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The objectives of this study were to determine the extent of delamination of the bonded concrete overlay on IH610 North in Houston, to determine if the delaminations are progressive, to identify probable causes of the delaminations, and to recommend remedial measures.

Condition surveys were conducted periodically and laboratory tests were performed on the cores obtained from the monitored areas. Statistical analyses were then performed on the condition surveys and laboratory test data. From these analyses, conclusions and recommendations were made to enable the Texas State Department of Highways and Public Transportation to design overlays for rehabilitation programs on CRCP.

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by

Kok Jin Teo
D. W. Fowler
B. Frank McCullough

Research Report Number 920-3

Evaluation of Thin Bonded Concrete Overlay in Houston

Research Project 3-12D-84-920

conducted for

**Texas State Department of Highways
and Public Transportation**

by the

CENTER FOR TRANSPORTATION RESEARCH

Bureau of Engineering Research
THE UNIVERSITY OF TEXAS AT AUSTIN

February 1989

PREFACE

Thanks are extended to all who assisted in the preparation of this report, especially James R. Lundy, for his invaluable comments and suggestions in the preparation of this report. Special thanks are also due to Amer Z. Durrani and Young Chan Suh for their time in discussion of this study.

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

LIST OF REPORTS

Report 920-1, "Design Analysis for Rehabilitation of the CRCP on the 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 the pavement. October 1986.

Report 920-2, "Evaluation of Thin Bonded Concrete Overlay in Houston," by Koestomo Koesno and B. Frank McCullough, presents the findings of a pavement monitoring program on the IH610 North, Houston, project. October 1987.

Report 920-3, "Monitoring and Testing of the Bonded Concrete Overlay on Interstate Highway 610 North in Houston, Texas," by Kok Jin Teo, D. W. Fowler, and B. Frank McCullough, presents the results of the monitoring and testing program on the two inside lanes on the IH610 North, Houston, project. November 1988.

ABSTRACT

The objectives of this study were to determine the extent of delamination of the bonded concrete overlay on IH610 North in Houston, to determine if the delaminations are progressive, to identify probable causes of the delaminations, and to recommend remedial measures.

Condition surveys were conducted periodically and laboratory tests were performed on the cores obtained from the monitored areas. Statistical analyses were then performed on the condition surveys and laboratory test data. From these analyses, conclusions and recommendations were made to enable the Texas State Department of Highways and Public Transportation to design overlays for rehabilitation programs on CRCP.

SUMMARY

The two inside lanes on IH610 in Houston, east and west bound, between T. C. Jester Blvd. and IH 45 were identified for monitoring to assess the extent of delaminations. In addition, Dynaflect deflections were measured and cracks counted on the identified areas.

Periodic condition surveys were made to monitor the extent of growth, if any, of the delaminations and to determine the crack spacings. During these surveys, cores were extracted for laboratory tests, and Dynaflect deflection measurements were taken. From these survey data, statistical analyses were performed to assess the condition of the bonded concrete overlays.

The report includes conclusions and recommendations derived from this study.

IMPLEMENTATION STATEMENT

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

(1) Use a bonded concrete overlay with some additional modifications on an existing PCC pavement to extend the life.

(2) Limit the evaporation rate during construction to less than 0.20 lb/feet^2/hour.

(3) Restrict the maximum allowable temperature difference between placement and the minimum for the following day to 25°F or less unless curing blankets are used.

(4) Repair failures before overlaying to reduce the effects of the failures on the overlays.

(5) Use cement grout as bonding agent.

(6) Cold milling should be used as the surface preparation technique until the level of texture required for successful bonding of the overlay can be established.

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CHAPTER 7. GENERAL CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 1. INTRODUCTION

This report is concerned with the monitoring and testing of the bonded concrete overlay project on IH610 North in Houston. This chapter presents background information, the objective, and the scope of the report.

BACKGROUND

The Interstate Highway System is nearing completion and the major attention has shifted from construction to maintaining, repairing, and rehabilitating the existing highway pavements, because most of the existing highway pavements are nearing the end of their theoretical twenty year design life.

In Houston, continuously reinforced concrete pavements (CRCP) have been used extensively for streets and highways. Many of these pavements are still in good structural condition and, depending on the pavement condition, may require only rehabilitation in the near future.

Portland cement concrete (PCC) overlays have been used to resurface existing pavements for sixty years but they primarily were limited to airport runways and bridge decks. Several U.S. Air Force runways and the Tulsa airport have used bonded concrete overlays. The performance of these overlays has ranged from good to very good.

During the last few years, the Center for Transportation Research has undertaken several research studies concerning the viability and usefulness of bonded concrete overlays for rehabilitating highway pavements. Theoretically, the rehabilitation of concrete pavements with bonded concrete overlays is desirable because of the thermal and structural compatibility of the overlay material and the overlaid pavement. Also, theoretical studies have shown that bonded concrete overlays will substantially increase the structural capacity of the existing concrete pavement and, consequently, its fatigue life.

The successful IH610 South overlay project encouraged the SDHPT to use a 4-inch bonded concrete overlay to improve the pavement condition on about 3-1/2 miles of IH610 North, between East T. C. Jester Blvd. and IH 45, in Houston. At this location, the roadway is an 8-lane divided highway with four through lanes in each direction and a concrete median barrier. Main lane widths are 12 feet and shoulders are 6 and 10 feet wide. The original pavement is an 8-inch CRCP which rests on a 6-inch-thick cement-stabilized subbase.

During the monitoring of the performance of the overlays, it was found that some delamination occurred. Five sections on the inside two lanes were then selected for further field evaluation and data collection. Appendix A shows the location of the five sections and the different types of overlay treatment. The five sections were selected on the basis of

(1) overlay reinforcements: welded wire fabric and fiber;
(2) aggregate: limestone and siliceous river gravel;
(3) bonding agent: grout (on most of the project) and no bonding agent;
(4) condition of existing pavements: several levels of distress and delamination.

OBJECTIVE OF THE STUDY

The primary objectives of this study were to determine the extent of delamination of the bonded concrete overlay on IH610 North in Houston, to determine if the delaminations are progressive, to identify probable causes of the delamination, and to recommend remedial measures.

The subobjectives of the study are

(1) to identify several sections to represent the variations in the present pavement, to investigate materials used for the overlay, and to observe construction procedures;
(2) to observe and record actual construction techniques and materials;
(3) to make observations and measure parameters influencing behavior immediately after opening the overlaid section to traffic and at 6-month intervals;
(4) to perform statistical analyses to evaluate the relative merits of alternatives actually used in this project;
(5) to perform condition surveys for detection of delamination and quantify the extent of delamination;
(6) to perform laboratory tests, field tests and mechanistic analyses and to investigate the causes of delamination;
(7) to compare the results of this study with the recommended design techniques developed in Project 357, Thin Bonded Concrete Overlay; and
(8) to give recommendations on construction procedures and techniques.

ORGANIZATION AND SCOPE OF THE REPORT

Chapter 2 describes the condition surveys done on IH610 North in Houston and tabulates the data collected.

Chapter 3 presents and discusses the Dynaflect deflection measurements.

Chapter 4 gives details of the laboratory tests performed and the analysis of the results from these tests.

Chapter 5 evaluates the repair techniques used on the debonded section on IH610 North in Houston.

Chapter 6 is concerned with the statistical analyses performed on the data collected from the condition surveys, deflection measurements, and the laboratory tests.

Chapter 7 discusses the findings and recommendations derived from this study. The recommendations are compared to those made in Project 357.

CHAPTER 2. CONDITION SURVEYS

Three condition surveys were made between March 1987 and March 1988 on IH610 North in Houston. The condition surveys were made to monitor the performance of the overlays and to quantify the extent of the delamination. They consisted of marking cracks and sounding for delamination.

MARCH 1987 CONDITION SURVEY

This was the first of three condition surveys performed on the two inside lanes of the bonded concrete overlay project on IH610 North in Houston. During this condition survey the extent of the delamination was quantified. Coring was also performed and the cores were brought back to Austin for laboratory tests, namely, direct shear, density, split tension, and coefficient of thermal expansion. Twelve cores were also examined petrographically by Erlin, Hime Associates.

AUGUST 1987 CONDITION SURVEY

During the periods of August 3 to 7 and August 10 to 14, 1987, a condition survey was performed and data were collected on the five test sections (101 to 105) of the bonded concrete overlay project, to minimize the facility closure. The two inside lanes at selected test locations were surveyed during the week of August 3. The activities that were performed during the survey included

(1) sounding for delamination,
(2) locating cracks and punchouts,
(3) deflection measurements,
(4) coring, and
(5) repairs of selected sections of the overlay project.

Permanent markers were also installed during this condition survey. These are bronze right-of-way markers approximately 4 inches in diameter that, when in place, protrude above the pavement surface about 1/4 inch On these test sections, they were placed in the inside lanes about 18 inches from the inside shoulder (or median).

The data from this survey were used to determine the increase, if any, in the delamination.

MARCH 1988 CONDITION SURVEY

A condition survey was performed on March 12 and 13, 1988, on the two inside lanes of the bonded concrete overlay project on IH610 North. During this condition survey, a new recording technique was tried. This method required the use of a machine called ARAN. The ARAN (Automated Road Analyzer) photologged the cracks and delaminations, which had been previously marked using a video camera mounted on a moving vehicle. The video cassette can be played back at a slower speed so that the cracks and delaminations can be counted manually.

SURVEY TECHNIQUES

The survey techniques used during the March 1987 and August 1987 surveys are described in the following subsections.

Marking of Cracks

Cracks were mapped directly onto a sheet of paper. A a reference point was located, and crack locations were measured from it. Only new cracks, or cracks not previously recorded, were mapped.

Sounding for Delamination

Delaminated areas were located by a technique called sounding (Fig 2.1). This technique required the use of a reinforcing steel bar, preferably No. 6 or 8 about 4 feet long, which was held in a vertical orientation and dropped onto the overlay. A solid sound indicated an absence of delaminations, while a hollow sound indicated the presence of delaminations. The limits of the delaminated areas were delineated by spray paint and were recorded by the recorder onto the scaled one-square-foot squares on the survey forms.

Fig 2.1. Sounding and marking off the delaminated area.

Recording with ARAN

During the March 1988 survey, it was decided that ARAN would be used to photolog the delaminations and cracks. The delaminated areas were marked as before and dots were put on each transverse crack. The longitudinal cracks were marked with dashed lines and small shrinkage cracks were marked with beginning and ending arrows. The ARAN photologged them on a video cassette and, by playing the video cassette back at slow speed, cracks and delaminations were read off the television monitor. This reduced the time spent on the IH610 North but additional time was required in reading the information off the monitor.

Some station numbers also were painted on the pavement with spray paint. This helped in identifying the location and also aided in checking the ARAN distance counter.

CONDITION SURVEYS RESULTS

The crack spacing and delamination results from the three surveys are tabulated in Tables 2.1 and 2.2, respectively. Since data were collected for only the five test sections during the August 1987 survey, a comparison was not made with the March 1987 survey. There was a significant increase in delamination indicated by this survey but the delamination for March 1988 was the same as that of March 1987. Therefore, the delamination was affected by the season in which the survey was conducted. During the colder months, the extent of delamination detected was smaller than that in the warmer months.

TABLE 2.1. AVERAGE CRACK SPACING (FEET)

Location and Condition	March 1987	March 1988	Change
West Bound Lane 1			
Overall	4.42	4.41	-0.01
No Grout	6.45	2.86	-3.59
West Bound Lane 2			
Overall	4.78	5.08	+0.30
No Grout	5.56	3.08	-2.48
West Bound Lane 1			
Overall	5.05	5.56	+0.51
Limestone	18.87	23.26	+4.39
Fiber	11.11	14.71	+3.60
SRG	4.26	4.65	+0.39
WestBound Lane 2			
Overall	5.21	5.81	+0.60
Limestone	20.83	11.24	-9.59
Fiber	11.76	12.99	+1.23
SRG	4.39	5.00	+0.61

TABLE 2.2. PERCENT DELAMINATION

Location and Condition	March 1987	March 1988	Percent Change	Significant ?
West Bound Lane 1				
Overall	0.25	0.27	+0.02	No
No Grout	2.15	1.75	-0.40	No
West Bound Lane 2				
Overall	0.25	0.27	+0.02	No
No Grout	3.40	4.45	+1.05	Yes
East Bound Lane 1				
Overall	1.41	1.37	-0.04	No
Limestone	0.00	0.06	+0.06	No
Fiber	0.06	0.08	+0.02	No
SRG	1.81	1.76	-0.05	No
East Bound Lane 2				
Overall	2.00	2.05	+0.05	No
Limestone	0.00	0.06	+0.06	No
Fiber	0.17	0.17	0.00	No
SRG	2.58	2.63	+0.05	No

Detailed results of the three condition surveys are given in Appendix B.

POSSIBLE ERRORS IN CONDITION SURVEYS

Several possible errors were identified during the three condition surveys, which may have contributed to the variability of the condition surveys results.

Marking and Recording of Cracks

The condition surveys were conducted during the daytime; therefore, the angle of incident of the sun was a factor in identifying the cracks. Cracks were difficult to see on bright sunny days and during hot weather since the expansion of the pavement closed up the smaller cracks. In general, it was easier to locate the cracks in March than in August, because of the lower temperature.

Another source of error was the inability of the recorder to differentiate the transverse cracks from the hairline shrinkage cracks. This was particularly true if the shrinkage cracks and the transverse cracks were close together.

The crack spacing found during the March 1988 survey was more than that of March 1987. One possible explanation for this increase was the fact that during the later survey, shrinkage cracks were marked and recorded as a whole block as compared to the earlier survey where they were recorded individually. Another reason could be the fact that ARAN was used during the latter survey and the station number did not match up with the station number of the earlier survey because of an inaccurate ARAN milepost counter. This can be attributed to the fact that all stations were not marked on the pavement when the ARAN was used. Therefore, in future surveys every station number should be marked on the pavement.

SOUNDING AND RECORDING FOR DELAMINATIONS

The extent of delamination was probably the most subject to variation of all the data collected during the three condition surveys since sounding was operator dependent. Different operators have varying levels of hearing sensitivity and, as a result, the detected delaminated areas varied in size.

An experiment was carried out to determine the operator variance, because of the difference in delamination between the March 1987 and August 1987 surveys. A detailed description of the experiment conducted is given in Appendix C. From the experiment, it was found that, in order to achieve a 95 percent confidence, the change in delamination had to be greater than 0.7 percent.

EVALUATION

Overall, it can be concluded that there were no significant changes in crack spacing because measurements were within the expected margin of error for the two techniques used, although the average crack spacing for the two surveys was different.

Based on the March 1987 and March 1988 surveys there was no significant increase in delamination except in the no-grout section. The no-grout section represents less than one percent of the total job. From successive surveys, it appeared that the delaminations were not growing.

From the condition surveys, it can be seen that the areas with the largest delaminated areas were in those overlays constructed with siliceous river gravel aggregates, with or without grout. The types of overlay which performed well in terms of delaminated areas were limestone reinforced with welded wire fabric or fiber with siliceous river gravel aggregate. However, it must be remembered that the siliceous river gravel overlay constitutes the vast majority of the project and, as a result, was placed in a wide variety of weather conditions. As will be shown, environmental conditions at the time of placement affect the early age performance of bonded overlays. Generally, the fiber reinforced and limestone aggregate concrete sections were placed in one or two days. Therefore, these sections were not subjected to a wide variety of environmental conditions which may adversely affect their performance.

CHAPTER 3. DEFLECTION MEASUREMENTS

This chapter presents the deflection measurements of the five test sections, 101 to 105, made during the three condition surveys. The deflections were measured using the Dynaflect (Fig 3.1). The corresponding changes in the measurements due to different effects are also discussed.

DYNAFLECT MEASUREMENTS LOCATION

Dynaflect measurements were made at the cracks and between cracks.These locations were at (1) the center of the lane, (2) in the right wheel path, and (3) in the left wheel path. A table describing these locations is given in Appendix D.

DYNAFLECT READINGS

A summary of the deflection measurements made during the three condition surveys is given in Table 3.1. Figures 3.2 to 3.6 show the deflections graphically. The deflection of section 105 was the highest because it had the highest amount of delamination.

COMPARISON OF RESULTS

The deflection changes in percent are tabulated in Table 3.2.

From the deflection readings, it can be seen that there was less than 5 percent change in deflections from March 1987 to March 1988 (measurements on Section 101 were not taken in March 1987). The changes between August 1987 and March 1988 are not believed to provide a good comparison due to temperature differences when the measurements were taken. This indicates that there was no significant deterioration in the pavement itself and the pavement did not lose stiffness. The summary of stiffness is presented later in this chapter.

FACTORS AFFECTING PAVEMENT DEFLECTIONS

The deflections on rigid pavements are influenced by a number of factors. These factors can be broadly classified into two categories:

(1) environmental factors, and
(2) pavement characteristics.

Environmental Factors

Temperature, seasonal and moisture effects are considered.

Temperature Effects. Seasonal variations in temperature cause pavements to contract or expand and consequently affect the development of frictional forces between the pavement and the underlying layer. Joints and cracks also expand as a result of the seasonal variations in temperature.

The daily variations of temperature cause temperature differentials in the pavement, which create curling and warping. Deflection measurements are higher when the daily and seasonal temperatures are high.

Moisture Effects. Seasonal changes in deflections can also be influenced by the seasonal variations of moisture in the unbound base layer and subgrade. The deflections in August were about 25 percent higher than in March 1987 and March 1988 although these increases are probably not entirely due to moisture changes.

Pavement Characteristics

Two factors in this category affect pavement deflections.

Effect of Void Size. The creation of voids under the concrete pavement can affect the Dynaflect deflection measurements. If voids are present, the deflection measurements will be higher. Voids can result from

(1) pumping of subbase material,
(2) movement or differential settlement in subsoil strata, and
(3) slab jacking.

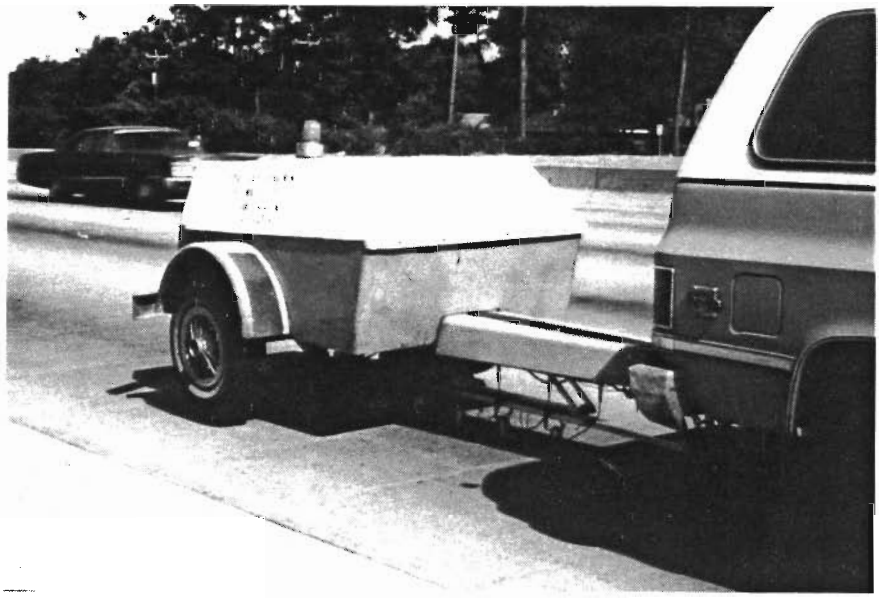


Fig 3.1. Dynaflect system in operating position.

TABLE 3.1. MEANS AND STANDARD DEVIATIONS OF DEFLECTIONS

Sensor	Survey Date	Deflection (10^{-5} in.)				
		Section 101	Section 102	Section 103	Section 104	Section 105
w1	Mar '87	-	35 (3.7)	43 (6.7)	39 (6.8)	50 (10.0)
	Aug '87	57 (8.0)	45 (8.4)	55 (9.0)	49 (7.6)	59 (16.2)
	Mar '88	49 (6.8)	37 (3.8)	52 (7.8)	43 (8.2)	54 (10.1)
w2	Mar '87	-	33 (3.6)	40 (6.2)	37 (6.1)	43 (5.6)
	Aug '87	56 (8.0)	43 (8.7)	51 (5.0)	47 (6.5)	55 (12.6)
	Mar '88	47 (6.9)	35 (3.1)	49 (6.7)	40 (4.2)	48 (10.0)
w3	Mar '87	-	30 (3.2)	38 (6.1)	35 (5.6)	37 (2.8)
	Aug '87	54 (7.5)	37 (8.9)	44 (4.2)	40 (6.4)	46 (6.1)
	Mar '88	43 (6.3)	31 (3.1)	43 (6.4)	35 (4.2)	40 (5.7)
w4	Mar '87	-	27 (3.0)	34 (5.3)	32 (4.1)	31 (1.1)
	Aug '87	50 (7.1)	32 (6.8)	40 (2.8)	37 (5.2)	40 (3.8)
	Mar '88	39 (6.1)	28 (3.1)	40 (6.7)	32 (3.4)	35 (3.3)
w5	Mar '87	-	23 (2.5)	28 (4.6)	27 (2.9)	26 (1.4)
	Aug '87	39 (5.6)	30 (7.6)	34 (2.8)	30 (6.8)	28 (2.6)
	Mar '88	36 (6.0)	24 (2.6)	36 (5.6)	28 (2.6)	29 (2.6)

Note: Numbers in parentheses represent standard deviations.

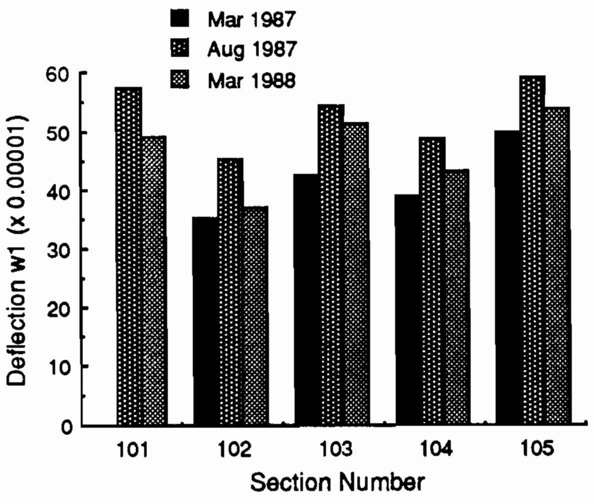


Fig 3.2. Deflection (Sensor w1).

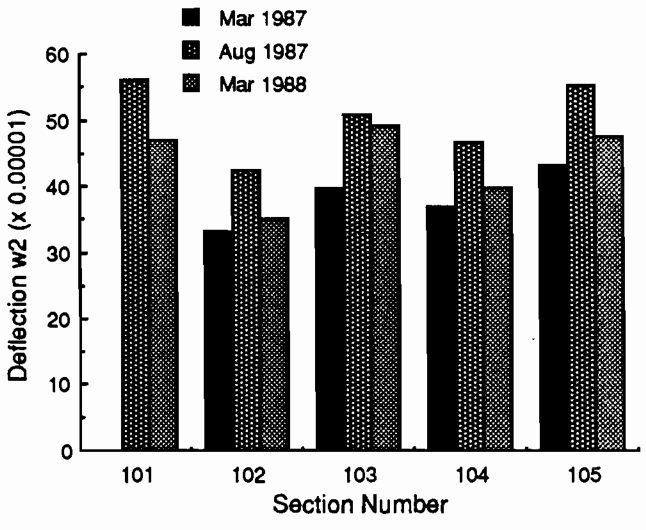


Fig 3.3. Deflection (Sensor w2).

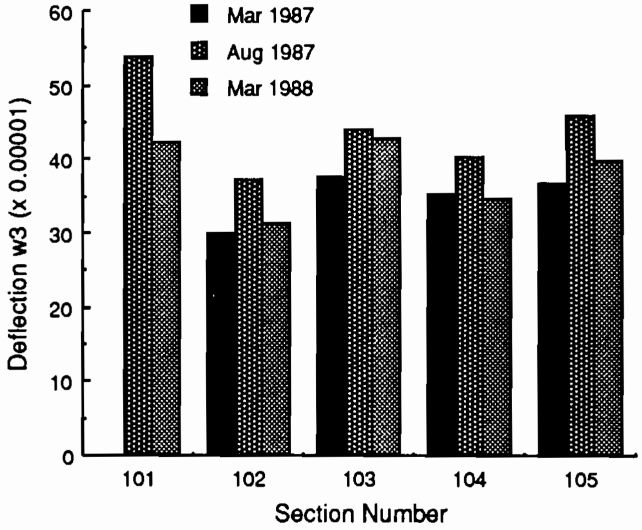


Fig 3.4. Deflection (Sensor w3).

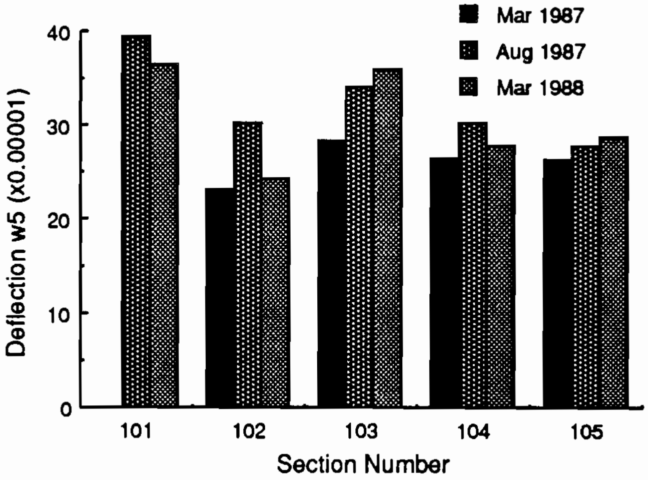


Fig 3.5. Deflection (Sensor w4).

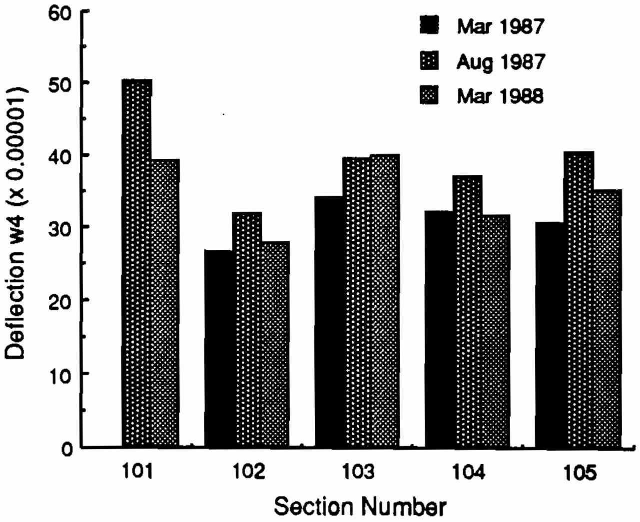


Fig 3.6. Deflection (Sensor w5).

TABLE 3.2. COMPARISON OF DEFLECTION CHANGES

	Changes in Deflection (percent)				
Difference	**Section 101**	**Section 102**	**Section 103**	**Section 104**	**Section 105**
Sensor w1					
Mar '88 - Mar '87	-	1.7 (5.0)	8.8 (21.0)	4.1 (11.0)	3.6 (8.0)
Aug '87 - Mar '87	-	9.9 (28.0)	11.8 (28.0)	9.9 (25.0)	9.1 (18.0)
Sensor w2					
Mar '88 - Mar '87	-	1.7 (5.0)	1.2 (3.0)	2.9 (8.0)	4.3 (10.0)
Aug '87 - Mar '87	-	9.1 (27.0)	10.9 (27.0)	9.9 (27.0)	12.1 (28.0)
Sensor w3					
Mar '88 - Mar '87	-	1.4 (5.0)	5.1 (14.0)	-0.6 (-2.0)	3.0 (8.0)
Aug '87 - Mar '87	-	7.3 (24.0)	6.3 (17.0)	5.0 (14.0)	9.1 (25.0)
Sensor w4					
Mar '88 - Mar '87	-	1.3 (20.0)	5.5 (16.0)	-0.6 (-2.0)	4.7 (15.0)
Aug '87 - Mar '87	-	5.2 (20.0)	5.2 (15.0)	4.9 (15.0)	9.8 (32.0)
Sensor w5					
Mar '88 - Mar '87	-	1.1 (5.0)	7.6 (27.0)	1.2 (5.0)	2.4 (9.0)
Aug '87 - Mar '87	-	5.2 (30.0)	5.2 (21.0)	4.9 (14.0)	9.8 (6.0)

Note: Numbers in parentheses represent standard deviations.

Effect of Discontinuities. The presence of discontinuities, such as at transverse cracks or joints, is an inherent characteristic of rigid pavements. A discontinuity means that the slab bending stiffness in the orthogonal direction is reduced and, consequently, test loads applied near these discontinuities yield higher deflections than those applied away from the discontinuities.

ANALYSIS OF RESULTS

Back calculations were made using the RPEDD1 (Ref 8) program to compare stiffness changes. The back calculation can be performed by using the Dynaflect measurements to calculate the pavements' modulus of elasticity from these deflections. Figure 3.7 shows the pavement structure used in the back calculations, where D_1, D_2, and D_3 are the depth of the overlay plus existing CRCP , the depth of subbase, and the depth of the roadbed, respectively; u_1, u_2 and u_3 are Poisson's ratios in the three materials.

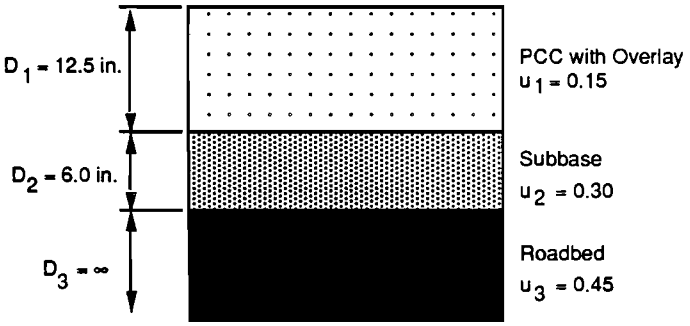


Fig 3.7. Pavement structure used for back calculations in RPEDD1.

The moduli of elasticity as calculated by RPEDD1 are given in Table 3.3. It can be seen that there were statistically no changes in the moduli of the pavement in sections 102 to 104. However, in section 105 the modulus had decreased. A possible explanation for this could be the large amount of delamination found in this section. Figures 3.8 to 3.10 show the changes in the moduli of elasticity of the structure from March 1987 to March 1988.

TABLE 3.3. MODULI OF ELASTICITY

		Modulus of Elasticity (ksi)				
Date		**Section 101**	**Section 102**	**Section 103**	**Section 104**	**Section 105**
Mar '87	E_1	-	3,581 (492)	3,085 (502)	3,016 (599)	3,373 (1,283)
	E_2	-	194 (60)	129 (76)	132 (70)	180 (161)
	E_3	-	23 (3)	18 (4)	19 (2)	19 (2)
Aug '87	E_1	-	3,517 (994)	2,601 (399)	2,880 (667)	2,063 (316)
	E_2	-	170 (90)	118 (47)	138 (87)	86 (27)
	E_3	-	19 (5)	16 (1)	17 (4)	18 (1)
Mar '88	E_1	-	3,509 (290)	3,085 (567)	3,249 (840)	2,273 (413)
	E_2	-	196 (75)	182 (102)	190 (88)	81 (37)
	E_3	-	22 (3)	15 (4)	20 (2)	19 (1)

Note: Numbers in parentheses represent standard deviations.

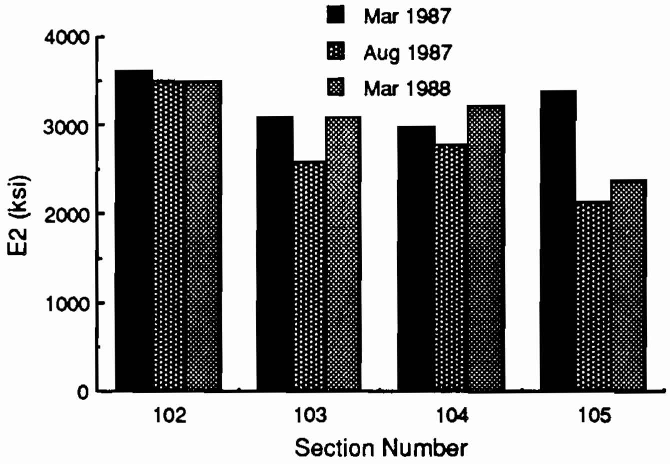


Fig 3.8. Modulus of elasticity of PCC slab.

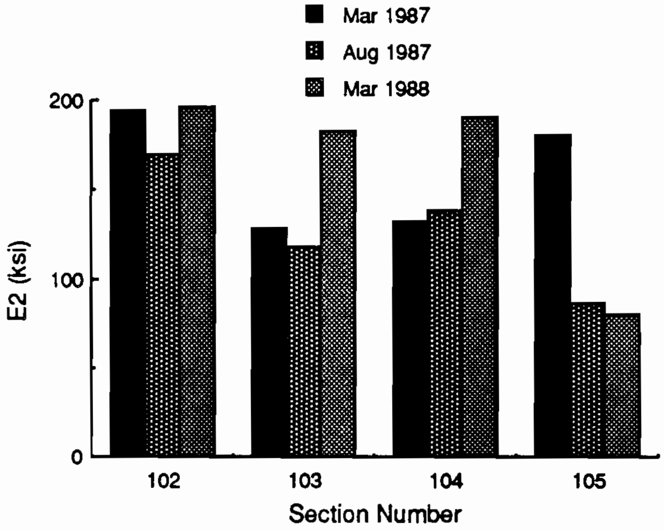


Fig 3.9. Modulus of elasticity of subbase.

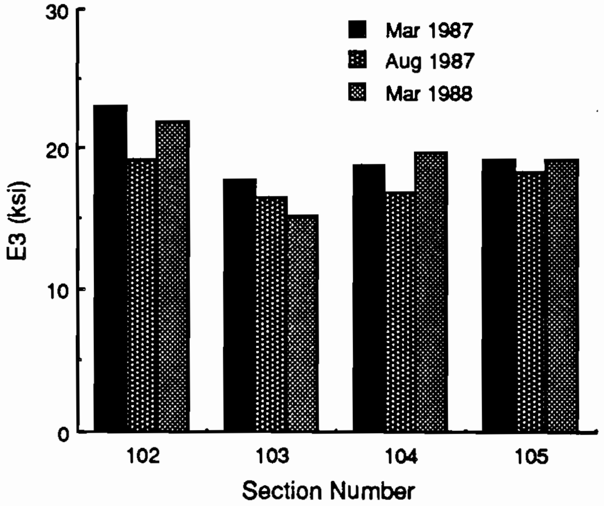


Fig 3.10. Modulus of elasticity of roadbed.

CHAPTER 4. LABORATORY TESTING

This chapter deals with the laboratory tests performed on the cores obtained from the five test sections on IH610 North in Houston. The testing program for this study consists of

(1) direct shear tests,
(2) density tests,
(3) indirect tensile tests,
(4) coefficient of thermal expansion tests, and
(5) petrographic studies.

OVERALL INTENT OF TESTING PROGRAM

The main intent of the testing program was to find properties of the overlay that may have significantly contributed to the debonding of the overlay from the overlaid pavement.

DIRECT SHEAR TEST

The feasibility of the bonded concrete overlay system depends primarily on the shear and tensile strength developed at the interface of the overlay material and the overlaid pavement. If the shear strength and tensile strength are greater than the shear stress and tensile stress at the interface during actual traffic loading, the overlay will remain bonded; otherwise, the bonded concrete overlay fails and the overlay acts like an independent unit. As a result, the system is no longer monolithic and the basic assumption of bonded concrete overlay design is not valid.

Shear Strength Test Apparatus

The shear strength was determined using the direct shear (guillotine) test procedure (Fig 4.1). The test apparatus consists of a flat piece of high strength steel (9 inches x 6 inches x 7/16 inch) welded to a semicircular section of pipe with a diameter of 4 inches and a length of 4 inches. Another steel plate (16 inches x 6 inches x 7/16 inch) was welded to a semicircular section of pipe. Four holes were drilled between the two semicircular sections of pipe and four high strength bolts were used to hold the core. The overlay portion of the core was projected out and another semicircular section of pipe, with a diameter of 4 inches and length of 3 inches, was placed on top of it. The load was applied on the semicircular section of pipe on the overlay with the apparatus clamped to the table of the testing machine by four C-clamps.

Test Procedure

The direct shear test was performed as follows :

(1) The diameter of each core was measured with a surface gage accurate to 0.001 inch. The core diameter was obtained from the average of three measurements at the interface.
(2) The core was held between the two semicircular sections of pipe with the overlay section projecting out.
(3) The load was applied uniformly at a rate of 2 inches per minute.
(4) The loading was automatically plotted on graph paper; the load at failure was obtained and recorded from the plot.
(5) Shear strength was calculated as

$$\tau = P/A \tag{4.1}$$

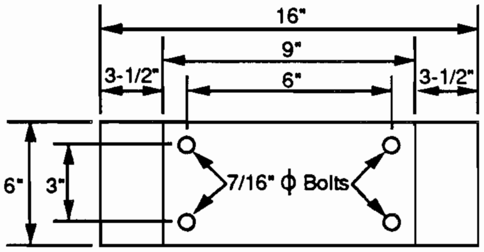
where

τ = shear strength, psi;
P = load at failure, lb; and
A = area of specimen (core), square inch.

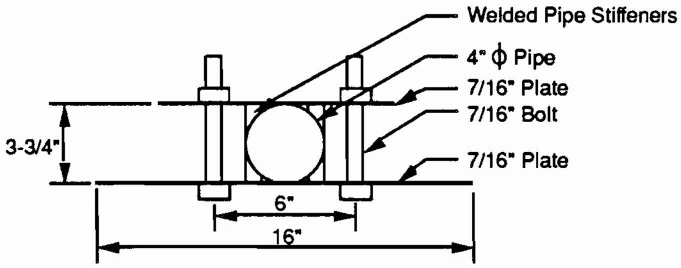
Direct Shear Test Results

The shear strength of the cores obtained from IH610 North in Houston showed significant variability because of the inconsistency of the test procedure. It is very difficult to apply a direct shear load on the specimen at the interface because of the flexibility of the apparatus and because rotation of the specimen occurs . The rotation of the specimen can be caused by

(1) slipping of the specimen, since it does not fit into the holder tightly,
(2) the deflection of the specimen due to the load,



(a) Plan view.



(b) Front view.

Fig 4.1. Direct shear test apparatus.

(3) irregularities of the interface during surface preparation, or
(4) the out-of-straightness of the specimen during coring.

Some of the specimens have very low shear strengths because of honeycombed or cracked overlaid pavement. The average shear strengths of the different types of overlay and pavement conditions are shown in Table 4.1, from which it is obvious that there are no significant differences in shear strength between the different types of overlays or pavement conditions, although the shear strength of the limestone overlay appears to be the highest.

TABLE 4.1. AVERAGE SHEAR STRENGTH OF CORES (PSI)

Pavement Condition	Siliceous River Gravel Aggregate	Limestone Aggregate	Fiber Reinforced
Delaminated [a]	425	-	443
Non-Delaminated	337	464	441

[a] Cores taken near delaminated areas. The cores were not delaminated.

DENSITY TEST

The purpose for running the density test was to determine if the overlays from the delaminated areas have densities that are significantly different from the overlays from the non-delaminated areas. It was speculated that, if the densities of overlays from the delaminated areas are significantly lower than those from the non-delaminated areas, it is possible that the delaminated areas have overlays of poorly consolidated concrete due to inadequate vibration. Consequently, the interface areas are not well bonded and the bond strength is lower.

Test Procedure

The procedure for obtaining the densities, percent voids, and percent absorption of the overlays is as follows:

(1) Dry overlay in oven at 212°F for at least 24 hours until two successive weighing at 68 to 77°F yield a difference in weight of less than 0.5 percent.
(2) Saturate the overlays by immersing them in water for at least 48 hours. Towel dry the specimen and weigh.
(3) Immerse and weigh overlay in water.
(4) Calculate density, percent voids, and percent absorption.

The calculations are as follows:

$$\text{Dry density} = A \,/\, (B-C) * 62.4 \text{ pcf} \qquad (4.2)$$

$$\text{Saturated density} = B \,/\, (B-C) * 62.4 \text{ pcf} \qquad (4.3)$$

$$\text{Apparent specific gravity} = A \,/\, (A-C) \qquad (4.4)$$

$$\%\ \text{Voids} = (B-A) \,/\, (B-C) * 100\% \qquad (4.5)$$

$$\%\ \text{absorption} = (B-A) \,/\, A * 100\% \qquad (4.6)$$

where

A = oven dry weight,
B = weight after 48 hours of immersion in water,
C = weight immersed in water.

Density Test Results

The cores were divided into two main categories:

(1) cores obtained from delaminated areas and
(2) cores obtained from non-delaminated areas.

They are further subdivided according to

(1) aggregate type: siliceous river gravel (SRG) and limestone (LS), and
(2) reinforcement type: welded wire fabric (WWF) and fiber.

The densities, percent voids, and percent absorption are tabulated in Table 4.2. As shown in the table, they are uniform throughout. There are no significant difference in properties.

INDIRECT TENSILE TEST

The indirect tensile test is performed to predict the cracking load of the overlay. This is because it is theorized that the debonding of the bonded concrete overlay starts from cracks and the growth of the delamination depends on the number of cracks. The test was also aimed at studying the variation of tensile strength among the different types of overlays.

TABLE 4.2. AVERAGE DENSITY, PERCENT VOIDS, AND PERCENT ABSORPTION

Pavement Condition	Saturated Density (pcf)	Dry Density (pcf)	Percent Voids	Percent Absorption
Delaminated	151.4	146.0	8.7	3.8
Non-Delaminated	150.7	145.1	8.8	3.9

The method used was the split cylinder tension test. It was performed in accordance with ASTM C496-85. Figures 4.2 and 4.3 show the specimen with the load applied and the failure of the specimen under the compressive load.

Test Apparatus

The test was performed on a loading machine capable of applying a compressive load at a controlled deformation rate, preferably 2 inches per minute, using half-inch-wide curved face loading strips.

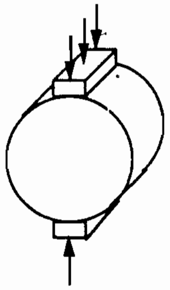


Fig 4.2. Cylindrical specimen with the applied compressive load.

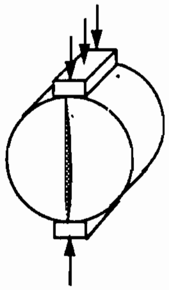


Fig 4.3. Specimen failing under the compressive load.

Test Procedure

The split cylinder tension test was performed as follows:

(1) Measure the length and the 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 loading head down until light contact is made with the core.
(4) Apply load at a rate of two inches per minute.
(5) Determine the maximum load at failure.
(6) Calculate the tensile strength of the overlay as

$$T = 2P/\pi LD \tag{4.7}$$

where

T = splitting tension strength, psi;
P = maximum applied load, lbs;
L = length of specimen, inch; and
D = diameter of the specimen, inch.

Indirect Tensile Test Results

The tensile strengths of the different types of overlay are shown in Table 4.3. There are no significant differences in tensile strength between siliceous river gravel and limestone aggregate overlay. The fiber reinforced overlay has a high tensile strength and, therefore, will have a lower number of cracks.

TABLE 4.3. AVERAGE TENSILE STRENGTH OF CORES (PSI)

Pavement Condition	Siliceous River Gravel	Limestone Aggregate	Fiber Reinforced
Delaminated	798	-	695
Non-Delaminated	793	772	1057

COEFFICIENT OF THERMAL EXPANSION TEST

It is assumed that the overlay will have the same physical properties as the overlaid pavement, but this is not true in many cases because of age and a difference in the materials used. It was initially thought that it was especially important for coefficient of thermal expansion for the overlay and the overlaid pavement to be as close as possible. If the difference is significant, then the two materials will expand and contract differently at the same temperature, which may cause additional cracking and debonding. However, because the overlay, or more correctly the top few inches of the pavement, is subjected to the greatest temperature differential, a lower thermal coefficient in the overlay may be desirable. This would result in more nearly equal movements between the overlay and the existing slab. Therefore, this test was performed to determine if there was a difference in thermal coefficients between the overlay and the overlaid pavement.

Test Apparatus

This test required an environmental chamber capable of controlling temperature in a range from 0 to 150°F.

Test Procedure

The coefficient of thermal expansion of the overlay was measured by mounting strain gages on the surface of the specimen. Each specimens was instrumented with two strain gages and the average reading of the two gage readings was used. Readings were taken at intervals of 40°F from approximately 0 to 140°F. Two complete cycles were performed to check the consistencies of the readings. The strain reading of the overlay was denoted by ε and the strain reading of the reference material, fused quartz, was denoted by ε_r. The coefficient of thermal expansion was calculated by first plotting (ε - ε_r) vs. temperature. The slope of the plot was then added to the coefficient of thermal expansion of the fused quartz to obtain the coefficient of thermal expansion of the overlays.

Coefficient of Thermal Expansion Results

The average values of the thermal coefficient are tabulated in Table 4.4. The thermal coefficient of the limestone overlay is the lowest. However, there is no significant

TABLE 4.4. AVERAGE COEFFICIENT OF THERMAL EXPANSION (INCH/INCH/ F)

Pavement Condition	Siliceous River Gravel Aggregate	Limestone Aggregate	Fiber Reinforced
Delaminated	6.8	-	-
Non-Delaminated	7.1	4.5	7.1
Existing CRC	5.3		

difference between the thermal coefficient for the delaminated areas and non-delaminated areas was siliceous aggregate.

PETROGRAPHIC STUDIES

Twelve field cores were sent to Erlin, Hime Associates, in Austin, for petrographic examinations. The twelve field cores were taken from areas with high and low delamination.

Optical studies made on the new overlay and the overlaid pavement of the field cores showed significant differences in cement, paste, air, and water/cement ratios. The overlaid pavement also showed traces of alkali-silica reaction. The presence of alkali-silica gel is common to old pavements but the presence of unusually "fresh" alkali-silica gel within the newly placed dense overlay may have had an impact on the debonding of the two concrete systems.

There were also reflective cracks in some of the cores. In all the cracks, there was evidence of water passage. In addition, some cores exhibited secondary deposits indicative of water migration along the interface between the overlay and the overlaid pavement. The secondary deposits, of ettringite (a calcium sulfoaluminate) are commonly found in concrete subjected to moist subgrade condition.

The air void system seemed to accommodate the secondary deposits, but when there is gel at the aggregate paste boundaries as well, distress due to the expansive force may occur. This reaction mechanism could have influenced the loss of bond observed in some areas. Moisture entering through joints may also have promoted this reaction.

Basic Concept of Alkali-Silica Reaction

Most chemical durability problems result from a reaction between reactive silica in aggregates and alkalis contained in cement. The alkali-silica gel formed can cause extensive map or pattern cracking, surface popouts, and spalling.

The reaction takes place in four steps:

(1) ***Initial Alkaline Depolymerization and Dissolution of Reactive Silica.*** A high alkalinity environment increases the rate and solubility of amorphous silica.

(2) ***Formation of Hydrous Alkali-Silica Gel.*** The chemical reaction is

$$S + N(K)H = N(K)\text{-}S\text{-}H$$

(3) ***Attraction of Water by Gel.*** The gel can imbibe a considerable amount of water, which is accompanied by volume expansion. This may cause cracks in the aggregates as well as in the cement paste.

(4) ***Formation of Fluid Sol.*** This step takes place after the critical expansion has occurred, when further ingestion of water turns the solid gel into a fluid sol which escapes into surrounding cracks and voids.

It is also known that the expansion of the alkali-silica gel is greatest in concrete with intermediate size particles (0.07 to 0.85 mm).

There are several ways to control the alkali-silica reaction:

(1) control the pH in the pore solution,
(2) control of alkali concentrations by using low-alkali cement,
(3) control of the amount of reactive silica by avoidance of a susceptible aggregate or by controlling the amount and size of the reactive aggregate,
(4) control of moisture, and
(5) alteration of alkali-silica gel.

CHAPTER 5. EVALUATION OF REPAIR TECHNIQUES

Several repair techniques were proposed and most were attempted for the distressed area in the bonded concrete overlay project on IH610 North, in Houston. This chapter discusses and evaluates the repair techniques used.

REPAIR TECHNIQUES

The recommended method of repairing depends upon the type of distress found in the pavement. As traffic control time was involved, cores were extracted whenever possible for evaluating repairs.

The following are the types of distress and the various repair techniques attempted.

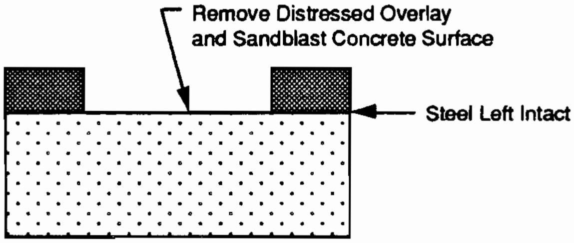
Punchouts

For repairing punchouts, an 80-pound jackhammer was used to remove broken concrete material because a smaller jackhammer, which was used in previous repairs, required too much time. In addition, the distressed overlay section was sawed out. Water was not introduced into the repair area because a dry cutting sawblade was used. Once the distressed area was removed, the base concrete surfaces and the edge faces of the remaining concrete were sandblasted and filled with polymer concrete (Fig 5.1).

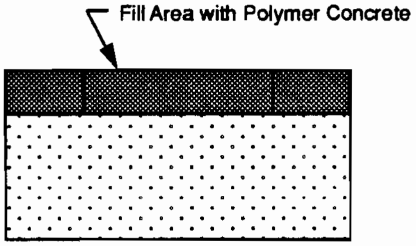
Cracks and Delaminations

The following procedure was used to repair cracks and delaminations :

(1) Where the pavement was fairly level, a scabbler unit was used to rout the cracks in order to provide a reservoir for the mixed monomer. This allowed more time for the monomer to soak deeper into the cracks. The widened cracks were filled with dry sand and resaturated with monomer to finish the repair.



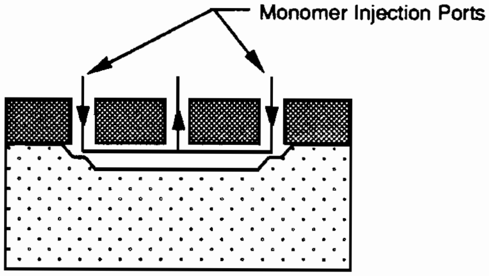
(a) Preparing punchouts in overlay.



(b) Filling punchouts in overlay with polymer concrete.

Fig 5.1. Repairing punchouts.

(2) Cracks with delaminations (Fig 5.2) and cracks running up significant slopes were injected with monomer. In these cases, injection ports were installed every foot along the crack length, and/or, where voids were present, at one-foot intervals along the void perimeter as marked on the previous condition survey. Monomer was pumped from the void perimeter ports to the cracks first, before any monomer was actually injected through a crack port (Fig 5.3).



Note: Crack and Void Size Exaggerated for Clarity

Fig 5.2. Drilling a hole at the edge of the delamination and then injecting monomer until it flows out of the sealed cracks.

Both standard hammer drilling and vacuum bit hammer drilling were used to open the holes in which the ports were installed.

Three variations of pressure injection procedures were compared:

(1) monomer injected into the cracks without any water flushing or compressed air drying;

(2) the cracks and voids were dried with dry compressed air before monomer injection, but no water flushing was attempted; and

(3) the cracks and delaminations were flushed with pressured water, then dry compressed air was used to dry the surfaces before monomer injection.

Similar procedures were used in the delaminated areas. In these areas, a vacuum was applied to some ports and monomer was pulled through the delaminated zone.

In addition, epoxy was injected by a contractor for the purpose of determining its effectiveness and costs.

An alternate method for repairing delaminated sections was developed:

(1) the overlay was sawcut to a depth of approximately 3 inches (just above the reinforcing steel) near the edge of the delaminated zone,

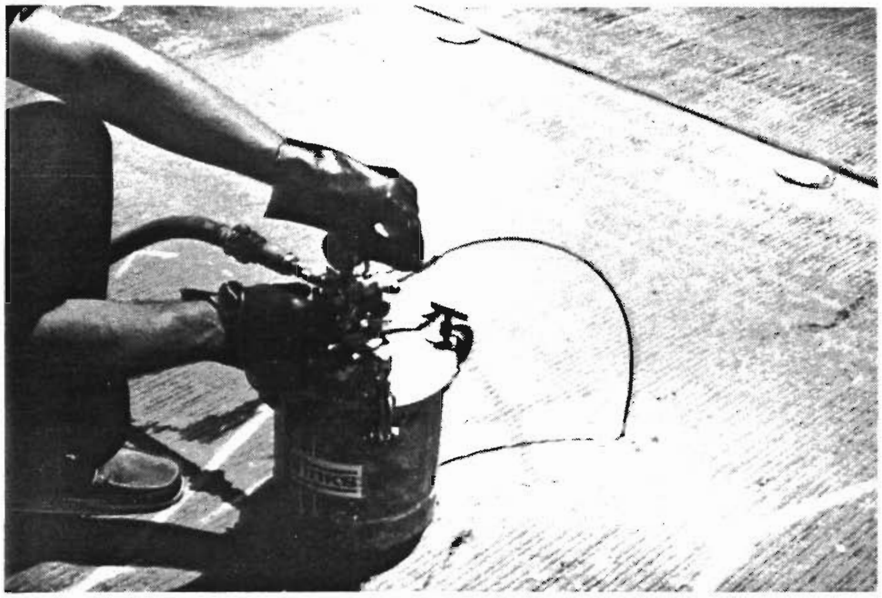
(2) the overlay was then removed using a 30 lb jackhammer, however, the steel was left intact,

(a) Drilling holes for injection ports.

(b) Installation of injection ports.

(Continued)

Fig 5.3. Repair of delaminated concrete by monomer injections.



(c) Injecting monomer into the delaminated area through the ports.

Fig 5.3. (Continued).

(3) the original pavement was thoroughly cleaned, and
(4) the area was filled with polymer concrete.

The progression of activities can be seen in Fig 5.5.

This was more time consuming and required more material but was expected to yield better results than other methods outlined this chapter.

REPAIR RESULTS

The repairs were made and cores were taken during the condition survey on August, 1987. A detailed description of the results is given below.

Punchouts

The repair technique for repairing punchouts worked very well. Adequate bond strengths were achieved because the punchouts were cut and sandblasted to ensure a dry, clean, sound surface for bonding.

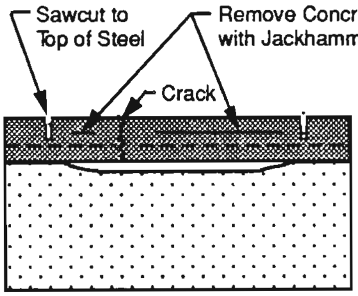


Fig 5.4. Sawing along edge of delamination and removing delamination, then sandblasting and filling with polymer concrete.

Cracks and Delaminations

(1) Most of the monomer used for these repairs did not penetrate the cracks that were not widened by the scabbler because of the hot weather; the pavement expanded and the cracks were sealed too tightly for the monomer to flow into them.
(2) Three variations for repairing cracks and delaminations with pressure injection were attempted, but only one method was successful.

For the second variation, drying the cracks and voids with compressed air, air was forced into the cracks via inlet ports but none flowed out from the outlet port. Apparently, the air was unable to penetrate the tight cracks caused by the expanded pavement. This variation was aborted after a pressure of 100 psi was used without success.

As a result of the failure of the second variation, it was decided to abort variation three (using water under pressure followed by drying with compressed air) since it would be impossible to flush water through the cracks and voids if the attempt with compressed air was unsuccessful.

The first variation (monomer injection without prior flushing with water or air) was attempted with some success. Some monomer managed to get into the cracks and voids and sealed some cracks and re-bonded some of the delaminated areas. However, since visual inspection of the cores indicated that most of the cracks were reflective cracks from the overlaid pavement and many of the cracks and delaminations were coated with silt and debris, the polymer could not bond to the concrete.

It should be noted that delaminated areas adjacent to the cracks bonded very well because of the absence of silt and

(a) Sawcutting the overlay.

(b) Removing the remaining concrete with a jackhammer.

(Continued)

Fig 5.5. Repair with polymer concrete.

(c) Repair area being filled with polymer concrete.

(d) Finishing the surface of the repaired area.

Fig 5.5. (Continued).

debris, and in these areas a shear strength of 412 psi was achieved (Appendix F).

Similarly, epoxy injection did not work very well. The reasons were the same as for pressure injected monomer.

The alternate method in which the delaminated area was cut and sandblasted worked very well. Similar to the method for repairing punchouts, this method provided a clean surface for bonding. A shear strength of 281 psi was obtained (see Appendix F), but the method was time consuming and a large quantity of polymer concrete was required.

EVALUATION OF THE REPAIRS

The repairs were generally unsuccessful. Further research is recommended for studying repairs on the delaminated areas. Future research should concentrate on finding efficient and effective repair techniques. The only successful technique identified in this study was too time consuming and there were insufficient areas repaired to verify the success.

CHAPTER 6. STATISTICAL ANALYSIS

In this chapter, all the results from the statistical analyses performed on the data collected from IH610 North in Houston are discussed. To facilitate management of the data, a database was created using the Excel spreadsheet on the Macintosh. The intent of the statistical analyses was to identify statistically the variables which are significant in affecting the performance of the bonded concrete overlay placed on IH610 North in Houston.

VARIABLES CONSIDERED

The statistical analyses were performed using data obtained from laboratory tests, construction, and the condition surveys. The data were classified according to the different types of aggregate, reinforcements, and bonding agents.

Construction variables considered in the statistical analyses were

1. placement temperature,
2. minimum temperature for the day following placement,
3. maximum temperature for day of placement,
4. average temperature for day of placement,
5. relative humidity for day of placement,
6. wind speed on day of placement, and
7. temperature of concrete.

The variables from the laboratory tests performed on the overlays used in the statistical analyses include

1. saturated density,
2. dry density,
3. percent voids,
4. percent absorption,
5. shear strength,
6. tensile strength,
7. coefficient of thermal expansion,
8. type of reinforcement,
9. type of aggregate,
10. grout or ungrouted condition,
11. lane number, and
12. direction of traffic.

GENERAL LINEAR MODEL (GLM) ANALYSIS

In this analysis, the method of least squares was used to fit general linear models. The analysis of variance was performed using the SAS general linear model procedure. For this analysis, the following model was used:

$$\text{D8887} = \text{REINF} \mid \text{AGG} \mid \text{GROUT} \mid \text{LANE} \mid \text{DIR} \qquad (6.1)$$

where

D8887 = difference between March 1988 and March 1987 delamination,
REINF = type of reinforcement,
AGG = type of aggregate,
GROUT = grout or ungrouted section,
LANE = lane number, and
DIR = lane direction (east or west).

This model was used to find the Type III sum of squares and F values. The five independent variables, reinforcement, aggregate, grout, lane, and direction, were used as classification variables. All possible interactions between the five class variables were considered in the analysis. However, not all interactions were possible because not all the data were available (Table 6.1). The results of the analysis are tabulated in Table 6.2. Conclusions that can be drawn from the analysis are given in Table 6.3.

It was determined that it would be sufficient to use an α-level of 0.05. Among all the interactions considered, only the interaction between grout and direction was significant in March 1987. However, statistically, this result was not reliable because, for the 560 grouted sections, there were only four non-grouted sections. In March 1988, however, the lane-direction interaction was shown to be significant.

Only 30 percent of all possible interactions were actually considered because of the way the experimental section was set up. Consequently, it was difficult to draw strong

TABLE 6.1. AVAILABILITY OF DATA

Reinforcement :		**Welded Wire Fabric**								**Fiber**							
Aggregate :		**Siliceous River Gravel**				**Limestone**				**Siliceous River Gravel**				**Limestone**			
Grout :		Yes		No		Yes		No		Yes		No		Yes		No	
Direction :		**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**
Lane No. :	**1**	✓	✓	x	✓	✓	x	x	x	✓	x	x	x	x	x	x	x
	2	✓	✓	x	✓	✓	x	x	x	✓	x	x	x	x	x	x	x

✓ : Data Available
x : Data Not Available

TABLE 6.2. RESULTS OF GENERAL LINEAR MODEL ANALYSIS

Ind Var	Obs		Class Variables and Interactions										
			Reinf	Agg	Grout	Lane	Dir	Reinf Lane	Agg Lane	Grout Lane	Grout Dir	Lane Dir	Grout Lane Dir
March 87	690	**Levels**	2	2	2	2	2	¥	¥	¥	¥	¥	¥
		Values	F, W	LS, SRG	No, Yes	1, 2	E, W	¥	¥	¥	¥	¥	¥
		Type III SS	144.76	79.79	1.36	0.04	0.67	2.11	1.60	0.01	34.25	1.06	3.43
		F - Value	18.20	10.03	0.17	0.01	0.08	0.27	0.20	0.00	4.31	0.13	0.43
		DF	1	1	1	1	1	1	1	1	1	1	1
August 87	84	**Levels**	2	2	2	2	2	¥	¥	¥	¥	¥	¥
		Values	F, W	LS, SRG	No, Yes	1, 2	E, W	¥	¥	¥	¥	¥	¥
		Type III SS	466.48	265.67	229.64	79.33	273.95	76.75	41.74	68.87	0.00	36.18	0.00
		F - Value	18.60	10.59	9.16	3.16	10.92	3.06	1.66	2.75	¥	1.44	¥
		DF	1	1	1	1	1	1	1	1	0	1	0
March 88	564	**Levels**	2	2	2	2	2	¥	¥	¥	¥	¥	¥
		Values	F, W	LS, SRG	No, Yes	1, 2	E, W	¥	¥	¥	¥	¥	¥
		Type III SS	157.02	83.72	32.44	5.92	467.28	5.59	3.42	7.35	0.00	24.15	0.00
		F - Value	18.08	9.64	3.74	0.68	53.79	0.64	0.39	0.85	¥	2.78	¥
		DF	1	1	1	1	1	1	1	1	0	1	0
Difference 87 - 88	564	**Levels**	2	2	2	2	2	¥	¥	¥	¥	¥	¥
		Values	F, W	LS, SRG	No, Yes	1, 2	E, W	¥	¥	¥	¥	¥	¥
		Type III SS	0.03	0.11	0.31	1.44	0.18	0.26	0.09	1.98	0.00	0.77	0.00
		F - Value	0.01	0.05	0.13	0.60	0.07	0.11	0.04	0.83	¥	0.32	¥
		DF	1	1	1	1	1	1	1	1	0	1	0

conclusions from the results of this analysis. This stresses the need for better design of future experimental sections in order to have all possible interactions.

ACI EVAPORATION RATE ANALYSIS

The ACI evaporation rate is a function of wind speed, relative humidity, air temperature, and concrete temperature. The wind speed and relative humidity were obtained from the National Oceanic and Atmospheric Administration (NOAA) or measured at the Intercontinental Airport in Houston. The concrete temperatures were found in the paving records. The placement time and date were correlated with the NOAA information to obtain the appropriate wind speed and relative humidity at the appropriate three-hour interval.

TABLE 6.3. SUMMARY OF RESULTS FROM THE ANALYSIS OF VARIANCE

	Significance			
Variable	March 1987	August 1987	March 1988	Difference
Reinforcement	Yes	Yes	Yes	No
Aggregate	Yes	Yes	Yes	No
Grout	No	Yes	Yes	No
Lane	No	No	No	No
Direction	No	Yes	Yes	No

The evaporation rate for each 100-foot station was determined using a nomograph (Fig 6.1) and the weather and paving information. Table 6.4 shows the delamination and the associated evaporation rate at each 100-foot interval in Sections 101 to 105, determined during placement of each 100-foot length. From the table, it appears that large delaminated areas were associated with high evaporation rates (greater than 0.15 lb/feet²/hour).

An equation for the evaporation rate was formulated to replace the calculation using the nomograph. Movement between quadrants of the nomograph was facilitated using "dummy" variables and regression analysis. For example, the relationship between air temperature, relative humidity, and a dummy variable, u, was established as

$$\ln(u) = -5.44 + 0.948 * \ln(\text{relative humidity}) + 0.333 * (\text{air temperature}) \qquad (6.2)$$

The variable u was related to a second variable, B, and concrete temperature using

$$u = 0.0002663 * (CT)^{2.2593} - 1.17 * B \qquad (6.3)$$

Finally, the evaporation rate was related to wind velocity and B by

$$ER = [0.012 + 0.00484 * (WS)] * B \qquad (6.4)$$

Substituting and solving for the evaporation rate yields

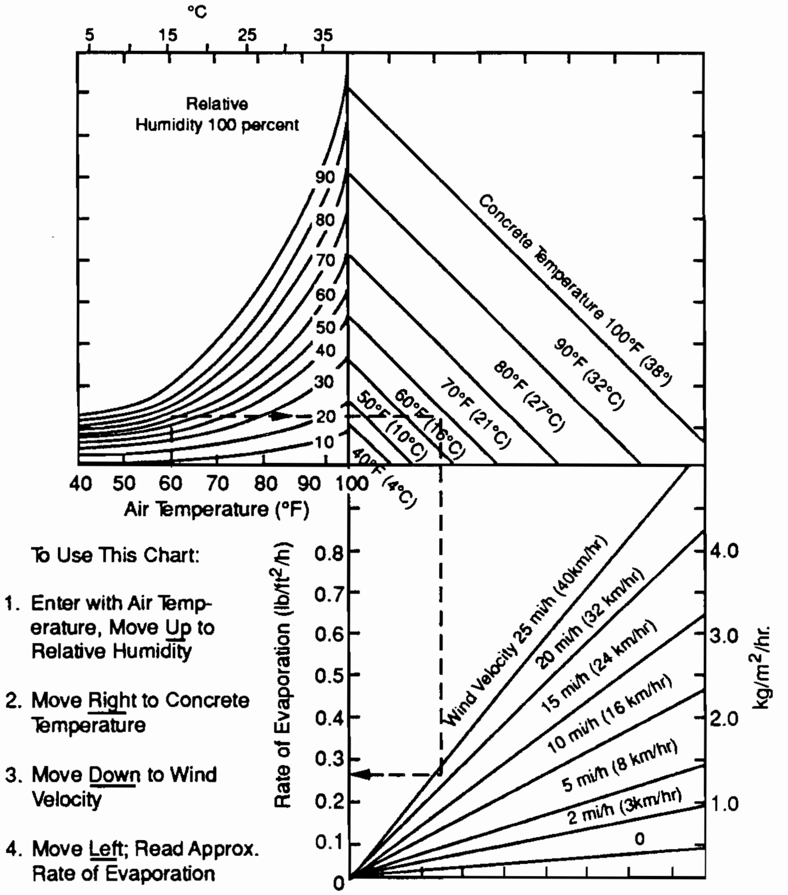
$$ER = [0.012 + 0.00484 * (WS)] * J \qquad (6.5)$$

where

$$J = \{0.000266*(CT)^{2.2593}-\exp[-5.44 + 0.948*\ln(RH)+0.033*(AT)]\}/1.17 \qquad (6.6)$$

and

ER = evaporation rate,
WS = wind speed,
CT = concrete temperature,
RH = relative humidity, and
AT = air temperature.



To Use This Chart:

1. Enter with Air Temperature, Move Up to Relative Humidity
2. Move Right to Concrete Temperature
3. Move Down to Wind Velocity
4. Move Left; Read Approx. Rate of Evaporation

Fig 6.1. Chart to calculate the rate of evaporation of water from freshly placed concrete (from Engineering Bulletin, 11th Ed., Portland Cement Association, Skokie, Illinois, 1968).

DISCRIMINANT ANALYSIS

The basic purpose of the discriminant analysis was to obtain a function of the form

$$y = a_0 + a_1 x_1 + a_2 x_2 + a_3 x_3 + \ldots + a_n x_n \qquad (6.7)$$

where $a_1, a_2, a_3, \ldots, a_n$ are the canonical coefficients for the variables $x_1, x_2, x_3, \ldots, x_n$ respectively, with a_0 being a constant, so that it would be possible to use the same variables to classify future data into one of the two categories DELAMINATED and NOT DELAMINATED.

The variables included in the discriminant analysis were

(1) placement temperature,
(2) minimum temperature for the day following placement,
(3) maximum temperature for day of placement,
(4) average temperature for day of placement,
(5) relative humidity for day of placement,
(6) wind speed on day of placement,
(7) cloud cover,
(8) temperature of concrete placed in the section,
(9) DTMP (variable 3 - variable 2),
(10) DTIME (age of overlay), and
(11) evaporation rate.

Various runs were conducted and the more significant ones are listed in Appendix G.

Sample Calculation For Probability of Misclassification

Figure 6.2 shows the curves for both the non-delaminated and the delaminated groups in Run 6 (Appendix G). Both the groups were not normally distributed and this accounted for the high percentage of misclassification during the discriminate analysis.

Further analysis was performed using a discriminant analysis option to maximize the Mahalonobis distance between groups. The Mahalonobis distance is a measure of the number of observations which are misclassified using the given equation. Table 6.5 summarizes the results of this analysis.

For example, in Run 6, the prior probabilities for the two groups were assumed to be $p_1 = p_2 = 0.5$, i.e., one-half the sample was delaminated, one-half non-delaminated. The sample linear discriminant function $x'\Sigma(x_1 - x_2)$ is

$$\begin{aligned} D = {} & 0.1205x_1 + 0.0357x_2 - 0.1369x_3 + \\ & 0.0045x_5 - 0.1189x_8 + 0.2090x_9 + \\ & 0.1183x_{10} + 24.3853x_{11} - \\ & 3.7846 \end{aligned} \qquad (6.8)$$

Then

$$c = \ln(p_1/p_2) + (\bar{x}_1 + \bar{x}_2)'\Sigma^{-1}(\bar{x}_1 - \bar{x}_2)/2 \qquad (6.9)$$

where

x_1, x_2 = sample means for each group and
Σ^{-1} = the sample pooled covariance matrix.

The probability for each distribution is 50 percent.

The value $(x_1 - x_2)'\Sigma^{-1}(x_1 - x_2)$ is actually the Mahalanobis distance function between two normal multivariate

TABLE 6.4. EVAPORATION RATES AT SECTIONS 101 TO 105

Section	Station	3/87 Delamination (ft^2)	8/87 Delamination (ft^2)	Evaporation Rate (lb/ft^2/hr)
101	352	12	42	0.17
	351	25	192	0.18
	350	43	252	0.18
	349	0	72	0.19
	348	25	116	0.18
	347	0	29	0.17
	346	8	52	0.15
	345	43	100	0.14
	344	118	150	0.12
	343	0	26	0.12
	342	0	0	0.12
102	256	0	0	0.04
	255	0	0	0.05
	254	35	39	0.06
	253	0	2	0.06
	252	0	0	0.06
	251	0	0	0.06
	250	0	5	0.07
	249	0	0	0.07
103	282	0	0	0.13
	283	23	23	0.15
	284	0	0	0.13
	285	0	0	0.13
	286	0	0	0.15
	287	0	0	0.13
	288	0	0	0.13
	289	0	0	0.02
	290	0	0	0.02
	291	0	0	0.05
	292	0	0	0.07
104	310	7	0	0.11
	311	4	7	0.11
	312	0	5	0.13
	313	0	0	0.13
	314	0	0	0.14
	315	11	13	0.14
	316	15	28	0.14
	317	0	0	0.15
	318	0	0	0.14
	319	0	0	0.13
	320	0	0	0.13
105	356	316	316	0.16
	357	366	433	0.15
	358	207	257	0.15
	359	48	87	0.14
	360	144	167	0.14
	361	332	367	0.15
	362	351	362	0.17

distributions represented by Δ^2. For Run 6, Δ^2 was 0.8090. Therefore,

$$c = \ln(0.5/0.5) + 0.5 * 0.8090 = 0.4045 \quad (6.10)$$

where

c = the point of overlap of the two distributions.

Hence, for the delaminated areas (z = -0.2, Area = 0.4207) 42 percent of its area is under the non-delaminated curve. Also (z = 0.6183, Area = 0.7257) 27 percent of the non-delaminated area lies under the delaminated curve. Therefore, the probability of misclassification = 0.5 * (0.42) + 0.5 * (0.27) = 0.345 or 35 percent.

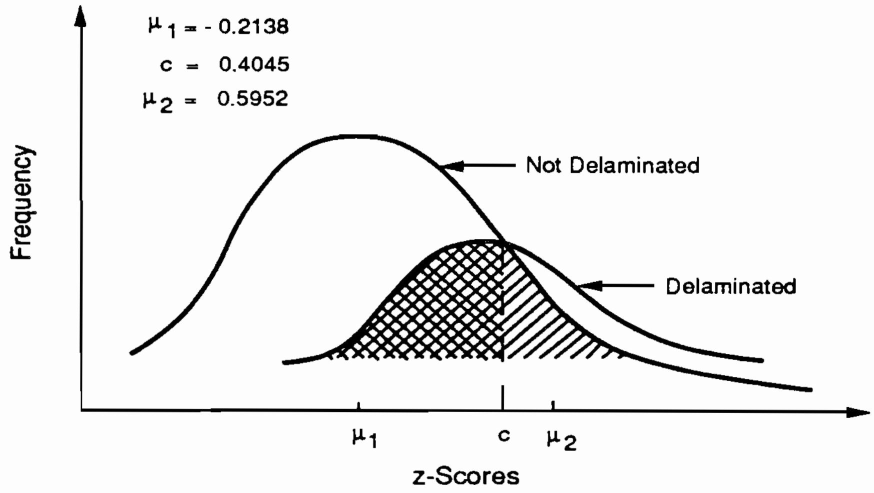


Fig 6.2. Curves showing the probability of misclassification in Run 6 (Appendix G).

Discussion of Results

From the analysis, it can be concluded that the data set cannot be classified into one of the two categories, delaminated and non-delaminated, with the variables used. This conclusion was drawn because the percentage of correct classifications (which ranges from 69 to 74 percent) was too low to be statistically reliable.

MOVING AVERAGE OF DELAMINATION

A three-point moving average of percent delamination was calculated by averaging the percent delamination for three consecutive 100-foot stations. Simply stated, the three point moving average of percent delamination for a particular 100-foot section is the delamination averaged over the previous 100-foot section, the section itself, and the next 100-foot section. Figures 6.3 and 6.4 show the number of stations from the start of the survey versus the percent delamination. Also shown are the shaded boxes which indicate the increase or decrease in delamination as determined with a 95 percent confidence level (greater than 0.7 percent change).

Examination of these plots shows that there are approximately as many decreases in delamination as increases between March 1987 and March 1988. Obviously the areas showing a statistically significant decrease in debonding have not rebonded. The "decrease" merely indicates the variability associated with the sounding and recording techniques.

Also, the area between Yale Blvd. and North Main has a substantially higher percent delamination compared to

TABLE 6.5. MAHALONOBIS DISTANCE ANALYSIS

Variable	Run 1	Run 2	Run 3
Placement Temperature	0.071	0.0715	0.1304
Minimum Temperature	-	-	-
Maximum Temperature	-	-	-01101
Average Temperature	-	-	-
Relative Humidity	-	0.0157	-
Wind Speed	-0.1893	-0.2615	-0.0770
Cloud Cover	0.1864	0.1816	0.1626
Concrete Temperature	-0.1089	-0.0739	-0.1107
DTMP	-	-	-
DTIME	-	0.0777	0.0803
Road Time	-	-	*
Evaporation Rate	-	23.4681	-
T (days)	0.0081	0.0085	0.0053
18 kip, ESAL	-	-	-
Log (DTMP)	-	*	-04.885
Log (Evaporation Rate)	22.1624	*	15.9337
Constant	-2.6303	-6.2856	3.8626

Method Used: Maximize Mahalonobis Distances between Groups (Stepwise)

Prior Probability	Proportional	Proportional	Proportional
Mean Value			
Non-Delaminated	-0.3076	-0.2964	-0.2698
Function Delaminated	0.8495	0.7896	0.6989
Percent Correctly			
Non-Delaminated	79.70%	76.50%	88.30%
Classified Delaminated	51.40%	51.40%	38.90%
Total Corectly Classified	71.68%	69.42%	74.27%

* Variable was not used in analysis.

\- Not Significant

adjacent areas. This is true of the east and westbound sides. Environment conditions were different during placement for the two sides. Other areas surveyed had evaporation rates and differential temperatures that were similar to those on the eastbound lanes between Yale and North Main, yet these did not exhibit the high degree of debonding. It is thought that the degree of distress in the existing CRC pavement contributes to the success of the bonded overlay. Although cirming records could not be located, the area between Yale and North Main may have had a high degree of distress before the overlay was placed.

ANALYSIS OF DATA FROM LABORATORY TESTS

Cores were taken from intact and delaminated regions on the North Loop. Laboratory tests were conducted on intact cores to determine if a correlation existed between measurable physical properites and interface shear strength. As shown in Figs 6.3 - 6.9, no correlation could be found between shear strength and saturated or dry density, percent voids, percent absorption, or tensile strength.

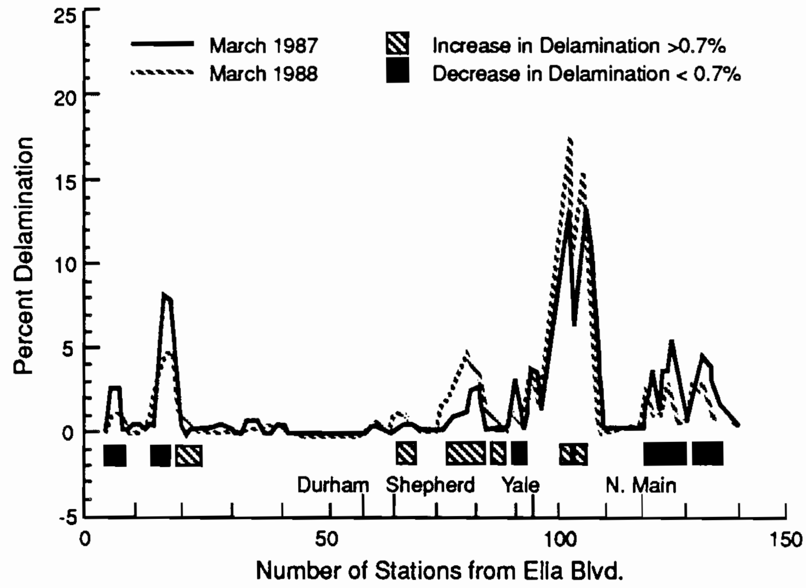


Fig 6.3. Three-point moving average of delamination.

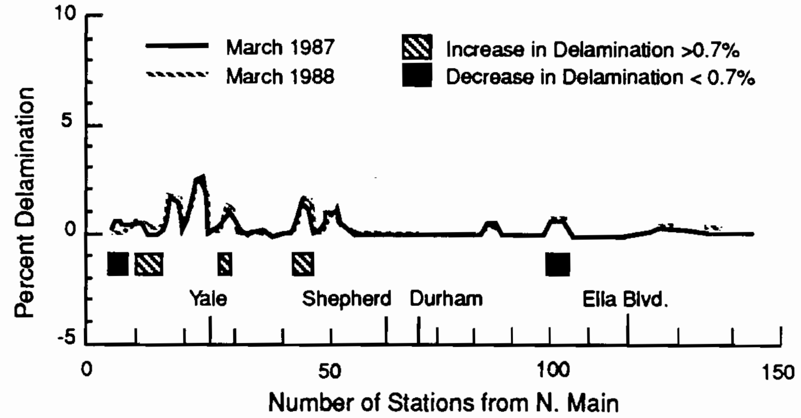


Fig 6.4. Three-point moving average of percent delamination (westbound both lanes).

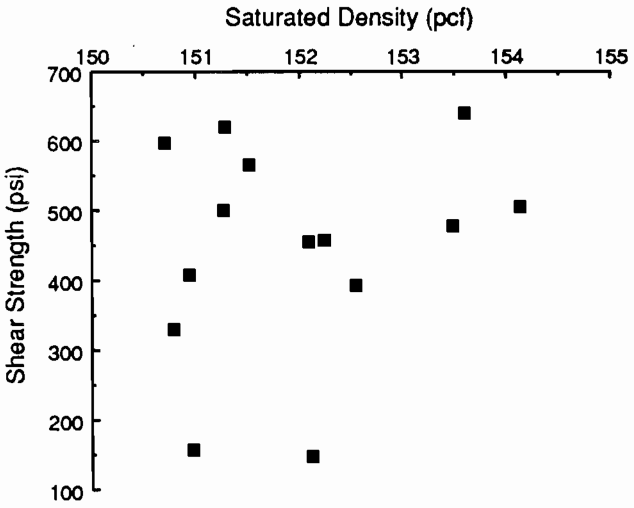


Fig.6.5. Shear strength vs saturated density.

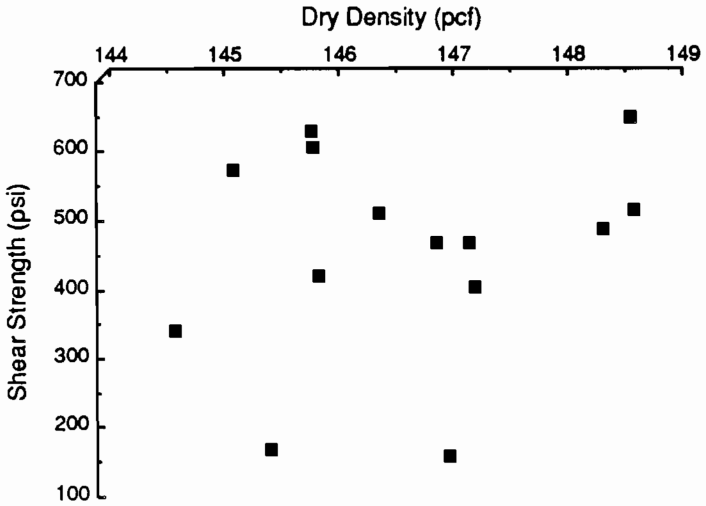


Fig 6.6. Shear strength vs dry density.

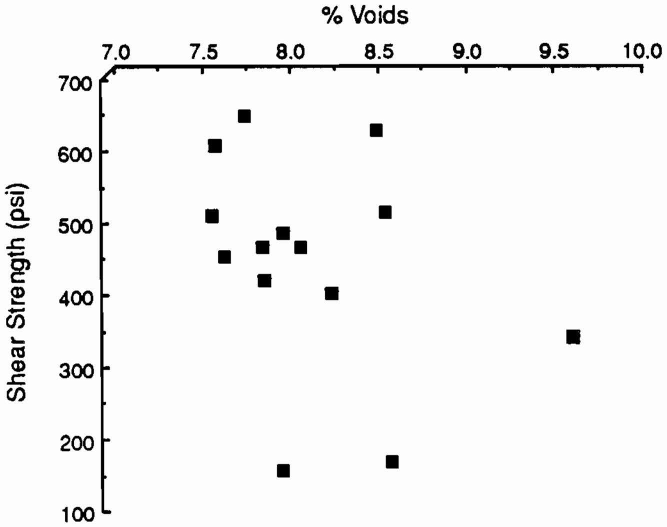


Fig 6.7. Shear strength vs percent voids.

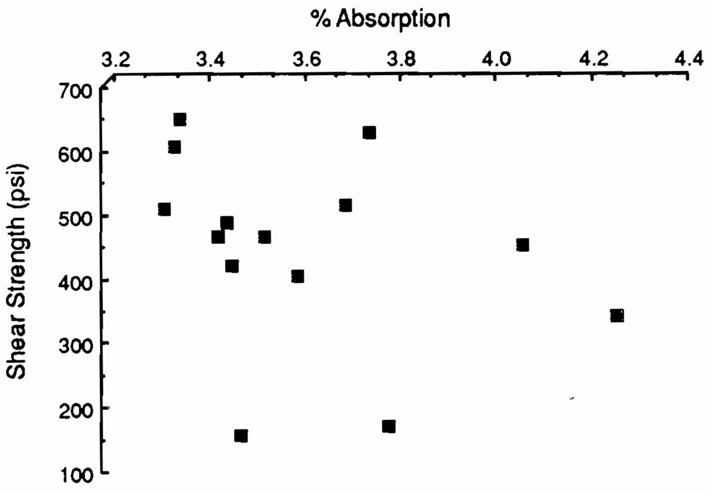


Fig 6.8. Shear strength vs percent absorption.

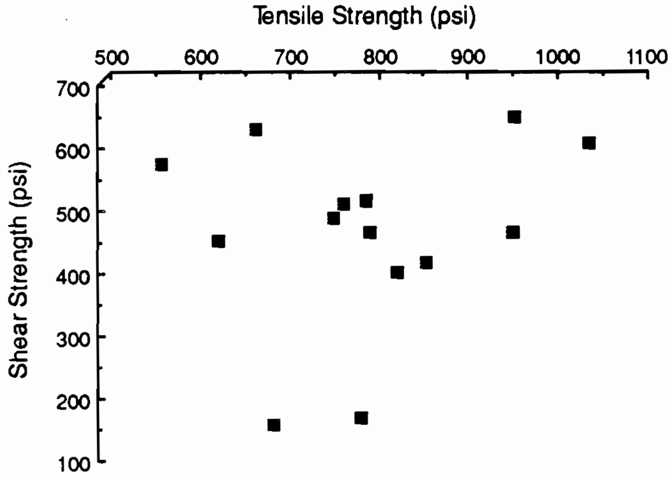


Fig 6.9. Shear strength vs tensile strength.

CHAPTER 7. GENERAL CONCLUSIONS AND RECOMMENDATIONS

In this chapter, the principal results reported throughout the study are assembled and organized for conciseness. Conclusions stemming from the study are presented first, followed by recommendations for this project and future research in the use of bonded concrete overlays. A brief comparison with the research findings of Project 357 is also given.

CONCLUSIONS

This study warrants the following conclusions :

(1) The bonded concrete overlays generally performed well and, with some additional modifications, represent a viable pavement rehabilitation alternative.

(2) The evaporation rate played an important role in determining the delamination of the overlay. The delaminated areas were found to be constructed when the evaporation rate was high (0.15 to 0.20 lb/feet^2/hour). Since the evaporation rate is a function of the wind speed, relative humidity, and air temperature, future construction of bonded concrete overlays should monitor these variables closely.

(3) Steel fibers resulted in reduced cracking of the overlay, as compared to overlays reinforced with welded wire fabric.

(4) Delaminations occurred at areas where the the difference between the temperature at the time of pour and the lowest temperature for the next day was greater than 25°F.

(5) The Dynaflect deflections were affected by the interaction of survey date, weather condition, and the lane number. During the warmer months, the deflections measured were higher, as compared to deflections measured during the cooler months.

(6) Grouting with a cement grout gave a higher bond strength than ungrouted section for the bonded concrete overlays. Furthermore, areas where no grout was used produced a higher percentage of delamination.

(7) During coring reflective cracking was not prevalent. However, where it occurred, silt and debris infiltrated the cracks. The repair of delamination at areas where reflective cracking occurred was difficult because the polymer and epoxy could not develop adequate bond to the concrete because of the silt and debris.

(8) There was no correlation between the density, split tensile strength, and coefficient of thermal expansion with the shear strength of the overlays; however it was found that overlays with limestone aggregates had the lowest coefficient of thermal expansion.

(9) The successful repair techniques were (a) the monomer injection without prior flushing with water or compressed air and (b) the method in which the overlay was sawcut and removed, sandblasted, and then the area was filled with polymer concrete. the long term success of these techniques has not been verified.

(10) Operator variance was the single most important source of error in the three condition surveys done on the IH 610 project.

(11) The results from shear tests used in this study cannot be easily reproduced because of the difficulty explained in Chapter 4.

(12) The degree of delamination varied according to the time of year in which the survey was done. In this study, the delamination was higher in August than in March. This difference is not due to a rebonding of the overlay, but to differences in environmental conditions at the time of the surveys.

(13) Based on successive surveys in March 1987 and March 1988, the total percent delamination is not increasing. No statistically significant increases were found in the limestone, welded-wire, siliceous, welded-wire, or siliceous, fiber overlays. Only the no-grout test sections had a significant increase in debonding.

RECOMMENDATIONS

From the conclusions drawn above, the following are recommended :

(1) The evaporation rate during construction should be limited to less than 0.20 lb/feet^2/hour. Construction should be done when the concrete temperature is low or, as an alternative, ice can also be used to reduce the concrete temperature.

(2) To reduce evaporation, use curing blankets such as plastic sheeting, waterproof paper, and cotton matting. The normal double application of sprayable curing compound should still be used to reduce moisture loss while the concrete sets. Fogging as used when placing bridge overlays could also be used. Protection for 24 to 48 hours would be adequate, although 48 hours would be preferable.

(3) The maximum allowable temperature difference between placement and the minimum expected for the following day should be 25°F. When a forecast indicates that this is likely to be more, concrete placement should not be allowed or should be stopped early to avoid the heat of the day unless curing blankets are used.

(4) Cold milling should be used to prepare the surface prior to placing the overlay. Additional testing should be undertaken to determine the level of texture required for successful overlay placement.

(5) Use of steel fibers over welded wire fabric as the primary reinforcement is recommended because steel fibers offer better control of transverse and longitudinal crackings. However, welded wire fabric may perform better when the overlay is required to bridge reflective cracks.

(6) Limestone coarse aggregate should be used because (a) it has a lower silica content, as compared to siliceous river gravel, and (b) it has a lower coefficient of thermal expansion. The lower silica content helps to reduce the possibility of an alkali-silica reaction.

(7) The alkali reactivity of the portland cement should be less than 0.6 when tested by ASTMC-164 (modified). This reduces the likelihood of introducing alkali which would react with the silica present in the overlaid pavement to form alkali-silica gel.

(8) Cement grout is an adequate bonding agent and should consist of one bag of portland cement and 11 gallons of water.

(9) In order to eliminate water infiltration into the cracks, they should be repaired with monomer. This would also reduce the water required for alkali-silica reaction.

(10) A new test method for determining the shear strength of the overlay cores should be developed. The tension bond test should be investigated as a primary evaluation method. The ASTM 503 Pullout test should be included in the investigation with additional study directed toward the use of a 4-inch diameter, rather than the specified 2-inch specimen.

(11) A study of the repair techniques for the delaminations should be conducted as no viable techniques were found in this study.

(12) Future condition surveys should be conducted in the same season so as to eliminate the variability of results due to seasonal effects.

(13) The ARAN should also be used in future surveys as it minimizes the facility closure time.

COMPARISON WITH THE RECOMMENDATIONS MADE IN PROJECT 357

The conclusions regarding the viability of bonded concrete overlay as a rehabilitation alternative made in this study reinforces the conclusions made in Project 357. There were no significant differences in the recommendations made in the two studies.

Both the studies recommended

(1) the use of water-cement grout as a bonding agent and

(2) the superiority of fiber-reinforced concrete in controlling transverse and longitudinal cracks.

REFERENCES

1. "Innovative Highways : A New Era Begins," *Transportation Research News*, No. 113, Transportation Research Board, July-August 1984.
2. Bergren, V. Jerry, "Bonded Portland Cement Concrete Resurfacing," Division of Highways, Iowa Department of Transportation, Ames, Iowa.
3. Furr, Howard, and Leonard Ingram, "Concrete Overlays for Bridge Deck Repair," Highway Research Record, Highway Research Board, Washington, D. C.
4. Koesno, Koestomo, and B. Frank McCullough, "Evaluation of Thin Bonded Concrete Overlay in Houston," Research Report 920-2, Center for Transportation Research, The University of Texas at Austin, December 1987.
5. Uddin, Waheed, Victor Torres-Verdin, W. Ronald Hudson, Alvin H. Meyer, B. Frank McCullough, and Richard B. Rogers, "Dynaflect Testing for Rigid Pavement Evaluation," Research Report 256-6, Center for Transportation Research, The University of Texas at Austin, October 1983.
6. Kailasanathan, Kandiah, B. Frank McCullough, and D. W. Fowler, " A Study of the Effects of Interface Condition on Thin Bonded PCC Overlays," Research Report 357-1, Center for Transportation Research, The University of Texas at Austin, December 1984.
7. Bagate, Moussa, B. Frank McCullough, David W. Fowler, and M. Muthu, "An Experimental Thin-Bonded Concrete Overlay Pavement," Research Report 357-2, Center for Transportation Research, The University of Texas at Austin, November 1985.
8. Uddin, Waheed, Alvin H. Meyer, and W. Ronald Hudson, "A User's Guide for Pavement Evaluation Programs RPEDD1 and FFPEDD1," Research Report 387-12, Center for Transportation Research, The University of Texas at Austin, July 1985.
9. SAS Institute Inc., "User's Guide : Basics, Version 5 Edition" Cary, NC : SAS Institute Inc., 1985.
10. SAS Institute Inc., "User's Guide : Statistics, Version 5 Edition" Cary, NC : SAS Institute Inc., 1985.

APPENDIX A. LOCATION OF THE FIVE EXPERIMENTAL SECTIONS

TABLE A.1. LOCATION OF THE FIVE EXPERIMENTAL SECTIONS

Section	Direction	Start	End
101	West Bound	352+00	342+00
102	West Bound	255+00	249+00
103	East Bound	282+00	292+00
104	East Bound	310+00	320+00
105	East Bound	356+00	362+00

TABLE A.2. LOCATION OF DIFFERENT PAVEMENT TREATMENTS

Treatment	Direction	Start	End	Length (ft)
Fiber Reinforced	East Bound	276+00	298+74.11	2274.11
Limestone Aggregate	East Bound	316+00	326+00	1000.0
Ungrouted Section	East Bound	215+00	217+00	200.0
Ungrouted Section	West Bound	349+50	351+50	200.0

APPENDIX B. CONDITION SURVEY DATA

TABLE B.1. CRACK COUNT PER STATION

			March 1987		March 1988	
Station	Section #	Direction	Lane 1	Lane 2	Lane 1	Lane 2
245+16 - 246		E	9	7	0	0
246 - 247		E	11	18	14	8
247 - 248		E	32	40	20	16
248 - 249		E	31	29	6	11
249 - 250		E	20	21	2	13
250 - 251		E	16	30	36	33
251 - 252		E	33	16	30	38
252 - 253		E	27	29	30	36
253 - 254		E	31	29	36	26
254 - 255		E	29	20	42	34
255 - 256		E	40	26	51	20
256 - 257		E	22	36	45	24
257 - 258		E	17	32	57	25
258 - 259		E	33	19	37	29
259 - 260		E	38	34	40	24
260 - 261		E	31	21	19	12
261 - 262		E	33	28	0	0
262 - 263		E	11	4	49	6
263 - 264		E	34	22	45	6
264 - 265		E	34	40	69	33
265 - 266		E	34	33	52	22
266 - 267		E	39	38	39	33
267 - 268		E	42	39	33	33
268 - 269		E	39	40	27	32
269 - 270		E	38	28	36	30
270 - 271		E	34	34	35	32
271 - 272		E	39	42	30	25
272 - 273		E	47	40	46	33
273 - 274		E	42	32	34	36
274 - 275		E	48	40	39	33

(continued)

TABLE B.1. (CONTINUED)

Station	Section #	Direction	March 1987		March 1988	
			Lane 1	Lane 2	Lane 1	Lane 2
275 - 276		E	50	44	51	46
276 - 277		E	17	13	20	17
277 - 278		E	7	4	8	3
278 - 279		E	16	10	11	8
279 - 280		E	5	2	8	6
280 - 281		E	8	13	0	0
281 - 282		E	14	15	10	13
282 - 283	103	E	19	18	8	8
283 - 284	103	E	17	23	12	13
284 - 285	103	E	12	24	9	15
285 - 286	103	E	10	7	9	7
286 - 287	103	E	4	4	5	7
287 - 288	103	E	4	3	6	5
288 - 289	103	E	2	2	0	2
289 - 290	103	E	4	2	1	6
290 - 291	103	E	3	3	2	11
291 - 292	103	E	10	11	7	0
292 - 293		E	11	13	10	7
293 - 294		E	8	4	4	2
294 - 295		E	2	2	4	1
295 - 296		E	12	9	5	10
296 - 297		E	13	5	2	8
297 - 298		E	0	1	1	12
305 - 306		E	3	3	2	4
306 - 307		E	6	8	10	33
307 - 308		E	16	13	20	31
308 - 309		E	28	25	29	30
309 - 310		E	19	22	31	20
310 - 311	104	E	29	29	28	15

(continued)

TABLE B.1. (CONTINUED)

			March 1987		March 1988	
Station	Section #	Direction	Lane 1	Lane 2	Lane 1	Lane 2
311 - 312	104	E	22	29	4	24
312 - 313	104	E	37	43	23	20
314 - 315	104	E	23	29	23	22
315 - 316	104	E	5	25	6	13
316 - 317	104	E	0	3	6	7
317 - 318	104	E	2	2	4	9
318 - 319	104	E	4	2	1	4
319 - 320	104	E	1	3	6	14
320 - 321		E	7	3	3	3
321 - 322		E	7	6	4	4
322 - 323		E	2	1	0	6
323 - 324		E	3	1	1	11
324 - 325		E	3	5	2	5
325 - 326		E	24	22	16	26
326 - 327		E	12	19	12	25
327 - 328		E	11	18	13	36
328 - 329		E	9	22	12	26
329 - 330		E	7	21	7	12
330 - 331		E	30	34	19	33
331 - 332		E	21	30	6	33
332 - 333		E	17	17	12	8
333 - 334		E	11	9	5	2
334 - 335		E	22	12	2	8
335 - 336		E	7	7	4	1
336 - 337		E	18	16	0	12
337 - 338		E	14	4	0	9
340+18 - 341		E	14	8	1	9
341 - 342		E	16	14	6	28
342 - 343		E	5	12	12	23

(continued)

TABLE B.1. (CONTINUED)

			March 1987		March 1988	
Station	Section #	Direction	Lane 1	Lane 2	Lane 1	Lane 2
343 - 344		E	8	7	18	12
344 - 345		E	8	9	45	18
345 - 346		E	14	5	11	14
346 - 347		E	19	1	11	6
347 - 348		E	19	12	32	13
348 - 349		E	15	15	19	16
349 - 350		E	9	16	16	16
350 - 351		E	19	12	14	15
351 - 352		E	21	21	25	22
352 - 353		E	12	20	22	18
353 - 354		E	15	13	16	17
354 - 355		E	20	14	15	25
355 - 356		E	24	17	23	17
356 - 357	105	E	22	20	15	22
357 - 358	105	E	18	17	11	18
358 - 359	105	E	24	1	13	12
359 - 360	105	E	21	23	18	14
360 - 361	105	E	24	28	9	6
361 - 362	105	E	10	16	3	2
362 - 363		E	11	14	1	3
363 - 364		E	0	0	1	6
365+21 - 366		E	9	9	4	8
366 - 367		E	18	6	6	8
367 - 368		E	26	29	21	15
368 - 369		E	28	26	18	24
369 - 370		E	23	21	31	36
370 - 371		E	19	21	21	40
371 - 372		E	11	15	41	39
372 - 373		E	16	15	36	27

(continued)

TABLE B.1. (CONTINUED)

			March 1987		March 1988	
Station	Section #	Direction	Lane 1	Lane 2	Lane 1	Lane 2
373 - 374		E	6	5	37	30
374 - 375		E	29	28	27	22
375 - 376		E	31	28	26	30
376 - 377		E	18	24	17	32
377 - 378		E	56	48	26	28
378 - 379		E	36	37	26	31
379 - 380		E	43	39	25	35
380 - 381		E	41	31	27	31
381 - 382		E	38	42	24	17
382 - 383		E	35	37	20	6
383 - 384		E	30	32	21	12
384 - 385		E	47	35	32	21
385 - 386		E	11	14	24	20
386 - 387		E	33	32	13	19
387 - 388		E	13	19	19	12
388 - 389		E	29	31	5	4
389 - 390		E	25	34	2	0
390 - 391		E	10	11	0	0
391 - 391+89		E	36	34	0	0
391+88.74		W	0	0	0	0
391 - 390		W	1	1	30	30
390 - 389		W	6	7	29	30
389 - 388		W	7	10	37	34
388 - 387		W	12	18	31	36
387 - 386		W	29	20	37	32
386 - 385		W	27	28	31	47
385 - 384		W	18	19	32	34
384 - 383		W	29	31	36	32
383 - 382		W	30	39	34	46

(continued)

TABLE B.1. (CONTINUED)

			March 1987		March 1988	
Station	Section #	Direction	Lane 1	Lane 2	Lane 1	Lane 2
382 - 381		W	25	30	38	38
381 - 380		W	26	39	40	40
380 - 379		W	21	29	35	25
379 - 378		W	12	18	38	41
378 - 377		W	12	24	35	50
377 - 376		W	14	12	34	49
376 - 375		W	18	19	36	44
375 - 374		W	23	22	45	41
374 - 373		W	18	21	46	49
373 - 372		W	19	19	38	37
372 - 371		W	28	26	18	2
371 - 370		W	35	38	1	0
370 - 369		W	19	21	4	15
369 - 368		W	18	30	26	20
368 - 367		W	30	28	23	30
367 - 366		W	42	34	30	34
366 - 365		W	16	20	23	30
363 - 362		W	0	0	24	25
362 - 361		W	2	0	32	50
361 - 360		W	2	7	23	37
360 - 359		W	22	22	25	41
359 - 358		W	16	22	25	39
358 - 357		W	6	20	27	35
357 - 356		W	21	21	38	44
356 - 355		W	8	21	21	29
355 - 354		W	5	9	25	31
354 - 353		W	6	3	23	22
353 - 352		W	7	9	31	36
352 - 351	101	W	25	29	34	34

(continued)

TABLE B.1. (CONTINUED)

			March 1987		March 1988	
Station	Section #	Direction	Lane 1	Lane 2	Lane 1	Lane 2
351 - 350	101	W	22	21	38	32
350 - 349	101	W	9	15	32	33
349 - 348	101	W	20	26	28	33
348 - 347	101	W	24	23	31	38
347 - 346	101	W	31	21	26	25
346 - 345	101	W	25	23	17	17
345 - 344	101	W	32	35	19	4
344 - 343	101	W	27	33	30	18
342 - 341		W	15	18	30	30
341 - 340		W	4	2	24	25
338 - 337		W	2	2	17	19
337 - 336		W	10	6	2	16
336 - 335		W	4	6	6	9
335 - 334		W	24	20	3	1
334 - 333		W	22	21	3	0
333 - 332		W	38	15	0	1
332 - 331		W	29	35	0	1
331 - 330		W	34	33	0	0
330 - 329		W	26	33	0	4
329 - 328		W	26	29	19	15
328 - 327		W	30	16	38	0
327 - 326		W	39	20	42	20
326 - 325		W	50	43	41	6
325 - 324		W	24	21	24	8
324 - 323		W	22	29	21	9
323 - 322		W	22	17	11	5
322 - 321		W	31	34	7	8
321 - 320		W	37	47	30	26
320 - 319		W	52	54	34	33

(continued)

TABLE B.1. (CONTINUED)

			March 1987		March 1988	
Station	Section #	Direction	Lane 1	Lane 2	Lane 1	Lane 2
319 - 318		W	37	38	39	43
318 - 317		W	37	31	46	39
317 - 316		W	33	32	48	36
316 - 315		W	33	27	53	52
315 - 314		W	16	17	47	40
314 - 313		W	18	18	28	11
313 - 312		W	14	14	27	12
312 - 311		W	19	21	22	11
311 - 310		W	27	29	11	3
310 - 309		W	24	23	14	2
309 - 308		W	15	15	7	0
308 - 307		W	8	10	5	2
307 - 306		W	5	6	3	2
306 - 305		W	9	10	14	4
298+74 - 298		W	4	1	23	20
298 - 297		W	6	2	29	19
297 - 296		W	30	19	22	16
296 - 295		W	30	35	23	11
295 - 294		W	25	32	17	15
294 - 293		W	30	22	12	20
293 - 292		W	13	2	26	10
292 - 291		W	14	12	21	7
291 - 290		W	24	16	23	13
290 - 289		W	11	2	47	22
289 - 288		W	7	8	31	19
288 - 287		W	12	10	39	27
287 - 286		W	6	5	22	19
286 - 285		W	17	11	23	8
285 - 284		W	14	9	14	12

(continued)

TABLE B.1. (CONTINUED)

			March 1987		March 1988	
Station	Section #	Direction	Lane 1	Lane 2	Lane 1	Lane 2
284 - 283		W	15	12	18	29
283 - 282		W	14	10	9	13
282 - 281		W	14	10	16	7
281 - 280		W	25	20	9	10
280 - 279		W	15	12	7	5
279 - 278		W	6	5	4	9
278 - 277		W	9	10	5	8
277 - 276		W	9	17	1	3
276 - 275		W	7	12	0	1
275 - 274		W	6	10	0	0
274 - 273		W	11	9	4	4
273 - 272		W	18	11	15	12
272 - 271		W	27	15	25	23
271 - 270		W	28	27	39	33
270 - 269		W	46	42	34	21
269 - 268		W	75	59	25	15
268 - 267		W	60	48	14	19
267 - 266		W	50	43	16	16
266 - 265		W	51	44	28	22
265 - 264		W	52	39	31	23
264 - 263		W	35	22	36	31
263 - 262		W	19	10	20	19
262 - 261		W	12	4	23	29
261 - 260		W	29	19	41	8
260 - 259		W	18	15	28	16
259 - 258		W	36	25	26	9
258 - 257		W	83	63	24	13
257 - 256		W	47	41	15	7
256 - 255		W	24	16	22	8

(continued)

TABLE B.1. (CONTINUED)

			March 1987		March 1988	
Station	Section #	Direction	Lane 1	Lane 2	Lane 1	Lane 2
255 - 254	102	W	35	38	5	0
254 - 253	102	W	35	34	8	4
253 - 252	102	W	54	47	19	4
252 - 251	102	W	36	32	27	18
251 - 250	102	W	31	23	11	8
250 - 249	102	W	41	29	5	9
249 - 248		W	18	12	9	6
248 - 247		W	5	2	17	12
247 - 246		W	13	1	27	16
246 - 245		W	16	5	25	10
243 - 242		W	8	3	15	17
242 - 241		W	29	27	14	5
241 - 240		W	29	21	8	2
240 - 239		W	47	32	3	0

TABLE B.2. PERCENT DELAMINATION PER STATION

Station	Sec #	Dir	Lane	3/87	8/87	3/88	3/88-3/87	Increase ?	Reinf	Agg	Grt
392-391		W	1	0.0		NA		-	Wire	SRG	YES
391-390		W	1	0.0		NA		-	Wire	SRG	YES
390-389		W	1	0.0		NA		-	Wire	SRG	YES
389-388		W	1	0.0		NA		-	Wire	SRG	YES
388-387		W	1	0.0		NA		-	Wire	SRG	YES
387-386		W	1	0.0		NA		-	Wire	SRG	YES
386-385		W	1	0.0		NA		-	Wire	SRG	YES
385-384		W	1	0.0		NA		-	Wire	SRG	YES
384-383		W	1	0.0		NA		-	Wire	SRG	YES
383-382		W	1	0.0		NA		-	Wire	SRG	YES
382-381		W	1	0.0		NA		-	Wire	SRG	YES
381-380		W	1	10.3		NA		-	Wire	SRG	YES
380-379		W	1	0.0		NA		-	Wire	SRG	YES
379-378		W	1	0.0		NA		-	Wire	SRG	YES
378-377		W	1	0.0		NA		-	Wire	SRG	YES
377-376		W	1	0.0		NA		-	Wire	SRG	YES
376-375		W	1	1.6		NA		-	Wire	SRG	YES
375-374		W	1	1.8		NA		-	Wire	SRG	YES
374-373		W	1	2.0		NA		-	Wire	SRG	YES
373-372		W	1	0.0		NA		-	Wire	SRG	YES
372-371		W	1	0.0		NA		-	Wire	SRG	YES
371-370		W	1	0.0		NA		-	Wire	SRG	YES
370-369		W	1	0.0		NA		-	Wire	SRG	YES
369-368		W	1	0.0		NA		-	Wire	SRG	YES
368-367		W	1	0.0		NA		-	Wire	SRG	YES
367-366		W	1	0.0		NA		-	Wire	SRG	YES
366-365		W	1	0.0		NA		-	Wire	SRG	YES
363-362		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
362-361		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
361-360		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
360-359		W	1	2.6		0.0	-2.6	Decrease	Wire	SRG	YES
359-358		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
358-357		W	1	0.0		0.1	0.1	-	Wire	SRG	YES
357-356		W	1	2.9		1.3	-1.6	Decrease	Wire	SRG	YES
356-355		W	1	0.0		2.2	2.2	Increase	Wire	SRG	YES
355-354		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
354-353		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
353-352		W	1	0.0		0.8	0.8	Increase	Wire	SRG	YES
352-351	101	W	1	0.0	0.0	0.2	0.2	-	Wire	SRG	YES
351-350	101	W	1	0.0	1.9	0.0	0.0	-	Wire	SRG	NO
350-349	101	W	1	4.3	7.6	3.5	-0.8	Decrease	Wire	SRG	NO
349-348	101	W	1	0.0	0.0	0.0	0.0	-	Wire	SRG	YES
348-347	101	W	1	1.7	2.5	1.8	0.1	-	Wire	SRG	YES
347-346	101	W	1	0.0	0.0	0.0	0.0	-	Wire	SRG	YES
346-345	101	W	1	0.0	0.6	0.0	0.0	-	Wire	SRG	YES
345-344	101	W	1	2.8	4.3	2.8	0.0	-	Wire	SRG	YES
344-343	101	W	1	2.5	3.6	0.4	-2.1	Decrease	Wire	SRG	YES
343-342	101	W	1	0.0	0.0	1.2	1.2	Increase	Wire	SRG	YES
342-341		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
341-340		W	1	0.0		0.0	0.0	-	Wire	SRG	YES

(continued)

TABLE B.2. (CONTINUED)

Station	Sec #	Dir	Lane	3/87	8/87 3/88	3/88-3/87	Increase ?	Reinf	Agg	Grt
338-337		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
337-336		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
336-335		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
335-334		W	1	1.0	1.0	0.0	-	Wire	SRG	YES
334-333		W	1	0.8	3.1	2.4	Increase	Wire	SRG	YES
333-332		W	1	0.0	0.9	0.9	Increase	Wire	SRG	YES
332-331		W	1	0.0	0.3	0.3	-	Wire	SRG	YES
331-330		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
330-329		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
329-328		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
328-327		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
327-326		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
326-325		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
325-324		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
324-323		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
323-322		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
322-321		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
321-320		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
320-319		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
319-318		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
318-317		W	1	0.0	0.4	0.4	-	Wire	SRG	YES
317-316		W	1	0.0	0.2	0.2	-	Wire	SRG	YES
316-315		W	1	0.7	1.5	0.8	Increase	Wire	SRG	YES
315-314		W	1	4.6	5.9	1.3	Increase	Wire	SRG	YES
314-313		W	1	0.5	2.7	2.2	Increase	Wire	SRG	YES
313-312		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
312-311		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
311-310		W	1	0.9	0.2	-0.7	-	Wire	SRG	YES
310-309		W	1	0.9	1.3	0.5	-	Wire	SRG	YES
309-308		W	1	3.7	3.0	-0.7	Decrease	Wire	SRG	YES
308-307		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
307-306		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
306-305		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
299-298		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
298-297		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
297-296		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
296-295		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
295-294		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
294-293		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
293-292		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
292-291		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
291-290		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
290-289		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
289-288		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
288-287		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
287-286		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
286-285		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
285-284		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
284-283		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
283-282		W	1	0.0	0.0	0.0	-	Wire	SRG	YES
282-281		W	1	0.0	0.0	0.0	-	Wire	SRG	YES

(continued)

TABLE B.2. (CONTINUED)

Station	Sec #	Dir	Lane	3/87	8/87	3/88	3/88-3/87	Increase ?	Reinf	Agg	Grt
281-280		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
280-279		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
279-278		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
278-277		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
277-276		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
276-275		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
275-274		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
274-273		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
273-272		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
272-271		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
271-270		W	1	2.5		2.9	0.4	-	Wire	SRG	YES
270-269		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
269-268		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
268-267		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
267-266		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
266-265		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
265-264		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
264-263		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
263-262		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
262-261		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
261-260		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
260-259		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
259-258		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
258-257		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
257-256		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
256-255		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
255-254	102	W	1	0.0	0.0	0.0	0.0	-	Wire	SRG	YES
254-253	102	W	1	3.5	3.8	0.8	-2.7	Decrease	Wire	SRG	YES
253-252	102	W	1	0.0	0.0	0.0	0.0	-	Wire	SRG	YES
252-251	102	W	1	0.0	0.0	0.0	0.0	-	Wire	SRG	YES
251-250	102	W	1	0.0	0.0	0.2	0.2	-	Wire	SRG	YES
250-249	102	W	1	0.0	0.4	0.0	0.0	-	Wire	SRG	YES
249-248		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
248-247		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
247-246		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
246-245		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
243-242		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
242-241		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
241-240		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
240-239		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
239-238		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
238-237		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
237-236		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
236-235		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
235-234		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
234-233		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
233-232		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
232-231		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
231-230		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
230-229		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
229-228		W	1	0.0		0.1	0.1	-	Wire	SRG	YES

(continued)

TABLE B.2. (CONTINUED)

Station	Sec #	Dir	Lane	3/87	8/87	3/88	3/88-3/87	Increase ?	Reinf	Agg	Grt
228-227		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
227-226		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
226-225		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
225-224		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
224-223		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
223-222		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
222-221		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
221-220		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
220-219		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
219-218		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
218-217		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
217-216		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
216-215		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
215-214		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
214-213		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
213-212		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
212-211		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
211-210		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
210-209		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
209-208		W	1	0.0		0.0	0.0	-	Wire	SRG	YES
207+78-208		E	1	0.0		NA		-	Wire	SRG	YES
208-209		E	1	0.0		NA		-	Wire	SRG	YES
209-210		E	1	0.5		NA		-	Wire	SRG	YES
210-211		E	1	0.7		NA		-	Wire	SRG	YES
211-212		E	1	0.7		NA		-	Wire	SRG	YES
212-213		E	1	0.9		NA		-	Wire	SRG	YES
213-214		E	1	0.0		NA		-	Wire	SRG	YES
214-215		E	1	0.0		NA		-	Wire	SRG	YES
215-216		E	1	0.0		NA		-	Wire	SRG	NO
216-217		E	1	1.6		NA		-	Wire	SRG	NO
217-218		E	1	0.0		NA		-	Wire	SRG	YES
218-219		E	1	1.3		NA		-	Wire	SRG	YES
219-220		E	1	2.6		NA		-	Wire	SRG	YES
220-221		E	1	0.8		NA		-	Wire	SRG	YES
221-222		E	1	0.0		NA		-	Wire	SRG	YES
222-223		E	1	0.4		NA		-	Wire	SRG	YES
223-224		E	1	0.2		NA		-	Wire	SRG	YES
224-225		E	1	0.0		NA		-	Wire	SRG	YES
225-226		E	1	0.0		NA		-	Wire	SRG	YES
226-227		E	1	3.0		NA		-	Wire	SRG	YES
227-228		E	1	3.6		NA		-	Wire	SRG	YES
228-229		E	1	1.4		NA		-	Wire	SRG	YES
229-230		E	1	11.0		NA		-	Wire	SRG	YES
230-231		E	1	0.0		NA		-	Wire	SRG	YES
231-232		E	1	0.0		NA		-	Wire	SRG	YES
232-233		E	1	9.9		NA		-	Wire	SRG	YES
233-234		E	1	10.7		NA		-	Wire	SRG	YES
234-235		E	1	0.0		NA		-	Wire	SRG	YES
235-236		E	1	0.0		NA		-	Wire	SRG	YES
236-237		E	1	0.0		NA		-	Wire	SRG	YES
237-238		E	1	1.9		NA		-	Wire	SRG	YES

(continued)

TABLE B.2. (CONTINUED)

Station	Sec #	Dir	Lane	3/87	8/87	3/88	3/88-3/87	Increase ?	Reinf	Agg	Grt
238-239		E	1	0.0		NA		-	Wire	SRG	YES
239-240		E	1	2.7		NA		-	Wire	SRG	YES
240-241		E	1	1.1		NA		-	Wire	SRG	YES
241-242		E	1	1.5		NA		-	Wire	SRG	YES
242-243		E	1	0.0		NA		-	Wire	SRG	YES
245-246		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
246-247		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
247-248		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
248-249		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
249-250		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
250-251		E	1	0.0		2.4	2.4	Increase	Wire	SRG	YES
251-252		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
252-253		E	1	0.0		0.1	0.1	-	Wire	SRG	YES
253-254		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
254-255		E	1	1.8		0.0	-1.8	Decrease	Wire	SRG	YES
255-256		E	1	0.0		0.5	0.5	-	Wire	SRG	YES
256-257		E	1	0.0		1.1	1.1	Increase	Wire	SRG	YES
257-258		E	1	0.0		0.1	0.1	-	Wire	SRG	YES
258-259		E	1	2.1		0.2	-1.9	Decrease	Wire	SRG	YES
259-260		E	1	19.3		7.4	-11.9	Decrease	Wire	SRG	YES
260-261		E	1	4.5		7.7	3.2	Increase	Wire	SRG	YES
261-262		E	1	2.3		3.1	0.8	Increase	Wire	SRG	YES
262-263		E	1	0.0		2.3	2.3	Increase	Wire	SRG	YES
263-264		E	1	0.0		1.0	1.0	Increase	Wire	SRG	YES
264-265		E	1	0.0		1.2	1.2	Increase	Wire	SRG	YES
265-266		E	1	0.6		2.1	1.5	Increase	Wire	SRG	YES
266-267		E	1	0.0		0.2	0.2	-	Wire	SRG	YES
267-268		E	1	0.0		0.1	0.1	-	Wire	SRG	YES
268-269		E	1	0.0		0.1	0.1	-	Wire	SRG	YES
269-270		E	1	0.8		0.7	-0.1	-	Wire	SRG	YES
270-271		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
271-272		E	1	1.1		0.0	-1.1	Decrease	Wire	SRG	YES
272-273		E	1	0.0		0.9	0.9	Increase	Wire	SRG	YES
273-274		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
274-275		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
275-276		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
276-277		E	1	0.0		0.0	0.0	-	Fiber	SRG	YES
277-278		E	1	0.0		0.0	0.0	-	Fiber	SRG	YES
278-279		E	1	0.0		0.3	0.3	-	Fiber	SRG	YES
279-280		E	1	0.0		0.0	0.0	-	Fiber	SRG	YES
280-281		E	1	0.0		0.5	0.5	-	Fiber	SRG	YES
281-282		E	1	0.0		0.0	0.0	-	Fiber	SRG	YES
282-283	103	E	1	1.3	1.3	1.0	-0.3	-	Fiber	SRG	YES
283-284	103	E	1	0.0	0.0	0.0	0.0	-	Fiber	SRG	YES
284-285	103	E	1	0.0	0.0	0.0	0.0	-	Fiber	SRG	YES
285-286	103	E	1	0.0	0.0	0.0	0.0	-	Fiber	SRG	YES
286-287	103	E	1	0.0	0.0	0.0	0.0	-	Fiber	SRG	YES
287-288	103	E	1	0.0	0.0	0.0	0.0	-	Fiber	SRG	YES
288-289	103	E	1	0.0	0.0	0.0	0.0	-	Fiber	SRG	YES
289-290	103	E	1	0.0	0.0	0.0	0.0	-	Fiber	SRG	YES
290-291	103	E	1	0.0	0.0	0.0	0.0	-	Fiber	SRG	YES

(continued)

TABLE B.2. (CONTINUED)

Station	Sec #	Dir	Lane	3/87	8/87	3/88	3/88-3/87	Increase ?	Reinf	Agg	Grt
291-292	103	E	1	0.0	0.0	0.0	0.0	-	Fiber	SRG	YES
292-293		E	1	0.0		0.0	0.0	-	Fiber	SRG	YES
293-294		E	1	0.0		0.0	0.0	-	Fiber	SRG	YES
294-295		E	1	0.0		0.0	0.0	-	Fiber	SRG	YES
295-296		E	1	0.0		0.0	0.0	-	Fiber	SRG	YES
296-297		E	1	0.0		0.0	0.0	-	Fiber	SRG	YES
297-298		E	1	0.0		0.0	0.0	-	Fiber	SRG	YES
305-306		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
306-307		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
307-308		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
308-309		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
309-310		E	1	0.0		0.9	0.9	Increase	Wire	SRG	YES
310-311	104	E	1	0.0	0.3	0.6	0.6	-	Wire	SRG	YES
311-312	104	E	1	0.0	0.4	0.6	0.6	-	Wire	SRG	YES
312-313	104	E	1	0.0	0.0	0.0	0.0	-	Wire	SRG	YES
313-314	104	E	1	0.0	0.0	0.3	0.3	-	Wire	SRG	YES
314-315	104	E	1	1.1	1.1	3.9	2.8	Increase	Wire	SRG	YES
315-316	104	E	1	0.3	0.5	0.7	0.4	-	Wire	SRG	YES
316-317	104	E	1	0.0	0.0	0.0	0.0	-	Wire	LIME	YES
317-318	104	E	1	0.0	0.0	0.0	0.0	-	Wire	LIME	YES
318-319	104	E	1	0.0	0.0	0.0	0.0	-	Wire	LIME	YES
319-320	104	E	1	0.0	0.0	0.0	0.0	-	Wire	LIME	YES
320-321		E	1	0.0		0.0	0.0	-	Wire	LIME	YES
321-322		E	1	0.0		0.0	0.0	-	Wire	LIME	YES
322-323		E	1	0.0		0.0	0.0	-	Wire	LIME	YES
323-324		E	1	0.0		0.0	0.0	-	Wire	LIME	YES
324-325		E	1	0.0		0.0	0.0	-	Wire	LIME	YES
325-326		E	1	0.0		0.6	0.6	-	Wire	LIME	YES
326-327		E	1	0.0		0.1	0.1	-	Wire	SRG	YES
327-328		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
328-329		E	1	0.0		0.2	0.2	-	Wire	SRG	YES
329-330		E	1	2.3		4.1	1.8	Increase	Wire	SRG	YES
330-331		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
331-332		E	1	0.0		1.4	1.4	Increase	Wire	SRG	YES
332-333		E	1	0.0		0.2	0.2	-	Wire	SRG	YES
333-334		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
334-335		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
335-336		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
336-337		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
337-338		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
340-341		E	1	1.2		3.3	2.1	Increase	Wire	SRG	YES
341-342		E	1	4.4		0.0	-4.4	Decrease	Wire	SRG	YES
342-343		E	1	3.7		4.7	1.0	Increase	Wire	SRG	YES
343-344		E	1	4.8		0.4	-4.4	Decrease	Wire	SRG	YES
344-345		E	1	0.3		0.4	0.1	-	Wire	SRG	YES
345-346		E	1	1.0		0.1	-0.9	Decrease	Wire	SRG	YES
346-347		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
347-348		E	1	2.1		4.2	2.1	Increase	Wire	SRG	YES
348-349		E	1	8.8		3.5	-5.3	Decrease	Wire	SRG	YES
349-350		E	1	0.3		1.0	0.7	-	Wire	SRG	YES
350-351		E	1	2.9		2.7	-0.2	-	Wire	SRG	YES

(continued)

TABLE B.2. (CONTINUED)

Station	Sec #	Dir	Lane	3/87	8/87	3/88	3/88-3/87	Increase ?	Reinf	Agg	Grt
351-352		E	1	2.3		4.1	1.9	Increase	Wire	SRG	YES
352-353		E	1	16.1		17.1	1.0	Increase	Wire	SRG	YES
353-354		E	1	9.8		3.2	-6.6	Decrease	Wire	SRG	YES
354-355		E	1	1.4		5.0	3.6	Increase	Wire	SRG	YES
355-356		E	1	7.7		14.5	6.8	Increase	Wire	SRG	YES
356-357	105	E	1	13.5	18.0	12.2	-1.3	Decrease	Wire	SRG	YES
357-358	105	E	1	0.8	3.9	0.6	-0.2	-	Wire	SRG	YES
358-359	105	E	1	3.0	3.4	2.8	-0.2	-	Wire	SRG	YES
359-360	105	E	1	1.5	2.4	2.1	0.7	-	Wire	SRG	YES
360-361	105	E	1	7.1	7.4	15.5	8.4	Increase	Wire	SRG	YES
361-362	105	E	1	10.6	10.8	0.9	-9.7	Decrease	Wire	SRG	YES
362-363		E	1	1.9		0.0	-1.9	Decrease	Wire	SRG	YES
363-364		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
365-366		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
366-367		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
367-368		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
368-369		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
369-370		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
370-371		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
371-372		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
372-373		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
373-374		E	1	0.0		0.5	0.5	-	Wire	SRG	YES
374-375		E	1	0.0		0.0	0.0	-	Wire	SRG	YES
375-376		E	1	0.0		2.3	2.3	Increase	Wire	SRG	YES
376-377		E	1	3.8		2.4	-1.4	Decrease	Wire	SRG	YES
377-378		E	1	0.0		4.4	4.4	Increase	Wire	SRG	YES
378-379		E	1	6.4		1.0	-5.4	Decrease	Wire	SRG	YES
379-380		E	1	0.0		2.0	2.0	Increase	Wire	SRG	YES
380-381		E	1	4.3		3.0	-1.3	Decrease	Wire	SRG	YES
381-382		E	1	6.3		6.0	-0.3	-	Wire	SRG	YES
382-383		E	1	5.5		0.5	-5.0	Decrease	Wire	SRG	YES
383-384		E	1	0.0		0.2	0.2	-	Wire	SRG	YES
384-385		E	1	2.1		1.6	-0.5	-	Wire	SRG	YES
385-386		E	1	0.0		1.9	1.9	Increase	Wire	SRG	YES
386-387		E	1	5.6		8.6	3.0	Increase	Wire	SRG	YES
387-388		E	1	8.3		1.2	-7.1	Decrease	Wire	SRG	YES
388-389		E	1	3.7		2.4	-1.3	Decrease	Wire	SRG	YES
389-390		E	1	4.5		1.7	-2.8	Decrease	Wire	SRG	YES
390-391		E	1	0.0		0.0		-	Wire	SRG	YES
391-392		E	1	0.0		0.0		-	Wire	SRG	YES
392-391		W	2	0.0		NA		-	Wire	SRG	YES
391-390		W	2	0.0		NA		-	Wire	SRG	YES
390-389		W	2	0.0		NA		-	Wire	SRG	YES
389-388		W	2	0.0		NA		-	Wire	SRG	YES
388-387		W	2	0.0		NA		-	Wire	SRG	YES
387-386		W	2	0.0		NA		-	Wire	SRG	YES
386-385		W	2	0.0		NA		-	Wire	SRG	YES
385-384		W	2	0.0		NA		-	Wire	SRG	YES
384-383		W	2	0.0		NA		-	Wire	SRG	YES
383-382		W	2	0.0		NA		-	Wire	SRG	YES
382-381		W	2	0.0		NA		-	Wire	SRG	YES

(continued)

TABLE B.2. (CONTINUED)

Station	Sec #	Dir	Lane	3/87	8/87	3/88	3/88-3/87	Increase ?	Reinf	Agg	Grt
381-380		W	2	12.5		NA		-	Wire	SRG	YES
380-379		W	2	0.4		NA		-	Wire	SRG	YES
379-378		W	2	0.0		NA		-	Wire	SRG	YES
378-377		W	2	0.0		NA		-	Wire	SRG	YES
377-376		W	2	0.0		NA		-	Wire	SRG	YES
376-375		W	2	0.3		NA		-	Wire	SRG	YES
375-374		W	2	0.0		NA		-	Wire	SRG	YES
374-373		W	2	1.2		NA		-	Wire	SRG	YES
373-372		W	2	0.0		NA		-	Wire	SRG	YES
372-371		W	2	0.0		NA		-	Wire	SRG	YES
371-370		W	2	0.0		NA		-	Wire	SRG	YES
370-369		W	2	1.3		NA		-	Wire	SRG	YES
369-368		W	2	1.6		NA		-	Wire	SRG	YES
368-367		W	2	0.0		NA		-	Wire	SRG	YES
367-366		W	2	0.0		NA		-	Wire	SRG	YES
366-365		W	2	0.0		NA		-	Wire	SRG	YES
363-362		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
362-361		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
361-360		W	2	0.6		0.0	-0.6	-	Wire	SRG	YES
360-359		W	2	0.0		0.3	0.3	-	Wire	SRG	YES
359-358		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
358-357		W	2	0.0		0.5	0.5	-	Wire	SRG	YES
357-356		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
356-355		W	2	0.0		0.1	0.1	-	Wire	SRG	YES
355-354		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
354-353		W	2	0.0		1.3	1.3	Increase	Wire	SRG	YES
353-352		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
352-351	101	W	2	1.2	4.7	1.2	0.0	-	Wire	SRG	YES
351-350	101	W	2	2.5	16.6	5.2	2.7	Increase	Wire	SRG	NO
350-349	101	W	2	4.3	14.5	3.7	-0.7	-	Wire	SRG	NO
349-348	101	W	2	0.0	6.0	0.2	0.2	-	Wire	SRG	YES
348-347	101	W	2	0.8	6.7	2.0	1.2	Increase	Wire	SRG	YES
347-346	101	W	2	0.0	2.4	0.9	0.9	Increase	Wire	SRG	YES
346-345	101	W	2	0.8	3.9	0.8	0.0	-	Wire	SRG	YES
345-344	101	W	2	1.5	5.4	4.2	2.7	Increase	Wire	SRG	YES
344-343	101	W	2	9.3	10.8	8.0	-1.2	Decrease	Wire	SRG	YES
343-342	101	W	2	0.0	2.1	0.5	0.5	-	Wire	SRG	YES
342-341		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
341-340		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
338-337		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
337-336		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
336-335		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
335-334		W	2	0.8		0.5	-0.3	-	Wire	SRG	YES
334-333		W	2	1.5		0.9	-0.6	-	Wire	SRG	YES
333-332		W	2	2.6		2.7	0.1	-	Wire	SRG	YES
332-331		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
331-330		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
330-329		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
329-328		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
328-327		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
327-326		W	2	1.2		0.0	-1.2	Decrease	Wire	SRG	YES

(continued)

TABLE B.2. (CONTINUED)

Station	Sec #	Dir	Lane	3/87	8/87	3/88	3/88-3/87	Increase ?	Reinf	Agg	Grt
326-325		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
325-324		W	2	0.0		1.0	1.0	Increase	Wire	SRG	YES
324-323		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
323-322		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
322-321		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
321-320		W	2	0.0		0.2	0.2	-	Wire	SRG	YES
320-319		W	2	0.4		0.7	0.4	-	Wire	SRG	YES
319-318		W	2	0.0		0.3	0.3	-	Wire	SRG	YES
318-317		W	2	1.4		0.6	-0.8	Decrease	Wire	SRG	YES
317-316		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
316-315		W	2	1.6		0.4	-1.2	Decrease	Wire	SRG	YES
315-314		W	2	1.0		0.6	-0.4	-	Wire	SRG	YES
314-313		W	2	0.2		0.0	-0.2	-	Wire	SRG	YES
313-312		W	2	0.0		0.6	0.6	-	Wire	SRG	YES
312-311		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
311-310		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
310-309		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
309-308		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
308-307		W	2	0.0		0.4	0.4	-	Wire	SRG	YES
307-306		W	2	1.7		1.0	-0.7	-	Wire	SRG	YES
306-305		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
299-298		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
298-297		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
297-296		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
296-295		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
295-294		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
294-293		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
293-292		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
292-291		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
291-290		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
290-289		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
289-288		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
288-287		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
287-286		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
286-285		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
285-284		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
284-283		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
283-282		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
282-281		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
281-280		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
280-279		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
279-278		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
278-277		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
277-276		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
276-275		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
275-274		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
274-273		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
273-272		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
272-271		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
271-270		W	2	0.7		0.0	-0.7	-	Wire	SRG	YES
270-269		W	2	0.8		0.3	-0.5	-	Wire	SRG	YES

(continued)

TABLE B.2. (CONTINUED)

Station	Sec #	Dir	Lane	3/87	8/87	3/88	3/88-3/87	Increase ?	Reinf	Agg	Grt
269-268		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
268-267		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
267-266		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
266-265		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
265-264		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
264-263		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
263-262		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
262-261		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
261-260		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
260-259		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
259-258		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
258-257		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
257-256		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
256-255		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
255-254	102	W	2	0.0	0.0	0.0	0.0	-	Wire	SRG	YES
254-253	102	W	2	0.0	0.0	0.0	0.0	-	Wire	SRG	YES
253-252	102	W	2	0.0	0.2	0.0	0.0	-	Wire	SRG	YES
252-251	102	W	2	0.0	0.0	0.0	0.0	-	Wire	SRG	YES
251-250	102	W	2	0.0	0.0	0.0	0.0	-	Wire	SRG	YES
250-249	102	W	2	0.0	0.0	0.0	0.0	-	Wire	SRG	YES
249-248		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
248-247		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
247-246		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
246-245		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
243-242		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
242-241		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
241-240		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
240-239		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
239-238		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
238-237		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
237-236		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
236-235		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
235-234		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
234-233		W	2	0.6		0.4	-0.2	-	Wire	SRG	YES
233-232		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
232-231		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
231-230		W	2	0.5		0.0	-0.5	-	Wire	SRG	YES
230-229		W	2	0.5		0.1	-0.4	-	Wire	SRG	YES
229-228		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
228-227		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
227-226		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
226-225		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
225-224		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
224-223		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
223-222		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
222-221		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
221-220		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
220-219		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
219-218		W	2	0.0		0.4	0.4	-	Wire	SRG	YES
218-217		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
217-216		W	2	0.0		0.0	0.0	-	Wire	SRG	YES

(continued)

TABLE B.2. (CONTINUED)

Station	Sec #	Dir	Lane	3/87	8/87	3/88	3/88-3/87	Increase ?	Reinf	Agg	Grt
216-215		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
215-214		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
214-213		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
213-212		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
212-211		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
211-210		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
210-209		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
209-208		W	2	0.0		0.0	0.0	-	Wire	SRG	YES
207+78-208		E	2	0.0		NA		-	Wire	SRG	YES
208-209		E	2	0.0		NA		-	Wire	SRG	YES
209-210		E	2	1.2		NA		-	Wire	SRG	YES
210-211		E	2	0.8		NA		-	Wire	SRG	YES
211-212		E	2	1.6		NA		-	Wire	SRG	YES
212-213		E	2	0.9		NA		-	Wire	SRG	YES
213-214		E	2	0.0		NA		-	Wire	SRG	YES
214-215		E	2	0.0		NA		-	Wire	SRG	YES
215-216		E	2	0.0		NA		-	Wire	SRG	NO
216-217		E	2	0.0		NA		-	Wire	SRG	NO
217-218		E	2	0.0		NA		-	Wire	SRG	YES
218-219		E	2	0.0		NA		-	Wire	SRG	YES
219-220		E	2	1.9		NA		-	Wire	SRG	YES
220-221		E	2	0.0		NA		-	Wire	SRG	YES
221-222		E	2	0.0		NA		-	Wire	SRG	YES
222-223		E	2	0.0		NA		-	Wire	SRG	YES
223-224		E	2	0.2		NA		-	Wire	SRG	YES
224-225		E	2	0.7		NA		-	Wire	SRG	YES
225-226		E	2	0.0		NA		-	Wire	SRG	YES
226-227		E	2	0.0		NA		-	Wire	SRG	YES
227-228		E	2	7.3		NA		-	Wire	SRG	YES
228-229		E	2	1.8		NA		-	Wire	SRG	YES
229-230		E	2	7.5		NA		-	Wire	SRG	YES
230-231		E	2	12.6		NA		-	Wire	SRG	YES
231-232		E	2	8.2		NA		-	Wire	SRG	YES
232-233		E	2	7.7		NA		-	Wire	SRG	YES
233-234		E	2	4.4		NA		-	Wire	SRG	YES
234-235		E	2	0.0		NA		-	Wire	SRG	YES
235-236		E	2	0.0		NA		-	Wire	SRG	YES
236-237		E	2	0.0		NA		-	Wire	SRG	YES
237-238		E	2	0.0		NA		-	Wire	SRG	YES
238-239		E	2	0.0		NA		-	Wire	SRG	YES
239-240		E	2	0.0		NA		-	Wire	SRG	YES
240-241		E	2	0.0		NA		-	Wire	SRG	YES
241-242		E	2	0.0		NA		-	Wire	SRG	YES
242-243		E	2	0.0		NA		-	Wire	SRG	YES
245-246		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
246-247		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
247-248		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
248-249		E	2	6.8		0.0	-6.8	Decrease	Wire	SRG	YES
249-250		E	2	5.8		2.3	-3.5	Decrease	Wire	SRG	YES
250-251		E	2	0.0		0.9	0.9	Increase	Wire	SRG	YES
251-252		E	2	0.0		0.6	0.6	-	Wire	SRG	YES

(continued)

TABLE B.2. (CONTINUED)

Station	Sec #	Dir	Lane	3/87	8/87	3/88	3/88-3/87	Increase ?	Reinf	Agg	Grt
252-253		E	2	0.0		0.3	0.3	-	Wire	SRG	YES
253-254		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
254-255		E	2	0.6		0.3	-0.3	-	Wire	SRG	YES
255-256		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
256-257		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
257-258		E	2	0.0		0.3	0.3	-	Wire	SRG	YES
258-259		E	2	2.5		1.5	-1.0	Decrease	Wire	SRG	YES
259-260		E	2	11.4		5.6	-5.8	Decrease	Wire	SRG	YES
260-261		E	2	4.9		4.4	-0.6	-	Wire	SRG	YES
261-262		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
262-263		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
263-264		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
264-265		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
265-266		E	2	0.3		0.0	-0.3	-	Wire	SRG	YES
266-267		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
267-268		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
268-269		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
269-270		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
270-271		E	2	1.2		1.0	-0.2	-	Wire	SRG	YES
271-272		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
272-273		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
273-274		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
274-275		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
275-276		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
276-277		E	2	2.8		1.7	-1.1	Decrease	Fiber	SRG	YES
277-278		E	2	0.0		0.0	0.0	-	Fiber	SRG	YES
278-279		E	2	0.0		0.0	0.0	-	Fiber	SRG	YES
279-280		E	2	0.0		0.3	0.3	-	Fiber	SRG	YES
280-281		E	2	0.0		0.0	0.0	-	Fiber	SRG	YES
281-282		E	2	0.0		0.1	0.1	-	Fiber	SRG	YES
282-283	103	E	2	1.0	1.0	0.8	-0.1	-	Fiber	SRG	YES
283-284	103	E	2	0.0	0.0	0.0	0.0	-	Fiber	SRG	YES
284-285	103	E	2	0.0	0.0	0.0	0.0	-	Fiber	SRG	YES
285-286	103	E	2	0.0	0.0	0.1	0.1	-	Fiber	SRG	YES
286-287	103	E	2	0.0	0.0	0.0	0.0	-	Fiber	SRG	YES
287-288	103	E	2	0.0	0.0	0.0	0.0	-	Fiber	SRG	YES
288-289	103	E	2	0.0	0.0	0.0	0.0	-	Fiber	SRG	YES
289-290	103	E	2	0.0	0.0	0.0	0.0	-	Fiber	SRG	YES
290-291	103	E	2	0.0	0.0	0.0	0.0	-	Fiber	SRG	YES
291-292	103	E	2	0.0	0.0	0.0	0.0	-	Fiber	SRG	YES
292-293		E	2	0.0		0.0	0.0	-	Fiber	SRG	YES
293-294		E	2	0.0		0.3	0.3	-	Fiber	SRG	YES
294-295		E	2	0.0		0.0	0.0	-	Fiber	SRG	YES
295-296		E	2	0.0		0.0	0.0	-	Fiber	SRG	YES
296-297		E	2	0.0		0.3	0.3	-	Fiber	SRG	YES
297-298		E	2	0.0		0.0	0.0	-	Fiber	SRG	YES
305-306		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
306-307		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
307-308		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
308-309		E	2	0.7		0.7	0.0	-	Wire	SRG	YES
309-310		E	2	0.7		0.7	0.0	-	Wire	SRG	YES

(continued)

TABLE B.2. (CONTINUED)

Station	Sec #	Dir	Lane	3/87	8/87	3/88	3/88-3/87	Increase ?	Reinf	Agg	Grt
310-311	104	E	2	0.4	0.4	0.7	0.3	-	Wire	SRG	YES
311-312	104	E	2	0.0	0.0	0.0	0.0	-	Wire	SRG	YES
312-313	104	E	2	0.0	0.0	0.0	0.0	-	Wire	SRG	YES
313-314	104	E	2	0.0	0.0	0.2	0.2	-	Wire	SRG	YES
314-315	104	E	2	0.0	0.0	0.2	0.2	-	Wire	SRG	YES
315-316	104	E	2	1.2	2.0	1.0	-0.2	-	Wire	SRG	YES
316-317	104	E	2	0.0	0.0	0.0	0.0	-	Wire	LIME	YES
317-318	104	E	2	0.0	0.0	0.0	0.0	-	Wire	LIME	YES
318-319	104	E	2	0.0	0.0	0.0	0.0	-	Wire	LIME	YES
319-320	104	E	2	0.0	0.0	0.0	0.0	-	Wire	LIME	YES
320-321		E	2	0.0		0.6	0.6	-	Wire	LIME	YES
321-322		E	2	0.0		0.0	0.0	-	Wire	LIME	YES
322-323		E	2	0.0		0.0	0.0	-	Wire	LIME	YES
323-324		E	2	0.0		0.0	0.0	-	Wire	LIME	YES
324-325		E	2	0.0		0.0	0.0	-	Wire	LIME	YES
325-326		E	2	0.0		0.0	0.0	-	Wire	LIME	YES
326-327		E	2	3.0		5.5	2.5	Increase	Wire	SRG	YES
327-328		E	2	0.3		2.9	2.7	Increase	Wire	SRG	YES
328-329		E	2	1.9		5.6	3.7	Increase	Wire	SRG	YES
329-330		E	2	4.8		11.5	6.7	Increase	Wire	SRG	YES
330-331		E	2	0.4		0.7	0.3	-	Wire	SRG	YES
331-332		E	2	0.0		0.7	0.7	-	Wire	SRG	YES
332-333		E	2	0.0		0.4	0.4	-	Wire	SRG	YES
333-334		E	2	1.1		2.9	1.8	Increase	Wire	SRG	YES
334-335		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
335-336		E	2	0.0		0.6	0.6	-	Wire	SRG	YES
336-337		E	2	0.8		0.6	-0.2	-	Wire	SRG	YES
337-338		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
340-341		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
341-342		E	2	1.0		0.7	-0.3	-	Wire	SRG	YES
342-343		E	2	1.3		0.8	-0.4	-	Wire	SRG	YES
343-344		E	2	3.0		1.7	-1.4	Decrease	Wire	SRG	YES
344-345		E	2	1.9		0.8	-1.1	Decrease	Wire	SRG	YES
345-346		E	2	1.3		1.0	-0.2	-	Wire	SRG	YES
346-347		E	2	0.0		0.2	0.2	-	Wire	SRG	YES
347-348		E	2	0.5		1.0	0.5	-	Wire	SRG	YES
348-349		E	2	9.9		10.5	0.7	-	Wire	SRG	YES
349-350		E	2	0.0		0.6	0.6	-	Wire	SRG	YES
350-351		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
351-352		E	2	0.9		0.0	-0.9	Decrease	Wire	SRG	YES
352-353		E	2	8.0		10.3	2.3	Increase	Wire	SRG	YES
353-354		E	2	9.3		8.9	-0.4	-	Wire	SRG	YES
354-355		E	2	15.3		12.3	-3.0	Decrease	Wire	SRG	YES
355-356		E	2	23.9		21.8	-2.1	Decrease	Wire	SRG	YES
356-357	105	E	2	17.0	18.0	25.7	8.6	Increase	Wire	SRG	YES
357-358	105	E	2	19.9	20.9	23.8	3.9	Increase	Wire	SRG	YES
358-359	105	E	2	1.8	4.0	6.2	4.4	Increase	Wire	SRG	YES
359-360	105	E	2	12.9	13.6	26.5	13.6	Increase	Wire	SRG	YES
360-361	105	E	2	26.1	27.4	22.9	-3.2	Decrease	Wire	SRG	YES
361-362	105	E	2	24.5	25.2	21.9	-2.6	Decrease	Wire	SRG	YES
362-363		E	2	2.1		2.3	0.2	-	Wire	SRG	YES

(continued)

TABLE B.2. (CONTINUED)

Station	Sec #	Dir	Lane	3/87	8/87	3/88	3/88-3/87	Increase ?	Reinf	Agg	Grt
363-364		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
365-366		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
366-367		E	2	1.2		0.2	-1.0	Decrease	Wire	SRG	YES
367-368		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
368-369		E	2	0.0		0.1	0.1	-	Wire	SRG	YES
369-370		E	2	0.4		0.3	-0.2	-	Wire	SRG	YES
370-371		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
371-372		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
372-373		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
373-374		E	2	0.0		0.2	0.2	-	Wire	SRG	YES
374-375		E	2	0.0		0.3	0.3	-	Wire	SRG	YES
375-376		E	2	0.0		0.2	0.2	-	Wire	SRG	YES
376-377		E	2	6.0		3.8	-2.2	Decrease	Wire	SRG	YES
377-378		E	2	0.7		0.3	-0.4	-	Wire	SRG	YES
378-379		E	2	5.6		2.2	-3.4	Decrease	Wire	SRG	YES
379-380		E	2	1.2		0.3	-1.0	Decrease	Wire	SRG	YES
380-381		E	2	3.7		1.2	-2.5	Decrease	Wire	SRG	YES
381-382		E	2	8.4		7.5	-0.9	Decrease	Wire	SRG	YES
382-383		E	2	1.9		1.3	-0.5	-	Wire	SRG	YES
383-384		E	2	1.2		0.4	-0.8	Decrease	Wire	SRG	YES
384-385		E	2	4.1		1.5	-2.6	Decrease	Wire	SRG	YES
385-386		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
386-387		E	2	1.9		1.5	-0.4	-	Wire	SRG	YES
387-388		E	2	3.6		1.3	-2.2	Decrease	Wire	SRG	YES
388-389		E	2	1.3		1.0	-0.3	-	Wire	SRG	YES
389-390		E	2	0.7		1.1	0.4	-	Wire	SRG	YES
390-391		E	2	0.0		0.0	0.0	-	Wire	SRG	YES
391-392		E	2	0.0		0.0	0.0	-	Wire	SRG	YES

APPENDIX C. ANALYSIS OF OPERATOR VARIANCE

BACKGROUND

The purpose of the analysis was to determine the extent of the operator variance in sounding for delamination. The analysis include an experiment in which sounding was performed on 400 feet of an inside lane. The delamination obtained by four different operators was compared.

TESTING TECHNIQUE

A study area in section 101 was selected for use in testing. This area was on the inside lane and had a length of 400 feet (344+00 to 348+00). This area was out of the area treated with epoxy repairs in August 1987 yet contained delaminated areas found in March and August 1987.

Two locations were selected in the study area containing delamination (Locations A and B). Location A was from station 344+25 to 344+75 and location B from station 347+25 to 347+75. A grid was established at each station. It was 12 feet wide (lane width) by 50 feet long with a one-foot grid interval. The grid was marked on the pavement by snapping a chalk line.

Four operators were used in sounding, as shown in Table C.1.

TABLE C.1. SOUNDING AND RECORDING FOR DELAMINATION

	Location A		Location B	
Activity	**Sounding**	**Recording**	**Sounding**	**Recording**
Pass 1	Operator 1	Operator 2	Operator 3	Operator 4
Pass 2	Operator 3	Operator 4	Operator 1	Operator 2
Pass 3	Operator 2	Operator 3	Operator 4	Operator 1
Pass 4	Operator 4	Operator 1	Operator 2	Operator 3

Data were recorded in terms of grid squares having delamination. Paint marks were not used and, therefore, the operator had to record delamination without any painted outline.

ANALYSIS OF OPERATOR VARIANCE

The delaminations observed by the four different operators are shown in Table C.2.

TABLE C.2. PERCENT DELAMINATION OBSERVED

Operator No.	Location A	Location B
Operator 1	1.92 %	3.87 %
Operator 2	1.35 %	4.08 %
Operator 3	2.25 %	4.17 %
Operator 4	2.02 %	3.48 %

The following statistical analysis was performed on the data collected :

Mean ($\overline{X}_A$)	= 1.89 %	Mean ($\overline{X}_B$)	= 3.90 %
Variance (S_A^2)	= 0.15	Variance (S_B^2)	= 0.09
Std. Dev. (S_A)	= 0.38 %	Std. Dev. (S_B)	= 0.31 %
No. of Data Points (n_A)	= 4	No. of Data Points (n_B)	= 4

The pooled variance (Sp^2) was

$$Sp^2 = \frac{(n_A - 1)\,S_A{}^2 + (n_B - 1)\,S_B{}^2}{n_A + n_B - 2} = 0.12$$

Therefore, the best estimate for the standard deviation, σ, was

$$\sigma = Sp = \sqrt{0.12} = 0.35\ \%$$

Assuming that the observations were normally distributed, the critical value for the operator with 95 percent confidence could be represented by the multiplication of the standard deviation and $Z_{0.025}$ (1.96) value. Therefore,

Critical operator error = $\overline{\sigma} \cdot Z_{0.025}$

= (0.35) * (1.96)

= 0.7 %

If the observed delamination increase or decrease was more than 0.7 percent, then it could be said that the delamination had increased or decreased with a 95 percent confidence.

APPENDIX D. LOCATION OF DYNAFLECT MEASUREMENTS

TABLE D.1. LOCATIONS OF DYNAFLECT MEASUREMENTS

Section	Direction	Station	Lane	Location	ID
101	WB	351+95	1 CL	A	
101	WB	351+94	1 CL	B	
101	WB	351+00	1 CL	A	
101	WB	350+99	1 CL	B	
101	WB	350+01	1 CL	A	
101	WB	349+99	1 CL	B	
101	WB	349+01	1 CL	A	
101	WB	349+00	1 CL	B	
101	WB	348+00	1 CL	A	
101	WB	347+99	1 CL	B	
101	WB	347+01	1 CL	A	
101	WB	346+98	1 CL	B	
101	WB	346+00	1 CL	A	
101	WB	345+99	1 CL	B	
101	WB	345+00	1 CL	A	
101	WB	344+99	1 CL	B	
101	WB	344+00	1 CL	A	
101	WB	343+99	1 CL	B	
101	WB	343+00	1 CL	A	
101	WB	342+99	1 CL	B	
101	WB	351+97	2 CL	A	
101	WB	351+96	2 CL	B	
101	WB	351+00	2 CL	A	
101	WB	350+99	2 CL	B	
101	WB	350+01	2 CL	A	
101	WB	350+00	2 CL	B	
101	WB	349+01	2 CL	A	
101	WB	349+00	2 CL	B	
101	WB	348+01	2 CL	A	
101	WB	348+00	2 CL	B	
101	WB	347+01	2 CL	A	
101	WB	347+00	2 CL	B	
101	WB	346+00	2 CL	A	
101	WB	345+99	2 CL	B	
102	WB	254+04	1 RWP	A	
102	WB	254+03	1 RWP	B	
102	WB	253+08	1 CL	U	209 A
102	WB	253+05	1 CL	C	209 A
102	WB	253+02	1 CL	D	209 A
102	WB	253+00	1 CL	A	
102	WB	252+99	1 CL	B	
102	WB	252+90	1 LWP	U	209 B
102	WB	252+87	1 LWP	C	209 B
102	WB	252+84	1 LWP	D	209 B
102	WB	251+98	1 CL	A	

(continued)

TABLE D.1. (CONTINUED)

Section	Direction	Station	Lane	Location	ID
102	WB	251+97	1 CL	B	
102	WB	251+02	1 CL	A	
102	WB	251+01	1 CL	B	
102	WB	250+76	1 LWP	U	211
102	WB	250+73	1 LWP	C	211
102	WB	250+70	1 LWP	D	211
102	WB	250+01	1 CL	A	
102	WB	250+00	1 CL	B	
102	WB	254+07	2 CL	U	208
102	WB	254+04	2 CL	C	208
102	WB	254+01	2 CL	D	208
102	WB	253+00	2 CL	A	
102	WB	252+99	2 CL	B	
102	WB	252+05	2 LWP	U	210
102	WB	252+02	2 LWP	C	210
102	WB	251+99	2 LWP	D	210
102	WB	251+99	2 CL	A	
102	WB	251+98	2 CL	B	
102	WB	251+02	2 CL	A	
102	WB	251+01	2 CL	B	
102	WB	250+01	2 CL	A	
102	WB	250+00	2 CL	B	
103	EB	282+02	1 RWP	A	
103	EB	282+15	1 RWP	B	
103	EB	283+00	1 RWP	A	
103	EB	283+03	1 RWP	B	
103	EB	285+04	1 RWP	A	
103	EB	285+07	1 RWP	B	
103	EB	286+00	1 RWP	A	
103	EB	286+09	1 RWP	B	
103	EB	287+00	1 RWP	A	
103	EB	287+03	1 RWP	B	
103	EB	288+00	1 RWP	A	
103	EB	288+01	1 RWP	B	
103	EB	289+00	1 RWP	A	
103	EB	289+02	1 RWP	B	
103	EB	290+06	1 RWP	A	
103	EB	290+10	1 RWP	B	
103	EB	290+99	1 CL	U	315
103	EB	291+02	1 CL	C	315
103	EB	291+05	1 CL	D	315
103	EB	283+00	2 CL	A	
103	EB	283+01	2 CL	B	

(continued)

TABLE D.1. (CONTINUED)

Section	Direction	Station	Lane	Location	ID
103	EB	285+00	2 CL	A	
103	EB	285+01	2 CL	B	
103	EB	286+00	2 CL	A	
103	EB	286+01	2 CL	B	
103	EB	287+00	2 CL	A	
103	EB	287+01	2 CL	B	
103	EB	288+01	2 LWP	U	314
103	EB	288+04	2 LWP	C	314
103	EB	288+07	2 LWP	D	314
103	EB	289+00	2 CL	A	
103	EB	289+01	2 CL	B	
103	EB	290+00	2 CL	A	
103	EB	290+01	2 CL	B	
103	EB	291+00	2 CL	A	
103	EB	291+01	2 CL	B	
103	EB	292+00	2 LWP	U	316
103	EB	292+03	2 LWP	C	316
103	EB	292+06	2 LWP	D	316
103	EB	292+00	2 CL	A	
103	EB	292+02	2 CL	B	
104	EB	310+00	1 RWP	A	
104	EB	310+01	1 RWP	B	
104	EB	311+00	1 RWP	A	
104	EB	311+01	1 RWP	B	
104	EB	312+04	1 RWP	A	
104	EB	312+05	1 RWP	B	
104	EB	313+04	1 RWP	A	
104	EB	313+06	1 RWP	B	
104	EB	314+05	1 RWP	A	
104	EB	314+06	1 RWP	B	
104	EB	314+95	1 CL	U	321
104	EB	314+98	1 CL	C	321
104	EB	315+01	1 CL	D	321
104	EB	315+02	1 RWP	A	
104	EB	315+03	1 RWP	B	
104	EB	315+90	1 RWP	A	
104	EB	315+98	1 RWP	B	
104	EB	317+02	1 RWP	A	
104	EB	317+04	1 RWP	B	
104	EB	317+98	1 RWP	A	
104	EB	318+05	1 RWP	B	
104	EB	318+95	1 RWP	A	
104	EB	319+00	1 RWP	B	

(continued)

TABLE D.1. (CONTINUED)

Section	Direction	Station	Lane	Location	ID
104	EB	319+01	1 LWP	U	323
104	EB	319+04	1 LWP	C	323
104	EB	319+07	1 LWP	D	323
104	EB	319+93	1 RWP	A	
104	EB	319+98	1 RWP	B	
104	EB	310+05	2 CL	A	
104	EB	310+07	2 CL	B	
104	EB	311+01	2 CL	A	
104	EB	311+04	2 CL	B	
104	EB	311+97	2 LWP	U	320
104	EB	312+00	2 LWP	C	320
104	EB	312+03	2 LWP	D	320
104	EB	313+04	2 CL	A	
104	EB	313+06	2 CL	B	
104	EB	314+04	2 CL	A	
104	EB	314+06	2 CL	B	
104	EB	315+20	2 CL	U	322
104	EB	315+23	2 CL	C	322
104	EB	315+26	2 CL	D	322
104	EB	315+92	2 CL	A	
104	EB	315+98	2 CL	B	
104	EB	316+88	2 CL	A	
104	EB	316+98	2 CL	B	
104	EB	318+00	2 CL	A	
104	EB	318+10	2 CL	B	
104	EB	318+94	2 CL	A	
104	EB	319+00	2 CL	B	
104	EB	319+91	2 CL	A	
104	EB	319+96	2 CL	B	
105	EB	356+50	1 RWP	A	
105	EB	356+53	1 RWP	B	
105	EB	356+95	1 RWP	A	
105	EB	357+02	1 RWP	B	
105	EB	357+53	1 RWP	A	
105	EB	357+56	1 RWP	B	
105	EB	357+96	1 RWP	A	
105	EB	357+97	1 RWP	B	
105	EB	358+44	1 RWP	A	
105	EB	358+48	1 RWP	B	
105	EB	359+02	1 RWP	A	
105	EB	359+05	1 RWP	B	
105	EB	359+50	1 RWP	A	
105	EB	359+52	1 RWP	B	

(continued)

TABLE D.1. (CONTINUED)

Section	Direction	Station	Lane	Location	ID
105	EB	360+01	1 RWP	A	
105	EB	360+02	1 RWP	B	
105	EB	360+50	1 RWP	A	
105	EB	360+51	1 RWP	B	
105	EB	361+02	1 RWP	A	
105	EB	361+05	1 RWP	B	
105	EB	361+50	1 RWP	A	
105	EB	361+52	1 RWP	B	
105	EB	356+00	2 CL	A	
105	EB	356+02	2 CL	B	
105	EB	356+50	2 CL	A	
105	EB	356+52	2 CL	B	
105	EB	356+82	2 RWP	U	64
105	EB	356+85	2 RWP	C	64
105	EB	356+88	2 RWP	D	64
105	EB	356+97	2 RWP	U	65
105	EB	357+00	2 RWP	C	65
105	EB	357+03	2 RWP	D	65
105	EB	357+43	2 CL	A	
105	EB	357+45	2 CL	B	
105	EB	357+60	2 RWP	U	66
105	EB	357+63	2 RWP	C	66
105	EB	357+66	2 RWP	D	66
105	EB	357+95	2 CL	A	
105	EB	357+96	2 CL	B	
105	EB	358+45	2 CL	A	
105	EB	358+48	2 CL	B	
105	EB	359+01	2 CL	A	
105	EB	359+04	2 CL	B	
105	EB	359+50	2 CL	A	
105	EB	359+51	2 CL	B	
105	EB	359+99	2 CL	A	
105	EB	360+00	2 CL	B	
105	EB	360+50	2 CL	A	
105	EB	360+51	2 CL	B	
105	EB	361+00	2 CL	A	
105	EB	361+01	2 CL	B	
105	EB	361+50	2 CL	A	
105	EB	361+51	2 CL	B	
105	EB	361+97	2 CL	A	
105	EB	361+99	2 CL	B	

APPENDIX E. LABORATORY TEST DATA

TABLE E.1. SHEAR STRENGTH OF CORES

Core Number	Station Number Type	Reinforcement Type	Aggregate	Shear Strength (psi)
1-0	209+98	WWF	SRG	330.9
38-0	342+87	WWF	SRG	408.7
53-0	347+98	WWF	SRG	456.2
67-0	356+21	WWF	SRG	639.2
100-B0	331+00	WWF	SRG	158.4
134-0D	309+00	WWF	SRG	564.1
218-0	230+00	WWF	SRG	392.7
300-0	262+00	WWF	SRG	505.4
302-0	264+00	WWF	SRG	476.7
306-0	270+00	WWF	SRG	316.7
312-0	269+00	Fiber	SRG	443.0

TABLE E.2. SHEAR STRENGTH OF CORES FROM NON-DELAMINATED AREAS

Core Number	Station Number Type	Reinforcement Type	Aggregate	Shear Strength (psi)
2-0	210+34	WWF	SRG	619.4
43-0	344+36	WWF	SRG	597.4
49-0	346+42	WWF	SRG	456.6
68-0	356+52	WWF	SRG	499.1
101-B0	331+00	WWF	SRG	147.2
204-C	260+00	WWF	SRG	540.1
E-A	361+62	WWF	SRG	282.9
2	313+30	WWF	SRG	227.0
5	317+27	WWF	LS	397.2
6	317+48	WWF	LS	519.6
7	317+49	WWF	LS	440.8
11	319+32	WWF	LS	408.2
12	319+69	WWF	LS	555.0
27	351+10	WWF	SRG	240.3
28	351+02	WWF	SRG	419.4
28B	351+02	WWF	SRG	277.5
29	350+98	WWF	SRG	268.3
31	350+56	WWF	SRG	166.0
32	350+49	WWF	SRG	173.4
36	352+00	WWF	SRG	506.6
42	351+00	Fiber	SRG	351.0
43	287+05	Fiber	SRG	530.5

TABLE E.3. CORES FROM DELAMINATED AREAS

Core Number	Station Number	Reinforcement Type	Aggregate Type	Saturated Density (psf)	Dry Density (pcf)	Apparent S.G.	Percent Voids	Percent Absorption
1-0	209+98	WWF	SRG	150.8	144.6	2.5	9.6	4.3
9-0	216+00	WWF	SRG	149.5	143.6	2.5	9.2	4.1
38-0	342+87	WWF	SRG	150.9	145.9	2.5	7.9	3.5
53-0	347+98	WWF	SRG	150.1	146.9	2.5	8.1	3.5
67-0	356+21	WWF	SRG	153.6	148.6	2.5	7.8	3.4
100-B0	331+00	WWF	SRG	151.0	145.5	2.5	8.6	3.8
134-0D	309+00	WWF	SRG	151.5	145.1	2.5	10.0	4.4
218-0	230+00	WWF	SRG	152.5	147.2	2.5	8.3	3.6
300-0	262+00	WWF	SRG	154.1	148.6	2.5	8.5	3.7
302-0	264+00	WWF	SRG	153.5	148.4	2.5	8.0	3.5
312-0	269+00	Fiber	SRG	149.4	142.6	2.5	10.5	4.7
402-0	377+00	WWF	SRG	149.8	144.4	2.5	8.4	3.7

TABLE E.4. CORES FROM NON-DELAMINATED AREAS

Core Number	Station Number	Reinforcement Type	Aggregate Type	Saturated Density (psf)	Dry Density (pcf)	Apparent S.G.	Percent Voids	Percent Absorption
2-0	210+34	WWF	SRG	151.3	145.8	2.5	8.5	3.8
43-0	344+36	WWF	SRG	150.7	145.8	2.5	7.6	3.3
49-0	346+42	WWF	SRG	152.2	147.2	2.5	7.9	3.4
68-0	356+52	WWF	SRG	151.3	146.4	2.5	7.6	3.3
101-B0	331+00	WWF	SRG	152.1	147.0	2.5	8.0	3.5
204-C	260+00	WWF	SRG	151.4	145.5	2.5	9.2	4.1
E-A	361+62	WWF	SRG	150.9	145.6	2.5	8.3	3.7
5	317+27	WWF	LS	148.9	142.6	2.5	10.0	4.5
6	317+48	WWF	LS	149.6	143.4	2.5	9.6	4.3
7	317+49	WWF	LS	150.1	143.8	2.5	9.9	4.4
11	319+32	WWF	LS	148.6	142.3	2.5	9.8	4.4
12	319+69	WWF	LS	149.7	143.4	2.5	9.7	4.3
27	351+10	WWF	SRG	151.7	147.4	2.5	6.8	2.9
29	350+98	WWF	SRG	150.2	145.0	2.5	8.0	3.5
42	284+84	Fiber	SRG	150.8	144.8	2.5	9.5	4.2
43	287+05	Fiber	SRG	151.9	145.3	2.5	10.3	4.5

TABLE E.5. TENSILE STRENGTH OF CORES FROM DELAMINATED AREAS

Core Number	Station Number	Reinforcement Type	Aggregate Type	Tensile Strength (psi)
9-0	216+00	WWF	SRG	845.5
38-0	342+87	WWF	SRG	860.5
53-0	347+98	WWF	SRG	957.3
67-0	356+21	WWF	SRG	960.0
100-B0	331+00	WWF	SRG	788.0
134-0D	309+00	WWF	SRG	563.2
218-0	230+00	WWF	SRG	828.1
300-0	262+00	WWF	SRG	793.7
302-0	264+00	WWF	SRG	756.3
306-0	270+00	WWF	SRG	626.7
312-0	269+00	Fiber	SRG	694.7

TABLE E.6. TENSILE STRENGTH OF CORES FROM NON-DELAMINATED AREAS

Core Number	Station Number	Reinforcement Type	Aggregate Type	Tensile Strength (psi)
2-0	210+34	WWF	SRG	669.0
43-0	344+36	WWF	SRG	1041.5
49-0	346+42	WWF	SRG	797.9
68-0	356+52	WWF	SRG	768.2
101-B0	331+00	WWF	SRG	688.9
5	317+27	WWF	LS	755.6
6	317+48	WWF	LS	666.5
7	317+49	WWF	LS	714.0
11	319+32	WWF	LS	811.7
12	319+69	WWF	LS	913.0
42	284+84	Fiber	SRG	1004.7
43	287+05	Fiber	SRG	1109.7

TABLE E.7. COEFFICIENT OF THERMAL EXPANSION OF OVERLAYS

Core Number	Station Number	Reinforcement Type	Aggregate Type	Coefficient of Thermal Expansion (μ/in.•F)
1-0	209+98	WWF	SRG	7.30
67-0	356+21	WWF	SRG	5.74
100-B0	331+00	WWF	SRG	7.03
101-B0	331+00	WWF	SRG	7.03
204-C	260+00	WWF	SRG	7.26
302-0	264+00	WWF	SRG	7.27
312-0	269+00	WWF	SRG	6.79
E-A	361+62	WWF	SRG	6.87
5	317+27	WWF	LS	4.33
6	317+48	WWF	LS	4.29
7	317+49	WWF	LS	4.52
11	319+32	WWF	LS	4.75
12	319+69	WWF	LS	4.42
42	284+84	Fiber	SRG	7.21
43	287+05	Fiber	SRG	6.97

APPENDIX F. SHEAR STRENGTH OF REPAIRED AREAS

TABLE F.1. SHEAR STRENGTHS OF REPAIRED CORES

Core Number	Repair Method	Shear Strength (psi)
51	Sawcut Overlay and Polymer Fill	181.5
52	Sawcut Overlay and Polymer Fill	306.4
57	Monomer Injection	483.5
58	Monomer Injection	340.1
59	Sawcut Overlay and Polymer Fill	90.5
60	Sawcut Overlay and Polymer Fill	452.6
71	Sawcut Overlay and Polymer Fill	372.5

APPENDIX G. SAMPLE DISCRIMINANT ANALYSIS RUNS

Sample runs using the Discriminant analysis.

Run 1

Variables used :	All (as listed)
Prior probability :	Equal (class variables only)
Cases :	All (no observations were excluded from data set)

$$y = 0.0703x_1 + 0.0350x_2 - 0.1575x_3 - 0.0424x_4 - 0.0241x_5 + 0.0039x_6 + 0.0978x_7 + 0.1438x_8 - 0.0292x_9 + 0.0899x_{10} - 0.0246x_{11} - 3.4462$$

Value of function evaluated at group means :

ND (Not Delaminated) = -0.1871

D (Delaminated) = 0.5429

Number of ND group accurately predicted = 64.0 percent

Number of D group accurately predicted = 35.2 percent

Percentage of grouped cases classified correctly = 64.2 percent

Run 2

Variables used : All except x_4, x_6 and x_7

Transformations : None

Prior probability : Proportional to group size

Cases : Only SRG, wire and grouted cases

Discriminant function :

$$y = 0.3543x_1 + 0.5283x_2 - 0.1535x_3 - 0.1233x_5 - 0.1233x_8 + 0.5043x_9 + 0.1117x_{10} + 21.6827x_{11} + 4.5562$$

Value of function evaluated at group means :

ND (Not Delaminated) = -0.2203

D (Delaminated) = 0.6050

Number of ND group accurately predicted = 93.4 percent

Number of D group accurately predicted = 13.3 percent

Percentage of grouped cases classified correctly = 72.1 percent

Run 3

Variables used :	All (as listed)
Transformations :	$x_9 = \log(DTMP)$ and $x_{11} = \log(1+x_{11})$
Prior probability :	Proportional to group size
Cases :	Only SRG, wire and grouted cases

Discriminant function :

$$y = 0.0919x_1 + 0.0045x_2 + 0.2158x_3 + 0.3020x_4 - 0.0281x_5 + 0.2865x_6 + 0.1702x_7 - 0.0556x_8 - 0.1972x_9 + 0.1303x_{10} + 2.8946x_{11} - 2.4433$$

Value of function evaluated at group means :

ND (Not Delaminated) = -0.2439

D (Delaminated) = 0.6791

Number of ND group accurately predicted = 90.8 percent

Number of D group accurately predicted = 31.3 percent

Percentage of grouped cases classified correctly = 74.91 percent

Run 4

Variables used :	All
Transformations :	None
Prior probability :	Proportional to group size
Cases :	Only SRG, wire and grouted cases

$$y = -0.3040x_1 + 0.4415x_2 + 0.1829x_3 - 0.2931x_4 - 0.0101x_5 + 0.1992x_6 + 0.2444x_7 - 0.0861x_8 + 0.4148x_9 + 0.1342x_{10} + 9.4043x_{11} - 2.3322$$

Value of function evaluated at group means :

ND (Not Delaminated) = -0.2467

D (Delaminated) = 0.6775

Number of ND group accurately predicted = 90.3 percent

Number of D group accurately predicted = 24.7 percent

Percentage of grouped cases classified correctly = 72.8 percent

Run 5

Variables used :	All except x_4, x_6 and x_7
Transformations :	$x_9 = \log(DTMP)$ and $x_{11} = \log(1+x_{11})$
Prior probability :	Proportional to group size
Cases :	Only SRG, wire and grouted cases

$$y = 0.1205x_1 + 0.0357x_2 - 0.1369x_3 + 0.0045x_5 - 0.1189x_8 + 0.2090x_9 + 0.1183x_{10} + 24.3853x_{11} - 3.7846$$

Value of function evaluated at group means :

ND (Not Delaminated) = -0.2138

D (Delaminated) = 0.5952

Number of ND group accurately predicted = 95.6 percent

Number of D group accurately predicted = 9.3 percent

Percentage of grouped cases classified correctly = 72.6 percent

Run 6

Variables used : All except x_4, x_6 and x_7

Transformations : $x_9 = \log(x_9)$ and $x_{11} = \log(1+x_{11})$

Prior probability : Equal (i.e. 0.5 for each group)

Cases : Only SRG, wire and grouted cases

$$y = 0.1205x_1 + 0.0357x_2 - 0.1369x_3 + 0.0045x_5 - 0.1189x_8 + 0.2090x_9 + 0.1183x_{10} + 24.3853x_{11} - 3.7846$$

Value of function evaluated at group means :

ND (Not Delaminated) = -0.2138

D (Delaminated) = 0.5952

Number of ND group accurately predicted = 63.1 percent

Number of D group accurately predicted = 66.0 percent

Percentage of grouped cases classified correctly = 63.9 percent