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16. Abstract

Uncontrolled longitudinal cracking was a commonly observed distress in continuously reinforced concrete pavements in the Houston, Texas, area in the 1970's. In the early 1980's, the cracks were repaired by grooving the pavement surface along the crack line and then filling the groove and underlying crack with a polymer mortar. In 1989-90, the pavement was reconstructed using a 4-inch bonded concrete overlay. Prior to the overlay, a condition survey was made and the performance and effectiveness of the crack repair treatment were analyzed and included in this report.

The concrete overlay project also included the restoration of a few hundred feet of longitudinal joints where the steel tie bars appeared to have failed. The load transfer was reestablished using a stitching process where 3-inch-deep slots were cut transversely across the joint into the slabs on both sides of the joint. A steel bar was placed in the slot and the slot filled with epoxy. Measurements and discussions of the effectiveness are included in this report.

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AN EVALUATION OF REPAIR TECHNIQUES USED FOR UNCONTROLLED LONGITUDINAL CRACKING AND FAILED LONGITUDINAL JOINTS

by

Brock E. Hoskins
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Research Report Number 920-4

Research Project 3-12D-84-920

Evaluation of Thin-Bonded Concrete Overlay in Houston

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

January 1991

PREFACE

The two concrete pavement restoration techniques described in this report were used to restore load transfer and seal surface cracks in several lane-miles of continuously reinforced concrete on IH-610 in Houston, Texas. One repair technique used polymer adhesives to seal the surface cracks. This technique, which was installed in 1980, was surveyed in 1990. Results show the majority of the repairs to be intact after ten years of heavy traffic. A second technique was used to restore the loss of transverse restraint provided by corroded tie bars located across longitudinal construction joints in the continuously reinforced concrete paving. Load transfer was reestablished by epoxying reinforcing steel in slots cut perpendicular to the joint. Falling Weight Deflectometer measurements demonstrate this technique increased the load transfer significantly.

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 the Performance of the Bonded Concrete Overlay on Interstate Highway 610 North, Houston, Texas" by Koestomo Koesno and B. Frank McCullough, presents the findings of a pavement monitoring program on the IH610 North, Houston, project. December 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. February 1989.

Report 920-4, "An Evaluation of Repair Techniques Used for Uncontrolled Longitudinal Cracking and Failed Longitudinal Joints," by Brock E. Hoskins, James Lundy, B. Frank McCullough, and David W. Fowler, presents information on the condition of the existing pavement prior to overlay, relative to random uncontrolled longitudinal cracks and longitudinal joints. The report discusses the treatment of the cracks and joints as well as the effectiveness of the treatment.

ABSTRACT

Uncontrolled longitudinal cracking was a commonly observed distress in continuously reinforced concrete pavements in the Houston, Texas, area in the 1970's. In the early 1980's, the cracks were repaired by grooving the pavement surface along the crack line and then filling the groove and underlying crack with a polymer mortar. In 1989-90, the pavement was reconstructed using a 4-inch bonded concrete overlay. Prior to the overlay, a condition survey was made and the performance and effectiveness of the crack repair treatment were analyzed and included in this report.

The concrete overlay project also included the restoration of a few hundred feet of longitudinal joints where the steel tie bars appeared to have failed. The load transfer was reestablished using a stitching process where 3-inch-deep slots were cut transversely across the joint into the slabs on both sides of the joint. A steel bar was placed in the slot and the slot filled with epoxy. Measurements and discussions of the effectiveness of this treatment are included in this report.

SUMMARY

Two concrete pavement restoration techniques are treated in this report. Both were used on continuously reinforced concrete (CRC) pavement and are related to a construction project which provided for the installation of a 4-inch bonded concrete overlay upon an existing 8-inch CRC pavement. The restoration techniques were accomplished prior to overlay. The first technique was actually tried in 1980. This technique provided for routing or widening the randomly occurring uncontrolled longitudinal cracks and then filling them with polymer mortar. A condition survey was performed prior to overlay to determine the performance of the treatment and to document the location and condition of the cracks. It was found that after ten years the repairs had performed well with 85 percent of the repaired length in good condition, 10 percent in fair condition, and 5 percent in poor condition.

A second technique was used in the restoration of longitudinal construction joints which had opened, probably due to the failure of the tie bars. This restoration technique, which has been described as "stitching," was specified in the overlay contract by SDHPT District 12. Load transfer was reestablished by bonding reinforcing bars with epoxy into slots cut transverse to the joint. The slot and short steel bar were centered at the joint and extended into the slabs on either side of the joint. The depth of the slot was about 3 inches. Falling Weight Deflectometer measurements indicate this treatment increased the load transfer significantly, with the deflection being decreased about 40 percent. This study finds that although the restoration techniques may be labor intensive, both are effective in restoring load transfer and sealing cracks. As procedures are improved and knowledge increases, the treatments should become more effective and less labor intensive.

IMPLEMENTATION STATEMENT

Improved specifications, materials, and construction techniques have reduced the occurrence of random longitudinal cracking and wide longitudinal joints. However, the occurrence of these failure mechanisms is still a problem, particularly in older pavements. The two repair techniques discussed in this report appear to be effective in restoring load transfer and sealing surface cracks. The "stitching" of the longitudinal joint is labor intensive and therefore costly, but it may be possible to improve the associated design and construction procedures. Larger bars and longer intervals between bars may be acceptable. A cold mill procedure rather than sawing the slot may prove cost-effective in some jobs. The construction is adaptable to the use of separate small crews which can be stationed along the roadway using the same handling arrangement.

The crack sealing operation could use a similar procedure in traffic control. The router is probably the most effective tool for grooving the crack. However, other equipment may be available or developed. The technique for sealing the crack can probably be improved if large volumes are needed.

In summary, both restoration techniques reported herein appear to be beneficial to extend pavement life and are offered for use as the need develops in the future.

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CHAPTER 1. INTRODUCTION

1.1 BACKGROUND

The Center for Transportation Research at The University of Texas at Austin and the Texas State Department of Highways and Public Transportation (SDHPT) have been working together to develop effective repair techniques for portland cement concrete pavement. Several distresses common in continuously reinforced concrete pavements (CRCP) are shown in Figs 1.1 through 1.5. Several repair techniques for these distresses have been investigated over the past several years.

1.2 SCOPE

This report discusses two repair techniques used on Loop 610 in Houston (see Fig 1.6). Chapter 2 discusses the repair of uncontrolled longitudinal cracking using a polymer concrete and the performance of the repair procedure. Chapter 3 discusses the repair of failed longitudinal joints and the effectiveness of the repair procedure. Chapter 4 presents conclusions and recommendations.

Fig 1.1. Uncontrolled longitudinal cracking.

Fig 1.2. Failed longitudinal joint.

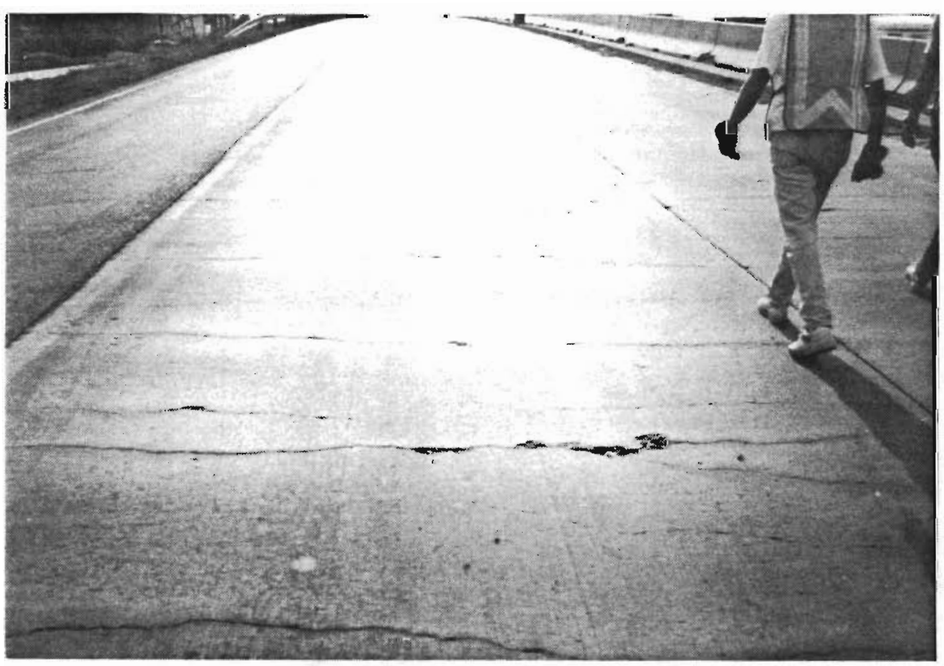

Fig 1.3. Transverse cracking.

Fig 1.4. Spalling.

Fig 1.5. Punchouts.

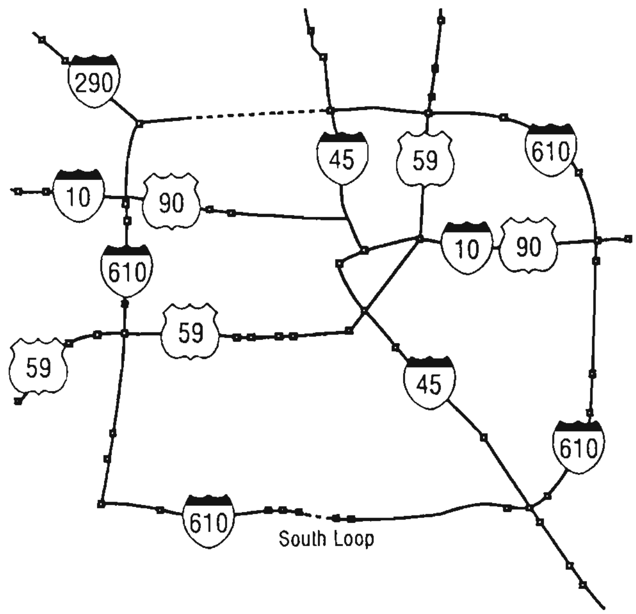

Fig 1.6. Houston area.

CHAPTER 2. POLYMER CONCRETE CRACK REPAIR

2.1 IDENTIFY DISTRESS

Over the past several years, longitudinal cracking has occurred in the continuously reinforced concrete pavements in Houston in areas other than longitudinal construction joints. Earlier investigations found that much of this cracking was reflective. Steps were then taken to eliminate the reflection cracking. However, similar problems were noted which could not be related to reflection cracking. It was found on a project that 69 percent of the sawed longitudinal joints had cracked and 31 percent had cracked within a distance of 1 to 2 feet from the joint. On several projects, these distress manifestations could be the result of various circumstances. For example, the 8-inch CRC pavement was placed on a gravel screenings subbase. Unexpected, extremely high traffic volumes occurred. The resulting performance may cause questions about pavement thicknesses and subbase properties along with relatively large pavement/subbase friction.

A mathematical model was developed to predict cracking at the joint. In using this model, the primary contributing factors were inadequate saw-cut depth, pavement thickness in excess of design values, and concrete strength variability. One of the factors related to concrete strength was the fact that the strength along the centerline was greater than that in adjacent areas, due to the absence of a steel bar down the centerline and better consolidation.

Results of the study showed that the previously used saw-cut depths were not providing the reduction in tensile strength required to ensure cracking at the joint. Therefore the ratio of the tensile strength at the joint to that in adjacent areas had to be reduced. It was found that the depth ratio of the saw-cut should be reduced from approximately 75 percent to 56 percent so that 90 percent cracking occurs along the centerline (Ref 1).

In 1980 the Center for Transportation Research assisted the Urban Office (now part of District 12) in developing a repair procedure for the extensive uncontrolled longitudinal cracking that was present on IH-610 in Houston. An example of this type of cracking is shown in Fig 1.1 in Chapter 1. After examining numerous cores, it was determined that the cracks generally formed around longitudinal bars (see Figs 2.1 and 2.2); therefore, the objective was to seal the cracks in order to prevent water intrusion and further corrosion of the reinforcing steel.

2.2 REPAIR TECHNIQUE

A polymer mortar was used for the repair of the portland cement concrete. The surface of the longitudinal cracks was grooved to allow for the placement of the PC. Several methods for enlarging the cracks were investigated. Sawing was not feasible for following the irregular cracks. High pressure water jetting was not feasible since polymer concrete does not bond well to wet surfaces, and it would have been necessary to allow the cracks to dry before placing the PC.

A single-piston pneumatic crack router (crack chaser) was selected as the best available piece of equipment to enlarge the cracks (Fig 2.3). The bit has a 0.75-inch diameter, and the crack is usually enlarged to a width of 1 inch in a single pass (Fig 2.4). The depth varies, but is usually 0.75 to 1 inch. The polymer was placed by filling the enlarged crack with clean, dry concrete sand and pouring methyl methacrylate (MMA) monomer system over the sand until it is completely saturated (Figs 2.5 and 2.6).

The monomer system consisted of 95 percent MMA and 5 percent trimethylol propane trimethacrylate (TMPTMA). Benzoyl peroxide (BzP) initiator, in dispersion form, was added at a level of about 1 percent (2.5 percent for 40 percent dispersion) and a promoter, dimethyl-para-toluidine (DMPT), was added at a level of 0.5 percent, both by weight of the MMA system. The levels of BzP and DMPT were dependent upon the ambient temperature.

The monomer had to be reapplied to keep the sand saturated, since monomer is lost due to evaporation and leakage down through the crack. In some repairs, silicone caulking was used to seal the crack below the PC to prevent monomer loss. In other repairs, polymethyl methacrylate (PMMA) powder was mixed with the sand before it was placed in the crack. PMMA powder acts as a thickener and prevents leakage of the monomer. Most repairs, however, were made without the silicone sealant or PMMA powder. The objective was to have monomer penetrate into the crack and bond to the concrete.

2.3 EVALUATION OF REPAIR

Over 100,000 linear feet of cracks on IH-610 were repaired by enlarging them and subsequently filling them with PC. In 1981, approximately one year after the first crack repairs were made on the West Loop (I-610), a visual examination was made by district and CTR personnel. Of the 14,066 feet of repaired cracks, 55.8 percent were found to be in good condition, 43.2 percent in fair condition, and only 1 percent in poor condition.

The repairs rated fair or poor generally showed evidence of wear or erosion on the surface, apparently due to evaporation of monomer from the surface or depletion of the monomer caused by leakage through the bottom of the crack. When a portion of the South Loop (IH-610S) was scarified in preparation for placement of bonded portland cement concrete overlays, many of the repaired cracks could easily be observed. In nearly every case, the repairs appeared to be very sound, with the bond to each face of the concrete still intact (Fig 2.7).

An inspection of repaired cracks on the South Loop in 1985 on repairs made approximately two years earlier indicated that 80 to 90 percent were in good condition. In a few cases, continued lateral movement of the pavement caused longitudinal cracks to reopen either in the repaired areas or adjacent to them. Some wear was observed in a few repaired cracks, again apparently due to lack of monomer (Ref 2).

On April 10, 1990, several crack repairs on the South Loop were inspected. The purpose of these inspections was to evaluate the long-term performance of the PC crack repair process. For orientation purposes, there are four lanes in each direction. Lane 1 is the lane adjacent to the median while lane 4 is the lane adjacent to the outside shoulder. Five 200-foot sections were surveyed. Three of these sections were located in the outside two lanes (lanes 3 and 4) in the eastbound direction; the other two sections were located in the outside two lanes (lanes 3 and 4) in the westbound direction.

The repairs were again evaluated as being in good, fair, or poor condition. A rating of "good" required that the crack be completely filled and sealed with the repair material. A rating of "fair" required that the majority of the repair material be in place; the crack could be slightly reopened, and small, infrequent cracks could be evident in the material. A rating of "poor" required that all of the repair material had spalled. Photos representing each rating condition are shown as Figs 2.8, 2.9, and 2.10.

Every effort was made in selecting the surveyed sections to insure that each adequately represented the crack repair conditions in that area. It was fairly difficult to find large areas for surveying due to several reasons:

(1) most areas were open to traffic,
(2) many areas were under construction, and
(3) many areas had been recently repaired.

When a suitable area was found, the section or sections to be surveyed were chosen near the center of the area or at least 100 feet from the end of a bridge. In all of the sections, only lanes 3 and 4 were surveyed, because traffic was open in lanes 1 and 2, and, in some cases, in lanes 3 and 4 as well.

The data obtained from the survey are given in Table 2.1. Of the repaired longitudinal cracks cracks surveyed, 85 percent were found to be in good condition, while only 10 percent and 5 percent were found to be in fair and poor condition, respectively.

An analysis of variance was performed on the data. The results are shown in Table 2.2. The variance was checked between sections, between lanes 3 and 4, and between ratings (good, fair, or poor). The interaction was checked between section and lane, rating and lane, and section and rating. In analyzing the results, the only parameter which showed significance was that between ratings, as was expected. The means were also checked between sections, between lanes, and between ratings. Again, the only parameter which showed significance was that between ratings.

2.4 CONCLUSIONS AND RECOMMENDATIONS

Overall, the repairs have performed quite well. It is recommended that this type of repair continue to be used for CRCP. However, the repair process is labor intensive. Alternate procedures and techniques should be investigated so that repair is more economical. The repairs on IH-610 were performed by several contractors. The cost for repair ranged from $6 to $8 per foot. The crack routing was performed at rate of 25 feet per hour. The bits had to be sharpened or replaced every 175 feet. The sand and monomer were placed manually. It was necessary to rewet the sand several times to maintain a saturated condition. To make the repair procedure more economical, the following improvements are needed: (1) a more rapid procedure for enlarging the cracks and (2) a less labor-intensive method for filling the crack with the PC (Ref 2).

TABLE 2.1. REPAIR PERFORMANCE DATA

		Rating*		
Section	**Lane**	**Good**	**Fair**	**Poor**
1	3	77	0	0
	4	143	0	0
2	3	58	15	36
	4	119	29	9
3	3	14	0	0
	4	140	0	0
4	3	31	7	0
	4	39	0	0
5	3	78	29	0
	4	0	0	0

*Values given represent linear feet of repair.

TABLE 2 2. ANALYSIS OF VARIANCE OF REPAIR

ROW	C1	C2	C3	C4
1	1	1	1	143
2	1	1	2	0
3	1	1	3	0
4	1	2	1	77
5	1	2	2	0
6	1	2	3	0
7	2	1	1	119
8	2	1	2	29
9	2	1	3	9
10	2	2	1	58
11	2	2	2	15
12	3	2	3	36
13	3	1	1	140
14	3	1	2	0
15	3	1	3	0
16	3	2	1	14
17	3	2	2	0
18	3	2	3	0
19	4	1	1	39
20	4	1	2	0
21	4	1	3	0
22	4	2	1	31
23	4	2	2	7
24	4	2	3	0
25	5	1	1	0
26	5	1	2	0
27	5	1	3	0
28	5	2	1	78
29	5	2	2	29
30	5	2	3	0

Means

C1	N	C4
1	6	39.667
2	6	44.333
3	6	25.667
4	6	12.833
5	6	17.833

C2	N	C4
1	15	31.933
2	15	23.000

C3	N	C4
1	10	69.900
2	10	8.000
3	10	4.500

MTB > ANOVA C4 = C1 C2 C3 C3*C2 C3*C1 C2*C1

Factor	Type	Levels	Values				
C1	Fixed	5	1	2	3	4	5
C2	Fixed	2	1	2			
C3	Fixed	3	1	2	3		

Analysis of Variance for C4

Source	DF	SS	MS	F	P
C1	4	4,075.8	1,019.0	1.10	0.420
C2	1	598.5	598.5	0.65	0.445
C3	2	27,070.1	13,535.0	14.59	0.002
C2*C3	2	2,871.7	1,435.8	1.55	0.270
C1*C3	8	5,861.6	7,32.7	0.79	0.627
C1*C2	4	5,065.8	1,266.4	1.37	0.327
Error	8	7,422.0	927.8		
Total	29	52,965.5	1,826.4		

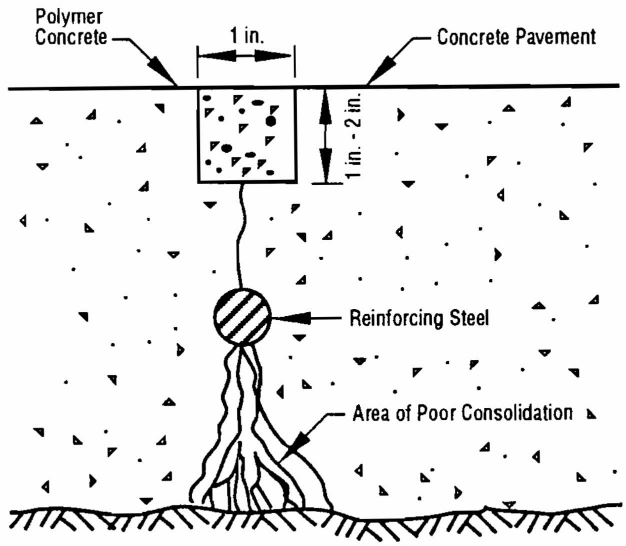

Fig 2.1. Distress illustration.

Fig 2.2. Core showing steel bar in crack.

Fig 2.3. Crack chaser.

Fig 2.4. Routed crack.

Fig 2.5. Application of sand.

Fig 2.6. Application of monomer.

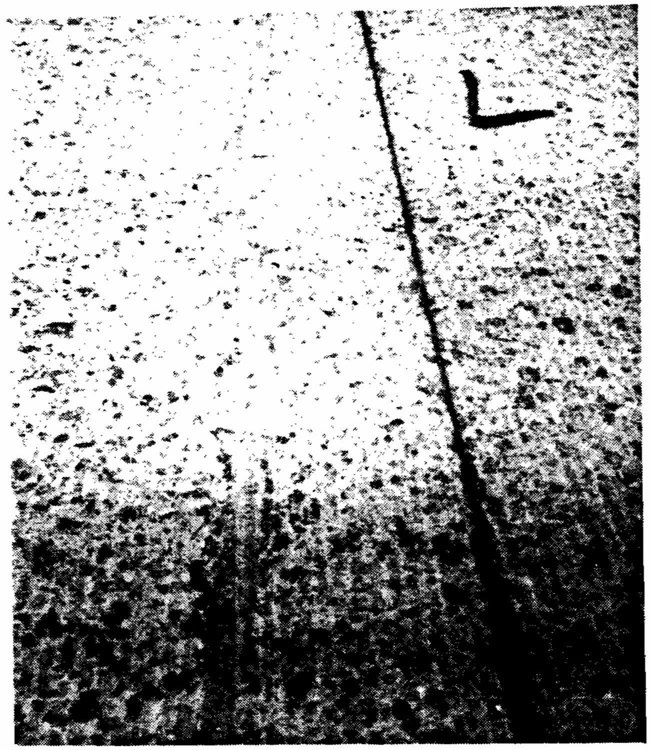

Fig 2.7. Repair after milling.

Fig 2.8. Good.

Fig 2.9. Fair.

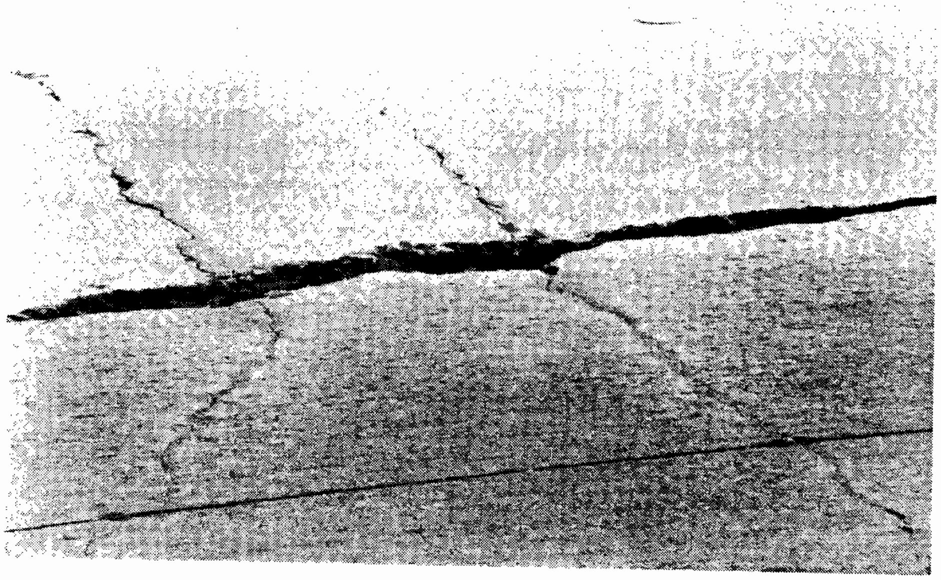

Fig 2.10. Poor.

CHAPTER 3. LONGITUDINAL JOINT REPAIR

3.1 IDENTIFY THE DISTRESS

In 1989, District 12 performed repairs on failed longitudinal joints on IH-610 in Houston. An example of this type of distress is given in Fig 1.2 in Chapter 1. The objective of the repair was to reestablish load transfer across failed longitudinal joints and cracks and to prevent further widening.

3.2 REPAIR TECHNIQUE

Load transfer was reestablished by "stitching" the two sides of the crack together. In this context, stitching refers to cutting 1-inch-wide slots at 12-inch centers perpendicular to the joint. These slots were cut to a depth of approximately 2 inches and an overall length of 54 inches, centered on the joint or crack. After the slot was cleaned, a #5 tiebar was epoxied in the slot. A drawing of the repair is shown in Fig 3.1. Normal surface preparation followed the specified curing time. Photos of the repair process are shown in Figs 3.2 and 3.3.

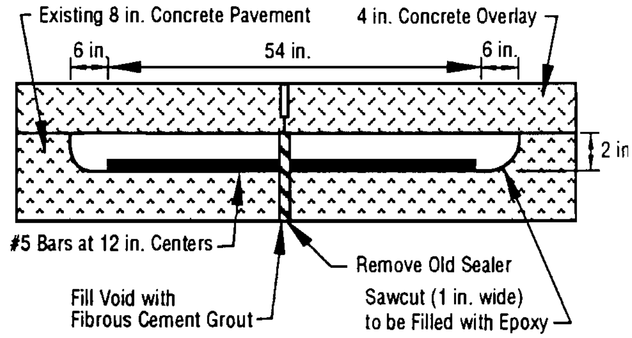

Fig 3.1. Cross section of stitching repair.

The majority of the stitching on the South Loop was performed on the longitudinal construction joint (between lanes 2 and 3). However, some repairs were made on the sawed longitudinal joint between lanes 1 and 2 and between lanes 3 and 4.

Fig 3.2. Stitching repair process - cutting slots.

Fig 3.3. Stitching repair process—bar placement.

3.3 EVALUATION OF REPAIR

Two of the repaired areas, each approximately 75 feet in length, were selected for investigation. Falling Weight Deflectometer (FWD) measurements were taken in each of these sections after the area had been closed to traffic. FWD measurements were taken before and after the repair (February 1989 and June 1989, respectively).

Deflection measurements obtained before and after repairs are shown in Tables 3.1 and 3.2, respectively. The deflection parameters calculated include the following:

(1) Surface Curvature Index (SCI) = sensor #1 – sensor #2
(2) Base Curvature Index (BCI) = sensor #6 – sensor #7
(3) Basin Slope (BS) = sensor #1 – sensor #7

These deflection parameters were calculated for each of the four FWD drop heights. The percent change in deflection was calculated for each deflection site before and after the repairs were made. These results are shown in Table 3.3.

These data indicate a substantial decrease in deflection as a result of the stitching repairs. However, because these measurements were taken at different times of the year under different environmental conditions, it is possible that some of the reduction in deflection may be attributed to seasonal effects rather than to the repairs themselves. Therefore, deflection measurements were taken in February and June at several sites (94) that were not repaired. These "non-repaired" sites allow the influence of season and environment to be factored out of the repair site measurements. Thus, the true effect of the repair may be determined. Table 3.4 shows these results.

These data indicate that the stitching repair has directly provided a substantial decrease in deflection. The deflection parameters most representative of the surface condition, namely the SCI, BS, and sensor #1 deflection, have all decreased approximately 40 percent as a result of the repairs.

The practical significance of this reduction in deflection is increased pavement life. A series of calculations was made to estimate the magnitude of the percent increase in fatigue life.

The modulus values for a three-layer pavement structure were back-calculated using RPEDD1 for the before and after repair conditions. Average deflections for each of the four FWD drop heights were used as inputs to the back-calculation program. The average modulus values for the three layers specified are shown below.

	Modulus Values in psi	
Pavement Layer	**Before Repair**	**After Repair**
CRC	4,300,000	6,500,000
Cement Treated Base	300,000	930,000
Roadbed Material	14,400	17,800

Stresses in the concrete layer before and after repair can be calculated using these modulus values and Westergaard's equations. The before repair case was assumed to be best represented by the edge loading condition described by Westergaard, due to the large crack width and relative lack of load transfer. The after repair condition was represented by an interior loading condition. The modulus of subgrade reaction required for the Westergaard analysis was obtained using the procedure described in the AASHTO Design Guide for determining a composite k-value. These results are shown below.

	Composite k	Radius of Relative Stiffness	Stress (psi)
Before Repair	1,000	20.7	243
After Repair	1,500	20.8	148

Using the fatigue equation presented by Taute and an assumed concrete strength of 650 psi, the expected life of the pavement before the repair was calculated to be 880,000 18-kip repetitions, while the expected life after the repair was calculated to be 3,900,000 18-kip repetitions. It should be emphasized that these values should not be used as accurate predictions of remaining life. The purpose of performing these calculations is to show a substantial increase in pavement fatigue life directly related to a reduction in deflection.

3.4 CONCLUSIONS AND RECOMMENDATIONS

An evaluation of the data indicates that the stitching repairs were effective. However, the process is labor intensive. For the procedure to be more economical, the most significant improvement would be to develop a more effective method for removing the concrete. It may also be possible to obtain the same effect by using larger bars at a larger spacing. A plot of bar size versus bar spacing for different percentages of steel is shown in Fig 3.4. It has been proposed that these alternatives and others be investigated in future repair projects so that a more cost-effective procedure can be developed.

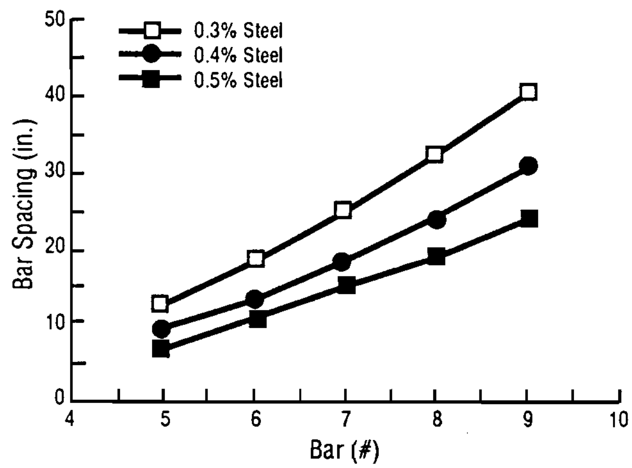

Fig 3.4. Spacing vs. bar size.

TABLE 3.1. FWD MEASUREMENTS BEFORE REPAIRS

Site	Station	PSI	DF1	DF2	DF3	DF4	DF5	DF6	DF7	SCI	BCI	BS
SITE #1	Stn:934+00	58.6	5.97	5.23	4.2	3.32	2.66	2.27	2	0.74	0.27	3.97
		91.1	8.93	7.82	6.38	5.14	4.23	3.56	3.04	1.11	0.52	5.89
		101.7	9.89	8.65	6.99	5.67	4.6	3.89	3.32	1.24	0.57	6.57
		143.4	12.9	11.2	9.17	7.45	6.09	5.18	4.44	1.69	0.74	8.49
	Stn:934+20	59.9	4.52	3.73	3.15	2.67	2.34	2.06	1.84	0.79	0.22	2.68
		90.1	7.05	6.01	5.09	4.38	3.79	3.28	2.92	1.04	0.36	4.13
		100.6	7.69	6.6	5.57	4.74	4.11	3.52	3.12	1.09	0.4	4.57
		143	10.6	9.12	7.76	6.6	5.72	4.94	4.4	1.45	0.54	6.17
	Stn:934+35	59.6	4.16	4.21	3.51	2.71	2.3	1.86	1.76	-0.1	0.1	2.4
		91.1	6.81	6.56	5.57	4.42	3.67	3.12	2.64	0.25	0.48	4.17
		101.5	7.45	7.15	6.06	4.82	3.99	3.32	2.8	0.3	0.52	4.65
		145.3	9.97	9.47	8.12	6.52	5.4	4.45	3.84	0.5	0.61	6.13
	Stn:934+53	59.3	4.32	4.44	4.04	3.4	2.86	2.43	2.04	-0.1	0.39	2.28
		89.8	7.21	7.04	6.38	5.35	4.43	3.72	3.16	0.17	0.56	4.05
		100.7	7.97	7.7	7.03	5.87	4.88	4.09	3.44	0.27	0.65	4.53
		143.9	10.6	10.3	9.45	7.9	6.61	5.59	4.72	0.27	0.87	5.89
	Stn:934+65	60.3	5.29	4.72	3.84	3.24	2.78	2.35	2.04	0.57	0.31	3.25
		89.8	8.97	7.74	6.3	5.35	4.6	4.17	3.36	1.23	0.81	5.61
		100.4	10	8.61	6.99	5.83	4.92	3.97	3.44	1.4	0.53	6.57
		144	13.4	11.7	9.49	7.86	6.65	5.46	4.56	1.74	0.9	8.85
SITE #2	Stn:935+30	60.6	4.8	4.68	3.76	3.04	2.46	2.1	1.84	0.12	0.26	2.96
		90	7.97	7.55	6.18	5.02	4.11	3.48	3.04	0.42	0.44	4.93
		100.5	8.97	8.45	6.95	5.63	4.68	3.93	3.44	0.52	0.49	5.53
		142.6	11.9	11.2	9.25	7.58	6.33	5.34	4.64	0.69	0.7	7.29
	Stn:935+44	62.5	4.6	4.17	3.43	2.71	2.26	1.98	1.64	0.43	0.34	2.96
		92.6	7.61	6.88	5.7	4.5	3.75	3.2	2.72	0.73	0.48	4.89
		99.6	8.45	7.59	6.26	4.98	4.03	3.4	2.88	0.86	0.52	5.57
		144.7	11.4	10.3	8.48	6.68	5.4	4.57	3.88	1.11	0.69	7.53
	Stn:935+61	72.3	4.52	4.25	3.51	2.92	2.42	1.98	1.64	0.27	0.34	2.88
		108.7	7.41	6.8	5.7	4.78	3.95	3.16	2.6	0.61	0.56	4.81
		117.3	8.41	7.59	6.38	5.35	4.43	3.56	2.8	0.82	0.76	5.61
		151.9	11.5	10.4	8.73	7.29	6.05	4.82	3.88	1.07	0.94	7.61
	Stn:935+78	65.3	4.08	3.69	3.07	2.59	2.22	1.86	1.6	0.39	0.26	2.48
		99.2	7.01	6.41	5.45	4.7	3.99	3.48	3	0.6	0.48	4.01
		107.2	7.97	7.27	6.18	5.35	4.6	3.97	3.48	0.7	0.49	4.49
		148.6	10.8	9.83	8.32	7.13	6.09	5.26	4.52	0.94	0.74	6.25
	Stn:935+96	66.9	4	3.81	3.27	2.8	2.46	1.94	1.76	0.19	0.18	2.24
		99.3	6.49	6.13	5.29	4.5	3.91	3.4	3.04	0.36	0.36	3.45
		107	7.17	6.76	5.82	4.98	4.35	3.8	3.32	0.41	0.48	3.85
		148.9	9.77	9.24	7.96	6.81	5.93	5.18	4.52	0.53	0.66	5.25

TABLE 3.2. FWD MEASUREMENTS AFTER REPAIRS

		PSI	DF1	DF2	DF3	DF4	DF5	DF6	DF7	SCI	BCI	BS
SITE #1	Stn:934+00	53.3	2.89	2.69	2.33	2.03	1.77	1.58	1.37	0.2	0.21	1.52
		-80	4.58	4.28	3.72	3.19	2.76	2.43	2.13	0.3	0.3	2.45
		96.4	5.67	5.33	4.57	3.91	3.38	2.94	2.51	0.34	0.43	3.16
		135.5	8.04	7.51	6.37	5.46	4.74	4.17	3.57	0.53	0.6	4.47
	Stn:934+20	49.7	2.21	2.01	1.8	1.64	1.44	1.31	1.18	0.2	0.13	1.03
		79.6	3.7	3.44	3.06	2.75	2.43	2.16	1.94	0.26	0.22	1.76
		96.1	4.62	4.24	3.76	3.39	3.01	2.7	2.39	0.38	0.31	2.23
		134.6	6.63	6.04	5.35	4.79	4.2	3.75	3.26	0.59	0.49	3.37
	Stn:934+35	48.6	2.33	2.18	1.92	1.71	1.48	1.27	1.14	0.15	0.13	1.19
		79.1	3.86	3.65	3.27	2.87	2.47	2.2	1.9	0.21	0.3	1.96
		93.8	4.58	4.36	3.88	3.35	2.93	2.55	2.2	0.22	0.35	2.38
		134.8	6.79	6.42	5.67	4.91	4.25	3.67	3.15	0.37	0.52	3.64
	Stn:934+53	47.8	2.21	2.18	1.92	1.68	1.48	1.31	1.14	0.03	0.17	1.07
		79.3	3.78	3.69	3.31	2.95	2.6	2.36	2.09	0.09	0.27	1.69
		95.4	4.66	4.53	4.08	3.59	3.17	2.74	2.39	0.13	0.35	2.27
		126.4	6.71	6.51	5.8	5.1	4.41	3.9	3.38	0.2	0.52	3.33
	Stn:934+65	48.6	2.57	2.43	2.16	1.95	1.69	1.55	1.37	0.14	0.18	1.2
		78.3	4.42	4.2	3.72	3.31	2.93	2.59	2.28	0.22	0.31	2.14
		94.3	5.23	4.91	4.29	3.79	3.26	2.86	2.47	0.32	0.39	2.76
		134.5	7.84	7.34	6.45	5.66	4.91	4.25	3.61	0.5	0.64	4.23
SITE #2	Stn:935+30	51.9	2.29	2.14	1.8	1.52	1.28	1.12	0.95	0.15	0.17	1.34
		79.1	4.18	3.99	3.43	2.95	2.56	2.32	2.01	0.19	0.31	2.17
		94.5	5.15	4.87	4.21	3.63	3.13	2.82	2.47	0.28	0.35	2.68
		133.5	7.48	7.13	6.08	5.22	4.49	4.02	3.45	0.35	0.57	4.03
	Stn:935+44	48.8	2.65	2.43	2.04	1.75	1.44	1.27	1.14	0.22	0.13	1.51
		78.4	4.62	4.2	3.59	3.03	2.51	2.12	1.75	0.42	0.37	2.87
		94.9	5.71	5.25	4.45	3.79	3.13	2.67	2.24	0.46	0.43	3.47
		133	8.08	7.39	6.25	5.22	4.29	3.55	2.96	0.69	0.59	5.12
	Stn:935+61	47.1	2.69	2.48	2.12	1.79	1.48	1.27	1.1	0.21	0.17	1.59
		77.5	4.7	4.36	3.72	3.19	2.64	2.28	1.97	0.34	0.31	2.73
		94.3	5.63	5.2	4.37	3.67	3.01	2.51	2.13	0.43	0.38	3.5
		133.2	8.24	7.51	6.37	5.3	4.33	3.67	3.07	0.73	0.6	5.17
	Stn:935+78	46.8	2.21	2.01	1.76	1.6	1.36	1.24	1.1	0.2	0.14	1.11
		77.7	3.9	3.65	3.18	2.79	2.43	2.16	1.86	0.25	0.3	2.04
		94.2	4.82	4.49	3.92	3.47	3.05	2.67	2.28	0.33	0.39	2.54
		133.6	6.83	6.3	5.43	4.79	4.12	3.59	3.07	0.53	0.52	3.76
	Stn:935+96	57.8	2.21	2.01	1.76	1.64	1.44	1.31	1.18	0.2	0.13	1.03
		85.9	3.66	3.4	2.98	2.71	2.43	2.2	1.94	0.26	0.26	1.72
		98	4.62	4.24	3.76	3.43	3.05	2.7	2.39	0.38	0.31	2.23
		137	6.67	6.09	5.35	4.79	4.29	3.9	3.42	0.58	0.48	3.25

TABLE 3.3. PERCENT CHANGE IN VARIOUS DEFLECTION PARAMETERS AFTER REPAIR

			Percent Change (June - February Readings)									
	Station	PSI	DF1	DF2	DF3	DF4	DF5	DF6	DF7	SCI	BCI	BS
SITE #1	934+00	-9	-52	-49	-45	-39	-33	-30	-31	-73	-22	-62
		-12	-49	-45	-42	-38	-35	-32	-30	-73	-42	-58
		-5	-43	-38	-35	-31	-27	-24	-24	-73	-25	-52
		-6	-38	-33	-31	-27	-22	-19	-20	-69	-19	-47
	934+20	-17	-51	-46	-43	-39	-38	-36	-36	-75	-41	-62
		-12	-48	-43	-40	-37	-36	-34	-34	-75	-39	-57
		-4	-40	-36	-32	-28	-27	-23	-23	-65	-22	-51
		-6	-37	-34	-31	-27	-27	-24	-26	-59	-9	-45
	934+35	-18	-44	-48	-45	-37	-36	-32	-35	-400	30	-50
		-13	-43	-44	-41	-35	-33	-29	-28	-16	-37	-53
		-8	-39	-39	-36	-30	-27	-23	-21	-27	-33	-49
		-7	-32	-32	-30	-25	-21	-18	-18	-26	-15	-41
	934+53	-19	-49	-51	-52	-51	-48	-46	-44	-125	-56	-53
		-12	-48	-48	-48	-45	-41	-37	-34	-47	-52	-58
		-5	-42	-41	-42	-39	-35	-33	-31	-52	-46	-50
		-12	-37	-37	-39	-35	-33	-30	-28	-26	-40	-43
	934+65	-19	-51	-49	-44	-40	-39	-34	-33	-75	-42	-63
		-13	-51	-46	-41	-38	-36	-38	-32	-82	-62	-62
		-6	-48	-43	-39	-35	-34	-28	-28	-77	-26	-58
		-7	-42	-37	-32	-28	-26	-22	-21	-71	-29	-52
SITE #2	935+30	-14	-52	-54	-52	-50	-48	-47	-48	25	-35	-55
		-12	-48	-47	-44	-41	-38	-33	-34	-55	-30	-56
		-6	-43	-42	-39	-36	-33	-28	-28	-46	-29	-52
		-6	-37	-37	-34	-31	-29	-25	-26	-49	-19	-45
	935+44	-22	-42	-42	-41	-35	-36	-36	-30	-49	-62	-49
		-15	-39	-39	-37	-33	-33	-34	-36	-42	-23	-41
		-5	-32	-31	-29	-24	-22	-21	-22	-47	-17	-38
		-8	-29	-28	-26	-22	-21	-22	-24	-38	-14	-32
	935+61	-35	-40	-42	-40	-39	-39	-36	-33	-22	-50	-45
		-29	-37	-36	-35	-33	-33	-28	-24	-44	-45	-43
		-20	-33	-31	-32	-31	-32	-29	-24	-48	-50	-38
		-12	-28	-28	-27	-27	-28	-24	-21	-32	-36	-32
	935+78	-28	-46	-46	-43	-38	-39	-33	-31	-49	-46	-55
		-22	-44	-43	-42	-41	-39	-38	-38	-58	-37	-49
		-12	-40	-38	-37	-35	-34	-33	-34	-53	-20	-43
		-10	-37	-36	-35	-33	-32	-32	-32	-44	-30	-40
	935+96	-14	-45	-47	-46	-41	-41	-32	-33	5	-28	-54
		-13	-44	-45	-44	-40	-38	-35	-36	-28	-28	-50
		-8	-36	-37	-35	-31	-30	-29	-28	-7	-35	-42
		-8	-32	-34	-33	-30	-28	-25	-24	9	-27	-38

TABLE 3.4. INFLUENCE OF SEASON (JUNE TO FEBRUARY) ON THE AVERAGE PERCENT DIFFERENCE OF VARIOUS DEFLECTION PARAMETERS

		Drop Height								Overall Average	
		1		2		3		4			
Deflection Parameter	Statistic	Non-Repair	Repair	Non-Repair	Repair	Non-Repair	Repair	Non-Repair	Repair		
Load	Average	-23	-20	-15	-15	-8	-8	-10	-8	-14	-13
	St. Dev.	5	6	5	5	5	4	3	2	7	7
DF1	Average	-18	-47	-13	-45	-4	-39	3	-35	-8	-42
	St. Dev.	23	4	23	4	25	4	27	4	26	6
DF2	Average	-20	-47	-13	-44	-3	-38	2	-34	-8	-41
	St. Dev.	21	4	22	3	24	4	25	3	25	6
DF3	Average	-20	-45	-12	-41	-3	-36	3	-32	-8	-38
	St. Dev.	19	4	20	4	22	4	23	3	23	6
DF4	Average	-19	-41	-12	-38	-2	-32	4	-29	-7	-35
	St. Dev.	17	5	18	4	20	4	20	4	21	6
DF5	Average	-20	-40	-12	-36	-2	-30	4	-27	-8	-33
	St. Dev.	15	4	15	3	17	4	17	4	18	7
DF6	Average	-20	-36	-12	-34	-2	-27	4	-24	-7	-30
	St. Dev.	15	5	12	3	14	4	15	4	17	7
DF7	Average	-21	-36	-12	-33	-3	-26	3	-24	-8	-30
	St. Dev.	12	6	11	4	12	4	12	4	15	7
SCI	Average	-48	-84	-1	-52	0	-49	16	-40	-8	-56
	St. Dev.	136	119	103	20	113	20	77	23	112	62
BCI	Average	-13	-35	-4	-39	6	-30	15	-24	1	-32
	St. Dev.	57	26	39	11	38	10	42	10	46	16
BS	Average	-13	-55	-12	-53	-2	-47	5	-42	-5	-49
	St. Dev.	43	5	38	6	41	6	45	6	42	8

CHAPTER 4. CONCLUSIONS AND RECOMMENDATIONS

Both repair procedures discussed in this report have proved effective. The polymer concrete crack repairs have been effective and have performed extremely well for several years. The longitudinal joint repairs have been very effective, as they have resulted in a significant reduction in deflection. It is recommended that both of these repair procedures continue to be used for the repair of continuously reinforced concrete pavements.

However, further investigation is recommended for both repair procedures. Both repair processes are labor intensive. Alternate techniques should be investigated so that the repair processes can be made more economical. For the polymer concrete crack repair, the following improvements are needed: (1) a more rapid procedure for enlarging the cracks and (2) a less labor-intensive method for filling the crack with the polymer concrete. For the longitudinal joint repair, the most significant improvement would be to develop a more effective method for removing the concrete. It is anticipated that using larger bars at a larger spacing will result in a more cost-effective process.

An additional technique may consist of removing the old sealer in the joint and refilling the joint with a cement grout (possibly with fibers). This joint repair would then be followed with a #5 rebar, or staple bar, placed at 12-inch centers along the joint. The #5 staple bar would be a "U"-shaped bar with the bottom some 36 to 54 inches in length and the ends bent at 90 degrees and extended to a length of approximately 3 to 4 inches. The "U" bar would be inverted and placed to straddle the joint. The ends would be placed into holes previously drilled into the slabs on either side of the joint and epoxied in the holes. The holes would have been drilled into the slabs at points equidistant and perpendicular to the joint. The result would have the appearance of a joint which had been stapled to prevent lateral movement.

The Center for Transportation Research and District 12 will continue to investigate the performance of these and other repair techniques for pavements in the Houston area. It is expected that existing repair techniques will be improved and that new techniques will be developed. For example, with the present increase in application of bonded concrete overlays in Houston, cost-effective repair procedures for these overlays will need to be investigated.

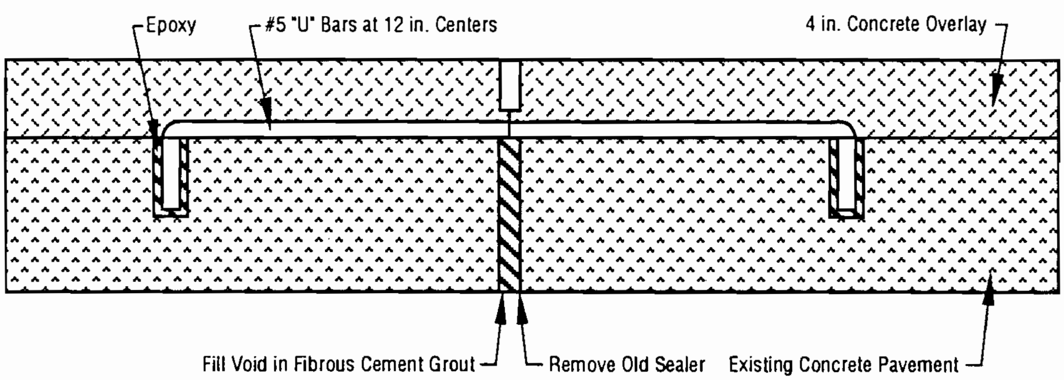

Fig 4.1. Stapling—a possible technique to prevent lateral movement.

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