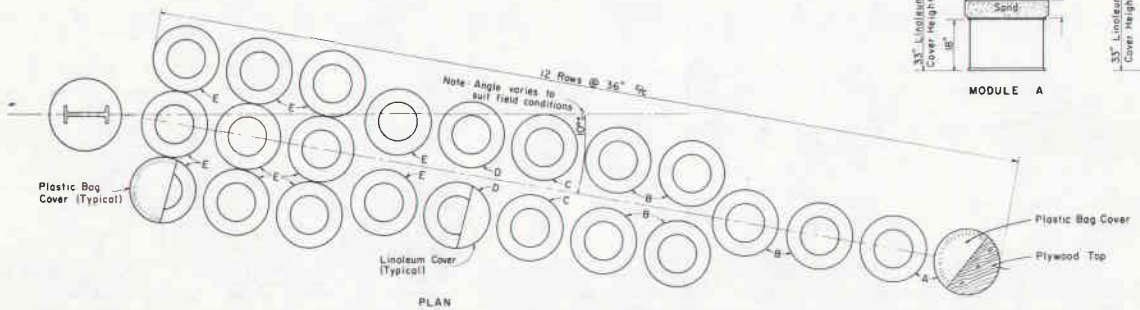
STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION

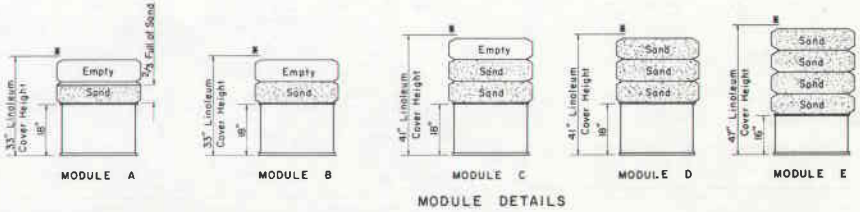
VEHICLE IMPACT ATTENUATOR

CRASH CUSHION DETAILS

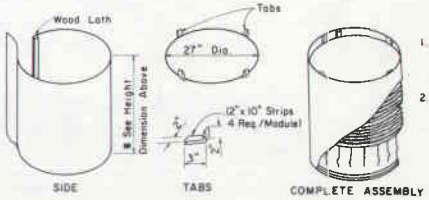
VIA (CCD)-76

	DRAWING	DATE	FED. AID PROJ. NO.	STATE	FEDERAL PROJECT NO.				SHEET NO.
	ORIGINAL			TEXAS					
	REVISED								
	REVISED		STATE DIST.	COUNTY		CONT.	SECT.	JOB	HIGHWAY NO.





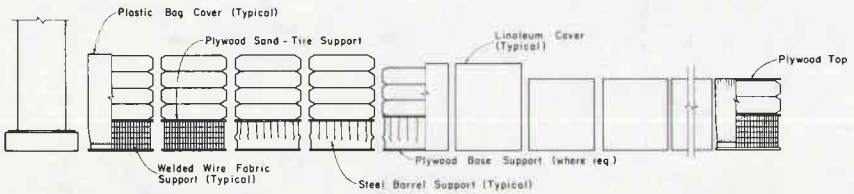
MODULE DETAILS



Linoleum Cover Notes

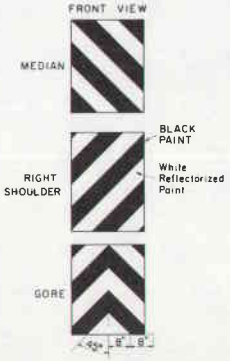
1. Lath, Side, Top and Tabs to be attached with galvanized staples.
2. Side, Top and Tabs to be constructed from Linoleum.

LINOLEUM COVER DETAILS



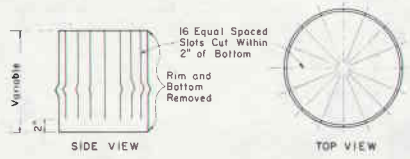
ELEVATION

LEAD MODULE HAZARD PAINT PATTERN

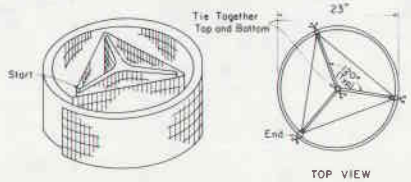


GENERAL NOTES

1. WHERE POSSIBLE THE ATTENUATOR SHALL BE ANGLED TOWARD THE ROADWAY AT AN ANGLE NOT TO EXCEED 10 DEGREES WITH PAVEMENT EDGE.
2. OLD PASSENGER CAR TIRES (14" & 13") SHALL BE USED AND FILLED WITH LOOSE SAND. THE TIRES SHALL NOT BE TIED TOGETHER.
3. EACH COMPLETED MODULE SHALL BE COVERED WITH A PLASTIC BAG COVER, A LINOLEUM COVER OR A COVER CONSTRUCTED OF OTHER WATERPROOF MATERIAL ACCEPTABLE TO THE ENGINEER. PLASTIC BAG COVERS SHALL BE A MINIMUM OF 4 MILS THICK.
4. COVERS SHALL BE WHITE OR YELLOW IN COLOR. IF PAINTING IS REQUIRED EXTERIOR GRADE PAINT SHALL BE USED.
5. PLYWOOD BASE AND SAND-TIRE SUPPORTS SHALL BE 1/4" EXTERIOR GRADE PLYWOOD SHEATHING AND SHALL BE EITHER CREOSOTE OR PENTACHLOROPHENOL TREATED.
6. PLYWOOD BASE SUPPORTS SHALL BE USED AS DIRECTED BY THE ENGINEER.
7. FOR COMPUTATION PURPOSES AN EMPTY TIRE WEIGHS APPROXIMATELY 20#, AND REQUIRES APPROXIMATELY 150# OF SAND.
8. WHEN ATTENUATOR IS PLACED IN A CURBED CORE, APPROACH CURB SHOULD BE REMOVED AND CORE SLOPED TO FLOW LINE OF CURB.
9. EITHER THE WEAKENED 20 GAUGE STEEL BARREL BASE OR WELDED WIRE FABRIC BASE MAY BE USED.
10. A TOP MADE FROM ¼" EXTERIOR GRADE PLYWOOD SHEATHING SHALL BE PLACED ON MODULE TYPES A, B AND C WHEN PLASTIC BAG COVERS ARE TO BE USED. PLYWOOD TOPS SHALL BE CREOSOTE OR PENTACHLOROPHENOL TREATED.



20 GAUGE STEEL BARREL SUPPORT FABRICATION DETAILS



Welded Wire Fabric Support Notes

1. Wire Fabric Supports shall be constructed from one continuous piece of 1" x 2" x 14 ga. galvanized welded wire fabric.
2. All points of contact between wire bends shall be tied with galvanized rebar ties.
3. Make all 180° bends with vertical wires on the inside of the bend.
4. Heights shall be as shown in the module details.
5. A 23" ± diameter support requires approximately 24' of welded wire fabric.

WELDED WIRE FABRIC SUPPORT DETAILS

PLYWOOD TOP, BASE AND SAND TIRE SUPPORT

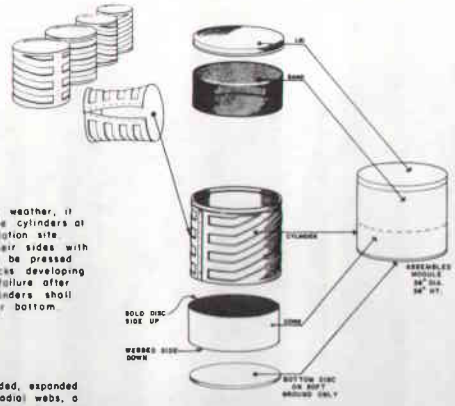
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

SAND-TIRE VEHICULAR IMPACT ATTENUATOR VIA(ST)-74

FED. ROAD DIV. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
6	TEXAS		
STATE DIST. NO.	COUNTY	CONT.	SECT.	JOB	HIGHWAY NO.

Assembling the Cylinders

Cylinders are assembled by placing the halves on a level surface and lining up the pre-bored holes. Rivets are inserted from the outside and washers are held in place from the inside and a standard pop rivet gun is used. Bored holes are approximately 1/4" in diameter, rivets are 3/16" diameter for easy installation. Rivets should be placed in all holes.



Due to traffic conditions or inclement weather, it is sometimes necessary to assemble the cylinders at the shop before delivery to the installation site. If assembled cylinders are placed on their sides with any weight placed thereon, they may be pressed into an oval shape, with possible cracks developing along the rivet lines and subsequent failure after installation. Therefore assembled cylinders shall be transported upright resting on their bottom.

Assembling Core

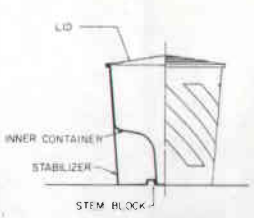
Each core consists of an integrally molded, expanded polystyrene structure which includes six radial webs, a circumferential outer wall, and a solid disc all formed in a single unit. Cores shall be placed in the bottom of the cylinders with the webbed side facing down and the solid disc side facing up.

MODULE LOCATING HALF RING DETAIL

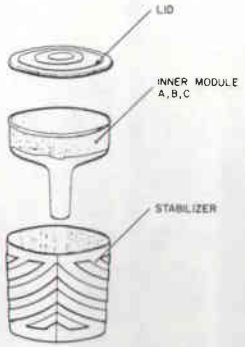
(To be used on elevated structures only)

Core Depth (in.)	Sand Fill Weight (lbs)
21 ½	200
21 ½	400
16 ½	700
11 ½	1400

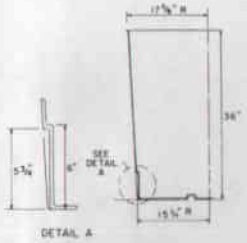
MODULE ASSEMBLY DETAIL TYPE A



BARREL ASSEMBLY



BARREL COMPONENTS

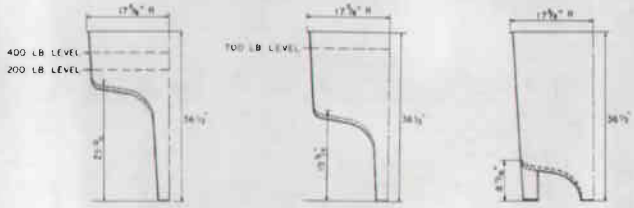


DETAIL A

STABILIZER

Inner Container (Type)	Sand Fill Weight (lbs)
A	200 - 400
B	700
C	1400 *

* FOR 1400 LB. MODULES, A SINGLE PIECE STYLE BARREL MAY BE USED. THE SINGLE PIECE MODULE SHALL BE APPROXIMATELY 6'-0" HIGH, 5'-0" DIAMETER AT THE TOP, WITH SUPPORT FOR STABILIZATION PROVIDED AT THE BOTTOM AROUND THE ENTIRE CIRCUMFERENCE AND BY A CENTER SUPPORT LEG.



INNER CONTAINER A, B, & C

In addition to the center support, each Type C inner container shall have four support legs at the quarter points along the circumference of the bottom.

MODULE ASSEMBLY DETAIL TYPE B

GENERAL NOTES

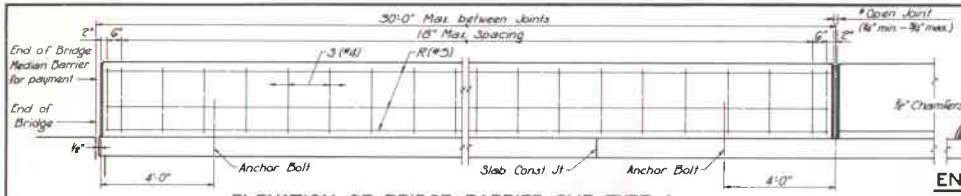
1. THE ENTIRE AREA OF THE CRASH CUSHION INSTALLATION AND APPROACHES SHALL BE GRADED SO THAT THE MAXIMUM SLOPE DOES NOT EXCEED 10:1 IN ANY DIRECTION.
2. SUPPORT PADS WILL BE MEASURED AND PAID FOR IN ACCORDANCE WITH PERTINENT BID ITEMS. DETAILS OF THE SUPPORT PAD ARE SHOWN ELSEWHERE IN THE PLANS.
3. ALL TYPE A MODULES PLACED ON ELEVATED STRUCTURES SHALL BE PROTECTED FROM DISLOCATION DUE TO BRIDGE VIBRATION BY INSTALLATION OF A MODULE LOCATING HALF RING. THE HALF RING SHALL BE POSITIONED ON THE DOWNSLOPE SIDE OF EACH MODULE AND ATTACHED TO THE BRIDGE SURFACE WITH EPOXY.
4. ALL TYPE B MODULES PLACED ON ELEVATED STRUCTURES SHALL BE PROTECTED FROM DISLOCATION DUE TO BRIDGE VIBRATION BY EPOXYING THE BOTTOM OF THE STABILIZER TO THE BRIDGE.

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

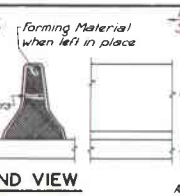
SAND FILLED PLASTIC BARRELS VEHICLE IMPACT ATTENUATOR

VIA (SFPB) - 79

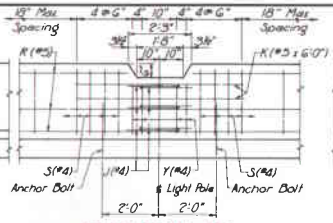
DN	DRAWING	DATE	FED. ROAD DIV. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK DN	ORIGINAL	2-1-79				
DW	REVISED		6	TEXAS		
CK DW	REVISED		STATE DIST. NO.	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
CK						
CK TR						



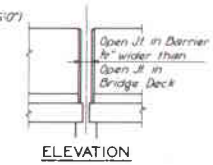
ELEVATION OF BRIDGE BARRIER-CMB-TYPE 1



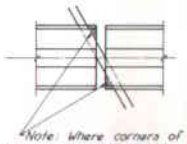
END VIEW



ELEVATION AT LIGHT POLE



ELEVATION

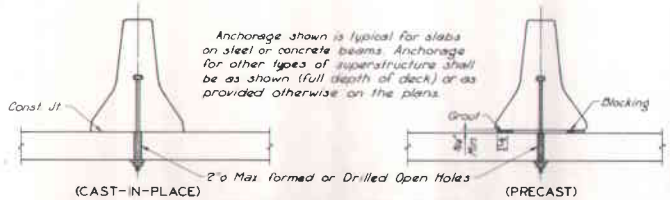


*Note: Where corners of barriers project over the slab of adjacent spans, care shall be taken to provide a minimum of ¼" clearance between bottom of barrier and top of adjacent slab. Polystyrene or other suitable compressible material may be used.

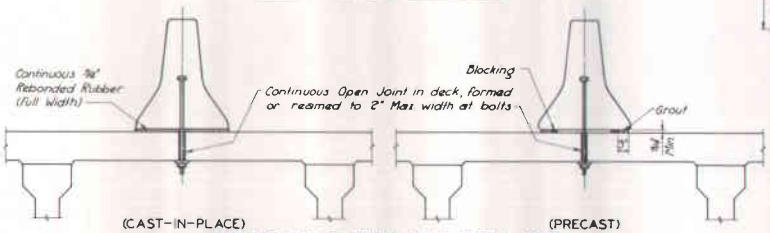
PLAN

EXPANSION JOINT

*Joints shall be prepared at ends of spans, over interior supports for continuous units, and at equal intervals in between as necessary to maintain a 30' Maximum and a 15' Minimum length of unbroken wall. Material used in forming joint may be left in place if it is compressible and light in color such as the following materials: polystyrene, molded cork granules, sponge rubber sheets, etc.

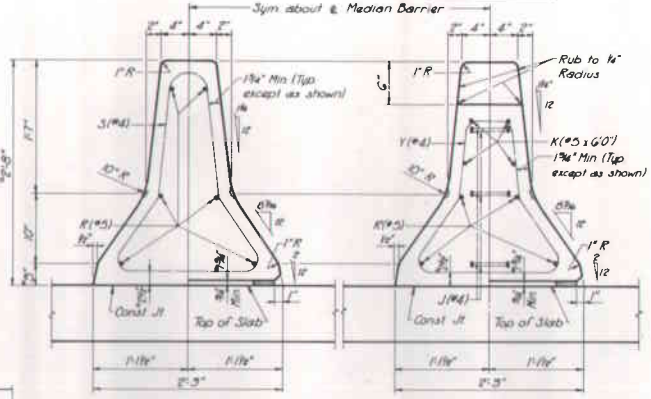


ANCHOR BOLTS THRU SLAB



ANCHOR BOLTS THRU SLAB OPEN JOINT

ANCHOR BOLT INSTALLATIONS



TYPICAL SECTION

TYPICAL SECTION AT LIGHT POLE

*Note
If bridge deck has Asphaltic Concrete Overlay, the height of cast-in-place and precast barriers must be adjusted accordingly. See bridge layout sheet for overlay thickness.

ESTIMATED QUANTITIES
(FOR INFORMATION ONLY)

	Concrete	Reinf. Steel	Str. Steel (Anchor Bolts)
	C.Y.	Lb.	Lb.
One - 30'-0" Section Barrier	3.54	292	13
Additional - One Light Pole Anchorage		67	7.5

GENERAL NOTES:

Designed according to A.A.S.H.O. 1973 Standard and Interim Specifications.

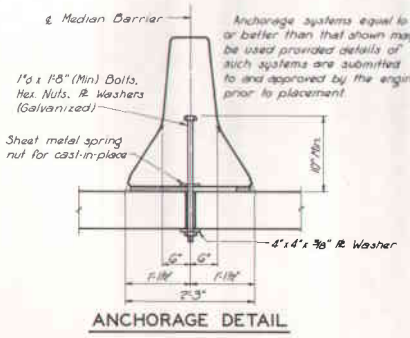
Reinforcing Steel, Anchor Bolts, Blocking, etc. as shown in Median Barrier Sections shall be paid for as price per linear foot for Concrete Median Barrier.

Axis of Median Barrier shall be vertical, except where median is superelevated, then axis shall be normal to roadway surface.

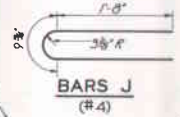
Unless otherwise shown in the plans, the Contractor has the option of furnishing either a precast or cast-in-place Concrete Median Barrier.

Concrete for Concrete Median Barrier shall be Class "A" or Class "C".

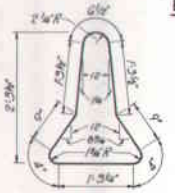
See Illumination Sheet for light pole anchor bolts and conduit details.



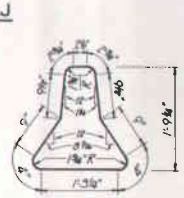
ANCHORAGE DETAIL



BARS J
(#4)



*BARS S
(#4)



*BARS Y
(#4)

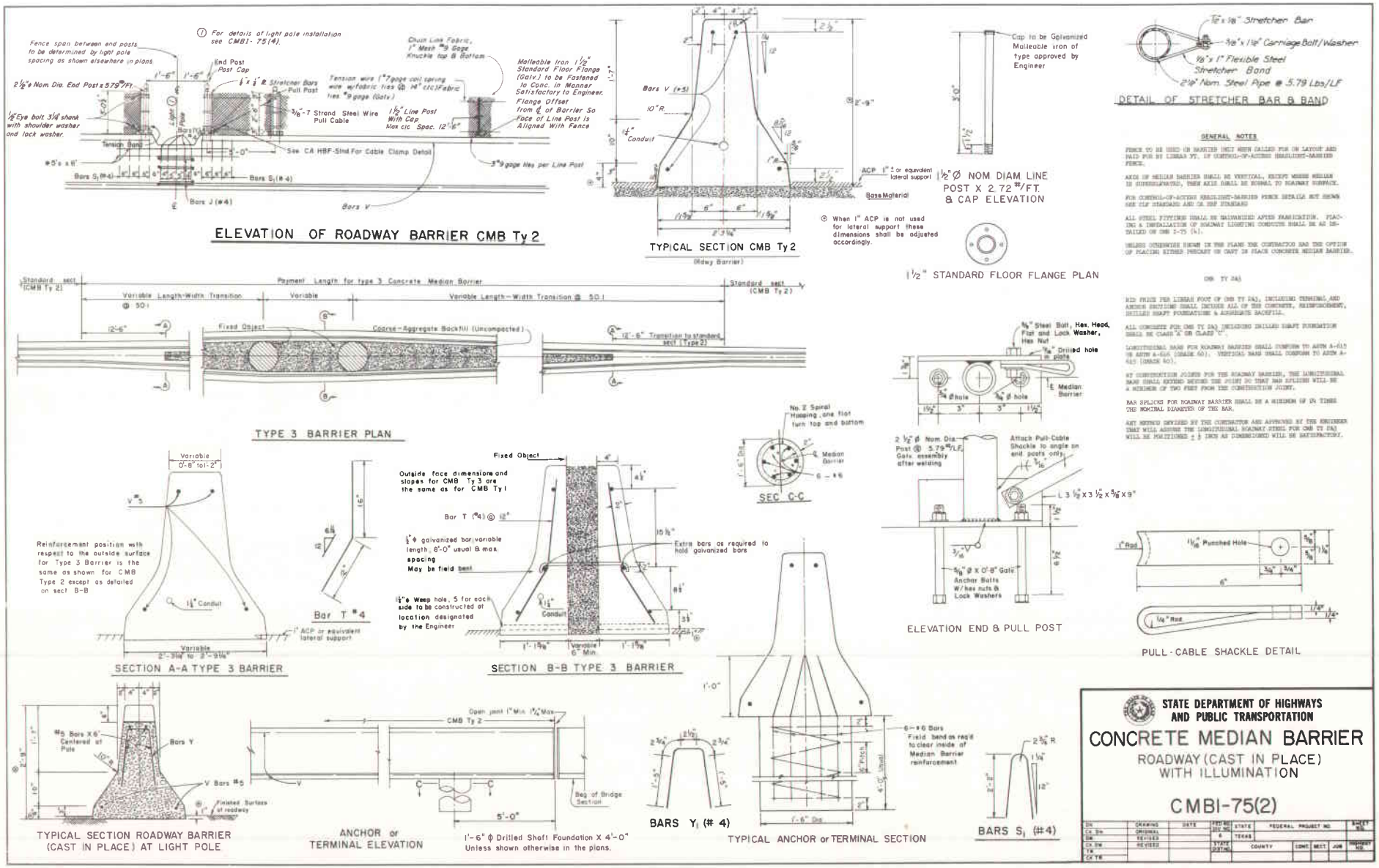
* Provide 4" min. bar lap.

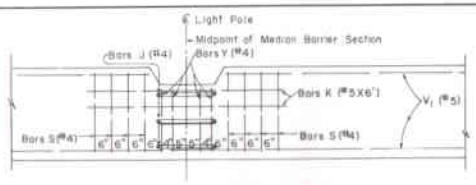
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

CONCRETE MEDIAN BARRIER
(BRIDGE)
CMBI-80(1)

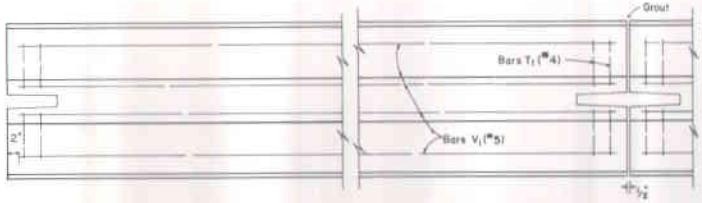
CN	DRAWING	DATE	FED. ROAD DIV. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
Ck. Dn.	ORIGINAL					
Dn.	REVISED		6	TEXAS		
Ck. Dn.	REVISED		STATE DISTRICT	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
Ck. Dn.						

A-50

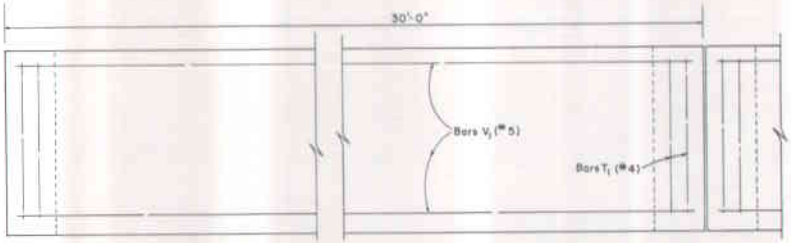

ELEVATION OF ROADWAY BARRIER CMB Ty 2
TYPICAL SECTION CMB Ty 2
(Rdwy Barrier)
DETAIL OF STRETCHER BAR & BAND
GENERAL NOTES
TYPE 3 BARRIER PLAN
SEC C-C
ELEVATION END & PULL POST
PULL-CABLE SHACKLE DETAIL
SECTION A-A TYPE 3 BARRIER
SECTION B-B TYPE 3 BARRIER
TYPICAL SECTION ROADWAY BARRIER (CAST IN PLACE) AT LIGHT POLE
ANCHOR or TERMINAL ELEVATION
BARS Y1 (# 4)
TYPICAL ANCHOR or TERMINAL SECTION
BARS S1 (#4)
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
CONCRETE MEDIAN BARRIER
ROADWAY (CAST IN PLACE) WITH ILLUMINATION
CMBI-75(2)



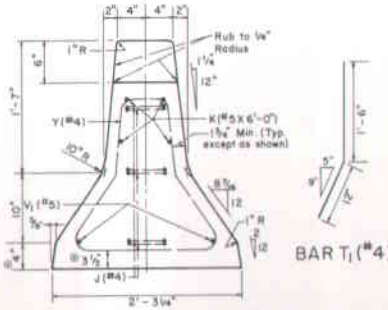
ELEVATION AT LIGHT POLE
(ILLUMINATION BARRIER SECTION)



PLAN VIEW

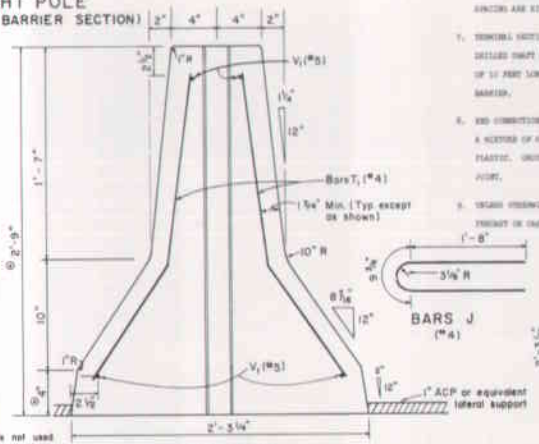


ELEVATION



TYPICAL SECTION
AT LIGHT POLE
(ILLUMINATION BARRIER SECTION)

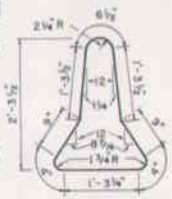
BAR T_1 (#4)



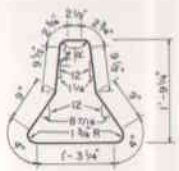
END VIEW

@ When 1" ACP is not used for lateral support these dimensions shall be adjusted accordingly.

BARS J
(#4)



* BARS S
(#4)

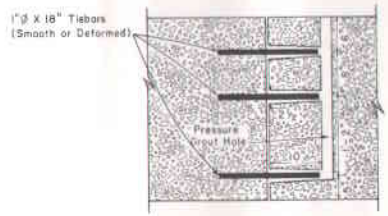


* BARS Y
(#4)

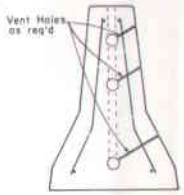
* Provide 4" min. bar lap.

GENERAL NOTES

1. LONGITUDINAL BARS SHALL CONFORM TO ASTM A-615 OR ASTM A-616 (GRADE 60). TRANSVERSE BARS SHALL CONFORM TO ASTM A-615 (GRADE 60).
2. CHAMFER ALL EXPOSED EDGES 3/4-INCH UNLESS NOTED OTHERWISE HEREIN.
3. CONCRETE SHALL BE CLASS "C".
4. REGARDLESS OF THE METHOD OF HANDLING, BARRIER SECTION LIFTING POINTS SHALL BE 6 @ FEET FROM THE ENDS OF THE BARRIER. LIFTING DEVICES AND ATTACHMENTS TO BARRIER SECTIONS SHALL BE AS APPROVED BY THE ENGINEER.
5. CONCRETE MEDIAN BARRIER (ROADWAY PRECAST) SHALL BE PLACED ON A MORTAR BED CONSISTING OF TWO PARTS SAND AND ONE PART CEMENT, OR AN ASPHALTIC CONCRETE BED, TO ENSURE UNIFORM BEARING AND ALIGNMENT. BEDDING MATERIALS SHALL BE FURNISHED TO THE MEDIAN BARRIER.
6. CONCRETE MEDIAN BARRIER (ROADWAY PRECAST) INCLUDES TWO TYPES OF BARRIER SECTIONS: NORMAL ROADWAY BARRIER SECTIONS, AND ILLUMINATION BARRIER SECTIONS. THE TWO TYPES OF SECTIONS ARE IDENTICAL EXCEPT THAT THE ILLUMINATION BARRIER SECTION HAS ADDITIONAL REINFORCING STEEL AND OTHER DETAILS AT THE MIDPOINT OF THE BARRIER SECTION AS SHOWN HEREON AND ELSEWHERE IN THE PLANS. WHEN ILLUMINATION IS TO BE INSTALLED ON ROADWAY PRECAST CONCRETE MEDIAN BARRIER, ILLUMINATION BARRIER SECTIONS SHALL BE PROVIDED FOR THOSE LIGHT POLE JUNCTION ARE EITHER 240 FEET OR 270 FEET AS SHOWN ELSEWHERE IN THE PLANS.
7. TERMINAL SECTIONS OF ROADWAY CONCRETE MEDIAN BARRIER SHALL BE CAST IN PLACE WITH A DETAILED SHAPE AS DETAILED IN TMUTCD(4). SUCH TERMINAL SECTIONS SHALL BE A MINIMUM OF 10 FEET LONG AND HAVE THE APPROPRIATE JOINT FOR ATTACHMENT TO THE PRECAST BARRIER.
8. END CONDITIONS OF THE CONCRETE MEDIAN BARRIER (ROADWAY PRECAST) SHALL BE ANCHORED WITH A MIXTURE OF ONE PART SAND AND TWO PARTS CEMENT MIXED THOROUGHLY WITH ENOUGH WATER TO MAKE THE MIXTURE PLASTIC. ANCHORING SHALL BE DONE IN A MANNER THAT WILL ASSURE A SMOOTH SURFACE AT THE JOINT.
9. SPLASH STRIPWORK SHOWN ON THE PLANS THE CONTRACTOR HAS THE OPTION OF PLACING STRIPS PRECAST OR CAST IN PLACE CONCRETE MEDIAN BARRIER.

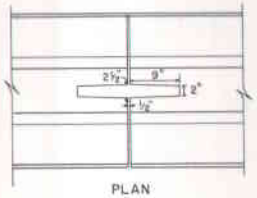


SECTION THROUGH ℄ AT JOINT

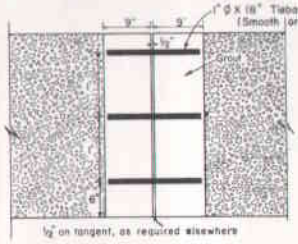


END
VIEW

JOINT TYPE B



PLAN



SECTION THROUGH ℄ AT JOINT

JOINT TYPE A

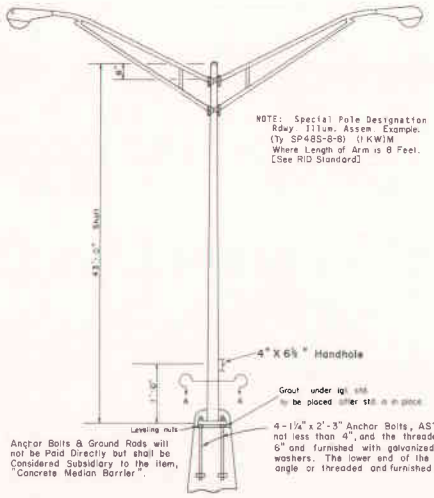
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

CONCRETE MEDIAN BARRIER ROADWAY (PRECAST) WITH ILLUMINATION

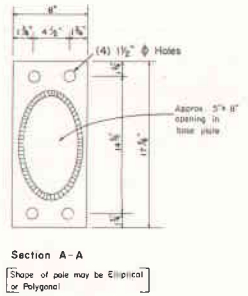
CMBI-75(3)

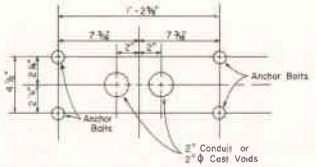
CK.	DRAWING	DATE	REVISION NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK. DR.	ORIGINAL					
DR.	REVISED			TEXAS		
CK. DR.	REVISED			COUNTY	CONT. SECT. JOB	HIGHWAY NO.
YR.			STATE DISTRICT			
CK. YR.						

A-52

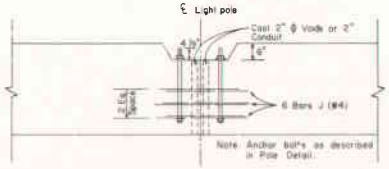


POLE DETAIL

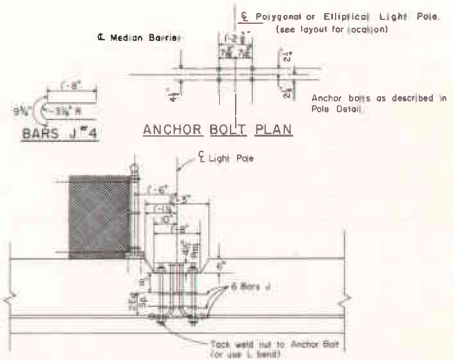




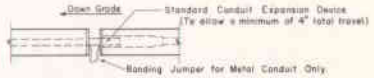
TOP VIEW (PRECAST ROADWAY BARRIER)



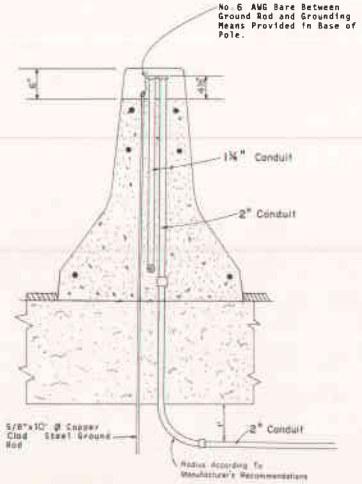
DETAIL AT LIGHT POLE (ROADWAY PRECAST)



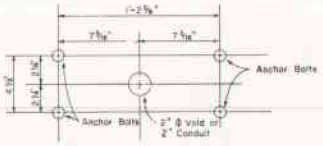
DETAILS AT LIGHT POLE ON BRIDGES AND ROADWAY (CAST-IN-PLACE)



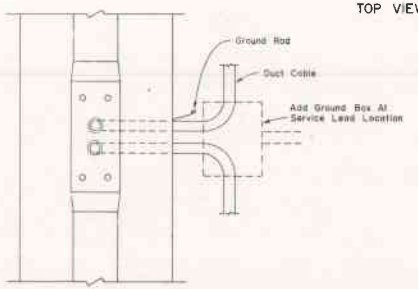
CONDUIT EXP JOINT FOR BRIDGE BARRIER



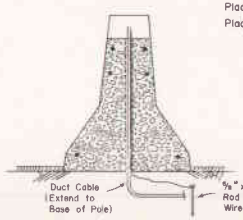
SERVICE LEAD DETAIL
(ROADWAY BARRIER, CAST-IN-PLACE)



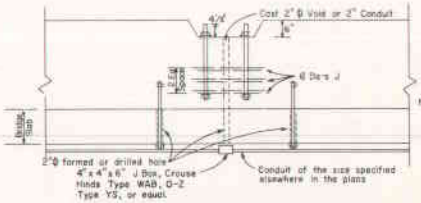
TOP VIEW (PRECAST BRIDGE BARRIER)



PLAN VIEW



DUCT CABLE DETAIL (ROADWAY BARRIER, PRECAST)



DETAIL AT LIGHT POLE (BRIDGE PRECAST BARRIER)

NOTE: Unless Otherwise Shown in the Plans The Contractor Has The Option of Placing Either Precast or Cast In Place Concrete Median Barrier.

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

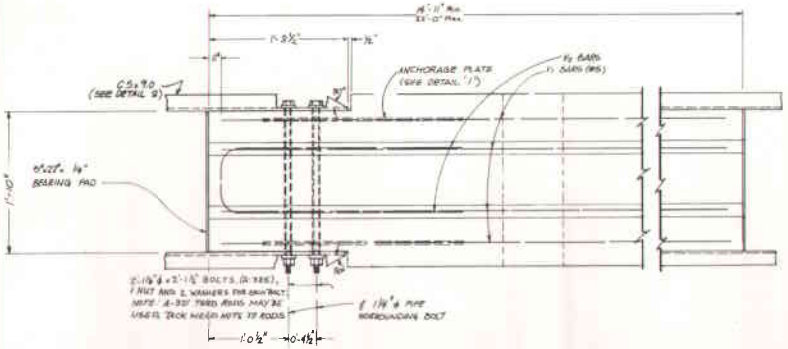
CONCRETE MEDIAN BARRIER

BRIDGE AND ROADWAY WITH ILLUMINATION

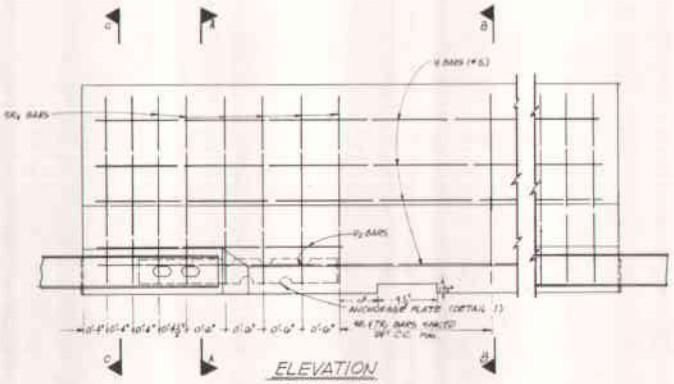
CMBI-75 (4)

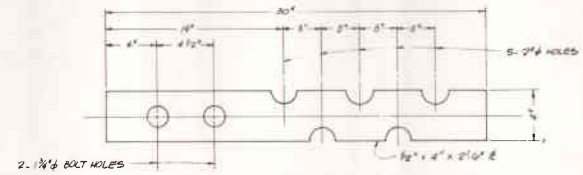
CH.	DRAWING	DATE	REVISIONS	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK. DW.	ORIGINAL					
DW.	REVISED			TEXAS		
CK. DW.	REVISED			STATE DISTRICT	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
TR.						
CK. TR.						

A-53

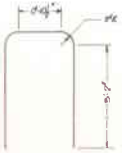


PLAN VIEW
(TYP BOTH ENDS)

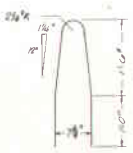




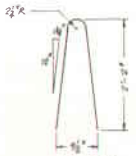
DETAIL 1
SCALE: 1½"=1"



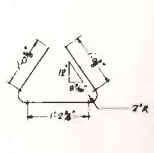
BAR V₈
(# 8)



BAR SR₂
(# 4)



BAR SR₁
(# 4)



BAR TR₂
(# 4)

REINFORCING STEEL DETAILS (N.T.S.)

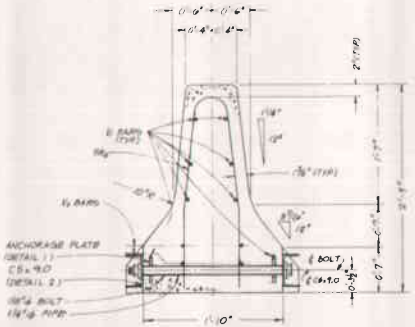
SECTION C-C

SECTION C-C IS IDENTICAL TO SECTION A-A W/O PIPE, BOLT OR ANCHORAGE PLATE

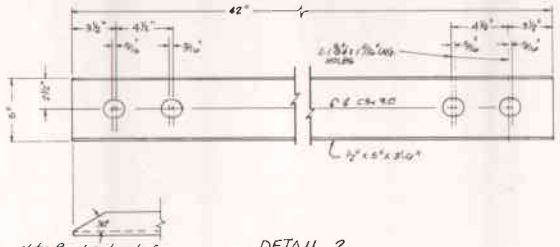
* APPROXIMATE QUANTITIES FOR A 20 FT. SECTION		
CONCRETE	CY.	2.24
REINFORCING STEEL	LBS.	180.2

APPROX. WEIGHT PER FOOT IS 463 LBS.

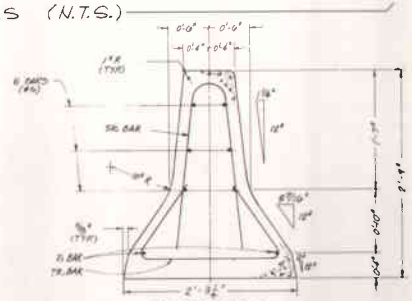
* FOR CONTRACTORS INFORMATION ONLY



SECTION A-A



DETAIL 2
SCALE: 1½"=1"



SECTION B-B

GENERAL NOTES

1. CHANNEL SECTIONS AND ALL STEEL PLATES SHALL CONFORM TO ASTM DESIGNATION A36.
2. BEARING PADS SHALL BE MADE OF AN ELASTOMERIC MATERIAL WITH A HARDNESS OF 90 DUROMETER AND ARE TO BE EPOXIED TO BARRIER UNIT AFTER CASTING.
3. ALL CONCRETE SHALL BE CLASS "C".
4. ALL LONGITUDINAL REINFORCING STEEL SHALL BE GRADE 60, ALL VERTICAL STEEL SHALL BE GRADE 40.
5. EACH BARRIER SHALL BE DELIVERED WITH 2 SPLICE C5x9.0 CHANNEL SECTIONS AND CONNECTING HARDWARE.
6. WHEN BARRIER IS TO BE PLACED IN A CURVING ALIGNMENT, THE C5x9.0 CHANNEL SECTIONS MAY BE HEATED AT THE MIDPOINT AND PRE-BENT.
7. ALL C5x9.0 CHANNELS SHALL BE HOT-DIP GALVANIZED IN CONFORMANCE TO ASTM DESIGNATION A123. BOLTS, NUTS, AND WASHERS SHALL BE HOT-DIP GALVANIZED TO CONFORM TO ASTM DESIGNATION A153.
8. CHAMFER END AND TOP EDGES ¾ - INCH.
9. INSERTS FOR LIFTING EYES MAY BE INSTALLED AT THE CONTRACTOR'S OPTION. OTHER LIFTING DEVICES OR ATTACHMENTS TO BARRIER SECTIONS SHALL BE APPROVED BY THE ENGINEER.
10. REINFORCING STEEL, BOLTS, NUTS, WASHERS, CHANNEL SECTIONS, AND ANCHORAGE PLATES SHALL BE INCLUDED IN THE PRICE PAID PER LINEAR FOOT FOR CONCRETE BARRIER RAIL (P & P).

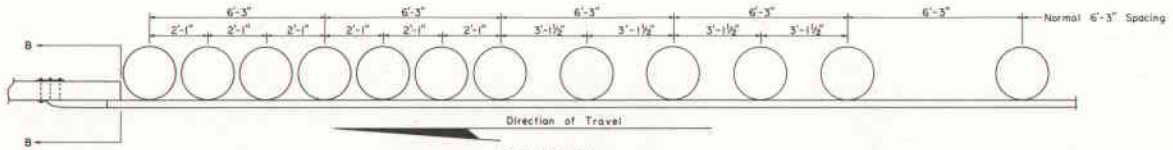
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

CONCRETE BARRIER RAIL
(PORTABLE AND PRECAST)

CBR (P&P) - 80

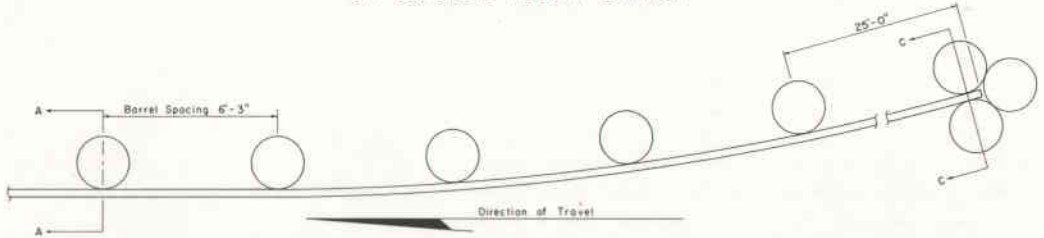
DN	DRAWING	DATE	FED. ROAD DIV. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK. DN.	ORIGINAL					
DW.	REVISED		6	TEXAS		
CK. DW.	REVISED		STATE DISTRICT	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
TR.						
CK. TR.						

A-53-A



PLAN VIEW

ATTACHMENT TO BRIDGE RAIL
OR CONCRETE MEDIAN BARRIER



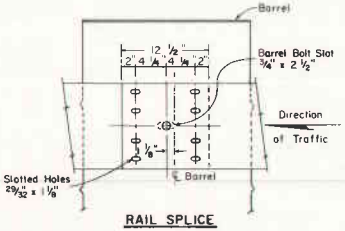
PLAN VIEW

NORMAL BARREL SPACING

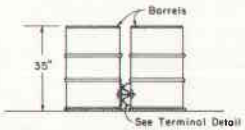
GENERAL NOTES

1. RAIL ELEMENT MAY BE EITHER 12½ OR 25 FOOT LENGTHS AND EITHER 10 OR 12 GAUGE.
2. MINIMUM LENGTH OF PLACEMENT EQUALS 100 FEET.
3. WHEN THE ROADWAY SURFACE IS ASPHALT, PLYWOOD SHALL BE PLACED UNDER THE BARRELS TO PREVENT DAMAGE TO THE PAVEMENT.
4. LOCATION OF BARREL MOUNTED GUARD FENCE IS SHOWN ELSEWHERE IN THE PLANS.
5. RAIL ELEMENT SPLICES SHALL BE LAPPED IN THE DIRECTION OF TRAFFIC.
6. RAIL SPLICES SHALL BE CONNECTED WITH THE NORMAL EIGHT ¾" LONG OVAL SHOULDER BUTTON HEAD BOLTS WHICH ARE 5/8" IN DIAMETER.
7. BARREL SPACING SHALL BE 6'-3", EXCEPT CLOSER SPACING SHALL BE USED AS SHOWN TO TRANSITION INTO A CONNECTION WITH A BRIDGE RAIL, CONCRETE MEDIAN BARRIER, OR SIMILAR FIXED OBJECT.
8. DRAINAGE HOLES SHALL BE DRILLED IN THE BOTTOM OF THE BARRELS TO ALLOW FOR DRAINAGE OF WATER.
9. APPROACH END OF THE TEMPORARY BARRIER SHALL BE FLARED AWAY FROM THE ROADWAY AND SHALL BE TREATED WITH THREE BARRELS AS SHOWN TO AVOID AN EXPOSED GUARD FENCE END. THE GUARD FENCE SHALL BE DROPPED FROM A HEIGHT OF 27" TO A HEIGHT OF 12½" WITH A 25 FOOT LONG SECTION OF GUARD FENCE. EACH OF THE BARRELS SHALL BE FILLED WITH APPROXIMATELY 4" OF SAND. THE THIRD BARREL SHALL BE ATTACHED USING ⅝" DIAMETER BOLTS WITH HEX NUTS AND WASHERS.

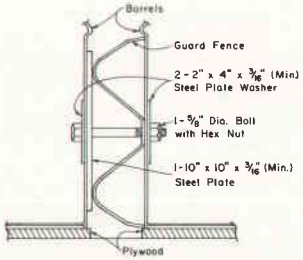
ANCHOR OR SPLICE BOLT ⅝" NUT
POST BOLT - Similar except length
(⅞ Hex bolts required for Terminal Connector)



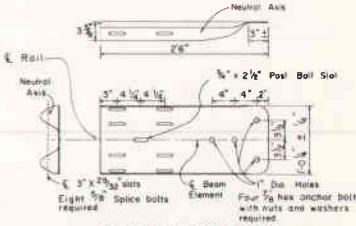
RAIL SPLICE



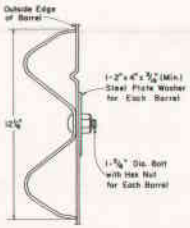
SECTION C-C



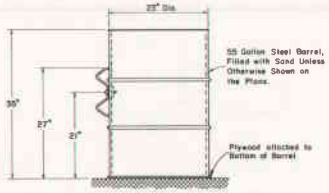
TERMINAL DETAIL



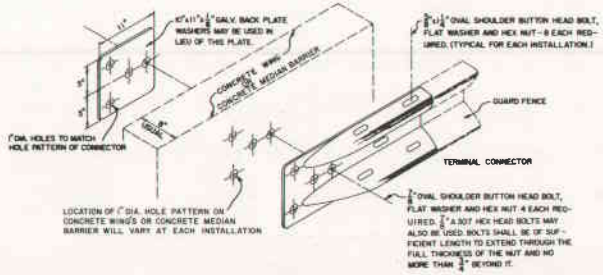
TERMINAL CONNECTOR
(10 GAGE MINIMUM)



DETAIL OF RAIL ELEMENT
CONNECTION TO BARREL



SECTION A - A



ATTACHMENT TO BRIDGE RAIL
OR CONCRETE MEDIAN BARRIER

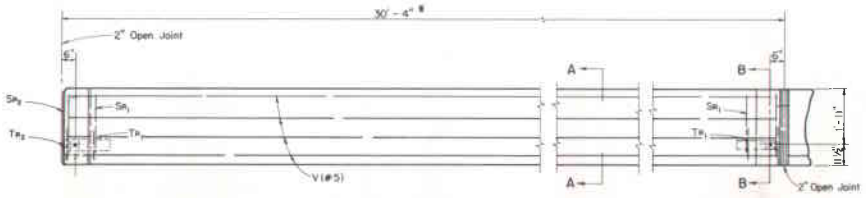
SECTION B-B

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

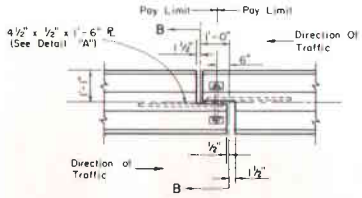
TEMPORARY BARRIER
BARREL-MOUNTED GUARD FENCE
TB (BMGF)-80A

DR.	DRAWING	DATE	FED. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK. DR.	ORIGINAL		64,80			
DW.	REVISED	11-1-82	6	15646		
CK. DW.	REVISED		STATE	COUNTY	CONT.	SECT.	JOB	HIGHWAY NO.
TB			601,80					
CK TB.								

A-53B

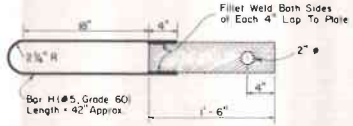


ELEVATION OF BARRIER ON ROADWAY



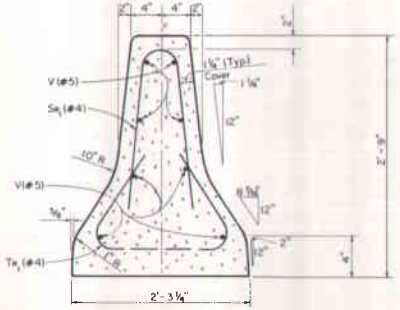
END DETAIL

* Length may be varied slightly with approval of the engineer

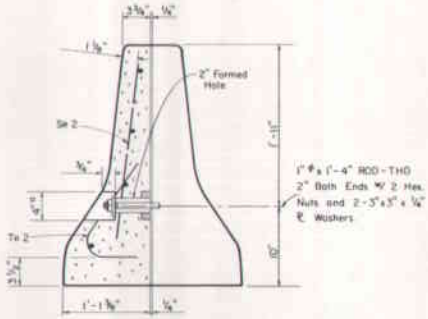


NOTE: Plates Conform to ASTM A 36 Steel

ANCHORAGE PLATE DETAIL A



SECTION A-A

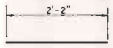


SECTION B-B

GENERAL NOTES

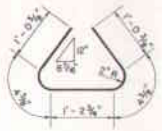
1. ALL FORMS FOR PRECAST MEDIAN BARRIER SHALL BE CONSTRUCTED OF STEEL.
2. LONGITUDINAL BARS FOR ROADWAY BARRIER SHALL CONFORM TO ASTM A-615 OR ASTM A-616 (GRADE 60). VERTICAL BARS SHALL CONFORM TO ASTM A-615 (GRADE 40). BAR SPLICES FOR ROADWAY BARRIER SHALL BE A MINIMUM OF 24 TIMES THE NOMINAL DIAMETER OF THE BAR.
3. CHAMFER ALL EXPOSED CORNERS 3/4" UNLESS OTHERWISE SHOWN.
4. THE CONCRETE MEDIAN BARRIER SHALL RECEIVE AN "ORDINARY SURFACE FINISH" FOR EXPOSED CONCRETE AS DESCRIBED IN THE ITEM CONCRETE STRUCTURES. CONCRETE SHALL BE CLASS "C". (CLASS "H"-4000 P.S.I. MAY BE USED IN LIEU OF CLASS "C" WHEN APPROVED BY THE ENGINEER.)
5. AXIS OF MEDIAN BARRIER SHALL BE VERTICAL.
6. ALL STEEL FITTINGS SHALL BE GALVANIZED AFTER FABRICATION.
7. THE REINFORCING CAGE MAY BE TACK WELDED IN LIEU OF TYING.
8. REGARDLESS OF METHOD OF HANDLING, BARRIER SECTION LIFTING POINTS SHALL BE 6½ FEET FROM THE ENDS OF THE BARRIER. LIFTING DEVICES AND ATTACHMENTS TO BARRIER SECTION SHALL BE AS APPROVED BY THE ENGINEER.

BARS Sr_1 (#4)



BARS Sr_2 (#4)

NOTE: BARS Sr_1 and Tr_1 may be furnished as one continuous BAR with a 4" lap at the Contractors Option.
BARS Sr_2 and Tr_2 may be furnished as one BAR.



BARS Tr_1 (#4)

BARS Tr_2 (#4)

# APPROXIMATE P.L.F. QUANTITIES		
CONCRETE	C.Y.	0.112
REINFORCING STEEL	LB.	8.8

FOR CONTRACTORS INFORMATION ONLY

WEIGHT OF ONE 30' UNIT = APPROXIMATELY 7 TONS

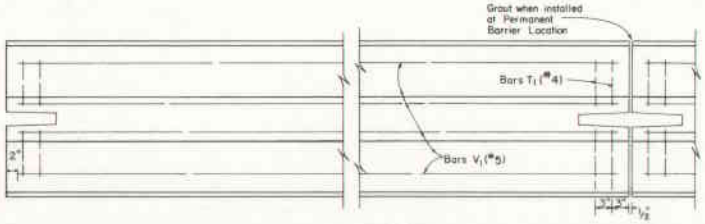
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

PRECAST CONCRETE MEDIAN BARRIER TYPE A

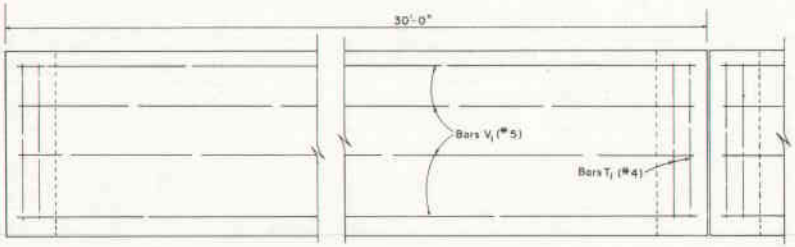
PCMB (A) - 80

	DRAWING	DATE	FED. AID PROJ. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
	ORIGINAL					
	REVISED			TEXAS		
	REVISED		STATE DIST. NO.	COUNTY	CONT. SECT. JOB	PROJECT NO.

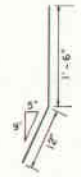
A-53D



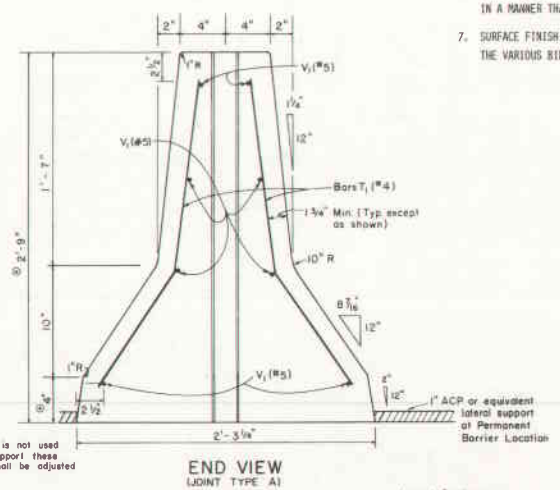
PLAN VIEW



ELEVATION



BAR T_1 (#4)



ⓞ When 1" ACP is not used for lateral support these dimensions shall be adjusted accordingly

END VIEW (JOINT TYPE A)

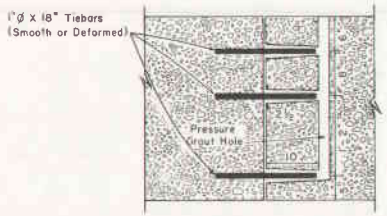
GENERAL NOTES

1. LONGITUDINAL BARS SHALL CONFORM TO ASTM A-615 OR ASTM A-616 (GRADE 60). VERTICAL BARS SHALL CONFORM TO ASTM A-615 (GRADE 40).
2. CHAMFER ALL EXPOSED EDGES 3/4-INCH, EXCEPT END EDGES UNLESS OTHERWISE SHOWN.
3. CONCRETE SHALL BE CLASS "C". THE CONCRETE SHALL RECEIVE AN "ORDINARY SURFACE FINISH" FOR EXPOSED CONCRETE AS DESCRIBED IN THE ITEM CONCRETE STRUCTURES.
4. REGARDLESS OF THE METHOD OF HANDLING, BARRIER SECTION LIFTING POINTS SHALL BE 64 FEET FROM THE ENDS OF THE BARRIER. LIFTING DEVICES AND ATTACHMENTS TO BARRIER SECTIONS SHALL BE AS APPROVED BY THE ENGINEER.
5. WHEN INSTALLED IN A TEMPORARY LOCATION, TIE BARS SHOULD BE PLACED IN THE SLOT OF JOINT TYPE A, OR, FOR JOINT TYPE B, THE MALE-FEMALE CONNECTIONS SHOULD BE MATED. NEITHER OF THE OPTIONAL JOINT TYPES SHOULD BE GROUTED FOR TEMPORARY LOCATIONS OF BARRIER.
6. WHEN INSTALLED IN A PERMANENT ROADWAY LOCATION, END CONNECTIONS OF THE PRECAST CONCRETE MEDIAN BARRIER SHALL BE GROUTED WITH A MIXTURE OF ONE PART SAND AND TWO PARTS CEMENT WITH ENOUGH WATER TO MAKE THE MIXTURE PLASTIC. GROUTING SHALL BE DONE IN A MANNER THAT WILL ASSURE A SMOOTH SURFACE AT THE JOINT.
7. SURFACE FINISHING AND GROUTING (WHERE REQUIRED) SHALL BE CONSIDERED SUBSIDIARY TO THE VARIOUS BID ITEMS INVOLVED.

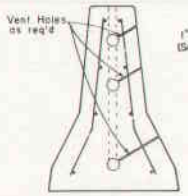
# APPROXIMATE P.L.F. QUANTITIES		
CONCRETE	CY.	0.112
REINFORCING STEEL	LB.	8.7

FOR CONTRACTORS INFORMATION ONLY

WEIGHT OF ONE 30' UNIT = APPROXIMATELY 7 TONS

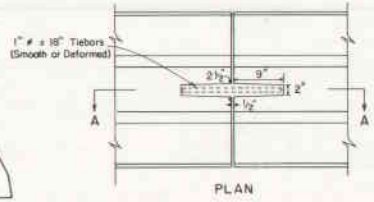


SECTION THROUGH ℄ AT JOINT

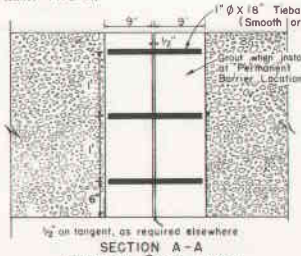


END VIEW

JOINT TYPE B



PLAN



SECTION A-A (THROUGH ℄ AT JOINT)

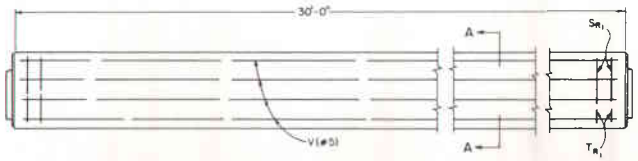
JOINT TYPE A

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

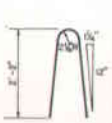
PRECAST CONCRETE MEDIAN BARRIER TYPE B

PCMB (B) - 80

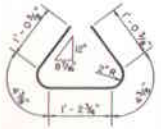
Ck.	DRAWING	DATE	FED. ROAD DIV. NO.	STATE	FEDERAL PROJECT NO.				SHEET NO.
Ck. Dr.	ORIGINAL		6	TEXAS					
Dr.	REVISED								
Co. Dir.	REVISED			STATE DISTRICT	COUNTY		DIST.	SECT.	JOB	HIGHWAY NO.
Ck.									
Ck. Y.R.									



ELEVATION OF BARRIER



BARS S_{R_1} (#4)

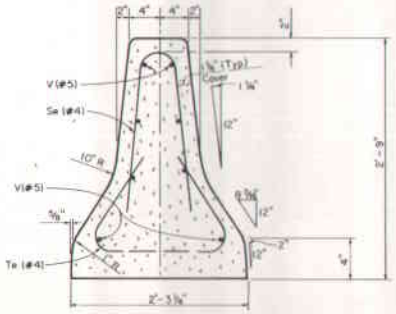


BARS T_{R_1} (#4)

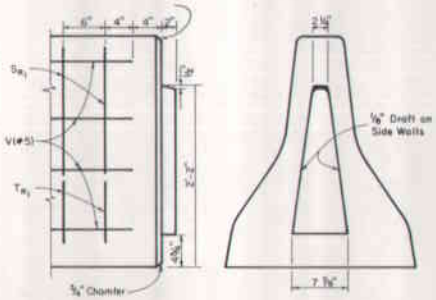
NOTE: BARS Sa_1 and T_{R_1} may be furnished as one continuous BAR with a 4" lap at the Contractors Option.

GENERAL NOTES

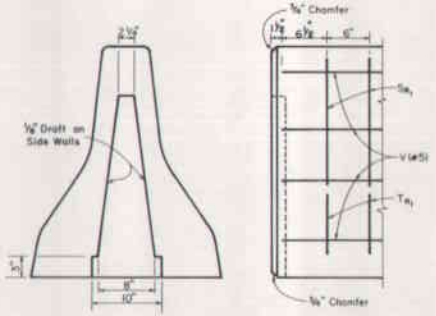
1. ALL FORMS FOR PRECAST MEDIAN BARRIER SHALL BE CONSTRUCTED OF STEEL.
2. LONGITUDINAL BARS FOR ROADWAY BARRIER SHALL CONFORM TO ASTM A-615 OR ASTM A-616 (GRADE 60). VERTICAL BARS SHALL CONFORM TO ASTM A 615 (GRADE 40). BAR SPLICES FOR ROADWAY BARRIER SHALL BE A MINIMUM OF 24 TIMES THE NOMINAL DIAMETER OF THE BAR.
3. CHAMFER ALL EXPOSED CORNERS 3/4" UNLESS OTHERWISE SHOWN.
4. THE CONCRETE MEDIAN BARRIER SHALL RECEIVE AN "ORDINARY SURFACE FINISH" FOR EXPOSED CONCRETE AS DESCRIBED IN THE ITEM CONCRETE STRUCTURES. CONCRETE SHALL BE CLASS "C". (CLASS "M"-4000 P.S.I. MAY BE USED IN LIEU OF CLASS "C" WHEN APPROVED BY THE ENGINEER.)
5. AXIS OF MEDIAN BARRIER SHALL BE VERTICAL.
6. THE REINFORCING CAGE MAY BE TACK WELDED IN LIEU OF TYING.
7. REGARDLESS OF METHOD OF HANDLING, BARRIER SECTION LIFTING POINTS SHALL BE 64 FEET FROM THE ENDS OF THE BARRIER. LIFTING DEVICES AND ATTACHMENTS TO BARRIER SECTION SHALL BE APPROVED BY THE ENGINEER.
8. MALE TONGUE TOLERANCE: +0",-1/16"
   FEMALE GROOVE TOLERANCE: +1/16",-0"
9. EDGES AND FILLETS OF KEYS HAVE ½" RADII
10. BARRIER SECTIONS CAST EITHER DOUBLE MALE OR FEMALE



SECTION A-A



DETAIL OF MALE KEY



DETAIL OF FEMALE KEYWAY

# APPROXIMATELY P.L.F. QUANTITIES		
CONCRETE	CY.	0.112
REINFORCED STEEL	LB.	8.7

FOR CONTRACTORS INFORMATION ONLY

WEIGHT OF ONE 30' UNIT = APPROXIMATELY 7 TONS

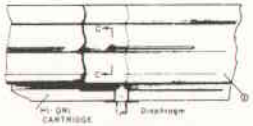
THE CONTRACTOR IS ADVISED THAT THE KEYWAY CONNECTION FOR PRECAST CONCRETE MEDIAN BARRIER TYPE C IS PATENTED BY EASI-SET INDUSTRIES, MIDLAND, VIRGINIA, 22728. IT IS THE CONTRACTOR'S SOLE RESPONSIBILITY TO PROVIDE FOR USE OF THE CONNECTION BY AGREEMENT WITH THE PATENTEE AND SAVE HARMLESS THE STATE FROM ANY AND ALL CLAIMS FOR INFRINGEMENT IN ACCORDANCE WITH ARTICLE 7.3 OF ITEM 7, "LEGAL RELATIONS AND RESPONSIBILITIES TO THE PUBLIC."

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

PRECAST CONCRETE MEDIAN BARRIER TYPE C

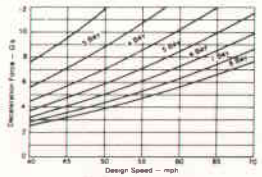
PCMB (C) - 80A

TOP ASSEMBLY VIEW



SIDE ASSEMBLY VIEW

ITEM	REQUIRED PARTS PER FENDER PANEL	QUANT
1	THRIE BEAM 10 Ga. 4'-4"	1
2	MUSHROOM BOLT	1
3	SHEAR BOLT 5/8" Ø X 2" H.H. W/NUT	2
4	SHEAR BOLT 5/8" Ø X 2" H.H. W/NUT	2
5	WASHER 5/16" (Flat)	4
6	WASHER 1/2" (Flat)	2



DESIGN INFORMATION

NOTE
Deceleration force of 6 G's recommended for design

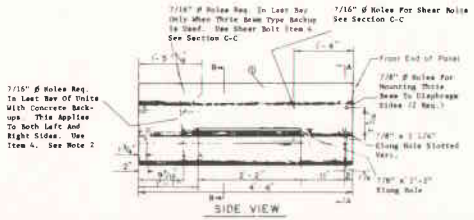
BACK-UP STRUCTURE INFORMATION

TYPE A TENSION STRUT: CONSISTS OF DIAGONAL STRUTS, CONNECTIONS, AND ACCESSORIES, AS DETAILED BY THE MANUFACTURER, LOCATED AT REAR OF G.R.E.A.T. UNIT. WHEN USED, A 4' X 4' X 24' REINFORCED CONCRETE TOE ANCHOR BLOCK SHALL BE PROVIDED BENEATH THE FRONT PORTION OF THE CONCRETE PAD EXCEPT WHERE THE G.R.E.A.T. UNIT IS TO BE PLACED ON CONTINUOUSLY REINFORCED CONCRETE PAVEMENT.

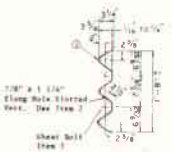
TYPE B CAST-IN-PLACE CONCRETE: CONCRETE MEDIAN BARRIER, BRIDGE PARAPETS, COLUMNS, OR SPECIAL WALLS WHICH ARE CAST-IN-PLACE MAY BE USED AS BACK-UP STRUCTURES FOR G.R.E.A.T. UNITS. WHERE USED, WALLS SHALL BE 2' - 8" IN HEIGHT, WIDTH EQUAL TO THAT OF THE G.R.E.A.T. UNIT, AND 2' - 0" THICKNESS AND SHALL BE REINFORCED WITH A STEEL CAGE. PRECAST CONCRETE MEDIAN BARRIER SHALL NOT BE USED AS A BACKUP STRUCTURE FOR THE G.R.E.A.T. UNIT.

TYPE C WIDE FLANGE BACK-UP: CONSISTS OF TWO 6W25 X 6'-2" STEEL POST ERECTED VERTICALLY AT REAR OF G.R.E.A.T. UNIT. POSTS ARE SET IN A CAST-IN-PLACE, REINFORCED CONCRETE FOUNDATION WHICH IS 4'-0" X 1'-6" X 3'-0", WITH THE 3'-0" DEPTH MEASURED FROM TOP OF CONCRETE PAD. DETAILS FOR CONNECTIONS AND ACCESSORIES FOR THE WIDE FLANGE BACK-UP PROVIDED BY THE MANUFACTURER.

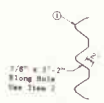
* NOTE: Type of Back up Structure for Each Location Specified elsewhere in the Plans



SIDE VIEW



SECTION A-A



SECTION B-B

SECTION C-C

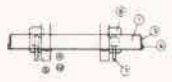
Left Panel Shown - Right Panel Opposite. Deflection Vanes Required On Left Side Panels For Two Direction Traffic. See Note 1

Note:

1. Use Shear Bolts As Follows: Item 3 Will Be Used In Bays 1, 2 & 3. Item 4 Will Be Used In The Remaining Bays.
2. These Two 7/16" Ø Holes Are Required Only In Last Bay Of Unit, And Only When Concrete Backup Is Used. Shear Bolt Item 4 To Be Used.
3. For Units In Two Direction Traffic, Deflector Panel Will Be Required On Left Side Fender Panels.
4. Shear Bolt Holes To Be Located And Drilled In The Field. Spray Hole With Galvanizing Compound.

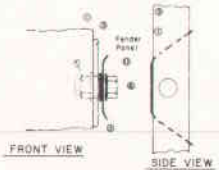
THRIE* BEAM FENDER PANEL DETAILS

* TRIPLE CORRUGATED GUARD FENCE, 10 GUAGE GALVANIZED STEEL



TOP VIEW

Note: Restraining Cable Guide Not shown on Top View



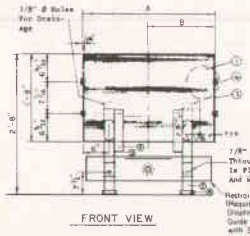
FRONT VIEW

SIDE VIEW

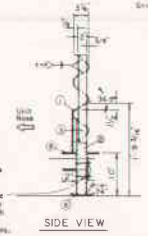
Detail A

ITEM	REQUIRED PARTS PER DIAPHRAGM	QUANT
1	THRIE BEAM 9'-3 MINUS 1/2"	1
2	PIPE 2" Ø SCH 80 X 1'-8 15/16"	2
3	2" x 1/4" x 1'-8"	2
4	2" x 3/16" x 9 5/8"	2
5	2" x 5/16" x 8 1/2"	2
6	H.H. BOLT 3/4" Ø x 5" GRADE 2 PLATED	4
7	STEEL ROD 3/4" Ø x 5 1/8"	2
8	3 1/2" x 1/4" x 0'-8"	2
9	3/4" H.H. NUT	4
10	CARRIAGE BOLT 3/8" Ø x 1" W/WASH & NUT	2
11	3/4" Ø FLAT WASHERS	8

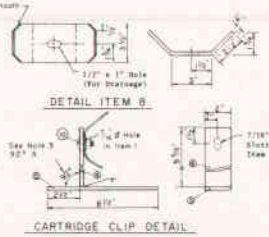
DIAPHRAGM WIDTH TABLE		
A	B	C
2'-0"	1'-0"	2 1/2"
2'-6"	1'-3"	5 3/4"
3'-0"	1'-6"	8 3/4"



FRONT VIEW



SIDE VIEW



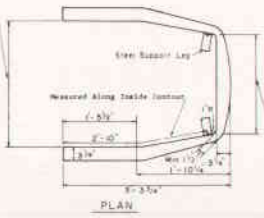
DETAIL ITEM 8

CARTRIDGE CLIP DETAIL

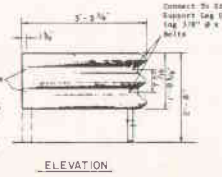
Note: Reuse Key's 2 Cartridge Fragments As Shown Above

THRIE* BEAM DIAPHRAGM DETAILS

* TRIPLE CORRUGATED GUARDFENCE, 10 GAUGE GALVANIZED STEEL

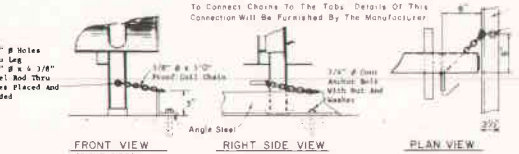


PLAN

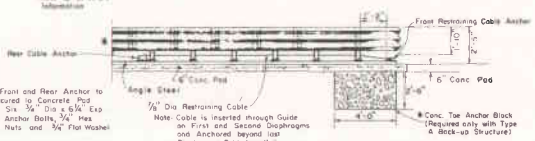


ELEVATION

NOSE COVER DETAILS

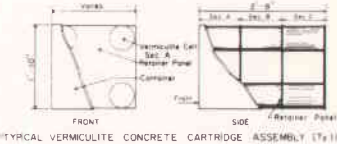


PLAN



Each Front and Rear Anchor to be secured to Concrete Pad using Six 3/4" Dia x 6 3/4" Exp Conc Anchor Bolts, 3/4" Hex Head Nuts and 3/4" Flat Washer

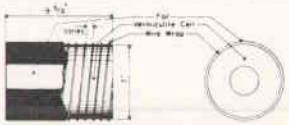
STABILIZING CHAIN DETAILS



TYPICAL VERMICULITE CONCRETE CARTRIDGE ASSEMBLY (Ty II)

ASSEMBLY WIDTH	CARTRIDGE TYPE NOSE	BAYS
8'-0"	Ty 13	Ty 10
8'-6"	Ty 10	Ty 11
9'-0"	Ty 10	Ty 11

NOTE
Each Ty 13 cartride shall have 18 cells, Ty 10 and Ty 11 cartridges shall have 18 cells each. Positioning of cells within the cartridge shall be in accordance with the manufacturer's recommendations



TYPICAL VERMICULITE CELL

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

GUARD RAIL ENERGY ABSORBING TERMINAL

GREAT - 80

FILE	CHANGED	DATE	SHEET NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
C.S.	ORIGINAL					
DW	REVISED			TEXAS		
C.K. DW	REVISED					
T.R.				STATE DISTRICT NO.	COUNTY	CONT. SECT. JOB
C.K. DW						HIGHWAY NO.

SPECIAL SPECIFICATION

ITEM 5352

GUARD RAIL ENERGY ABSORBING TERMINAL

1. DESCRIPTION. This Item shall govern for the furnishing and installation of Guard Rail Energy Absorbing Terminal (G.R.E.A.T.) crash cushions, or equal (based on equivalent crash-test results and equivalent site-space requirements), at the locations shown in the plans. After installation, the crash cushions should remain intact and redirect side vehicular impacts but should telescope and crush to attenuate head-on vehicular crashes. G.R.E.A.T. crash cushions may be obtained from Energy Absorption Systems, Inc., One East Wacker Drive, Chicago, Illinois 60601, (312) 467-6750.

2. MATERIALS. All materials shall be new. G.R.E.A.T. crash cushions shall consist of nominal 7-inch diameter vermiculite (lightweight concrete) cyclinders of varying lengths to absorb impact energy. Cylinders shall be bonded to retainer panels and placed inside vinyl-coated weather-resistant boxes to form replaceable, crushable cartridge units. Standard 10-gauge, triple-corrugated steel guard fence beams shall be used for diaphragms to separate and support cartridges, thereby forming bays. The length of the triple-corrugated beams shall match the nominal width (3 ft., 2.5 ft., or 2.0 ft.) of the crash cushion as shown on the plans. Each diaphragm shall have two pipes welded to the triple-corrugated beam for support legs. Ski-shaped plates shall be welded to the bottom of the support legs to facilitate the sliding action of the assembly upon head-on impact. Metal tabs shall be welded or bolted to the bottom of the diaphragm to support the cartridges. Fender panels shall also be fabricated from standard 10-gauge, triple-corrugated steel guard fence. Fender panels shall be drilled, slotted, overlapped and bolted to the diaphragms so as to permit movement, front to back, in a telescoping manner when impacted head-on. Restraining chains shall be used to prevent significant lateral movement of the crash cushion during side impacts. Chains shall be anchored securely to a concrete support pad and attached to pipe support legs so as to permit longitudinal but restrict significant lateral movement of the crash cushion during impact. Details for the concrete support pad are shown on the plans. A high density polyethylene plastic nose cover shall be provided and installed at the front of the crash cushion. The nose cover shall be supported by two legs and shaped with triple corrugations to match the fender panels.

Dimensions and detailed material requirements will be as shown on the plans.

3. CONSTRUCTION. G.R.E.A.T. crash cushions shall be fabricated and installed so as to provide an assembly which telescopes and crushes to attenuate head-on impacts but remains intact and redirects for side impacts.

Further information regarding assembly and installation of the G.R.E.A.T. crash cushion may be obtained from Energy Absorption Systems, Inc.

4. MEASUREMENT. Completed and accepted work as described by this Item shall be measured as each Guard Rail Energy Absorbing Terminal installation complete in place.

5. PAYMENT. The work performed and the materials furnished as prescribed by this Item, measured as provided for under "Measurement," shall be paid for at the unit price bid for "Guard Rail Energy Absorbing Terminal" of the width, number of bays, and type of back-up structure specified. The unit price bid shall be full compensation for all labor, equipment, tools, incidentals, and services, and for furnishing all materials necessary to complete the work described by this Item, including vermiculite concrete cylinders, triple-corrugated steel beam diaphragms and fender panels, nose covers, restraining chains, pipe posts, brackets, steel plates, fasteners and fittings, back-up structures and concrete support pads as shown in the plans.

APPENDIX A-200

ROADSIDE DESIGN GUIDELINES (A-200)

A-201 GENERAL

The objective of this appendix is to make data and guidelines for use in roadside design available in a consolidated and understandable form. Although all the answers are not provided, much information which can be useful in providing a safe roadside is included. Optimistically, it is predicted that the use of these guidelines will be a significant factor in the planning, construction and maintenance necessary for safe highways.

The use of these roadside design guidelines should obviously be supplemented with sound engineering judgement.

A-201.1 INTRODUCTION

The roadside or area immediately adjacent to the traveled way plays an important part in the safe operation of the highway. Modern highways are designed in such a manner that it is not difficult for a capable driver to operate his vehicle safely within the roadway, but statistics show that a certain percentage of drivers in any stream of traffic are likely to leave the roadway unintentionally. A driver may fall asleep, he may be distracted by some influence within the vehicle or he may be under the influence of drugs or alcohol. In addition, factors within the vehicle, such as tires or some type of mechanical failure, may cause a vehicle to become uncontrollable and to leave the traveled way.

The responsibility of the highway engineer cannot be confined to only the roadway. The roadside must be designed with as much care and detail as is devoted to the design of the traveled way.

A-201.2 CRITERIA AND PROCEDURE

This section presents a brief outline of the reason for treatment of the roadside as a part of the design of the highway and suggests criteria and procedure for treatment of the roadside in such a manner that a safe highway will be the result. The objective in placing protective barriers is to lessen the hazard to traffic and not to protect any part of the roadway. As protective barriers are a hazard themselves, the primary endeavor should be to preclude or minimize the need for a protective barrier through design of geometric features.

Should a hazard exist such as unyielding landscape, drainage facilities, structures, highway hardware such as signs, luminaire poles, utility poles, or steep grades, treatment of the hazard should be considered in the following priority:

1. Eliminate the hazard: First, every effort should be made to clear the roadside of all obstructions and obstacles and to develop the terrain of the roadside in such a manner that it can be safely traveled by an out-of-control vehicle for a distance sufficient to permit the vehicle to be brought under control or to a safe stop.

2. Relocate the hazard to a point where it is less likely to be struck.

3. Use breakaway devices to reduce the hazard.

4. Select a cost-effective device for the re-direction (longitudinal barrier) or the reduction of accident severity (impact attenuator). See Figure A-1.

A-202 BEHAVIOR OF VEHICLES LEAVING THE ROAD

The path which an out-of-control vehicle follows after it leaves the traveled portion of the roadway is very difficult to predict and is related to a great number of factors. Depending on the nature of the roadside and circumstances which caused the vehicle to leave the roadway, the driver may or may not have some control over the vehicle, and he may or may not be able to regain some control after a portion of the energy of the vehicle has been dissipated. Precise knowledge of the experience of various drivers under these conditions is also very difficult to acquire. If these incidents do not involve a collision, they will probably not be reported, and no evidence of their having occurred, other than tire marks, will exist. If the incident does result in a collision, the path which the vehicle would have followed had the collision not occurred is obscured. Accident reports and observed incidents of vehicles leaving the traveled way provide some information here, and additional data has been acquired by observing tracks left on the roadside during wet weather.

The longitudinal distance, or distance parallel to the roadway traveled by a vehicle moving down the roadside, is of primary concern in determining what roadside conditions need attention. The angle at which the vehicle departs from the pavement, although it is not likely to remain constant, is also of interest. The lateral distance traveled and the speed and performance characteristics of the vehicle also play an important part in determining what parts of the roadside are critical.

Figure A-2 shows measured values in a cumulative form of the lateral distance from the edge of the pavement that vehicles departing from the roadway might be expected to reach. This information provides an indication of the lateral distance from the edge of the pavement which must be of concern although, any given situation may, due to unusual conditions of grade, alignment or terrain, require the consideration of a greater or lesser area.

Figure A-3 is a plotting of data indicating the longitudinal distance along the roadway which an out-of-control vehicle has been found to travel, and Figure A-4 shows the angle at which out-of-control vehicles have been known to depart from the traveled way. The speed of the vehicle, the weight of the vehicle, the nature of the terrain over which the vehicle must pass, and the ability of the driver are important factors in the behavior of the vehicle. The alignment of the roadway is also an important factor, particularly where unusual alignment is involved.

These data were collected on a variety of roadways and do not represent a statistically sound basis for determining critical areas. They do, however, provide indications as to what may be expected and will be used as a basis for determining the Area of Concern discussed later in this appendix. Additional data and experience with improved situations will be considered as information becomes available.

A-203 ROADSIDE GEOMETRICS

Of primary concern in design of the roadside is the terrain or contour of the land. In relatively flat country, gentle slopes in the vicinity of the road are easily provided. In hilly and mountainous country, flat slopes become more difficult and costly to construct. In many cases, however, flat slopes constructed as a safety measure at an additional cost have proven to be a valuable asset in reducing maintenance and operational costs and the possibility of earth slides is greatly diminished. Also, construction operations are accomplished in a safer manner and with less difficulty.

TRAFFIC BARRIER WARRANTING CONSIDERATIONS

	Barrier Warranting Factor	Barrier Candidate	
		Longitudinal	Vehicle Impact Attenuator
1. Lateral Drop-Off			
a. Bridge**	A	X	
b. Abrupt Embankment	B, C	X	
c. Sloped Embankment	D	X	
2. Roadside Obstacle			
a. Non-traversable Hazard			
(1) Rough rock cut	B	X	
(2) Large boulders	B	X	
(3) Water (permanent bodies)	B, C	X	
(4) Line of trees	B, E	X	
(5) Gores	F		X
(6) Space between twin bridges	G	X	X***
b. Fixed Object			
(1) Bridge parapet; bridge rail end	H	X	X
(2) Sign support	B, E	X	X
(3) Bridge piers; abutments	B	X	X
(4) Retaining walls, culvert headwalls	B	X	X
(5) Trees	B, E	X	X
(6) Wood poles, posts	B, E	X	X
(7) Tower lighting structures	B, E	X	X
3. Opposing Traffic	I	X	

*A - all bridges
B - distance from pavement
C - depth of drop (water)
D - height and slope
E - size
F - elevated exit ramp
G - adverse accident experience
H - bridge width, traffic redirection
I - median width, traffic volume
** - Bridge approach barrier and bridge rail should be an integrated barrier system
*** - Safety net installation

Figure A-1

COMPARISON OF PROVING GROUND, HUTCHINSON, AND CORNELL "HAZARD" CURVES

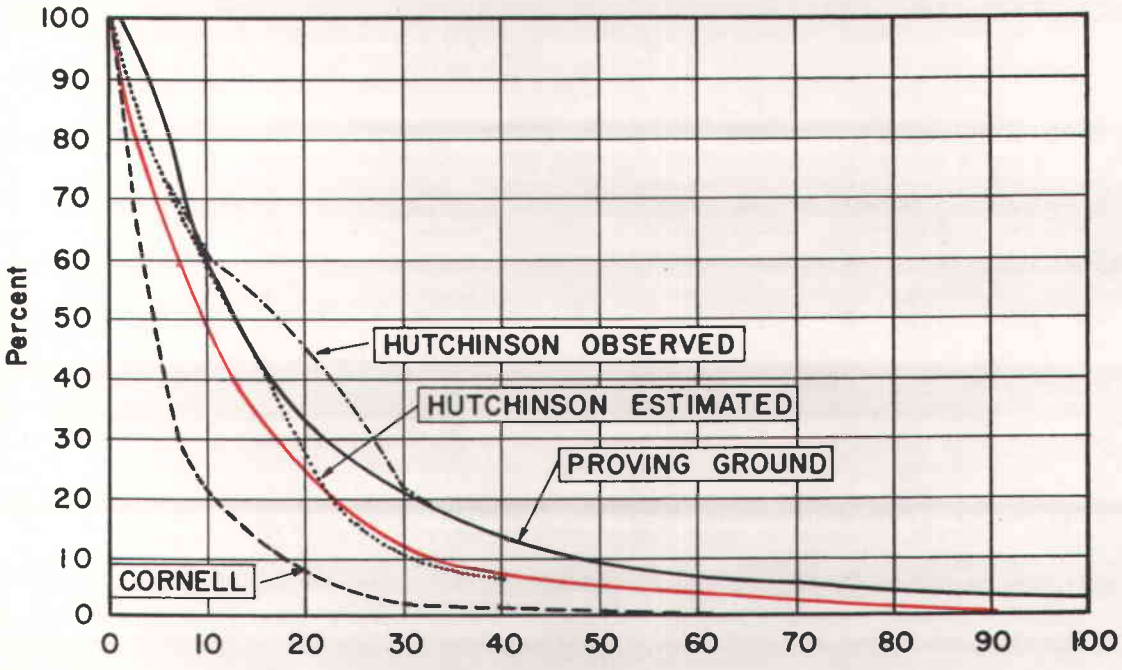
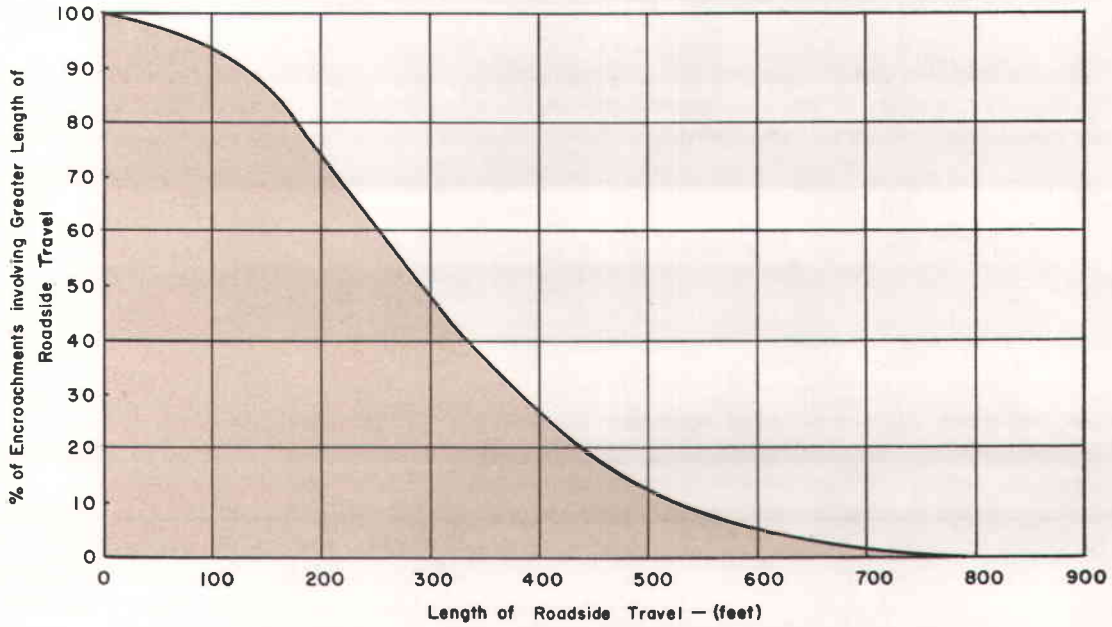
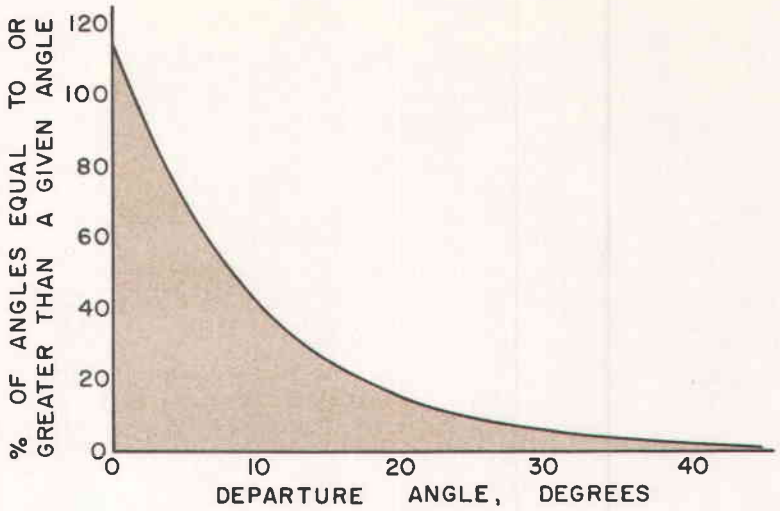


FIGURE A-2



LENGTH OF VEHICLE TRAVEL ON ROADSIDE

FIGURE A-3



DISTRIBUTION OF ANGLES FOR VEHICLES DEPARTING FROM THE ROADWAY

FIGURE A-4

It is desirable to permit slopes to vary, taking advantage of all of the area available rather than to require a fixed slope ratio. The warped slope illustrated in Figure A-5 presents a pleasing view to the motorist and could be traveled in relative safety. Abrupt changes in slope, such as that shown in Figure A-6, should be avoided. To do so not only results in a more pleasing roadway but should reduce the cost of grading since it is not necessary to be as exact as where earthwork is shaped to precise dimensions. While the shaping of the roadside is of prime importance, it is necessary also to design appurtenances adjacent to the roadway in such a way that they blend into the slope. Culvert ends frequently exist such as shown in Figure A-7. Figures A-8 and A-9 indicate how other types of drainage hazards can be treated. Several inlets such as these may be used where larger volumes of water must be accomodated.

The modification of existing structures to conform to these shapes will require ingenuity but is usually preferable to installing a rail. Broad shallow channels provide better vegetation possibilities and also result in less erosion and few drainage problems. Mowing and other maintenance functions are also less costly and safer.

In rural areas, roadside signs and illumination poles (Figure A-10) can be fitted with slip joint or frangible bases to eliminate the possibility of a serious collision. Other roadside installations can be dealt with in a similar manner. Where mast-arm poles such as the one shown in Figure A-11 are used, it may not be feasible to use a frangible mount due to the danger of the pole falling onto the road. If this type pole cannot be shielded with protective device, it should be eliminated and the signal heads suspended from a cable wire supported by poles located farther from the roadway.

In urban areas, every effort should be made to reduce the number of poles adjacent to a roadway. The joint use of poles by several agencies presents certain problems, but is a preferable alternative and should be encouraged.

On new projects, obstructions can generally be eliminated. Many can also be eliminated on existing facilities. Only when no better treatment is available should a protective device be considered.

FIGURE A-5

FIGURE A-6

FIGURE A-7

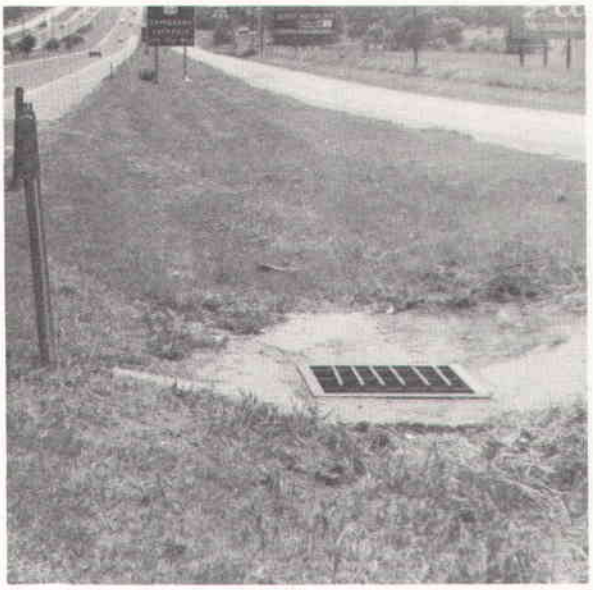


FIGURE A-8

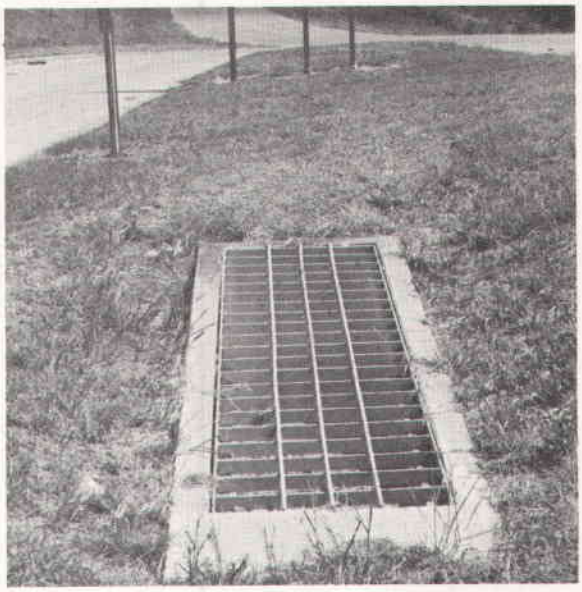


FIGURE A-9

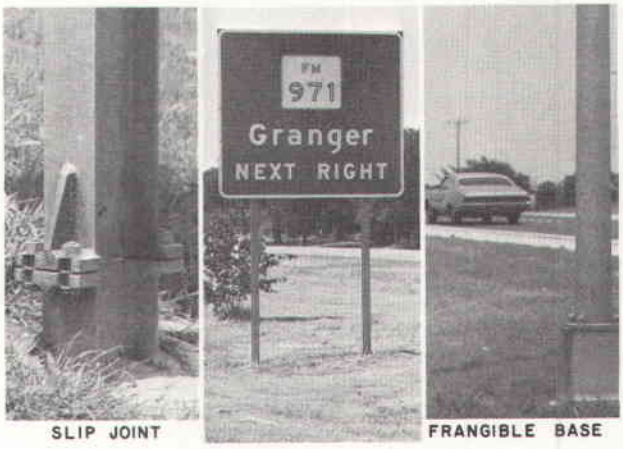


FIGURE A-10

FIGURE A-11

A-204 AREA OF CONCERN

After all possible means have been used to free the roadside of obstacles and all slopes reduced as much as possible, it is likely, particularly on existing roadways which are being modernized, that certain areas will remain which will constitute a hazard to moving traffic. Even on new construction, some hazards may remain. Since these hazards may take various shapes such as a bridge column covering only a few square feet of area or a drainage ditch covering many square feet of area and extending from the vicinity of the roadway to the right of way line, a hazard will be referred to as an "Area of Concern." At this point, all other means of eliminating these Areas of Concern as hazards have been exhausted and it must be assumed that a protective device will be required to prevent errant vehicles from entering or reaching the Area of Concern.

In determining the boundaries of the Area of Concern, the information furnished in Sections A-202 and A-203 of these guidelines must be considered. Both the behavior of the out-of-control vehicle and the geometry of the roadside are controlling factors - the roadside geometry from the standpoint of what areas are not safe for travel, and the behavior of the vehicle from the standpoint of where the errant vehicle is apt to go after leaving the roadway.

Certain types of obstructions are obvious in that they present a positive barrier to the movement of traffic. Other features, such as slopes, are not as positive in nature and must be viewed in the light of past experience and research results to determine the degree of hazard.

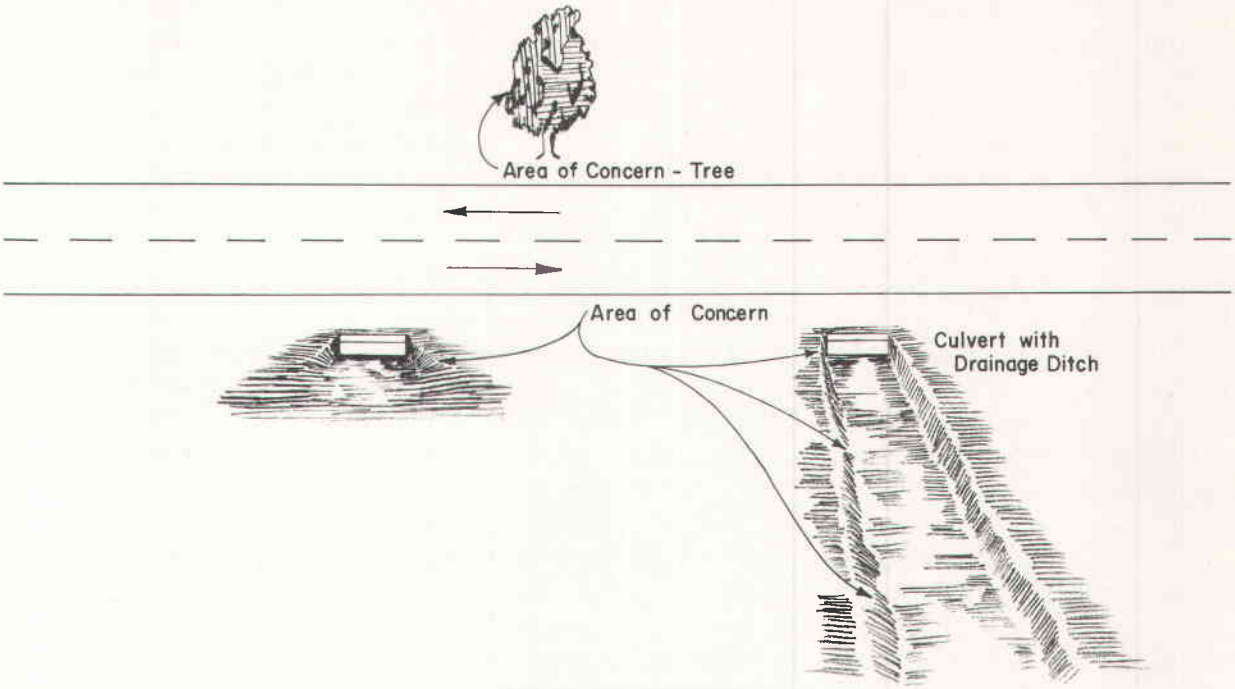
Several types of Areas of Concern are shown in Figure A-12. An abrupt ditch or cut at right angles to the traveled way and extending across the right of way is an unquestionable hazard and one of the most difficult to protect against. Many of these hazards could be avoided by the use of flat slopes on drainage ditches. This would allow maintenance equipment and vehicles out of control to cross in reasonable safety. A slope, however, increasing in severity as the driver approaches a grade separation, is not necessarily a hazard depending on the height of the fill and the angle of the slope. Figure A-13 provides a guide which is applicable in most situations. For low fill heights a more abrupt slope can be tolerated, but as the height of fill increases a flatter slope is required or a protective rail provided in lieu of the flat slope. Because a particular cross section frequently does not prevail for a great distance along a road, Figure A-13 necessarily indicates an area where judgement must be used to determine the need for a guardfence.

As shown in Figure A-2, vehicles leaving the roadway usually do not travel more than thirty feet from the pavement edge. This should be considered as an indication of the width of the Area of Concern but not necessarily an exact boundary. Roadway alignment or severe terrain could indicate the need for consideration of a wider area.

In describing the Area of Concern, the location of all obstructions should be determined and indicated either on the plans or a working drawing to be used for this purpose. The lateral location and lateral dimensions of this area are of primary importance in determining the beginning point of a rail installation.

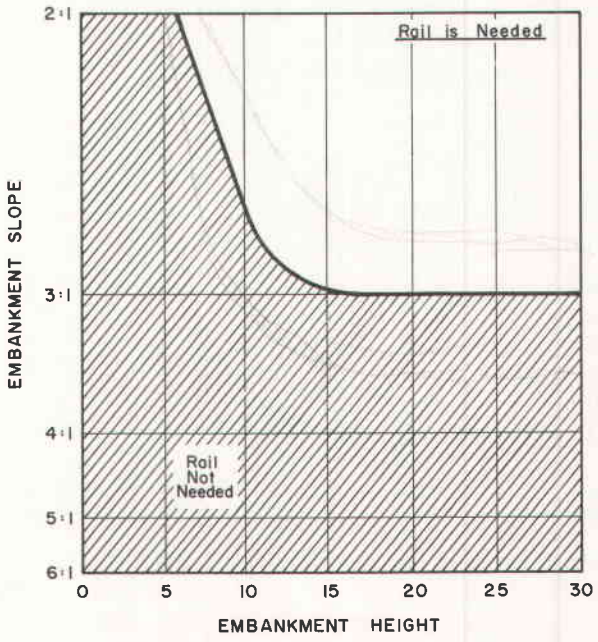
A-205 GUARDFENCE DESIGN AND PERFORMANCE

While a number of different types of barrier rail are available commercially, there are several reasons for continuing the use of the flex-beam rail element. The most important of these would be (1) that it performs in a satisfactory manner when properly located and properly constructed; (2) that it is more reasonable in cost than other types of rail element now available; (3) that standardizing on one rail element type reduces both construction and maintenance costs; and (4) it is available from a number of sources.



AREAS OF CONCERN

FIGURE A-12



GUIDE FOR USE OF GUARD FENCE FOR
EMBANKMENT HEIGHTS AND SLOPES

FIGURE A-13

Guardfence designed in this manner can function in two distinct ways. The vehicle impracting the side of the rail usually will be contained and redirected with some damage to the vehicle and some damage to a rail, possibly as illustrated in Figure A-14. A vehicle hitting the end of the rail installation of this type may straddle the rail and crush it to the ground, with the decelerating action of the posts bringing the vehicle to a stop with considerable damage to the rail element and the underside of the vehicle but with driver and passengers uninjured. A minimum length of 150 feet of rail is needed in advance of a stiffer bridge rail and in advance of an obstruction behind the guardfence and nearer than four feet to the rail. Otherwise, a vehicle which has straddled the rail may hit the obstruction before being brought to a halt.

There are several other conditions which are necessary to the proper performance of a protective rail. Although the rail does have a cross section which would resist some bending moment, it is primarily a tension member since the section will often be crushed when the rail is hit. For this reason, it must be securely anchored at both ends. The strength of the rail is adequate for average size vehicles but becomes marginal for heavy trucks, particularly at extreme angles. For this reason, it is necessary that every effort be made to properly position the rail to take full advantage of all of the strength characteristics it possesses.

A rail installation should preferably be located on level ground with no curbs or slopes nearby, as any irregularity which might impart a vertical force to an out-of-control vehicle is likely to detract from the performance of the rail. When curbs are necessary to portect fill slopes from erosion, they should be placed behind the face of the guardrail. An illustration of this is shown in Figure A-15 where the skid marks of an out-of-control vehicle indicate that it was on the ground until striking a three-inch curb. From this point on, the vehicle left no skid marks and hit the rail near the top. The vehicle rolled over the rail and down the embankment. This illustrates the need to provide uniform slopes between the travel lane and the guardrail. It is desirable to limit the slope on the roadside of the barrier to 10:1 or flatter.

Other obstructions and slopes in the vicinity of the fence can also have an adverse effect on the performance of the rail. A steep slope immediately behind the fence, might permit a straddling vehicle to roll down the slope even though it had been redirected by the rail.

A-206 GUARDFENCE LOCATION

The elements necessary to determine where a protective rail should be located to function properly have now been discussed. The behavior of the vehicle leaving the roadway, the Area of Concern, and the design and performance of the rail have been reviewed in some detail. It remains to devise a method to use this information in an orderly manner. Obviously, a protective rail must be located so that it will prevent a vehicle from entering an Area of Concern. From the data presented in Section A-202 it is obvious that almost every imaginable path has been followed by some vehicle at some time. By rationalizing these data, however, it is possible to establish reasonable limits of consideration.

Data strongly indicates that the area within 30 feet of the traveled way is critical and that greater distances depending on vertical and horizontal alignment may be considered. The distance along the roadway which an out-of-control vehicle can be expected to travel is even less predictable but the data presented in Figure A-3 can be interpreted to indicate a travel distance along the roadway of 400 feet after the vehicle leaves the pavement. This figure is somewhat arbitrary and the designer may wish to consider a greater distance in some instances. Establishing a figure to be used here is necessary, however, in order to develop a procedure for determining the beginning point for a protective rail system.

FIGURE A-14

FIGURE A-15

Guardfence Location Chart

The chart shown in Figure A-16 has been developed to assist in the proper positioning of a rail element with respect to an area of concern. It is based on the criteria previously discussed, making it possible to apply these in an orderly manner and including only those factors which are of controlling nature. The lower portion of this chart is a scale drawing of a portion of highway 400 feet in length and extending 30 feet laterally from the edge of the traveled lane, these dimensions having been determined as described earlier. The upper portion of the chart represents the same length of road but is drawn with the lateral scale at right angles to the traveled way, expanded to 8 times that of the longitudinal scale. The purpose of this lateral expansion is to clarify the chart so that measurements may be taken directly from it. The lateral and longitudinal scales are regular but angle measurements are distorted as indicated.

The lengths derived from the chart are the lengths of guardfence necessary at the approach to an Area of Concern. In addition, rail will be required immediately adjacent to the Area of Concern and an anchor section 25 feet in length will be required at the approach end and at the departure end if the departure end does not become an approach situation from the opposite direction or is not anchored in some other manner.

In making use of this chart, it is first necessary to determine the lateral dimensions of the Area of Concern and to indicate these along the line at the left edge of the chart. Obviously, a guardfence should be located between the Area of Concern and the traveled way. Because a vehicle entering the Area of Concern is likely to approach it at a flat angle however, the rail must be extended a suitable distance in advance of the Area of Concern. This distance can be determined by viewing the Area of Concern from a point of departure 400 feet in advance as indicated at the right edge of the chart.

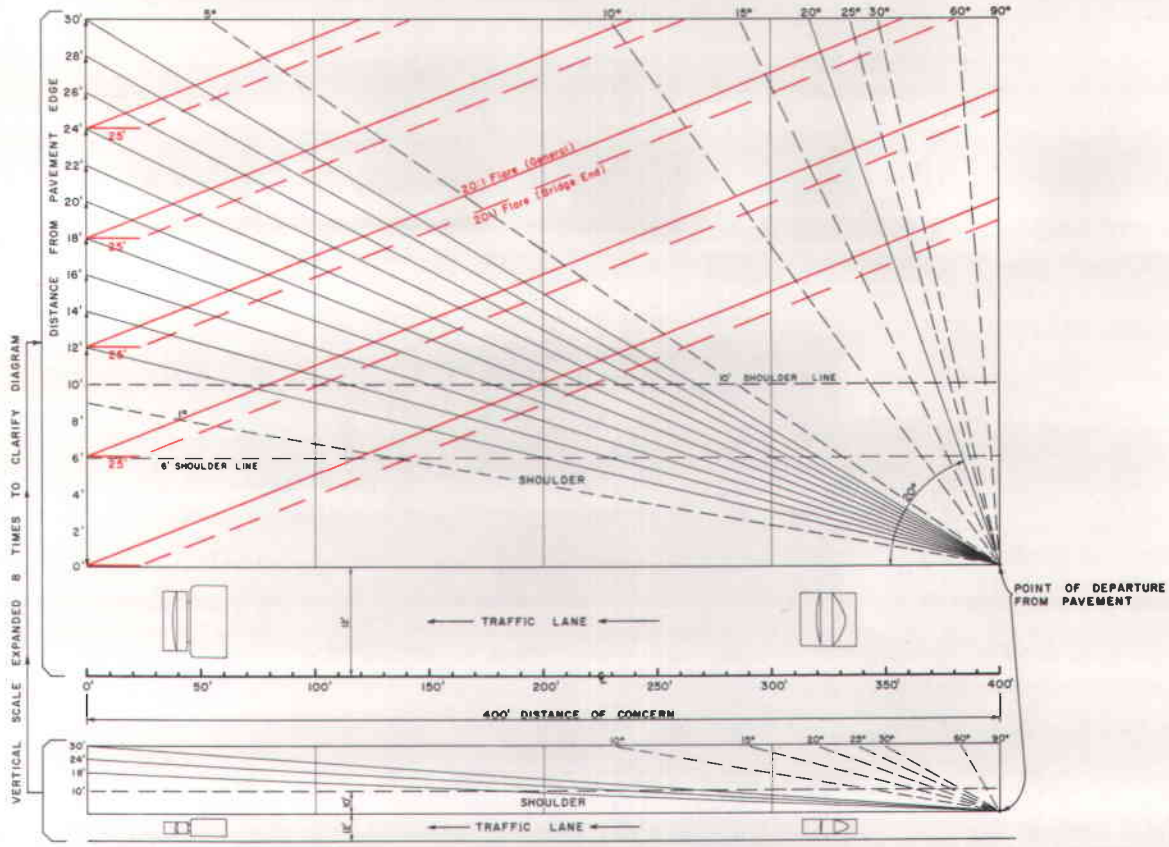


FIGURE A-16

The point at which this line of sight intersects the rail location line is the point at which a protective rail should begin. If the Area of Concern extends to the full width of the 30 foot roadside as indicated in Figure A-17, guardfence located on a 20:1 flare would begin approximately 150 feet from the edge of the Area of Concern as shown. If, however, the Area of Concern is a column two feet in diameter located as shown in Figure A-19 would indicate a rail beginning 50 feet in advance of the obstruction, but since the obstruction is nearer to the rail than the four foot clearance necessary to permit a vehicle which has straddled the rail to be redirected past the obstruction, the minimum 150 foot length would be required. When an obstruction such as in Figure A-20, which is farther from the roadway is encountered, the rail may be moved closer to the obstruction, resulting in a shorter approach section as shown on Rail Line 14. However, it should not be closer than 4 feet to the obstruction. Obstruction D would require a guardfence on Rail Line 14 beginning 60 feet in advance of the obstruction as indicated. In those instances where the guardfence is moved more than 12 feet from the edge of the pavement, the area between the guardfence and the edge of the pavement should have a 10:1 or flatter slope. Where a 10:1 or flatter slope is recommended, a transition section must be provided back to the usual side slope. The length of this transition should be based on the line of travel a vehicle would follow in order to strike the end of the guardfence installation leaving the travel lane 400' in advance of the hazard.

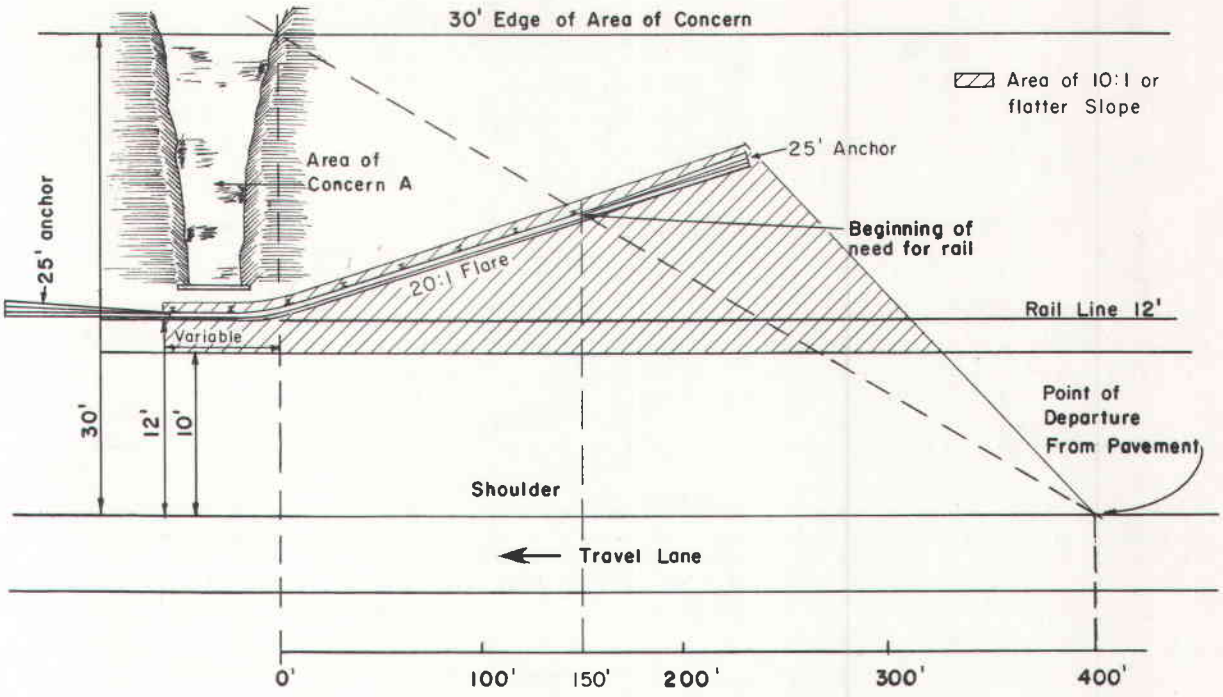


FIGURE A-17

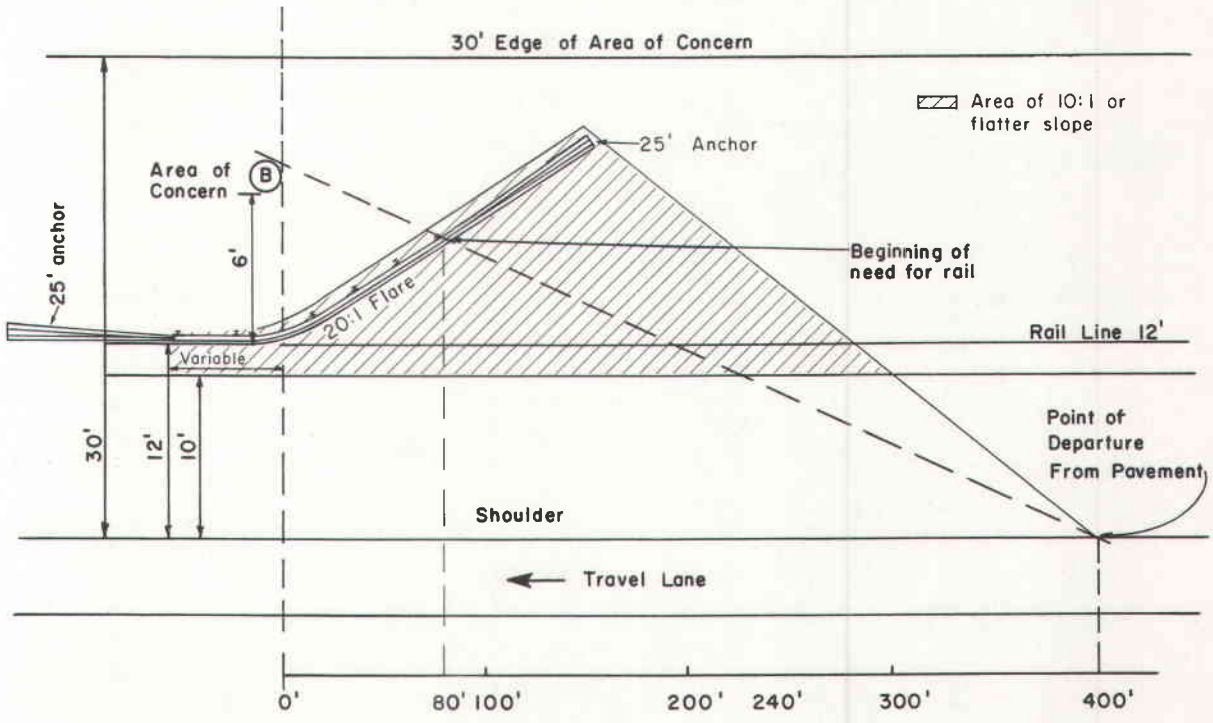


FIGURE A-18

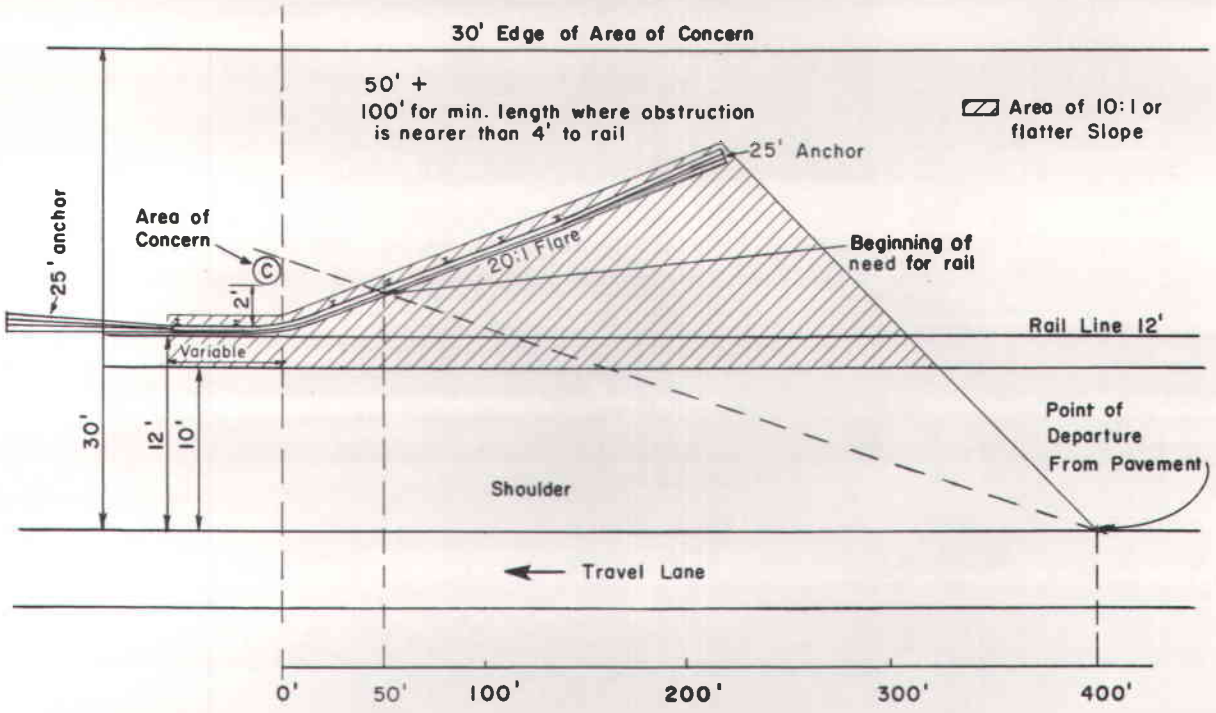


FIGURE A-19

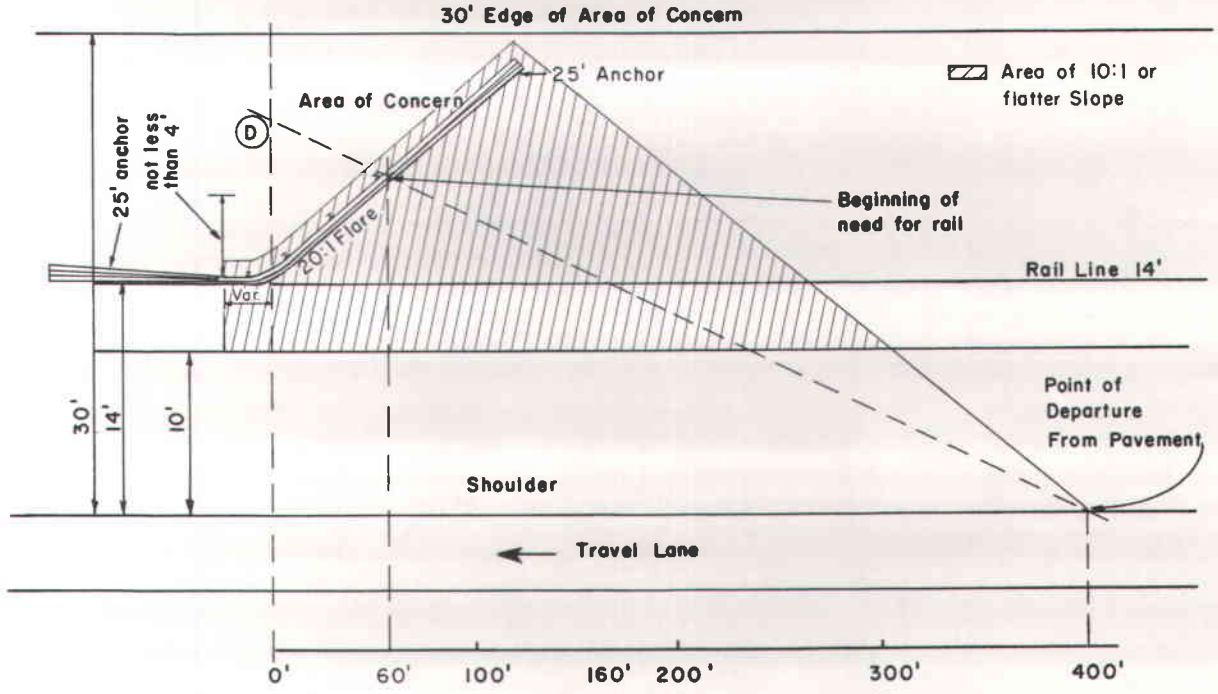


FIGURE A-20

When guardfence is deemed necessary adjacent to a curbed roadway, the guardfence should be placed parallel to the curb, with the face of the flex beam in line with the face of curb. The rail element should also be blocked out.

Divided Highways

On one-way roadways, obstructions on both the right and left would be dealt with in the same manner on the approach side. The rail can be terminated at a point adjacent to the termination of the Area of Concern as shown in Figure A-21.

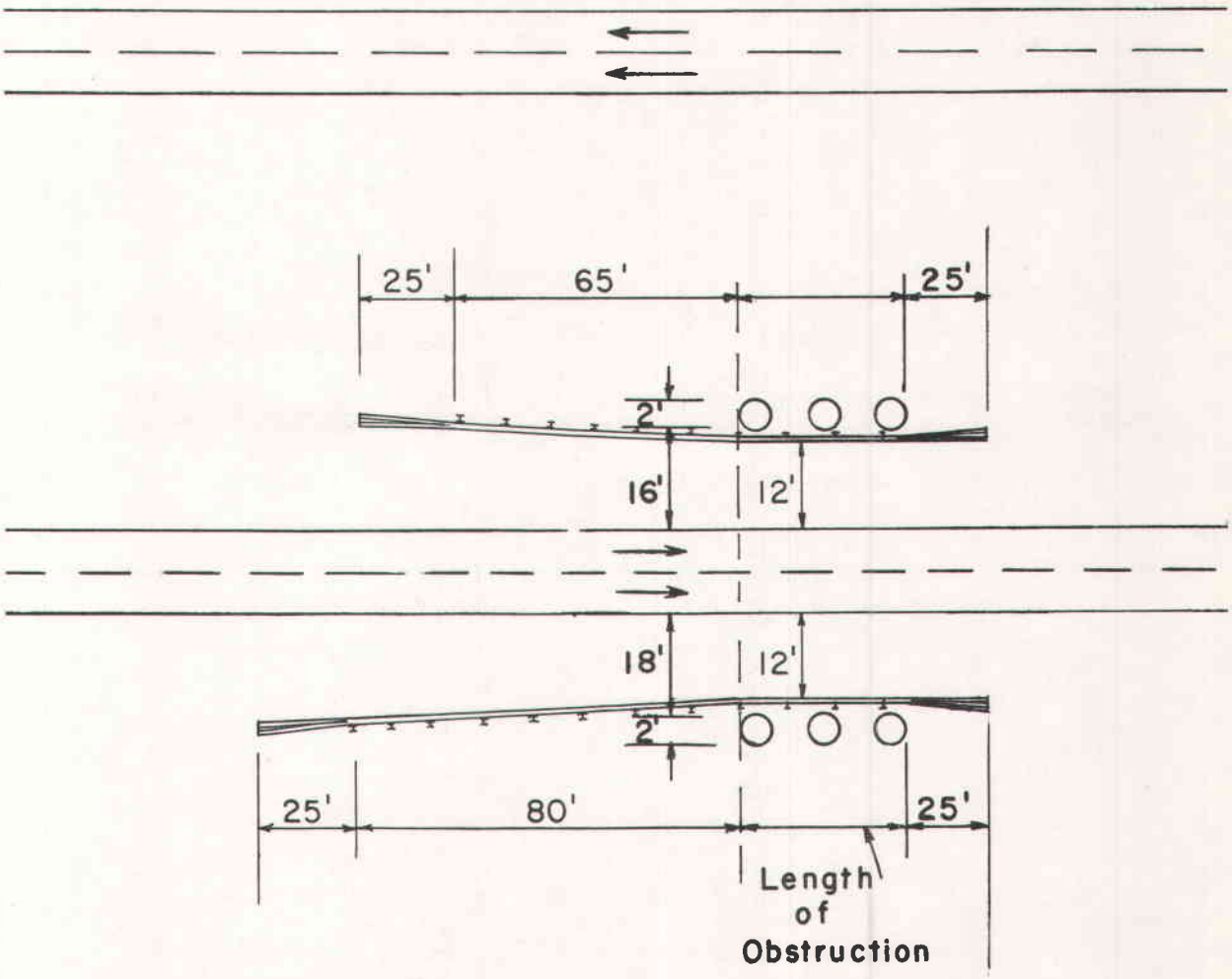


FIGURE A-21

Undivided Highways

On two-lane two-direction roads, approaches from both directions should be treated in the same manner because statistics show that vehicles departing from a two-lane roadway are as likely to go the left as to the right. This is illustrated in Figure A-22.

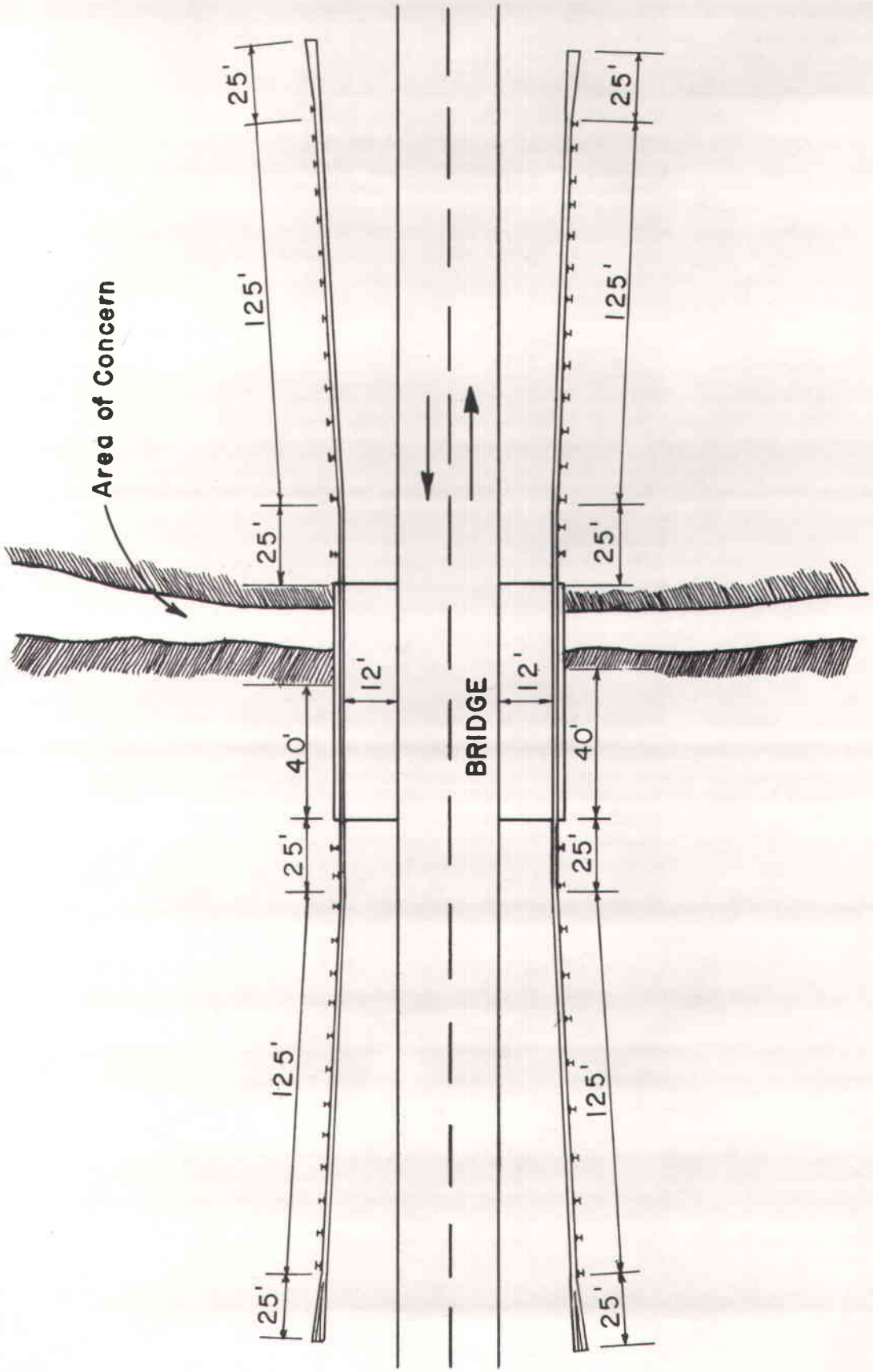

Area of Concern
25'
125'
25'
12'
40'
25'
125'
25'
BRIDGE
25'
125'
25'
12'
40'
25'
125'
25'

FIGURE A-22

Alignment

Obviously, the alignment of the roadway is also a factor in the location of protective rail. The chart was developed for a tangent section. The data used in this development was taken from sections of roadway having varying but generally good alignment. With this in mind, it is possible to adapt the chart to varying alignments with some degree of confidence, particularly on higher type roads.

Bridge Rail Approaches

One of the most prevalent uses of protective rail will be in connection with structures. Columns should be dealt with as discussed earlier, but, where a protective rail is used on the approach to a structure, it becomes a part of a rail system which includes the bridge rail. Preferably, the system will be completely compatible, as shown in Figure A-23 with alignment of the rails matching and giving little indication to the motorist that he is crossing a structure. The length of rail required here would be dependent on the width of the Area of Concern and would be approximately as shown in Figure A-22.

Where the structure is narrower than the crown of the road, the rail should be transitioned as shown in Figure A-24 and the beginning point determined from the chart as in the case where a transition is not necessary.

Where an approach rail is used with a bridge rail of a type not incorporating a flex beam rail, the approach rail should be anchored to the bridge rail with a connector developing the full strength of the rail. In some cases, it may be feasible to extend the approach rail across the bridge in front of the existing bridge rail and thus eliminate the need for an anchor as shown in Figure A-25. Due to the many types of existing rail, many variations of this treatment will be needed. In each case however, the top of the rail should be 27 inches above the traveled way and the face of the flex beam flush with or in front of the face of the curb.

A-207 MEDIAN BARRIERS

Since the median is exposed to traffic on both sides, it requires special consideration in the design and location of a barrier fence. In most cases, a median 48 feet or less in width will require a continuous median barrier at some stage in the design life of the facility, and this should be kept in mind at the time the freeway is designed. In urban areas, median widths up to 30 feet with a continuous median barrier are common on new construction. The same general rules which apply to other areas also apply to the median, but the double exposure factor plus the other factors involved result in a continuous rail being the most practical solution in most cases.

The 24 foot median section with a continuous barrier rail as shown in Figure A-26 is satisfactory in most cases. However, it should be free of obstructions within the barrier. Recent developments in freeway lighting have resulted in the placing of illumination standards in the median, and, where this is the case, a completely non-yielding barrier such as that illustrated in Figure A-27, may be preferable.

Except where additional lanes in the median are planned, median widths between the 30 foot minimum and the 60 foot width which provides minimum clearances for out-of-control vehicles are impractical. Freeway medians 30 feet wide and less will, in most cases, initially require the installation of a median barrier fence. Where illumination is comtemplated, a concrete median barrier of the type shown in Figure A-27 is recommended.

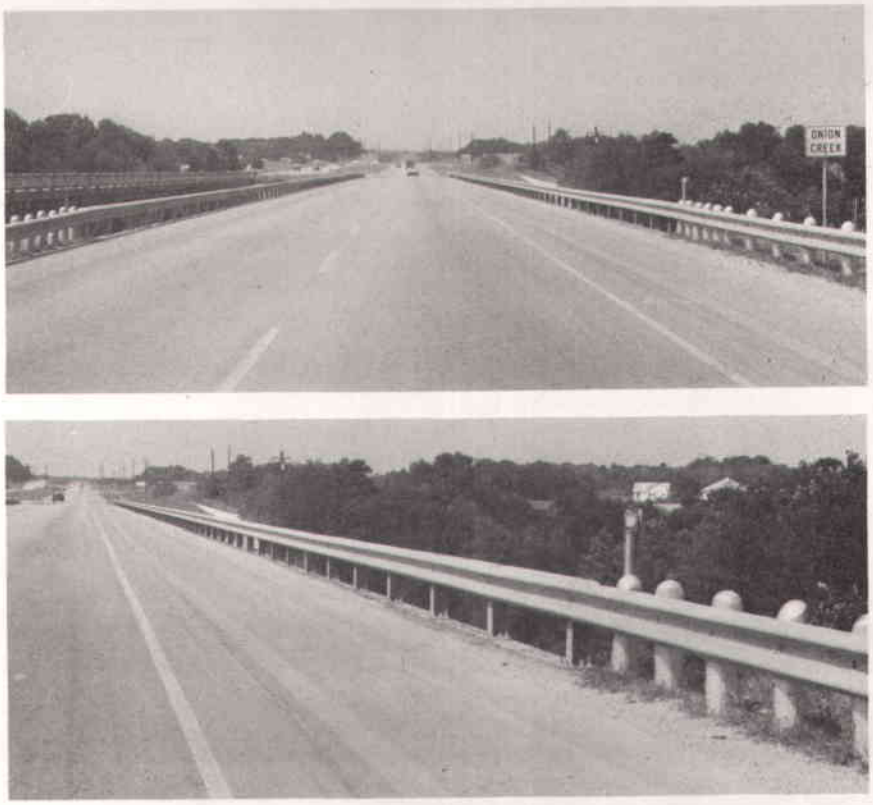


FIGURE A-23

FIGURE A-24

FIGURE A-25

FIGURE A-26

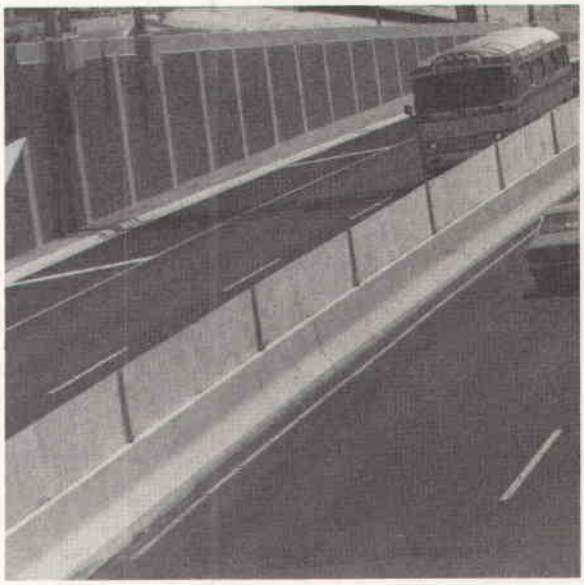


FIGURE A-27

In all cases, the median barrier should be continuous across structures with no change in the design of the barrier.

Where older freeways are being modified it would be desirable to eliminate median curbs and to extend the median across the structure. Situations such as the one illustrated in Figure A-28 could be modified in this manner.

The beginning or termination point of a median barrier will normally fall at a place where the median transitions into a wider section. When this occurs, the approach rail should extend well into the approach roadway with the termination point being determined by the guidance set forth earlier. The rail on the side where traffic is departing from the continuous rail section should extend to a point where the roadways have departed sufficiently so that a median barrier is no longer required.

FIGURE A-28

A-208 TREATMENT OF AREA BETWEEN TWIN STRUCTURES

In narrow medians, less than 30 feet wide, an appropriate median barrier should be provided and carried across the structure. In such cases the problem of protecting the area between the twin structures does not exist. However, most medians are greater than 30 feet wide. These cases require evaluation of the area between the twin structures. The design process in determining the length of guardfence required for this location is the same as that outlined in Section A-206.

A-209 VEHICLE IMPACT ATTENUATION DEVICE DESIGN AND PERFORMANCE

Like guardfence, an attenuation device serves to lessen the consequences of run off the road accidents involving single vehicles striking fixed objects.

In providing adequate protection for a particular area of concern, it is important to select and design the attenuation device to not only provide adequate protection, but also to meet performance criteria concerning redirection, ease of maintenance, etc. as dictated by its location with respect to travel lanes. For example, a sand filled tire attenuator may not be appropriate as a means of protection for a gore area which on either side would be carrying heavy traffic, since it does not have redirection capabilities. Similarly, a more elaborate attenuation device may not be necessary to protect a bridge pier located twenty feet from high speed lanes.

After it has been determined that an attenuation device is more desirable than guardfence for protecting a particular area of concern, design criteria such as redirect capability, special grading or foundation requirements for installation, etc. should be evaluated in light of design guidelines contained in Appendix C "Attenuation System Design Guidelines (C-100)."

A-209.1 ATTENUATION DEVICE LOCATION

Due to the nature of protection offered by an attenuation device, location with respect to the area of concern is relatively simple, and should be in accordance with recommended locations as shown in Appendix C.

A-210 SUMMARY OF RECOMMENDATIONS

1. Design standards exceeding those established as minimums should be used to increase safety. Evaluation of the effectiveness and cost efficiency of improved designs should be made by constant field checks.

2. As far as practical, grading should be planned to develop a roadside that a driver may traverse at a reasonable speed without major damage to the vehicle or injury to himself so that he can recover control of the vehicle and return to the road.

3. As far as practical, the roadside should be clear of obstacles.

4. As a minimum, a 30 foot zone adjacent to the travelway is recommended to be clear of roadside obstacles; more than a 30 foot zone is desirable.

5. Where a 30 foot zone cannot be provided clear of obstacles because of economic or practical reasons, protective devices are usually warranted. Such obstacles include but are not limited to bridge approaches, bridge piers and abutments at underpasses, retaining walls, concrete foundations extending more than 6 inches above the ground, non-flush culvert headwalls, trees and sign bridge supports.

   Information regarding "Area of Concern," guardfence design and guardfence location is presented in Sections A-204, A-205 and A-206. See guardfence standards listed in Section A-100 for type, design details, length and geometric layout. Figure A-16 shows the recommended positioning of guardfence relative to areas of concern.

6. Guardfence may be needed at hazards located more than 30 feet from the travelway to provide roadsides with a consistent degree of safety where non-traversable hazards are located along the roadway for considerable distance. Non-traversable hazards would include but would not be limited to lines of large boulders, permanent bodies of water of appreciable depth, drop-offs with steep slopes and rows of large trees.

   Experience has not demonstrated a positive need for blocking out the guardrail; however, it is recommended that where the posts are set in concrete the rail be blocked out in accordance with the appropriate design standard.

7. When in doubt of a need for a protective device, engineering judgement should prevail.

8. If, after an evaluation has been made of a hazard, a choice of protective devices is warranted, then the selection of the protective should be based on cost effectiveness.

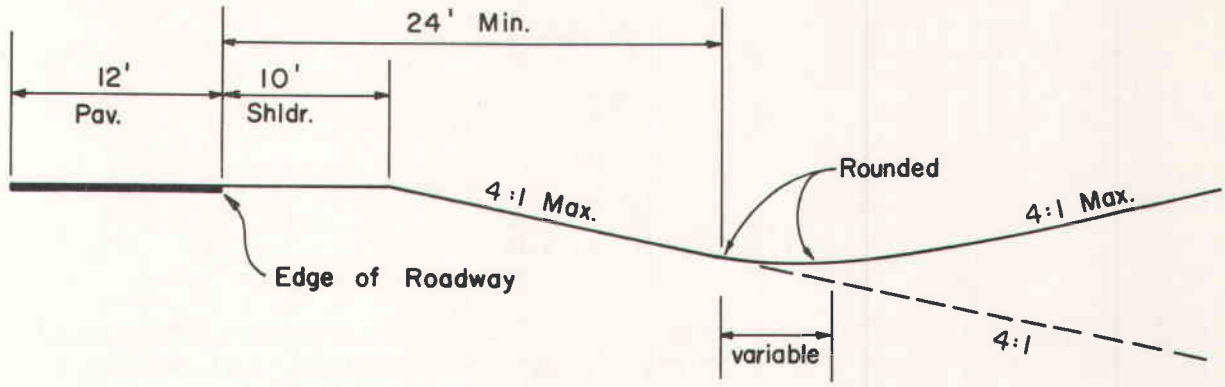
Bridge Approach Warrants

Traffic Direction	W* (Ft.)	Guardrail Required At
North and South	60 or less	A,B,C,D
North and South	Greater than 60	A,D
South Only	All Widths	A,B
North Only	All Widths	C,D

Note: See Bridge End Detail standard for guardrail placement.

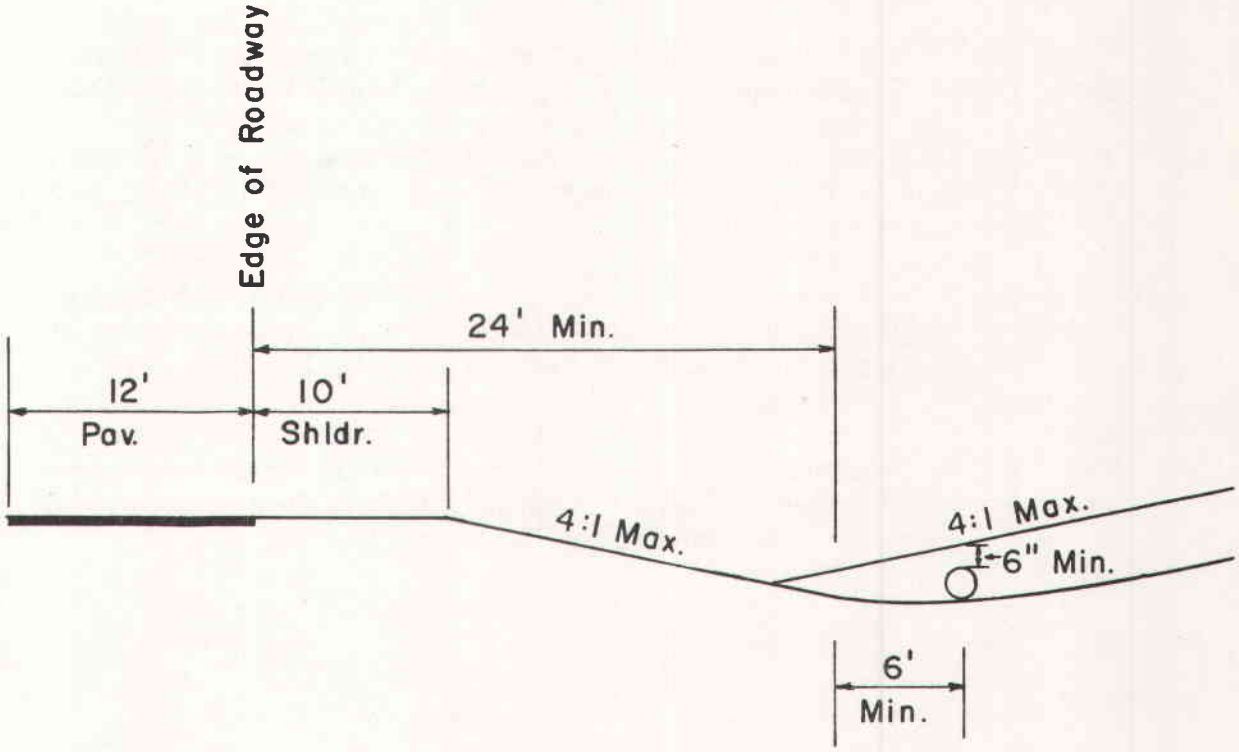
*W denotes width between curbs

FIGURE A-29



DESIRABLE SECTION

FIGURE A-30



SATISFACTORY SECTION AT
SIDE ROAD OR PRIVATE ENTRANCE

FIGURE A-31

REFERENCES

1. "Highway Guard Rail - Determination of Need and Geometric Requirements with Particular Reference to Beam Type Guardrail." HRB Special Report 81, Washington, D.C. (1963).

2. Cichowski, W. G., Skeels, P. C., and Hawkins, W. R., "Guardrail Installations - Appraisal by Proving Ground Car Impact and Laboratory Tests." Proc., HRB, 40: 137-178 (1961).

3. Beaton, J. L., and Field, R. N., "Dynamic Full-Scale Tests of Median Barriers." HRB Bull. 266, pp. 78-125 (1960).

4. "Development of an Analytical Approach to Highway Barrier Design and Evaluation." Research Report 63-2, State of New York, Department of Public Works (May 1963).

5. Hutchinson, J. W., and Kennedy, T. W., "Medians of Divided Highways-Frequency and Nature of Encroachments." Engineering Experiment Station Bulletin 487, University of Illinois, Urbana, Illinois (1966).

6. Hutchinson, J. W., "The Significance and Nature of Vehicle Encroachments on Medians of Divided Highways," (Civil Engineering Studies, Highway Engineering Series. No. 8). Urbana, Ill.: Department of Civil Engineering, University of Illinois, December, 1962.

7. Michie, I. D. and Bronstod, M. E., "Location, Selection, And Maintenance Of Highway Traffic Barriers." National Cooperative Highway Research Program Report 118. Southwest Research Institute, San Antonio, Texas (1971).

APPENDIX B-100

ILLUMINATION (B-100)

B-101 GENERAL INFORMATION

This manual is designed to be of benefit to individuals in the field who are responsible for the design, construction and inspection of roadway lighting projects.

B-102 HIGHWAY LIGHTING TERMS

CONTINUOUS LIGHTING - Roadway illumination assemblies installed to provide a minimum initial intensity of 0.4 horizontal footcandles on all main lanes and direct connections, and complete interchange lighting of all interchanges within the project.

SAFETY LIGHTING - Highway lighting systems installed at urban, suburban or rural interchanges, highway intersections and points of night-time hazard to the extent necessary to provide for the safe and orderly movement of night-time traffic.

COMPLETE INTERCHANGE LIGHTING - The lighting of the main lanes, acceleration and deceleration lanes, ramps, all ramp terminals and the crossroad between the outermost ramp terminals. A minimum initial intensity of 0.4 horizontal footcandles should be provided on all main lanes and direct connections within the interchange.

PARTIAL INTERCHANGE LIGHTING - The lighting of acceleration and deceleration lanes, ramp terminals, crossroads at ramp or frontage road intersections, understructure lighting and other areas of night-time hazard. Lighting of curbed lane dividers is particularly important.

CONVENTIONAL LIGHTING - A highway lighting system in which the luminaires are mounted no higher than 50 feet.

HIGH MAST LIGHTING - Lighting units mounted at heights of 100 feet or more.

LUMINAIRE - A device which directs, controls and modifies the light produced by a lamp. It consists of a light source, reflector, refractor, housing and such support as may be integral with the housing.

FLOODLIGHTS - Luminaires which are generally employed for spot or wide-area lighting.

LAMP - A light source.

LUMEN - Unit quantity of light output.

FOOTCANDLE - Luminous intensity of one lumen per square foot.

PHOTOMETRIC DATA - Derived from metered measurements of horizontal or vertical footcandles. These metered measurements are obtained by the use of a light meter usually calibrated in footcandles.

ISO-FOOTCANDLE CURVES - Curves plotted from metered photometric readings for a specific lighting unit, of a particular design and rated wattage, when the unit is mounted at a certain height. These readings are taken on a rectangular grid which is oriented from the center of the light source. From such readings, contour lines are then plotted for identical values in footcandles; and when contours are plotted for equal increments of increase in illumination intensity, the resulting contour lines produce a series of generally concentric semiparabolic curves which are described as iso-footcandle curves. Iso-footcandle curves for the 400 watt and 250 watt HPS roadway luminaires are available from File D-8.

The iso-footcandle curves are indispensable in the location and spacing of lighting units on the layout or plan for a lighting installation.

UNIFORMITY - Uniformity of illumination is the ratio of the average level of illumination to the minimum level of illumination on the roadway.

MOUNTING HEIGHT - Generally the vertical distance between the base of the pole and the luminaire.

SPACING - The distance in feet between successive lighting units measured along the center line of the roadway.

ROADWAY ILLUMINATION ASSEMBLY - The luminaire and supporting members (pole, bracket, etc.) with other related lighting equipment attached thereto.

POLE OR LIGHTING STANDARD - A galvanized steel or aluminum shaft to support the lighting unit.

MAST ARM - An attachment to a lighting pole on the end of which a luminaire is mounted.

UPSWEEP OF A MAST ARM - The difference in elevation between the top of the pole and the outer end of the mast arm.

REGULATED OUTPUT BALLAST - A form of an electrical transformer by which the wattage to the lamp is maintained at a nearly constant value though the line voltage may fluctuate as much as ± 10%. Such ballasts or transformers may be integrally mounted within the luminaire or separately mounted in a ballast enclosure.

CONDUCTOR - Electrical wire, bare or insulated.

TRANSFORMER BASE - A hollow cast aluminum base, the bottom of which is bolted to a concrete foundation and to the top of which the bottom flange of the pole is bolted.

BREAKAWAY SUPPORT - A lighting pole designed to shear easily under vehicular impact. The breakaway feature can be an aluminum transformer base, a frangible insert between pole base and foundation, a slip base or other device. The breakaway support must meet current AASHTO and FHWA requirements.

ROADWAY ILLUMINATION PLAN SYMBOLS - (See Figure B-3)

B-103 HIGHWAY LIGHTING

A. Construction and Maintenance Responsibility of Highway Lighting Systems

1. Continuous Lighting: Requires a partnership between the State and a municipality.

2. Safety Lighting: State is responsible for all installation, operation and maintenance expense.

B. Types of Highways on Which State Funds May be Spent for Continuous and Safety Lighting

1. Continuous Lighting

a. Freeways which are multi-lane divided facilities for which full control of access is provided.

b. Expressways which are defined as multi-lane highways with partial control of access where access is provided to abutting property; where at-grade crossings are provided at minor streets and roads; and where grade separation structures are provided at the minor crossings of arterial highways, streets and roads.

c. Certain city streets with a high incidence of night-time accidents and which are part of the State Highway System.

2. Safety Lighting

Any designated highway or marked highway route.

C. Highway Lighting Systems Which May Be Installed and Financed by Other Governmental Agencies

Local governments, upon approval by the State Department of Highways and Public Transportation, may finance, install and operate lighting systems on those portions of designated and/or marked highway routes in cities and towns where such funds are not available for Departmental financial participation in the cost of such lighting systems. It is the policy of the State Department of Highways and Public Transportation to cooperate with local governments in the consideration of such lighting systems and to prescribe that the design and installation of the systems be in accordance with desirable traffic safety provisions. Personnel of the State Department of Highways and Public Transportation will be permitted to assist and advise in the development of planning and design of such systems when requested to do so by a local governmental agency.

D. Lighting Agreements

There must be an agreement executed between the municipality and the State Department of Highways and Public Transportation covering all lighting projects within the corporate limits of a city or town when State financing is involved. This agreement must be executed before the project may be let to contract and sets out the responsibilities of each party for the construction, maintenance and operation of the lighting system.

For those projects in rural areas where a utility company will perform the maintenance and operation, the agreement will be executed with the utility company. If only electric energy is to be purchased from the utility company, only an agreement on a rate schedule is required. The agreement can be in the form of a letter from the utility company describing the rate schedule and other terms of the agreement (e.g., points of service, voltage, etc.). A copy of the rate schedule should be attached to the letter agreement.

1. Continuous Lighting Systems

   a. 50-50 Agreement

   The 50-50 agreement provides that the State Department of Highways and Public Transportation and the local government will each share one-half of the cost of the installation, operation and maintenance of a continuous highway lighting system. Under the terms of this agreement, the State Department of Highways and Public Transportation will assume all of the cost of preliminary engineering incident to the preparation of plans and the contracting of same.

   b. 100 Percent Agreement

   The State Department of Highways and Public Transportation will assume the total cost of designing and installing continuous lighting systems on those urban highways which are eligible under terms of State Policy, provided the local government will agree to assume all the cost of the subsequent operation and maintenance of such a system in accordance with the established terms of a lighting agreement between the State Department of Highways and Public Transportation and the local governmental agency.

2. Safety Lighting Systems

   a. The State Department of Highways and Public Transportation will bear the cost installation, operation and maintenance of safety lighting at interchanges, highway intersections and points of night-time hazard in both urban and rural areas as the traffic needs may dictate.

   b. In those instances where safety lighting systems have been installed by the State Department of Highways and Public Transportation at its expense and such systems are later incorporated within the limits of a continuously-lighted urban freeway or expressway, the cost of operation and maintenance of the safety lighting system shall be shared by the State Department of Highways and Public Transportation and the local government on the same basis as the cost of operation and maintenance of the continuously lighted section is shared.

B-104 HIGHWAY LIGHTING DESIGN PRACTICES

A. Specifications for Highway Lighting

Current highway lighting specifications for the State Department of Highways and Public Transportation are reflected in the Roadway Illumination and High Mast Illumination Detail standard sheets which are available from File D-8. The specifications on these sheets reflect the various hardware components of a lighting assembly, together with the photometric and testing requirements of the lighting units and related equipment.

B. Design Criteria for Highway Lighting

1. Recommended Designs for Conventional Lighting Systems

Conventional lighting systems are those in which mounting heights of 50 feet or less are utilized. This description is employed in order to differentiate between the categories of conventional mounting heights and those of 100 feet to 150 feet employed in high mast lighting.

a. Continuous Lighting Systems. House side lighting and median lighting sketches (Figure B-1 and Figure B-2) illustrate the recommended lighting designs for various roadway sections. The system should be so designed that a minimum initial intensity of 0.4 horizontal footcandle is provided on all main lanes and direct connections.

b. Safety (Partial Interchange) Lighting. The 250 watt high pressure sodium luminaire at 40 feet MH is recommended for safety lighting.

2. High Mast Lighting

a. Multiple luminaires may be mounted on a pole at a height of 100 feet or greater to effectively light interchange areas and may be utilized in conjunction with a conventional lighting system on the roadway approaches to an interchange. This will permit a driving decision to be made well in advance of the need to execute a driving maneuver, thus contributing to greater safety, comfort and convenience of the driver.

b. Floodlights with aiming capabilities have proven very satisfactory in providing the necessary flexibility and adjustment to fit the irregular geometrics of complex interchanges.

c. High mast lighting provides a panoramic view of the roadway geometrics; thus, a lower minimum design level of illumination is acceptable. The system should be so designed that a minimum initial intensity of 0.3 horizontal footcandle is provided on all main lanes and direct connections.

d. The utilization of high mast lighting is warranted when the needs of the traveling public will be better served through its use than by a conventional illumination system.

3. Safety Lighting

Safety lighting design is based on providing a sufficient number of lighting units to best light the through lanes and speed change lanes at diverging and merging locations, and other points of conflict.

C. AASHTO Warrants for Lighting (taken from AASHTO, March, 1976 Edition of "An Informational Guide for Roadway Lighting")

1. Continuous Freeway Lighting

Case CFL-1 — Continuous freeway lighting is considered to be warranted on those sections in and near cities where the current ADT is 30,000 or more.

Case CFL-2 — Continuous freeway lighting is considered to be warranted on those sections where three or more successive interchanges are located with an average spacing of 1-1/2 miles or less, and adjacent areas outside the right-of-way are substantially urban in character.

Case CFL-3 — Continuous freeway lighting is considered to be warranted where for a length of two or more miles the freeway passes through a substantially developed suburban or urban area in which one or more of the following conditions exists: (a) local traffic operates on a complete street grid having some form of street lighting, parts of which are visible from the freeway; (b) the freeway passes through a series of developments such as residential, commercial, industrial and civic areas, colleges, parks, terminals, etc., which include roads, streets and parking areas, yards, etc., that are lighted; (c) separate cross streets, both with and without connecting ramps, occur with an average spacing of 1/2 mile or less, some of which are lighted as part of the local street system; and (d) the freeway cross section elements, such as median and borders, are substantially reduced in width below desirable sections used in relatively open country because of the high costs of right-of-way due to proximity of existing land developments.

Case CFL-4 — Continuous freeway lighting is considered to be warranted on those sections where the ratio of night-to-day accident rate is at least 2.0 or higher than the statewide average for all unlighted similar sections, and a study indicates that lighting may be expected to result in a significant reduction in the night accident rate.

2. Complete Interchange Lighting

Case CIL-1 — Complete interchange lighting is considered to be warranted where the total current ADT ramp traffic entering and leaving the freeway within the interchange areas exceeds 10,000 for urban conditions, 8,000 for suburban conditions, or 5,000 for rural conditions.

Case CIL-2 — Complete interchange lighting is considered to be warranted where the current ADT on the crossroad exceeds 10,000 for urban conditions, 8,000 for suburban conditions, or 5,000 for rural conditions.

Case CIL-3 — Complete interchange lighting on unlighted freeways is considered to be warranted at locations where existing substantial commercial or industrial development, which is lighted during hours of darkness, is located in the immediate vicinity of the interchange or where the crossroad approach legs are lighted for 1/2 mile or more on each side of the interchange.

Case CIL-4 — Complete interchange lighting is considered to be warranted where the ratio of night-to-day accident rate within the interchange area is at least 1.5 or higher than the statewide average for all unlighted similar sections, and a study indicates that lighting may be expected to result in a significant reduction in the night accident rate.

3. Partial Interchange Lighting

Case PIL-1 — Partial interchange lighting is considered to be warranted where the total current ADT ramp traffic entering and leaving the freeway within the interchange area exceeds 5,000 for urban conditions, 3,000 for suburban conditions, or 1,000 for rural conditions.

Case PIL-2 — Partial interchange lighting is considered to be warranted where the current ADT on the freeway through traffic lanes exceeds 25,000 for urban conditions, 20,000 for suburban conditions, or 10,000 for rural conditions.

Case PIL-3 — Partial interchange lighting is considered to be warranted where the ratio of night-to-day accident rate within the interchange area is at least 1.25 or higher than the statewide average for all unlighted similar sections, and a study indicates that lighting may be expected to result in a significant reduction in the night accident rate.

4. Lighting on Streets and Highways Other Than Freeways

In general, lighting is considered to be warranted for those locations where the respective governmental agencies concur that lighting will contribute substantially to the efficiency, safety, and comfort of vehicular and pedestrian traffic. Lighting should be provided for all major arterials in urbanized areas and for locations or sections of streets and highways where the ratio of night-to-day accident rates is high (say, higher than the statewide average for all similar locations) and a study indicates that lighting may be expected to significantly reduce the night accident rate. In other situations, lighting may be warranted where studies indicate that the resulting benefits, both tangible and intangible, are in the interest of the general public.

D. Electrical Circuit Design

1. Specifications require HPS ballast to operate satisfactorily at line voltage fluctuations of ± 10 percent of nominal line voltage. Good design practice requires electrical conductor sized to provide no more than approximately 8 percent volt drop to any luminaire on the circuit (38 to 40 volts at a line voltage of 480 volts). Following are recommended design amperes for various luminaires at differing line voltages:

Line Voltage / Lamp Watts	120 v.	240 v.	480 v.
150	1.8	0.9	0.45
250	3.0	1.5	0.75
400	4.8	2.4	1.2
1000	12.0	6.0	3.0

2. For voltage drop calculations, it is recommended that the resistance of copper conductors at 25° C (77°F) be used for buried conductors and resistance at 40° C (104°F) be used for conductors installed in conduit above grade (conduit on structures, etc.). Resistance tables are available from the Design Section of Highway Design Division.

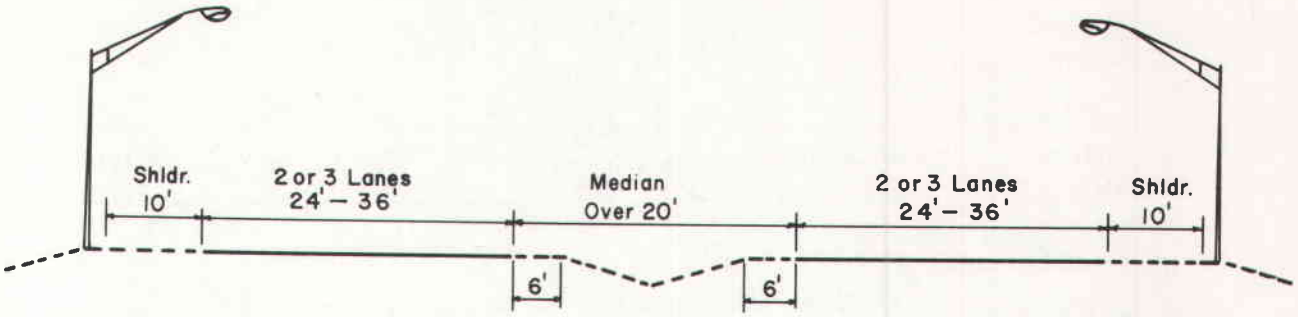
E. Economic Considerations in Lighting Design

1. The high pressure sodium luminaire is at present the most efficient, widely-available light source for roadway lighting. In general, the 400 watt HPS will replace the 1000 watt mercury vapor (MV), the 250 watt HPS will replace the 400 watt MV, and the 150 watt HPS will replace the 250 watt MV. Further reduction in costs may be made by using the 400 watt HPS for lighting main lanes and using the 250 watt or 150 watt HPS for lighting the ramp terminals and crossroads.

2. Mast Arm Length. A roadway luminaire meeting State Department of Highways and Public Transportation specifications has a light distribution pattern such that the maximum beam candlepower strikes the pavement at a point 18 feet beyond the point directly under the luminaire when mounted 50 feet above the pavement in a level position. Additional lateral coverage may be obtained by tilting the luminaire (an adjustment of 5° - 8° is provided by the slipfitter attachment). In the interest of economy in pole and mast arm costs, it is recommended that 8-foot mast arms be specified.

HOUSE SIDE LIGHTING

DESIGN 1-A

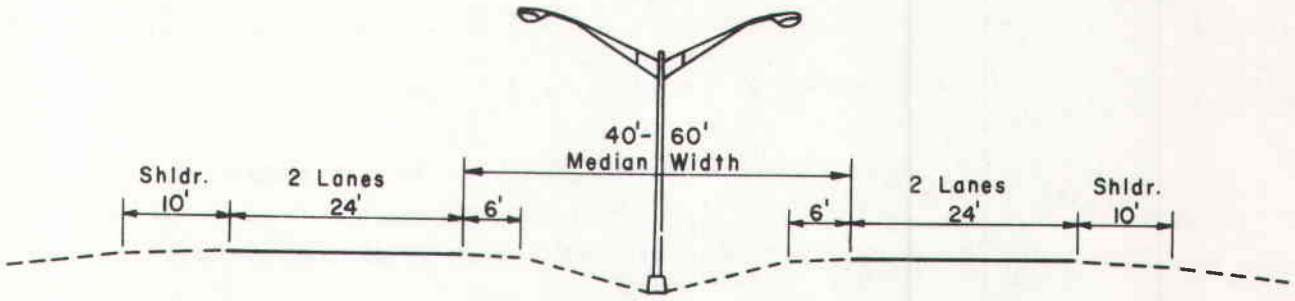


250 Watt High Pressure Sodium
Luminaire - Mounting Height 40' – 240' Spacing
on each side

Poles should be located as far from the shoulder edge as practicable. Generally, 2' should be considered as minimum. Optimum light distribution is obtained when the luminaire is aligned from 5' to 10' outside of lane edge.

MEDIAN LIGHTING

DESIGN 2-A

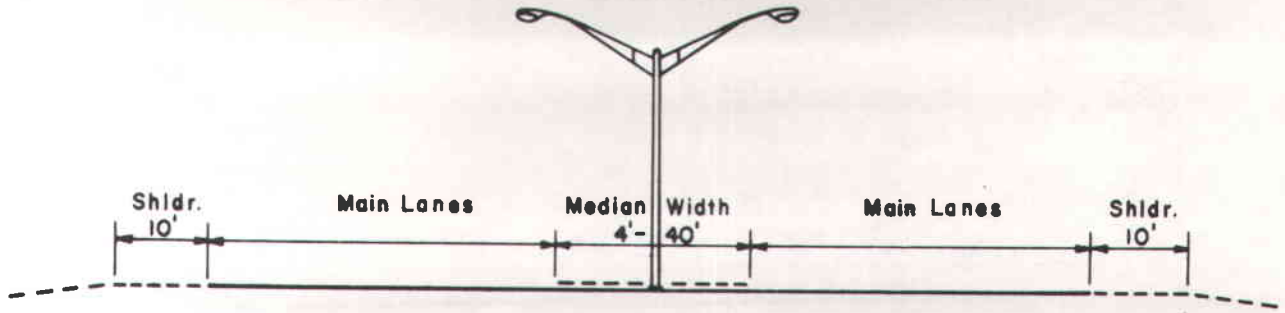


Dual-mounted 250 Watt High Pressure Sodium Luminaires - Mounting Height 40' - 240' Spacing. Where Median Width Exceeds 60' it May Be Necessary To Treat Each Main Lane As A Separate Roadway and Place Poles on House-Side (See Design 1-A).

FIGURE B-1 Refers to Paragraph B-104(b)

MEDIAN LIGHTING (Cont.)

DESIGN 2-B
DOUBLE FLEXBEAM MEDIAN BARRIER

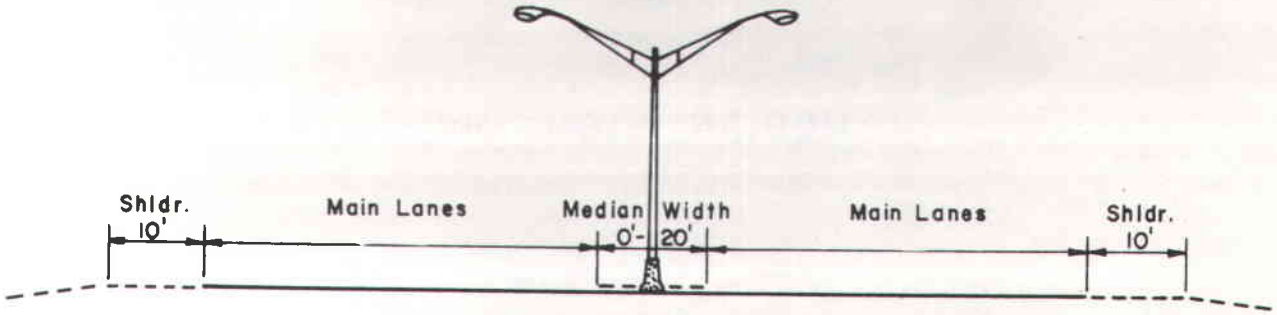


Poles Must Be Protected by Median Barrier.

For 2 or 3 Lanes Each Way, use 250 Watt High Pressure Sodium at 40' MH, Spaced 240'

For 4 or 5 Lanes Each Way, use 400 Watt High Pressure Sodium at 50' MH, Spaced 300'

DESIGN 2-C
CONCRETE MEDIAN BARRIER



Poles mounted on Concrete Median Barrier.

For 2 or 3 Lanes Each Way, use 250 Watt High Pressure Sodium at 40' MH, Spaced 240'

For 4 or 5 Lanes Each Way, use 400 Watt High Pressure Sodium at 50' MH, Spaced 300'.

The 150 Watt High Pressure Sodium Wall Mounted Luminaire is Recommended for Underpass Lighting.

FIGURE B-2 Refers to Paragraph B-104(b)

STANDARD ROADWAY ILLUMINATION PLAN SYMBOLS

X	Mast Arm Length - 8' Recommended Length	
M	Mercury Vapor	
S	Sodium Vapor	
■—●	50B-X-1KWM or .4KWS	B - Pole with Break a Way Base
●—●	50S-X-1KWM or .4KWS	S - Shoe Base Pole
●—■—●	50B-X-X-1KWM or .4KWS	
●—●—●	50S-X-X-1KWM or .4KWS	
□—○	40B-X-.4KWM or .25KWS	
○—○	40S-X-.4KWM or .25KWS	
○—□—○	40B-X-X-.4KWM or .25KWS	
○—○—○	40S-X-X-.4KWM or .25KWS	
◉	High Mast Pole — 150'	
▲	Underpass Luminaire	
⬡	Service Pole, Circuit Protector or Transformer Station	
■	Ground Box, Below Grade	
⊠	Junction Box, above grade	
—8/2—	Duct Cable - size and number of conductors	
—2—8— 1"c.	THW Conductor in conduit	
50-2"RMC	Duct Cable under roadway	

FIGURE B-3 Refers to Paragraph B-102

APPENDIX C-100

ATTENUATION SYSTEM DESIGN GUIDELINES (C-100)

C-101 THE ROADSIDE DESIGN PROBLEM

Accident records indicate that the single vehicle collision with a fixed object is the most frequent cause of injuries and fatalities. Texas accident statistics show that 35% of statewide accidents involve single vehicles striking fixed objects or running off the roadway. Several concepts have been proposed in an effort to reduce this toll. Automobiles, for example, are becoming safer and roadsides are being improved by removing or relocating at a safer distance fixed objects which previously had been located at or near the roadway edge. Objects which cannot be removed or relocated are generally made break-away, encompassed by guardrail, or cushioned by an attenuation device.

Specialized problem areas such as the gores of exit ramps on structures are recognized hazards and generally cannot be handled by techniques other than attenuation. Other problem locations may include a slope or obstacles in the gore area, bridge piers in medians and adjacent to the traveled way, overhead sign-supports, and the space between twin structures. Removing or relocating such hazards is often impractical and therefore a feasible alternative is to protect motorists from these hazards with attenuation devices.

The basic purpose of an attenuation device is the dissipation of kinetic energy of the impacting vehicle over enough distance to result in an acceptable deceleration rate. The following are among the several types of attenuation systems in various stages of development:

1. Steel Drum Barrier (Texas Crash Cushion)
2. Sand-Tire Vehicular Impact Attenuator
3. Sand Filled Plastic Barrels
4. Hi-dri and Hi-dro Cushion Cells
5. Dragnet System

C-102 DESIGN OF THE TEXAS CRASH CUSHION

The Texas Crash Cushion was developed through the cooperative research of the Federal Highway Administration, Texas Transportation Institute, and State Department of Highways and Public Transportation. Utilized in the system are 55 gallon steel drums arranged in rows to control the deceleration of an impacting vehicle. The barrels are welded, bolted or clipped together, top and bottom, to form a cohesive system. Steel cables are incorporated into the system for the purpose of providing lateral stability. The assembly is raised to the optimum height for cushioning vehicles thereby reducing friction at ground level. Redirectional panels may be incorporated into the system design to provide fendering capabilities where site conditions indicate their need.

Experience with the Texas Crash Cushion under controlled testing and in actual field installations has provided a basis for the establishment of design criteria. The size and shape of the system is primarily dependent on three design inputs - vehicle weight, speed and tolerable average g-forces.

In the design of an attenuator system, although the minimum required depth of the system is a fixed distance for a given speed, the energy absorbing capacity, i.e. number of barrels, is related directly to the weight of the vehicle to be attenuated.

Since most passenger cars and some trucks fall within the 2,000 to 4,500 pound range, the procedure presented will result in an attenuation system design capable of restraining a vehicle weighing up to 4,500 pounds. Furthermore successful attenuation requires tolerable g-forces on the vehicle's occupants. The field of biomechanics is not an exact science and an immense amount of progress is yet to be achieved in order to more fully understand human impact tolerability and insure safety.

In 1961 the Cornell Aeronautical Laboratory suggested tolerable average limits of deceleration as shown in Table 1:

Table 1 - Suggested Tolerable Deceleration Limits

Average Deceleration (g's)			
Occupant Restraint	Lateral	Longitudinal	Total
Unrestrained	3	5	6
Lap Belt	5	10	12
Lap Belt & Shoulder Harness	15	25	25

Although minimum levels of deceleration are desirable frequently they can be achieved only at the expense of vehicle maneuvering room. In actual impact experience with attenuators in over 200 in-service impacts, optimum design in terms of overall safety to the motorist can be achieved by a system which is capable of attenuating a 2000 pound vehicle at a speed of 55 mph with approximately 10 g's (i.e. the suggested tolerable g-force level for occupants restrained by seat belts only).

Design Example:

An impact attenuator which will provide an acceptable deceleration level for a 4,500 pound vehicle traveling at 55 mph must be placed at an elevated gore. 55 gallon steel drums are available for the construction of a Texas Crash Cushion. The problem is to determine the arrangement of barrels that will fulfill these design criterion.

Enter Figure 1 with the predetermined design speed (55 mph) and design vehicular weight (4,500 pounds) and determine the minimum number of barrels required ($N_b = 34$) to absorb the vehicle kinetic energy.

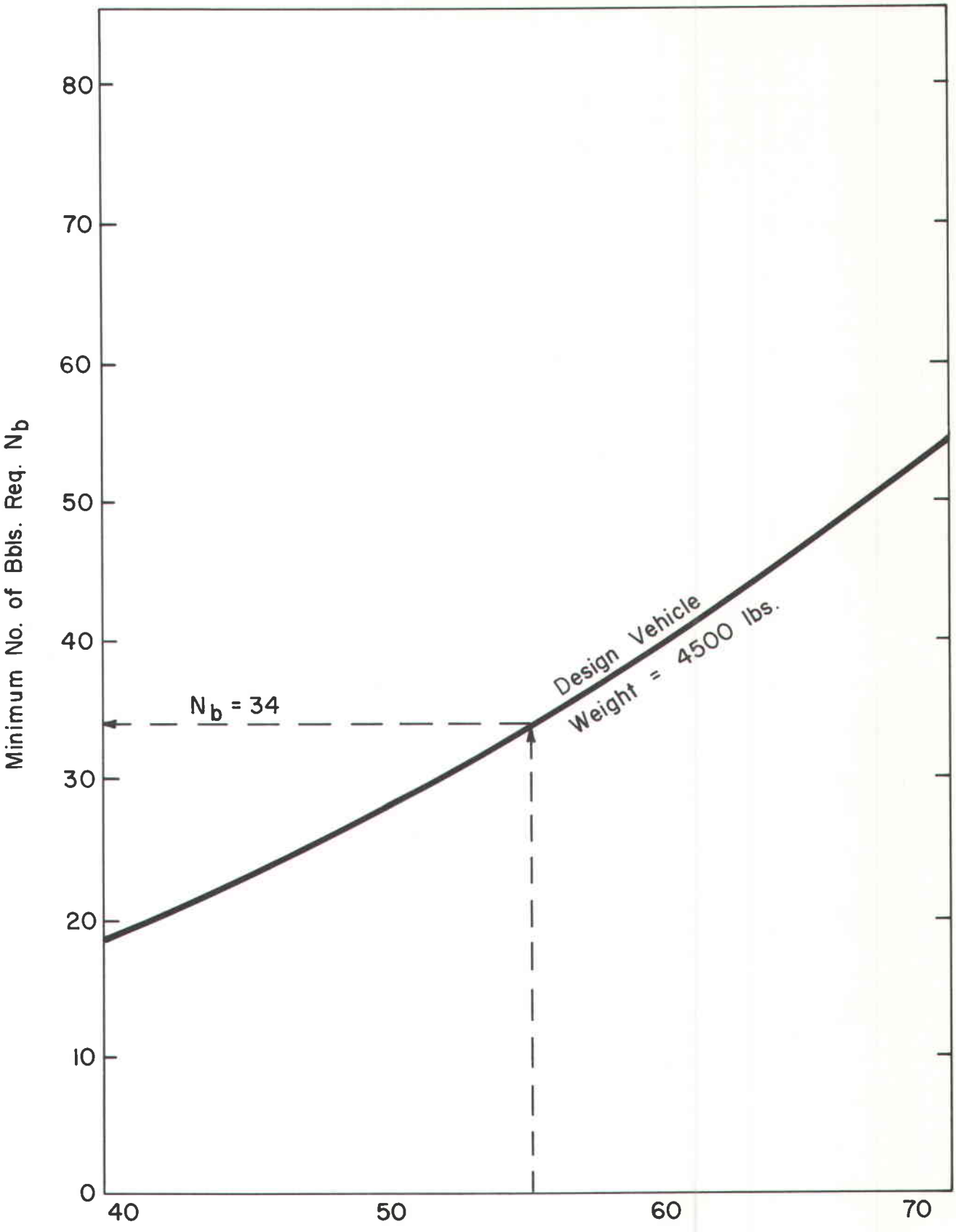

Minimum No. of Bbls. Req. N_b
80
70
60
50
40
30
20
10
0
N_b = 34
Design Vehicle
Weight = 4500 lbs.
40
50
60
70
Design Speed (mph)

Figure I

Figure 2 illustrates a typical attenuator design. Tolerable g-forces at 55 mph for both heavy and light vehicles require a design which incorporates two barrels in the lead row, 7 rows of 3 barrels, and 3 rows of 4 barrels. Thirty-five barrels are used to produce a symmetrical design. When additional capacity is required, 4 barrel rows may be added to the attenuator rear to achieve the number of barrels determined from Figure 1. At least one-half barrel should be located outside of the buttress corner but should not infringe on the shoulder area.

Also, it is desirable to construct rigid barriers, such as parapet walls, at a taper rate of 10:1 with the adjacent roadway as shown on Figure 2. Where roadway geometrics require attenuators with additional redirectional capability, (i.e. short radius curves with possible high angles of fixed object impact) the use of plywood redirectional panels should be considered.

Usually there are a number of different designs that will perform satisfactorily, but often a particular design may be much more economical and less complicated to fabricate, install, and maintain. Since attenuators will be installed at hazardous locations, impacts and system repair or replacement are expected.

The modular arrangement of barrels in the Type "R" design allows for a more standardized unit construction. Units may be prefabricated at the maintenance shop, hauled to the field, and placed with medium weight equipment. The remaining hardware may be installed quickly and easily within non-peak traffic hours.

The Type "T" design is slightly more costly to fabricate and maintain when compared to the Type "R" design; however, often less site modification may be required if the Type "T" arrangement is utilized. Good engineering judgment must be exercised by the designer to determine the best shape of the attenuator system for each design problem.

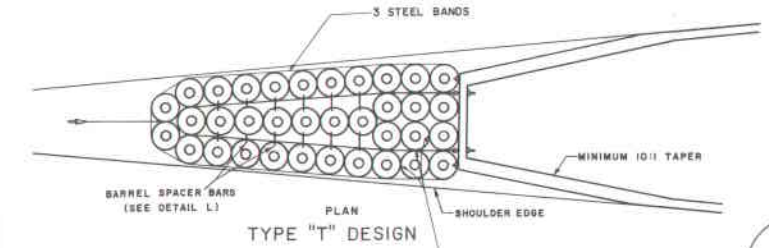
Replacement should be relatively easy after the Texas Crash Cushion has been struck by a vehicle. In most cases the system will be partially salvageable and one only needs to replace the damaged section of the attenuator with a prefabricated section from the maintenance yard. It may prove feasible to replace the entire system with a spare system which could be stored in the maintenance yard. The system which was struck could then be removed to the maintenance yard and repaired by maintenance personnel if elements of it or reusable. To facilitate maintenance, components should be stocked in the maintenance shop. The major components are listed below:

1. Barrels (55 gallon steel drums)
2. Chair Supports
3. Barrel Connectors (welds, bolts, or clips)
4. Steel Cables and Clips
5. Cable Anchorage Components (nose and rear of attenuator)

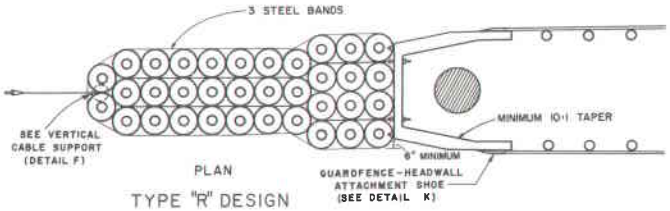
C-103 CONCLUSIONS AND RECOMMENDATIONS CONCERNING THE TEXAS CRASH CUSHION

As the result of research and development of the Texas Crash Cushion, the following general conclusions and recommendations can be made:

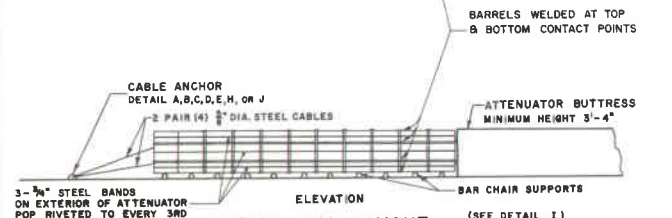
1. The Texas Crash Cushion is an effective attenuation device for both head-on and



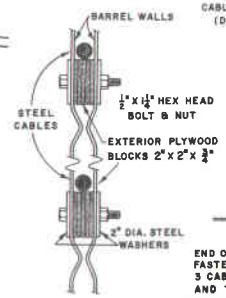
TYPE "T" DESIGN



TYPE "R" DESIGN

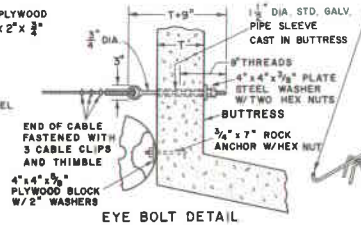


TYPICAL VIA LAYOUT



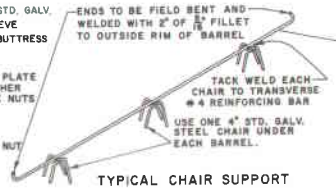
VERTICAL CABLE SUPPORT

DETAIL F



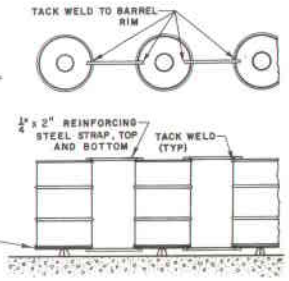
EYE BOLT DETAIL

DETAIL G



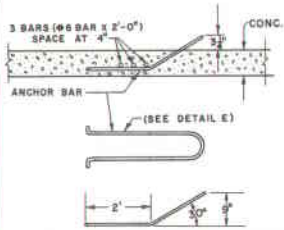
TYPICAL CHAIR SUPPORT

DETAIL I



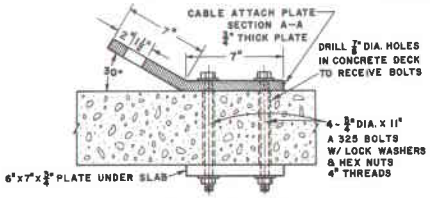
BARREL SPACER BAR

DETAIL L



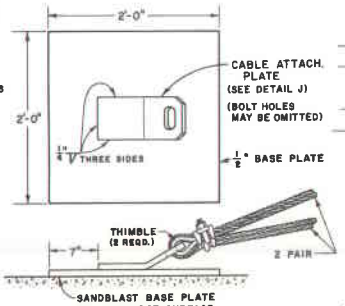
(BRIDGE SLABS OR CONCRETE SHOULDERS)

DETAIL A



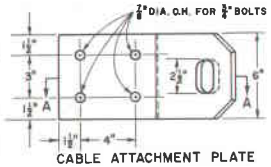
(FOR EXISTING BRIDGE SLABS)

DETAIL D



FOR EXISTING BRIDGE SLABS - EPOXY PLATE

DETAIL H

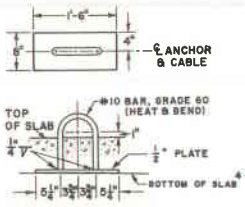


CABLE ATTACHMENT PLATE (TOP VIEW)

DETAIL J

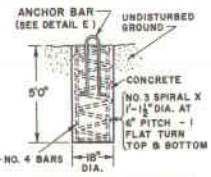
GENERAL NOTES

1. ALL CABLE FITTINGS, ANCHOR BARS, BOLTS, NUTS, WASHERS AND MISCELLANEOUS HARDWARE SHALL BE GALVANIZED. STEEL CABLES MAY BE FURNISHED BLACK, UNLESS OTHERWISE SPECIFIED. NUTS AND BOLTS SHALL BE IN ACCORD WITH ASTM - A325.
2. STEEL CABLE FURNISHED SHALL BE AT LEAST 5/8 INCH IN DIAMETER AND SHALL HAVE A MINIMUM BREAKING STRENGTH OF 20 TONS. CABLE SHOULD BE TENSIONED AS DIRECTED BY THE ENGINEER.
3. STEEL BARRELS WILL BE INTERCONNECTED AT THE TOP AND BOTTOM AT ALL POINTS OF CONTACT BY BOLTING OR WELDING AS DIRECTED BY THE ENGINEER. WHERE ADJACENT BARRELS ARE NOT IN CONTACT, SPACER BARS SHALL BE PROVIDED AND ATTACHED TO THE TOPS AND BOTTOMS OF THE BARRELS.
4. BARREL CRUSH STRENGTH IS DETERMINED BY HOLE CUT-OUTS SIZE IN TOP AND BOTTOM OF EACH BARREL. BARRELS WITH 20 GAUGE TOPS AND BOTTOMS SHALL BE SUPPLIED WITH 7 INCH DIAMETER HOLES ON TOP AND BOTTOM. WHERE USED PAINT BARRELS ARE PROVIDED, HOLE SIZE SHALL BE 13 1/2 INCHES IN TOP AND BOTTOM FOR BOTH TIGHT AND LOOSE HEADED DRUMS. 6" CLAMPS ON LOOSE HEADED DRUMS SHALL BE DISCARDED AND LIDS WELDED TO RIMS WITH EIGHT EQUALLY SPACED 1-INCH BEADS. UNLESS OTHERWISE SPECIFIED, BARRELS NEED NOT BE GALVANIZED AND THIN LAYERS OF PAINT RESIDUE IN PAINT BARRELS NEED NOT BE REMOVED. WHERE SPECIFIED BARREL EXTERIORS SHALL BE PAINTED WITH TWO COATS OF EXTERIOR GRADE REFLECTORIZED PAINT OF THE COLOR SPECIFIED BY THE ENGINEER.
5. CONCRETE FOR THE INSTALLATION SHALL BE CLASS A OR CLASS C CONCRETE.



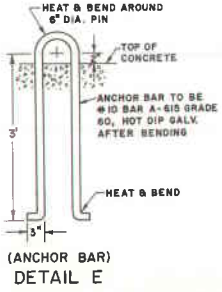
(NEW BRIDGE SLABS)

DETAIL B



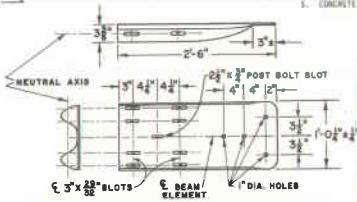
(FOR ROADWAY & ROADSIDE)

DETAIL C



(ANCHOR BAR)

DETAIL E



GUARDFENCE-HEADWALL ATTACHMENT SHOE

DETAIL K

CABLE ANCHORS

Figure 2

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

VEHICLE IMPACT ATTENUATOR

CRASH CUSHION DETAILS

VIA (CCD)-76

LR	DRAWING	DATE	FED. AID PROJ. NO.	STATE	FEDERAL PROJECT NO.				SHEET NO.
LR SM	ORIGINAL								
LM	REVISED			4	YEARS				
LR SM	REVISED			STATE DESIGN	COUNTY		CONT.	SECT.	JOB	HIGHWAY NO.
LR									
LR									

C-5

angular collisions. It must be realized, however, that the barrel cushion is not a substitute for prudent roadside design, but should be utilized as an interim measure until fixed objects can be removed or relocated to a safer position or should be used as a permanent design feature where removing, relocating, or protecting by other methods is impossible or impractical.

2. Future facilities should be designed to be free of fixed objects located near the roadway. Where this is impossible or impractical, the highway should be designed so that hazardous areas are receptive to protection by the Texas Crash Cushion.

3. Tentative, approximate locations for attenuators should be noted on the project schematic and bridge layouts where applicable. Barrel layouts, design details, specifications, etc. need not be submitted until the P.S.&E. stage of project development.

4. Maintenance costs are minimal and repair costs are reasonable.

5. Appearance is unobstrusive.

6. If a particular cushion is impacted frequently, additional safety treatments such as providing illumination, additional pavement marking or other delineation, enlarging the maneuver area, improving sight distance, etc., should be considered by the engineer.

These design methods generally render minimum values and should be considered by the designer as the lowest acceptable limits in design. As research findings permit, refinements to the attenuator design will be made. The barrel layouts shown are merely typical arrangements and are not intended to serve as a standard design and it is expected that the designer will utilize the highest design values commensurate with conditions.

C-104 DESIGN OF THE SAND-TIRE VEHICULAR ATTENUATOR

The Sand-Tire Vehicular Attenuator was developed to provide a low cost attenuator to complement the steel barrel system so that additional hazard locations may be economically protected.

The sand-tire attenuator is an inertial system which employs Newton's second law of motion.

$$m_1 V_1 = m_2 V_2$$

In this case m_1 is the mass of the vehicle; V_1, is the velocity of the vehicle immediately prior to impact; m_2 is the combined mass of the vehicle and the attenuator module set in motion by the impact; and V_2 is the velocity of the vehicle and attenuator module after impact. Speed reduction of the vehicle per row of attenuator can be calculated from this equation.

Speed reductions are calculated until the vehicle is within a safe range of approximately ten miles per hour. Also, since occupant loadings upon collision are a very important indication of expected injury severity, G forces are individually determined for each attenuator row. Design criteria upon which the sand-tire system is based is a 6 G average for a 2000 to 5000 pound vehicle impacting at 60

mph. This loading rate should provide tolerable decelerations to the unrestrained occupant without producing serious injury. Determination of the G force encountered was computed from the following equations:

$$\text{Average Velocity} = \frac{V_1 + V_2}{2}$$

$$\Delta T = \frac{2.5'}{\text{Average Velocity}}$$

$$G\text{'s} = \frac{V_2 - V_1}{(\Delta T)\quad(32.2)}$$

These computations are also continued until vehicle speed has decreased to ten miles per hour. Figure 3 illustrates performance curves of the sand-tire attenuator for the 2000 and 5000 pound vehicle impacting the system at 60 mph. Deceleration levels are kept in the 6 G range through the use of lightweight front modules. As the heavier weight vehicles penetrate deeper into the system, deceleration remains at a safe level. Completely filled modules at the rear of the attenuator provide a backup for the system to insure containment of the vehicle and to reduce debris scatter. Attenuator buttresses are not needed with sand-tire systems.

Figure 4 illustrates details of the sand-tire attenuator which is designed to attenuate 2000 to 5000 pound vehicles impacting at 60 mph with 6 G's average deceleration.

Modules are constructed by loosely filling tire units with pit run sand in the amounts indicated. When the modules are to be placed on unconsolidated surfaces which may cause support penetration and module instability. It is recommended that treated plywood disks be placed under the bases. Base design is critically important since to reduce vehicle ramping, tire supports must fully and readily collapse upon vehicle impact. Two types of supports, the modified steel barrel and the wire-mesh support, have been tested and are equally satisfactory for this purpose.

Covering of the sand-tire unit is desirable to prevent moisture from saturating the sand. The material used should be durable, waterproof, present a neat appearance to the finished unit and clearly delineate the presence of a roadside hazard.

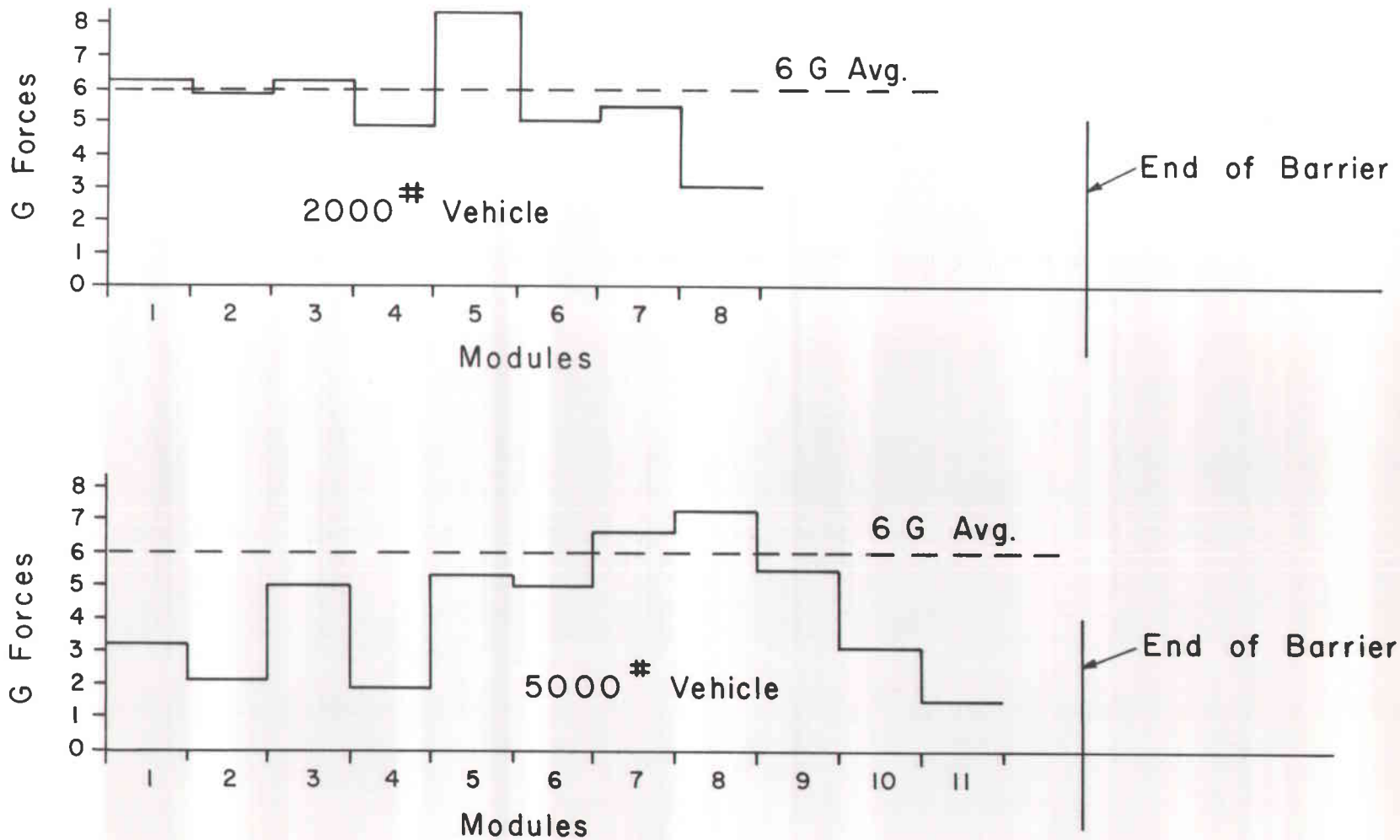
Several typical sand-tire installations are illustrated in Figure 5. Where obstacles need treatment wider than can be accommodated through use of a single attenuator unit, multiples of the basic unit can be combined until the necessary width has been achieved.

C-105 CONCLUSIONS AND RECOMMENDATIONS CONCERNING THE SAND-TIRE ATTENUATOR

As in any attenuation system the sand-tire attenuator does possess certain limitations which should be fully understood. It is not recommended for the following situations:

1) Where its limited debris scatter can cause operational difficulties when placed in close proximity to the travelled way.

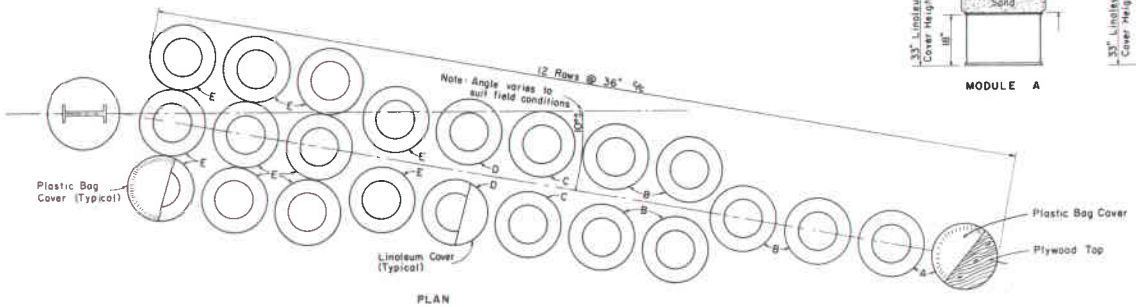
2) Where vibration of bridge structures is apt to cause distress of the modules.



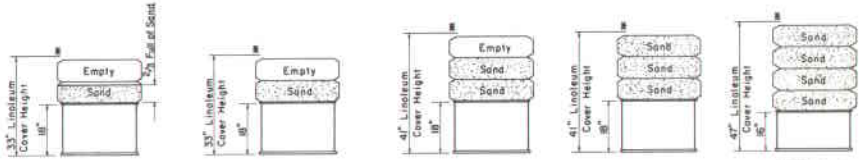
SAND - TIRE VEHICULAR IMPACT ATTENUATOR

AVERAGE COMPUTED G FORCES

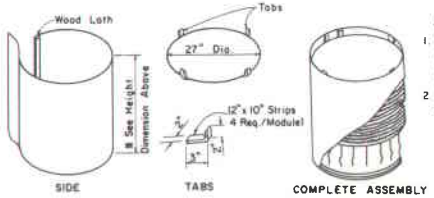
FIGURE 3



PLAN



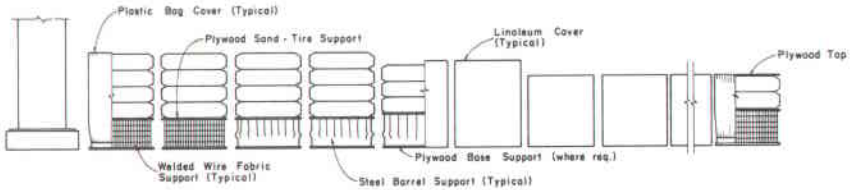
MODULE DETAILS



Linoleum Cover Notes

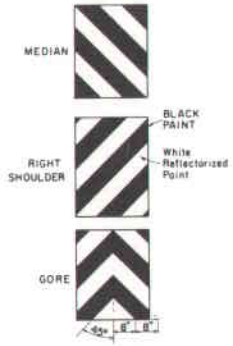
1. Lath, Side, Top and Tabs to be attached with galvanized staples.
2. Side, Top and Tabs to be constructed from Linoleum.

LINOLEUM COVER DETAILS



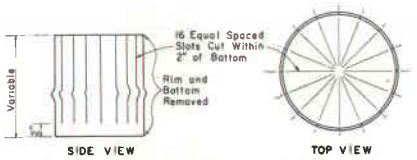
ELEVATION

LEAD MODULE HAZARD PAINT PATTERN



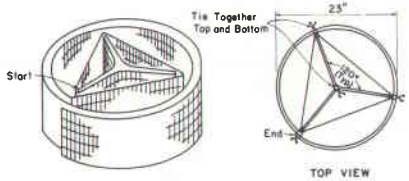
GENERAL NOTES

1. WHERE POSSIBLE THE ATTENUATOR SHALL BE ANGLED TOWARD THE ROADWAY AT AN ANGLE NOT TO EXCEED 10 DEGREES WITH PAVEMENT EDGE.
2. OLD PASSENGER CAR TIRES (14" & 15") SHALL BE USED AND FILLED WITH LOOSE SAND. THE TIRES SHALL NOT BE TIED TOGETHER.
3. EACH COMPLETED MODULE SHALL BE COVERED WITH A PLASTIC BAG COVER, A LINOLEUM COVER OR A COVER CONSTRUCTED OF OTHER WATERPROOF MATERIAL ACCEPTABLE TO THE ENGINEER. PLASTIC BAG COVERS SHALL BE A MINIMUM OF 4 MILS THICK.
4. COVERS SHALL BE WHITE OR YELLOW IN COLOR. IF PAINTING IS REQUIRED EXTERIOR GRADE PAINT SHALL BE USED.
5. PLYWOOD BASE AND SAND-TIRE SUPPORTS SHALL BE 1/4" EXTERIOR GRADE PLYWOOD SHEATHING AND SHALL BE EITHER CREOSOTE OR PENTACHLOROPHENOL TREATED.
6. PLYWOOD BASE SUPPORTS SHALL BE USED AS DIRECTED BY THE ENGINEER.
7. FOR COMPUTATION PURPOSES AN EMPTY TIRE WEIGHS APPROXIMATELY 20#, AND REQUIRES APPROXIMATELY 130# OF SAND.
8. WHEN ATTENUATOR IS PLACED IN A CURBED GORE, APPROACH CURB SHOULD BE REMOVED AND GORE SLOPED TO FLOW LINE OF CURB.
9. EITHER THE WEAKENED 20 GAUGE STEEL BARREL BASE OR WELDED WIRE FABRIC BASE MAY BE USED.
10. A TOP MADE FROM ¼" EXTERIOR GRADE PLYWOOD SHEATHING SHALL BE PLACED ON MODULE TYPES A, B AND C WHEN PLASTIC BAG COVERS ARE TO BE USED. PLYWOOD TOPS SHALL BE CREOSOTE OR PENTACHLOROPHENOL TREATED.



20 GAUGE STEEL BARREL SUPPORT FABRICATION DETAILS

PLYWOOD TOP, BASE AND SAND TIRE SUPPORT



WELDED WIRE FABRIC SUPPORT DETAILS

Welded Wire Fabric Support Notes

1. Wire Fabric Supports shall be constructed from one continuous piece of 1" x 2" x 14 ga. galvanized welded wire fabric.
2. All points of contact between wire bends shall be tied with galvanized rebar ties.
3. Make all 180° bends with vertical wires on the inside of the bend.
4. Heights shall be as shown in the module details.
5. A 23" ± diameter support requires approximately 24' of welded wire fabric.

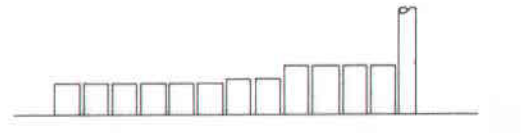
Figure 4

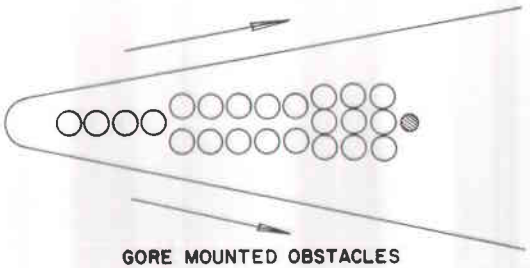
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

SAND-TIRE VEHICULAR IMPACT ATTENUATOR VIA (ST)-74

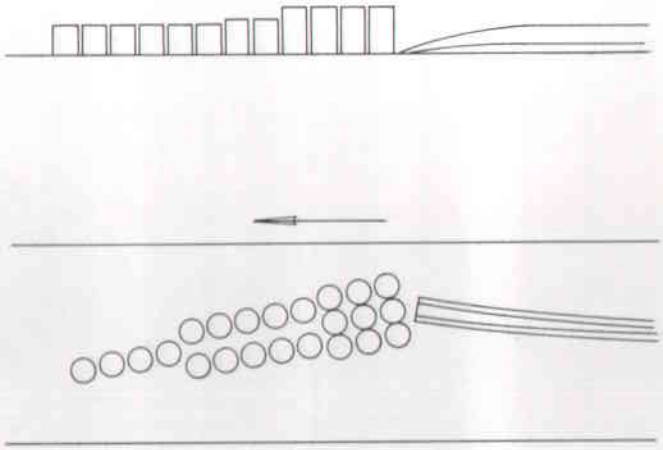
DN	DRAWING	DATE	FED. ROAD DIV. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK DN	ORIGINAL		6	TEXAS		
DW	REVISED					
CK DW	REVISED		STATE DIST. NO.	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
TR						
CK TR						

C-9

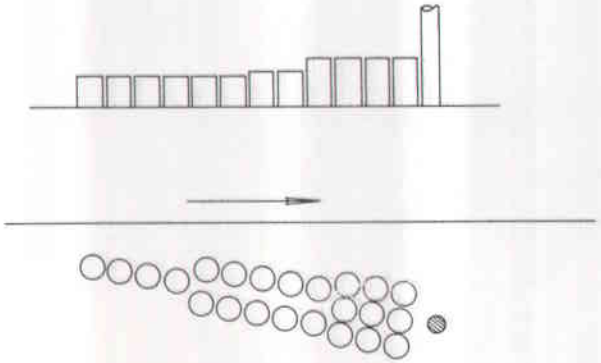




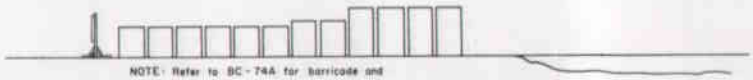
GORE MOUNTED OBSTACLES



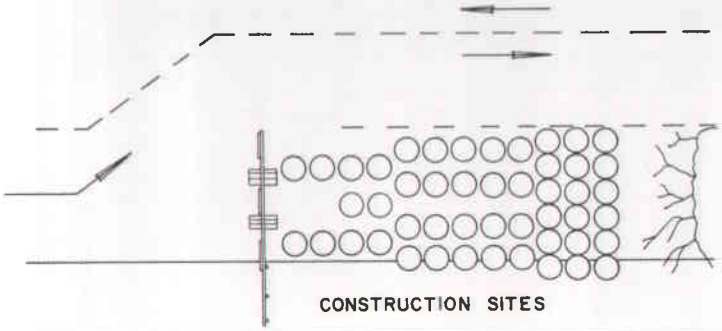
CONCRETE MEDIAN BARRIER TERMINAL



ROADSIDE OBSTRUCTIONS



NOTE: Refer to BC-74A for barricade and warning device details.



CONSTRUCTION SITES

Figure 5

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

SAND-TIRE VEHICULAR IMPACT ATTENUATOR

TYPICAL TREATMENTS

FED. AID PROJ. NO.	STATE	D. FEDERAL PROJECT NO.	SHEET NO.
9	TEXAS		
STATE DIST. NO.	COUNTY	CONT.	SECT.	JOB	HIGHWAY NO.

3) Where redirectional capability is needed.

4) Where a level cross slope is impractical.

The sand-tire attenuator is a low-cost, effective attenuation unit. Its low-cost combined with simplicity of construction and readily available waste material should enable its adaption to many locations not presently considered for attenuation units.

C-106 DESIGN OF THE SAND FILLED PLASTIC BARRELS VEHICLE IMPACT ATTENUATOR

The sand filled plastic barrels VIA is an inertial system which includes free standing, energy dissipating modules. The individual containers are made of a highly frangible plastic material and are filled with known sand masses as desired. The concept is adaptable to almost any hazardous fixed object site since the free standing units may be arranged into a variety of configurations.

Design of this inertial barrier at a given location is primarily dependent on expected impact speed, width of the object to be protected, and depth available to accommodate the attenuation system. Each installation should be designed to attenuate impacts at the expected speed with deceleration forces not exceeding 12 G's per row (see Figure 6) and exit speed desirably 5 mph or less.

Sand filled plastic barrel VIA's are typically designed in four basic lengths (15′, 18′, 21′, and 24′). Figure 6 illustrates typical arrangements of the sand filled modules to form a VIA system; Figures 7 and 8 show details of commercially available systems.

C-107 CONCLUSIONS AND RECOMMENDATIONS CONCERNING THE SAND FILLED PLASTIC BARRELS VEHICLE IMPACT ATTENUATOR

The following general conclusions and recommendations may be made regarding the sand filled plastic barrel VIA system.

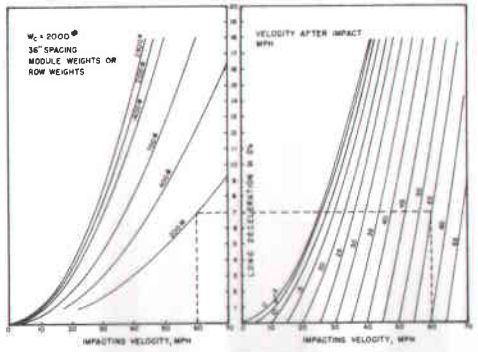
1. The system is an effective attenuation device for head-on collisions. This system, however, does not include redirectional capability for side impacts.

2. Vibration of bridge structures may cause movement of the sand filled modules. Other alternative VIA systems should be carefully considered for bridge structures, however, should the sand filled plastic barrels be used, special design precautions should be taken to minimize module movement.

3. Debris scatter may result in a traffic hazard to lower roadways where used on elevated gores.

4. The system may be quickly restored if replacement materials are readily available.

The sand filled plastic barrel barrier is a moderate cost, effective vehicle impact attenuation unit. It is adaptable to most fixed object sites, and can be restored to service through simple and quick maintenance activities.



SAND – FILLED PLASTIC BARREL BARRIER
(36" Row Spacing – 2000 lb. Vehicle)

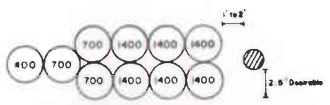
EXAMPLE PROBLEM

EXAMPLE PROBLEM: Determine Barrier Array for 60 MPH Design Speed

For 2000 lbs Vehicle

Impact Velocity	Row No.	Row Wt. (lbs)	$G_{long.}$ **	Velocity After Impact MPH
60 +	1	400	7.0	56.5
56.5	2	400	10.1	45.5
45.5	3	700	10.4	33.7
33.7	4	1400	8.3	19.8
19.8	5	2800	1.6	8.3 ***
8.3	6	2800	0.6	3.4

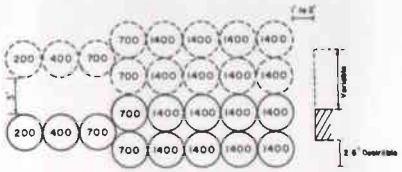
* Design Speed
** In design, G's should be less than 12
*** Final Velocity should be a minimum 10 mph, a desirable 5 mph



40 MPH DESIGN SPEED

50 MPH DESIGN SPEED

60 MPH DESIGN SPEED

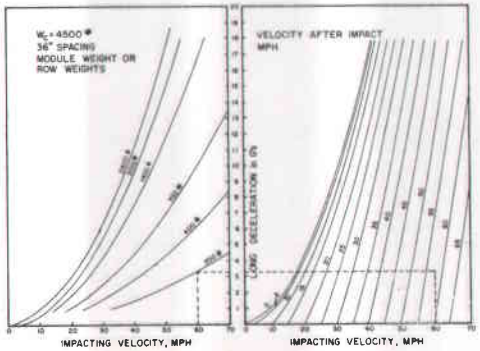


BARRIER ARRAY FOR FIXED OBJECT OF VARIABLE WIDTH

GENERAL NOTES

1. IF SPACE ALLOWS, A 1' TO 2' INTERVAL SHOULD BE LEFT BETWEEN FIXED OBJECT AND REAR LINE OF MODULES.
2. REAR MODULES SHOULD OVERLAP (IN WIDTH) THE FIXED OBJECT ON EACH SIDE BY A MINIMUM OF 30".
3. MODIFICATION OF ARRAYS: WHEN PROXIMITY OF TRAFFIC LANES EXCLUDE THE USE OF A WIDER BARRIER, THE FRONT OF THE BARRIER MAY RETAIN THE STANDARD WIDTH, BUT THE REAR CAN BE WIDENED BY SPACING AS SHOWN IN THIS DIAGRAM.

4. BARRIERS CAN BE PLACED AT ANY DISTANCE FROM THE EDGELINE BOTH AT MINIMUM AND IN MEDIAN SIDES FROM 0 TO 30° DEPENDING ON THE LOCATION OF THE HAZARDOUS FIXED OBJECT. ANGLING OF THE BARRIER TOWARD ON-COMING TRAFFIC IS SUGGESTED FROM 5 DEGREES TO 15 DEGREES DEPENDING ON SPACE AVAILABLE.
5. WHENEVER POSSIBLE, CURBS 6" AND HIGHER SHOULD BE REMOVED FROM HAZARDOUS SIDES. HOWEVER, WHERE REMOVAL IS NOT POSSIBLE, MODULES CAN BE SEPARATED ALONG THE BARRIER AXIS TO FIT THE SITUATION.
6. LONGITUDINAL SPACING OF MODULES MAY BE INCREASED WHERE SPACE PERMITS. FOR EXAMPLE, 2' OR EVEN 3' SPACING OF SOME OF THE MODULES MAY PERMIT THE DESIGN ENGINEER TO DEFLECT ALL THE SPACE ALLOCATED FOR AN ENERGY-ABSORBING BARRIER.
7. THE ENTIRE AREA OF THE CRASH CUSHION INSTALLATION AND APPROACHES SHALL BE GRADED SO THAT THE MAXIMUM SLOPE DOES NOT EXCEED 10:1 IN ANY DIRECTION.
8. WHERE REQUIRED, SUPPORT PADS WILL BE MEASURED AND PAID FOR IN ACCORDANCE WITH APPROPRIATE BID ITEMS.



SAND-FILLED PLASTIC BARREL BARRIER
(36" Row Spacing – 4500 lb. Vehicle)

EXAMPLE PROBLEM

EXAMPLE PROBLEM: Determine Barrier Array for 60 MPH Design Speed

For 4500 lbs. Vehicle

Impact Velocity	Row No.	Row Wt. (lbs)	$G_{long.}$ **	Velocity After Impact MPH
60.0 +	1	800	3.3	57.1
57.1	2	800	5.8	50.8
50.8	3	700	7.8	43.7
43.7	4	1400	9.7	34.8
34.8	5	2800	8.4	21.9
21.9	6	2800	3.2	13.2
13.2	7	2800	1.2	8.2
8.2	8	2800	0.3	5.0 ***

* Design Speed
** In design, G's should be less than 12
*** Final Velocity should be a minimum 10 mph, a desirable 5 mph

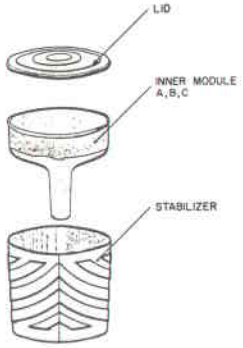
Figure 6

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

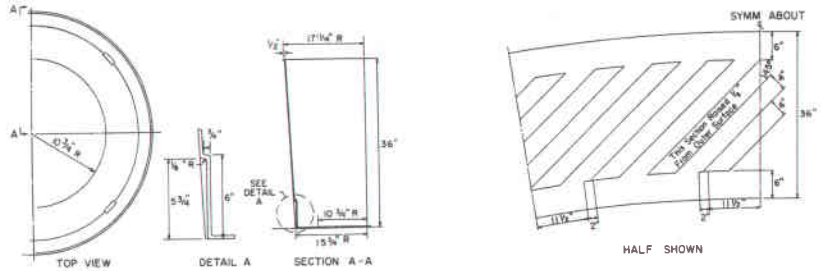
DESIGN GUIDELINES AND TYPICAL BARRIER ARRAYS

VIA (SFPB)

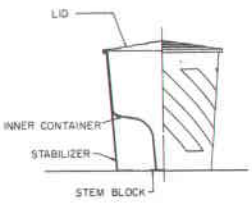
CH.	DRAWING	DATE	FED. AID PROJ. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK. BY	ORIGINAL		6	TEXAS		
DR.	REVISED					
CK. DR.			STATE DIST. NO.	COUNTY	CONT.	SECT.	JOB	HIGHWAY NO.
TR.								
CK. TR.								



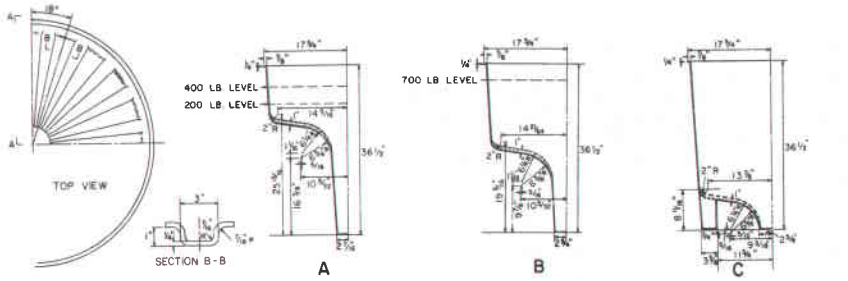
BARREL COMPONENTS



STABILIZER



BARREL ASSEMBLY



INNER CONTAINER A, B, & C

In addition to the center support, each Type C inner container shall have four support legs at the quarter points along the circumference of the bottom.

GENERAL NOTES

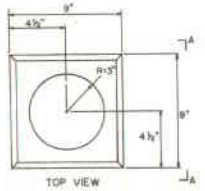
1. THE SAND-FILLED PLASTIC BARREL SHALL BE FREE-STANDING AND PLACED IN A PRESCRIBED ARRAY OF SPECIFIED WEIGHTS IN INDIVIDUAL BARRELS IN ACCORDANCE WITH THE PLANS OR AS DIRECTED BY THE ENGINEER.

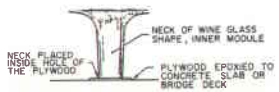
2. ALL BARRELS PLACED ON ELEVATED STRUCTURES SHALL BE PROTECTED FROM DISLOCATION DUE TO BRIDGE VIBRATION BY THE INSTALLATION OF A STEM BLOCK. THIS ALSO APPLIES TO UNITS ON GRADE WITH A CROSSLOPE EXCEEDING 3%. IF ON CONCRETE, THE STEM BLOCK SHALL BE EPOXIED TO THE SURFACE. WHEN MOUNTING THE BLOCK TO ASPHALTIC CONCRETE, IT WILL BE NECESSARY TO NAIL THE STEM BLOCK TO THE SURFACE IN A MANNER SATISFACTORY TO THE ENGINEER.

3. THE ENTIRE AREA OF THE CRASH CUSHION INSTALLATION AND APPROACHES SHALL BE GRADED SO THAT THE MAXIMUM SLOPE DOES NOT EXCEED 10:1 IN ANY DIRECTION.

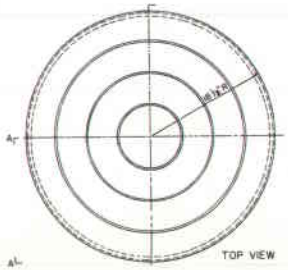
4. SUPPORT PADS WILL BE MEASURED AND PAID FOR IN ACCORDANCE WITH PERTINENT BID ITEMS. DETAILS OF THE SUPPORT PAD ARE SHOWN ELSEWHERE IN THE PLANS.

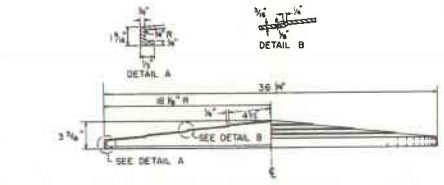
Inner Container (Type)	Sand Fill Weight (lbs)
A	200 - 400
B	700
C	1400
NONE	2100





STEM BLOCK





Lid to be reinforced by six radial spokes spaced at 60° angles. Spokes shall be raised approximately 3/16".

LID

Figure 7

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

SAND FILLED PLASTIC BARRELS VEHICLE IMPACT ATTENUATOR TYPE B

VIA(SFPB)(B)-76

C-13

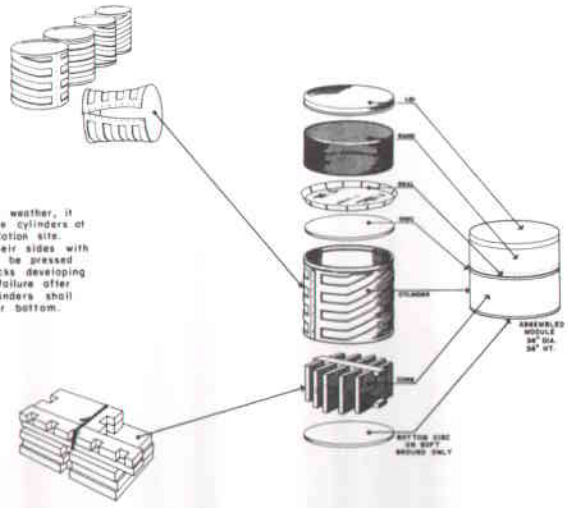
Assembling the Cylinders

Cylinders are assembled by placing the halves on a level surface and lining up the pre-bored holes. Rivets are inserted from the outside and washers are held in place from the inside and a standard pop rivet gun is used. Bored holes are approximately ¼" in diameter, rivets are $^{15}/_{16}$ diameter for easy installation. Rivers should be placed in all holes.

Due to traffic conditions or inclement weather, it is sometimes necessary to assemble the cylinders at the shop before delivery to the installation site. If assembled cylinders are placed on their sides with any weight placed thereon, they may be pressed into an oval shape, with possible cracks developing along the rivet lines and subsequent failure after installation. Therefore assembled cylinders shall be transported upright resting on their bottom.

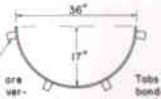
Assembling Core

Each color coded core consists of seven parts - five plastic boards and two 6 inch cross bars. The cross bars, which press fit into notches cut in the plastic boards, hold the load - bearing plastic boards in a vertical position and evenly spaced to carry the sand load most efficiently.



MODULE ASSEMBLY DETAIL

Core Depth (in.)	Sand Fill Weight (lbs.)
20 ½	200
20 ½	400
16 ½	700
11 ½	1400
No Core	2100



4 Tabs 3" long are butt welded onto vertical face of strip.

Tabs and Straps bonded to bridge surface with epoxy

1½" x ⅛" strap 55" long before bending

4 Tabs spaced equally starting 1½" from end of strap.

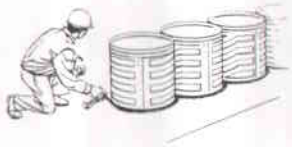
MODULE LOCATING HALF RING DETAIL

(To be used on elevated structures only)

GENERAL NOTES

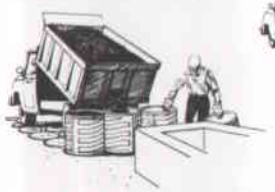
1. WHEN THE PROPOSED SITE IS SLOPING, THE CENTER VERTICAL BOARD OF CORE IN ALL MODULES SHALL BE ALIGNED WITH THE SLOPE TO PREVENT EXCESSIVE STRESS ON THE CORE PARTS.
2. THE ENTIRE AREA OF THE CRASH CUSHION INSTALLATION AND APPROACHES SHALL BE GRADED SO THAT THE MAXIMUM SLOPE DOES NOT EXCEED 10:1 IN ANY DIRECTION.
3. ALL MODULES PLACED ON ELEVATED STRUCTURES SHALL BE PROTECTED FROM DISLOCATION DUE TO BRIDGE VIBRATION BY INSTALLATION OF A MODULE LOCATING HALF RING. THE HALF RING SHALL BE POSITIONED ON THE DOWNSLOPE SIDE OF EACH MODULE AND ATTACHED TO THE BRIDGE SURFACE WITH EPOXY.
4. SUPPORT PADS WILL BE MEASURED AND PAID FOR IN ACCORDANCE WITH PERTINENT BID ITEMS. DETAILS OF THE SUPPORT PADS ARE SHOWN ELSEWHERE IN THE PLANS.

1. Put empty modules in place to conform with plan for site with 1 to 2 ft. clearance to fixed object for access. Leave at least 1 inch between modules to facilitate lid placement. Center line of barrier should line up with center of fixed object and point of gore area (or in line with probable impact, if they are different.) See site plan for location detail.

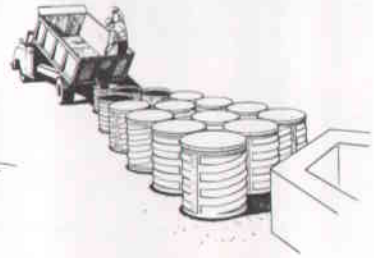


2. Where practical the location of the modules shall be outlined in paint for future reference. A can of pressurized paint in a contrasting color may be used for this purpose.

3. Move modules from site and again using paint, mark the weight of sand in each module as indicated on sheet showing site plan.



4. Place one row of modules nearest fixed object in proper location and fill with prescribed amount of sand from truck backed up to them. Place lids on securely.



5. Position next row of modules and fill to proper level with sand - move forward in this manner using required cores, discs and seals until barrier is completed and all lids are securely snapped on.

6. Lids shall be drilled at 4 equidistant points and pop riveted in place.

SUGGESTED PROCEDURES FOR TYPICAL INSTALLATION

Figure 8

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

SAND FILLED PLASTIC BARRELS VEHICLE IMPACT ATTENUATOR TYPE A

VIA (SFPB)(A)-75

DN.	DRAWING	DATE	FED. ROAD DIV. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK. DN.	ORIGINAL					
DN.	REVISED		6	TEXAS		
CK. DW.	REVISED		STATE DIST. NO.	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
TR.						
CK. TR.						

C1-14

C-108 CELL SANDWICH ASSEMBLIES

Cell sandwich assemblies consist of vermiculite concrete cartridges or water filled cells forming bays which are "sandwiched" between diaphrams along the VIA longitudinal axis. Backup walls are required for all cell sandwich VIA assembly installations; available standard units require the backup wall to be 3'0", 5'2", or 7'6" in width, and a usual 3'3" in height. The system includes side panels which provide redirectional capability.

Figure 9 shows typical features and design data for both types of cell sandwich units. Additional information such as design details, specifications, etc. may be obtained upon request from the Highway Design Division.

C-109 CONCLUSIONS AND RECOMMENDATIONS CONCERNING THE CELL SANDWICH ASSEMBLY VIA

The following general conclusions and recommendations may be made regarding both types of cell sandwich units:

1. Both types through full testing and field use have proven to be effective crash moderation systems.

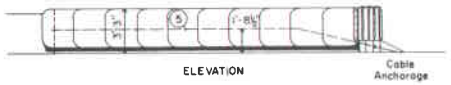
2. The dry system may be favored for use, especially where frequent freezing weather occurs, since the need for antifreeze solution is eliminated.

3. Both systems may be restored to service in a short time if replacement materials are stocked. The dry system may be restored to service at a more rapid rate than the wet system.

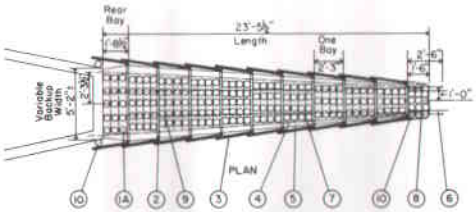
4. Both systems have redirectional capability for side impacts.

5. Both systems are sensitive to impacting mass and velocity, and substantially all available deceleration distance is used for all velocities of impacts up to design velocity.

6. The cost of a cell sandwich assembly generally exceeds other alternative VIA systems.



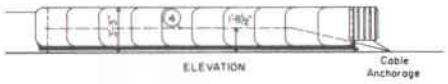
NOTE: Length varied as dictated by design speed and available space; see table for listing of lengths for standard installations.

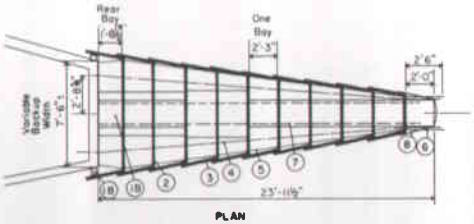


TYPICAL CELL SANDWICH INSTALLATION (Water Filled Cells)

KEY

(1A) Water Filled Cells
(1B) Vermiculite Concrete Cartridges
(2) Diaphragms
(3) Fender Panels
(4) Restraining Cables
(5) Pull-Out Cables
(6) Secondary Cables
(7) Slide Straps
(8) Flexible Nose Cover
(9) Interior Panels
(10) Standard Vinyl Cells

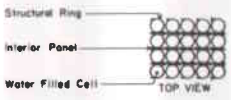




TYPICAL CELL SANDWICH INSTALLATION
(Vermiculite Concrete Cartridges)

GENERAL NOTES

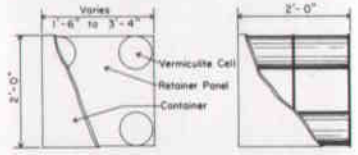
1. BACKUP WIDTH SHOULD BE 3'-0", 5'-2", or 7'-6" TO ACCOMMODATE STANDARD ASSEMBLIES FOR CELL SANDWICH UNITS. BACKUP WALL HEIGHT IS USUAL 3'-3"
2. FOR COLD CLIMATES, ETHYLENE GLYCOL ANTI-FREEZE IS RECOMMENDED FOR USE IN WATER FILLED CELLS.
3. CELL SANDWICH VIA ASSEMBLIES ARE PREMARILY USED TO PROVIDE A CRASH CUSHION ON HIGH VOLUME FREEWAY GORES. SITES SHOULD BE SURFACED TO SUPPORT A MINIMUM FIVE POUNDS PER SQUARE INCH. CURBING IN THE SITE AREA SHOULD BE REMOVED.



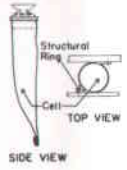
TYPICAL BAY ASSEMBLY

TABLE

SYSTEM TYPE	LENGTH *	NO. OF BAYS	MAXIMUM DESIGN SPEED	AVERAGE "G" FORCES **
VERMICULITE CONCRETE CARTRIDGES	19' -5½"	8	50 MPH	5.3
	21' -8½"	9	50 MPH	4.8
	23' -11½"	10	50 MPH	4.3
	26' -2½"	11	60 MPH	5.6
	28' -5½"	12	60 MPH	5.2
WATER FILLED CELLS	18' -11½"	8	50 MPH	5.9
	21' -2½"	9	50 MPH	5.3
	23' -5½"	10	50 MPH	4.7
	25' -8½"	11	50 MPH	4.3
	27' -11½"	12	60 MPH	5.7



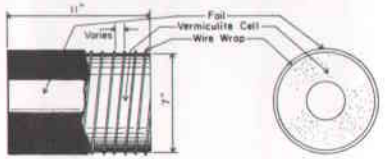
TYPICAL VERMICULITE CONCRETE CARTRIDGE ASSEMBLY
(For wide bays, multiple cartridge assemblies required.)



TYPICAL CELL

* TOTAL LENGTH OF UNIT AS MEASURED FROM FRONT FACE OF BACKUP TO FORWARD EDGE OF FRONT CELLS.

** AVERAGED OVER ENTIRE VIA SYSTEM LENGTH; 50 MILLISECOND PEAK "G" FORCES EXCEED THESE VALUES.



TYPICAL VERMICULITE CELL

Figure 9

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

CELL SANDWICH ASSEMBLIES

WATER FILLED CELLS WFC (VIA)

VERMICULITE CONCRETE CARTRIDGES VCC (VIA)

DN	DRAWING	DATE	FED. RD. DIV. NO.	STATE	FEDERAL PROJECT NO.	SHEET NO.
CK. BY.	ORIGINAL					
DW	REVISED		6	TEXAS		
CK. DW	REVISED		STATE DISTRICT	COUNTY	CONT. SECT. JOB	HIGHWAY NO.
TR						
CK. TR						

TABLE 2: CHARACTERISTICS OF CRASH CUSHIONS

Property	Type of Vehicle Impact Attenuator				
	Steel Drum	Sand Tire	Sand-Filled Plastic Barrels	Water-Filled Cells	Vermiculite Concrete Cartridges
1. Longitudinal Deceleration and Length values for 60 mph design speed:					
(a) Highest average value for a 50-millisecond interval	6 g's @ L = 30'	6 g's @ L = 36'	11 g's @ L = 24'	Unknown	Unknown
(b) Average value over entire barrier length	4 g's @ L = 30'	3 g's @ L = 36'	6 g's @ L - 24'	6 g's @ L = 28'	6 g's @ L = 26'
2. Requirement for backup	Yes	No	No	Yes	Yes
3. Redirectional capability	Yes	No	No	Yes	Yes
4. Generation of debris	No	Yes, sand and module fragments	Yes, sand and barrel scatter	No	No
5. Effect of temperature	No	No	No	Yes, freezing in cold climates and evaporation in hot climates	No
6. Penetrable	No	Yes, at impact velocities exceeding design speed	Yes, at impact velocities exceeding design speed	No	No
7. Width					
(a) Minimum	9'-0"	9'-0"	6'-0"	4'-6"$\pm$	4'-6"$\pm$
(b) Maximum	-	-	-	8'-8"$\pm$	8'-8"$\pm$
8. Maintenance after crash					
(a) Site cleanup requirements	Minor	Substantial	Substantial	Minor	Minor
(b) Exposure time factor for restoration	4	2	1	1	1
(c) Materials storage requirements	Yes, steel drums, redirectional panels, cables, hardware	Yes, sand, plywood discs, wire cage supports, covers	Yes, sand, plastic barrels, cores, discs, covers	Yes, repair kit, cable, redirectional panels, diaphrams	Yes, vermiculite concrete cartridges, redirectional panels, cable, diaphram hardware
(d) Cost	High	Moderate	Moderate	Low	Low
9. Initial Cost	Moderately High	Low	Moderate	High	High

APPENDIX D-100

CAPACITY AND LEVEL OF SERVICE (D-100)

D-101 INTRODUCTION

Level of service evaluation, mentioned briefly in part IV, is an important tool in the design of a highway facility. With a reasonably accurate projection of design year traffic volumes in hand the designer can select the physical characteristics of a facility needed to obtain a desired level of service.

The different levels of service are measures of quality of flow as affected by a number of factors including speed, travel time, traffic interruptions, freedom to maneuver, safety, driving comfort, convenience, and operational costs. Specific levels of service range from ideal operation (Level "A") to complete congestion (Level "F"). Characteristics of the various levels of service, as defined for different types of highways, are summarized in Figure D-1. In the description of characteristics for levels of service, certain factors are used. The limiting values of these factors are indicative of the various service levels and, therefore, a more particular description of these factors is in order.

(a) Load Factors

A ratio of the total number of green signal intervals during the peak hour that are fully utilized by traffic to the total number of green signal intervals available for that approach during the same period. The maximum value obtainable for this ratio would be 1.0; however, the maximum value is seldom obtained and should not be used for design.

(b) Peak Hour Factor (PHF)

A ratio of the volume occurring during the peak hour to the maximum rate of flow during a given time period within the peak hour. As with the load factor, the maximum attainable value is 1.0. As a general rule, on controlled access facilities, the following peak hour factors are appropriate: (1) 0.91 for large metropolitan areas of over one million population; (2) 0.83 for areas between 500,000 and one million; and (3) 0.77 for areas under 500,000 population. A PHF of 1.0 is seldom obtained and should not be used for design.

(c) Service Volume/Capacity (V/C) Ratio

A ratio of the number of vehicles that can pass over a given section during an hour while operating at a given or selected service level to the maximum number of vehicles that could be accommodated on the same section during the same period under the prevailing roadway and traffic conditions.

(d) Factors Affecting Capacity and Service Volumes

Figure D-1 includes the service volumes that can be handled on various types of facilities based on capacities appropriate for ideal conditions; however, many times a highway will not offer ideal conditions. As a result, the capacity and service volumes must be adjusted by application of certain factors before its ability to serve traffic can be determined. The adjustment factors which may need to be applied fall into two broad categories: roadway and traffic.

LEVEL OF SERVICE CHARACTERISTICS BY HIGHWAY TYPE

LEVEL OF SERVICE	TWO-LANE	MULTI-LANE RURAL w/o ACCESS CONTROL	URBAN AND SUB-URBAN ARTERIALS	CONTROLLED ACCESS HIGHWAYS
A	Space mean speeds of 60 m.p.h. or higher. 75% of passing maneuvers can be made with little or no delay. Under ideal conditions, a service volume of 400 passenger vehicles/hour, total both directions, can be achieved.	Space mean speed 60 m.p.h. or greater. Under ideal conditions, volume is limited to 600 passenger cars per lane per hour or 30 per cent of capacity. Average speeds are likely to be influenced by speed limits.	Average over-all travel speed of 30 m.p.h. or more. Free flowing with volume/capacity ratio of 0.60. Load factor at intersections near the limit of the 0.0 range. Peak-hour factor at about 0.70.	Free flow. Space mean speeds at or greater than 60 m.p.h. Service volume of 1400 passenger cars per hour on 2 lanes one direction. Each additional lane serves volume of 1000 v.p.h./lane.
B	Space mean speeds of 50 m.p.h. or higher. Volumes may reach 45% of capacity with continuous passing sight distance. Volumes of 900 passenger cars per hour, total both directions, can be carried under ideal conditions.	Beginning of stable flow area. Volume at which actions of proceding vehicle will have some influence on following vehicles. Volume will not exceed 50% of capacity or 1000 passenger vehicles per lane per hour at a 55 m.p.h. space mean speed under ideal conditions.	Average over-all speeds drop due to intersection delay and intervehicular conflicts, but remain at 25 m.p.h. or above. Delay is not unreasonable. Volumes at 0.70 of capacity and peak-hour factor approximately 0.80. Load factor at intersections approx. 0.1.	Higher speed range of stable flow. Space mean speed at or greater than 55 m.p.h. Service volume on 2-lanes in one direction not greater than 2000 passenger vehicles per hour. Each additional lane above two in one direction can serve 1500 v.p.h.
C	Flow still stable. Space mean speeds of 40 m.p.h. or above with total volume under ideal conditions equal to 70% of capacity with continuous passing sight distance, or 1400 passenger vehicles per hour, total both directions.	Stable flow to a volume not exceeding 75% of capacity or 1500 passenger cars per lane per hour, under ideal conditions, maintaining at least a 45 m.p.h. space mean speed.	Service volumes about 0.80 of capacity. Average over-all travel speeds of 20 m.p.h. Operating conditions at most intersections approximate load factor of 0.3. Peak hour factor approximately 0.85. Traffic flow still stable with acceptable delays.	Operation still stable, but becoming more critical. Space mean speed of 50 m.p.h. and service flow on two-lanes in one direction at 75% of capacity or not more than 5 min. flow rate of 3000 passenger cars per hour. Under ideal conditions each additional lane above two in one direction would serve 1800 v.p.h.
D	Approaching unstable flow. Space mean speeds approx. 35 m.p.h. Volumes, two-direction, at 85% of capacity with continuous passing opportunity, or 1700 passenger cars per hour total both directions under ideal conditions.	Approaching unstable flow at volumes up to 90% of capacity or 1800 passenger cars per lane per hour at a space mean speed of about 35 m.p.h. under ideal conditions.	Beginning to tax capabilities of street section. Approaching unstable flow. Service volumes approach 0.90 of capacity. Average over-all speeds down to 15 m.p.h. Delays at intersections may become extensive with some cars waiting two or more cycles. Peak hour factor approx. 0.90; load factor 0.7.	Lower speed range of stable flow. Operation approaches instability and is susceptible to changing conditions. Space mean speeds approx. 40 m.p.h. & service flow rates at 90% of capacity. Peak 5 min. flow under ideal conditions cannot exceed 3600 v.p.h. for 2-lanes, 1 direction; 1800 v.p.h. each added lane. Not used for design of new facilities.
E	Space mean speeds in neighborhood of 30 m.p.h. but may vary considerable. Volumes under ideal conditions, total both directions, equal to 2000 passenger vehicles per hour. Level E may never be attained. Operation may go directly from Level D to Level F.	Flow at 100% of capacity or 2000 passenger cars per lane per hour under ideal conditions. Space mean speeds of about 30 m.p.h. or less.	Service volumes at capacity. Average over-all traffic variable, but in area of 15 m.p.h. Unstable flow. Continuous back-up on approaches to intersections. Load factor at intersections in range between 0.7 and 1.0. Peak hour factor likely to be 0.95.	Unstable flow. Over-all space mean speeds of 30-35 m.p.h. Volumes at capacity or about 2000 v.p.h./lane under ideal conditions. Traffic flow metered by design constrictions and bottlenecks, but long back-ups do not normally develop upstream. This level not used for design.
F	Forced, congested flow with unpredictable characteristics. Space mean speeds less then 30 m.p.h. Volumes under 2000 passenger cars per hour, total both directions.	Forced flow, congested condition with widely varying volume characteristics. Space mean speeds of less than 30 m.p.h.	Forced flow. Average over-all traffic speed below 15 m.p.h. All intersections handling traffic in excess of capacity with storage distributed throughout the section. Vehicular back-ups extend back from signalized intersections, through unsignalized intersections.	Forced flow. Freeway acts as a storage for vehicles backed-up from downstream bottleneck. Space mean speeds range from near 30 m.p.h. to stop-and-go operation. This type service is unacceptable and is not used for design.

NOTE: Space mean speed is defined as the average of the speeds of vehicles within a given section of roadway at a given instant, or the average speed of a group of vehicles based on their average travel time over a section of roadway.

FIGURE D-1

1. Roadway Factors

(a) Lane Width

Narrower lanes have lower capacity under uninterrupted conditions than do 12-ft. lanes which have been accepted as the optimum width.

(b) Lateral Clearance

Fixed obstructions located less than 6 feet from the edge of the travel lane reduce the capacity and service volumes of a 12-ft. lane by reducing the effective width of the lane. Except in the case of mountable curbs or those of less than 6 inches in height, factors should be applied to adjust the capacities and service volumes or demand volumes of highways which have obstructions within 6 feet of the lane edge.

Continuous obstructions may have less adverse effect on effective pavement width than intermittent, short obstructions, because drivers become accustomed to them. This effect is also true in the case of commuter type highways which have a high percentage of repeat drivers.

Since lane width and lateral clearance are interrelated, there is seldom a need to know the individual effects of each. Therefore, the adjustment factors presented in Figure D-2 are based on their combined effects.

(c) Shoulders

Adequate shoulders are essential if the capacity provided by the traffic lanes is to be maintained continuously. Unless a disabled vehicle is provided a refuge area outside the travel lanes, it can reduce the capacity by more than the capacity of one lane. This occurs due to the disabled vehicle blocking one lane and forcing other vehicles to merge into fewer lanes at speeds below those at which capacity can be achieved. No direct adjustment can be applied for inadequate shoulders except when they include obstructions within 6 feet of lane edge. Otherwise, the designer will have to exercise his judgment about the effects of inadequate shoulders.

(d) Horizontal Alignment

The horizontal alignment of a highway has a definite effect on its traffic-carrying capability. No specific capacity reduction is required; however, the overall average travel speed within a section will be affected as illustrated in Figure D-24.

(e) Vertical Alignment

The vertical alignment of a highway affects the capacity of the highway in the following ways:

(1.) For two-lane highways the profile generally determines the restrictions in passing sight distance.

COMBINED EFFECT OF LANE WIDTH AND RESTRICTED LATERAL CLEARANCE ON CAPACITY AND SERVICE VOLUMES

(Uninterrupted Flow Conditions)

DISTANCE TRAFFIC LANE EDGE TO OBSTRUCTION (FT.)	ADJUSTMENT FACTOR, W, FOR LATERAL CLEARANCE & LANE WIDTH			
	OBSTRUCTION ON ONE SIDE ONLY[1]		OBSTRUCTIONS ON BOTH SIDES OF ROADWAY	
	12 Ft. Lanes	11 Ft. Lanes	12 Ft. Lanes	11 Ft. Lanes
a. Two-Lane Highway (Based on Level of Service B which is appropriate for design)				
6	1.00	0.86	1.00	0.86
4	0.96	0.83	0.92	0.79
2	0.91	0.78	0.81	0.70
0	0.85	0.73	0.70	0.60
b. Four-Lane Undivided Highway, Non-controlled Access, One Direction of Travel[2]				
6	1.00	0.95	N.A.	N.A.
4	0.99	0.94	N.A.	N.A.
2	0.97	0.93	0.96	0.92
0	0.94	0.90	0.91	0.87
c. Four-Lane Divided Highway (Conventional or Freeway), One Direction of Travel				
6	1.00	0.97	1.00	0.97
4	0.99	0.96	0.98	0.95
2	0.97	0.94	0.94	0.91
0	0.90	0.87	0.81	0.79
d. Six and Eight-Lane Divided Highway (Conventional or Freeway), One Direction of Travel				
6	1.00	0.96	1.00	0.96
4	0.99	0.95	0.98	0.94
2	0.97	0.93	0.96	0.92
0	0.94	0.91	0.91	0.87

[1]In case of two-lane highways, Table includes allowance for opposing traffic on left.

[2]For six-lane undivided, see Table 10.2, Page 286, Highway Capacity Manual 1965.

FIGURE D-2

(2.) The profile determines the safe headway distance between vehicles. Since braking distances are greater on downgrades and less on upgrades, longer and shorter spaces respectively between vehicles are required for safe operation.

(3.) Trucks generally travel at lower speeds on upgrades than do passenger vehicles. The latter can generally negotiate sustained grades of up to 7 percent without adverse effects; however, the effect of sustained grades on trucks results in a capacity restriction that is exemplified by the truck-automobile equivalencies shown in Figures 4-1A and 4-1B. Generally, no adjustment will need to be made for the effect of trucks on grades as this will have been accomplished by the reduction of mixed traffic to equivalent passenger cars (see section 4-201(e)).

2. Traffic Factors

(a) Lane Distribution

On multi-lane facilities all lanes do not carry the same amount of traffic. For example, on a six-lane freeway section operating at capacity in one direction under ideal conditions (2000 x 3 = 6000 vph), typical lane volumes might be 1700 vph in lane 1 (the outside lane), 2100 vph in lane 2, and 2200 vph in lane 3. No absolute values for lane distribution can be established; however, it can be said that for ideal conditions, greater use is made of the left lanes and less use is made of lane 1 than would be indicated by the average lane volume at each level of service. Although lane distribution is an important variable, no special adjustment is required because where it is of such significance to warrant consideration (as on certain freeways, grades, or at ramp junctions) its effect is included in the basic procedures employed in such evaluations.

(b) Traffic Interruptions

Obviously, where features are built into the highway which force some or all traffic to stop, the highway's ability to carry traffic will be impaired. A basic rule to remember in considering traffic interruptions is that passenger vehicles stopped in a line will rarely get underway at a rate greater than 1500 pcph per lane (an average headway of 2.4 sec.). When it is recalled that the capacity of an uninterrupted flow is 2000 pcph per lane, it is easy to understand why back-ups can develop rapidly where traffic is stopped. For the purpose of this discussion, traffic interruptions are divided into two broad categories: at-grade intersections and other interruptions.

(1.) At-Grade Intersections

Intersections are the most common type of interruptions and the most difficult to eliminate since they involve the sharing of a common roadway by two or more conflicting traffic flows. Their influence on capacity and service volumes are so great that they often govern the capacity determination rather than being handled as adjustments to uninterrupted flow criteria.

(2.) Other Interruptions

This would include such items as drawbridges, at-grade railroad crossings, toll booths,

etc. Generally, no adjustment factors can be provided to correct for such influences. Each will be a special case that must be considered individually. To a varying degree even speed limits may be traffic interruptions. If speeds are reduced to approximately 30 mph (or possibly 40 mph on freeways) they do not greatly affect capacity but do affect level of service.

D-102 LEVEL OF SERVICE EVALUATION PROCEDURES

(a) General

The procedures outlined herein, unless otherwise noted, were developed after a comprehensive analysis of the information contained in the Highway Capacity Manual, 1965, and various research findings. The procedures recommended by these sources are based on actual traffic operations on existing facilities. The methodologies presented here are derived from these publications and experience with traffic operations on the Texas Highway System.

The first step in performing a level of service analysis, regardless of the type of facility involved, is the reduction of traffic to adjusted design hourly volumes as detailed in Part 4. Traffic should be adjusted for directional distribution, design hourly volume factor, percent trucks, and grades, whether for the project as a whole or for individual grades. The basic procedure, then, is to compare this traffic with the service volume for the desired level of service adjusted for lane width, lateral clearance, etc.

The general equation for calculating adjusted service volumes is:

$$SV_L = MSV_L \times W$$

Where:

SV_L = Service volume for a given level of service (equivalent passenger cars total for one direction except for two lane highways which is total both directions).

MSV_L = Maximum service volume, from Figure D-23 for two-lane highways; Figure D-21 for multilane rural highways, or Figure D-3 for freeways.

W = Adjustment factor for obstructions less than 6 feet from the edge of travel lane and/or lane widths less than 12 feet. (See Figure D-2.)

(b) Level of Service Evaluation Procedures for Freeways

1. Main Lanes

The procedure for main lane L.O.S. evaluation involves checking the demand volume across the freeway main lanes against the service volumes shown in Figure D-3 to determine L.O.S. Figure D-4 is an example that illustrates main lane L.O.S. evaluation.

2. Weaving

Weaving is the crossing of traffic streams moving in the same general direction, accomplished by successive merging and diverging. While weaving analyses are usually more important for

LEVELS OF SERVICE AND MAXIMUM SERVICE VOLUME FREEWAYS (UNINTERRUPTED FLOW CONDITIONS)

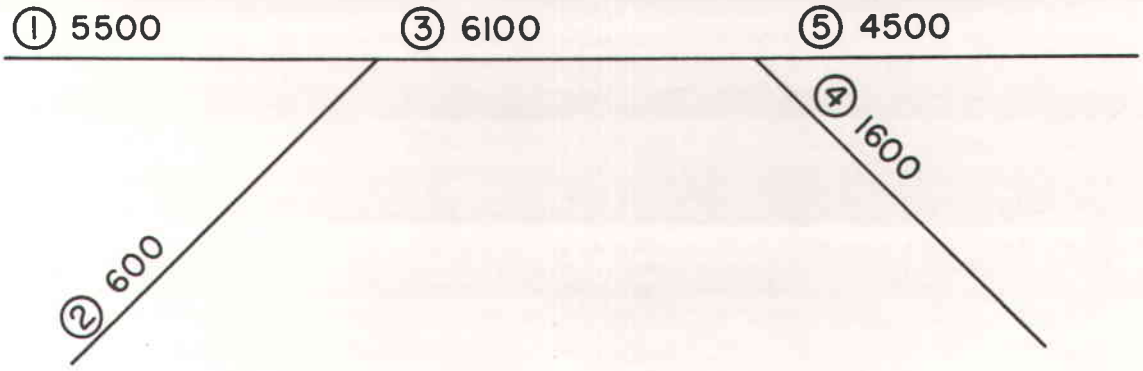
LEVEL OF SERVICE	TRAFFIC FLOW CONDITIONS		SERVICE VOLUME/CAPACITY (v/c) RATIO[a]					MAXIMUM SERVICE VOLUME UNDER IDEAL CONDITIONS, INCLUDING 70-MPH AVERAGE HIGHWAY SPEED (TOTAL PASSENGER CARS PER HOUR, ONE DIRECTION)															
	DESCRIPTION	Space Mean Speed[a] (MPH)	BASIC LIMITING VALUE FOR AVERAGE HIGHWAY SPEED (AHS) OF 70 MPH, FOR:			APPROXIMATE WORKING VALUE FOR ANY NUMBER OF LANES FOR RESTRICTED AVERAGE HIGHWAY SPEED OF		4-LANE FREEWAY (2 LANES ONE DIRECTION)				6-LANE FREEWAY (3 LANES ONE DIRECTION				8-LANE FREEWAY (4 LANES ONE DIRECTION)				EACH ADDITIONAL LANE ABOVE FOUR IN ONE DIRECTION			
			4-LANE FREEWAY (2 LANES/ DIRECTION)	6-LANE FREEWAY (3 LANES/ DIRECTION	8-LANE FREEWAY (4 LANES/ DIRECTION)	60 MPH	50 MPH															
A	Free Flow	$\geq$ 60	$\leq$ 0.35	$\leq$ 0.40	$\leq$ 0.43	[b]	[b]	1400				2400				3400				1000			
B	Stable Flow (Upper Speed Range)	55-60	$\leq$ 0.50	$\leq$ 0.58	$\leq$ 0.63	$\leq$ 0.25	[b]	2000				3500				5000				1500			
	Peak-Hour Factor (PHF)[c]							0.77	0.83	0.91	1.00[d]	0.77	0.83	0.91	1.00[d]	0.77	0.83	0.91	1.00[d]	0.77	0.83	0.91	1.00[d]
C	Stable Flow	50-55	$\leq$ 0.75 (PHF)	$\leq$ 0.80 (PHF)	$\leq$ 0.83 (PHF)	$\leq$ 0.45 (PHF)	[b]	2300	2500	2750	3000	3700	4000	4350	4800	5100	5500	6000	6600	1400	1500	1650	1800
D	Approaching Unstable Flow	38-50	$\leq$ 0.90 (PHF)			$\leq$ 0.80 (PHF)	$\leq$ 0.45 (PHF)	2800	3000	3300	3600	4150	4500	4900	5400	5600	6000	6600	7200	1400	1500	1650	1800
E[f]	Unstable Flow	30-38	$\leq$ 1.00					4000[e]				6000[e]				8000[e]				2000[e]			
F	Forced Flow	< 30[e]	← Not Meaningful →					← Widely Variable (0 to capacity) →															

[a] Space mean speed and basic v/c ratio are independent measures of level of service; both limits must be satisfied in any determination of level.
[b] Space mean speed required for this level is not attainable even at low volumes.
[c] Peak-hour factor for freeways is the ratio of the whole-hour volume to the highest rate of flow occurring during a 5-minute interval within the peak hour.
[d] A peak-hour factor of 1.00 is seldom attained; the values listed here should be considered as maximum average flow rates likely to be obtained during the peak 5-minute interval within the peak hour.
[e] Approximately.
[f] Capacity.

METROPOLITAN AREA POPULATION (1,000's)	PEAK HOUR FACTOR (PHF)
Under 500	0.77
500 to 1,000	0.83
Over 1,000	0.91

FIGURE D-3

MAIN LANE LEVEL OF SERVICE EVALUATION



The line diagram above shows the demand DHV on an existing highway in equivalent passenger cars per hour (EPCPH) adjusted for percent trucks and grade. This is an 8-lane freeway with 11-foot wide lanes and a 4-foot wide median with a barrier (distance to obstruction = 2 feet). There is adequate clearance on the outside. The freeway is in an area with a population in excess of one million persons.

Determine:

The level of service for each of the main lane sections ("1", "3", and "5").

Solution:

Area of over one million population means PHF = 0.91.
Adjustment for obstructions, from Figure D-2, W = 0.93.

Make a table of adjusted service volumes using the Maximum Service Volumes from Figure D-3 and W. Recall the equation $SV_L = MSV_L \times W$.

LOS	MSV	W	SV
A	3400	0.93	3162
B	5000	0.93	4650
C	6000	0.93	5580
D	6600	0.93	6138
E	8000	0.93	7440

By comparing demand volumes to adjusted service volumes, level of service is determined.

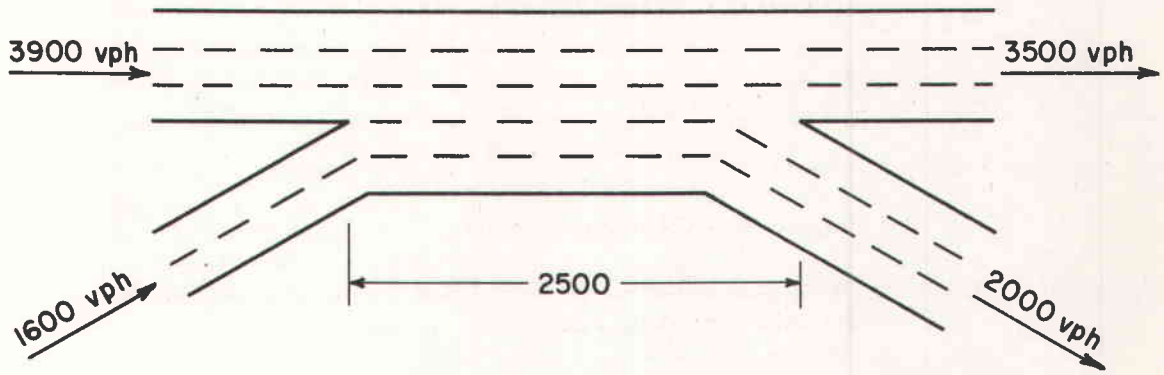
Section 1: $4650 < 5500 < 5580$, LOS "C"
Section 2: $5580 < 6100 < 6138$, LOS "D"
Section 3: $3162 < 4500 < 4650$, LOS "B"

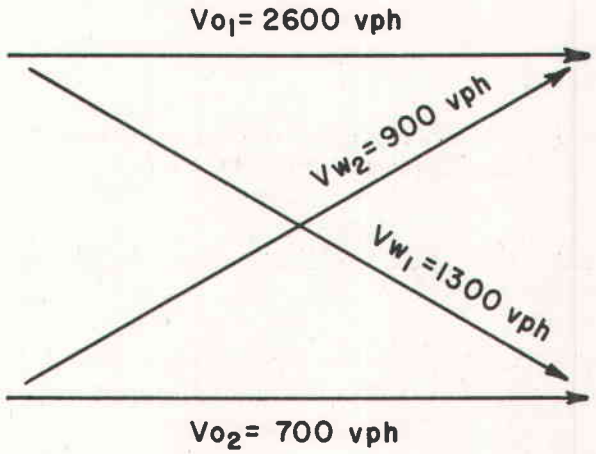
Figure D-4

WEAVING LEVEL OF SERVICE EVALUATION

Given: The proposed weaving section design and the traffic volumes shown (in epcph).
PHF = 0.91

Determine: Is the design adequate to provide level of service "C."





Check: Are all legs of the section adequate to provide LOS "C" ? From Figure D-3 the answer is yes. Proceed with weaving analysis.

Total weaving volume = $V_{w_1} + V_{w_2}$ = 1300 + 900 = 2200

From Figure D-6, using L = 2500', k (weaving influence factor) = 2.9, QF (Quality of Flow) = II - III. From the Table in Figure D-6, LOS = "C "
Therefore, weaving distance is adequate for design.

Figure D-5

Check the number of lanes by the equation:

$$N = \frac{V_{w_1} + kV_{w_2} + V_{o_1} + V_{o_2}}{SV} \text{ or } \frac{V + (k-1)\,V_{w_2}}{SV}$$

Where: V_{w_1} = larger weaving volume, vph

V_{w_2} = smaller weaving volume

V_{o_1} & V_{o_2} = outer flows

V = total volume

k = weaving influence factor

SV = average service volume, per lane, on approaches to the weaving section

In this case, use three lanes as the average approach.

$$SV = \frac{4350}{3} = 1450$$

Note: 4350 is the maximum service volume for LOS "C" on a 6-lane freeway with PHF = 0.91

Hence: $N = \frac{1300 + 2.9 \times 900 + 2600 + 700}{1450} = \frac{7210}{1450} = 4.97$

Therefore, the design is adequate to provide LOS "C".

major junctions of multi-lane urban freeways, a weaving analysis should be performed for the section of highway with an entrance ramp followed by an exit ramp.

The procedure for evaluating the weaving level of service between ramps and/or major freeway legs is illustrated in Figure D-5.

In many cases it may be necessary to obtain information as to the volumes of weaving traffic from File D-10. Weaving volumes for ramp-weave problems will usually be obvious. For other conditions this may not be the case.

3. Ramps (Merge-Diverge Analysis)

Many times the traffic interruptions that occur on freeways are due to the merge and/or diverge conditions near ramp connections with the main lanes. Therefore, it is essential that acceptable merge-diverge conditions be provided in order to reduce traffic congestion on the main lanes.

Figure D-8 is an example problem illustrating some of the techniques used in merge-diverge analyses.

Merge or diverge analyses should be performed even for isolated ramps (greater than 4000' from the nearest affecting ramp).

4. Special Cases

There are several special cases that have not been addressed in this discussion. These special cases include multiple ramp systems, multiple weaving sections, two-lane entrance or exit ramps, and lane additions or reductions.

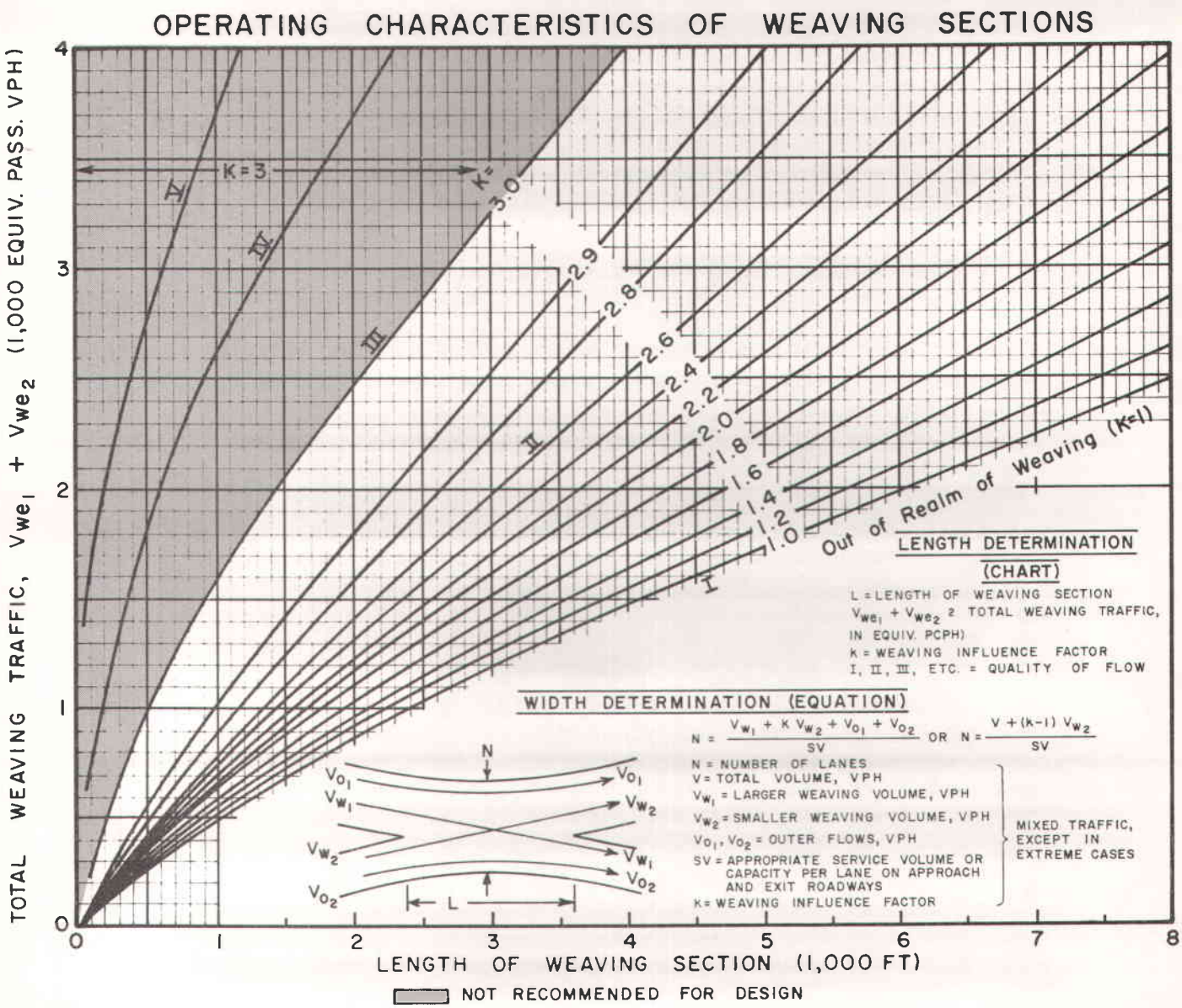
Multiple ramp systems are defined as three or more ramps within 4000 feet which can affect each other. An example would be an on-ramp followed by two downstream off-ramps.

Multiple weave sections are the major highway junction equivalent of multiple ramp systems, i.e., three or more major junctions and/or splits within 4000 feet.

Two-lane ramps should not be confused with major highway junctions or major splits, such as a 4-lane (one way) roadway splitting into two 2-lane roadways. Two-lane ramps are characterized by the merging or diverging maneuvers vehicles must undergo in the vicinity of the ramp. A general rule of thumb is that the capacity of a two-lane ramp will be less than twice the capacity of a one lane ramp.

Lane additions or deletions occur when a lane is added at an entrance ramp or dropped at an exit ramp.

The Highway Capacity Manual may be useful in evaluating such special cases. Other publications that may be of interest include: NCHRP Report 159, "Weaving Areas, Design and Analysis;" Report No. FHWA-RD-74-24, "Capacity Analysis Techniques for Design and Operation of Freeway Facilities," by Jack E. Leisch; and "A Policy on Design of Urban Highways and Arterial Streets," 1973, AASHO ("Red Book").

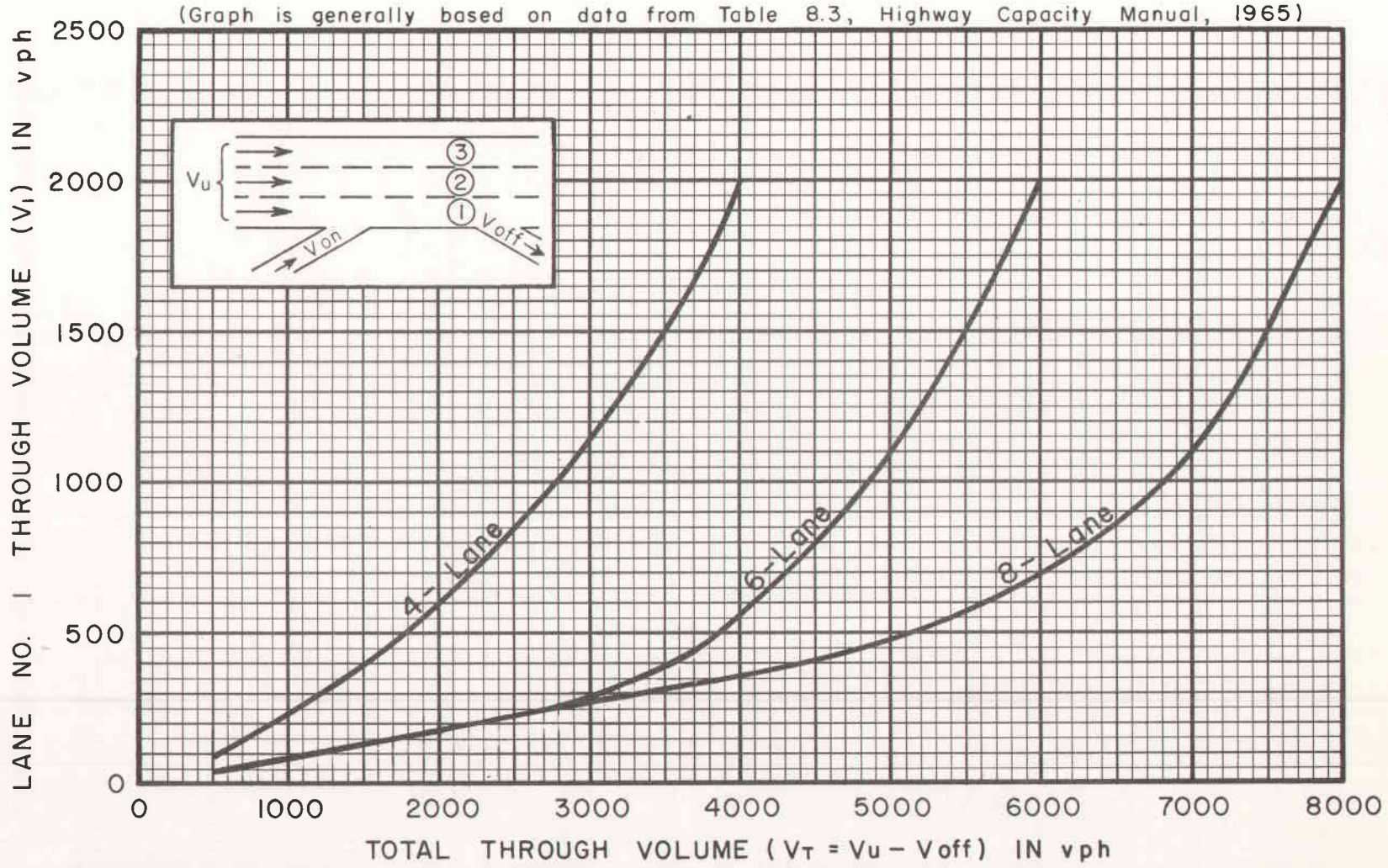


TABLE

ROADWAY LEVELS OF SERVICE AND QUALITY OF FLOW ON WEAVING SECTIONS

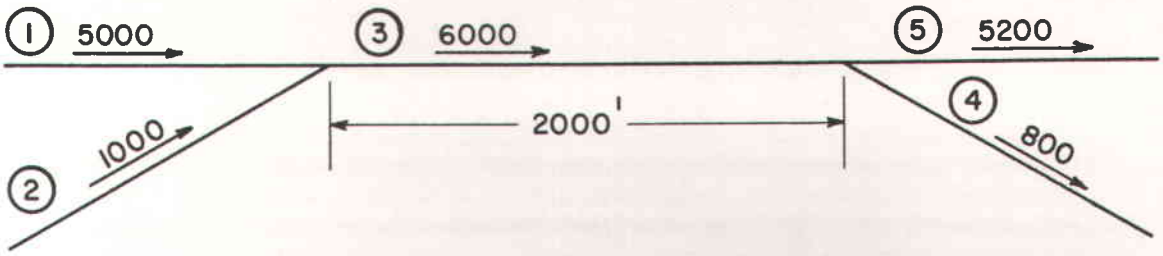
LEVEL OF SERVICE	QUALITY OF FLOW			
	FREEWAYS AND MULTILANE RURAL HIGHWAYS		TWO-LANE RURAL HIGHWAYS	URBAN AND SUBURBAN ARTERIALS
	HIGHWAY PROPER	CONNECTING COLLECTOR-DISTRIBUTOR ROADS AND OTHER INTERCHANGE ROADWAYS		
A	I-II	II-III	II	III-IV
B	II	III	II-III	III-IV
C	II-III	III-IV	III	IV
D	III-IV	IV	IV	IV
E	IV-V	V	V	V
F	UNSATISFACTORY			

FIGURE D-6



APPROXIMATE VOLUME OF THROUGH TRAFFIC IN LANE NO. 1 IN THE VICINITY OF RAMP GORES

RAMPS (MERGE - DIVERGE ANALYSIS) LEVEL OF SERVICE ANALYSIS



Given: An eight-lane freeway section with a pair of on-off ramps having the demand volumes shown. PHF = 0.91

Determine: The design configuration needed to provide level of service "C" operation or better.

The steps in the analysis are as follow:

1. The through traffic in lane 1 in the vicinity of the ramp needs to be determined. Through traffic can be defined as that traffic which traverses a section of highway without interchanging. In this case, the through traffic would be the 5000 vehicles at point (1) less the 800 vehicles exiting at point (4) or 4200 vehicles. Enter Figure D-7 with 4200 and reflect off the 8-lane curve across to V_1 = 375.

2. The "critical point" for the merge and/or diverge must now be determined. For isolated ramps the critical point will always be at the merge or diverge point where 100 percent of the on or off ramp traffic is in lane 1. For this example, the procedure is to determine from Figure D-9 where the sum of on-ramp, off-ramp, and lane 1 traffic is the greatest. In this example, the critical point will be 500 feet from the merge ramp gore at which point 79 percent of the off-ramp traffic and 100 percent of the on-ramp traffic will be in lane 1.

3. Calculating the total lane 1 volume at the critical point:

   $$0.79 \times 800 + 1 \times 1000 + 375 = 2007 \text{ vph.}$$

   From the Table in Figure D-9, this is LOS "F." Rework the problem with an auxiliary lane between the ramps.

4. Again from Figure D-9, the critical point for the lane 1 merge for this case will be 1000 feet from the merge ramp gore at which point 66 percent of the on-ramp traffic and 19 percent of the off-ramp traffic will be in lane 1.

5. Calculating the total lane 1 volume at the critical point:

   $$0.66 \times 1000 + 0.19 \times 800 + 375 = 1187 \text{ vph.}$$

   From the Table in Figure D-9, this is LOS "B."

Figure D-8

Figure D-8 Continued

6. Check the auxiliary lane merge. Again from Figure D-9, the critical point is at the merge ramp gore where 100 percent of the on-ramp traffic is in this lane.

   A volume of 1000 vph is LOS "A" for the auxiliary lane merge.

7. A rudimentary weaving check may be performed. Total weaving volume is 1000 + 800 = 1800 vph over 2000 feet, or 450 vph per 500 feet. Therefore, referring to the weaving portion of Figure D-9, this is LOS "A." Had the weaving level of service thus determined been closer to LOS "C," the necessary level for this example, it would have been necessary to evaluate the weave by the method in Figure D-5.

8. The last necessary check is an evaluation of the level of service of the main lanes, exclusive of the auxiliary lane traffic. The "critical point" for the analysis of the main lanes adjacent to the auxiliary lane is the point where the least traffic is in the auxiliary lane. In this example, this point is 1000 feet from the merge ramp gore.

9. Calculating the auxiliary lane volume at this point:

   $$0.76 \times 800 + 0.14 \times 1000 = 748 \text{ vph.}$$

   Main lane volume at the critical point:

   $$6000 - 748 = 5252 \text{ vph.}$$

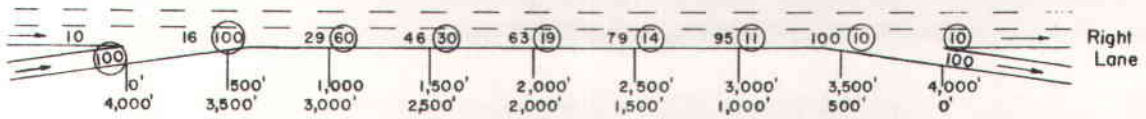
   From Figure D-3, this results in LOS "C."

10. Conclusion: This ramp pair will operate at LOS "C" or better under the traffic shown and with the distance between ramps of 2000 feet only if an auxiliary lane is provided.

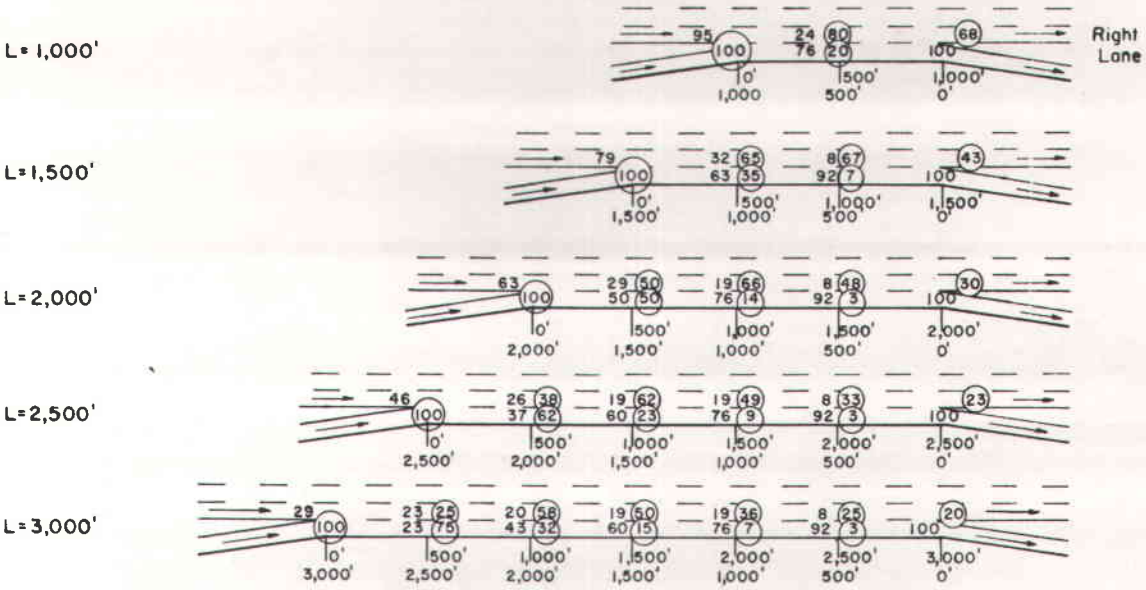
PERCENTAGE DISTRIBUTION OF ON AND OFF RAMP TRAFFIC IN LANE 1 AND AUXILIARY LANE

SINGLE-LANE ON- AND OFF-RAMPS WITHOUT AUXILIARY LANE

(This chart may be used regardless of actual spacing between on- and off-ramps)



SINGLE-LANE ON- AND OFF-RAMPS WITH AUXILIARY LANE



Circled values ⊙ indicate percentage of on-ramp traffic in lane shown. Uncircled values indicate percentage of off-ramp traffic in lane shown. (Remaining portion of ramp traffic is in lane(s) to left of lane 1.)
These percentages are not necessarily the distributions under free flow or light ramp traffic, but under pressure of high volumes in the right lanes at the point being considered and with room available in other lanes.

TABLE
SERVICE VOLUMES AND CAPACITY IN VICINITY OF RAMP TERMINALS

LEVEL OF SERVICE	CHECKPOINT VOLUME (VPH)								WEAVING VOLUME (VPH) PER 500 FT. OF ROADWAY SEGMENT			
	MERGE				DIVERGE							
A B	1000 1200				1100 1300				800 1000			
Peak-Hour Factor	0.77	0.83	0.91	1.00	0.77	0.83	0.91	1.00	0.77	0.83	0.91	1.00
C D E F	1300 1400	1400 1500 ≤ 2000	1550 1650	1700 1800	1400 1500	1500 1600 ≤ 2000	1650 1750	1800 1900	1100 1400	1200 1500 ≤ 2000	1350 1650	1450 1800
	← Widely Variable →											

Figure D-9

(c) Critical Lane Analysis for Diamond Interchange

Traffic interchange between major arterials and freeways is generally accomplished by the use of conventional-type diamond interchanges. The diamond interchange, like other facilities, cannot operate satisfactorily when traffic demand exceeds the capacity of the interchange. A capacity design procedure for evaluating the diamond interchange was developed by the Texas Transportation Institute and is known as the "critical lane" method. It is based on the assumption that each approach has a critical volume per lane that can be accommodated with basic 4 phase signalization. If the critical volume can be accommodated, then the adjacent lane or lanes on the same approach can accommodate less or equal volumes during the same green phase. Thus, it is necessary to consider only one lane (critical lane) per approach when determining the design of the interchange. For design purposes, a sum of critical lane volumes of 1650 vph is considered to be capacity (L.O.S. = E). The various levels of service are shown in Figure D-10. The procedures for determining the level of service for signalized intersections, as outlined in Paragraph D-102(e), may be employed for the diamond interchange, however, the critical lane volume method is recommended due to its simplicity. The procedures involved in critical lane analysis are illustrated in Figure D-11.

(d) Urban and Suburban Arterials

Generally, the capacity and level of service for urban and suburban arterials is controlled by signalized intersections within their lengths. Consequently, no attempt is made here to present material to analyze arterials as such. If such information is required, reference should be made to the Highway Capacity Manual, 1965. See Section D-102(e) for a discussion of signalized intersections.

(e) Signalized Intersections

1. General

At-grade intersections, like other highway elements, operate at identifiable levels of service under various roadway and traffic conditions. While speeds are used as a measure of level of service for most other highway elements, they are of little use in at-grade intersection level of service analysis.

The procedure outlined herein is based on preliminary results of Research Project 2-18-75-203, "Effects of Design and Operational Performance of Signal Systems," conducted by Texas Transportation Institute. This procedure uses the critical lane analysis technique to determine if a proposed intersection design will provide an acceptable level of service.

The critical lane analysis procedure is based on the fact that for any phase of a signalized intersection one of the movements of the phase will be "critical." As an example, take the case of a street phased so that the opposing left turn bays receive the green indication at the same time. In this example, the "critical" lane for the phase would be the left turn lane that had the greatest demand volume. For a phase with multi-lane movements, each of the movement volumes would be divided by the number of lanes provided for the movement and the largest resulting value then would be selected as the critical lane volume.

2. Traffic Volume Preparation

The first step in traffic volume preparation is the reduction of traffic volumes to design hourly volume for each movement on each approach (i.e., left turning, through, and right turning). This is accomplished as detailed in Part 4 of this Manual.

CRITICAL LANE VOLUME LEVEL OF SERVICE
FOR DIAMOND INTERCHANGES*

Level of Service	Critical Lane Volumes
A	≤ 1250
B	≤ 1300
C	≤ 1350
D	≤ 1480
E	≤ 1650

* Derived from TTI critical lane analysis and extrapolations based on level of service for signalized intersections as contained in "Highway Capacity Manual, 1965."

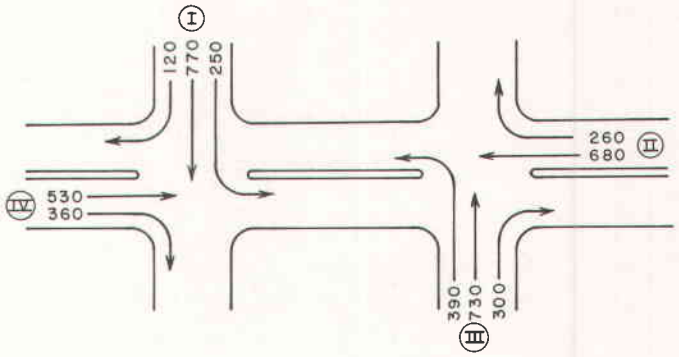
Figure D-10

CRITICAL LANE ANALYSIS
LEVEL OF SERVICE EVALUATION
FOR DIAMOND INTERCHANGES

Given: The diamond interchange with AM design hourly volumes as shown on the sketch below.

Determine:

The number of lanes required to accommodate traffic at capacity (LOS = E) and at the level of service "C"



Solution:

Assume 3-lanes for all approaches

Critical Lane Volumes

Approach (I): $\frac{120 + 770 + 250}{3} = 380$

Approach (II): $\frac{260 + 680}{3} = 310$

Approach (III): $\frac{390 + 730 + 300}{3} = 470$

Approach (IV): $\frac{530 + 360}{3} = 300$

Vc = 380 + 310 + 470 + 300 = 1460 vph

Adjustment for peak period: 1460 x 1.15 = 1680 vph

(This adjustment factor of 1.15 is common to all diamond interchanges and should be used accordingly.)

∴ 1680 > 1650 - not adequate for design.

Assume:

4-lanes for approach (I) and (III)
3-lanes for approach (II) and (IV)

Critical lane volumes

Approach (I): $\frac{120 + 770 + 250}{4} = 280$

Approach (II): = 310

Approach (III): $\frac{390 + 730 + 300}{4} = 300$

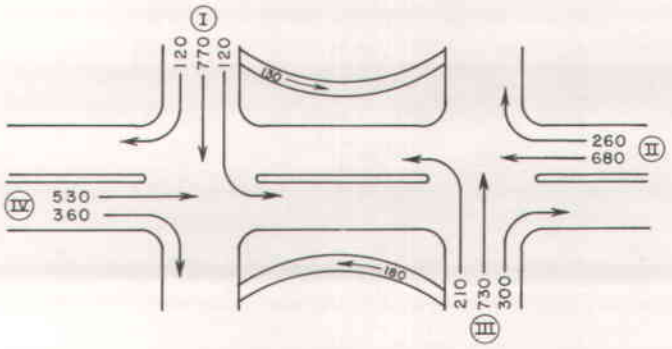
Approach (IV): = 300

FIGURE D-11

Vc = 280 + 310 + 360 + 300 = 1250
Adjustment for peak period = 1250 x 1.15 = 1440
∴ 1440 < 1650 - OK for design

From Figure D-10 (using V_c = 1440) L.O.S. = "D"

The next step would be to check the L.O.S. with turnarounds added. This can be determined by subtracting the turnaround volume from the left turn movement on Approachs (I) and (III), then recalculate the critical lane volumes. It is advantageous to request turnaround traffic movements from File D-10 on all proposed diamond interchanges. If the turnaround is not required, then this volume can be added to the left turn movements and the delay in obtaining the turnaround volumes is omitted in cases where their need was not anticipated.



Assume:

4-lanes for Approach (I) and (III)
3-lanes for Approach (II) and (IV)

Turnarounds

Critical Lane Volumes

Approach (I): $\frac{120 + 770 + 120}{4}$ = 250

Approach (II): = 310

Approach (III): $\frac{210 + 730 + 300}{4}$ = 310

Approach (IV): = 300

Vc = 250 + 310 + 310 + 300 = 1170
Adjustment for peak period = 1170 x 1.15 = 1350
∴ 1350 < 1650 - OK for design

From Figure D-10 (using Vc = 1350) L.O.S. = "C"

Summary: The following is recommended for the intersection:

1. 4-lanes for Approaches (I) and (III)
2. 3-lanes for Approaches (II) and (IV)
3. Addition of turnarounds

FIGURE D-11 (Continued)

The traffic volumes thus obtained should then be adjusted for peaking. The traffic flow rate used to evaluate the level of service at an intersection is the flow rate of the peak 15 minutes of the design hour. The traffic volume flow rates during this 15-minute period consistently exceed the design hour flow rate by approximately 20-30 percent. For this reason it is necessary to adjust the design hour volume up to account for peaking by the application of a peaking factor. These peaking factors have been found in Texas to vary with the population of the city and are shown in Figure D-12.

The peaking factor should be applied to the design hour volume in accordance with the equation:

$$PPV = DHV \cdot PF \qquad (1)$$

where PPV is the peak period volume (flow rate), DHV is the design hour volume previously calculated, and PF is the appropriate peaking factor from Figure D-12. These traffic volume figures can then be arranged on a diagram similar to that shown in Figure D-13 to aid in further analysis.

3. Critical Lane Analysis Procedure

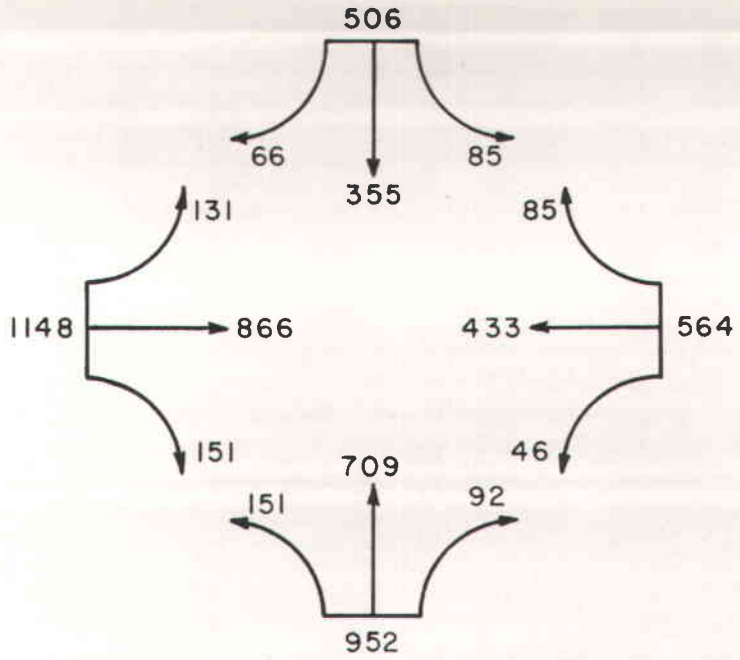
The first step in the critical lane analysis procedure is the selection of an intersection design and signal phasing scheme. Since the design will generally be based on the "twenty year" design traffic, it is important to analyze the expected ultimate intersection even if it will not be built initially. The reason for this is to ensure that the design year traffic can be accommodated at an acceptable level of service. In addition, this analysis procedure is iterative in nature and it is, therefore, best to select the most reasonable design possible for initial consideration.

The individual peak period volumes shown in Figure D-13 should then be assembled as necessary into traffic movement volumes (MV_m). Eight basic traffic movements are shown in Figure D-14, four for Street A and four for Street B. Depending on intersection configuration and signal phasing, some of these movements may be missing, as at a Tee intersection, or combined with other movements, as for a street with one phase operation. In this case, all movements on each approach would be combined. Normally, thru and right turning movements are considered as a single thru-right movement unless an adequate free right turn lane is provided. Then the right turning volume would be eliminated from the movement volume and neglected in further level of service calculations.

VARIATION OF PEAKING FACTOR, PF, WITH POPULATION OF CITY IN DESIGN YEAR

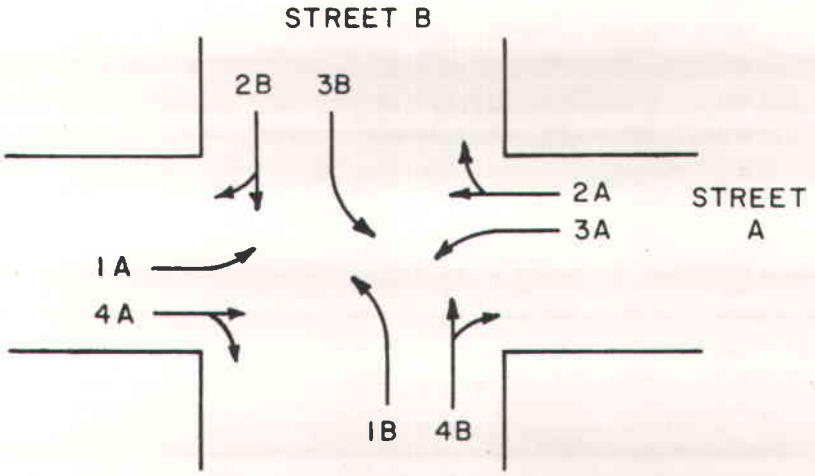
Population	PF
< 100,000	1.35
100,000 - 300,000	1.30
300,000 - 500,000	1.25
> 500,000	1.18

Figure D-12



PPV, PEAK PERIOD VOLUME

FIGURE D-13



DEFINITION OF MOVEMENTS

FIGURE D-14

When an approach does not have a left turn bay, the left turn volume is combined with (added to) the thru-right movement volumes, i.e., left plus thru-right (1 + 4 or 2 + 3). Left turns remain separated from the thru-right movement volume when a left turn bay is provided.

All resulting movement volumes, either singles or combinations, are then adjusted to account for design and operational features of the intersection by calculating adjusted traffic volumes:

$$Q_m = U \cdot W \cdot TF \cdot MV_m \qquad (2)$$

where:

Q_m	=	Adjusted volume for movement(s) m, vph
U	=	Lane utilization factor (Figure D-15)
W	=	Lane width factor (Figure D-15)
TF	=	Turning movements factor (Equation 3)
MV_m	=	Volume of appropriate traffic movement(s) m, vph

Lane Utilization. As the number of lanes serving a movement increases, there is an increasing tendency for one lane to become more highly utilized than the others. This effect is accounted for by the lane utilization factor, U, presented in Figure D-15.

Lane Width. Lane widths 10 feet or greater have little influence on rush hour traffic flow rates as reflected by the lane width adjustment factor, W, given in Figure D-15. Narrow or meandering lanes may create safety problems, however. Lane width may not include any pavement used for parking.

VOLUME ADJUSTMENT FACTORS FOR LANE WIDTH AND UTILIZATION

Factor	Conditions	Value
Lane Utilization, U	Number of Lanes	
	1	1.0
	2	1.1
	3	1.2
Lane Width, W	Average Lane Width, Feet	
	9.0 - 9.9	1.1
	≥10.0	1.0

Figure D-15

Turns. The effects of left and right turning vehicles on flow are given by the turning factor, TF, as

$$TF = 1.0 + L + R \quad (3)$$

where L adjusts for left turns and R for right turns.

For designs providing no left turn bay, the left turn adjustment factor, L, is calculated from

$$L = P_L(E - 1.0) \quad (4)$$

where P_L is the decimal fraction of the total approach volume turning left and E is the appropriate equivalence factor from Figure D-16.

For designs providing a left turn bay, the left turn adjustment factor for the left turn movement only, is

$$L = \frac{1700 \cdot E}{S} - 1.0 \quad (5)$$

where S is the saturation flow of the left turn bay obtained from Figure D-17 for a given storage length and equivalent left turning volume from Figure D-13. Left turn equivalencies have been found to be somewhat dependent on G/C ratios. In this regard, the equivalencies for two-phase intersection operation were derived using an assumed G/C ratio of 0.5 and the equivalencies for three or more phase operation were derived using an assumed G/C ratio of 0.35.

The desired minimum left turn bay storage length for a given equivalent turning volume is presented at the top of Figure D-17. These desirable storage lengths should be used when possible as shorter bay storage lengths result in saturation flow rates, S, less than 1700 vph. The storage length does not include either the taper section of the left turn bay or any length of the bay that may be provided beyond a stop line or crosswalk. For normal urban street conditions, a taper length of 70 to 100 feet may be considered appropriate; for high-type urban facilities and rural highways, taper length should be 150 to 300 feet.

When a left turn bay is provided it is necessary to adjust the thru-right movement to account for any blockage effects that left turns may cause due to inadequate bay lengths. The left turn adjustment factor to be supplied to the thru-right movement is calculated from

$$L = \frac{1700 - S}{1700\ (N-1)\ + S} \quad (6)$$

where S is the saturation flow from Figure D-17 as in Equation 5, and N is the number of lanes serving the adjacent thru-right movement.

When a separate right turn lane is provided, the right turning volume and right turn lane are not analyzed. Beyond this, the analysis of right turns depends on accuracy requirements. If a detailed analysis is desired, the following approach may be used to estimate the effects of right turns as related to design and operational variables. This approach assumes that

$$R = \frac{5 \cdot P_r}{c} \quad (7)$$

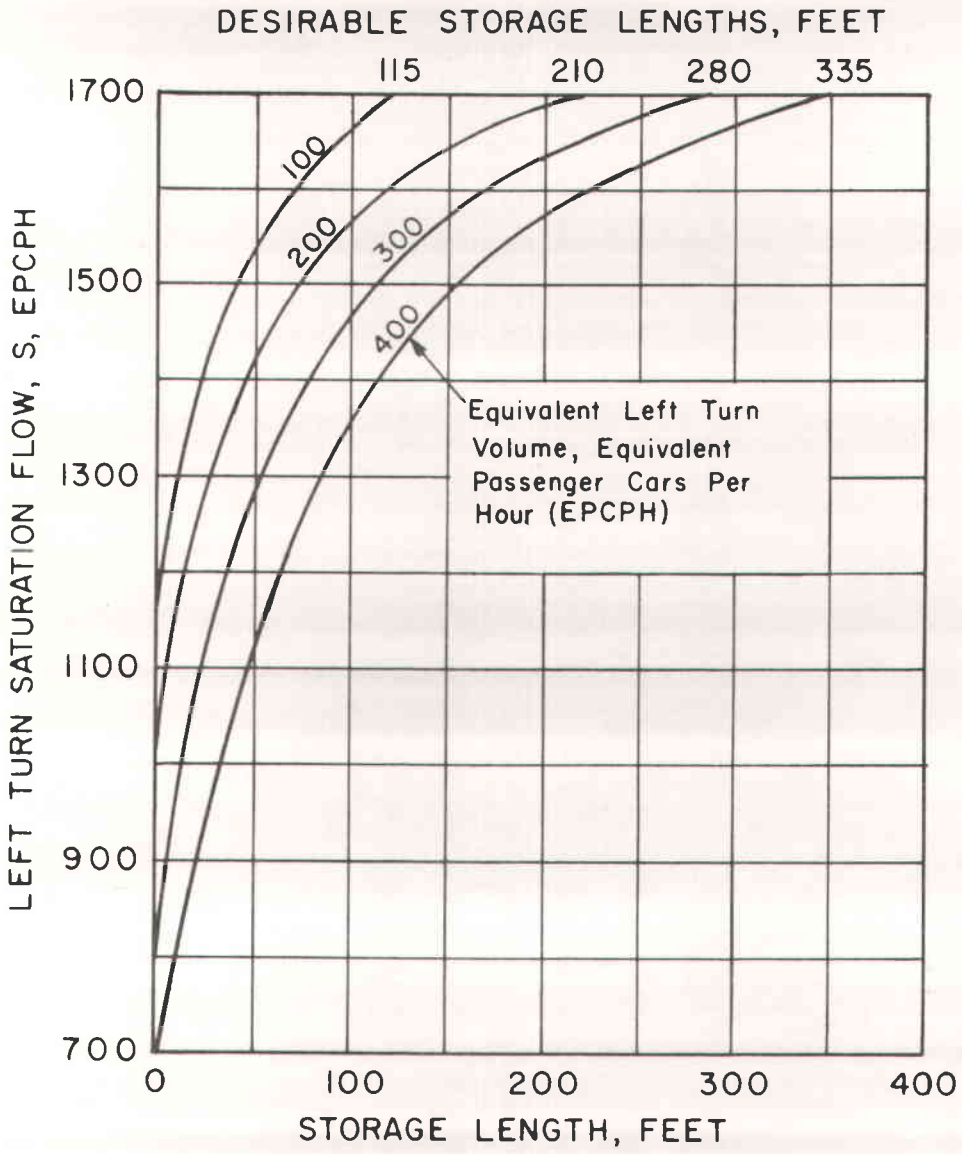
LEFT TURNING EQUIVALENTS, E

Intersection Signal Phasing	Traffic Movement	Number of Opposing Lanes	Opposing Volume* 200	400	600	800	1000
No Protected Turning							
• Two-Phase							
o No Bay	Left & Thru	1	2.0	3.3	6.5	**	**
	Left & Thru	2	1.9	2.6	3.6	6.0	**
	Left & Thru	3	1.8	2.5	3.4	4.5	6.0
o With Bay	Left	1	1.7	2.6	4.7	**	**
	Left	2	1.6	2.2	2.9	4.1	6.2
	Left	3	1.6	2.1	2.8	3.6	4.8
• Three or More Phases							
o No Bay	Left & Thru	1	2.2	4.5	**	**	**
	Left & Thru	2	2.0	3.1	4.7	**	**
	Left & Thru	3	2.0	2.9	4.2	6.0	**
o With Bay	Left	1	1.8	3.3	**	**	**
	Left	2	1.7	2.4	3.6	5.9	**
	Left	3	1.7	2.4	3.3	4.6	6.8
Protected Turning							
o No Bay	Left	Any	1.2		1.2		1.2
o With Bay	Left	Any	1.03		1.03		1.03

* Total opposing volume (thru, right, and left) from Figure D-13 where no bay is provided. Opposing thru-right volume from Figure D-13 where bays are provided or for narrow one-lane opposing approaches.

** Opposing volume exceeds capacity; not recommended for design.

Figure D-16



SATURATION FLOW OF LEFT TURN PHASE AS A FUNCTION OF BAY STORAGE LENGTH AND TURNING VOLUME

FIGURE D-17

where R = right turning adjustment factor in Equation 3

P_r = decimal fraction of movement combination turning right

c = related curb return radius, feet.

In addition, the number of vehicles turning right on red are estimated and subtracted from the total movement combination volume. This estimate, which should not exceed 0.5 of the actual right turning volume, is

$$ROR = 50 \frac{P_e}{1 - P_e} \quad (8)$$

where ROR = estimated right on red volume

P_e = estimated decimal fraction of traffic in curb lane turning right.

The usual effect of these right turn adjustments is that they effectively cancel each other. Therefore, from the viewpoint of practicality and simplicity, the adjustment factor R for most designs can be set to zero, i.e., R = 0 in Equation 3, if right turns on red will be permitted.

Capacity. It is assumed throughout this procedure that the capacity of a normal protected thru lane is 1750 passenger cars per hour. This corresponds to a minimum average headway of 2.06 seconds per car. The type of signalization also affects the capacity of the intersection as will be reflected in the critical lane analysis technique to follow.

The critical lane analysis technique is used to evaluate the acceptability of a proposed design. To begin the analysis, the adjusted traffic volume for each movement Q_m, as calculated in Equation 1, is divided by the number of usable lanes serving the movements to obtain a design volume per lane, V_m of

$$V_m = Q_m/N \quad (9)$$

where N is the number of lanes provided for the movement. If a left turn lane is provided on an approach, then N = 1 for the separate left turning movement and N = 1, 2, or 3 for the thru-right movement, depending on the number of thru lanes provided by the design. If no left turn lane is provided, N will be the total number of approach lanes since Q_m is the total approach movement volumes (the sum of the thru-right traffic and the left turning traffic).

Figure D-14 defined the movements to be considered at a typical intersection in the critical lane analysis technique. Depending on the signalization scheme used, these movements are combined in different ways as shown in Figure D-18. For a given type of signalization on a street, one movement volume or a sum of two movement volumes will be larger (critical). Different types of signalization result in different sums of critical lane volumes. To evaluate the acceptability of the design, it is necessary to calculate the sum of critical lane volumes for both (all) intersecting streets at the intersection.

METHOD FOR CALCULATING SUM OF CRITICAL LANE VOLUMES AT INTERSECTION

Type of Signal Phasing On Street A or Street B	For Streets A and B Calculate the Maximum Lane Volume Sum of:
"One phase with no left turn bay"	1 + 4, or 2 + 3
"One phase with left turn bays"	1, 2, 3, or 4
"Two phases (no overlap) with bays"	
• Dual Lefts Leading	1 or 3, + 2 or 4
• Dual Lefts Lagging	2 or 4, + 1 or 3
• Leading Left	1 or 4, + 2 or 3
• Lagging Left	2 or 3, + 1 or 4
"Multi-Phase (overlap) with bays"	
Overlap Phasings of	
• Dual Lefts Leading	1 + 2, or 3 + 4
• Dual Lefts Lagging	1 + 2, or 3 + 4
• Leading Left	1 + 2, or 3 + 4
• Lagging Left	1 + 2, or 3 + 4

Figure D-18

4. Level of Service Evaluation

The sum of all the critical lane volumes at the intersection is compared against maximum values established for a given level of service as presented in Figure D-19. Level of Service "C" is recommended for design of intersections. The maximum service volumes vary slightly depending on the signalization used. Two-phase signalization has no protected left turning on either street; three-phase has protected turning on only one of the two streets; while multi-phase signalization has protected left turning on both streets. Capacity values are based on practical peak hour cycle lengths.

The purpose of this procedure is to enable the designer to provide an intersection with physical characteristics that will allow it to operate at an acceptable level of service from initial construction thru the design year regardless of the signal timing requirements.

Figure D-20 is an example problem illustrating the procedures involved in the Critical Lane Analysis Procedure and the Level of Service Evaluation. Some assumptions made in the example were selected to illustrate computational procedures of this analysis guide rather than optimum design practice.

No attempt will be made in this Manual to explore optimum signal timing, cycle length, etc. If information or assistance is needed in these areas, contact File D-18.

(f) Level of Service Evaluation Procedures for Multi-Lane Rural Highways

The procedure for evaluating the capacity and level of service for a multi-lane rural highway is similar to that used for freeways. Figure D-21 shows level of service definitions and maximum service volumes for multi-lane rural facilities. An example problem is worked in Figure D-22.

LEVEL OF SERVICE MAXIMUM SUM OF CRITICAL LANE VOLUMES AT SIGNALIZED INTERSECTIONS

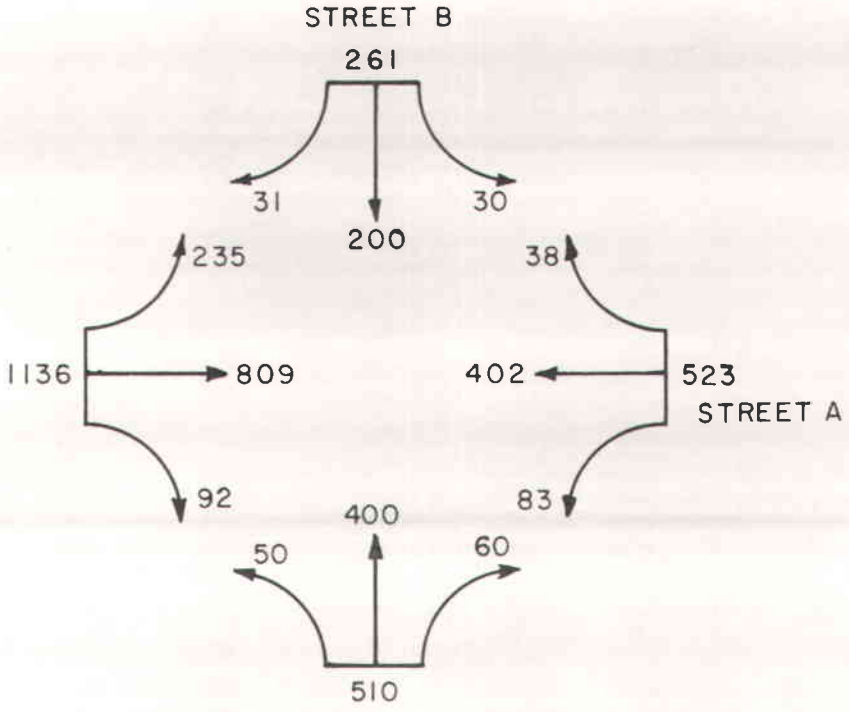
Level of Service	Traffic Flow Condition	Volume to Capacity Ratio	Maximum Sum of Critical Lane Volumes, Σ V for Intersection*		
			Two-Phase 2ϕ **	Three-Phase 3ϕ ***	Multi-Phase $\geq$4ϕ ****
A	Stable	$\leq$0.6	900	855	825
B	Stable	$\leq$0.7	1050	1000	965
C	Stable	$\leq$0.8	1200	1140	1100
D	Unstable	$\leq$0.85	1275	1200	1175
E	Capacity	$\leq$1.0	1500	1425	1375

* Sum of critical lane volume for Street A and Street B (Figure D-18).
** One-phase operation on Street A and
One-phase operation on Street B.
*** Two-phase operation on Street A (or B) and
One-phase operation on Street B (or A).
**** Two- (or multi-) phase operation on Street A and Street B, or
Multi-phase operation on Street A (or B), and
One-phase operation on Street B (or A).

Figure D-19

SIGNALIZED INTERSECTION LEVEL OF SERVICE ANALYSIS

Given: Design hour traffic volume data in equivalent passenger cars per hour as shown
Adequate right-of-way (no restriction on geometrics)
All bay lengths are 100 feet
Right turn adjustment factors assumed equal to zero
Location is in a city of population >500,000



Determine: Intersection configuration and phasing needed to provide a Level of Service "C"

Figure D-20

Step 1: Adjust traffic volumes for peaking, Equation 1, PPV = DHV · PF
City population > 500,000 means PF = 1.18
Make new traffic diagram.

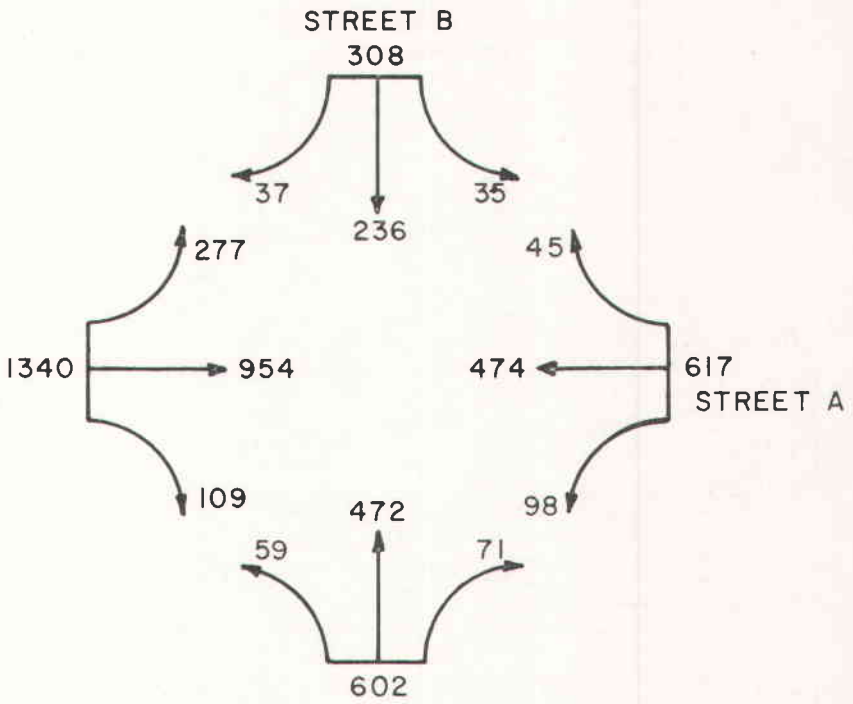


FIGURE D-20 (Cont.)

Step 2: Assume a reasonable intersection configuration and phasing, generate movement combination diagram.

Street A will probably require three-lane approaches plus left turn bays.

For Street B, two-lane approaches will probably be adequate. See the figure.

For Street A phasing try three phase with dual lefts leading. Try one phase operation on Street B.

Now define movement volumes, MV_m.

MV_{1A}	=	277
MV_{2A}	= 474 + 45	= 519
MV_{3A}	=	98
MV_{4A}	= 954 + 109	= 1063
MV_{1B+4B}	=	602
MV_{2B+3B}	=	308

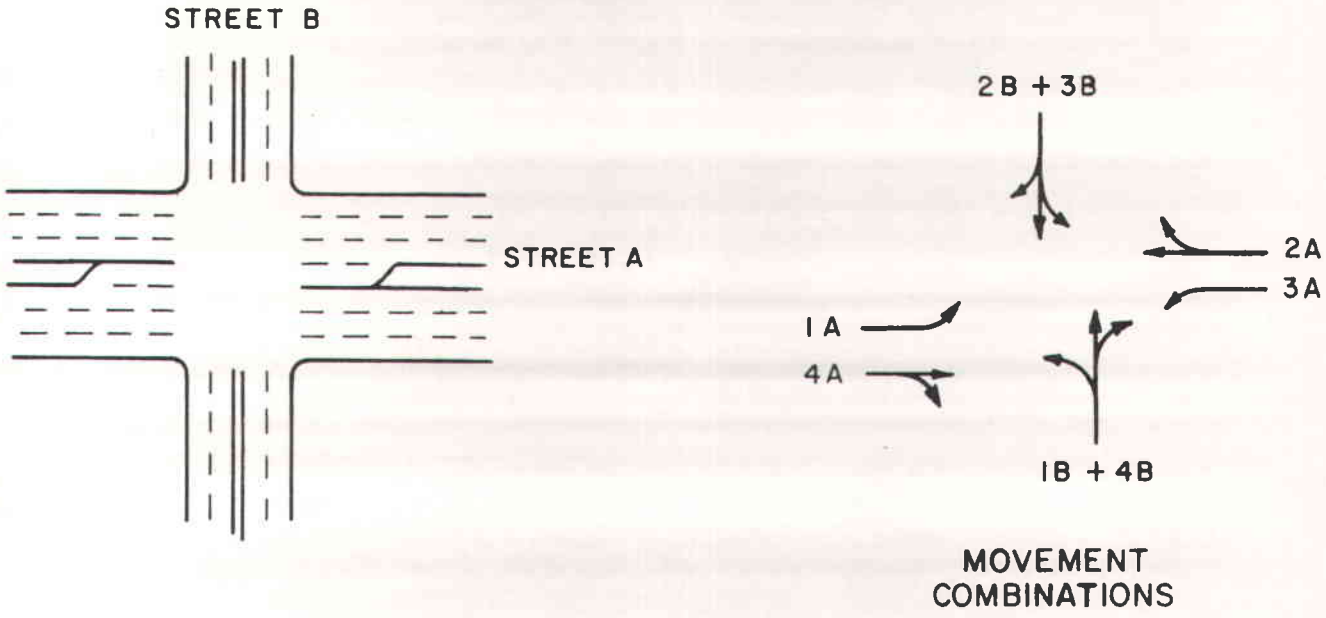


FIGURE D-20 (Cont.)

Step 3: Calculate left turn adjustment factors.
For Street A, movements MV_{1A} and MV_{3A}, use

Equation 5: $L = \frac{1700 \cdot E}{S} - 1$; for movements

MV_{2A} and MV_{4A}, use Equation 6: $L = \frac{1700 - S}{1700 \times (N-1) + S}$

$$L_{1A} = \frac{1700 \times 1.03}{1520} - 1.0 = 0.15$$

$$L_{3A} = \frac{1700 \times 1.03}{1700} - 1.0 = 0.03$$

L_{2A} = 0 (adequate bay length)

$$L_{4A} = \frac{1700 - 1520}{(1700 \times 2) + 1520} = 0.04$$

For Street B, use Equation 4: $L = P_L\ (E-1.0)$

L_{1B+4B} = (59/602) x (2.6 - 1.0) = 0.16

L_{2B+3B} = (35/308) x (4.7 - 1.0) = 0.42

Step 4: Calculate adjusted volumes from Equation 2: $Q_m = V \cdot W \cdot TF \cdot MV_m$

Q_{1A} = 1.0 x 1.0 x (1.0 + 0.15 + 0.0) x 277 = 319

Q_{2A} = 1.2 x 1.0 x (1.0 + 0.0 + 0.0) x 519 = 623

Q_{3A} = 1.0 x 1.0 x (1.0 + 0.03 + 0.0) x 98 = 101

Q_{4A} = 1.2 x 1.0 x (1.0 + 0.04 + 0.0) x 1063 = 1327

Q_{1B+4B} = 1.1 x 1.0 x (1.0 + 0.16 + 0.0) x 602 = 768

Q_{2B+3B} = 1.1 x 1.0 x (1.0 + 0.42 + 0.0) x 308 = 481

Step 5: Design volume per lane for each movement from Equation 9: $V_m = Q_m/N$

V_{1A} = 319/1 = 319

V_{2A} = 623/3 = 208

V_{3A} = 101/1 = 101

V_{4A} = 1327/3 = 442

V_{1B+4B} = 768/2 = 384

V_{2B+3B} = 481/2 = 241

Figure D-20 (continued)

Step 6: Sum of critical lane volumes. From Figure D-18, critical lane volume for Street A will be movements 1 + 2 or 3 + 4. For Street B, critical lane volumes will be movements 1 + 4 or 2 + 3.

$V_{1A} = 319$ $V_{3A} = 101$

$V_{2A} = \underline{208}$ $V_{4A} = \underline{442}$

$V_{1A+2A} = 527$ $V_{3A+4A} = 543$

For Street A, 3 + 4 will be critical.

By observation, movements 1 + 4 on Street B will be critical.

Therefore:

$V_{3A+4A} = 543$

$V_{1B+4B} = \frac{384}{927}$

From Figure D-19, $927 < 1100$ (LOS "C" for multi-phase),

Therefore, design is acceptable.

If the level of service had not been acceptable, it would have been necessary to return to Step 2 and make adjustments to the assumed intersection configuration and/or phasing scheme and proceed with the analysis.

Figure D-20 (continued)

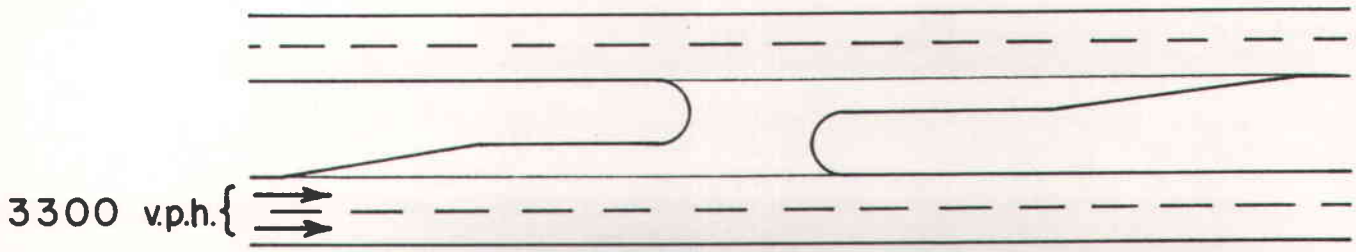
MULTILANE HIGHWAYS
LEVELS OF SERVICE AND MAXIMUM SERVICE VOLUMES
(UNDER UNINTERRUPTED FLOW CONDITIONS - NORMALLY REPRESENTATIVE OF RURAL OPERATION)

LEVEL OF SERVICE	TRAFFIC FLOW CONDITIONS		SERVICE VOLUME/CAPACITY (v/c) RATIO			MAXIMUM SERVICE VOLUME UNDER IDEAL CONDITIONS INCLUDING 70-MPH AHS (TOTAL PASSENGER CARS PER HOUR, ONE DIRECTION)		
	DESCRIPTION	Space Mean Speed[a] (MPH)	BASIC LIMITING VALUE[a] FOR AHS OF 70 MPH	APPROXIMATE WORKING VALUE FOR RESTRICTED AHS OF		4-LANE HWY. (2 LANES ONE DIRECTION)	6-LANE HWY. (3 LANES ONE DIRECTION)	EACH ADDITIONAL LANE
				60 MPH	50 MPH			
A	Free Flow	$\geq$ 60	$\leq$ 0.30	—[b]	—[b]	1200	1800	600
B	Stable Flow (Upper Speed range)	55-60	$\leq$ 0.50	$\leq$ 0.20	—[b]	2000	3000	1000
C	Stable Flow	45-55	$\leq$ 0.75	$\leq$ 0.50	$\leq$ 0.25	3000	4500	1500
D	Approaching Unstable Flow	35-45	$\leq$ 0.90	$\leq$ 0.85	$\leq$ 0.70	3600	5400	1800
E[c]	Unstable Flow	30-35	$\leq$ 1.00			4000	6000	2000
F	Forced Flow	< 30[d]	Not Meaningful[e]			Widely variable (0 to capacity)		

FIGURE D-21

[a] Space mean speed and basic v/c ratio are independent measures of level of service; both limits must be satisfied in any determination of level.
[b] Space mean speed required for this level is not attainable even at low volumes.
[c] Capacity.
[d] Approximately.
[e] Demand volume/capacity ratio may well exceed 1.00, indicating overloading.

MULTI-LANE RURAL HIGHWAY
LEVEL OF SERVICE EVALUATION



Given: Rural divided section as shown
Demand volume = 3300 epcph in one direction
Average Highway Speed (AHS) = 70 mph
W = 1.0 (12-ft. lanes with adequate clearance)

Determine: Number of lanes required to provide a Level of Service "C"

Solution: Try 4 lanes
From Figure D-21 (using L.O.S. "C")
MSV_c = 3000 vph (4-lane highway)
No adjustments to service volume are necessary
Compare demand volume to SV_c:

$$3300 > 3000$$

The demand volume is greater than SV_c; therefore, the L.O.S. is lower than "C" and a 4-lane design is not recommended.

Try 6 lanes.
MSV_c = 4500

$$3300 < 4500$$

The section will operate at L.O.S. "C" with 6 lanes.

Figure D-22

Fixed traffic interruptions have an adverse effect on multi-lane rural highways. When signalized intersections are less than a mile apart and/or speed limits or attainable speeds are below 45 mph, the procedures outlined for urban-suburban signalized intersections, Paragraph D-102 (e) should be used. The determination of which procedure to use will require engineering judgment based on anticipated development of the area by the design year.

(g) Level of Service Evaluation Procedures for Two-Lane Highways

Two-lane rural highway traffic operations differ from those of multi-lane facilities by two basic features:

1. Directional distribution of traffic has practically no effect on operating conditions in most cases. Therefore, the capacity and service volumes are expressed in total vehicles per hour in both directions.

2. Overtaking and passing maneuvers must be made in traffic lane normally occupied by opposing traffic. Therefore, whenever service volumes are considered, the corresponding range in average available passing sight distance (1500 feet or greater) must also be considered.

Fixed traffic interruptions have an adverse effect on two-lane rural highway operation and should be considered if present to an appreciable extent. Whenever interruptions and interferences are restrictive enough to result in signalized intersections closer than a mile apart or speed limits or attainable speeds are below 35 mph, then the highway should be analyzed as an urban-suburban arterial street. This is a general rule and engineering judgment must be used to determine the significance of the interruption presented in a particular case. However, when the designer is considering which procedure to employ, he must remember that the basic traffic data is for future traffic; therefore, the decision should be based on what conditions are anticipated to exist by the design year.

It should be noted that an overall level of service of a highway section composed partly of two-lane and four-lane subsections cannot be evaluated. The two-lane and four-lane subsections must be analyzed separately using the appropriate procedures.

Figure D-23 shows the level of service definitions and maximum v/c ratios for two-lane highways. Figure D-24 is an example problem determining the level of service of a two-lane highway.

(h) Climbing Lane Warrants and Design

Climbing lane design is a problem generally associated with two-lane highways, although some of the procedures outlined herein may be useful for multi-lane highway design or analysis.

Climbing lanes are important on two-lane highways because of the effect of grades on truck performance. On long, steep upgrades there is a large difference between the normal speed of passenger cars and the normal speed of trucks. In effect, trucks on grades take up the space of a larger number of passenger cars (that is, have higher passenger car equivalents) than they do on level sections, particularly on two-lane highways. This situation results in high equivalent traffic volumes and, in effect, lower capacity for uphill sections than for level sections. Climbing lanes can alleviate these problems.

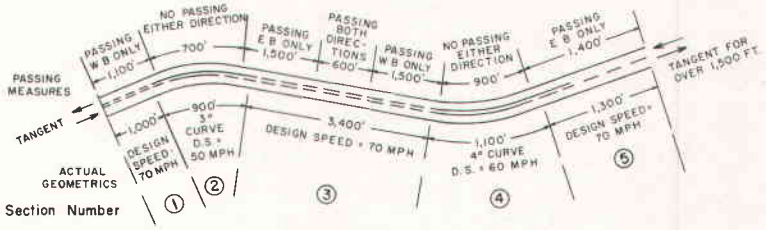
TWO-LANE HIGHWAYS
LEVELS OF SERVICE AND MAXIMUM SERVICE VOLUMES
(UNDER UNINTERRUPTED FLOW CONDITIONS – NORMALLY REPRESENTATIVE OF RURAL OPERATION)

LEVEL OF SERVICE	TRAFFIC FLOW CONDITIONS		PASSING SIGHT DISTANCE > 1,500 FT (%)	SERVICE VOLUME/CAPACITY (v/c) RATIO						MAXIMUM SERVICE VOLUME UNDER IDEAL CONDITIONS INCLUDING 70-MPH AHS (PASSENGER CARS, TOTAL, BOTH DIRECTIONS, PER HOUR)
	DESCRIPTION	Space Mean Speed[a] (MPH)		BASIC LIMITING VALUE[a] FOR AHS OF 70 MPH	WORKING VALUE FOR RESTRICTED AVERAGE HIGHWAY SPEED[b] OF					
					60 MPH	50 MPH	45 MPH	40 MPH	35 MPH	
A	Free Flow	≥ 60	100	≤ 0.20	-	-	-	-	-	400
			80	0.18	-	-	-	-	-	
			60	0.15	-	-	-	-	-	
			40	0.12	-	-	-	-	-	
			20	0.08	-	-	-	-	-	
			0	0.04	-	-	-	-	-	
B	Stable Flow (Upper Speed Range)	50-60	100	≤ 0.45	≤ 0.40	-	-	-	-	900
			80	0.42	0.35	-	-	-	-	
			60	0.38	0.30	-	-	-	-	
			40	0.34	0.24	-	-	-	-	
			20	0.30	0.18	-	-	-	-	
			0	0.24	0.12	-	-	-	-	
C	Stable Flow	40-50	100	≤ 0.70	≤ 0.66	≤ 0.56	≤ 0.51	-	-	1400
			80	0.68	0.61	0.53	0.46	-	-	
			60	0.65	0.56	0.47	0.41	-	-	
			40	0.62	0.51	0.38	0.32	-	-	
			20	0.59	0.45	0.28	0.22	-	-	
			0	0.54	0.38	0.18	0.12	-	-	
D	Approaching Unstable Flow	35-40	100	≤ 0.85	≤ 0.83	≤ 0.75	≤ 0.67	≤ 0.58	-	1700
			80	0.84	0.81	0.72	0.62	0.55	-	
			60	0.83	0.79	0.69	0.57	0.51	-	
			40	0.82	0.76	0.66	0.52	0.45	-	
			20	0.81	0.71	0.61	0.44	0.35	-	
			0	0.80	0.66	0.51	0.30	0.19	-	
E[c]	Unstable Flow	30-35	Not Applicable[e]	≤ 1.00						2000
F	Forced Flow	< 30[d]	Not Applicable[e]	Not Meaningful[f]						Widely Variable (0 to capacity)

a Space mean speed and basic v/c ratio are independent measures of level of service; both limits must be satisfied in any determination of level.
b Where no entry appears, space mean speed required for this level is unattainable even at low volumes.
c Capacity.
d Approximately.
e No passing.
f Demand volume/capacity ratio may well exceed 1.00, indicating overloading.

FIGURE D-23

TWO-LANE HIGHWAY
LEVEL OF SERVICE EVALUATION



Given: Rural two-lane highway with geometrics as shown in above sketch.

Lane Widths = 12 ft.
Shoulder Widths = 10 ft. paved
Obstructions within 6 ft. of roadway - none
Length of section = 7,700 ft. (1.5 Mile)
Demand Volume = 540 equivalent passenger cars per hour, total both directions

Determine:

Level of Service for the given section.

Solution:

(1) Average Highway Speed

Subsection	Distance		Design Speed		
1	1,000	x	70	=	70,000
2	900	x	50	=	45,000
3	3,400	x	70	=	238,000
4	1,100	x	60	=	66,000
5	1,300	x	70	=	91,000
	7,700				510,000

Average Highway Speed (AHS) = 510,000 ÷ 7,700 = 66 MPH

(2) Passing Sight Distance

The areas of available passing sight distance are those having passing sight distance of 1500 ft. or more. The available passing sight distance is generally the same for both directions; therefore, it will seldom justify separate consideration or averaging. Therefore, we will consider the eastbound conditions for this problem.

Subsection	Available Passing Sight Distance
1	None
2	None
3	2100
4	None
5	1400
	3500 ft.

Available passing sight distance = 3500 ÷ 7700 = 45%

FIGURE D-24

(3) Level of Service

The level of service for two-lane highways can be determined by two methods.

A. Volume/capacity ratio.

Calculate the V/C ratio for the section by dividing the demand volume by the calculated capacity (C = 2000 x W).

Then, enter the percentage of available passing sight distance and average highway speed into Figure D-23 to determine what level of service the calculated V/C will provide.

Example:

As previously determined:

AHS = 66 mph
PSD = 45%

Demand Volume = 540 vph
W = 1.0 (adequate clearance)

C = 2000 x W = 2000 x 1.0 = 2000

V/C = 540 ÷ 2000 = 0.27

From Figure D-3 (using ASH = 66 mph, PSD = 45% and V/C = 0.27) LOS = "B".

B. Maximum service volume formula.

The second method is suitable only where alignment is ideal; that is, average highway speed (AHS) = 70 mph, passing sight distance (PSD) = 100%. This method is similar to the other procedures in computing the service volume of a facility except that the maximum service volume (MSV) from Figure D-23 for the level of service desired is used in place of the basic value adjusted by a V/C ratio.

SV = MSV x W

Using the same problem as before, except assuming ideal alignment, determine the level of service for the given section.

Assume level of service "B".

From Figure D-23 (using LOS "B") MSV = 900

Demand Volume = 540 vph

∴ SV = MSV x W = 900 x 1.0 = 900 vph

540 < 900 OK for level of service "B".

FIGURE D-24 (Continued)

The procedure for warranting and designing climbing lanes follows. Given the design year traffic and the profile of the section of highway under consideration perform the following steps:

Step 1. Does a 15 mph speed reduction occur? Use Figure D-25 to determine this. Figure D-25 is derived from data generated by the research project "Speed of Vehicles on Grades," Project Number 3-8-73-20, being conducted by the Center for Highway Research, and from Figure 5.1 of the Highway Capacity Manual. The deceleration curves of Figure D-25 are entered with the approach speed of the truck traffic, the percent grade, and the length of grade. If a 15 mph speed reduction does not occur, a climbing lane is not warranted; if it does occur, proceed.

Step 2. Is a climbing lane warranted by capacity analysis? Using a slight modification of the ADT to DHV conversion outlined in Part 4 of this manual, determine the DHV on the grade in question. If this volume is greater than the maximum service volume for the desired level of service, a climbing lane should be provided.

Climbing lanes on multi-lane facilities can be warranted by a similar procedure.

Step 3. Design the Climbing Lane.

A climbing lane should begin at the point where the 15 mph speed reduction occurs and continue to the point where a speed of 40 mph is expected to be re-attained. A 600-foot transition is added at each end of the climbing lane.

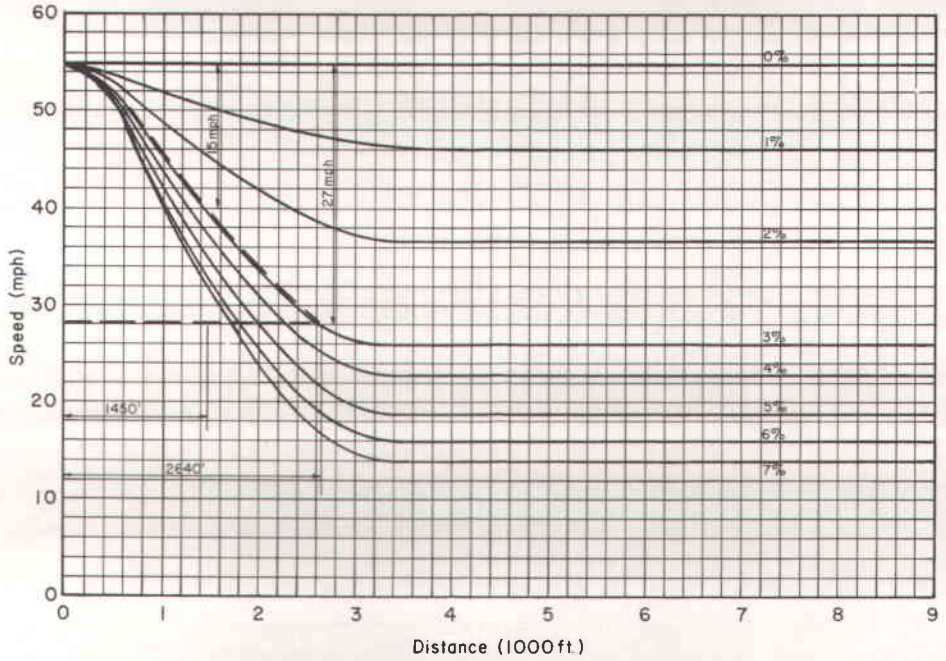
See Figure D-26 for an example problem illustrating the warranting and design of a climbing lane.

In instances where regrading or relocation of an existing highway is proposed, the economics of providing an improved grade line in lieu of providing climbing lanes should be investigated. Attention should be given to the location of ends of climbing lanes. Such lanes should not end in a curve or just prior to obstructions such as culverts, etc. It is preferable to carry the lane beyond these hazards for obvious safety reasons even though theoretical warrants may not indicate a need for the additional length.

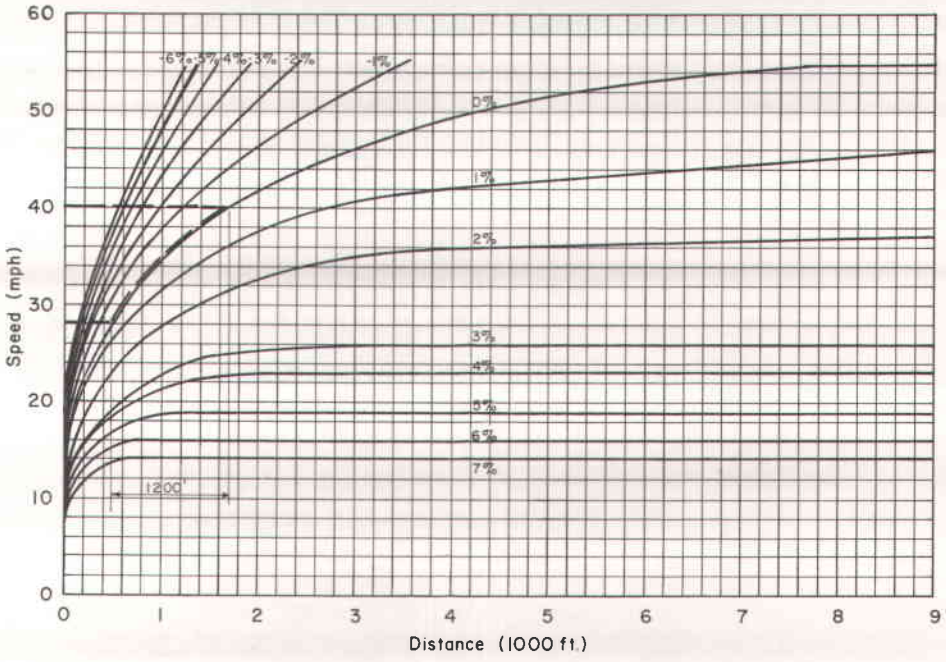
In an area of rolling terrain where climbing lanes are warranted almost continuously, it may be preferable to connect these lanes making a four-lane section. This would eliminate the hazard caused by relatively slowmoving traffic entering the through lane at various points and would further alleviate congestion caused by slow-moving traffic.

SPEED - DISTANCE CURVES

FOR TYPICAL HEAVY TRUCKS
OPERATING ON VARIOUS GRADES



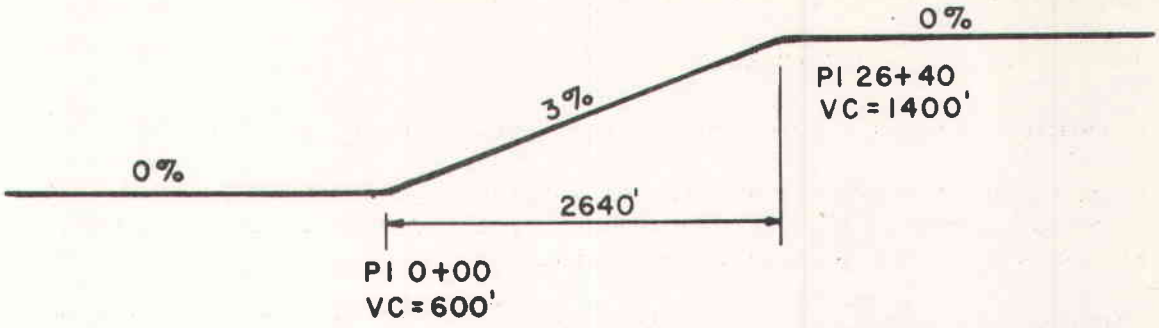
DECELERATION ON GRADES SHOWN



ACCELERATION ON GRADES SHOWN

FIGURE D-25

CLIMBING LANE
EXAMPLE PROBLEM



Given: Two-lane highway, design speed = 70 mph
Design year ADT = 4000
K factor = 15%
D = 60% - 40%
T = 10%

From the procedure outlined on page 150 of the 1965 edition of A Policy on Geometric Design of Rural Highways (AASHO "Blue Book"), the percent passing sight distance greater than 1500 feet is 80%.

Determine: Is a climbing lane warranted for Level of Service "B" operation? If so, design it.

Step 1: Does a 15 mph speed reduction occur? The dashed lines on Figure D-25 indicate the solution to this problem. From the deceleration curves of the figure, determine the speed reduction = 27 mph >15 mph.

Step 2: Is a climbing lane warranted by capacity analysis? Assume the peak traffic is in the upgrade direction and calculate DHV.

Recalling the ADT to DHV conversion equation and restating it for this example:

$$DHV = ADT \times \left[\underbrace{K \times D_p(1 + T(E_{T_p} - 1))}_{\text{upgrade}} + \underbrace{K \times D_{op}(1 + T(E_{T_{op}} - 1))}_{\text{downgrade}} \right]$$

$E_{T_p} = E_{T_{peak}} = 10$ (Figure 4-1A of this Manual)

$E_{T_{op}} = E_{T_{off\ peak}} = 2$ (ibid)

Figure D-26

$$DHV = 4000 \left[0.15 \times 0.6(1 + 0.10(10-1)) + 0.15 \times 0.4(1 + 0.10(2-1))\right]$$

$$DHV = 4000 \left[0.15 \times 0.6 \times 1.9 + 0.15 \times 0.4 \times 1.1\right]$$

DHV = 948 equivalent passenger cars

Determine maximum service volume for level of service "B" operation.

From Figure D-23, the basic limiting value of the V/C ratio is 0.42 for level of service "B", average highway speed (design speed) = 70 mph, and 80% passing sight distance greater than 1500 feet.

Therefore, maximum service volumes (SV) adjusted for 80% passing sight distance for L.O.S. "B" may be determined as follows:

$$SV_{max} = \text{Capacity} \times V/C$$

$$= 2000 \times 0.42$$

$$SV_{max} = 840 \text{ vph}$$

Compare DHV with SV_{max}:

948 > 840 vph; design traffic exceeds maximum service volume for given conditions. Therefore, climbing lane is warranted.

Step 3: Design climbing lane.

Since the approach to the grade is level, assume an initial speed of 55 mph. (In the case of speed zones, adverse geometrics, etc., the appropriate initial speed should be used.) From the deceleration curves of the figure, determine that a 15 mph speed reduction occurs 1450 feet (at Sta. 14+50) from the P.I. at Sta. 0+00. Therefore, begin transition to climbing lane 600 feet in advance of this point (at Sta. 8+50). Minimum speed on the grade is 28 mph and occurs at the P.I. at Sta. 26+40. (The effects of vertical curves on speed are ignored in this analysis.)

From the acceleration curves of Figure D-25, determine that 1200 feet of speed recovery lane is needed (from Sta. 26+40 to Sta. 38+40) to allow re-attainment of a speed of 40 mph. A 600-ft. transition would be added to this distance. The design of the climbing lane would then be as shown.

Figure D-26 (continued)

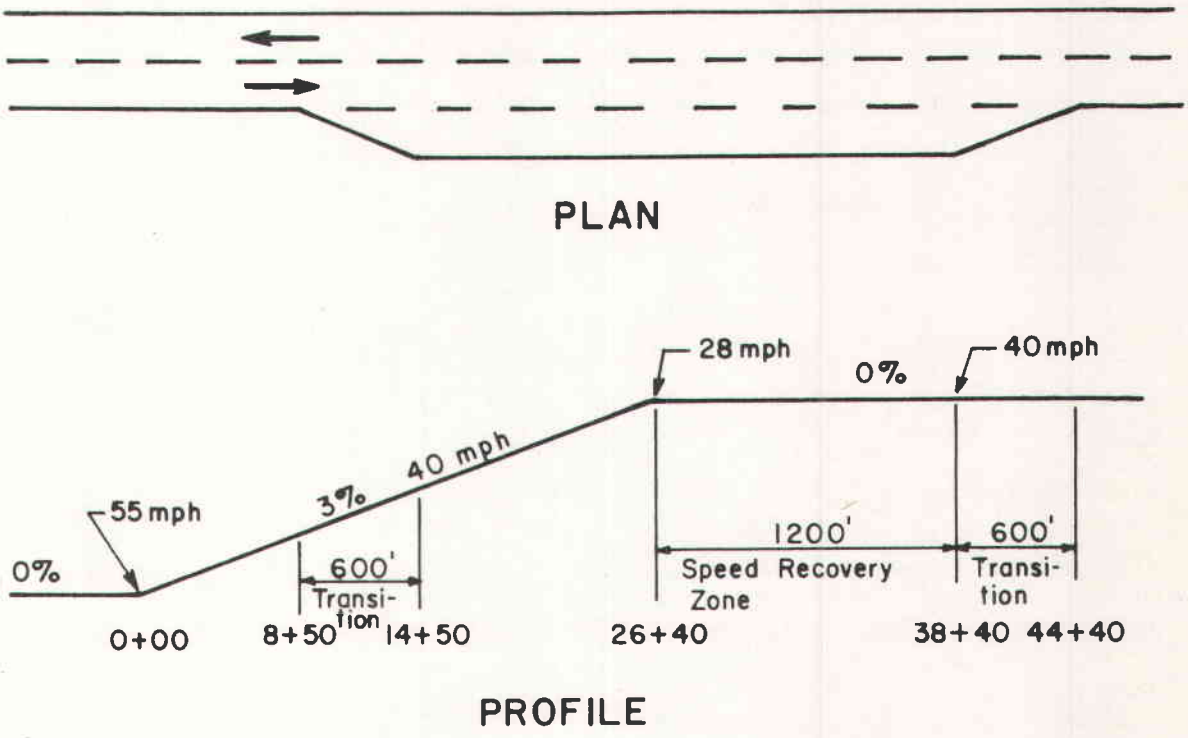


Figure D-26 (continued)

APPENDIX E-100

ECONOMIC ANALYSES (E-100)

E-101 INTRODUCTION

Economy in highway construction has been a part of design decision making from the beginning. The purpose of this appendix is to provide the engineer a design tool specifically applicable to evaluating design choices. It is anticipated that the discussion and sample problems contained herein will clarify the objectives of cost evaluation in the design process and promote application of these principles in all areas of design.

The following, from NCHRP Report 122, defines engineering economy and provides some insight into the scope and application of this type analysis.

"Engineering economy has to do with the analysis of proposed engineering works, equipment, and processes for the purpose of comparing the worth of the economic gains expected to result from the proposed investment with the economic cost required to produce the gains. Engineering economy is a comparison of the input cost with the net output of revenues, benefits, gains, or profits to determine whether the proposed design or whether the proposed facility is economically feasible. In addition to determining economic feasibility, the process of analysis is also used to determine the most economical design with reference to those factors of design over which the engineer has some choice.

In much of the application of the principles and procedures of engineering economy to highway transportation there is no dollar cash sales or income involved. However, there are the dollar values of the benefits to the road user, or to the community as a whole, that are the equivalent of income when they can be priced on a dollar basis. It is always possible, of course, to estimate the costs of construction, operation, and maintenance of a specific public works or highway proposal.

In this particular type of analysis, only those factors that involve the input and output consequences that can be evaluated on a dollar basis are included. Certain other economic and social factors of consequences involved are not included in the analysis for economy because they cannot be priced on a dollar basis. These irreducibles (or nonmarket items, as they may be called) involve a broad scale of consequences, including the effects on business and industry and the community factors that are altered because of the highway improvement. These items are considered separately and given such weight as the decision maker thinks is reasonable.

As presented, highway engineering economy is not intended to include all costs and all net benefits of highway construction, but only those factors, that are affected directly by highway engineering decisions and that can be dollar priced. Therefore, highway engineering economy analysis deals primarily with highway costs, motor vehicle running costs, and other cost or benefit factors pertaining to the road users. This process in no way indicates that the general social and economic consequences are of less importance than are the road-user consequences, but separates them primarily because of necessity in the process of making an economic analysis."

At all times it should be noted that an economic evaluation is a design tool which when used in conjunction with sound engineering judgment will aid the designer in making design decisions.

E-102 COST EVALUATION IN HIGHWAY DESIGN AND CONSTRUCTION:

The engineer is faced with many decisions in the process of highway design and construction. Although an actual cost evaluation may not be made, economy is the basis for many of these decisions. As design variables become more complex, cost evaluation becomes a valuable index of cost effectiveness of particular design variables.

In general, there are three types of cost evaluation which will be discussed in this appendix. These are: (1) overall project design; (2) stage construction application; and (3) design of particular elements. It should also be noted that cost evaluation is useful in project conception. This type analysis, however, involves in depth study of non-road user consequences, and will not be covered in this appendix.

(a) Overall Project Design:

At some point in time, basic design criteria must be established which will govern in later design decisions involving particular design elements. Such items as whether the facility will be elevated or depressed, controlled access with frontage roads, multilane divided or multilane with continuous left turn lane, etc., are representative of design decisions which must be made early in design development.

Heretofore, decisions concerning these items have been based on engineering judgment, past experience or community desire. However, it may be worthwhile to evaluate these items from a cost standpoint especially when design alternates are considerably widespread in cost and operational characteristics.

(b) Stage Construction Application:

In many instances, stage construction is a viable alternate which should be considered since it is often possible to defer large expenditures without undue inconvenience to the public or lower than desirable operational levels by using stage construction.

Cost evaluation for stage construction is somewhat more complex, in that investments, user costs and maintenance expenditures are made at more than one point in time and vary depending on the sequence improvements are made. It is important to keep expenditures relative to the point in time they occur, in order to realistically establish comparative results.

(c) Design of Particular Elements:

The simplest form of cost evaluation compares two elements of design. In such cases parameters are usually easy to define and the analysis is usually straightforward. It is noted that this case is most prevalent. This appendix will, therefore, dwell primarily on this aspect of cost analysis. For more complex problems, we refer the reader to Stanford Research Institute Report NCHRP Project 2-12, "User Benefit Analysis for Highway and Bus Transit Improvements".

E-103 DEFINITION OF PARAMETERS:

There are six basic parameters associated with cost evaluation. General definitions of the parameters are as follows:

(a) Investment Cost

Initial right of way and construction cost and/or subsequent right of way or construction cost associated with a particular improvement or design.

(b) Terminal Value

Certain types of highway facilities and appurtenances may have a terminal value at the end of the period used in the analysis. Such value is, in effect, a recovery of invested capital and becomes a factor that reduces the capital cost from the level of the original investment.

In most analyses for economic evaluation and for project formulation the terminal value may be assumed to be zero. Its discounted value is often small, its value is highly uncertain, and, as between mutually exclusive alternatives, its value will not vary appreciably. Therefore, its omission will usually not affect the results significantly.

(c) Maintenance, Operation and Administrative Costs

Cost associated with a particular design required to maintain a particular level of operation.

Where no better data is available, maintenance costs can be approximated by using maintenance appropriations for the particular type facility being studied.

(d) User Costs

1. Road-User Costs and Benefits

The benefits to the road user of highway improvements arise almost wholly from reducing the cost of travel from its present level. Travel cost reductions and benefits include: (1) reductions in motor vehicle running cost, (2) reductions in travel time, and (3) reductions in traffic accident cost. Thus, these travel factors are related to the alternatives of highway design in the normal procedure of calculating the relative economy of the alternative being considered.

2. Vehicle Running Cost

Distance traveled is directly related to vehicle cost such as fuel, lubricants, tire wear, vehicle depreciation and maintenance. The vehicle operator is often willing to sacrifice operating cost by traveling a longer route if a savings in travel time is realized. Estimated vehicle miles are based on projected traffic volumes and distance traveled on the facility. Generally, the unit values per vehicle mile are for passenger cars and for trucks; however, specific values for a given highway, based on the operational and physical characteristics of the same, should be determined in each case.

Figures 2 through 5 present graphically the relation of geometric features and operational characteristics to vehicle running cost.

3. Travel Time

One of the greatest benefits that can be realized from any roadway improvement is a reduction

in travel time. To commercial operators, travel time is directly related to driver's wages, equipment cost and maintenance. The savings in time for passenger vehicles are not as great per unit as for trucks and buses; however, all vehicle operators are attaching an increasing importance to and are willing to pay for travel on facilities that result in a saving of time. Total travel time can be estimated from projected traffic volumes, average running speeds and anticipated delays at intersections. Unit values to be used are $7.50 to $8.00 per hour per truck and $2.50 per hour per passenger car. The relationship between approach speed, standing delay and cost per vehicle stop is illustrated in Figure 11.

In urban areas, where approximately one half of the trips are work oriented, it may be appropriate to raise the value of travel time to reflect the average hourly income of the traffic flow.

4. Accident Cost

The cost of motor vehicle accidents could be a major component of road user cost and, as such, it would be an important element for inclusion in road user benefit analysis. However, while there are many types of accident data, the statistics available are general and usually do not provide the desired correlation with highway design and operation necessary for direct application in a road user benefit analysis. Therefore, inclusion of accident cost in a road user benefit analysis should be at the District's discretion.

Certain types of hazards associated with highway geometrics and appurtenances can justify spot improvements on existing highways. A procedure has been developed by the Safety Section of File D-18 and accepted by the Federal Highway Administration for use in such cases.

(e) Discount Rate

The discount rate for performing present value calculations should represent the opportunity cost to the taxpayer, i.e., the estimated average market rate of return that would be achieved if more public transportation funds were left in private hands rather than being paid to the government in taxes.

A range of 6 to 12 percent is common in current economy studies of public projects; for example, the U. S. Office of Management and Budget recommends a 10 percent discount rate for Federal Government economy studies. The possible effects of uniform future price increases (inflation) should be ignored.

Because the results of the net present value calculations are sensitive to the discount rate, the analyst may wish to perform the economic calculations at two or three alternative discount rates. However, all final comparisons of projects should be made using a consistent value of the discount rate. It is recommended that a discount rate of 10 percent or greater be used.

(f) Analysis Period

The period of time over which an analysis is to be made should be based primarily on the ability of the analyst to forecast the future. One of the principles of analysis for economy is that the benefits to be received from the facility should be included in the analysis over the same future time as are the forecasts of highway costs. Because perhaps 20 years is a maximum for a general highway facility for which the traffic volume can be estimated within an acceptable degree of reliability, it is probable then that the analysis for economy should likewise not exceed a period of 20 years. On the other hand, for specific types of facilities, particularly for traffic control devices, a period much shorter than 20 years

would be in order. The main thing is to stay on sound ground insofar as estimates of the future are concerned.

In project formulation, the type of materials or particular devices to be used may have different service lives due to variations in physical durability. It is important in such cases to make the analysis over the best estimate of service life that can be achieved.

Variations in the above parameters from the values used to prepare Figures 1 through 6 may be appropriate when special conditions warrant. However, for most studies, the following nomographs can be assumed to apply with little error reflected in the results when compared to an in-depth study which would specifically set values for these parameters.

(g) Modeling Hourly or Daily Benefits

The nomographs and tables in this manual provide estimates of hourly traffic costs, for those cases where wide traffic variations during the day make separate user benefit calculations advisable for significantly different traffic condiserations. In most cases, it will be sufficient to calculate benefits for a typical peak hour and a typical off-peak hour. The daily benefit estimate may then be obtained through weighing these estimates by the number of peak and off-peak hours in the day.

In order to represent or model all daily traffic within peak and off-peak periods, it is suggested that the traffic in minimum traffic hours be added to off-peak traffic and minimum traffic hours be represented as having zero traffic. The total peak and off-peak hours will then add up to less than the total hours in a day. A model day of 18 hours is suggested, with traffic in the six hours from 12 midnight to 6 am added to off-peak traffic.

As an example of the above suggestion, if two one-way peak hours per weekday and 2 per weekend of the same magnitude are assumed together with 16 off-peak hours per weekday and 34 per weekend, then total annual traffic would be represented as follows:

	One-way Hours	Two-way Hours
2 peak hours x 253 weekdays	506	
2 peak hours x 56 weekends (taking 8 holidays as equivalent to 4 weekends)	112	
Total peak hours per year	618	1236
16 off-peak hours x 253 weekdays	4048	
34 off-peak hours x 56 weekends	1904	
Total off-peak hours	5952	5334
Total hours in model (18 x 365)	6570	6570

In cases where AADT is the only traffic estimate available, users of the manual can derive peak and off-peak traffic levels through K and D factors. To assist in this process for average conditions, Figure 1 provides a nomograph for estimating peak and off peak traffic levels from AADT per lane and the number of peak hours in the day. The upper lines in Figure 1 are regressions based on actual hourly vs AADT traffic observations, from the HCM. They show the relationship between *AADT per lane and average 30th and 100th hour traffic volume per lane.* The product of K and D factors implied by these curves is indicated at selected points along the curves.

Use of Figure 1 is illustrated on the figure itself. Note that the off-peak volume calculation is incorporated in the lower curves of Figure 1 for cases in which daily one-way peaks occur at the rate of 1, 2, or 3 hours a day for 365 days a year (or less regular peak hours can be converted to an average daily rate). The lower curves are based on an average of the upper curves, and will serve for approximating average off-peak hourly volume within ± 3 percent for an 18 hour model day, as suggested earlier.

An important aspect of this procedure is that Figure 1 cannot be used for bottleneck sections because it will never result in more peak period hourly traffic than 2,000 vph (which serves in effect as an upper asymptote for the graph). One way of obtaining the correct demand volume for bottleneck sections is to use the estimated peak period hourly demand in the upstream section as derived from Figure1.

The capacity for two lane highways is generally expressed as two-way capacity (e.g., 2,000 vehicles per hour) rather than capacity per lane because capacity in one direction is reduced by traffic in the opposite direction. For one-way analysis during a single typical hour of the day, half the hourly capacity can be used. For more precise analysis, as during a peak hour, peak direction capacity can be estimated by subtracting from two-way capacity the estimated hourly traffic in the non-peak direction during the peak period. For example, if two-way capacity = 2,000 vph (vehicles per hour) and peak period traffic in the off peak direction = 800 vph, then peak period capacity in the peak direction = 2,000 - 800 or 1200 vph.

In cases where there is no need to analyze peak and off-peak traffic separately, manual users can estimate average daily highway user benefits through using a single typical hour and multiplying by the number of such hours in the model day.

Conversion of daily highway user benefits to annual benefits is accomplished by multiplying average daily benefits by 365.

E-104 NOMOGRAPHS

The following nomographs (Figure 1 through 10) and corresponding discussions are taken from 'User Benefit Analysis for Highway and Bus Transit Improvements, Part II' published by Stanford Research Institute. The methodology promoted in this publication is condensed and somewhat simplified in this appendix for easy application in economic analysis of highway projects. Also presented is a methodology for analyzing spot improvements.

(a) Basic Section Costs

The nomographs in Figures 2 through 5 enable direct calculation of B, basic section costs, as a function of the level of traffic (v/c ratio) or the average running speed.

Examples illustrating the use of these figures are provided on the passenger car nomographs, Figures 2

through 5. The nomographs are entered at the lower left, either with volume/capacity ratios (estimated by the analyst for the representative hour of operation of the analysis section) or with average running speed. The analysis proceeds to determination of travel time, the inverse of running speed, portrayed on the left-hand scale of the lower left-hand graph of Figures 2 through 5, tangent running costs, and added running costs due to curves. Then added running costs due to speed change cycles are derived by entering the upper left-hand graph with the v/c ratio from the lower left-hand graph. The indicated costs of speed changes are minor except for level of service F (queueing) conditions.

When a large percentage of the traffic stream consists of trucks, it may be necessary to refer to nomographs in "User Benefit Analysis for Highway and Bus Transit Improvements, Part II" to determine more correctly the impact of trucks in the economic analysis. However, when the percentage of trucks in the traffic stream is relatively small, equivalent passenger cars can be found by assuming one truck equals three passenger cars. Then the nomograph included in this appendix can be used with negligible error.

Examples 1 and 2 are taken from 'User Benefit Analysis for Highway and Bus Transit Improvements, Part II' published by Stanford Research Institute.

(b) Section Transition Costs (T)

The basic section costs discussed in the previous section represent user costs incurred by vehicles running along a section with uniform physical and traffic characteristics. When a vehicle passes between sections with different physical or traffic characteristics, small but measurable additional running costs may be imposed on highway vehicles to slow down or speed up in accordance with different operating conditions on the adjacent sections. For example, a vehicle on a level tangent section of highway must have to slow down when entering and traversing a curved section of highway. A vehicle traveling in the opposite direction would be able to speed up in passing from the curved section to a straight section having a higher design speed.

In this manual, the additional costs imposed by such changes in operating conditions between adjacent sections are termed transition cost - - denoted by T - -and should be added to vehicle running costs. It is arbitrarily suggested that transition costs be added to the downstream section, except for the last section analyzed which should include transition costs at both ends.

Transition costs are calculated from differences in the average running speeds in the upstream and downstream analysis sections. Estimation of running speeds is a by-product of basic section cost calculations, based on the speed-flow relationships noted in the lower left-hand chart of Figures 2 through 5 or on any other data providing running speed estimates by section. Where estimated speeds on adjacent sections are different, transition costs will exist and can be calculated using Figure 6.

The chart on Figure 6 indicates the additional running cost experienced by passenger cars in changing speeds because of different operating conditions on adjacent sections. Adjustment factors to reflect the existence of trucks in the traffic stream are also provided. The example provided illustrates the use of this figure.

An assumption of equal two-way traffic is embedded in Figure 6 because the costs indicated are equal to one-half the excess running costs associated with a full speed change cycle*. This is consistent with

*Speed change cycle costs are usually expressed as excess running cost above that experienced by continuing at a uniform speed and are usually expressed in terms of reducing speed from an initial speed to an intermediate speed and accelerating back to the initial speed.

the usual analysis of traffic for a single direction and later multiplication by two to obtain two-way results. In such cases, transition costs due to decelerations in one direction will be complemented by an equal number of accelerations in the opposite direction, producing complete speed change cycles.

Where separate directional analyses are necessary- -e. g., where total traffic over an entire day in one direction is significantly different from that in the other direction, or where running speeds on a given section are always different in different directions- -costs derived from Figure 6 should in theory be modified to show differential effects for each direction of traffic (e.g., higher cost for acceleration phase of the cycle than for the deceleration phase). Speed change cost data is normally expressed in terms of speed change cycles, however, and little empirical evidence as to added costs for the acceleration or deceleration phase only is available. Where the analyst possesses such information, it could be used to modify results from Figure 6.

(c) Choice of Study Years

The most accurate calculation of the present value of a stream of benefits of costs requires an estimate of annual benefits and costs for each year of the analysis period. Since calculation of year-by-year values is laborious, most analysts choose only two years of the study period and extrapolate or interpolate for the other years. Sensitivity checks show that this procedure typically leads to negligible errors. Even if calculations are facilitated by a computer program, the use of only two analysis years may be efficient because it permits more detailed modeling at the same cost as cruder modeling of all years. However, if extreme congestion, with extensive queueing, is anticipated at some point within the study period, it would be best to include an example of such a year as one of those chosen for analysis.

Figure 7 enables the analyst to calculate the present value of any stream of annual values using only the estimates of two years' values, an early year and a later year. After calculating the ratio of these two values, the figure provides a present worth factor which, when multiplied times the first year's value, yields a close approximation of present value of the entire stream. An example at the right of the figure illustrates the use of the procedure.

(d) Intersection Delay Costs (D)

Intersection delay costs consist of additional time and running costs due to slowing down to and speeding up from a stop caused at an intersection or by a traffic signal, and from idling while stopped. Such costs, symbolized by the letter D, are calculated on a per thousand vehicle basis and should be added to previous estimates of basic section costs and transition costs.

Intersection delay costs depend primarily on the type and configuration of the traffic control devices employed, the level of traffic on the section, and the speed at which the stop or signal is approached. Figures 8 and 9 are provided to facilitate the calculation of stopping and idling costs as functions of the above factors. Examples provided on the figures illustrate their use. Approximate adjustment factors are also provided to account for trucks in the traffic stream.

These figures are based on Webster's equations for computing delays at signalized intersections with fixed time signals. The use of these figures (including applications to stop signs) is discussed below.

Figures 8 and 9 require data on the following parameters of the signalization and traffic of the intersection under study:

- Green-to-cycle time ratio (λ): The ratio of effective green time of the signal to the cycle length of the signal, both expressed in the same unit of time (usually seconds). In terms of the *Highway Capacity Manual,* effective green time is the actual green time of the signal. If the HCM is not used, effective green time is defined as the total available for vehicular movement. (If it is assumed that the part of the yellow interval used for vehicular movement and the time lost while the queue gets in motion are equal, then both methods of defining effective green time are equivalent.) The cycle length of a signal is the total time taken for display of all of the several indications provided by the signal.
- Saturation flow (s): In terms of the *Highway Capacity Manual*, saturation flow is the approach volume in vehicles per hour of green time that is found for the intersection when the load factor is 1.0 and the appropriate adjustment factors are applied. In the absence of HCM solutions, recommended values for saturation flow are 1,700 to 1,800 vehicles per hour times the number of approach lanes.
- Capacity (c): Where the HCM is used, capacity is the service volume of the approach at a load factor of 1.0. It is also equal to the saturation flow times the green to cycle time ratio.
- Degree of saturation (x): The ratio of the volume of traffic approaching the intersection (usually in vehicles per hour) to the capacity of the intersection (usually in vehicles per hour).
- Approach speed: Also termed "midblock speed," this is the average running speed at which the signalized intersection is approached by the vehicle stream. Where the distance between signals (signal spacing) is one quarter mile or greater, approach speed can generally be estimated according to the speed flow relationships of Figure 2 through 5 or other such relationships. Alternatively, a midblock speed equal to the prevailing speed limit is often a good approximation to approach speed where congestion is not a factor. Where signal spacing is such that one signal affects the traffic at an adjacent upstream or downstream signal or under situations of significant congestion, approach speeds may have to be estimated empirically.

  Figure 8 aids in the estimation of added intersection delay costs due to stopping. The lower left-hand chart is entered with degree of saturation and the green-to-cycle time ratio and determines first the percentage of the traffic stream that is caused to stop at least once at the signal (or, equivalently, the average stops per vehicle per signal). The formula from which the lower left-hand chart of Figure 9 is derived is given by:

$$E = (1-\lambda)/(1-\lambda x)$$

where E is the proportion of traffic required to stop and the other parameters are as defined above. The percentage of vehicles that stop are then transformed in the two lower right-hand charts of Figure 8 to determine added time and running cost due to stopping which, on a unit or per thousand vehicle basis, can be associated with the total traffic stream. Time cost adjustment factors are based on assumptions that truck speeds are generally 10% less than equivalent passenger car speeds and that the unit value of time is 2.33 that of passenger cars for single unit trucks and 2.67 times that for 3-S2 combination trucks.

Figure 9 aids in the estimation of idling costs. Entering with a degree of saturation, intersection capacity, and green-to-cycle-time ratio enables one to determine the intersection idling delay averaged over all vehicles in the traffic stream. Multiplying average delay per vehicle in seconds by 0.2778 converts delay into corresponding hours per thousand vehicles. Passenger car idling costs are then derived using a figure of $0.3126 per hour of idling.

Average delays at stop and yield signs do not normally lend themselves to analytic derivation and are generally influenced by the configuration of such signs, the traffic volumes through the intersection (especially in regard to crossing traffic), and the turning patterns that characterize the intersection. Once an average delay at a stop sign is estimated, however, Figures 8 and 9 can be used to estimate associated intersection delay costs. Where all vehicles can be assumed to stop at a stop sign (only a fraction may do so at a yield sign) a green-to-cycle-time ratio of 0.0 can be assumed in Figure 8 such that the average stops per vehicle is 1.0. Added stopping time and cost at a stop sign can then be determined along the top of the lower charts in Figure 8 as a function of approach speed.

In addition, once the average delay per vehicle at the stop sign is determined, idling time and costs can then be easily estimated using Figure 9.

The analysis of intersection delay often requires separate calculations for each direction of approach, especially where opposing and/or crossing approaches have unequal traffic flows or different characteristics (e.g., number and types of lanes, capacity, signalization parameters, etc.). Where, however, intersection characteristics are similar, results of the analysis of one intersection or approach may be multiplied by the appropriate number of similar situations to obtain an overall result. For example, if there are three signalized intersections of approximately the same characteristics included in the overall roadway being analyzed, one intersection might be analyzed and the results multiplied by three. Also, where differing traffic flows in opposing directions during a given time period are offset or reversed according to say, A.M. and P.M. peaks and all other characteristics are the same, multiplying results of a one-directional analysis by two to obtain two-way results is appropriate.

The condition of intersection congestion or queueing- -analogous to level of service F conditions for basic section costs- -is implied where potential traffic volume exceeds intersection capacity and therefore the degree of saturation would exceed 1.0. As indicated in Figures 8 and 9, a degree of saturation of 1.0 implies that all vehicles in the traffic stream would stop at the signal at least once and that average delay per vehicle would at least equal the signal cycle time. Average delays equal to signal cycle time are generally sufficient to represent conditions of queueing at signalized intersections since additional increments of delay associated with further increments of congestion are small relative to total cycle time, and it can often be assumed that traffic would be diverted to other parts of the network under more extreme conditions of queueing. NCHRP Report 133 should be referred to if assistance is needed in estimating the effect of queues in interrupted flow beyond assuming average delay to be equal to signal cycle time.

The Highway Capacity Manual should be consulted for determination of the effects of turning movements at intersections on the capacity of the affected legs.

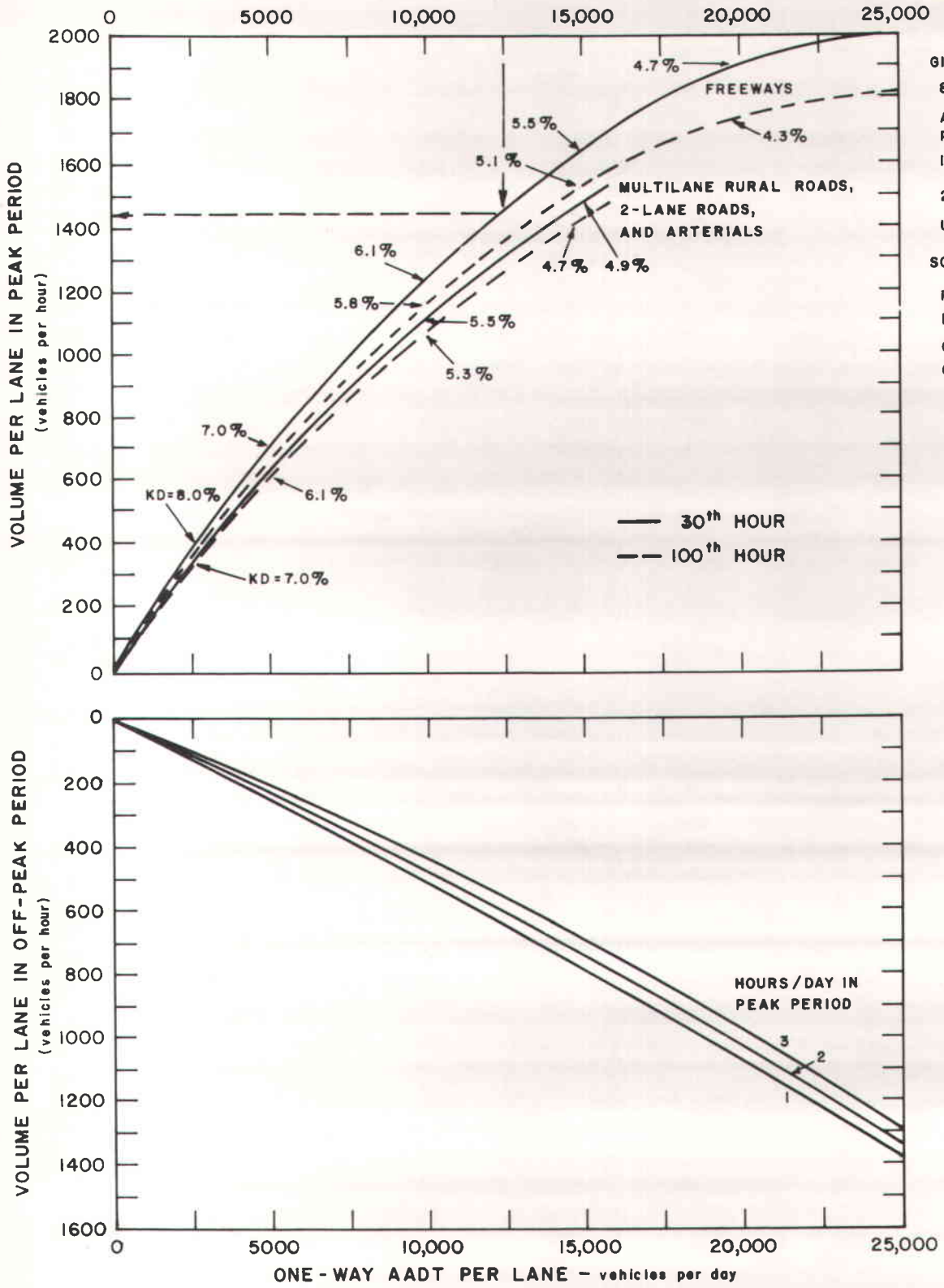
(e) Road Surface

Two types of unpaved roads may be distinguished for practical purposes: those with loose surfaces and those that are completely unsurfaced. A loose surface is one for which a surface of loose stone, rock, or gravel has been added to the basic alignment and grading. An unsurfaced or earth road provides only the graded and smoothed right-of-way itself for use by the vehicles.

The data presented in Figures 2 through 5 for basic section costs are for paved facilities only. The costs of operating vehicles on an unpaved section can be derived by application of an adjustment factor to the vehicle running costs for paved sections. These factors are greater than one because the motion of a vehicle on an unpaved surface meets with greater rolling resistance and hence requires more fuel than travel at a similar speed on a paved facility. Traction may also be lower because of a lower coefficient of friction for the tire contact with the road, causing power losses when accelerating or negotiating grades or curves. The roughness of the surface contributes to additional tire wear and may influence the maintenance and repair expenses incurred in keeping the vehicle in operation.

While the effect of these influences on costs could be evaluated precisely for a particular type of unpaved facility, the wide variation in actual surface conditions makes such precision useless in application. Nor is the influence of potholes, mud, washboarding, and erosion generalizable in a useful way. Figure 10, therefore, provides some basic factors for adjusting the vehicle running costs derived for paved roads to approximate the costs on unpaved roads. The effect of such roads on highway speeds will vary with their condition, but in general the design speeds of high-type loose surfaced roads are probably 20% or about 10 mph below similar surfaced roads, and about 15 mph lower for unsurfaced sections.

CONVERSION OF AADT PER LANE TO HOURLY PEAK PERIOD AND OFF-PEAK PERIOD TRAFFIC PER LANE



EXAMPLE

GIVEN:

8-Lane Freeway

AADT = 100,000 vehicles per day = 12,500 vpd/lane

18 hour Traffic Day

2 Peak hours/day

Use 30th hour Curve

SOLUTION:

Peak Period Volume
1440 veh/hr/lane

Off Peak Volume =
600 veh/hr/lane

FIGURE 1

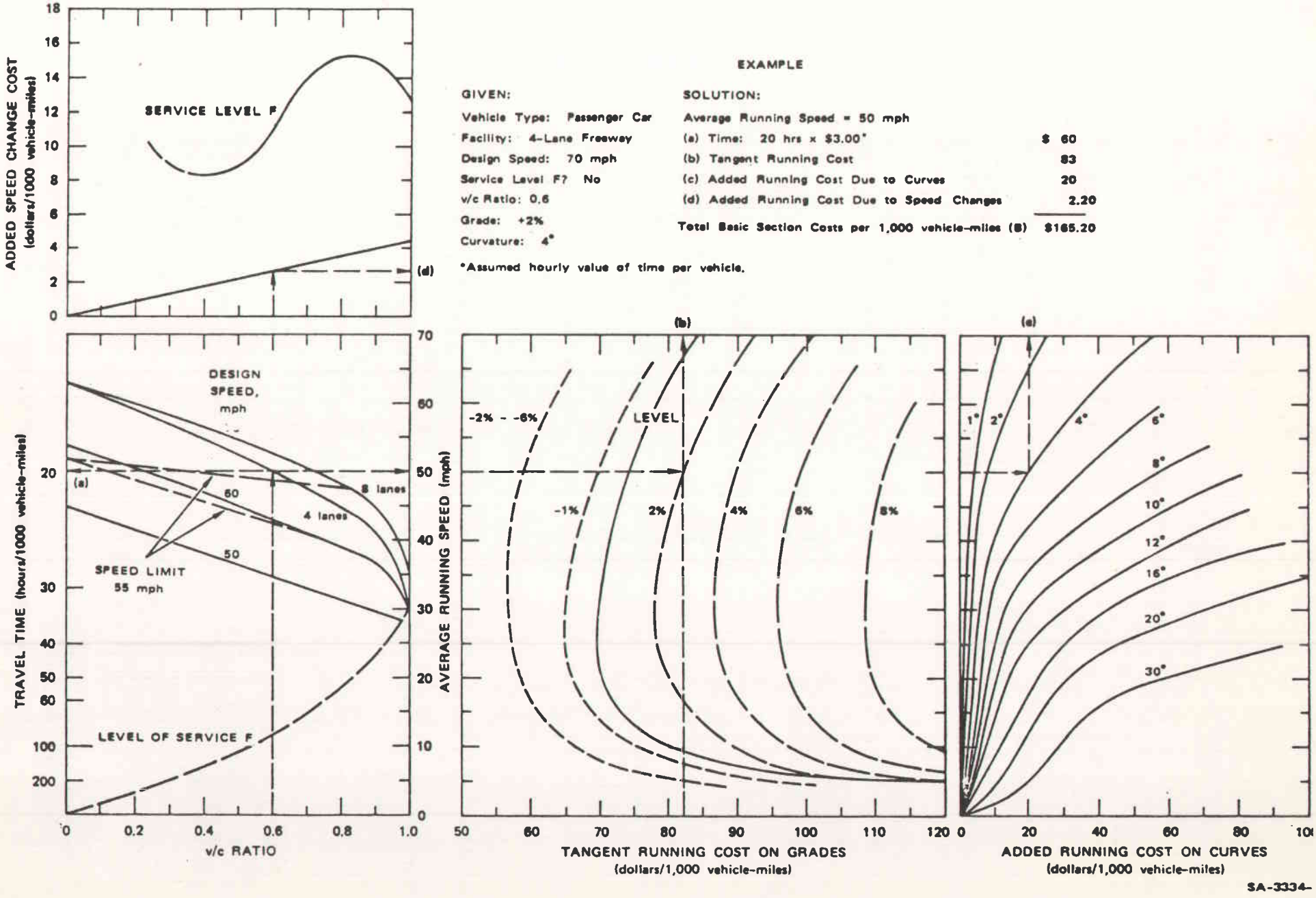


FIGURE 2 BASIC SECTION COSTS (B) FOR PASSENGER CARS ON FREEWAYS

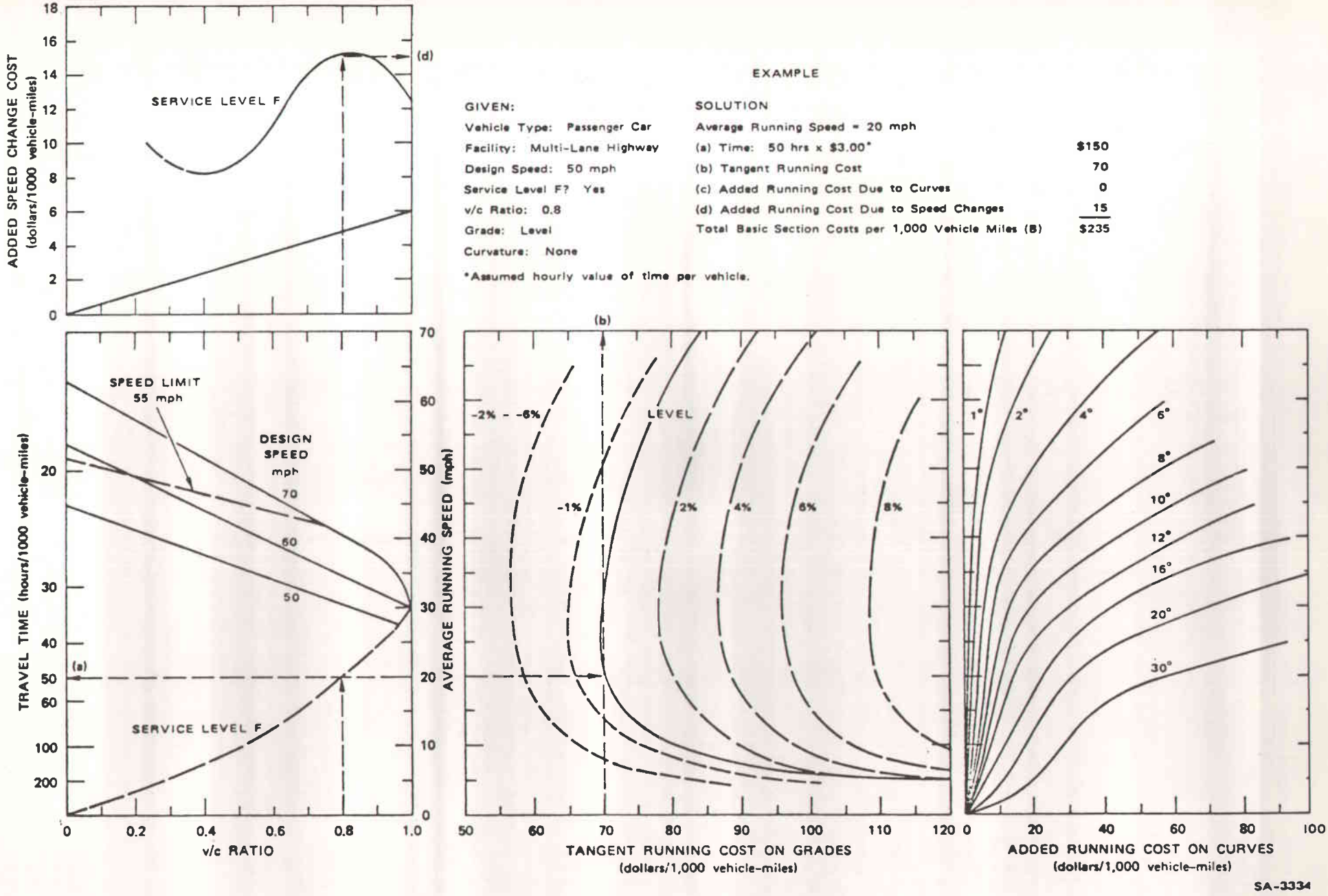


FIGURE 3 BASIC SECTION COSTS (B) FOR PASSENGER CARS ON MULTI-LANE HIGHWAYS

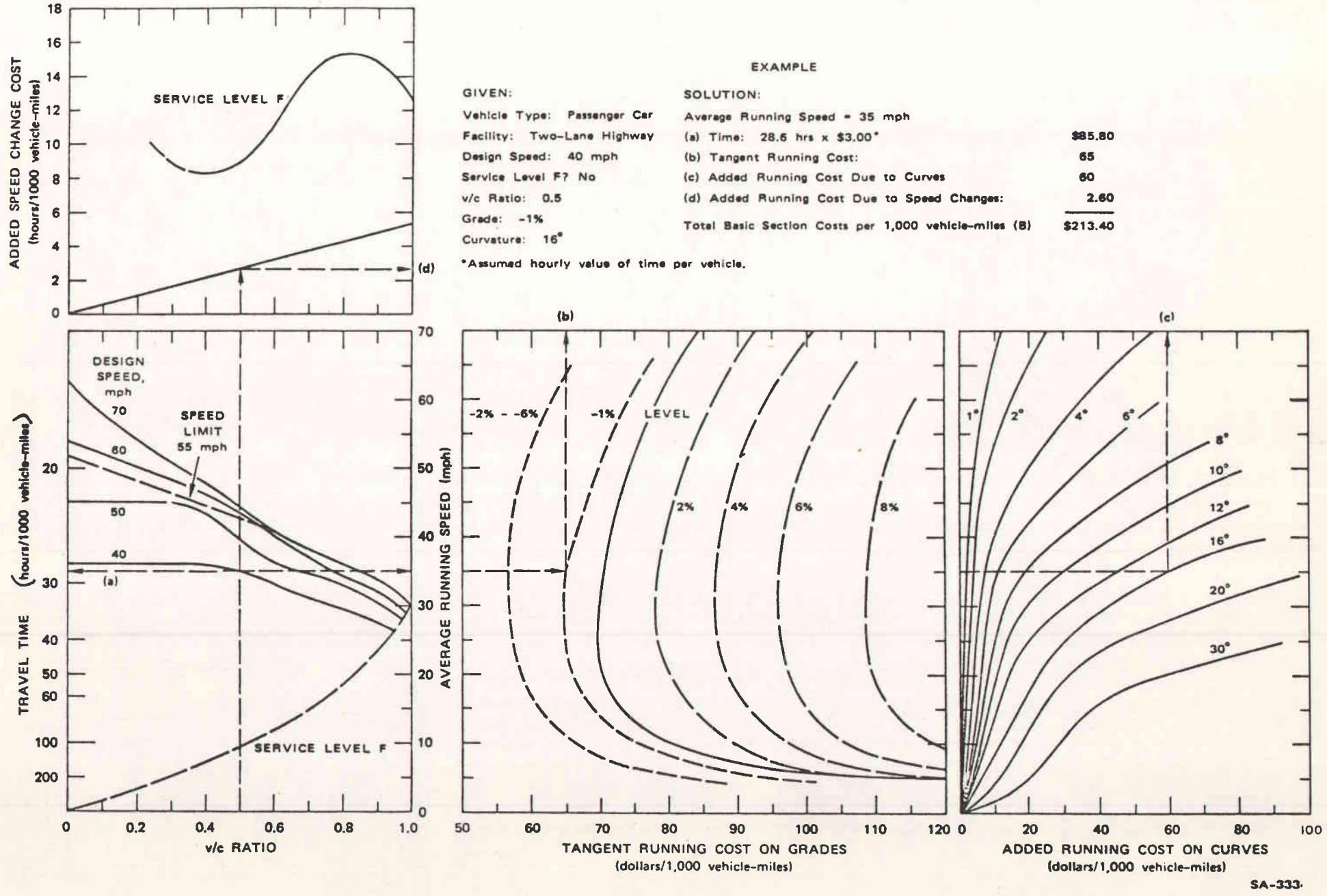


FIGURE 4 BASIC SECTION COSTS (B) FOR PASSENGER CARS ON TWO-LANE HIGHWAYS

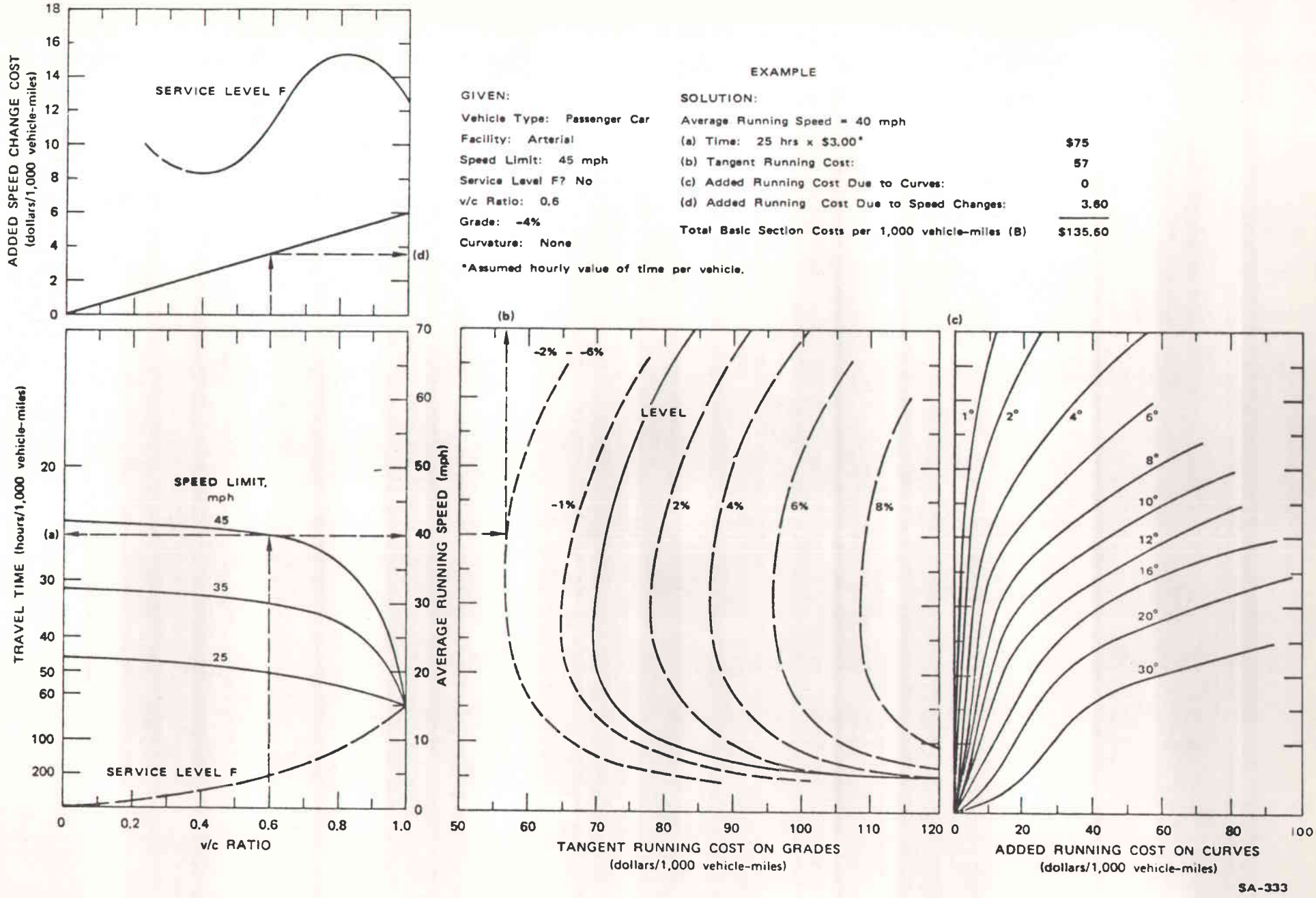
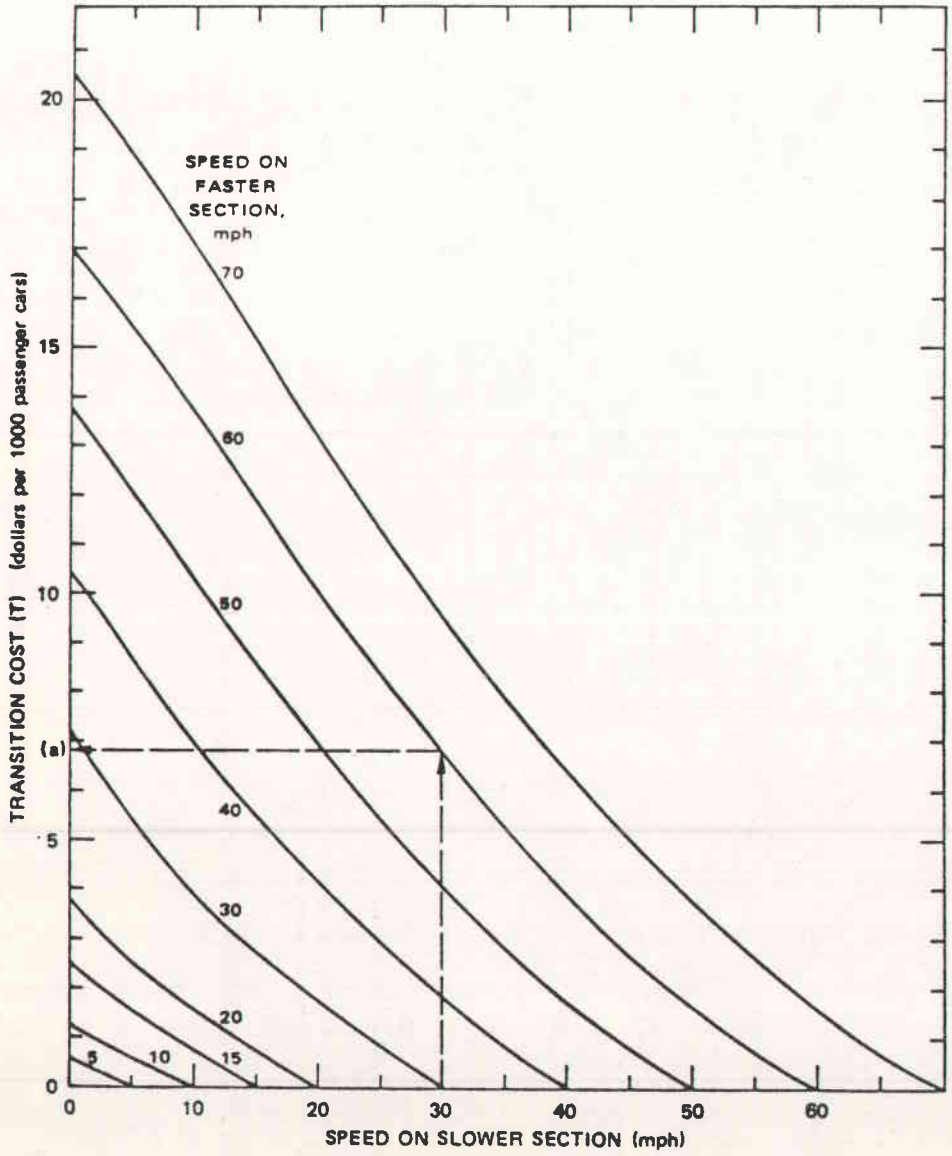


FIGURE 5 BASIC SECTION COSTS (B) FOR PASSENGER CARS ON ARTERIALS



ADJUSTMENT FACTORS FOR TRUCK TRAFFIC

SINGLE UNIT TRUCKS (percent)	3-S2 COMBINATION TRUCKS (percent)											
	0	1	2	3	4	5	6	8	10	20	50	100
0	1.00	1.10	1.19	1.29	1.38	1.48	1.57	1.77	1.96	2.92	5.79	10.58
1	1.02	1.12	1.21	1.31	1.40	1.50	1.59	1.79	1.98	2.94	5.81	–
2	1.04	1.14	1.23	1.33	1.42	1.52	1.61	1.81	2.00	2.96	5.83	–
3	1.06	1.16	1.25	1.35	1.44	1.54	1.63	1.83	2.02	2.98	5.85	–
4	1.08	1.18	1.27	1.37	1.46	1.56	1.65	1.85	2.04	3.00	5.87	–
5	1.10	1.20	1.29	1.39	1.48	1.58	1.67	1.87	2.06	3.02	5.89	–
6	1.12	1.22	1.31	1.41	1.50	1.60	1.69	1.89	2.08	3.04	5.91	–
8	1.16	1.26	1.35	1.45	1.54	1.64	1.73	1.93	2.12	3.08	5.93	–
10	1.20	1.30	1.40	1.49	1.58	1.68	1.77	1.97	2.14	3.12	5.97	–
20	1.41	1.50	1.60	1.70	1.78	1.88	1.94	2.17	2.34	3.32	6.17	–
50	2.02	2.12	2.21	2.31	2.39	2.49	2.58	2.78	2.95	3.93	6.78	–
100	3.04	–	–	–	–	–	–	–	–	–	–	–

EXAMPLE

GIVEN:

A stream of traffic consists of 5% single unit trucks and 10% combination trucks. The traffic is travelling at 60 mph and enters a slower section on which the speed is 30 mph.

SOLUTION:

(a) Passenger Car Cost = $6.75

T = $6.75 x 2.06

= $13.91 per 1000 Vehicles

SA-3334-19

FIGURE 6 SECTION TRANSITION COSTS

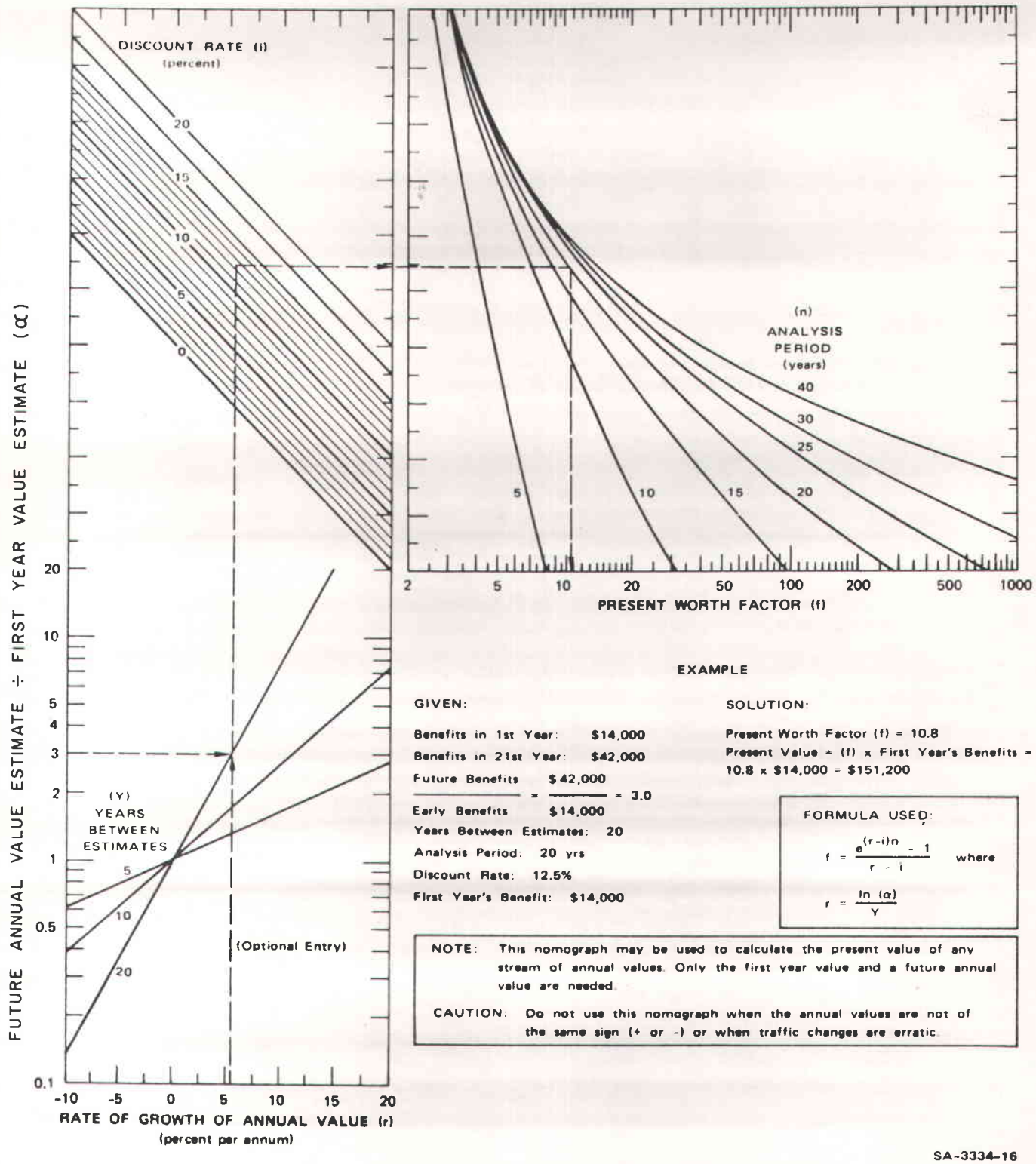


FIGURE 7 NOMOGRAPH FOR CALCULATING PRESENT VALUE FROM TWO ANNUAL VALUE ESTIMATES

EXAMPLE

GIVEN:

Volume: 480 vehicles/hr
Saturation Flow: 1,600 vehicles/hr
Signal Cycle Time: 60 sec
Effective Green Time: 30 sec
Intersection Approach Speed: 30 mph
5% Single Unit Trucks
5% 3-S2 Combination Trucks

SOLUTION:

$\lambda = 30/60 = 0.5$
Capacity of Approach = 0.5 x 1600 = 800
$x = 480/800 = 0.6$
(a) Average Stops per Vehicle (per Signal): 0.71
(b) Stopping Delay per Signal: 2.5 hrs
(c) Cost of Stopping: $10.30

Time Cost: 2.5 x $3.00* x 1.35†	$10.13
Running Cost: $10.30 x 1.42†	14.63
Total Cost Due to Stopping per 1,000 vehicles per Signal (excludes idling):	$24.76

*Assumed hourly value of time per passenger car.
†Adjustment factors for trucks in traffic stream.

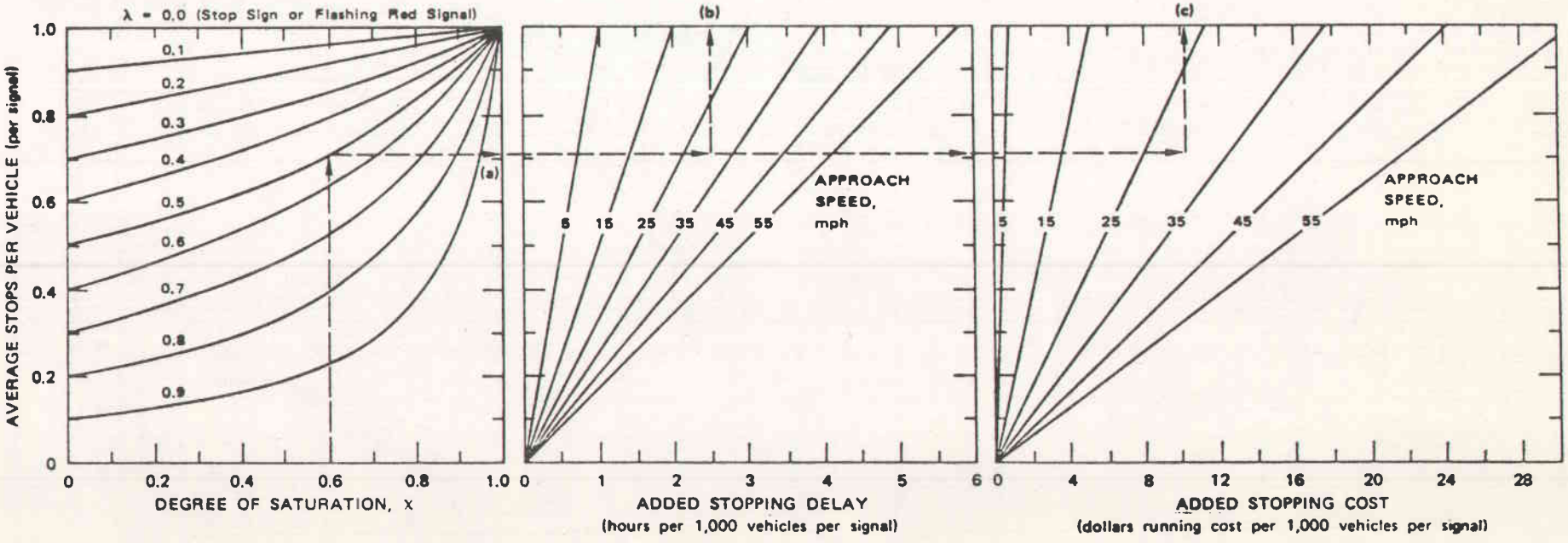
ADJUSTMENT FACTORS FOR PERCENT TRUCKS IN TRAFFIC STREAM

TIME COST

APPROACH SPEED (mph)	SINGLE UNIT TRUCKS (percent)	3 S-2 COMBINATION DIESEL TRUCKS (percent in traffic stream)				
		0	5	10	20	100
5-20	0	1.00	1.15	1.30	1.61	4.03
	5	1.07	1.22	1.37	1.67	–
	10	1.13	1.28	1.43	1.74	–
	20	1.26	1.41	1.57	1.87	–
	100	2.31	–	–	–	–
21-40	0	1.00	1.25	1.51	2.01	6.05
	5	1.10	1.35	1.60	2.11	–
	10	1.20	1.45	1.70	2.21	–
	20	1.40	1.65	1.90	2.41	–
	100	2.99	–	–	–	–
41-60	0	1.00	1.41	1.82	2.63	9.17
	5	1.11	1.56	1.93	2.74	–
	10	1.22	1.61	2.04	2.85	–
	20	1.44	1.85	2.26	3.07	–
	100	3.20	–	–	–	–

RUNNING COST

APPROACH SPEED (mph)	SINGLE UNIT TRUCKS (percent)	3 S-2 COMBINATION DIESEL TRUCKS (percent in traffic stream)				
		0	5	10	20	100
5-20	0	1.00	1.35	1.70	2.40	8.02
	5	1.08	1.43	1.78	2.49	–
	10	1.16	1.51	1.86	2.57	–
	20	1.32	1.68	2.03	2.73	–
	100	2.62	–	–	–	–
21-40	0	1.00	1.35	1.71	2.41	8.07
	5	1.07	1.42	1.78	2.48	–
	10	1.14	1.49	1.84	2.55	–
	20	1.27	1.63	1.98	2.69	–
	100	2.37	–	–	–	–
41-60	0	1.00	1.35	1.70	2.39	7.96
	5	1.06	1.41	1.76	2.45	–
	10	1.12	1.47	1.82	2.51	–
	20	1.24	1.59	1.94	2.63	–
	100	2.21	–	–	–	–



NOTE: Where $X = v/\lambda s$ = v/capacity s = saturation flow v = volume λ = green to cycle time ratio

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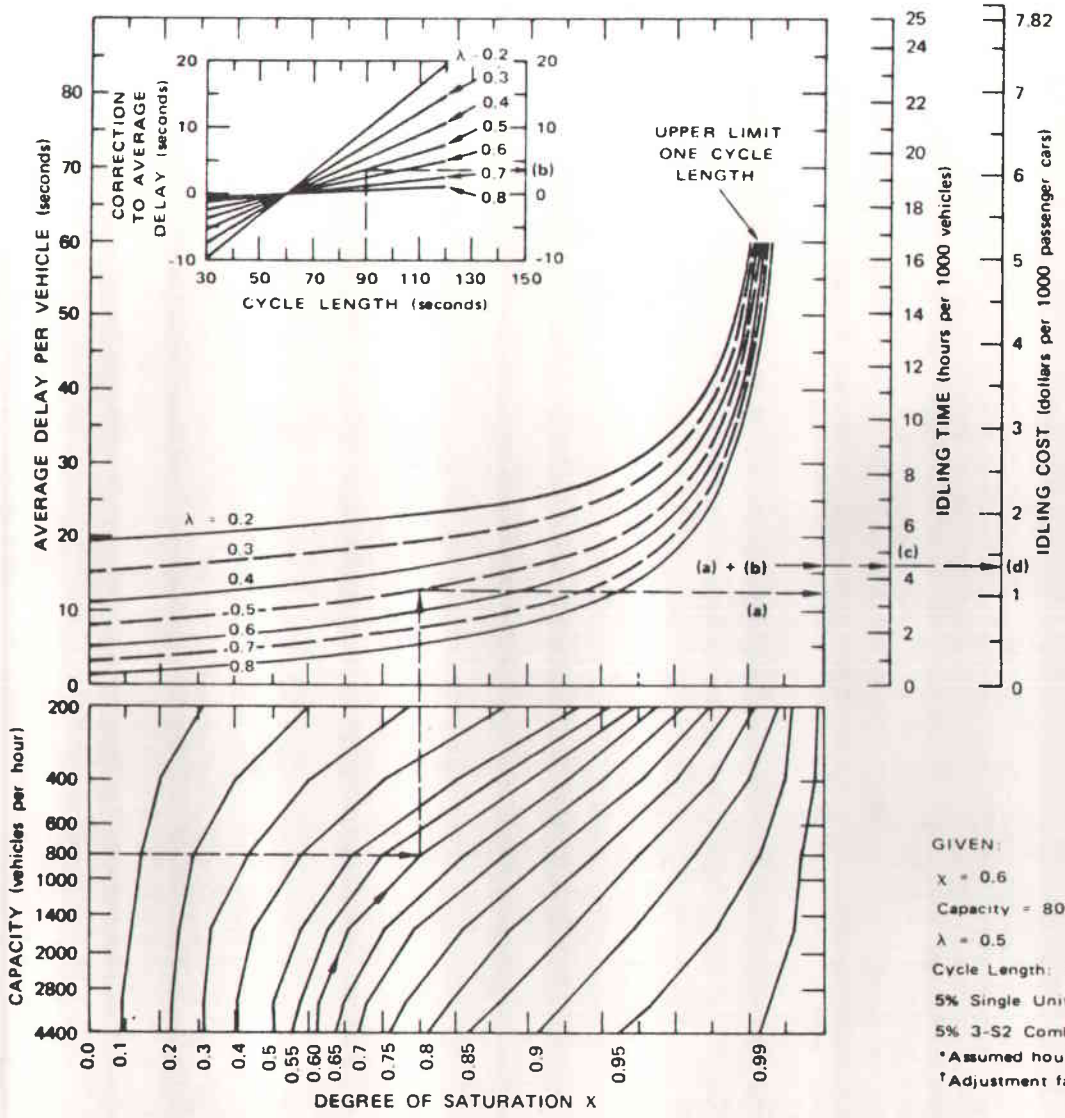
FIGURE 8 COSTS DUE TO STOPPING AT INTERSECTIONS (EXCLUDES IDLING)



ADJUSTMENT FACTORS FOR PERCENT TRUCKS IN TRAFFIC STREAM

IDLING TIME FACTOR		3-S2 COMBINATION TRUCKS (percent)				
		0	5	10	20	100
SINGLE UNIT TRUCKS (percent)	0	1.00	1.08	1.17	1.33	2.67
	5	1.07	1.15	1.23	1.40	-
	10	1.13	1.22	1.30	1.47	-
	20	1.27	1.35	1.43	1.60	-
	100	2.33	-	-	-	-

IDLING COST FACTOR		3-S2 COMBINATION TRUCKS (percent)				
		0	5	10	20	100
SINGLE UNIT TRUCKS (percent)	0	1.00	0.98	0.96	0.92	0.62
	5	0.99	0.98	0.96	0.92	-
	10	0.99	0.97	0.95	0.91	-
	20	0.98	0.96	0.94	0.90	-
	100	0.89	-	-	-	-

EXAMPLE

GIVEN:

X = 0.6

Capacity = 800

λ = 0.5

Cycle Length: 90 seconds

5% Single Unit Trucks

5% 3-S2 Combination Trucks

SOLUTION: Average Delay per Vehicle (a) + (b) 16.2 sec

(c) Idling Hours: 4.5 hrs

(d) Idling Cost: $1.40

Total Delay: 4.5 hrs x $3.00* x 1.15† $15.53

Total Idling Cost: $1.40 x 0.98† 1.38

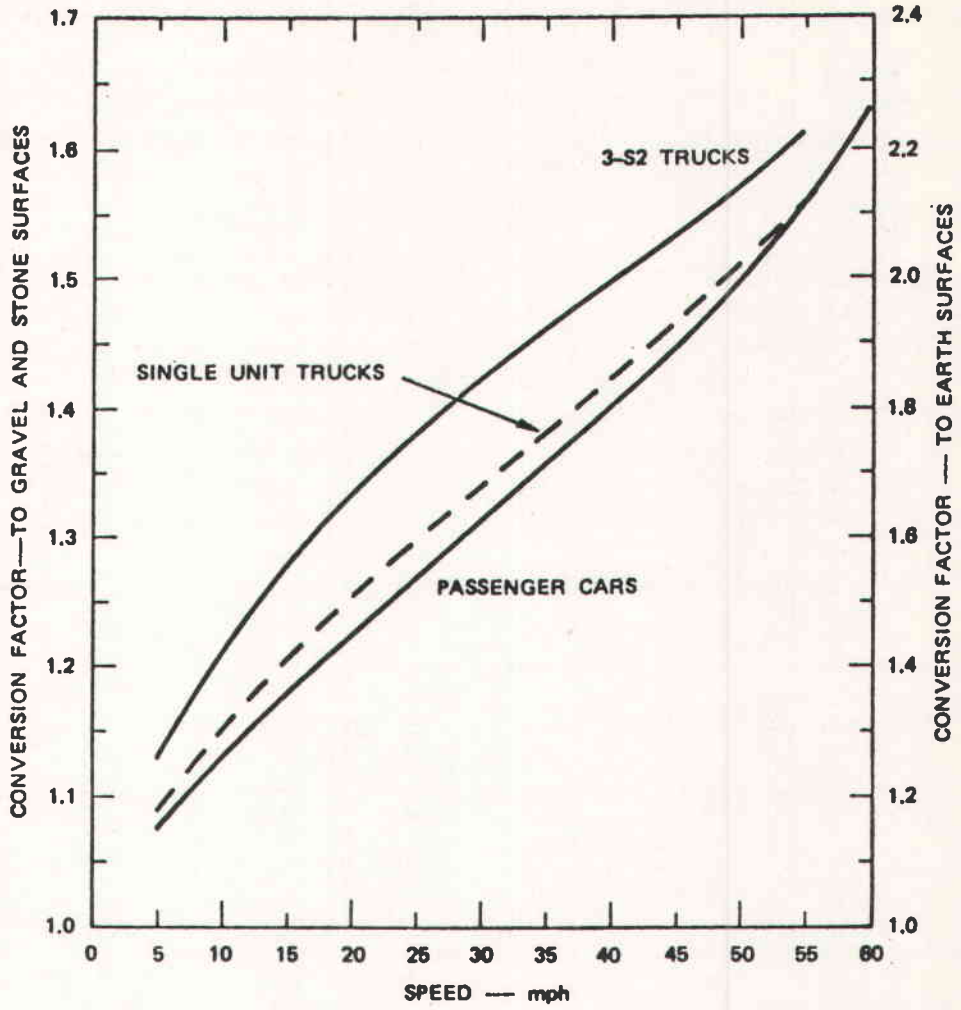
Total Cost Due to Idling per 1000 Vehicles (per signal) $16.91

*Assumed hourly value of time per passenger car

†Adjustment factors for percent trucks in traffic stream.

NOTE: Where: λ = v/λs = v/capacity s = saturation flow v = demand volume λ = green to cycle time ratio

FIGURE 9 COSTS DUE TO IDLING AT INTERSECTIONS



SOURCE: Winfrey (3, page 727).

SA-3334-5

FIGURE 10 MULTIPLICATIVE FACTORS TO CONVERT MOTOR VEHICLE RUNNING COST ON HIGH TYPE PAVEMENTS TO COST ON GRAVEL AND STONE OR TO EARTH ROADWAY SURFACES

E-105 EXAMPLES

Example 1: Curve Elimination

A highway agency is considering eliminating an S-curve on a multi-lane highway. Because there is only one curve and traffic characteristics are uniform, the analyst may view the improvement as a single section, designated ab. The characteristics of the existing route (alternative 0) and the proposed route (alternative 1) are summarized in Table 1. Note that after the improvement, the design speed of the straightened section will be 60 miles per hour rather than 50 miles per hour.

The analyst has obtained the traffic estimates with and without the proposed improvement for the first and eleventh year of the study period. It is assumed that level of service F conditions will not occur during the analysis period, and that the diurnal variation of traffic is small enough that explicit consideration of peaking characteristics is unnecessary. Hence the analysis can be performed essentially on an ADT basis. This involves utilizing traffic volume data for a typical hour of the day in each of the analysis years. Such traffic data is summarized in Table 2, where typical one-way hourly volume is defined as ADT divided by 18 (the number of hours assumed, for analysis purposes, in a day). Note that a small increment of traffic is estimated to be induced as a result of the proposed improvement.

There are so few trucks that the traffic stream will be considered to consist entirely of passenger cars--otherwise, the percentage of trucks by type would also be shown in Table 2 or converted to equivalent passenger cars.

Average running speeds (determined from Figure 3 as a function of v/c) are also noted on Table 2. Since speeds on the analysis section will change as a result of the improvement, transition costs between sections will change, thus speed on the previous and subsequent sections must be specified (as in Table 2).

These traffic and facility data enable calculation of user costs on the existing route and the proposed route, as in Table 3. Unit highway user costs (HU) are calculated from the Formula $HU=(B + A) \times L + T + D$; using basic section costs (B), section length (L), and transition costs (T). Intersection delay costs (D) are not relevant in this example. Accident costs (A) are not considered in this example, but if accident rates were known and changes in accidents were discernible as a result of this improvement, their unit cost would be added to B before multiplication by L. The numbers for B and T are derived from Figures 3 and 6 using the facility and traffic data in Tables 1 and 2. A unit value of time of $3 per hour per vehicle is assumed.

Table 1

FACILITY DATA

Basic Section Data						
Alternative	Section	Length (mi.)	Lanes (one way)	Grade (%)	Curvature (°)	Design speed (mph)
0	ab	.10	2	0	8	50
1	ab	.08	2	0	0	60

Table 2

TRAFFIC DATA

Alternative and Section	Analysis Year	Period	One-Way Volume (000)	One-Way Capacity (000)	v/c Ratio	Average Running Speed (mph)	Speed (mph) on: Previous Section	Speed (mph) on: Next Section
0ab	1	typ.hr.	1.900	3.800	.50	36	45	60
1ab	1	typ.hr.	2.000	3.800	.53	41	45	60
0ab	11	typ.hr.	3.000	3.800	.79	31	40	55
1ab	11	typ.hr.	3.100	3.800	.82	34	40	55

Table 3

CALCULATION OF HU

Alternative	Section	Year	Period	(B x L) + T =	HU per KV
0	ab	1	typ.hr.	177.4 x 0.1 mi + 6.7 =	$24.4
1	ab	1	typ.hr.	147.7 x 0.08 + 4.5 =	16.3
0	ab	11	typ.hr.	182.9 x 0.1 + 6.8 =	25.1
1	ab	11	typ.hr.	162.2 x 0.08 + 5.5 =	18.5
KV = thousand vehicles					

Determination of B and T for the existing route (alternative 0) in year 1 is further described as follows. Entering the lower left-hand (speed-flow) chart of Figure 3, with a v/c ratio of 0.50 and design speed of 50 mph yields an average running speed of approximately 36 mph and a corresponding travel time of 27.8 hours per thousand vehicle miles.* Tangent running cost at 36 mph on a level or 0% grade is approximately \$71* per 1,000 vehicle miles; added running cost due to an 8° curve is approximately \$20 per 1,000 vehicle-miles; and added running cost due to speed changes at a v/c ratio of 0.50 is approximately \$3 per 1,000 vehicle miles. Total running cost per thousand vehicle miles on the existing route is thus \$94 (71 + 20 +3). Adding this to a total time value of about \$83.40 (27.8 x \$3/hr) per thousand vehicle miles yields a total unit basic section cost (B) for the existing route in year 1 of \$177.40 per thousand vehicle-miles.

Entering Figure 6 with a speed of 45 mph on the "faster" previous section and 36 mph on the section being analyzed yields an added one-way transition cost of approximately \$1.70 per thousand vehicles. Similarly, for the transition from the section being analyzed to the next section, with an assumed speed of 60 mph transition cost is from Figure 6, approximately \$5.00. Total one-way section transition cost is thus \$6.70 per thousand vehicle miles.

Similar utilization of Figures 3 and 6 applied to the proposed route in year 1 and both the existing and proposed route in year 11 yield corresponding values for B and T. Multiplying basic section costs by section length (L) and adding section transition costs then results in the highway user costs (HU) per KV in Table 3.

Benefits in the representative first and eleventh years can be calculated from the above user cost (HU) estimates by applying the Formula User Benefits = $(U_o - U_1)\frac{(V_o+V_1)}{2}$ as demonstrated below:

The benefits for the two representative years may be converted into an estimate of the present value of all benefits by use of Figure 7. Using the ratio of benefits in the eleventh year to those in the first year (132,254/103,773 = 1.27) and using assumptions of a 30 year project life and a 10% discount rate, a present value factor (f) of approximately 12 is obtained. The present value of benefits is then f x first year benefits or

$$12 \times \$103{,}773 = \$1{,}245{,}276$$

Since the improvement affects traffic symmetrically in both directions this one-way benefit estimate can be multiplied by two to yield the total present value of the project's benefits, or \$2.49 million.

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*Note that the 36 mph running speed is below the probable minimum road speed on an 8° curve of 45 mph. This is due to the effect of traffic on running speed.

*The nomographs of this manual are accurate to probably the nearest \$1 per thousand vehicle miles or to the nearest 0.1¢ per vehicle mile. For greater accuracy refer to the running cost tables of Appendix B of *"User Benefit Analysis for Highway and Bus Transit Improvements - Part 2"*.

A complete project analysis requires conversion of the costs of the project into present values. The cost of the project includes the cost of construction and the change in maintenance expenses that are incurred on the section as a result of the improvement, with adjustments for any residual or scrap value of the project at the end of the 30 year period. The total construction cost is estimated to be $1,000,000 and will be incurred at the inception of the project. Annual maintenance costs are anticipated to be $2,000 less after the improvement because the elimination of the curve reduces pavement and guard rail damage. The project is likely to have a residual value of roughly $300,000 in the 30th year of the project. Again using a discount rate of 10% the stream of annual maintenance savings is converted to present value. The present value of the residual value in the 30th years is also calculated. The conversion of all costs to present value is summarized in Table 5.

Table 4

USER BENEFIT CALCULATIONS

Section	Year	Period	365 x hours per day in period	x $(HU_0 - HU_1)$	x $(V_0+V_1)/2$	= Annual Benefit
ab	1	typ.hr.	365 x 18	x (24.4-16.3)	x (1.9+2.0)/2	= $103,773
ab	11	typ.hr.	365 x 18	x (25.1-18.5)	x (3.0+3.1)/2	= $132,254

Table 5

CALCULATION OF PRESENT VALUE

	Item		Present Value
1.	Construction costs		$1,000,000
2.	Changes in annual maintenance expenditures	- $ 2,000 x 9.43	= -18,854
3.	Residual value in 30 years	- $300,000 x .057	= -17,193
	Present value of all costs		$963,953

The net present value of the project is the difference between the present value of benefits and the present value of costs:

Net present value = present value of benefits - present value of costs

= $2,490,552 - $963,953

= $1,526,599

The net present value of $1,526,599 indicates that the project is economically feasible. The benefit/cost ratio can also be derived as $2.49 million ÷ $.96 million or 2.6, for comparison with alternative highway projects. Before a decision is made to implement the project, the decision maker should also investigate any significant community benefits or costs such as air and noise pollution that may be associated with this project.

Example 2: Intersection Delay and Accident Costs

A four-leg intersection under study has two lanes of traffic in each direction, undivided, on each leg. At present, stop signs exist on the cross street (the street with the lower level of traffic). Due to high traffic levels on the main street(the more heavily travelled street) cross street traffic experiences excessive delays during peak periods. In addition, the intersection is considered dangerous due to its high rate of accidents.

One proposal to alleviate this situation is to install traffic signals at the intersection. Analysis of this proposal involves the calculation and comparison of intersection delay and accident costs for the existing (alternative 0) and the proposed (alternative 1) situation.

Intersection Delay Costs

Under the present situation, it is assumed that traffic on the main street- -designated AB- -experiences no delay, while traffic on the cross street- -designated CD- -experiences delay due to the existence of stop signs and interference with traffic on the main street. Since this delay is significantly different from peak to off-peak periods, the analysis will be conducted in terms of representative peak and off-peak hourly traffic.

Table 6 presents estimates of representative peak and off-peak period one-way hourly traffic flow for intersection approaches AB and CD for analysis years l and 15. It is assumed that the proposed installation of a traffic signal will not affect these predictions. Trucks are assumed to be a negligible portion of the traffic. The duration of the peak and off-peak periods in each direction is assumed to be 3 and 15 hours, respectively. Symmetric traffic flows are also assumed such that the peak flow in one direction is opposed by the off-peak flow in the opposite direction during the morning peak, and vice-versa during the afternoon peak. During the rest of the day, traffic flows at the off-peak level.

Table 6

TRAFFIC DATA

Approach Section	Analysis Year	Period	One-Way Hourly Volume (000)
AB	1	Peak	1.20
AB	1	Off-Peak	0.50
AB	15	Peak	2.40
AB	15	Off-Peak	1.00
CD	1	Peak	0.50
CD	1	Off-Peak	0.10
CD	15	Peak	1.00
CD	15	Off-Peak	0.20

Table 7 summarizes the calculations for intersection delay costs (D) associated with alternative 0, that is, those costs associated with stopping at the stop signs. Note the relatively large estimated per vehicle delays- -due mostly to interference with traffic on the main street- -during the peak periods. Stopping costs are derived from Figure 8, under the assumption that all vehicles stop at the stop sign (average stops per vehicle = 1.0 in the lower left-hand chart of Figure 8. An approach speed of 40 mph is assumed throughout the analysis.

Idling costs are derived by entering the upper left-hand chart of Figure 9, with average delay per vehicle. Stopping and idling time costs are derived by multiplying stopping and idling times derived from these figures by an assumed value of time of $1.00 per vehicle hour. This value is assumed throughout the anlysis.

To illustrate the individual calculations for deriving the above results, consider the peak period in year 1. Entering Figure 8 along the upper edge of the charts (average stops per vehicle = 1.0) and assuming an approach speed of 40 mph results in an added stopping delay of about 4.4 hours per thousand vehicles and an added stopping cost of about $21 per thousand vehicles. The time delay of 4.4 hours multiplied by a unit time value of $1 results in a time cost of $4.4 per thousand vehicles. This added to added stopping cost of $21 results in a total stopping cost of $25.40 per thousand vehicles. Note that since the approach speed is assumed the same for all situations, stopping costs are also the same. Entering Figure 9 with an average delay of 30 seconds per vehicle results in an idling time of about 8.3 hours per thousand vehicles and an added cost of about $2.6 per thousand vehicles. Total idling cost assuming a $1 unit value of time is $10.90.

Table 7

INTERSECTION DELAY COSTS FOR ALTERNATIVE 0

Year	Period	Average Delay Per Vehicle (Seconds)	Dollars per Thousand Vehicles			
			Stopping Costs (Figure 8)	+ Idling Costs (Figure 9)	=	Intersection Delay Costs (D)
1	Peak	30	$25.40	+ $10.90	=	$36.30
1	Off-Peak	15	25.40	+ 5.50	=	30.90
15	Peak	45	25.40	+ 16.40	=	41.80
15	Off-Peak	25	25.40	+ 9.20	=	34.60

Table 8 summarizes the derivation of unit intersection delay costs (D) associated with the proposed installation of a traffic signal. Assumed traffic and signalization parameters are noted in the upper portion of the table while factors derived from Figures 8 and 9 are noted in the lower half. Note that approaches AB and CD must be analyzed separately due to different traffic and signalization parameters associated with each of them. It is only necessary, however, to analyze these approaches in one direction of travel due to the simplifying assumption of symmetric traffic flows over the day. Note also that in year 15 traffic on approach AB reaches a saturation degree of 1.0 during the peak period, implying an average delay equal to the signal cycle time and resulting in a relatively large unit intersection delay cost. This condition indicates the beginning of significant congestion at the intersection.

Table 9 summarizes unit user benefit calculations associated with the proposed improvement for each approach, analysis period, and analysis year assuming that intersection delay costs are the only elements of user cost involved. The values used for D in this table are the corresponding values found in Tables 7 and 8. Note that it is not necessary to average traffic volumes in the benefits formula since such volumes are the same for both the existing (alternative 0) and the proposed (alternative 1) situations. Note also that for approach AB, intersection delay costs are assumed to equal zero since the only relevant delay on that approach would be due in the proposed improvement.

From Table 9 it appears that, although positive benefits (intersection delay savings) would accrue to traffic on approach CD as a result of installing a traffic signal, a net increase in costs, or negative benefits, would accrue to all affected highway users taken as a group. In fact, with total "benefits" in year 1 of -$96,688 (twice one-way annual benefits) and -$469,158 in year 15, and assuming a discount rate of 10% and an analysis period of 20 years we find, using Figure 7, that total net present value related to intersection delay is

-$96,688 x 22.8 (factor from Figure 7) = -$2,204,486.

It is therefore necessary to determine whether potential accident savings are sufficient to offset the negative benefits of increased overall intersection delay.

Table 8

INTERSECTION DELAY COSTS--ALTERNATIVE 1

	Approach: AB				Approach: CD			
	Year 1		Year 15		Year 1		Year 15	
	Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak
1. Volume, veh/hr	1,200	500	2,400	1,000	500	100	1,000	200
2. Saturation Flow, veh/hr	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600
3. Effective Signal Green Time, sec	60	30	60	30	30	30	30	30
4. Signal Cycle Time, sec	90	60	90	60	90	60	90	60
5. Green/Cycle Time Ratio (line 3/line 4)	0.67	0.50	0.67	0.50	0.33	0.50	0.33	0.50
6. Capacity of Approach, veh/hr (line 2 x line 5)	2,400	1,800	2,400	1,800	1,200	1,800	1,200	1,800
7. Degree of Saturation (line 1/line 6)	0.50	0.28	1.00	0.56	0.42	0.06	0.83	0.11
8. Approach Speed, mph	40	40	40	40	40	40	40	40
9. Added Stopping Time, hptv (from Fig. 8)	2.2	2.6	4.4	3.0	3.6	2.2	4.0	2.3
10. Stopping Time Cost, $ptv (unit VOT = $1)	$2.20	$2.60	$4.40	$3.00	$3.60	$2.20	$4.00	$2.30
11. Added Stopping Cost, $ptv (from Fig. 8)	$10.50	$12.20	$21.00	$14.50	$17.00	$10.50	$18.90	$11.10
12. Idling Time, hptv (from Fig. 9)	1.8	2.2	25.0	2.5	4.1	2.0	6.1	2.0
13. Idling Time Cost, $ptv (unit VOT = $1)	$1.80	$2.20	$25.00	$2.50	$4.10	$2.00	$6.10	$2.00
14. Idling Vehicle Cost, $ptv (Fig. 9)	$0.50	$0.70	$7.82	$0.80	$1.30	$0.60	$1.90	$0.60
15. Intersection Delay Cost (D), $ptv (lines 10 + 11 + 13 + 14)	$15.00	$17.70	$58.22	$20.80	$26.00	$15.30	$30.90	$16.00

Table 9

USER BENEFIT CALCULATIONS

Approach Section	Year	Period	365 x Per Day x $(D_o - D_1)$ x V^* =	One-Way Annual Benefits
AB	1	Peak	365 x 3 x (0-15.00) x 1.2 =	$-19,710
AB	1	Off-Peak	365 x 15 x (0-17.70) x 0.5 =	-48,454
CD	1	Peak	365 x 3 x (36.30-26.00) x 0.5 =	11,279
CD	1	Off-Peak	365 x 15 x (30.90-15.30) x 0.1 =	8,541
			Total One-Way Annual Benefits - Yr 1 =	$-48,344
AB	15	Peak	365 x 3 x (0-58.22) x 2.4 =	-153,002
AB	15	Off-Peak	365 x 15 x (0-20.80) x 1.0 =	-113,880
CD	15	Peak	365 x 3 x (41.80-30.90) x 1.0 =	11,936
CD	15	Off-Peak	365 x 15 x (34.60-16.00) x 0.2 =	20,367
			Total One-Way Annual Benefits -Yr 15 =	$-234,579

*Instead of $\frac{V_0 + V_1}{2}$, since the level of traffic is not affected by the improvement

Accident Costs

Over the past several years, an average of twenty accidents occured at the intersection under study. Included, on the average, have been 1.5 fatal accidents per year (two every three years), 4 injury accidents per year, and 14.5 property damage accidents per year. It is postulated that although the number of accidents will not change with the installation of traffic signals, the number of fatal accidents would be reduced to zero.* Table 10 summarizes the postulated accident distribution for alternatives 0 and 1 and calculates the net benefits assumed in year 1 using accident costs for urban areas as follows: $82,000 per fatal accident, $3,400 per injury and $480 per property damage accident. Since intersection accident estimates are expressed annually and are not directly related to vehicle miles, it is not necessary to perform calculations on a per vehicle mile basis and annualized calculations can be made directly.

Table 10

ACCIDENT COST CALCULATIONS - YEAR 1

	Number Per Year			Cost/Accident	Net Annual Benefit Per Year
	Alt. 0	Alt. 1	Net Change		
Fatal Accidents	1.5	0	1.5	$82,000.	$123,000.
Injury Accidents	4.0	5.0	-1.0	3,400.	-3,400.
P.D.O. Accidents	14.5	15.0	-0.5	480.	-240.
Total	20.0	20.0	0		$119,360.

Based on the assumption that the number and severity of accidents is proportional to the amount of traffic, it is assumed that potential accident savings would double by year 15 to $238,720. per year. Using a discount rate of 10%, an analysis period of 20 years, and a ratio of benefits of 2.0, Figure 7 indicates a present worth factor of 12.6 which yields a net present value of accident savings of

$$\$119,360 \times 12.6 = \$1,503,936.$$

Conclusion

Comparing net present value of added intersection delay costs with the present value of accident savings results in a net present value of user benefits for the proposal of

$$-\$2,204,486 + 1,503,936 = \$-700,550.^{**}$$

*Some evidence exists that installation of traffic signals tends, in certain instances, to increase the number of accidents at an intersection, but also tends to reduce fatalities. In addition, the relative percent of fatal accidents indicated in this example is much larger than most data would indicate. This assumption is included in this example, however, to illustrate concepts rather than to reflect reality.

**Note that Figure 7 could not have been used to develop this value directly from the ratio of net present values in each analysis year for both intersection delay and accident savings since in year 1 the corresponding value would be positive ($-98,688 + $119,360) while in year 15 the value would be negative ($-469,158 + $238,720).

Taken literally, this implies the project is not economically feasible. The result would be even more negative if, as should be, the costs associated with the traffic signal and its installation were included. The proposed traffic signal installation would have to be justified, where appropriate, based on other factors.

Example Problem 3: Stage Construction

A two mile section of highway on the perimeter of a rapidly growing urban area is being considered for upgrading to urban freeway standards.

Characteristics of the existing facility (Alternate 0) and the proposed facility (Alternates 1 & 2) are given in Table 11 below. It should be noted that the proposed faciltiy will have five lanes each direction.

Table 11

BASIC SECTION DATA

Alternate	Section	Length (Miles)	Lanes (One-Way)	Grade (%)	Curvature (°)	Design Speed (MPH)
0	(do nothing)	2	2	0	0	60
1 & 2	a (add main-lanes)	2	3	0	0	70
	b (add front-age road)	2	2	0	0	50

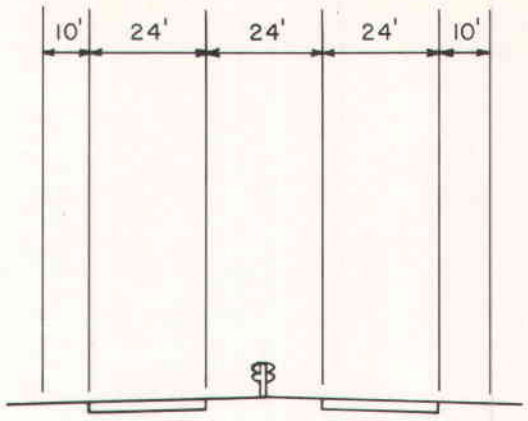
Next, traffic data should be obtained and displayed in tabular form for the particular alternates being considered.

These traffic and facility data enable calculation of user costs on the existing route and the proposed route, as in Table 13. Unit highway user costs (HU) are calculated from the Formula a: $HU = (B+A) \times L + T+D$; using basic section costs (B), section length (L), and transition costs (T). Intersection delay costs, (D) are not relevant in this example. Accident costs (A) are not considered in this example, but if accident rates were known and changes in accidents were discernible as a result of this improvement, their unit cost would be added to B before multiplication by L. The numbers for B and T are derived from Figures 3 and 6 using the facility and traffic data in Tables 11 and 12. A unit value of time of $3 per hour per vehicle is assumed.

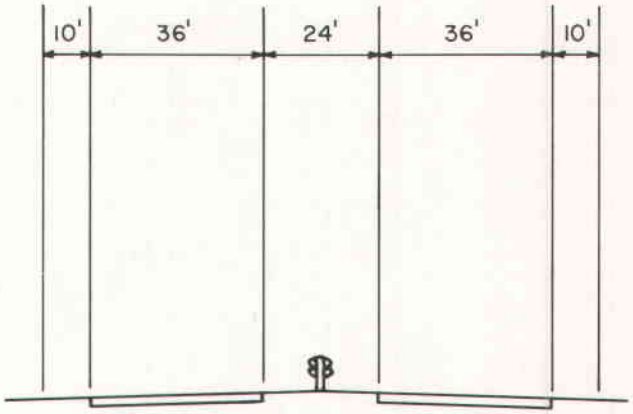
Further discussion of calculating HU may be found in Example Problem 1.

Benefits in the representative first, eleventh and twenty-first years can be calculated for the user cost estimates in Table 14 by applying the formula: User Benefits $= (U_0 - U_1)\frac{(V_0+V_1)}{2}$ as demonstrated in the following table.

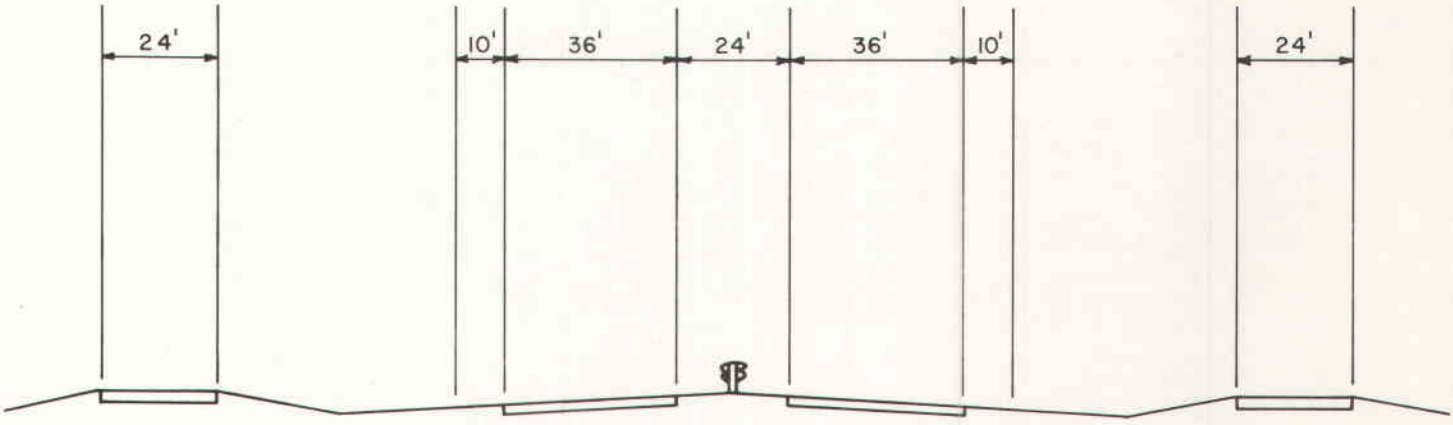
STAGE CONSTRUCTION SEQUENCE



EXISTING



PROPOSED (STAGE 1)



PROPOSED ULTIMATE (STAGE 1&2)

Table 12

TRAFFIC DATA

Alternate	Section	Analysis Year	Period	One-Way Volume (1000 Veh)	One-Way Capacity (1000 Veh)	v/c	Speed (MPH)	Speed on Previous Section (MPH)	Speed on Next Section (MPH)
0		1	typ. hr.	2.2	3.4	.65	38	60	50
0		11	typ. hr.	4.4	3.4	(Los F)	20	55	45
0		21	typ. hr.	6.7	3.4	(Los F)	20	50	40
Stage Construction Alternate Stage 1:									
1	a	1	typ. hr.	2.2	5.1	.43	51	60	50
1	a	11	typ. hr.	4.4	5.1	.86	39	55	45
Stage 2:									
1	a'	11	typ. hr.	3.4	5.1	.67	48	55	45
1	b	11	typ. hr.	1.0	3.4	.30	39	45	--
1	a'	21	typ. hr.	5.0	5.1	.98	34	50	40
1	b	21	typ. hr.	1.7	3.4	.50	36	40	--
Ultimate Facility Alternate									
2	a	1	typ. hr.	1.7	5.1	.33	56	60	50
2	b	1	typ. hr.	.5	3.4	.15	42	45	--
2	a	21	typ. hr.	5.0	5.1	.98	34	50	40
2	b	21	typ. hr.	1.7	3.4	.50	36	40	--
Average running speed is found as a function of v/c ratio using Figure 1 or 2.									

Table 13

CALCULATION OF USER COST (HU)

Alternate - Section	Year	Period	(B x L) + T = HU/1000 Veh.
0	1	typ. hr.	(160 x 2) + 6.4 = 326.4
0	11	typ. hr.	(235 x 2) + 14.0 = 484.0
0	21	typ. hr.	(235 x 2) + 11.1 = 481.1
Stage Construction Alternate Stage 1:			
1_a	1	typ. hr.	(134.5 x 2) + 1.5 = 270.5
1_a	11	typ. hr.	(154.0 x 2) + 3.9 = 311.9
Stage 2:			
$1_a'$	11	typ. hr.	(140.0 x 2) + 0.8 = 280.8
1_b,	11	typ. hr.	(151.0 x 2) + 0.9 = 302.9
1_a	21	typ. hr.	(161.1 x 2) + 3.9 = 326.1
1_b	21	typ. hr.	(158.0 x 2) + 0.5 = 316.5
Ultimate Facility Alternate			
2_a	1	typ. hr.	(129.5 x 2) + 1.2 = 260.2
2_b	1	typ. hr.	(145.0 x 2) + 0.4 = 290.4
2_a	21	typ. hr.	(161.1 x 2) + 3.9 = 326.1
2_b	21	typ. hr.	(158.0 x 2) + 0.5 = 316.5

Table 14

ANNUAL USER BENEFIT CALCULATIONS

Section	Year	Period	365 x Hrs per day in typ. period x $(HU_o - HU_1)$ x $\frac{(V_o + V_1)}{2}$ = Annual Benefit
Stage Construction Alternate: Stage 1:			
a vs 0	1	typ. hr.	365 x 18 x (326.4)-270.5) x 2.2 = 807,979.
a vs 0	11	typ. hr.	(6570) x (484.0-311.9) x 4.4 = 4,975,067.
Stage 2:			
a'b vs 0	11	typ. hr.	(6570) x (484.0 x 4.4)-(280.8 x 3.4)-(302.9 x 1.0) = 5,613,408.
a'b vs 0	21	typ. hr.	(6570) x (481.1 x 6.7)-(326.1 x 5.0)-(316.5 x 1.7) = 6,924,780.
Ultimate Construction Alternate:			
ab vs 0	1	typ. hr.	(6570) (326.4 x 2.2)-(260.2 x 1.7)-(290.4 x .5) = 858,042.
ab vs 0	21	typ. hr.	(6570) (481.1 x 6.7)-(326.1 x 5.0)-(316.5 x 1.7) = 6,924,780.

Having determined the benefits for the representative years, present value can be calculated for all benefits by the use of Figure 7, as follows in Table 15.

The reader is referred to Example Problem 1 and the text associated with Figure 7 for detailed discussion of the process invloved.

The net present value of the project is the difference between the present value of benefits and the present value of costs.

Observations and Recommendations:

It is obvious, from traffic demand within this corridor, that the existing facility will have to be upgraded. From the above economic comparison, it is found that stage construction will provide the most cost efficient means to provide the necessary additional capacity, and would be the recommended alternate.

Table 15

CALCULATION OF PRESENT VALUE (PV)

Alternate 1:

Stage 1: $\frac{4,975,067}{807,979} = 6.16 \quad 6.2$ Assume: Discount Rate = 10%

Y = 10

n = 10

Find f: f = 15.5

$PV = (807,979)(15.5) = 12,523,675.$

Stage 2: $\frac{6,924,780}{5,613,408} = 1.23 = 1.2$ Assume: Discount Rate = 10%

Y = 10

n = 10

Find f: f = 7

$PV_{11} = (5,613,408)(7) = 39,293,856.$

$PV_1 = PV_{11} \left(\frac{1}{(1 + i)}\right)$

$= 39,293,856 \left(\frac{1}{(1 + .1)}10\right) = 15,128,135.$

Total PV for Alternate 1 = 12,523,675 + 15,128,135 = 27,651,810

Alternate 2:

$\frac{6,924,780}{858,042} = 8.07 - 8.1$ Assume: Discount Rate = 10%

Y = 20

n = 20

Find f: f = 19

$PV = (858,042)(19) = 16,302,798.$

Table 16

DETERMINATION OF NET PRESENT VALUE (NPV)

Alternate 1: Stage Construction

PV (Benefits) = $27,651,810.

PV (Costs) = $ 5,000,000 (Initial Construction)

$ 1,400,000 (In Year 11)

PV (Cost in 11th Year) = $ 1,400,000 $\left(\frac{1}{(1+i)^n}\right)$

= $ 1,400,000

= $ 539,000

PV (Costs) = $ 5,000,000 + $ 539,000

= $ 5,539,000

PV(Benefits) - PV (Costs)

NPV (Alt. 1) = $27,651,810 - $5,539,000

= $22,112,810

Alternate 2: Ultimate Construction Initially

PV (Benefits) = $16,302,798

PV (Costs) = $ 6,400,000

NPV (Alt. 2) = $16,302,798 - $6,400,000

= $ 9,902,798

In terms of Benefit to Cost Ratio:

Alternate 1: $B/c = \frac{27,651,810}{5,539,000} = 4.99$ say 5.0

Alternate 2: $B/c = \frac{16,302,798}{6,400,000} = 2.54$ say 2.5

E-106 ABBREVIATED PROCEDURE FOR APPLICATION OF ECONOMIC ANALYSIS FOR MINOR IMPROVEMENTS

At times the analyst will be faced with one to one design choices which can readily be based on travel of small portion of the total traffic stream. In such cases use of the preceding nomographs may be somewhat cumberson. It is for this reason the charts in Figures 11 and 12 were developed.

This method is based on the format previously used for justification documentation submitted to the Federal Highway Administration with some updating.

In Figure 11, "Extra Cost Per Vehicle Stop Above That for Constant Speed Operation", the cost associated with travel delay to the operator can be found. This chart differs from those in Figures 8 and 9 in that operating cost of the vehicle is not included. This feature can be found in Figure 12 as a constant speed cost.

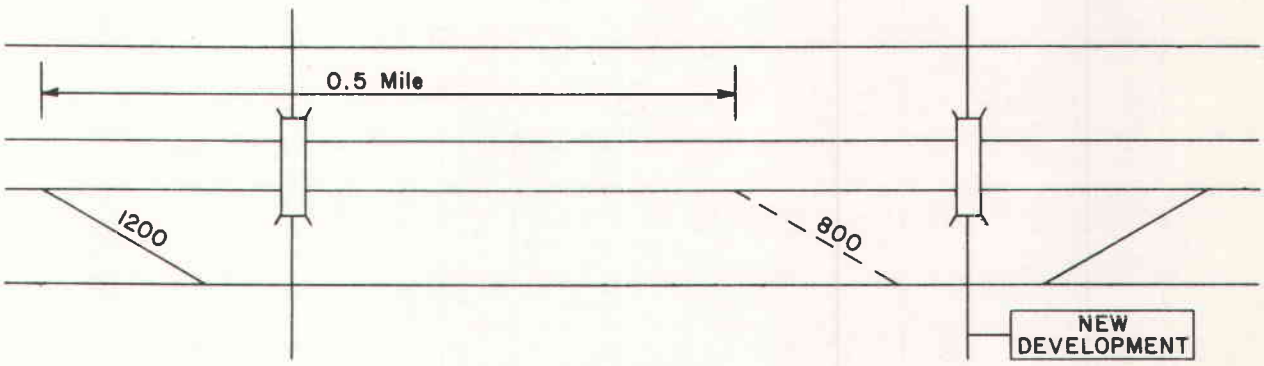
The error involved in such simplification is minor, especially when applied to low volume movements.

Example Problems Using Abbreviated Method:

In some cases, user benefits can be reduced to the difference in operating costs associated with traveling alternate types of facilities. Examples of this follow.

Example Problem 4: Ramp Location:

A ramp is requested by a city to more directly serve new development as indicated in the sketch.



This problem reduces to simply the difference in operating cost on the mainlanes versus the operating cost on the frontage road for the ramp traffic destine to the new development.

Two cases will be shown in this problem: Case 1 for urban application, and Case 2 for rural application. For Case 1, it is assumed that the mainlanes will have an average highway speed (AHS) of 50 MPH, and the frontage roads will have an AHS of 35 MPH. From Figure 12 it is found that a cost of $.158 per vehicle mile to travel the frontage road and a cost of $.136 per vehicle mile to travel the main lane.

Also, assuming each vehicle will have to stop once, and be delayed twenty seconds, from Figure 11 it is found that an additional cost of $.03 per vehicle.

Determination of the benefit-to-cost ratio for the proposed revision is shown in the following table.

ROAD USER COSTS		
RURAL APPLICATION		
TRAFFIC	WITHOUT RAMPS	WITH RAMPS
800 VPD	___ Mi. Interstate @ = $____	0.5 Mi. Interstate @ 1.35 = $54.00
	0.5 Mi. Paved @ .141 = $56.40	___ Mi. Paved @ = $____
	___ Mi. Non-Paved @ = $____	___ Mi. Non-Paved @ = $____
1	1 Stops @ 0.02 = $16.00	___ Stops @ 0.02 = $____
	(WOR) Total Per Day = $ 72.40	(WR) Total Per Day = $ 54.00
NET DAILY ROAD USER BENEFIT (WOR) - (WR) = $ 18.40		
NET ANNUAL ROAD USER BENEFIT 18.40 x 365 = $6,716 = (B)		
BENEFIT COST RATIO (1.0 MINIMUM REQUIRED)		
NET ANNUAL ROAD USER BENEFITS / ADDED ANNUAL COSTS	B = 10% (R/C)	6,716 = $ 3,000 = 2.258
REMARKS: R = ROW Cost = $0 for this case		
C = Construction Cost = $30,000		

For Case 2 the same general conditions are assumed, except AHS for main-lanes is assumed to be 55 MPH, and 45 MPH for the frontage road. Also, no standing delay is assumed at the stop.

Determination of the benefit-to-cost ratio is shown in the following table.

ROAD USER COSTS		
URBAN APPLICATION		
TRAFFIC	WITHOUT RAMPS	WITH RAMPS
800 VPD	___ Mi. Interstate @ = $____	0.5 Mi. Interstate @ .136 = $54.40
	0.5 Mi. Paved @ .158 = $63.20	___ Mi. Paved @ = $____
	___ Mi. Non-Paved @ = $____	___ Mi. Non-Paved @ = $____
1	1 Stops @ 0.03 = $24.00	___ Stops @ 0.02 = $____
	(WOR) Total Per Day = $ 87.20	(WR) Total Per Day = $ 54.40
NET DAILY ROAD USER BENEFIT (WOR) - (WR) = $ 32.80		
NET ANNUAL ROAD USER BENEFIT 32.80 x 365 = $11,972 = (B)		
BENEFIT COST RATIO (1.0 MINIMUM REQUIRED)		
NET ANNUAL ROAD USER BENEFITS / ADDED ANNUAL COSTS	B = 10% (R/C)	11,972 = 4,000 = 2.99
REMARKS: R = ROW Cost = $0		
C = Construction Cost = $40,000		
Operating costs are determined from Figure 12 by entering from bottom with Average highway speed (AHS).		

Since benefit-to-cost ratio is greater than 1.0, construction of the ramp is justified from an economic standpoint.

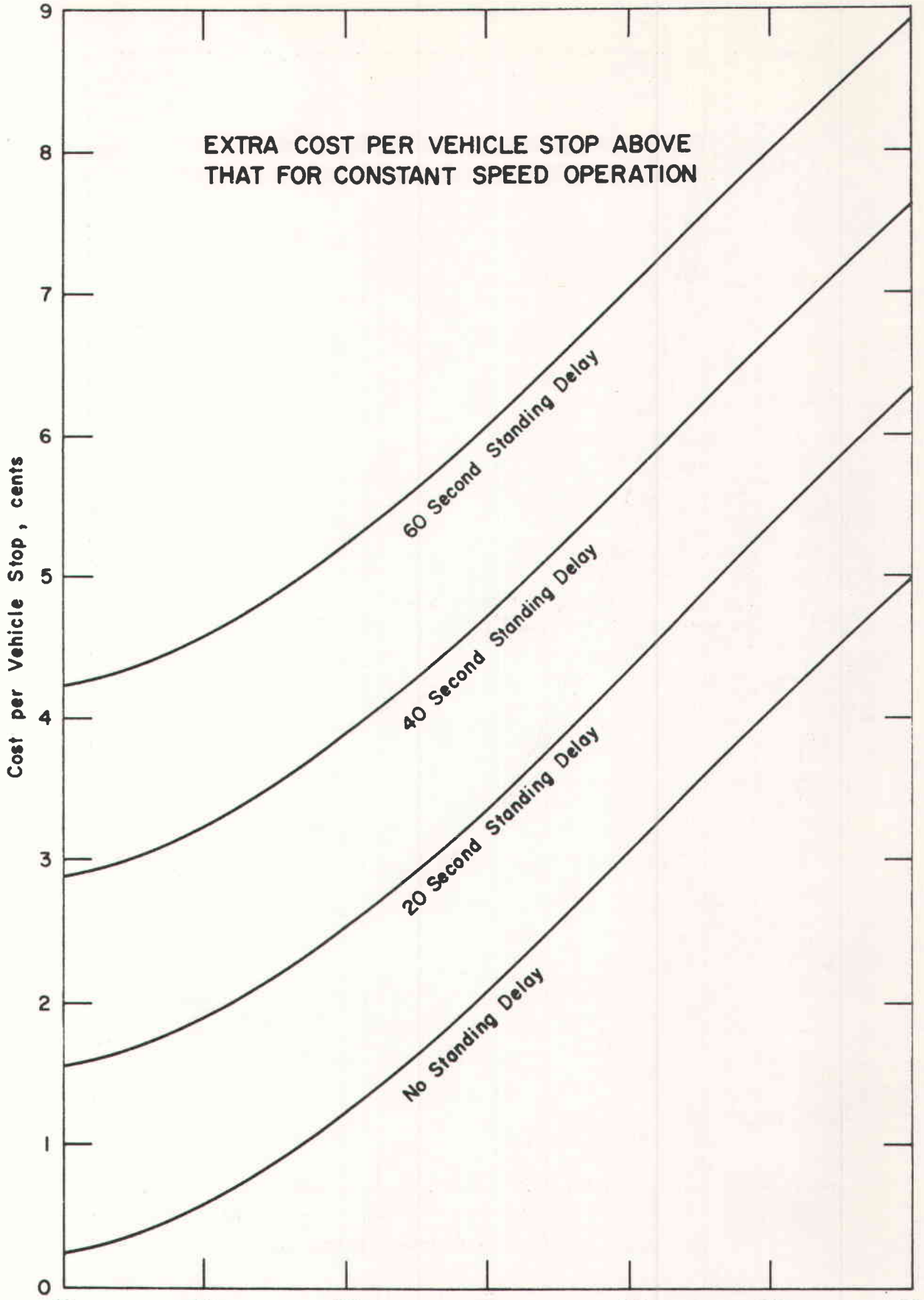

EXTRA COST PER VEHICLE STOP ABOVE
THAT FOR CONSTANT SPEED OPERATION
60 Second Standing Delay
40 Second Standing Delay
20 Second Standing Delay
No Standing Delay
Cost per Vehicle Stop, cents
Approach Speed, mph
0
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70

FIGURE 11

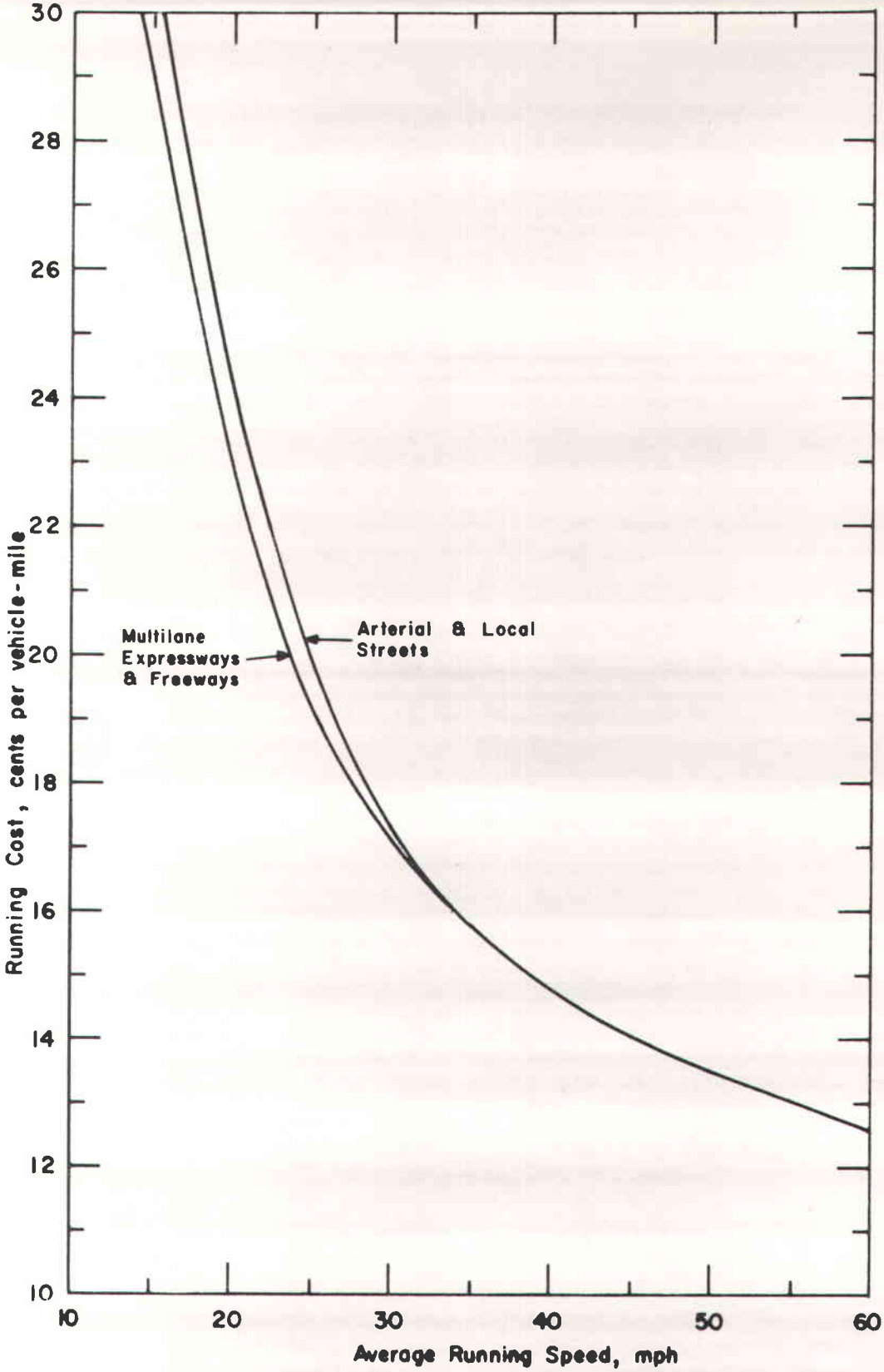
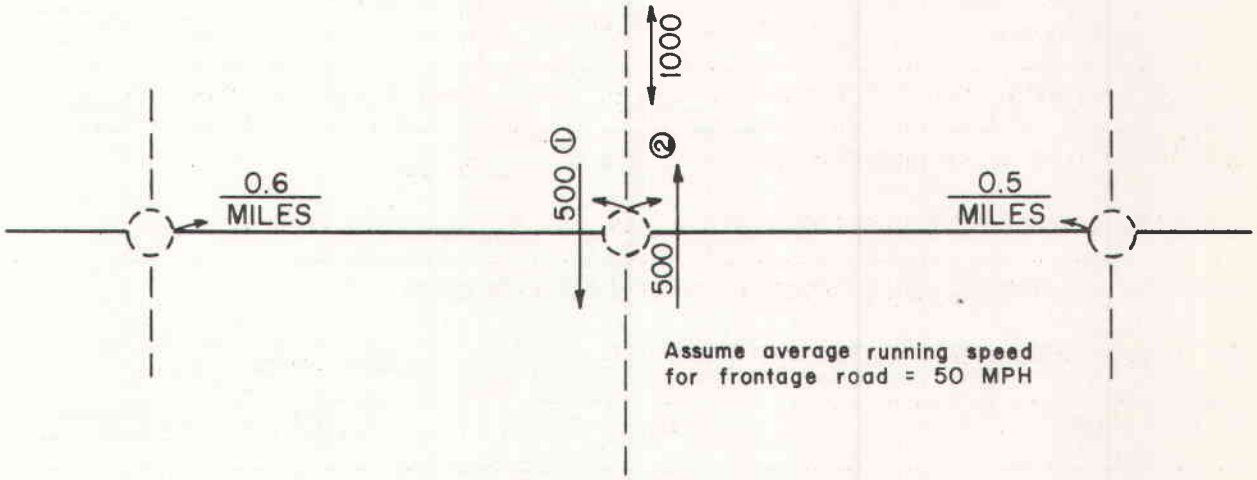

30
28
26
24
22
20
18
16
14
12
10
Running Cost, cents per vehicle-mile
Multilane
Expressways
& Freeways
Arterial & Local
Streets
10
20
30
40
50
60
Average Running Speed, mph

FIGURE 12

Example Problem 5: Grade Separation:

In a rural location considerable demand has been generated to cross a controlled access facility. Without a grade separation, traffic would be forced to travel 0.5 mile one-way to the nearest grade separation to cross the facility.

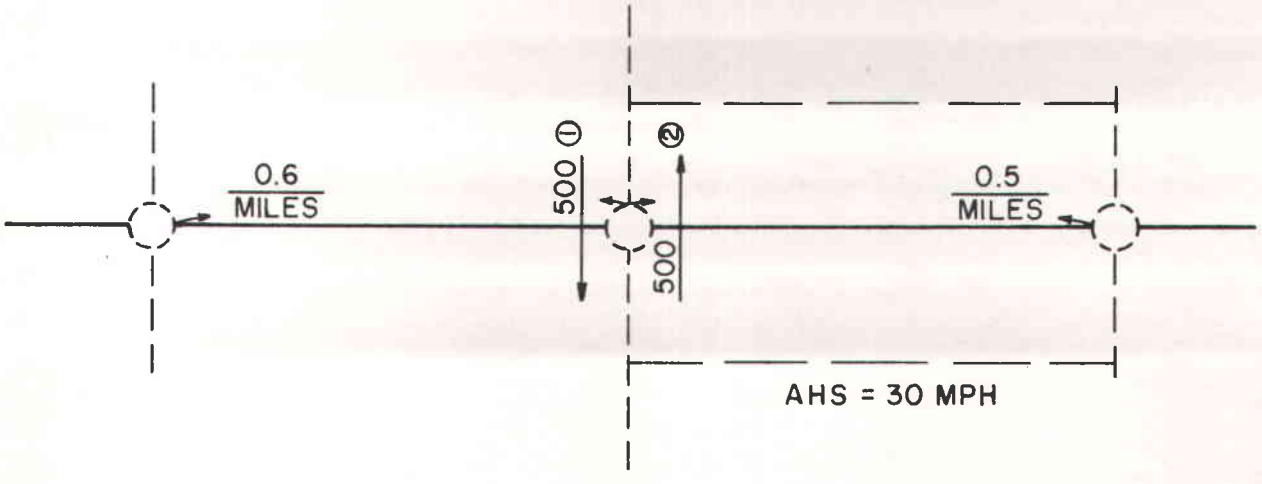


The problem reduces to the cost involved in traveling the additional distance. Average highway speed of 50 MPH is assumed for travel on the frontage road and no standing delay is involved in stopping.

Determination of the benefit-to-cost ratio for the proposed improvement is shown in the following table.

ROAD USER COSTS		
TRAFFIC	WITHOUR GRADE SEPARATION	WITH GRADE SEPARATION
500 VPD	____Mi. Interstate @ = $____ 1.0 Mi. Paved @ .135 = $67.50 ____Mi. Non-Paved @ = $____	____Mi. Interstate @ = $____ ____Mi. Paved @ = $____ ____Mi. Non-Paved @ = $____
1	2 Stops @ 0.02 = $10.00	____Stops @ 0.02 = $____
500 VPD	____Mi. Interstate @ = $____ 1.0 Mi. Paved @ .135 = $67.50 ____Mi. Non-Paved @ = $____	____Mi. Interstate @ = $____ ____Mi. Paved @ = $____ ____Mi. Non-Paved @ = $____
2	2 Stops @ 0.02 = $10.00	____Stops @ 0.02 = $____
	(WOGS) Total Per Day = $ 155.00	(WGS) Total Per Day = $_____
NET DAILY ROAD USER BENEFIT (WOGS) - (WGS) = $ 155.00		
NET ANNUAL ROAD USER BENEFIT $155. x 365 = $_____ = (B)		
BENEFIT COST RATIO (1.0 MINIMUM REQUIRED)		
NET ANNUAL ROAD USER BENEFITS / ADDED ANNUAL COSTS = B / 10% (R/C) = 56,575.00 / 25,000 = 2.26		
REMARKS: R = ROW Cost = $50,000. C = Construction Cost = $200,000.		

For the same problem as above except travel to the nearest grade separation must be accomplished on gravel roads between the recently developed facility and an existing facility. Determination of the benefit-to-cost ratio for this case is shown in the following table.



ROAD USER COSTS		
TRAFFIC	WITHOUT GRADE SEPARATION	WITH GRADE SEPARATION
500 VPD 1	___ Mi. Interstate @ = $_____ ___ Mi. Paved @ = $_____ 1.0 Mi. Non-Paved @ .227 = $113.50 2 Stops @ 0.02 = $ 10.00	___ Mi. Interstate @ = $_____ ___ Mi. Paved @ = $_____ ___ Mi. Non-Paved @ = $_____ ___ Stops @ 0.02 = $_____
500 VPD 2	___ Mi. Interstate @ = $_____ ___ Mi. Paved @ = $_____ 1.0 Mi. Non-Paved @ .227 = $113.50 2 Stops @ 0.02 = $ 10.00	___ Mi. Interstate @ = $_____ ___ Mi. Paved @ = $_____ ___ Mi. Non-Paved @ = $_____ ___ Stops @ 0.02 = $_____
(WOGS) Total Per Day = $ 247.00		(WGS) Total Per Day = $_____

NET DAILY ROAD USER BENEFIT (WOGS) - (WGS)= $ 247.00

NET ANNUAL ROAD USER BENEFIT 247.00 x 365 = $ 90,155 = (B)

BENEFIT COST RATIO (1.0 MINIMUM REQUIRED)

$$\frac{\text{NET ANNUAL ROAD USER BENEFITS}}{\text{ADDED ANNUAL COSTS}} = \frac{A + B}{10\% \quad (R/C)} = \frac{90{,}155}{25{,}000} = 3.61$$

REMARKS: Cost to travel on paved road = $.172/mile

conversion factor to covert to gravel surface = 1.32

Cost to travel gravel road = ($.172)(1.32) = $.227

R = ROW Cost = $50,000

C = Construction Cost = $200,000

In both of the above cases, the benefit-to-cost ratio is greater than 1.0, thereby indicating that the proposed expenditure would be cost effective.

The above problem could be expanded to consider two or more possible locations for grade separations.

REFERENCES

1. Andersen, D. G., Curry, D. A. and Pozdena, R. J., "User Benefit Analysis for Highway and Bus Transit Improvements", Stanford Research Institute, Project 3334 (June 1975).

2. American Association of State Highway Officials, Road User Benefit Analysis for Highway Improvements, Washington, D. C. (1960) 152 pp (The Red Book).

3. Winfrey, R. and Zellner, C. "Summary and Evaluation of Economic Consequences of Highway Improvements", NCHRP Report 122 (1971) 324 pp.

4. Winfrey, R., Economic Analysis for Highways, International Textbook company (1969), 923 pp.

5. "Highway Capacity Manual - 1965" HRB Special Report 87 (1965) 418 pp.

6. Curry, D. A. and Andersen, D. G. "Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects", NCHRP Report 133 (1972) 127 pp.

APPENDIX F-100

RIGID PAVEMENT STRUCTURES (F-100)

F-101 INTRODUCTION

"Rigid pavement" as used in this Appendix includes all pavement structures that contain portland cement concrete. This section discusses design traffic and wheel loads, materials evaluation, selection of thicknesses, subbases, shoulders, reinforcement, joints, and terminal treatment.

F-102 CONSIDERATIONS FOR SELECTION OF CONCRETE PAVEMENT

The selection of the type of pavement to be constructed should be based on economic and safety considerations for the design life of the pavement. Traditionally, portland cement concrete pavement has been more expensive initially than bituminous pavements. However, because of its strength, durability and resistance to damage from wheel loads and the environment it requires less maintenance over a longer period of time. The greater increase in the cost of asphalt and the use of greater thickness of asphaltic layers have produced pavements that approach the cost of portland cement concrete pavements. The increased thickness has also improved the reliability of bituminous pavement. The factors that affect economics vary throughout the State and the conditions that influence maintenance strategies are different for different locations. It is, therefore, difficult to establish explicit guidelines for pavement type selection. A general statement can be made that the more expensive and more reliable pavement types should be used on high-volume, high-load carrying arteries where maintenance is difficult and the consequences of failure are severe.

F-103 PORTLAND CEMENT CONCRETE PAVEMENT TYPES

(a) Continuously Reinforced. When properly designed and constructed, CRCP provides good riding characteristics with less required maintenance than any other pavement type. Because of a lack of experience, many early CRCP projects were deficient in design thickness, subbase type and construction techniques. The one factor where experience is still lacking is the influence on performance of thickness. The majority of experience has been limited to pavements of 8-inch thickness or less. However, according to theoretical considerations and our experience with jointed concrete pavements and flexible pavements, we should be able to design the thickness of this pavement type based on projected traffic, subgrade and environmental conditions. Experience to date indicates the thickness of CRCP should be approximately the same as jointed concrete pavement for equivalent wheel loads. Because of the amount of steel required this, generally, will make CRCP the most expensive pavement type. Its selection should be based on the need to provide a high type of pavement with the minimum of maintenance requirements.

(b) Jointed Reinforced. The use of light reinforcement in concrete pavement permits a reduction in the number of transverse joints and keeps tightly closed any cracks that form in the pavement. It has been found that joint spacings longer than about 40 feet usually result in excessive joint movement, thus making joint maintenance extremely difficult. Based on experience and theoretical consideration, it is recommended that transverse joint spacings be 30 feet 6 inches for jointed reinforced concrete. The selection of jointed reinforced concrete pavement should be based on the consideration of the number and difficulty of joints to be maintained or it could be set up as an alternate or Contractor's option to one or more of the other concrete pavement types.

(c) Contraction Design (Plain Concrete).

1. With Load Transfer Devices. This type of pavement provides for 15-foot transverse joint spacing with load transfer devices at the joints. No reinforcing is necessary for these short slabs. There are twice as many joints to maintain as with the reinforced slab, but joint movement should be less because of the shorter slabs. Load transfer is accomplished by the use of dowels or other approved load transfer devices.

2. Without Load Transfer Devices. Where this type of pavement is used without load transfer devices at transverse joints, it is recommended that the thickness be increased by two inches. Considerable success has been achieved with the contraction designed slabs, both with and without dowels at transverse joints, and it is recommended as an alternate or Contractor's option to other concrete pavement designs where maintenance of the joints can be assured.

(d) Skewed Joint. There is no experience with skewed joints design in Texas, but other states have had extensive experience and excellent results with proper designs. Load transfer at joints is achieved by aggregate interlock which depends on short joint spacing to reduce crack width. Skewed joints reduce the effects of wheel loads at joints and the random spacing of joints prevents the objectionable noise effect and vehicle harmonics that can occur with evenly spaced joints. Two additional inches of thickness is recommended to compensate for the absence of load transfer devices, and it is suggested that a well-stabilized subbase be considered until more experience with this pavement type is obtained. It appears that this design would be an attractive alternate or Contractor's option to other concrete pavement types. A recent survey indicated that 16 states are building skewed transverse joints with nine of these designs calling for random spaced joints and no dowels (Ref. 1).

F-104 SWELLING CLAY

It is recommended that concrete pavement not be used in areas of extensive swelling clay subgrades. The changing profile of the swelling clay area invariably results in the need to level up the surface to restore a suitable riding surface - -usually a long time before the structural life of the pavement is expended. In such areas it may be more appropriate to consider a flexible pavement or to use the concrete structure as a base. In this case, serviceability could be restored by overlaying or leveling-up with bituminous surface or by removing the humps with a heater-planer.

In locations where minor swelling clay areas intrude on the otherwise suitable subgrade, or where experience has shown that concrete pavement is the most suitable type, extra precautions may be taken to minimize the effects of the swelling clay. Deep lime stabilization, ponding, dry land farming and delaying paving operations have proven helpful but none of these is a positive cure-all.

Experience has indicated that voids under the pavement created by differential movement contribute to early distress in concrete pavement. Increasing design thickness in these areas would help to reduce wheel load stress and prolong pavement life. Properly sealed joints and the use of concrete shoulders would reduce the amount of water available to cause the differential movement. Positive sealing of the subgrade after obtaining moisture equilibrium and construction of an effective drainage system is another technique which might prove helpful.

F-105 DESIGN TRAFFIC

A traffic analysis similar to the one shown in Figure F-1 should be obtained from D-10. The one direction Equivalent 18 Kip Single Axle Load Application (18KSA) must be multiplied by the lane factor (LF) to determine the number of 18KSA in the design lane. The appropriate LF can be found in Figure F-2.

F-106 SELECTION OF PAVEMENT STRUCTURE

(a) Concrete Slab. Figure F-3 summarizes the maximum allowable 18KSA or Design Wheel Loads for the different slab thicknesses. This figure contains design values for conventional concrete under our present Specifications. If light-weight concrete, high strength concrete, Econocrete or other concrete is used which has properties significantly different from those assumed (shown in Figure F-4), then a special analysis should be made to obtain the design thickness.

References 2, 4, 5, 6 and 7 give a number of sound analysis techniques which can be used in the design of concrete slab thickness. The design thicknesses shown in Figure F-3 are based on a composite of analysis and performance of these pavements in Texas. A recent survey (Refs. 8 and 9) has documented the performance of continuously reinforced concrete pavement and has shown that CRCP pavements have not satisfactorily carried the 18KSA loads that had been predicted. The results of this survey led to the recommendation that CRCP slabs be built to the same thickness required for doweled jointed concrete pavements. It is recommended that jointed slabs without dowels be built two inches thicker to provide a larger safety factor against possible wear-out of aggregate interlock at contraction joints which has been a major problem of under-designed plain concrete slabs.

It is noted that the design thicknesses in Figure F-3 for CRCP slabs and for jointed slabs without dowels have not been given general approval by the Federal Highway Administration. To justify using these designs, a detailed analysis must be submitted in advance of P.S. and E. so that Federal Highway Administration approval may be obtained. A detailed structural analysis may be warranted when special design features require the design slab thickness to be different from values in Figure F-3. The special conditions could be such items as the following:

1. Thickened slab edge
2. Concrete shoulders
3. Monolithic curbs
4. Concrete overlays
5. Material properties different from Figure F-4
6. Change in slab thickness with traffic lane

Upon request, the Roadway Design Section will assist in an analysis of the above or other special conditions. This section has available computer programs for calculating stress and deflection on variable width and thickness slabs and for making economic analyses of construction, maintenance and traffic user costs.

TRAFFIC ANALYSIS FOR HIGHWAY DESIGN

Description of Location	Average Daily Traffic 1975	Average Daily Traffic 1995	Directional Distribution Factor	Design Hourly Volume	Percent Trucks ADT	Percent Trucks DHV	Anticipated Annual Rate of Growth	ATHWLD	Percent Tandem Axles in ATHWLD	Total Number of Equivalent 18K Single Axle Load Applications One Direction Expected for a 20-Year Design Period (19 to 19) Flexible Pavement	Total Number of Equivalent 18K Single Axle Load Applications One Direction Expected for a 20-Year Design Period (19 to 19) Rigid Pavement
1. West Loop Freeway (IH 610) North of Southwest Freeway (US 59)	168,600	263,000	57-43%	10.9%	8.0	5.0	2.8%	14,500	10	55,619,000	81,655,000
2. South Freeway (SH 288) North of South Loop Freeway (IH 610)	40,000	130,000	65-35%	14.1%	4.7	2.9	11.2%	14,500	10	11,879,000	17,566,000

Fig. F-1 Refers to Paragraph F-105

LANE FACTOR FOR 18 KSA IN DESIGN LANE

No. of Lanes in Design Facility	Lane Factor
8 or Greater	0.7
6	0.8
4 or Less	1.0

Fig. F-2. Refers to Paragraph F-105

SLAB THICKNESS IN INCHES FOR DESIGN 18 KSA

	18 KSA in Million	0	0.5	1	1.5	3	6	12	20
Good Subgrade	CPCR * CPJR CPCD	6	6	7	8	9	10	11	
	CPCD, No Dowels CPSJ, No Dowels	7	8	9	10	11	12	13	
Poor Subgrade	CPCR CPJR CPCD	6	7	8	9	10	11	12	
	CPCD, No Dowels CPSJ, No Dowels	8	9	10	11	12	13	14	
	18 KSA in Million	0	0.5	1	1.5	3	6	12	20

* Where an adequate subbase is utilized and where a full depth tied concrete shoulder, curb, or pavement widening is utilized and where the subgrade, drainage, and experience indicates, one inch may be deducted from these thickness values (except 6" pavement).

Fig. F-3 Refers to Paragraph F-106(a)

MATERIAL PROPERTIES

Concrete	
Modulus of Elasticity (psi)	4,000,000
Flexural Strength (psi) (28 day third pt. loading)	670
Flexural Strength (psi) (7 day mid pt. loading)	600
Tensile Strength (psi)*	270
Static load design strength (psi)	300
* (.4 x Flexural Strength @ 28 day)	
Subbase	
Friction Factor	1.5 to 2.0
Modulus of Elasticity (psi)	Less than 200,000
Subgrade	
Ke - Good Subgrade (pci)	100
Ke - Poor Subgrade (pci)	30

(Refs. 2, 3, 4, and 5)

Fig. F-4. Refers to Paragraph F-106(a)

(b) Subgrade. Evaluations for modulus of subgrade, Ke, by the plate-load test, are too cumbersome to be repeated often enough to account for variation within any new location project. Generally, the Engineer's experience and knowledge of local material is the best source of information (Ref. 10). Soil surveys and laboratory tests will aid the Engineer in his estimate. For evaluation of existing pavements the Dynaflect (Refs. 11 and 12) has given useful data.

Because of the difficulty in obtaining a modulus of subgrade value, the design chart in Figure F-3 has divided subgrade into only two categories: good and poor subgrade. The definition for a good subgrade is "a subgrade that will provide a uniform support throughout the design life." To obtain this condition the subgrade must be constructed with uniformity in composition, density, and consolidation and it is required that this condition be retained for the life of the pavement. Definition of a poor subgrade is "a subgrade which will not retain uniform support throughout the design life." Loss of support is usually caused by infiltration of water into the upper portion of the subgrade which causes the material to weaken and provides a vessel for pumping. Pavement designed with good internal drainage or built in dry climate would be expected to have a good performing subgrade.

If the Engineer's experience shows that the design values obtained from Figure F-3 do not apply to his condition, then a special analysis should be made, using his best estimate for modulus of subgrade.

It has been common practice to lime-stabilize clay subgrades to provide an all-weather working table to promote faster construction. Lime stabilization has also been used to reduce potential swelling problems. In general, lime-stabilized subgrade does not provide significant structural support for the concrete slab. Asphalt and portland cement stabilization of sandy soils has been used infrequently for special problems; and, because of the lack of performance experience with this type design, it should not be considered as having additional structural value unless experience can be documented.

(c) Subbase. A subbase is defined as a foundation course placed between the subgrade and the concrete pavement. The primary function of a subbase is to improve the foundation for the pavement so that the foundation can withstand the effect of large amounts of water that infiltrate the concrete pavement. Secondary functions include providing a working table for construction traffic and strengthening the foundation so that a lesser slab is required. A subbase achieves its primary function by being either erosion-resistant or a drainage layer in an overall drainage system that rapidly carries away the infiltrating water so that high pore pressures under load do not develop. The value of the subbase as a part of the load-carrying structure depends on its strength or modulus of elasticity as compared to the strength or modulus of the pavement slab. A stress analysis should be performed if consideration is to be given to the structural value of the subbase.

The three types of materials that have proven most successful as water-resistant (non-pumping) subbases are: (1) durable, lean concrete; (2) erosion resistant soil cement; and (3) moisture resistant (non-stripping) bituminous mixtures.

1. A lean portland cement concrete base of four inches or greater may be used if a bond breaker is provided to prevent cracks in the base from reflecting into the concrete pavement. It appears that the concrete base can have a relatively low cement factor if a good entrained air system can be achieved to provide adequate workability and sufficient durability. The optimum cement and air content for the material to be used should be determined in the laboratory.

2. Enough cement should be used in soil cement base to assure an erosion resistant material. The Portland Cement Association recommends an increase in cement content for soil cement base to resist erosion where this material is used as riprap on dams (Ref. 13). Bases under concrete pavement should have the same consideration since they are subject to similar or greater erosive action due to pumping.

3. To provide erosion resistance in bituminous mixtures, relatively high asphalt contents (low air voids) and either non-stripping aggregates or anti-stripping agents are required. Recent observations have indicated that the benefits of a bituminous subbase may be reduced by the bonding of the concrete pavement to the subbase and the resultant reflection cracking of the pavement joints down through the subbase.

After providing materials that will satisfy the primary function of being non-erosive, the designer must be assured that these materials are of such quality and quantity that will provide an adequate working table for construction equipment and for foundation improvement (if this is a consideration in design).

Stabilized subbases will be required under all concrete pavement except for the following three cases:

1. In areas where other materials have given satisfactory performance for a similar design and traffic.

2. In areas where the cost of subbase approaches the cost of the concrete slab and where there are concrete curbs, concrete shoulders or where concrete slab extends a minimum of three feet beyond the outside shoulder line, the subbase may be deleted by increasing the slab thickness a minimum of three inches. A cost analysis will be necessary to justify the extra slab thickness in lieu of a design with a subbase.

3. Where the Contractor elects to place the subbase with the concrete pavement in one pass, the material specified for the pavement will be used for the entire depth. This would probably be economical in only a few locations and where the design is non-reinforced or lightly reinforced slabs. In this type design the dowel bars remain the same size but reinforcing steel and tie bars will have to be increased in size to keep the area of the steel at approximately the same percentage of the slab's cross-sectioned area.

(d) Drainage of Subbase. A large percentage of the failures in rural concrete pavements in Texas which have required full depth patches have been in the outside wheel path of the outside lane. These failures can be attributed to edge loading in combination with water which collects through the joints and cracks and stands in the subbase on the lower side of the pavement (normally the outside edge). Proper drainage of the subbase, or water-tight pavement joints (Ref. 14) are two possible solutions to the problem.

In some areas, internal drainage has been the most economical solution. The most successful drainage has been where the subgrade was a well-drained sand and the subbase was a fairly permeable material. Where clay subgrade is involved and drainage must be taken horizontally through the subbase and shoulder to the ditch there have been few economical solutions for drainage.

There are two very critical areas in the control of surface water in these designs. The first area is the joint seal between the concrete slab and the shoulder material and of transverse joints in jointed pavements. A good seal here can prevent most of the drainage problems in concrete pavements. To keep a good seal, replacement maintenance must be scheduled for every second or third year. The second problem area is the design and maintenance of the drain. A properly designed drain will need little maintenance except at the outfall, but provision for periodic inspection should be made and maintenance performed if necessary.

Figure F-5 shows typical sections with positive drainage design which could be considered in areas where past performance of concrete pavement has been unsatisfactory and part of the problem is believed to be water in the subbase. Generally, the longitudinal drains will be needed only along the lower edge of the travel lanes. In steep terrain, cross drains may be required periodically to provide proper drainage. For superelevated curves, collector drains should be installed along the lower side of the curve, and cross collector drains should be installed wherever required to prevent the build-up of a hydrostatic head in the drainage layer. Details for design are described in Reference 15.

TYPICAL CROSS SECTIONS OF SUBDRAINAGE SYSTEMS

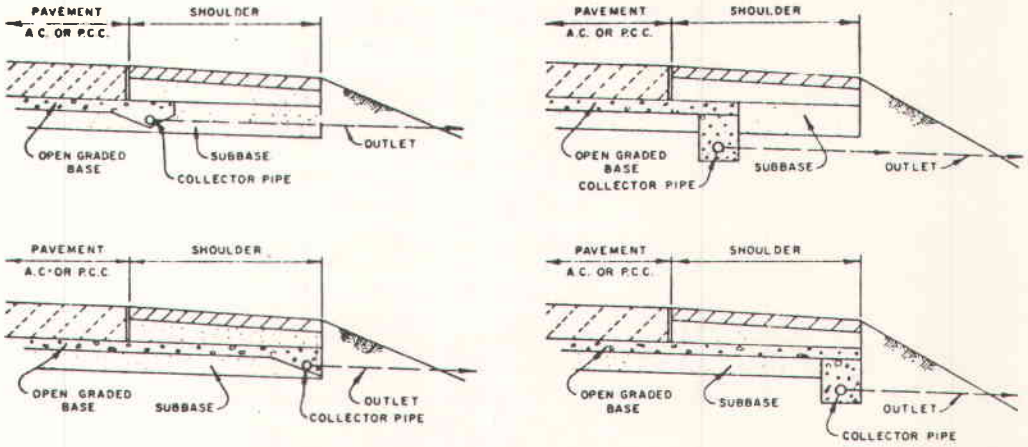


Fig. F-5 Refers to Paragraph F-106(d)

(e) Shoulder Design. Shoulders built with cement and asphalt stabilized bases which have large shrinkage characteristics have not performed satisfactorily. Many of these shoulders have pulled away from the concrete slab a distance of 1/2" to 1" within three to five years and maintenance funds have not been available to seal the joints. A non-shrinking, good quality flexible base with a surface treatment, in many cases, can reduce the joint problem between concrete slab and shoulder.

Building a concrete shoulder is another solution for consideration. The increasing cost of asphalt combined with the extremely poor performance and required maintenance of asphalt or cement stabilized shoulders makes the consideration of tied concrete shoulders attractive. This would eliminate the joint problem, reduce the amount of water infiltrating the subbase and subgrade and add structural support so that the edge loads would not be so detrimental. In addition to this, in urban areas particularly, the concrete shoulder can be utilized as an added traffic lane to alleviate bottlenecks due to accidents, lane striping operations, joint repair or other maintenance operations. Shoulders have also been converted to permanent traffic lanes through deficient interchanges. Where stage construction is employed and it is contemplated that a future lane will be needed, the full width concrete shoulder would be entirely appropriate.

Where financial conditions for a project preclude the construction of eight-foot or ten-foot concrete shoulder, consideration should be given to the construction of a partial width concrete shoulder. Investigations have determined that existing slipforming equipment can be economically widened so that a 27-foot width can be placed in one pass. Theoretically, a three-foot widening will reduce stress and deflection caused by edge loads approximately 80 percent as effectively as a ten-foot concrete shoulder. Concrete slabs widened three feet into the shoulder will move the joint farther from expected large wheel loads. To be effective, the concrete in the shoulder must be tied to the main slab or placed in the same pass. The three-foot widened portion should be delineated or treated to discourage the encroachment of vehicles. (Details for several 27-foot designs are included in Appendix A.) The remainder of the shoulder may be constructed of a less expensive material. The use of flexible base with a surface treatment has provided as good service as, or better than, stabilized shoulders.

F-107 JOINT DESIGN

Joints used in portland cement concrete pavement include transverse contraction, transverse expansion, transverse construction, longitudinal grooved, and longitudinal construction joints. These joints should be carefully designed to accommodate the expected environmental and traffic loading conditions. (See Standard Design Details listed in Appendix A.) Load transfer should be developed in all transverse joints either by the use of coated dowels or by other approved load transfer devices or by short joint spacing and thicker slabs. The thicker slabs will reduce deflection and stress under load and reduce the need for load transfer devices. Short joint spacings of less than 15-foot average length will insure load transfer by aggregate interlock. A skew of 6:1 on transverse joints will also reduce the need for load transfer by causing the wheels to go over the joints one at a time (Ref. 16). Random joint spacings are added to reduce possible vehicle harmonics which can cause larger dynamic loads and unsatisfactory riding characteristics. Proper selection and careful installation of load transfer devices are essential to assure the proper function of load transfer. It is mandatory that dowels be correctly positioned and aligned. Improperly functioning load transfer devices are worse than none. Recommended practice for load transfer devices are reflected on the respective design details. Details for recommended joint seals are shown in Standard Design details. (See Standard Details listed in Appendix A.)

Load transfer in all longitudinal joints and maintenance of a water-tight joint should be accomplished by use of tie bars. Unlike dowel bars, the alignment is not as critical for tie bars. The bar should be kept as nearly parallel as possible to the surface but can be placed up to 45° off perpendicular to the face of the construction joint. In slipforming, this will make bending of the bars easier (if they are to be bent). A detail can be furnished if this option is desired.

The proper design of joints and their required maintenance should be carefully considered when a decision is made to construct jointed concrete pavement. Where future maintenance will be difficult due to any cause such as traffic handling, safety, shortage of funds or maintenance forces, the difficulties of maintenance should be weighed against the added cost of a more reliable pavement. Very few jointed concrete pavements have reached their potential design lives without proper joint design and maintenance.

(a) Forming of Weakened Plane Joints. A weakened plane or contraction joint is created simply by weakening the cross section of the pavement (Ref. 1). Generally, one of three methods is used to create the weakness: (1) an insert is placed in the surface of the pavement; (2) a groove is formed in the surface of the wet concrete; or (3) a sawcut is made shortly after the concrete has set.

Regardless of the method used, it is important that the insert or groove be located over the center line of the dowel assembly, if dowels are used for transverse joints. This requires that the position of the dowels be marked clearly on the side form or by stake or flag when a slipform paver is used.

1. When the joint is formed by insertion of a thin plastic strip, or asphalt-impregnated fiber strip, the strip is placed automatically by a machine following the finisher or slipform paver. An alternate is the placement by vibrating a full width or lane width bar into the concrete. The strip is folded over the edge of the bar which is then positioned by workmen, and the assembly is vibrated into the wet concrete. The bar is then withdrawn, leaving the strip embedded.

2. Grooves in the wet concrete can be made by vibrating a working T-shaped grooving bar into the mix. The bar should have a tapered web to permit easy withdrawal and should be embedded the full depth of the web. The bar should be coated with oil or other appropriate parting materials. After the concrete has hardened sufficiently to prevent flow, the grooving bar is withdrawn and the groove is edged. Even though the joint appears to be well formed, some edging is desirable because of the tendency to disturb the edges when the bar is withdrawn. However, the handwork often produces rougher riding joints.

3. Sawed grooves are made after the concrete has attained sufficient strength to enable the saw to cut through the aggregate with a minimum of aggregate pull-out. The time of sawing is critical and normally should be accomplished within four to eight hours after placing. The selection of this time should be made by experienced personnel who are familiar with local materials. Where hard aggregate requires that sawing be done more than eight hours after placement, strong consideration should be given to inserts or grooving of joints unless experience has shown that longer waiting periods will not result in premature, random cracking.

A majority of weakened plane joints constructed in Texas have been by sawing because of the ability to consistently obtain a more aesthetic and smoother riding joint. However, some projects have experienced cracking near the end of dowel bars and other projects have experienced longitudinal cracking a foot or two either side of the longitudinal saw cut. These cracks usually occurred on projects which could not be sawed within the four to eight-hour period of placement. However, all random cracking should not be attributed to late sawing. If a strong stabilized base is used that has high frictional characteristics or a base that will bond to the hydrating concrete, problems can occur for any type of weakened plane joint. Shrinkage cracks in stabilized subbases act as weakened planes in longitudinal, transverse and diagonal directions when this bonding has occurred. This results in the reflection of these cracks through the concrete pavement. In areas where there is a bond problem, a bond breaking layer must be placed between the base and the concrete.

(b) Sealants. The primary function of joint sealants is to keep foreign solid material out of the joint, and the secondary function is to keep water out to protect the subbase, subgrade, and reinforcing bar or dowels. When solid material enters the joint,spalling occurs very rapidly. Even worse, this can lead to blowups or longitudinal butterfly cracks which usually lead to full depth pavement breakout near the edge of the slab. The entrance of water because of a bad seal weakens the subbase and subgrade but failures usually occur at a much slower rate. Slab thickness and/or proper load transfer design can reduce this rate of failure caused by water weakened support.

Experience has shown that for the best joint seal, the sealant reservoir should be constructed as narrow as possible, yet wide enough to allow for expected movements (Ref. 16). The narrow joint probably works best because it prevents large material from being pushed into the joint and cutting the sealant. However, contrary to the need for keeping the joint narrow, theoretical calculation shows that the greater the width of the joint, the less the sealer will be strained for a given movement. Theory also shows that the shallower the joint is sealed, the less the sealant will be strained when the joint opens (Ref. 17). The optimum width to depth ratio for elasticity is about 2:1 but from a practical standpoint this makes the reservoir too shallow for bond when short joint spaces are used. Practice has shown that a minimum depth of 1/2-inch should be used for bond (Refs. 18 and 19) and a maximum width of 1/2-inch should be used to prevent intrusion of solids. It is recommended that a maximum joint width of 3/8-inch be used for non-reinforced slab joint spacing of less than 20 feet, and that the joint width of 1/2-inch be used for reinforced slabs with joint spacing greater than 20 feet. Joint spacings longer than 30 feet are not recommended unless a special sealant can be designed to handle movement and prevent intrusion of foreign materials.

Hot poured rubber or cold-applied joint and crack sealer as specified in the Item "Concrete Pavement" of the Standard Specifications (Ref. 20) has not proven satisfactory in transverse joints wider than 3/8-inch. Therefore, this type sealant should be restricted to longitudinal joints and transverse joints with joint spacings of less than 20 feet. For wider joints and joint spacings, as in standard drawing for CPJR, the sealant must be more resilient. The two component synthetic polymers and pre-formed compression seals have given better performance. New specifications and materials should be sought for better performance and longer life.

F-108 REINFORCEMENT

(a) Continuous. The selection of continuous longitudinal steel is based on Vetter's analysis of

reinforced concrete (Ref. 21). For the assumed material properties in Figure F-4, the steel percentage of 0.5 to 0.6 by area has been selected and placed in the standard drawing of Appendix A. A special analysis should be made when non-stabilized subbase or no subbase is used. This situation may reduce friction to the point that additional steel will be required.

The transverse steel requirement in continuously reinforced concrete pavement is based on the subgrade drag theory (Ref. 22) and is defined under "(b) Jointed" of this section. Again, steel has been chosen based on values in Figure F-4 and a special analysis should be made for subbase with friction factors different from those shown.

(b) Jointed. The amount of longitudinal and transverse steel required for jointed reinforced concrete pavement is calculated by the subgrade drag equation as follows:

$$Ps = \frac{L\,F}{2fs} \times 100$$

Where: Ps = Percent steel by area
L = Length or width of slab (ft.)
F = Friction factor of subbase or subgrade
fs = Allowable working stress in steel - psi (.75 x yield point)

Example Problem: L = 30'6"
F = 1.75
fs = 45,000 (for grade 60 steel)
Answer: Ps = 0.06%

Standard details are provided in Appendix A for the case of bar reinforcement of a 30'6" joint spacing and a width of 27 feet. It is anticipated that this will be used only for the rural four-lane divided highway. Designs for wire fabric, barmats, and for the numerous possible combination of joint spacings and pavement width will be developed upon request. Also, a new design technique is now being developed by research and is expected to be usable in the near future (Ref. 9).

F-109 OVERLAY

The design of an overlay is unique to each particular project. The most common practice is the use of asphaltic concrete pavement to restore serviceability. This may also, for a time, reduce joint maintenance and improve drainage characteristics, but it does not provide a long-term solution to most problems. Considerable thickness of asphaltic concrete is needed to provide structural value and to postpone reflection cracking. A detailed study of the existing surface and a thorough analysis of the expected results should be performed in the consideration of an asphaltic concrete pavement overlay.

A limited amount of experience is available with the use of relatively thin continuously reinforced overlays. A minimum thickness of six inches has given satisfactory performance. Experience in other states indicate that thinner and more economical overlays may be appropriate in some cases. A thorough analysis of existing conditions and possible solutions should be performed for each project. A good method for designing overlays with confidence does not exist. More experience with actual performance is needed.

F-110 TERMINAL TREATMENT

(a) Anchorage Systems. The termini or ends of portland cement concrete pavement may require special treatment in order to reduce the detrimental effects of pavement movement. The use of anchor lug systems is optional, depending upon the District's experience with such pavement movement. For continuously reinforced concrete pavements, the recommended number of anchor lugs can be selected from the tabulation following:

Subbase type	No. Lugs*
Cement Stabilized	2
Asphalt Stabilized	2

* These recommendations are for a total allowable movement of 0.5 inch. They were derived from Reference 23.

An anchorage system for CRCP containing up to five anchor lugs is shown in Standard Design Details. (See Standard Design Details listed in Appendix A).

The recommended anchor lug details for jointed concrete pavement are shown in Standard Design Details. (See Standard Design Details listed in Appendix A).

(b) Bridge Approach Slabs. The bridge approach slab is a heavily reinforced slab placed between a bridge and pavement end. The approach slab is designed to perform as an unsupported slab over a short length. The use of approach slabs is optional depending upon experience in the locality. Recommended design details are shown in Standard Design Details (See Standard Design Details listed in Appendix A).

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APPENDIX G-100

MULTIPLE USE OF HIGHWAYS RIGHT OF WAY (G-100)

G-101 POLICY

(a) General

In the development of highway projects, the Department usually initially acquires all right of way needed for full scale project development; however, certain areas of this right of way may not be used in the initial stage of construction. These areas and areas beneath elevated structures may be made available for other public functions such as parking areas, recreational areas, public parks, immigration control, law enforcement functions, special gas tax inspections or other such legal inspections.

The following general policy provisions on multiple use of right of way have been established:

1. The public use of specified areas beneath overhead structures or certain other areas of right of way will be considered by the State Department of Highways and Public Transportation when local governmental authorities or other State or Federal Agencies indicate a willingness to cooperate in the development of the same. Each proposed instance of joint use will be considered on its individual merits and the respective responsibilities of the State Department of Highways and Public Transportation and other parties involved shall be fixed by agreement.

2. State Department of Highways and Public Transportation approval for the joint use of highway right of way may be given only when it is considered to be in the public's interest and it has been determined from engineering and traffic investigations that it would not damage the highway facilities, impair safety, impede highway maintenance, or in any way restrict the operation of the freeway or highway facility.

3. Prior approval by the State Department of Highways and Public Transportation will be required before any permanent improvements are installed or constructed by other governmental units within any joint use area.

4. Where the approved joint use of an area would require increased span length for structures or modifications or variations of structures or highway cross-section to accommodate the public use of land area beneath, above or adjacent to the highway facility and such can be accomplished with reasonable economy without adverse effect upon the operation or maintenance of the highway facility, consideration may be given to the applicability of such modifications. Such considerations shall include evaluating the possible use of structure in lieu of embankment where the former would be more conducive to the public use of land space beneath the structures, improve local traffic circulation, provide for better public services, be more aesthetically pleasing, or better fit the highway into the environment.

5. The governmental agency or unit of local government specified in the agreement shall bear full responsibility for operation of the entire multiple use area. If at any time property is used for any purpose other than that outlined in the agreement, such will constitute grounds for termination of the agreement.

6. If in the sole judgment of the State Department of Highways and Public Transportation, it is found at any future time that traffic conditions have so changed that the existence or use of the area for other than traffic purposes is impeding maintenance, damaging the highway facility, restricting operation of the freeway or arterial street, impairing safety, or that the facility is not being properly maintained or operated, that it constitutes a public hazard or nuisance, or if for any other reason, it is the Department's judgment that the facility is not in the public interest, the agreement under which the facility was constructed may be: (1) modified if corrective measures acceptable to both parties can be applied to eliminate the objectionable features or practices that exist, or (2) terminated and the use of the area as a joint use facility discontinued.

7. Upon written notification by the State Department of Highways and Public Transportation that the multiple use facility should be discontinued, or if the responsible governmental unit in its own judgment determines that such facility should be discontinued, the responsible agency shall, within the period specified in the agreement, at their entire expense, clear the area of all facilities which had been its financial responsibility which were used in conjunction with the operation and maintenance of the facility, restoring the areas thus cleared to a condition satisfactory to the State Department of Highways and Public Transportation. Any and all construction or appurtenances which had been the responsibility of the Department will remain.

8. Maintenance of the joint use area and facilities thereon will be the responsibility of the operating governmental unit. Such responsibility shall not be transferred, assigned or conveyed to a third party without approval of the State Department of Highways and Public Transportation. Any fees levied for use of the facilities on the area should be nominal and no more than are sufficient to defray the cost of construction, maintenance, and operation thereof. Maintenance of lighting installations will conform with the Department's illumination policy and will be covered under separate agreement.

9. The governmental unit or agency responsible for maintenance and operation of the multiple use facility will indemnify the State Department of Highways and Public Transportation against any and all damages and claims for damages, including those resulting from injury to or death of persons or loss of or damage to property, arising out of, incident to or in any manner connected with the operation or maintenance of the multiple use facility, which indemnification shall extend to and include any and all court costs, attorney's fees and expenses related to or connected with any claims or suits for damages and shall, if requested in writing by the State Department of Highways and Public Transportation to do so, assist the State Department of Highways and Public Transportation or relieve the State Department of Highways and Public Transportation from defending any such suits brought against it.

10. The State Department of Highways and Public Transportation, by execution of an agreement with another local, state or federal unit of government for the joint use of any area of highway right of way, does not impair or relinquish the Department's right to use such land for right of way purposes when it is required for construction or reconstruction of the traffic facility for which it was acquired, nor shall use of the land for other than highway purposes under such agreement ever be construed as abandonment by the State Department of Highways and Public Transportation of such land acquired for highway purposes.

(b) Offstreet Parking

Where it has been determined that an area within the highway right of way would be appropriate for use as a parking facility, the following provisions will apply:

1. The State Department of Highways and Public Transportation will generally be responsible for the site grading, construction of access driveways, paving, installation of curbs, or other such traffic control devices, lighting, basic landscaping and screening to insure its aesthetic balance with the overall highway design and the environment of the area. The maintenance and operation of the entire joint use facility will be the responsibility of local governmental agencies. The installation of parking meters, gates, attendant's shelters, or other appurtenances necessary to the operation of the facility will generally be the financial responsibility of the local governmental agency.

2. Regulations shall be enforced by the responsible governmental officials prohibiting the use of any area for the parking of vehicles carrying highly inflammable or explosive loads. Under overhead structures, adequate provision shall be made for protection of piers and the operating agency shall enforce parking regulations limiting parking to motor vehicles of size and capacity as set forth in the agreement, such vehicles to conform in size and use to governing State statutes.

3. This policy pertains only to multiple use of highway right of way with controlled points for ingress and egress, and in no way modifies current policies governing parking on or access to freeways, highways and arterial streets, including auxiliary frontage streets, connecting roadways, ramps, or turning lanes.

(c) Recreational Areas

1. In the development of parks, mini-parks, hike and bike trails, nature trails, bridle paths, etc., within the highway right of way the State Department of Highways and Public Transportation will generally be responsible for the site grading, and drainage requirements, walks or other paved areas, fencing, curbing, basic landscaping or other treatment where safety and aesthetic considerations are involved.

2. In the development of recreational facilities, such as basketball or handball courts, play areas, tennis courts, etc., the State Department of Highways and Public Transportation will generally be responsible for the necessary grading and drainage facilities, the provision of minimum hard surfacing, lighting, fencing and basic landscaping as may be warranted by safety and aesthetic considerations. The maintenance and operation of the entire joint use facility will be the responsibility of local governmental agencies. Local governmental agencies will generally be financially responsible for any play equipment, backstops, goals, nets, or other appurtenances necessary for the enjoyment of the recreational functions intended.

3. At highway crossings of streams or reservoirs the State Department of Highways and Public Transportation shall cooperate with the Texas Parks and Wildlife Department or other legally constituted river and reservoir authorities in determining whether the use of highway right of way for boat launch facilities, recreational purposes or parking areas would be in the public interest. If it is determined that such facilities should be provided, the State Department of Highways and Public Transportation will provide

and be responsible for the access connection from the highway facility, all other construction necessary to their development will be the financial responsibility of the Texas Parks and Wildlife Department or the appropriate stream or reservoir authority.

(d) Inspection Stations

The provision of Inspection Stations will be considered only upon request from the Texas Department of Public Safety, the U.S. Department of Transportation, the U.S. Immigration Service, the Texas Comptroller of Public Accounts, or other responsible governmental agencies. The following will be considered in the design of Inspection Stations:

1. Each inspection station will serve only one direction of travel, regardless of the type of facility. Where two inspection stations are required (one for each direction of travel) their locations will be staggered a sufficient distance apart to discourage inspectors from crossing the road and creating a hazardous condition.

2. Border Patrol Inspection Stations will generally be located only on the lane(s) departing Mexico.

3. All driveways and ramps will conform to the standards set forth under Paragraph 4-602(j) and as shown in Figure G-1.

4. A parking area of 40 ft. width is desirable to provide adequate passing and storage areas for large tractor-trailer combinations.

5. The State Department of Highways and Public Transportation will generally be responsible for the necessary grading and drainage facilities, construction of ramps and driveways, installation of curbs, or other protective devices, and necessary highway signing to direct traffic safely into and out of the inspection station. The installation, maintenance, and operation of inspector's shelters, scales, or other appurtenances necessary to the operation of the facility will generally be the financial responsibility of the inspecting agency.

Insofar as possible, the various inspection stations should be combined, consistent with proper operation of the highway. The Highway Design Division is responsible for all main office review, coordination with other agencies and further handling of requests for approval of Inspection Stations on the State Department of Highways and Public Transportation System.

(e) Passes and Cattle Guards

The provision of grade separated private passes will be in accordance with the policy and procedures set forth in the Right of Way and Appraisal and Appraisal Review Manuals.

(f) Other

In the event that a local governmental unit or State Agency should desire to enter into an agreement with the Department for the use of highway right of way as sites for law enforcement centers, emergency service centers, or any other public functions not specifically described herein, such requests will be independently considered by the State Department of Highways and Public Transportation and each instance judged according to its particular merits, subject to the specific provisions contained herein.

TYPICAL INSPECTION STATION

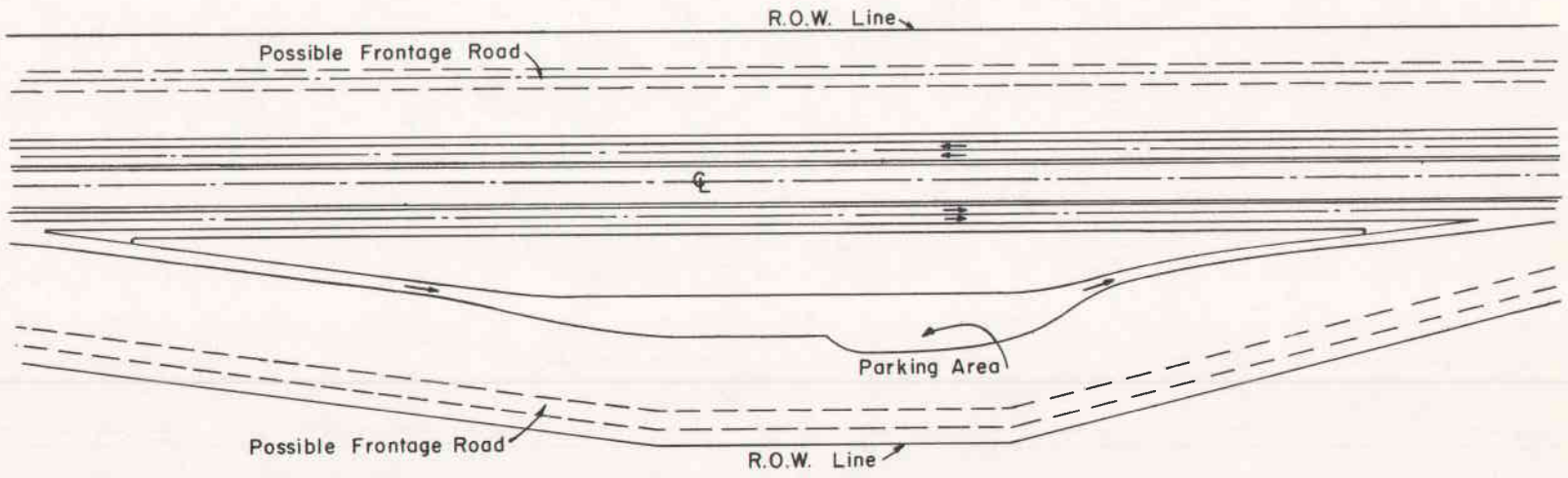


FIGURE G-1 Refers to Paragraph G-101(d)

(g) Administration of Policy

The responsibility for administering this policy will be shared by File D-8 and File D-18. On projects which are in the design stage or under construction, proposals for multiple use development will be submitted to File D-8 who will then correlate the same with File D-18 and other appropriate Austin Office Divisions. On completed projects, proposals for multiple use will be submitted to File D-18 for further handling with File D-8 and other appropriate Divisions.

G-102 SAFETY REST AREAS

(a) Rest Area on Controlled Access Highways and Multi-Lane Highways

Rest areas should be located on the Interstate Highway System in accordance with the proposed plan as approved by the Administration which provides for a spacing of approximately thirty minutes driving time. Similar criteria for spacing should be used on other controlled access highways. It is desirable to obtain rest area sites at the time right of way for highway construction or reconstruction is being acquired.

Figure G-2 shows a typical rest area on a freeway or multi-lane facility.

Rest areas should have direct access to and from the main lanes and be so located as to provide safe ingress and egress. In selection of a site, consideration should be given to scenic values, such as trees, streams, and views. Generally, the site should be from five to ten acres with the extra width of right of way being from 200 to 300 feet. It is desirable to locate rest areas in rural areas, preferably four miles or more from a city.

The necessary grading of the rest area, along with the driveway construction, should be included with the highway construction contract.

The water supply, if obtained from wells, shall be developed prior to letting of a contract for the construction of comfort stations and/or other rest area facilities. It is necessary that separate contracts be let for roadway construction and for rest area facilities with comfort stations, since two different wage scales are involved. Generally, all construction of rest area facilities will utilize desirable fireproof materials in order to reduce vandalism. For certain soil conditions, large amounts of right-of-way may be required to dispose of effluent at comfort stations. In the selection, planning and development of rest area sites, the Landscape Section of D-18 will assist the Districts.

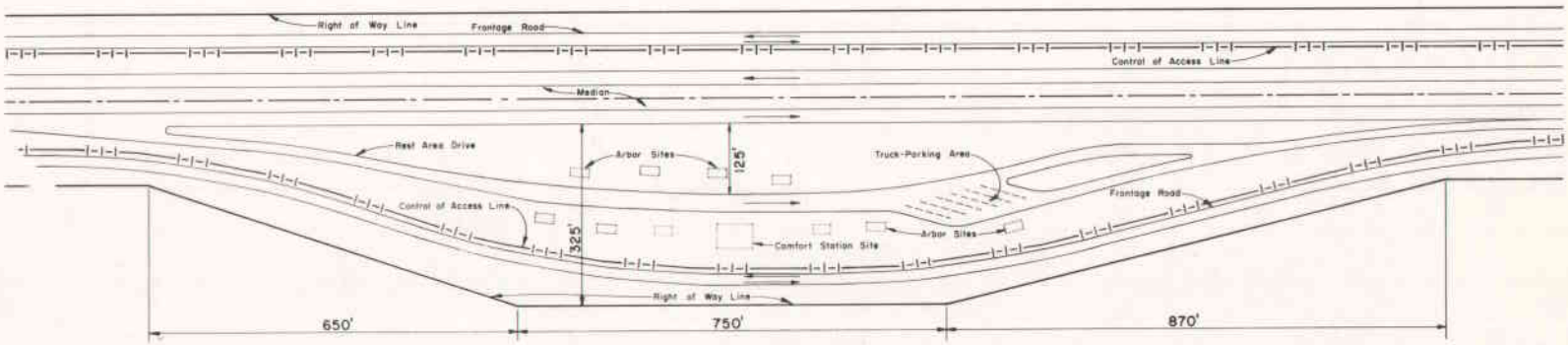
(b) Rest Areas on Two-Lane Highways

The spacing of rest areas on two-lane highways is dependent upon the volume of through and recreational traffic. Generally, Farm to Market Roads having State Highway characteristics with adequate traffic may have rest areas where sites of outstanding qualities can be obtained. On State Highways having a low volume of through or recreational traffic, the installation of rest areas should be only at those locations having outstanding qualities. Generally, rest areas should be provided on the main traveled State Highway System at intervals of thirty to forty-five miles or between county seats.

Figure G-3 shows a typical rest area on a two-lane highway.

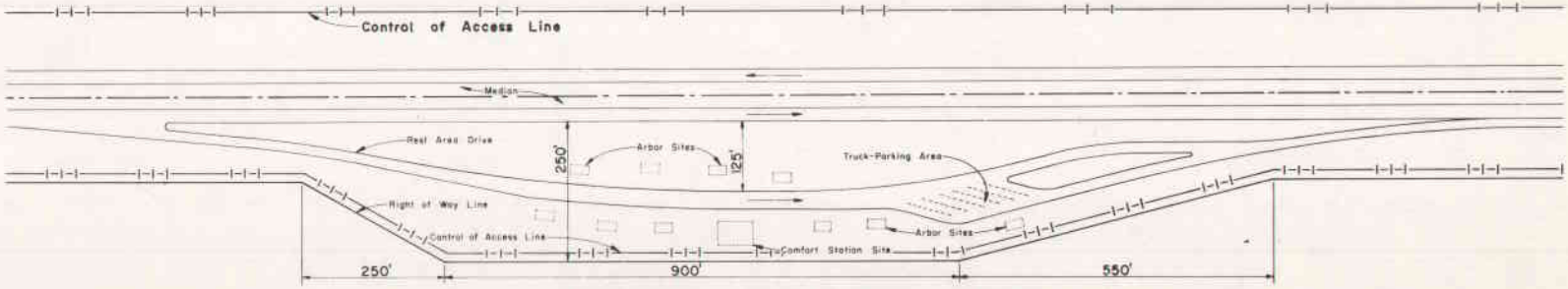
It is desirable to obtain rest area sites at the time right of way for highway construction or reconstruction is being acquired. Generally, these sites should be located four miles or more from a city.

TYPICAL DESIGNS FOR SAFETY REST AREAS



WITH FRONTAGE ROAD

NO SCALE



WITHOUT FRONTAGE ROAD

FIGURE G-2 Refers to Paragraph G-102(a)

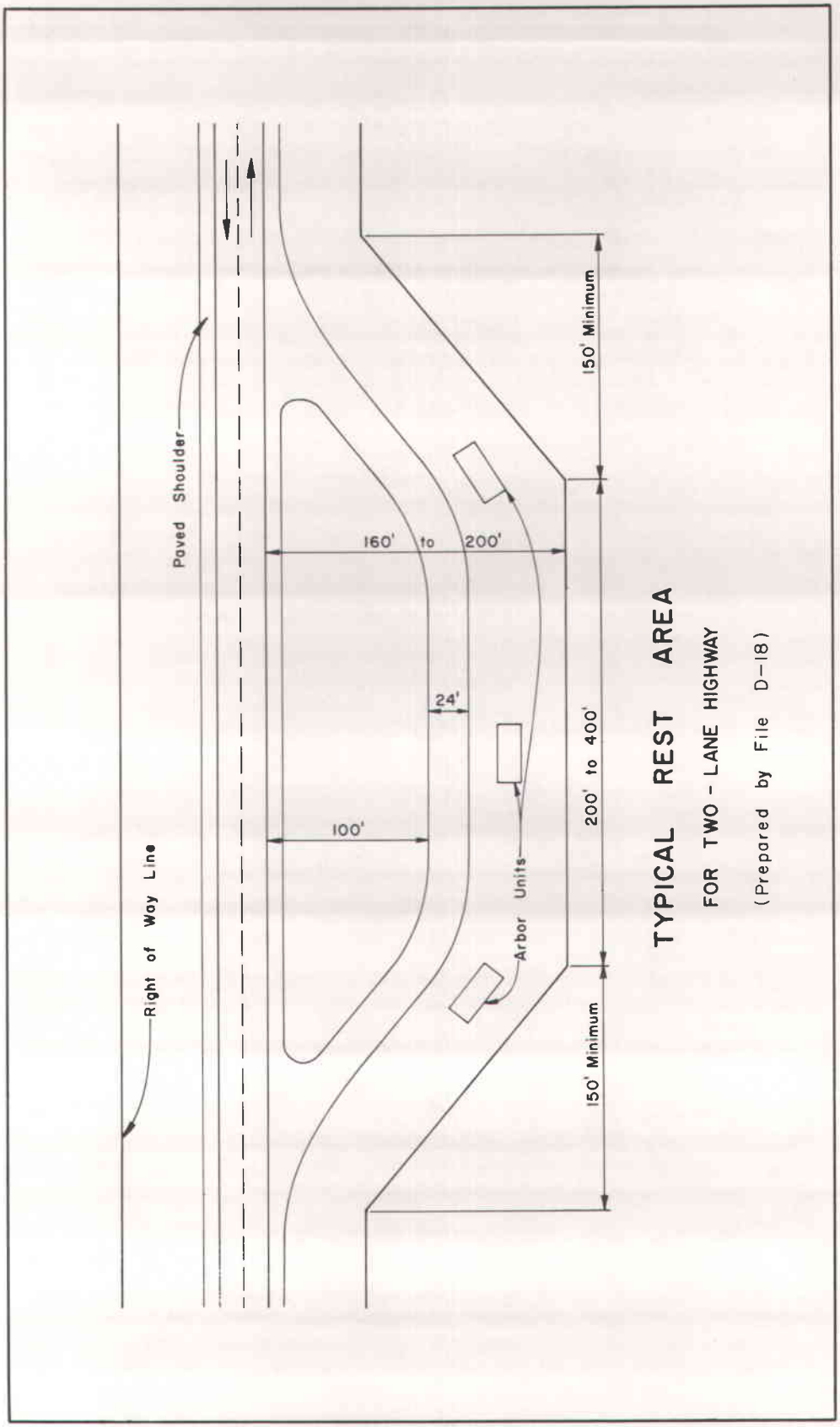


FIGURE G-3 Refers to Paragraph G-102(b)

Safe ingress and egress should be provided for all sites. Consideration should be given those having good scenic values which are not subject to excessive flooding. Generally, the site should have from one to five acres with the extra width of right of way being from 100 to 200 feet.

The necessary grading of the rest area, along with the driveway construction, should be included with the highway construction contract.

Development of certain rest areas on selected sections of the more heavily traveled highway system may have comfort stations in which case these will be handled as specified for those on controlled access highways. Generally, the rest area facilities will be developed with State Maintenance Forces. In the selection, planning and development of these rest areas, the Landscape Section of D-18 will assist the Districts.

G-103 INFORMATION STATIONS

(a) Information stations are located within the right of way of a highway for the purpose of furnishing information to the incoming traffic concerning highway routes and conditions, parks, recreational centers, cities and tourists accommodations.

(b) Information stations shall be located along controlled access highways which enter the State. They shall be within the right of way of the controlled access highway and between the main incoming lanes and the frontage road, if frontage roads are provided. In no case will information stations be located between the through lanes. They shall be near the point of entrance into the State, preferably adjacent to a town or village for the convenience of the operating personnel, as directed by the District Engineer.

(c) The information station shall be directly accessible from the main incoming lanes of travel by way of standard exit and entrance ramps.

The area shall have sufficient parking space to enable passenger vehicles, with or without mobile homes, and truck vehicles to leave the main lanes, with ease, thus discouraging parking adjacent to the main lanes.

The size of the area should be governed by the traffic volume of such projections as to preclude the necessity of acquisition of additional area in the foreseeable future.

The type of building for the facility should be of a construction type that will conform with the local architecture. Figure G-4 shows a typical information station design.

(d) The area for the parking and driveways from the main lanes shall be included in the P.S.&E. as construction items. The building itself will be constructed under a separate contract.

(e) The area of the information station and other facilities shall be maintained by the State Department of Highways and Public Transportation.

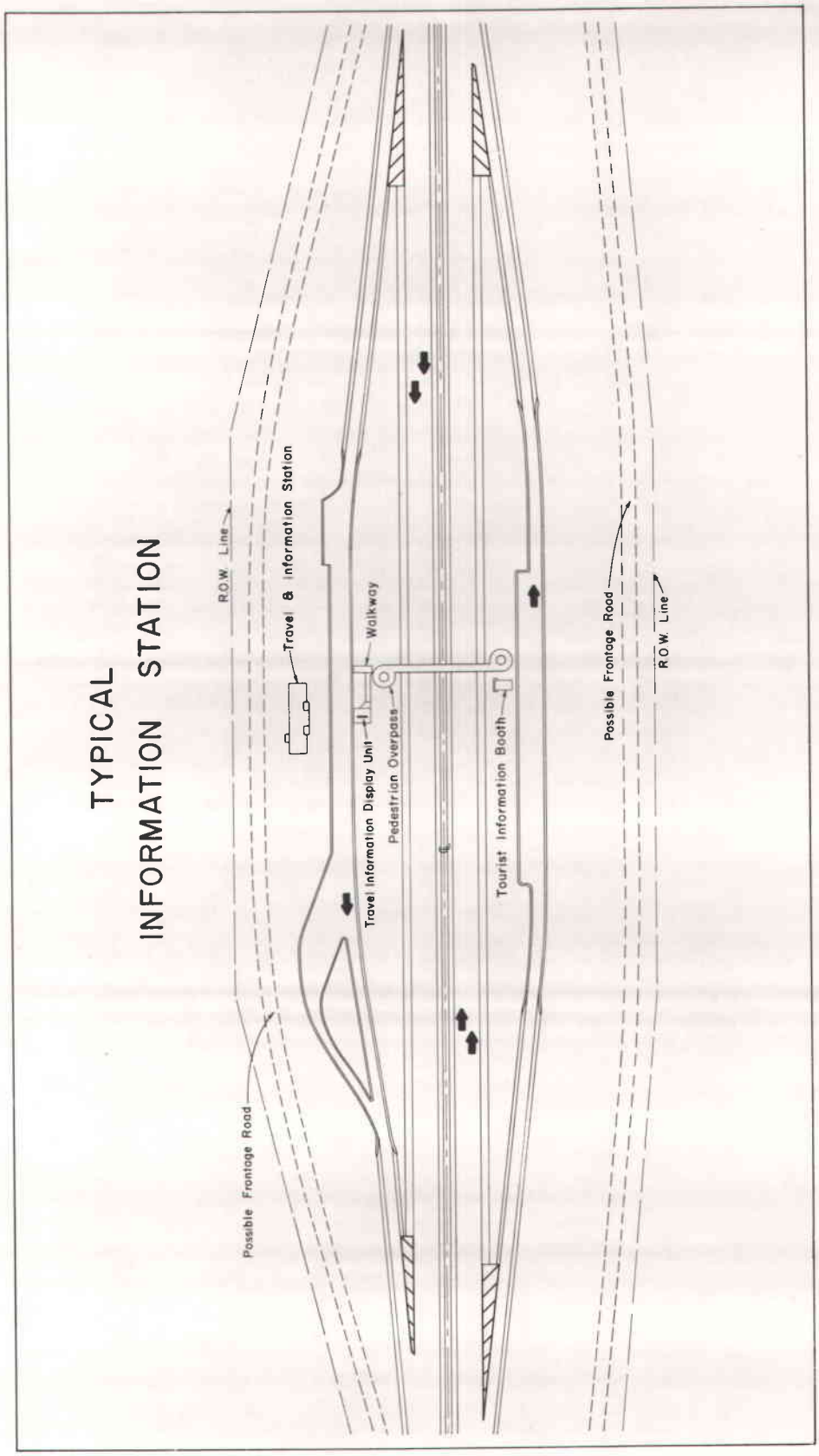


FIGURE G-4 Refers to Paragraph G-103(c)

APPENDIX H-100

BIKEWAY DESIGN GUIDELINES (H-100)

H-101 GENERAL

The bicycle is just another mode of transportation, and like automobile transportation, it is necessary to follow a transportation planning process in order to warrant, coordinate, design and produce a facility that will best serve the public for its investment.

H-102 POLICY

Under the 1973 Federal-Aid Highway Act, money apportioned for the urban and rural Primary and Secondary Systems and the Urban System can be used to construct separate or preferential facilities for bicycles in conjunction with Federal-aid highway projects. It is the responsibility of local officials to make such proposals to the State for the facilities. Projects proposed for Federal-aid funding on the Urban System are selected by locally elected officials of the jurisdiction involved acting through the metropolitan planning agency designated by the Governor. These projects must have the specific concurrence of the State Department of Highways and Public Transportation. The State will work directly with County or City officials in the development of the project details.

Before a proposal is pursued to any great length, the following conditions must be satisfied:

1. The facility will not impair the safety of the motorist or bicyclist.

2. The facility will be accessible to users or will form a segment located and designed pursuant to an overall plan.

3. A public agency has formally agreed to:

   (a) Operate and maintain the facility

   (b) Ban all motorized vehicles other than maintenance vehicles

4. It is reasonably expected that the facility will have sufficient use in relation to cost to justify its construction and maintenance.

H-103 FUNDING

State highway construction funds may be spent only within the confines of right-of-way limits. Therefore, for bicycle facilities constructed within the highway right of way, highway (State or combination of Federal and State) construction funds, if available, may be used to construct bicycle facilities as an incidental feature of a highway construction project.

State highway funds may not be spent for bicycle facility construction outside of right-of-way limits. However, the Federal Aid Highway Act of 1973 does allow Federal highway funds to be used for these projects subject to Departmental and FHWA concurrence. Where "off" right-of-way bikeway projects are selected by local officials for inclusion in the Federal Aid Urban System, Federal highway funds may be matched with local funds to finance bikeway project preliminary planning and construction.

H-104 WARRANTS

Many considerations should be weighed before developing a bikeway facility. First of all, it must be determined whether or not the expected bicycle traffic is sufficient to justify the cost involved. Where bicycles are to share facilities designed mainly to accomodate other transportation modes, the safety and capacity of the transportation system must be considered. The warrants for determining a separated facility exist where (a) bicycle volumes will be 200 or more per day in conjunction with motor vehicular volumes of 2000 ADT or more, or (b) where the same bicycle volumes will be in conjunction with motor vehicular speeds of 40 mph or higher. Bicycle travel should be prohibited on the traveled way of freeways and other high speed highways.

H-105 DEFINITIONS

(a) Bicycle - A device having two tandem wheels propelled exclusively by human power upon which any person may ride.

(b) Bicycle Trail - A separate trail or path which is for the exclusive use of bicycles. Where such a trail or path forms part of a highway, it is separated from the roadways for motor vehicular traffic by an open space or barrier.

(c) Bicycle Lane - A portion of a roadway which has been designated for preferential or exclusive use by bicycles. It is distinguished from the portion of the roadway for motor vehicular traffic by a paint stripe, curb or other similar device.

(d) Shared Bike Route - A roadway which is officially designated, signed and marked as a bicycle route but which is open to motor vehicular travel and upon which no bicycle lane is designated.

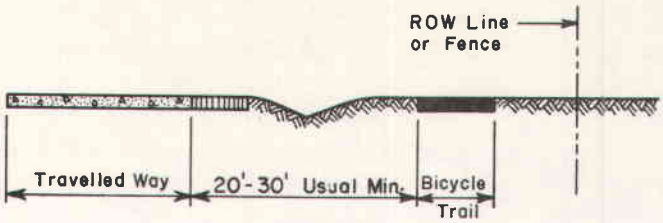
H-106 TYPES OF BIKEWAYS

(a) General

The preferred method of providing bicycle travel is the bicycle trail. It can be designed to specifically satisfy the needs and physical characteristics of the bicycle mode of transportation. However, it is not always possible to provide a bicycle trail. In urban areas where availability of right of way, associated land use and costs are the governing factors, bicycle lanes and shared bike route are the only feasible alternatives. These two facilities do not always provide the most satisfactory riding environment but they are feasible alternatives. Where possible, bicycle and motor vehicle traffic should be separated in order to decrease bicycle-motor vehicle conflict. The design criteria will be presented separately for each of the three different types of bikeway facilities (1) Bicycle Trails (2) Bicycle Lanes and (3) Shared Bike Routes.

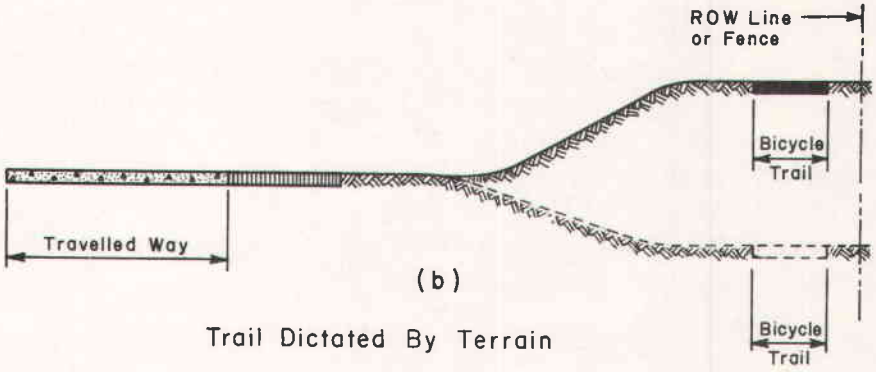
(b) Types of Bikeway Facilities

1. Type I Bikeway - "Bicycle Trails." The bicycle trail should be located as far from the traveled way as practicable in order to minimize bicycle-motorist conflicts. There should be a usual minimum distance of 20 feet and desirable 30 feet separating the trail from the roadway unless some form of natural barrier is available such as a ditch, earth berm, etc. Figure H-1 shows three typical cross sections where bicycle trails are located within the right of way. As an alternate arrangement to the design shown in Figure H-1(c), it may be desirable to place a control-of-access fence along the physical barrier strip a sufficient distance inside the right-of-way line to allow space for a trail outside the fence but still within the right of way.



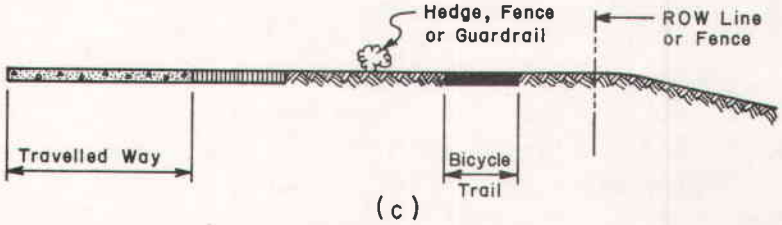
(a)

Trail Outside Ditch Section



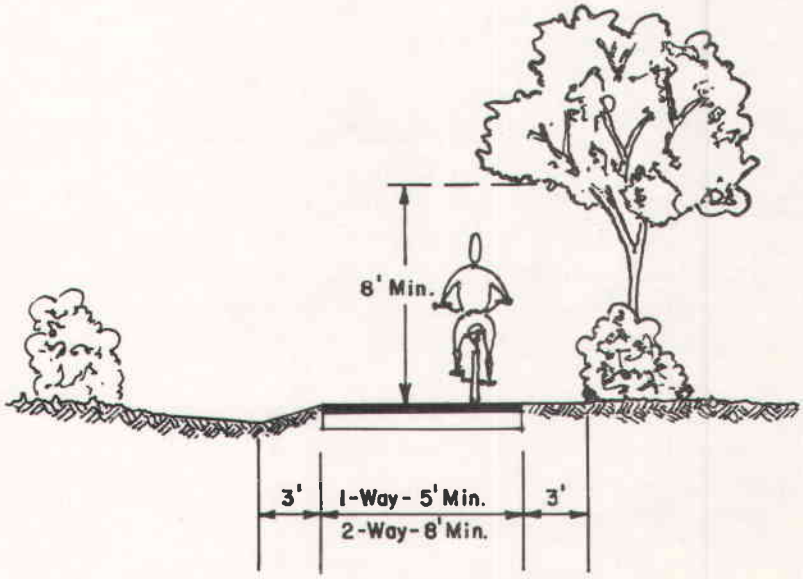
(b)

Trail Dictated By Terrain



(c)

Physical Barrier



(d)

Horizontal and Vertical Clearances

Typical Bicycle Trails
(Type I Bikeway)

FIGURE H-1

2. Type II Bikeway - "Bicycle Lane". The bicycle lane is developed within the cross-section of the vehicular roadway in the outside lane and is intended for the exclusive use of bicycles. The bicycle lane is delineated by means of pavement markings or curbs (See Section H-113). The three general locations for bicycle lanes with respect to the vehicular roadway are shown in Figure H-2.

Bicycle lanes on roadways are usually one-way because of the limited available width and the potential hazards associated with opposing directions of travel. One-way lanes are preferable where attainable.

3. Type III Bikeway - "Shared Bike Route". The shared bike route is specified for bicycle operation by signs and markings but is also shared with motor vehicle traffic. There are no barriers - either symbolic or physical - to delineate a portion of the travelway for bicycles. This type of facility is considered suitable only if motor vehicle volumes are fairly light (less than 2000 ADT) with low speed. Identification of the shared bike route is made by posted signs along the roadway or perhaps by words or symbols painted on the pavement in order to alert the cyclist and motorist.

H-107 GEOMETRICS

(a) Design speed

The speed that a bicyclist travels is dependant upon geometric features of the traveled way, type of bicycle, weather conditions and physical condition of the rider. In determining the design speed of a bikeway, the geometric features of curvature, superelevation, gradient and width of travelled way are used to produce a traveling speed that is at least as high as the preferred speed of the faster travelers. Nearly all bicyclists travel within a speed range of 7-15 mph with the average speed being between 10-11 mph. On long downgrades, speeds of 20 mph or more should be considered. For Type II and Type III bikeways, the design speed necessary to serve motor vehicle operation will adequately serve bicycle traffic needs.

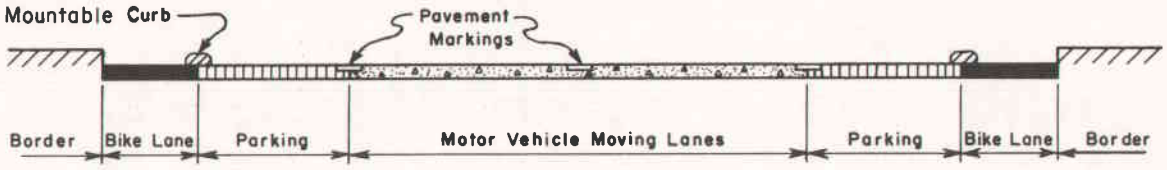
(b) Curvature

For a given design speed of a bikeway, consideration must be given to the minimum radius of curvature. Where bicycle lanes and shared bike routes follow the roadway alignment, the curvatures designed to accommodate the motor vehicles will be more than adequate for bicycles. However, care should be taken for bikeways not paralleling roadways to insure that the minimum radius of curvature is provided to permit unbraked turns at the design speed. Figure H-3 shows a family of curves for determining the curvature and superelevation for various bikeway design speeds. It should be noted that the superelevation should never exceed 0.12 foot per foot.

Where the radius of curvature is less than 100 feet, it is advisable to widen the bikeway in order to increase the lateral space required by the cyclists as he leans to the inside of a turn. Figure H-4 shows the methodology used in determining the necessary widening to compensate for lean. The amount of widening should be limited to a maximum of 4 feet.

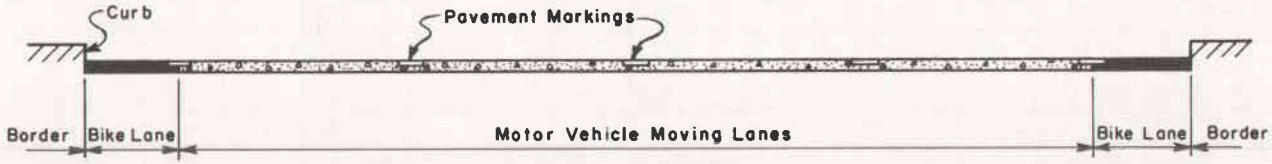
(c) Grades

Whether or not a bikeway is favorable to cyclists is largely dependant upon the grade and alignment of the bikeway. The amount of energy a cyclist expends in using a bikeway will affect the usage of the bikeway. Therefore, the grades should be kept to a minimum. A bikeway gradient should not exceed 10 percent. Figure H-5 shows the desirable gradients for various lengths of grade.



(a) Parking permitted - Bicycle lane located between sidewalk and parking lane

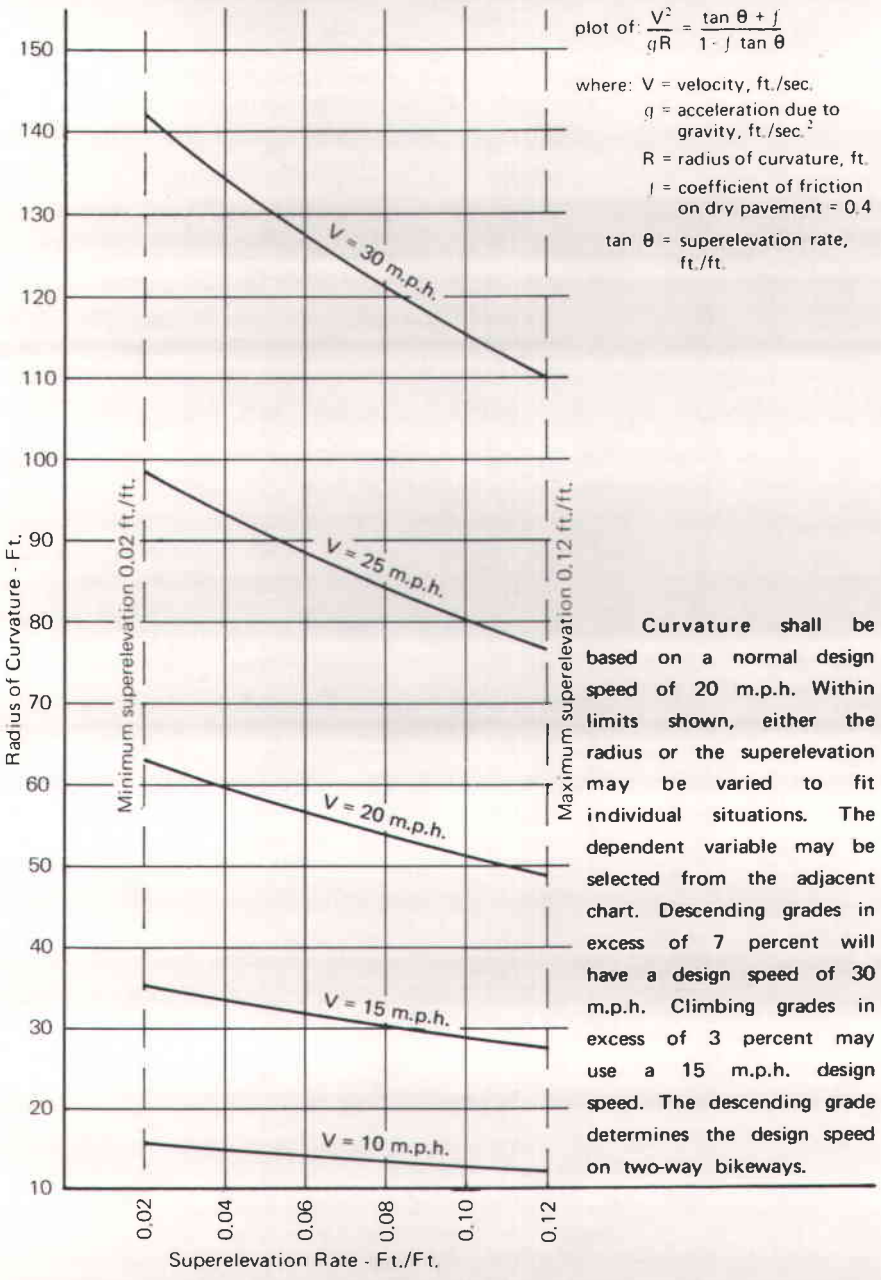
(b) Parking permitted - Bicycle lane located between parking lane and motor vehicle moving lanes



(c) Parking prohibited - Bicycle lane located between sidewalk and motor vehicle moving lanes

ONE-WAY BICYCLE LANES ON ROADWAYS

FIGURE H-2

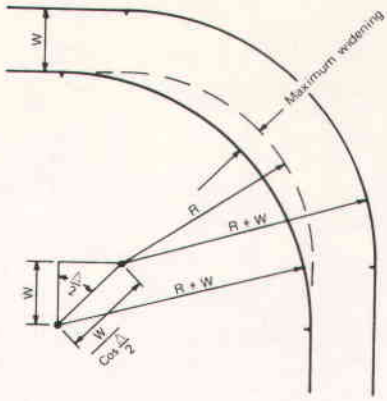


Curvature shall be based on a normal design speed of 20 m.p.h. Within limits shown, either the radius or the superelevation may be varied to fit individual situations. The dependent variable may be selected from the adjacent chart. Descending grades in excess of 7 percent will have a design speed of 30 m.p.h. Climbing grades in excess of 3 percent may use a 15 m.p.h. design speed. The descending grade determines the design speed on two-way bikeways.

STANDARD SUPERELEVATION FOR BIKEWAYS

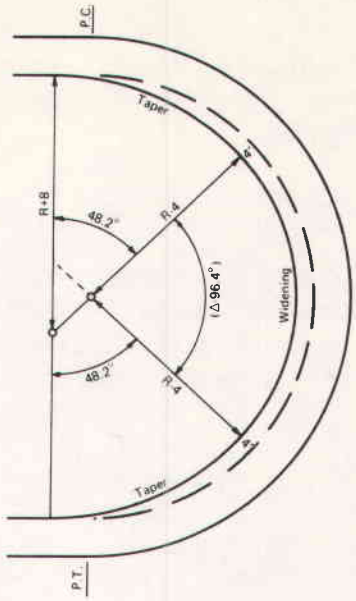
Source: State Of Oregon

FIGURE H - 3



R = Radius of curvature (from Figure 4)
W = Width of bikeway
Δ = Central angle of the curve or the deflection between tangents

Maximum widening shall be limited to 4 feet.

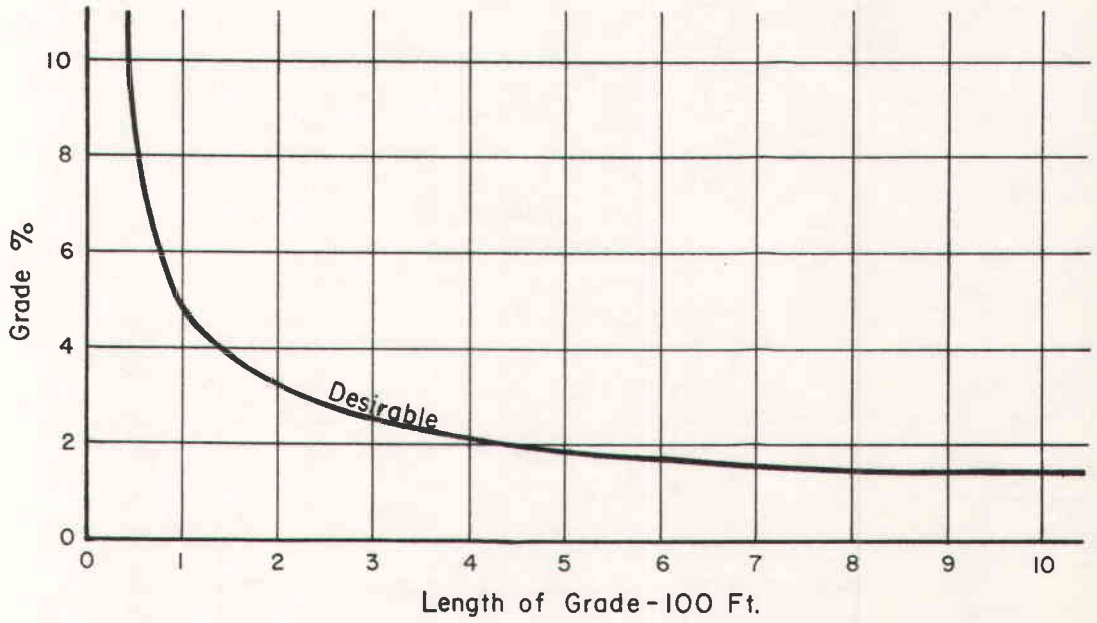


When widening reaches 4 ft. ($\Delta > 96.4^\circ$), that width shall be carried on a radius of R-4 through the central portion of the curve (Δ -96.4°) as shown on the right.

CURVE WIDENING

Source: State Of Oregon

FIGURE H-4



DESIRABLE GRADIENT

Figure H-5

(d) Sight Distance

Also associated with design speed is stopping sight distance. Figure H-6 gives the stopping sight distance for various speeds and related grades. The stopping sight distance for vertical curves can be determined from Figure H-7.

(e) Clearance

In order to prevent encroachment conflicts, adequate vertical and horizontal clearances must be provided. The minimum vertical clearance for overhead obstructions is 8.0 feet. The minimum lateral clearance to an obstruction from the edge of the bike trail pavement is 3 feet. These clearances are illustrated in Figure H-1(d).

TABLE 1. BIKEWAY SURFACE WIDTHS

H-108 CROSS SECTION DESIGN

The cross section design for bikeways will be presented separately for each of the three types of bikeways - bicycle trails, bicycle lanes and shared bike routes.

(a) Bicycle Trails

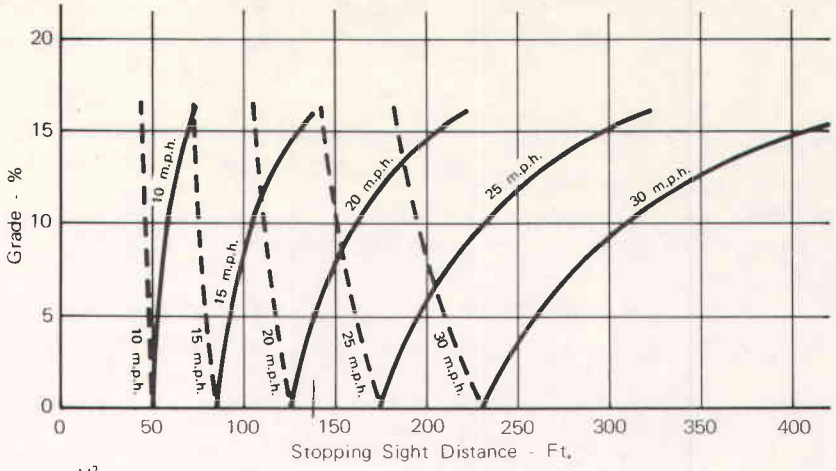
In determining the minimum widths for bicycle trails, the surface widths shown in Table H-1 should be added to the recommended vertical and horizontal clearances. Where maintenance vehicles are expected to utilize the bicycle trail, it may be necessary to adjust these minimum widths in order to accommodate these vehicles.

Number of lanes	Minimum width, feet	Desirable width, feet
1	3.5	4.0
2	7.0	8.0
3	10.5	12.5
4	14.0	17.0

Adjustments to Basic Bikeway Widths

Condition	Additional Width, feet	
	Minimum	Desirable
Raised curb on one side	0.5	1.0
Raised curb on both sides	1.0	2.0
Parked cars adjacent	2.0	2.0

Table 1. Bikeway Surface Widths



$$S = \frac{V^2}{30\,(f \pm G)} + 3.67\,V$$

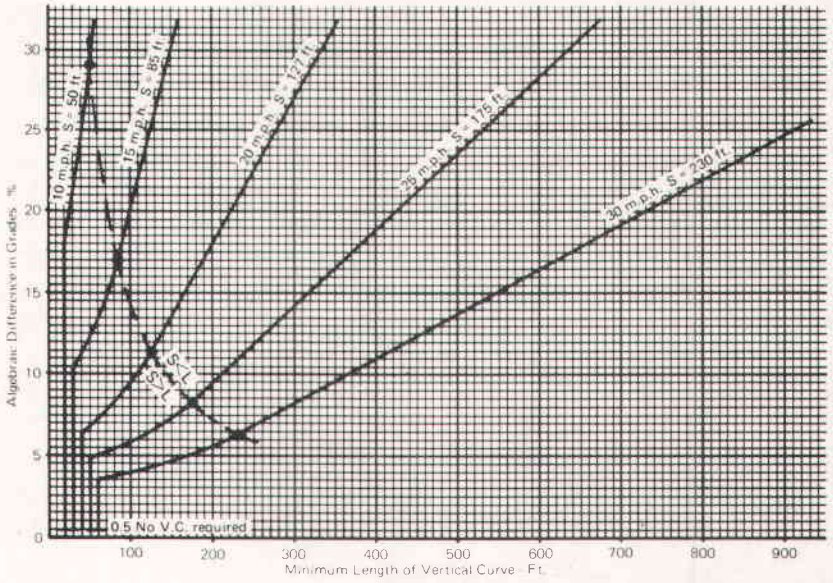
Where: S = stopping sight distance, ft.
V = velocity, m.p.h.
f = coefficient of friction (use 0.25)
G = grade, ft./ft. (rise/run)

Descend ——————
Ascend - - - - - -

STOPPING SIGHT DISTANCE

Source: State Of Oregon

FIGURE H-6



$$L = 2S - \frac{200(\sqrt{h_1}+\sqrt{h_2})^2}{A} \quad \text{when } S > L$$

$$L = \frac{AS^2}{100(\sqrt{2h_1}+\sqrt{2h_2})^2} \quad \text{when } S < L$$

where: S = Stopping sight distance
A = Algebraic difference in grade
h_1 = 4½ ft.—eye height of cyclist
h_2 = ⅓ ft.—height of object
L = Minimum vertical curve length

BIKEWAY SIGHT DISTANCE FOR CREST VERTICAL CURVES

Source: State Of Oregon

FIGURE H-7

(b) Bicycle Lanes

It is desirable for bicycle lanes to be restricted to one-way operation. The minimum width of the bicycle lane is dependant on the location of the bicycle lane with respect to the roadway and the parking conditions. Where the bicycle lane is between the curb and the parking lane as shown in Figure H-2(a), the minimum width for one lane should be 3.5 feet plus 0.5 foot clearance to each curb or a total of 4.5 feet. In this case, the 2-foot additional width for clearance to adjacent parked cars as indicated in Table H-1 is not required.

Where the bicycle lane is between the parking lane and travelled lane as in Figure H-2(b), the minimum width should be 3.5 feet (one-lane minimum) plus a 2-foot allowance for car-door openings or a total of 5.5 feet.

Where parking on the roadway is prohibited and the bicycle lane is between the curb and the traveled way, as in Figure H-2(c), the minimum width should be 3.5 feet (one-lane minimum) plus a 0.5 foot clearance to the curb or a total of 4.0 feet.

(c) Shared Bike Route

Where a low volume street is designated as a bike route and is to share the roadway with cyclists, the outer lane must have a width of 10 feet or greater. Heavier volume streets would require a width of 12 feet or greater. If parking is to be accommodated, the combined width of the outer lane plus the parking lane should total at least 22 feet.

H-109 BICYCLE TRAIL PAVEMENT STRUCTURES

The pavement structural section of a bicycle trail must not only be adequate to support the wheel loads of bicycles and riders but also maintenance vehicles or motorized vehicles which may cross the trail. This structural section will consist of a base course and a riding surface which is stable and traversable even in wet weather. Material which might be used for a base course include aggregate, stabilized earth, soil cement, asphaltic concrete and portland cement concrete. A desirable riding surface would consist of an asphaltic material or portland cement concrete. For recreational travel, a dense grade surface of crushed aggregate, sand, clay or stabilized soil may be acceptable. Figure H-8 shows several pavement structural sections. Exposed base rock next to the bikeway surface should be avoided and sod or topsoil used instead.

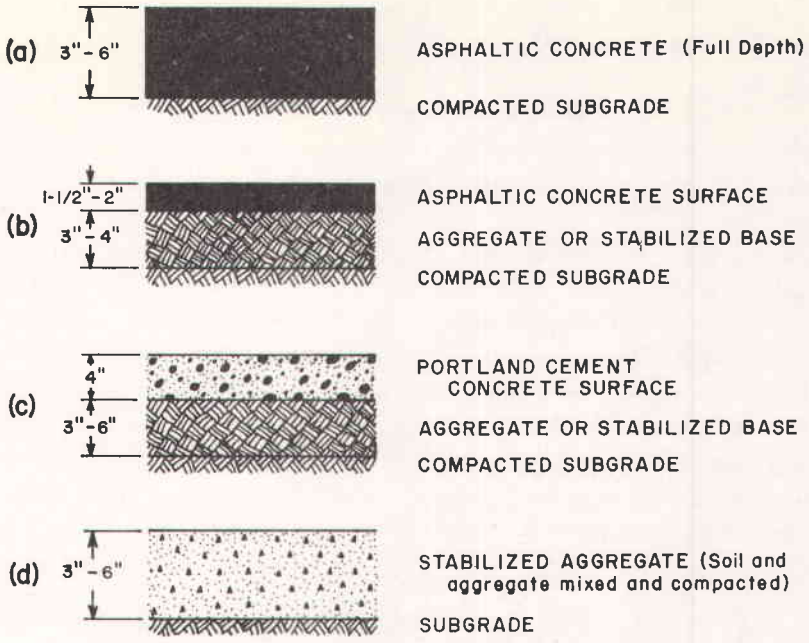
H-110 BRIDGES

Bridges designed exclusively to carry two-way bicycle traffic should have a minimum width of 8 feet. Where it is necessary to carry a bicycle trail across a highway structure on a controlled access highway with high volumes of vehicle traffic, the trail should be carried outside of the normal bridge shoulder and separated from the shoulder by a physical barrier (concrete barrier, railing or fence). On low speed, low volume highways, the bridge shoulder can be utilized for the trail. In this case, the shoulder should be adequately signed and marked. The widths shown in Table H-1 are applicable in determining the bikeway section on a bridge.

H-111 DRAINAGE GRATES AND BICYCLE RAMPS

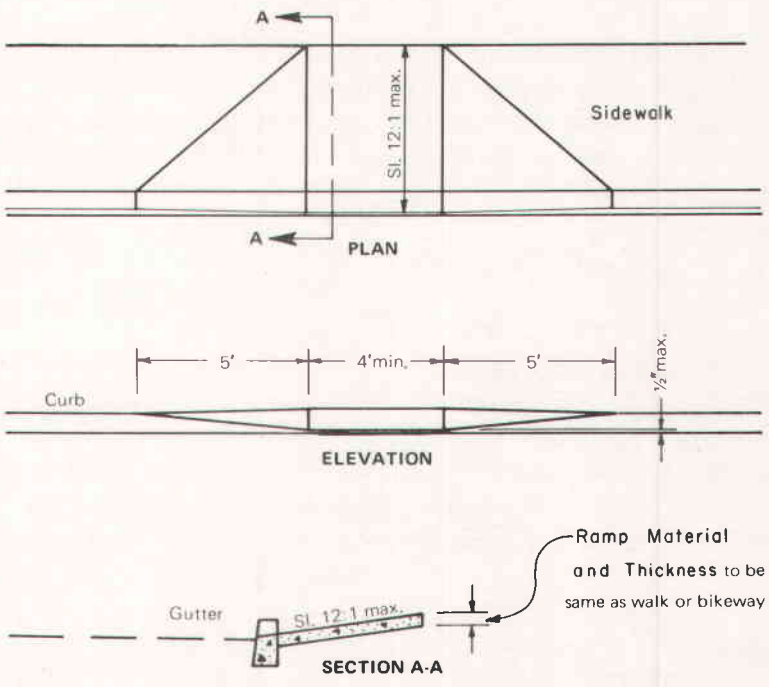
For bicycle lanes and shared bicycle routes, the existing street drainage inlet grates may prove to be a hazard. Drainage inlet grates with openings large enough to entrap narrow bicycle wheels should be either replaced with a bicycle-proof grate or modified by welding 1'' X ¼ steel straps to the grates at a spacing of 6'' to 8'' on centers.

Figure H-9 depicts standard bicycle and wheelchair ramp design.



Typical Pavement Structural Sections for Bicycle Trails

FIGURE H-8



BICYCLE AND WHEELCHAIR RAMP

Source: State Of Oregon

FIGURE H-9

H-112 INTERSECTIONS AND CROSSINGS

The greatest number of conflicts between motorist, bicyclists and pedestrians occur at intersections and crossings. Elimination of conflicts where bicycle routes cross a roadway can be accomplished by providing a grade separation but this is not always possible or economically feasible. However, some form of channelization with specific routings for bicycles should be provided to minimize these conflicts. Channelization of the bicycle crossing can be accomplished by some form of striping or marking which clearly delineates the path which the bicycles must take in crossing the intersection. The crossing should be adjacent to-but stripped separately from the pedestrian crosswalk. Figure H-10 shows some examples of typical channelization arrangements. The arrangement in Figure H-10(a) shows a pair of bicycle lanes which are carried straight through the intersection. Where there is heavy vehicular right-turn movement across the bicycle crossing the bicycle crossing should be offset from the approach alignment of the bicycle lane approximately 10 to 20 feet as shown in Figure H-10(b). For bicycle lanes which are continued on cross streets, Figure H-10(c) depicts a channelization arrangement to provide for bicyclists turning right or left depending on direction of travel. At unsignalized intersections it may be desirable to stripe the bikeway through the intersection as shown in Figure H-11 so as to cause the drivers to be more conscious of cyclists presence and alert the drivers to right-of-way situations.

Where bicycle trails cross highways, at-grade intersection should be located where the sight distance along the highway is sufficient to provide time for bicyclists to cross the highway safely. In the case where two highways intersect, it may be desirable to offset the bicycle trail similar to that shown in Figure H-10(b) a distance of 100 feet or more so as to remove the bikeway crossing from the influence of the highway intersection.

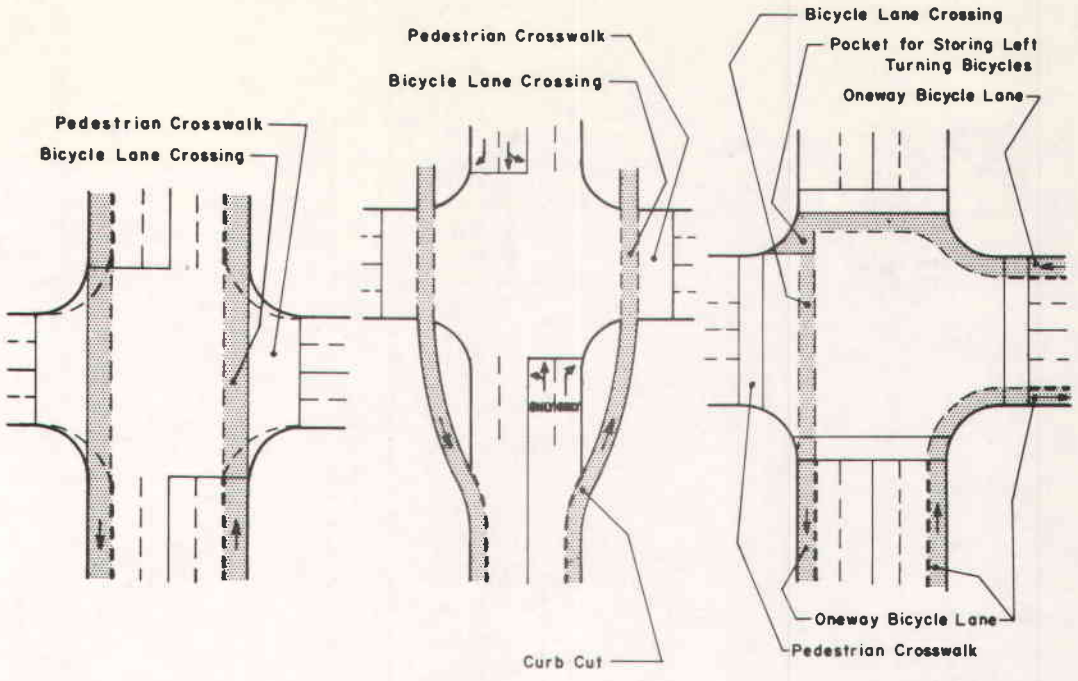
H-113 SIGNS AND PAVEMENT MARKINGS

In order to insure the safe and efficient operation of a bikeway, there must exist adequate signs and markings to warn bicyclists of hazardous conditions or obstacles, to delineate bicycles rights-of-way, to exclude undesired vehicles from the route, and to warn motorists and pedestrians of the presence of bicycle traffic. The standard signs to be used on bikeways can be found in the "Texas Manual on Uniform Traffic Control Devices" (MUTCD). Figure H-12 shows some of the standard signs pertaining to bicycle operation.

(a) Sign Placement

The placement of signs is dependant on whether the bikeway is or is not an independant bikeway. The MUTCD prescribes that signs erected on the roadside be mounted with the lower edge of the sign a specified minimum above the pavement edge. Specified minimums include 5 feet on rural highways, 7 feet in business, commercial and residential districts and 7 feet on expressways and freeways. These specifications reflect normal driver vision characteristics. However, because of head inclination, the bicyclist's field of vision appears to be focused lower than that of motor vehicle operators.

Therefore, on independant bike trails, it may be desirable to mount signs so that the bottom of the sign is 4 to 5 feet above the pavement elevation. Lateral placement should be according to the Texas MUTCD except that signs along curbs should have a desirable minimum clearance of 2 feet from edge of curb to edge of sign. Warning signs informing bicyclists of potential hazards should be positioned not less than 50 feet in advance of the hazardous condition. In urban areas, warning signs directed to motorist should be positioned a minimum of one-half block in advance of any point where bicycles may be encountered.



(a.) Bicycle Lanes crossing intersection

(b.) Bicycle Lanes offset to cross intersection

(c.) Bicycle Lanes continued on cross street

Typical Bicycle Channelization Arrangements At Street Intersections

FIGURE H-10

Bikeway Marked Thru Intersection With Diagonal Lines For Added Visibility And Emphasis

FIGURE H-11

(a) (b) (c)

(d) (e) (f)

FIGURE H-12

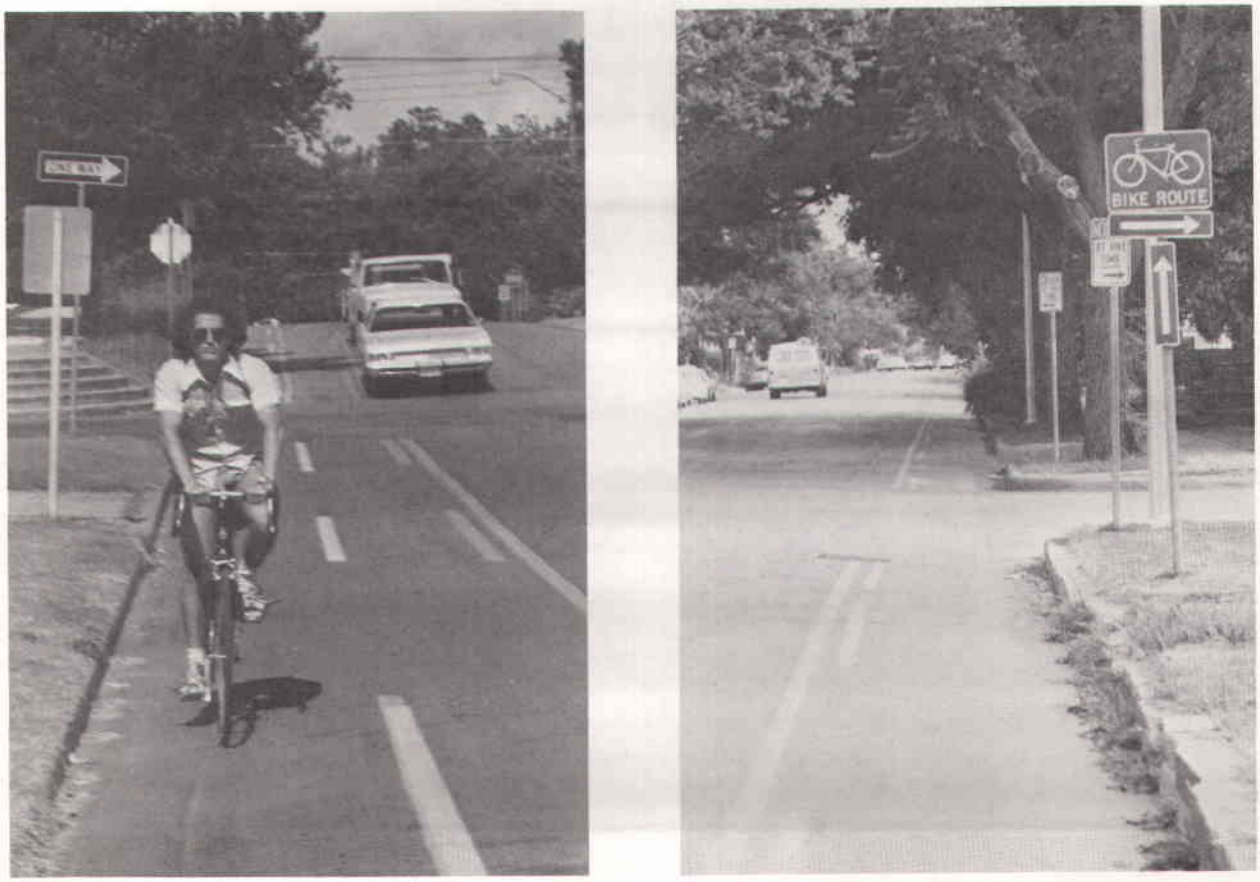


FIGURE H-13

(b) Lane Demarcation

Figure H-13 shows a typical demarcation striping of on-street bike lanes. The MUTCD specifies that solid white line be used to delineate the edge of a travel path where travel in the same direction is permitted on both sides of the line but crossing the line is discouraged. It is very important to maintain bikeway lane lines and other pavement markings in good condition so as not to be confused with an old traffic lane marking which is no longer applicable.

(c) Pavement Message Markings

Pavement message markings should be used on all bike lane departures from intersections to ensure that turning vehicles do not stray unknowingly into the bikeway. Word messages such as "BIKE LANE" or "BIKE ONLY" painted in at least 5 foot letters appears to be the most effective in informing motorists of lane function. Pavement markings in the form of directional arrows should not be used in bike lanes at intersections to indicate that the bikeway turns at that point.

(d) Transition Areas

The termination of any on-street bike lane, the change from a two-way facility to a one-way facility or from one side of the street to the other are some examples of transition areas and the designer should attempt to achieve as smooth a transition as possible rather than an abrupt termination.

H-114 CONTROL, MAINTENANCE AND POLICING

Prior to the construction of the project, an agreement as to the control, maintenance and policing of the bikeway should be established. In most cases, this will be an agency of the municipal government.

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