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16. Abstract

In recent years, it has been found that one of the most significant factors in the reduction of the life of concrete pavements is the presence of voids beneath the slab. In the design of pavements, it is assumed that there is full support throughout the length of the pavement. When a void develops, this assumption is no longer valid. Studies presented in the report illustrate that increasing void size results in a significant increase in the slab stress. Also, with increasing void size, tandem axle loads have a very significant increase in stress. Thus, the combination of existing voids and increasing tandem axle loads results in significant pavement life reduction.

Based on information collected from an experiment performed at Victoria, Texas, in 1981 on a CRCP, this report is intended to establish a procedure which provides the optimum method for detecting voids and a grouting operation to fill them. In this respect, various alternatives involving field observation of pumping and several combinations of deflection measurements recorded by means of the Dynaflect device were evaluated. Among these, it was found that the optimum results were obtained with a combination of field observation of pumping and a normalized version of the deflection measurements recorded with sensor 1 and sensor 5 of the Dynaflect device. Using discriminant analysis, an equation was obtained to weight the different variables involved in the alternative.

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VOID DETECTION AND GROUTING PROCESS

by

Francisco Torres
B. Frank McCullough

Research Report Number 249-3

Implementation of Rigid Pavement Overlay and Design System
Research Project 3-8-79-249

conducted for

Texas
State Department of Highways and Public Transportation

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

by the

Center for Transportation Research
Bureau of Engineering Research
The University of Texas at Austin

April 1983

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

PREFACE

This report summarizes the results of an experiment focused toward the detection of voids beneath CRCP, and developing the grouting operation to fill these voids.

This is the third in a series of reports that describe the work done in Research Project 3-8-79-249, "Implementation of Rigid Pavement Overlay and Design System." The project is supervised by Dr. B. Frank McCullough, Professor of Civil Engineering, and is being conducted at the Center for Transportation Research, The University of Texas at Austin, as part of the Cooperative Highway Research Program sponsored by the Texas State Department of Highways and Public Transportation and the Federal Highway Administration. Thanks are expressed to Victor Torres-Verdin and Jeff Kessel for their cooperation in correcting the preliminary review copy of this report. Graditude is also expressed to Gerald Peck at the Texas SDHPT for his excellent comments.

Francisco Torres

B. Frank McCullough

LIST OF REPORTS

Report No. 249-1, "Improvements to the Materials Characterization and Fatigue Life Prediction Methods of the Texas Rigid Pavement Overlay Design Procedure," by Arthur Taute, B. Frank McCullough, and W. Ronald Hudson, presents certain improvements to the Texas Rigid Pavement Overlay Design Procedure (RPOD2) with regard to materials characterization and fatigue life predictions.

Report No. 249-2, "A Design for Rigid Pavement Rehabilitation," by Stephen Seeds, B. Frank McCullough, and W. Ronald Hudson, describes the development, use and applicability of a Rigid Pavement Rehabilitation Design System, RPRDS, developed for use by the Texas State Department of Highways and Public Transportation.

Report No. 249-3, "Void Detection and Grouting Process," by Francisco Torres and B. Frank McCullough, presents the results of an experiment and a theoretical analysis to determine an optimum procedure for detecting voids beneath CRC pavements.

ABSTRACT

In recent years, it has been found that one of the most significant factors in the reduction of the life of concrete pavements is the presence of voids beneath the slab. In the design of pavements, it is assumed that there is a full support through the length of the pavement. When a void develops, this assumption is no longer valid. Studies presented in the report illustrate increasing void size results in a significant increase in the slab stress. Also with increasing void size, tamdem axle loads have a very significant increase in stress. Thus, the combination of existing voids and increasing tandem loads results in significant pavement life reduction.

Based on information collected from an experiment performed at Victoria, Texas, in 1981 on a CRCP, this report is intended to establish a procedure which provides the optimum method for detecting voids and a grouting operation to fill them. In this respect, various alternatives involving field observation of pumping and several combinations of deflection measurements recorded by means of the Dynaflect device were evaluated. Among these, it was found that the optimum results are obtained with a combination of field observation of pumping, and a normalized version of the deflections measurements recorded with sensor 1 and sensor 5 of the Dynaflect device. Using discriminant analysis, an equation was obtained to weight the different variables involved in the alternative.

Two overlay designs were performed using the RPRDS1 computer program. One considerated grout injection prior to overlay, and the other assumed no improvements to the original pavement. From both designs, it was found for the Victoria section that grouting would represent a reduction in the total net present value of the optimal design strategy of about 13 percent.

Other relevant results that were found are:

(1) The highest sensitivity for void detection purposes is obtained when the deflection measurements are recorded at one foot from the edge.

(2) In most of the cases, it was observed that the development of voids occurs close to the edge of the pavement.

(3) The optimum benefits for the pavement are obtained when the grout is pumped just beneath the slab.

(4) The success of the grouting operation is a direct function of the percentage of voids filled.

KEYWORDS: Continuously reinforced concrete pavement (CRCP), void detection, grouting operation, Dynaflect, pumping, normalized Dynaflect deflection, discriminant analysis.

SUMMARY

This report presents the results of an experiment and a theoretical analysis to determine the optimum procedure for detecting voids beneath continuously reinforced concrete pavement and filling them by grouting. First, a discussion of void effect and an evaluation of the effectiveness of the existing techniques for void detection and grouting operation are discussed. Based on the analysis of the results obtained from the experiment, a procedure to carry out a grouting project is proposed.

Finally, an evaluation of the grouting operation performed several years ago at the Columbus and Fairfield projects on IH10 and IH45, respectively is presented.

IMPLEMENTATION STATEMENT

Results from this study indicate that voids underneath CRC pavements can be successfully detected and filled. After an evaluation of several alternatives, one that provides a procedure that could be used in the preventive maintenance of the pavement sections analyzed in this report was selected.

In a more detailed study, the findings developed in this study could be used to perform a statewide experiment to evaluate the effectiveness and feasibility of the grouting operation.

Finally, adoption of this technique of void detection and grouting would represent a more economical option for restoring the initial condition to the pavement than an overlay procedure does.

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CHAPTER 1. EVALUATION OF THE GROUTING PROCESS TO FILL VOIDS UNDERNEATH CONTINUOUSLY REINFORCED CONCRETE PAVEMENTS

INTRODUCTION

In recent years, it has been found that one of the most significant factors in the reduction of the life of concrete pavements is the presence of voids beneath the slab. In the design of pavements, it is assumed that there is uniform support from the underlying material, but when a void develops beneath the pavement this assumption is no longer valid. As a result of the void, the stress level in a pavement increases significantly, and, thus, the fatigue life of the pavement is considerably reduced.

In order to understand the problem, the reader must keep in mind that a void does not necessarily imply a large hole beneath the pavement. For example, a gap of 0.050 in. (1.27×10^{-1} cm) between the slab and the subbase will allow sufficient deflection in the pavement to significantly increase stress. Voids can develop in a number of ways, but the most important factors creating void conditions beneath concrete pavements are

(1) erosion and pumping of the subbase material,

(2) differential soil movements developed by swelling or settlement action, and

(3) mudjacking, which causes the pavement to raise excessively, thus producing a high point with a void on each side.

NEED FOR STUDY IN TEXAS

The first step from an engineering standpoint is detection of the voids prior to development of a condition that is detrimental to the pavement. Over the past few years, a number of different methods have been proposed for investigation, including the use of density measuring equipment, vibratory equipment, deflection measuring equipment (Ref 3), infrared thermography (Ref 8), radioactive tracers (Ref 1), and visual observation of distress manifestations, such as pumping (Ref 3).

In addition to detecting the voids, it is necessary to fill them in some way. In recent years, a variety of grout mixtures has been used successfully for undersealing and slab jacking.

For a successful application, an undersealing grout must be fluid enough to flow into very small voids, and yet develop adequate strength and durability properties. The use of nonsanded grout has generally been found to provide good flow characteristics during pumping, especially where the voids are very thin and discontinuous in nature. Some states, such as Georgia, Illinois, and Mississippi, have developed methods for undersealing CRC pavements with cement grout (Ref 7). The method that Mississippi has applied with some success has been used by the Texas State Department of Highways and Public Transportation (SDHPT) on both an experimental and a contract basis. In relation to this, representatives from the Highway Design Division, the Research and Development Section of the Transportation Planning Division, and the Safety and Maintenance Division, along with Center for Transportation Research representatives, met to explore methods that could provide optimum results from detecting and filling voids beneath CRC pavement. As a result of several conferences, it was decided that a study should be developed in two parts. The first objective would be to evaluate several alternative methods of detecting the voids beneath the CRCP. The second overall objective would be to evaluate the capabilities for undersealing the pavement and the long-term performance of pavements that were undersealed.

Regarding the first objective, a contract was prepared for a 0.47-mile (0.76-km) project on Interstate 10 in District 13 and a 0.47-mile (0.76-km) project on Interstate 45 in District 17. Since it was not practical to evaluate the entire length of the projects being undersealed, the decision to select two 2500-foot (762-m) test sections on each project was made. The basic criteria for choice of these sections were minimal grade changes along the 2500 feet (762 m), uniform soil conditions, and uniform cross section. Test sections to meet these criteria were selected through a joint inspection by representatives of the SDHPT and the Center for Transportation Research.

The locations of the test sections on IH-10 and IH-45 are shown in Fig 1.1. As may be seen, one section is east of Columbus, Texas, and one is south of Fairfield, Texas. A cross section of the pavement structures on IH-10 consisted of 8 inches (20.32 cm) of CRCP and 6 inches (15.24 cm) of cement-stabilized base. The project on IH-45 had a cross section consisting of 8 inches (20.32 cm) of CRCP on a 4-inch (10.16-cm) asphalt-stabilized base.

For void detection purposes, the methods evaluated were deflection techniques, use of vibratory equipment, and visual survey. After application of the procedures, an experiment was designed for a field investigation to determine if voids existed in the area predicted by the various procedures. From the results obtained in this study (Ref 3), it was concluded that deflection techniques can be used successfully to predict the presence of voids beneath the CRC pavements. In these instances, the Dynaflect was used

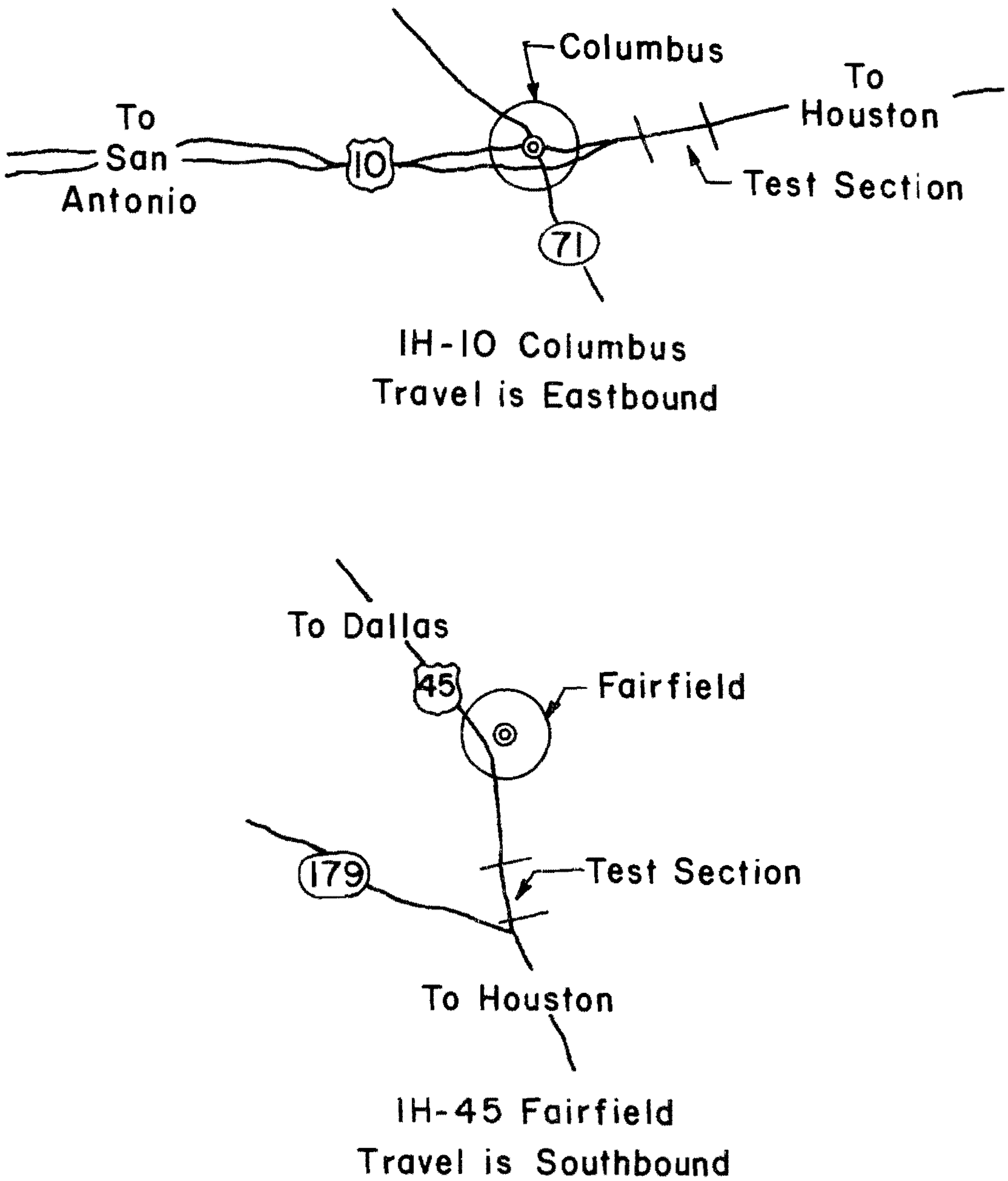

Fig 1.1. Locations of test sections.

successfully. The use of condition surveys, e.g., using pumping as an indicator, indicated that the probability of successfully locating a void was only 50 percent. Finally, in relation to the vibratory equipment, it was found that the measurements obtained were inconsistent and no patterns appeared. Therefore, it was decided that using the vibratory equipment was not a feasible method for selecting voids beneath concrete pavements.

Based on these results, it was decided to follow up in a more detailed way the method proposed for void detection as well as the grouting process that should be utilized to fill those voids. For these purposes, the representatives from the SDHPT and the Center for Transportation Research met together to select the section that best fulfilled the requirements for such an experiment. After analyzing condition surveys and deflection measurements for several projects, the one located on Highway US-59 about ten miles northeast of Victoria, Texas, was selected. The area shows considerable evidence of pumping and distress in the form of punchouts. The basic decision to select a 1000-ft (304-m) test section that is typical of the average conditions for the project was made. The cross section of the pavement consisted of 8 inches (20.24 cm) CRC pavement on a 6-inch (15.31-cm) cement-treated base which extends into the shoulder area. A map showing the location of the test section is presented in Fig 1.2.

OBJECTIVES OF STUDY

The general objective of this study is to ascertain the feasibility of detecting voids beneath concrete pavements as well as analyzing the influence of the grouting process used to fill the voids. Specifically, the objectives of this study are (1) to evaluate, in a controlled experiment, the feasibility of using the Dynaflect to select the areas with high probability

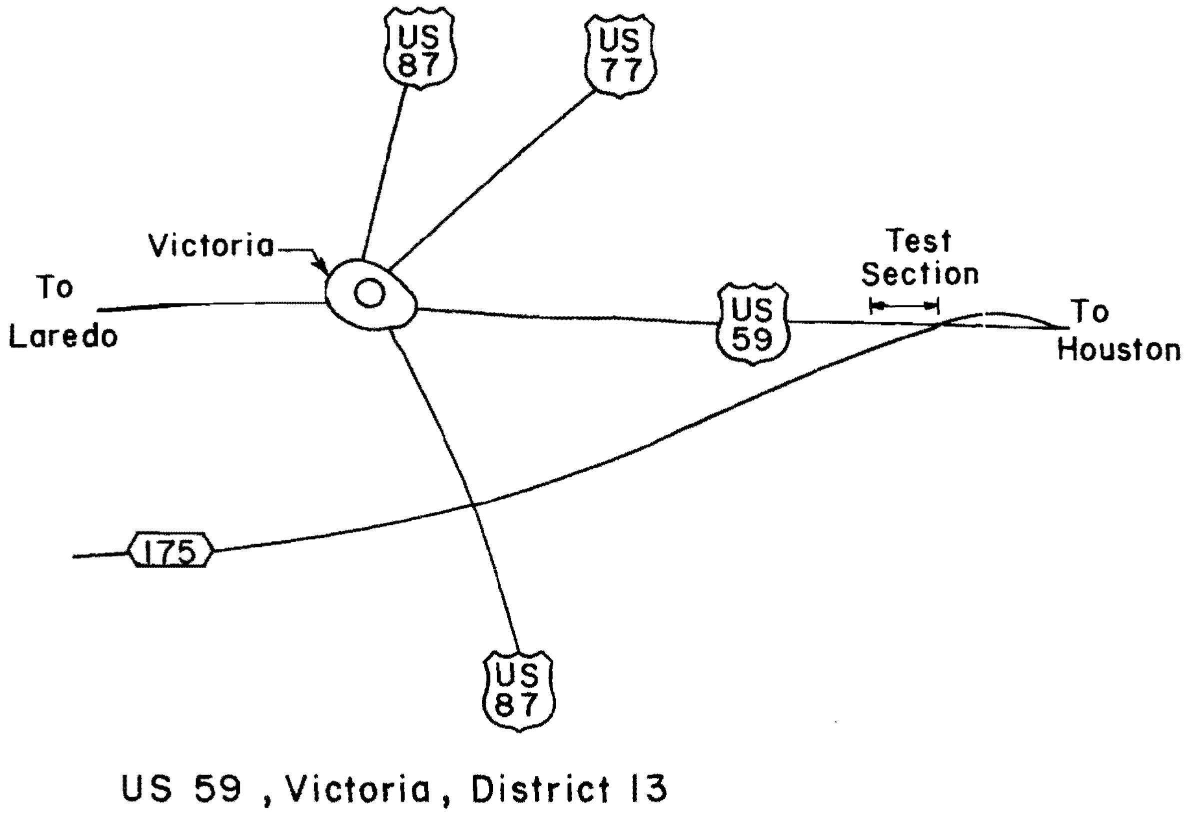

Fig 1.2. Location of the test sections, Victoria project US-59, District 13.

of voids, (2) to analyze the influence the grouting process had on the pavement deflection, (3) to make predictions of future performance, and (4) to evaluate economic aspects of using the process.

SCOPE OF REPORT

In Chapter 2, a theoretical analysis of the effect of a void beneath the slab on the performance of the pavement as well as an evaluation of the effectiveness of the grouting process is presented.

Chapter 3 deals with some of the techniques that are currently used for void detection and grouting.

In Chapter 4, a description of the steps involved in the development of the grouting experiment at Victoria is presented.

Chapter 5 contains the evaluation of results regarding the effectiveness of the grouting depth on deflections, the influence of weather conditions on Dynaflect deflections, the technique used for void detection, the grouting pressure required to fill voids beneath the pavement, and finally a proposed method for void area selection based on the results obtained in this experiment.

Chapter 6 presents the performance evaluation by means of Dynaflect deflections and Profilometer data on the grouting process used at Fairfield and Columbus.

In Chapter 7 the results are discussed.

Chapter 8 contains the conclusions and recommendations for a future grouting project.

Finally, in Appendices A and B, the procedure for carrying out a grouting operation, and the results of the condition surveys, as well as profile data for Columbus and Fairfield projects, are presented.

CHAPTER 2. DISCUSSION OF VOID EFFECT AND EVALUATION OF THE EFFECTIVENESS OF THE GROUTING OPERATION PROCESS

One of the important assumptions in designing for CRC pavement is that support conditions are good. This emphasizes the need for observing and evaluating actual conditions as a guide to preventative maintenance in an effort to prevent future pavement distress. This study is concerned with pavement performance as affected by voids beneath the pavement and with general observations that help define where and how distress occurs when voids are present under the pavement. Several observations of both the tops and bottom of CRC pavements on Texas highways show that some of the distress occurring in the pavement is due to loss of support under the pavement. The distress occurrence rate depends on the traffic frequency, load magnitude, and environmental conditions (temperature changes, rain, snow, etc.). In addition, the soil support characteristics (swelling, settlement, densification, etc.) will influence the distress occurrence rate (Ref 16).

STUDY SCOPE AND APPROACH

The presence of voids underneath a pavement is detrimental because of the associated loss in support, and the subsequent increase of stresses in the slab. In order to solve for the stresses in the slab due to the existence of voids beneath the pavement, the SLAB 49 computer program was used (Ref 9). This program is a discrete element analytical technique which solves a physical model of the slab consisting of rigid bars connected by elastic blocks and supported on appropriate springs to represent the foundation.

The method allows for nonlinear input, discontinuities in the slab and the subgrade, and varying support in the subgrade. The model also allows for axial loads in the slab similar to those imposed by continuous reinforcement. With the SLAB 49 computer program, it is possible knowing the physical properties of the slab and the subgrade to directly model the dimension of the slab and solve for the respective deflection and stresses.

To correlate with current design methods, which are based on fatigue analysis, the Texas Fatigue Equation for PCC pavements was selected as the fatigue model.

For the analysis presented below, three void sizes were selected and a rectangular configuration was assumed. The simulation for the SLAB 49 computer program of the conditions incurred when a void existed beneath the pavement was done by reducing the K-values of the subbase and subgrade. This was done because whenever a void existed, a reduction in the support conditions of the slab is experimented. For most cases, a k-value equal to 100 pci was assumed. However, in one case the k-value was changed to 300 pci to account for the effect of increasing subgrade support. A summary of the values assumed for the parameters in this study is provided in Table 2.1. Finally, using the stresses obtained from SLAB 49, the fatigue life for various conditions was computed using the fatigue equation developed for Texas (Ref 17). The model is given by the expression:

$$N = 46{,}000(f/s)^{3.0} \tag{2.1}$$

TABLE 2.1. SUMMARY OF PARAMETER VALUES USED IN THE STUDY

	Parameter	Value(s)
(1)	Slab size	24' x 12'
(2)	Void size	2' x 6', 4' x 12', 6' x 18'
(3)	Pavement thickness	8", 10", 12"
(4)	K-value	100 pci, 300 pci
(5)	Wheel load	18-kip single axle with dual tire 32-kip tandem axle
(6)	Load position (reckoned from center of wheel load)	0.5' from edge, 1.5' from edge, 2.5' from edge
(7)	Modulus of Elasticity for concrete	5,000,000 psi
(8)	Poisson's ratio	0.20
(9)	Flexural strength of concrete	650 psi

where

N = Number of load applications to failure

f = Flexural strength of concrete (psi); and

s = Stress in the concrete (psi).

PRESENTATION OF RESULTS

Table 2.2 provides a summary of the stresses obtained from SLAB 49 Program for various combinations of voids size, load position and pavement thickness. In addition, the corresponding values for the number of load applications were calculated using the Texas Fatigue Model mentioned earlier. Analyzing Table 2.2, it can be observed that the closer the load is from the edge, the greater the stress in the slab is (as stated in Westergard's theory the optimum condition for the slab is at the center). In addition, it can also be noticed that as the slab increases in thickness, the stress in the slab decreases whereas the reverse happens when the size of the void is increased.

Because the study was also aimed to determine the effect of the k-value and the wheel configuration, the stresses for a different k-value and wheel load were likewise obtained and the results are summarized in Table 2.3. By examining the data given in the two tables, the relationship between fatigue life and each of the factors included in this study become readily apparent.

In order to show the relationship more clearly, several plots of the data presented in Tables 2.2 and 2.3 were constructed. A brief discussion of these relationships is given in the succeeding section.

TABLE 2.2. SUMMARY OF RESULTS FOR VARIOUS COMBINATIONS OF THICKNESS, VOID SIZE, AND LOAD POSITION

Thickness (in.)	Load Position (ft from edge)	Void Size (sq ft) 0		12		48		108	
		S (psi)	N	S (psi)	N	S (psi)	N	S (psi)	N
	0.5	288.0	531.599	340.0	321,128	400.0	197,683	460.0	129,700
8	1.5	249.0	818,276	292.0	506,358	356.0	306,039	402.0	195,037
	2.5	210.0	1,356,315	237.0	955,000	281.0	568,742	331.0	348,033
	0.5	203.0	1,503,439	234.0	982,157	274.0	614,783	317.0	396,946
10	1.5	177.0	2,281,993	203.0	1,510,114	238.0	931,178	278.0	587,347
	2.5	150.0	3,773,142	167.0	2,731,951	197.0	1,662,445	232.0	1,011,659
	0.5	153.0	3,541,016	173.0	2,427,181	202.0	1,530,379	234.0	980,901
12	1.5	134.0	5,297,592	151.0	3,661,883	177.0	2,281,993	207.0	1,432,541
	2.5	114.0	8,639,932	125.0	6,406,271	147.0	3,944,623	174.0	2,402,145
		100		114		134		156	

NOTE: k = 100 pci
N = fatigue life
Wheel load = 18-kip single-axle

TABLE 2.3. SUMMARY OF RESULTS FOR VARIOUS LOADS, k-VALUES AND VOID SIZES

Wheel Load	k-Value (pci)	Void Size (sq ft)							
		0		12		48		108	
		S (psi)	N	S (psi)	N	S (psi)	N	S (psi)	N
18-Kip Single	300	130	5,736,751	153	3,520,240	180	2,176,976	207	1,424,252
32-Kip Tandem	100	142	4,393,383	171	2,522,016	221	1,171,955	276	600,204

NOTE: T = 12 in.
Load 0.5 ft from edge

DISCUSSION OF RESULTS

As mentioned previously, the loss of soil support associated with voids leads to an increase in slab stresses. Furthermore, as shown in Fig 2.1, the stresses increase with increasing void size, but the increase is relatively lower for a thicker pavement than for a thinner one. Because of the increase in stresses, the fatigue life of the pavement is significantly reduced as clearly illustrated in Fig 2.2. As such, the designer is advised to take this into account in his design, thus requiring greater thicknesses when there is a high probability that voids will occur, such as where differential movements are a problem.

In addition, the position of the wheel load has a significant effect because the stresses in the slab are higher nearer the edge than away from it. This is confirmed by the program results, and it is, therefore, to be expected that the number of load applications nearer the slab edge will be relatively lower before the pavement fails (Fig 2.3).

The effect of increasing the k-value is shown in Fig 2.4. As expected, a slab resting on a strong subgrade would provide a better service life than one resting on a poor subgrade (k = 100 pci) which correspond to the existing conditions when a void exists beneath the pavement.

Finally, a comparison of the effects of tandem and single axles is shown in Fig 2.5. It was found that the stresses generated by the standard 32 kip tandem axle load were lower than those generated by the 18 kip single axle load for the condition of bno void. This shows that when there is full subgrade support, a tandem axle does help to reduce the stress level due to a heavier load. However, if voids are present, the load distribution effect of the tandem axle is lost, and, thus, stresses generated in the slab will

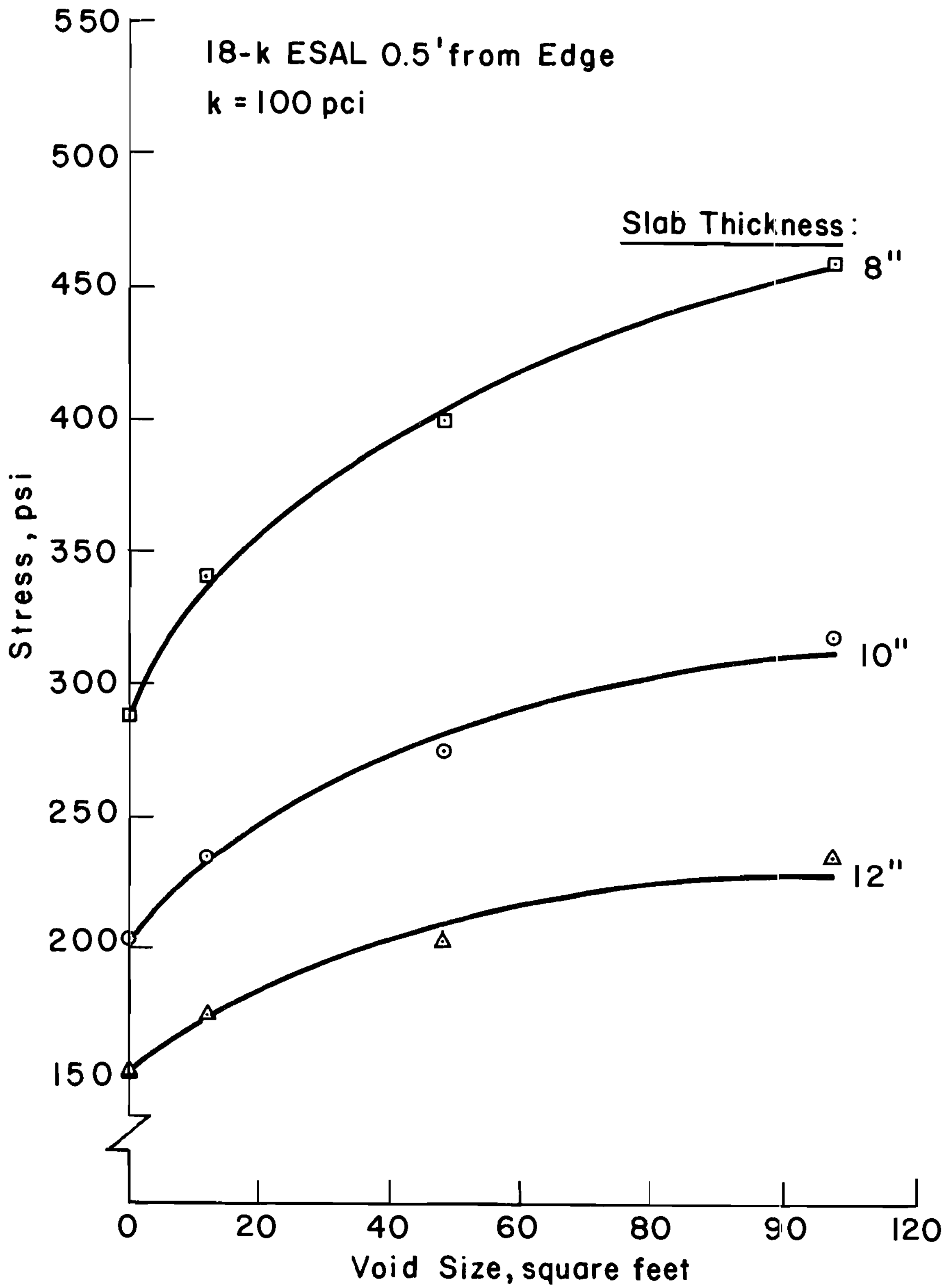

Fig 2.1. Effect of void size on the stress of the pavement for different thicknesses of the slab using 18-K ESAL at 0.5 feet from the edge for a soil support value K = 100 pci.

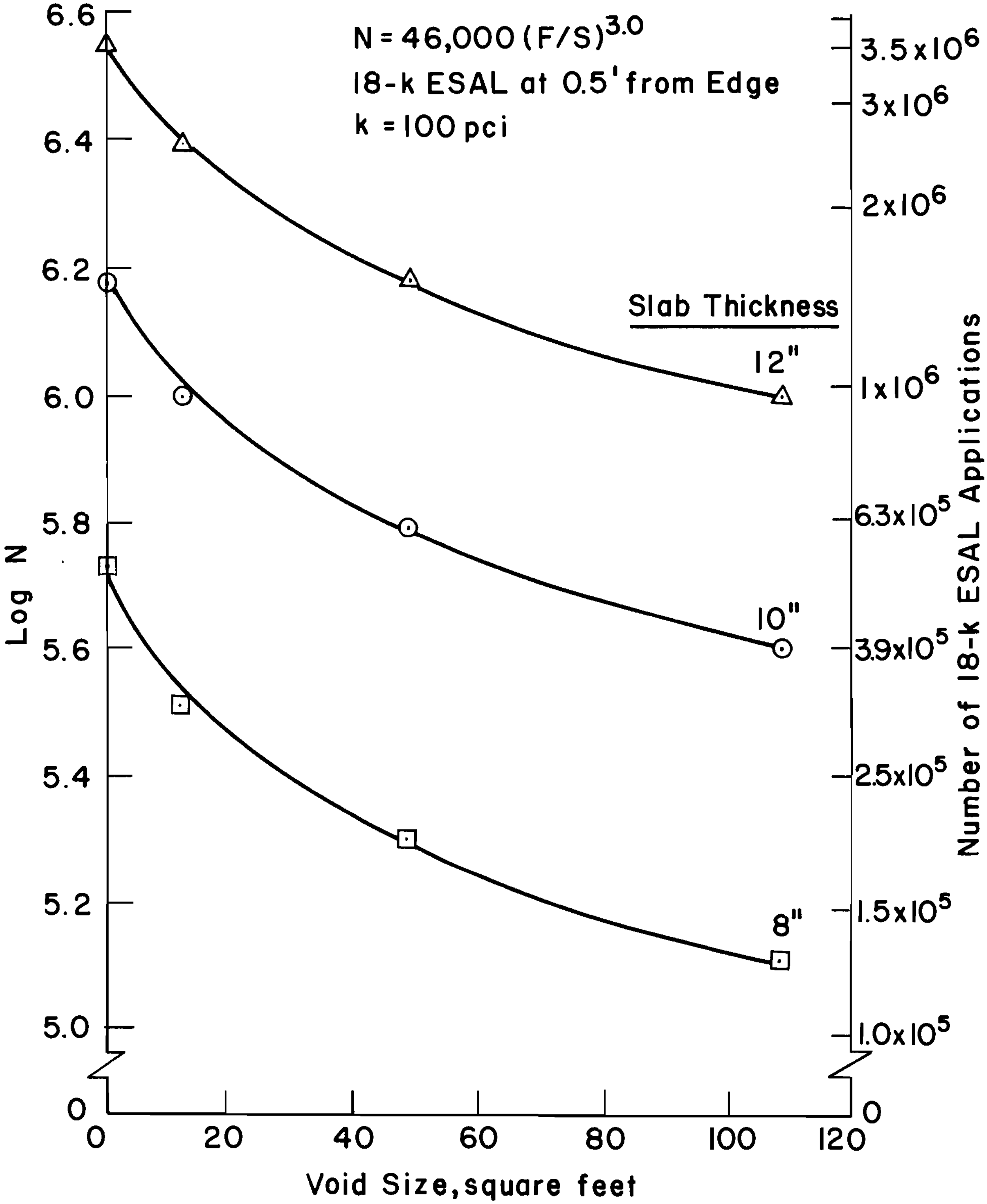

Fig 2.2. Effect of void size on the fatigue life of the pavement for different thicknesses of the slab using 18-k ESAL at 0.5 feet from the edge for a soil support value K = 100 pci.

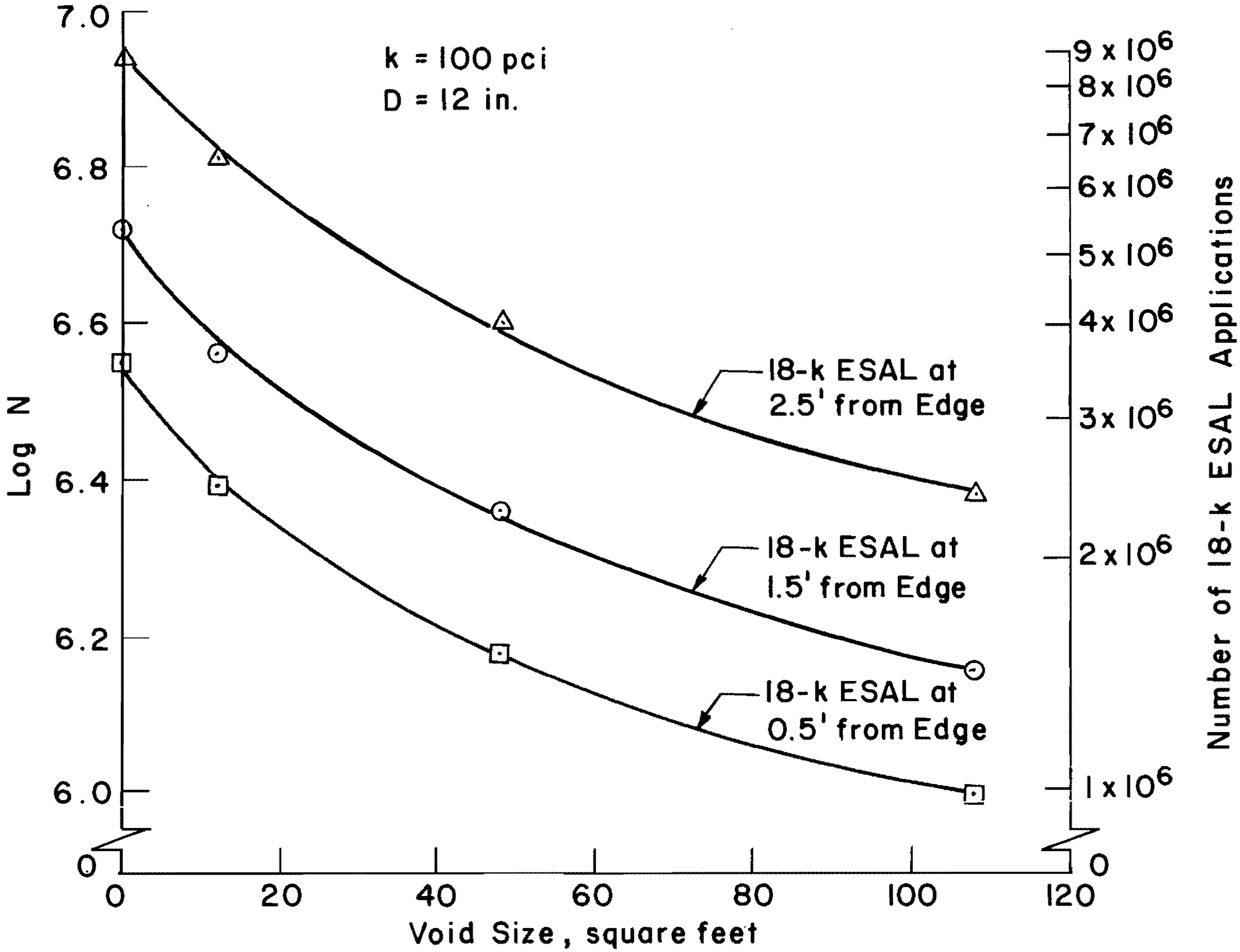

Fig 2.3. Effect of the position of the application of the load on the fatigue life of the pavement for a 12-inch slab on a soil support value K = 100 pci.

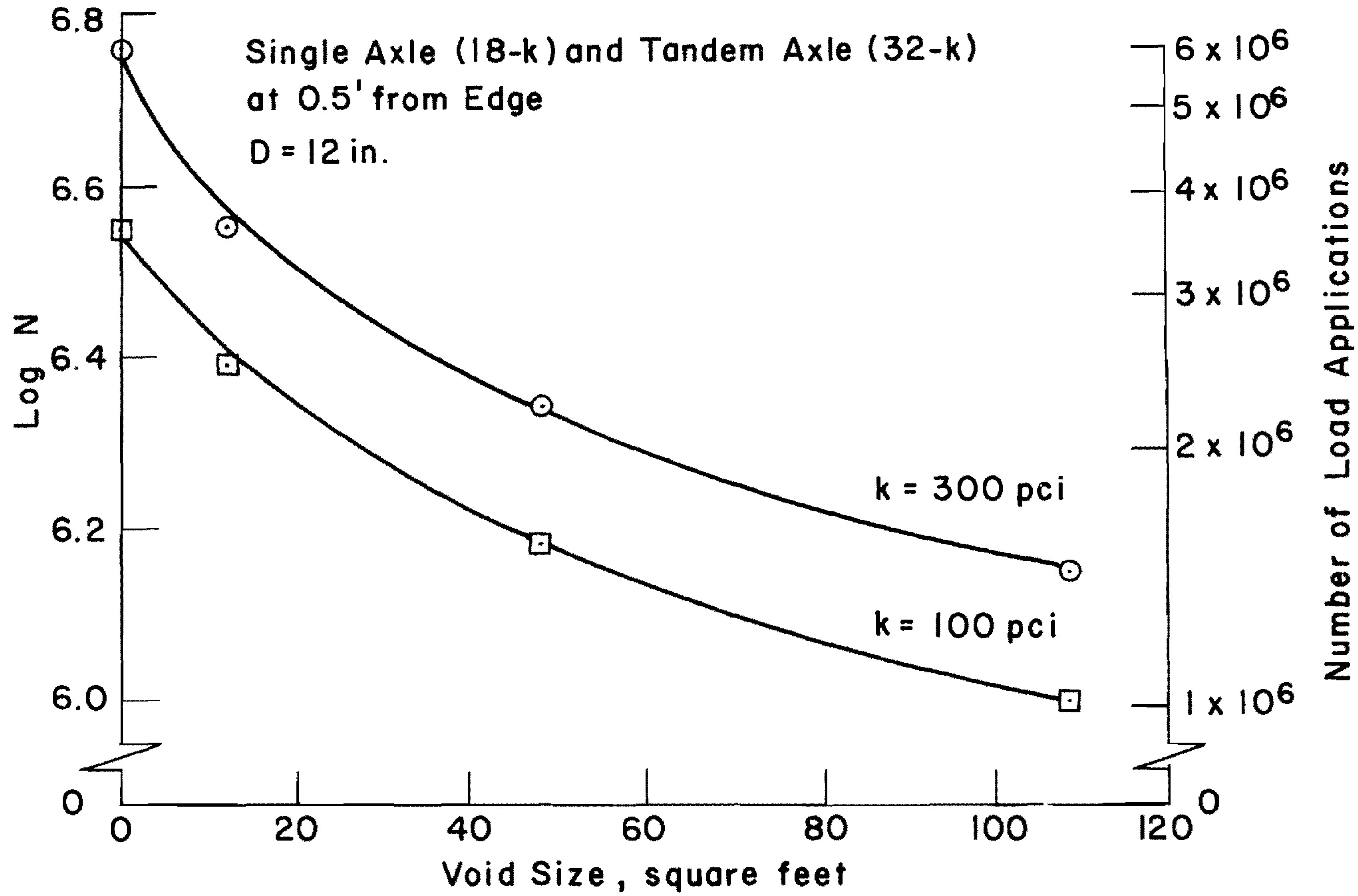

Fig 2.4. Effect of the soil support value on the fatigue life of the pavement with single axle (18k) and tandem axle (32k) loads applied at 0.5 feet from the edge on a 12-inch pavement.

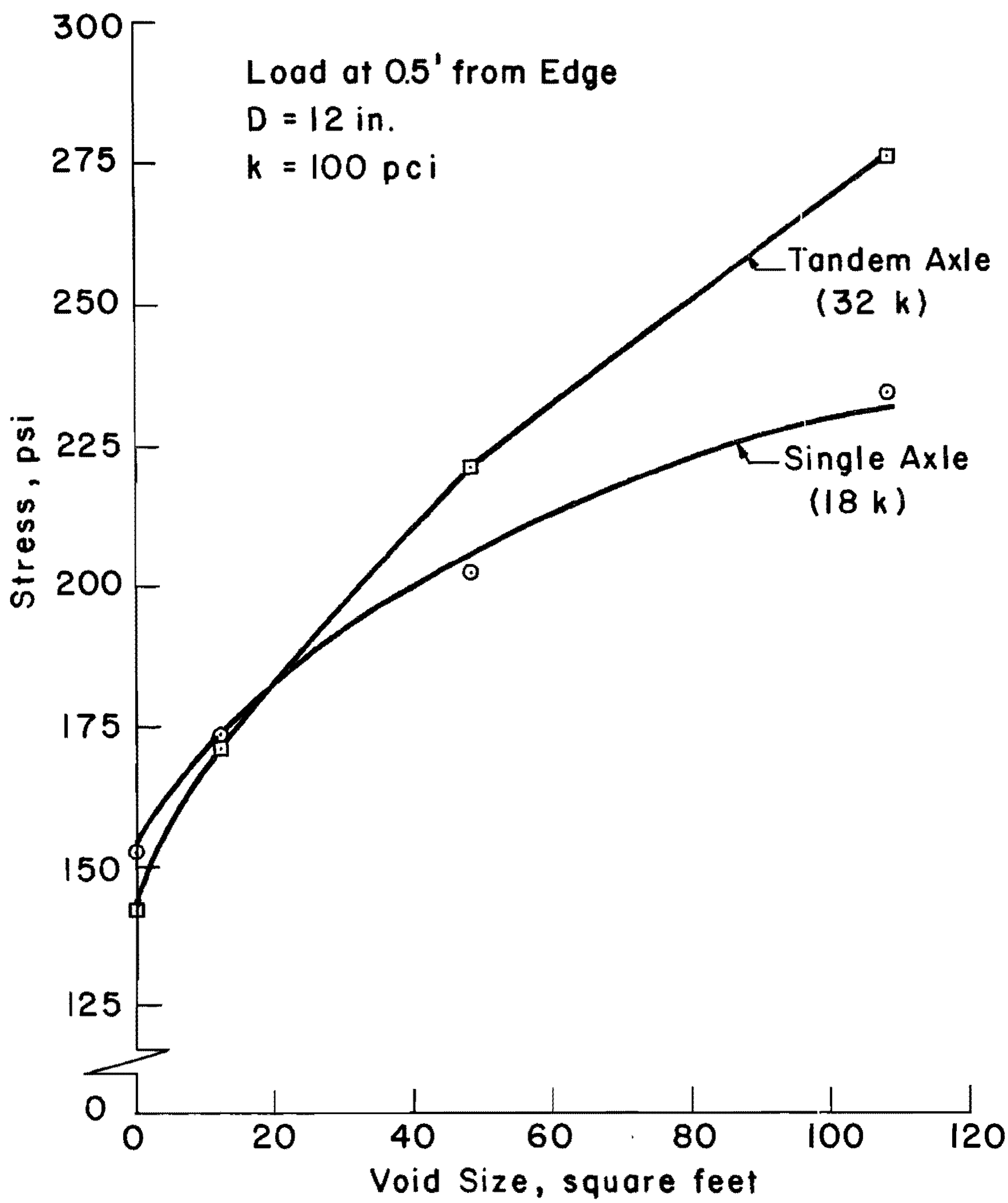

Fig 2.5. Effect of wheel configuration on the fatigue life of the pavement for a single axle (18k) and tandem axle (32k) applied at 0.5 feet from the edge on a 12-inch pavement with soil support value K = 100 pci.

actually be much higher because of the total load. Hence, the trend toward higher tandem-axle loads in the state will result in a more rapid decrease in the pavement condition.

SUMMARY

Table 2.4 summarizes the findings made in this study. Basically, the results have shown that voids significantly reduce the service life of portland cement concrete pavements. Because of this, it is important for the designer to take them into consideration and make allowances for them in his design. In addition, future research efforts should probably address the question of incorporating the problem of voids into the design procedures to reflect actual conditions that are experienced by pavements in the field.

EVALUATION OF THE EFFECTIVENESS OF THE GROUTING OPERATION PROCESS USING THEORECTICAL ANALYSIS

There are several processes for filling voids underneath the pavement, with undersealing being one of the methods currently used for that purpose. In order to evaluate how effective the grouting is in a particular pavement section, Dynaflect deflections are usually taken before and after the voids are filled. Then deflections before the grouting are plotted against deflections after the grouting. By inspecting this graph, the efficiency of the process for a pavement section can be determined.

For this purpose a theoretical analysis regarding the efficiency of the grouting operation was conducted at the Center for Transportation Research (Ref 13).

Using the results obtained in this study, it was possible to prepare Fig 2.6, which compares before and after deflections. Since the distinct void

TABLE 2.4. SUMMARY OF FACTORS AFFECTING FATIGUE LIFE OF RIGID PAVEMENTS

Factor	Effects on Stress	Effect on Fatigue Life
Void size	- Increase in stress as void size increases	- Decrease in fatigue life as void size increases
Thickness	- Increase in stress as thickness decreases	- Decrease in fatigue life as thickness decreases
k-value	- Increase in stress as k decreases	- Decrease in fatigue life as k decreases
Load position	- Increase in stress as load gets nearer the edge	- Decrease in fatigue life as load gets nearer the edge
Wheel configuration	- Greater stress with single axles up to a certain void size, beyond which greater stresses with tandem axles	- Lesser fatigue life with single axles up to a certain void size, beyond which lesser fatigue life with tandem axles

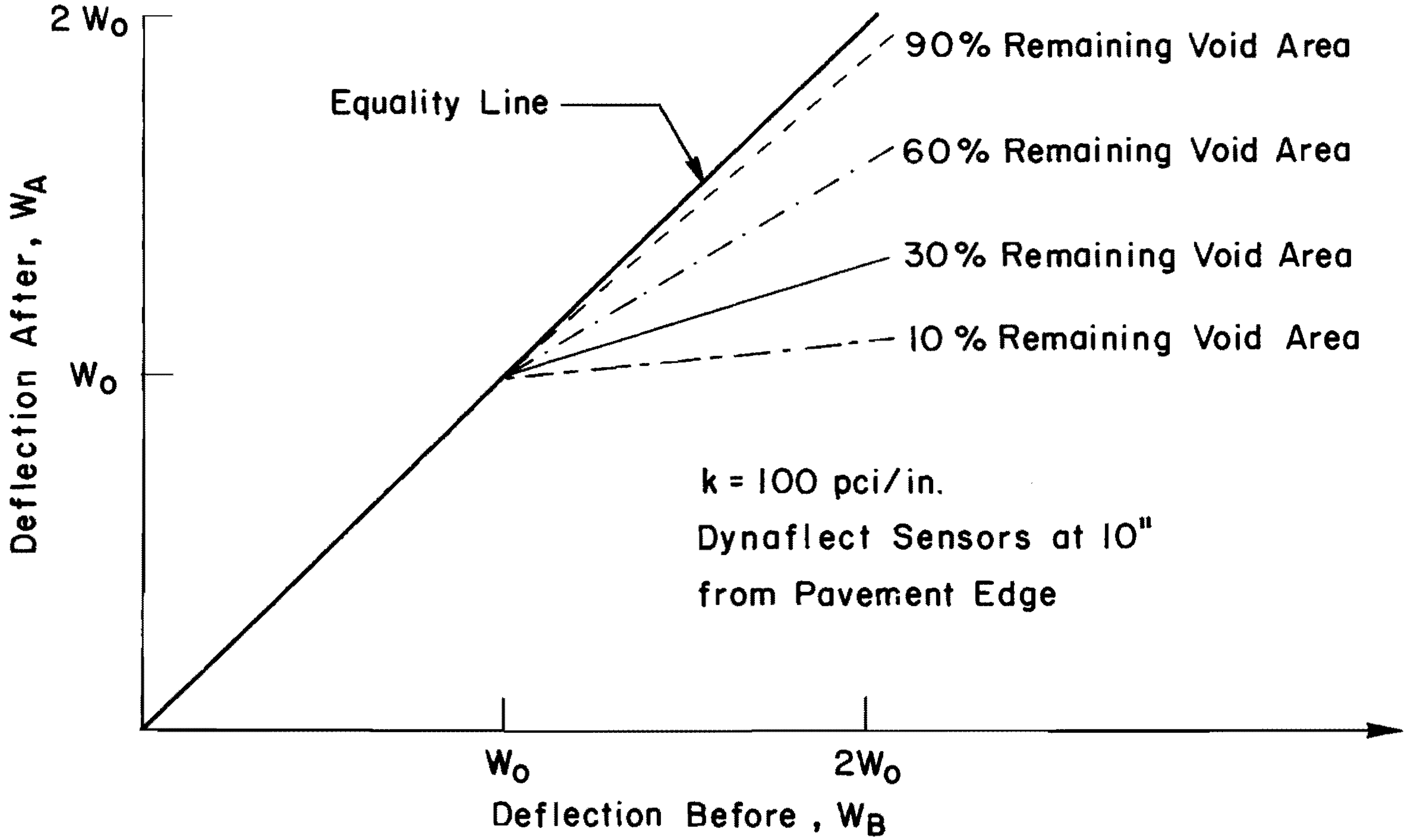

Fig 2.6. Deflections after a certain void area has been reduced by a given percent compared to deflections for the original void area. Deflection is expressed as a function of zero-void deflection, W_o.

size were known, the deflection for certain percents of the original void areas could be determined and then plotted as shown. It should be noticed that all the lines converge at the point (W_o , W_o) which is the only point plotted on the line of equality. This means that the minimum deflection to be expected equals W_o . Furthermore, a closer a line is to the horizontal the more effective the undersealing operation.

After plotting deflections before the grouting against deflections after the grouting with the data from the pavement, the approximate percent of void area filled could be estimated. Using Fig 2.6, a slope for each condition of percent of void area filled can be developed. Note that this table is valid for the value assigned to the variables in the analysis. However, results may be generalized because of the use of normilized deflections.

The steps to follow are

(1) Plot deflections after the undersealing operation versus eflections before the process. These data are represented by the dots in Fig 2.7.

(2) Fit a regression line (dashed) having its origin in the area where he greatest concentration of dots on the line of equality (solid) exists. These values approximately represent the mean deflection of a given pavement section.

(3) Compute the slope of the dashed line.

(4) Compare slope to the values shown in Table 2.5 for estimating the effectiveness of the undersealing operation.

The reader is reminded that the effects of such variables as temperature, placement error, and season of the year were neglected to facilitate the explanation of this procedure. If adequate data and corresponding analysis methods are available, corrections should be made.

TABLE 2.5. PERCENT OF VOID AREA FILLED AS A FUNCTION OF SLOPE, M

M	Percent of Void Area Filled
1.0	0
0.8	20
0.6	40
0.4	60
0.2	80
0.0	100

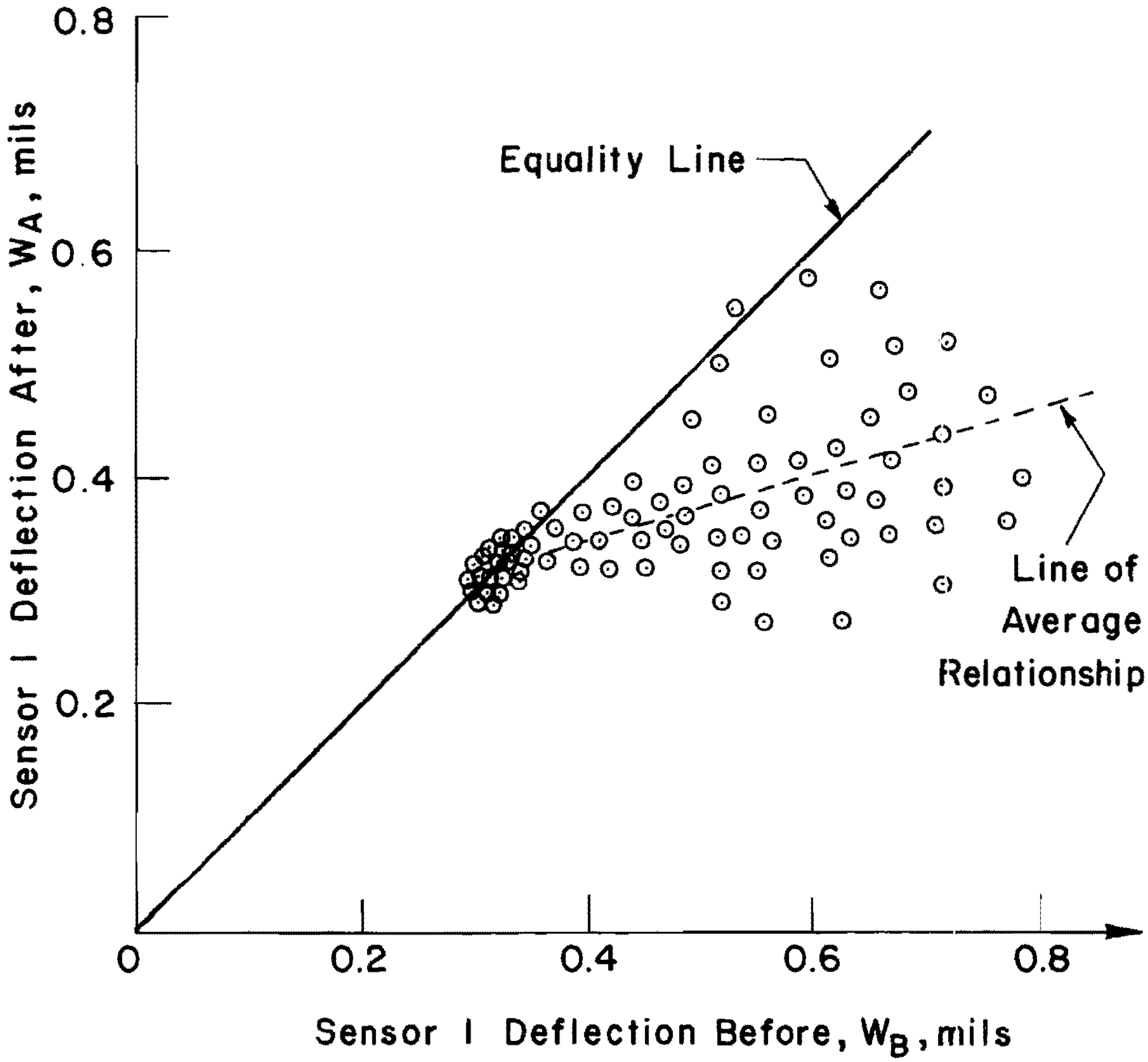

Fig 2.7. Example plot used in the recommended procedure for estimating the effectiveness of undersealing operations.

CHAPTER 3. EXISTING TECHNIQUES FOR GROUTING

The grouting process involves the injection by pressure of a cement grout mixture beneath the slab and/or subbase to fill voids while simultaneously producing a thin layer that should improve deflections and resist future pumping action (Ref 7). The cement grout undersealing process has become a highly specialized operation requiring specially trained personnel and specifically designed equipment. Three basic considerations has to be taken into account for successful grouting work: materials, equipment, and methods. In the following sections, current practices for these items are presented.

MATERIAL

A variety of grout mixtures have been used for undersealing. For any grout mixture to be successful, three important conditions must be fulfilled; the grout mixture, during pumping and curing, must be incompressible, insoluble, and non-erodible. Early grout slurries utilized top soil, but while it was found to reduce pumping and restore the original pavement profile, it provided only temporary improvement.

One important requirement for a grout mixture is that it be fluid enough to flow into very small voids. Cement and fine-sand-slurry grout generally does not provide flow characteristics during pumping comparable to those of non-sand grouts. This is especially true where the voids are very thin and discontinuous in nature. The cement and sand grout mixtures are best used for the filling of large voids (Ref 7). Mixture compositions used by DOT agencies in Georgia, Illinois, and Mississippi are discussed in the following sections.

Georgia DOT

Fine mixtures currently approved are given in Table 3.1. Actually, only mix No 3, consisting of 1 part cement and 3 parts limestone dust (by weight of dry materials), is used. Flow of the mix is also specified, using a flow cone (US Army Corps of Engineers Test Method No CRD-C79-58). A flow time of 16 to 22 seconds is required. It is preferred that the mix have a flow time of 16 seconds to facilitate distribution of the grout under the slab without excessively lifting it (Ref 7).

Illiniois DOT

One 3R (Resurfacing, Restoring, and Restorating) underseal project on I-57 used a Type 1 portland cement, aggregate, and limestone-dust grout mixture with the following gradation:

Sieve Number	% Passing
30	100
100	8 - 92
200	18 - 82

The cement and aggregate were premixed so that an intimate mixture of materials was obtained. The ratio of cement to lime dust was approximately by weight. Regular concrete cylinder molds were filled with material and tested in compression at various times, giving the results shown in Fig 3.1. The strength increase curve is similar to that for normal concrete, but the values are lower.

TABLE 3.1. APPROVED GROUT MIXTURES IN GEORGIA: MIX PROPERTIES PERCENT BY WEIGHT OF DRY MATERIALS

	Grout Types				
Material	1	2	3	4	5
Cement	25	25	25	25	100
Limestone dust	--	25	75	50	--
Fly ash	25	--	--	25	--
Fine aggregate	50	50	--	--	--

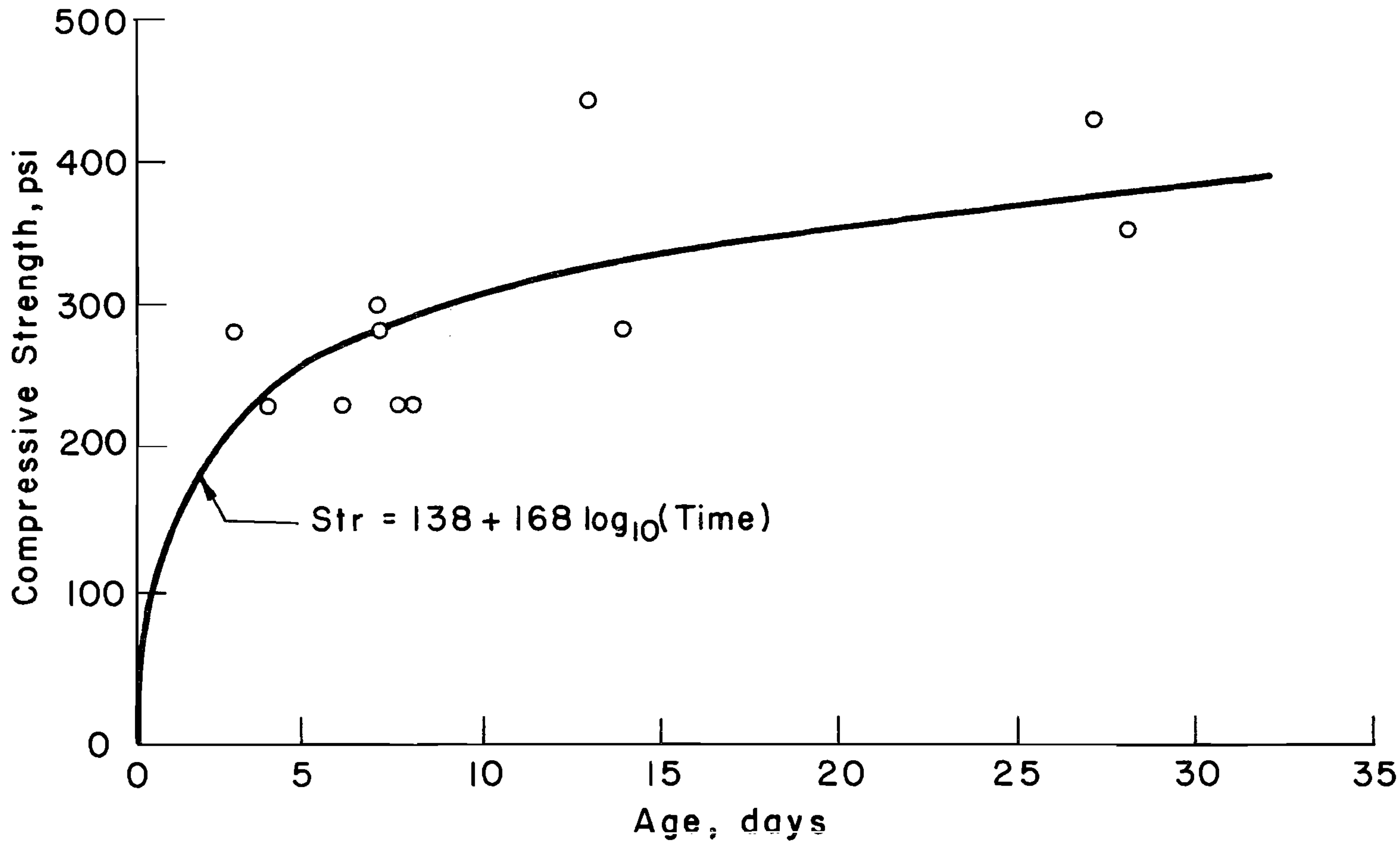

Fig 3.1. Compressive strength (6 x 12 in. cylinders) vs time for cement-lime dust. Grout used in Illinois RRR project (Ref 7).

Mississippi

An implementation package on slab jacking slurries (Ref 14) specifies that the proportions of cement to fine sand (by volume) can vary between 1:2 and 1:3. Calcium chloride should be thoroughly premixed in the approximate quantity of mixing water required for a predetermined batch size before the sand and cement are added. The consistency of the grout should produce a minimum time of efflux from the Corps of Engineers flow cone of 20 seconds. The gradation specification for the fine sand is as follows:

SIEVE NUMBER	% PASSING
10	100
60	40 - 90
200	0 - 50
% silt	0 - 25
% clay	0 - 12

Additives are available that increase the fluidity of the grout. For example, powdered ammonium lignin sulphonate will increase the fluidity of the grout without the adding of water. Thus a stronger, denser grout is obtained without increasing the cement content (Ref 7).

EQUIPMENT

For most projects, the following equipment is used during undersealing:

(1) Air compressor to drive the pneumatic hammers.

(2) Pneumatic hammers equipped with drills that will cut 1 to 2-inch holes through the concrete slab and subbase.

(3) A grout plant that is capable of accurately measuring and proportioning by volume or weight and mixing various materials composing the grout. The plant should contain a pump capable of applying at least 50 to 250 psi at the end of the discharge pipe.

(4) A flow cone (if required) with all the necessary components so that the consistency of the mixture can be determined. The flow cone should conform to the dimensions and other requirements of the Texas Highway Department Test Method Tex-415A.

(5) Cylindrical wooden plugs or other approved plugs that can effectively plug holes until the grout has set.

(6) Tank truck for water supply. The capacity may vary depending on the proportion and volume of the mix expected to be pumped per day.

(7) A device to measure slab lifting during pumping. A Dumpy Level and a rod placed on the pavement, or a modified Benkelman Beam may be used.

METHODS

After an area specified for undersealing has been located, a drilling pattern must be developed using appropriate criteria and procedures described in the previous chapter. The depth to which the grouting hole should be drilled, as well as the distances between holes and from the edges, needs to be stated. In the field, the grout crew superintendent, with the approval of the field supervisor, may slightly modify the hole drilling patterns for pavement grouting if conditions different than the ones considered during the hole patterns are found. After the holes are drilled, a discharge hose, connected to the pressure grout pump is lowered into the holes. It should be noted that the discharge end of the nozzle should not extend below the lower surface of the concrete slab.

The actual process of pumping grout varies greatly and requires close inspection by the contractor and the inspector. The purpose of the undersealing process is to stabilize the slab by filling existing voids with grout without raising the slab.

The project specifications should not allow the slab to be lifted more than 1/8 inch. Therefore, a device to monitor lift is necessary so that the pumping process can be stopped when the maximum is reached. Another factor that is used to determine when to cease pumping is the appearance of grout in adjacent holes, joints or cracks.

After grouting has been completed in any one hole, the hose is withdrawn from that hole and it is plugged immediately. Wooden plugs driven flush with the top of the slab may remain in place permanently. Temporary plugs that protrude above the top of the slab should not be removed before sufficient time has elapsed to permit the grout to set; early removal may result in back pressure which will force the grout through the hole. After a plug has been stiff grout or an approved concrete mixture (Ref 7).

EXISTING TECHNIQUES FOR VOIDS DETECTION

From the previous chapter, it is apparent that slab voids affect pavement life. Thus the purpose of this section is to present some of the existing techniques that may be used for void detection. As mentioned previously, deflection testing, use of vibratory equipment, visual observations, infrared thermography, and use of radioactive tracers are among the methods to be considered.

The first method proposed is deflection testing, in which the Dynaflect, which is standard equipment in Texas, is utilized for measuring the deflections in the pavement. The principle of operation involves a cycle force generated by a pair of unbalanced flywheels which rotate in opposite directions at 480 rpm. This produces a cyclic vertical force of 1,000 lb on the loading wheels. The resulting deflections are picked up by the five geophones, each 12 in. apart, on the surface of the pavement, as shown in Fig 3.2 (Ref 6).

Fig 3.2. Dynaflect device currently used as the standard equipment in Texas to measure deflections on the pavement.

Vibratory equipment has been used by many agencies in many countries. This method consists of applying sinusoidal forces of varying frequency to the characteristics of the waves that are propagated. Reference signals from the force generator are picked up by a geophone. Average wavelengths are calculated for a number of frequencies to produce a "dispersion curve." These measured curves can be compared with theoretical curves that are based on elastic theory calculations; dynamic moduli of the various pavement layers can then be derived. In this method, it is assumed that, if a void was present, a sharp change in the output would be observed.

Edge pumping can be used as a criterion for visual surveys. Definitions of major and minor pumping were discussed in Research Report 21-1F, "A Performance Survey of Continuously Reinforced Concrete Pavements in Texas." Primarily, minor pumping was denoted by the presence of water stains on the edge of the pavement, whereas major pumping was shown by deposits of material on the edge.

In August 1978, at the Fourth Biennial Infrared Information Exchange, Holt and Manning presented a paper which demonstrated that infrared thermography (IRT) is capable of detecting shallow voids 2 inches below the pavement surface. Void detection by means of infrared thermography is based on the hypothesis that areas with voids have significantly different surface temperatures than areas of solid concrete. In November 1979, at the Balcones Research Center at The University of Texas at Austin, a preliminary study to through 8 inches of concrete using IRT was conducted (Ref 7). The results from this experiment show that a temperature differential corresponding to the location of a void beneath the pavement was obtained.

The radioactive tracer method was used on several experimental projects in France to locate voids beneath the pavement. For this method, it is necessary to inject marked water to delimit the plane, utilizing a radioactive tracer. Once the void is located, its volume can be determined from the tracer configuration (Ref 15).

CHAPTER 4. DESCRIPTION OF THE VICTORIA GROUTING EXPERIMENT

LOCATING THE TEST SECTION

The first step involved in the development of this experiment was Texas State Department of Highways and Public Transportation and representatives of the Center for Transportation Research at The University of Texas at Austin met to determine the section at which the experiment would be developed. Based on condition surveys and field observations, a section located on Highway US-59 about 10 miles northeast of Victoria, Texas, was selected. Then, based on Dynaflect deflection measurements taken before the experiment, the area was divided into three sections; one with a high probability of voids, one with a low probability of voids, and one which was unlikely to have voids.

DESCRIPTION OF THE EXPERIMENT

The experiment was performed on March 10, 11, and 18, 1981. All of the testing was done in the traffic lane; pits were dug at various locations along the outside edge of the pavement. This project was set up so that observations could be made in pits excavated along the edge of the pavement before, during, and after the grouting process. The pits were to be excavated at alternate locations prior to the grouting so that some of the grouting would be done adjacent to the open pit and the rest would be done in about one week later (Fig 4.1).

Fig 4.1. Excavation of undisturbed sections one week later.

Fig 4.2. Breaking the CTB with an air hammer.

The hole spacing was varied, from 3 to 6 feet apart, and holes were drilled as close as one foot from the edge of the pavement and as far away as the center of the traveled lane (6 feet from the edge).

To see the influence on the structural capacity of the pavement when the grouting is done at different depths, holes were drilled

(1) through the concrete pavement only, and

(2) extending through the concrete pavement and the cement treated base (sometimes these holes were extended well down into the subgrade material).

Excavation of the observation pits was made by District 13 with a backhoe; it was quickly found that the CTB (Cement Treated Base) was too hard to be taken out without first breaking it, with an air hammer (Fig 4.2). Initially the CTB was cut with a pavement breaker; later the personnel used a jack hammer mounted on the backhoe. The pits were dug to a depth of approximately 22 in. The subgrade material was a clay, blue-green in color and quite plastic. There was no evidence of free water, and no water came out of the interface between the pavement and the CTB. In several places, the face of the excavation was cleaned with a water hose in order to better observe evidence of existing voids. Figure 4.3 presents a layout of the experiment in which the adjacent excavations as well as the distribution of the hole patterns are presented.

The material used for the grout subsealing was a mixture of portland cement and Puzzolan, which was one part portland cement, 3 parts flyash, and water to achieve the fluidity equal to a flow cone flux time of 12 to 14 seconds. The material was mixed in a high speed centrifugal mixer and placed with a Moyno positive displacement pump (Fig 4.4).

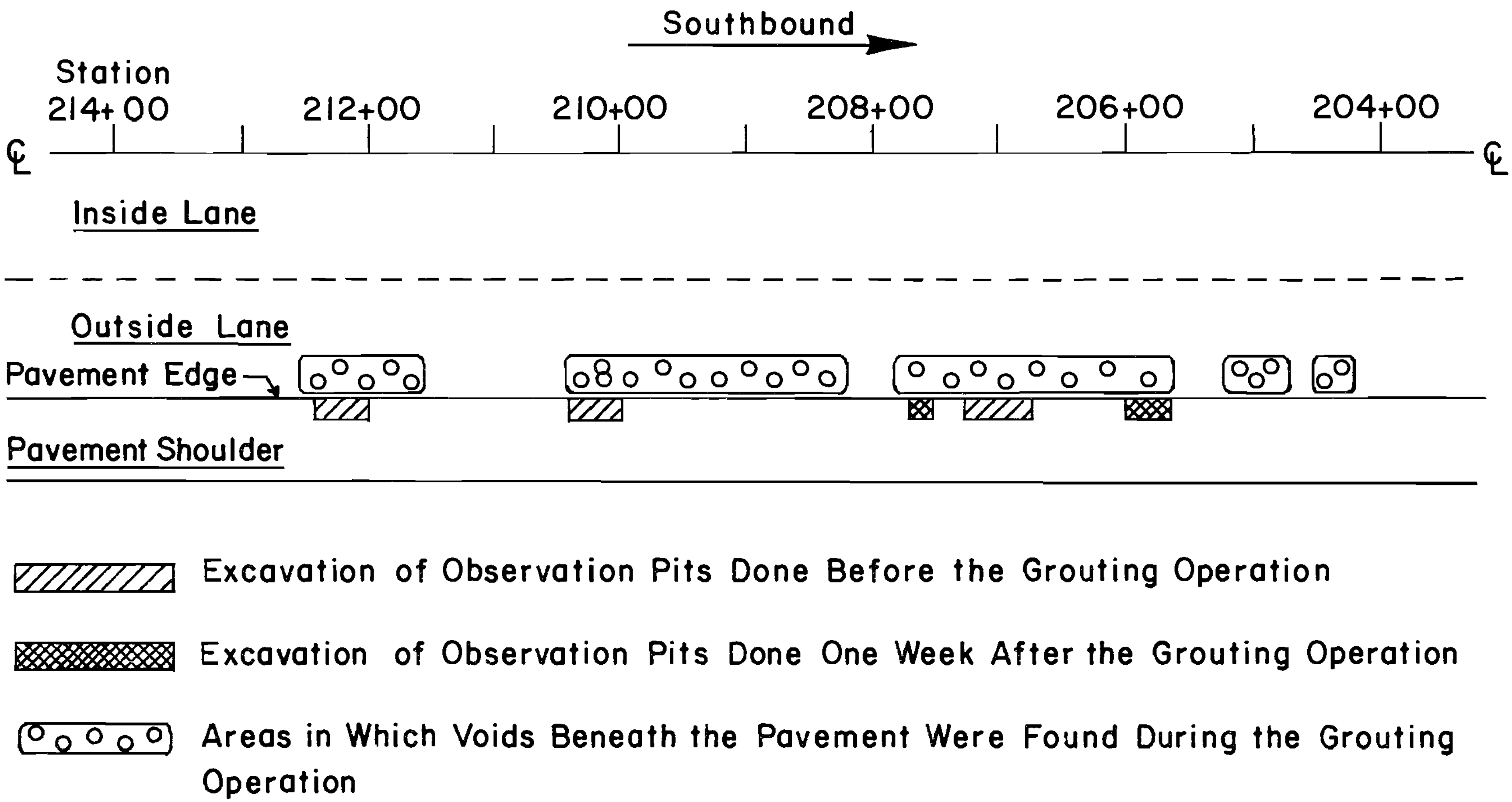

Fig 4.3. Layout of the experiment done at Victoria identifying observation pits excavated before and after grouting operation, and the location of areas in which voids beneath the pavement were found.

Fig 4.4. High speed centrifugal mixer.

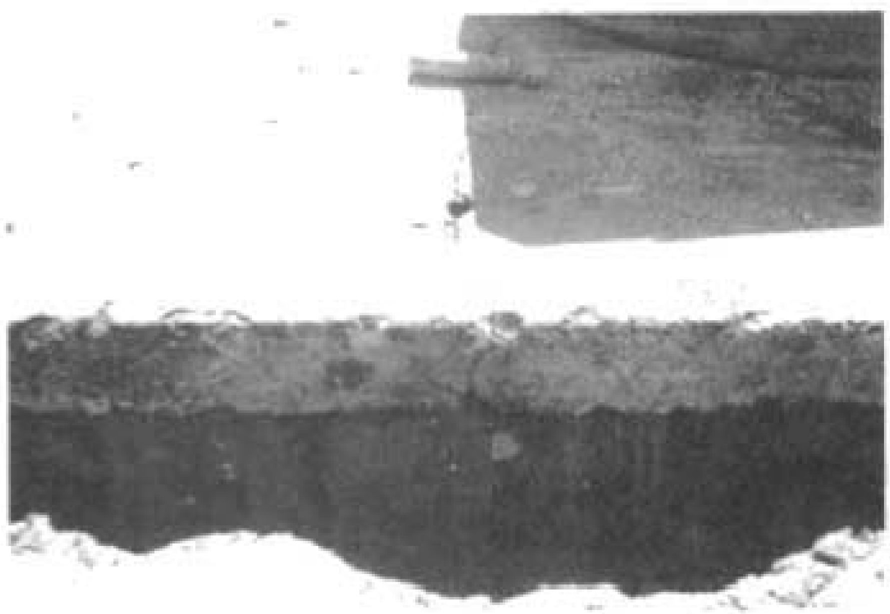

Fig 4.5. Grout coming out at the interface between the pavement and the CTB.

EXPERIMENT DEVELOPMENT

Grout injection was begun in an area in which neither the Dynaflect deflections nor the pumping of fines showed evidence of distress. In this area, the injection pressures were immediately in excess of 200 psi, and there was no acceptance of grout. The injection holes had been drilled to alternate depths as described earlier. As the subsealing operation continued, the operations moved into an area in which Dynaflect deflection measurements and pumping of fines indicated that there was a probability of finding voids underneath the pavement. The grout began to flow into the holes and shortly exited into the adjacent pit.

The grout came into the pit at various elevations as follows:

(1) At rare intervals (particularly where there was an existing punchout or when the hole was close to the edge of the pavement), grout came out at the interface between the pavement and the CTB (shallow hole) (Fig 4.5).

(2) In some instances, the grout came out at the interface of the CTB and the clay subgrade material (deep hole) (Fig 4.6).

(3) Grout came out in apparent lenses of the subgrade material, approximately 6 to 8 inches below the CTB (deep hole).

When the grout was first injected, the average pressure was usually about 150 psi. However, immediately after the grout began to flow, pressures quickly dropped into the range of 30 to 60 psi. These measurements were made at the pump manifold and do not take into consideration the pressure loss in the 50-foot hose line. It is anticipated that the actual injection pressures were probably 20 psi less (Ref 9).

In several cases, injection holes were drilled through the concrete pavement at a temperature crack. It was not possible to achieve a grout flow along these temperature cracks into the pit until a hole had been drilled as

Fig 4.6. Grout coming out at the interface of CTB and the Clay Subgrade material.

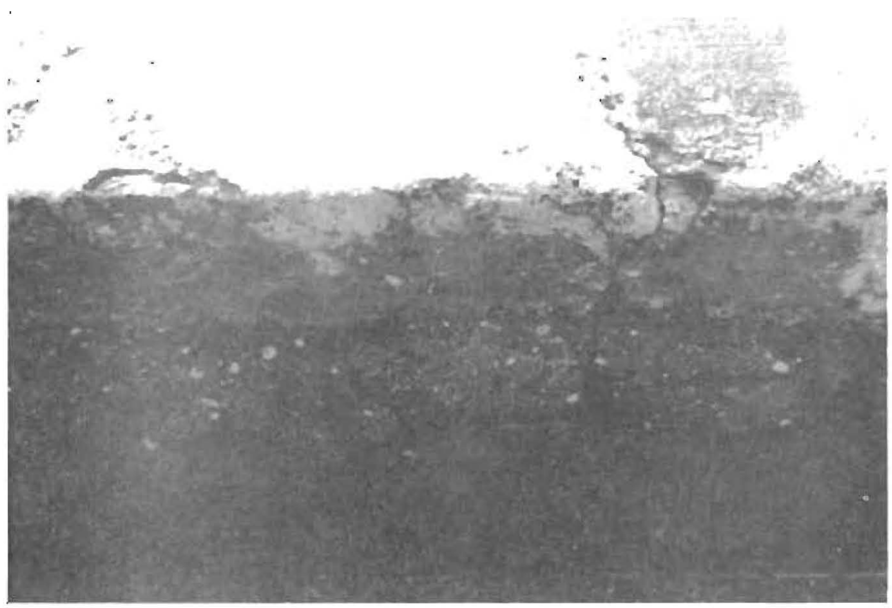

Fig 4.7. Punchout crack going through the CTB.

close as 18 in. from the edge of the pavement. The grout then flowed and fanned out horizontally about 15 in. on either side of the temperature crack. In general, there was no indication that the temperature cracks propagated vertically into the CTB.

When the punchouts were grouted, one of the holes was found to be only through the pavement slab. No flow of grout was achieved; the hole was washed and repumped twice with no flow of grout. Eventually, when the hole was drilled through the CTB, the grout flowed into the pit from beneath the CTB. A hole was then drilled directly into the punchout perimeter crack and into the pit at the interface between the pavement and the CTB.

After the face of the excavation was cleaned, there was evidence of very thin voids at the interface between the slab and the CTB at several locations. At one of these, there was quite a bit of sand and shell from the shoulder construction that had been drawn into that interface. Apparently, this resulted from the pumping action of the free water as vehicles passed over the pavement.

It was also noted that, wherever a punchout existed or was in an early stage of development, the punchout crack went through the CTB, down to the subgrade (Figs 4.7 and 4.8).

During the grouting operation, the slabs were continually monitored for any lifting. At any time that the vertical movement reached 0.005 feet, the pressure was immediately cut off. This monitoring was done with a K & E Dumpy Level and a rod placed on the pavement. It was noted that in virtually every case, as the grout pressure increased, the pavement moved vertically at the same time. As soon as the amount of rise equaled 0.005 feet, the pumping ceased and the pavement quickly receded to about half of that

Fig 4.8. Punchout crack going through the CTB.

Fig 4.9. Lenses of grout at the interface between CTB and the Subgrade Clay material.

distance. Subsequently, over a short period of time, the pavement apparently continued to relax and then went back to its original position (Ref 9).

When pits were excavated in the undisturbed grout areas on March 18, lenses of grout generally on the order of 1/4 to 3/8 inch thick were observed at the interface between the cement treated base and the subgrade clay material (Fig 4.9). In no event were any grout lenses found any deeper than this. The grout lenses also extended out into the shoulder beyond the 2-foot width of the excavation. Again, the lenses were directly beneath the CTB.

Forms Proposed for Data Collection During the Experiment

The form presented in Fig 4.10 is the data form used to record the information for the experiment evaluation. In the upper level of this form the identification of the project should be stated in terms of District, county, and highway. The location of the experimental section is defined by the stations at which the project was done. The existing pavement as well as the mix characteristics should be included, specifying the type of material and layer thicknesses as well as the proportions of the mix that were used to fill the voids.

In the first column of the form, the station numbers of the points at next column identifies the depth of the drilled holes, denoted by shallow (hole through the pavement slab) or deep (hole through the slab and the subbase). The third column indicates when an adjacent pit was excavated for observation during the experiment or at a later date. The fourth column is a plan view for illustrating the hole pattern used for the experiment, as well as the distress manifestations found in the sections. The distress manifestations should be identified using the symbols presented at the bottom of the form, which include cracking, pumping, punchouts, and patches.

Page __ / __

DISTRICT __________ COUNTY __________ HIGHWAY __________

EXISTING PAVEMENT Material Type — Layer Thick.	Mix Characteristics	DATE __________ TEMPERATURE __________
— — — —		Description of Location: From Station - To Station -

STATION	Deep or Shallow	Adjacent Pit	Distress Manif. & Hole Pattern	Continuity	Grouting Pressure	Time Grouting	Slab Behavior	Comments & Remarks

Crack ~~~, Pumping ///, Punchout =I=, Patch ⊃

Fig 4.10. Form used for data collection during the experiment.

The next columns are for recording the continuity found between holes during the grouting process; the pressure at which the mix was injected, in psi; the time employed pumping the mix into each hole; the slab behavior, to note if the slab raises due to the grouting pressure; and, in the last column, any comments or remarks made during the experiment.

CHAPTER 5. ANALYSIS OF RESULTS AND DEVELOPMENT OF PROCEDURE

RESULTS OF THE GROUTING EXPERIMENT AT VICTORIA

The evaluation of results was based primarily on Dynaflect deflections field observations made during the experiment. For the analysis, different combinations of Dynaflect deflections were evaluated. These combinations take into account the depth of the drilled holes, the distances from the edge at which the holes were drilled, and the positions at which the Dynaflect deflections were recorded. Since some of the variables were controlled and others were uncontrolled, it was necessary to organize the data in a format for analysis. Tables 5.1 and 5.2 present in a factorial format the different combinations of Dynaflect deflections that were considered. Table 5.1 shows the analysis format for the control sections, where Dynaflect deflections were taken in locations where grout was not applied. Table 5.2 considers the different combinations of data for sections which were grouted.

In recent studies performed at the Center for Transportation Research (Ref 13), it was observed that the Dynaflect deflection measurements recorded at one foot from the edge provided the more reliable information for void detection.

Since the data collected for this experiment also show that the deflection measurements at this distance are the most sensitive, the subsequent analysis will be essentially based on the deflection measurements recorded at approximately one foot from the edge.

TABLE 5.1. DIFFERENT COMBINATIONS OF DATA FOR THE SECTIONS WHERE GROUT WAS NOT APPLIED

VICTORIA GROUTING EXPERIMENT

Hole Depth	Hole Pattern (Distance from the Edge)	Dynaflect Position			Hole Pattern (All Positions)		
		At 1.0'	At 3.0'	At 6.0'	At 1.0'	At 3.0'	At 6.0'
		W_1(B) vs W_1(A)	W_1(B) vs W_1(A)	W_1(B) vs W_1(A)	W_1(B) vs W_1(A)	W_1(B) vs W_1(A)	W_1(B) vs W_1(A)
Deep	1.5'	✓	✓	x			
	2.0'	✓	✓	✓			
	3.0'	✓	✓	x	✓	✓	✓
	4.0'	x	x	x			
	6.0'	x	x	x			
Shallow	1.5'	✓	✓	✓	✓	✓	✓
	2.0'	✓	✓	✓			
	3.0'	✓	x	x	✓	✓	✓
	4.0'	x	x	x			
	6.0'	x	x	x			

W_1(B) - Sensor 1 Dynaflect Deflections Before the Experiment

W_1(A) - Sensor 1 Dynaflect Deflections After the Experiment

x - No Analysis Performed (Lack of Data)

✓ - Analysis Performed

TABLE 5.2. DIFFERENT COMBINATIONS OF DATA FOR SECTIONS WHERE GROUT WAS APPLIED

VICTORIA GROUTING EXPERIMENT

Hole Depth	Hole Pattern (Distance from the Edge)	Dynaflect Position			Hole Pattern (All Positions)		
		At 1.0'	At 3.0'	At 6.0'	At 1.0'	At 3.0'	At 6.0'
		W_1(B) vs W_1(A)	W_1(B) vs W_1(A)	W_1(B) vs W_1(A)	W_1(B) vs W_1(A)	W_1(B) vs W_1(A)	W_1(B) vs W_1(A)
	1.5'	✓	✓	✓			
	2.0'	✓	✓	✓			
Deep	3.0'	✓	✓	x	✓	✓	✓
	4.0'	✓	✓	✓			
	6.0'	✓	✓	✓			
	1.5'	✓	✓	x			
	2.0'	✓	✓	✓			
Shallow	3.0'	x	x	x	✓	✓	✓
	4.0'	x	x	x			
	6.0'	x	x	x			

W_1(B) - Sensor 1 Dynaflect Deflections Before the Experiment

W_1(A) - Sensor 1 Dynaflect Deflections After the Experiment

x - No Analysis Performed (Lack of Data)

✓ - Analysis Performed

Weather and Moisture Influence on Dynaflect Deflections

In order to evaluate the influence temperature and moisture conditions on the dynaflect deflections recorded during the experiment, the following analysis was performed. This evaluation mainly consisted of a comparison of deflections recorded before and after the experiment in the control section where grout was not applied. Figure 5.1 presents the graph of sensor 1 readings, considering the Dynaflect load at one foot from the edge. The solid line represents the equality line, which implies there is no variation due to temperature and moisture conditions. Therefore, the slope should be equal to one. On the other hand, the dashed line is the linear regression of the deflections recorded before and after the experiment. In this case, the regression line equation is

$$y = 0.04 + 0.91x$$

A variation of approximately 9 percent due to the effect of environmental factors was obtained. Deflection measurements recorded at 3 and 6 feet from the edge for this project show a small variation. For the analysis presented in this chapter, corrections due to temperature or moisture conditions are required on Dynaflect deflections.

Effect of Grouting Depth on Deflection

The scope of this section is to determine the influence of the grout applied at different depths on the pavement structural capacity. The evaluation is done by means of the Dynaflect deflections recorded before and after the experiment. For this study, one group has been considered for each depth to which the holes were drilled. The groups are as follows:

(1) Shallow hole: the holes that go through the concrete pavement and sometimes 2 or 3 in. into the cement treated base (Fig 5.2).

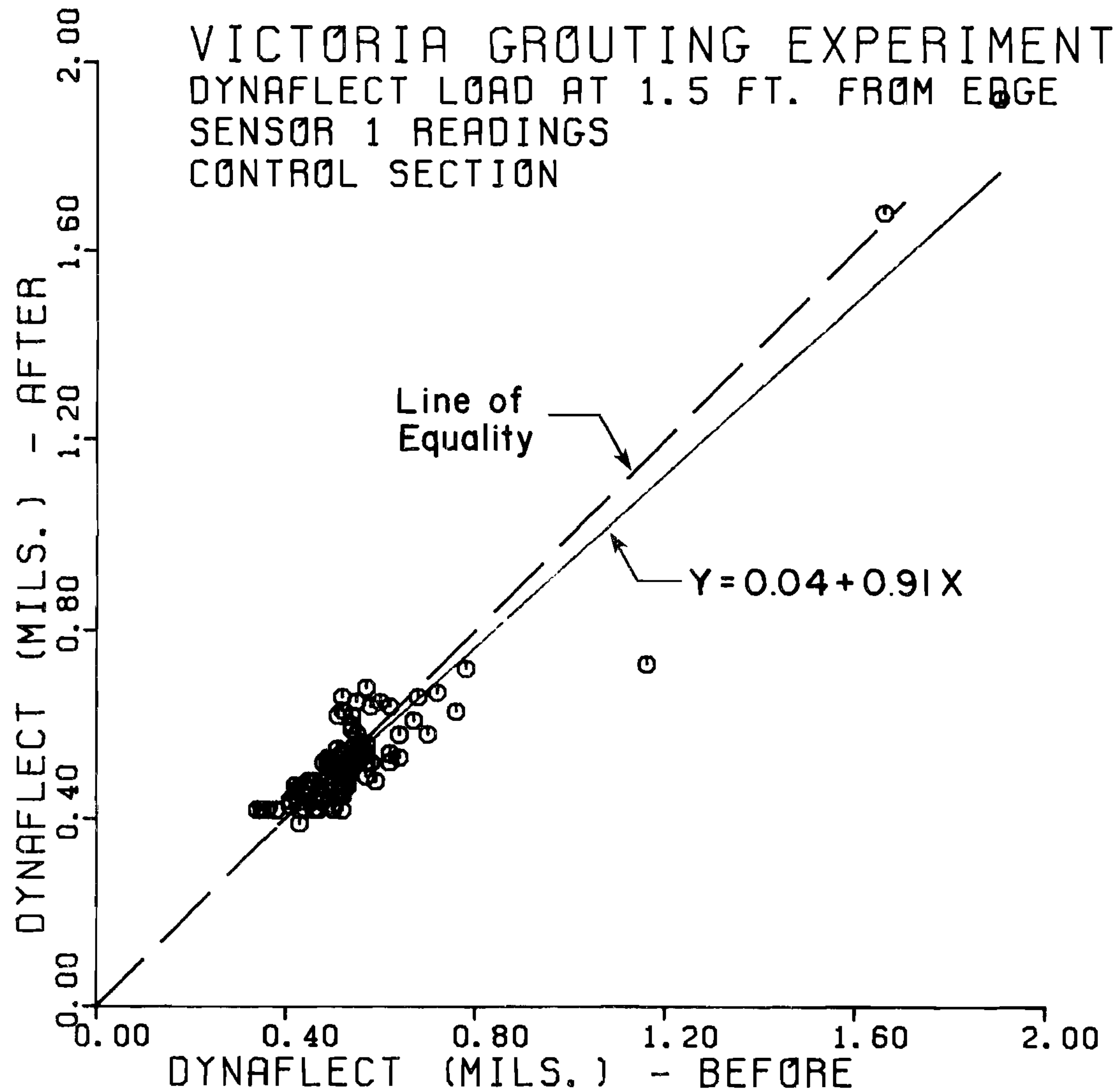

Fig 5.1. Influence of weather conditions on Dynaflect deflections. Victoria project, US-59, District 13. Regression equation is applicable only for the range of data shown.

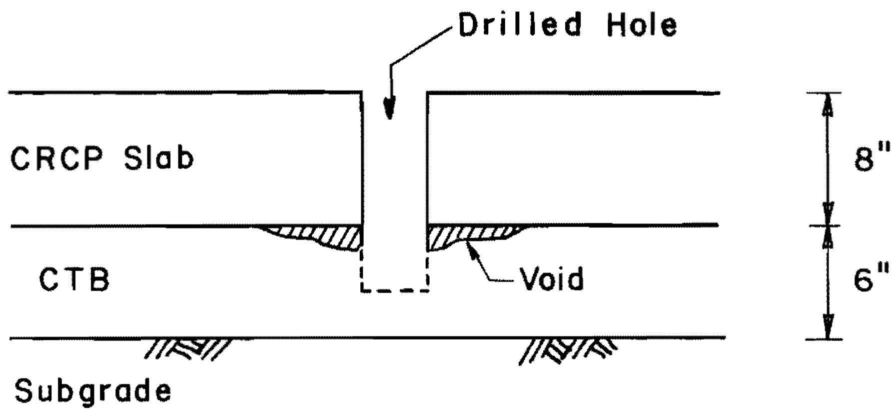

Fig 5.2. Shallow hole pattern.

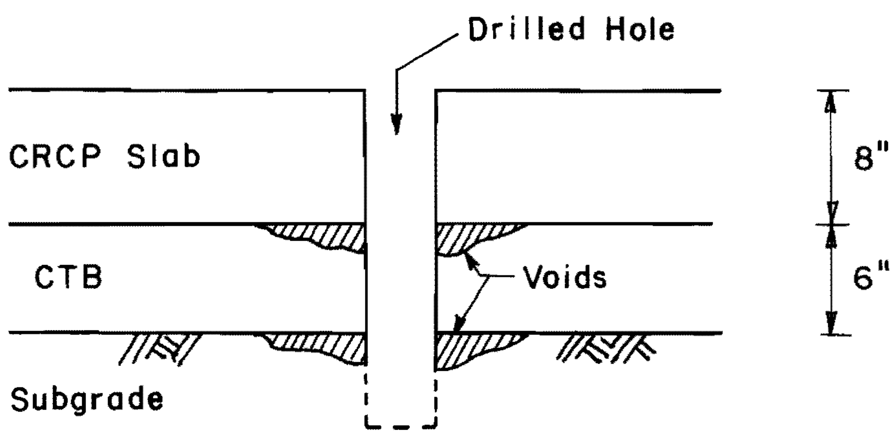

Fig 5.3. Deep hole pattern.

(2) Deep hole: the holes that extend through the cement treated base (Fig 5.3. Sometimes these holes extended well down into the subgrade material.)

For each one of these groups, a graph plotting Dynaflect deflections before and after the grouting was used in the evaluation. Figures 5.4 and 5.5 esent the graphs for the shallow and the deep hole groups, respectively. Analyzing these graphs, it may be concluded that the greatest improvement in Dynaflect deflections is obtained when grout is applied using the shallow hole pattern. It can be observed that, the net improvement obtained for the mean deflection when the grout was applied following the shallow hole pattern was 41 percent (Fig 5.4), whereas following the deep hole pattern it was only 4 percent (Fig 5.5). Thus, it can be concluded that the grout applied just beneath the pavement has the largest influence on the pavement structural capacity. The grout applied with the deep hole pattern is primarily dispersed in subgrade fissures and shrinkage cracks and to a limited extent fills voids. In this respect, and based on the analysis presented in Chapter 2 regarding the effectiveness of the grouting operation, it can be said that the improvement obtained in deflections after the grout has been applied is directly related to the percent of the void area filled.

Void Areas Selection

Prior to the grouting experiment, several areas with various void were selected. These sections were chosen based primarily on deflection measurements recorded with sensor 1 of the Dynaflect and on pumping observations. There was generally a reasonable overlap between the deflection and pumping-observation approaches; however, a disagreement did appear, in that, in some areas where voids were selected that were selected on the basis of high deflections, there was no evidence of pumping. In other

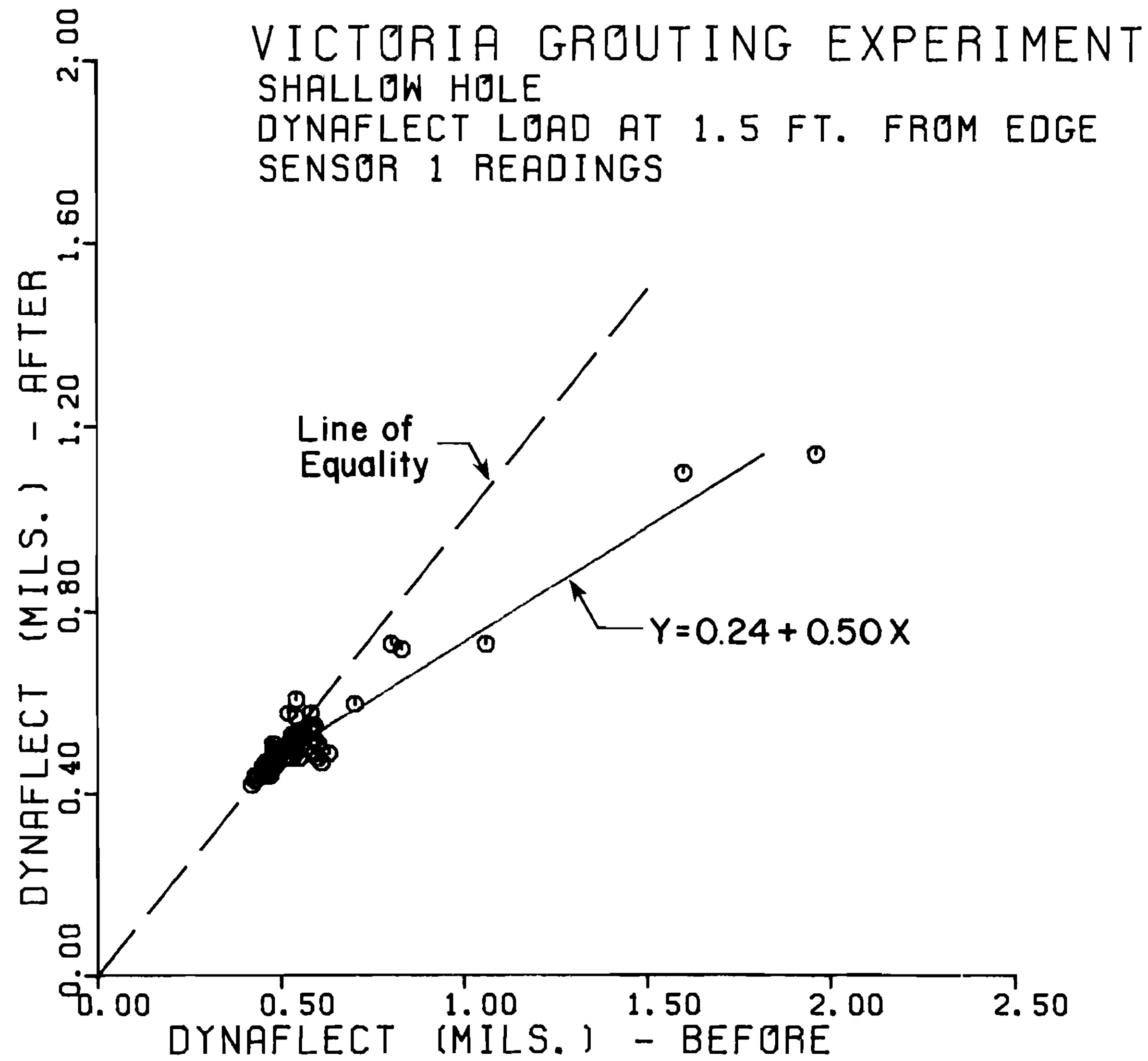

Fig 5.4. Deflections obtained before and after the grouting operation following the shallow hole pattern. Victoria project, US-59, District 13. Regression equation is applicable only for the range of the data shown.

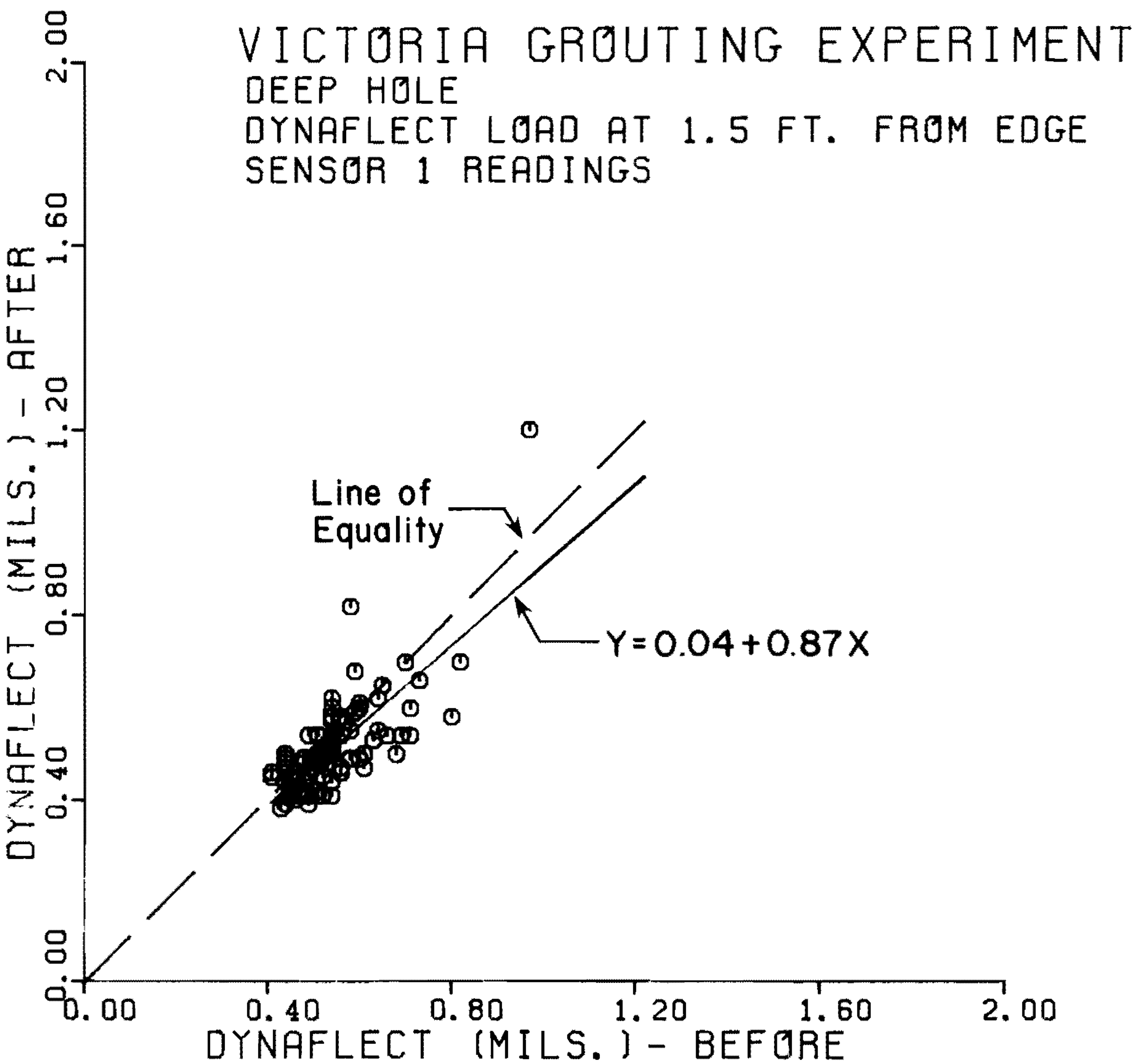

Fig 5.5. Deflections obtained before and after the grouting operation following the deep hole pattern. Victoria project, US-59, District 13. Regression equation is applicable only for the range of data shown.

cases, where pumping was used as an indicator, low deflections were recorded. Analyzing the data collected after the experiment, it was found that the pumping-observation approach used provided just 60 percent success, which was considered an unsatisfactory level for void detection.

Regarding this result, several other strategies involving sensor 4, sensor 5, field observation of pumping, and a normalized form of sensor 1 minus sensor 5 of the Dynaflect device were evaluated.

Among the combinations considered, the alternative of normalizing sensor 1 minus sensor 5 of the Dynaflect device provides the greatest sensitivity for detecting areas in which voids exist beneath the pavement. Figure 5.6 presents the frequency distribution of the normalized Dynaflect deflections for void detection purposes using the data collected during the experiment.

In this figure, it can be observed that for deflection measurements recorded at about one foot from the edge there is a slight tendency for the higher values of normalized Dynaflect deflection to correspond with void areas.

Grouting Pressure

During the experiment, field observations of the pressure applied in the grout injection process were recorded as indicated in Chapter 4. As was expected, the pressure required in the case in which the grout was injected (when a void existed) was considerably lower than the case where no voids were present.

Figure 5.7 shows the frequency distribution of the pressure applied during the grouting process, considering both cases. It was observed that whenever the grout was first injected for the void case, the pressure was usually about 150 psi. However, immediately after the grout began to flow, pressures quickly dropped into the range of 30 to 65 psi. On the other hand,

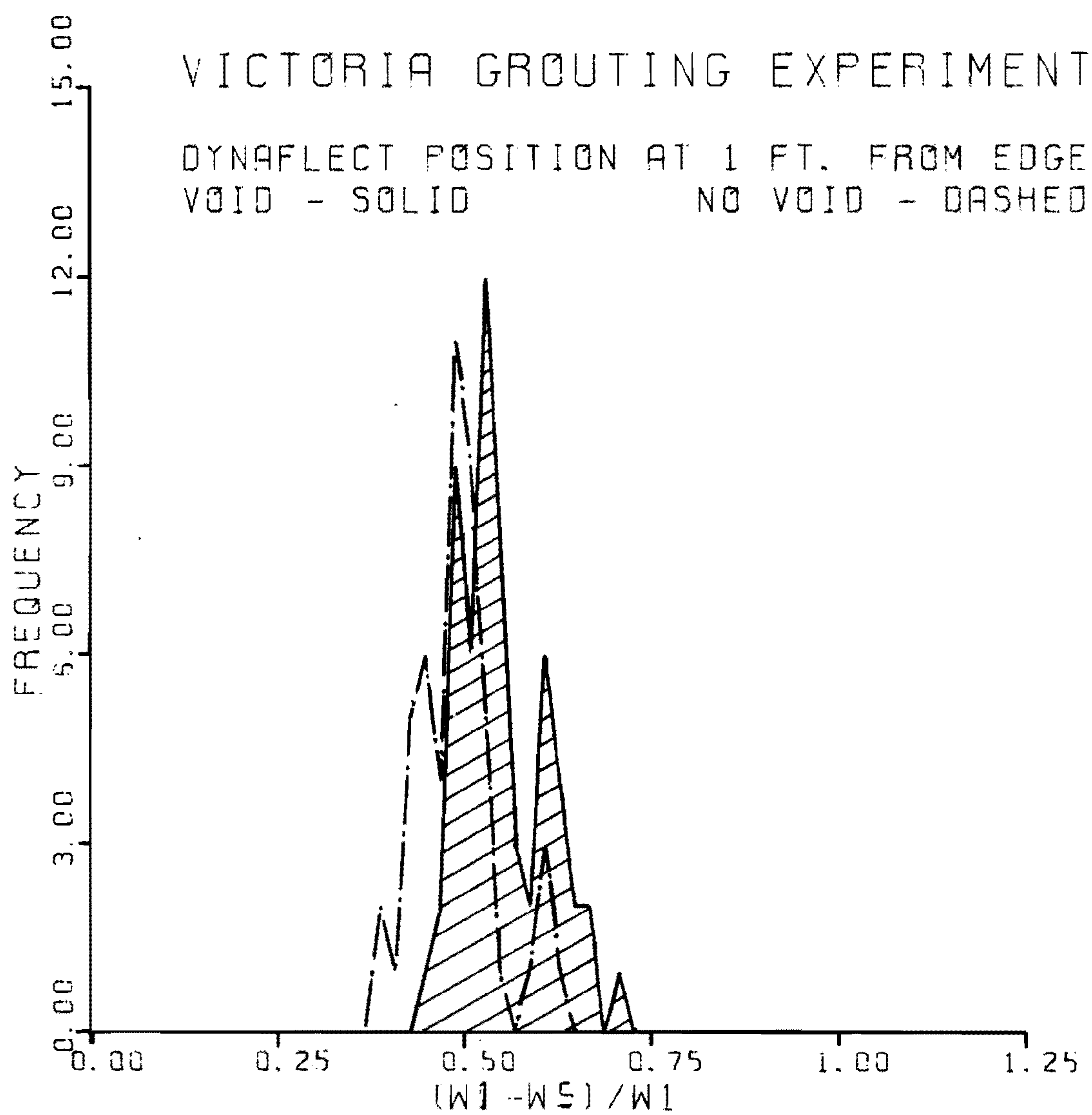

Fig 5.6. Frequency distribution of normalized Dynaflect deflections recorded at one foot from the edge.

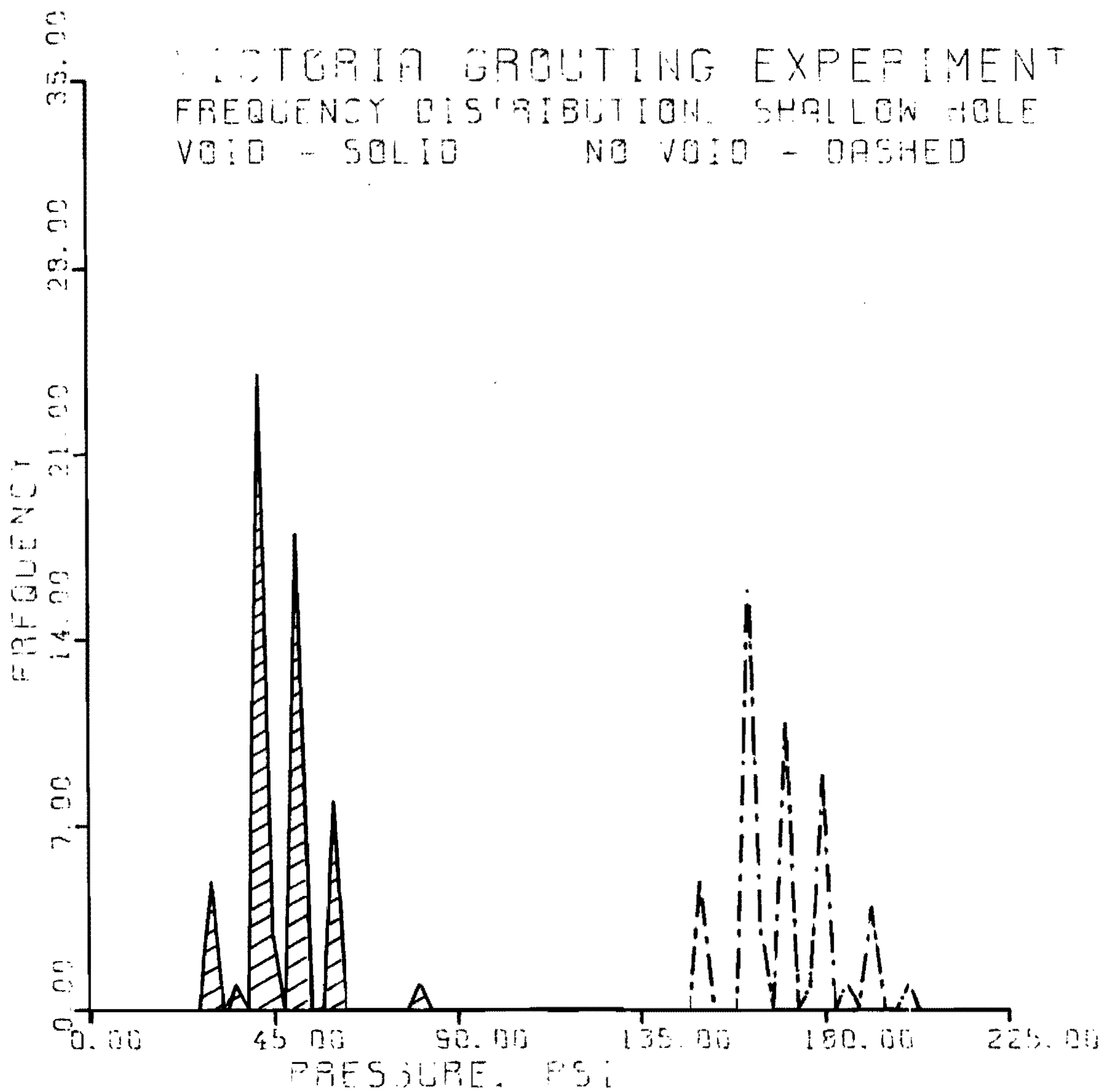

Fig 5.7. Frequency distribution for grouting pressure following the shallow hole pattern.

for the cases in which no voids existed beneath the pavement, the pressure varied from 140 to 185 psi, which means that no injection of grout was achieved.

PROPOSED METHOD FOR VOID AREA SELECTION

Based on the results obtained from this experiment, an analysis procedure has been developed in order to select the optimum procedure for the detection of voids beneath the pavement. For this purpose, the analysis is presented in three different steps:

(1) selection of the optimum position for recording the deflection,

(2) evaluation of alternatives,and

(3) selection of the most viable strategy.

Optimum Position for Deflection Measurementsts

Analyzing the deflection measurements recorded during the experiment, were more sensitive for void detection purposes than the ones recorded at any other point on the pavement. In order to corroborate this result, a theoretical analysis using the SLAB 49 computer program was developed (Ref 13). The results of this study are presented in Fig 5.8, which shows the effect of void size on the deflection measurement taken at different distances from the edge. The graph evaluates the effect for three different soil support values, i.e., K = 100 pci, K = 400 pci, and K = 800 pci. Studying this graph, it may be noted that the greatest sensitivity of Dynaflect deflection is obtained when measurements are taken at 12 in. from the edge. No matter what soil support value is considered, the slope of the line is greater as the load approaches the pavement edge, and the effect of voids is more noticeable in high strength soils. Therefore, according to the results obtained in both analyses, it may be concluded that deflection

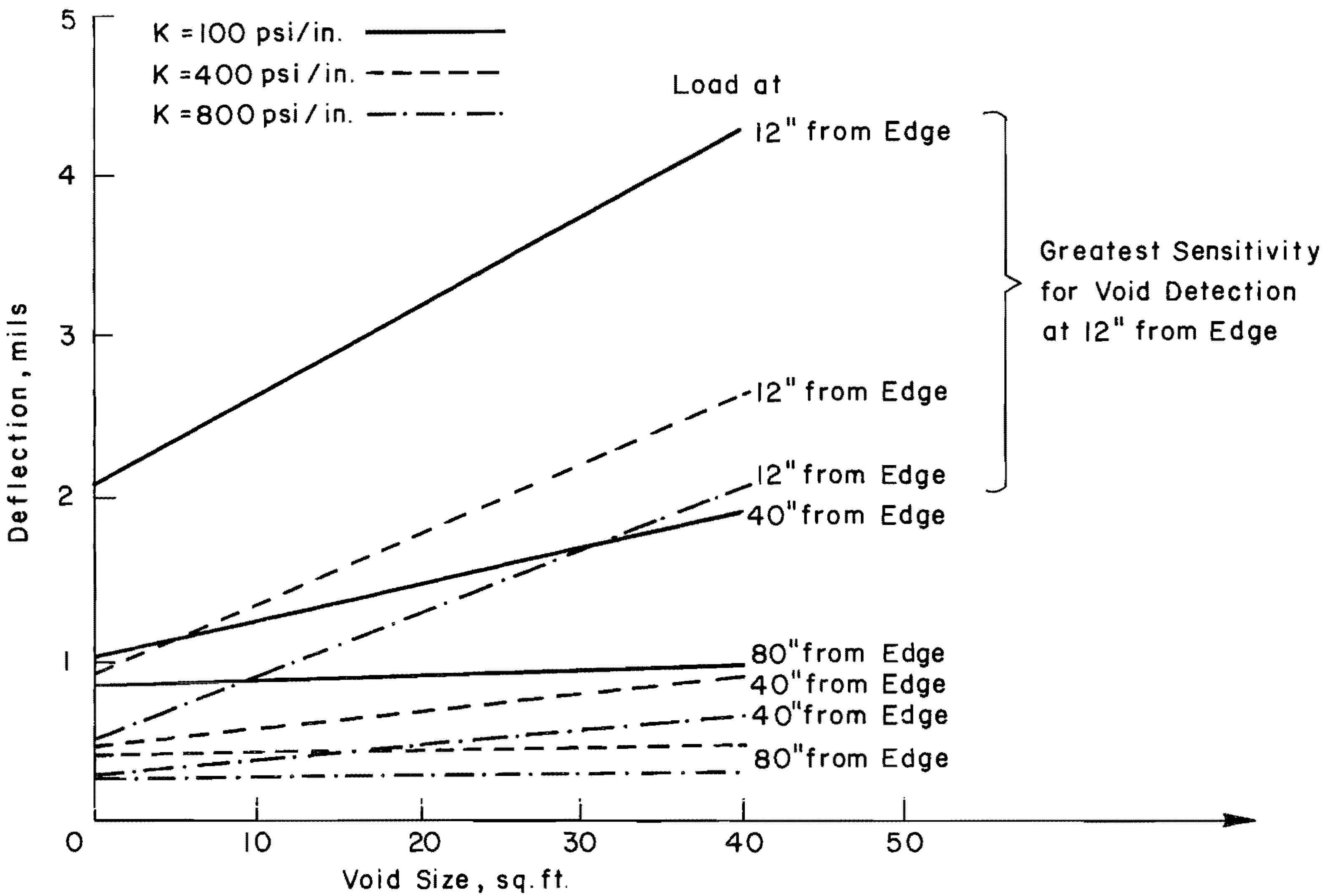

Fig 5.8. Effect of void size on Dynaflect deflection measurements.

measurements recorded at 12 in. from the edge provide the most reliable information for void detection purposes. Of course, temperature corrections may be required for measurements near the edge.

Evaluation of Alternatives

As was concluded in the previous section, the greatest benefits to the pavement's structural capacity are obtained in the case in which the voids that exist just beneath the pavement are filled. Therefore, this study will be focused on the selection of the strategy that best satisfies this condition.

From the analysis of the data collected during the experiment, several options that could fulfill the requirements for void area selection have been obtained. In the following analysis, four combinations which were considered as being more reliable are evaluated.

For this purpose, a sample of 98 points, randomly selected, has been chosen. This sample consists of 52 cases with voids and 46 cases in which no void was found beneath the pavement.

The sample is described in the table below. The variables that are involved in each of the strategies selected are

Variable Notation		Variables Description		
Strategy 1	NDEF W1 W5 PUMP	NDEF	=	Normalized Dynaflect Deflection (W1 - W5)/W1
Strategy 2	NDEF	W1	=	Deflection recorded by means of Sensor 1 of the Dynaflect device
Strategy 3	NDEF PUMP	W5	=	Deflection recorded by means of Sensor 5 of the Dynaflect device
Strategy 4	W1 W5 PUMP	PUMP	=	Field observations of pumping

The evaluation of each one of these combinations was performed considering the following criteria:

Criterion 1 - Evaluation of the success of the prediction of the total number of cases with voids (52).

Criterion 2 - Evaluation of success on the basis of the number of void cases predicted with each one of the strategies.

Table 5.3 presents the evaluation of the success of the prediction of the total number of cases with voids for the four strategies selected. From an overall standpoint, it can be noticed that strategies 1 and 3 have the highest percentages of success for detecting voids, with 81.6 and 79.6 percent, respectively. In Table 5.4 an evaluation considering the total number of predictions made for each one of the strategies is presented. In this case, it may be observed that even though strategies 1 and 2 have the greatest number of correct predictions (41 and 39, respectively), the optimum percent of success for void prediction purposes is obtained by means of strategy 3, with 86.36 percent. Nevertheless, if this table is evaluated from an overall standpoint, then strategies 1 and 3 are again the ones that present the highest percentages of success, with 81.6 and 79.6 percent, respectively.

Selection of the Most Viable Strategy

Evaluating the results obtained for each criterion, it can be determined that strategies 1, 2, and 3 are the ones that achieve the highest results. Among these, we consider that, for practical purposes, strategy 3 is the one that should be selected. This recommendation has been based on the fact that, even though strategy 1 shows better results, the amount of variables involved represents a more complex analysis for void detection purposes in future

TABLE 5.3. CRITERION 1 - EVALUATION OF THE SUCCESS OF THE PREDICTION OF THE TOTAL NUMBER OF CASES WITH VOIDS

Strategy	Case Type	Correct Prediction	Wrong Prediction	Total Cases	Percent of Success
1	Void cases	41	11	52	78.8%
	No void cases	39	7	46	81.6%
2	Void cases	39	13	52	75.0%
	No void cases	38	8	46	82.6%
3	Void cases	38	14	52	73.07%
	No void cases	40	6	46	86.95%
4	Void cases	35	17	52	67.3%
	No void cases	40	6	46	86.95%

TABLE 5.4. CRITERION 2 - EVALUATION OF SUCCESS ON THE BASIS OF THE NUMBER OF VOID CASES PREDICTED BY EACH ONE OF THE STRATEGIES

Strategy	Formula Prediction	Correct Prediction	Wrong Prediction	Total Cases	Percent of Success
1	Voids	41	7	48	85.41%
	No Voids	39	11	50	78.0 %
2	Voids	39	8	47	82.97%
	No Voids	38	13	51	74.50%
3	Voids	38	6	44	86.36%
	No Voids	40	14	54	74.07%
4	Voids	35	6	41	85.36%
	No Voids	40	17	57	70.17%

projects. On the other hand, although the results obtained with strategy 2 are satisfactory, it is considered that the void prediction based on just one variable may not provide accurate results when it will be used in projects with different conditions.

Strategy 3, which has been selected as the more viable for void detection, is based on two variables: normalized Dynaflect deflections and field observations of pumping. In order to assign each variable its corresponding weight, a discriminant function analysis was used (Ref 10). The equation developed to discriminate between sections with voids and without voids is of the form

$$Z = \sum_{i=1}^{n} A_i Z_i \qquad (i = 1, \ldots, n) \qquad (5.1)$$

where

Z = discriminant score,

A_i = weighting coefficients, and

Z_i = standardized values of the n discriminating variable in the analysis.

The standardized values are calculated as follows:

$$Z_i = \frac{X_i - \overline{X}_i}{\sigma_{xi}} \qquad (5.2)$$

where

X_i = value of the variable i for the case being classified,

$\overline{X}_i$ = mean value of the variable i , and

σ_{xi} = standard deviation for $\overline{X}_i$.

Thus, evaluating the normalized Dynaflect deflections and the field observations of pumping obtained from the experiment using Eq 5.1 the discriminant equation for this project is

$$Z = -0.045 + 0.904Z_{NDEF} + 0.390Z_{PUMP} \qquad (5.3)$$

where

Z = discriminant score,

Z_{NDEF} = normalized NDEF (normalized Dynaflect deflection) for a specific location, and

Z_{PUMP} = PUMP (pumping manifestation) for the same location.

Thus, if any section of a pavement is evaluated by using the equation presented, a discriminant score, or zeta value, is obtained. This zeta value indicates if, using the experimental section scores as a guideline, a void exists beneath the pavement. In order to simplify the interpretation of the discriminant factor, the equation presented above is a modified version of the discriminant equation so that it is compared to zero rather than to + 0.045. In this way, if Z is greater than 0, there is a large probability that a void exists beneath the pavement. Similarly, for a pavement with a Z value smaller than 0 there is a large probability that there is not a void beneath it.

CRITERION FOR DETECTING VOIDS

According to the discriminant function we have already developed, if Z is greater than zero, that section is a very likely candidate to have a void beneath it. Nevertheless, in some cases in which there is a discrepancy between the data collected (field observation of pumping and the normalized a void does not exist beneath the pavement although a discriminant value greater than 0 has been obtained.

In order to help understand the discriminant factor, Fig 5.9 represents distribution of pavements with and without voids beneath them. Pavements located in the "zone of conflict" are pavements for which it is not possible to determine if there is a void beneath the pavement.

From this analysis, it can be concluded that the greater the value of zeta, the higher the probability of finding a void beneath the pavement, whereas, as the value of zeta decreases, the probability of no void increases.

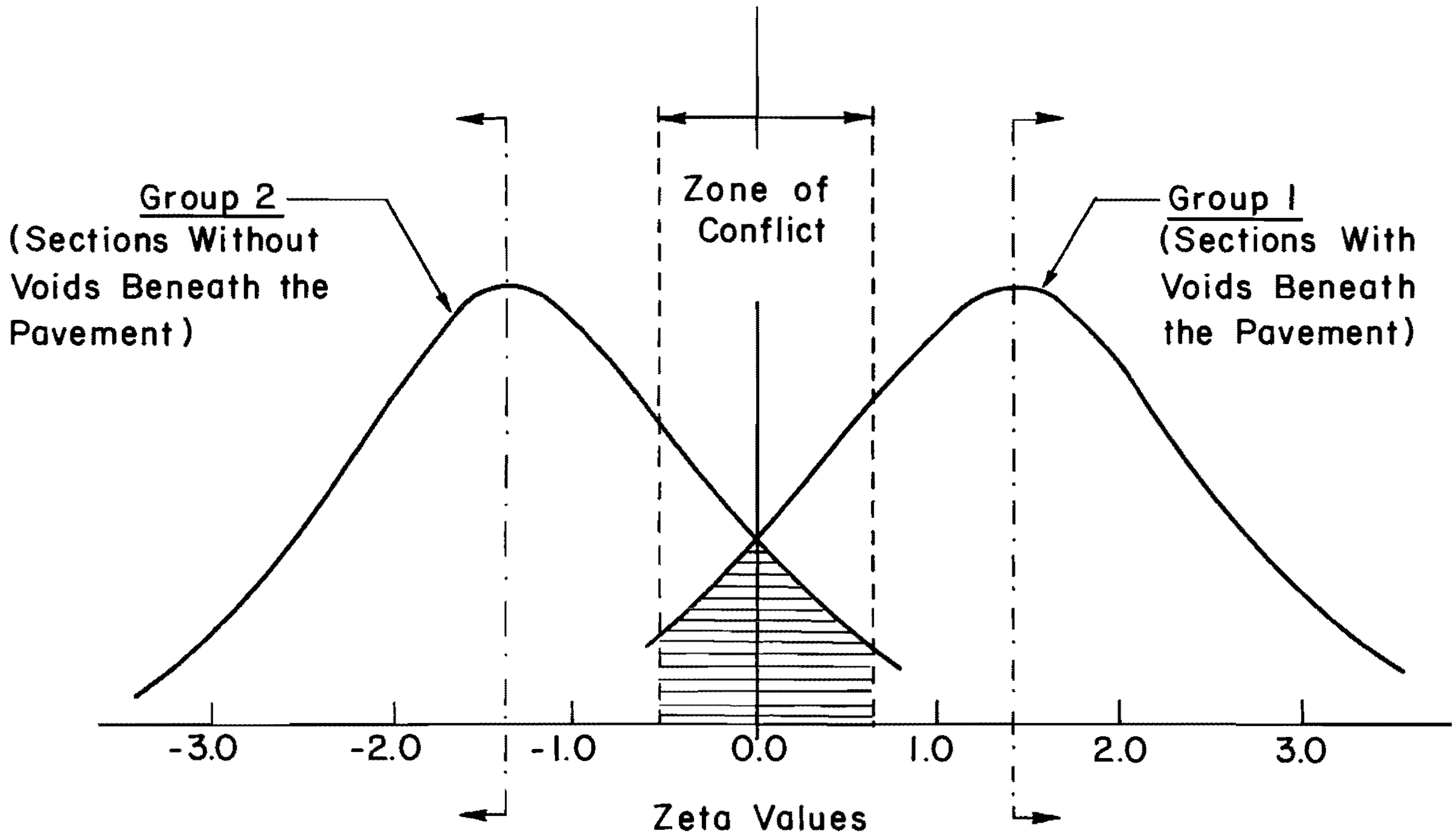

Fig 5.9. Graphic representation of the distribution of data for the development of a criterion to detect voids beneath pavements.

CHAPTER 6. CRCP PERFORMANCE BEFORE AND AFTER THE GROUTING PROCESS (COLUMBUS AND FAIRFIELD)

In order to evaluate the influence that the grouting process had in the Columbus and Fairfield projects, two criteria were selected; the first one and after the grouting process, whereas the second one considers the influence of grouting on the roughness of the pavement.

Since it was not practical to evaluate the entire length of the projects being undersealed, the decision to select two 2,500-foot (762-m) test sections on each project was made, as shown on Fig 6.1. The basic criteria for choosing these sections were minimal grade changes along the 2,500 feet, uniform soil conditions, and uniform cross section.

The limits for the test sections on the respective highways are presented in Table 6.1. These limits are shown in terms of both mile posts and station numbers. The roadway directions are also shown.

It is important to point out that, since this project was done several years ago, the data available in most of the cases do not have the format required to accomplish an approachable evaluation of the projects. To illustrate this point, only the deflection measurements recorded at 3 feet from the edge were available; these cannot be considered to reflect the real conditions of the project. As was concluded in Chapter 5, the optimum position at which the deflection measurements should be recorded is at one foot from the edge, since this position the highest sensitivity is obtained at this position.

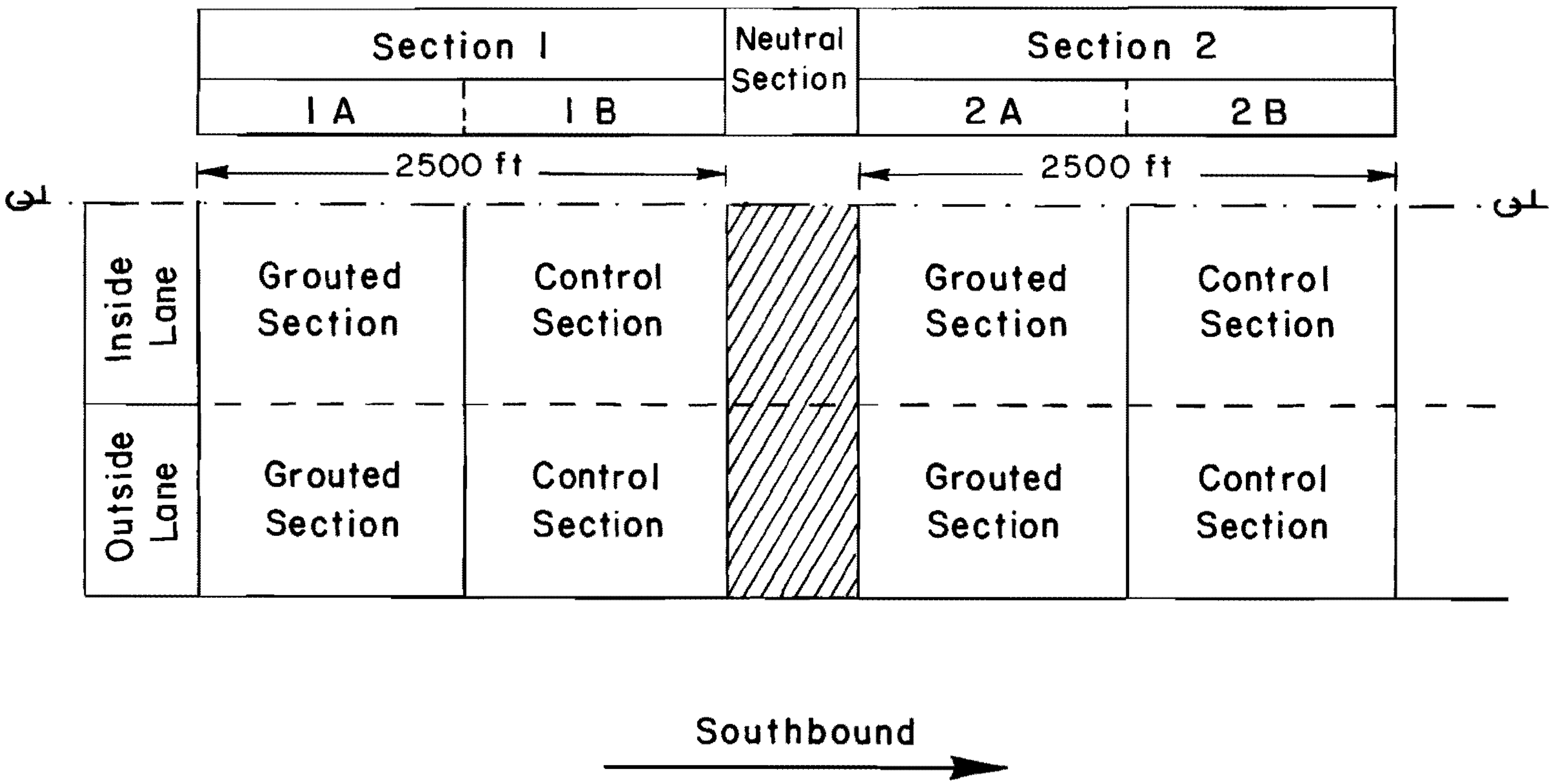

Fig 6.1. Layout of test sections for Columbus and Fairfield projects.

TABLE 6.1. LIMITS FOR THE TEST SECTIONS FOR COLUMBUS AND FAIRFIELD PROJECTS IN TERMS OF MILE POSTS AND STATION NUMBER

Location	Section	Mile Post	Section
IH 10 Columbus	1	700.75 to 701.22	221+54 to 245+50
Travel eastbound	2	704.6 to 705.1	427+50 to 452+49
IH 45 Fairfield	1	191.9 to 191.3	577+70 to 552+70
Travel southbound	2	190.7 to 190.1	521+02 to 496+02

District 13 IH 10 (Columbus) Test Sections

Test Section	Station	Grout Applied
1A	221+50 - 234+00 EBL	Yes
1B	234+00 - 246+50 EBL	No
2A	427+50 - 440+00 EBL	Yes
2B	440+00 - 452+50 EBL	No

District 17 IH 45 (Fairfield) Test Sections

Test Section	Station	Grout Applied
1A	577+70 - 565+20 SBL	No
1B	565+20 - 552+70 SBL	Yes
2A	521+02 - 508+52 SBL	No
2B	508+52 - 496+02 SBL	Yes

Appendix B presents the data available on the Columbus and Fairfield projects regarding condition surveys done before and after the grouting operation. Finally, in Appendix C, the summary data obtained using the VERTAC computer program (Ref 11), regarding the roughness of the pavements, are presented.

EVALUATION WITH DYNAFLECT DEFLECTIONS

In regard to the Columbus project (District 13, IH-10), it can be observed in Fig 6.2 that an improvement of 93 percent in the number of deflections recorded before and after the grouting process was achieved. Nonetheless, regarding the control section (Fig 6.3), a correction due to moisture at the subsurface of approximately 67 percent is required. Therefore, a net improvement of 26 percent in Dynaflect deflections can be considered as the benefit to the pavement achieved due to the grout applied beneath the pavement.

Regarding the Fairfield project (District 17, IH-45), an improvement of about 47 percent can be noticed in the deflections recorded before and after the grouting process, as shown in Fig 6.4. However, net improvement cannot be determined because there was no information available concerning the effect of weather conditions on Dynaflect deflections for this project.

EVALUATION WITH PROFILOMETER DATA

The scope of this section is to evaluate the influence of the grouting process on pavement roughness. For this purpose, computer program VERTAC was used (Ref 11). This program computes various roughness indices from a road profile, including the Serviceability Index (SI) used by the Texas State Department of Highways and Public Transportation (SDHPT) for Maysmeter

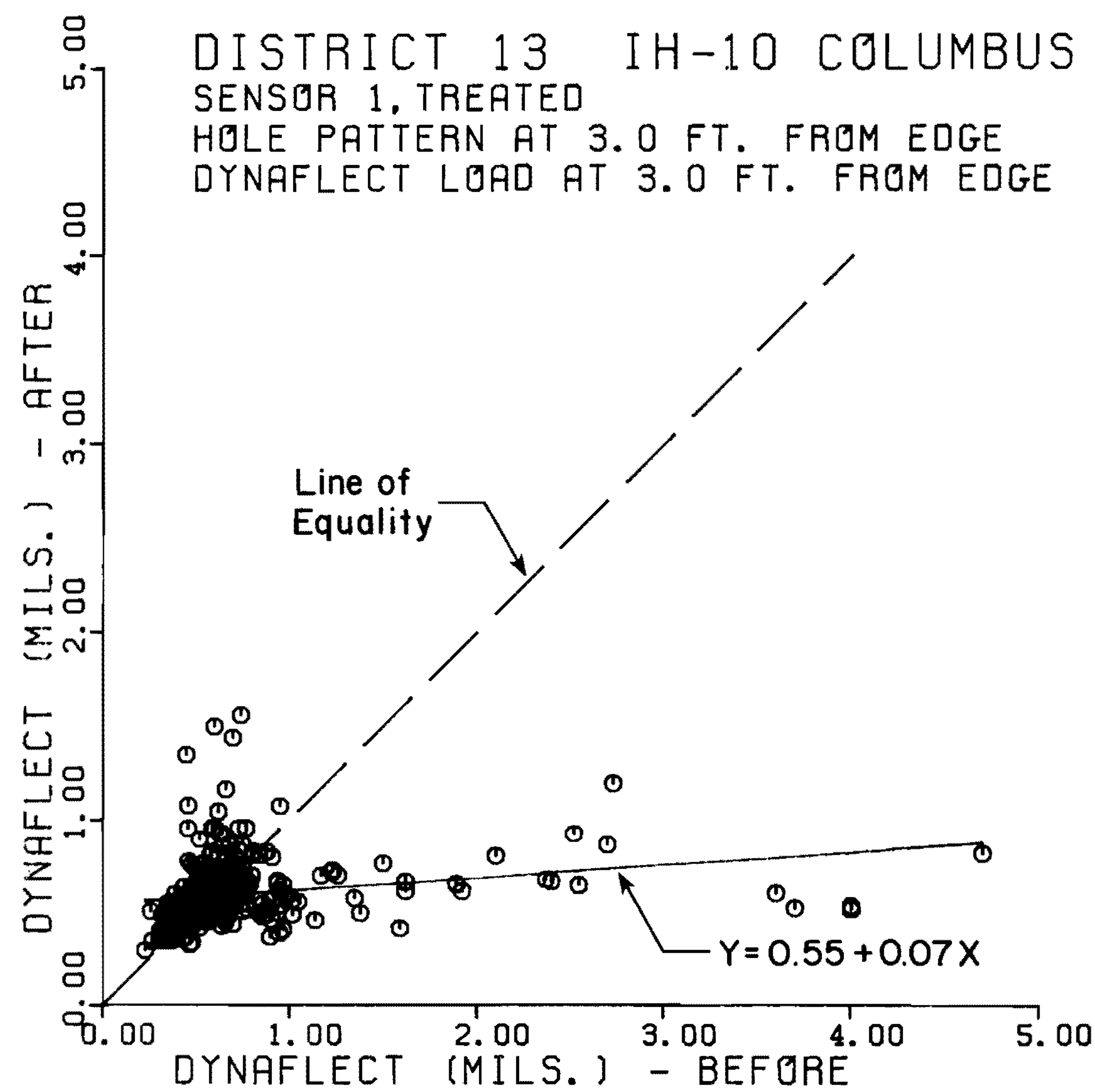

Fig 6.2. Columbus deflections recorded before and after the grouting process. Regression equation is applicable only for the range of data shown.

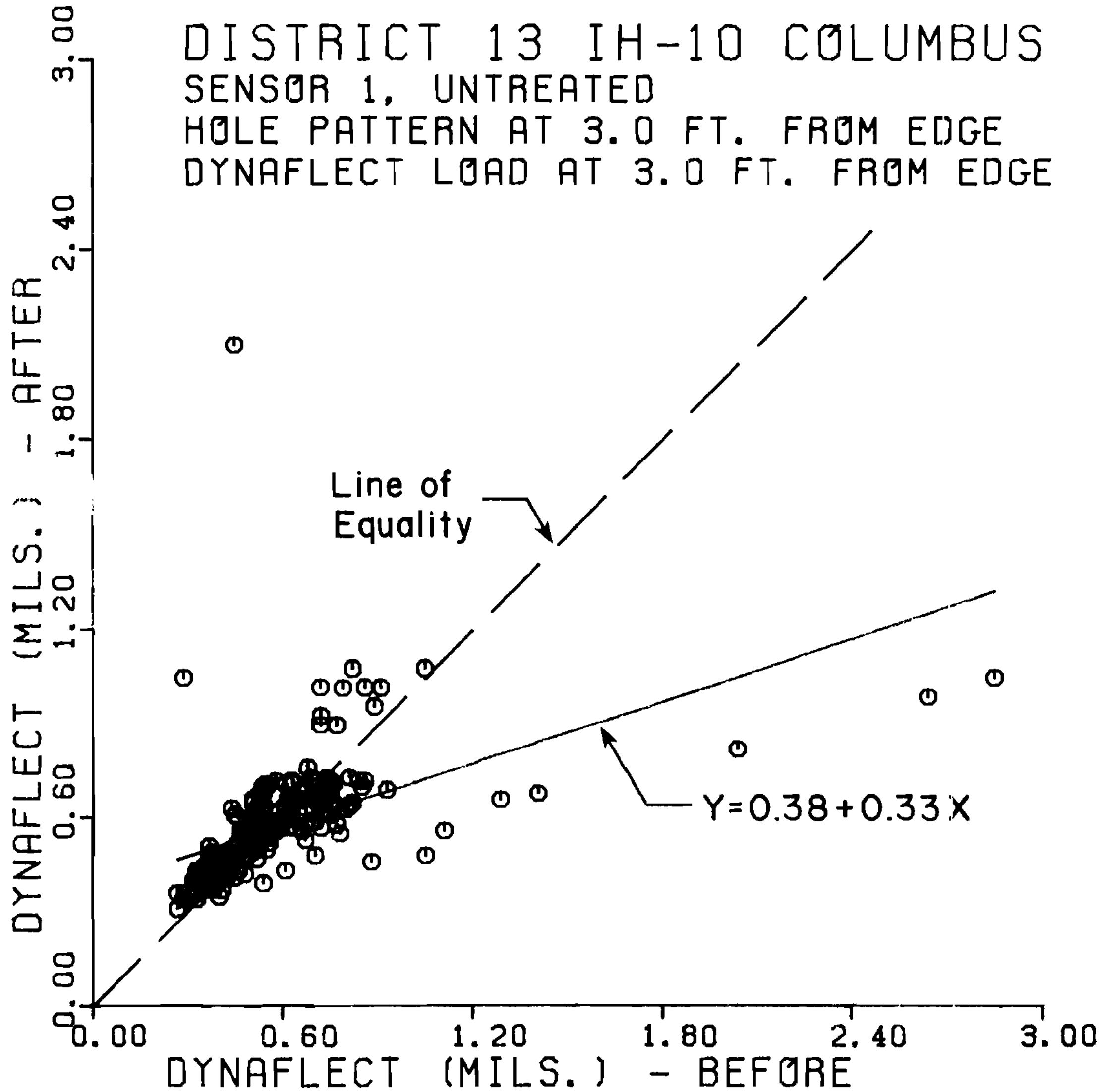

Fig 6.3. Columbus control section. District 13, IH-10. Regression equation is applicable only for the range of data shown.

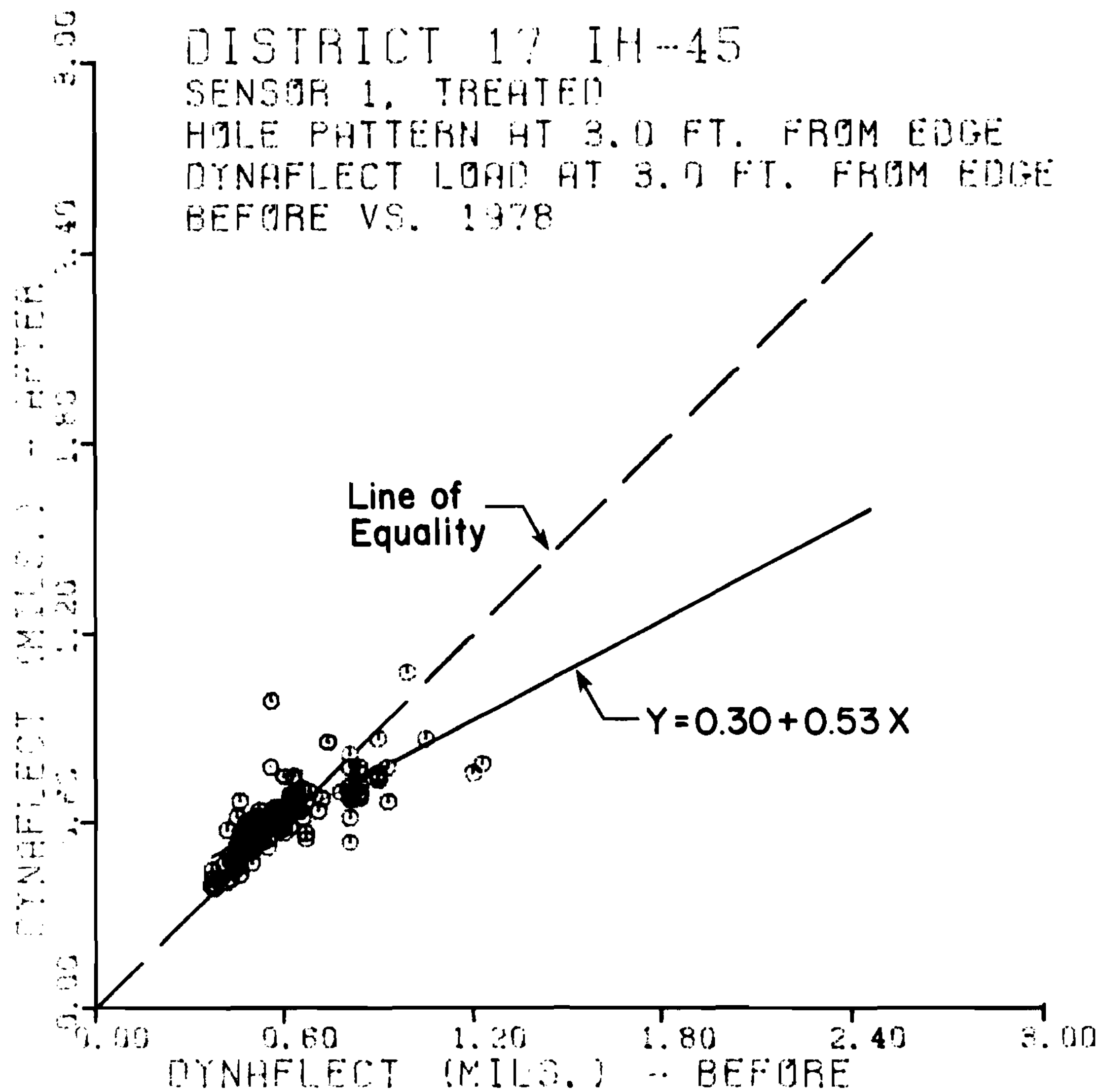

Fig 6.4. Fairfield deflections recorded before and after the grouting process. Regression equation is applicable only for the range of data shown.

calibration. The program judges the pavement's relative roughness at different wave lengths.

Figures 6.5 and 6.6 provide graphs for the Columbus and Fairfield projects in which the Serviceability Index (SI) and the wave length (feet) of the pavement before and after the grout was applied are plotted.

Analyzing the results obtained from the VERTAC computer program for both the Columbus and Fairfield projects, considering the before and after grouting conditions, the following points were noticed:

(1) A student's t test analysis with a 90 percent confidence level showed that there was not a significant difference between the means of the serviceability values obtained before and after the grouting.

(2) It was observed that, for a wave length of 20 feet, a decrease in the serviceability level of the pavement was produced, possibly due to minor lifting of the slab (Figs 6.5 and 6.6).

As can be noticed on these projects, the lack of procedures and of specifications for when a grouting operation is performed may provide negative results for the pavement, instead of the benefits expected from a grouting operation.

In order to avoid negative consequences from the grouting operation, the following points have to be very carefully considered:

(1) Special attention should be given to avoiding slab lifting during the grouting process. Elevation of the slab should be monitored each time the mix is pumped to determine if there are changes.

(2) The pressure at which the grout is pumped has to be checked. Lack of pressure may allow incomplete filling of the void.

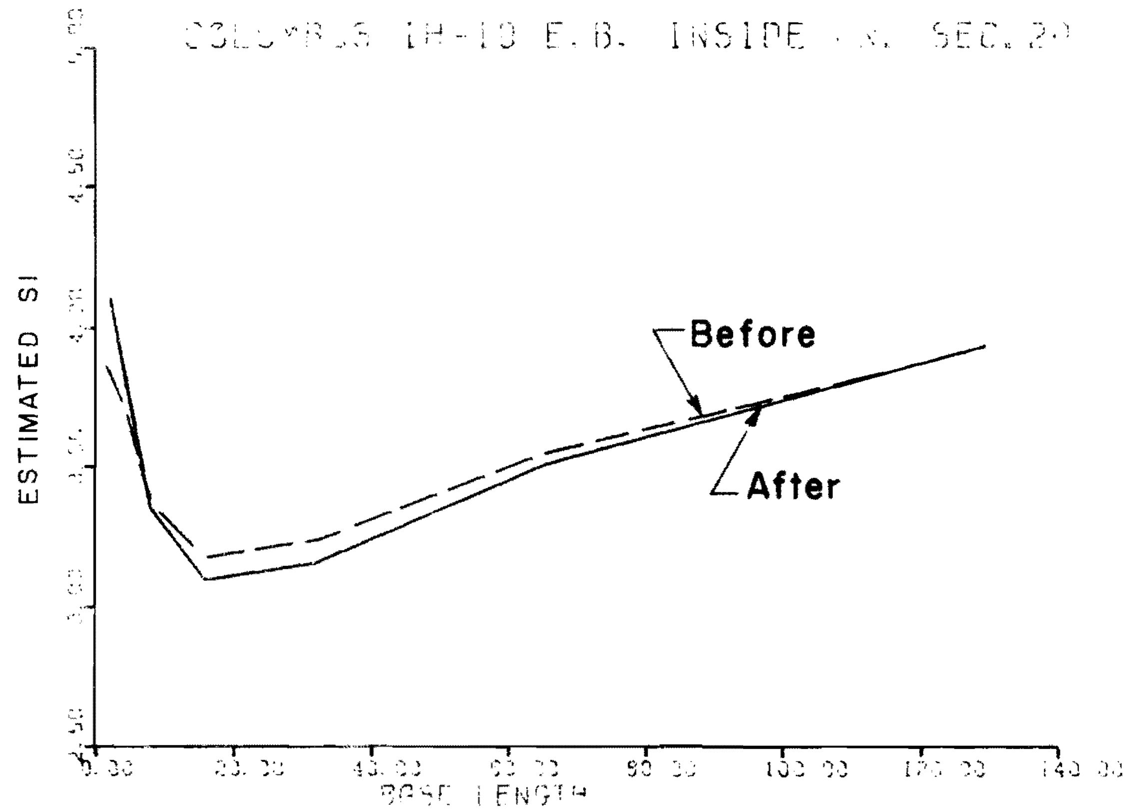

Fig 6.5. Pavement serviceability for different base lengths. Columbus, IH-10, District 13.

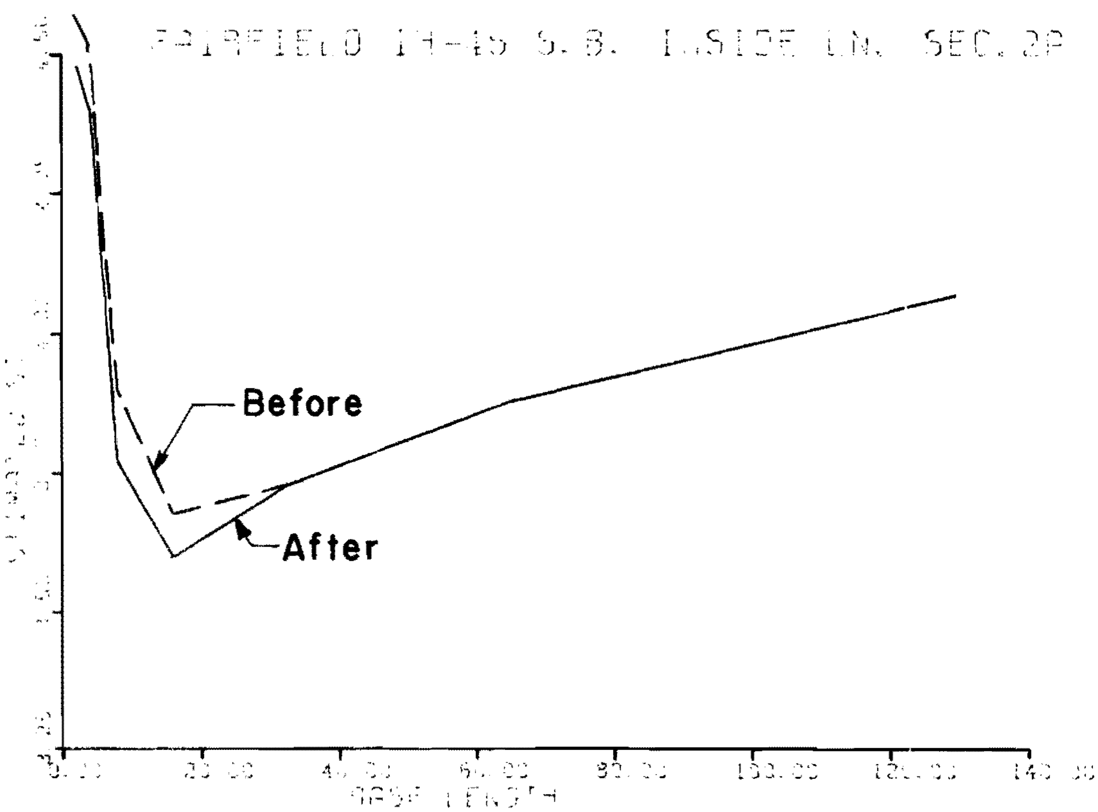

Fig 6.6. Pavement serviceability for different base lengths. Fairfield, IH-45, District 17.

SUMMARY

In this chapter an evaluation of the grouting process performed on the Columbus and Fairfield projects was presented. For this purpose, Dynaflect deflection measurements before and after the grouting operation, as well as profilometer data using the VERTAC computer program, were utilized. Special attention was given to the consequences of grouting without following the procedures and specifications required.

CHAPTER 7. DISCUSSION OF RESULTS

In the previous chapters, several analyses regarding the effect of voids beneath the pavement, the experiment carried out on the Victoria project, proposed techniques for void detection, and grouting operations, as well as the benefits to the pavement obtained from the correct application of these techniques, have been analyzed. In addition, an evaluation using Dynaflect deflections and profile data on the grouting operation performed several years ago on the Columbus and Fairfield projects were included. In this section, a discussion of the results and the way in which they were obtained is presented.

The major question at this point is "What are the benefits obtained due to the grouting?"

An analysis can be made regarding the benefits in terms of asphalt concrete thickness when an overlay is to be placed. In addition, an economic analysis of this approach is made below.

To determine the benefits obtained when an improvement in deflection is achieved, a slope fitting basin program, along with the RPRDS-1 computer program (Ref 12), was utilized.

Based on the average deflection measurements recorded before and after the grouting operation, the characterization of the pavement in terms of modulus of elasticity was determined using a slope fitting basin computer program.

Since deflections were taken close to the pavement edge both before and after the grout injection, they must be corrected to obtain the equivalent deflections for the center of the slab. It must be pointed out that deflections at the center of the slab are used to characterize the modulus of elasticity of the different pavement layers (Ref 13). Approximate corrections factors to obtain equivalent deflections at the center of the slab were developed from the information generated in Ref 13. Mean Dynaflect deflections and resulting moduli of elasticity are given in Table 7.1.

The before-grouting condition can be taken into account in the RPRDS-1 program by using an adequate critical stress factor, which obviously must be greater than the value considered for the after-grouting condition. These critical stress factors were obtained from an analysis of the maximum stresses for the various void sizes and subgrade K-values considered in Ref 13.

With this information ad the information presented in Table 7.2, an overlay design for the conditions before and after the grouting operation was developed using the RPRDS-1 computer program.

Tables 7.3 and 7.4, presents the results obtained from the RPRDS-1 for the conditions before and after the grouting experiment, respectively. From these results, it is important to point out that the overlay thickness required before the grout was applied is 6 inches (see line 7 on Table 7.3), whereas the overlay thickness required after the grout was applied is 5 inches (see line 7 on Table 7.4). Thus, a 1-inch reduction in asphalt overlay thickness was achieved. Furthermore, the total number of 18-kip ESAL cycles from the time the analysis is made to the year of the first overlay placement is increased from 1.08 to 3.19 million by injection of the grout to fill voids underneath the existing pavement.

TABLE 7.1. CHARACTERIZATION OF THE PAVEMENT LAYERS USING THE MEAN DYNAFLECT DEFLECTIONS AT THE CENTER OF THE SLAB

Mean Dynaflect Deflections at the Center of the Slab, mils	Moduli of Elasticity from the Slope Fitting Basin Program, psi	
$W_1 = 0.39$	$E_1 = 5,200,000$	Concrete Slab
$W_2 = 0.34$	$E_2 = 450,000$	Cement Treated Base
$W_3 = 0.29$	$E_3 = 27,000$	Natural Soil
$W_4 = 0.23$		
$W_5 = 0.20$		

TABLE 7.2. DATA USED FOR THE OVERLAY DESIGN FOR THE CONDITIONS BEFORE AND AFTER THE GROUTING OPERATION

RPRDS1 - Rigid Pavement Rehabilitation Design System - Version 1
November 1980

RPRDS INPUT SUMMARY

Note - Variable Numbers correspond to those in the RPRDS User's Manual

Project Description

1.1 Title
1305 US 59 Victoria Project Overlay Design

Original Pavement

2.1	Surface type	CRCP
2.2	Concrete shoulder	NO
2.3	No. of lanes (one direction)	2
2.4	No. of pavement layers	3
3.1	Project length, miles	.19
3.2	Lane width, feet	12.0
3.3	Total shoulder width, feet	10.

Pavement Structure

Layer No.	4.0 Thickness (in.)	6.0 Poisson's Ratio
1	8.0	5200000.
2	6.0	450000.
3	Semi-infinite	27000.

7.1	Concrete flexural strength, psi	690.
7.2	Critical stress factor	
	after grouting	1.43
	before grouting	2.05
7.3	Concrete stifffness after cracking, psi	800000.
8.1	No. of existing defects per mile	15.
8.2	Cost of repairing a defect, dol	460.
8.3	Rate of defect development, no./yr/mile	2.

(continued)

TABLE 7.2. (cont)

Traffic Variable

9.1	Average daily traffic (ADT)	20000.
9.2	ADT growth rate, percent	6.00
9.3	Initial yearly 18-kip ESAL, millions	.980
9.4	18-kip ESAL growth rate, percent	7.40
9.5	Directional distribution factor, percent	50.0
9.6	Lane distribution factor, percent	90.0

Time Constraints

10.1	Analysis period, years	20.0
10.2	Minimum time between overlays, years	0.0
10.3	Maximum allowable years of heavy maintenance after loss of structural load-carrying capacity	0.0

Remaining Life Variables

11.1	No. of original pavement remaining life values to consider	2
11.2	Minimum existing pavement remaining life below which a bonded PCC overlay may not be placed	0
11.3	Values of original pavement remaining life at which first overlay may be placed	

No.	Remaining Life (percent)
1	40.
2	0.

12.1	No. of first overlay remaining life values to consider	0
12.2	Values of first overlay remaining life at which second overlay may be placed (none)	

(continued)

TABLE 7.2. (cont)

Overlay Characteristics

13.0 Types of first overlay to consider

.1	ACP	- Yes
.2	Bonded CRCP	- No
.3	Unbonded CRCP	- No
.4	Bonded JCP	- No
.5	Unbonded JCP	- No

14.0 Types of second overlay to consider

.1	ACP	- No
.2	CRCP	- No
.3	JCP	- No

15.0 No. of different thicknesses to consider

.1	ACP first overlay	- 8
.2	ACP second overlay	- 0
.3	PCC overlay	- 0

16.0 ACP first overlay thicknesses, inches

.1	3.0
.2	4.0
.3	4.5
.4	5.0
.5	5.5
.6	6.0
.7	7.0
.8	8.0

17.0 ACP second overlay thicknesses, inches

(none)

18.0 PCC overlay thicknesses, inches

(none)

19.1	Allowable total overlay thickness, inches	20.0
19.2	Average level-up thickness, inches	1.0
19.3	Bond breaker thickness, inches	0.0

(continued)

TABLE 7.2. (cont)

20.1	ACP overlay design stiffness, psi	400000.
20.2	Poisson's ratio, ACP overlay	.30
20.3	PCC overlay design stiffness, psi	0
20.4	Poisson's ratio, PCC overlay	0
20.5	Bond breaker stiffness, spi	0
20.6	Poisson's ratio, bond breaker	0
21.1	No. of overlay flexural strengths to consider	0
21.2	No. which identifies which flexural strength in the list to use for a bonded PCC overlay	0
22.2	PCC overlay flexural strength(s), psi	0
	(none)	

TABLE 7.3. OVERLAY DESIGN OBTAINED FROM RPRDS1 COMPUTER PROGRAM FOR THE CONDITIONS BEFORE THE GROUTING OPERATION

RPRDS1 - Rigid Pavement Rehabilitation Design System - Version 1
November 1980

Project Description
1305 US 59 Victoria Project Overlay Design (Before Grouting)

Optimal Strategy No. 1

	Component of Strategy	Quantity
1.	Existing pavement remaining life at 1st overlay, percent	0
2.	Year of 1st overlay placement	2.
3.	Total 18-kip ESAL cycles (now till 1st overlay), millions	1.08
4.	Cost of maintaining existing pavement, dol/sq yd	.61
5.	1st overlay type	ACP
6.	Type of shoulder	FLEX
7.	1st overlay thickness, inches	6.0
8.	PCC Flexural strength of 1st overlay, psi	0
9.	Fatigue life after 1st overlay, years	20.0
10.	Fatigue life after 1st overlay, 18-kip ESAL in millions	15.84
11.	1st overlay construction cost, dol/sq yd	10.24
12.	1st overlay traffic delay cost, dol/sq yd	0.44
13.	1st overlay maintenance cost, dol/sq yd	0.44
14.	1st overlay remaining life at 2nd overlay, percent	----
15.	Year of 2nd overlay placement	----
16.	Total 18-kip ESAL cycles (now till 2nd overlay), millions	----
17.	2nd overlay type	----
18.	Type of shoulder	----
19.	2nd overlay thickness, inches	----
20.	PCC Flexural strength of 2nd overlay, psi	----
21.	Fatigue life after 2nd overlay, years	----
22.	Fatigue life ater 2nd overlay, 18-kip ESAL in millions	----
23.	2nd overlay construction cost, dol/sq yd	----
24.	2nd overlay traffic delay cost, dol/sq yd	----
25.	2nd overlay miantenance cost, dol/sq yd	----

TABLE 7.3. (cont)

	Component of Strategy	Quantity
26.	Value of extended life, dol/sq yd	0
27.	Overlay salvage value, dol/sq yd	.32
28.	Total net present value of strategy, dol/sq yd	11.40

TABLE 7.4. OVERLAY DESIGN OBTAINED FROM RPRDS1 COMPUTER PROGRAM FOR THE CONDITIONS AFTER THE GROUTING OPERATION

RPRDS1 - Rigid Pavement Rehabilitation Design System - Version 1, November 1980

Project Description

1305 US 59 Victoria Project Overlay Design (After Grouting)

Optimal Strategy No. 1

	Component of Strategy	Quantity
1.	Existing pavement remaining life at 1st overlay, percent	0
2.	Year of 1st overlay placement	6.
3.	Total 18-kip ESAL cycles (now till 1st overlay), millions	3.19
4.	Cost of maintaining existing pavement, dol/sq yd	.82
5.	1st overlay type	ACP
6.	Type of shoulder	FLEX
7.	1st overlay thickness, inches	5.0
8.	PCC Flexural strength of 1st overlay, psi	0.0
9.	Fatigue life ater 1st overlay, years	20.1
10.	Fatigue life after 1st overlay, 18-kip ESAL in millions	15.74
11.	1st overlay construction cost, dol/sq yd	7.95
12.	1st overlay traffic delay cost, dol/sq yd	.36
13.	1st overlay maintenance cost, dol/sq yd	.17
14.	1st overlay remaining life at 2nd overlay, percent	---
15.	Year of 2nd overlay placement	---
16.	Total 18-kip ESAL cycles (now till 2nd overlay), million	---
17.	2nd overlay type	---
18.	Type of shoulder	---
19.	2nd overlay thickness, inches	---
20.	PCC Flexural strength of 2nd overlay, psi	---
21.	Fatigue life after 2nd overlay, years	---
22.	Fatigue life after 2nd overlay, 18-kip ESAL in millions	---

TABLE 7.4. (cont)

	Component of Strategy	Quantity
23.	2nd overlay construction cost, dol/sq yd	---
24.	2nd overlay traffic delay cost, dol/sq yd	---
25.	2nd overlay maintenance cost, dol/sq yd	---
26.	Value of extended life, dol/sq yd	0
27.	Overlay salvage value, dol/sq yd	.29
28.	Total net present value of strategy, dol/sq yd	9.02

The total net present values of the optimal strategies are 11.40 and 9.02 dollars per square yard, for before and after the grouting operation, respectively. The value corresponding to the after-grouting condition does not take into account the cost of grouting.

The approximate current cost of the grouting operation, considering a 6-foot lane width is $12,000 per mile. In the Victoria project, grouting was applied only in the right lane. In order to determine the average cost of grouting per square yard, the total width of the pavement (24 feet) must be considered.

Approximate Current Cost of the Grouting Operation on CRCP = $0.85 Per Square Yard

Total Net Present Value of Optimal Stragegy Considering the Grouting Operation = 9.02 + 0.85 = $9.87/Square Yard

It can be concluded that in this particular pavement section, injection of grout would represent a reduction in the total net present value of $1.53/square yard, or approximately 13 percent per square yard.

CHAPTER 8. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Based on the results obtained in this study, it may be stated that voids beneath the pavement can be successfully detected and filled. It has been demonstrated that correct application of the techniques proposed for void detection and for grouting operations can improve the structural capacity of the pavement, restoring the full support conditions assumed in the design.

An evaluation of the analyses and results presented in this report leads to the following conclusions:

(1) Voids beneath a pavement will significantly reduce the life of the pavement depending on void size, pavement thickness, support conditions, load position and load configuration (see Table 2.4).

  (a) For example, loads near the edge may reduce pavement life by 70-75 percent for a void size of 108 square feet (see Table 2.2), and

  (b) A 32-kip tandem axle load will be much more damaging to a pavement than an 18-kip single axle load, for a void condition. The reverse is true for a full support condition (see Fig 2.5).

(2) Considering conclusion 1 and the fact that the number of tandem axle trucks is increasing rapidly on Texas highways, voids beneath the pavement must be located and filled to extend the pavement life.

(3) The Dynaflect deflections recorded at one foot from the edge are more sensitive to areas in which voids exist beneath the pavement (see Fig 5.8).

(4) An anlaysis using Dynaflect deflections and field observations of pumping has proved to be the optimal procedure for void area detection (see Eq 5.3).

(5) The grout applied just beneath the pavement slab provides the optimum benefits for the structural capacity of the pavement. A

net improvement of 41 percent in the deflections recorded before and after the grout was applied at Victoria was obtained, whereas only minimum improvement was observed for grout beneath the subbase.

(6) A comparison of before and after deflection measurements may be used to determine the effectiveness of filling the voids (see Fig 2.6 and Table 2.5).

(7) Taking into account the information obtained at Victoria, an overlay design using the RPRDS1 computer program (Ref 12) showed that the overlay required for a 20-year design period before the grout is applied is 6 inches, whereas the overlay thickness required once the grout has been applied is 5 inches, which represents a one-inch difference in the overlay thickness required.

(8) Using information from conclusion 7 and the cost information provided by the Texas State Department of Highways and Public Transportation and a private construction company, a reduction in the total net present value of the optimal design strategy of about 13 percent is obtained when a grouting operation is performed.

(9) Regarding the riding quality of the pavement, there was not any direct correlation between the application of grout and the change in the level of serviceability. As a word of caution, it is important to state that special care must be taken during the grouting process to avoid slab lifting, which could decrease the riding quality and service life of the pavement.

RECOMMENDATIONS

By successfully locating void areas in advance of failures and correcting them, the failure problem can be drastically reduced and the life of the pavement extended. Since it is not possible to run a detailed deflection survey of the pavement, the procedure described in this report could be applied primarily in areas where evidence of pumping indicates that there is a possibility that a void exists beneath the pavement.

It is recommended that additional work be conducted in the areas of void detection and grouting. Likewise, monitoring of the pavement section in which grout is applied would generate very valuable information about the long-term effect of grouting on pavement performance and structural capacity.

Additionally, the susceptibility to pumping of the various types of base and subbase used in Texas should be analyzed.

Finally, a different method of measurement and payment for contract grouting could be developed, because, in the present method, large quantities of grouting are injected to fill voids beneath the pavement that are generally small and require little grout.

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APPENDIX A

RECOMMENDED PROCEDURES AND FORMS FOR CARRYING OUT GROUTING PROJECTS

APPENDIX A. RECOMMENDED PROCEDURES AND FORMS FOR CARRYING OUT GROUTING PROJECTS

RECOMMENDED PROCEDURE

In order to define the steps involved in the procedure for locating voids beneath a pavement, filling voids, and evaluating the results, the procedure is divided into the following steps:

(1) analysis of data,

(2) execution of the grouting operation, and

(3) evaluation of results.

Analysis of Data

In order to locate the areas with probability of voids, first a condition survey recorded from the project has to be analyzed. In this analysis special attention should be given to areas in which patches, punchouts, and evidence of pumping exist. Having identified these areas, it is necessary to make a combined analysis (as presented in Chapter 5) of normalized deflections of sensors 1 and 5 of the Dynaflect device recorded at one foot from the edge and of field observations of pumping. From this analysis, the specific areas with voids beneath the pavement can be identified. After the areas with voids have been identified, a pattern defining the location of the holes in which the grout will be injected needs to be developed. It is important to remember that the optimum benefits are obtained when the grout is applied just beneath the pavement and at one foot from the edge. Finally, a profile of the pavement has to be obtained before the grouting operation. This information will be used during the evaluation of results.

Execution of the Grouting Operation

Once the areas have been identified and the hole pattern defined, the next step is to locate these areas in the field. For this, special care should be given to marking the separation between holes and the distance from the edge at which the holes should be drilled, in order to avoid misinterpretations. The depth to which the holes are drilled must be very carefully controlled, to insure that the grout will be pumped just beneath the pavement. During the execution of the grouting operation, the slab has to be continuously monitored to avoid slab lifting. If that happens, the operation must be stopped at that point.

Evaluation of Results

After the grouting operation is finished, Dynaflect deflection measurements, as well as profile measurements of the pavement, have to be recorded at the same locations approximately one week later. Then the evaluation is achieved. First the deflection measurements before and after the grouting operation are compared. From this, it can be determined whether or not any improvement in the deflections was obtained. Second the profile measurements recorded before and after the experiment are compared to determine if there was any slab lifting, which would represent a reduction in the serviceability level of the pavement.

FORMS RECOMMENDED FOR GROUTING PROJECTS

Based on the recommended procedure for carrying out grouting projects presented in the previous section, the forms presented below were developed for gathering the main data required. These forms deal with void area selection, collection of data during the project construction, and evaluation of results.

Figure A.1 satisfies the data requirements, following the proposed method for void area selection and, later, the evaluation of results. The procedure for filling out the form beginning with the identification of the working section; the corresponding station is written in column 1. Following that, a condition survey of the section is made, with cracks, pumping, minor spalling, severe spalling, punchouts, and patches represented in the second column. The final step is to plot the normalized Dynaflect deflections in the right section of the form. Analyzing the data gathered so far, we can determine the areas in which there is a high probability of finding a void beneath the pavement.

Figure A.2 presents a form for data collection during the construction of the grouting project. Basically this form will include the same information as that proposed in Fig 4.10, which is for experimental purposes, but without the data regarding the adjacent pit and the distress manifestations, since those are not useful in this step. Finally, the evaluation of results should be made again using the form presented in Fig A.1. In this case the evaluation of the grouting process is done plotting the dynaflect deflections of sensor 1 recorded at 12 inches from the edge before and after the grouting was done. The results obtained will become evident in analyzing if there was any improvement between the deflections before and after the grouting.

Page ___/___

DISTRICT __________ COUNTY __________ HIGHWAY __________ DATE __________

STATION	CONDITION SURVEY	NORMALIZED DYNAFLECT DEFLECTIONS At 12" from the Edge $\frac{W_1 - W_5}{W_1}$, $W_{1(B)}$, $W_{1(A)}$
		0.0 0.2 0.4 0.6 0.8 1.0

Fig A.1. Form proposed for evaluation of data before and after the project construction.

Page __ / __

DISTRICT __________ COUNTY __________ HIGHWAY __________

DATE __________

TEMPERATURE ________

EXISTING PAVEMENT Material Type — Layer Thick	Mix Characteristics
— — — —	

Description of Location:
From Station -
To Station -

STATION	Deep or Shallow	Proposed Hole Pattern	Continuity	Grouting Pressure	Time Grouting	Slab Behavior	Comments & Remarks

Fig A.2. Form proposed for data collection during the construction of the grouting project.

APPENDIX B

SUMMARY OF THE CONDITION SURVEYS DONE BEFORE AND AFTER THE GROUTING OPERATION FOR COLUMBUS AND FAIRFIELD PROJECTS

COLUMBUS
*CRCP UNDERSEALING PROJ. OUTSIDE LN. TREATED SECT. U13-1T A
*STATION 221+50 TO 227+75
13 271 1 9 1333IH-10 COLORADO

221+50	227+75	DEC-77	101	17	2	0	0	0	0	0	1	34	0
		APR-81	118	48	10	4	0	0	0	0	1	30	0

COLUMBUS
*CRCP UNDERSEALING PROJ. OUTSIDE LN. TREATED SECT. U13-1T B
*STATION 227+75 TO 234+00
13 271 1 9 1333IH-10 COLORADO

227+75	234+00	DEC-77	108	19	3	1	0	0	0	0	0	89	10
		APR-81	127	41	10	1	0	2	0	0	1	13	97

COLUMBUS
*CRCP UNDERSEALING PROJ. OUTSIDE LN. NONTREATED SECT. U13-1N A
*STATION 234+00 TO 240+25
13 271 1 9 1333IH-10 COLORADO

234+00	240+25	DEC-77	127	0	0	1	0	0	0	0	2	28	40
		APR-81	127	44	5	1	0	0	0	0	3	0	0

COLUMBUS
*CRCP UNDERSEALING PROJ. OUTSIDE LN. NONTREATED SECT. U13-1N B
*STATION 240+25 TO 246+50
13 271 1 9 1333IH-10 COLORADO

240+25	246+50	DEC-77	157	0	0	1	0	0	0	0	0	15	0
		APR-81	158	53	12	3	0	0	1	2	2	21	0

SMALL SECTIONS CONDITION SURVEY

COLUMBUS

CRCP UNDERSEALING PROJ. OUTSIDE LN. TREATED SECT. U13-1T A
STATION 221+50 TO 227+75

DIST: 13 CFTR NO: 1303 HIGHWAY: IH-10 COUNTY: COLORADO
SECT: 1 CONTROL: 271 JOB NO: 9 REPORT DATE: 21 JAN 82

SEGMENTS -

FR: 221+50 LENGTH: 625 FT
TO: 227+75 COMMENTS:

SURVEYS -	DEC-77	APR-81
CRACKS /NO.PER MI:	101/ 853.2	118/ 996.9
MIN SPALL/NO.PER MI:	17/ 143.6	48/ 405.5
SEV SPALL/NO.PER MI:	2/ 16.9	10/ 84.5
MPO. <20 /NO.PER MI:	0/ 0.0	4/ 33.8
MPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0
SPO. <20 /NO.PER MI:	0/ 0.0	0/ 0.0
SPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0
AC. PATCH/NO.PER MI:	0/ 0.0	0/ 0.0
PCC PATCH/NO.PER MI:	1/ 8.4	1/ 8.4
MINOR PUMPING FEET:	34	30
SEVERE PUMPING FEET:	0	0
FAILURES /NO.PER MI:	1/ 8.4	1/ 8.4

SMALL SECTIONS CONDITION SURVEY

COLUMBUS

CRCP UNDERSEALING PROJ. OUTSIDE LN. TREATED SECT. U13-17 R
STATION 227+75 TO 234+00

DIST: 13 CFTR NO: 1303 HIGHWAY: IH-10 COUNTY: COLORADO
SECT: 1 CONTROL: 271 JOB NO: 9 REPORT DATE: 21 JAN 82

SEGMENTS -

FR: 227+75 LENGTH: 625 FT
TO: 234+ 0 COMMENTS:

SURVEYS -	DEC-77	APR-81
CRACKS /NO.PER MI:	108/ 912.4	127/1072.9
MIN SPALL/NO.PER MI:	19/ 160.5	41/ 346.4
SEV SPALL/NO.PER MI:	3/ 25.3	10/ 84.5
MPO. <20 /NO.PER MI:	1/ 8.4	1/ 8.4
MPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0
SPO. <20 /NO.PER MI:	0/ 0.0	2/ 16.9
SPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0
AC. PATCH/NO.PER MI:	0/ 0.0	0/ 0.0
PCC PATCH/NO.PER MI:	0/ 0.0	1/ 8.4
MINOR PUMPING FEET:	89	13
SEVERE PUMPING FEET:	10	97
FAILURES /NO.PER MI:	0/ 0.0	3/ 25.3

SMALL SECTIONS CONDITION SURVEY

COLUMBUS

CRCP UNDERSEALING PROJ. OUTSIDE LN. NONTREATED SECT. U13-IN A
STATION 234+00 TO 240+25

DIST:	13	CFTR NO:	1303	HIGHWAY:	TH-10	COUNTY:	COLORADO
SECT:	1	CONTROL:	271	JOB NO:	9	REPORT DATE:	21 JAN 82

SEGMENTS -

FR: 234+ 0 LENGTH: 625 FT
TO: 240+25 COMMENTS:

SURVEYS -	DEC-77	APR-81
CRACKS /NO.PER MI:	127/1072.9	127/1072.9
MIN SPALL/NO.PER MI:	0/ 0.0	44/ 371.7
SEV SPALL/NO.PER MI:	0/ 0.0	5/ 42.2
MPO. <20 /NO.PER MI:	1/ 8.4	1/ 8.4
MPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0
SPO. <20 /NO.PER MI:	0/ 0.0	0/ 0.0
SPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0
AC PATCH/NO.PER MI:	0/ 0.0	0/ 0.0
PCC PATCH/NO.PER MI:	2/ 16.9	3/ 25.3
MINOR PUMPING FEET:	28	0
SEVERE PUMPING FEET:	40	0
FAILURES /NO.PER MI:	2/ 16.9	3/ 25.3

SMALL SECTIONS CONDITION SURVEY

COLUMBUS

CRCP UNDERSEALING PROJ. OUTSIDE LN. NONTREATED SECT. U13-1N B
STATION 240+25 TO 246+50

DIST: 13 CFTR NO: 1303 HIGHWAY: IH-10 COUNTY: COLORADO
SECT: 1 CONTROL: 271 JOB NO: 9 REPORT DATE: 21 JAN 82

SEGMENTS -

FR: 240+25 LENGTH: 625 FT
TO: 246+50 COMMENTS:

SURVEYS -	DEC-77	APR-81
CRACKS /NO.PER MI:	157/1326.3	158/1334.8
MIN SPALL/NO.PER MI:	0/ 0.0	53/ 447.7
SEV SPALL/NO.PER MI:	0/ 0.0	12/ 101.4
MPO. <20 /NO.PER MI:	1/ 8.4	3/ 25.3
MPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0
SPO. <20 /NO.PER MI:	0/ 0.0	0/ 0.0
SPO. >20 /NO.PER MI:	0/ 0.0	1/ 8.4
AC. PATCH/NO.PER MI:	0/ 0.0	2/ 16.9
PCC PATCH/NO.PER MI:	0/ 0.0	2/ 16.9
MINOR PUMPING FEET:	15	21
SEVERE PUMPING FEET:	0	0
FAILURES /NO.PER MI:	0/ 0.0	5/ 42.2

*FAIRFIELD SMALL SECTIONS COMPARING PRESSURE INJECTED AND NON-PRESSURE

17 675 2 5 1710IH 45 S.R. FREESTONE MAY 1980

571+45	577+70	1A	INJECTED	NO	MAY 80	159	35	6	0	0	0	0	0	0	0	0
					MAY 81	164	49	6	0	1	0	0	0	2	0	0
565+20	571+45	1B	INJECTED	NO	MAY 80	132	34	4	2	0	1	1	0	1	2	0
					MAY 81	167	47	7	2	0	1	1	0	2	2	3
558+95	565+20	1C	INJECTED	YES	MAY 80	119	40	1	1	0	2	0	0	0	0	30
					MAY 81	135	56	4	1	0	2	0	0	6	1	30
552+70	558+95	1D	INJECTED	YES	MAY 80	138	39	3	1	0	1	0	0	0	0	95
					MAY 81	142	58	5	1	0	1	0	0	1	2	96
514+77	521+02	2A	INJECTED	NO	MAY 80	136	53	1	0	0	0	0	0	0	0	0
					MAY 81	138	81	3	0	0	0	0	0	0	5	1
508+52	514+77	2B	INJECTED	NO	MAY 80	114	45	2	1	1	3	0	1	0	2	0
					MAY 81	129	53	10	1	2	3	0	1	3	7	4
502+27	508+52	2C	INJECTED	YES	MAY 80	126	46	7	4	0	0	0	2	0	0	0
					MAY 81	157	67	7	5	0	1	0	2	2	0	0
496+02	502+27	2D	INJECTED	YES	MAY 80	210	54	1	0	0	1	0	1	0	0	0
					MAY 81	229	72	1	0	0	1	0	1	2	0	0

SMALL SECTIONS CONDITION SURVEY

FAIRFIELD SMALL SECTIONS COMPARING PRESSURE INJECTED AND NON-PRESSURE

DIST: 17 CFTR NO: 1710 HIGHWAY: IH 45 S.B. COUNTY: FREESTONE
SECT: 2 CONTROL: 675 JOB NO: 5 REPORT DATE: 21 JAN 82

SEGMENTS -

FR: 571+45 LENGTH: 625 FT
TO: 577+70 COMMENTS:1A INJECTED NO

SURVEYS -	MAY 80	MAY 81	
CRACKS /NO.PER MI:	159/1343.2	164/1385.5	0/ 0.0
MIN SPALL/NO.PER MI:	35/ 295.7	49/ 414.0	0/ 0.0
SEV SPALL/NO.PER MI:	6/ 50.7	6/ 50.7	0/ 0.0
MPO. <20 /NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
MPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
SPO. <20 /NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
SPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
AC. PATCH/NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
PCC PATCH/NO.PER MI:	0/ 0.0	2/ 16.9	0/ 0.0
MINOR PUMPING FEET:	0	0	0
SEVERE PUMPING FEET:	0	0	0
FAILURES /NO.PER MI:	0/ 0.0	2/ 16.9	0/ 0.0

FR: 565+20 LENGTH: 625 FT
TO: 571+45 COMMENTS:1B INJECTED NO

SURVEYS -	MAY 80	MAY 81	
CRACKS /NO.PER MI:	132/1115.1	167/1410.8	0/ 0.0
MIN SPALL/NO.PER MI:	34/ 287.2	47/ 397.1	0/ 0.0
SEV SPALL/NO.PER MI:	4/ 33.8	7/ 59.1	0/ 0.0
MPO. <20 /NO.PER MI:	2/ 16.9	2/ 16.9	0/ 0.0
MPO. >2 /NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
SPO. <20 /NO.PER MI:	1/ 8.4	1/ 8.4	0/ 0.0
SPO. >20 /NO.PER MI:	1/ 8.4	1/ 8.4	0/ 0.0
AC. PATCH/NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
PCC PATCH/NO.PER MI:	1/ 8.4	2/ 16.9	0/ 0.0
MINOR PUMPING FEET:	0	0	0
SEVERE PUMPING FEET:	0	3	0
FAILURES /NO.PER MI:	3/ 25.3	4/ 33.8	0/ 0.0

SMALL SECTIONS CONDITION SURVEY
(CONT.)

FR: 558+95 LENGTH: 625 FT
TO: 565+20 COMMENTS:1C INJECTED YES

SURVEYS -	MAY 80	MAY 81	
CRACKS /NO.PER MI:	119/1005.3	135/1140.5	0/ 0.0
MIN SPALL/NO.PER MI:	40/ 337.9	56/ 473.1	0/ 0.0
SEV SPALL/NO.PER MI:	1/ 8.4	4/ 33.8	0/ 0.0
MPO. <20 /NO.PER MI:	1/ 8.4	1/ 8.4	0/ 0.0
MPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
SPO. <20 /NO.PER MI:	2/ 16.9	2/ 16.9	0/ 0.0
SPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
AC. PATCH/NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
PCC PATCH/NO.PER MI:	0/ 0.0	6/ 50.7	1/ 0.0
MINOR PUMPING FEET:	0	1	
SEVERE PUMPING FEET:	30	30	0
FAILURES /NO.PER MI:	2/ 16.9	8/ 67.6	0/ 0.0

FR: 552+70 LENGTH: 625 FT
TO: 558+95 COMMENTS:1D INJECTED YES

SURVEYS -	MAY 80	MAY 81	
CRACKS /NO.PER MI:	138/1165.8	142/1199.6	0/ 0.0
MIN SPALL/NO.PER MI:	39/ 329.5	58/ 490.0	0/ 0.0
SEV SPALL/NO.PER MI:	3/ 25.3	5/ 42.2	0/ 0.0
MPO. <20 /NO.PER MI:	1/ 8.4	1/ 8.4	0/ 0.0
MPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
SPO. <20 /NO.PER MI:	1/ 8.4	1/ 8.4	0/ 0.0
SPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
AC. PATCH/NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
PCC PATCH/NO.PER MI:	0/ 0.0	1/ 8.4	0/ 0.0
MINOR PUMPING FEET:	0	2	0
SEVERE PUMPING FEET:	95	96	0
FAILURES /NO.PER MI:	1/ 8.4	2/ 16.9	0/ 0.0

SMALL SECTIONS CONDITION SURVEY
(CONT.)

FR: 502+27 LENGTH: 625 FT
TO: 508+52 COMMENTS:PC INJECTED YES

SURVEYS =	MAY 80	MAY 81	
CRACKS /NO.PER MI:	126/1064.4	157/1326.3	0/ 0.0
MIN SPALL/NO.PER MI:	46/ 388.6	67/ 566.0	0/ 0.0
SEV SPALL/NO.PER MI:	7/ 59.1	7/ 59.1	0/ 0.0
MPO. <20 /NO.PER MI:	4/ 33.8	5/ 42.2	0/ 0.0
MPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
SPO. <20 /NO.PER MI:	0/ 0.0	1/ 8.4	0/ 0.0
SPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
AC. PATCH/NO.PER MI:	2/ 16.9	2/ 16.9	0/ 0.0
PCC PATCH/NO.PER MI:	0/ 0.0	2/ 16.9	0/ 0.0
MINOR PUMPING FEET:	0	0	0
SEVERE PUMPING FEET:	0	0	0
FAILURES /NO.PER MI:	2/ 16.9	5/ 42.2	0/ 0.0

FR: 496+ 2 LENGTH: 625 FT
TO: 502+27 COMMENTS:PC INJECTED YES

SURVEYS =	MAY 80	MAY 81	
CRACKS /NO.PER MI:	210/1774.1	229/1934.6	0/ 0.0
MIN SPALL/NO.PER MI:	54/ 456.2	72/ [illegible]	0/ 0.0
SEV SPALL/NO.PER MI:	1/ 8.4	1/ 8.4	0/ 0.0
MPO. <20 /NO.PER MI:	0/ 0.0	0/ [illegible]	0/ 0.0
MPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
SPO. <20 /NO.PER MI:	1/ 8.4	1/ 8.4	0/ 0.0
SPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
AC. PATCH/NO.PER MI:	1/ 8.4	1/ 8.4	0/ 0.0
PCC PATCH/NO.PER MI:	0/ 0.0	2/ 16.9	0/ 0.0
MINOR PUMPING FEET:	0	0	0
SEVERE PUMPING FEET:	0	0	0
FAILURES /NO.PER MI:	2/ 16.9	4/ 33.8	0/ 0.0

SMALL SECTIONS CONDITION SURVEY
(CONT.)

FR: 514+77 LENGTH: 625 FT
TO: 521+02 COMMENTS:2A INJECTED NO

SURVEYS -	MAY 80	MAY 81	
CRACKS /NO.PER MI:	136/1148.9	138/1165.8	0/ 0.0
MIN SPALL/NO.PER MI:	53/ 447.7	81/ 684.3	0/ 0.0
SEV SPALL/NO.PER MI:	1/ 8.4	3/ 25.3	0/ 0.0
MPO. <20 /NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
MPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
SPO. <20 /NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
SPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
AC. PATCH/NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
PCC PATCH/NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
MINOR PUMPING FEET:	0	5	0
SEVERE PUMPING FEET:	0	1	0
FAILURES /NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0

FR: 508+52 LENGTH: 625 FT
TO: 514+77 COMMENTS:2B INJECTED NO

SURVEYS -	MAY 80	MAY 81	
CRACKS /NO.PER MI:	114/ 963.1	129/1089.8	0/ 0.0
MIN SPALL/NO.PER MI:	45/ 380.2	53/ 447.7	0/ 0.0
SEV SPALL/NO.PER MI:	2/ 16.9	10/ 84.5	0/ 0.0
MPO. <20 /NO.PER MI:	1/ 8.4	1/ 8.4	0/ 0.0
MPO. >20 /NO.PER MI:	1/ 8.4	2/ 16.9	0/ 0.0
SPO. <20 /NO.PER MI:	3/ 25.3	3/ 25.3	0/ 0.0
SPO. >20 /NO.PER MI:	0/ 0.0	0/ 0.0	0/ 0.0
AC. PATCH/NO.PER MI:	1/ 8.4	1/ 8.4	0/ 0.0
PCC PATCH/NO.PER MI:	0/ 0.0	3/ 25.3	0/ 0.0
MINOR PUMPING FEET:	0	7	0
SEVERE PUMPING FEET:	0	4	0
FAILURES /NO.PER MI:	4/ 33.8	7/ 59.1	0/ 0.0

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COLUMBUS IH-10 PRESSURE GROUT DEC 77 -- SEC 1A, EB OUTSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 2
(FILE: 2 SEC: 1 RECORDS: 22)

GAINR: 551.5 GAINL: 549.2

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	38.51	46.88	42.70	3.17
1.0	12.92	14.59	13.76	3.66
2.0	4.60	5.46	5.03	4.12
4.1	1.96	2.39	2.18	3.79
8.1	.88	.94	.91	3.42
16.2	.48	.46	.47	3.18
32.4	.22	.24	.23	3.12
64.9	.11	.11	.10	3.09
129.8	.04	.04	.04	2.88

MRM ROUGHNESS (COUNTS/.2 MILE): 57.42

FLEXIBLE PAVEMENT SERVICEABILITY: 3.60

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COLUMBUS IH-10 PRESSURE GROUT DEC 77 -- SEC 1B, EB OUTSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 2

GAINR: 551.5 GAINL: 549.2

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	44.57	51.67	48.12	3.10
1.0	15.44	17.44	16.44	3.46
2.0	5.31	6.31	5.86	3.83
4.1	2.23	2.45	2.34	3.64
8.1	1.13	1.17	1.15	3.05
16.2	.56	.59	.58	2.87
32.4	.26	.26	.26	2.95
64.9	.11	.11	.11	3.00
129.8	.03	.03	.03	3.28

MRM ROUGHNESS (COUNTS/.2 MILE): 67.20

FLEXIBLE PAVEMENT SERVICEABILITY: 3.40

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COLUMBUS IH-10 PRESSURE GROUT DEC 77 -- SEC 1A, FB OUTSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 3
(FILE: 3 SEC: 1 RECORDS: 22)

GAINR: 551.4 GAINL: 548.9

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	48.61	38.09	43.35	3.16
1.0	14.82	12.94	13.88	3.65
2.0	5.45	4.54	4.99	4.14
4.1	2.36	1.95	2.15	3.81
8.1	.93	.87	.90	3.44
16.2	.47	.48	.47	3.17
32.4	.24	.22	.23	3.12
64.9	.11	.10	.10	3.08
129.8	.04	.04	.04	2.83

MRM ROUGHNESS (COUNTS/.2 MILE): 57.00

FLEXIBLE PAVEMENT SERVICEABILITY: 3.65

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COLUMBUS IH-10 PRESSURE GROUT DEC 77 -- SEC 1B, FB OUTSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 3

GAINR: 551.4 GAINL: 548.9

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	52.27	42.97	47.62	3.11
1.0	17.29	15.29	16.29	3.47
2.0	6.35	5.11	5.73	3.87
4.1	2.43	2.20	2.32	3.66
8.1	1.16	1.13	1.14	3.06
16.2	.59	.56	.57	2.88
32.4	.26	.26	.26	2.95
64.9	.12	.11	.11	2.96
129.8	.03	.03	.03	3.28

MRM ROUGHNESS (COUNTS/.2 MILE): 66.40

FLEXIBLE PAVEMENT SERVICEABILITY: 3.41

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COLUMBUS IH-10 PRESSURE GROUT MAR 78 -- SEC 1A, EB OUTSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 1
(FILE:*8034 SEC:*88 RECORDS:*8398)

GAINR: 545.8 GAINL: 535.1

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	40.13	53.93	47.03	3.12
1.0	13.34	16.19	14.76	3.58
2.0	4.95	5.94	5.45	3.97
4.1	2.21	2.54	2.38	3.61
8.1	1.14	1.19	1.17	3.03
16.2	.76	.74	.75	2.40
32.4	.41	.40	.40	2.18
64.9	.17	.17	.17	2.31
129.8	.04	.05	.05	2.64

MRM ROUGHNESS (COUNTS/.2 MILE): 78.31

FLEXIBLE PAVEMENT SERVICEABILITY: 3.14

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COLUMBUS IH-10 PRESSURE GROUT MAR 78 -- SEC 1B, EB OUTSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 1

GAINR: 545.8 GAINL: 535.1

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	44.62	51.42	48.02	3.10
1.0	15.69	17.80	16.74	3.44
2.0	5.34	6.41	5.88	3.82
4.1	2.31	2.41	2.36	3.62
8.1	1.17	1.15	1.16	3.04
16.2	.58	.59	.59	2.84
32.4	.25	.26	.26	2.97
64.9	.10	.10	.10	3.15
129.8	.02	.02	.02	3.57

MRM ROUGHNESS (COUNTS/.2 MILE): 68.33

FLEXIBLE PAVEMENT SERVICEABILITY: 3.37

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COLUMBUS IH-10 PRESSURE GROUT MAR 78 -- SEC 1A, EB OUTSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 2
(FILE: 2 SEC: 1 RECORDS: 22)

GAINR: 540.5 GAINL: 535.3

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	39.05	51.11	45.08	3.14
1.0	12.82	15.26	14.04	3.64
2.0	4.81	5.69	5.25	4.04
4.1	2.21	2.56	2.38	3.61
8.1	1.12	1.15	1.14	3.07
16.2	.73	.70	.71	2.50
32.4	.36	.36	.36	2.40
64.9	.12	.12	.12	2.82
129.8	.04	.05	.04	2.71

MRM ROUGHNESS (COUNTS/.2 MILE): 76.11

FLEXIBLE PAVEMENT SERVICEABILITY: 3.19

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COLUMBUS IH-10 PRESSURE GROUT MAR 78 -- SEC 1B, EB OUTSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 2

GAINR: 540.5 GAINL: 535.3

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	44.44	53.69	49.07	3.09
1.0	15.55	17.84	16.69	3.45
2.0	5.49	6.63	6.06	3.76
4.1	2.40	2.52	2.46	3.54
8.1	1.21	1.21	1.21	2.97
16.2	.61	.62	.62	2.76
32.4	.26	.27	.27	2.90
64.9	.11	.12	.11	2.95
129.8	.03	.03	.03	3.28

MRM ROUGHNESS (COUNTS/.2 MILE): 72.28

FLEXIBLE PAVEMENT SERVICEABILITY: 3.28

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COLUMBUS IH-10 PRESSURE GROUT DEC 77 -- SEC 2A, EB OUTSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 4
(FILE: 4 SEC: 2 RECORDS: 22)

GAINR: 1062.5 GAINL: 1054.6

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	43.06	37.93	40.50	3.20
1.0	14.10	13.52	13.81	3.65
2.0	5.52	5.14	5.33	4.02
4.1	2.32	2.33	2.32	3.66
8.1	.95	1.12	1.04	3.22
16.2	.48	.51	.50	3.11
32.4	.21	.21	.21	3.28
64.9	.08	.09	.09	3.31
129.8	.01	.01	.01	3.90

MRM ROUGHNESS (COUNTS/.2 MILE): 62.16

FLEXIBLE PAVEMENT SERVICEABILITY: 3.52

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COLUMBUS IH-10 PRESSURE GROUT DEC 77 -- SEC 2B, EB OUTSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 4

GAINR: 1062.5 GAINL: 1054.6

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	40.05	37.44	38.75	3.22
1.0	13.40	13.18	13.29	3.69
2.0	5.42	4.95	5.19	4.07
4.1	2.22	2.03	2.13	3.83
8.1	.80	.85	.82	3.56
16.2	.36	.37	.37	3.52
32.4	.17	.16	.16	3.60
64.9	.05	.05	.05	3.85
129.8	.01	.01	.01	3.98

MRM ROUGHNESS (COUNTS/.2 MILE): 50.20

FLEXIBLE PAVEMENT SERVICEABILITY: 3.82

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COLUMBUS IH-10 PRESSURE GROUT DEC 77 -- SEC 2A, EB OUTSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 5
(FILE: 5 SEC: 2 RECORDS: 22)

GAINR: 1053.6 GAINL: 1059.5

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	43.04	39.44	41.24	3.19
1.0	14.00	13.45	13.73	3.66
2.0	5.60	5.19	5.40	3.99
4.1	2.36	2.34	2.35	3.63
8.1	.96	1.12	1.04	3.21
16.2	.48	.51	.50	3.10
32.4	.21	.21	.21	3.27
64.9	.08	.09	.09	3.31
129.8	.01	.01	.01	3.91

MRM ROUGHNESS (COUNTS/.2 MILE): 62.90

FLEXIBLE PAVEMENT SERVICEABILITY: 3.50

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COLUMBUS IH-10 PRESSURE GROUT DEC 77 -- SEC 2B, EB OUTSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 5

GAINR: 1053.6 GAINL: 1059.5

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	40.27	38.17	39.22	3.22
1.0	13.16	13.79	13.48	3.68
2.0	5.28	5.08	5.18	4.07
4.1	2.21	2.06	2.13	3.82
8.1	.81	.87	.84	3.53
16.2	.37	.38	.37	3.50
32.4	.17	.16	.17	3.58
64.9	.05	.05	.05	3.83
129.8	.01	.01	.01	3.95

MRM ROUGHNESS (COUNTS/.2 MILE): 50.83

FLEXIBLE PAVEMENT SERVICEABILITY: 3.80

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COLUMBUS IH-10 PRESSURE GROUT MAR 78 -- SEC 2A, EB OUTSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 3
(FILE: 3 SEC: 2 RECORDS: 22)

GAINR: 1059.5 GAINL: 1045.6

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	38.72	44.53	41.62	3.18
1.0	13.83	15.05	14.44	3.61
2.0	5.23	5.93	5.58	3.93
4.1	2.40	2.44	2.42	3.58
8.1	1.22	1.07	1.15	3.06
16.2	.60	.56	.58	2.85
32.4	.24	.25	.25	3.04
64.9	.09	.09	.09	3.23
129.8	.01	.01	.01	3.91

MRM ROUGHNESS (COUNTS/.2 MILE): 69.40

FLEXIBLE PAVEMENT SERVICEABILITY: 3.30

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COLUMBUS IH-10 PRESSURE GROUT MAR 78 -- SEC 2B, EB OUTSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 3

GAINR: 1059.5 GAINL: 1045.6

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	39.58	42.31	40.95	3.19
1.0	13.76	14.08	13.92	3.65
2.0	5.04	5.53	5.28	4.03
4.1	2.12	2.33	2.22	3.74
8.1	.91	.86	.88	3.46
16.2	.39	.39	.39	3.46
32.4	.16	.19	.18	3.51
64.9	.05	.07	.06	3.69
129.8	.01	.01	.01	3.92

MRM ROUGHNESS (COUNTS/.2 MILE): 53.60

FLEXIBLE PAVEMENT SERVICEABILITY: 3.73

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COLUMBUS IH-10 PRESSURE GROUT MAR 78 -- SEC 2A, EB OUTSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 4
(FILE: 4 SEC: 2 RECORDS: 22)

GAINR: 1055.8 GAINL: 1042.1

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	42.50	48.88	45.69	3.13
1.0	14.27	15.99	15.13	3.56
2.0	5.22	5.81	5.51	3.95
4.1	2.32	2.39	2.36	3.63
8.1	1.16	1.06	1.11	3.11
16.2	.58	.55	.56	2.91
32.4	.23	.24	.24	3.09
64.9	.09	.08	.08	3.33
129.8	.01	.01	.01	3.92

MRM ROUGHNESS (COUNTS/.2 MILE): 66.82

FLEXIBLE PAVEMENT SERVICEABILITY: 3.41

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COLUMBUS IH-10 PRESSURE GROUT MAR 78 -- SEC 2B, EB OUTSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 4

GAINR: 1055.8 GAINL: 1042.1

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	52.84	41.70	47.27	3.11
1.0	15.13	14.26	14.70	3.59
2.0	5.27	5.71	5.49	3.96
4.1	2.13	2.35	2.24	3.73
8.1	.90	.85	.88	3.47
16.2	.39	.38	.38	3.47
32.4	.16	.18	.17	3.55
64.9	.05	.06	.05	3.81
129.8	.01	.01	.01	3.95

MRM ROUGHNESS (COUNTS/.2 MILE): 53.83

FLEXIBLE PAVEMENT SERVICEABILITY: 3.73

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COLUMBUS IH-10 PRESSURE GROUT DEC 77 -- SEC 1A, EB INSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 6
(FILE: 6 SEC: 1 RECORDS: 22)

GAINR: 546.9 GAINL: 549.6

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	46.74	45.91	46.32	3.12
1.0	14.69	14.56	14.63	3.59
2.0	4.89	5.23	5.06	4.11
4.1	2.02	2.36	2.19	3.77
8.1	.80	1.07	.94	3.37
16.2	.42	.57	.50	3.10
32.4	.25	.34	.29	2.76
64.9	.11	.14	.12	2.82
129.8	.04	.05	.04	2.71

MRM ROUGHNESS (COUNTS/.2 MILE): 59.22

FLEXIBLE PAVEMENT SERVICEABILITY: 3.59

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COLUMBUS IH-10 PRESSURE GROUT DEC 77 -- SEC 1B, EB INSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 6

GAINR: 546.9 GAINL: 549.6

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	44.54	138.62	91.58	2.60
1.0	14.86	41.15	28.01	2.72
2.0	5.06	10.87	7.97	3.15
4.1	2.03	3.33	2.68	3.36
8.1	.96	1.22	1.09	3.14
16.2	.51	.58	.54	2.96
32.4	.23	.26	.25	3.02
64.9	.11	.12	.12	2.92
129.8	.03	.03	.03	3.17

MRM ROUGHNESS (COUNTS/.2 MILE): 73.23

FLEXIBLE PAVEMENT SERVICEABILITY: 3.25

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COLUMBUS IH-10 PRESSURE GROUT DEC 77 -- SEC 1A, EB INSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 7
(FILE: 7 SEC: 1 RECORDS: 22)

GAINR: 549.3 GAINL: 549.0

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	48.82	46.05	47.44	3.11
1.0	15.11	14.47	14.79	3.58
2.0	4.92	5.13	5.03	4.13
4.1	2.01	2.34	2.17	3.79
8.1	.80	1.07	.94	3.37
16.2	.42	.56	.49	3.12
32.4	.25	.34	.29	2.76
64.9	.11	.15	.13	2.72
129.8	.04	.05	.04	2.72

MRM ROUGHNESS (COUNTS/.2 MILE): 58.51

FLEXIBLE PAVEMENT SERVICEABILITY: 3.61

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COLUMBUS IH-10 PRESSURE GROUT DEC 77 -- SEC 1B, EB INSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 7

GAINR: 549.3 GAINL: 549.0

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	44.11	61.15	52.63	3.05
1.0	15.03	18.61	16.82	3.44
2.0	5.05	6.15	5.60	3.92
4.1	2.04	2.50	2.27	3.71
8.1	.96	1.10	1.03	3.24
16.2	.50	.55	.52	3.02
32.4	.23	.25	.24	3.07
64.9	.10	.12	.11	2.98
129.8	.03	.03	.03	3.13

MRM ROUGHNESS (COUNTS/.2 MILE): 62.56

FLEXIBLE PAVEMENT SERVICEABILITY: 3.51

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COLUMBUS IH-10 PRESSURE GROUT MAR 78 -- SEC 1A, EB INSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 5
(FILE: 5 SEC: 1 RECORDS: 22)

GAINR: 540.5 GAINL: 534.6

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	40.96	46.18	43.57	3.16
1.0	13.10	14.21	13.65	3.67
2.0	4.81	5.18	5.00	4.14
4.1	2.09	2.41	2.25	3.72
8.1	.88	1.13	1.01	3.27
16.2	.52	.61	.57	2.89
32.4	.28	.35	.32	2.60
64.9	.11	.15	.13	2.77
129.8	.04	.05	.05	2.65

MRM ROUGHNESS (COUNTS/.2 MILE): 64.73

FLEXIBLE PAVEMENT SERVICEABILITY: 3.46

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COLUMBUS IH-10 PRESSURE GROUT MAR 78 -- SEC 1B, EB INSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 5

GAINR: 540.5 GAINL: 534.6

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	52.09	115.79	83.94	2.68
1.0	15.80	29.01	22.41	3.06
2.0	5.26	8.43	6.85	3.50
4.1	2.04	2.87	2.45	3.55
8.1	.97	1.16	1.07	3.18
16.2	.51	.58	.55	2.96
32.4	.23	.27	.25	3.01
64.9	.11	.13	.12	2.91
129.8	.03	.04	.03	3.13

MRM ROUGHNESS (COUNTS/.2 MILE): 68.05

FLEXIBLE PAVEMENT SERVICEABILITY: 3.38

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COLUMBUS IH-10 PRESSURE GROUT MAR 78 -- SEC 1A, EB INSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 6
(FILE: 6 SEC: 1 RECORDS: 22)

GAINR: 541.3 GAINL: 536.4

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	43.76	45.92	44.84	3.14
1.0	13.98	14.30	14.14	3.63
2.0	5.04	5.28	5.16	4.08
4.1	2.16	2.42	2.29	3.69
8.1	.89	1.11	1.00	3.28
16.2	.52	.61	.57	2.90
32.4	.28	.35	.32	2.61
64.9	.11	.14	.13	2.74
129.8	.04	.05	.05	2.60

MRM ROUGHNESS (COUNTS/.2 MILE): 65.44

FLEXIBLE PAVEMENT SERVICEABILITY: 3.40

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COLUMBUS IH-10 PRESSURE GROUT MAR 78 -- SEC 1B, EB INSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE [illegible]

GAINR: 541.3 GAINL: 536.4

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	44.36	85.58	64.97	2.90
1.0	14.39	22.03	18.21	3.34
2.0	5.21	6.94	6.07	3.76
4.1	2.12	2.63	2.38	3.61
8.1	.99	1.13	1.06	3.19
16.2	.52	.57	.54	2.96
32.4	.23	.26	.25	3.03
64.9	.11	.12	.12	2.92
129.8	.03	.03	.03	3.17

MRM ROUGHNESS (COUNTS/.2 MILE): 66.14

FLEXIBLE PAVEMENT SERVICEABILITY: 3.42

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COLUMBUS IH-10 PRESSURE GROUT DEC 77 -- SEC 2A, EB INSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 8
(FILE: 8 SEC: 2 RECORDS: 22)

GAINR: 1058.9 GAINL: 1053.2

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	47.17	38.94	43.05	3.17
1.0	14.50	13.04	13.77	3.66
2.0	5.15	4.55	4.85	4.19
4.1	2.26	1.85	2.06	3.89
8.1	.98	.85	.91	3.41
16.2	.51	.43	.47	3.19
32.4	.23	.20	.21	3.25
64.9	.07	.07	.07	3.55
129.8	.01	.01	.01	3.95

MRM ROUGHNESS (COUNTS/.2 MILE): 54.50

FLEXIBLE PAVEMENT SERVICEABILITY: 3.71

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COLUMBUS IH-10 PRESSURE GROUT DEC 77 -- SEC 2B, EB INSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 8

GAINR: 1058.9 GAINL: 1053.2

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	45.67	109.66	77.66	2.75
1.0	14.88	28.53	21.71	3.11
2.0	5.69	8.25	6.97	3.46
4.1	2.44	2.55	2.49	3.51
8.1	.81	.76	.78	3.62
16.2	.40	.33	.37	3.52
32.4	.17	.16	.17	3.59
64.9	.05	.05	.05	3.82
129.8	.01	.01	.01	3.85

MRM ROUGHNESS (COUNTS/.2 MILE): 58.75

FLEXIBLE PAVEMENT SERVICEABILITY: 3.60

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COLUMBUS IH-10 PRESSURE GROUT MAR 78 -- SEC 2A, EB INSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 7
(FILE: 7 SEC: 2 RECORDS: 22)

GAINR: 1059.6 GAINL: 1042.3

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	38.00	47.15	42.57	3.17
1.0	13.08	15.03	14.06	3.64
2.0	4.74	5.37	5.05	4.12
4.1	1.97	2.32	2.14	3.82
8.1	.88	1.03	.95	3.35
16.2	.45	.54	.50	3.10
32.4	.21	.25	.23	3.16
64.9	.07	.07	.07	3.51
129.8	.01	.01	.01	3.93

MRM ROUGHNESS (COUNTS/.2 MILE): 58.12

FLEXIBLE PAVEMENT SERVICEABILITY: 3.62

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COLUMBUS IH-10 PRESSURE GROUT MAR 78 -- SEC 2B, EB INSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 7

GAINR: 1059.6 GAINL: 1042.3

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	38.76	45.24	42.00	3.18
1.0	13.31	14.40	13.86	3.65
2.0	4.87	5.37	5.12	4.09
4.1	1.94	2.37	2.16	3.81
8.1	.64	.88	.76	3.66
16.2	.32	.44	.38	3.48
32.4	.16	.19	.17	3.54
64.9	.05	.06	.06	3.73
129.8	.01	.01	.01	3.88

MRM ROUGHNESS (COUNTS/.2 MILE): 51.64

FLEXIBLE PAVEMENT SERVICEABILITY: 3.78

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COLUMBUS IH-10 PRESSURE GROUT DEC 77 -- SEC 2A, EB INSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 9
(FILE: 9 SEC: 2 RECORDS: 22)

GAINR: 1061.1 GAINL: 1053.4

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	46.02	112.62	79.32	2.73
1.0	14.45	28.72	21.58	3.11
2.0	5.13	8.31	6.72	3.54
4.1	2.23	2.57	2.40	3.59
8.1	.97	.96	.96	3.33
16.2	.50	.45	.48	3.17
32.4	.23	.20	.21	3.24
64.9	.07	.07	.07	3.55
129.8	.01	.01	.01	3.92

MRM ROUGHNESS (COUNTS/.2 MILE): 62.88

FLEXIBLE PAVEMENT SERVICEABILITY: 3.50

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COLUMBUS IH-10 PRESSURE GROUT DEC 77 -- SEC 2B, EB INSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 9

GAINR: 1061.1 GAINL: 1053.4

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	45.61	48.49	47.05	3.12
1.0	15.22	15.95	15.58	3.52
2.0	5.70	5.55	5.62	3.91
4.1	2.44	2.10	2.27	3.70
8.1	.81	.67	.74	3.70
16.2	.40	.32	.36	3.54
32.4	.17	.16	.17	3.59
64.9	.06	.05	.05	3.81
129.8	.02	.01	.01	3.82

MRM ROUGHNESS (COUNTS/.2 MILE): 53.18

FLEXIBLE PAVEMENT SERVICEABILITY: 3.74

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COLUMBUS IH-10 PRESSURE GROUT MAR 78 -- SEC 2A, EB INSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 8
(FILE: 8 SEC: 2 RECORDS: 22)

GAINR: 1059.0 GAINL: 1041.8

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	37.58	48.03	42.80	3.17
1.0	12.88	15.27	14.08	3.63
2.0	4.70	5.45	5.08	4.11
4.1	1.96	2.34	2.15	3.81
8.1	.88	1.02	.95	3.36
16.2	.45	.54	.50	3.10
32.4	.21	.25	.23	3.16
64.9	.07	.07	.07	3.52
129.8	.01	.01	.01	3.96

MRM ROUGHNESS (COUNTS/.2 MILE): 58.14

FLEXIBLE PAVEMENT SERVICEABILITY: 3.62

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COLUMBUS IH-10 PRESSURE GROUT MAR 78 -- SEC 2B, EB INSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 8

GAINR: 1059.0 GAINL: 1041.8

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	39.88	51.96	45.92	3.13
1.0	13.68	16.34	15.01	3.57
2.0	5.03	5.84	5.44	3.98
4.1	1.99	2.50	2.24	3.73
8.1	.65	.87	.76	3.66
16.2	.32	.43	.37	3.50
32.4	.16	.18	.17	3.55
64.9	.05	.06	.05	3.77
129.8	.01	.02	.01	3.85

MRM ROUGHNESS (COUNTS/.2 MILE): 53.33

FLEXIBLE PAVEMENT SERVICEABILITY: 3.70

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FAIRFIELD IH-45 PRESSURE GROUT NOV 77 -- SEC 1A, SB OUTSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 1
(FILE:*1639 SEC:*16 RECORDS:*1640)

GAINR: 535.0 GAINL: 540.9

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	40.20	42.33	41.26	3.19
1.0	13.27	11.91	12.59	3.74
2.0	3.49	3.55	3.52	4.67
4.1	1.48	1.49	1.49	4.42
8.1	.80	.84	.82	3.56
16.2	.49	.52	.51	3.07
32.4	.22	.23	.23	3.16
64.9	.06	.07	.06	3.62
129.8	.02	.02	.02	3.59

MRM ROUGHNESS (COUNTS/.2 MILE): 43.61

FLEXIBLE PAVEMENT SERVICEABILITY: 3.90

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FAIRFIELD IH-45 PRESSURE GROUT NOV 77 -- SEC 1B, SB OUTSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 1

GAINR: 535.0 GAINL: 540.9

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	39.03	41.16	40.09	3.20
1.0	12.04	11.35	11.69	3.81
2.0	3.63	3.73	3.68	4.61
4.1	1.70	1.78	1.74	4.19
8.1	1.08	1.17	1.13	3.09
16.2	.76	.86	.81	2.27
32.4	.42	.49	.45	1.96
64.9	.11	.14	.12	2.80
129.8	.03	.04	.03	3.03

MRM ROUGHNESS (COUNTS/.2 MILE): 66.90

FLEXIBLE PAVEMENT SERVICEABILITY: 3.40

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FAIRFIELD IH-45 PRESSURE GROUT NOV 77 -- SEC 1A, SB OUTSIDE RUN 2

1350 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 2
(FILE: 2 SEC: 1 RECORDS: 21)

GAINR: 533.3 GAINL: 541.6

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	37.32	40.27	38.79	3.22
1.0	12.75	11.53	12.14	3.78
2.0	3.40	3.53	3.47	4.66
4.1	1.40	1.48	1.44	4.46
8.1	.75	.82	.79	3.61
16.2	.43	.48	.45	3.24
32.4	.15	.17	.16	3.60
64.9	.06	.07	.06	3.65
129.8	.02	.02	.02	3.63

MRM ROUGHNESS (COUNTS/.2 MILE): 39.39

FLEXIBLE PAVEMENT SERVICEABILITY: 4.11

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FAIRFIELD IH-45 PRESSURE GROUT NOV 77 -- SEC 1B, SB OUTSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 2

GAINR: 533.3 GAINL: 541.6

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	45.29	41.49	43.39	3.16
1.0	15.07	11.63	13.35	3.69
2.0	5.21	3.83	4.52	4.31
4.1	2.09	1.85	1.97	3.97
8.1	1.23	1.23	1.23	2.94
16.2	.80	.89	.84	2.19
32.4	.43	.49	.46	1.94
64.9	.12	.15	.14	2.67
129.8	.03	.03	.03	3.15

MRM ROUGHNESS (COUNTS/.2 MILE): 74.29

FLEXIBLE PAVEMENT SERVICEABILITY: 3.23

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FAIRFIELD IH-45 PRESSURE GROUT APR 78 -- SEC. 1A, SB OUTSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 1
(FILE#=1659 SEC#=16 RECORDS#=1657)

GAINR: 1062.7 GAINL: 1048.7

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	36.37	41.03	38.76	3.22
1.0	12.01	11.79	11.90	3.80
2.0	3.41	3.70	3.56	4.65
4.1	1.45	1.59	1.52	4.39
8.1	.83	.88	.85	3.51
16.2	.50	.55	.52	3.02
32.4	.23	.24	.24	3.10
64.9	.06	.07	.07	3.59
129.8	.02	.02	.02	3.56

MRM ROUGHNESS (COUNTS/.2 MILE): 45.30

FLEXIBLE PAVEMENT SERVICEABILITY: 3.95

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FAIRFIELD IH-45 PRESSURE GROUT APR 78 -- SEC. 1B, SB OUTSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 1

GAINR: 1062.7 GAINL: 1048.7

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	39.65	41.41	40.53	3.20
1.0	13.28	11.15	12.22	3.77
2.0	5.19	3.92	4.55	4.30
4.1	2.20	1.90	2.05	3.90
8.1	1.21	1.25	1.23	2.94
16.2	.80	.92	.86	2.15
32.4	.43	.51	.47	1.88
64.9	.11	.14	.13	2.79
129.8	.03	.04	.04	3.02

MRM ROUGHNESS (COUNTS/.2 MILE): 77.23

FLEXIBLE PAVEMENT SERVICEABILITY: 3.16

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FAIRFIELD IH-45 PRESSURE GROUT APR 78 -- SEC. 1A, SB OUTSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 2
(FILE: 2 SEC: 1 RECORDS: 23)

GAINR: 1062.5 GAINL: 1047.6

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	36.35	40.82	38.58	3.22
1.0	12.24	11.73	11.98	3.79
2.0	3.39	3.63	3.51	4.67
4.1	1.46	1.56	1.51	4.40
8.1	.79	.87	.83	3.55
16.2	.45	.51	.48	3.16
32.4	.17	.19	.18	3.50
64.9	.07	.07	.07	3.50
129.8	.02	.02	.02	3.41

MRM ROUGHNESS (COUNTS/.2 MILE): 42.45

FLEXIBLE PAVEMENT SERVICEABILITY: 4.02

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FAIRFIELD IH-45 PRESSURE GROUT APR 78 -- SEC. 1B, SB OUTSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 2

GAINR: 1062.5 GAINL: 1047.6

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	47.45	40.31	43.88	3.16
1.0	16.75	11.52	14.13	3.63
2.0	6.19	3.92	5.05	4.12
4.1	2.62	1.97	2.30	3.68
8.1	1.34	1.32	1.33	2.80
16.2	.85	.95	.90	2.07
32.4	.45	.53	.49	1.81
64.9	.13	.15	.14	2.63
129.8	.03	.04	.03	3.06

MRM ROUGHNESS (COUNTS/.2 MILE): 85.15

FLEXIBLE PAVEMENT SERVICEABILITY: 2.99

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FAIRFIELD IH-45 PRESSURE GROUT NOV 77 -- SEC 2A, SB OUTSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 3
(FILE: 3 SEC: 2 RECORDS: 21)

GAINR: 533.7 GAINL: 539.1

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	47.01	45.26	46.14	3.13
1.0	13.81	12.01	12.91	3.72
2.0	3.82	3.66	3.74	4.59
4.1	1.43	1.40	1.42	4.49
8.1	.65	.66	.66	3.84
16.2	.36	.35	.36	3.55
32.4	.15	.15	.15	3.69
64.9	.04	.04	.04	3.99
129.8	.01	.01	.01	4.11

MRM ROUGHNESS (COUNTS/.2 MILE): 33.37

FLEXIBLE PAVEMENT SERVICEABILITY: 4.27

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FAIRFIELD IH-45 PRESSURE GROUT NOV 77 -- SEC 2B, SB OUTSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 3

GAINR: 533.7 GAINL: 539.1

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	49.76	44.57	47.17	3.11
1.0	18.61	12.41	15.51	3.53
2.0	6.17	3.92	5.04	4.12
4.1	2.10	1.69	1.89	4.04
8.1	.96	.86	.91	3.42
16.2	.50	.50	.50	3.08
32.4	.26	.27	.27	2.89
64.9	.12	.14	.13	2.73
129.8	.03	.04	.03	3.07

MRM ROUGHNESS (COUNTS/.2 MILE): 52.73

FLEXIBLE PAVEMENT SERVICEABILITY: 3.75

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FAIRFIELD IH-45 PRESSURE GROUT NOV 77 -- SEC 2A, SB OUTSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 4
(FILE: 4 SEC: 2 RECORDS: 21)

GAINR: 532.8 GAINL: 540.9

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	44.49	46.52	45.50	3.14
1.0	13.22	12.74	12.98	3.72
2.0	3.70	3.81	3.76	4.58
4.1	1.35	1.45	1.40	4.50
8.1	.64	.67	.65	3.84
16.2	.36	.36	.36	3.55
32.4	.14	.14	.14	3.77
64.9	.04	.04	.04	3.99
129.8	.01	.01	.01	4.11

MRM ROUGHNESS (COUNTS/.2 MILE): 33.00

FLEXIBLE PAVEMENT SERVICEABILITY: 4.20

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FAIRFIELD IH-45 PRESSURE GROUT NOV 77 -- SEC 2B, SB OUTSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 4

GAINR: 532.8 GAINL: 540.9

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	47.84	44.38	46.11	3.13
1.0	15.52	12.33	13.92	3.65
2.0	4.44	3.84	4.14	4.45
4.1	1.78	1.67	1.73	4.20
8.1	.92	.87	.89	3.44
16.2	.49	.50	.50	3.11
32.4	.26	.27	.27	2.91
64.9	.12	.14	.13	2.70
129.8	.03	.04	.03	3.13

MRM ROUGHNESS (COUNTS/.2 MILE): 48.40

FLEXIBLE PAVEMENT SERVICEABILITY: 3.87

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FAIRFIELD IH-45 PRESSURE GROUT APR 78 -- SEC. 2A, SB OUTSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 3
(FILE: 3 SEC: 2 RECORDS: 22)

GAINR: 1062.8 GAINL: 1048.2

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	138.10	44.42	91.26	2.60
1.0	43.08	12.03	27.56	2.75
2.0	10.72	3.67	7.19	3.39
4.1	2.82	1.45	2.13	3.82
8.1	.89	.68	.79	3.62
16.2	.40	.37	.38	3.47
32.4	.15	.15	.15	3.71
64.9	.04	.04	.04	3.97
129.8	.01	.01	.01	4.06

MRM ROUGHNESS (COUNTS/.2 MILE): 51.34

FLEXIBLE PAVEMENT SERVICEABILITY: 3.70

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FAIRFIELD IH-45 PRESSURE GROUT APR 78 -- SEC. 2B, SB OUTSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 3

GAINR: 1062.8 GAINL: 1048.2

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	246.64	43.94	145.29	2.09
1.0	62.15	12.52	37.33	2.23
2.0	14.90	3.94	9.42	2.74
4.1	4.01	1.72	2.87	3.21
8.1	1.32	.93	1.13	3.09
16.2	.55	.52	.54	2.98
32.4	.26	.26	.26	2.93
64.9	.12	.14	.13	2.73
129.8	.03	.04	.03	3.09

MRM ROUGHNESS (COUNTS/.2 MILE): 77.02

FLEXIBLE PAVEMENT SERVICEABILITY: 3.17

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FAIRFIELD IH-45 PRESSURE GROUT APR 78 -- SEC. 2A, SB OUTSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 4
(FILE: 4 SEC: 2 RECORDS: 22)

GAINR: 1061.9 GAINL: 1048.2

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	42.29	44.21	43.25	3.16
1.0	12.65	11.52	12.09	3.78
2.0	3.65	3.67	3.66	4.62
4.1	1.36	1.48	1.42	4.48
8.1	.65	.69	.67	3.82
16.2	.37	.37	.37	3.52
32.4	.14	.15	.14	3.75
64.9	.04	.04	.04	3.98
129.8	.01	.01	.01	4.09

MRM ROUGHNESS (COUNTS/.2 MILE): 34.05

FLEXIBLE PAVEMENT SERVICEABILITY: 4.25

****

FAIRFIELD IH-45 PRESSURE GROUT APR 78 -- SEC. 2B, SB OUTSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 4

GAINR: 1061.9 GAINL: 1048.2

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	88.36	43.38	65.87	2.89
1.0	25.25	11.97	18.61	3.31
2.0	7.10	3.92	5.51	3.95
4.1	2.29	1.75	2.02	3.93
8.1	1.02	.94	.98	3.31
16.2	.51	.52	.52	3.04
32.4	.25	.27	.26	2.96
64.9	.12	.14	.13	2.74
129.8	.03	.04	.03	3.07

MRM ROUGHNESS (COUNTS/.2 MILE): 56.41

FLEXIBLE PAVEMENT SERVICEABILITY: 3.66

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****

FAIRFIELD IH-45 PRESSURE GROUT NOV 77 -- SEC 1A, SB INSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 5
(FILE: 5 SEC: 1 RECORDS: 21)

GAINR: 530.6 GAINL: 539.0

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	39.05	43.75	41.40	3.19
1.0	11.86	13.52	12.69	3.74
2.0	3.40	3.85	3.62	4.63
4.1	1.37	1.60	1.48	4.42
8.1	.79	.91	.85	3.52
16.2	.47	.55	.51	3.08
32.4	.20	.29	.24	3.05
64.9	.07	.09	.08	3.40
129.8	.02	.02	.02	3.52

MRM ROUGHNESS (COUNTS/.2 MILE): 43.46

FLEXIBLE PAVEMENT SERVICEABILITY: 4.00

****

FAIRFIELD IH-45 PRESSURE GROUT NOV 77 -- SEC 1B, SB INSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 5

GAINR: 530.6 GAINL: 539.0

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	37.21	45.19	41.20	3.19
1.0	11.44	14.57	13.01	3.71
2.0	3.58	4.05	3.81	4.56
4.1	1.69	1.96	1.82	4.11
8.1	1.17	1.35	1.26	2.91
16.2	.87	.99	.93	2.01
32.4	.45	.49	.47	1.87
64.9	.13	.14	.14	2.68
129.8	.03	.04	.04	2.97

MRM ROUGHNESS (COUNTS/.2 MILE): 75.84

FLEXIBLE PAVEMENT SERVICEABILITY: 3.20

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****

FAIRFIELD IH-45 PRESSURE GROUT NOV 77 -- SEC 1A, SB INSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 6
(FILE: 6 SEC: 1 RECORDS: 21)

GAINR: 532.7 GAINL: 541.1

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	40.27	44.47	42.37	3.17
1.0	11.81	12.82	12.31	3.77
2.0	3.48	3.79	3.64	4.63
4.1	1.39	1.57	1.48	4.43
8.1	.78	.89	.83	3.54
16.2	.46	.55	.50	3.08
32.4	.22	.28	.24	3.07
64.9	.07	.09	.08	3.39
129.8	.02	.02	.02	3.54

HRM ROUGHNESS (COUNTS/.2 MILE): 43.34

FLEXIBLE PAVEMENT SERVICEABILITY: 4.00

****

FAIRFIELD IH-45 PRESSURE GROUT NOV 77 -- SEC 1B, SB INSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 6

GAINR: 532.7 GAINL: 541.1

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	38.26	45.03	41.65	3.18
1.0	11.37	13.17	12.27	3.77
2.0	3.57	3.94	3.76	4.58
4.1	1.70	1.92	1.81	4.12
8.1	1.15	1.33	1.24	2.92
16.2	.86	.98	.92	2.03
32.4	.45	.49	.47	1.88
64.9	.13	.14	.13	2.72
129.8	.03	.04	.03	3.05

HRM ROUGHNESS (COUNTS/.2 MILE): 75.07

FLEXIBLE PAVEMENT SERVICEABILITY: 3.21

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****

FAIRFIELD IH-45 PRESSURE GROUT APR 78 -- SEC. 1A, SB INSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 5
(FILE: 5 SEC: 1 RECORDS: 22)

GAINR: 1064.5 GAINL: 1050.1

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	39.13	42.19	40.66	3.24
1.0	11.28	12.44	11.86	3.8[illegible]
2.0	3.60	3.81	3.70	4.62
4.1	1.47	1.64	1.55	4.36
8.1	.79	.92	.86	3.50
16.2	.47	.56	.52	3.04
32.4	.20	.29	.25	3.03
64.9	.07	.10	.08	3.33
129.8	.02	.02	.02	3.50

MRM ROUGHNESS (COUNTS/.2 MILE): 45.66

FLEXIBLE PAVEMENT SERVICEABILITY: 3.94

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FAIRFIELD IH-45 PRESSURE GROUT APR 78 -- SEC. 1B, SB INSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 5

GAINR: 1064.5 GAINL: 1050.1

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	36.59	243.72	140.15	2.13
1.0	10.98	60.81	35.89	2.30
2.0	3.69	15.36	9.52	2.71
4.1	1.78	4.14	2.96	3.14
8.1	1.19	1.65	1.42	2.69
16.2	.88	1.03	.96	1.96
32.4	.46	.51	.49	1.81
64.9	.13	.14	.13	2.72
129.8	.03	.04	.03	3.05

MRM ROUGHNESS (COUNTS/.2 MILE): 103.53

FLEXIBLE PAVEMENT SERVICEABILITY: 2.62

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FAIRFIELD IH-45 PRESSURE GROUT APR 78 -- SEC. 1A, SB INSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 6
(FILE: 6 SEC: 1 RECORDS: 22)

GAINR: 540.8 GAINL: 535.9

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	40.76	44.13	42.44	3.17
1.0	12.53	13.07	12.80	3.73
2.0	3.77	3.97	3.87	4.54
4.1	1.49	1.67	1.58	4.34
8.1	.80	.92	.86	3.49
16.2	.47	.56	.52	3.04
32.4	.20	.29	.25	3.02
64.9	.07	.10	.08	3.36
129.8	.02	.02	.02	3.51

MRM ROUGHNESS (COUNTS/.2 MILE): 46.30

FLEXIBLE PAVEMENT SERVICEABILITY: 3.92

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FAIRFIELD IH-45 PRESSURE GROUT APR 78 -- SEC. 1B, SB INSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 6

GAINR: 540.8 GAINL: 535.9

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	40.52	46.50	43.51	3.16
1.0	12.19	13.45	12.82	3.73
2.0	3.96	4.24	4.10	4.46
4.1	1.84	2.03	1.93	4.01
8.1	1.19	1.39	1.29	2.86
16.2	.88	1.01	.95	1.98
32.4	.47	.51	.49	1.80
64.9	.13	.14	.13	2.70
129.8	.03	.04	.04	3.00

MRM ROUGHNESS (COUNTS/.2 MILE): 79.39

FLEXIBLE PAVEMENT SERVICEABILITY: 3.12

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FAIRFIELD IH-45 PRESSURE GROUT NOV 77 -- SEC 2A, SB INSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 7
(FILE: 7 SEC: 2 RECORDS: 22)

GAINR: 532.9 GAINL: 540.9

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	45.32	46.21	45.76	3.13
1.0	13.41	13.15	13.28	3.69
2.0	3.76	3.76	3.76	4.58
4.1	1.39	1.40	1.40	4.51
8.1	.64	.70	.67	3.82
16.2	.31	.36	.34	3.63
32.4	.13	.16	.14	3.75
64.9	.04	.05	.05	3.89
129.8	.01	.01	.01	4.07

MRM ROUGHNESS (COUNTS/.2 MILE): 31.68

FLEXIBLE PAVEMENT SERVICEABILITY: 4.31

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FAIRFIELD IH-45 PRESSURE GROUT NOV 77 -- SEC 2B, SB INSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 7

GAINR: 532.9 GAINL: 540.9

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	44.65	51.09	47.87	3.11
1.0	13.16	13.89	13.52	3.67
2.0	3.89	4.26	4.07	4.47
4.1	1.53	1.71	1.62	4.30
8.1	.76	.92	.84	3.54
16.2	.45	.55	.50	3.10
32.4	.26	.33	.30	2.73
64.9	.14	.17	.16	2.45
129.8	.04	.04	.04	2.86

MRM ROUGHNESS (COUNTS/.2 MILE): 46.23

FLEXIBLE PAVEMENT SERVICEABILITY: 3.92

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FAIRFIELD IH-45 PRESSURE GROUT NOV 77 -- SEC 2A, SB INSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 8
(FILE: 8 SEC: 2 RECORDS: 22)

GAINR: 532.9 GAINL: 540.9

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	45.47	47.42	46.45	3.12
1.0	13.44	13.19	13.31	3.69
2.0	3.65	3.97	3.81	4.56
4.1	1.32	1.42	1.37	4.53
8.1	.55	.62	.59	3.96
16.2	.28	.33	.31	3.74
32.4	.14	.16	.15	3.71
64.9	.04	.05	.05	3.88
129.8	.01	.01	.01	4.08

MRM ROUGHNESS (COUNTS/.2 MILE): 29.18

FLEXIBLE PAVEMENT SERVICEABILITY: 4.38

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FAIRFIELD IH-45 PRESSURE GROUT NOV 77 -- SEC 2B, SB INSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 8

GAINR: 532.9 GAINL: 540.9

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	43.23	48.92	46.08	3.13
1.0	12.89	13.74	13.32	3.69
2.0	3.78	4.18	3.98	4.50
4.1	1.50	1.73	1.61	4.30
8.1	.79	.94	.86	3.49
16.2	.49	.58	.53	2.99
32.4	.29	.36	.32	2.57
64.9	.15	.18	.16	2.37
129.8	.04	.04	.04	2.90

MRM ROUGHNESS (COUNTS/.2 MILE): 48.12

FLEXIBLE PAVEMENT SERVICEABILITY: 3.87

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FAIRFIELD IH-45 PRESSURE GROUT APR 78 -- SEC. 2A, SB INSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 7
(FILE: 7 SEC: 2 RECORDS: 22)

GAINR: 1063.0 GAINL: 1048.9

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	45.39	49.60	47.50	3.11
1.0	13.42	13.15	13.29	3.69
2.0	3.95	4.01	3.98	4.50
4.1	1.51	1.49	1.50	4.41
8.1	.67	.72	.69	3.78
16.2	.31	.37	.34	3.61
32.4	.13	.16	.14	3.75
64.9	.04	.05	.05	3.89
129.8	.01	.01	.01	4.06

MRM ROUGHNESS (COUNTS/.2 MILE): 34.34

FLEXIBLE PAVEMENT SERVICEABILITY: 4.24

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FAIRFIELD IH-45 PRESSURE GROUT APR 78 -- SEC. 2B, SB INSIDE RUN 1

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 7

GAINR: 1063.0 GAINL: 1048.9

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	43.02	391.88	217.45	1.55
1.0	13.22	124.41	68.82	1.15
2.0	4.01	26.96	15.48	1.52
4.1	1.61	8.98	5.29	1.76
8.1	.80	3.03	1.92	2.12
16.2	.47	.89	.68	2.60
32.4	.27	.35	.31	2.65
64.9	.15	.16	.16	2.46
129.8	.04	.04	.04	2.86

MRM ROUGHNESS (COUNTS/.2 MILE): 140.93

FLEXIBLE PAVEMENT SERVICEABILITY: 2.00

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FAIRFIELD IH-45 PRESSURE GROUT APR 78 -- SEC. 2A, SB INSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 1 OF FILE 8
(FILE: 8 SEC: 2 RECORDS: 23)

GAINR: 540.2 GAINL: 534.1

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	47.26	49.33	48.29	3.10
1.0	13.95	13.65	13.80	3.65
2.0	4.05	4.08	4.07	4.47
4.1	1.54	1.52	1.53	4.38
8.1	.66	.73	.69	3.77
16.2	.32	.37	.34	3.60
32.4	.13	.16	.15	3.71
64.9	.04	.05	.05	3.87
129.8	.01	.01	.01	4.08

HRM ROUGHNESS (COUNTS/.2 MILE): 35.19

FLEXIBLE PAVEMENT SERVICEABILITY: 4.22

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FAIRFIELD IH-45 PRESSURE GROUT APR 78 -- SEC. 2B, SB INSIDE RUN 2

1050 FT SECTION BEGINS 0 FT FROM START OF REC 10 OF FILE 8

GAINR: 540.2 GAINL: 534.1

RMS VERTICAL ACCELERATION (FT/SEC SQ) AT 50 MPH:

BASE LENGTH	RIGHT	LEFT	COMBINED	ESTIMATED SI
.5	44.42	76.12	60.27	2.95
1.0	13.33	19.61	16.47	3.46
2.0	4.02	5.38	4.70	4.24
4.1	1.63	1.86	1.75	4.18
8.1	.80	.95	.88	3.47
16.2	.47	.56	.52	3.05
32.4	.26	.33	.30	2.72
64.9	.14	.17	.16	2.41
129.8	.04	.04	.04	2.83

HRM ROUGHNESS (COUNTS/.2 MILE): 50.12

FLEXIBLE PAVEMENT SERVICEABILITY: 3.82

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APPENDIX C

ROAD ROUGHNESS SUMMARIES PRODUCED BY THE COMPUTER PROGRAM VERTAC FOR COLUMBUS AND FAIRFIELD PROJECTS BEFORE AND AFTER THE GROUTING OPERATION

APPENDIX C. ROAD ROUGHNESS SUMMARIES PRODUCED BY THE COMPUTER PROGRAM VERTAC FOR COLUMBUS AND FAIRFIELD PROJECTS BEFORE AND AFTER THE GROUTING OPERATION

DESCRIPTION OF ITEMS ON THE VERTAC PRINTOUT

(1) Title - usually a road name, date of profilometer run, section number, and run number.

(2) Length of section actually processed (in feet), along with profilometer tape format and positioning information.

(3) GAINR, GAINL - right wheelpath and left wheelpath scale factors used by program to convert profile elevations to proper units.

(4) A row of roughness indices corresponding to each RMSVA base length examined - normally multiples of the sampling interval (.169 ft) in the range .5 ft to 130 ft:

Col 1 base length (feet)

Col 2 right wheelpath RMSVA

Col 3 left wheelpath RMSVA

Col 4 mean RMSVA from both wheelpaths

Col 5 SI value - Eq 2 with MO replaced with a linear function of the mean RMSVA (Col 4)

(5) MRM Roughness (counts/.2 mile) - equivalent to MO (Eq 1) with units of inches/mile

(6) Flexible Pavement Serviceability - SIV

TABLE C.1. STUDENT'S t TEST TO FIND OUT IF THERE IS ANY SIGNIFICANT DIFFERENCE ON THE SERVICEABILITY INDEX BEFORE AND AFTER THE GROUTING OPERATION FOR COLUMBUS PROJECT, IH-10, E. B. INSIDE LANE

Section	Treatment	Before $\bar{X}$		After $\bar{X}$		σ Before	σ After	$\|t\|$	2.910
1	A	3.59 3.61	$\bar{X}$ = 3.60	3.46 3.44	$\bar{X}$ = 3.45	0.01	0.01	10.61	≠
	B	3.25 3.51	$\bar{X}$ = 3.38	3.38 3.42	$\bar{X}$ = 3.40	0.13	0.02	0.15	=
2	A	3.71 3.50	$\bar{X}$ = 3.605	3.62 3.62	$\bar{X}$ = 3.62	0.105	0.0	0.14	=
	B	3.60 3.74	$\bar{X}$ = 3.67	3.78 3.74	$\bar{X}$ = 3.76	0.07	0.02	0.24	=

Confidence Level 90%
A = Treated
B = No Treatment

TABLE C.2. STUDENT'S t TEST TO FIND OUT IF THERE IS ANY SIGNIFICANT DIFFERENCE ON THE SERVICEABILITY INDEX BEFORE AND AFTER THE GROUTING OPERATION FOR COLUMBUS PROJECT, IH-10, E. B. OUTSIDE LANE

Section	Treatment	Before $\bar{X}$		After $\bar{X}$		σ Before	σ After	$\lvert t \rvert$	2.910
1	A	3.64 3.65	$\bar{X}$ = 3.645	3.14 3.19	$\bar{X}$ = 3.165	0.005	0.25	18.85	≠
	B	3.40 3.41	$\bar{X}$ = 3.405	3.37 3.28	$\bar{X}$ = 3.325	0.005	0.045	1.77	=
2	A	3.52 3.50	$\bar{X}$ = 3.51	3.34 3.41	$\bar{X}$ = 3.375	0.01	0.035	3.71	≠
	B	3.82 3.80	$\bar{X}$ = 3.81	3.73 3.73	$\bar{X}$ = 3.73	0.01	0.00	8.00	≠

Confidence Level 90%
A = Treated
B = No Treatment

TABLE C.3. STUDENT'S t TEST TO FIND OUT IF THERE IS ANY SIGNIFICANT DIFFERENCE ON THE SERVICEABILITY INDEX BEFORE AND AFTER THE GROUTING OPERATION FOR FAIRFIELD PROJECT, IH-45, E. B. OUTSIDE LANE

Section	Treatment	Before	$\bar{X}$	After	$\bar{X}$	σ Before	σ After	|t|	2.910
1	A	3.99 4.11	$\bar{X}$ = 4.05	3.95 4.02	$\bar{X}$ = 3.985	0.06	0.035	0.94	=
	B	3.40 3.23	$\bar{X}$ = 3.315	3.16 2.99	$\bar{X}$ = 3.075	0.085	0.085	2.00	=
2	A	4.27 4.28	$\bar{X}$ = 4.275	3.79 4.25	$\bar{X}$ = 4.02	0.005	0.23	1.11	=
	B	3.75 3.87	$\bar{X}$ = 3.81	3.17 3.66	$\bar{X}$ = 3.415	0.06	0.245	1.57	=

Confidence Level 90%

A = Treated

B = No Treatment

TABLE C.4. STUDENT'S t TEST TO FIND OUT IF THERE IS ANY SIGNIFICANT DIFFERENCE ON THE SERVICEABILITY INDEX BEFORE AND AFTER THE GROUTING OPERATION FOR FAIRFIELD PROJECT, IH-45, S. B. INSIDE LANE

Section	Treatment	Before $\bar{X}$		After $\bar{X}$		σ Before	σ After	$\lvert t \rvert$	2.910
1	A	4.00 4.00	$\bar{X}$ = 4.00	3.94 2.92	$\bar{X}$ = 3.93	0.00	0.01	7.0	≠
	B	3.20 3.21	$\bar{X}$ = 3.205	2.62 3.12	$\bar{X}$ = 2.87	0.005	0.25	1.34	=
2	A	4.31 4.38	$\bar{X}$ = 4.345	4.24 4.22	$\bar{X}$ = 4.23	0.035	0.01	3.16	≠
	B	3.92 3.87	$\bar{X}$ = 3.895	2.00 3.82	$\bar{X}$ = 2.91	0.025	0.91	1.08	=

Confidence Level 90%

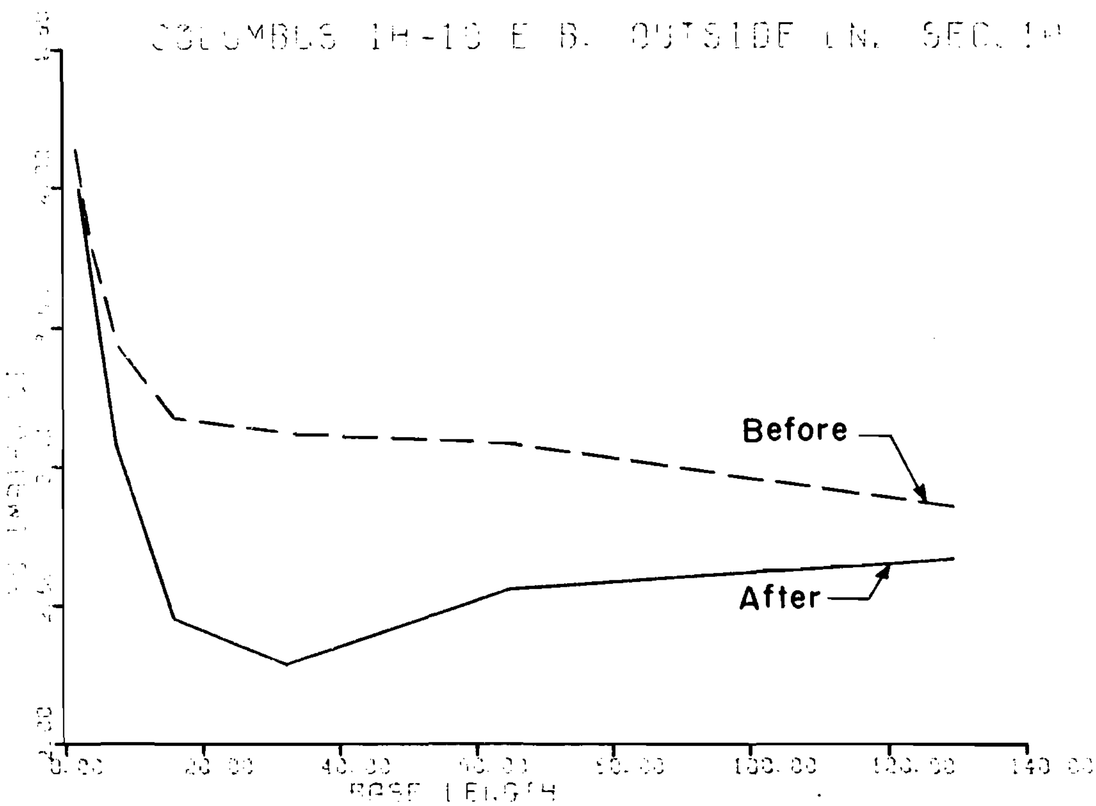
A = Treated

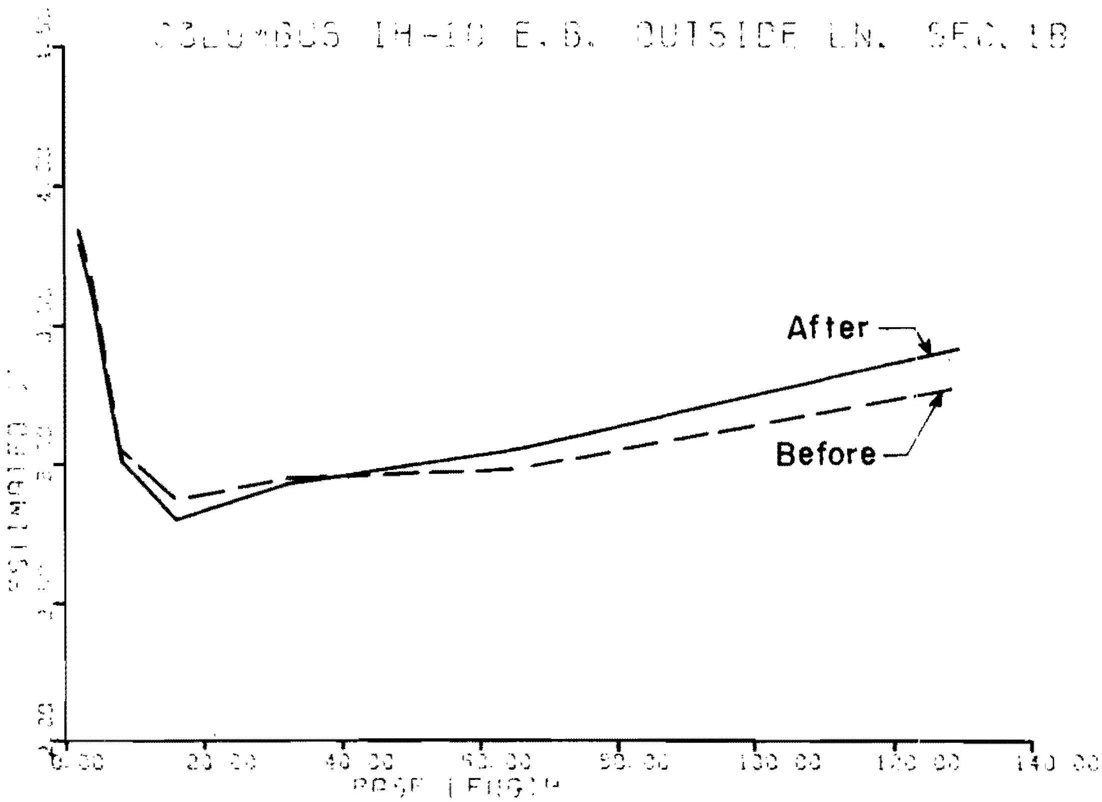
B = No Treatment

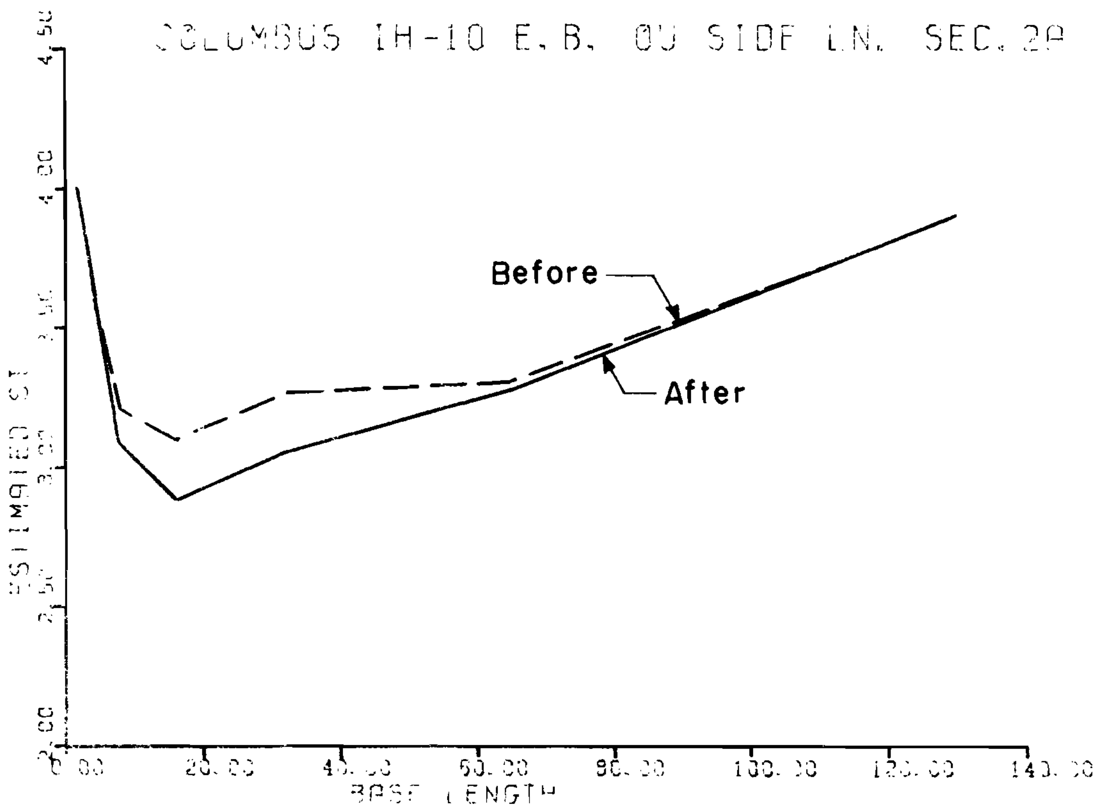
TABLE C.5. SERVICEABILITY INDEX OBTAINED BEFORE AND AFTER THE GROUTING OPERATION USING VERTAC COMPUTER PROGRAM FOR THE DATA COLLECTED AT COLUMBUS PROJECT, IH-10, E. B. OUTSIDE LANE

Section	Treatment	Before (Dec 77)	After (Mar 78)
1	A	SI = 3.645	SI = 3.165
	B	SI = 3.405	SI = 3.325
2	A	SI = 3.51	SI = 3.375
	B	SI = 3.81	SI = 3.73

A = Treated
B = No Treatment


Before
After


After
Before


COLUMBUS IH-10 E.B. OU SIDE LN. SEC.2A
Before
After
ESTIMATED ST
BASE LENGTH
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
2.00
2.50
3.00
3.50
4.00
4.50

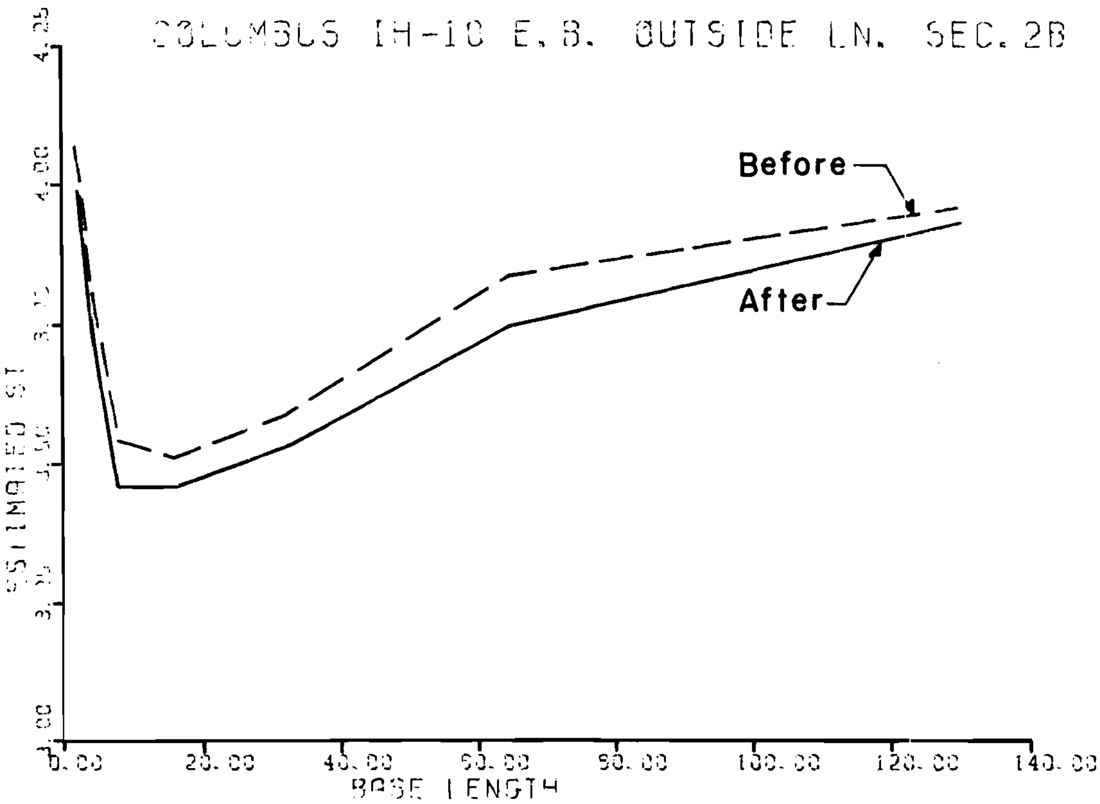
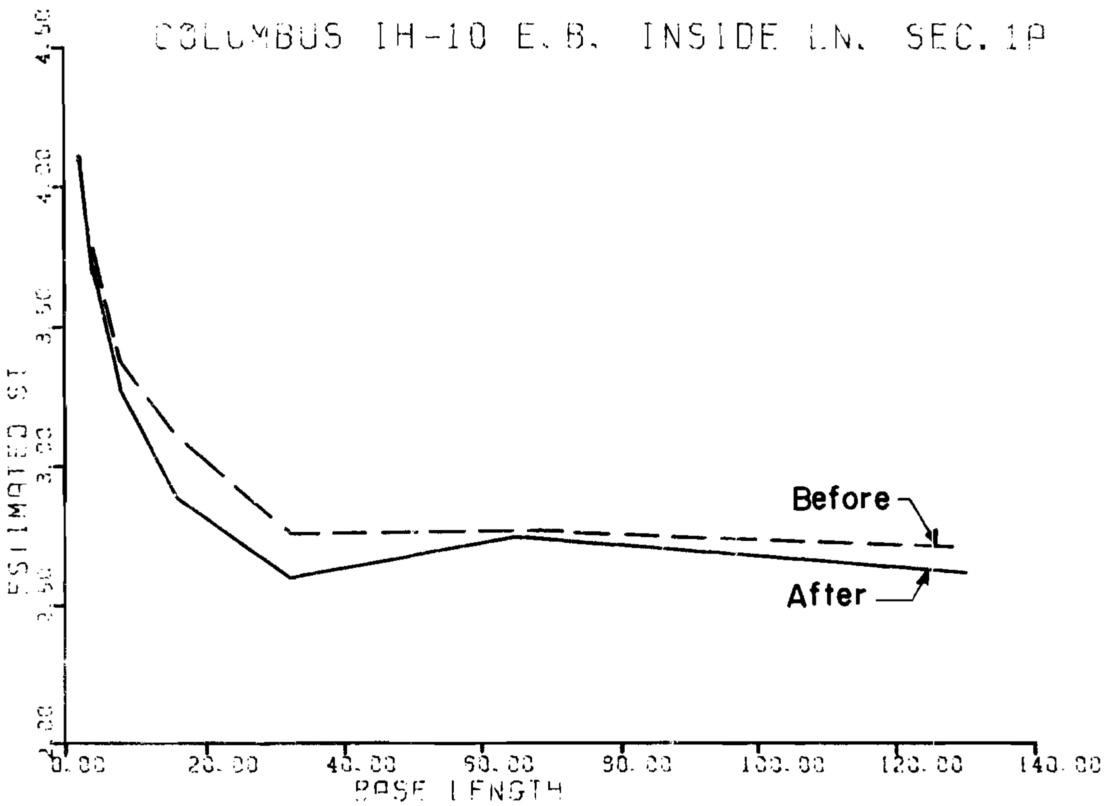
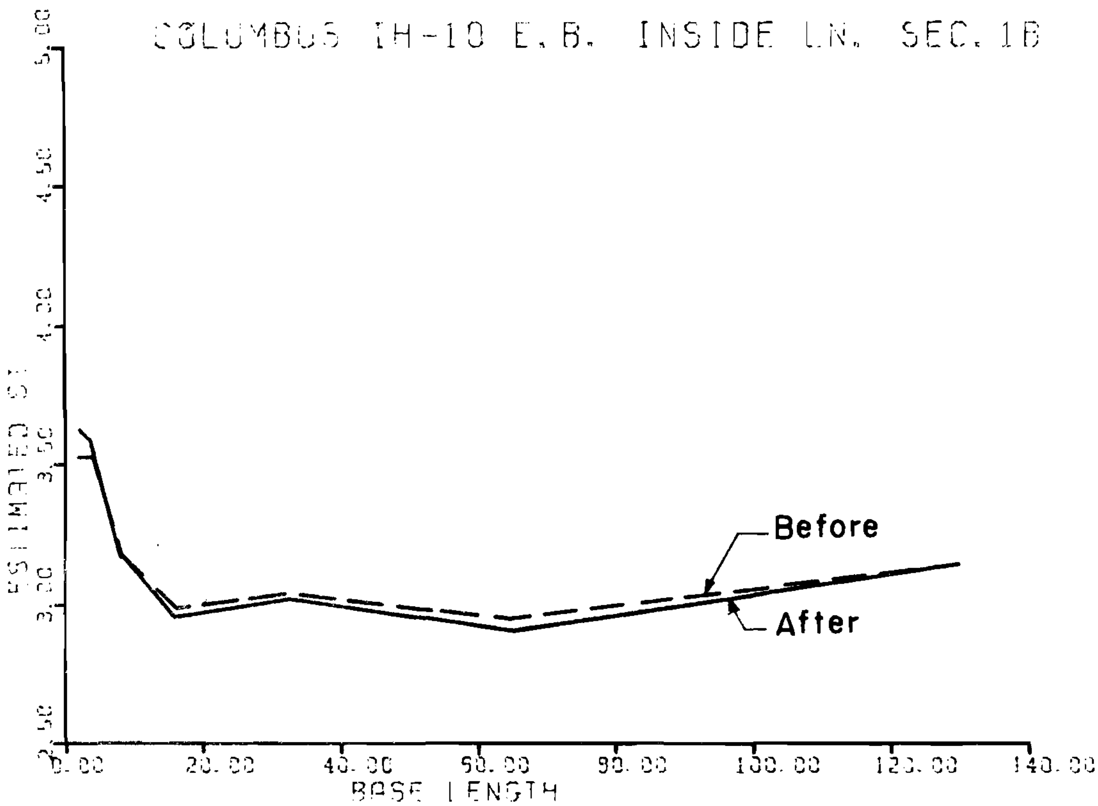

COLUMBUS IH-10 E.B. OUTSIDE LN. SEC. 2B
Before
After
ESTIMATED SI
4.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
BASE LENGTH

TABLE C.6. SERVICEABILITY INDEX OBTAINED BEFORE AND AFTER THE GROUTING OPERATION USING VERTAC COMPUTER PROGRAM FOR THE DATA COLLECTED AT COLUMBUS PROJECT, IH-10, E. B. INSIDE LANE

Section	Treatment	Before (Dec 77)	After (Mar 78)
1	A	SI = 3.605	SI = 3.62
	B	SI = 3.38	SI = 3.40
2	A	SI = 3.605	SI = 3.62
	B	SI = 3.67	SI = 3.76

A = Treated
B = No Treatment


COLUMBUS IH-10 E.B. INSIDE LN. SEC.1P
ESTIMATED SI
BASE LENGTH
Before
After
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
2.00
2.50
3.00
3.50
4.00
4.50


COLUMBUS IH-10 E.B. INSIDE LN. SEC. 1B
ESTIMATED SI
BASE LENGTH
Before
After
5.00
4.50
4.00
3.50
3.00
2.50
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00

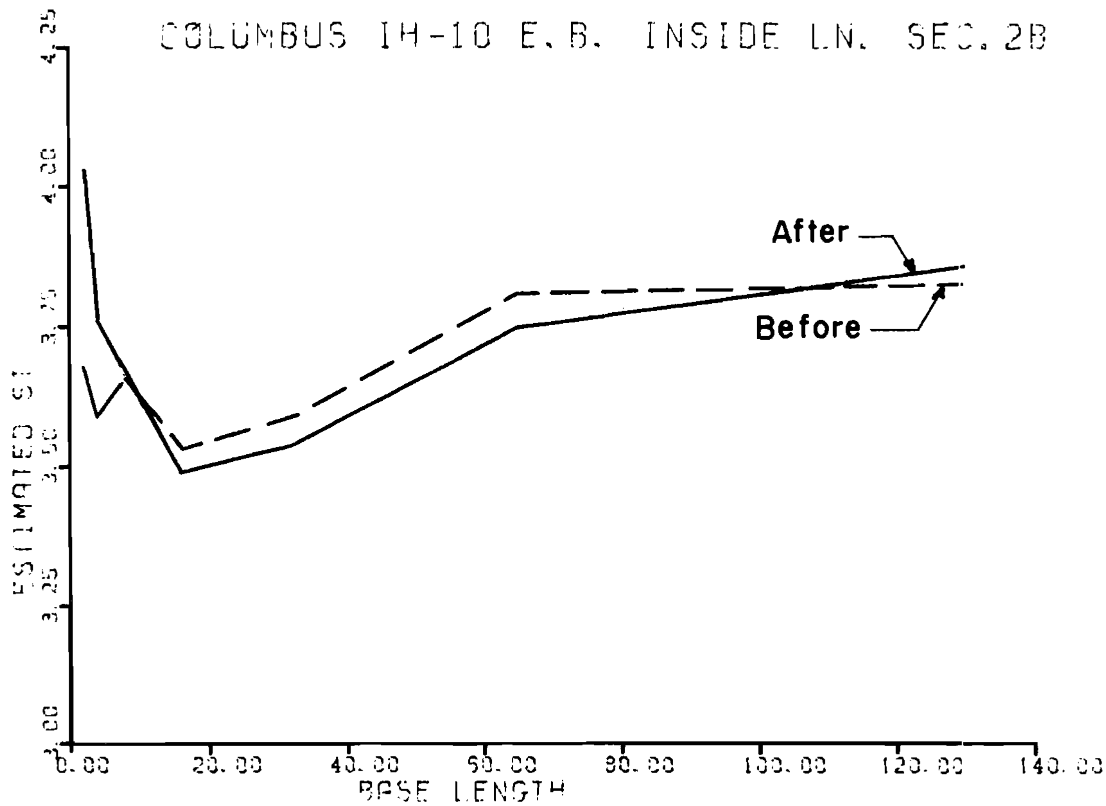
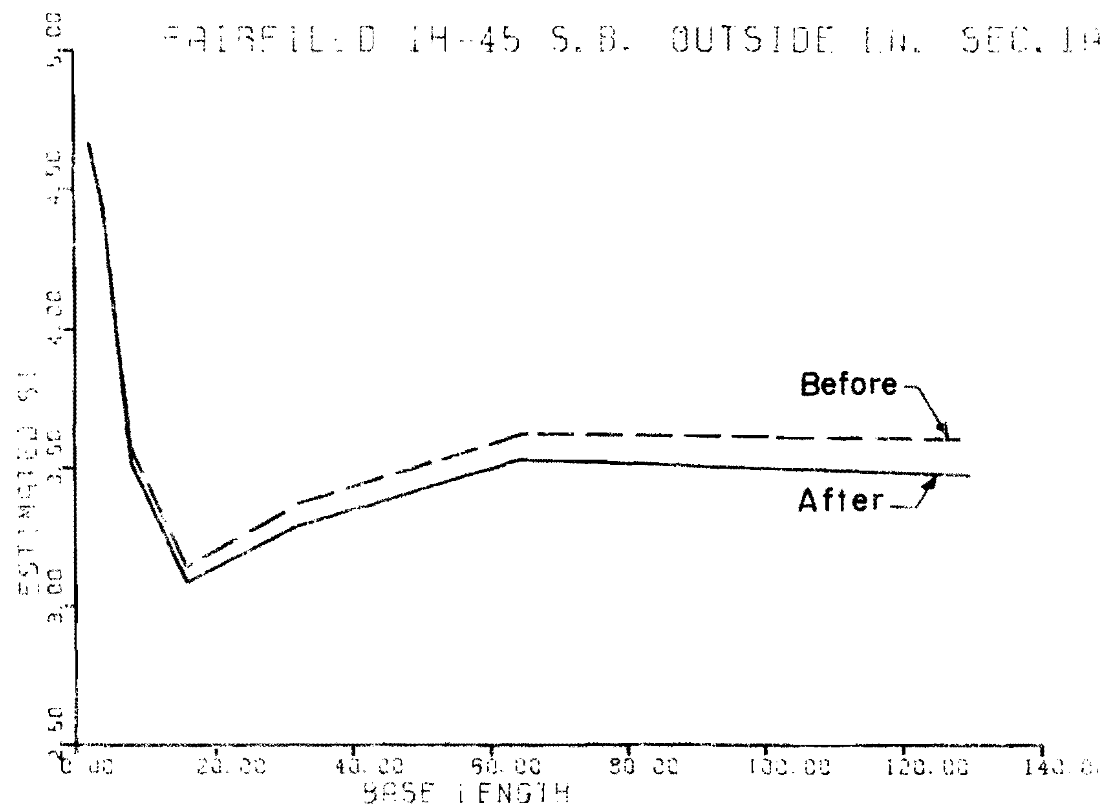

COLUMBUS IH-10 E.B. INSIDE LN. SEC.2B
ESTIMATED SI
BASE LENGTH
After
Before
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
3.00
3.25
3.50
3.75
4.00
4.25

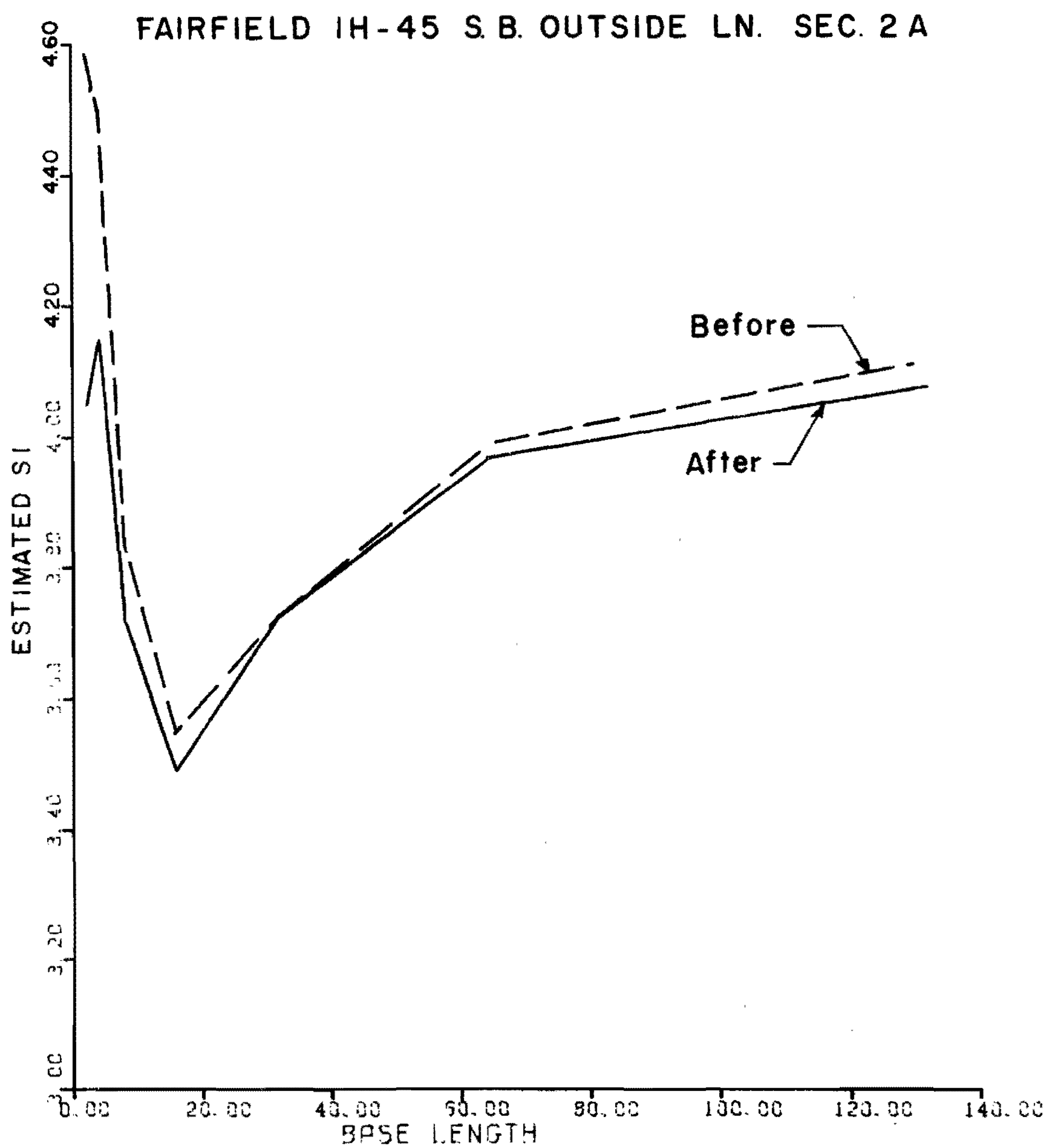
TABLE C.7. SERVICEABILITY INDEX OBTAINED BEFORE AND AFTER THE GROUTING OPERATION USING VERTAC COMPUTER PROGRAM FOR THE DATA COLLECTED AT FAIRFIELD PROJECT, IH-45, S. B. OUTSIDE LANE

Section	Treatment	Before (Nov 77)	After (April 78)
1	A	SI = 4.05	SI = 3.985
	B	SI = 3.315	SI = 3.075
2	A	SI = 4.275	SI = 4.02
	B	SI = 3.81	SI = 3.415

A = Treated
B = No Treatment



FAIRFIELD IH-45 S.B. OUTSIDE LN. SEC.1A
ESTIMATED SI
BASE LENGTH
Before
After
0.00
20.00
40.00
60.00
80.00
100.00
120.00
2.50
3.00
3.50
4.00
4.50
5.00


FAIRFIELD IH-45 S.B. OUTSIDE LN. SEC. 2 A
Before
After
ESTIMATED SI
BASE LENGTH
4.60
4.40
4.20
4.00
3.80
3.60
3.40
3.20
3.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00

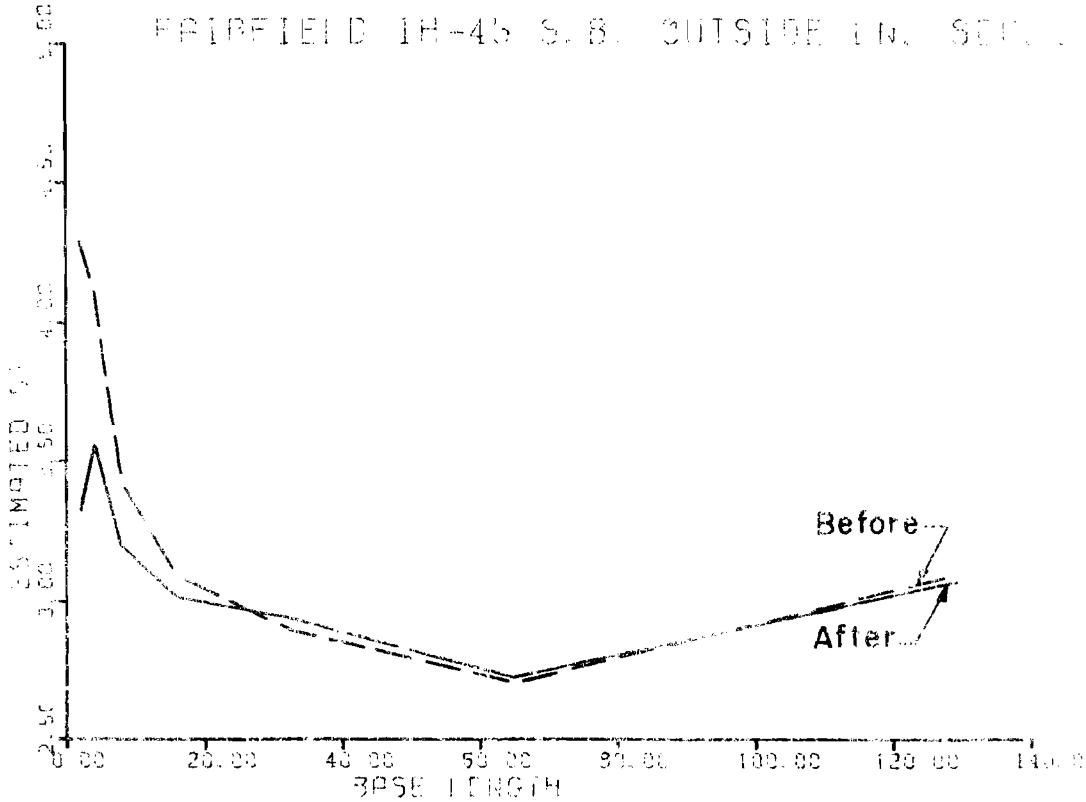
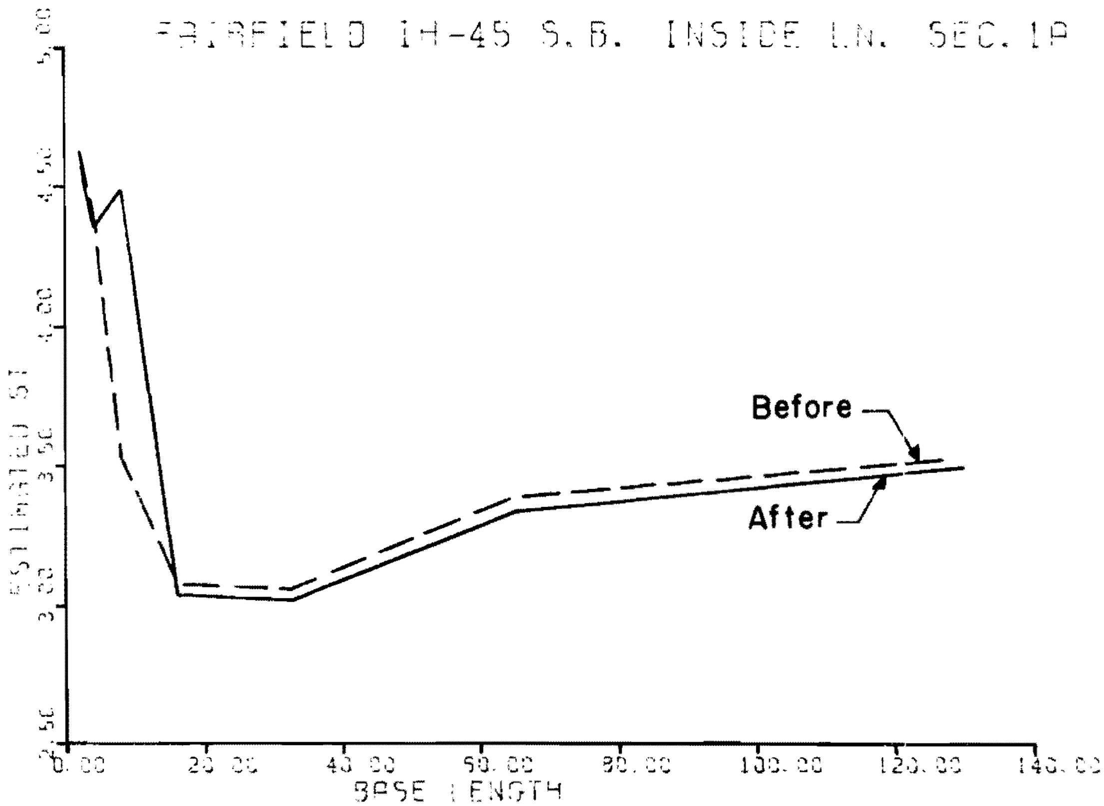
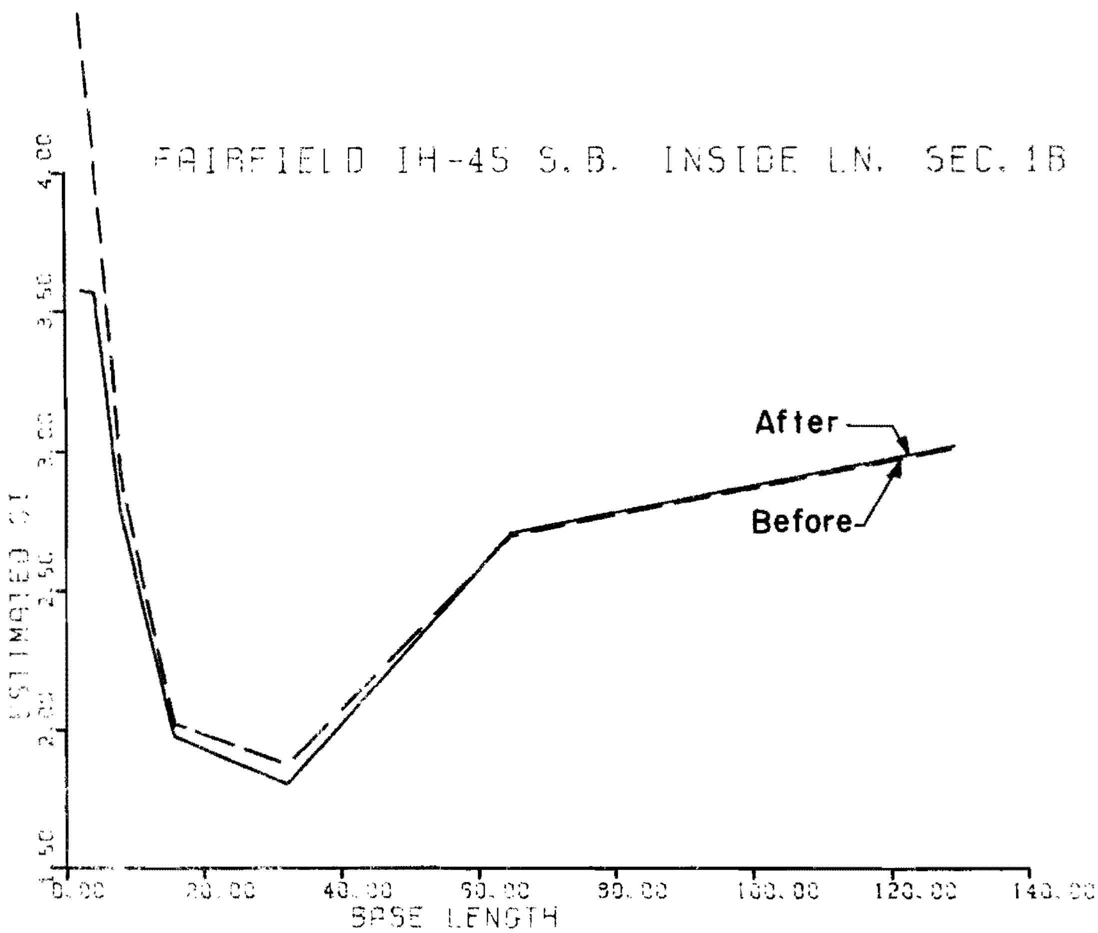

Before
After
20.00
40.00
100.00
BASE LENGTH

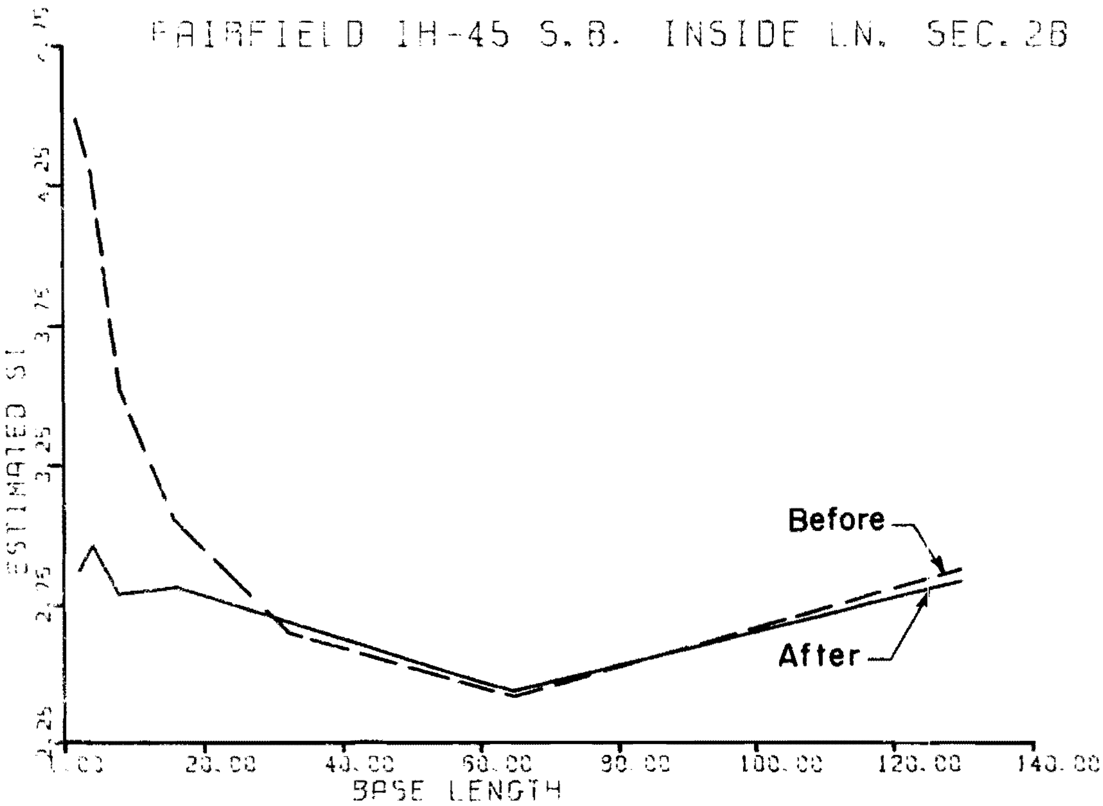
TABLE C.8. SERVICEABILITY INDEX OBTAINED BEFORE AND AFTER THE GROUTING OPERATION USING VERTAC COMPUTER PROGRAM FOR THE DATA COLLECTED AT FAIRFIELD PROJECT, IH-45, S. B. INSIDE LANE

Section	Treatment	Before (Nov 77)	After (April 78)
1	A	SI = 4.00	SI = 3.93
	B	SI = 3.205	SI = 2.87
2	A	SI = 4.345	SI = 4.23
	B	SI = 3.895	SI = 2.91

A = Treatment
B = No Treatment


FAIRFIELD IH-45 S.B. INSIDE LN. SEC.1A
Before
After
BASE LENGTH
ESTIMATED SI
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
2.50
3.00
3.50
4.00
4.50
5.00


FAIRFIELD IH-45 S.B. INSIDE LN. SEC. 1B
After
Before
BASE LENGTH
ESTIMATED SI
1.50
2.00
2.50
3.00
3.50
4.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00


FAIRFIELD IH-45 S.B. INSIDE LN. SEC.2B
ESTIMATED SI
BASE LENGTH
20.00
40.00
60.00
80.00
100.00
120.00
140.00
Before
After

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Francisco Torres received his Bachelor's Degree in Civil Engineering at the Universidad Nacional Autonoma de Mexico, in 1976. During the following years he was employed by several construction companies in Mexico as a Civil Engineer at various levels of responsibility. Resident and Superintendent were his initial levels on the construction of wharfs and deep foundations (1976-1978); then he was Head of the Organization Company (1978-1979), Head of the Organization Supervision and Control Department, and later Technical Manager in a construction company (1979-1980). From January to August 1980, he studied Management in the Economic Institute at the University of Colorado. In September 1980, he entered the Graduate School of The University of Texas at Austin and was employed by the Center for Transportation Research as a Research Engineer Assistant.

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