

PERFORMANCE EVALUATION OF  
CONCRETE PAVEMENT OVERLAYS  
(CONSTRUCTION REPORT)



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PERFORMANCE EVALUATION OF  
CONCRETE PAVEMENT OVERLAYS  
(CONSTRUCTION REPORT)

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Technology Laboratory Section  
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With a large portion of the concrete highway system in need of major rehabilitation work, a renewed interest in concrete overlays has surfaced as a possible alternate to recycling the existing pavement. During 1984 the Department constructed two concrete overlays for the purpose of evaluating their performance compared to recycled pavement and to compare the long-term cost effectiveness of the two 'rehabilitation' systems. Also, the use of a thin sand-asphalt layer as a bond-breaker between the existing concrete surface and the new overlay would be evaluated with respect to controlling reflective cracking in the concrete overlay.

### Project Locations

One overlay (Project FRR 58034, Job No. 20915A, Federal No. MAFR 23-1 (312), Federal Item FJ 432), is located on US 23 in Monroe County from Ida Center Rd northerly to one mile north of M 50 and consists of 7.8 miles of freeway (Fig. 1). The other overlay (Project IR 34044, Job No. 20730A, Federal No. IR 96-2 (112) 67, Federal Item NPO 241) is located on I 96 in Ionia County and consists of 2.86 miles of eastbound and 5.45 miles of westbound I 96 beginning just east of M 66 easterly to the Grand River (Fig. 2).

### Existing Pavement Design

The overlaid US 23 pavement was constructed in 1959-61 and consists of a 9-in. thick reinforced concrete pavement with 99-ft joint spacing. The outside shoulder was sealcoated and the inside one was a Class A gravel shoulder. The joints were constructed with load transfer (1-1/4-in. diameter dowels, 18 in. long, on 12-in. centers) and the 1/2 in. by 2-in. formed joint grooves were originally sealed with a hot-poured sealant but have never been resealed.

The existing pavement on I 96 that was overlaid was built in 1958-59 and consists of 0.9 mi of 9-in. reinforced concrete and 2.0 mi of 8-in. continuously reinforced concrete on the eastbound roadway and 3.4 mi of 9-in. reinforced concrete and 2.0 mi of 8-in. continuously reinforced concrete on the westbound roadway. The 9-in pavement has dowelled joints (1-1/4-in. diameter dowels, 18 in. long, on 12-in centers) with 1/2 in. by 2-in. formed joint grooves initially sealed with a hot-poured sealant but which have not been resealed since. The existing shoulders consisted of a 2-1/2-in. bituminous mat over gravel.

Both the US 23 and I 96 pavements were constructed on a clay grade with a 10-in. sand subbase and a 4-in. aggregate base. The sand base extended to the ditch foreslopes to provide for 'daylight drainage.'

The average daily traffic volume (ADT) on US 23 was 18,200 with 16 percent commercial in 1981 and for the same year the I 96 ADT volume was 12,100 with 18 percent commercial.

Figure 1. Location of US 23 concrete overlay.

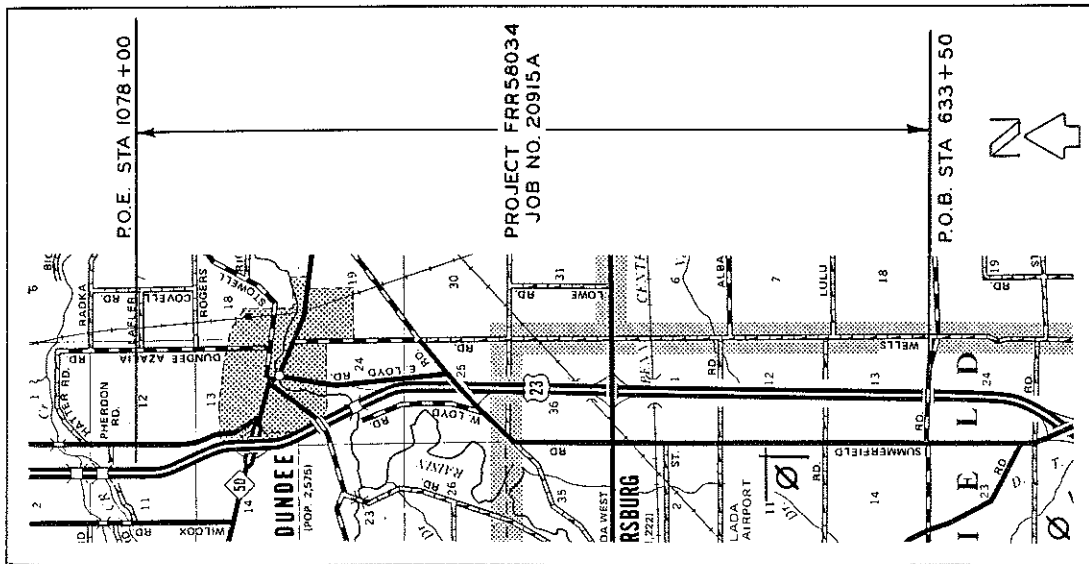
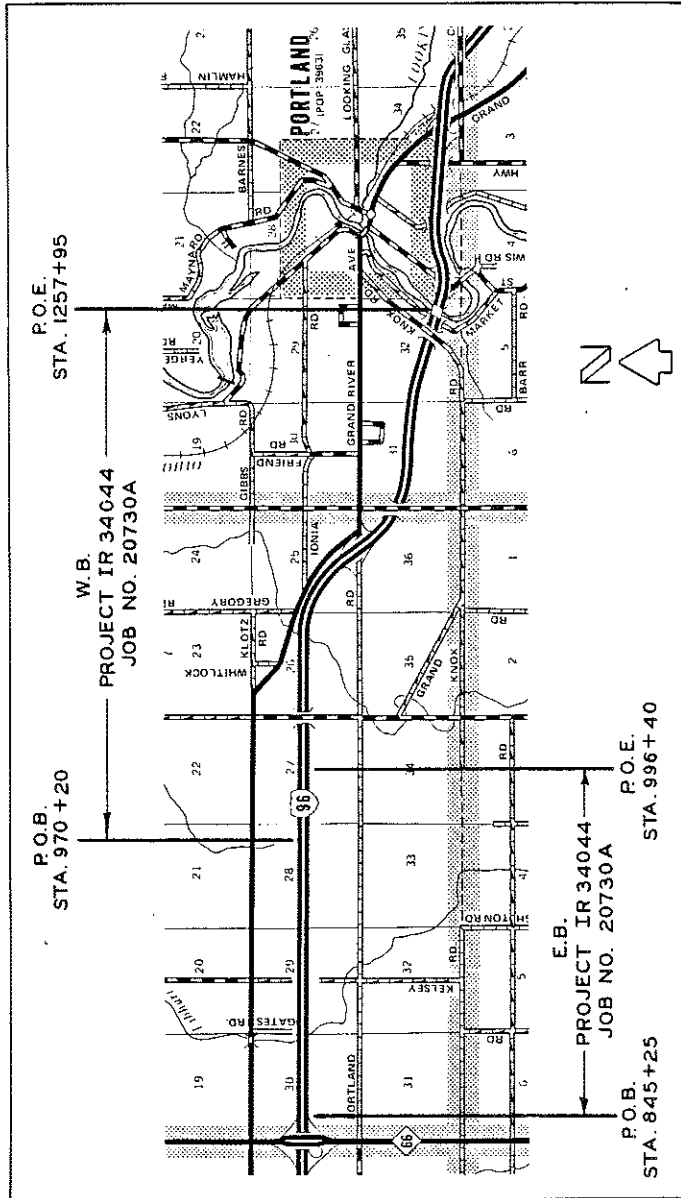


Figure 2. Location of I 96 concrete overlay.



## Overlay Description

The overlays were of the unbonded type. The bond-breaker consisted of a sand-asphalt mix (Bituminous Mixture No. 1100T, 35A). The placement rate varied from 80 lb/sq yd at the outer edges to 150 lb/sq yd at the pavement centerline to change from a parabolic crown to a straight line crown in the overlay.

Both overlays consisted of two 12-ft lanes of 7-in. reinforced concrete with reinforced concrete shoulders. The shoulder thickness tapered from 7 in. at the pavement edge to 6 in. at the outside shoulder edge. The width of the righthand concrete shoulder was ~~2~~ 9 ft on the I 96 project and 9 ft on the US 23 project; the lefthand shoulder width was ~~3~~ 5 ft and 5 ft on the I 96 and US 23 projects, respectively.

A grade 35P concrete with an anticipated 28-day compressive strength of 3,500 psi and flexure strength of 650 psi was used for the roadway lanes and a Grade 30P concrete was used on the shoulders. The I 96 overlay used a 6A gravel and the US 23 project used a 6A crushed limestone. Fly ash was used in the US 23 35P concrete mixtures at the rate of 72 lb/cu yd with 5.1 sacks of cement and a water reducer. The reinforcement for both the roadway and shoulders consisted of wire mesh weighing 6.3 lb/sq yd. The transverse joints in the roadway slab contain load transfer assemblies consisting of 1-1/4-in. diameter epoxy coated dowels 18 in. long and spaced on 12-in. centers. The shoulder joints were not dowelled. The longitudinal roadway centerline joint and the roadway-shoulder joints were tied with 24-in. long No. 5 epoxy coated deformed bars. The tie bar spacing in the centerline joint was 2 ft 6-3/4 in. and 4 ft 6-2/3 in. in the roadway-shoulder joints.

The transverse joints were required to be located at least 3 ft away from a joint or crack in the existing pavement slab. A maximum joint spacing of 41 ft was specified with reduced spacing permitted to conform to the location requirement with respect to cracks and joints in the underlying concrete slab. The shoulder slab lengths were adjusted to coincide with the pavement slab lengths. Rumble strips were formed in the center of every other shoulder slab.

Both transverse and longitudinal joints were constructed by sawing. The transverse joints in both mainline pavement and shoulders were sealed with a preformed neoprene seal. The seal extended across both the pavement and shoulder and down the edge groove of the shoulders (nominal groove size 9/16 in. wide by 2-1/8 in. deep). The longitudinal centerline and the pavement-shoulder joints were sealed with a hot-poured sealant (nominal groove size 1/4 in. wide by 1 in. deep).

At structures, a 224-ft length of the existing concrete slab was removed so the overlay could be transitioned down to meet the elevation of the existing bridge deck surface. A 235-ft long bituminous taper was used to meet the elevation of the existing slab at the project limits or at ramp

pavements. Since the clearance was good under structures on both projects, the 7-in. concrete overlay and debonding layer were carried under them with no special treatment.

#### Overlay Construction Procedure

Both overlays were constructed using central mixed concrete and slip-form pavers. A brief description of the procedure used by the two contractors follows:

Traffic - On both projects traffic was diverted to the other roadway during construction operations. To accomplish this, temporary median cross-overs were built and on the roadway carrying two-way traffic, striping delineators and signs were used to indicate no passing through the construction zone.

Underdrains - On the I 96 project the underdrains were installed prior to placing the bituminous bond-breaker course whereas on US 23 they were placed after the mainline pavement was constructed. The I 96 drains were plowed in, but on US 23 they were placed using a trencher. On both projects the 4-in. drain pipe was filter-wrapped and backfill material consisted of 2NS sand. Outlets were spaced at 500-ft intervals.

Bituminous Bond-Breaker - The bituminous bond-breaker course was placed without any special preparation work being done to the existing concrete pavement surface except on I 96 where the CRC pavement was sawed into 100-ft segments. On the US 23 project the bond-breaker was placed 24 ft wide whereas on the I 96 project the contractor elected to place it to a width of 28 ft. This allowed for a 2-ft apron on either side for the slipformer grade ski to travel on. On both projects the location of the transverse joints in the overlay were marked by spikes with red streamers set in the shoulder at both slab edges.

Load Transfer - The load transfer assemblies were held in position by using sheet metal clips fastened to the bituminous and concrete base with a 0.22 cartridge-driven nail. Nine clips on each 12-ft assembly were used on the I 96 project and on this job the assemblies were installed ahead of the paving train.

On the US 23 project the assemblies were installed just ahead of the front paver because the contractor elected to back up his concrete delivery trucks on the bituminous surface and deposit the concrete. Seven clips were used to hold each 12-ft assembly in place.

Concrete Placement Operations - The construction of the overlay pavement utilized the normal procedure for placing a concrete pavement. First the bottom layer of concrete was placed and the reinforcement was laid on top of it (on US 23 the concrete was placed full depth and the steel reinforcement vibrated into position). Then additional concrete was placed ahead of the second paver. Hand finishing of the surface followed and finally the surface was textured and a curing membrane applied.

Joints - Bent tie bars were installed manually in the overlay edges which were then straightened before the shoulder concrete was placed. The longitudinal centerline joint was tied using straight bars installed by use of a drop wheel mounted on the back of the first paver. Both longitudinal and transverse joint grooves were sawed. A hot-poured sealant was used in both the centerline and pavement-shoulder joint. The transverse pavement contraction and shoulder joints were sealed with a preformed neoprene sealant.

### Concrete Properties

The Department's specifications covering concrete pavement give requirements concerning slab thickness, reinforcement depth, concrete flexure strength, and concrete compressive strength. The flexure strength is determined by casting test beams from the pavement concrete and then breaking them after seven days cure in moist sand. Slab thickness, steel depth, and compressive strength are determined from cores taken through the slab after 28 days or more of curing time.

The distribution of these data along with the mean, standard deviation, and number of samples taken are shown on Figures 3 and 4 for I 96 and US 23, respectively. As can be seen, the average flexural strength on the I 96 project was 110 psi higher than the strength measured on the US 23 project. The average compressive strength was also slightly higher (150 psi) on the I 96 job. The anticipated flexural strength of 550 psi at seven days was met on I 96 and also on US 23 except for six beams which ranged in strength from 500 to 550 psi and two beams with a strength range of 450 to 500 psi. The minimum compressive strengths on both projects were well above the anticipated 3,500 psi 28-day strength.

The average slab thickness measured was 7.27 in. on both projects but the standard deviation was somewhat greater (0.39) on US 23 compared to 0.17 on I 96. The average steel depth and standard deviation were 3.83 and 0.58 and 3.45 and 0.52 on I 96 and US 23, respectively. Both slab thickness and steel depth on both projects met the specification requirements based on the prescribed sampling procedure.

### Cost Comparison

One of the objectives of this study is to determine the life cycle cost of a concrete overlay for the purpose of comparing it to the life cycle cost of a recycled concrete pavement. As a first step in determining these costs the initial construction cost needs to be calculated. Since, to date, only two concrete overlays and four recycled concrete pavements have been built, the current cost data available may not as yet reflect the lowest prices at which overlaying and recycling can be done. As contractors acquire more experience, and better equipment is developed, it is possible that the cost for these pavement types may be reduced somewhat.

The bid proposals for the projects let to date contain from about 80 to well over 100 individual items for which the contractors must give



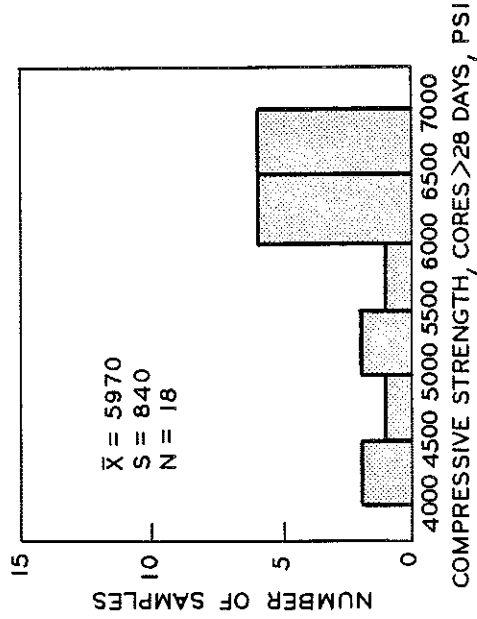
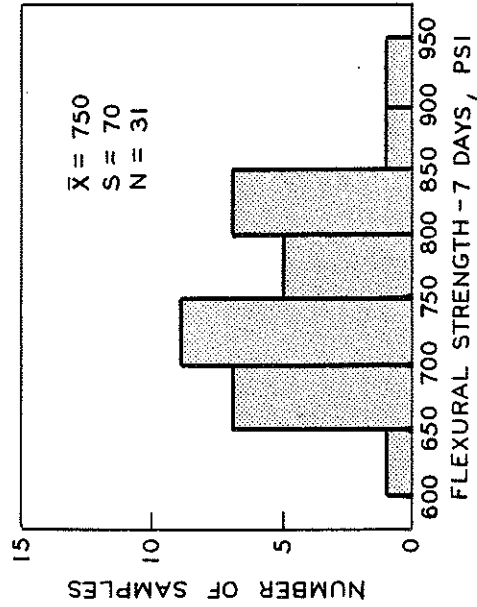
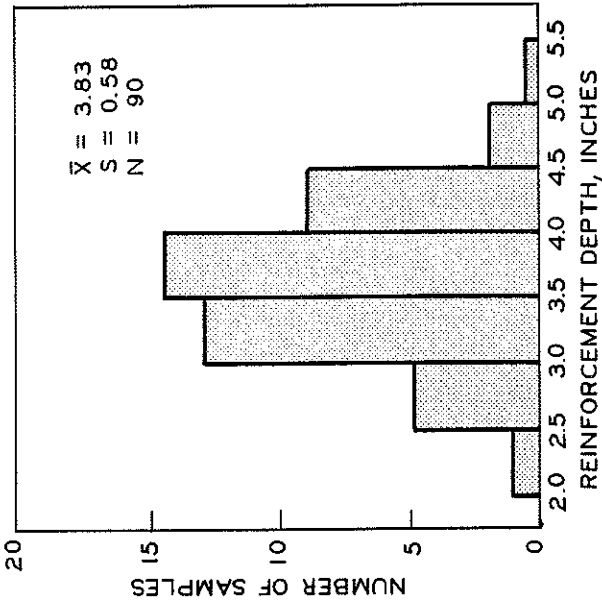
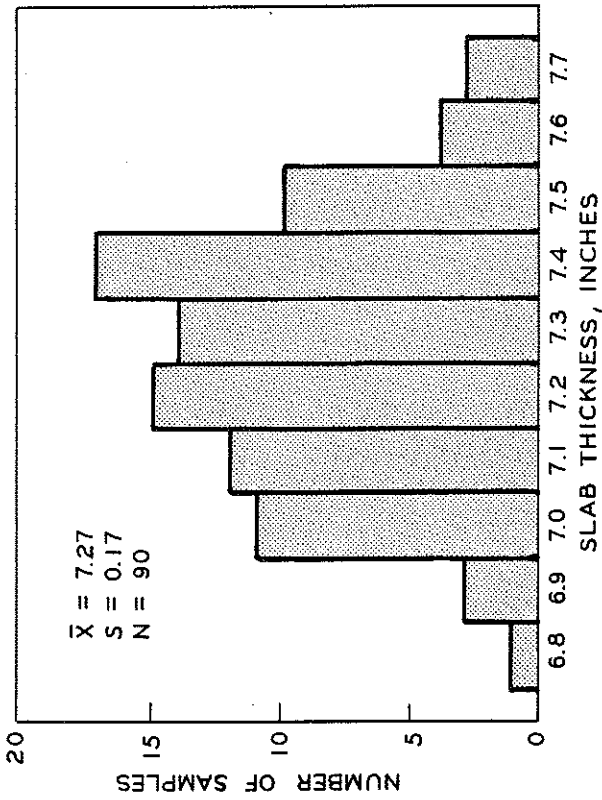


Figure 3. Distribution of slab thickness (top left), reinforcement depth (top right), concrete flexure strength (bottom left), and concrete compressive strength (bottom right) on I 96 concrete overlay.

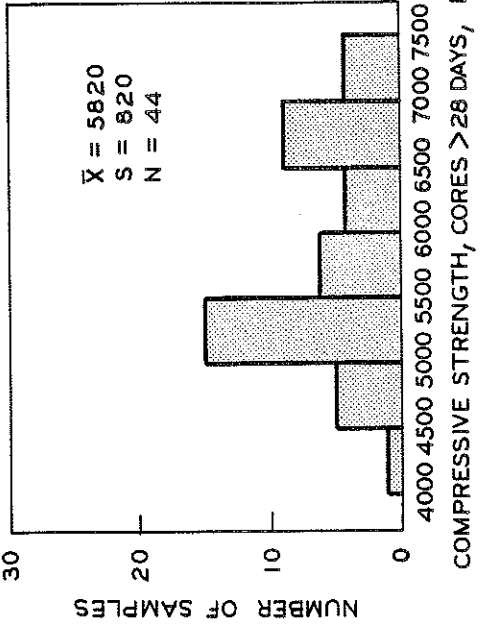
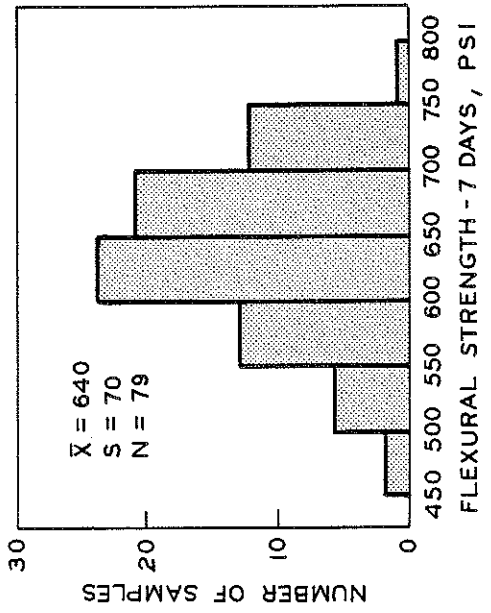
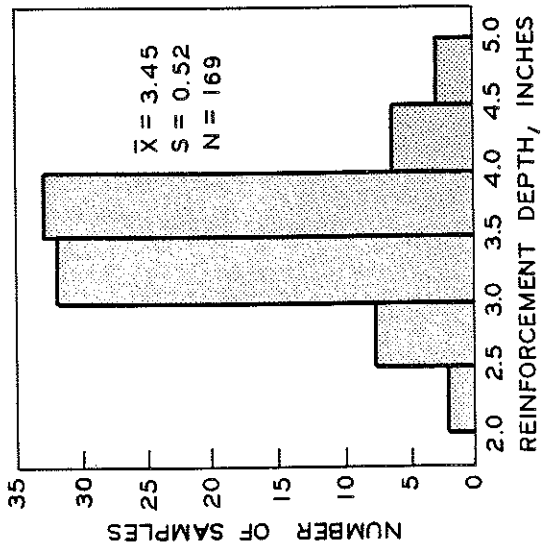
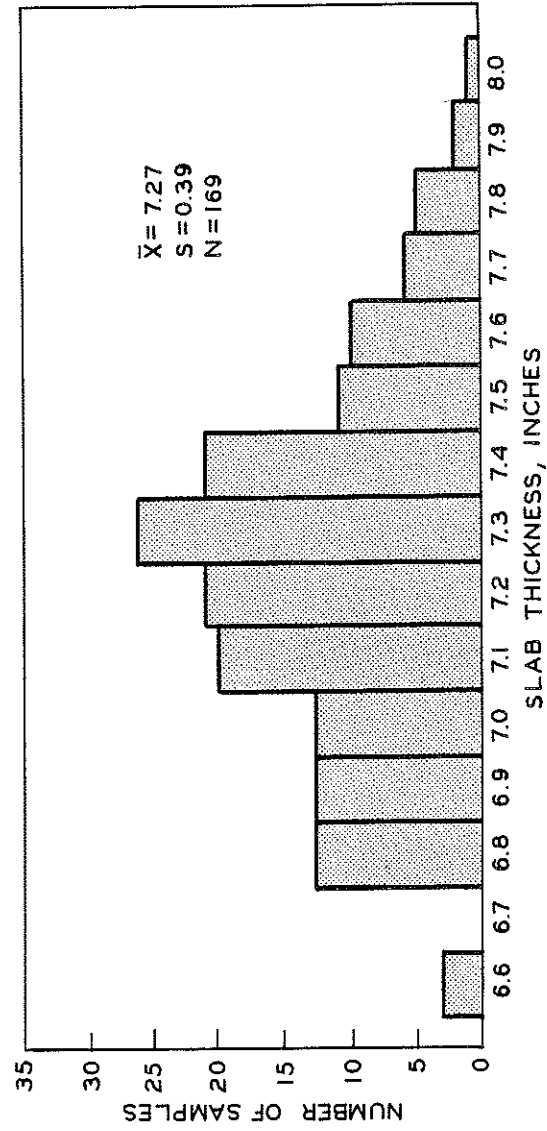


Figure 4. Distribution of slab thickness (top left), reinforcement depth (top right), concrete flexure strength (bottom left), and concrete compressive strength (bottom right) on US 23 concrete overlay.

unit prices. Examination of the bid unit prices reveals considerable variation among the bidders for the same bid item. Such variations make it difficult to obtain the true cost for a particular item. Also the size of the project and traffic volumes certainly will affect the cost of a project. Although, as mentioned, unit prices vary among bidders, it appears that using these prices for just the items contributing to the cost per sq yd of pavement is closer to the real cost than using cost per mile of roadway. The bid prices for the four recycled and two overlay projects are as follows:

Recycled Pavement, 10 in. - \$15.56 (1.56) and \$16.30 (1.63) per sq yd  
 Recycled Pavement, 11 in. - \$18.88 (1.72) and \$19.36 (1.76) per sq yd  
 Overlay Pavement, 7 in. - \$11.89 (1.69) and \$15.36 (2.19) per sq yd

The cost figures in parentheses are the cost per inch of depth of concrete per sq yd. As can be seen the variation in these costs is relatively small except for one of the overlays.

For the recycled concrete the unit prices include the cost of removing and crushing the existing concrete slab, reshaping the base, transverse joints and the reinforced concrete. For the overlays the cost of the bituminous bond-breaker course, transverse joints, and the reinforced concrete are included in the cost per sq yd.

#### Performance Evaluation

A total of eight test sections, each 2,000 ft long were established prior to beginning the construction of the two overlay projects. Two test sections representing the range in condition of the existing concrete pavement were set up on each roadway of both the US 23 and the I 96 overlay. On the I 96 project one test section on each roadway was selected in the CRC portion of the existing pavement. As mentioned previously, the CRC pavement was sawed into slab lengths of 100 ft maximum to reduce movement at previously placed repairs and steel fractures.

The location of the test sections are:

<u>Route</u>	<u>Roadway</u>	<u>Test Section No.</u>	<u>Sta. to Sta.</u>
US 23	Southbound	A	975+00 - 955+00
US 23	Southbound	B	775+00 - 755+00
US 23	Northbound	C*	774+97 - 792+97
US 23	Northbound	D	957+31 - 977+29
I 96	Westbound	A	1238+90 - 1218+90
I 96	Westbound	B**	1018+00 - 998+00
I 96	Eastbound	C**	867+84 - 887+84
I 96	Eastbound	D	957+00 - 977+00

\* Section C only 1800 ft long

\*\* Existing CRC Pavement

Since the length of slab segments, the location of points of movement, and the deteriorated conditions of the existing pavement may affect the performance of the overlay and the bond-breaker layer, information on these factors was obtained prior to beginning the construction operations. First, a reference line was established at the beginning of each test section and each joint and crack with fractured steel reinforcement (cracks acting as joints) were located with respect to the reference line. From these measurements the length of slab segments contributing to movement at cracks and joints in the existing pavement was obtained. A distribution of the slab segment lengths in the traffic lane for the US 23 project is shown in Figure 5 and for I 96 in Figure 6. As can be seen in Figure 5, Sections A and D on US 23 contain mostly slab segments in the 10 to 20 and 20 to 30 ft length group, whereas the segment lengths in Sections B and C are more distributed. Slab segment lengths in Sections A and D on I 96 (Fig. 6) are also fairly well distributed. The slab lengths in Sections B and C in the CRC pavement are generally longer than those in the jointed pavement. As shown in Figure 6, more than 50 percent of the slab segments in these sections are over 60 ft in length.

The deteriorated condition of joints and cracks was rated using the procedure and definitions given in the Department's concrete pavement survey manual. Figures 7 and 8 give the description and severity levels for joint and crack conditions, respectively. Severity Level 5 for cracks is not included in the survey manual but has been added so information on the total number of transverse cracks would be available. The photographs shown in Figures 7 and 8 are from the US 23 project.

In addition to locating joints and cracks in the test sections, previous repairs and pressure relief joints were also located. Since the joints at repairs and the relief joints were basically free of deterioration they were not rated with respect to current condition. A typical repair condition is shown in Figure 9. The deteriorated condition of joints and cracks for test sections in the jointed pavement is summarized in Table 1. As can be seen, the US 23 test sections show more deterioration than the I 96 sections. However, it should be noted that Section D on I 96 had previously been extensively repaired which would reduce the severity of the rated surface defects.

The condition of the CRC pavement in test sections B and C is shown in Figures 10 and 11. As shown in Figure 10, the transverse cracks exhibited medium to heavy spalling and patching in some areas and only minor spalling and patching at other locations. Six failed areas were previously repaired with undowelled joints in Section B and seven areas in Section C. The condition of the centerline joint, Figure 11, in the CRC sections was generally good with only minor patching. The condition of the centerline joint on the sections in the jointed pavement (Fig. 12) varied from minor to medium to heavy patching and fracture of the tie bars was evident because of separation of the slabs.

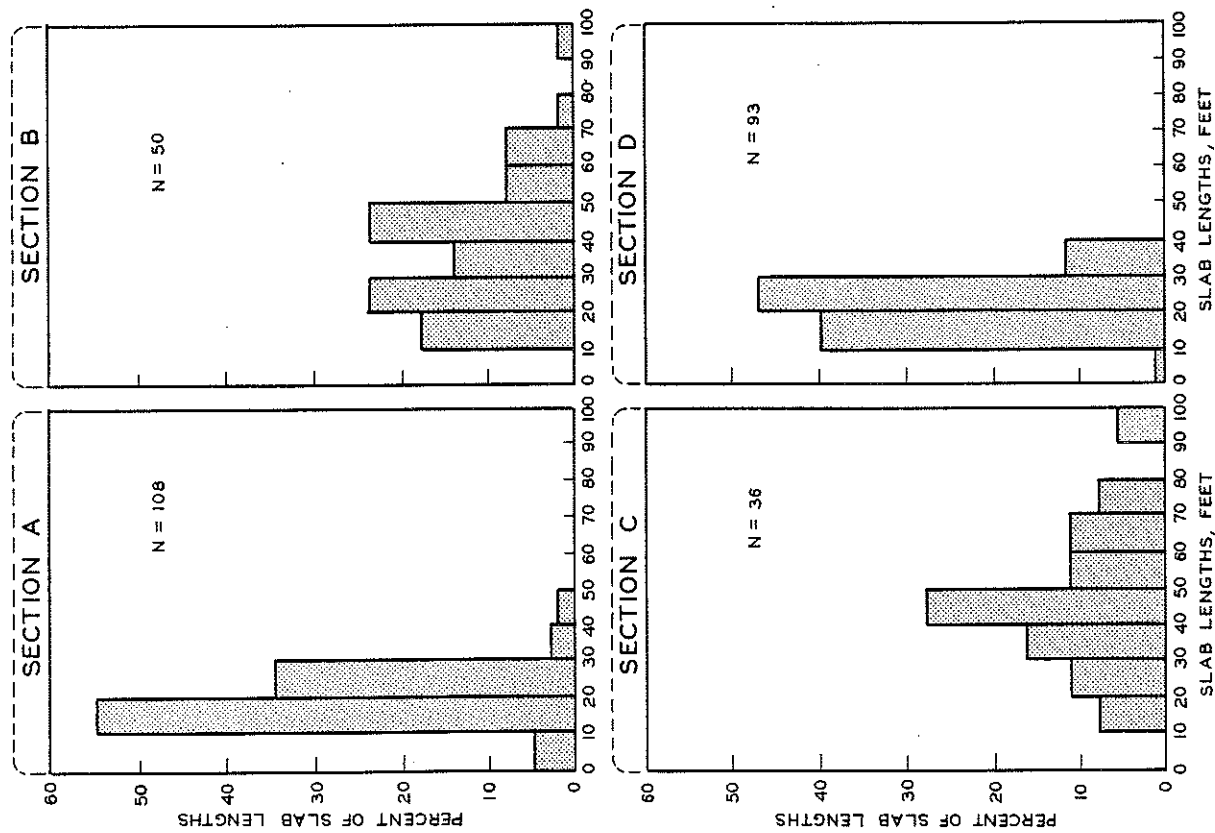


Figure 5. Distribution of slab lengths in the traffic lane contributing to movement at cracks and joints in the overlaid standard concrete pavement on US 23.

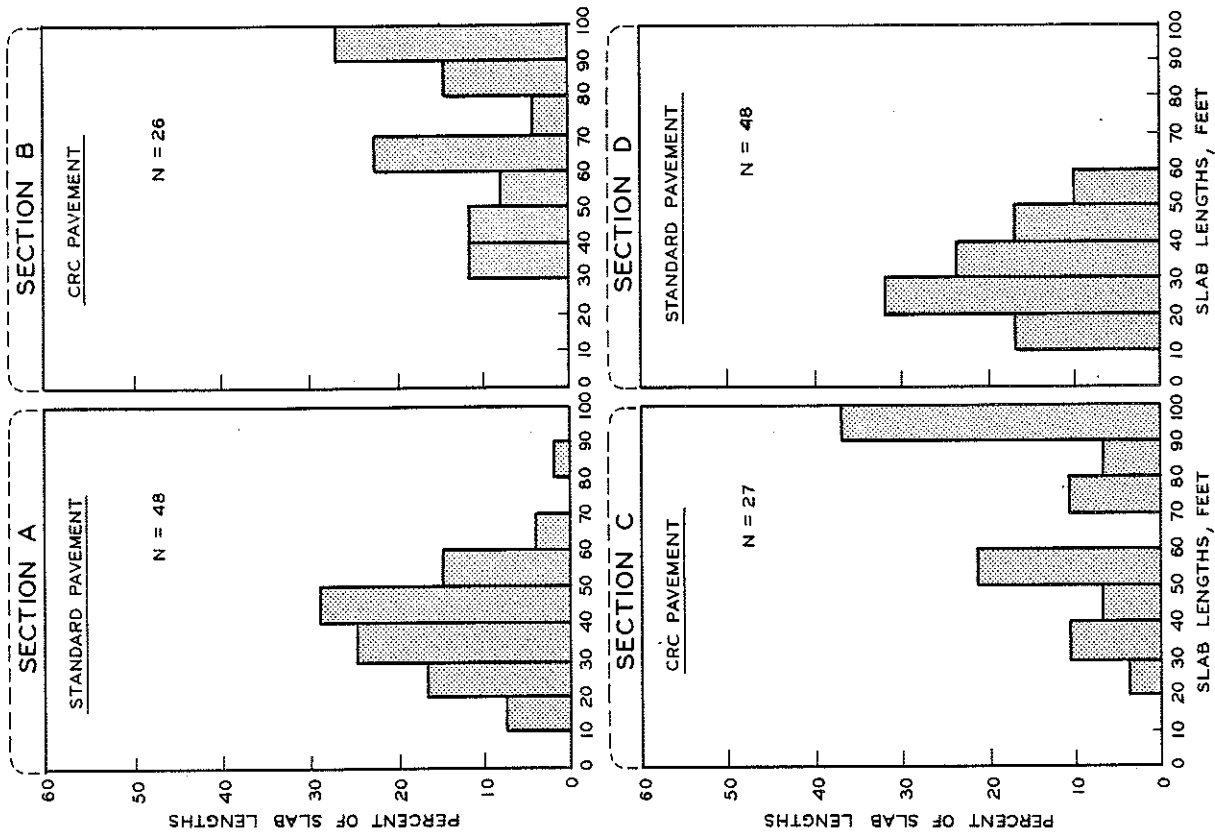
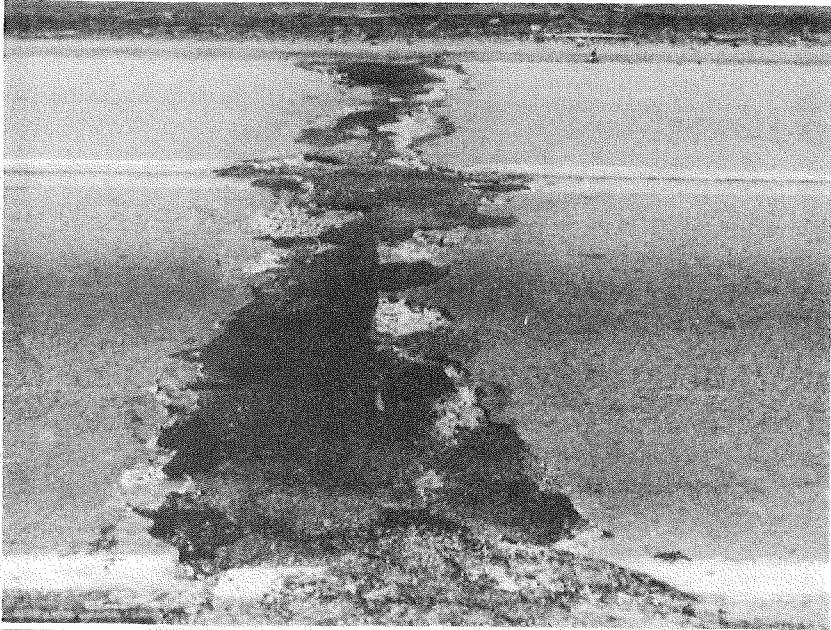
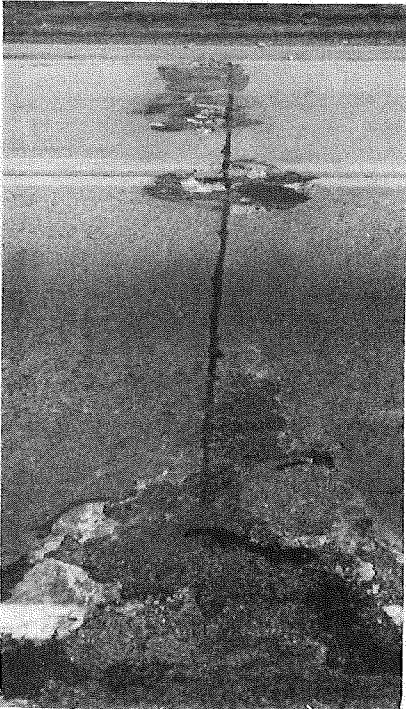


Figure 6. Distribution of slab lengths in the traffic lane contributing to movement at cracks and joints in the overlaid standard and CRC pavement on I 96.

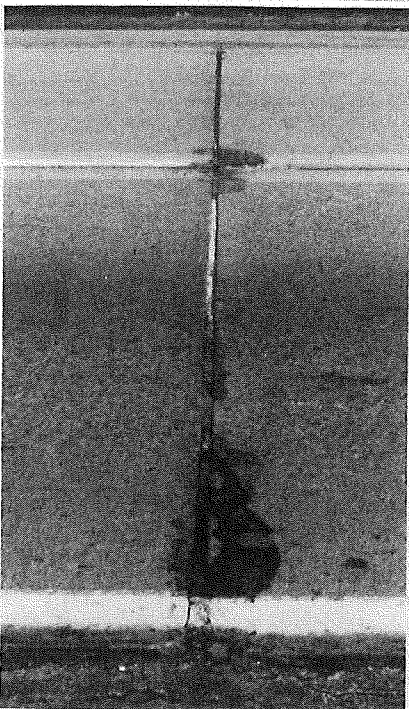
Description: Failure of the transverse joints is the spalling, breaking, or buckling of the concrete along one or both edges of the joint groove for a total width of 4 in. or more. Failures normally occur gradually and are maintained by temporary bituminous patching.



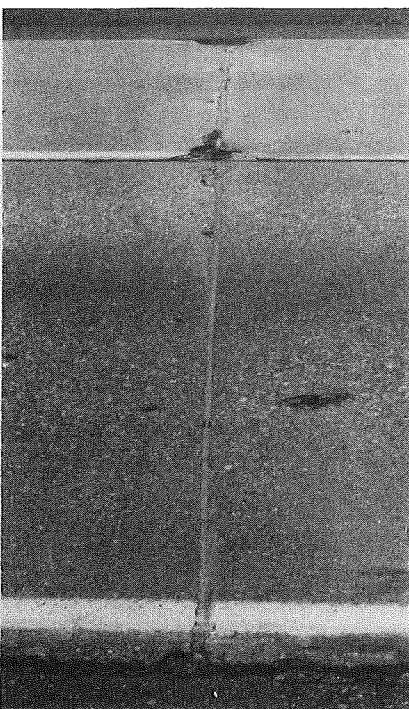
Severity Level 1-From 6 to 12 ft of spall or bituminous patching.



Severity Level 2-From 3 to 6 ft of spall or bituminous patching.



Severity Level 3-From 1 to 3 ft of spall or bituminous patching.

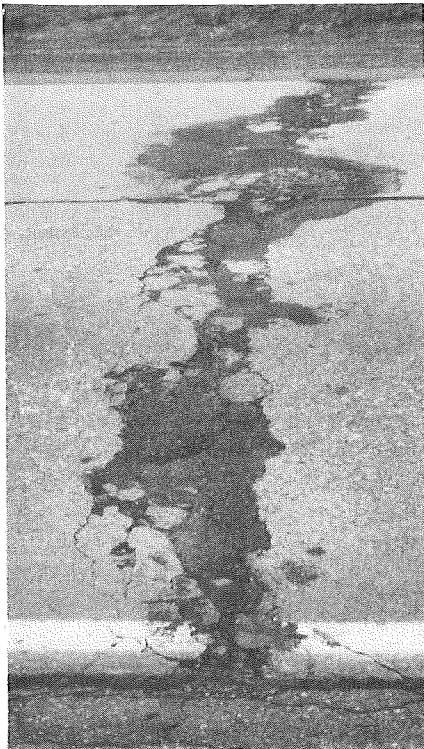


Severity Level 4-From 0 to 1 ft of spall or bituminous patching.

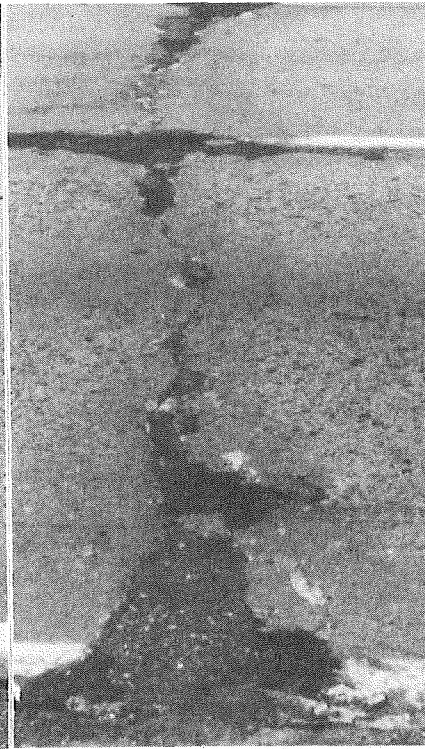
Figure 7. Description of transverse joint failure and severity levels.



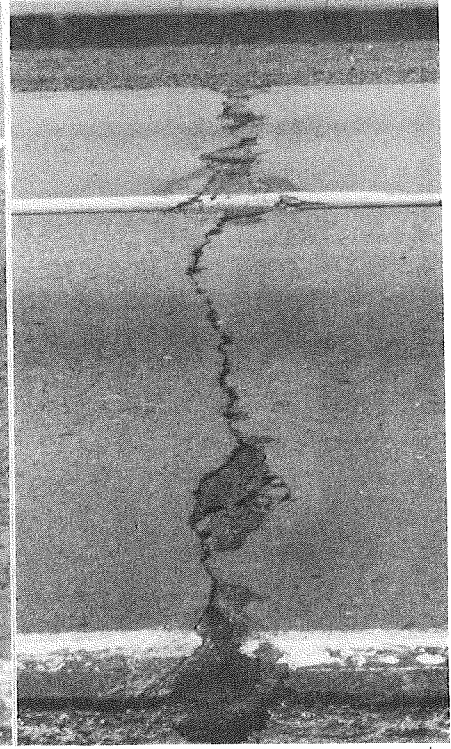
Description: An open transverse crack is a small gap in the pavement slab between joints. The reinforcement has fractured and the crack acts as a joint. Normally the width of the crack must be 1/4 in. or more to be considered open. Spalling, bituminous patching, and faulting may have occurred.



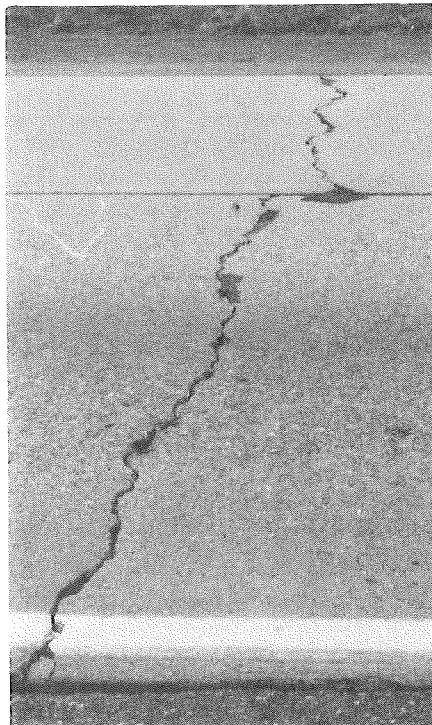
Severity Level 1-From 6 to 12 ft of spall or bituminous patching. Faulting may have occurred.



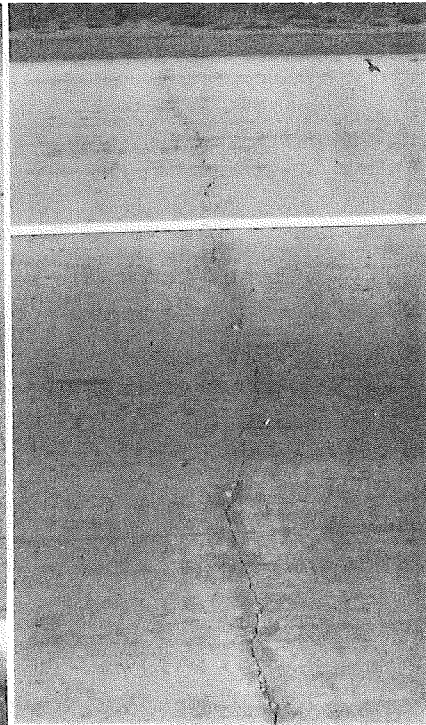
Severity Level 2-From 3 to 6 ft of spall or bituminous patching. Faulting may have occurred.



Severity Level 3-From 1 to 3 ft of spall or bituminous patching. Faulting may have occurred.



Severity Level 4-From 0 to 1 ft of spall or bituminous patching. Faulting may have occurred.



Severity Level 5-Transverse cracks with only minor spalls and reinforcement still intact.

Figure 8. Description of transverse crack deterioration and severity levels.

Table 1  
Number of Joints and Cracks in the Traffic and Passing Lane in  
Each Severity Distress Level

Route	Test Section No.	Severity Levels																	
		Traffic Lane									Passing Lane								
		Joints				Cracks					Joints				Cracks				
		1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	5
US 23	A	18	0	1	0	64	14	3	1	15	18	0	1	0	49	10	4	7	9
US 23	B	14	4	3	0	14	8	6	0	30	18	2	1	0	7	5	5	1	7
US 23	C	7	4	7	1	14	4	5	0	26	18	1	0	0	8	2	1	1	9
US 23	D	18	0	0	1	36	20	10	3	29	14	5	1	0	26	10	10	4	17
I 96	A	10	6	1	2	7	3	7	10	44	5	10	4	0	7	9	6	9	27
I 96	D	6	1	4	0	7	14	7	2	39	4	3	5	0	9	8	12	2	27

Note: The condition of the I 96 CRC pavement test sections is not included in the table but is discussed in the text.  
Sections A and D on I 96 contain 2 and 23 repairs, respectively. Section A on US 23 contains 2 pressure relief joints and 4 repairs. Sections B, C and D on US 23 contain 3, 2 and 2 pressure relief joints, respectively.

Following placement of the overlay the reference line at the beginning of each test section was re-established and the locations of the joints in the overlay were determined. Knowing the overlay joint locations and the locations of the existing joints, cracks, and deteriorated condition of the underlying pavement, it may be possible to relate the cause of cracks in the overlay (should they occur) to slab segment length or deteriorated condition of the old concrete pavement. Twenty joints in each test section were instrumented with stainless steel gage plugs for measuring horizontal and vertical movement at the joints. The horizontal measurements are planned to be taken summer and winter and the vertical once in the summertime only. A crack survey is scheduled to be conducted each winter. Should cracks be found they will be accurately located by measuring to the nearest joint. These data will be included in subsequent reports.



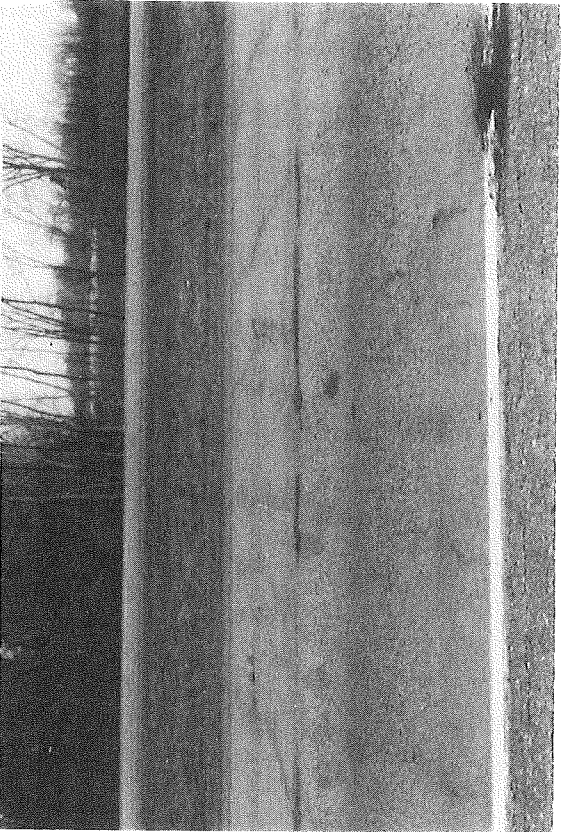


Figure 9. Typical condition of undoweled repairs located within the test section limits.

Figure 10. The condition of the I 96 CRC pavement ranged from medium (top) to minor spalling and patching of the transverse cracks (bottom).



Figure 11. The longitudinal joint in the CRCP test sections exhibited only minor to moderate spalling and patching and only occasional areas where the joint had separated.

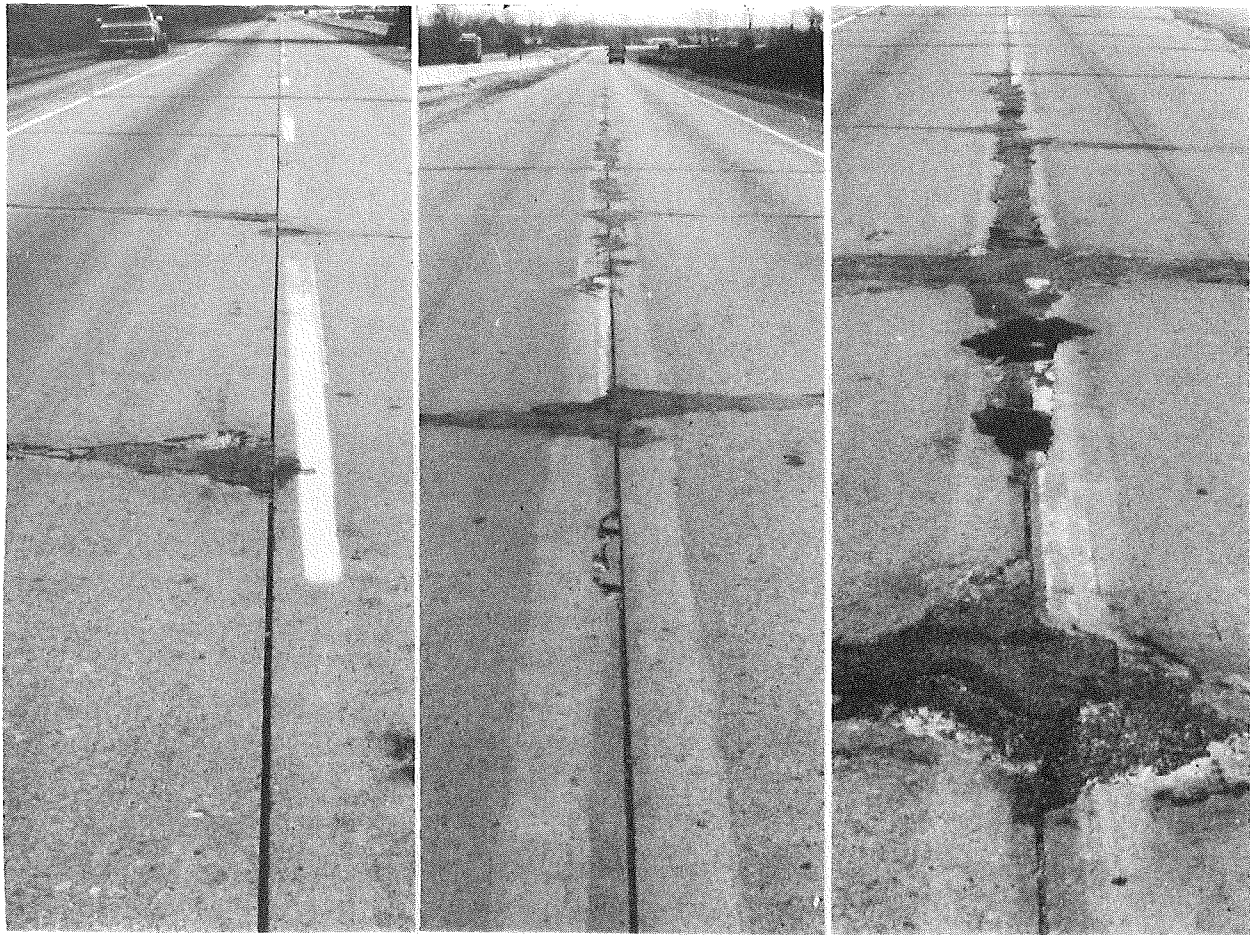


Figure 12. Condition of the longitudinal joint varied from basically no spalling (left) to medium spalling and patching (center) to heavy spalling and patching (right). Throughout most of the test sections' lengths separation of the joint had occurred indicating that the tie bars had fractured.