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This report is the first in a series dealing with structural and geometric characteristics of highway-railroad grade crossings. The report details a study of crossing distribution and geometric characteristics, crossing appraisals, drainage, dynamic loadings, stabilization fabrics, and structural details for improved life and rideability.

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STRUCTURAL AND GEOMETRIC CHARACTERISTICS
OF
HIGHWAY-RAILROAD GRADE CROSSINGS


by

Thomas M. Newton
Robert L. Lytton
Robert M. Olson


Research Report Number 164-1

Structural and Geometric Design of
Highway-Railroad Grade Crossings

Research Project 2-18-74-164


conducted for

The State Department of Highways and Public Transportation

in cooperation with the

U. S. Department of Transportation
Federal Highway Administration


by the

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


August 1975

# ABSTRACT

This report is the first in a series dealing with structural and geometric characteristics of highway-railroad grade crossings. The report details a study of crossing distribution and geometric characteristics, crossing appraisals, drainage, dynamic loadings, stabilization fabrics, and structural details for improved life and rideability.

Key Words: Geometric Characteristics, Track Structure, Highway Structure, Crossing Materials, Foundation Materials, Surface and Subsurface Drainage, Roughness, Rideability, Dynamic Behavior, Subgrade Stabilization Fabrics, Shock Absorption, Rubber Products.

# DISCLAIMER

# ACKNOWLEDGEMENTS

## SUMMARY OF FINDINGS AND RESULTS

This report is the first in a series dealing with structural and geometric characteristics of highway-railroad grade crossings. The seven chapters cover distribution and geometric characteristics of crossings, appraisals of some existing crossings, surface and subsurface drainage systems, crossing evaluations, computer simulation of dynamic loads at crossings, subgrade stabilization fabrics, and structural details.

In the study of grade crossing distribution it was revealed that approximately 60 percent of crossings in Texas are on the Farm-to-Market system, with approximately 15 percent on the state numbered system, 15 percent on the U.S. number system, and the remaining 10 percent distributed over loops, spurs, and other road types. This is a significant observation because the geometric standards for FM highways, U.S. highways, etc., are decidedly different.

Geometrically, it was observed that the railroad is frequently higher than the roadway, requiring vertical curves at the approaches. In addition, a highway is frequently located parallel and adjacent to the railroad requiring a highway intersection near the grade crossing. Horizontal alignment often includes curves with radii less than 1000 feet.

Various crossing surfaces were investigated and ways and means to improve current techniques were studied. Crossing surfaces include timber, bituminous, concrete slab, and metal sections. Overall comparisons indicated that crossings of a more permanent type surface appear warranted at many locations. Although initial costs are high, longer life and smoother, safer rides are offsetting factors.

Adequate drainage must be provided to eliminate or minimize intrusion of surface water into the crossing which permits excessive saturation and

flooding of the pavement structural section.  Evidence of this is seen by pavement failure adjacent to the crossing.  Subsurface drainage was observed at several sites, and this area will be further investigated in the research effort.

A survey of crossings was made to provide an estimate of general conditions at a site.  Composite indices were developed to indicate when a crossing is a candidate for replacement.  The indices represent the weighted sum of visual ratings of the highway, the railroad, and drainage conditions.  Roughness indices were also developed for crossings based on the Mays Ride Meter measurements.

Foundation conditions were studied and revealed that moisture content indicates lower shear strength and lower suction levels which could cause large deformation, pumping, and ultimately failure of the foundation.

Sources of information were examined in an effort to define dynamic behavior of track and highway.  In addition, the DYMOL computer program was used to compute dynamic loads at grade crossings.  It was determined that three geometric features in a crossing are important from a dynamic load standpoint: 1) ramp rise, 2) step difference between pavement and crossings, and 3) rail height above the surface.  Ramp rise was the most important factor.  The dynamic forces were very large on top of the first rail and on the pavement approximately 5 to 6 feet beyond the crossing.  Certain geometric features in a grade crossing can cause a dynamic wheel load to become 2 to 3 times as large as its static weight.  Design life may be reduced to as low as 70 percent of its design value.  The study showed that dynamic loads and their influence are very important for the design of a crossing and its approaching pavements.

Several subgrade stabilization fabrics were also appraised in this

study.  A polypropylene with nylon fiber, a polypropylene fibrous sheet,
a nonwoven polyester fabric, and a nonwoven polypropylene fabric were
included.  Further investigations of their merit must be conducted before
reporting recommendations.

Finally, structural details for extending crossing life and improving
rideability were suggested for further consideration.  Some of these include
the use of continuous tie plates, rubber cushions and flangeway inserts, and
concrete approach slab.

# IMPLEMENTATION STATEMENT

Several procedures have been suggested which could be employed immediately at sites which are in good repair, but which are expected to deteriorate rapidly. These relatively inexpensive maintenance functions which could extend crossing life several years and enhance rideability include:

1. Improve ground contours by grading to permit surface drainage away from the roadway and track structure. At many locations outfall to existing borrow ditches could be improved by hand labor. One or two man days would be required to produce shallow swales through waste materials which block outfall from these crossings. At other sites a small backhoe might be required.

2. Install bituminous, timber, or rubber materials in flangeway, and on the outside of the running rail to prevent intrusion of surface water to eliminate pumping. This procedure used in conjunction with grading discussed previously can be readily accomplished at minimal cost.

3. Provide underground drainage by constructing inlets near the crossing. Outfall through minimum diameter pipe to borrow ditches would be required where surface contouring can not be accomplished.

These operations can be performed without removing roadway or track structure.

4. At some locations additional subsurface drainage could be provided by cutting a trench across the highway and installing subsurface drainage systems. This improvement should reduce flexible pavement deterioration, and can be accomplished without disrupting rail traffic.

The preceding suggestions are listed in order of increasing cost, and are recommended for immediate implementation at appropriately selected crossings.

Additional procedures are suggested at sites where crossings are to be replaced. Several excellent crossing surfaces fabricated from timber, rubber-covered metal, and pre-cast concrete are available. The life and rideability of such crossing surfaces is heavily dependent upon careful attention to structural details, installing adequate subgrade, flexible base and ballast materials, and providing drainage.

Some innovative materials have been proposed to produce subgrade stabilization. These fabrics are recommended for installation at selected sites.

Finally, a reinforced concrete approach slab has been suggested for use in conjunction with conventional crossing surface materials. This slab is intended for installation at locations having high traffic volumes, and heavy truck loads. It could be used at sites where braking and increasing speed aggravate the deterioration of pavement structure adjacent to crossings.

It is recognized that track resurfacing is a regular railroad function, and thus, crossings are subject to grade changes periodically. The suggestions contained in this report have considered this requirement. Whatever steps are taken to improve highway characteristics must be compatible with railroad operations.

Conventional and innovative methods and materials are available which will produce smoother, safer and more durable crossings. The early implementation of the several suggestions at existing sites which are in good repair should extend the life of such crossings one to five years. Sites requiring replacement should be designed, constructed, and maintained in accordance with suggestions contained in this report.

# TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

LIST OF FIGURES

LIST OF FIGURES (cont.)

# LIST OF TABLES

# INTRODUCTION

An estimate made in 1972 indicated that the State Department of Highways and Public Transportation spends approximately $500,000.00 per year reconstructing grade crossings. A major portion of this is necessary due to the inadequacy of present designs. Many of those which were reconstructed still have unsatisfactory rideability due to lack of geometric design standards. This deficiency is one which invites public criticism.

At the outset of this study, the problem was stated as follows:

> Many highway-railroad grade crossings are rough and require frequent replacement. The poor rideability occurs where the highway and/or railroad are on a grade or are superelevated for a curve. Frequent replacement is primarily due to the wide difference in load bearing requirements of the pavement and rails. No criteria exists for vertical curvature and crown warping geometrics related to rideability needs, and the current timber crossing designs fail rapidly due to displacement of bolts and deterioration of the timber.

The research commenced in September, 1973; eight tasks were delineated and incorporated into the approved work plan. A brief discussion of progress in each task follows:

## Task 1. Literature Review

A continuing review of technical literature has been conducted and has produced much usable information which is the basis of the findings to be discussed later in this report.

## Task 2. Advisory Committee

Representatives of the State Department of Highways and Public Transportation, the Federal Highway Administration, several railroad companies, the Federal Railroad Administration, and the Texas Transportation Institute

1

graciously agreed to serve as an advisory committee. Review of progress and discussion of ways and means to proceed were discussed at three meetings in October, 1973, February, 1974, and June, 1974. The active participation of all members has greatly enhanced the progress which has been made.

## Task 3. Field Studies

Several types of information have been acquired from continuing investigations in the field. These include:

1. Visual observations and photographic documentation of conditions at more than 200 sites.

2. Profilometer data have been obtained through cooperation with the Center for Highway Research (THD Study 3-8-71-56).

3. Mays Ride Meter readings have been acquired at twenty-two crossing sites.

4. Soil borings have been obtained at five sites selected for crossing reconstruction.

5. High speed films of trains and highway vehicles have been made and examined to determine relative movement of the track structure with respect to the pavement.

## Task 4. Laboratory Tests

Soil classification tests and moisture determinations have been made on boring samples. Resilient modulus, permanent set, and suction measurements are underway. This information should prove valuable in making prediction of pavement and railroad deformations.

## Task 5. Analytical Studies

Development of computer programs to predict dynamic loads, performance characteristics, comfort index, and other design related information are

2

underway.

## Task 6. Design Studies

Information concerning drainage, surfacing, base and subgrade character-
istics for the highway and railroad traveled ways have been carefully
considered.  Some widely used techniques, as well as some innovative appli-
cations, are discussed at some length in later chapters.

## Task 7. Field Installations

A field installation of full depth timber plank crossing and an expanded
polyurethane foam crossing surface at a two-track crossing near Dime Box,
Texas, is being planned.  The crossing is at FM Highway 141 and the Southern
Pacific Railroad.

## Task 8. Reports

Several reports are planned, of which this is the first.

CHAPTER ONE
DISTRIBUTION AND GEOMETRIC CHARACTERISTICS OF CROSSINGS

## Location of Grade Crossings

A summary of grade crossings by district and system classification was prepared from computer listings in the State Department of Highways and Public Transportation "Rail-Highway Grade Crossing Log" (1).*

Distribution of the crossings in each District is shown in Table 1-1. The total number of crossings is indicated and also the number of crossings in each of the following categories (2):

| | |
|---|---|
| Farm to Market Highways | (FM) |
| Interstate Highways | (IH) |
| State Highway Loops | (LP) |
| Ranch to Market Highways | (RM) |
| Park Roads | (PR) |
| State Highways | (SH) |
| State Highway Spur | (SP) |
| U.S. Numbered Highways | (US) |

An examination of Table 1-1 reveals that nearly 60 percent of the crossings are on the Farm to Market System, approximately 15 percent are on the State Highway System, and another 15 percent are on the U.S. Numbered System. The remaining 10 percent are distributed as shown in the table. This is a significant observation because the geometric standards for FM highways, state highways, and U.S. highways are decidedly different.

The distribution of grade crossings by district is shown graphically in Figure 1-1. The horizontal line represents the number of crossings each district would have if crossings were equally distributed. Twelve districts have 1591 crossings or nearly two-thirds of the total crossings in the state. Similar comparisons can be made by inspection of Figures 1-2, 1-3, and 1-4

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* Numbers in parentheses refer to corresponding numbers in the References.

4

| District No. | Crossings in District | System Classification | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | FM | SH | US | LP | IH | SP | RM | PR |
| 1 | 140 | 84 | 18 | 20 | 17 | -- | 1 | -- | -- |
| 2 | 91 | 51 | 12 | 14 | 5 | 4 | 5 | -- | -- |
| 3 | 53 | 26 | 13 | 10 | 4 | -- | -- | -- | -- |
| 4 | 119 | 70 | 14 | 16 | 3 | 11 | 3 | 2 | -- |
| 5 | 175 | 110 | 14 | 33 | 14 | -- | 4 | -- | -- |
| 6 | 51 | 20 | 9 | 9 | -- | 11 | 1 | -- | 1 |
| 7 | 30 | 12 | 4 | 7 | 2 | -- | -- | 5 | -- |
| 8 | 100 | 71 | 8 | 14 | 7 | -- | -- | -- | -- |
| 9 | 82 | 62 | 12 | 2 | 3 | 3 | -- | -- | -- |
| 10 | 104 | 66 | 20 | 6 | 9 | 1 | 1 | 1 | -- |
| 11 | 72 | 47 | 14 | 7 | 3 | -- | 1 | -- | -- |
| 12 | 190 | 102 | 55 | 15 | 8 | 8 | 2 | -- | -- |
| 13 | 104 | 60 | 20 | 22 | 1 | -- | 1 | | |
| 14 | 108 | 46 | 15 | 11 | 19 | 9 | -- | 8 | -- |
| 15 | 87 | 49 | 5 | 11 | 5 | 16 | 1 | -- | -- |
| 16 | 116 | 52 | 26 | 15 | 14 | 6 | 1 | -- | 2 |
| 17 | 94 | 67 | 12 | 5 | 8 | -- | 2 | -- | -- |
| 18 | 139 | 76 | 21 | 21 | 14 | 7 | -- | -- | -- |
| 19 | 61 | 41 | 8 | 8 | 3 | -- | 1 | -- | -- |
| 20 | 140 | 79 | 31 | 18 | 3 | 2 | 7 | -- | -- |
| 21 | 156 | 82 | 23 | 28 | 12 | 4 | 7 | -- | -- |
| 22 | 33 | 17 | 4 | 6 | 3 | -- | 1 | 2 | -- |
| 23 | 46 | 26 | 4 | 13 | 2 | -- | 1 | -- | -- |
| 24 | 34 | 14 | -- | 6 | 9 | 4 | 1 | -- | -- |
| 25 | 69 | 46 | 11 | 7 | 3 | -- | 2 | -- | -- |
| Totals | 2394 | 1376 | 373 | 324 | 171 | 86 | 43 | 18 | 3 |

TABLE I-I - SUMMARY OF HIGHWAY-RAILROAD GRADE CROSSINGS
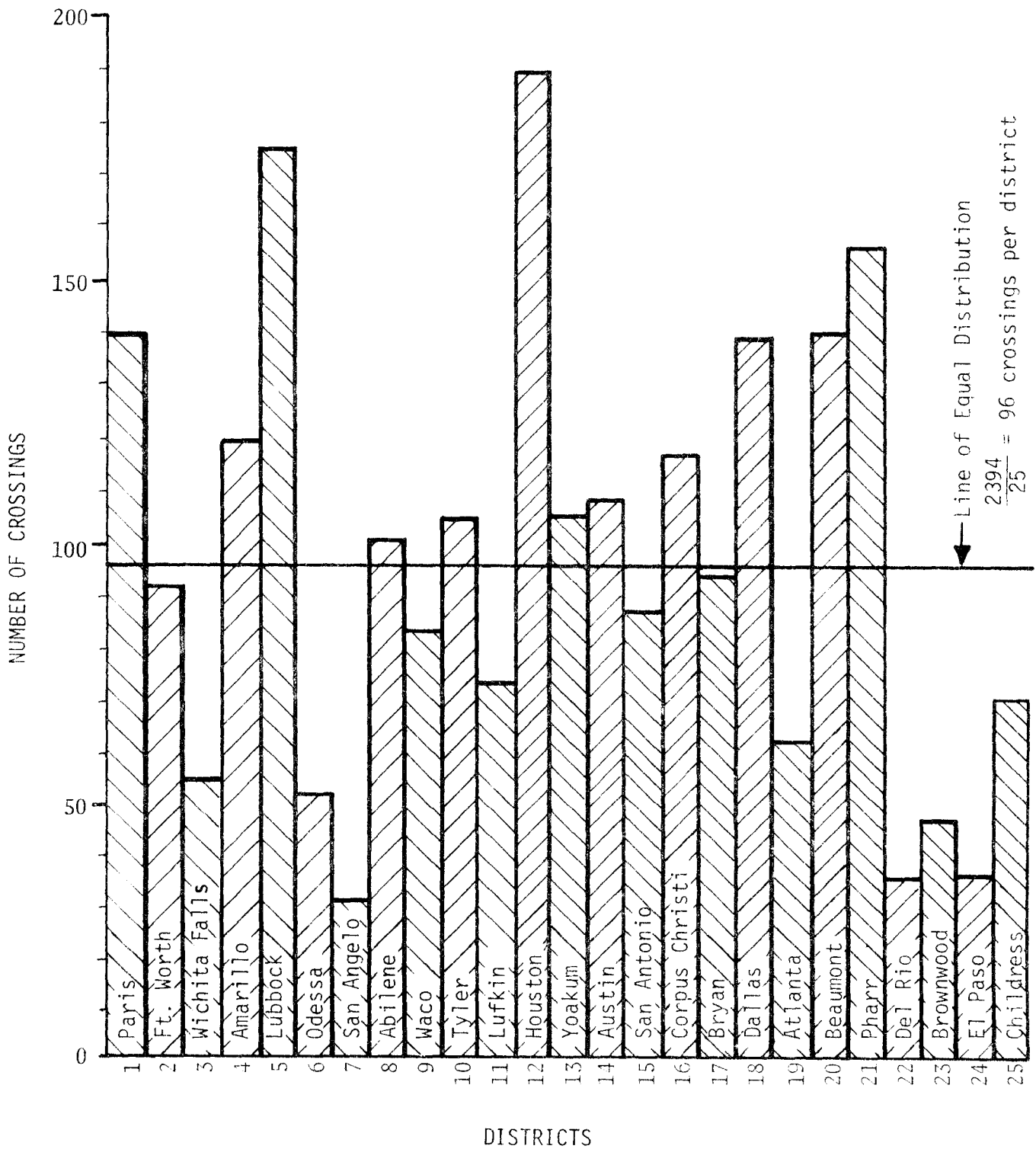
FIGURE I-1 — NUMBER OF RAIL-HIGHWAY GRADE CROSSINGS PER DISTRICT
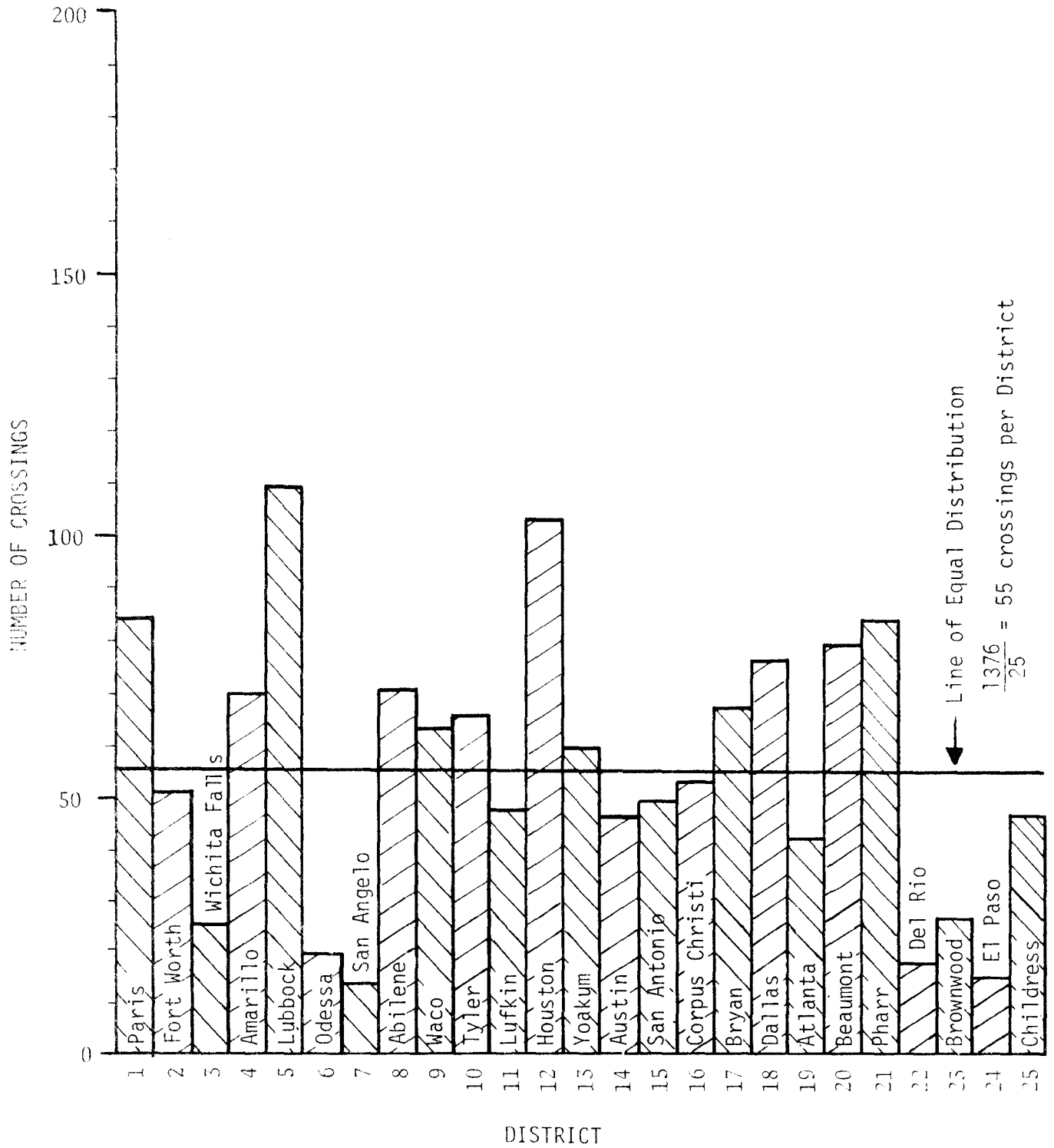
FIGURE I-2 — NUMBER OF F.M. RAIL-HIGHWAY GRADE CROSSINGS PER DISTRICT

7
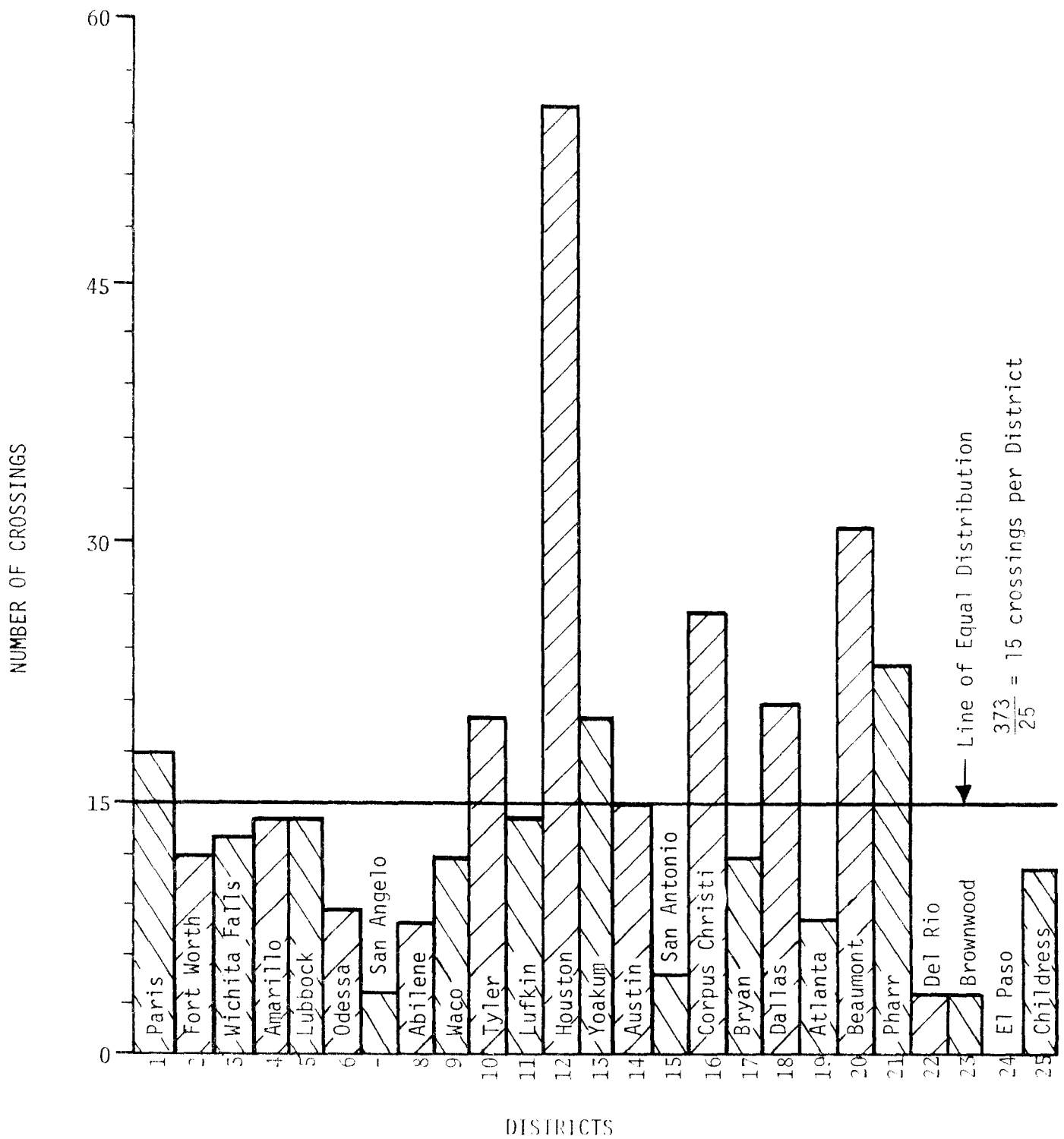
FIGURE I-3 - NUMBER OF S.H. RAIL-HIGHWAY GRADE CROSSINGS PER DISTRICT

8
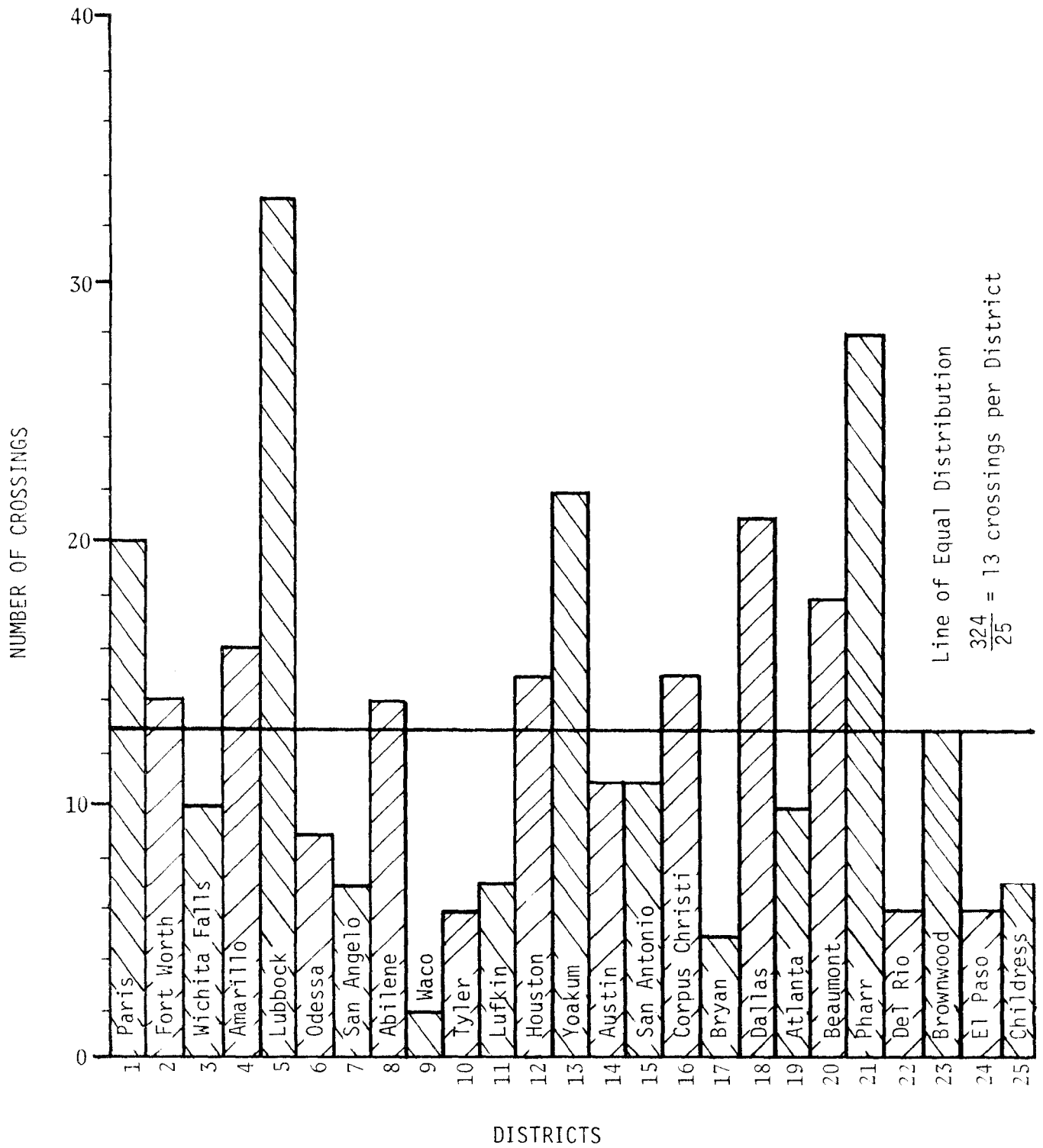
FIGURE I-4 - NUMBER OF U.S. RAIL-HIGHWAY GRADE CROSSINGS PER DISTRICT

9

for Farm, State, and U.S. Numbered highways.

## Geometric Characteristics at Crossings

Visual observation and photographic documentation of crossing conditions were conducted in thirteen districts which contain nearly sixty percent of all crossings in the state. The counties visited are shaded on the map in Figure 1-5. Some important observations were made during these inspections.

1. The railroad is frequently higher than the roadway, thus requiring vertical curves at the approaches to the railroad.

2. A highway is frequently located parallel and adjacent to the railroad property, and a highway intersection is required near the grade crossing. Approximately 65 percent of the sites inspected had a highway intersection within 200 feet of the railroad crossing. Table 1-2 contains a summary of these conditions.

3. Horizontal alignment in approaches to crossings often includes curves having radii less than 1000 feet. In most cases, the highway alignment is tangential at the crossing, as is the railroad alignment.

Geometric conditions at or near crossings are shown in Figures 1-6 and 1-7.

Several interim conclusions have been reached at this time:

- Railroad elevation must be maintained.

- Highway locations must be preserved.

- Acceleration and deceleration at crossings produce deterioration in the highway pavement.

| District | Highway Type | | | | Number of Sites | Configuration | | |
|---|---|---|---|---|---|---|---|---|
| | FM | SH | US | IH | | Near "Tee" Intersection | Near 4-Leg Intersection | Other |
| 1 | 4 | 1 | 1 | | 6 | 2 | 1 | 3 |
| 2 | 14 | 2 | 7 | | 23 | 13 | 2 | 8 |
| 3 | 1 | | | | 1 | | 1 | |
| 9 | 16 | 8 | 1 | | 25 | 5 | 15 | 5 |
| 11 | 20 | 5 | 8 | | 33 | 8 | 14 | 11 |
| 12 | 6 | 5 | | | 11 | 7 | 1 | 3 |
| 13 | 1 | | 6 | | 7 | | 2 | 5 |
| 14 | 10 | 11 | | | 23 | 6 | 7 | 10 |
| 15 | 7 | 1 | 1 | | 9 | 3 | 1 | 5 |
| 16 | 8 | 1 | 7 | | 16 | 4 | 8 | 4 |
| 17 | 29 | 12 | 2 | | 43 | 14 | 21 | 8 |
| 18 | 6 | 2 | | | 8 | | 2 | 6 |
| 20 | 3 | 4 | 1 | | 8 | 2 | 1 | 5 |
| Total | 125 | 54 | 34 | 2 | 213 | 64 | 76 | 73 |

TABLE I-2- HIGHWAY CONFIGURATION NEAR CROSSINGS
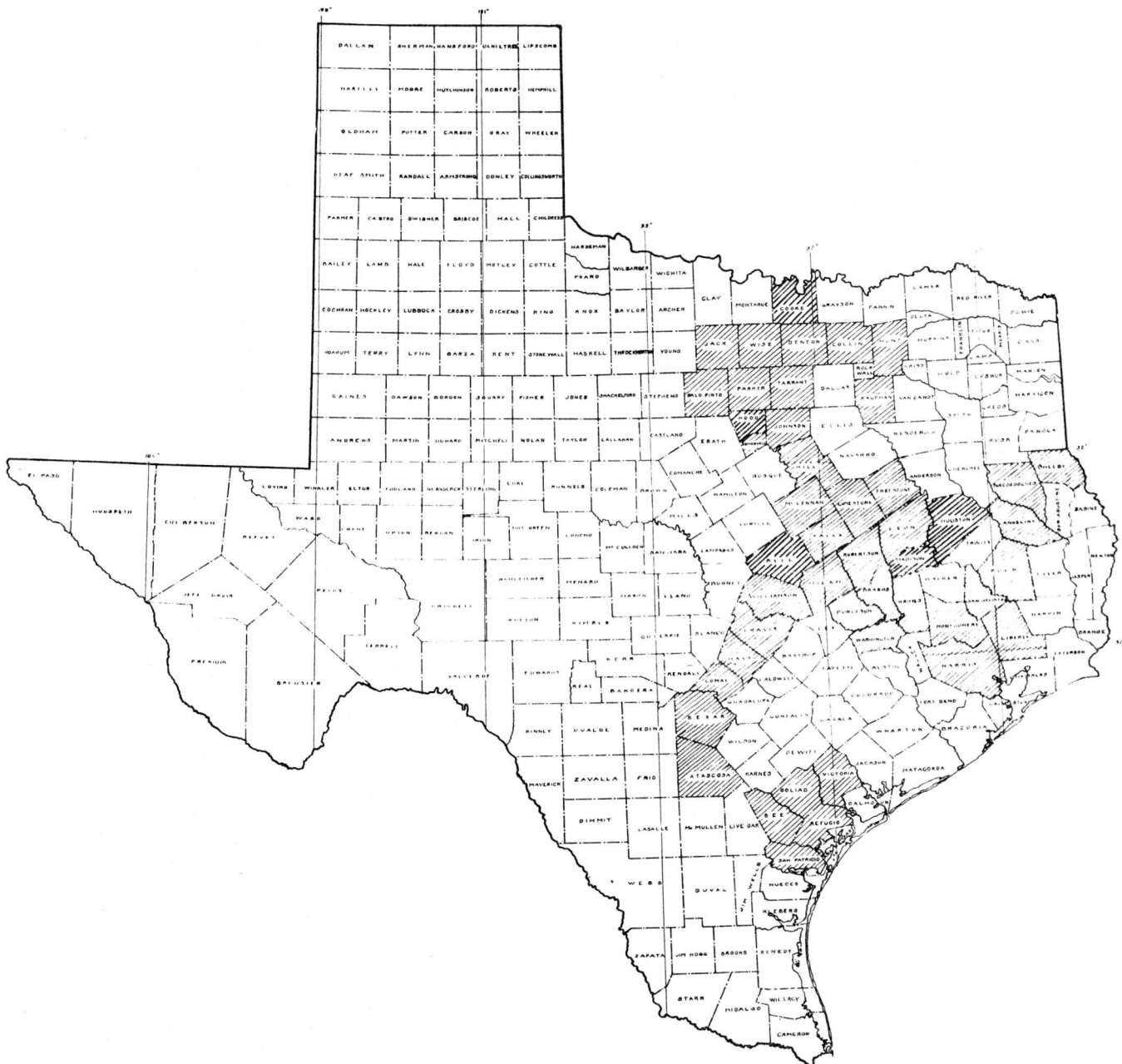
FIGURE I-5 - COUNTIES IN WHICH SITE INSPECTIONS WERE CONDUCTED
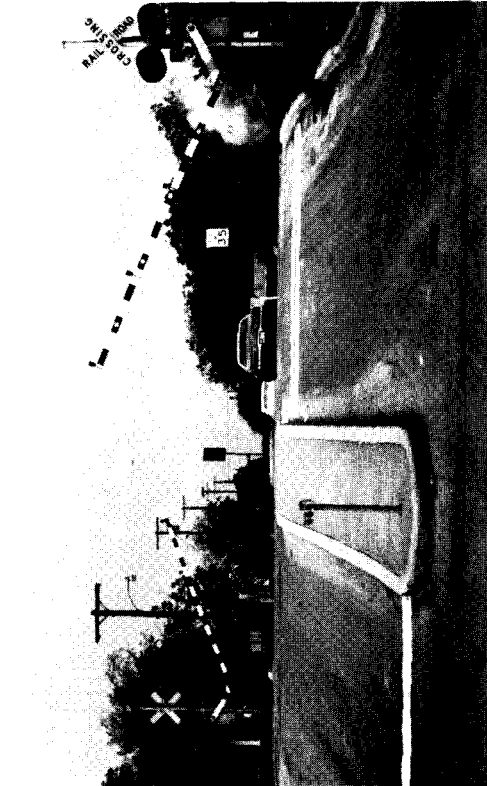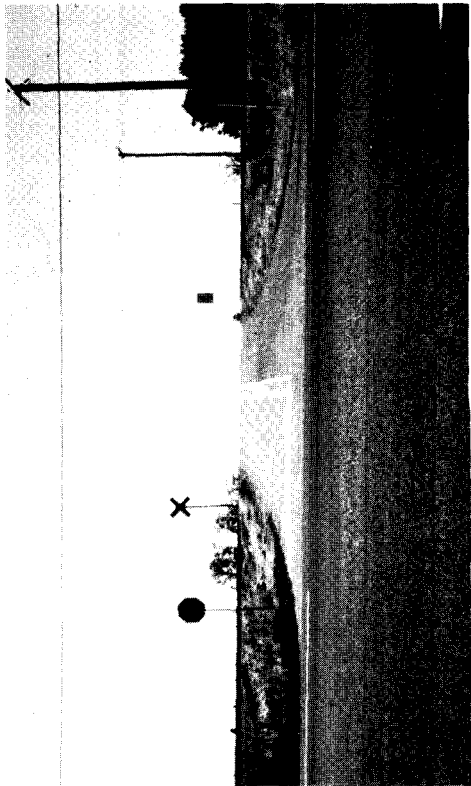
FIGURE I-6 - TYPICAL CONDITIONS AT HIGHWAY RAILROAD GRADE CROSSINGS

13

**PLAN VIEW**

APPROX. 100'

STOP

**PROFILE**
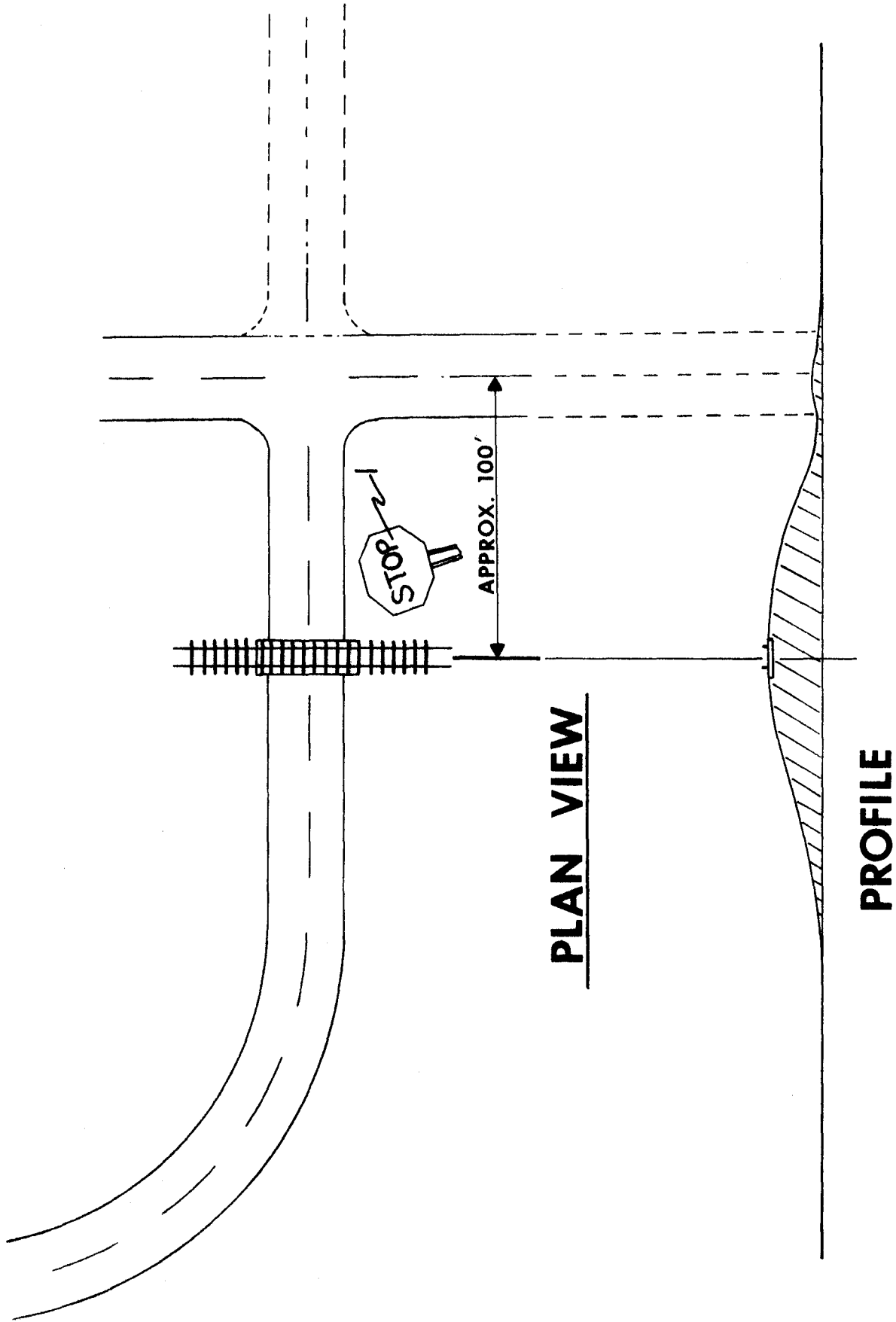
FIGURE I-7 — TYPICAL CROSSING GEOMETRY

14

# CHAPTER TWO
## AN APPRAISAL OF SOME EXISTING CROSSINGS

According to Bundy (17), the right-of-way at highway-railroad grade crossings in Texas is owned by the operating railroad companies. The construction and maintenance of suitable grade crossing pavements ...are the responsibility of the respective railroad companies... In 1959, the Texas Highway Commission (by Minute Order 45564) authorized the expenditure of State funds for construction and reconstruction of highways at railroad grade crossings. At that time, full depth timber was selected as the standard crossing pavement. Approximately 100 new timber crossings have been placed each year since 1959. It became apparent that subgrade stabilization was required to protect the investment in the surfacing materials. The typical section currently used is shown in Figure 2-1. Instructions were issued in 1970 to the Districts and railroad companies outlining a procedure for requiring stabilization.

Each District is encouraged to inspect existing crossings and to program replacements where necessary. Program information is submitted to the Maintenance Division (File D-18), as outlined in the Bridge Division Operation and Planning Manual. Careful consideration is given to need for surface and sub-surface drainage. Railroad companies are requested to renew ties and weld rail joints in the crossing at their expense. They are also requested to remove and adjust track at their expense as required to permit subgrade stabilization by State forces. Other work items are performed by railroad forces and the charges are reimbursed to the railroads from State funds. Thus, the replacement program is a cooperative effort between State and railroad forces. The current rate of crossing replacement is less than the rate of deterioration.

8'-0" or 9'-0"
(Planking)

1'-0"

1'-0"

Surface

Solid Timbers

Base

7"

Base

7" Tie

8" Ballast

20

20

6" Perf. pipe Underdrain
where required

1'-2"

Cement Stabilized
Base
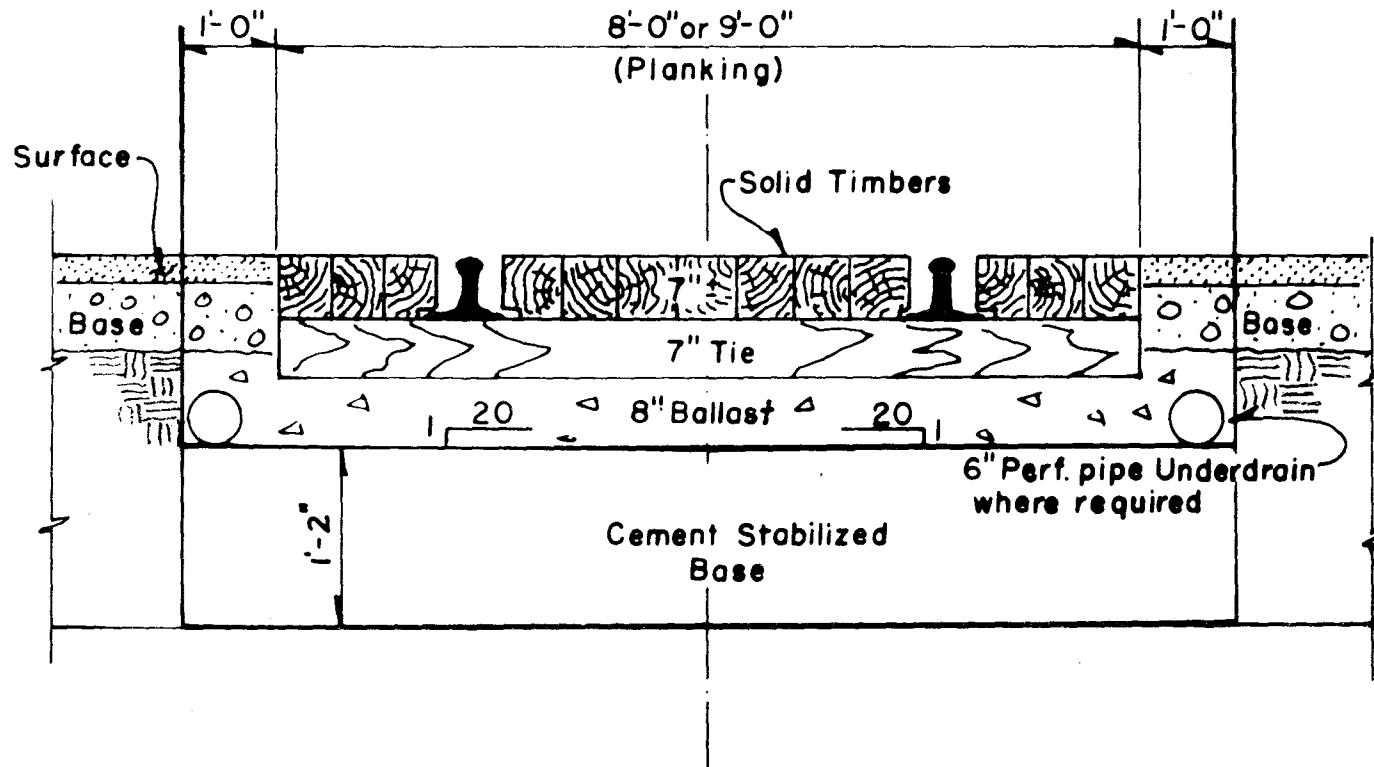
FIGURE 2-I - STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
TYPICAL SECTION FOR INSTALLATION OF TIMBER PLANKING AT
RAILROAD CROSSING

In September, 1973, the Texas Transportation Institute commenced a study to find ways and means to improve currently employed techniques. In the same month, W. J. Hedley completed a study for the U. S. Department of Transportation (11). His report on the findings of the study contain much information which can assist in selecting a suitable surface to serve railroad and highway traffic. The following summary of types of crossing surfaces is taken from the Hedley report.

1. Bituminous. Either a bituminous surface over the entire crossing area or only in the area between planks or flange rails forming flangeway openings on the inside of the running rails, with a line of planks or flange rails on the outside of the running rails as an optional feature.

2. Full Wood Plank. A wood surface formed by installing planks or timbers as individually separate units over the entire crossing area above the crossties.

3. Sectional Treated Timber. A wood surface consisting of an assembly of prefabricated sectional units of treated timber, usually 8 or 9 feet in length and of such width that two sections form the surface between flangeway openings inside the running rails and one section covers the crossties outside of each rail. Each section is so assembled and secured that it may be installed and removed individually for track maintenance and crossing surface replacement purposes.

4. Concrete Slab. Precast concrete slabs which may be installed and removed individually for maintenance and replacement purposes. Slabs are made in various lengths, ranging from 6 feet to 9 feet. Some are produced so that one section is wide enough to fit between the flangeway openings inside the running rails but usually this inside space is filled with either two or three slabs. In all cases only one slab section is used on each side to cover the crossings outside the rail.

5. Concrete Pavement. Continuous concrete surface covering the entire crossing area at least from end to end of the crossties, excepting only the space occupied by the running rails and necessary flangeway spaces inside the rails.

6. Rubber Panels. Steel-reinforced molded rubber panels with a patterned surface. The inside panels extend from rail web to rail web, with flangeway openings provided. Each outside panel is designed to extend slightly beyond the ends of the crossties. Rubber panels may be installed and removed individually for maintenance and replacement purposes.

7. <u>Metal Sections</u>. Preformed sections of steel or other metal, usually of an open grid pattern, which may be installed and removed individually for maintenance and replacement purposes. Some variety of sizes may be used.

8. <u>Other Metals</u>. Complete coverage of the crossing area with railroad rails or other metal materials not removable in limited sectional units. Crossings of this type are no longer being installed, although some are still in use.

9. <u>Unconsolidated</u>. Ballast, or other unconsolidated material placed above the tops of crossties, with or without planks on one or both sides of the running rails.

## Field Studies in Texas

Inspections and evaluations have been conducted at 213 crossing sites in forty-three of the 254 Texas counties which represent 13 of the 25 Highway Department Districts. As might be anticipated, more than seventy percent of the crossing surfaces consist of full depth timber. Approximately twenty percent have bituminous materials on top of the crossties, and only a few have other types of surfacing, including rubber panels, concrete slabs, metal sections, and unconsolidated materials. Location and type of surfacing are summarized in Table 2-1.

An example of a typical timber crossing was shown in Figure 1-6. Because of general interest in other surfacing materials, a discussion of several crossing surfaces will be presented in the ensuing paragraphs.

Two important requirements for crossing surfaces need to be emphasized. One of the requirements is to have the planking or other surfacing founded on the cross ties. Thus, the crossing surface moves upward and downward with the track structure as trains traverse the crossing area.

Another important requirement is insulation between crossing surface and the track and appurtenances. This is necessary to permit the rails to serve as conductors for electric current to operate warning signals and train

18

| District No. | Number of Sites | Crossing Surface Material | | | |
|---|---|---|---|---|---|
| | | Full Depth Timber | Asphaltic Concrete | Reinforced Concrete | Other -- Description |
| 1 | 6 | 4 | 2 | | |
| 2 | 23 | 19 | 3 | 1 | |
| 3 | 1 | 1 | | | |
| 9 | 25 | 23 | 1 | 1 | |
| 11 | 33 | 26 | 4 | 1 | 2   Fab-Ra-Cast |
| 12 | 11 | 7 | 1 | | 3   Rubber Panels |
| 13 | 7 | 6 | | | |
| 14 | 23 | 16 | 6 | | |
| 15 | 9 | 7 | 1 | | 1   Thin Planks (Shims on cross ties) |
| 16 | 16 | 3 | 13 | | |
| 17 | 43 | 31 | 11 | | 1   Unconsolidated |
| 18 | 8 | 7 | 1 | | |
| 20 | 8 | 5 | 3 | | |
| Totals | 213 | 155 | 46 | 7 | |

## TABLE 2-1 - SUMMARY OF CROSSING SURFACES INSPECTED

traffic control apparatus.

## Rubber Covered Metal Crossing Surfaces

Goodyear Tire and Rubber Company's Industrial Products Division introduced rubber crossing pads in 1955. By June, 1972, over 200 crossing installations had been made on streets and highways. A like number of industrial installations have been made.

Goodyear (3) lists the following advantages for the installation of rubber crossings:

1. Damage to automobiles, trucks, and cargoes caused by rough crossings can be eliminated.

2. Drivers are safer and more comfortable.

3. Vehicles move at normal speeds over rubber crossings.

4. Rubber crossings stay smooth, even under heavily-loaded trucks. The resilient rubber and bridge-type steel construction absorbs the impact of heavy highway traffic.

5. Pedestrians are safer -- no toe stubbing, no high heels caught between broken planks, no uncertain footing due to rough wood planking or chipped concrete or broken asphalt.

6. Rubber crossings prevent detours caused by periodic crossing maintenance.

7. Rubber crossings are easy to install and easily relocated should highway improvements alter crossing locations.

8. Rubber crossings allow water to drain off instead of seeping through and causing damage to ties and ballast.

9. The sealed construction also prevents mud and dust from getting into the ballast eliminating "heaving" of surfacing material.

10. Metal load carrying member of the rubber crossing is entirely incased in rubber eliminating rusting.

## Texas Installations

There are three rubber crossing installations in Texas. One is at the crossing of FM Highway 1960 and the Rock Island Railroad, in Harris County,

District 12. The others are also in Harris County on the frontage roads of State Highway 225.

FM Highway 1960 carries an average daily traffic of 8680 vehicles. The Rock Island has 7 trains per day. This is considered to be low traffic volume for railroads; however, heavily loaded freight cars are carried over the crossing. The highway traffic volume is classified as high by the State Department of Highways and Public Transportation Highway Design Division Operation and Procedures Manual, Part IV (4). This crossing was installed in July, 1971 (5). It was examined on January 26, 1975, and appears to be one of the smoother crossings observed during the studies made to date.

The climate is considered wet because the average annual rainfall exceeds the average annual evaporation (6). This climatic condition increases the problems of crossing maintenance. It is located in an area with predominantly Lakes Charles-Benard clays (7) on the surface. The crossing appears well drained and has held up well under these adverse conditions.

Figure 2-2 shows the excellent conditions at this crossing. Observed highway traffic did not slow noticeably for the crossing. Rail traffic did not traverse the crossing during the inspection. A typical cross-section of a rubber panel crossing is reproduced in Figure 2-3.

The frontage roads of State Highway 225 cross the Southern Pacific industry spur which serves the Goodyear plant in Houston. Rubber covered metal planking was installed at these crossings in 1964. The climate and soil conditions are similar to the FM 1960 crossing. A detailed inspection by District personnel revealed that the crossings were in good condition in December, 1969. Photographs taken at that time are shown in Figure 2-4. The crossings were revisited in January, 1974, at which time one of the crossings had been damaged by a derailed railroad car.

FIGURE 2-2 – RUBBER PANEL CROSSING INSTALLATION AT
FM HIGHWAY 1960 AND ROCK ISLAND RAILROAD
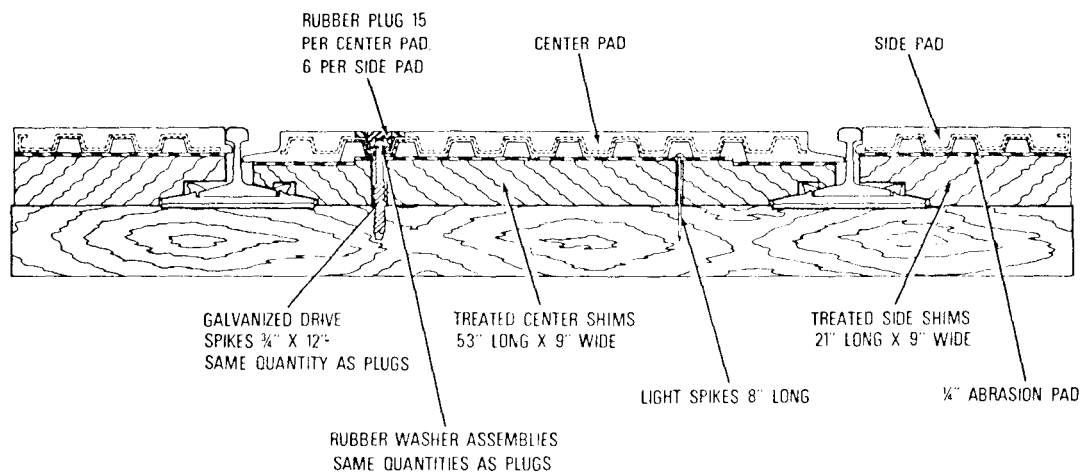


FIGURE 2-3 – CROSS SECTION THROUGH RUBBER PANEL
CROSSING (REF. 11)

22
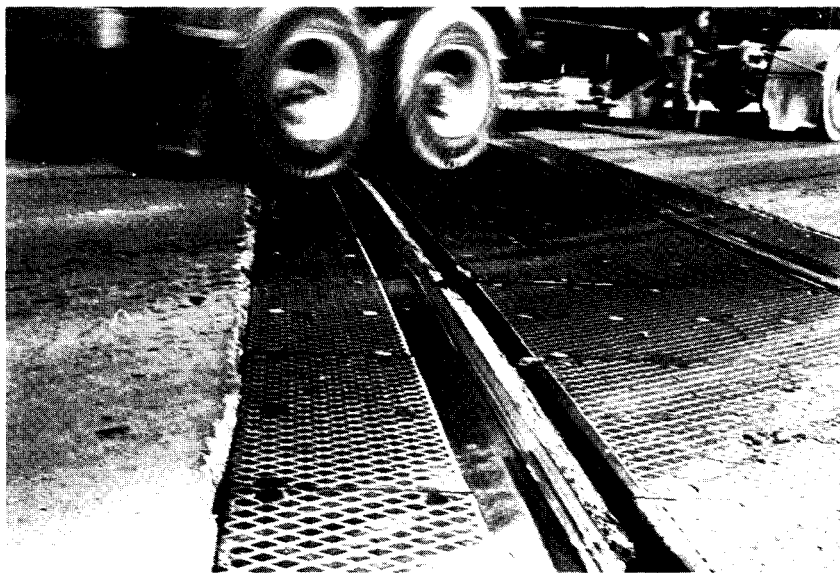
FIGURE 2-4–RUBBER PANEL CROSSING IN HOUSTON
(PHOTOGRAPH FURNISHED BY DISTRICT 12,
STATE DEPARTMENT OF HIGHWAYS AND
PUBLIC TRANSPORTATION)

## Louisiana Installations

The Louisiana Department of Highways Director's Policy and Procedure
Memorandum No. 75, effective September 19, 1972 (8), states the following:

> The Department will require use of rubberized crossings
> on all new construction where ADT is 1000 vpd or over
> and the Department is responsible for all costs. Where
> ADT is less than 1000 vpd and the crossing is not subject
> to vehicles stopping on the crossing, full width timber
> crossings shall be used, except that if the crossing is
> at an angle of 45° or less, measured from the centerline
> of the highway, rubberized crossings may be used. If the
> crossing is subject to vehicles stopping on the crossing,
> rubberized crossings shall be used.

A continuing study is being made of two crossings in Louisiana by the
Department of Highway's Research and Development Section (9, 10). The study
was initiated in the fall of 1968 by the Products Evaluation Committee.
Questionnaires were mailed to a number of states and railroad companies.
Table 2-2 summarizes the results obtained from the questionnaires.
The report states that the consensus of the replies of states indicate an
enthusiastic endorsement of the rubber pad crossing. Periods of from three
to ten years were covered in the experience of the use of rubber crossings.
Durability and riding surface smoothness were the primary assets listed while
high initial cost was a major disadvantage.

The first Louisiana rubber crossing was on La. 2 at Sterlington, which
carried 3430 vehicles in May, 1972. The later report gives the ADT as 4460
vehicles per day (vpd). Both reports state that the crossing is only
periodically used by the railroad. The name of the carrier is not given.
Both reports state that this crossing is in very good condition. No main-
tenance has been performed since installation.

The second crossing installed in Louisiana was on US Highway 190 near
the Huey P. Long Bridge in East Baton Rouge Parish. The Highway 190 average
daily traffic is stated as 18,000 vpd in the earlier report, and as 16,400

24

Railroad Rubber Pad Crossing
Questionnaire Summary
(Conducted Nov. & Dec. 1968)

| User | Installed by User | Number | Durability | Riding Surface | Ease to Install | Ease to Adjust/Repair | Length In Service | Present Condition | Cost Per Linear Ft. | Other Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| Pennsylvania Hwy. Dept. | Yes | 1 | Apparently Good | Good | By RR | | 10 years | | | |
| New York Dept. of Transportation | Yes | 9, 5 more proposed | Excellent, 1 withstood train derailment | Excellent | By RR | | 4 years | Excellent | $129.00 | Direct that this crossing be installed where motor traffic volume justifies expense |
| Illinois Dept. of Public Works & Buildings | Yes | 1 experimental | | Pads tilting | Considerable Labor | | 9 years | Not good | 4 times cost of treated timber | Crossing had 16 trains per day and 2,000 vehicles per day |
| Arizona Highway Dept. | Yes | 3 | Excellent | Excellent | Slightly more difficult by RR | None to date | 9 years | 1-good 2-excell. | $107.50 | One RR installer reported higher initial costs offset by durability and lower maintenance cost |
| Ohio Highway Dept. | Yes | 6 in use 3 under construction | Excellent | Remains smooth | By RR | Negligible amount required | 8 years | | $90-120 | Should have good subbase and foundation |
| Indiana Highway Commission | Yes | 6 | Excellent | Superior to other types | No more difficult than other types | No experience | 8 years | Good | $117.00 | Bureau of Public Roads authorized installation of two Goodyear Rubber Crossing Pad Grade Crossings. These crossings give better riding surface to motorists. |
| North Dakota Highway Department | Yes | 1 | Very Good | Good | By RR | | 3 years | Good | $125.62 | Crossing installed on major highway with relatively heavy traffic |
| California Division of Highways | No | | | | | | | | | Atchison, Topeka and Santa Fe RR has installed one. (See RR Report) Asphalt & Timber now being used in State |
| Michigan Department of Highways | Yes | 4, 2 by RR, 2 by Dept. | Good (slight pad deflection) | Twice as smooth as timber x-ing | Relatively simple | Difficulty in removing lag bolts | 3 years | Good | $104.35 | Railroad replaced pads with timber panels at one location |
| Kansas City Southern Railway; Louisiana & Arkansas Railway | No | | | | | | | | | Willing to try one as experiment at State's expense |
| Southern Pacific Transportation Company | No | | | | | | | | | Same as above |
| Missouri Pacific Railroad Texas & Pacific Railway | No | | | | | | | | | Same as above. State also assume maintenance cost |
| Louisville & Nashville Railroad | Yes | 1 | Apparently Good | Good | With ease | None to date | 6 years | Good | $85.00 | Same as above. Prefab. timber very satisfactory, with life 17 years on one noted, at $32.00 per foot. |
| The Atchison, Topeka and Santa Fe Railway | Yes | 2 | Stood up well. 1 needed pad replacement after 1 year. Covered by guarantee. | Very good | Satisfactory | No particular advantage | 9 years | Good | $68.27 another recent crossing $111.00 | |

# TABLE 2-2- LOUISIANA DEPARTMENT OF HIGHWAYS QUESTIONNAIRE SUMMARY (9)

vpd in 1973. Both reports give the railroad traffic volume as 6 trains per day. The initial report gives the crossing a rating of very smooth for tests driven at 50 mph, the posted speed limit. The crossing installation was made in the fall of 1970 at a cost of $233.00 per track foot.

The Highway 190 crossing was damaged by a train derailment in March, 1973. As of the date of the second report, repairs had not been made to the crossing. Heavy traffic has continued to use the crossing during the year since the derailment and it continues to deteriorate badly. The report states, "The crossing is no longer considered to be serviceable." Six months before the derailment an inspection had been made of the crossing installation and the crossing was classified as very smooth and with little signs of wear or deterioration.

A conclusion of the second report is that the continued excellent performance of the rubber pad crossing at Sterlington and, until the train derailment, in East Baton Rouge Parish, supports existing Department Policy concerning the use of this type of crossing. Table 2-3 gives a summary of the data available for the four crossing installations previously discussed.

Normally the manufacturer recommends that the outside panels extend past the ends of the ties. The extension will insure that the pavement does not come into contact with the ties. Under rail traffic, the ties deflect and the movement would damage the pavement.

This crossing surface requires the use of shims, stringers, or some type of support between the surface and the cross ties. The shim or the top of the tie must be cut or adzed to provide the proper distance to the top of the rail. Use of shims is undesirable and field cutting of treated timber should be avoided.

| STATE | DISTRICT | COUNTY OR PARISH | HIGHWAY | | RAILROAD | | DATE INSTALLED | COST PER TRACK FOOT | PRESENT CONDITION |
|---|---|---|---|---|---|---|---|---|---|
| | | | NUMBER | VOLUME AVERAGE VEHICLES PER DAY | NAME | VOLUME AVERAGE TRAINS PER DAY | | | |
| Texas | 12 | Harris | FM1960 | 8680 | Rock Island | 7 | 7/71 | N.A.* | Very Smooth |
| Texas | 12 | Harris | SH 225 | 40 | South. Pacific | 4 | 4/64 | N.A. | Very good condition until damaged by train derailment prior to Jan. 26, 1974 |
| Louisiana | | More-house | LA 2 | 4460 | Indus. Spur | | Summer 1970 | N.A. | Very Smooth |
| Louisiana | | East Baton Rouge | US 190 | 16,400 | | 6 | Fall 1970 | $233.00 | Unserviceable--Damaged by train derailment on March 13, 1973. |

*Not available.

TABLE 2-3- SUMMARY OF DATA ON RUBBER SURFACE RAILROAD-HIGHWAY GRADE CROSSINGS

Rigid panels are hand-fitted, soon the panels begin to rock. This permits loosening of drive spikes or lag screws intended to anchor the panels.

The flexible nature of the rubber encased steel sections enhances the connective strength of the drive spikes.


## The FAP-RA-CAST Crossing at Center, Texas

The FAB-RA-CAST crossing ([13]) is a patented pre-cast concrete panel installation. This system was invented by Mathias Holthausen of Dusseldorf, Germany, and first installed in this country about ten years ago. It is manufactured by Szarka Enterprises, Inc., of Livonia, Michigan.

The panels are formed in a standard eight-foot length of 6000 psi concrete. Five-inch or six-inch panel thicknesses can be specified. The sides of the panel parallel to the running rail are armored with rail a size smaller than the running rail. Where the armor rail will be near the running rail, it is inverted with the flange up. The outer armor adjacent to the paved surfaces of the roadway is installed with the ball up. This arrangement serves two purposes. The wider section of the rail is buried in the pavement and strengthens the joint between the panel and the pavement. Secondly, the rounded edge of the ball gives a ramping effect if the surface of the pavement is depressed below the top elevation of the panel.

Other systems have employed the armor rail for forming the wheel flangeway as this sytem does, using the rail in the normal position or lying on its side, particularly in asphalt paved roadways.

The normal position for the armor rail is definitely an advantage in those installations. The paved surface of the panels of other types rested

28

upon and were attached to the track ties. In the FAB-RA-CAST crossing, the panels are supported by only three ties and are not attached directly to the ties. A special preformed bracket extends completely across the track. The panel between the running rails and both outside panels are attached to this hardware. Bolts are used instead of lag screws.

As shown in Figure 2-5, the panels are supported by grout-filled plastic bags which rest on the track ties. The number of bags varies from 4 to 6 bags per slab for light traffic or temporary crossing, to 6 to 10 bags for high intensity or heavy traffic.

The grout used is very fast setting, which is usually considered an advantage, but which proved to be a disadvantage at the Center installation because the bags of grout set up in some cases before the panels could be placed. Thus, the panels could not settle to the temporary shim height and projected above the top of the running rail. Time was lost in removing the panel and placing new grout bags.

Because of the weight of each panel, it is necessary to have a crane on the job when they are installed and when they must be removed and replaced for track maintenance. In the Center installation, it was necessary to fabricate a sling for handling the panels (Figure 2-6) which proved to be unsatisfactory. Several panels were dropped. The factory representative stated that future panels would have threaded lifting inserts for attachment of lifting cables.

It is necessary to handle each panel several times. The procedure for installation requires shims to be placed on the track ties (Figure 2-7). The thickness of the shims varies as may be required to bring the surface of the panel to the elevation of the running rail. The panel is placed on the shims and checked with a hand level (Figure 2-8), removed for the first

FIGURE 2-5 – PLACING A FAB-RA-CAST SLAB ON GROUT-FILLED BAGS



FIGURE 2-6 – A CRANE FOR HANDLING FAB-RA-CAST SLABS

FIGURE 2-7- SHIMS AND HARDWARE FOR FAB-RA-CAST SLAB
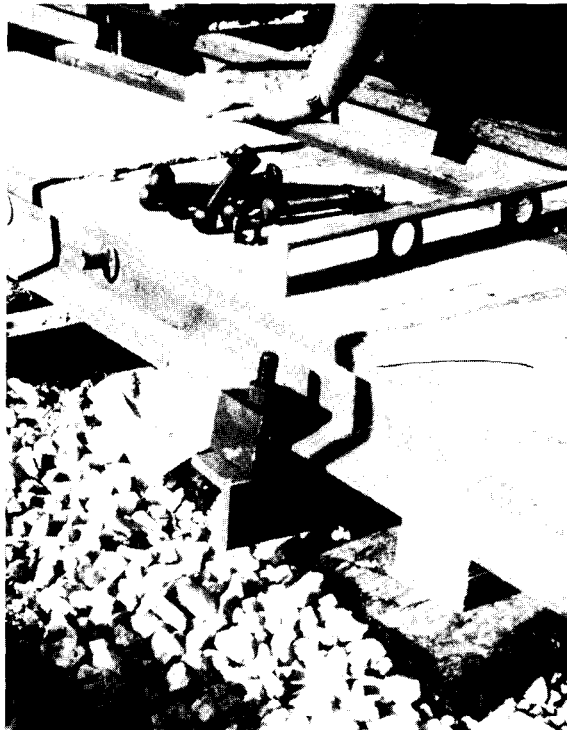


FIGURE 2-8- CLIPS HOLDING FAB-RA-CAST SLAB

time and the shims adjusted. The panel is again placed on the temporary shims and again checked for elevation. This procedure is repeated until the proper elevation is achieved. When the final adjustment has been made, the grout bags are placed on the cross ties and the panel is replaced. The weight of the panel flattens the grout bags until the panel is supported by the shims. Eventually the temporary shims will rot away, and the panel will be supported by the hardened grout in the bags.

Clips are employed to attach the special angle iron hardware to the armor rails of the panel as shown in Figure 2-8. A grout bag adjacent to this assembly is seen in the same figure. Bolting adjacent to the running rails requires special wrenches to tighten the nuts. Field side connections are easily made.

Two other problems encountered in the Center installation were the turnout or switch in the crossing and the flashing signals. As shown in Figure 2-7, there were two running rails on each side of the center line of track. Special panels were fabricated for this crossing. Standard anchor hardware could not be used. Fortunately, the switch points were not within the crossing area.

Also shown in Figure 2-7 are the insulators that were installed under the clips. These were a stiff fiberboard-like material. The sharp edges of the clips cut and wore through the insulators within a period of days. Signalmen for the railroad substituted some sections of an insulating material that is used in insulated track joints and have had no further trouble.

The panels between the running rails shown in Figure 2-9 are typical of the special tapered panels required for the main line installation. In addition to the mainline crossing, an industry track also was crossed. In

the industry track installation much faster production was obtained, since it was a tangent track as shown in Figure 2-9.

Initially, the panels appear to be adequate and durable. Figure 2-10 shows the smooth riding surface of the mainline crossing after the completion of the installation, and the asphalt placed at the ends of the panels to protect them from dragging equipment.

An inspection at the crossing site in March, 1975, revealed that one of the special panels shown in Figure 2-9 had displaced in such a manner that one edge of the panel was two to three inches above the surrounding surface. Another panel in the highway traffic lane has fractured and the traveled lane is very rough.

FIGURE 2-9- A COMPLETED FAB-RA-CAST CROSSING WITH A TURNOUT
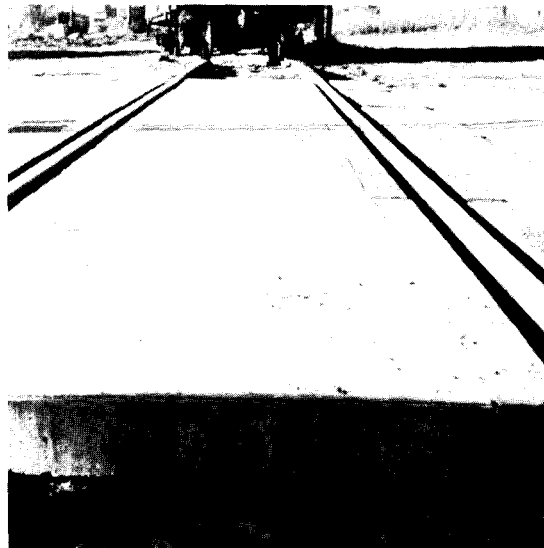


FIGURE 2-10-A COMPLETED FAB-RA-CAST CROSSING ON TANGENT TRACK

## Pre-Cast Reinforced Concrete Crossing at Waco, Texas

The Missouri, Kansas, and Texas Railroad crosses U.S. Highway 84 at a skewed angle. Two trains per day traverse the crossing at 10 miles per hour, and 20,000 vehicles per day are carried by the urban business route. The crossing is 238 feet long.

A joint agreement between the railroad and the highway department resulted in the installation of pre-cast reinforced concrete panels attached to the track ties by lag bolts. The ties in turn are supported by eight inches of ballast and 14 inches of cement stabilized subgrade. No sub-surface drainage is provided at the crossing. Details of the crossing are shown in Figure 2-11. The pre-cast panels are armored on the field and flange sides of the rail, and are anchored to the ties by 3/4" Lag Bolts.

The crossing was constructed in 1975, and remains in good condition. The rideability is excellent at the posted speed of 35 miles per hour. The installed cost was $41.72 per track foot.

4'- 8 1/2"

2 1/4"

1 7/8"

3 at 4"= 1'-0"   1" 3"   2"    12 Spaces at 4" = 4'-0"    2"   2 1/4"

1 7/8"

#5 Bars at 4" c.c. each way

Armor Plate
1" X 3/8"

#5 Bars each way

Asphalt Impregnated Fiber Board

7" Tie

8" Ballast

20            20

14" Cement Stabilized Base
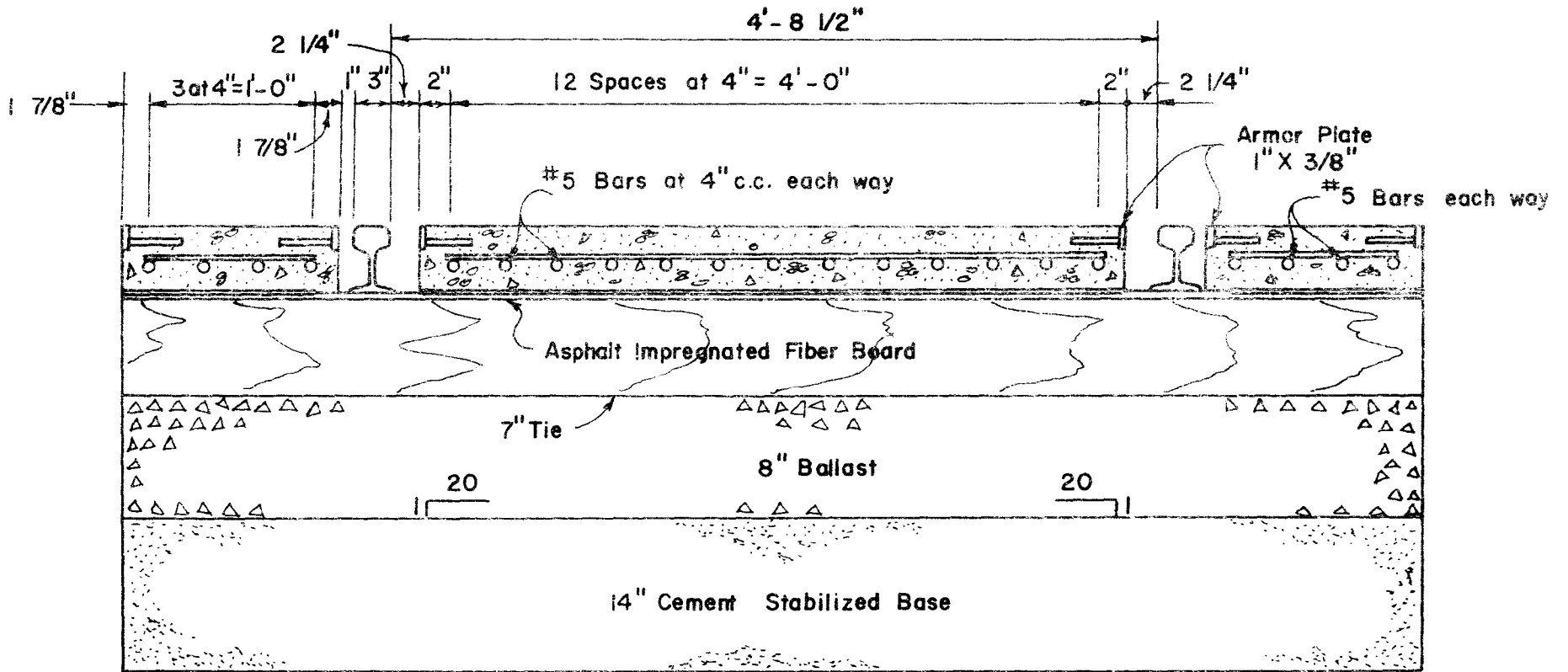
FIGURE 2-11-REINFORCED CONCRETE CROSSING AT WACO, TEXAS

## Comparison of Crossing Materials

W. J. Hedley (11) prepared a checklist of merits for comparing various types of crossing surfaces. This list is reproduced in Table 2-4. Hedley also discussed comparative economics and found:

> Relatively few tests have been conducted to determine the comparative costs of initial construction and the comparative costs of maintenance of two or more types of railroad-highway grade crossing surfaces under similar conditions, including physical conditions of location and use by similar volumes of railroad and highway traffic.

> A report on one such test is contained in AREA Bulletin 635, November 1971, showing comparative maintenance costs at a double track crossing of the Santa Fe Railway with Illinois State Route 179 near Streator, Illinois. Although the track structure and the age of the crossing were not identical, they were reasonably comparable during the 5-year period, 1952 to 1956, inclusive. In that period, $180.36 was spent to clean and resurface an open metal grate crossing in the westbound track and $577.07 was spent on a sectional treated timber crossing in the eastbound track. In July 1967, new welded rail was laid in the westbound track and both tracks were resurfaced and put to the same elevation through the crossing. From that time to the date of the report, the only maintenance cost at the crossing was $17.01 to resurface the eastbound track.

Hedley also prepared a tabulation of estimated costs for several types of crossing material, which is reproduced in Table 2-5. The comparative costs were based on limited data, and Hedley suggested that agencies having better estimates should make appropriate adjustments in assessing annual costs. He concluded that crossings having a high initial cost may have a longer life and may produce smoother, safer, and more economical riding surfaces. Further, he concluded that installation of a more permanent type of crossing surface appears warranted at many locations.

| | Type of Crossing Surface | | | | | |
|---|---|---|---|---|---|---|
| | Bituminous | Full Wood Plank | Sectional Treated Timber | Concrete Slab | Rubber Panels | Metal Sections |
| 1. Relatively low material cost | X | X | X | | | |
| 2. Relatively low installation cost | X | X | X | | | |
| 3. Relatively low maintenance cost | | | X | X | X | X |
| 4. Relatively low annual depreciation | X | X | X | | | |
| 5. Relatively long service life | | | | X | X | X |
| 6. Attention required infrequently | | | X | X | X | X |
| 7. Removal and reuse simplified | | | X | X | X | X |
| 8. Headers not required at end of ties | X | | X | X | | |
| 9. Flangeway fillers not needed | | | | | X | |
| 10. Shims not required* | | | X | X | | |
| 11. No probability of shunting track circuits | X | X | X | | X | |
| 12. Minimum damage to crossties | X | X | X | | X | X |
| 13. Little effect by brine, oil or salt | | X | X | | X | |
| 14. Minimized subgrade moisture | | | | | X | X |
| 15. Minor damage by dragging equipment | X | | X | X | X | |
| 16. Not seriously affected by track movements | | X | X | | X | |
| 17. Adaptable for use through turnouts | X | X | X | | | |
| 18. Materials accept rough handling | X | X | X | | X | |
| 19. High resistance to abrasive wear | | | | X | X | X |
| 20. Retains good riding quality | | | X | X | X | X |

* Check mark "X" assumes use of "full-depth" material.

TABLE 2-4 – CHECKLIST OF MERITS OF VARIOUS TYPES OF RAILROAD-HIGHWAY GRADE CROSSING SURFACES (AFTER HEDLEY, REF. 11)

| | Estimated Average Life, Years | Costs Per Track Foot[1] | | | | |
|---|---|---|---|---|---|---|
| | | Original Cost[2] | 6-Year Cyclic Cost[3] | Comparative Annual Total Covering Original Cost, Replacement & Cyclic Cost[4] | Annual[5] Maintenance | Annual Cost |
| Bituminous, plain | 6 | $30.00 | $18.00* | $ 5.41 | $10.00 | $15.41 |
| Bituminous, with treated guard timbers on each side of running rails | 12 | $40.00 | $18.00* | $ 6.87 | $ 8.00 | $14.87 |
| Bituminous, with rail flangeway | 12 | $40.00 | $18.00* | $ 6.87 | $ 7.00 | $13.87 |
| Structural foam pads | 12 | $65.00 | $ 6.00 | $ 9.83 | $ 3.00 | $12.83 |
| Full treated wood plank | 15 | $60.00 | $10.00 | $ 9.05 | $ 4.00 | $13.05 |
| Sectional treated timber, gum | 15 | $65.00 | $ 7.00 | $ 9.15 | $ 3.00 | $12.15 |
| Precast concrete slabs | 20 | $75.00 | $15.00 | $10.61 | $ 3.00 | $13.61 |
| Metal sections, open grating | 20 | $95.00 | $ 6.00 | $11.80 | $ 3.00 | $14.80 |
| Rubber panels | 30 | $200.00 | $ 6.00 | $21.96 | $ 2.00 | $23.96 |

NOTES:

1. Based upon a crossing carrying 3,000 to 5,000 vehicles per day and 10 to 15 trains per day under average conditions of subgrade and climatic conditions, requiring a complete track resurfacing at 6-year intervals.

2. Including renewal of all crossties, new ballast and track surfacing, but making no allowance for subgrade compaction and installation of drainage facilities which may be required at some locations. These trackwork items estimated to cost $12.00 per track foot and have a service life of 30 years.

3. Includes cost of removal and replacement of crossing surface material in connection with 6-year cycle of track resurfacing, exclusive of tie renewals or any other cost related to resurfacing of normal track not involving a grade crossing.

4. Based on 10 percent annum interest charge, with future costs converted to present worth.

5. Estimated cost of continuously maintaining riding surface in good condition.

* - Represents complete replacement of bituminous material.

## TABLE 2-5 – ESTIMATED AVERAGE COSTS OF VARIOUS TYPES OF CROSSING SURFACES (AFTER HEDLEY, REF. 11)

# CHAPTER THREE
## SURFACE AND SUBSURFACE DRAINAGE SYSTEMS

Highways and railroads are constructed with open ditches adjacent to the traveled way. The riding surface is constructed on an embankment of compacted material (base course or ballast). The highway pavement surface is intended to prevent surface water inflow to the base course. The railroad ballast permits some transverse flow of water to the ditches.

Cedergren, et al., "...estimated that more than 90 percent of the major pavements in the United States may be periodically exposed to surface water inflows in sufficient quantities to cause significant saturation and flooding of pavement structural sections," (18). This inflow through cracks and joints into the base material drains very slowly out of the subsurface system. These observations led to the recommendation that subsurface drainage systems should be installed on highways.

It is clear that surface water inflow at a railroad crossing permits excessive saturation and flooding of the pavement structural section. Evidence of this is seen by pavement failure adjacent to the crossing. Failure of the pavement may extend an appreciable distance on each side of the crossing. Such rough conditions may be aggravated by the inflow of surface water described by Cedergren.

An open trench is a necessary condition at the intersection of a highway and a railroad. The differences in the base and ballasting present a discontinuity in the pavement structure. The replacement of crossing surfaces continues to be an expensive maintenance function.

Highway and railroad engineers agree that proper drainage is an important consideration in the maintenance of crossing sites. As Hedley put it: "...regardless of the type of surface material used, adequate

preparation of the track structure and the subgrade, including adequate drainage, is essential to good performance and longer service life of a grade crossing surface improvement," (11, p. 2).

At many sites inspected in this study, surface drainage could have been improved. Adequate difference in elevation existed between crossing surface and borrow ditch; however, positive outfall was not provided.

Subsurface drainage was found at several sites. Six crossing improvement projects constructed since 1975 in District 12 have included subsurface drainage. These projects are listed in Table 3-1, and were constructed in accordance with the typical cross-section shown in Figure 2-1.

District 12 furnished information concerning the U.S. 90A (Old Spanish Trail) crossing at the Houston Belt and Terminal Railway main line. Track length of the crossing is 138 feet, the angle of crossing is 43° 08', and the highway is a four-lane facility. Depth of the excavation was approximately 3 feet below the finished roadway surface. Top of the natural subgrade was sloped at 20:1 each way from the railroad centerline, as was the top of the cement stabilized base. One string of 6" perforated corrogated metal pipe was placed at each edge of the base course. The excavation was filled with ballast rock to the bottoms of the track ties. The track structure was placed on this ballast and the crossing was surfaced with creosoted gum timber panels.

The cost of the subdrain installation was $2,944.56, or $21.34 per track foot. The State Department of Highways and Public Transportation employees performed the excavation and subgrade and base work. Installation of the ballast and the track and railroad surface above the track was accomplished by the railroad company.

The Fab-Ra-Cast crossing at Center, Texas, described in Chapter Two, was installed with similar subsurface drainage. The Santa Fe track gang

41

| Location | Road No. | County | R.R. Co. | Serial No. | Date |
|----------|----------|--------|----------|-----------|------|
| Houston | US 90A | Harris | HB&T | 12755 | 2-73 |
| Pledger | FM 1301 | Matagorda | SPT | 8017 | 7-73 |
| Arcola | SH 6 | Fort Bend | MP | 1410 | 10-73 |
| Simonton | FM 1093 | Fort Bend | SPT | 7335 | 2-74 |
| Sugarland | FM 1876 | Fort Bend | AT&SF | 7211 | 3-74 |
| Wadsworth | FM 521 | Matagorda | AT&SF | 4847 | 3-74 |

TABLE 3-I – SUBSURFACE DRAINAGE SYSTEMS IN DISTRICT I2



FIGURE 3-I - BACKHOE LEVELING BASE MATERIAL

removed the old crossing surface, rails, and ties. State forces
excavated the fouled ballast and subgrade material. Figure 3-1 shows
a backhoe beginning to level the base material dumped into the excavation.
After the base material was finished to the proper configuration, the
strings of perforated pipe were installed on each lower edge of the base
surface (see Figure 3-2). These strings had been pre-assembled while the
excavation was being prepared. These perforated pipes were connected to
others as shown in Figure 3-3, which permitted positive outfall to a drainage
ditch.

Ballast rock had been stockpiled and was trucked to the excavation by
the State forces. The ballast rock was dumped and leveled to the
proper elevation, as shown in Figure 3-4. The track installation was made
by railroad forces who also installed the Fab-Ra-Cast roadway panels.
State forces leveled up the highway surface with asphaltic concrete to
complete the job.

The crossing sites just described will be inspected again during the
course of this study.



FIGURE 3-2 - TWO STRINGS OF PERFORATED SUBDRAIN PIPE

43

FIGURE 3-3 - OUTFALL LINE FOR SUBDRAIN SYSTEM



FIGURE 3-4 - LIMESTONE BALLAST COVERING SUBDRAIN PIPES

# CHAPTER FOUR
## EVALUATION OF CROSSINGS

Several factors must be considered in making a crossing evaluation:

1. Condition of Crossing

2. Roughness (Ridability)

3. Foundation Characteristics

4. Dynamic Behavior

Each of these factors has been examined, and methods have been devised to provide estimates of crossing characteristics. It is anticipated that revisions in techniques will be required as the work progresses.

## Condition of Crossing

A visual survey of crossings provides an estimate of the general conditions at a site. Elements considered are listed in Table 4-1. The surveyor inspects these conditions and makes a rating of each of the three crossing elements: highway, railroad and drainage. These data are recorded on a crossing evaluation form, Figure 4-1. Provision is made on these forms for other information to be added; such as Mays Ride Meter, Profilometer, and Climate conditions. The results of surveys performed thus far are tabulated in Table 4-2, which indicates the investigator's rating of the three elements, and a composite rating of each crossing. The composite rating of each crossing is computed by a method to be discussed later. The month in which the indivudual survey was conducted is also shown. A plot of the composite rating for each of the 219 crossings visited is shown in Figure 4-2. Each of the 219 crossings was evaluated individually and the composite rating is plotted for comparison with the composite crossing index. Crossing number one, for example, has a rating of 32.5. This value is greater than 20.4; and hence this crossing is a candidate for replacement, as are all crossings

|          HIGHWAY          |          RAILROAD          |          DRAINAGE          |
|---|---|---|
| 1. Condition of adjacent pavement | 1. Condition of track | 1. Condition within crossing |
|    a. Potholes<br>   b. Ravelling<br>   c. Profile<br>   d. Cross-section |    a. Gage<br>   b. Track surface<br>   c. Flangeways |    a. Ballast fouling<br>   b. Standing water |
| 2. Condition of crossing surface | 2. Condition of rail | 2. Condition adjacent to crossing |
|    a. Roughness<br>   b. Deterioration<br>   c. Hardware |    a. Angle bars<br>   b. Rail anchors<br>   c. Tie plates<br>   d. Spikes and bolts<br>   e. Ties<br>   f. Ballast |    a. Grading contour<br>   b. Culverts<br>   c. Subdrains |
| 3. Traffic behavior | | |
|    a. Speed reduction<br>   b. Braking | | |

```
0         1         2         3         4         5
EXCELLENT                                     POOR
              RATING SCALE
```
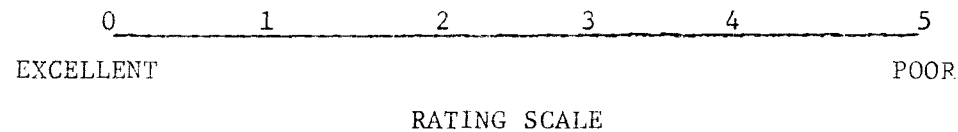
TABLE 4-1 — ELEMENTS CONSIDERED IN VISUAL RATINGS OF HIGHWAY-RAILROAD GRADE CROSSINGS

CROSSING EVALUATION SURVEY


Number_____ Date_____

General Location_____

Highway No._____

    Volume_____ Rating_____

Railroad_____ Inventory Number_____

    Volume_____ Rating_____

    Classification_____ Class_____ Max. Speed_____

    Weight of Adjacent Rail_____

    Weight of Rail in Crossing_____

    Rail in Crossing (Welded)(Suspended/Supported Joints)

    No. Joints in Crossing_____

    Distance to Nearest Joint_____

    Rail Anchors in Line_____ In Crossing_____

Type of Crossing Surface_____

Drainage_____ Rating_____

Mays Ride Meter_____

Profilometer_____

Climate_____

Sketch and Comments:


FIGURE 4-I - CROSSING EVALUATION SURVEY FORM

**Block 1**

| District | Crossing Number by TXD District | Highway | Railroad | Drainage | Composite Rating | Month Rated |
|---|---|---|---|---|---|---|
| ONE | 117-1 | 4 | 4 | 5 | 32.5 | 2 |
| | 2 | 3 | 3 | 3 | 25.0 | 2 |
| | 3 | 4 | 4 | 4 | 30.0 | 2 |
| | 4 | 3 | 3 | 3 | 22.5 | 2 |
| | 5 | 3 | 3 | 4 | 25.0 | 2 |
| | 6 | 4 | 3 | 4 | 27.5 | 2 |
| | 112-1 | 2 | 2 | 2 | 15.0 | 2 |
| | 2 | 3 | 3 | 2 | 20.0 | 2 |
| | 120-1A | 3 | 4 | 3 | 25.0 | 2 |
| | 1B | 4 | 4 | 4 | 30.0 | 2 |
| | 2 | 2 | 4 | 4 | 25.0 | 2 |
| | 127-1 | 3 | 2 | 3 | 20.0 | 2 |
| | 2 | 4 | 2 | 4 | 25.0 | 2 |
| | 3 | 3 | 2 | 2 | 22.5 | 2 |
| | 4 | 2 | 3 | 3 | 20.0 | 2 |
| | 5 | 3 | 2 | 2 | 17.5 | 2 |
| TWO | 6 | 2 | 2 | 2 | 30.0 | 2 |
| | 7 | 4 | 3 | 3 | 25.0 | 2 |
| | 8 | 2 | 2 | 2 | 15.0 | 2 |
| | 184-1 | 2 | 1 | 2 | 12.5 | 2 |
| | 2A | 3 | 3 | 3 | 22.5 | 2 |
| | 2B | 2 | 3 | 3 | 20.0 | 2 |
| | 3 | 2 | 3 | 3 | 20.0 | 2 |
| | 220-1 | 2 | 1 | 3 | 15.0 | 2 |
| | 249-1 | 3 | 2 | 3 | 20.0 | 2 |
| | 2 | 4 | 2 | 4 | 25.0 | 2 |
| | 3 | 2 | 4 | 3 | 22.5 | 2 |
| | 4 | 3 | 2 | 2 | 17.5 | 2 |
| THREE | 5 | 4 | 2 | 4 | 25.0 | 2 |
| | 49-1 | 4 | 1 | 3 | 20.0 | 2 |
| | 14-1 | 3 | 1 | 2 | 15.0 | 12 |
| | 2 | 5 | 5 | 5 | 37.5 | 12 |
| | 3 | 3 | 3 | 2 | 20.0 | 12 |
| | 4 | 3 | 1 | 3 | 17.5 | 12 |
| | 5 | 3 | 2 | 2 | 17.5 | 12 |
| | 6 | 2 | 4 | 2 | 25.0 | 2 |
| | 7 | 4 | 3 | 3 | 25.0 | 2 |
| | 74-1 | 2 | 2 | 3 | 17.5 | 2 |
| | 110-2 | 3 | 3 | 4 | 25.0 | 2 |
| NINE | 3 | 3 | 3 | 4 | 25.0 | 2 |
| | 4 | 3 | 3 | 3 | 22.5 | 2 |
| | 5 | 3 | 1 | 1 | 12.5 | 2 |
| | 147-1 | 1 | 1 | 2 | 10.0 | 1 |
| | 2 | 2 | 2 | 2 | 15.0 | 1 |
| | 3 | 2 | 2 | 3 | 17.5 | 1 |
| | 4 | 4 | 4 | 4 | 30.0 | 2 |
| | 161-1 | 1 | 2 | 2 | 12.5 | 1 |
| | 2 | 3 | 2 | 2 | 17.5 | 1 |
| | 3 | 2 | 2 | 1 | 12.5 | 1 |
| | 4 | 1 | 2 | 1 | 10.0 | 1 |
| | 5 | 1 | 2 | 2 | 12.5 | 1 |
| | 6 | 1 | 4 | 4 | 22.5 | 1 |
| | 7A | 2 | 3 | 3 | 20.0 | 1 |
| | 7B | 2 | 3 | 3 | 20.0 | 1 |
| | 8 | 2 | 2 | 1 | 12.5 | 1 |

**Block 2**

| District | Crossing Number by TXD District | Highway | Railroad | Drainage | Composite Rating | Month Rated |
|---|---|---|---|---|---|---|
| | 3-1 | 3 | 3 | 4 | 25.0 | 1 |
| | 2 | 2 | 3 | 4 | 22.5 | 1 |
| | 3 | 3 | 3 | 4 | 25.0 | 1 |
| | 4 | 3 | 2 | 4 | 22.5 | 1 |
| | 5 | 4 | 3 | 4 | 27.5 | 1 |
| | 6 | 3 | 4 | 5 | 30.0 | 1 |
| | 7 | 3 | 4 | 4 | 27.5 | 1 |
| | 8 | 2 | 3 | 3 | 20.0 | 1 |
| | 9 | 2 | 4 | 5 | 27.5 | 2 |
| | 10 | 2 | 2 | 4 | 20.0 | 1 |
| | 11 | 2 | 3 | 3 | 20.0 | 1 |
| ELEVEN | 12 | 2 | 4 | 4 | 25.0 | 1 |
| | 13 | 3 | 4 | 4 | 27.5 | 1 |
| | 14 | 1 | 1 | 2 | 10.0 | 2 |
| | 15 | 4 | 2 | 3 | 22.5 | 2 |
| | 16 | 2 | 4 | 5 | 27.5 | 2 |
| | 114-1 | 1 | 1 | 1 | 12.5 | 1 |
| | 2 | 2 | 1 | 2 | 12.5 | 1 |
| | 3 | 4 | 1 | 1 | 15.0 | 1 |
| | 4 | 2 | 1 | 2 | 12.5 | 1 |
| | 174-1 | 1 | 4 | 5 | 25.0 | 8 |
| | 2 | 2 | 3 | 2 | 17.5 | 8 |
| | 3X | 3 | 4 | 5 | 30.0 | 8 |
| | 187-1 | 2 | 3 | 4 | 17.5 | 2 |
| | 2 | 3 | 2 | 3 | 20.0 | 2 |
| | 3A | 4 | 4 | 4 | 30.0 | 2 |
| | 3B | 3 | 4 | 4 | 27.5 | 2 |
| | 4 | 2 | 2 | 2 | 20.0 | 2 |
| | 5 | 2 | 2 | 3 | 17.5 | 2 |
| | 6 | 1 | 3 | 4 | 20.0 | 2 |
| | 7 | 3 | 1 | 1 | 12.5 | 2 |
| | 8 | 3 | 2 | 4 | 22.5 | 2 |
| | 9 | 4 | 2 | 3 | 22.5 | 2 |
| | 204-1 | 2 | 2 | 1 | 12.5 | 2 |
| | 2 | 3 | 2 | 2 | 17.5 | 2 |
| | 210-1 | 1 | 1 | 1 | 7.5 | 9 |
| | 102-1X | 3 | 3 | 4 | 25.0 | 1 |
| | 2 | 3 | 2 | 4 | 27.5 | 1 |
| TWELVE | 3 | 1 | 1 | 1 | 7.5 | 1 |
| | 170-1 | 3 | 2 | 2 | 17.5 | 2 |
| | 2 | 2 | 2 | 2 | 22.5 | 2 |
| | 3 | 2 | 3 | 4 | 22.5 | 2 |
| | 4 | 2 | 2 | 4 | 20.0 | 2 |
| | 5 | 4 | 2 | 4 | 25.0 | 2 |
| | 6 | 3 | 2 | 2 | 17.5 | 2 |
| | 7 | 3 | 2 | 4 | 22.5 | 2 |
| | 8 | 2 | 2 | 2 | 15.0 | 2 |
| | 235-1 | 2 | 4 | 5 | 27.5 | 1 |
| THIRTEEN | 2 | 2 | 2 | 2 | 15.0 | 1 |
| | 3 | 2 | 2 | 3 | 17.5 | 1 |
| | 4 | 1 | 3 | 3 | 17.5 | 1 |
| | 5 | 3 | 3 | 3 | 17.5 | 1 |
| | 6 | 2 | 2 | 2 | 15.0 | 1 |
| | 7 | 0 | 2 | 1 | 7.5 | 1 |

**Block 3**

| District | Crossing Number by TXD District | Highway | Railroad | Drainage | Composite Rating | Month Rated |
|---|---|---|---|---|---|---|
| | 106-1 | 4 | 1 | 1 | 15.0 | 1 |
| | 2 | 4 | 1 | 1 | 15.0 | 1 |
| | 3 | 4 | 3 | 2 | 22.5 | 1 |
| | 4 | 3 | 5 | 3 | 27.5 | 1 |
| | 5 | 3 | 3 | 2 | 20.0 | 1 |
| | 6 | 3 | 1 | 1 | 12.5 | 1 |
| | 7 | 3 | 5 | 4 | 30.0 | 1 |
| | 8 | 3 | 3 | 2 | 20.0 | 1 |
| | 9 | 4 | 3 | 4 | 27.5 | 1 |
| FOURTEEN | 10 | 2 | 2 | 2 | 15.0 | 1 |
| | 11 | 3 | 3 | 3 | 22.5 | 1 |
| | 12 | 2 | 3 | 2 | 17.5 | 1 |
| | 13 | 1 | 1 | 2 | 10.0 | 1 |
| | 14 | 5 | 2 | 4 | 27.5 | 1 |
| | 15 | 2 | 3 | 3 | 17.5 | 1 |
| | 16 | 2 | 2 | 3 | 17.5 | 1 |
| | 17 | 4 | 2 | 2 | 20.0 | 1 |
| | 227-1 | 2 | 5 | 1 | 20.0 | 1 |
| | 2 | 2 | 2 | 1 | 12.5 | 1 |
| | 3 | 2 | 3 | 0 | 12.5 | 1 |
| | 4 | 3 | 3 | 5 | 27.5 | 1 |
| | 246-1 | | | 3 | 7.5 | 11 |
| | 2 | | | 3 | 7.5 | 11 |
| | 7-1 | 3 | 3 | 3 | 22.5 | 1 |
| FIFTEEN | 2 | 4 | 2 | 3 | 22.5 | 1 |
| | 3 | 2 | 2 | 3 | 17.5 | 1 |
| | 15-1 | 3 | 4 | 5 | 30.0 | 1 |
| | 46-1 | 1 | 1 | 1 | 7.5 | 1 |
| | 2 | 2 | 3 | 2 | 20.0 | 1 |
| | 3 | 2 | 3 | 2 | 17.5 | 1 |
| | 4 | 3 | 3 | 2 | 20.0 | 1 |
| | 5 | 2 | 1 | 5 | 20.0 | 1 |
| | 13-1 | 3 | 2 | 3 | 20.0 | 1 |
| | 2 | 3 | 2 | 3 | 20.0 | 1 |
| | 3 | 2 | 4 | 1 | 17.5 | 1 |
| | 4 | 3 | 2 | 3 | 20.0 | 1 |
| | 5 | 2 | 3 | 4 | 22.5 | 1 |
| SIXTEEN | 6 | 3 | 4 | 4 | 27.5 | 1 |
| | 196-2 | 2 | 1 | 1 | 15.0 | 1 |
| | 3 | 4 | 2 | 3 | 22.5 | 1 |
| | 4 | 3 | 4 | 4 | 27.5 | 1 |
| | 5 | 2 | 5 | 5 | 30.0 | 1 |
| | 6 | 3 | 5 | 4 | 30.0 | 1 |
| | 205-1 | 2 | 2 | 2 | 15.0 | 1 |
| | 2 | 2 | 1 | 2 | 10.0 | 1 |
| | 3 | 4 | 4 | 0 | 20.0 | 1 |
| | 4 | 4 | 3 | 2 | 22.5 | 1 |
| SEVENTEEN | 21-1 | 2 | 2 | 2 | 15.0 | 11 |
| | 2 | 1 | 1 | 1 | 7.5 | 1 |
| | 3 | 4 | 2 | 5 | 27.5 | 1 |
| | 4 | 3 | 2 | 3 | 20.0 | 1 |
| | 5 | 1 | 3 | 1 | 12.5 | 2 |
| | 6 | 2 | 2 | 4 | 20.0 | 1 |

**Block 4**

| District | Crossing Number by TXD Districts | Highway | Railroad | Drainage | Composite Rating | Month Rated |
|---|---|---|---|---|---|---|
| | 7 | 3 | 3 | 2 | 20.0 | 1 |
| | 8 | 3 | 4 | 4 | 27.5 | 1 |
| SEVENTEEN | 9 | 3 | 5 | 5 | 32.5 | 1 |
| | 10 | 2 | 2 | 3 | 17.5 | 1 |
| | 11 | 3 | 2 | 4 | 22.5 | 1 |
| | 12 | 3 | 3 | 4 | 30.0 | 1 |
| | 13 | 2 | 1 | 3 | 15.0 | 1 |
| | 14 | 3 | 2 | 3 | 20.0 | 1 |
| | 15 | 3 | 1 | 4 | 20.0 | 1 |
| | 15B | 3 | 3 | 4 | 30.0 | 1 |
| | 15C | 2 | 4 | 4 | 22.5 | 1 |
| Cont'd | 26-1 | 4 | 2 | 4 | 22.5 | 1 |
| | 2 | 3 | 2 | 2 | 20.0 | 10 |
| | 82-1 | 3 | 2 | 4 | 22.5 | 1 |
| | 94-1 | 4 | 3 | 5 | 30.0 | 2 |
| | 2 | 2 | 2 | 2 | 15.0 | 2 |
| | 3 | 3 | 2 | 2 | 17.5 | 2 |
| | 4 | 4 | 2 | 4 | 25.0 | 2 |
| | 5 | 4 | 2 | 4 | 25.0 | 2 |
| | 6 | 4 | 2 | 4 | 25.0 | 2 |
| | 145-1 | 2 | 1 | 2 | 12.5 | 1 |
| | 2 | 2 | 2 | 2 | 15.0 | 1 |
| | 3 | 3 | 2 | 4 | 22.5 | 1 |
| | 4 | 4 | 3 | 4 | 27.5 | 1 |
| | 5 | 2 | 3 | 5 | 25.0 | 1 |
| | 154-1 | 3 | 3 | 4 | 25.0 | 1 |
| | 2 | 2 | 2 | 2 | 15.0 | 1 |
| | 3 | 3 | 2 | 3 | 20.0 | 1 |
| | 4 | 3 | 2 | 2 | 17.5 | 1 |
| | 166-1 | 1 | 1 | 5 | 17.5 | 1 |
| | 2 | 1 | 1 | 1 | 7.5 | 1 |
| | 3 | 1 | 1 | 1 | 7.5 | 1 |
| | 4 | 3 | 5 | 5 | 32.5 | 1 |
| | 5 | 2 | 3 | 3 | 20.0 | 2 |
| | 6 | 2 | 3 | 3 | 20.0 | 2 |
| | 198-1 | 4 | 2 | 4 | 25.0 | 2 |
| | 2 | 2 | 2 | 3 | 17.5 | 2 |
| EIGHTEEN | 43-1 | 3 | 3 | 3 | 22.5 | 2 |
| | 2 | 4 | 4 | 4 | 30.0 | 2 |
| | 61-1 | 4 | 1 | 2 | 17.5 | 2 |
| | 2 | 3 | 1 | 2 | 15.0 | 2 |
| | 3 | 4 | 2 | 3 | 22.5 | 2 |
| | 130-1 | 3 | 2 | 3 | 17.5 | 2 |
| | 2 | 4 | 4 | 5 | 32.5 | 2 |
| TWENTY | 146-1 | 2 | 2 | 2 | 15.0 | 2 |
| | 2 | 3 | 4 | 5 | 30.0 | 2 |
| | 3 | 2 | 2 | 3 | 17.5 | 2 |
| | 4 | 3 | 4 | 5 | 30.0 | 2 |
| | 5 | 3 | 2 | 3 | 20.0 | 2 |
| | 6 | 3 | 2 | 5 | 25.0 | 2 |
| | 7 | 2 | 2 | 2 | 15.0 | 2 |
| | 8 | 3 | 2 | 3 | 20.0 | 2 |

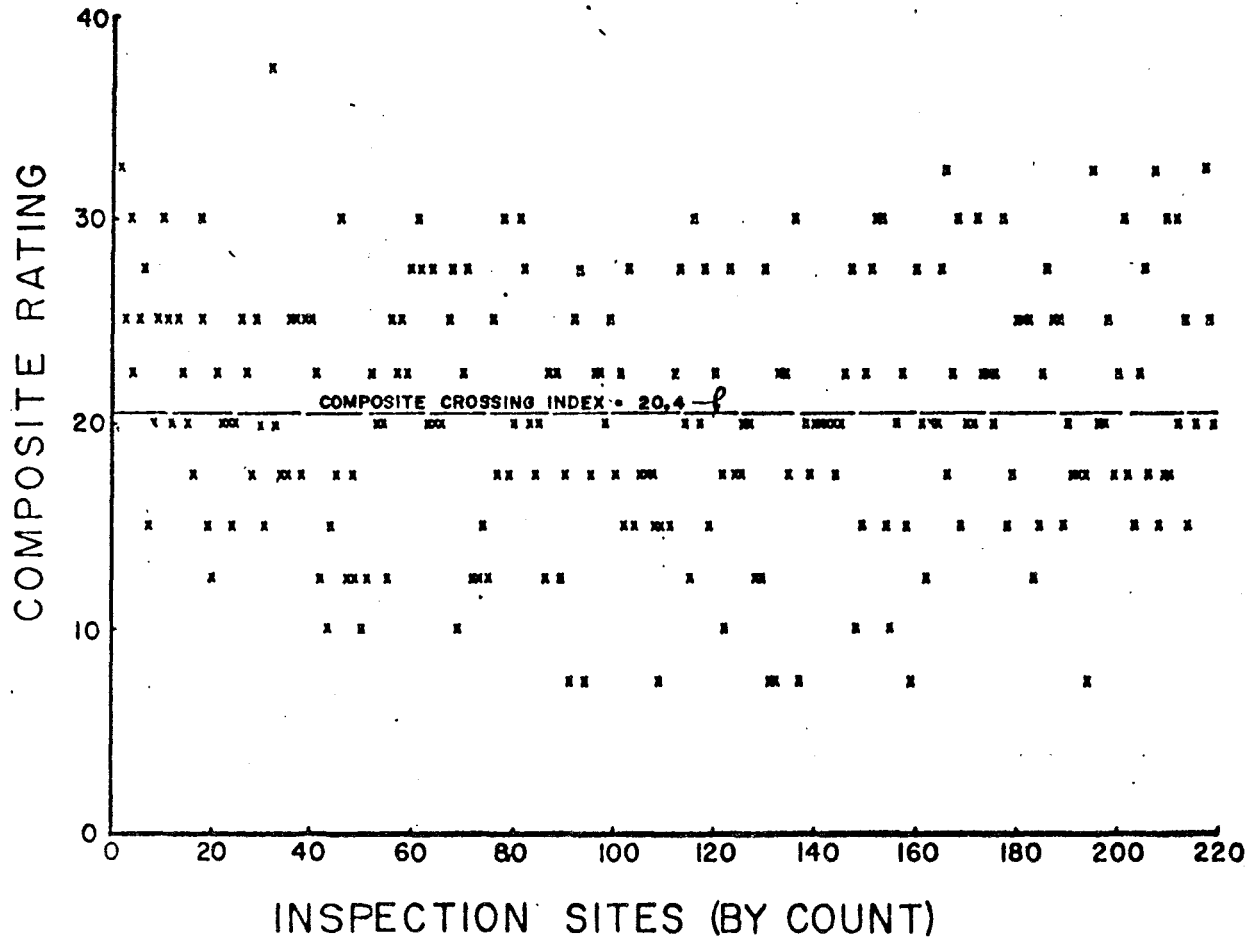TABLE 4-2 – SUMMARY OF FIELD SURVEY RATINGS

FIGURE 4-2 - COMPOSITE RATINGS OF 219 INDIVIDUAL CROSSINGS

above the index line. Individual crossings below the index line are rated as being adequate by the proposed method. However, special attention should be given to the maintenance of any individual element having a rating of 5.

The majority of the field surveys were made in the winter months of 1973-74. Examination of Figure 4-3 indicates the location of the crossings rated superimposed on a mean annual precipitation map of the state of Texas. It may be that the rating of drainage conditions in winter months in this part of Texas may have been affected by the time of year in which the ratings were made. The locations surveyed were in the eastern part of the state where the annual rainfall is more than 24 inches.

An evaluation index has been proposed. This index represents the weighted sum of average visual ratings of three elements: highway, railroad, and drainage. It must be emphasized that the proposed index is not intended to be employed in its present form, but is included as a guide for future development.
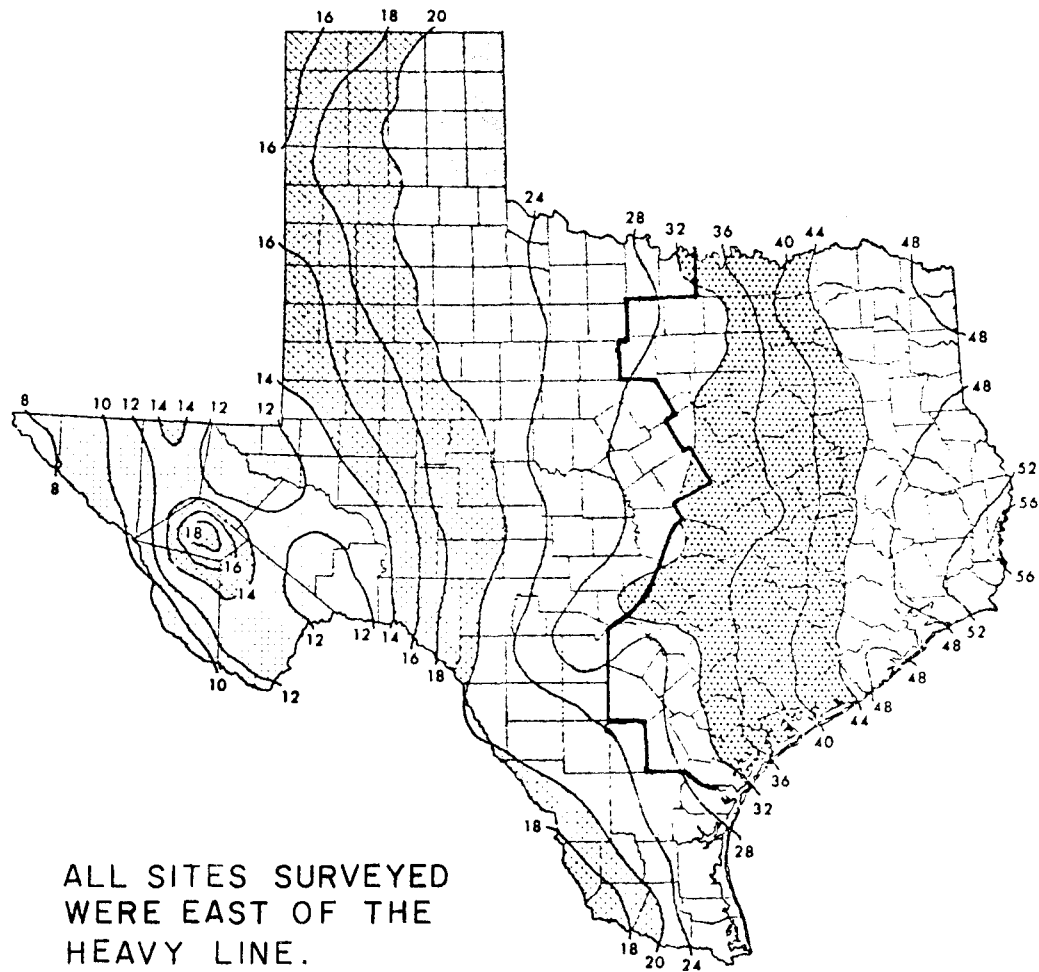
ALL SITES SURVEYED
WERE EAST OF THE
HEAVY LINE.

ALL NUMBERS ARE
INCHES.

FIGURE 4-3 – AREA OF CROSSING CLASSIFICATION
SURVEYS ON MEAN ANNUAL PRECIPITATION
MAP OF TEXAS (SOURCE: TEXAS STATE
CLIMATOLOGIST, U.S. WEATHER BUREAU, AUSTIN, TEXAS.

A frequency tabulation of the three elements rated at each survey site is presented in Table 4-3. The expected mean or midpoint of the rating range is 2.50 for each of the three components.

A weighted mean, defined as

$$\text{Weighted } \overline{X} = \frac{\sum_{i=1}^{i=n} f_i x_i}{\sum f_i}$$

where, Weighted $\overline{X}$ = Weighted mean

$f_i$ = Frequency of observed rating value

$x_i$ = Rating Value

was calculated for each component with the following results:

Highway

$$\text{Weighted } \overline{X} = \frac{0 + 20 + 142 + 243 + 176 + 10}{1 + 20 + 71 + 81 + 44 + 2} = \frac{591}{219} = 2.70$$

Railroad

$$\text{Weighted } \overline{X} = \frac{0 + 35 + 174 + 174 + 120 + 45}{0 + 35 + 87 + 58 + 30 + 9} = \frac{548}{219} = 2.50$$

Drainage

$$\text{Weighted } \overline{X} = \frac{0 + 25 + 106 + 171 + 236 + 115}{2 + 25 + 53 + 57 + 59 + 23} = \frac{653}{219} = 2.98$$

| RATING VALUE $(X_i)$ | FREQUENCY $(f_i)$ | FREQUENCY (% of total) | CUMULATIVE FREQUENCY | WEIGHTED RATING $(f_i X_i)$ |
|---|---|---|---|---|
| **Highway** | | | | |
| 0 | 1 | 0.5 | 1 | 0 |
| 1 | 20 | 9.1 | 21 | 20 |
| 2 | 71 | 32.4 | 92 | 142 |
| 3 | 81 | 37.0 | 173 | 243 |
| 4 | 44 | 20.1 | 217 | 176 |
| 5 | 2 | 0.9 | 219 | 10 |
| | 219 | 100.0 | | 591 |
| **Railroad** | | | | |
| 0 | 0 | 0.0 | 0 | 0 |
| 1 | 35 | 16.0 | 35 | 35 |
| 2 | 87 | 39.7 | 122 | 174 |
| 3 | 58 | 26.5 | 180 | 174 |
| 4 | 30 | 13.7 | 210 | 120 |
| 5 | 9 | 4.1 | 219 | 45 |
| | 219 | 100.0 | | 548 |
| **Drainage** | | | | |
| 0 | 2 | 0.9 | 2 | 0 |
| 1 | 25 | 11.4 | 27 | 25 |
| 2 | 53 | 24.2 | 80 | 106 |
| 3 | 57 | 26.0 | 137 | 171 |
| 4 | 59 | 27.0 | 196 | 236 |
| 5 | 23 | 10.5 | 219 | 115 |
| | 219 | 100.0 | | 653 |

# TABLE 4-3 - FREQUENCY TABULATION OF RATING VALUES

Engineering judgement indicated the need for drainage improvements at the sites surveyed, and this is reflected in the weighted mean for drainage which is greater than the values determined for highway and railroad components. Each of these values probably reflects the degree of attention given to each component by regular maintenance activities.

An evaluation index may be defined in the form:

$$\text{CROSSING INDEX} = X_1 H_{avg} + X_2 R_{avg} + X_3 D_{avg}$$

where $X_1$, $X_2$, and $X_3$ are arbitrary coefficients

$H_{avg}$ = Arithmetic mean highway rating

$R_{avg}$ = Arithmetic mean railroad rating

$D_{avg}$ = Arithmetic mean drainage rating

The coefficients may be taken as the weighted mean rating, giving:

$$\text{CROSSING INDEX} = 2.70(2.50) + 2.50(2.50) + 2.98(2.50) = 20.4$$

These calculations are given here to show the method that was used. It must be kept in mind that the coefficients will need to be constantly modified and up-dated as more data are available. A great improvement should be shown when composite ratings by several qualified observers are combined.

<u>Roughness Surveys</u>

The Mays Ride Meter is an instrument installed in an automobile which permits pavement ridability comparisons. The transmitter, attached to the body of an automobile, produces one electrical impulse for each 0.1 inch of upward or downward displacements of the rear axle. These excursions of the axle are recorded on a paper chart actuated by a variable rate feeding mechanism. Perfectly smooth pavement will not drive the chart, whereas rough pavement will drive the chart rapidly. Pavement discontinuities such as railroad crossings are readily observed on the paper record.

Three traces are recorded by pens on the paper chart, as shown in Figure 4-4.

(a) Distance Trace. This square wave record is produced by a special odometer, independent of chart feed; an upward zig represents 0.05 miles and a downward zig represents 0.05 miles traveled by the automobile.

(b) Profile Trace. A record of excursions of the axle with respect to the vehicle body. One-half inch on the chart represents one inch of vertical movement of the axle. Axle movements of less than 0.1 inch are filtered by the transmitter and are not recorded.

(c) Landmark Trace. An event mark manually placed on the record by the operator.

The location of the railroad crossing can be readily observed on the distance trace, the profile trace, and the landmark trace of Figure 4-4. Some quantitative comparisons can be made between the roadway roughness near the crossing and the roughness of the crossing itself.

A roughness index may be defined as the ratio of the summation of the axle excursions to the distance the automobile travels:

55

$$\text{Roughness Index} = \frac{\sum\limits_{i=1}^{n} 2y_i}{x}$$

where:  $y_i$ = measured excursion of axle, inches

2 = multiplying factor

$x$ = event distance, miles

The measured excursions need to be doubled because the recording pen moves 1/20 inch when the axle moves 1/10 inch.

The following procedure may be followed to compute the Roughness Index at the crossing:

1. Identify the crossing area; beginning and end of the crossing are shown in Figure 4-4.

2. Determine the length of the crossing by using the distance trace and the profile trace:

   a. Measure the event distance

   b. Measure the distance trace

   c. Compute length  as shown on the figure

3. Determine total axle excursions by summing $y_i$.

4. Compute Roughness Index.

In the example shown, the crossing roughness index is 308 inches per mile.

An alternate method produces a similar index.  The Mays Ride Meter drives the chart 5 inches for 32 inches of total vertical movement of the axle.  Thus, the distance trace may be employed to compute the crossing roughness directly:

$$\text{Crossing Roughness Index} = \frac{2.60 \text{ in.}}{0.05 \text{ mi.}} \times 6.4 = 332 \frac{\text{in.}}{\text{mile}}$$

The roadway roughness index can also be computed by using the distance trace:

56

DISTANCE TRACE

0.05 mi. = 2.60 in.    1.75 in = 0.10 mi.

1.3

0.2

1.0

0.5

0.4

PROFILE TRACE

0.5

0.7

0.5
1.0
0.2
0.5
0.3
0.7
0.4

$\Sigma Y = \overline{4.6}$ in.

BEGINNING    X mi. = 1.55 in.    END

$X = \dfrac{1.55 \text{ in.}}{2.60 \text{ in.}} (0.05 \text{ mi.}) = 0.0298$ mi.

$\text{CROSSING ROUGHNESS INDEX} = \dfrac{2\Sigma Y}{X} = \dfrac{2(4.6)}{0.0298}$
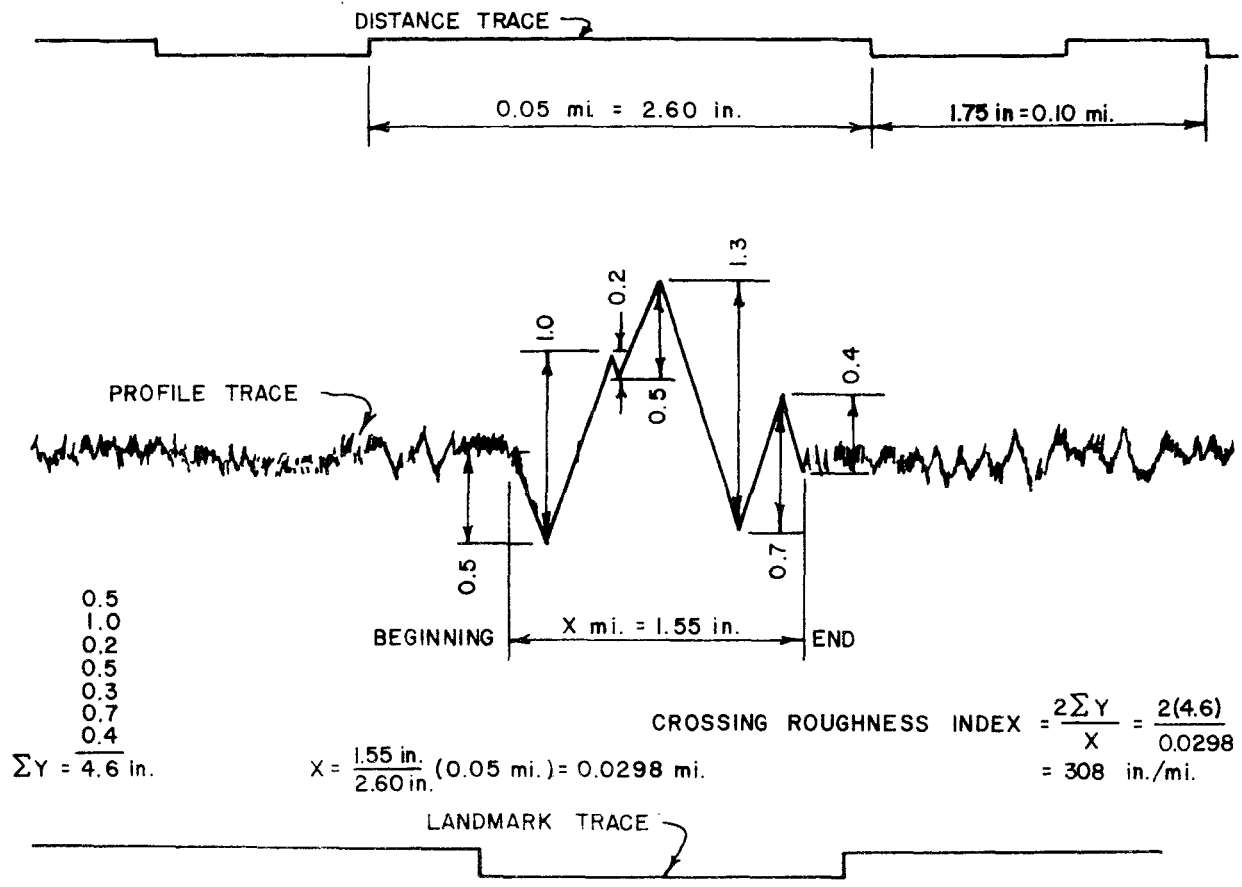
$= 308$ in./mi.

LANDMARK TRACE

FIGURE 4-4 - TYPICAL MAYS RIDE METER CHART (WITH SAMPLE CALCULATIONS)

$$\text{Roadway Roughness Index} = \frac{1.75 \text{ in.}}{0.01 \text{ mi.}} \times 6.4 = 112 \frac{\text{in.}}{\text{mile}}$$

The alternate method has been used to compute the comparative roughness indices for twenty-two crossings listed in Table 4-4. It should be noted that it was necessary to reduce speed at most of the crossings.

The twenty-two records were reduced using the basic measuring system described above, and it was found that axle excursions at smoother crossings were difficult to measure, as are axle excursions on smoother highways. Therefore, the alternate method using the distance trace was adapted and employed for comparisons.

It is apparent that braking and rough approach pavement near the crossing affect axle excursions as seen on the record, and as a result the effective length of the crossing can be established. For the example shown in Figure 4-4, the effective length of the crossing is 150 feet to 260 feet. Thus, crossing evaluation must include the pavement adjacent to the crossing.

Observation of driver behavior indicates that deceleration and acceleration near crossings is prevalent. Slowing is imperative when a highway crossing is near the railroad crossing.

| Run No. | County | Highway | Speed (mph) Hwy | Speed (mph) Xing | Roughness Index Hwy | Roughness Index Xing |
|---------|--------|---------|-----|------|-----|------|
| 1 | Runnels | FM 1692 | 50 | 25 | 70 | 160 |
| 2 | Runnels | FM 2133 | 50 | 25 | 90 | 180 |
| 3 | Tom Green | FM 1692 | 50 | 20 | 380 | 480 |
| 4 | Runnels | FM 2133 | 50 | 20 | 350 | 350 |
| 5 | Runnels | FM 2872 | 50 | 25 | 640 | 740 |
| 6 | Irion | RM 915 | 50 | 20 | 130 | 260 |
| 7 | Irion | SH 163 | 50 | 20 | 190 | 200 |
| 8 | Irion | FM 72 | 50 | 20 | 135 | 160 |
| 9 | Tom Green | FM 2335 | 50 | 20 | 120 | 330 |
| 10 | Tom Green | FM 2335 | 50 | 20 | 140 | 220 |
| 11 | Coke | RM 2662 | 50 | 20 | 40 | 230 |
| 12 | Tom Green | US 277 | 50 | 50 | 90 | 220 |
| 13 | Tom Green | FM 2105 | 50 | 50 | 70 | 135 |
| 14 | Runnels | FM 1692 | 50 | 20 | 300 | 480 |
| 15 | Runnels | FM 1692 | 50 | 50 | 75 | 205 |
| 16 | Runnels | FM 2872 | 50 | 35 | 480 | 480 |
| 17 | Runnels | FM 2133 | 50 | 30 | 100 | 185 |
| 18 | Runnels | FM 2133 | 50 | 50 | 90 | 165 |
| 19 | Tom Green | FM 2105 | 50 | 50 | 40 | 75 |
| 20 | Nolan | SH 158 | 50 | 25 | 45 | 130 |
| 21 | Coke | FM 2662 | 50 | 50 | 40 | 120 |
| 22 | Tom Green | US 277 | 50 | 20 | 25 | 135 |

## TABLE 4-4 – MAYS METER EVALUATION (DISTRICT 7)

## Foundation Characteristics

Soil samples were taken at seven of the railroad crossings which were visually rated. These samples consisted of disturbed samples representing the materials at depths of zero to three feet; and undisturbed samples at depths below three feet. A 2.5 inch inside diameter Shelby tube given by a trailer mounted drill rig was used to obtain the latter samples. Four holes were drilled at each site, as shown in Figure 4-5. Laboratory studies have been commenced on samples obtained, and partial results are shown in the figure. Poor drainage contributes to crossing failures, and low permeability clay subgrade is the primary cause of poor drainage conditions. This can be observed in Figure 4-5, where at a depth of five feet the moisture content increases greatly and then decreases again.

This severe increase in moisture content, indicating excess water which may have penetrated from the surface, or lateral movement of water through the sandy clay which may serve as an aquifier. Whatever the method of entry it is believed that the presence of water causes a lower shear strength and lower suction levels which could cause large deformation pumping and ultimately failure of the foundation.

It can be seen in Figure 4-5 that the soil suction decreases as moisture content increases. Thus, soil suction is a good measure of the subgrade condition as far as determining impending deterioration of the crossings. The equilibrium soil suction can be determined from the graph shown in Figure 4-6. The Thornthwaite Index is

$$I = \frac{100S - 60d}{E_p}$$

where:

        S = surplus of water in inches

        d = deficit of water in inches

        $E_p$ = potential evapo-transpiration in inches

60

This index is a measure of the climatic moisture balance between rainfall and evapo-transpiration. By knowing the Thornthwaite Index and the percent material finer than the #200 sieve, the equilibrium soil suction can be determined. When the in situ soil suction is much lower than the equilibrium suction, this indicates the presence of an excessive amount of water and a weakened soil condition.

Soil suction is a measure of a soils ability to attract water. This attracting energy or suction is expressed in terms of inch-pounds/cubic inch (pounds/square inch) or gram-centimeters/gram of water vapor (centimeters of water). The equation for total suction (h) in gram-centimeters/gram of water vapor is:

$$h = \frac{RT}{gm} \log_e P/P_0$$

where

$R$ = gas constant, $8.314 \times 10^7$ ergs/$^0$Cmol

$T$ = absolute temperature, $^0$C

$g$ = gravitational force, $981$ cm/sec$^2$

$M$ = molecular weight of water, $18.02$

$p$ = vapor pressure of soil water

$p_0$ = vapor pressure of free water

$P/P_0$   is the relative humidity, and therefore suction represents the relative humidity of the soil. Since the relative humidity is always 1.0 or less, its logarithm is always 0 or negative and thus h is always negative.

In this project, soil suction is measured by the thermocouple psychrometric technique. This apparatus indicates the relative humidity in the soil sample by the number of microvolts it puts out. A calibration curve relating microvolts to soil suction is used to obtain the value of soil suction.
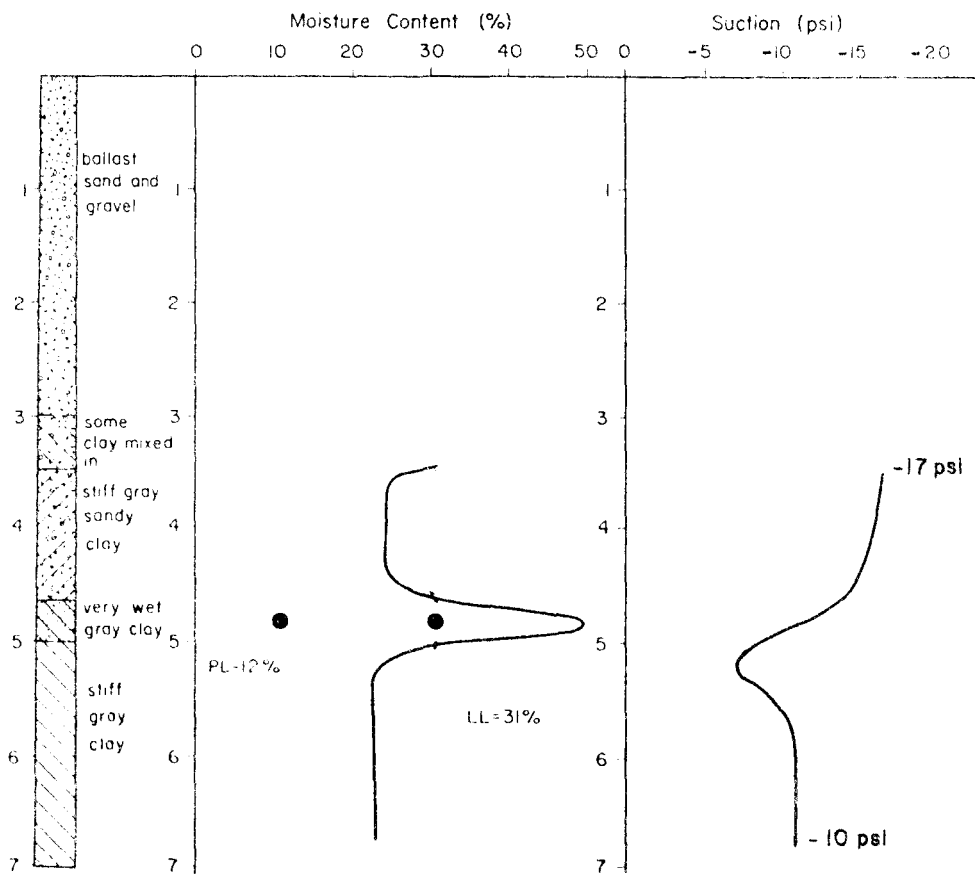
Average Soil Properties For Each Hole
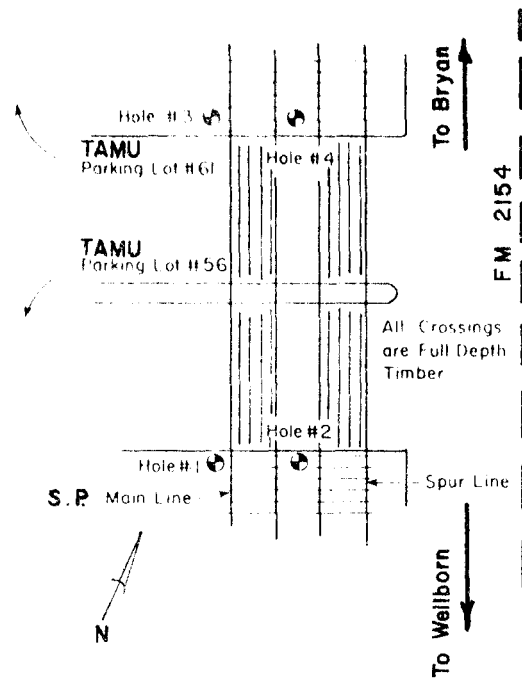
| | Liquid Limit | Plastic Index | % Passing '00 Sieve |
|---|---|---|---|
| Hole #1 | 28.5% | 17.0% | 64.9% |
| Hole #2 | 31.7% | 19.4% | 65.4% |
| Hole #3 | 32.6% | 19.8% | 66.1% |
| Hole #4 | 31.3% | 18.6% | 64.1% |
| Avg. | 31.0% | 19.0% | 65.1% |

NOTES

Unified Classification is CL

AASHO Classification is A-6(10)

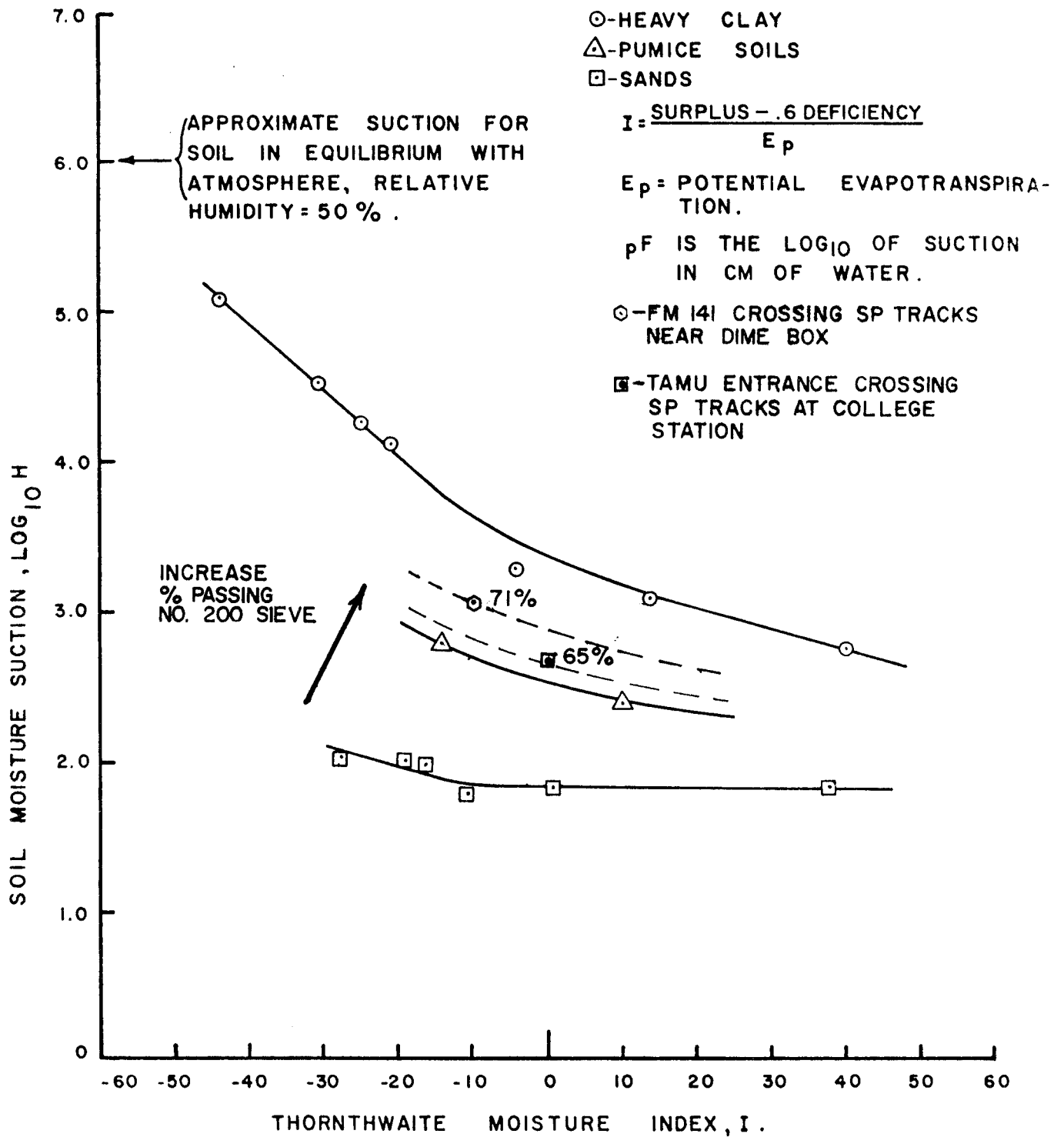FIGURE 4-5 - TEXAS A&M UNIVERSITY ENTRANCE CROSSING AT SOUTHERN PACIFIC TRACKS (CROSSING BUILT 1974)

FIGURE 4-6 - SUBGRADE SUCTION AS A FUNCTION OF
THE MOISTURE INDEX. (29)

## Dynamic Behavior

A railroad track may be considered as an elastic structure subjected to dynamic wheel loads applied on top of the rails which act as flexible beams. The rails bear on flexible supports (ties), and the ties rest on the ballast and roadway which are also flexible or yielding. The roadway transmits pressure to the natural subgrade. The track, tie, ballast, and subgrade system is an extremely complex one which has been considered carefully for many years.

A Special Committee to Report on Stresses in Railroad Track was organized in 1914. Arthur N. Talbot of the University of Illinois served as chairman and several reports were prepared which were published in Transactions of the American Society of Civil Engineers (19, 20, 21, 22) and in Proceedings of the American Railway Engineering Association. Theoretical and experimental information is presented in these reports. It is anticipated that this information will be useful in mathematical simulation of dynamic behavior of the rail system. The development of computer simulation of the highway system is discussed in Chapter 5, and a similar treatment of the rail system is being attempted.

Some field measurements of track depression (vertical displacement) were made during 1973; however, because of the wealth of information contained in the Talbot reports, these field studies were discontinued.

Several railroads employ track geometry cars which measure up to ten track characteristics including: surface and alignment of each rail, twist, gauge, superelevation, lateral and vertical acceleration, key bench marks, distance and speed (23).

These and other sources of information are being examined in an attempt to define dynamic behavior of track and highway.

64

# CHAPTER FIVE
## COMPUTATION OF DYNAMIC LOADS AT GRADE CROSSINGS USING COMPUTER PROGRAM DYMOL

A major part of the structural design of a railroad crossing involves an estimate of the loading applied by highway traffic as it travels over the crossing. Any roughness caused by the geometry of the crossing will increase the dynamic loading and thus make the crossing and the approach pavements even rougher.

Due to the required geometrics and the differential settlements caused by highway and railway traffic and other practical construction complexities, it is almost impossible to have a perfectly smooth grade crossing. Therefore, it is desirable to determine the effect of a grade crossing profile upon dynamic tire forces. Pavements stressed by high dynamic tire forces may be damaged considerably. These higher dynamic forces are also undesirable for riding comfort and safe handling of a vehicle. Therefore, it is very important to design a grade crossing with characteristics which will cause relatively low dynamic forces for any vehicle traveling over it.

A computer program DYMOL is used to study the influence of grade crossing profiles upon dynamic tire forces acting normal to the surface of the pavement. This program was originally developed by Nasser I. Al-Rashid, et al. (24), and has been revised to suit the purposes of this study. A complete description of the revised version is available in the unpublished users manual (25). However, a short description of the program and its revisions is included here.

## Description of the Program DYMOL

Vehicles with two axles are simulated in this program by considering them to be damped oscillatory systems with several degrees of freedom. Figure

5-1 shows the two-axle vehicle model. In this model the vehicle is represented by three distinct masses: (1) the main body, (2) the front axle, and (3) the rear axle. The main body is considered to be rigid. It rests on two axles through four springs, and a shock absorber is connected in parallel with each spring. Again, the two axles rest on at least four tires which are simulated by springs and dashpots. These springs and shock absorbers (or dashpots) may be different for different wheels. The following movements of these three masses are used to calculate the dynamic loads for each wheel:

1.  Main body translation in the vertical plane

2.  Main body pitching (rotation about a lateral axis of the body)

3.  Main body rolling (rotation about a longitudinal axis of the body)

4.  Front axle translation in the vertical plane

5.  Rear axle translation in the vertical plane

6.  Rolling of the front axle

7.  Rolling of the rear axle

The last four motions of the axles may be accounted for by considering the vertical translation of each of the individual wheels. The masses (main body, front axle and rear axle) are excited by surface profiles, which cause vibration in them. Differential equations of motion are set up for each individual mass. These equations are solved by numerical methods, resulting in the total dynamic loads for each wheel. General Motors profilometer data from natural surfaces which have been digitized on magnetic tape can be used as input in the program. These data are averaged for each contact length between the wheel and the ground to calculate the wheel path excitation. Artificial profiles can also be generated within the program in place of or in addition to natural surface profile input.
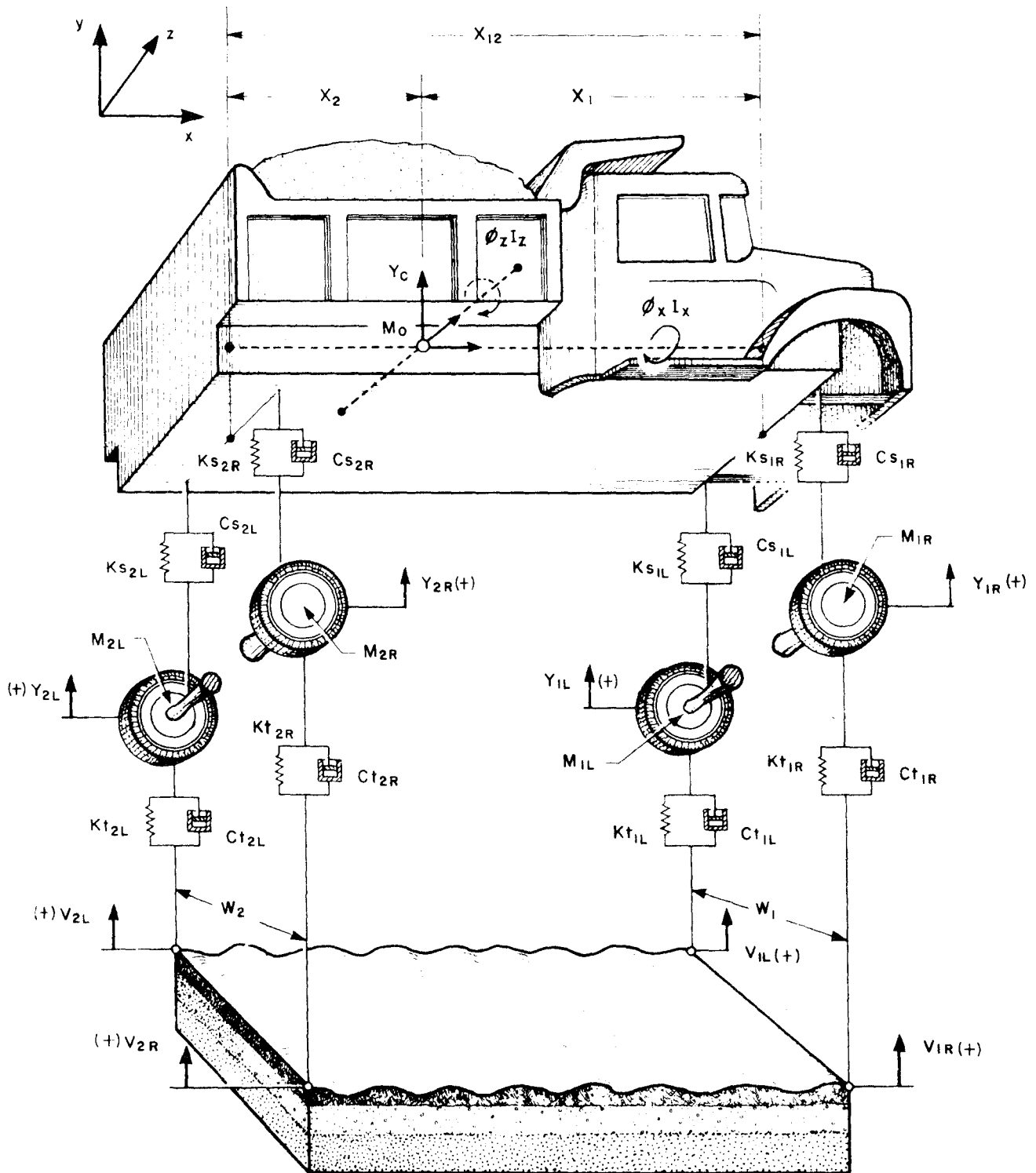
66

FIGURE 5-1 - TWO AXLE VEHICLE MODEL USED
COMPUTER PROGRAM DYMOL

## Revisions of the Program DYMOL

The original version of DYMOL considers the surface over which the vehicle rides to be rigid. In reality, a pavement acts more like a visco-elastic material. A definite quantity of pavement and soil mass also vibrates with the vibrating wheel while being resisted by the inertia of the pavement. Consideration of the stiffness, damping and inertia of the pavement was incorporated into the program by rewriting the basic differential equations of motion. These equations were solved by the same numerical method as before. Figure 5-2 shows the original and revised model of the program.

The revised simulation caused four additional degrees of freedom in the model, one for each mass of pavement in contact with a tire. Accurate data for determining the pavement inertia, stiffness and damping characteristics have seldom been measured. For the purpose of our present study pavement stiffness and dampness characteristics are approximated from the data obtained from the laboratory tests conducted by Cold Regions Research & Engineering Laboratory (26) in April 1966. The mass of the pavement is also roughly calculated according to the method shown in (27) by J. G. Theisen, et al. A number of laboratory tests have been initiated in this study to obtain these data more accurately for specific grade crossings.

A special subroutine which generates the profile of a typical grade crossing has been written and added to the DYMOL program. Figure 5-3 shows a typical grade crossing profile.

Finally, a set of FORTRAN statements were added to the program to accumulate the relative vertical movements of the rear axle with respect to the vehicle body. This movement is recorded by the Mays Ride Meter reading in an actual vehicle as an indication of pavement roughness. The Mays Ride Meter simulator is intended for comparison with the data from actual runs on

68
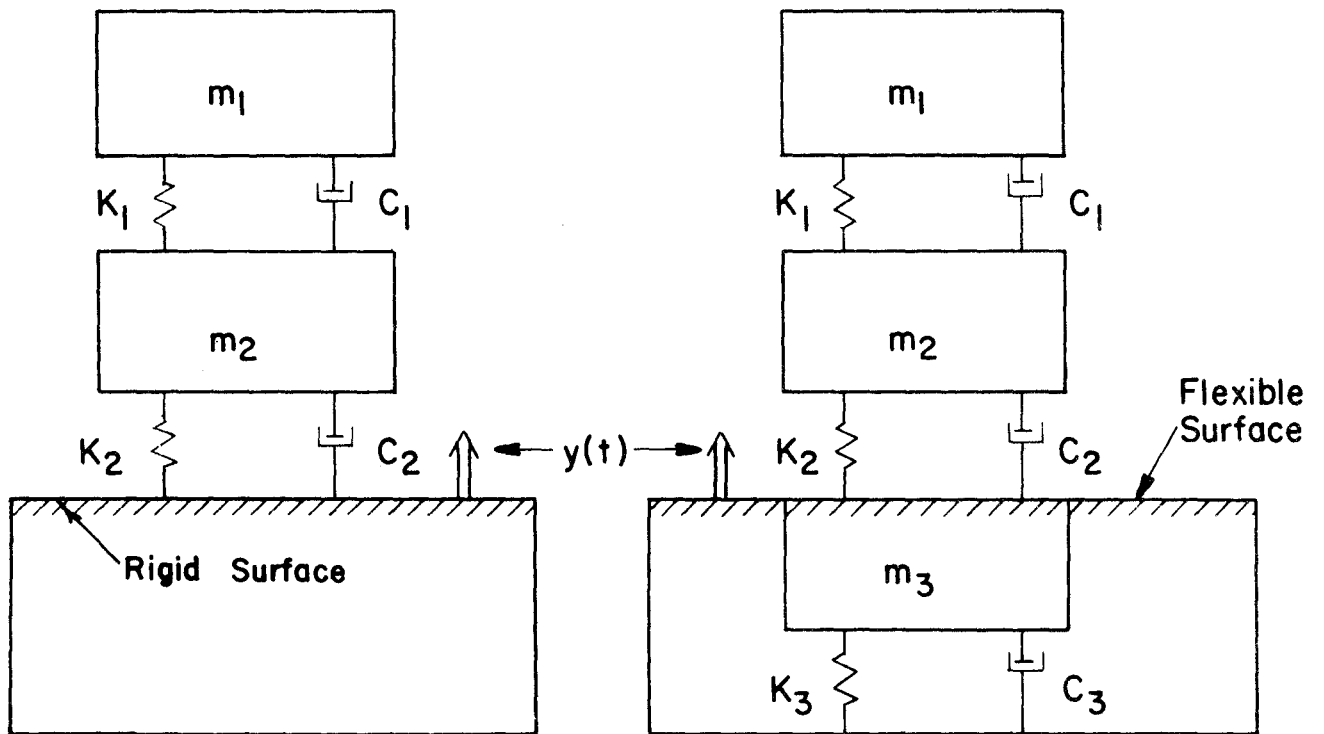
m₁ = Mass of Vehicle Body
m₂ = Mass of Tire and 1/2 Axle
m₃ = Mass of Soil That Vibrates in Phase With the Wheel
y(t) = Excitation

$K_1$ = Suspension Stiffness
$C_1$ = Suspension Damping Constant
$K_2$ = Tire Stiffness
$C_2$ = Tire Damping Constant
$K_3$ = Soil Spring Constant
$C_3$ = Soil Damping Constant

2(a) Original Simulation Model

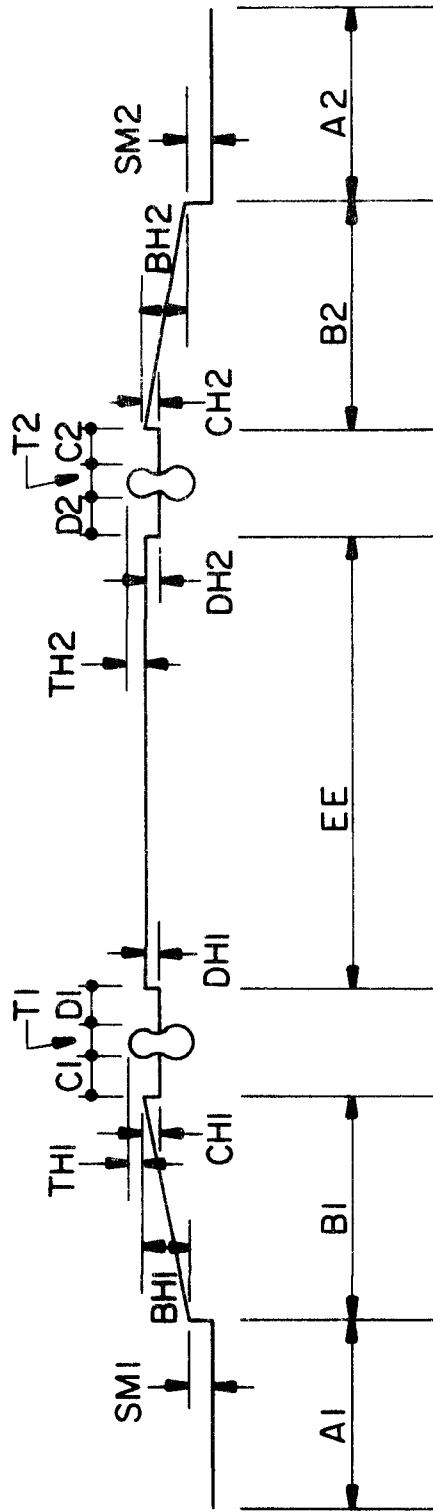2(b) Revised Simulation Model

# FIGURE 5-2, SIMULATION MODEL

FIGURE 5-3 - TYPICAL GRADE CROSSING

railroad crossings.

## Input and Output Data for DYMOL

Although much more detail can be found in the DYMOL Users Manual (<u>2</u>), a brief description of the input and output information will be given here.

Basically, the <u>input data</u> consists of four parts:

1. Vehicle Characteristics

   a. dimensions

   b. masses of vehicle body and tires

   c. spring stiffness of suspension, tires and pavement

   d. damping coefficients for suspension, tires and pavement

2. Pavement Surface Characteristics

   This is the surface profile in the right and left wheel paths. Surface elevations are either measured by the GM Profilometer every 2.027 inches and input on a magnetic data tape or, at the users option, they may be calculated within the program according to an internally prescribed geometry. The geometries prescribed internally to DYMOL are the following:

   a. sine wave

   b. periodic rectangular bump

   c. railroad grade crossing

   In each case where the surface elevations are calculated internally, the dimensions of the profile feature must be input as follows:

   a. sine wave:  amplitude and wave length

   b. periodic rectangular bump:  height of bump, distance across the top of the bump, distance between bumps

   c. railroad grade crossing:  all of the dimensions shown in Figure 5-3

3. Vehicle Speed

   This is input in miles per hour

4. Program Control Data

   These are numbers which indicate various options the program

user may elect.

The following _output_ information from DYMOL is printed out at very closely

spaced intervals of simulated time:

1. Simulated time from the start of the vehicle motion

2. Pavement profile elevation under each tire

3. Load applied to the pavement beneath each tire

4. Accumulated vertical body movement of the simulated maysmeter

The time intervals for output are set internally and depend upon the simulated

speed of the vehicle.

## Dynamic Loads at Grade Crossings

The dynamic force applied to a pavement surface depend upon the surface

roughness, the characteristics of the vehicle, and the vehicle speed. The

first study made with DYMOL was to determine the effect of vehicle speed on

the dynamic load factor which will be defined below. Subsequent studies with

DYMOL were made with the vehicle speed held constant to determine the effect

of railroad crossing geometry on the dynamic load factor.

_Speed Study_. A typical grade crossing profile (No. 6 in Table 5-1) was

chosen for this study using DYMOL. Computer runs were made with a simulated

dump truck over the same profile with 3 different vehicle speeds: 30, 50,

and 70 miles per hour. A dynamic load factor is defined as the percent by

which the dynamic load exceeds the static load. The expression for the

dynamic load factor is

$$DLF = (F_D - F_S) / F_S$$

| Grade-crossing No. | A1* | A2 | B1 | B2 | C1 | C2 | D1 | D2 | T1 | T2 | CH1 | CH2 | DH1 | DH2 | EE | SM1 | SM2 | BH1 | BH2 | TH1 | TH2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 20** | 150 | 24.25 | 24.25 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2 | 2 | 2 | 2 | 56.5 | .5 | .5 | 1 | 1 | .5 | .5 |
| 2 | | | | | | | | | | | | | | | | .5 | .5 | 1 | 1 | 1 | 1 |
| 3 | | | | | | | | | | | | | | | | .5 | .5 | 2 | 2 | .5 | .5 |
| 4 | | | | | All of these values are constant. | | | | | | | | | | | .5 | .5 | 2 | 2 | 1 | 1 |
| 5 | | | | | | | | | | | | | | | | 1 | 1 | 1 | 1 | .5 | .5 |
| 6 | | | | | | | | | | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 |
| 7 | | | | | | | | | | | | | | | | 1 | 1 | 2 | 2 | .5 | .5 |
| 8 | | | | | | | | | | | | | | | | 1 | 1 | 2 | 2 | 1 | 1 |

* – See Figure 5-1 for these dimensions

** – All dimensions are in inches

TABLE 5-1– TYPICAL DIMENSIONS OF DIFFERENT GRADE CROSSINGS AS APPROXIMATED FROM FIELD MEASUREMENTS (IN INCHES)

where:  DLF = dynamic load factor

$F_D$ = dynamic wheel load

$F_S$ = static wheel load

A dynamic load factor of -1 means that the wheel has lifted free of the surface. Similarly, the maximum dynamic load factor ($DLF_{max}$) can be expressed as:

$$DLF_{max} = (F_{Dmax} - F_S) / F_S$$

where:  $F_{Dmax}$ = maximum dynamic wheel load

Figure 5-4 shows the maximum dynamic load factor as a function of speed for both the front and rear wheels. The curves show that the higher vehicle speeds produce larger dynamic loads for any given crossing profile.

Although smaller dynamic loads would be computed for lower speeds, a vehicle speed of 70 mph was chosen for further study to determine the critical factors in grade crossing geometry.

Study of the Grade Crossing Geometry. Eight grade crossing profiles were selected to determine their influence upon the dynamic loads. Their dimensions as approximated from field measurements are given in Table 5-1 and explained in Figure 5-3. Figures 5-5 and 5-6 show the variation of dynamic forces, computed by DYMOL, on the front and rear wheels respectively as they traverse each grade crossing. The shapes of these curves are similar for all crossings. As expected, the magnitudes of dynamic forces were greater for rougher profiles. Three important geometric features in a crossing were rated by the effect they have on the dynamic load factor: (1) ramp-rise (BH1, BH2), (2) step difference between pavement and crossing (SM1, SM2), and (3) rail-height above the surface (TH1, TH2). Ramp rise was the most important factor. Table 5-2 shows the ratios of dynamic load factor (DLF) due to the ratio of variation of dimensions in these three geometric features of a grade

74
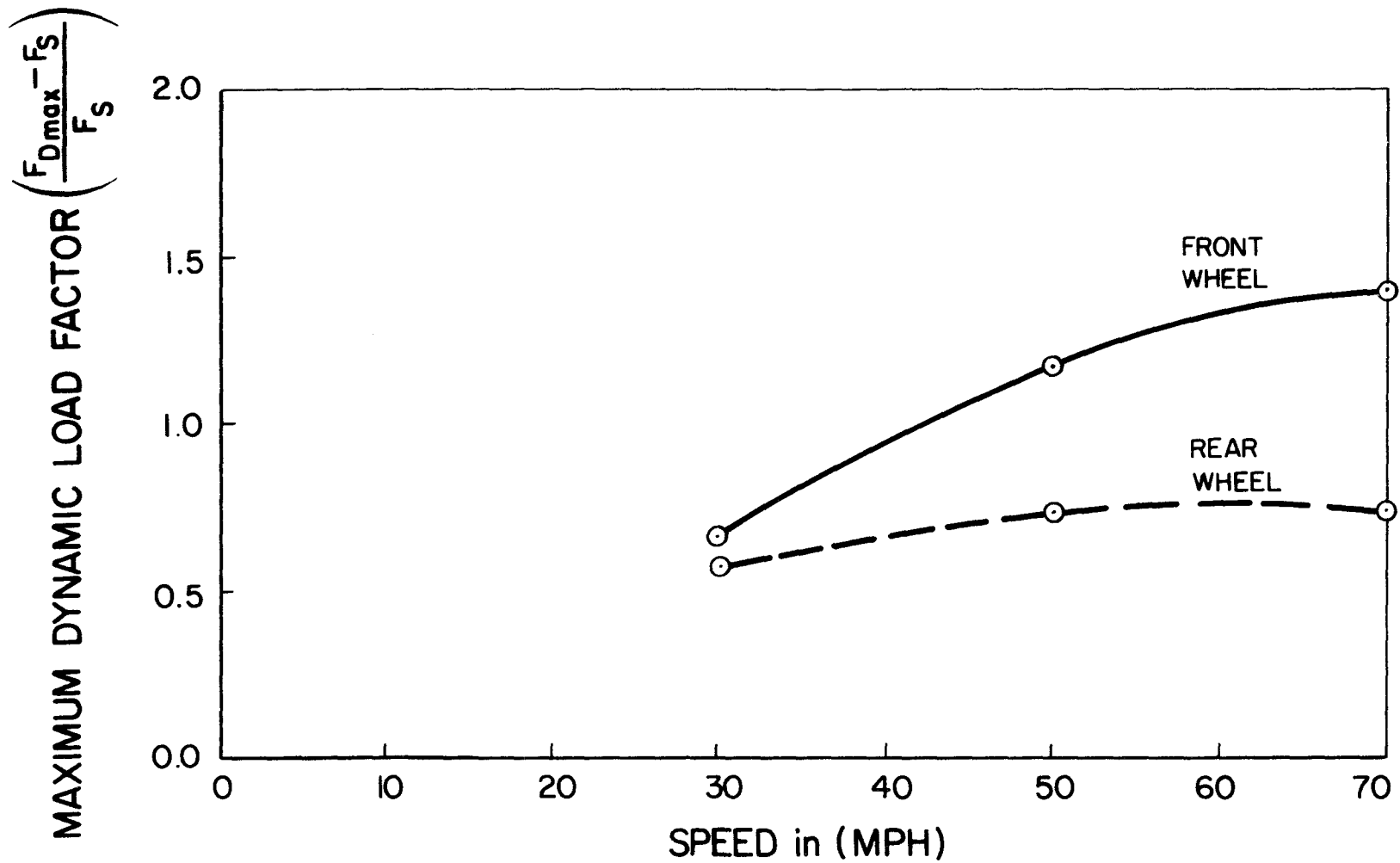
FIGURE 5-4 - VARIATION OF MAXIMUM DYNAMIC
FORCE DUE TO VEHICLE SPEED
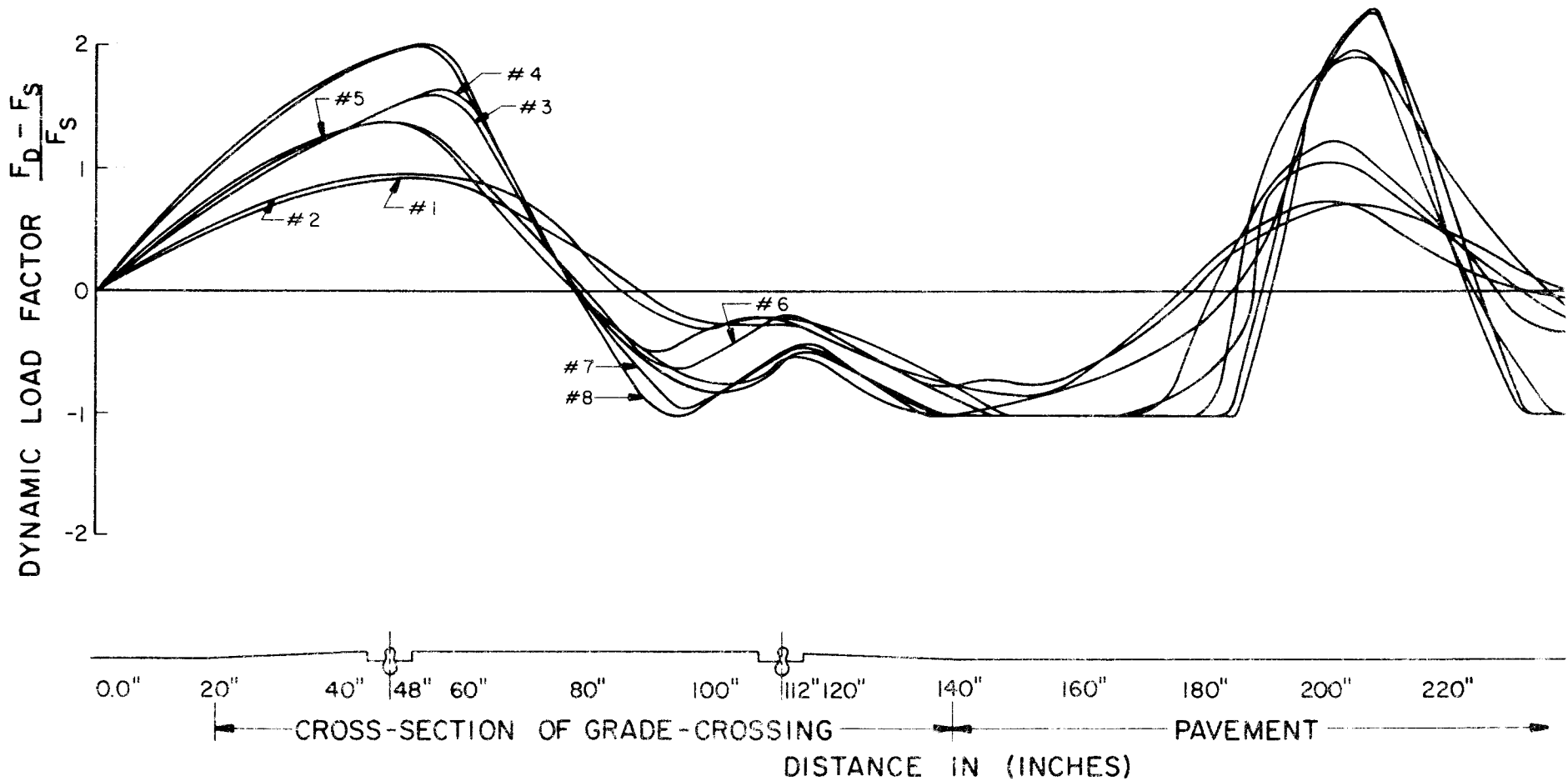
FIGURE 5-5 – VARIATION OF DYNAMIC FORCES ON FRONT WHEEL
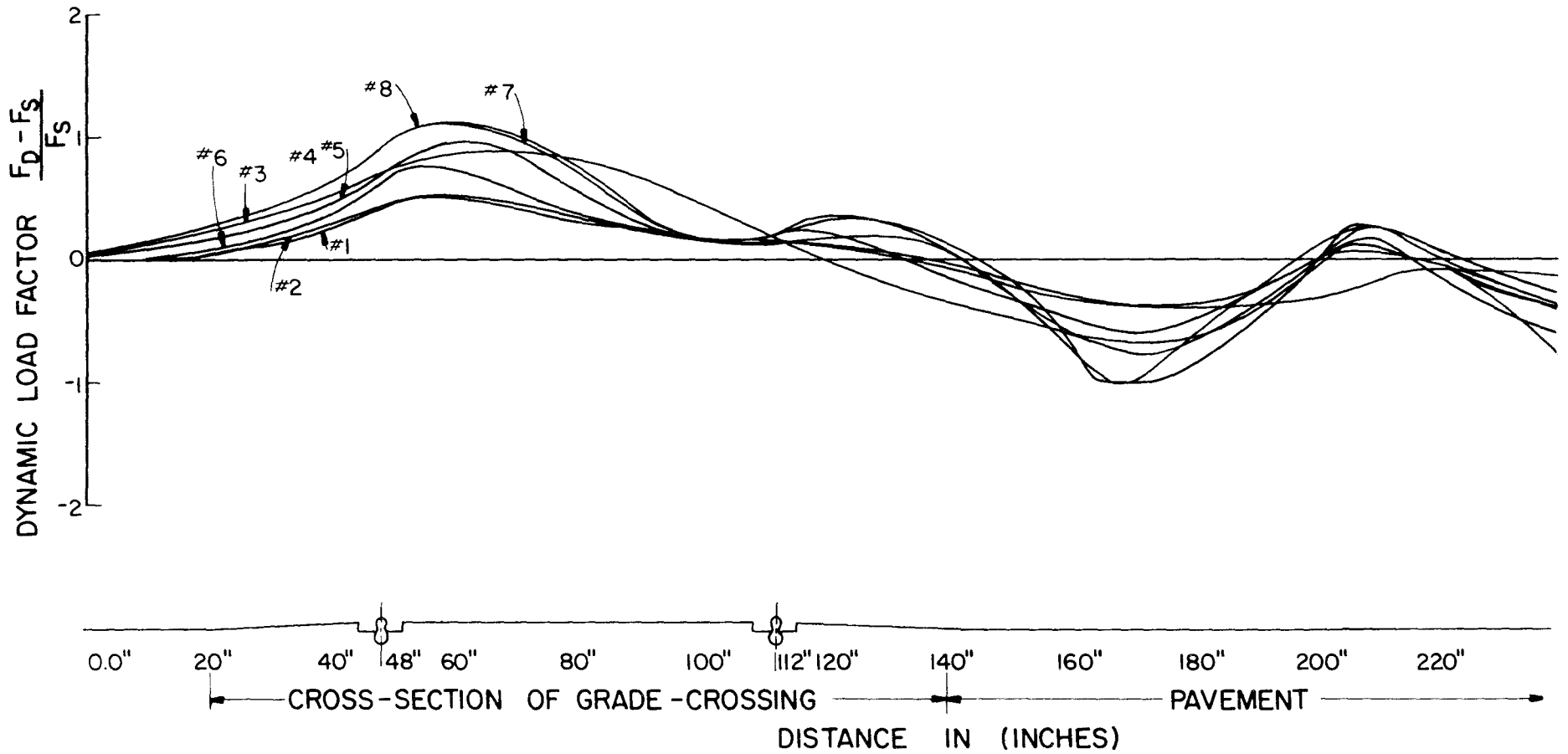AT DIFFERENT LOCATIONS OF GRADE CROSSINGS

FIGURE 5-6 — VARIATION OF DYNAMIC FORCES ON REAR WHEEL AT DIFFERENT
LOCATIONS OF GRADE CROSSINGS

crossing.

The Dynamic forces were very large at two locations along the wheel path over the crossing:

a) on top of the first rail, and

b) on the pavement approximately 5 to 6 feet beyond the grade crossing. The latter location is not as critical for rear wheel loading. These forces were very low just past the crossing due to the upward lift of the wheel. It was found that the lift was greater with rougher profile. In some cases, the wheels lost contact with the ground. This can be seen in Figures 5-5 and 5-6 where the value of dynamic load factor (DLF) becomes -1. At lower speeds, loss of contact between the wheels and the ground may not occur.

It has been shown that certain geometric features in a grade crossing can cause a dynamic wheel load to become 2 to 3 times as large as its static weight. This would influence the serviceable life of a grade crossing and its approaching pavements. The design life may be reduced to as low as 70% of its design value if the wheel load becomes double the size for which the pavement was designed. This study has shown that the most important reduction in the dynamic load factor can be made by reducing the height of the ramp rise. To put it more simply, the closer the elevation of the crossing is to that of the pavement, the less damage may be expected from the effects of passing traffic.

This study has also shown that a clear understanding of the geometrics of a grade crossing and their influence upon the magnitude of dynamic loads is very important for the design of a crossing and its approaching pavements.

| Variation of Geometric Feature | Ratio of Variations of Dimension | Ratio of Dynamic Load Factor due to Variation of a Geometric Feature | |
|---|---|---|---|
| | | Front Wheel | Rear Wheel |
| Ramp-rise (BH1 and BH2) | 2 | 1.68 | 1.55 |
| Step difference between pavement and crossing (SM1 and SM2) | 2 | 1.18 | 1.24 |
| Rail-height above the surface (TH1 and TH2) | 2 | 1.02 | 1.02 |

TABLE 5-2 - RATIO OF DLF TO THE RATIO OF VARIATIONS OF DIMENSION IN DIFFERENT GEOMETRIC FEATURE OF A GRADE CROSSING

# CHAPTER SIX
## SUBGRADE STABILIZATION FABRICS

Several fabrics have been produced by the petrochemical industry for use in the construction of roads and railroads. Some of the available products are listed in Table 6-1, and will be discussed in succeeding paragraphs.

## Celanese MIRAFI® 140 Fabric

A brochure prepared by the Celanese Fibers Marketing Company describes this product as follows:

> Mirafi 140 fabric is a unique fabric constructed from two types of continuous-filament fibers. One is wholly polypropylene, and the other is a heterofilament comprising a polypropylene core covered with a nylon sheath. A random mixture of these filaments is formed into a sheet that is heat bonded; the result is direct fusion at points of contact between heterofilaments. No bonding agent or resin is used. The polypropylene filaments remain unaffected during the heat-bonding process. Purely mechanical links operate between these homofilaments. This unique fabric construction makes a uniformly strong fabric with good tear resistance because it is elastic in all directions. It has excellent soil-filtration capabilities because the randomly distributed pore openings are roughly equivalent to the particle-size distribution in a well-graded sand. Mirafi 140 fabric retains its durability and strength, wet or dry, hot or cold, and can conform to irregularities in subgrade surfaces because it has excellent energy-absorption capabilities.
>
> Mirafi 140 fabric is rotproof. Controlled laboratory tests, as well as tests performed on fabric removed from the ground after two years of service, show no significant deterioration in the fabric's physical properties.
>
> Mirafi 140 fabric has excellent durability under most chemical conditions. Alkalies and weak acids (pH > 3) have no significant effect on Mirafi 140 fabric, but sustained attack from strong acids and phenolic compounds or lengthy exposure to sunlight can cause fabric property deterioration. Because of these factors, Mirafi 140 fabric (although shipped in black plastic wrappers) should not be stored outdoors for extended periods of time without special protection from sunlight.

| MANUFACTURER | PRODUCT | DESCRIPTION |
|---|---|---|
| Celanese Fibers Marketing Company | MIRAFI®140 | A fabric constructed from polypropylene and nylon continuous filament fibers, randomly mixed and heat bonded |
| E.I.DuPont de Nemours & Co. (Inc.) | TYPAR® | A fibrous sheet structure produced by spinning and bonding continuous filaments of polypropylene |
| Monsanto Textiles Company | E2B | A spunbonded, needle-punched, nonwoven polyester fabric |
| Phillips Petroleum Company | PETROMAT® | A nonwoven polypropylene fabric |

Note: ® indicates manufacturer's registered trademark

TABLE 6-I- PETROCHEMICAL GROUND STABILIZATION MATERIALS

The use of membranes in ground stabilization dates from the Roman practice of using heather and sheepskin in road construction. What was achieved by the Romans and what is accomplished by using Mirafi 140 fabric is -- simply stated -- the separation of unstable subsoil and granular fill material.

Mirafi 140 fabric performs three functions in soil stabilization applications, i.e., separation, filtration, and tensile reinforcement. The relative importance of the three functions depends on the soil conditions, the type of aggregate used, and the traffic requirements.

*As a separator*, Mirafi 140 fabric provides a barrier between poor subsoil and compactable fill, thus preventing penetration and subsequent loss of the fill into the subsoil. This fabric barrier acts as a platform or base from which to begin compaction. By using the fabric, *all* of the granular fill can be compacted.

*As a filter*, Mirafi 140 fabric prevents most fine soil particles from contaminating the fill material. Subsoil conditions continue to improve because water and moisture are squeezed out of the soil by the surcharge load (fill material) and are filtered through the fabric.

*As tensile reinforcement*, Mirafi 140 fabric provides nondirectional tensile support for the compactable surface fill. With no loss of fill, rutting in nonpaved roads is greatly reduced.

When combined, the three separate functions of separation, filtration, and tensile reinforcement permit a wheel load to be transferred through a minimum depth of compacted aggregate. Thus, a low load-bearing-capacity subsoil can support the wheel load, because the wheel load is felt as a distributed pressure transferred along the Mirafi 140 fabric.

Literature provided by Celanese indicates that the fabric has been used in the United Kingdom, and describes a recent installation on the Florida East Coast Railroad main track crossing of 32nd Street in Fort Lauderdale, Florida (see Figure 6-1). Other installations are anticipated.

## DuPont TYPAR ® Fabric

This fibrous sheet structure produced by spinning and bonding continuous filaments of polypropylene is available in several weights. The unit weight
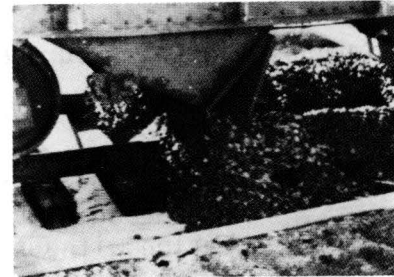
82

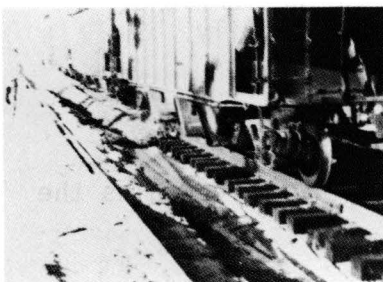EXCAVATION

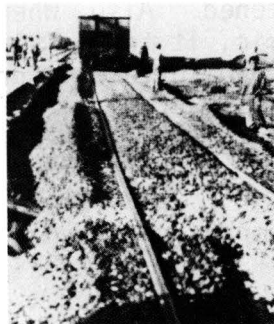SUBGRADE PREPARATION

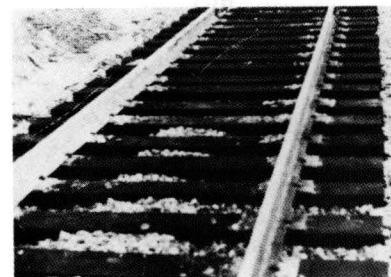PLACING MIRAFI® 140

LAYING TIES

REPLACING TRACK
STRUCTURE

SPREADING BALLAST

BALLAST CARS

BALLAST IN PLACE

RESURFACED TRACK

FIGURE 6-1 - INSTALLATION OF MIRAFI 140 ON FLORIDA
EAST COAST RAILROAD, FORT LAUDERDALE,
FLORIDA. (COURTESY OF CELANESE FIBERS
MARKETING COMPANY)

83

varies from 1.5 ounces per square yard to 4.0 ounces per square yard. DuPont suggests using the fabric as a filter material and as an underlayment or support for roads.

## Monsanto E2B Fabric

According to information furnished by Monsanto Textiles Corporation, this spunbonded, needlepunched polyester nonwoven fabric is strong, durable, resistant to soil acids and alkali; and is rot and mildew resistant, too.

The Monsanto technical brochure also suggests using this fabric for stabilization of subgrades composed of clay-type and peat-type soils, and lists three "noticeable benefits:"

> *Load Distribution* -- The load of the tire or tracked vehicle is spread over an area many times greater than the distribution without the fabric's use.
>
> *Anticontamination* -- Because the fabric filters out fines greater than 60 microns in size, the fines from the soil underneath the fabric remain there, providing a noncontaminated, always usable road surface.
>
> *Water Wicking* -- By wicking the water from the soil underneath and depositing it at the fabric's edges, consolidation of that soil is hastened. Also, when rainwater works its way down to the fabric, it too is siphoned to the fabric's edges, causing the road surface to dry up more readily.

## Phillips Petromat®

The Phillips Petroleum Company provided a brochure which contains the statement:

> This non-woven polypropylene fabric lends outstanding tensile strength to paving, forming an exceptionally strong moisture barrier which enables it to retard and control crack reflection.

A non-woven polypropylene fabric having near non-directional high tensile strength, when incorporated with asphalt, lends tensile strength to the pavement. Further, according to Phillips literature, the material forms a strong moisture barrier, which can withstand considerable movement without rupture.

84

These commercially available fabrics show promise for improving sub-grade conditions. As discussed earlier, the inflow of surface water and the immigration of ground water and fines from the subgrade are detrimental to crossing life and rideability.

Two types of track failure have been identified in literature furnished by ICI Fibres of Harrogate, England. These are discussed in the following paragraphs:

THE PROBLEM

Track performance depends principally on the adequacy or otherwise of the strength and stability of the ballast and other strata supporting the sleepers. In fact, tracks fail due to either Pumping Failure or Cumulative Bearing Capacity failure.

Pumping failure is due to the presence of a fine slurry at or above the level of the base of the sleepers. This fine slurry may 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 derive from the pumping of a soft subgrade up through the ballast which leads to "Erosion Failure."

Cumulative bearing capacity failure is due to the over-stressing of the subgrade soil and is characterized by the continual loss of track level and "Cess Heaving" which occurs in wet weather. This mode of failure is, in fact, an effective stress condition and is associated with soils subject to fatigue.

PRESENTLY ACCEPTED SOLUTIONS

The remedial measures necessary in case of track distress vary with the mode of failure. Where dirty ballast failure has occurred it is remedied by cleaning the ballast. For erosion failure the permanent remedy is the introduction of a separation/filtration layer, usually sand. With bearing capacity failure a number of possible solutions are available as follows:

Increase in depth of formation to lower pressure intensity on the soil surface.

Change of the elastic modulus by introduction of new ballast or sub-ballast layers or strengthening of existing layers by grouting or similar techniques, again resulting in re-distribution of pressure in the sub grade.

Reduction of water transmission across the interface between the sub grade and the ballast or sub-ballast layer by either (or both), inserting an impermeable layer or improving drainage of water from the formation surface.

## THE FUNCTION OF FABRIC MEMBRANES

The function of a fabric membrane layer at the interface between the ballast and sub-ballast layers or sub-ballast and sub-grade layers will be threefold, as follows:

Separation - i.e., the physical separation of the strata beneath the track. If the membrane is impermeable it will separate completely both the mineral and water constituents of these strata. If the membrane is not impermeable, then it may have the second function of filtration.

Filtration - i.e., the selective separation of strata in terms both of selection of size of mineral particles to be transmitted from one stratum to another and the amount of water to be transmitted.

Reinforcement - i.e., increase in overall strength of the strata supporting the track by the combination of maintenance or improvement of intrinisc strength of the ballast, sub-ballast, sub-ballast and sub-grade layer and reduction in tensile strains in the ballast and sub-ballast layers.

In terms of remedial measures a fabric membrane would be of no assistance in the case of dirty ballast failure. Where conditions are such that erosion failure is possible a separation/filtration layer would be useful if slurry could be prevented from approaching the level of the sleepers. For good drainage and track performance the top 9 inches of ballast should be free draining and this must therefore be the design criteria in this case. With bearing capacity failure the membrane would not in itself provide increased depth thereby lowering the pressure intensity on the sub-grade, but it could induce changes in elastic modulii of the ballast and could reduce water transmission across the sub-grade ballast interface.

## USE OF FABRIC MEMBRANCES

The use of impermeable layers or membranes has previously been widely advocated and adopted, but only recently has the use of permeable membranes been investigated in Scandinavia and Britain. Whereas the impermeable membranes seek to prevent any movement of mineral particles or water across the sub-grade/ballast interface the permeable membranes seek only to control movements. The main advantages of the latter are that pore water pressures in the sub-grade can be more readily equalised, and the more durable nature of most permeable fabrics, renders them less likely to tear and cause local failures.

86

Various trials are presently in progress using ICI PRF 140 with British Rail. Each trial site selected was predominantly clay with high moisture content and low shear strength. A particular trial length in Birmingham is on clay, in a cutting where difficulty has been prevalent for many years with unstable formation and distorted lines. Since the introduction of PRF 140 overlayed by 9 inches of ballast, some nine months ago, no track deflections have occurred apart from initial settling and the formation appears stable. Comparative performances suggest that a double layer of PRF 140 is equivalent to 2 feet of ash in this particular case.

These trials therefore suggest that PRF 140 carries out permeable membrane functions of separation, filtration, and reinforcement.

Separation was not complete but mixing of the ballast with the unsuitable soil underneath was minimized. The ballast was therefore kept clean and its drainage properties maintained.

The fabric appears to allow the passage of water both downwards into the sub grade and upwards into the ballast. The passage of water upwards was, however, not accompanied by mass migration of fine material because of the fabric structure. This filtration property has another advantage, in that it allows the dissipation of pore water pressure from the sub grade and alleviates the danger of pumping. It also reduced the moisture content of the sub grade, which being cohesive increased its strength.

The tensile strength and high extensibility of the fabric allowed it to take up the natural deflected configuration of the soil without puncture or tearing. This deflected form was bowl shaped which ensured that the ballast was in compression, an ideal state for creating inter granular reaction.

DISCUSSION

In certain cases of track failure or where failure is likely to occur, the use of impervious membranes has been established. The use of permeable membranes is now being proven. The latter appear to have certain advantages associated with increased durability and relief of pore pressures in the sub grade.

In certain special circumstances it is appreciated that no moisture movement within the sub grade will be permissable such as swelling clay sub grades, and that impermeable membranes must be used. The use of permeable fabric membranes would thus otherwise seem to be a viable technical solution to many problems. The economics of the technique should now be fully investigated in terms of short term remedial gains and long term reductions in maintenance.

The fabric membrane, ICI RFP 140, called Terram, is produced by Imperial Chemicals, Inc., in the United Kingdom. A business agreement between Celanese Corp. and ICI allows Terram to be produced by Celanese Corp. in the United States under the trade name Mirafi 140 Ground Stabilization and Filtration Fabric. British Rail Birmingham constructed five sections in December, 1972. Inspection of these sites in January, 1974, indicated that the track had been usable for twice its normal maintenance period.

# CHAPTER SEVEN
## STRUCTURAL DETAILS

Site inspections have produced several observations concerning drainage, subgrade requirements, and methods for improving unsatisfactory conditions. These have been discussed in previous chapters. A review of drawings provided by several railroads and others leads one to conclude that crossing life can be extended and rideability improved by careful attention to structural details. Some of these include:

1. Eliminate rail joints within roadway and for a distance of at least 30 feet beyond each end of the roadway crossing surface.

2. Install heavier rail within the crossing.

3. Use rubber tie pads under tie plates on each crosstie within limit of crossing.

4. Bevel ends of crossing planks.

5. Seal flangeway openings and spaces outside the head of the running rails with bituminous or other material.

6. Use four spikes in each tie plate.

7. Install rail anchors at each tie.

8. Field side planks must be fully supported on crossties.

Application of these procedures will produce a stiffer track structure, a smoother riding surface for the rail and highway traffic, and will reduce or eliminate surface water intrusion into ballast and subgrade.

The following paragraphs will discuss some innovative details which are suggested for further consideration.

## Innovative Details

1. Continuous Tie Plates.

An adequately spiked steel plate placed on top of the crossties and beneath each running rail will increase the structural integrity of the track structure. Rail wheel loads would be distributed over several ties. The moment of inertia of the rail would be increased, and the rail deflection would be reduced. A rolled steel plate placed across seven to eight ties over the length of the crossing will cost more than individual tie plates, but fewer spikes will be required and labor costs will be reduced. A possible detail is shown in Figure 7-1.

This concept has been refined by Railco, Inc., by using a rolled shaped configuration illustrated in Figure 7-2. This commercially available system has several advantages over the use of a flat steel plate over several crossties.

2. Rubber Cushions and Flangeway Inserts.

Two firms in Ashtabula, Ohio, Railroad Rubber Crossings, Inc., and International Track Systems, Inc., fabricate elements for shipment to a crossing site. Details of a timber deck crossing are shown in Figure 7-3, and details of a concrete deck crossing are shown in Figure 7-4. The use of screw spikes for attaching timber panels to cross ties is recommended by the fabricators. The installation of Butyl rubber tie pads on each tie and Butyl rubber abrasion pads between rail base and tie plates provide shock resistance to rail and highway wheel loads. The guard timber and flangeway rubber insert are intended to eliminate intrusion of surface water and debris.

An article in the September, 1966, issue of Railway Track and Structures indicates that these products have been employed with some success on the Chicago Belt at several crossings. According to W. D. Chapel, Superintendent
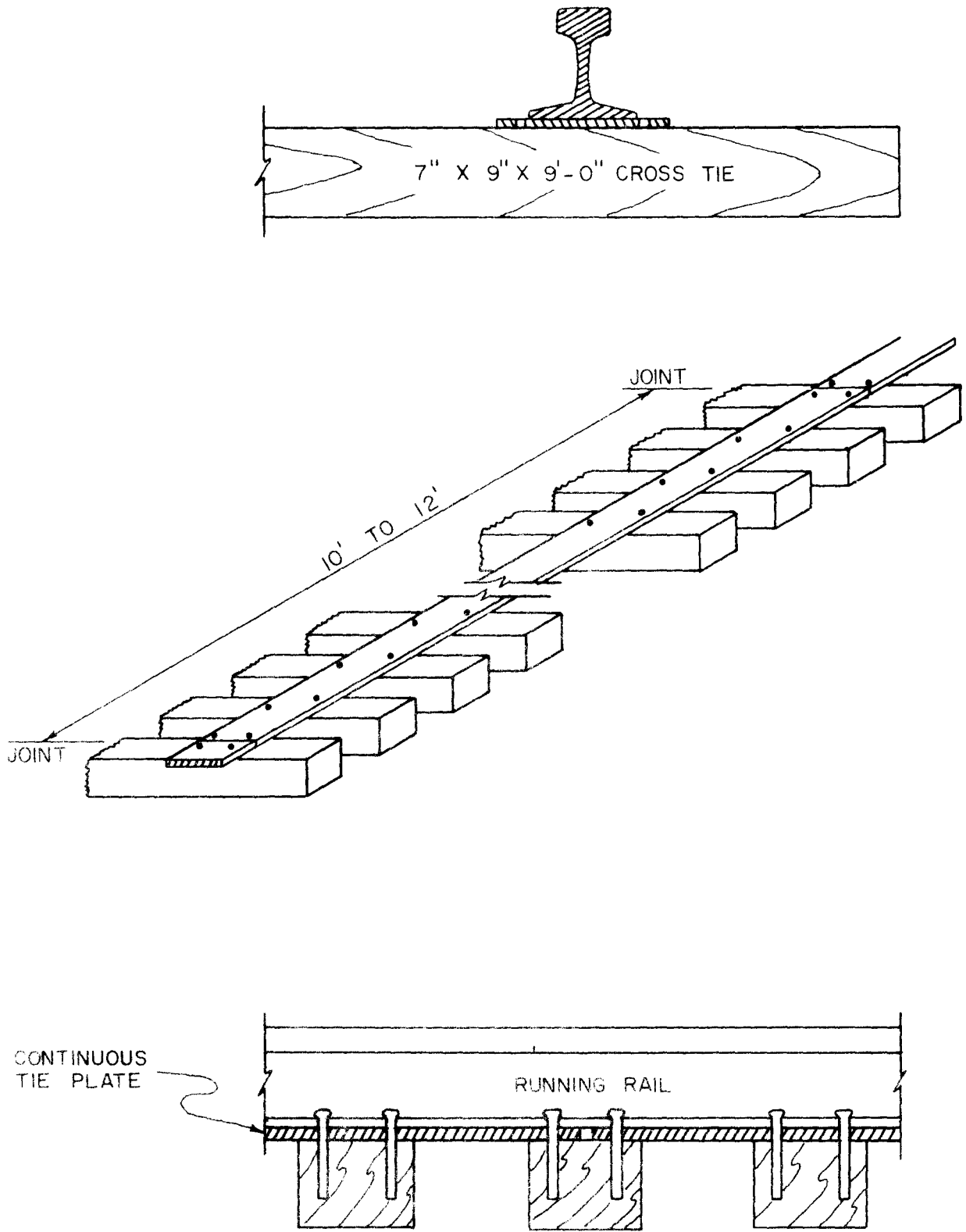
7" X 9" X 9'-0" CROSS TIE
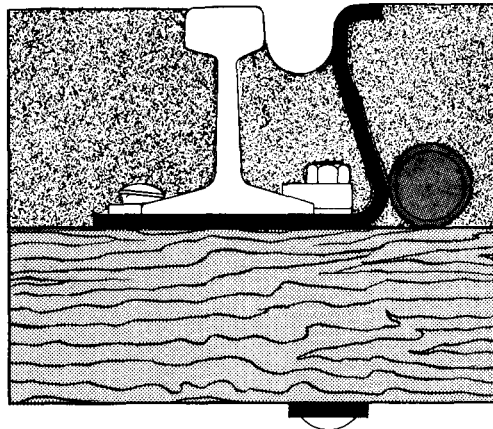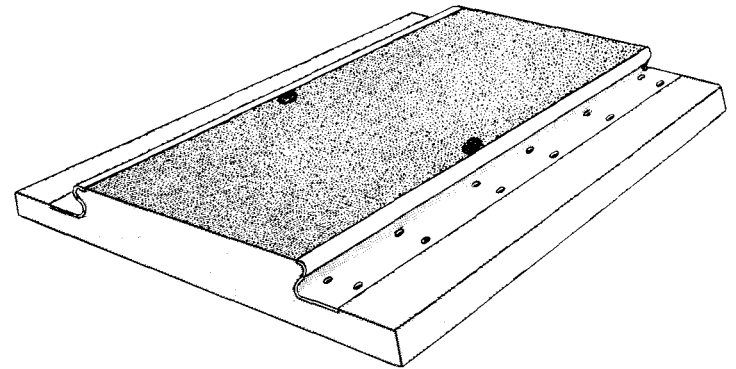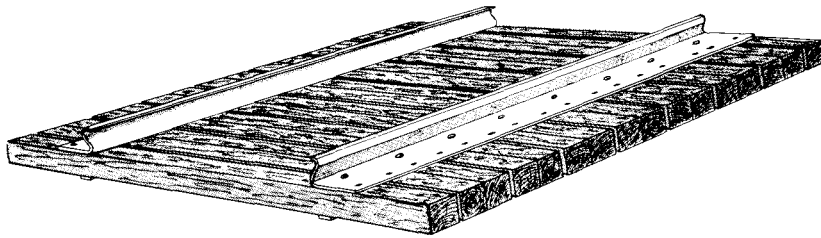
JOINT

10' TO 12'

JOINT

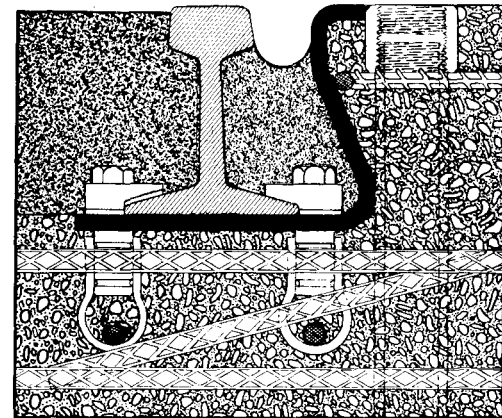CONTINUOUS
TIE PLATE

RUNNING RAIL

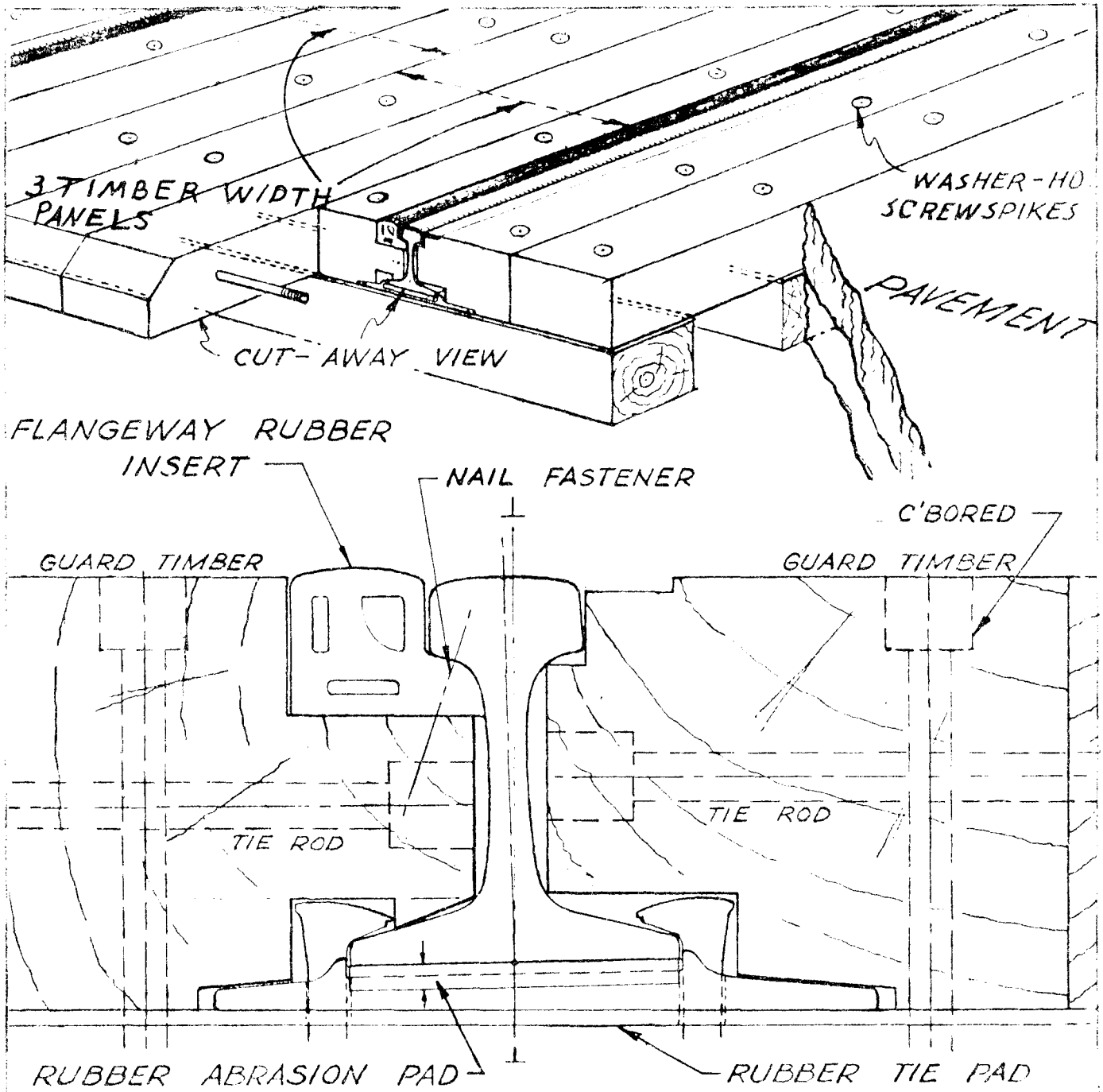FIGURE 7-1 STEEL TIE PLATE SPANNING SEVERAL
CROSS TIES

STEEL/WOOD  PLATFORM  STRUCTURE                    PRECAST  CONCRETE MODULES

FIGURE  7-2 – COMMERCIALLY-AVAILABLE ROLLED SHAPE  SYSTEMS
(COURTESY OF *RAILCO, INC.*)

3 TIMBER WIDTH PANELS

WASHER-HD SCREWSPIKES

PAVEMENT

CUT-AWAY VIEW

FLANGEWAY RUBBER INSERT

NAIL FASTENER

C'BORED

GUARD TIMBER

GUARD TIMBER

TIE ROD

TIE ROD

RUBBER ABRASION PAD

RUBBER TIE PAD

TITLE  RUBBER PRODUCTS FOR TIMBER DECK GRADE CROSSINGS SPECIAL GUARD TIMBERS (TREATED)

FOR

DRAWN  T F H  6-5-75

APPROVED  6-14-75

DWG. No.  PICTORIAL  MA-2-4B

FIGURE 7-3 - TIMBER DECK CROSSING WITH RUBBER INSERT

93

Labels in illustration: WASHER-HD. SCREW SPIKES · PAVEMENT · TWO 8' SLABS · CUT-AWAY VIEW · C'BORED · FLANGEWAY RUBBER INSERT · GUARD TIMBER · NAIL · REINFORCED CONCRETE · TIE ROD · —TIE— · RUBBER TIE PAD · RUBBER ABRASION PAD

TITLE  RUBBER  PRODUCTS  FOR
CONCRETE  DECK  GRADE  CROSSINGS
(TREATED) SPECIAL  GUARD  TIMBER

FOR

DRAWN  T E H    6-12-75     DWG. No.  PICTORIAL

APPROVED    6-14-75              MA-2-4C

FIGURE 7-4 - CONCRETE DECK CROSSING WITH RUBBER INSERT

of Maintenance, at least one crossing served very well from 1960 to 1966. He also stressed the need for attention to details, use of new materials in crossing renovation, and fresh ballast at least one foot deep under the ties. New ties are spaced at 19-1/4 inch centers. A. B. Hillman, Chief Engineer of the Belt, added:

> "With other types of construction, it has been necessary, within a year after installation of a crossing, to make an adjustment in the resistance of the island circuit for the crossing protection system, apparently because of leakage due to moisture in the ballast. It has not been necessary to make this adjustment with any of the crossings of the new type.... His explanation is that the use of rubber prevents the pumping action of the ties that causes the ballast to become fouled with water and mud."

3. Concrete Approach Slab.

An example of a structural system which is intended to reduce pavement distress adjacent to the railroad track structure is shown in Figure 7-5. The cantilevered portion of the concrete slab on the field side of the track structure is armored at the surface. This design detail can be employed with more conventional crossing surface materials or with some of the designs discussed in the previous section.

It is anticipated that an installation such as this would be cost-effective on heavily traveled highways.

It is apparent that several types of crossing details should be con-sidered. Highway traffic and rail volumes, consists, and speeds are primary indicators in selecting the type of crossing. For example: a rail highway intersection carrying many trains per day transporting heavy loads at high speed would require a treatment different from one which carried a few trains, with light loads at low speed; even though the highway traffic conditions were the same at each of the intersections.

PLAN

3/8" X 9" STEEL PLATE

5/8" DIA. X 1'- 0" ROD

5/8" DIA. X 4" ROD

ARMOR PLATE DETAIL

SECTION A-A

COMPACTED BASE

8" COMPACTED SUBGRADE

SEE ARMOR PLATE DETAIL

2 1/4"
2 1/2"
1'- 8 1/4"     2'- 2"     2'- 4 1/4"     1'- 10 3/4"

7" X 9" X 9'-0" CROSS TIE

8"-12" BALLAST

COMPACTED BASE

8" COMPACTED SUBGRADE

SELECT MATERIAL FOR
6" DIA. PERFORATED
SUBDRAIN PIPE

3'-0"     3'-0"

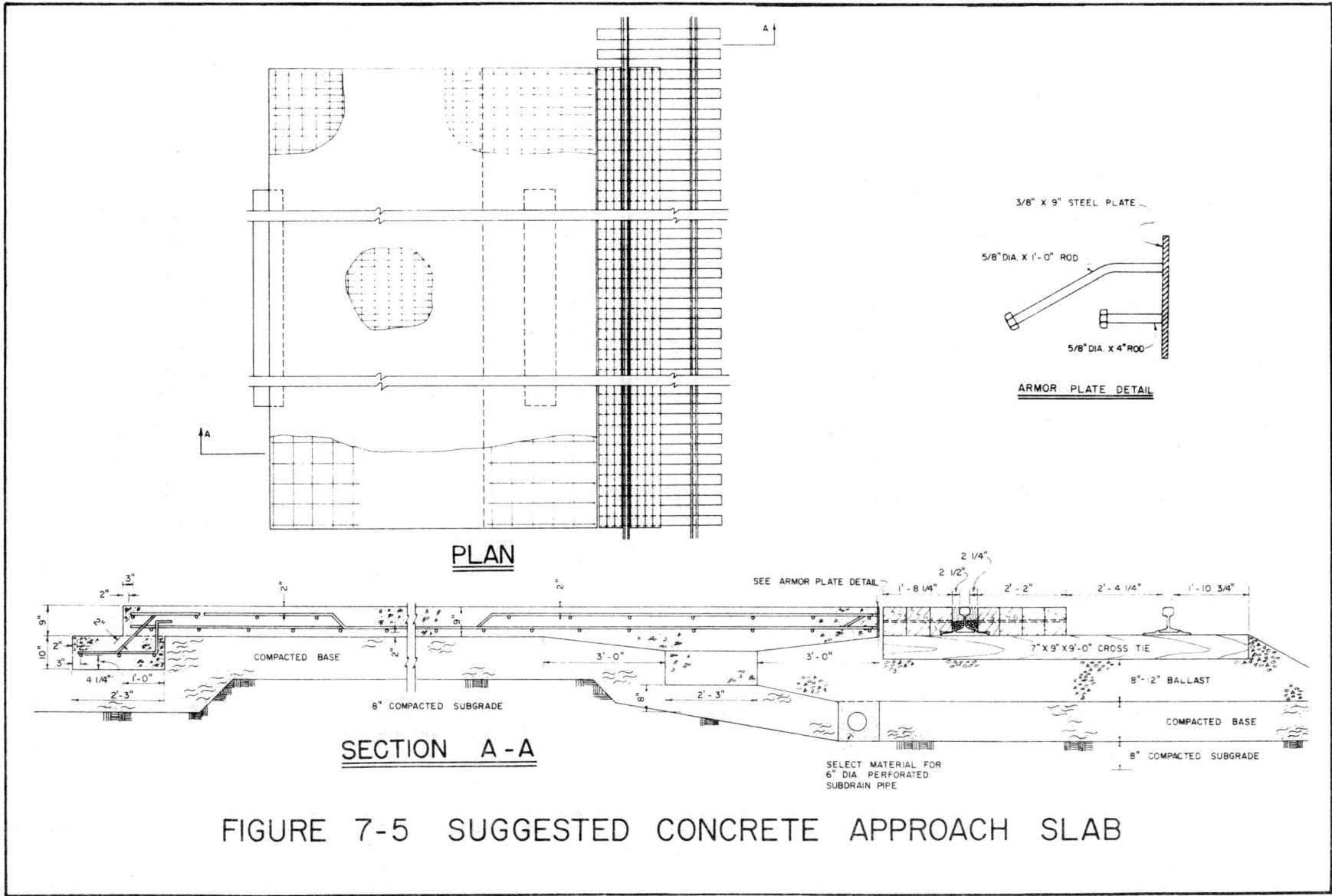2'- 3"     2'- 3"

4 1/4"     1'- 0"

9"
10"
3"
2"
3"

FIGURE 7-5 SUGGESTED CONCRETE APPROACH SLAB

# CHAPTER EIGHT
## FINDINGS AND RECOMMENDATIONS

Application of conventional and innovative crossing surface materials accompanied by attention to details of design in construction and maintenance can extend the life of crossings.

## Findings

1. Nearly sixty percent of the crossings are on Farm-to-Market highways. More than 200 crossings were inspected; at these sites, approximately 65 percent had a highway intersection within 200 feet of the grade crossing.

2. Location and elevation of railroad track structure must be maintained. Highway horizontal and vertical curvature are for the most part fixed.

3. Several excellent surfacing materials are available including full depth timber, concrete, rubber covered metal, and others.

4. Surface and subsurface drainage design, construction, and maintenance will extend crossing life and enhance rideability. Intrusion of ground water into ballast and subgrade produces pumping, ballast fouling, and flexible base failure. These in turn reduce the strength of the track structure and roadway adjacent to the crossing.

5. Roughness at crossings is aggravated along the highway by braking and acceleration of highway traffic; and along the track by fouling of ballast and deterioration of elements of the track structure. The effects of dynamic forces along the highway are evident in Mays Meter Readings. At some locations roughness is apparent over 100 to 200 feet on each approach to the railroad grade crossing.

6. At sites where crossings are to be replaced, improvements need to be made along each traveled way for a distance of 30 feet to 100 or more feet from

the point of intersection.

7. Crossing conditions can be evaluated by on-site inspections, roughness measurements, borings, and mathematical simulation.

8. Several fabrics are available which show promise of improving subgrade stabilization characteristics.

9. The use of Butyl rubber tie pads and Butyl rubber abrasion pads between rail base and tie plates provide shock resistance to rail and highway wheel loads.

10. Sealing of flangeway and space on the field side of the running rail eliminates or reduces intrusion of surface water.

11. Installation of tie plates continuous over several ties improves strength of track structures.

## Recommendations

The information contained in this study and the findings indicate that conventional and innovative techniques and materials when properly applied can produce smooth and durable crossings. They are offered here for early use. It is specifically recommended that sites be selected for installation of innovative concepts described in the preceding pages. Rubber covered metal surfaces, and molded structural foam pads fabricated from expanded linear polyethylene are recommended for early installation at sites having heavy highway traffic (volumes and wheel loads).

Selection of sites for such installations should be made at crossings where major track rehabilitation has been accomplished recently. Such locations will provide adequate track structure to support the more durable crossing surfaces.

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