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TRANSITIONS FROM UNDIVIDED TO

DIVIDED SECTIONS OF HIGHWAYS

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TRANSITIONS FROM UNDIVIDED TO DIVIDED SECTIONS OF HIGHWAYS

The topic which I have chosen, "Transitions from Undivided to Divided Sections of Highways," is certainly not a new subject to anyone familiar with the design and construction of our widespread highway system. It would be difficult to estimate the number of such transitions which have been utilized State-wide. It is obvious, however, that a number of different designs have been developed in different sections of the State, and it is toward this variance in practice that my remarks are primarily directed.

Transitioning from a two-lane to a four-lane highway is not restricted to our new, high volume, controlled access facilities. It has been utilized throughout the years as a safe and effective means whereby turning traffic can pause within the intersection area without impeding the flow of through traffic. In addition to regulating the flow of traffic through the intersection, the introduction of a median on the approaches to an intersecting road tends to alert the drivers to the crossroad ahead. This visual means is particularly effective at night, since visibility ahead is severely restricted by the short range illumination of each driver's headlights. It also follows, however, that selection of the proper design for introducing a median is of greater importance under restrictive night-time visibility than it would be during daylight hours.

As we approach the point where our existing two-lane highways will be interspersed with completed segments of divided highways, as in the case of our Interstate Highway System, it becomes even more imperative that some definite criteria for transition lengths be developed. The need for such specific information becomes increasingly greater when we consider that stage construction will entail the use of transitions at increased frequencies within any given portion of our existing highways.

Another condition where transitions will be increasingly utilized would be at bridge or overpass locations which are presently served by a restrictive width structure that must either be reconstructed or replaced in order to safely serve traffic. In some instances, it is more economical to build a new structure, adjacent to the old, and permit both structures to individually serve one direction of traffic. Such a design has been satisfactorily applied in a number of cases where the old structure can safely serve one direction of traffic for a number of years but could be widened to accommodate two-direction traffic only at great expense.

In all the cases previously noted, the safe and expeditious operation of traffic within a four-lane portion can be realized only if a safe transition on the approaches is incorporated. When a roadway is increased from a two-lane section into a multi-lane divided section, the alignment should be such that the proper paths to follow are unmistakably evident to the average driver. In order to achieve this result, the alignment should be such that no appreciable effort in steering or reduction in speed is introducted by the transition. On tangent alignment, widening may produce some appearance of distortion, even when flat curves are used. It is often necessary to resort to the use of reverse curves to achieve the necessary separation of traffic lanes when widening on tangent alignment. The American Association of State Highway Officials' "Policy on Geometric Design of Rural Highways" stipulates that necessary reversals in curvature should preferably be of one degree or less in rural areas, where speeds are generally high, and that sharper curves may be used on low speed roads; however, the degree of curvature, even where lower speeds are encountered, should preferably not exceed one and one-half or two degrees. The required length of reverse curvature for transitions utilizing two degrees or less are set forth in Table No. A. It should be noted that the lateral offset indicated is that along one edge of pavement for either one-half or the whole median width as determined by the alignment of the adjacent highway sections. You will also note that Table No. A does not specify the design speed which would govern selection of a particular reverse curvature.

TABLE NO. A

LENGTHS OF REVERSE CURVES FOR EFFECTING WIDENING AT INTERSECTIONS

LATERAL OFFSET, (feet)	LENGTH OF REVERSE CURVE, IN FEET, WHEN RADIUS OR DEGREE OF CURVE IS:				
	R=11,460' D=0°30'	R=7640' D=0°45'	R=5730' D=1°00'	R=3820' D=1°30'	R=2865' D=2°00'
4	428	350	306	247	214
6	524	428	371	306	262
8	606	494	428	350	303
10	677	553	479	391	338
12	742	606	524	428	371
14	801	654	566	462	400
16	856	699	605	495	428
18	908	741	642	524	454
20	957	782	677	552	478
30	1172	957	829	676	585
40	1353	1105	957	781	676
50	1513	1235	1069	873	755

A study of existing Departmental publications indicates that the only definite designation of transition lengths which has been established by our Department exists in the Texas "Manual on Uniform Traffic Control Devices for Streets and Highways." Table No. D-3 which appears in this manual is shown as Table No. B in the next slide. The range in reverse curvature offered by this table varies from approximately zero degrees, forty-five minutes for 70 m.p.h. speed to approximately four degrees, fifteen minutes for 40 m.p.h. speed. The maximum curvature, of course, exceeds that recommended by the American Association of State Highway Officials. It should be stressed that Table No. D-3 does not exceed the limits of safe side friction or super-elevation; however, a conscious effort in steering would be required within the lower speed ranges.

TABLE NO. B

TRANSITIONS FROM UNDIVIDED TO DIVIDED HIGHWAYS

OFFSET (feet)	DESIGN SPEED 40	DESIGN SPEED 50	DESIGN SPEED 60	DESIGN SPEED 70
1	100	100	100	110
2	100	100	130	160
3	100	120	160	200
4	100	140	180	230
5	110	150	200	260
6	120	170	220	280
7	130	180	240	300
8	140	200	250	320
9	150	210	270	340
10	160	220	280	360
11	170	230	300	380
12	170	240	310	400
13	180	250	320	410
14	190	260	340	430
15	200	270	350	440
16	200	280	360	460
17	210	290	370	470
18	220	290	380	490
19	220	300	390	500
20	230	310	400	510
30	280	380	490	630
40	330	440	570	720
50	360	490	630	810
60	400	540	690	890
70	430	580	750	960
80	460	620	800	1020
90	490	660	850	1090
100	520	690	900	1150

A study of criteria utilized by several other State Highway Departments reveals that a number of different transition lengths are utilized throughout the nation. In Table No. C, the next slide, the approximate lengths of taper furnished by Tables Nos. A and B are shown. The rates of taper indicated are necessarily an average range, since design speed and lateral offset will result in an extreme range of values when determined individually for each case. The California Division of Highways stipulates that a minimum transition of three hundred and fifty feet be used in narrowing from two lanes to one lane or expanding one lane into two lanes. This length would result in a taper of approximately thirty longitudinal feet for one foot of offset. California further specifies that the alignment and radius of curve will vary depending upon median widths and other local considerations.

TABLE NO. C

DESIGN AGENCY	APPROXIMATE LENGTH OF TAPER IN LENGTH (FEET) PER FOOT OF OFFSET*
Texas Highway Department	From 14:1 To 30:1
American Association of State Highway Officials	From 30:1** To 60:1
California Division of Highways	30:1
Massachusetts Department of Public Works	From 100:1 To 125:1

* All values predicated on a narrowing of one lane width.

** Values shown are predicated on a degree of curvature of 1°00'. Other curvature will give either higher or lower ratios depending upon the rate of curvature.

The Massachusetts Department of Public Works stipulates that a transition length of 1,500 feet is desirable to effect a narrowing of one lane width at a design speed of 70 m.p.h., and a transition length of 1,200 feet is desirable for narrowing one lane width at a design speed of 50 m.p.h.

From data available, it appears that the Illinois Division of Highways uses the transition lengths recommended by the American Association of State Highway Officials as previously shown in Table No. A.

As demonstrated by the foregoing discussion, the nominal rate of taper utilized by these representative Highway Departments offers a widely diversified range in designs; however, it should also be noted that, as a general rule, all of these agencies employ a longer transition length than does our Department and that their approximate lengths of required taper either correspond to or exceed the values set forth by the American Association of State Highway Officials. It is believed that the stipulation of a standard rate of taper as used by several agencies would not appear to be a desirable practice because, for example, a 50:1 taper would result in a length of 2,400 feet if a lateral offset of 48 feet, our usual median width, were required. Such a length is, of course, definitely unwarranted. Therefore, a "sliding-scale" type of length designation, as afforded by the use of reverse curvature, would be far more applicable.

As previously noted, the values set forth by the American Association of State Highway Officials do not specifically refer to a given design speed; however, by applying the restrictions recommended by their organization, where high speed traffic would be limited to approximately one degree of reverse curvature and lower speed traffic would be limited to approximately two degree reverse curvature, the values set forth in Table No. A can be grouped under speed classifications. Show Table No. D

TABLE NO. D

TRANSITIONS FROM UNDIVIDED TO DIVIDED HIGHWAYS

LATERAL OFFSET (Feet)	LENGTH OF TRANSITION IN FEET FOR DESIGN SPEEDS OF: 40 m.p.h. D=2°30' Min.	40 m.p.h. D=1°30' Des.	50 m.p.h. D=2°00' Min.	50 m.p.h. D=1°00' Des.	60 m.p.h. D=1°30' Min.	60 m.p.h. D=0°45' Des.	70 m.p.h. D=1°00' Min.	70 m.p.h. D=0°30' Des.
4	190	250	210	300	250	350	300	430
6	230	300	260	370	300	430	370	520
8	270	350	300	430	350	500	430	610
10	300	390	340	480	390	550	480	680
12	330	430	370	520	430	610	520	740
14	360	460	400	570	460	650	570	800
16	380	500	430	610	500	700	610	860
18	410	520	450	640	520	740	640	910
20	430	550	480	680	550	780	680	960
30	520	680	590	830	680	960	830	1170
40	600	780	680	960	780	1110	960	1350
50	670	870	760	1070	870	1240	1070	1510

Rather than specifying only one particular rate of curvature for each design speed, a more effective guide could be achieved by stipulating minimum and desirable degrees of curvature for each speed. Thus, a certain degree of flexibility will result. In those cases where a necessary transition will be relatively temporary in nature, the minimum curvature could be used. Conversely, for permanent or semi-permanent transitions, the desirable lengths should be adopted.

The lengths stipulated in Table No. D are approximately one-half the length arbitrarily specified by the State of Massachusetts. As shown by Table No. E, the appropriate values set forth by Table No. B (as appearing in our Maintenance Manual) would be increased somewhat by the minimum lengths specified in the American Association of State Highway Officials' table as modified to include design speed.

TABLE NO. E

COMPARISON OF TABLE NO. B (T.H.D. MAINTENANCE MANUAL)
VS. TABLE NO. D (AASHO REVISED)

OFFSET	40 m.p.h.		50 m.p.h.		60 m.p.h.		70 m.p.h.	
(Feet)	THD	*AASHO	THD	*AASHO	THD	*AASHO	THD	*AASHO
4	100	190	140	210	180	250	230	300
6	120	230	170	260	220	300	280	370
8	140	270	200	300	250	350	320	430
10	160	300	220	340	280	390	360	480
12	170	330	240	370	310	430	400	520
14	190	360	260	400	340	460	430	570
16	200	380	280	430	360	500	460	610
18	220	410	290	450	380	520	490	640
20	230	430	310	480	400	550	510	680
30	280	520	380	590	490	680	630	830
40	330	600	440	680	570	780	720	960
50	360	670	490	760	630	870	810	1070

* Minimum transition length.

The Operations Division has compiled a book entitled "Table of Tangent Offsets" which is of benefit in determining required lengths of transition for a specific offset and degree of curvature. I am sure that copies of this publication could be obtained by addressing your requests to their Division.

As discussed in the foregoing analysis, the length and degree of curvature of a transition are important considerations in its design; however, the alignment and constituent geometric features are also of paramount importance. As previously noted, the alignment should be such that no appreciable effort in selecting and negotiating the proper path should be introduced. This is particularly true when split-second decisions could result in hazardous high-speed conflicts. It is imperative that the transition be designed so that high speed traffic is directed away from other opposing high speed traffic, thus insuring that mistakes or confusion will not create a head-on collision.

There are two general means whereby two lanes are transitioned into four lanes. The pavement in each direction of travel may be bowed out, more or less symetrically about the centerline, or widening may be effected by retaining the existing two-lane facility for one direction of traffic and constructing two additional lanes either on the right or left of the existing highway to serve the other direction of traffic. The latter arrangement is usual practice where the two-lane highway beyond the four-lane portion will ultimately be converted to a divided highway with the pavement tangent being a permanent part of the ultimate development.

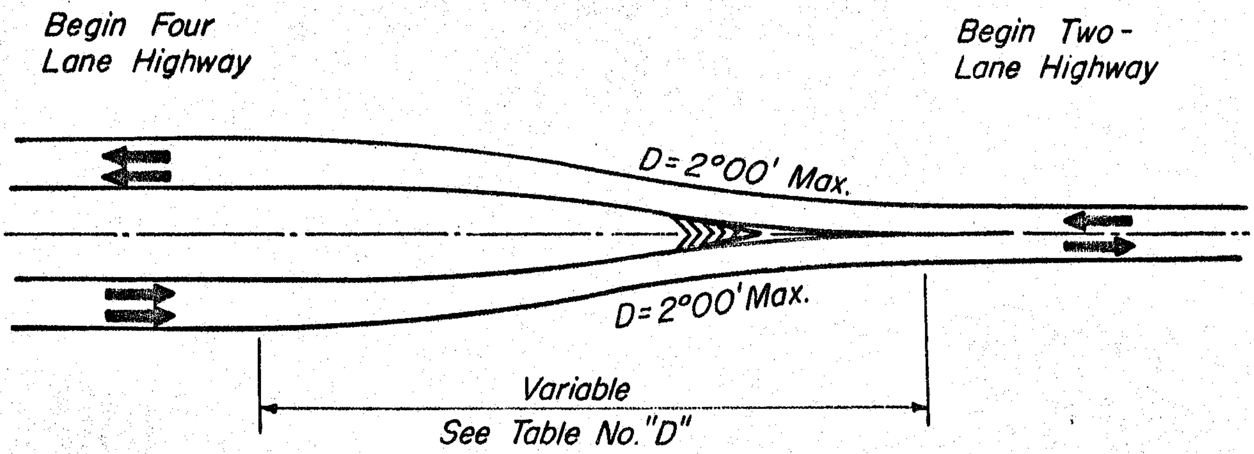
(SHOW SLIDE NO. 1) Whenever it is necessary to expand an existing facility symetrically about the centerline, it is mandatory that adequate approach sight distance and warning signs be incorporated into the design. In addition, an appropriate no-passing distance on the approaches to the transition must be established in order to insure that wrong way entry of vehicles is avoided. Where ideal conditions cannot be met, it is advisable to provide two traffic lanes for vehicles entering the transition and one lane for those leaving the divided section. In this way, ample width is provided to insure entry of traffic into the proper path.

If the original highway is to serve as a future extension of the ultimate divided highway, an alignment similar to that shown in the second slide (SHOW SLIDE NO. 2) is the most desirable arrangement since traffic entering the transition can continue in its normal path without being forced to negotiate a reverse curve. Traffic leaving the divided section is warped in toward the existing highway. As can be seen, anyone failing to negotiate the reverse curve will simply continue onward in the direction of the future extension and thereby avoid colliding with oncoming traffic. There are a number of different designs that can be utilized in the vicinity of the actual transition, depending upon topographical limitations at each particular point; however, the basic feature which should be incorporated is the provision of two lanes for traffic approaching the transition and one lane for traffic leaving the divided portion. The necessity for such a provision is predicated on the fact that drivers approaching a divided highway are anxious to pass cars ahead at the earliest opportunity, whereas drivers leaving the divided portion have had passing opportunities and should be more alert to the narrowing of the highway through the advance warning signs and physical constriction of the roadway to one lane flow. By providing the two-lane approach to the transition, traffic should have no difficulty in entering the transition in the proper path even if they are illegally in the process of passing.

You will note that in the next slide (SHOW SLIDE NO. 3) a wider highway section at the point of divergence is indicated and that a longer taper for traffic is provided. This design represents an improvement over that shown in the preceding slide; however, unless sight restriction or other topographic features would require such a treatment, this design may be too elaborate for temporary connections.

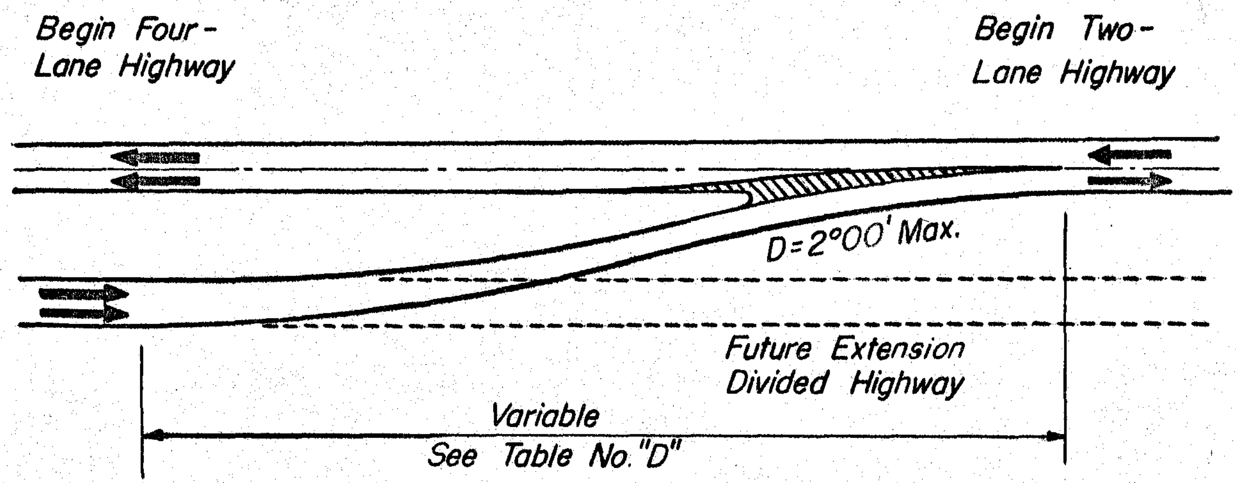
If the existing roadway is to be eventually utilized for directional flow opposite from that shown on the preceding slide, an alignment similar to that indicated on this slide (SHOW SLIDE NO. 4) will be required. As you will note, traffic on the two-lane roadway approaching the transition is directed straight toward the reverse flow within the expanded section, thereby immeasurably increasing the possibility of wrong way entry and resultant head-on collisions. If at all possible, such an alignment should be avoided; however, if an arrangement similar to that shown must needs be used, signing, delineation, and channelization should be amply provided to insure safe operation.

Whatever alignment and curvature is chosen for a particular transition, its operation under traffic is markedly affected by the proper or improper provision of signs and pavement marking. The driver approaching a transition from either direction should be amply forewarned that the highway widens or narrows directly ahead. Upon encountering the actual transition, regulatory signs indicating the proper path to follow, along with pavement marking and channelization, should be appropriately employed. Above all, each transition is an independent roadway feature and should be designed as such. The general precepts that I have discussed today should be considered in determining the most desirable design. In order to achieve the best possible design, commensurate with conditions present at each location, each transition should be considered a separate and distinct problem much as each highway intersection is considered an individual study.



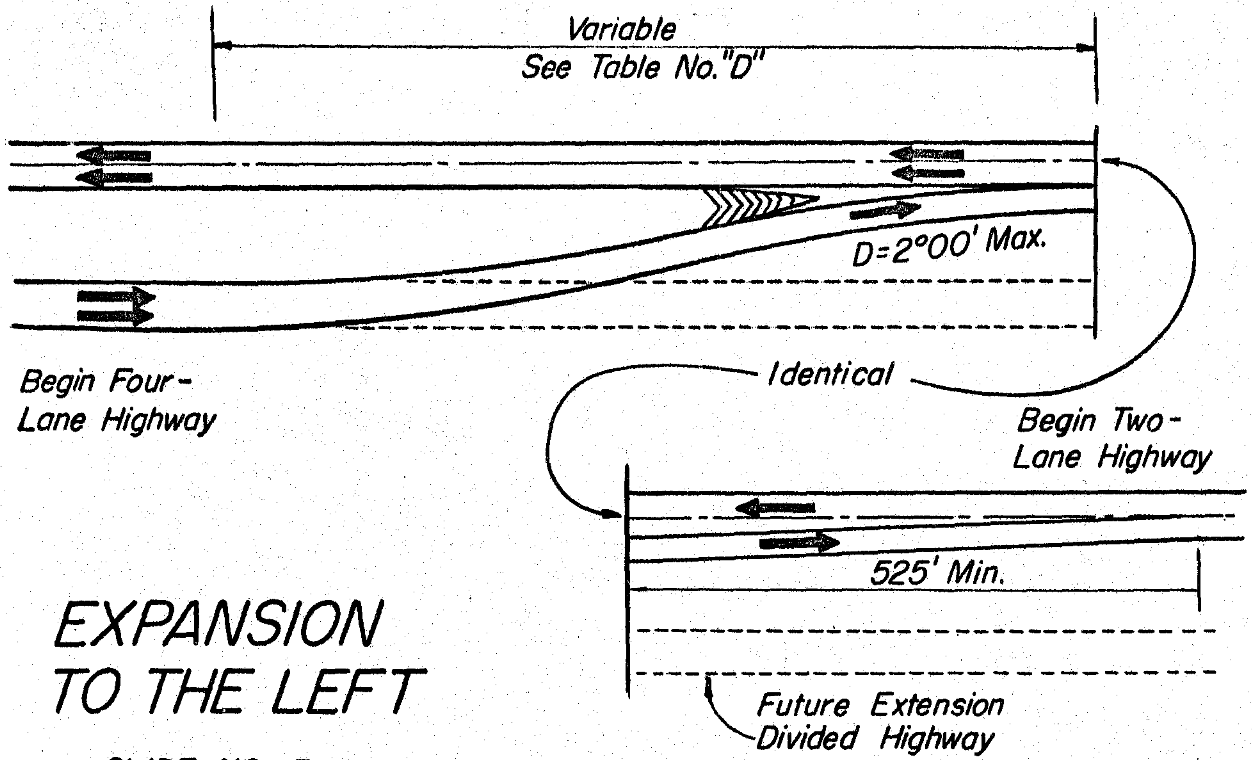
EXPANDED SYMETRICALLY
ABOUT CENTERLINE

SLIDE NO. 1



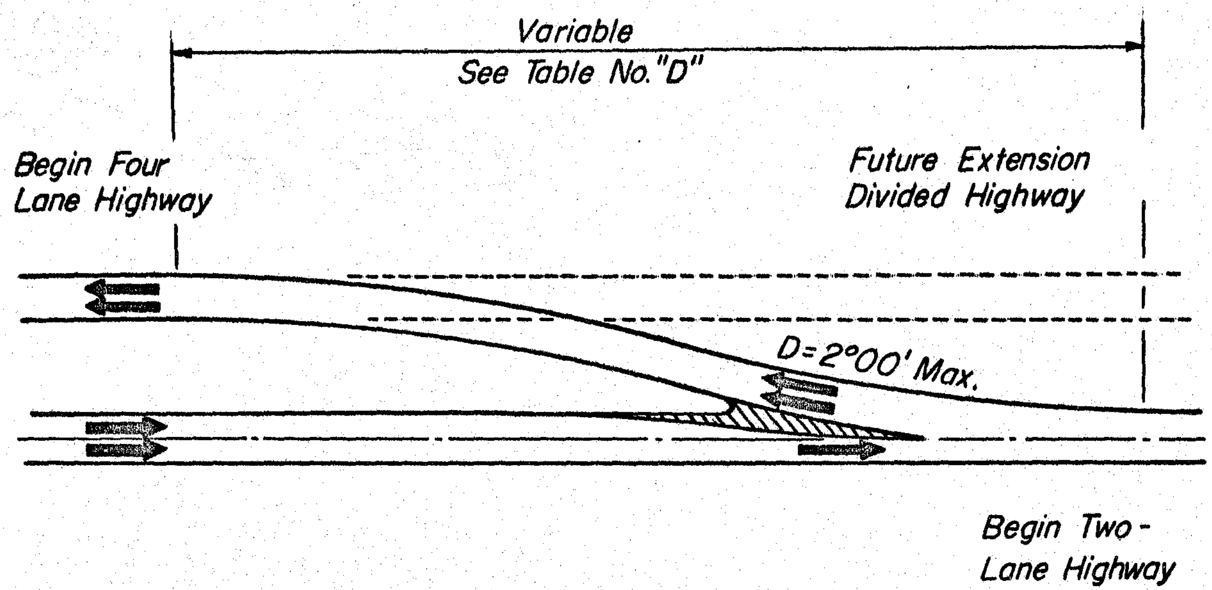
EXPANSION TO THE LEFT

SLIDE NO. 2



EXPANSION
TO THE LEFT

SLIDE NO. 3



EXPANSION TO THE RIGHT

SLIDE NO. 4