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16. Abstract

A rating scale for Highway-Railroad Grade Crossings has been presented. This scale has been used in a field evaluation survey of 40 crossing sites which have been improved since 1973 in district 17 of the Texas State Department of Highways and Public Transportation. The evaluation procedure can be used in conjunction with the rating scale to determine the crossings which are most in need of repair or replacement. A modified version of the rating form is currently being used by SDHPT personnel in an attempt to build the data base needed for evaluation.

Also presented in this report is a conceptual design for an improved highway-railroad grade crossing. This design is intended to reduce the temporal variations in subgrade stiffness and to minimize the deterioration of the highway pavement and railroad trackbed approaches to the crossing.

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Development of a Stable Foundation

for

Highway - Railroad Grade Crossings

by

James R. Morgan
Robert M. Olson

Research Report Number 483-1F

Research Project 2-5-85-483

conducted for

The State Department of Highways
and Public Transportation

in cooperation with
U.S. Department of Transportation
Federal Highway Administration

by the

Texas Transportation Institute
Texas A&M University System
College Station, Texas 77843

April 1987

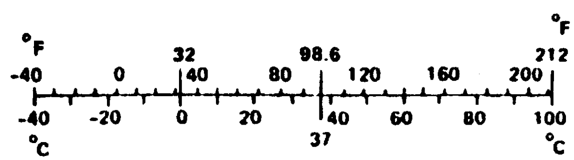
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

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In particular, this report is dedicated to Dr. Robert M. Olson, Professor Emeritus of Texas A&M University who died suddenly on April 4, 1986. He had a major influence on this work and on the author. This final product is much poorer for his passing; however, the influence and inspiration of Bob Olson will live on in the students he taught and in the associates he so unselfishly helped. Without his insight into the problem this study never could have been completed.

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ABSTRACT

A rating scale for Highway-Railroad Grade Crossings has been presented (Chapter II). This scale has been used in a field evaluation survey of 40 crossing sites which have been improved since 1973 in district 17 of the Texas State Department of Highways and Public Transportation. The evaluation procedure (presented in Chapter III) can be used in conjunction with the rating scale to determine the crossings which are most in need of repair or replacement. A modified version of the rating form is currently being used by SDHPT personnel in an attempt to build the data base needed for evaluation.

Also presented in this report is a conceptual design for an improved highway-railroad grade crossing. This design is intended to reduce the temporal variations in subgrade stiffness and to minimize the deterioration of the highway pavement and railroad trackbed approaches to the crossing.

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CHAPTER I.
BACKGROUND AND INTRODUCTION

The objective of this study was to design and construct a track substructure which would provide a more stable foundation for the grade crossing surface. The project reported herein consisted of the following steps:

1. Development of a rating system for existing systems
2. An evaluation of existing crossings in selected locations (Chapter III)
3. An investigation of the better crossings, and
4. Development and design of an improved highway-railroad grade crossing (Chapter IV)

A variety of railroad crossing surfaces has been installed on Texas highways in recent years. Types of crossing surfaces include:

1. Bituminous Materials
2. Full Depth Timber Panels
3. Reinforced Concrete Panels
4. Steel Encase in Rubber Panels
5. Elastomeric Panels

These and other surfaces have been placed on a variety of foundation materials:

- Uncompacted subgrade
- Compacted subgrade
- Compacted base materials placed on compacted subgrade

Many of the crossings have received additional treatments, such as:

- Adequate surface drainage has been provided
- Underground drainage has been constructed
- Fabric materials have been installed

At some locations a combination of the above construction methods has been employed. Deterioration of crossings at some locations has emphasized the need for an evaluation of current techniques and recommendations for improved techniques.

Following the investigation and evaluation presented in Chapter III, it became apparent that many of the problems seen in the deterioration of the highway-railroad grade crossing could be attributed to distinct characteristics of the crossing system. The most important of these characteristics are (1) changes in the stiffness of the track and/or highway pavement structure and (2) drainage (or the lack thereof).

The value of the modulus of elasticity varies greatly with the passage of time. Weather, dynamic loading from trains and trucks, water intrusion and other conditions influence the value of the modulus.

Talbot employed Foppl's method of attack in solving the equation:

$$EI\frac{d^4y}{dx^4} = uy$$

Where:

- y is the depression of the rail at any point, x, and
- u is an elastic constant which denotes the pressure per unit length of rail necessary to depress the track one unit. u represents the stiffness of the track and involves conditions of tie, ballast, base, and subgrade. It is termed the modulus of elasticity of rail support.

A concept for construction, using available materials, has been developed by Robert M. Olson (see Chapter IV). The concept consists of gradually increasing the stiffness of the track and highway approaches to the grade crossing surface. This concept is intended to reduce the temporal variability of the elastic modulus.

CHAPTER II.
A RATING SCALE FOR HIGHWAY-RAILROAD GRADE CROSSING

This chapter contains the basic elements of a manual describing a rating system for Highway-Railroad Grade Crossings. The purpose of this manual is to aid personnel in evaluating the condition of grade crossings. The scale consists of several pages of photographs of conditions, such as ballast fouling at crossings. Three photographs are on each page. Rating 1 - excellent, Rating 3 - fair, Rating 5 - Poor

The evaluator uses these photographs to compare actual crossing conditions. For example if a condition is considered better than a "1" a "0" may be assigned. If the condition is between "1" and "3" a "2" may be assigned.

Figures 1 through 4 present a proposed evaluation manual.

Metalpeate

BALLAST FOULING

Ballast Fouling is primarily the presence of fine slurry (dirt) at or above the level of the base of the ties. The dirt in ballast destroys its drainage, sterility, resilience and stability. Water accumulates and pump track ensues (see bottom photograph as a typical example).

The accumulated dirt is of cementing quality which forms a hard impermeable, uneven mass with the ballast section. This fine slurry or dirt can be accumulated in two ways:

Firstly, it may be due to the build up of attrition and aeolian products within the ballast which can lead to 'Dirty Ballast Failure'.

Secondly, the slurry may be derived from the pumping of a soft subgrade up through the ballast which leads to 'Erosion Failure'.

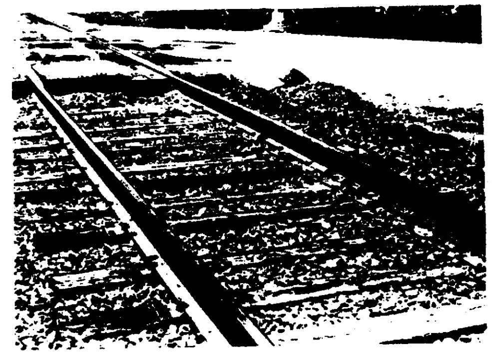
REMEDIAL MEASURES

The remedial measures used varies significantly with the mode of failures. Where dirty ballast failure has occurred, it is remedied by cleaning the ballast. A variety of cleaning procedures such as shoulder cleaning, sledding and plowing and undercutting are in use, depending on the source and extent of ballast fouling.

Furthermore, for erosion failures, the permanent remedy is the introduction of a separation/filtration layer, usually sand is recommended.

Evaluation Rating

1



3

5

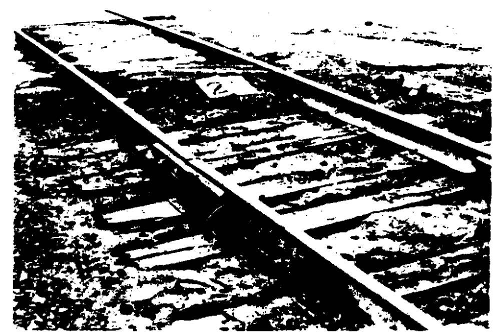


Figure 1. Typical Ratings for Ballast Fouling

Metal plate

EDGE RAVELLING

Edge ravelling is a collective term used to define the state of texture observed especially at road edges. Surface cracks appear as a result of irregular stresses applied to a particular area.

Edge ravelling condition exhibits mainly on the shoulders of highways and longitudinal deterioration occurs as a result of excessive braking at highway-railroad crossing.

REMEDIAL MEASURES

Resurfacing the road surface is the best method to remedy this edge ravelling problem. The top photograph is a typical example shown to overcome this problem at highway-railroad grade crossing.

Evaluation Rating

1

3

5

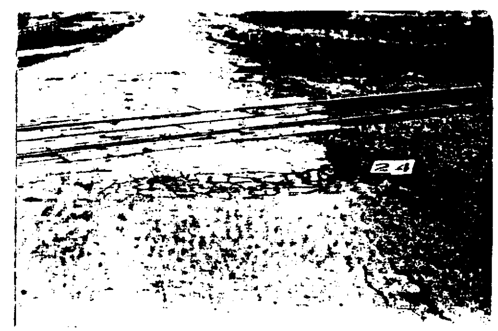


Figure 2. Typical Ratings for Edge Ravelling

Metal plate

SUBDRAINS

Proper drainage system is an important consideration in the maintenance of crossing site. Adequate preparation of the track structure, the subgrade and drainage is essential to the good performance and longer service life of a good crossing surface improvement.

Poor drainage conditions result in deteriorated ties, joint-bar and tie wear, flooded and washed-out track situation.

REMEDIAL MEASURES

Subdrainage systems consisting of longitudinal drains must be laid between tracks or under the sides ditches at a depth of 4 to 8 feet or deeper, depending on the depth of water pockets encountered, with lateral pipes extending at right angles under the track bed. The pipes may consist of 6, 8 or 10 inches tile laid with open joints or of 6-10 inches corrugated asphalt-coated and perforated metal pipe laid with perforations downwards (see figure 4).

A better method is to investigate subsurface conditions beneath the ballast, locating the low points of the ballast pockets and placing the pipe about 12 inches below the pocket bottom.

Evaluation Rating

1

3

5

Figure 3. Typical Ratings for Subdrains

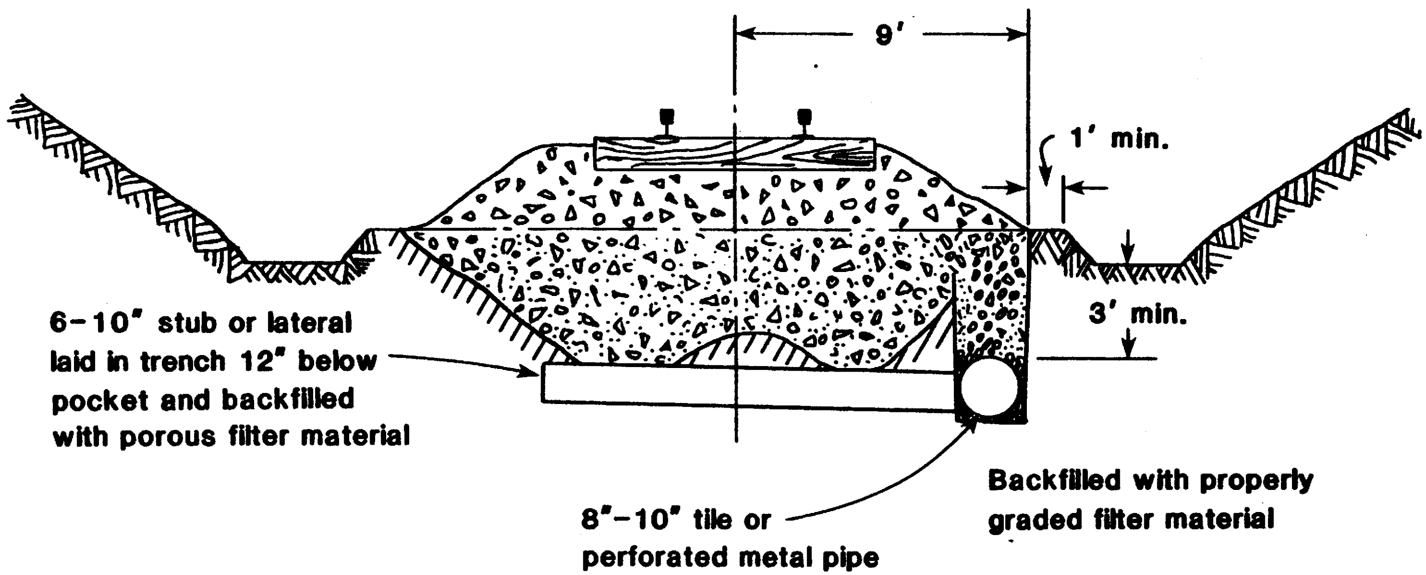


Figure 4. Subdrainage System

The Texas State Department of Highways and Public Transportation already has adopted this procedure to a one page submission form (see Figure 5). Utilization of this form will make it possible to obtain a ranking of the "worst" highway-railroad grade crossings in the state.

RR Crossing Submission Sheet
(Must be completed for each Xing submitted for replacement on 1987 Railroad Grade-Crossing Replanking Program)

DISTRICT: ________

DATE: ________
District Priority Number: ________

DOT NO.: ________

Name of RR: ________

COUNTY: ________

No. of Trains Per Day: ________

CSJ: ________

No. of Tracks at Xing: ________

HWY.: ________

No. of Tracks Proposed for Resurfacing: ________

General Location(town): ________

Type of Surfacing Proposed: ________

**ADT: ________

Length of each Surface: ________

CONDITION OF CROSSING*

Overall Visual Rating:
(From scale below)

HIGHWAY: ____

1. Condition of Pavement
   a. Potholes
   b. Edge Ravelling
   c. Profile(high/low)
   d. Cross Section

2. Crossing Surface
   a. Roughness
   b. Deterioration
   c. Headerboards
   d. Hardware (missing/loose)

3. Traffic Behavior
   A. Speed Reduction
   b. Braking
   c. % of Trucks to Cars (Est.)

RAILROAD: ____

1. Condition of Track
   a. Change of gage thru xing
   b. Track surface(high/low)
   c. Flangeway (open/fouled)

2. Condition of Rail
   a. Anchors, plates, spikes (loose/missing)
   b. Ties (rotten/loose/broken)
   c. Ballast (clean/fouled)
   d. Rail movement under loads (pumping)
   e. Subgrade Stabilization

DRAINAGE: ____

1. Crossing Condition
   a. Ballast fouling-How man feet out from xing?
   b. Standing water-How many feet out from xing?

2. Crossing Area
   a. Grading Contour (into/away from xing)
   b. Culverts (existing, open/fouled)
   c. Subdrains (exposed, damaged, etc.)
   d. Adjacent Vegetation (blocking drainage)

0 1 2 3 4 5
Excellent Condition — Poor Condition

Overall Visual Rating Scale*

*Each factor should be considered in assigning an overall rating for each catagory (Hwy., RR, Drain.). Please check or make notes next to any and all factors that are a particul problem.
**Over 5,000 VPD; rubber, concrete or other "high" type crossings should be considered.

Figure 5. Railroad Crossing Submission Sheet

D-5RR
6-16-86

CHAPTER III.
FIELD EVALUATION SURVEY

Field investigation and evaluation surveys were conducted at 40 crossing sites which have been improved since 1973 in district 17. More than eighty-seven percent of these crossing surfaces were full depth timber. The remaining crossings investigated were rubber panel crossings (see Table 1).

GENERAL CROSSING CONDITION

A visual survey of crossing sites in district 17 provides an estimate of the general conditions on highway-railroad crossings. The elements considered in visual rating of highway-railroad grade crossing are listed below:

HIGHWAY

1. Condition of pavement
   a. Potholes
   b. Edge ravelling
   c. Profile
   d. Cross-section
2. Crossing surface
   a. Roughness
   b. Deterioration
   c. Hardware
3. Traffic behavior
   a. Speed reduction
   b. Braking

RAILROAD

1. Condition of track
   a. Gage
   b. Track surface
   c. Flangeways
2. Condition of rail
   a. Angle bars
   b. Rail anchors
   c. Tie plates
   d. Spikes and bolts
   e. Ties
   f. Ballast

DRAINAGE

1. Crossing condition
   a. Ballast fouling
   b. Standing water
2. Crossing adjacent
   a. Grading cont our
   b. Culverts
   c. Subdrains

PROJECT 2483H (District 17)

S.No.	COUNTY	HIGHWAY	RAIL ROAD	XING NO.	DATE PROJ. COMPLETED	INSP. DATE	ADT	# OF TRAINS
01	Burleson	FM 1363	AT&SF	022896P	12-22-82	05-16-85	350	23
02	Burleson	FM 60	AT&SF	022874P	07-25-83	05-16-85	3300	21
03 *	Grimes	SH 105	MP	430351K	08-10-82	03-08-85	3800	01
04	Grimes	LP 508	MP	024292S	09- -80	08-02-85	2100	08
05	Grimes	FM 379	SP	743257M	04-13-82	03-08-85	1900	05
06	Grimes	SH 105	SP	743251W	08-10-82	03-08-85	3800	12
07	Grimes	LP 508	MP	430132W	11-29-83	03-08-85	2100	08
08 *	Grimes	SH 105	AT&SF	024283T	11-17-83	03-08-85	3800	06
09	Madison	FM 1372	FW&D	597144E	12-01-83	05-22-85	310	12
10	Madison	OSR	FW&D	597155S	10-10-83	05-22-85	1050	12
11	Milam	FM 845	SP	6035	11-18-81	05-16-85	420	15
12 *	Robertson	US 79	MP	432273M	09-22-82	05-22-85	9500	09
13	Robertson	FM 1940	MP	432241G	10-06-80	05-22-85	770	04
14	Robertson	FM 50	MP	430178K	02-17-83	05-16-85	520	08
15	Walker	FM 2929	MP	427997X	12-09-83	05-23-85	730	
16	Walker	FM 2296	MP	428003G	08- -82	05-23-85	850	01
17	Walker	FM 2296	MP	428007J	12-17-82	05-23-85	850	01
18	Walker	SH 105	MP	427983P	03-20-81	05-23-85	1800	04
19	Washington	FM 389	AT&SF	022843R	09-17-82	05-17-85	3700	17
20	Brazos	FM 2818	SP&MP	743219D	04-03-81	05-24-85	6200	12
21	Brazos	FM 2347	SP	743215B	04-10-81	05-24-85	7200	12
22	Brazos	OSR	MP	430167X	06-16-76	12-20-84	200	06
23 *	Brazos	LP 158	SP	743197F	04-24-81	12-20-84	3100	05
24	Brazos	FM 1687	MP	430168E	08- -79	12-20-84	280	08
25	Burleson	FM 1362	SP	6894	03-09-77	05-20-85	400	01
26	Washington	LP 283	SP	765689X	02-06-80	05-17-85	8700	01
27	Walker	FM 2296	MP	756	02- -79	05-23-85	670	01
28	Walker	FM 980	MP	432286N	07- -79	05-23-85	1200	04
29	Robertson	FM 979	MP	430217Y	10-06-80	05-16-85	420	05
30 *	Robertson	US 79	SP	763408E	09-23-81	08-06-85	9500	
31	Robertson	FM 2549	SP	6349	07-26-76	05-18-85	240	06
32	Robertson	FM 46	MP	432247X	12- -76	05-22-85	710	04
33	Robertson	FM 50	SP	745200T	04-04-75	05-18-85	910	20
34	Grimes	SH 30	FW&D	597127N	02-09-79	05-23-85	2400	10
35	Grimes	FM 149	FW&D	597123L	12- -79	05-23-85	670	10
36	Freestone	SH 164	FW&D	597177S	02-06-80	05-22-85	1150	10
37	Leon	LP 208	MP	432377U	10-29-82	05-22-85	270	04
38	Leon	FM 3	MP	432233P	11-16-82	05-22-85	770	04
39	Milam	US 190	SP	6039	07- -77	05-16-85	4600	17
40	Grimes	FM 1774	AT&SF	024313H	11-20-81	05-23-85	2200	08

NOTES:

1. Average Daily Traffic (ADT) data is obtained from traffic map 1983.
2. Number of Trains data is obtained from 1975 survey on railroads.
3. Asterisk (*) indicates Rubber crossing, and all other crossings are Full Depth Timber.

TABLE 1. SUMMARY OF HIGHWAY-RAILROAD GRADE CROSSING IN DISTRICT 17.

The elements are mainly subdivided into three major categories namely: highway, railroad and drainage. The rating range varies between 0 and 5. The results of the visual survey conducted are tabulated in Table 2 (a) and (b) and a summary of the field ratings on district 17 are shown in Table 3.

STATISTICAL TECHNIQUE

An evaluation crossing index proposed in Research Report No. 164-1 was used in this study. The field rating calculation is based on the frequency tabulation of the three major elements rated respectively on each site as shown in Table 4.

The mean of the rating range is 2.50 for each major crossing element; that is H avg = R avg = D avg = 2.50.

Method for weighted average

Weighted $\bar{X} = \sum_{i=1}^{n} \frac{fiXi}{\Sigma fi}$ where $\Sigma fi = n$

n = Total number of selected sites

$X = \sum_{i=1}^{n} \frac{fiXi}{n}$

fi = Frequency of observed rating

Xi = Rating value

Each of the three elements are calculated according to this statistical criteria with the following results listed below:

HIGHWAY

$$\bar{X}_H = \frac{0+23+16+0+0+5}{8+23+8+0+0+1} = \frac{44}{40} = 1.10$$

RAILROAD

$$\bar{X}_R = \frac{0+25+22+3+0+0}{3+25+11+1+0+0} = \frac{50}{40} = 1.25$$

DRAINAGE

$$\bar{X}_D = \frac{0+18+20+24+8+5}{1+18+10+8+2+1} = \frac{75}{40} = 1.88$$

	CROSSING SITE No.	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
HIGHWAY	Potholes	0	0	0	1	1	0	1	0	0	1	0	0	0	0	1	2	1	0	0	1
	Edge Ravelling	0	1	1	1	1	3	1	1	1	1	0	1	1	0	2	3	3	0	1	1
	Profile	1	1	0	0	0	0	1	0	2	1	1	1	1	2	2	2	2	1	1	1
	Cross-section	1	1	0	1	0	0	1	0	2	1	1	1	2	1	1	2	3	1	0	1
	Roughness	1	1	1	1	1	0	1	0	1	1	1	0	1	0	1	3	1	1	2	1
	Deterioration	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	2	1	0	1	0
	Hardware	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Speed Reduction	1	1	0	1	0	0	0	0	1	1	1	0	1	0	1	2	2	1	0	1
	Braking	1	2	1	1	1	0	1	0	2	1	1	0	2	0	2	2	3	1	1	1
RAILROAD	Gage	0	0	0	0	1	1	0	1	1	1	0	1	1	0	3	2	1	1	1	1
	Track Surface	1	1	0	1	1	2	0	1	1	1	1	0	1	0	3	2	1	1	1	1
	Flangeways	1	1	0	1	1	1	1	1	2	1	1	1	1	0	3	3	1	1	1	1
	Angle Bars	0	1	0	1	1	1	1	-	1	1	1	1	1	1	2	2	2	1	1	1
	Rail Anchors	0	1	1	1	1	1	1	1	2	1	2	1	2	1	3	2	1	1	1	1
	Tie Plates	1	0	1	1	1	1	2	1	2	2	1	1	2	0	2	3	1	1	2	1
	Spikes & Bolts	0	0	0	2	3	1	2	1	1	2	2	1	2	1	2	2	1	0	1	1
	Ties	1	0	0	2	1	2	4	1	2	2	1	2	3	1	3	3	3	1	2	2
	Ballast	1	1	2	2	2	2	1	1	1	2	1	2	2	2	1	2	2	1	2	1
DRAINAGE	Ballast Fouling	0	-	3	2	4	4	5	1	0	5	1	0	1	4	0	0	0	3	5	0
	Standing Water	-	-	0	-	1	0	2	2	0	-	-	-	-	-	0	-	-	-	2	-
	Grading Contour	1	1	0	0	1	1	2	0	1	1	3	2	1	1	2	2	1	2	2	1
	Culverts	-	-	-	2	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-
	Subdrains	2	2	2	1	2	2	3	0	-	-	-	-	-	1	-	-	2	2	2	2

TABLE 2 (a). ELEMENTS CONSIDERED IN VISUAL RATINGS OF HIGHWAY-RAILROAD GRADE CROSSING.

	CROSSING SITE No.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
HIGHWAY	Potholes	1	0	0	5	0	2	3	0	0	1	0	1	0	0	0	2	2	0	0	0
	Edge Ravelling	2	0	0	5	0	2	2	1	0	0	1	3	1	1	1	3	2	1	0	1
	Profile	1	0	3	5	1	2	2	2	1	1	0	2	0	1	3	1	1	1	1	1
	Cross-section	1	0	0	5	1	1	2	1	1	1	0	1	0	2	3	1	1	1	1	2
	Roughness	1	-	0	5	1	2	2	1	1	0	1	2	1	1	1	2	2	1	1	1
	Deterioration	0	2	0	5	0	1	1	0	0	0	1	2	2	0	1	1	1	1	1	1
	Hardware	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Speed Reduction	3	0	0	3	1	1	2	2	1	0	1	2	2	1	5	2	2	2	0	0
	Braking	2	0	0	3	1	1	2	1	1	0	1	2	2	1	4	3	2	2	0	1
RAILROAD	Gage	1	1	1	1	0	3	2	2	0	1	1	2	0	1	1	1	1	1	3	1
	Track Surface	1	1	2	1	1	3	2	1	0	1	1	1	0	1	0	1	1	1	2	1
	Flangeways	1	1	0	1	1	3	2	1	0	1	1	2	0	1	1	1	1	1	2	1
	Angle Bars	1	0	0	0	0	-	2	1	1	1	1	1	0	1	1	2	1	2	2	1
	Rail Anchors	1	1	0	1	1	-	3	1	0	1	1	2	0	1	1	1	1	2	2	2
	Tie Plates	1	1	1	1	1	-	2	1	0	2	0	2	0	0	1	2	1	2	2	2
	Spikes & Bolts	1	1	3	1	1	-	2	0	1	1	0	1	1	0	1	2	1	1	1	1
	Ties	2	3	4	3	1	-	3	2	1	2	1	2	0	3	2	3	2	3	2	4
	Ballast	1	2	4	1	2	1	3	1	1	2	2	3	1	2	2	2	3	2	2	3
DRAINAGE	Ballast Fouling	0	4	4	2	1	-	-	0	5	0	5	5	0	5	5	5	5	1	5	0
	Standing Water	-	0	5	0	0	-	-	0	-	-	-	-	-	3	1	2	4	-	1	0
	Grading Contour	1	1	5	1	1	2	2	1	1	2	2	1	1	2	0	2	2	1	2	1
	Culverts	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Subdrains	2	-	-	5	-	-	-	1	-	-	-	-	-	3	-	-	-	1	-	2

TABLE 2 (b). ELEMENTS CONSIDERED IN VISUAL RATINGS OF HIGHWAY-RAILROAD GRADE CROSSING

PROJECT 2483H

S.No.	CROSSING NUMBER	HIGHWAY	RAILROAD	DRAINAGE	COMPOSITE RATING	MONTH RATED
01	022896P	1	1	1	7.5	5
02	022874P	1	1	1	7.5	5
03	430351K	0	0	1	2.5	3
04	024292S	1	1	1	7.5	8
05	743257M	1	1	2	10.0	3
06	743251W	0	1	2	7.5	3
07	430132W	1	1	3	12.5	3
08	024283T	0	1	1	5.0	3
09	597144E	1	2	0	7.5	5
10	597155S	1	1	3	12.5	5
11	6035	1	1	2	10.0	5
12	432273M	0	1	1	5.0	5
13	432241G	1	2	1	10.0	5
14	430178K	0	1	2	7.5	5
15	427997X	1	2	1	10.0	5
16	428003G	2	2	1	12.5	5
17	428007J	2	1	1	10.0	5
18	427983P	1	1	2	10.0	5
19	022843R	1	1	2	10.0	5
20	743219D	1	1	1	7.5	5
21	743215B	1	1	1	7.5	5
22	502	0	1	2	7.5	12
23	743197F	0	2	5	17.5	12
24	430168E	5	1	2	20.0	12
25	6894	1	1	1	7.5	5
26	765689X	2	3	2	17.5	5
27	756	2	2	2	15.0	5
28	432286N	1	1	1	7.5	5
29	430217Y	1	0	3	10.0	5
30	763408E	0	1	1	5.0	8
31	6349	1	1	4	15.0	5
32	432247X	2	2	3	17.5	5
33	745200T	1	0	1	5.0	5
34	597127N	1	1	3	12.5	5
35	597123L	2	1	3	15.0	5
36	597177S	2	2	3	17.5	5
37	432377U	2	1	4	17.5	5
38	432233P	1	2	1	10.0	5
39	6039	1	2	3	12.5	5
40	024313H	1	2	1	10.0	5

Notes: 1. Rating based on Arithmetic mean of highway, railroad and drainage visual ratings respectively.
2. Composite Crossing Index = 10.58

TABLE 3. SUMMARY OF FIELD SURVEY RATINGS ON DISTRICT 17.

RATING VALUE (Xi)	FREQUENCY (fi)	FREQUENCY (% of total)	CUMULATIVE FREQUENCY	WEIGHTED RATING (fiXi)
HIGHWAY				
0	8	0.20	8	0
1	23	0.58	31	23
2	8	0.20	39	16
3	0	0.00	39	0
4	0	0.00	39	0
5	1	0.02	40	5
	40	1.00		44
RAILROAD				
0	3	0.08	3	0
1	25	0.62	28	25
2	11	0.28	39	22
3	1	0.02	40	3
4	0	0.00	40	0
5	0	0.00	40	0
	40	1.00		50
DRAINAGE				
0	1	0.02	1	0
1	18	0.46	19	18
2	10	0.25	29	20
3	8	0.20	37	24
4	2	0.05	39	8
5	1	0.02	40	5
	40	1.00		75

TABLE 4. FREQUENCY TABULATION OF RATINGS VALUES.

Now, the composite crossing index is defined as the weighted sum of the average rating of the three major elements: highway, railroad and drainage as shown in the following form:

CROSSING INDEX (C.I.) = $\overline{X}_H$ (H avg) + $\overline{X}_R$ (R avg) + $\overline{X}_D$ (D avg)

where $\overline{X}_H$, $\overline{X}_R$ and $\overline{X}_D$ are respective coefficients of crossing elements and H avg, R avg and D avg are arithmetic mean of highway, railroad and drainage rating range respectively.

The crossing index is computed for the survey rating as follows:

$$C.I. = 1.10\ (2.5) + 1.25\ (2.5) + 1.88\ (2.5)$$

$$C.I. = 10.58$$

Next, the composite crossing rating of each crossing is computed as follows:

Crossing Site No. 1

CROSSING RATING = $\overline{X}_H$ (H avg) + $\overline{X}_R$ (R avg) + $\overline{X}_D$ (D avg)

= 1 (2.5) + 1 (2.5) + 1 (2.5)

= 7.5

The summary of field survey ratings on district 17 of individual crossing sites are listed in Table 3. Each of the forty crossings was evaluated individually and the composite crossing rating was plotted for comparison with the composite crossing index (see Figure 6). For example crossing site No. 24 has a composite crossing rating of 20.0. This value is greater than the crossing index of 10.58; and hence this crossing is a candidate for immediate maintenance work.

Furthermore, according to the visual rating (see Table 2 (b)), crossing site No. 24 shows that the highway element has a rating of 5. Thus immediate resurfacing of the highway is strongly recommended. During the research study, the highway at crossing site No. 24 was resurfaced

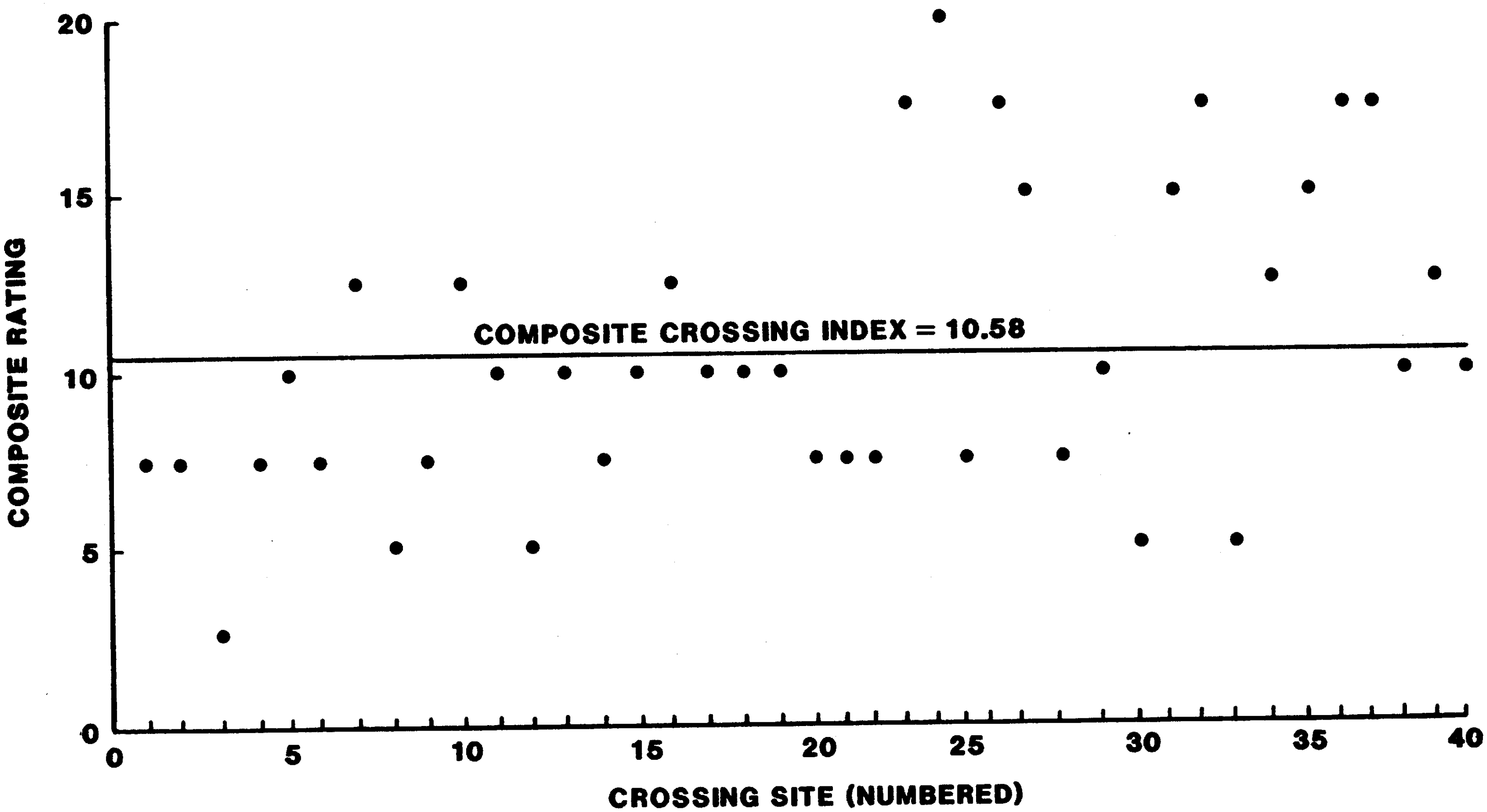


Figure 6. Composite Rating of 40 Individual Crossing in District 17

(see the photographs on edge ravelling condition in the first section of this chapter), six months after our field investigation.

EVALUATION

Since, the composite crossing index computed according to this statistical study is 10.58 (see Figure 6), then crossings having composite ratings below this value are considered to be satisfactory. However, individual crossings having an index value greater than 10.58 require maintenance work or future replacement. It is noted in Table 2 that most of these crossings show improper subdrainage and fouled ballast.

CHAPTER IV.
DESIGN OF A SUPER-HIGHWAY-RAILROAD GRADE CROSSING

The primary purpose of this study was to develop a design for an improved highway-railroad grade crossing system. The system described herein differs in two important aspects from the common crossing designs. First and foremost is the provision for adequate drainage. As reported earlier, lack of adequate drainage accounted for the majority of problems encountered in the field survey (see Chapter III). The second feature of the super-crossing design is the concept of tapering the stiffness of the approaches (both road or track) to the crossing.

Current crossing designs result in an abrupt change of subgrade stiffness when either the highway or the railroad reaches the edge of the crossing. This apparent hard spot in the elastic foundation and the associated stress concentrations are the most likely explanations for the deterioration of the approaches to the crossing. The concept of the super crossing is illustrated in Figure 7. It consists of gradually increasing the stiffness of the support as either the road or track approach the crossing. In the case of the highway this can be done by gradually increasing the depth of the pavement (over 100 to 150 feet), maintaining a constant depth through the crossing, and gradually reducing the depth of pavement over the next 100 to 150 feet. This tapering will drastically reduce the stress concentration and, with adequate drainage, should eliminate the edge ravelling problem.

Tapering the stiffness of the railroad trackbed is much more difficult. However, anything which can be done to spread out the effect of the crossing will reduce the potential for deterioration of the trackbed. The proposed super crossing consists of three phases:

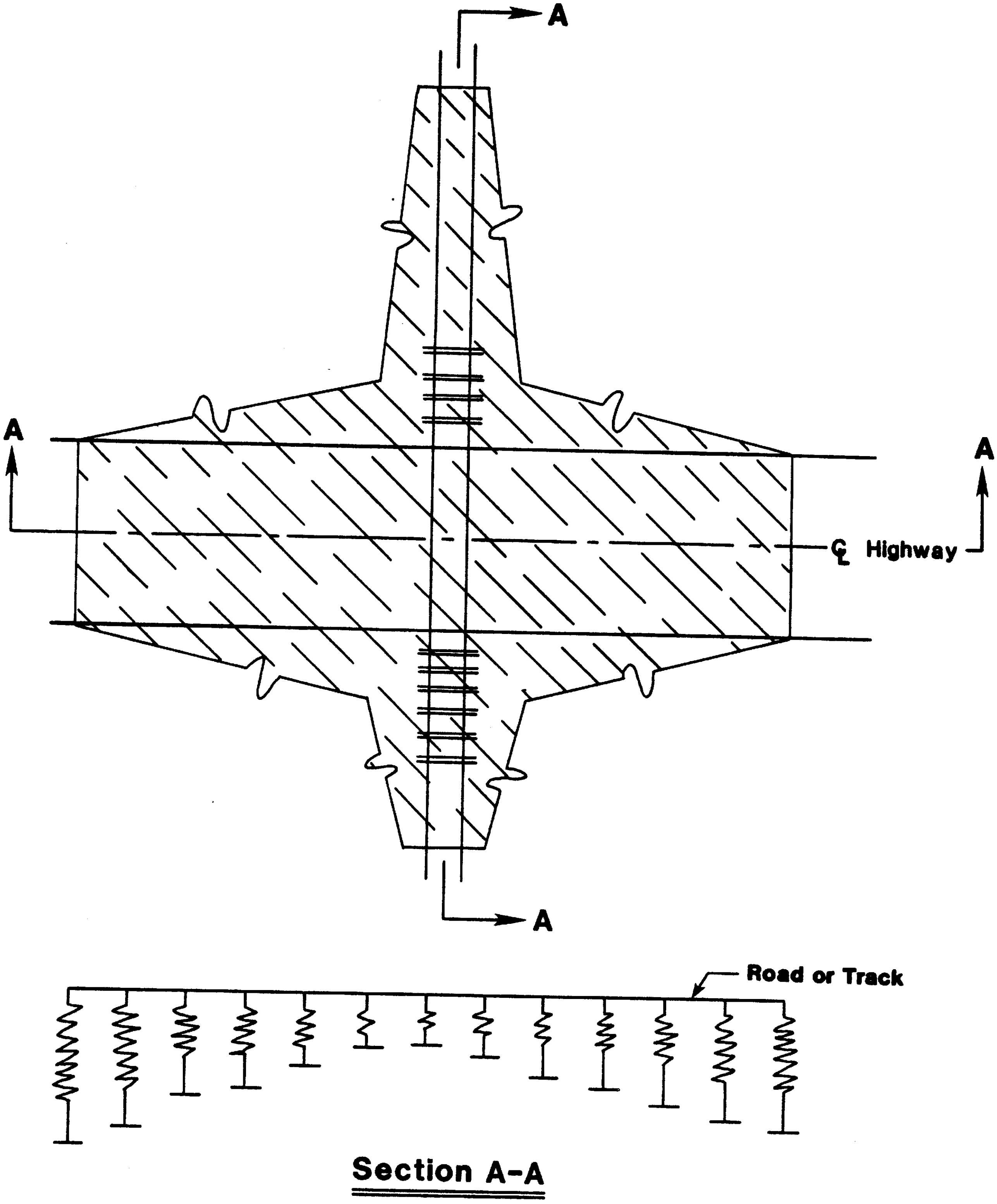


Figure 7. Variable Stiffness of Road and Track

(1) maintain existing track structure until within 50 to 100 feet of the crossing,

(2) improve subgrade by adding a hot mix asphaltic concrete and geotextile underlayer below the normal ballast section. (In addition, a suitable crushed stone subbase should be added unless the strength and drainage characteristics of the existing soil are judged equivalent to the crushed stone system), and

(3) maintain the asphaltic concrete section below the ties throughout the crossing itself.

Existing and proposed crossing sections are illustrated in Figures 8 and 9. It should be noted that both the depth of pavement and the total height of improved subgrade are increased in the proposed super crossing design. The normal 6 or 8 inch ballast section remains unchanged, it is only the depth of improved subgrade below the ballast which is increased. Above the ties, any of the available crossing surface treatments [timber, concrete, steel/rubber, elastomers, bituminous, etc.] could be used.

The level of compaction and type of base material, along with adequate drainage of the crossing, are the most important parameters in the design and performance of a crossing.

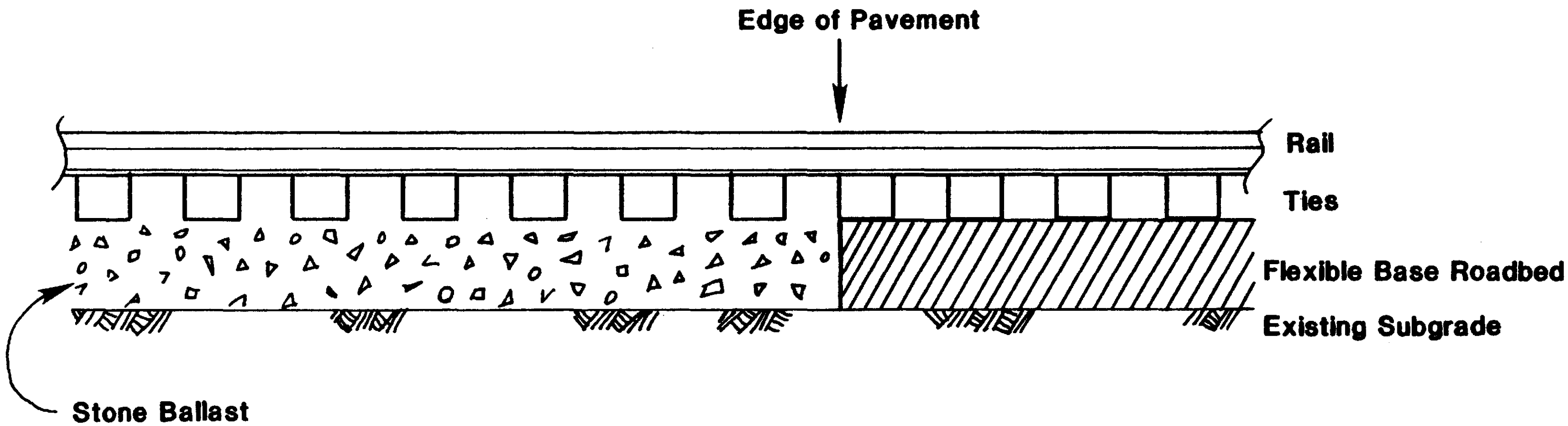


Figure 8. Existing Crossing.

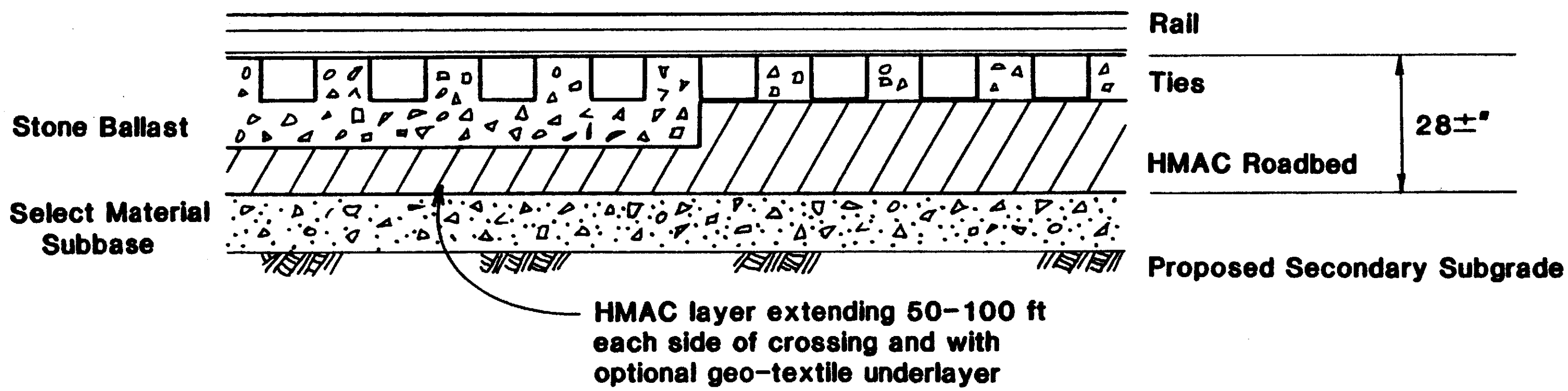


Figure 9. Proposed Crossing.

CHAPTER IV.
CONCLUSIONS AND RECOMMENDATIONS

A new "super" grade crossing was designed for the intersection of State Highway 7 and the Union Pacific Railroad in Marquez, Texas. Several modifications to this design have been proposed and discussed among representatives of the Texas State Department of Highways and Public Transportation (D5-RR & District 17), the Union Pacific Railroad, and the Texas Transportation Institute. Significant modifications have been incorporated into the design in response to concerns expressed by Union Pacific. Continued scheduling and railroad operation problems have delayed construction of this crossing beyond the end of this study.

This study also has included an evaluation of selected crossings in Texas. As a part of this process a quick field evaluation procedure was developed. This procedure has been adapted to a short one page form by the SDHPT and is being used for scheduling of routine maintenance. It is hoped that such an evaluation also can be used to identify the best candidates for crossing upgrades. A survey of available "better" crossings was completed in a previous study.

The design treatments which have been considered include crossing surfaces of timber, concrete, steel/rubber, elastomers, and bituminous which are placed on a variety of foundation materials. The level of compaction and type of base material, along with adequate drainage of the crossing, are important parameters in the design and performance of a crossing. Drainage can be improved through conventional means or by incorporation of a geo-fabric in the base course.

The evaluation procedure reported herein already is in use by SDHPT personnel. Its use should make the identification of the crossings most in need of repair and/or upgrade easier.

This study has clearly identified the benefits of improved drainage. It also is clear that the proposed design will reduce the severity of the problems associated with highway-railroad grade crossings. A complete benefit/cost analysis of the proposed super crossing awaits a field performance trial.

Construction of an experimental super grade crossing such as that proposed for the intersection of State Highway 7 and the Union Pacific Railroad in Marquez, Texas is highly recommended. This project will provide accurate cost figures for the proposed system. These figures, along with an ongoing performance evaluation, should demonstrate the effectiveness of the super crossing concept in reducing crossing maintenance.

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