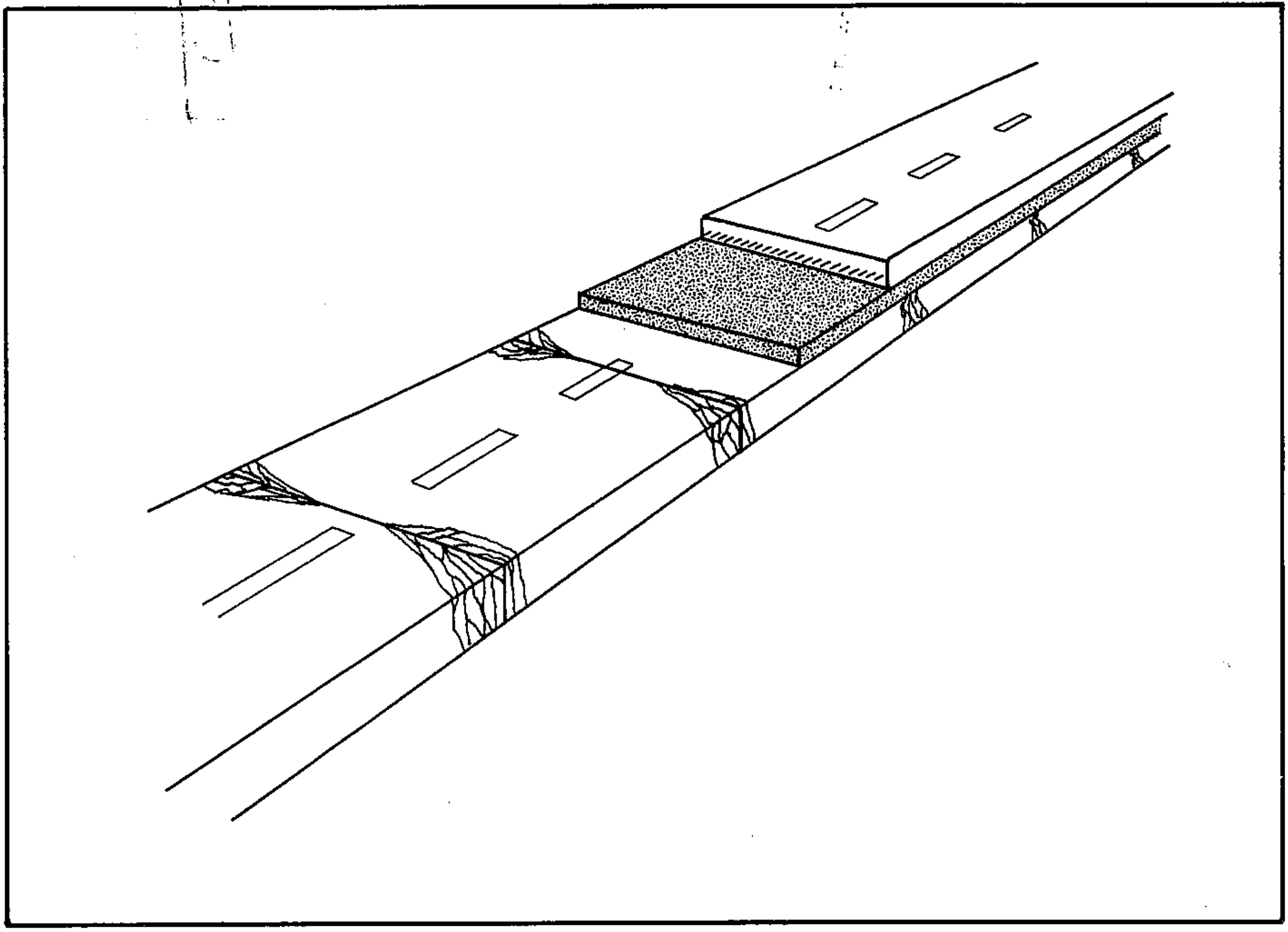

Performance Evaluation of Concrete Overlays

Final Report

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This study conducted in cooperation with the U. S. Department of Transportation, Federal Highway Administration.

16. Abstract

This paper describes and summarizes the performance of three unbonded Continuously Reinforced Concrete Pavement (CRCP) overlays of existing jointed pavements. One project studied has performed for over 20 years with a variety of CRCP overlay thickness and steel percentages. Also studied was one concrete overlay or "white topping" of an existing flexible pavement. Traffic on the CRCP overlays ranged from 1,150,000 to 17,000,000 ESALs while the "white topping" received approximately 89,300 ESALs.

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FINAL REPORT

IHR-516

PERFORMANCE EVALUATION OF CONCRETE OVERLAYS

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I. INTRODUCTION

The State of Illinois has constructed approximately 12 two-lane miles of unbonded concrete overlays since 1967. At the time of construction several concerns were expressed as to performance and life expectancy of PCC overlays. Several of these overlays are nearing the end of their service life; therefore, this study was conducted to review the cost effectiveness of this strategy when compared to reconstruction or other rehabilitation techniques.

The main objective of this study was to determine performance of existing concrete overlays, construct new concrete overlays to give contractors and the Department experience with construction methods, and to monitor the performance of new overlays.

Unfortunately, suitable sites for constructing new overlays could not be found in time to be included in the study. Therefore, the scope of the study was reduced to a performance evaluation of previous unbonded PCC overlays on I-70, I-55, and Rock Island County Highway 63.

II. PAVEMENT EVALUATION SECTIONS

Four projects, which were located on Interstate Routes 55 and 70 and on Rock Island County Highway 63 were evaluated. The three sections constructed on Interstate highways were unbonded continuously reinforced concrete (CRC) overlays placed over existing jointed reinforced concrete pavements (JRCP). The Rock Island County Highway 63 project consisted of constructing a jointed plain concrete (JPC) overlay over an existing flexible pavement.

Project Number 1

This project is located on Interstate 55 south of Springfield, Illinois between milepost 89.00 and 91.61 and has three lanes of traffic in each direction. The sections evaluated are located in inner passing lanes and a portion of the center lane. The exact limits of the sections are from stations 167+00 to 236+00 and stations 245+00 to 259+00 in the northbound lanes and from stations 159+00 to 237+00 and stations 244+60 to 261+50 in the southbound lanes. Current two-way traffic on this section averages 24,600 vehicles per day with 15 percent trucks. The pavement overlaid was part of former US 66 and consists of a 9-9-7-9-9 jointed concrete pavement placed on grade which was widened to 24 feet and overlaid with approximately 8 inches of bituminous resurfacing.

In 1970, the construction of I-55 resulted in a CRC overlay of the jointed pavement. A minimum 4-inch bituminous aggregate mixture (BAM) layer was placed on the existing pavement and a new 8-inch CRC overlay placed over it. No pipe underdrains were installed. Figure 1 details the pavement cross-section on Project 1.

Project Number 2

This project is located on Interstate 55 north of Springfield, Illinois between mileposts 105.52 and 108.03 and consists of three lanes of traffic in each directions. The concrete overlay is located in the northbound driving and center passing lanes from stations 1250+06 to 1267+00 and 176+84 to 262+10. Currently two-way traffic on this project averages 17,000 vehicles per day with 22 percent trucks. The pavement overlaid was part of former US 66 which consisted of a 10-inch JRCP over a 6-inch granular subbase.

In 1974, the construction of I-55 resulted in a CRC overlay of the jointed pavement. A minimum 4-inch BAM layer was placed on the existing jointed pavement and a new 9-inch CRC pavement paved over it. Pipe underdrains were also installed to facilitate drainage. Figure 2 details the pavement cross-section on Project 2.

Project Number 3

This project is located on Interstate 70 west of Pocahontas, Illinois between milepost 31.38 and 35.19 and consists of two lanes of traffic in each direction. The experimental sections are located in the westbound lanes only. Currently two-way traffic on this section averages 14,000 vehicles per day with 34 percent trucks. The pavement overlaid was part of former US 40 and consisted of a 10-10-8-10-10 jointed pavement on grade. Previous resurfacing projects resulted in approximately 6 inches of bituminous surface material being placed over the original concrete pavement.

In 1967 the construction of I-70 resulted in a CRC overlay of the jointed pavement. The existing pavement was widened and a leveling BAM subbase was placed over the existing pavement and widening. This resulted in a smooth subbase, which permitted proper pavement thickness tolerances to be achieved when the new CRC overlay was placed. Three thicknesses and three different steel percentages were used in the overlay experiment. The experimental sections included an 8-inch CRC overlay with 0.6 percent steel for control, a 7-inch CRC overlay with 0.7 and 1.0 percent steel, and a 6-inch CRC overlay with 0.7 and 1.0 percent steel. Figure 3 details the pavement cross-section and Figure 4 details the experimental layout of the pavement section.

Paving started on May 4, 1967, and was completed on May 23, requiring a total of ten working days. During the paving operation, the average low temperature was 50° F., and the average high temperature was 71° F. No rain occurred during this period. Construction details have been reported in a previous report (1).

Project Number 4

This project is located near Sherrard, Illinois on Rock Island County Highway 63 in Rural Township from Knoxville Road to the Merçer County line for a length of 3.0 miles and consists of two lanes, one in each direction. Currently, the traffic on this section averages 1200 vehicles per day. The existing pavement in need of rehabilitation was a conventional flexible pavement consisting of 10 inches of aggregate base course and a 2.5-inch bituminous surface.

In 1983 a minimum 5-inch jointed plain concrete overlay was constructed over the existing flexible roadway. A maximum of 20 feet was maintained between contraction joints. Figure 5 details the pavement cross-section for Project 4.

III. PERFORMANCE OF PAVEMENT SECTIONS

Detailed crack surveys were conducted on all projects. From the detailed crack surveys, crack spacing and patching quantities were determined. The patch quantities and crack spacings for Projects 1 through 3 are summarized in Tables 1 and 2, respectively.

Roadometer testing was performed on Projects 1 through 3 to determine the relative roughness of the pavements. The results from these tests are summarized in Table 3.

In addition, Falling Weight Deflectometer (FWD) testing was performed on Project 3 during March, 1987. Testing was done at the edges, both wheelpaths, and at patch joints. Table 4 lists the average 9 kip deflections and standard deviations for each experimental section.

Finally, the accumulated 18 kip equivalent single axle loads (ESALs) carried by each section were calculated using traffic data. The accumulated ESALs carried by each section are broken down by their lane distribution and summarized in Table 5.

Project Number 1

Overall pavement performance of this section, which was constructed in 1970, has been good. The 1986 Condition Rating Survey (CRS) gave the section a 6.5 rating. The CRS scale ranges from 1 (failed), to 9 (excellent). The rating is slightly below the 1985 interstate average of 6.9. A small amount of maintenance patching has been done on the study and control sections. Differences in study and control section patching quantities shown in Table 1 should not be viewed as significant since patch quantities are very small. The pavement priority on this project is in the "greater than 10-year" group. The pavement priority is a measure of rehabilitation needs and use for planning funding needs.

Project Number 2

This project is the best performing of the four investigated to date due to its young age and also being the thickest pavement. The 1986 CRS gave this section a 7.2 rating. No patching has been done on this project to date. Material source records indicate that the coarse aggregate used is D-cracking susceptible. For this reason, the pavement priority is in the 5-year to 10-year range despite its current performance.

Of note on this project, was the existence of "Y" or birds feet cracking. This is where one crack would branch out into 2 or 3 cracks from the center to the edge of lane. To date, this has not caused any distress and seems to be confined to the overlay lanes.

Project Number 3

This project has served for over 20 years and the 6-inch overlay is reaching the end of its service-life. Percent steel did not seem to affect the performance of the sections other than reducing the average crack spacing. However, this did not seem to influence any distress which required patching. Overlay thickness did have a great influence on the amount of pavement patching which ranged from 7.3% for the 6-inch section to 0.0% for the 8-inch section.

As noted in an earlier report (1) longitudinal cracking was noted early in the project's life. This has been attributed to the widening of the existing pavement prior to overlay. A substantial amount of the patching in the 6- and 7-inch sections was to replace the areas in which the longitudinal cracking was located.

Also recommended in the earlier performance report (1) was the use of a minimum CRC overlay of 7 inches. Performance of the sections confirms that a 7-inch section will perform better than the 6-inch section. This may be partly due to the difficulties previously noted by the report in steel placement and concrete consolidation. The performance of the sections justify the additional cost of the use of a 7-inch minimum CRC concrete overlay.

It was hoped that deflection testing would provide some insight into the longitudinal cracking failure mode. Void detection procedures using the Falling Weight Deflectometer (FWD) failed to indicate any voids or non-uniformity of support with regard to the longitudinal cracking. Results of the testing are presented in Table 4.

The 1986 CRS rating on the project was 5.7 with a pavement priority of 3-5 years. The performance of the various thicknesses would seem to indicate that a thickness design procedure is appropriate.

This section was overlaid during the Fall of 1988 and Spring of 1989 after 21 years of service. The eastbound lanes, which were constructed at the same time, but consisted of a new 8" CRC pavement, were overlaid at the same time.

Project Number 4

A detailed condition survey was performed on this project on August 25, 1988. Overall, the pavement was in very good condition structurally and the pavement was very rough. However, some areas did exhibit longitudinal cracking. Most of the longitudinal cracks were of low severity with the exception of an 87-foot long, high severity crack which began at the west edge of the pavement and wandered to the middle of the southbound lane before terminating at the west pavement edge. The width of this crack was approximately 0.75 inch. The low severity longitudinal cracks appear to be caused by late sawing of the centerline joint, whereas the high severity crack is probably due to inadequate support at the pavement edge.

The performance of all the concrete overlays has been good. There is one factor which may contribute to the performance of CRC overlays of existing concrete pavements. That is the use of Bituminous Aggregate Mixtures (BAM) for subbases or interlayers . However, since all sections (projects 1, 2 and 3) used bond-breaking layers in the range of 4-8 inches, it is difficult to determine how much, if any, contribution is made by the BAM layer.

IV. CONCLUSIONS

The sections evaluated indicate that concrete overlays of existing pavements should perform well for at least 20 years with one project surviving over 17 million ESAL applications.

Although these projects did not demonstrate the necessity of an interlayer, due to the thickness of bituminous material used, from Illinois' good experience, it would seem a substantial interlayer is required to provide a uniform cross section and support under a CRC overlay. Other research (8, 11) has shown that distress from the overlaid pavement may reflect through the overlay.

Laboratory testing of bituminous "bond breakers" (13) indicate that thin bituminous layers result in very high friction between layers and, in effect, bond the layers together. The laboratory testing also indicated that "when a bituminous treated base is used, the results are highly dependent on loading rate and temperature." Not studied to a great extent was the effect of thickness of bituminous materials on interlayer friction. It would seem that the same factors that effect viscosity of liquids between sliding plates would effect the bituminous "bond breaker" interlayer, of which thickness is a major variable.

Care should be taken in selecting pavements to be overlaid. The overlay should be the same width as the pavement being overlaid. This would have prevented a great deal of distress which shortened the pavement life and eventually required patching and overlay on Project 3.

As expected, increased thickness provides increased performance. This seems to indicate that a thickness design procedure would be appropriate for CRC overlays. However, it is felt that the data presented herein is not sufficient to develop a procedure. Perhaps this information can be used with pavement modeling techniques in the future to develop a procedure if desired.

Concerning the design of concrete overlays of flexible pavements, as in Project 4, current pavement design procedures can be used for thickness determination.

In CRC overlays, there seems to be little influence of steel percentage on performance. Current reinforcement percentages used in pavements and current construction practices should be adequate.

V. RECOMMENDATIONS

- Concrete overlays should be made to the same width and alignment as the pavement being overlaid.
- Further work is needed over a large range of interlay thicknesses and types to determine factors influencing performance and proper design.
- A CRC overlay design procedure will require more research with pavement modeling. The data presented may be used to confirm the procedure.
- For designing concrete overlays, of flexible pavements, current design procedures may be used. However, a study of each project is recommended as to possible thickness reductions depending upon the cross-section of the existing pavement.
- The design steel percentage for CRC overlays may be the same as used in normal pavement design procedures.

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ACKNOWLEDGMENTS/DISCLAIMER

This paper is based on the results of Project IHR 516 - Performance Evaluation of Concrete Overlays.

IHR 516 was sponsored by the Illinois Department of Transportation (Division of Highways) and the U. S. Department of Transportation (Federal Highway Administration).

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

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TABLE 1: PATCHING QUANTITIES IN EXPERIMENTAL AND CONTROL SECTIONS AS OF 1986

Project Number	Pavement Thickness	Steel Percentage	Percent Patching in Concrete Overlay Experimental Section	Percent Patching in Conventional Construction Control Section
1	8"	0.6	0.1	0.8
2	9"	0.6	0.0	0.0
3	6"	0.7	7.3	N/A
3	6"	1.0	4.9	N/A
3	7"	0.7	0.6	N/A
3	7"	1.0	2.3	N/A
3	8"	0.6	0.0	N/A

N/A - Not applicable.

TABLE 2: TRANSVERSE CRACK INTERVAL HISTORY

Project Number	Pavement Thickness	Steel Percentage	Average Crack Interval (Feet) 5/67	7/67	9/68	8/70	6/74	8/77	8/85
1	8"	0.6	---	---	---	---	---	---	2.9
2	9"	0.6	---	---	---	---	---	---	3.2
3	6"	0.7	38.8	24.9	4.2	3.9	3.3	2.9	2.7
3	6"	1.0	50.0	27.6	4.4	4.0	3.2	2.5	2.3
3	7"	0.7	30.8	18.4	4.8	4.6	3.6	3.1	3.1
3	7"	1.0	110.0	69.5	4.2	4.0	3.0	2.5	2.4
3	8"	0.6	53.2	35.6	5.1	4.5	3.3	2.9	2.9

--- No data.

TABLE 3: ROUGHNESS INDEX HISTORY FOR EXPERIMENTAL PROJECTS

Project Number	Roughness Index (Inches Per Mile) 1968	1970	1974	1984	1985	1986
1	---	---	---	86	84	85
2	---	---	---	---	82	97
3	86	100	86	91	100	86

--- Not tested.

NOTE: The following ranges are used to rate quality.

R.I. (Inches/Mile)

Under 75	Very Smooth
76-90	Smooth
91-125	Slightly Rough
126-170	Rough
Over 171	Very Rough

TABLE 4: DEFLECTION TESTING OF PROJECT 3
MARCH 1987

9 Kip Deflections at Transverse Cracks (Mils)

		Edge	IWP	OWP	Patches
6"	0.7%	8.3 ± 1.1	3.4 ± 0.2	3.7 ± 0.3	N/A
6"	1.0%	7.6 ± 0.7	3.1 ± 0.2	4.3 ± 0.6	7.7 ± 3.6
7"	0.7%	6.7 ± 0.9	2.3 ± 0.2	3.6 ± 1.6	7.0 ± 2.9
7"	1.0%	7.2 ± 1.6	2.3 ± 0.1	2.6 ± 0.4	7.5 ± 3.1
8"	0.6%	6.0 ± 1.0	2.3 ± 0.3	2.6 ± 0.2	N/A

N/A - Not Applicable

TABLE 5: DESIGN LANE TOTAL ACCUMULATED 18 KIP EQUIVALENT SINGLE-AXLE LOAD APPLICATIONS THROUGH 1986

Project Number	Year Constructed	Estimated Accumulated 18^K ESAL Lane 1	Lane 2	Lane 3
1	1970	9,200,000	1,150,000	1,150,000*
2	1974	9,100,000*	1,140,000	1,140,000
3	1967	17,000,000	1,890,000	---
4	1983	89,300**	---	---

*Location of CRC overlay on Projects 1 and 2.

**ESAL in each direction.

--- Not available.

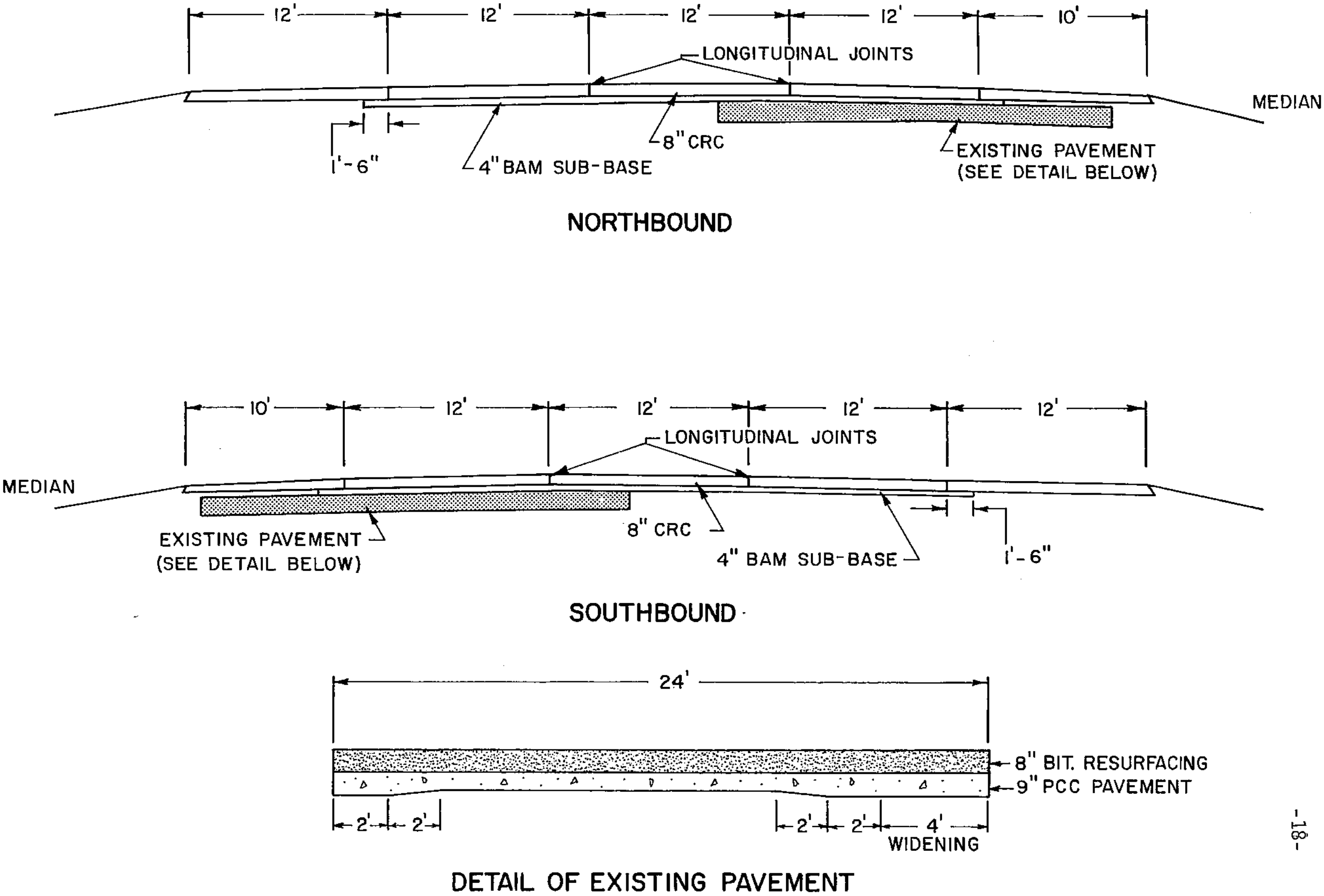

FIGURE 1. CROSS-SECTION OF PROJECT 1, I-55

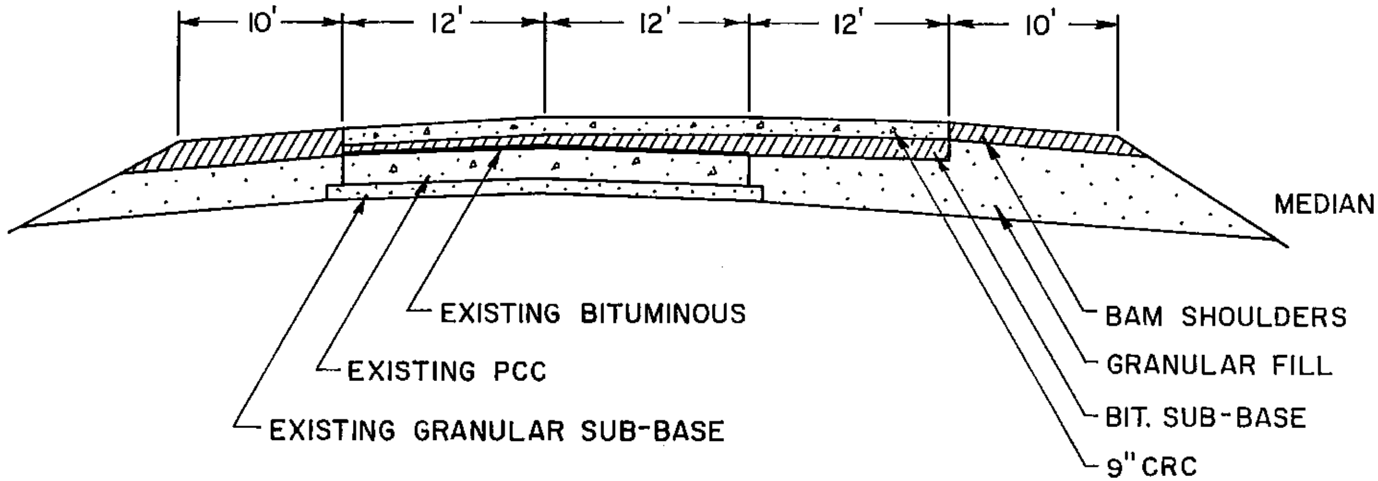

FIGURE 2. CROSS-SECTION OF PROJECT 2, I-55

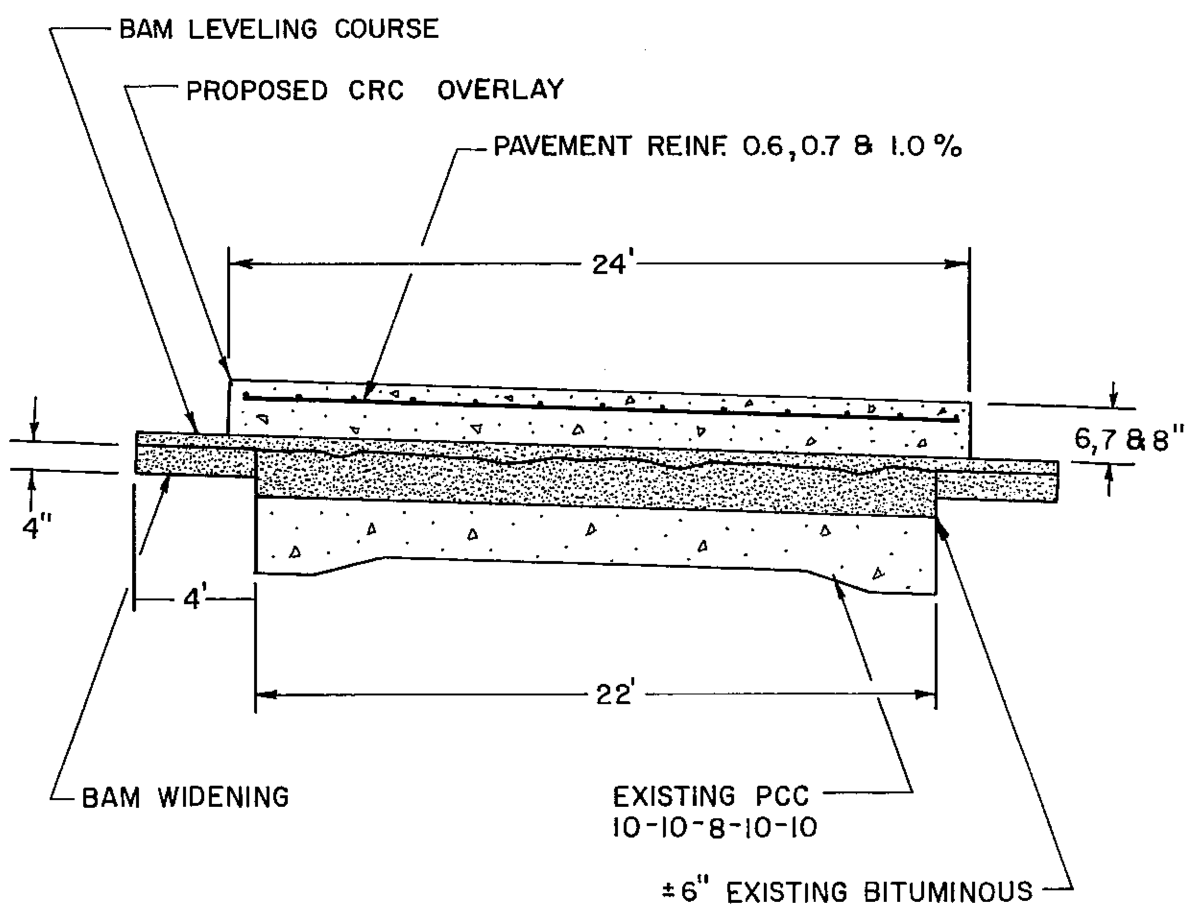

FIGURE 3. CROSS-SECTION OF PROJECT 3, I-70

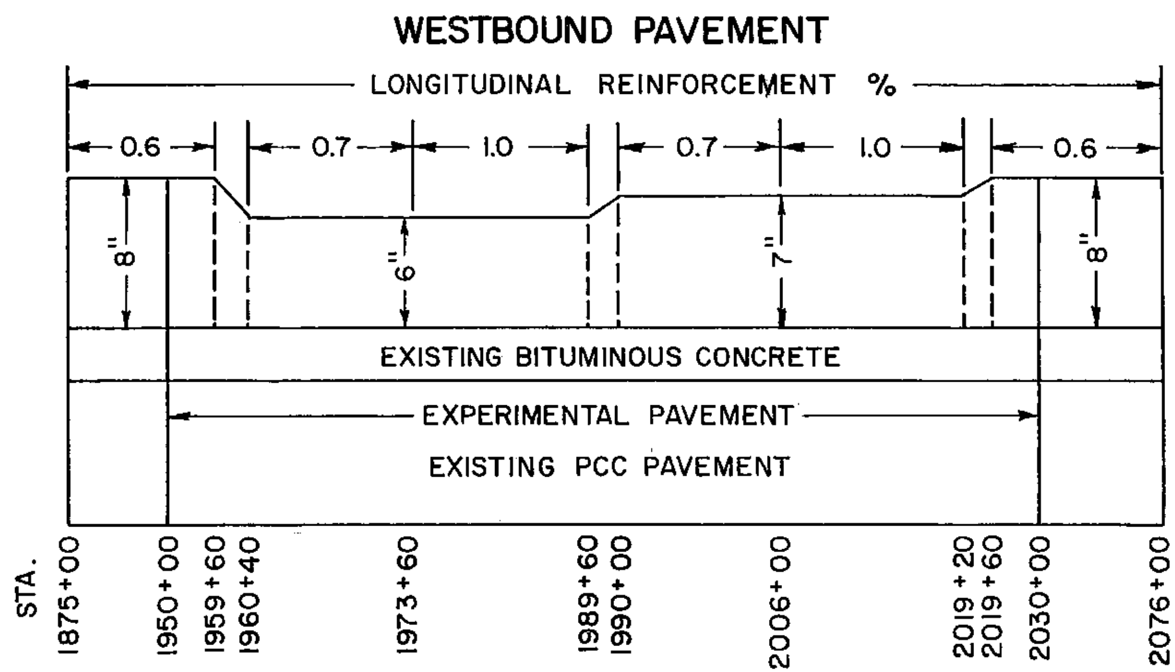

FIGURE 4. EXPERIMENTAL LAYOUT OF PROJECT 3, I-70

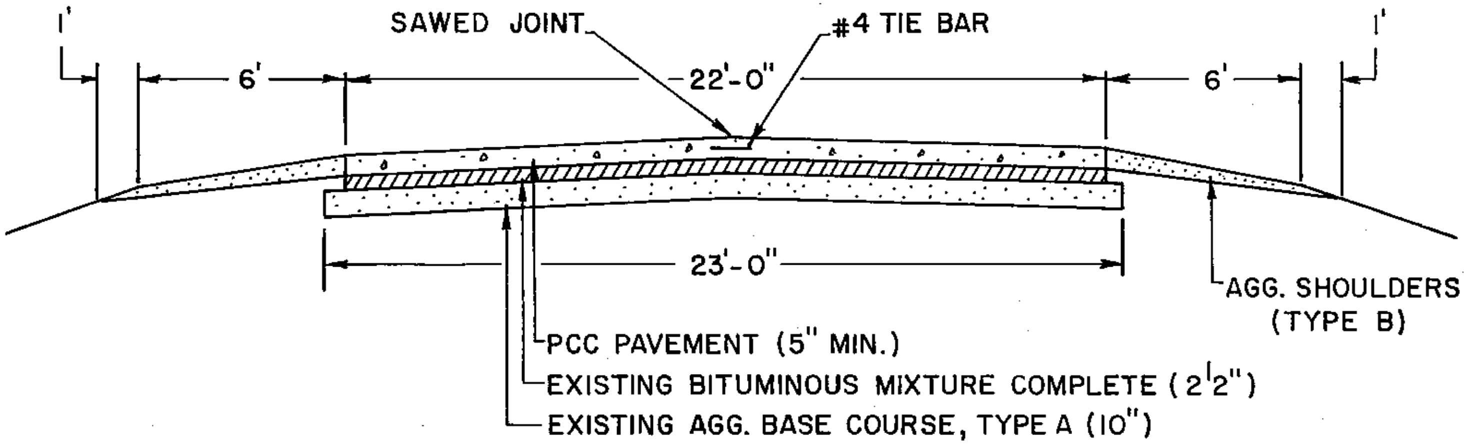

FIGURE 5. CROSS-SECTION OF PROJECT 4