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16. Abstract

The objective of the study was to evaluate the performance of the bonded concrete overlay project on IH 610 North in Houston and implement the findings in other studies on bonded concrete overlay.

Field measurements were conducted periodically and laboratory testings were performed on the cores obtained from experimental sections. Then an assessment of overlay pavement life was made to arrive at conclusions and recommendations that would enable the Texas State Department of Highways and Public Transportation to design overlays for rehabilitation programs on CRCP.

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EVALUATION OF THE PERFORMANCE OF THE BONDED CONCRETE OVERLAY ON INTERSTATE HIGHWAY 610 NORTH, HOUSTON, TEXAS

by
Koestomo Koesno
B. Frank McCullough

Research Report 920-2

Research Project 3-12D-84-920

Evaluation of Thin Bonded Concrete Overlay in Houston

conducted for the

Texas State Department of Highways
and Public Transportation

by the

Center for Transportation Research

Bureau of Engineering Research
The University of Texas at Austin

December 1987

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PREFACE

This is the second report produced under Research Study 920. The project was conducted as part of a cooperative highway research program between the Center for Transportation Research and the Texas State Department of Highways and Public Transportation.

In addition, thanks are extended to all who assisted in the preparation of this report, especially to Lyn Gabbert for help in typing and Michele Mason Sewell for drafting. Special thanks are also due to James R. Lundy and Dr. Waheed Uddin for their time in discussion of the study.

LIST OF REPORTS

Report 920-1, "Design Analysis for Rehabilitation of the CRCP on Southeast Quadrant of Houston Loop 610," by Center for Transportation Research staff and faculty, presents existing pavement and support materials characteristics and the development of the most economical design based on the expected traffic over the life of pavement. October 1986.

Report 920-2, "Evaluation of the Performance of the Bonded Concrete Overlay on Interstate Highway 610 North, Houston, Texas," by Koestomo Koesmo and B. Frank McCullough, presents the findings of a pavement monitoring program on the IH 610 North, Houston project. December 1987.

ABSTRACT

The objective of the study was to evaluate the performance of the bonded concrete overlay project on IH 610 North in Houston and implement the findings in other studies on bonded concrete overlay.

Field measurements were conducted periodically and laboratory testings were performed on the cores obtained from experimental sections. Then an assessment of overlay pavement life was made to arrive at conclusions and recommendations that would enable the Texas State Department of Highways and Public Transportation to design overlays for rehabilitation programs on CRCP.

SUMMARY

Ten experimental sections with lengths ranging from 400 to 600 feet were identified from a 3–1/2 mile overlay project on IH 610 North, East Bound, for monitoring to assess the performance of bonded concrete overlay.

Periodic field measurements were made and a series of laboratory tests were conducted to study the correlations between materials and performance based on different environmental conditions. An assessment of overlay pavement life was also made on this study.

The report includes conclusions and recommendations derived from this study.

IMPLEMENTATION STATEMENT

Based on this study, the following are recommended for implementation:

(1) This study shows that a bonded concrete overlay may be used on an existing PCC pavement to extend the life.

(2) Based on the outside lanes only, the surface of the existing pavement may be successfully cleaned and excellent bond strength may be obtained with "shot blast" equipment. Limited delaminations on the inside lanes have prompted the Highway Department to use cold milling on the next job pending further investigations into the cause of this debonding.

(3) Failures should be repaired before an overlay is placed. The results show that the existing pavement condition does not affect the overlay pavement performance if the existing punchouts are repaired before placement of concrete overlay.

(4) Concrete with limestone coarse aggregates may be used to overlay an existing concrete pavement with siliceous river gravel coarse aggregates.

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CHAPTER 1. INTRODUCTION

This report is concerned with the evaluation of the bonded concrete overlay on IH 610 North in Houston. This chapter presents background information, objectives, and the scope of the report.

BACKGROUND

Since 1956 the United Sates has been involved in the largest public works project ever undertaken - the 42,500-mile system of Interstate Highways. By this time, some of these highways have begun to wear out. Not only are we reaching the design life of many of the highways, but also the amount of traffic has far exceeded the design estimates (Ref 1). As a result, considerable attention is now being given to maintenance, rehabilitation, and resurfacing.

Portland cement concrete (PCC) overlays have been used to resurface existing pavements for more than 60 years. There is considerable experience in the practical use of bonded concrete overlay with airport runways and bridge decks. There are some instances where bonded concrete overlays have been used for improving skid resistance (Refs 2 and 3).

The U.S. Air Force has more than 20 years of experience with thin bonded concrete overlays (Ref 4). Overlays ranging from 2 to 4 inches in thickness have been constructed on runways subjected to light as well as heavy traffic and used by small and large aircraft. The condition of the overlays over a period of 17 years has ranged from good to very good. But there have also been a number of cases where problems were encountered. One involves a taxiway at the Tulsa airport which experienced severe reflection cracking and rapid deterioration following loss of interface bond.

However, experience with bonded concrete overlays on highway pavements is limited. During the past two to three years, several research studies have been undertaken at the Center for Transportation Research to address the questions on the viability and usefulness of adopting bonded concrete overlays for highway pavement rehabilitation. Tests were made on laboratory specimens and cores from slabs constructed in the field. A major finding in this research (Ref 5) was that the interface between the existing slab and the overlay develops a shear strength of 3 to 4 times the theoretically predicted shear stress under expected traffic. Also, the condition survey on the overlaid section soon after overlaying and again over a period of of six months did not show any significant distress. This experience encouraged the SDHPT to use 4-inch bonded concrete overlay on a length of about 3 1/2 miles to improve the pavement condition on Interstate Highway 610 North in Houston. It was suggested that several sections of this pavement be identified and monitored to gather performance information periodically. It was anticipated that the analysis carried out would answer questions about the relative merits of different types of overlay materials.

The overlay project is located on IH 610 North between East T.C. Jester Blvd and IH 45 (from station 207+78.37 to station 400+00). At this location the mainlane roadway is an eight-lane freeway with four 12-foot through lanes in each direction, a 20-foot median with a concrete median barrier, and 10-foot outside shoulders.

The original mainlane pavement structure is an 8–inch continuously reinforced concrete pavement (CRCP). The concrete pavement rests on a 6-inch–thick cement stabilized subbase. The median and outside shoulders consist of asphalt concrete pavement on cement stabilized base. Figures 1.1 and 1.2 show the project location and a typical cross section, respectively.

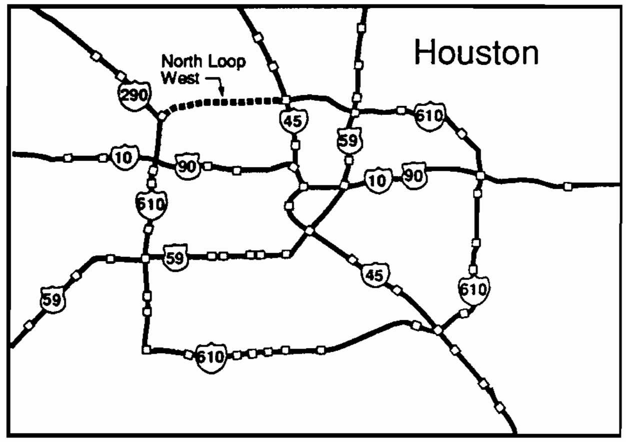


Fig 1.1. ***Location of the overlay project.***

The variables considered in this overlay project were:

(1) Overlay reinforcements: welded wire fabric and steel fibers.
(2) Course Aggregate: crushed limestone and silicious river gravel.
(3) Bonding agent: cement water grout, which was used throughout the project, except on one short experimental section.
(4) Condition of existing pavement: several levels of distress.

The locations and dimensions of the sections where these variables were applied in the field are shown in Appendix A, Table A.1 and Figs A.1 through A.5.

OBJECTIVE OF THE STUDY

The primary objective of the study was to evaluate the performance of the bonded concrete overlay on IH 610

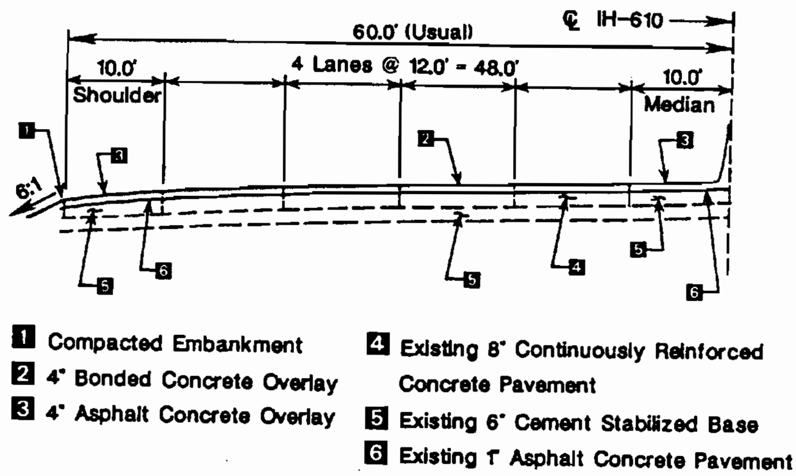


Fig 1.2. ***A typical cross section of the bonded concrete overlay pavement on IH 610 North, Houston.***

North in Houston and implement the findings on subsequent bonded concrete overlay projects.

The sub-objectives of the study are

(1) to identify several sections that represent the variations in the original pavement condition and the materials used for the overlay,

(2) to observe and record the actual materials used for overlay,

(3) to make observations on the behavior parameters before and after-overlay, and

(4) to analyze and evaluate the field data.

SCOPE OF THE REPORT

Chapter 2 describes the study, including the design variables and a description of the test sections.

Chapter 3 presents field measurements, including before and after overlay deflection data, condition survey, roughness data, and skid resistance.

Chapter 4 presents the laboratory study. Details of the apparatus and procedures used in the direct shear test and indirect tensile test are presented, together with the test results.

Chapter 5 explains the analysis of performance data, including deflections and condition survey results.

Chapter 6 discusses the trends of the field data. It also presents a comparison of predicted and measured after overlay deflections and an assessment of pavement life resulting from the overlay placement.

Chapter 7 presents a recommended measurement program.

Chapter 8 summarizes the conclusions of the study and presents recommendations for field implementations and further studies.

CHAPTER 2. DESCRIPTION OF STUDY

This chapter presents a description of the study on eastbound IH 610 North, which used various types of bonded concrete overlay.

EXPERIMENT DESIGN

The variables considered in this study are:

(1) overlay reinforcement: welded wire fabric and steel fibers;

(2) overlay coarse aggregates: silicious river gravel and crushed limestone; and

(3) existing pavement condition: no distress, moderate distress, and severe distress.

From the 3–1/2 mile overlay project on eastbound IH 610 North, ten test sections with lengths ranging from 400 to 600 feet were identified on the basis of maintaining homogeneity within a section (similar overlay material, overlay aggregate, and distress), and also having an adequate length to make meaningful observations. It was planned that periodical monitoring would be conducted for at least three years. Thus, it will be possible to identify any correlations between materials and performance based on the different environmental conditions.

Based on the results of the before overlay condition survey, which are summarized in Table 2.1, the distress indices of each experimental section were determined with the following formula (Ref 6):

$$Z_c = 1.0 - 0.065\,FF - 0.015\,MS - 0.009\,SS \quad (1)$$

where

Z_c = distress index,

FF = number of failures per mile (sum of punchouts and patches),

MS = percent minor spalling, and

SS = percent severe spalling.

The calculated distress indices of each test section were plotted as shown in Fig 2.1, and based on this plot, the distress level of each section was determined. Three levels of distress were used in this study:

(1) no distress, with the distress index ranging from 0 to 1;

(2) moderate distress, with the distress index ranging from -2 to 0; and

(3) severe distress, with the distress index less than -2.

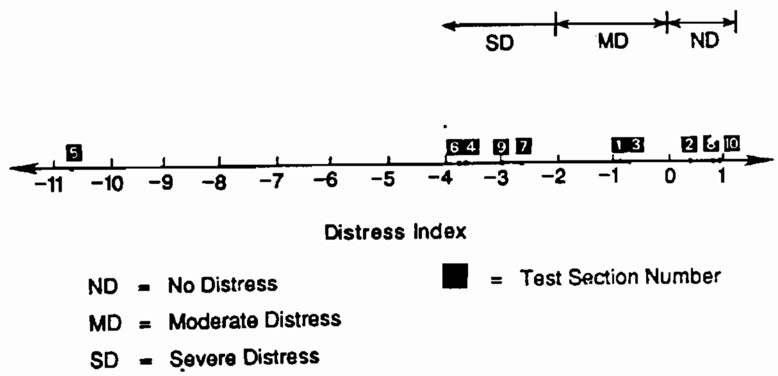


Fig 2.1. *A line diagram of distress index of each test section.*

TABLE 2.1. ***SUMMARY OF CONDITION SURVEY BEFORE OVERLAY (MAY 1985)***

Test Sect No.	Total Number of Transverse Cracks	Total Length of Longitudinal Cracks (feet)	Total Number of Punchouts	Total Number of Patches	Total No. of Failures: Per Sect	Total No. of Failures: Per Mile	Total Number of Minor Spallings	Total Number of Severe Spallings	Distress Index Z_c
1	238	80	1	2	3	26.4	26	2	-1.12
2	272	309	1	0	1	8.8	1	0	0.42
3	322	447	1	2	3	26.2	5	0	-0.73
4	311	172	8	0	8	71.0	15	0	-3.69
5	262	361	17	2	19	179.5	1	0	-10.67
6	319	233	8	0	8	72.2	6	3	-3.73
7	306	192	4	2	6	54.6	8	2	-2.59
8	179	6	0	0	0	0	15	0	0.87
9	288	366	6	1	7	61.6	1	2	-3.02
10	259	388	0	0	0	0	2	1	0.98

Note: Total number of failures is the sum of punchouts and patches.

The factorial design of the study is shown in Fig 2.2. Note that the factorial design of the experiment does not include fiber reinforced concrete with limestone aggregate.

DESCRIPTION OF TEST SECTION

The 10 test sections are located on the east bound portion of IH 610 North, between Ella Boulevard and about 700 feet north of Yale Boulevard. At this location, the roadway is a 4–lane highway in each direction. All the test sections are on the outside lane (the lane which is the furthest from the median barrier). The main lane widths are 12 feet and the shoulders are 10 feet wide. A typical plan view of a test section is shown in Fig 2.3.

Figure 2.4 and Table 2.2 show the location and the dimension of each test section. As can be seen in Fig 2.5, the test sections are on embankment and at natural grade.

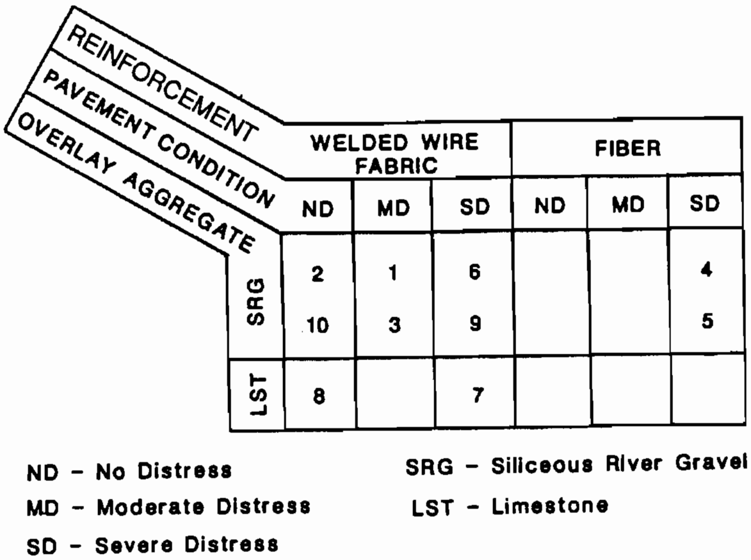


Fig 2.2. ***Factorial design of the east bound IH 610 North, Houston, experimental project.***

TABLE 2.2. ***THE LOCATIONS AND DIMENSIONS OF THE 10 TEST SECTIONS***

Test Sect No.	Beginning Sta No.	Total Length of Test Sect (ft)	End Sta No.
1	246 + 23	252 + 22	599
2	252 + 22	258 + 18	596
3	258 + 18	264 + 23	605
4	286 + 22	292 + 17	595
5	292 + 17	297 + 76	559
6	306 + 15	312 + 00	585
7	316 + 20	322 + 00	580
8	322 + 00	326 + 00	400
9	332 + 00	338 + 00	600
10	341 + 00	347 + 00	600

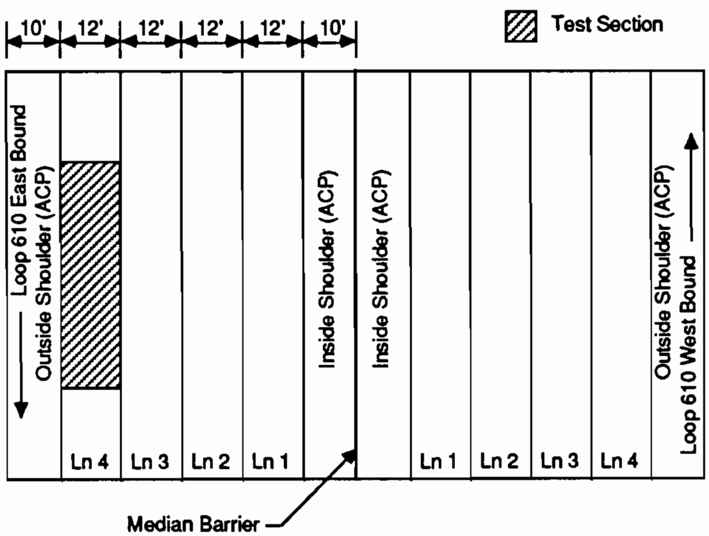


Fig 2.3. ***Typical plan view of a test section on IH 610 North experimental project, showing details of layout.***

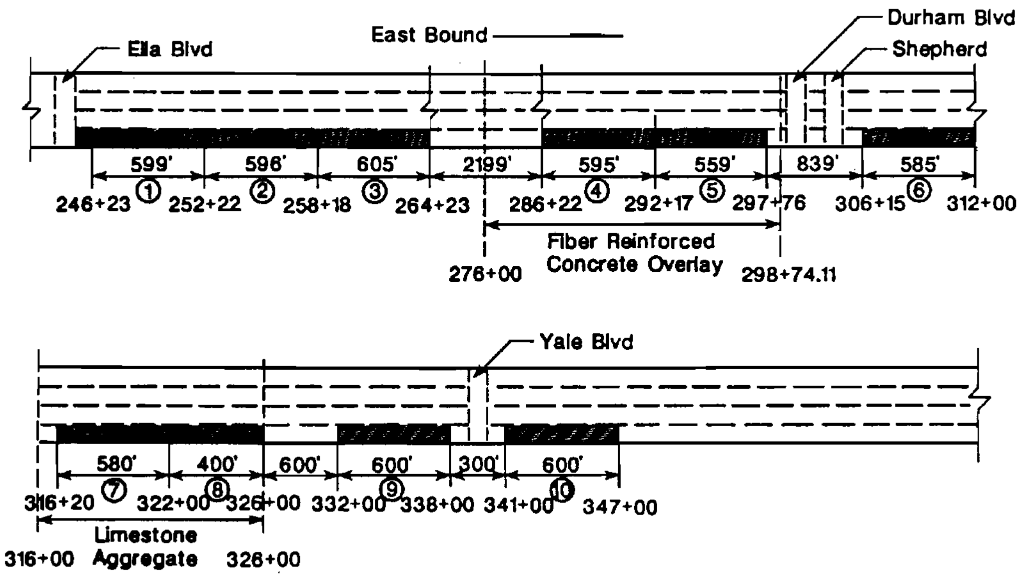


Fig 2.4 . ***Plan view and locations of the 10 test sections, east bound IH 610 North, Houston.***

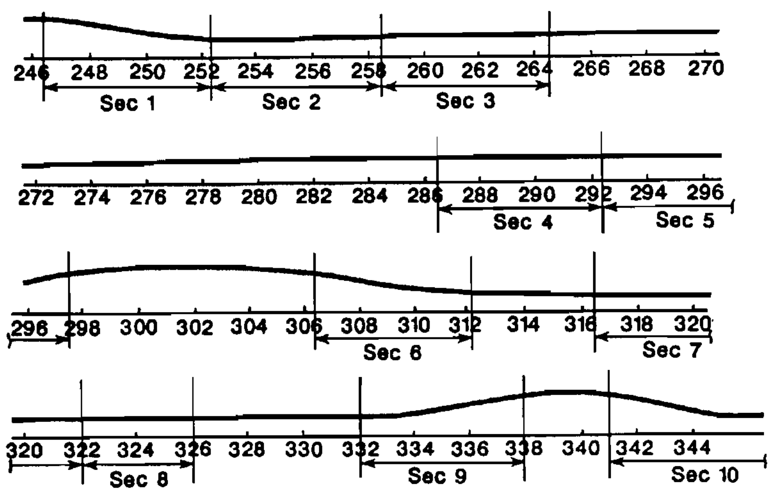


Fig 2.5. ***Profile of the 10 test sections, east bound IH 610 North, Houston.***

CHAPTER 3. PRESENTATION OF FIELD DATA

This chapter presents the field data collected as part of the study observing the performance of bonded concrete overlay on IH 610 North in Houston. Various measurements were made to evaluate behavior before and after overlay construction. The data obtained concerned deflection, condition survey, roughness, skid resistance, and delamination. Besides these data, many cores were secured from various test sections.

DEFLECTION MEASUREMENTS

The Dynaflect was used to measure the pavement deflection before and after overlay (see Fig 3.1). The deflection readings were taken every 50 feet, approximately on the centerline of the outside lane within each experimental section. For evaluating the performance of the pavement before and after overlay, repeated measurements were conducted at approximately the same location before and after overlay construction.

During the period of the study, Center for Transportation Research personnel conducted deflection measurements at 5 different times:

(1) May 22, 1985 (before overlay): Sections 1-10;
(2) December 3, 1985 (before overlay): Sections 1-5;
(3) February 4, 1986 (after overlay): Sections 1-5;
(4) January 13, 1987 (after overlay): Sections 6-10 and 1 control section; and
(5) March 19, 1987 (after overlay): Sections 1-5.

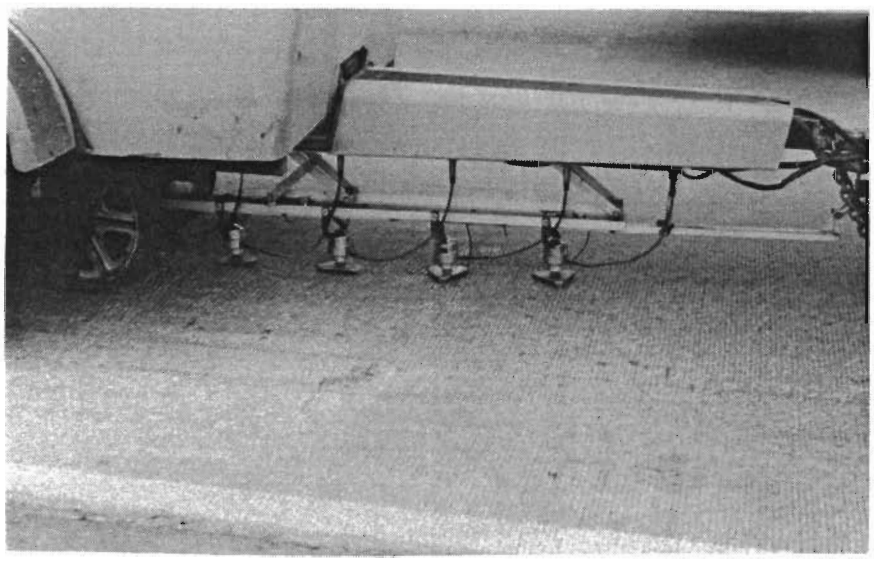


Fig 3.1. ***Dynaflect system in operating position.***

Note that on January 13, 1987, deflection measurements could not be conducted on the first five test sections because of equipment problems and the traffic control plan.

Tables 3.1 through 3.5 show the means and standard deviations of deflections of all sensors (sensors 1 through 5) by date and test section number (the complete data are presented in Appendix B).

TABLE 3.1. ***MEANS AND STANDARD DEVIATIONS OF DEFLECTIONS, MAY 22, 1985 (BEFORE OVERLAY), IH 610 NORTH, HOUSTON***

Test Sect No.	Sensor 1 Mean	Sensor 1 Std. Dev.	Sensor 2 Mean	Sensor 2 Std. Dev.	Sensor 3 Mean	Sensor 3 Std. Dev.	Sensor 4 Mean	Sensor 4 Std. Dev.	Sensor 5 Mean	Sensor 5 Std. Dev.
1	0.492	0.113	0.447	0.097	0.398	0.079	0.337	0.056	0.279	0.037
2	0.688	0.122	0.625	0.118	0.555	0.104	0.447	0.077	0.351	0.063
3	0.598	0.080	0.549	0.084	0.488	0.062	0.396	0.046	0.319	0.032
4	0.621	0.048	0.571	0.059	0.534	0.056	0.447	0.038	0.368	0.035
5	0.538	0.098	0.482	0.088	0.451	0.076	0.375	0.061	0.304	0.041
6	0.494	0.108	0.445	0.098	0.419	0.081	0.353	0.063	0.293	0.052
7	0.602	0.060	0.502	0.046	0.508	0.055	0.427	0.055	0.357	0.048
8	0.592	0.100	0.510	0.085	0.511	0.080	0.434	0.072	0.361	0.057
9	0.542	0.084	0.448	0.073	0.452	0.048	0.386	0.038	0.327	0.037
10	0.520	0.139	0.402	0.104	0.429	0.113	0.353	0.094	0.298	0.064

CONDITION SURVEYS

Condition surveys were conducted in order to monitor the development of various distress types on the pavement before and after overlay construction. The method used in this study is designated the "small section method." It is a detailed procedure and is conducted by a team of two people. The team walks along the lane; one person walks with a rolling meter and the other maps all visible distress with reference to highway mileposts (see Fig 3.2). The types of distress mapped are transverse and longitudinal cracks, spallings, punch-

TABLE 3.2. ***MEANS AND STANDARD DEVIATIONS OF DEFLECTIONS, DECEMBER 3, 1985 (BEFORE OVERLAY), IH 610 NORTH, HOUSTON***

Test Sect No.	Sensor Number 1 Mean	1 Std. Dev.	2 Mean	2 Std. Dev.	3 Mean	3 Std. Dev.	4 Mean	4 Std. Dev.	5 Mean	5 Std. Dev.
1	.627	.142	.514	.098	.453	.058	.369	.048	.308	.031
2	.725	.082	.615	.071	.526	.062	.421	.055	.342	.048
3	.785	.117	.656	.087	.569	.077	.454	.058	.376	.048
4	.803	.054	.682	.054	.623	.058	.521	.042	.449	.038
5	.662	.128	.547	.103	.508	.096	.420	.070	.357	.053

TABLE 3.3. ***MEANS AND STANDARD DEVIATIONS OF DEFLECTIONS, FEBRUARY 4, 1986 (AFTER OVERLAY), IH 610 NORTH, HOUSTON***

Test Sect No.	Sensor Number 1 Mean	1 Std. Dev.	2 Mean	2 Std. Dev.	3 Mean	3 Std. Dev.	4 Mean	4 Std. Dev.	5 Mean	5 Std. Dev.
1	.330	.043	.296	.040	.265	.031	.228	.022	.206	.016
2	.364	.042	.331	.040	.293	.035	.256	.031	.230	.030
3	.388	.071	.352	.065	.311	.053	.266	.048	.243	.038
4	.437	.025	.402	.024	.362	.024	.316	.021	.287	.020
5	.412	.041	.377	.038	.332	.029	.292	.025	.262	.017

TABLE 3.4. ***MEANS AND STANDARD DEVIATIONS OF DEFLECTIONS, JANUARY 13, 1987 (AFTER OVERLAY), IH 610 NORTH, HOUSTON***

Test Sect No.	Sensor Number 1 Mean	1 Std. Dev.	2 Mean	2 Std. Dev.	3 Mean	3 Std. Dev.	4 Mean	4 Std. Dev.	5 Mean	5 Std. Dev.
6	.334	.081	.313	.067	.300	.064	.224	.047	.215	.043
7	.434	.062	.408	.060	.394	.059	.325	.045	.281	.036
8	.396	.054	.371	.050	.355	.048	.289	.037	.255	.036
9	.396	.051	.376	.047	.362	.042	.297	.036	.265	.029
10	.363	.054	.344	.051	.332	.049	.266	.039	.235	.029

TABLE 3.5. ***MEANS AND STANDARD DEVIATIONS OF DEFLECTIONS, MARCH 19, 1987 (AFTER OVERLAY), IH 610 NORTH, HOUSTON***

Test Sect No.	Sensor Number 1 Mean	1 Std. Dev.	2 Mean	2 Std. Dev.	3 Mean	3 Std. Dev.	4 Mean	4 Std. Dev.	5 Mean	5 Std. Dev.
1	.283	.029	.263	.029	.236	.024	.210	.021	.184	.014
2	.348	.038	.319	.033	.281	.031	.247	.029	.218	.023
3	.373	.101	.346	.097	.309	.092	.265	.084	.233	.073
4	.430	.021	.402	.023	.362	.022	.322	.022	.282	.018
5	.411	.024	.376	.026	.333	.023	.285	.024	.248	.019

outs, and patches. This detailed procedure has been used for CRCP when detailed information is desired (Ref 6).

During the time of the study, condition surveys were conducted before and after overlay construction as follows:

(1) May 22, 1985 (before overlay): Sections 1-10; and
(2) January 13, 1987 (after overlay): Sections 1-10 and 1 control section.

Tables 3.6 through 3.9 summarize the distress types of transverse cracks (Table 3.6), longitudinal cracks (Table 3.7), spallings (Table 3.8), and punchouts (Table 3.9).

ROUGHNESS DATA

The profilometer was used to evaluate the riding quality and changes in profile of the pavement (Fig 3.3). The profilometer measurements after overlay construction provide an indication of the improvement in the riding quality resulting from the overlay.

During the course of the study, four profilometer readings were conducted on the outside lane:

(1) May, 1985 (before overlay): Sections 1-10; and
(2) February, 1986 (after overlay): Sections 1-4;
(3) May, 1986 (after overlay): Sections 1-3; and
(4) March, 1987 (after overlay): Sections 1-5 and 7-10.

The profilometer readings obtained in May, 1985, provided a before overlay

Present Serviceability Index (PSI). Profilometer readings were taken again on February 12, 1986, soon after the first five sections were overlaid. The reading on Section 2 was in error, and had to be discarded. The results shows that the after–overlay PSI for Section 3 is lower than the before–overlay value. This may have been due to the presence of construction dirt on the section. As a result, it was felt necessary to retake the after–overlay readings on these sections.

On March, 1987, personnel of the Texas State Department of Highways and Public Transportation were not able to take the reading from Section 6 since the section was located next to an exit ramp, and the way the traffic control was set up, made it difficult to close that ramp.

The summary of Present Serviceability Indices before and after overlay are presented in Table 3.10.

SKID RESISTANCE DATA

Skid resistance measurements were taken before the overlay construction on May 22, 1985. The values are tabulated in Table 3.11.

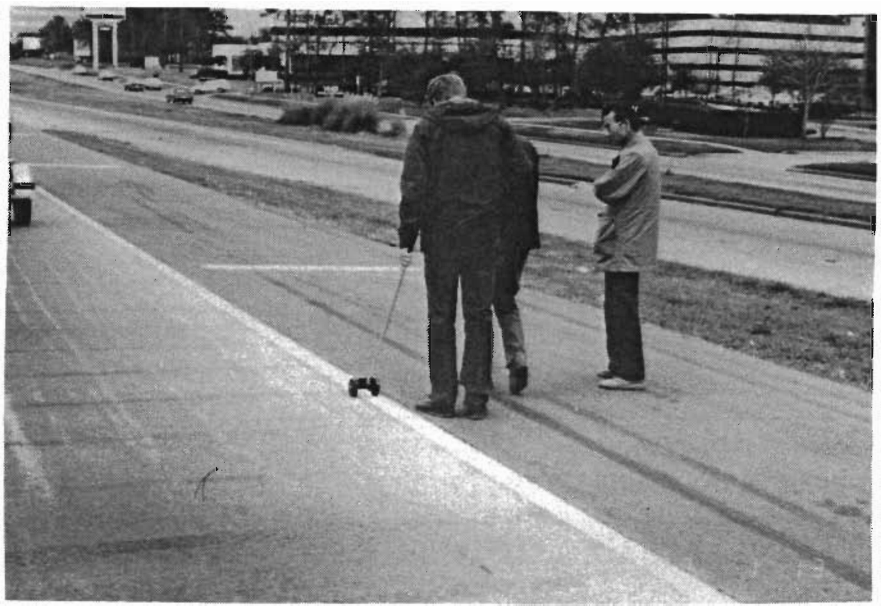


Fig 3.2. ***CTR personnel are conducting condition survey on the 10 test sections, IH 610 North, Houston.***

TABLE 3.6. ***TRANSVERSE CRACKING BY DATE AND SECTION (ACTUAL COUNT), IH 610 NORTH, HOUSTON***

	May 1985 (Before Overlay)		Jan 1987 (After Overlay)	
Test Sect No.	Total No. of Transverse Cracks	Av Crack Spacing (ft)	Total No. of Transverse Cracks	Av Crack Spacing (ft)
1	238	2.52	181	3.31
2	272	2.19	200	2.98
3	322	1.88	135	4.48
4	311	1.91	68	8.75
5	262	2.13	96	5.82
6	319	1.83	75	7.80
7	306	1.90	76	7.63
8	179	2.23	23	17.39
9	288	2.08	126	4.76
10	259	2.32	68	8.82

SOUNDING

The condition survey team consisted of three people walking along the lane where sounding was conducted. The crew identified the delaminated areas and performed a detailed condition survey by mapping those areas. The sounding was conducted in August, 1987. The percent delaminated areas are tabulated in Table 3.12.

TABLE 3.7. *LONGITUDINAL CRACKING BY DATE AND SECTION, IH 610 NORTH, HOUSTON*

	May 1985 (Before Overlay)		January 1987 (After Overlay)	
Test Sect. No.	Total Length of Longitudinal Crack (ft)	Av Longitudinal Crack per 100-Ft Section	Total Length of Longitudinal Crack (ft)	Av Longitudinal Crack per 100-Ft Section
1	80	13.4	0	0
2	309	51.8	0	0
3	447	73.9	0	0
4	172	28.9	42	7.0
5	361	64.6	0	0
6	233	39.8	0	0
7	192	33.1	0	0
8	6	1.5	0	0
9	366	61.0	0	0
10	388	64.7	11	1.8

TABLE 3.8. *NUMBER OF SPALLED CRACKS BY DATE AND SECTION, IH 610 NORTH, HOUSTON*

Test	Minor Spalling		Severe Spalling	
Sect No.	May 1985	Jan 1987	May 1985	Jan 1987
1	26	0	2	0
2	1	0	0	0
3	5	0	0	0
4	15	0	0	0
5	1	0	0	0
6	6	0	3	0
7	8	0	2	0
8	15	0	0	0
9	1	0	2	0
10	2	0	1	0

TABLE 3.9. *NUMBER OF PUNCHOUTS BY DATE AND SECTION, IH 610 NORTH, HOUSTON*

Test	Minor Punchout		Severe Punchout	
Sect No.	May 1985	Jan 1987	May 1985	Jan 1987
1	1	0	0	0
2	1	0	0	0
3	1	0	0	0
4	7	0	1	0
5	17	0	0	0
6	5	0	3	0
7	4	0	0	0
8	0	0	0	0
9	6	0	0	0
10	0	0	0	0

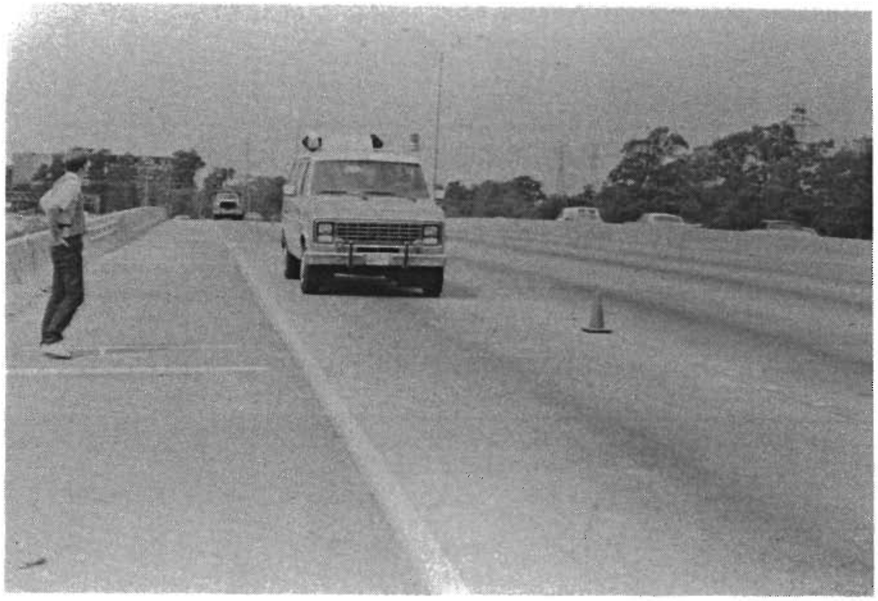


Fig 3.3. ***The SDHPT profilometer van run along the 10 test sections on IH 610 North, Houston.***

TABLE 3.10. ***SERVICEABILITY INDEXES BY DATE AND SECTION, IH 610 NORTH, HOUSTON***

Test Sect No.	May 1985 (B/O)	Feb 1986 (A/O)	May 1986 (A/O)	March 1987 (A/O)
1	2.99	3.63	3.70	3.70
2	2.86	--	4.09	4.20
3	2.85	2.44	4.01	4.13
4	2.87	3.73		4.08
5	2.94	3.42		3.64
6	2.77			--
7	2.87			4.08
8	3.27			4.06
9	2.98			4.04
10	3.12			3.03

Note: B/O - Before Overlay
A/O - After Overlay

TABLE 3.11. ***SKID RESISTANCE DATA BY SECTION NUMBER, IH 610 NORTH, HOUSTON***

Test Sect No.	Skid Resistance
1	50
2	48
3	46
4	47
5	48
6	48
7	51
8	51
9	47
10	48

TABLE 3.12. ***PERCENT DELAMINATED AREA BY SECTION NUMBER, IH 610 NORTH, HOUSTON***

Test Sect No.	Percent Delaminated Area
1	0.2
2	0.1
3	0.0
4	0.6
5	0.2
6	0.2
7	0.0
8	0.0
9	0.0
10	0.2

CHAPTER 4. LABORATORY TESTING

This chapter deals with laboratory testing. The testing program for this research study consisted of two laboratory tests, direct shear test and indirect tensile test. These tests were conducted on the cores taken from experimental test sections.

Details of the apparatus and procedures used on these two tests are given here, together with the test results.

DIRECT SHEAR TEST

The shear strength of the interface of a bonded concrete overlay system contributes to the success and feasibility of this type of system (Ref 5). If this shear strength is greater than the actual shear stress at the interface due to traffic and environment, then the overlay will remain bonded to the existing pavement. However, if the shear strength is less than the actual shear stress at the interface, then the bond between the existing pavement and the overlay will fail. As a result, the old and new concrete layers will behave as two independent units, and, thus, can no longer be considered as a bonded concrete overlay.

Apparatus to Measure Shear Strength

For this study the shear strength at the interface was measured and defined as a function of bond strength (Ref 5). The test was performed on the universal testing machine with the help of an instrument developed by the Center for Transportation Research (Fig 4.1).

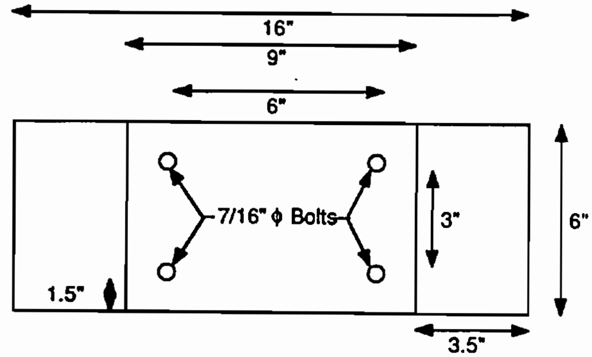
The instrument consists of a flat piece of high strength steel (9 inches by 6 inches by 7/16 inch) welded to a semicircular section of pipe with a diameter of 4 inches and length of 4 inches. Another steel plate (16 inches by 6 inches by 7/16 inch) was welded to another semicircular section of pipe with a diameter of 4 inches and length of 4 inches. Four holes were drilled through both top and bottom plates. Four high-strength bolts were used to keep the core between the two semicircular section of pipe. The overlaid portion of the core was projected out (see Fig 4.2). Another semicircular section of pipe, with a diameter of 4 inches and length of 3 inches, which had a 3-inch-thick steel plate welded to it, was placed above the projecting portion of the core. The load was applied on the last semicircular section of pipe.

This instrument was clamped to the table of a uniform testing machine by means of four C-clamps.

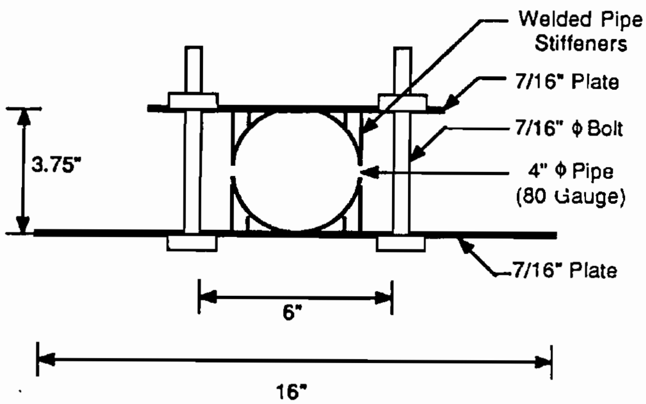
Test Procedure

(1) The diameter of each core was measured with a surface gauge accurate to one-thousandth of an inch (Fig 4.3). The core diameter obtained was an average of three measurements at the interface.

(2) The core was held between the two semicircular section of pipes with the overlaid portion projected out.



(a) *Plan View.*



(b) *Side view.*

Fig 4.1. ***Direct shear test instrument.***

(3) The load was applied in a uniform manner at a rate of 2 inches per minute.

(4) The loading was automatically plotted on a graph paper by a plotter. The load at failure was obtained and recorded from the graph paper.

(5) Shear strength at the interface was calculated as

$$V = \frac{P}{A}$$

where

V = shear strength, psi;
P = load at failure, pounds; and
A = area of the specimen (core); inches^2.

Test Results

The cores were secured from the first five sections in February 1986, soon after those sections were overlaid. After all test sections were completely overlaid, CTR personnel planned to secure cores from all of them in January 1987. Because of the limited time available in the field, cores were not secured from Section 10.

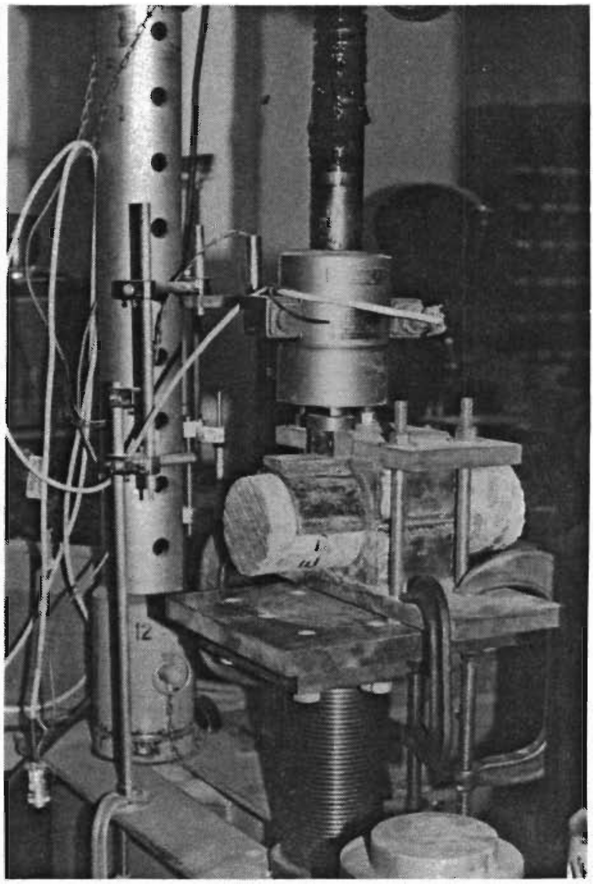


Fig 4.2. *Sample being tested.*

TABLE 4.1. ***SUMMARY OF AVERAGE SHEAR STRENGTH DATA (PSI) BY SECTION NUMBER AND DATE, IH 610 NORTH, HOUSTON***

Test Sect No.	Dates Cores Taken Feb 1986	Jan 1987	Aug 1987
1	205	253	--
2	210	300	--
3	50	155	--
4	136	436	--
5	141	429	--
6		266	--
7		408	--
8			523
9			553
10			441

Shear strength could not be obtained from the cores from Sections 8 and 9 since the diameter of the core taken from Section 8 was too big to fit on the shear test apparatus, and the core taken from Section 9 was broken on the interface. Fulfilling the purpose of the study, cores from Sections 8, 9, and 10 were obtained on the next survey, in August 1987.

The summary of the shear strength of every core taken and the average shear strength data are tabulated in Appendix Table C.1 and in Table 4.1, respectively.

The average shear strength of fiber reinforced, welded wire reinforced with limestone aggregate, and welded wire reinforced with siliceous river gravel sections were 236, 446, and 257 psi, respectively. Overall, there was an increase in bond strength with time.

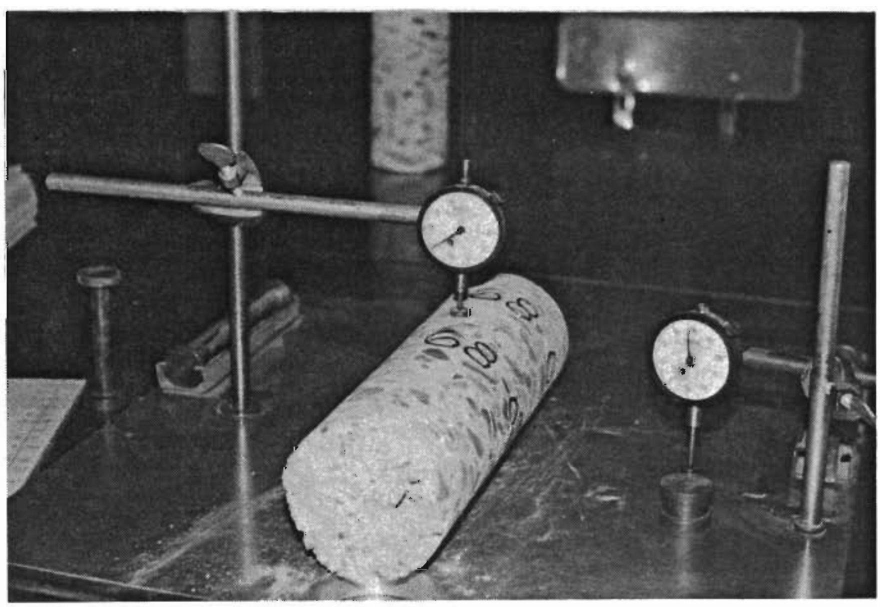


Fig 4.3. *The diameter of one of the cores secured from the test sections being measured with a surface gauge.*

INDIRECT TENSILE TEST

The indirect tensile test is a test that performs loading on a cylindrical specimen with a compression load which acts parallel to and along the vertical diametrical plane, as shown in Fig 4.4 (Ref 7). To distribute the load and maintain a constant loading area, the compressive load is applied through a half-inch-wide wood loading strip which is curved at the interface of the specimen and has a radius equal to that of the specimen. This loading configuration ultimately causes the specimen to fail by splitting or rupturing along the vertical diameter (see Fig 4.5).

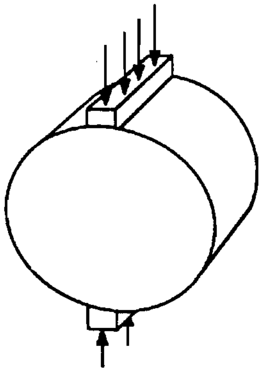


Fig 4.4 ***Cylindrical specimen with compressive load being applied.***

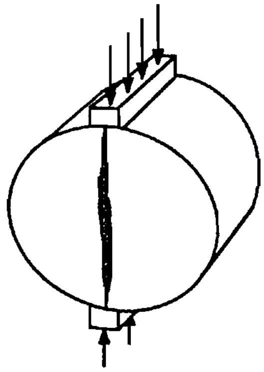


Fig 4.5. ***Specimen failing under compressive load.***

Apparatus to Measure Indirect Tensile Strength

The test was performed on loading equipment capable of applying compressive loads at a controlled deformation rate, preferably 2 inches per minute, with the help of a means of measuring the applied load and half-inch-wide curved face loading strips.

The Procedure

(1) Measure the length and diameter of the test specimen. The core diameter was the average of three measurements.

(2) Center the test specimen on the lower loading strip.

(3) Slowly bring the head down until light contact is made with the core.

(4) Apply the load at a rate of 2 inches per minute.

(5) Determine the maximum load at failure.

(6) Calculate the tensile strength of the core using the following equation:

$$T = \frac{2P}{LD}$$

where

T = splitting tensile strength, psi;
P = maximum applied load, pounds;
L = length of specimen, inches; and
D = diameter of specimen, inches.

Test Results

The summary of average tensile strength is presented in Table 4.2. Results for all cores tested are shown in Appendix Table C. .2. The average tensile strengths of fiber reinforced sections, welded wire fabric with limestone sections, and welded wire fabric with silicious river gravel sections are 698, 642, and 615 psi, respectively.

TABLE 4.2. ***SUMMARY OF AVERAGE TENSILE STRENGTH (PSI) (OVERLAY PORTION), IH 610 NORTH, HOUSTON***

Test Sect No.	Dates Core Taken: Feb 1986	Dates Core Taken: Jan 1987
1	676	615
2	582	544
3	422	575
4	671	625
5	650	950
6		718
7		638
8		652
9		868

CHAPTER 5. ANALYSIS OF PERFORMANCE DATA

This chapter analyzes the performance of the test sections in terms of deflection data, transverse and longitudinal cracks, present serviceability index (psi), and modulus of pavement layers.

DEFLECTION DATA

The average deflection before and after overlay of each experimental section is presented in Chapter 3 of this report. Plotting the before and after–overlay deflection with the experimental section number, it may be clearly seen that the average deflection after overlay construction decreased significantly for all test sections (see Figs 5.1 through 5.5). Tables 5.1 through 5.5 show percent decreases in deflection (relative to May 1985 deflection data) of Sensors 1 through 5, respectively.

The first set of before–overlay deflection data, which was taken in May 1985, showed that Section 1 had the lowest mean deflection and Section 2 had the highest. The second set of data showed that Section 1 had the lowest mean deflection and Section 4 had the highest among the first five test sections. The overall data showed that there was an increase in deflection on the second set of data. The increase may have been caused by a combination of factors. Weather conditions and pavement temperatures may have influenced the pavement performance, and this will be discussed in more detail in the next chapter.

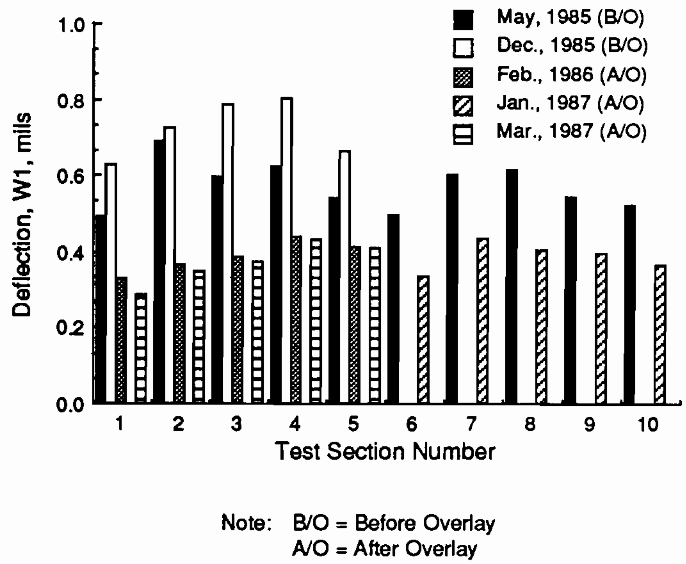


Figure 5.1. ***Comparison of before and after-overlay average deflection of Sensor 1, IH 610 North, Houston.***

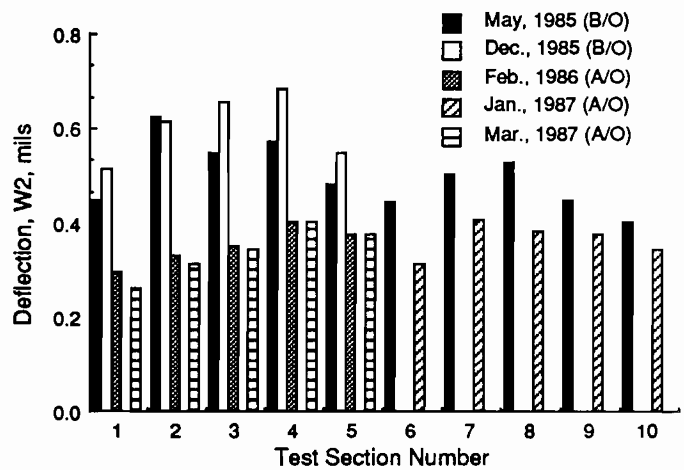


Figure 5.2. ***Comparison of before and after-overlay average deflection of Sensor 2, IH 610 North, Houston.***

CONDITION SURVEY DATA

As can be seen in the summary of condition survey data presented in Chapter 3, there was a significant decrease in the amount of all types of distress after overlay placement.

Two types of cracking were recorded: transverse and longitudinal. The transverse cracking was presented as average crack spacing, which was obtained by dividing the total length of a test section with the number (actual count) of transverse cracks in the section. The longitudinal cracking was measured in units of lineal feet per 100–foot section.

The average crack spacings before overlay placement, were generally uniform for all test sections (see Fig 5.6). But, after overlay placement, the average crack spacings were varied on all 10 test sections. It shows that the overlay materials may affect the crack spacing of the pavement. Section 8 (CRCP with limestone aggregate) has the greatest transverse crack spacing, with Section 10 (CRCP with silicious river gravel) and Section 4 (fiber reinforced concrete overlay) second and third respectively.

The longitudinal cracks before the overlay was placed were varied for the 10 test sections (see Fig 5.7). After overlay, longitudinal cracks existed only in Sections 4 and 10.

It is important to note that spalling and punchouts do not exist on any of the test sections.

ROUGHNESS DATA (PRESENT SERVICEABILITY INDEX)

The profilometer readings were conducted before and after overlay. The profilometer measurements after overlay

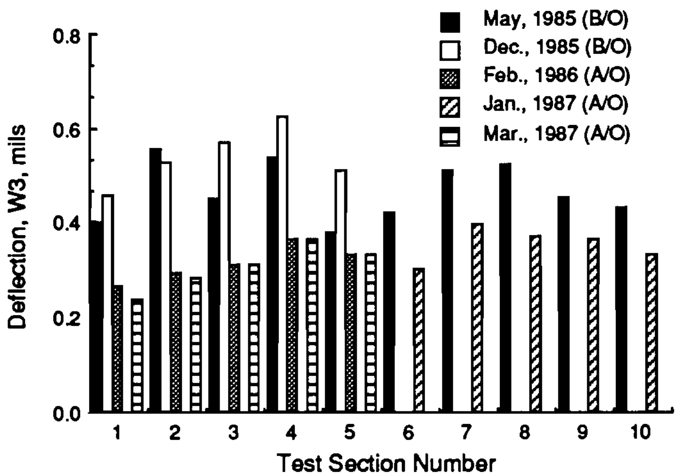


Figure 5.3. ***Comparison of before and after-overlay average deflection of Sensor 3, IH 610 North, Houston.***

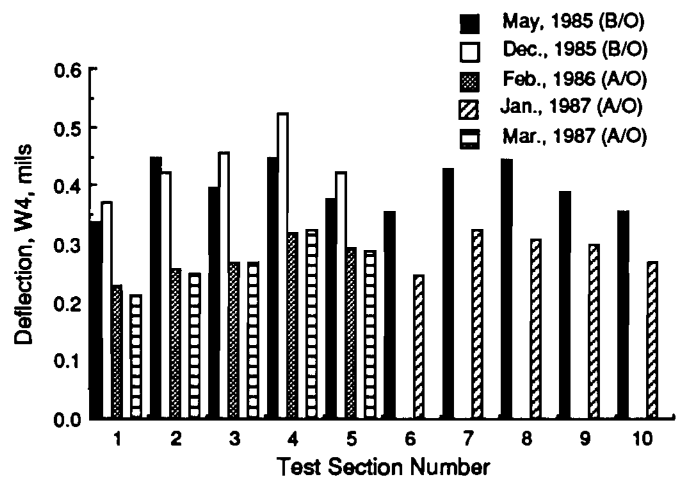


Figure 5.4 ***Comparison of before and after-overlay average deflection of Sensor 4, IH 610 North, Houston***

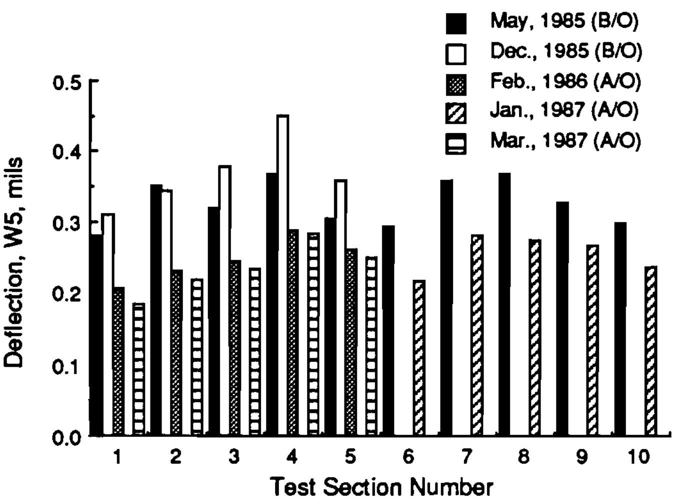


Figure 5.5. ***Comparison of before and after-overlay average deflection of Sensor 5, IH 35 North, Houston.***

construction give an indication of the improvement in the riding quality. This trend can be clearly seen in Fig 5.8, that after overlay construction, a general increase in present serviceability index (PSI) occurred on all test sections but Section 10. Percent increases in present serviceability index are tabulated in Table 5.6.

LAYER CHARACTERISTICS

The existing pavement materials were characterized using deflection measurements. The moduli of elasticity of the concrete layer (E_1), subbase (E_2), and subgrade (E_3) were determined by back-calculating from deflection data from each test section before and after overlay. The back-calculation was accomplished by using program RPEDD1 (Ref 8), which is available in the Center for Transportation Research.

Figure 5.9 illustrates the rigid structure before and after overlay construction. To calculate the before–overlay modulus of elasticity the following assumptions were made:

(1) the thicknesses of PCC, subbase, and subgrade are 8 inches, 6 inches, and semi-infinite, respectively; and

(2) Poisson's ratios of PCC, subbase, and subgrade are 0.15, 0.30, and 0.45, respectively.

To compare the modulus of elasticity of the concrete layer before and after overlay, a 12.5–inch thickness of composite concrete layers were used in calculating the after overlay modulus values, with the same assumptions for the rest of variables. Twelve-inch thickness was not used to describe the composite PCC layer because cores taken from the test sections showed the average overlay thickness to be 4.5 inches.

Tables 5.7 through 5.9 present the before and after–overlay modulus values. Note that some of the test sections are on the embankment and some are on the flat area (see Fig 2.7). With the location of the test section and various seasons, the moduli are plotted in Figs 5.10 through 5.12.

The various seasons may be found in Figs 5.10 through 5.12 by noting different air temperatures and cumulative precipitation values. It was believed that a cumulative precipitation over a period of time prior to obtaining deflection values would influence the layer characteristics.

Several methods were studied in determining a value for expressing cumulative precipitations. The methods are the following:

TABLE 5.1. ***PERCENT DECREASE IN DEFLECTION OF SENSOR 1, AFTER OVERLAY PLACEMENT, IH 610 NORTH, HOUSTON***

Test Sect No.	Feb 1986	Jan 1987	March 1987
1	32.9		43.0
2	47.1		49.4
3	35.1		37.6
4	29.6		30.8
5	23.4		23.6
6		32.4	
7		27.9	
8		33.1	
9		26.9	
10		30.2	

TABLE 5.2. ***PERCENT DECREASE IN DEFLECTION OF SENSOR 2, AFTER OVERLAY PLACEMENT, IH 610 NORTH, HOUSTON***

Test Sect No.	Feb 1986	Jan 1987	March 1987
1	33.8		41.2
2	47.0		49.0
3	35.1		37.0
4	29.6		29.6
5	21.8		22.0
6		29.7	
7		18.7	
8		27.3	
9		16.1	
10		14.4	

TABLE 5.3. ***PERCENT DECREASE IN DEFLECTION OF SENSOR 3, AFTER OVERLAY PLACEMENT, IH 610 NORTH, HOUSTON***

Test Sect No.	Feb 1986	Jan 1987	March 1987
1	33.4		40.7
2	47.2		49.4
3	36.3		36.7
4	32.2		32.2
5	26.4		26.2
6		28.4	
7		22.4	
8		30.5	
9		19.9	
10		22.6	

TABLE 5.4. ***PERCENT DECREASE IN DEFLECTION OF SENSOR 4, AFTER OVERLAY PLACEMENT, IH 610 NORTH, HOUSTON***

Test Sect No.	Feb 1986	Jan 1987	March 1987
1	32.3		37.7
2	42.7		44.7
3	32.8		33.1
4	29.3		28.0
5	22.1		24.0
6		30.9	
7		23.9	
8		33.4	
9		23.1	
10		24.6	

TABLE 5.5. ***PERCENT DECREASE IN DEFLECTION OF SENSOR 5, AFTER OVERLAY PLACEMENT, IH 610 NORTH, HOUSTON***

Test Sect No.	Feb 1986	Jan 1987	March 1987
1	26.2	34.0	34.0
2	34.5	37.9	37.9
3	23.8	27.0	27.0
4	22.0	23.4	23.4
5	13.8	18.4	18.4
6		26.6	
7		21.3	
8		29.4	
9		19.0	
10		21.1	

(1) cumulative precipitation over a 20-day period prior to the deflection readings,

(2) cumulative precipitation over a 10-day period prior to the deflection readings, and

(3) cumulative precipitation over a 12-day period prior to the deflection readings, disregarding any precipitation for the last two days.

Among these three methods, the 10-day cumulative precipitation has the best correlation to the layer characteristics.

CAUSES OF VARIATION IN LAYER STIFFNESSES

As can be seen, the moduli vary with test section location and the environmental condition when deflection readings were conducted.

CRC Layer

As can be seen in Fig 5.10, modulus values of the CRC layer (E_1) of the first five sections were higher in May 1985 than in December 1985. It also may be noted that the moduli of Sections 6 through 10 in May 1985 were higher than in July 1987. This trend may have been the result of higher temperatures in May 1985. A high temperature condition will result in a decrease in pavement deflection due to pavement expansion and narrowing of transverse cracks in CRC pavement. As the cracks narrow, the load transfer increases, which results in stiffer CRC (see Fig 5.11).

Subbase Layer

Better construction control may limit the variation in layer thickness and moduli. Some variation in the subbase modulus as shown in Fig 5.12 may be caused by the use of material from different sources in different areas of the project or the use of different quantities of stabilizing agent. It also may be caused by different drainage conditions in different sections of the project.

Subgrade Layer

Pavement in cut and fill areas may have different subgrade moduli. As can be seen in Fig 5.13, most of the sections on the embankment have higher moduli. This may be caused by free drainage on the embank-

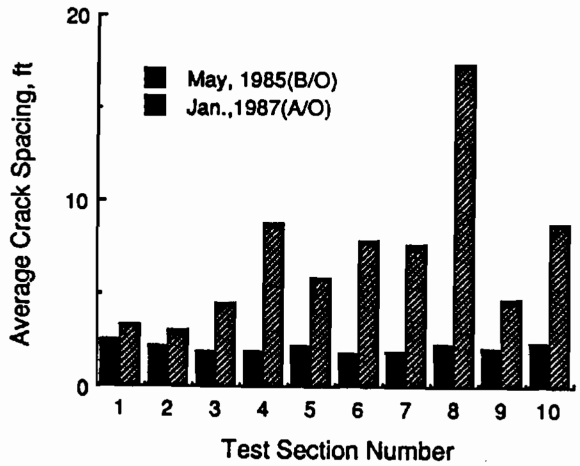


Figure 5.6. ***Comparison of before and after-overlay transverse crack spacing of the 10 test sections, IH 35 North, Houston***

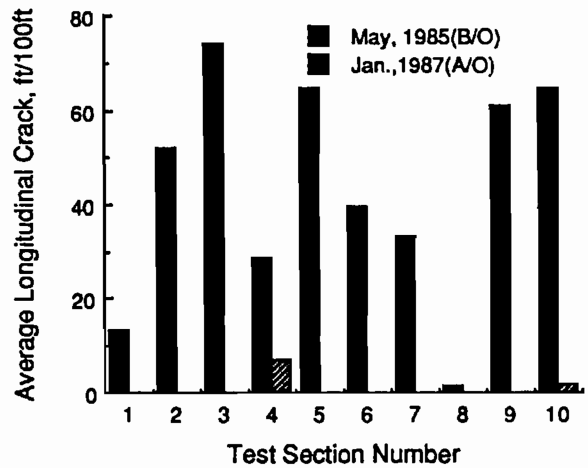


Figure 5.7. ***Comparison of before and after-overlay average longitudinal crack per 100-foot section of the 10 test sections, IH 35 North, Houston.***

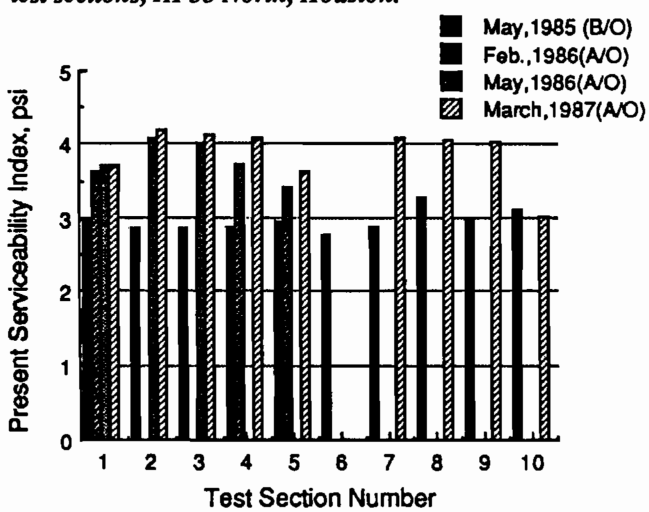
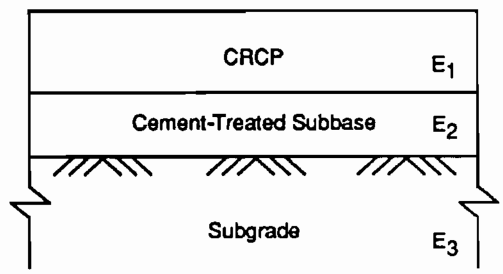


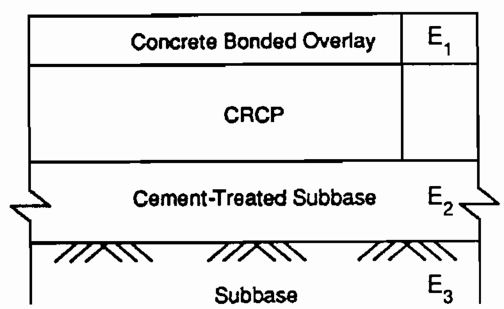
Figure 5.8. ***Comparison of before and after-overlay present serviceability indices of the test sections, IH 35 North, Houston.***

TABLE 5.6. ***PERCENT INCREASE IN PRESENT SERVICEABILITY INDEX AFTER OVERLAY PLACEMENT, IH 610 NORTH, HOUSTON***

Test Sect No.	Feb 1986	May 1986	March 1987
1	21	24	24
2	--	43	47
3	--	41	45
4	30		42
5	16		24
6			--
7			42
8			24
9			36
10			- 2.88



(a) Rigid pavement structures before overlay.



(b) Rigid pavement structures after overlay.

Figure 5.9. ***Layer characteristics used deflection data analysis.***

ment sections. With better drainage, there will be less water penetrating into the subgrade layer. On the other hand, low (flat) areas with higher water tables may be softer.

It can also be seen, in Fig 5.14, that the subgrade moduli vary with seasons. Periods of higher rainfall result in higher moisture content in the subgrade and a corresponding lower subgrade modulus.

TABLE 5.7. *MODULUS OF ELASTICITY OF CONCRETE LAYER, E_1 (psi)*

Test Sect No.	May 1985 (B/O)	December 1985 (B/O)	February 1986 (A/O)	January 1987 (A/O)	March 1987 (A/O)
1	4,819,000	2,517,000	4,885,000		3,839,000
2	3,013,000	3,073,000	4,046,000		4,270,000
3	3,330,000	3,039,000	3,668,000		3,825,000
4	4,624,000	2,896,000	3,768,000		3,517,000
5	4,820,000	3,388,000	3,403,000		3,237,000
6	5,933,000			4,691,000	
7	5,489,000			3,381,000	
8	5,027,000			3,919,000	
9	6,090,000			3,365,000	
10	6,207,000			3,911,000	

Note: B/O - Before Overlay
A/O - After Overlay

TABLE 5.8. *MODULUS OF ELASTICITY OF SUBBASE LAYER, E_2 (psi)*

Test Sect No.	May 1985 (B/O)	December 1985 (B/O)	February 1986 (A/O)	January 1987 (A/O)	March 1987 (A/O)
1	295,600	289,900	384,600		202,800
2	78,400	101,000	292,200		302,600
3	124,200	161,300	191,400		159,200
4	242,500	307,500	216,200		188,300
5	225,800	308,600	175,800		123,000
6	312,600			140,900	
7	493,700			77,800	
8	313,400			90,900	
9	621,000			84,000	
10	746,000			104,400	

Note: B/O - Before Overlay
A/O - After Overlay

TABLE 5.9. *MODULUS OF ELASTICITY OF SUB-GRADE LAYER, E_3 (psi)*

Test Sect No.	May 1985 (B/O)	December 1985 (B/O)	February 1986 (A/O)	January 1987 (A/O)	March 1987 (A/O)
1	18,290	17,070	24,800		28,440
2	14,400	14,810	22,280		22,130
3	16,050	12,000	21,120		23,860
4	14,070	11,240	17,030		18,180
5	17,600	11,240	20,160		21,490
6	18,150	14,400		23,980	
7	13,780			18,900	
8	13,590			19,350	
9	15,070			20,180	
10	16,780			21,640	

Note: B/O - Before Overlay
A/O - After Overlay

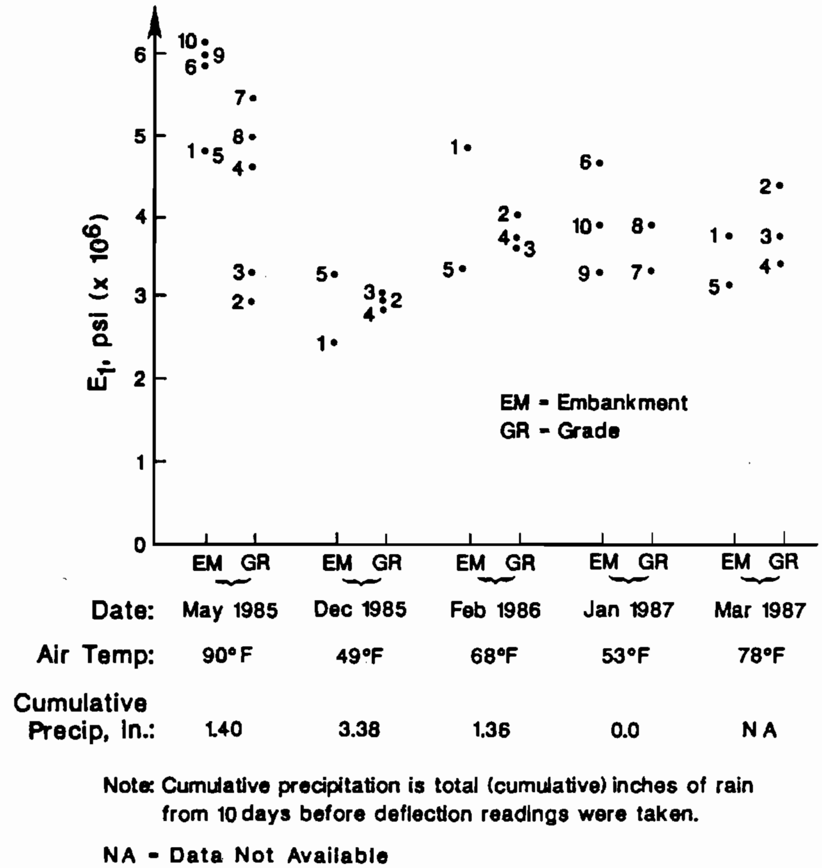


Fig 5.10. *Moduli of elasticity of concrete layer, E_1 vary with test sections locations and the environmental conditions.*

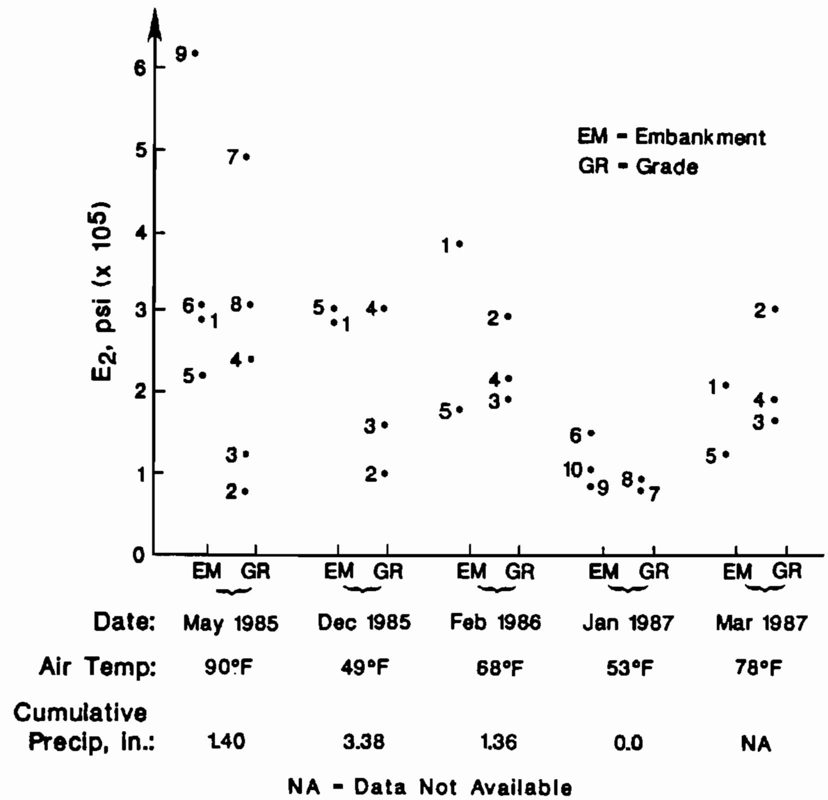


Fig 5.11. *Moduli of elasticity of concrete layer, E_1 vary with air temperature.*

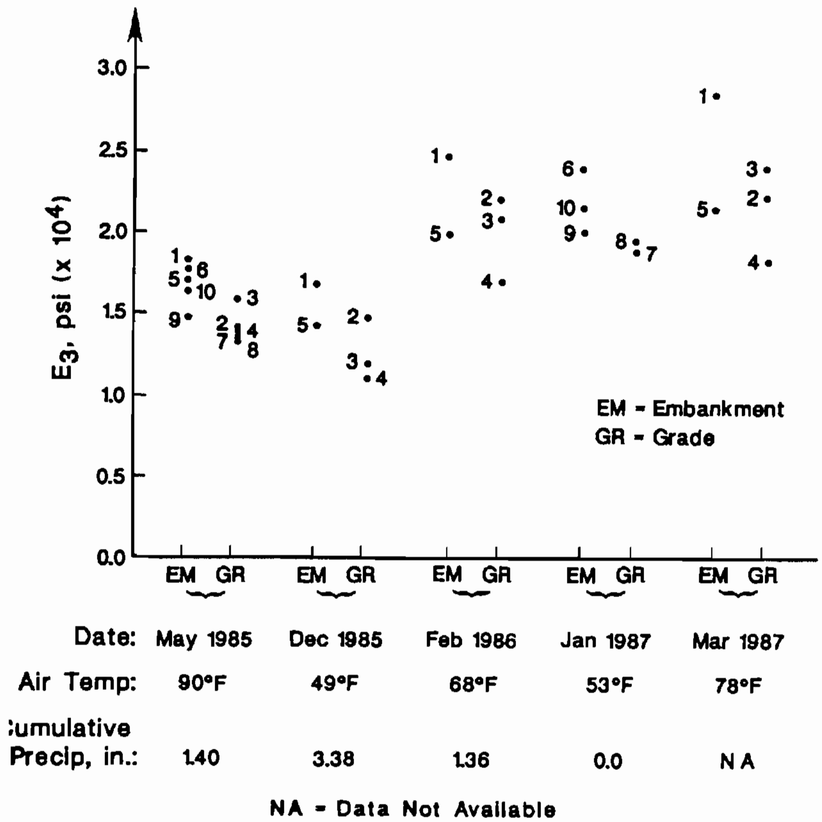


Fig 5.12. *Modulus of elasticity of subbase layer, E_2 vary with test section locations and environmental conditions.*

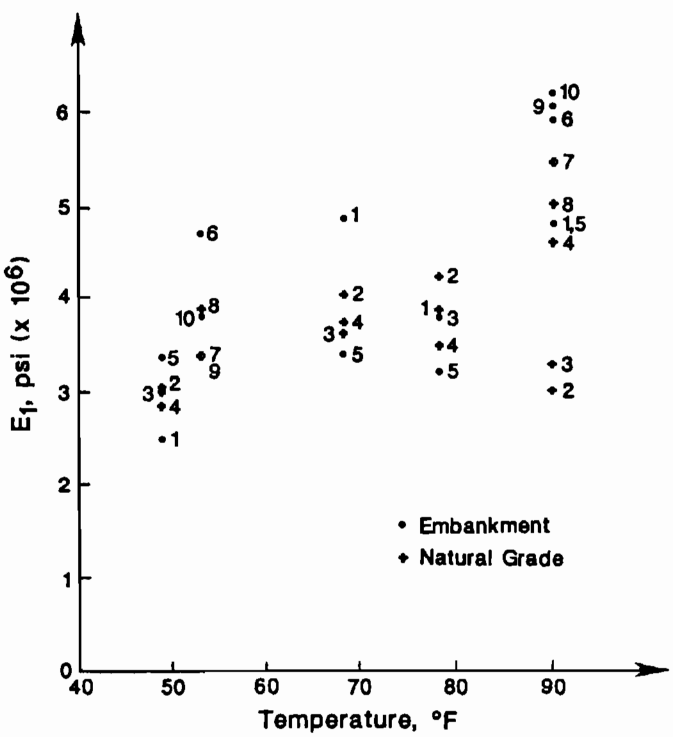


Fig 5.13. *Moduli of elasticity of subgrade layer, E_3 vary with test section locations and the environmental conditions.*

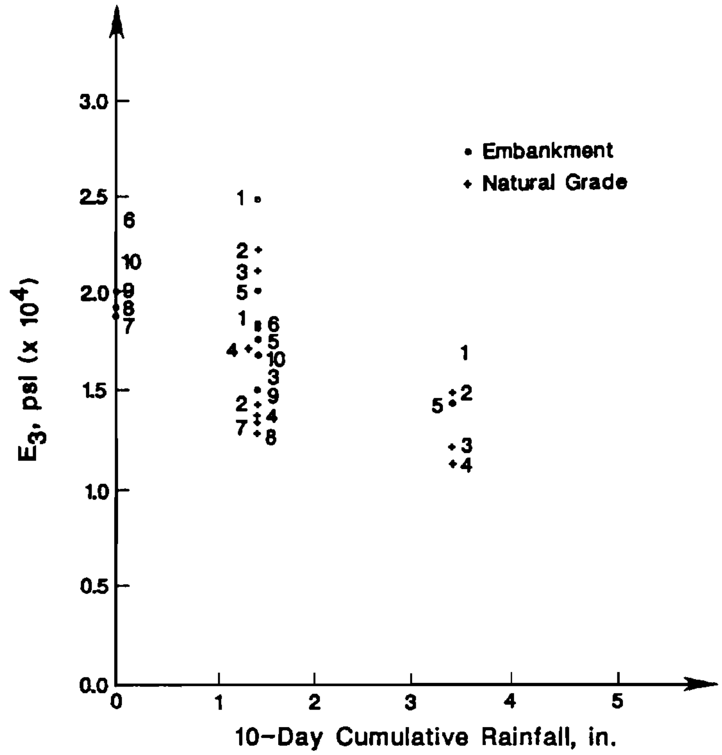


Fig 5.14. ***Moduli of elasticity of subgrade layer, E_3 vary with 10-day cumulative rainfall.***

CHAPTER 6. DISCUSSION OF RESULTS

In this chapter, the results gained from 10 experimental sections on IH 610 North, Houston, are discussed. A comparison of after–overlay predicted and measured deflections and an assessment of pavement life resulting from the overlay placement are also presented.

OVERALL OBSERVATION

Three variables considered in this study are overlay reinforcement (CRCP and fiber reinforced concrete), overlay aggregate (silicious river gravel and limestone), and condition of existing CRCP (no distress, moderate distress, and severe distress). Periodic evaluation of the 10 test sections after being overlaid indicates a good performance for all variables measured. In general, the project can be considered as successful.

The average deflection after overlay construction decreased significantly for all test sections. The CRC with silicious river gravel sections, fiber reinforced concrete sections, and sections with limestone performed differently in deflection. The CRC with siliceous river gravel sections showed a better performance than the other sections, with a 38 percent decrease in the deflection of Sensor 1. The limestone and the fiber sections had 31 percent and 27 percent decreases in average deflection, respectively.

Overlay materials may have had an impact on the transverse crack spacings. As can be seen in Fig 5.6, the limestone section (Section 8) had the largest transverse crack spacing. Overlay materials may not have been the only cause of the large variability in after–overlay crack spacings. Concrete temperature during overlay placement, which was not considered in this study, may have been another cause of this variability. Until the last condition survey was conducted, longitudinal cracks existed only in Section 4 (fiber reinforced) and Section 10 (CRCP). Moreover, neither spalling nor punchouts appeared on any of the test sections. Other important results from this study include the following:

(1) the bonded concrete overlay system improved the riding quality, and
(2) the existing pavement condition did not affect the overlaid pavement performance, since most existing distresses had been repaired before the overlay was placed.

COMPARISON OF PREDICTED AND MEASURED AFTER OVERLAY DEFLECTION

Layer characterization was established before the predicted after–overlay deflection was calculated. Calculating the after–overlay deflection involved the following steps:

(1) The mean ($\bar{x}$) and standard deviation (s) of before–overlay deflection were calculated of each experimental section.
(2) The modulus of concrete layer (CRCP), subbase, and subgrade were found by back-calculating three deflection values ($\bar{x}$, $\bar{x}$ + s , and $\bar{x}$ - s).
(3) A modulus value was assumed for the concrete overlay layer. Note E_o = 5,000,000 psi was used for after–overlay deflection calculation in this study.
(4) The overlay thicknesses were used of the cores secured from the experimental sections. Use the average thickness for deflection calculation purpose.
(5) With the new four–layer system, the after–overlay deflections($\bar{x}$, $\bar{x}$ + s , and $\bar{x}$ - s) were calculated using program RPEDD1.

The accuracy of this method is reflected by the results presented on Fig 6.1 (deflection of sensor 1) and Fig 6.2 (deflection of sensor 5). As can be seen from these figures, the calculated deflections were a little above the equality line.

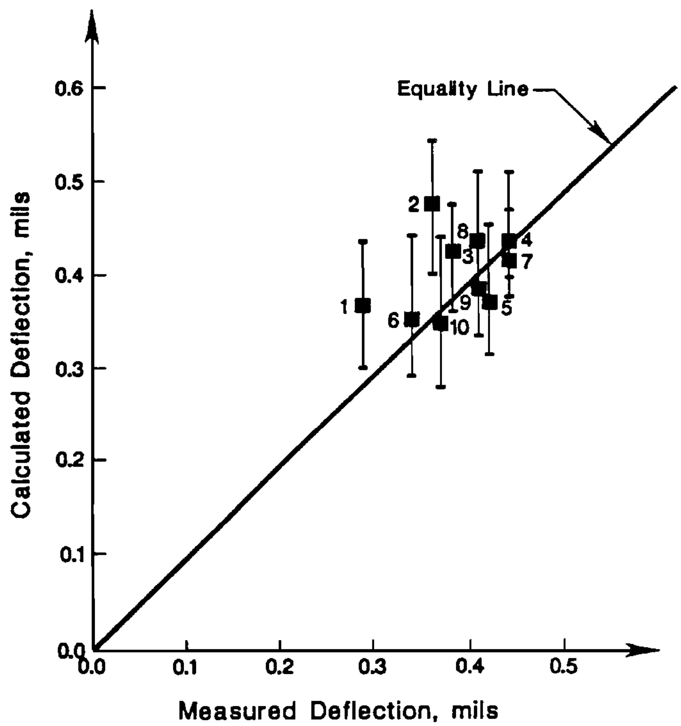


Fig 6.1. ***Comparison of calculated and measured after-overlay deflection of Sensor 1.***

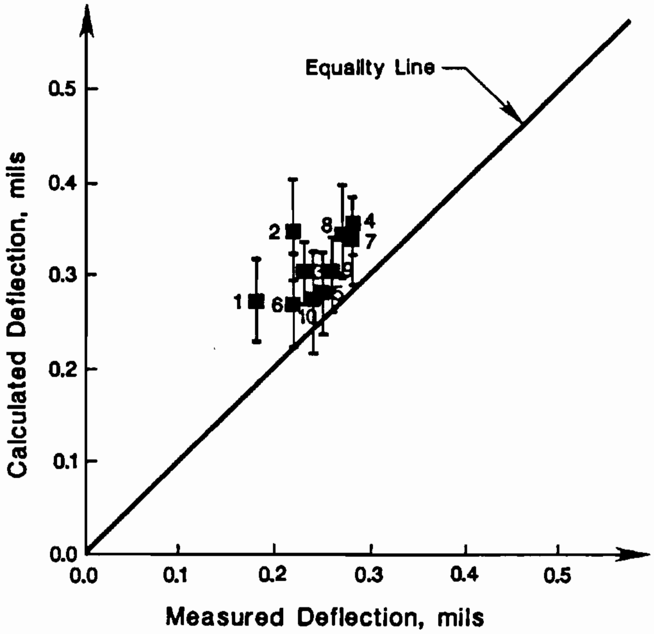


Figure 6.2. ***Comparison of calculated and measured after-overlay deflection of Sensor 5.***

There are a number of factors which exist that may result in inaccurate prediction of after–overlay deflections:

(1) seasonal effects,

(2) concrete temperature effects, and

(3) assumptions made for overlay layer modulus.

As mentioned before, the first two factors led to significant changes in the deflection measurements and, consequently, to the moduli predicted from these deflections.

ESTIMATION OF PAVEMENT FATIGUE LIFE AFTER OVERLAY PLACEMENT

A bonded concrete overlay is used not only to improve the riding quality and to correct grade problems, but also to add fatigue life to an existing pavement by utilizing the remaining structural capacity. Estimating the pavement fatigue life after overlay placement includes the following steps:

(1) Calculate the mean, $\bar{x}$, after overlay deflection of each experimental section.

(2) Determine the moduli of pavement layers and predict the fatigue life of the pavement in 18-kip ESAL after the overlay was placed. Note that a 12.5–inch monolithic pavement was used in this calculation, which was performed by back-calculating from the deflection obtained from step 1 using program RPEDD1.

(3) Calculate the total 18-kip ESAL per lane for the first year of overlaid pavement opened to traffic.

   (a) Average daily traffic, ADT = 166,300 (Ref 9);

   (b) Percent light trucks = 5.90 (Ref 10)
   Percent heavy trucks = 7.66 (Ref 10);

   (c) Directional distribution factor = 57.5 percent (Ref 9);

   (d) Lane distribution factor = 38.0 percent (Ref 10);

   (e) Constant traffic growth = 3.7 percent; and

   (f) Distribution of axle weights obtained from the Research Section of the Texas SDHPT Transportation Planning Division.

(4) Predict the pavement life after overlay using the following formula:

$$N_{18} = n_{18}\left[\frac{(1+g)^n - 1}{g}\right]$$

where

N_{18} = predicted fatigue life in 18-kip ESAL from program RPEDD1,

n_{18} = total 18-kip ESAL for the first year,

n = predicted pavement life in years, and

g = growth rate/100

The results are presented in Table 6.1.

TABLE 6.1. ***PREDICTED FATIGUE LIFE***

Test Sect No.	Predicted Fatigue Life (18-kip ESAL)	Predicted Pavement Life (Years)
1	109,389,698	24.7
2	108,527,896	24.6
3	94,766,533	22.5
4	87,176,902	21.1
5	95,764,724	22.6
6	73,963,028	18.9
7	72,673,279	18.6
8	76,668,727	19.4
9	76,668,727	19.4
10	74,778,917	19.2

CHAPTER 7. RECOMMENDED MONITORING PROGRAM

This chapter presents a recommended monitoring program. The main objective of the program is to evaluate the long term performance of bonded concrete overlay on IH 610 North in Houston. This important objective can be met by conducting a long-term monitoring program on the ten existing experimental sections.

It is suggested that surveys be conducted every 6 months (in February and August) and the monitoring be continued at least another 2 years. The monitoring program will consist of field measurements, laboratory testings, and theoretical analysis. A summary of the field monitoring program is presented on Table 7.1. As the study progresses, the findings will be documented and a short report will be written. At the end of the study, a final report will be furnished, documenting study methods, conclusions, and recommendations for future guidance.

By performing the monitoring program, the following sub-objectives can be fulfilled:

(1) monitor development of various types of distress on different types of overlay material,

(2) evaluate the bond strength of the concrete overlay,

(3) evaluate the riding quality and changes in profile,

(4) monitor the changes of layer properties with weather conditions and temperature, and

(5) investigate the progression of delamination on the bonded concrete overlay.

Some recommendations for conducting these field activities are included in the following paragraphs.

CONDITION SURVEY

A detailed condition survey should be conducted by mapping various types of distress, including transverse and longitudinal cracks, punchouts, spallings, and pumpings. This condition survey method is an appropriate way to monitor the progress of reflecting cracks.

Weather conditions and pavement temperatures at the time of the condition survey may have an influence on the visual aspects of the condition survey. The ideal condition survey should be conducted shortly after a light rain, when the cracks on CRCP can be best seen.

DEFLECTION READINGS AND ANALYSIS

Repeated deflection readings should be taken at approximately the same point, in order to be able to evaluate the performance of the pavement with time. Using deflection data which are collected periodically, the changes in layer properties and stresses of the pavement with time can be monitored.

TABLE 7.1. ***SUMMARY FIELD MONITORING PROGRAM (IH 610 NORTH, HOUSTON)***

Field Activities	Location: Lane Number	Location: Test Sect No.	Activity Items	Comments
Condition Survey	4	1-10 + Control Section	Mapping -Transverse Cracks -Longitudinal Cracks -Spalls -Punchouts -Pumpings -Delaminated Area	
Deflection Readings	4	1-10 + Control ection	Readings at -Cracks -Midspans	12 readings for each category on each test section
Corings	4	1-10		3 cores from each test section
Profilometer Readings	4	1-10 + Control Section		3 runs for each test section
Sounding	4	1-10	-Sounding -Marking Delaminated Area	

CORES AND LABORATORY TESTINGS

Core locations should be identified for reference later. New cores should be obtained close to where the last cores were secured, so that the progress of bond strength with time (age) can be monitored. Also, if there is a problem with delamination, it can be easily detected.

PROFILOMETER READINGS

Profilometer readings should be repeated at least three times in every data collection period. The present serviceability index (PSI) of each test section is obtained by averaging these three readings.

SOUNDING

The condition survey team consists of three people, who walk along the lane where sounding is conducted. The crew should identify the delaminated areas and perform a detailed condition survey by mapping those areas. Performing the sounding periodically, makes it possible to monitor the progress of the delaminated area.

CHAPTER 8. CONCLUSIONS AND RECOMMENDATIONS

The conclusions from the field and laboratory measurements and the theoretical analysis described in the previous chapters are presented in this chapter. These conclusions are based on the results of limited tests and may not necessarily be applicable for other conditions. Conclusions are presented first and are followed by recommendations for future studies on bonded concrete overlay.

CONCLUSIONS

1. Bonded concrete overlays significantly reduce the pavement deflection. The deflection reduction magnitudes indicate the slab performed monolithically. The section of CRC with siliceous river gravel reduced deflection the most as expected due to its higher modulus of elasticity.

2. The construction of bonded concrete overlays not only improved the riding quality, but also reestablished load transfer across the CRCP cracks. Thus, a bonded concrete overlay added significant fatigue life to an existing rigid pavement.

3. The existing pavement conditions did not affect the overlay pavement performance, as long as most of the existing distresses were repaired before the overlay was placed.

4. Overall, there was a significant decrease in the amount of all types of distress. The section of CRC with limestone had the least number of transverse cracks, and the siliceous river gravel and fiber reinforced sections were second and third, respectively. Spalling and punchouts did not exist on any of the test sections.

5. Moduli vary with test section locations and the environmental conditions. This trend was shown by the following findings:

   a. high temperature conditions resulted in an increase in pavement modulus due to pavement expansion and narrowing of transverse cracks,
   b. the subbase layer was stiffer on sections with better surface drainage, and
   c. periods of higher rainfall resulted in a higher moisture content in the subgrade and a correspondingly lower subgrade modulus.

6. The interface between the existing slab and the overlay developed good shear strength, especially in the fiber and limestone sections.

7. Although delamination has been reported elsewhere in the inside lanes, delamination was almost nonexistent in the test sections located in the outside lanes. Additional studies are being undertaken to determine the location, extent, and possible causes of the delamination on the inside lanes.

RECOMMENDATIONS

The recommendations are presented in two parts: field implementation and future studies.

These are recommendations concerning field implementation:

1. The condition survey should be conducted shortly after a light rain, when the cracks on the CRCP can be best seen.
2. The new cores should be taken close to the points where the old cores were secured in order to be able to monitor the progress of bond strength.
3. Sounding should be included in monitoring activities, so that the progress of delamination can be monitored periodically.

Recommendations for future studies include:

1. Continuation of the long term monitoring program in order to be able to evaluate the long term performance of bonded concrete overlay on IH 610 North, Houston.
2. Collection of past and future traffic loadings, which is very important for predicting the life of overlay pavement.
3. Investigation of the following problems.
   a. The modes of failure of bonded concrete overlay pavement.
   b. The nature of bond failures on IH 610 North and methods for repairing the delaminated sections.
   c. The effect of the temperature differential between the substrate and the overlay.

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APPENDIX A. LOCATIONS AND DIMENSTIONS OF VARIOUS SECTIONS (IH 610 NORTH, HOUSTON)

TABLE A.1. ***LOCATIONS AND DIMENSIONS OF SECTIONS***

Overlay Project, IH 610 North						
Treatment	**Direction**	**Start**	**End**	**Length (ft)**	**Width (ft)**	**Legend**
Fiber Reinforced Concrete Overlay	E. Bound	276 + 00	298 + 74.11	2274.11	48.0	
Limestone Aggregate Concrete Overlay	E. Bound	316 + 00	326 + 00	1000.00	48.0	
No Grout Section	E. Bound	215 + 00	217 + 00	200.00	48.0	
No Grout Section	W. Bound	349 + 50	351 + 50	200.00	48.0	

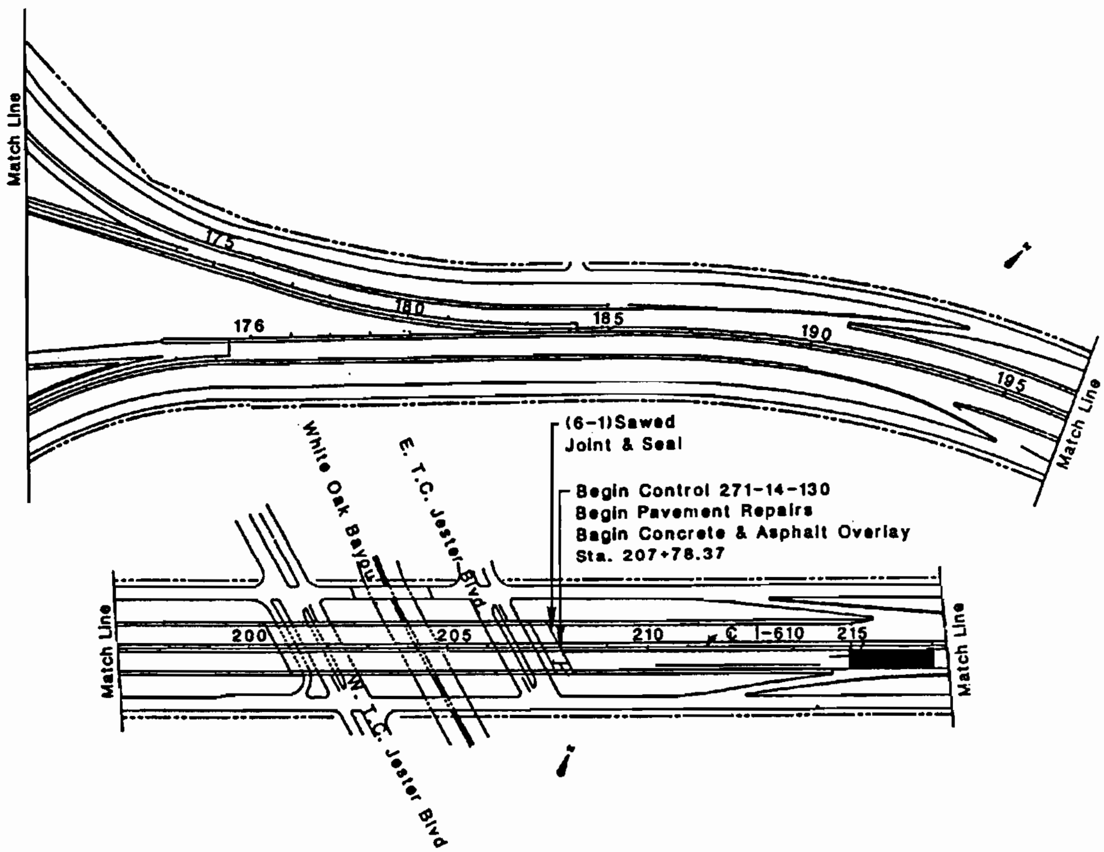

Figure A.1. ***Plan view.***

Note: Numbers in circles on Figs A.2 - A.4 represent corresponding test section identification.

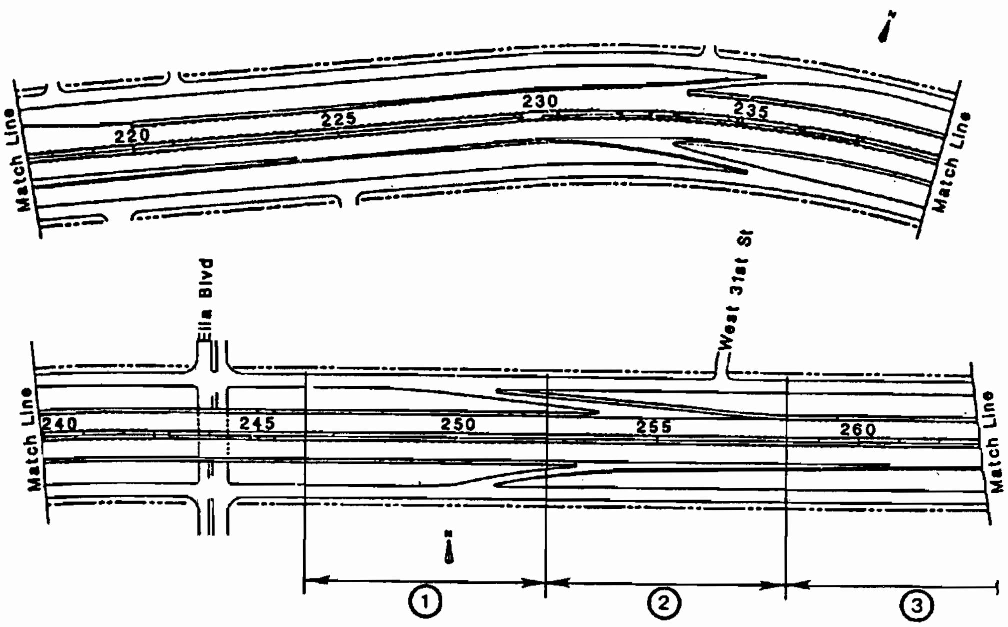

Figure A.2. ***Plan view.***

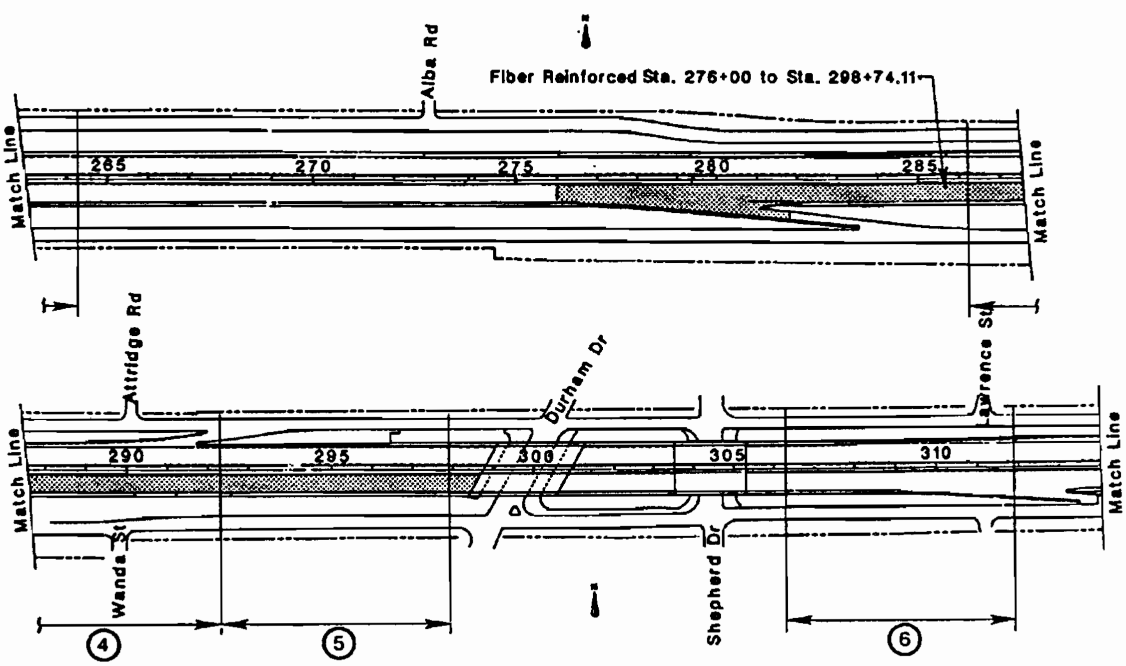

Figure A.3. ***Plan view.***

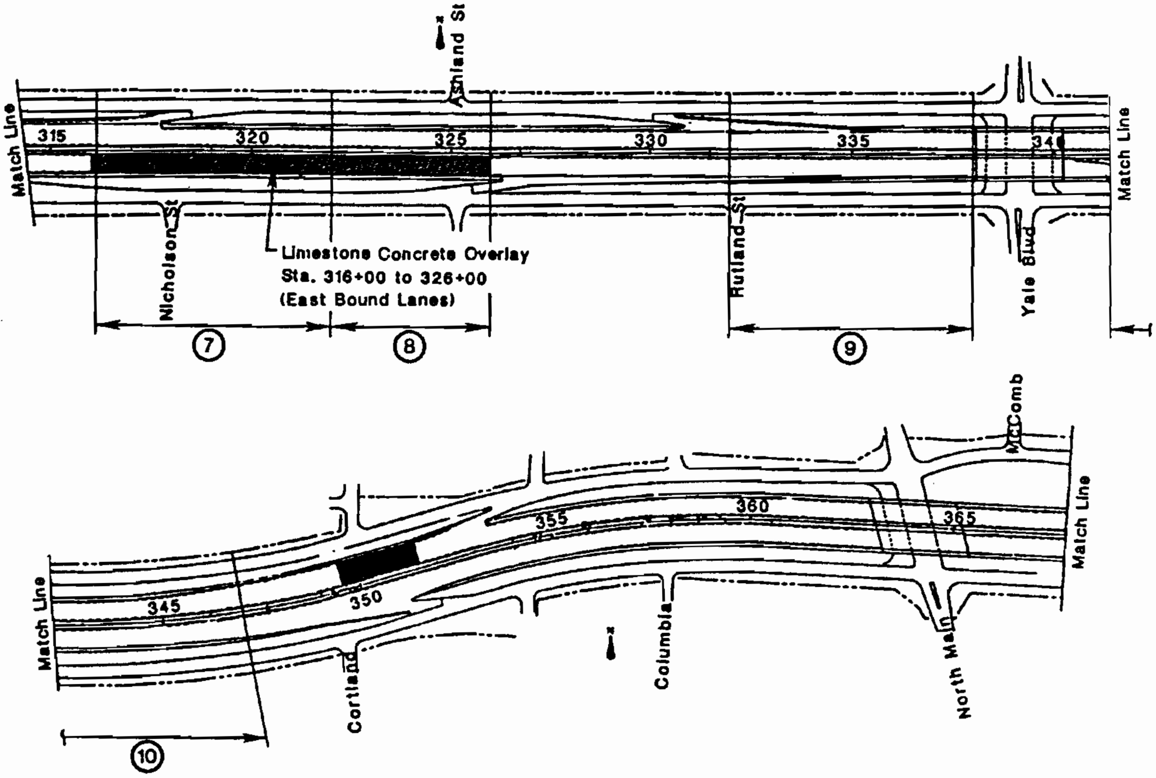

Fig A.4. *Plan view.*

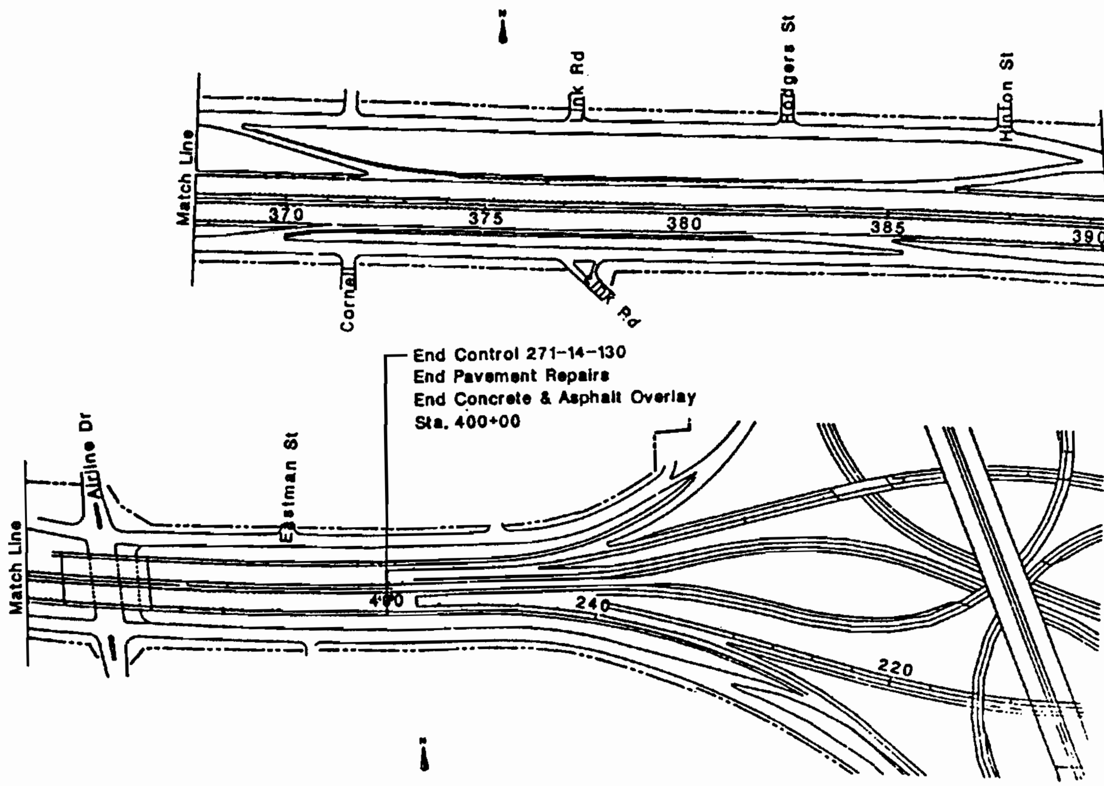

Fig A.5. *Plan view.*

APPENDIX B. DYNAFLECT DEFLECTION DATA

```
PROJECT: 920 PF A797 FILENAME TB0610E    ***** EDUARDO RICCI *****
TYPE OF MEASUREMENT: DEFLECTION BEFORE OVERLAY - MAY 22,1985
PAVEMENT TYPE: CRCP
EQUIPMENT USED: DYNAFLECT
LOCATION: LOOP 610 NORTH, HOUSTON - EAST BOUND
DIRECTION
EAST BOUND OUTSIDE LANE EVERY 50 FT. 10 EXP.  SECTIONS
FORMATS:
1-5  HIGHWAY NUMBER
7-12  SECTION NUMBER
15-18 STATION NUMBER
21-23 DEF AT SENSOR # 1 IN MILS
26-28               # 2
31-33               # 3
36-38               # 4
41-43               # 5
62-63 TEMPERATURE F.
65-69 TIME
***** DELETE LINES 1 TO 19 TO RUN A PROGRAM *****
L610N  SEC01  0.00  .42  .37  .36  .31  .26          90 13:25
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L610N  SEC01  2.50  .37  .33  .33  .28  .25          90 13:25
L610N  SEC01  3.00  .33  .36  .29  .26  .22          90 13:25
L610N  SEC01  3.50  .35  .31  .31  .28  .24          90 13:25
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L610N  SEC01  4.50  .62  .56  .36  .31  .27          90 13:25
L610N  SEC01  5.00  .59  .54  .49  .41  .32          90 13:25
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L610N	SEC08	1.00	.56	.47	.47	.39	.32	87	14:35
L610N	SEC08	1.50	.68	.59	.57	.46	.36	87	14:35
L610N	SEC08	2.00	.42	.37	.39	.34	.30	87	14:35
L610N	SEC08	2.50	.50	.43	.42	.34	.28	87	14:35
L610N	SEC08	3.00	.63	.56	.57	.49	.40	87	14:35
L610N	SEC08	3.50	.58	.51	.51	.44	.39	87	14:35
L610N	SEC08	4.00	.68	.58	.55	.46	.39	87	14:35
L610N	SEC08	4.50	.73	.60	.60	.49	.39	87	14:35
L610N	SEC08	5.00	.73	.60	.58	.47	.38	87	14:40
L610N	SEC08	5.50	.51	.46	.46	.41	.36	87	14:40
L610N	SEC09	0.00	.47	.41	.40	.34	.29	87	14:40
L610N	SEC09	0.50	.53	.40	.45	.39	.33	87	14:40
L610N	SEC09	1.00	.62	.51	.50	.41	.35	87	14:40
L610N	SEC09	1.50	.60	.51	.49	.43	.38	87	14:40
L610N	SEC09	2.00	.45	.35	.41	.38	.33	87	14:40
L610N	SEC09	2.50	.42	.35	.39	.35	.31	87	14:40
L610N	SEC09	3.00	.71	.59	.56	.46	.38	87	14:40
L610N	SEC09	3.50	.46	.39	.43	.38	.33	87	14:40
L610N	SEC09	4.00	.54	.46	.47	.41	.35	87	14:40
L610N	SEC09	4.50	.55	.44	.45	.37	.31	87	14:40
L610N	SEC09	5.00	.54	.46	.44	.38	.31	87	14:40
L610N	SEC09	5.50	.61	.51	.4[illegible]	.33	.25	87	14:45

L610N	SEC10	0.00	.24	.19	.21	.19	.18	86 14:45
L610N	SEC10	0.50	.47	.39	.39	.32	.26	86 14:45
L610N	SEC10	1.00	.59	.53	.51	.44	.36	86 14:45
L610N	SEC10	1.50	.62	.41	.47	.36	.29	86 14:45
L610N	SEC10	2.00	.50	.38	.41	.35	.29	86 14:45
L610N	SEC10	2.50	.43	.29	.35	.30	.26	86 14:45
L610N	SEC10	3.00	.40	.33	.34	.25	.25	86 14:45
L610N	SEC10	3.50	.65	.52	.51	.42	.34	86 14:45
L610N	SEC10	4.00	.52	.44	.45	.36	.32	86 14:45
L610N	SEC10	4.50	.43	.34	.35	.29	.26	86 14:45
L610N	SEC10	5.00	.63	.47	.51	.42	.33	86 14:45
L610N	SEC10	5.50	.76	.53	.65	.54	.43	86 14:50

PROJECT: 920 PF A797 FILENAME TB0610D ***** ABDULREHMAN SOLANKI *****
TYPE OF MEASUREMENT: DEFLECTION BEFORE OVERLAY - DEC. 3,1985
PAVEMENT TYPE: CRCP
EQUIPMENT USED: DYNAFLECT
LOCATION: LOOP 610 NORTH, HOUSTON - EAST BOUND
DIRECTION
EAST BOUND OUTSIDE LANE EVERY 50 FT. 10 EXP. SECTIONS
FORMATS:
1-5 HIGHWAY NUMBER
7-12 SECTION NUMBER
15-18 STATION NUMBER
21-23 DEF AT SENSOR # 1 IN MILS
26-28 # 2
31-33 # 3
36-38 # 4
41-43 # 5
***** DELETE LINES 1 TO 17 TO RUN A PROGRAM *****

L610N	SEC01	0.50	.59	.51	.50	.36	.28
L610N	SEC01	1.00	.49	.43	.41	.36	.33
L610N	SEC01	1.50	.55	.46	.44	.36	.32
L610N	SEC01	2.00	.64	.51	.45	.35	.29
L610N	SEC01	2.50	.43	.36	.34	.29	.25
L610N	SEC01	3.00	.54	.48	.46	.38	.32
L610N	SEC01	3.50	.59	.47	.42	.34	.30
L610N	SEC01	4.00	.85	.68	.57	.46	.34
L610N	SEC01	4.50	.61	.50	.43	.33	.29
L610N	SEC01	5.00	.72	.58	.49	.39	.31
L610N	SEC01	5.50	.89	.68	.47	.44	.36
L610N	SEC02	0.00	.72	.62	.53	.43	.35
L610N	SEC02	0.50	.79	.69	.59	.47	.38
L610N	SEC02	3.50	.83	.71	.62	.51	.42
L610N	SEC02	4.00	.78	.63	.56	.45	.38
L610N	SEC02	4.50	.78	.62	.52	.41	.32
L610N	SEC02	5.00	.62	.51	.45	.36	.30
L610N	SEC02	5.50	.62	.52	.45	.35	.28
L610N	SEC02	6.00	.66	.62	.49	.39	.31
L610N	SEC03	0.00	.66	.62	.49	.39	.31
L610N	SEC03	0.50	.73	.60	.52	.43	.36
L610N	SEC03	1.00	.83	.73	.62	.48	.38
L610N	SEC03	2.50	.87	.67	.57	.44	.35
L610N	SEC03	3.00	.67	.56	.50	.41	.35
L610N	SEC03	3.50	1.03	.83	.71	.55	.44
L610N	SEC03	4.00	.81	.67	.57	.46	.39
L610N	SEC03	4.50	.84	.69	.62	.50	.42
L610N	SEC03	5.00	.82	.70	.64	.52	.44
L610N	SEC03	5.50	.77	.65	.58	.47	.40
L610N	SEC03	6.00	.61	.50	.44	.35	.30
L610N	SEC04	0.00	.84	.68	.53	.50	.43
L610N	SEC04	0.50	.75	.64	.59	.50	.42
L610N	SEC04	1.00	.79	.70	.65	.55	.48
L610N	SEC04	1.50	.75	.64	.60	.51	.46
L610N	SEC04	2.00	.80	.66	.61	.50	.44
L610N	SEC04	2.50	.80	.66	.62	.52	.45
L610N	SEC04	3.00	.80	.71	.65	.54	.47
L610N	SEC04	3.50	.95	.83	.77	.63	.54
L610N	SEC04	4.00	.81	.71	.66	.55	.47
L610N	SEC04	4.50	.77	.65	.61	.49	.42
L610N	SEC04	5.00	.82	.68	.61	.49	.41
L610N	SEC04	5.50	.76	.63	.58	.47	.40
L610N	SEC05	0.00	.88	.75	.68	.55	.46
L610N	SEC05	0.50	.82	.65	.64	.52	.43
L610N	SEC05	2.00	.69	.56	.49	.39	.33
L610N	SEC05	2.50	.67	.55	.50	.41	.34

L610N	SEC05	3.00	.64	.53	.47	.38	.32
L610N	SEC05	3.50	.60	.49	.45	.37	.31
L610N	SEC05	4.00	.56	.46	.45	.37	.32
L610N	SEC05	4.50	.69	.58	.56	.46	.39
L610N	SEC05	5.00	.42	.37	.35	.33	.31
L610N	SEC05	5.50	.65	.53	.49	.42	.36

PROJECT: 920 PF A797 FILENAME: TB0610G **** ABDULREHMAN SOLANKI ****
TYPE OF MEASUREMENT: DEFLECTION AFTER OVERLAY - FEB. 4,1986
PAVEMENT TYPE: CRCP
EQUIPMENT USED: DYNAFLECT
LOCATION: LOOP 610 NORTH, HOUSTON - EAST BOUND
DIRECTION
EAST BOUND OUTSIDE LANE EVERY 50 FT. 5 EXP. SECTIONS
FORMATS:
1-5 HIGHWAY NUMBER
7-12 SECTION NUMBER
15-18 STATION NUMBER
21-23 DEF AT SENSOR # 1 IN MILS
26-28 # 2
31-33 # 3
36-38 # 4
41-43 # 5
***** DELETE LINES 1 TO 20 TO RUN A PROGRAM *****

L610N	SEC01	0.00	.30	.27	.24	.21	.19
L610N	SEC01	1.50	.33	.30	.28	.24	.21
L610N	SEC01	2.00	.36	.33	.29	.24	.21
L610N	SEC01	2.50	.36	.31	.28	.23	.21
L610N	SEC01	3.00	.39	.36	.31	.26	.22
L610N	SEC01	3.50	.28	.25	.23	.21	.19
L610N	SEC01	4.00	.28	.24	.22	.20	.19
L610N	SEC01	4.50	.28	.26	.24	.21	.20
L610N	SEC01	5.00	.31	.28	.25	.22	.21
L610N	SEC01	5.50	.40	.35	.30	.26	.23
L610N	SEC01	6.00	.31	.27	.24	.20	.18
L610N	SEC01	6.50	.36	.33	.30	.25	.23
L610N	SEC02	0.00	.39	.36	.31	.27	.23
L610N	SEC02	0.50	.35	.34	.31	.27	.24
L610N	SEC02	1.00	.34	.30	.28	.24	.22
L610N	SEC02	3.00	.44	.40	.35	.31	.28
L610N	SEC02	3.50	.40	.36	.32	.28	.26
L610N	SEC02	4.00	.38	.34	.30	.26	.24
L610N	SEC02	4.50	.35	.32	.28	.24	.22
L610N	SEC02	5.00	.33	.29	.25	.22	.19
L610N	SEC02	5.50	.30	.27	.24	.21	.19
L610N	SEC03	0.00	.33	.30	.26	.23	.21
L610N	SEC03	0.50	.36	.33	.29	.24	.22
L610N	SEC03	1.00	.34	.30	.27	.23	.21
L610N	SEC03	1.50	.33	.30	.28	.24	.23
L610N	SEC03	2.00	.38	.34	.30	.26	.24
L610N	SEC03	2.50	.33	.29	.26	.20	.21
L610N	SEC03	3.00	.54	.48	.42	.36	.32
L610N	SEC03	3.50	.50	.46	.39	.34	.30
L610N	SEC03	4.00	.43	.39	.35	.30	.27
L610N	SEC03	4.50	.40	.37	.33	.28	.25
L610N	SEC03	5.00	.40	.37	.32	.28	.26
L610N	SEC03	5.50	.32	.29	.26	.23	.20
L610N	SEC04	0.00	.46	.43	.39	.34	.31
L610N	SEC04	0.50	.39	.37	.34	.28	.26
L610N	SEC04	1.00	.45	.42	.39	.33	.30
L610N	SEC04	1.50	.45	.42	.37	.33	.30
L610N	SEC04	2.00	.45	.40	.37	.32	.28
L610N	SEC04	2.50	.45	.42	.36	.32	.29
L610N	SEC04	3.00	.44	.41	.37	.32	.29
L610N	SEC04	3.50	.48	.44	.40	.35	.33
L610N	SEC04	4.00	.43	.39	.35	.31	.27
L610N	SEC04	4.50	.42	.38	.34	.30	.27
L610N	SEC04	5.00	.41	.37	.33	.29	.27
L610N	SEC04	5.50	.41	.38	.33	.30	.27
L610N	SEC05	0.00	.48	.45	.39	.34	.30

L610N	SEC05	0.50	.45	.42	.36	.32	.28
L610N	SEC05	1.00	.46	.42	.36	.31	.27
L610N	SEC05	1.50	.41	.38	.34	.30	.27
L610N	SEC05	2.00	.40	.37	.33	.28	.26
L610N	SEC05	2.50	.38	.35	.30	.27	.24
L610N	SEC05	3.00	.39	.35	.31	.30	.24
L610N	SEC05	3.50	.39	.35	.32	.28	.25
L610N	SEC05	4.00	.44	.39	.34	.30	.26
L610N	SEC05	4.50	.41	.37	.33	.28	.25
L610N	SEC05	5.00	.33	.31	.28	.25	.26
L610N	SEC05	5.50	.40	.36	.32	.27	.26

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PROJECT: 920 PF A797 FILENAME: TB0610B ***** KOESTOMO KOESNO *****
TYPE OF MEASUREMENT: DEFLECTION AFTER OVERLAY - JAN. 13,1987
PAVEMENT TYPE: CRCP
EQUIPMENT USED: DYNAFLECT
LOCATION: LOOP 610 NORTH, HOUSTON - EAST BOUND
DIRECTION
EAST BOUND OUTSIDE LANE EVERY 50 FT. 1 CONTROL & 5 EXP.  SECTIONS
FORMATS:
1-5  HIGHWAY NUMBER
7-12  SECTION NUMBER
15-18 STATION NUMBER
21-23 DEF AT SENSOR # 1 IN MILS
26-28              # 2
31-33              # 3
36-38              # 4
41-43              # 5
***** DELETE LINES 1 TO 17 TO RUN A PROGRAM *****
L610N  COSEC  0.00  .49  .47  .46  .34  .28
L610N  COSEC  0.50  .54  .50  .47  .35  .28
L610N  COSEC  1.00  .62  .53  .46  .34  .29
L610N  COSEC  1.50  .48  .44  .40  .32  .29
L610N  COSEC  2.00  .61  .53  .50  .37  .30
L610N  COSEC  2.50  .57  .52  .48  .33  .26
L610N  COSEC  3.00  .55  .53  .52  .38  .32
L610N  COSEC  3.50  .59  .58  .57  .43  .34
L610N  COSEC  4.00  .60  .57  .56  .43  .35
L610N  COSEC  4.50  .69  .63  .55  .39  .33
L610N  COSEC  5.00  .57  .53  .51  .41  .36
L610N  SEC06  0.00  .22  .21  .20  .17  .15
L610N  SEC06  0.50  .22  .21  .20  .17  .15
L610N  SEC06  1.00  .27  .25  .24  .20  .18
L610N  SEC06  1.50  .29  .28  .27  .22  .20
L610N  SEC06  2.00  .39  .38  .37  .30  .20
L610N  SEC06  2.50  .37  .35  .33  .27  .25
L610N  SEC06  3.00  .34  .33  .32  .27  .25
L610N  SEC06  3.50  .36  .35  .34  .27  .25
L610N  SEC06  4.00  .40  .37  .35  .27  .24
L610N  SEC06  4.50  .32  .31  .30  .25  .22
L610N  SEC06  5.00
L610N  SEC06  5.50  .49  .40  .38  .30  .28
L610N  SEC07  0.00  .48  .44  .41  .33  .29
L610N  SEC07  0.50  .39  .37  .36  .30  .26
L610N  SEC07  1.00  .31  .29  .28  .24  .22
L610N  SEC07  1.50  .40  .37  .35  .29  .25
L610N  SEC07  2.00  .42  .39  .38  .29  .24
L610N  SEC07  2.50  .41  .39  .37  .32  .28
L610N  SEC07  3.00  .45  .42  .41  .34  .30
L610N  SEC07  3.50  .42  .41  .40  .36  .29
L610N  SEC07  4.00  .47  .44  .42  .35  .30
L610N  SEC07  4.50  .55  .53  .52  .41  .35
L610N  SEC07  5.00  .47  .44  .43  .35  .31
L610N  SEC08  0.00  .43  .40  .39  .32  .29
L610N  SEC08  0.50  .43  .40  .39  .31  .28
L610N  SEC08  1.00  .45  .41  .39  .32  .28
L610N  SEC08  1.50  .39  .36  .33  .27  .23
L610N  SEC08  2.00  .31  .30  .29  .23  .20
L610N  SEC08  2.50  .30  .29  .28  .24  .21
L610N  SEC08  3.00  .44  .40  .38  .31  .28
L610N  SEC08  3.50  .42  .41  .39  .31  .27
L610N  SEC08  4.00  .50  .49  .48  .40  .36
L610N  SEC08  4.50  .47  .45  .44  .38  .35
L610N  SEC08  5.00  .36  .35  .34  .29  .26
L610N  SEC08  5.50  .36  .35  .34  .28  .26
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L610N	SEC09	0.00	.39	.36	.35	.29	.26
L610N	SEC09	0.50	.44	.41	.40	.32	.28
L610N	SEC09	1.00	.51	.48	.45	.37	.32
L610N	SEC09	1.50	.42	.41	.40	.32	.29
L610N	SEC09	2.00	.39	.37	.36	.29	.25
L610N	SEC09	2.50	.39	.38	.37	.31	.27
L610N	SEC09	3.00	.44	.41	.38	.33	.30
L610N	SEC09	3.50	.36	.34	.33	.27	.25
L610N	SEC09	4.00	.38	.36	.35	.29	.26
L610N	SEC09	4.50	.32	.31	.30	.25	.23
L610N	SEC09	5.00	.37	.36	.35	.28	.25
L610N	SEC09	5.50	.34	.32	.31	.24	.22
L610N	SEC10	0.00	.25	.23	.22	.18	.17
L610N	SEC10	0.50	.33	.32	.31	.23	.21
L610N	SEC10	1.00	.35	.34	.33	.27	.24
L610N	SEC10	1.50	.44	.42	.40	.31	.26
L610N	SEC10	2.00	.32	.31	.30	.26	.24
L610N	SEC10	2.50	.33	.32	.31	.25	.23
L610N	SEC10	3.00	.38	.36	.35	.28	.24
L610N	SEC10	3.50	.41	.38	.37	.28	.24
L610N	SEC10	4.00	.39	.36	.34	.27	.24
L610N	SEC10	4.50	.37	.35	.33	.27	.23
L610N	SEC10	5.00	.42	.40	.39	.33	.29

PROJECT: 920 PF A797 FILENAME: TB0610A ****** KOESTOMO KOESNO ******
TYPE OF MEASUREMENT: DEFLECTION AFTER OVERLAY - MARCH 19,1987
PAVEMENT TYPE: CRCP
EQUIPMENT USED: DYNAFLECT
LOCATION: LOOP 610 NORTH, HOUSTON - EAST BOUND
DIRECTION
EAST BOUND OUTSIDE LANE EVERY 50 FT. 5 EXP. SECTIONS
FORMATS:
1-5 HIGHWAY NUMBER
7-12 SECTION NUMBER
15-18 STATION NUMBER
21-23 DEF AT SENSOR # 1 IN MILS
26-28 # 2
31-33 # 3
36-38 # 4
41-43 # 5
***** DELETE LINES 1 TO 17 TO RUN A PROGRAM *****

L610N	SEC01	0.00	.23	.22	.20	.18	.17
L610N	SEC01	0.50	.31	.29	.25	.22	.19
L610N	SEC01	1.00	.26	.25	.23	.20	.18
L610N	SEC01	1.50	.28	.25	.22	.20	.18
L610N	SEC01	2.00	.27	.26	.25	.22	.19
L610N	SEC01	2.50	.27	.25	.22	.20	.18
L610N	SEC01	3.00	.30	.27	.24	.20	.17
L610N	SEC01	3.50	.27	.24	.21	.18	.17
L610N	SEC01	4.00	.29	.26	.23	.22	.18
L610N	SEC01	4.50	.27	.25	.23	.21	.18
L610N	SEC01	5.00	.34	.33	.28	.24	.20
L610N	SEC01	5.50	.31	.29	.27	.25	.22
L610N	SEC02	0.00	.31	.29	.26	.22	.20
L610N	SEC02	0.50	.36	.33	.29	.25	.22
L610N	SEC02	1.00	.34	.32	.30	.27	.23
L610N	SEC02	1.50	.40	.31	.26	.25	.24
L610N	SEC02	2.00	.33	.30	.27	.24	.21
L610N	SEC02	2.50	.33	.30	.27	.24	.21
L610N	SEC02	3.00	.39	.37	.32	.28	.25
L610N	SEC02	3.50	.37	.34	.28	.24	.22
L610N	SEC02	4.00	.40	.37	.34	.29	.25
L610N	SEC02	4.50	.35	.34	.29	.28	.23
L610N	SEC02	5.00	.37	.34	.30	.25	.22
L610N	SEC02	5.50	.29	.27	.24	.20	.19
L610N	SEC02	6.00	.29	.27	.23	.20	.17
L610N	SEC03	0.00	.28	.26	.23	.19	.17
L610N	SEC03	0.50	.31	.28	.24	.20	.17
L610N	SEC03	1.00	.31	.29	.26	.21	.19
L610N	SEC03	1.50	.28	.27	.24	.21	.19
L610N	SEC03	2.00	.33	.31	.27	.23	.20
L610N	SEC03	2.50	.35	.33	.30	.26	.22
L610N	SEC03	3.00	.33	.30	.28	.24	.21
L610N	SEC03	3.50	.37	.32	.27	.23	.21
L610N	SEC03	4.00	.35	.34	.29	.25	.22
L610N	SEC03	4.50	.45	.40	.36	.31	.27
L610N	SEC03	5.00	.66	.63	.58	.51	.45
L610N	SEC03	5.50	.43	.40	.36	.31	.27
L610N	SEC03	6.00	.40	.37	.34	.29	.26
L610N	SEC04	0.00	.45	.42	.38	.36	.30
L610N	SEC04	0.50	.44	.41	.38	.32	.28
L610N	SEC04	1.00	.45	.44	.38	.34	.30
L610N	SEC04	1.50	.45	.41	.38	.34	.30
L610N	SEC04	2.00	.44	.41	.37	.33	.29
L610N	SEC04	2.50	.45	.42	.38	.34	.29
L610N	SEC04	3.00	.42	.41	.35	.31	.28
L610N	SEC04	3.50	.42	.40	.37	.33	.30

L610N	SEC04	4.00	.38	.35	.31	.28	.25
L610N	SEC04	4.50	.41	.38	.34	.30	.26
L610N	SEC04	5.00	.43	.39	.35	.31	.26
L610N	SEC04	5.50	.42	.39	.35	.31	.27
L610N	SEC05	0.00	.42	.39	.35	.31	.27
L610N	SEC05	0.50	.43	.40	.36	.31	.27
L610N	SEC05	1.00	.40	.36	.33	.28	.25
L610N	SEC05	1.50	.38	.35	.32	.28	.25
L610N	SEC05	2.00	.38	.35	.31	.27	.24
L610N	SEC05	2.50	.41	.36	.32	.27	.23
L610N	SEC05	3.00	.40	.36	.32	.27	.24
L610N	SEC05	3.50	.44	.40	.36	.31	.26
L610N	SEC05	4.00	.46	.43	.36	.31	.26
L610N	SEC05	4.50	.40	.37	.33	.29	.25
L610N	SEC05	5.00	.39	.35	.29	.23	.20
L610N	SEC05	5.50	.42	.39	.35	.29	.25

APPENDIX C. LABORATORY TESTING RESULTS

TABLE C.1. ***SUMMARY OF SHEAR STRENGTH RESULTS (PSI) BY SECTION NUMBER AND DATE, IH 610 NORTH, HOUSTON***

Test Sect No.	Dates Cores Taken: Feb 1986	Jan 1987	Aug 1987
1	205	140	
		390	
		180	
		303*	
2	309	120	
	111	480	
3	50	150	
		160	
4	131	436	
	140		
5	79	429	
	203		
6		266	
7		346	
		470	
8			523
9			553
10			441

*Taken on longitudinal crack.

TABLE C.2. ***SUMMARY OF SPLITTING TENSILE STRENGTH (PSI) (OVERLAY PORTION), IH 610 NORTH, HOUSTON***

Test Sect No.	Dates Cores Taken: Feb 1986	Jan 1987
1	789	572
	563	728
		546
2	588	637
	576	450
3	422	726
		424
4	757	625
	523	
	733	
5	436	950
	865	
6		718
7		698
		577
8		652
9		868