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16. Abstract

Five experimental sections of CRC overlay over an existing resurfaced PCC pavement on Route US 40 were constructed in 1967 as part of Interstate Route 70 construction near Pocahontas, Illinois. Three thicknesses of overlay and two separate amounts of longitudinal reinforcement were used in the experimental sections. Observations and measurements were carried out over a 10-year period to evaluate the behavior of the experimental overlays under I-80 regular mixed traffic. During that period the pavements carried in excess of 7,000,000 equivalent 18-kip single-axle load applications with very little change in riding quality or level of service, without requiring any structural maintenance. Transverse cracking followed the normal trend for regular CRC pavement, and edge deflections were very small for all test sections. Changes in transverse crack width from summer to winter were small for all sections, and decreased with increasing slab thickness. Recommendations are included for design and construction of overlays relative to minimum overlay thickness, amount of longitudinal steel, use of a bituminous leveling course as a bond breaker, and tolerances for overlay thickness control during construction.

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CONTINUOUSLY REINFORCED CONCRETE OVERLAYS ON EXISTING PORTLAND CEMENT CONCRETE PAVEMENT

By

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and

Donald R. Schwartz

Interim Report
IHR-36
Continuously Reinforced Concrete Pavement

A Research Project conducted by
Illinois Department of Transportation
in cooperation with
U. S. Department of Transportation
Federal Highway Administration

May 1978

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CONTINUOUSLY REINFORCED CONCRETE OVERLAYS ON EXISTING PORTLAND CEMENT CONCRETE PAVEMENT

INTRODUCTION

Because traffic volumes have far exceeded projections, many miles of interstate and major elements of the National highway network within the State of Illinois and also major State highway networks currently require, or in the near future will require, pavement rehabilitation much sooner than originally contemplated. Interstate system and other major highways in Illinois have been designed with good geometric alignment; thus, future emphasis will be more likely on rehabilitation by overlaying these highways. In the spring of 1967, the Illinois Division of Highways, in cooperation with the Federal Highway Administration, constructed 3.8 miles (6.1 km) of an experimental continuously reinforced concrete (CRC) overlay on existing portland cement concrete (PCC) pavement to obtain information to refine the design of continuously reinforced concrete overlays. This research overlay is divided into five test sections.

The experimental overlay is located just west of Pocahontas, Illinois, which is approximately 35 miles (56 km) east of St. Louis, Missouri.

The experimental project was conceived following the determination in December 1962 that it was economically feasible to utilize this portion of the alignment of Route US 40 as part of the ultimate alignment for the westbound traffic of Interstate Route 70. Because of the high volume of heavy axle loads that would be carried by the new route, it was proposed to rehabilitate the existing pavement with a CRC overlay. No standard procedure was available for use in determining the needed thickness of CRC overlay. The first known overlay of this kind in the United States was completed in 1959 (1), but the performance data from this project were not available. Thus, the final decision was made to make the project experimental and to include 6-inch (152-mm) and 7-inch (178-mm) thicknesses, each with 0.7 and 1.0 percent reinforcement. Also included was an 8-inch-thick (203-mm) overlay with 0.6 percent reinforcement. Depth of the longitudinal reinforcement below the finished surface of the pavement was kept constant throughout the project at 2½ ± ½ inch (64 ± 13 mm).

Design features of the experimental overlays and their layout are shown in Figures 1 and 2, respectively.

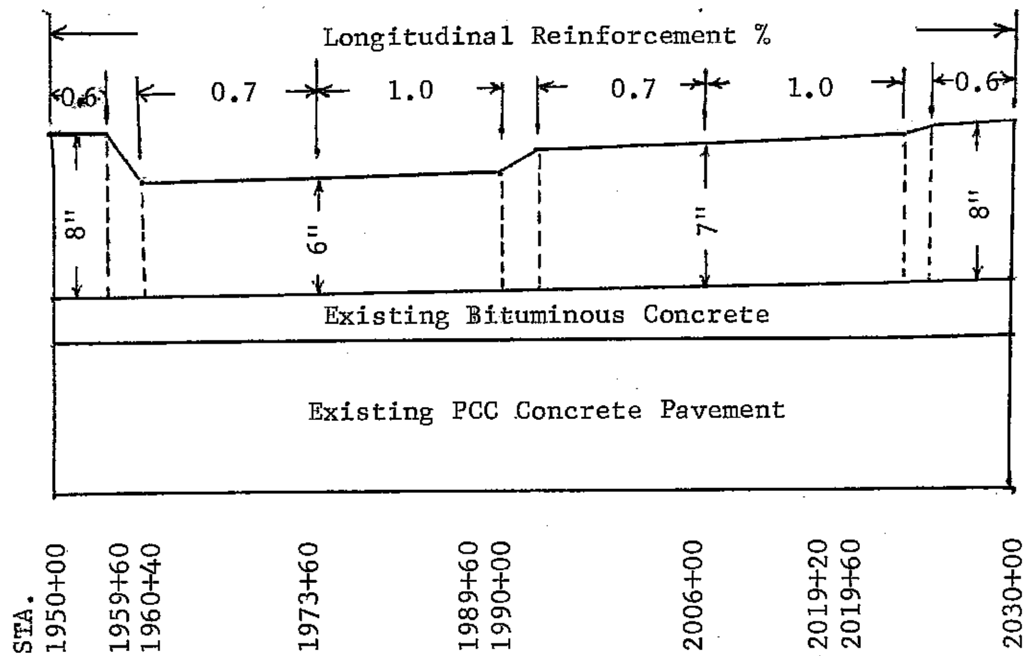
The object of this research project initially was to obtain information on the performance of the CRC overlays, and to ultimately establish relationships between pavement performance and design variables (overlay thickness and amount of longitudinal reinforcement) for use in the structural design. The work plan, however, was revised to shorten the study period, which permitted the variables of design to be related only to behavior expressed in terms of transverse cracking and deflection.

It is the purpose of this report to describe the structural condition of the base pavement, design details of the overlay, construction of the overlay, and to discuss the behavior of the overlay during the 10-year period following its construction.

EXISTING PAVEMENT

The existing concrete pavement on this project was 22 feet (7 m) wide, and constructed in 1939 to a variable 10-10-8-10-10-inch thickness, directly over the existing soil subgrade. It was conventionally reinforced, had 3/4-inch (19-mm) expansion joints at 50-foot (15-m) intervals, and load-transfer devices were used at all transverse joints. The pavement was constructed to a 1/8-inch

WESTBOUND PAVEMENT



1" = 25.4 mm

Figure 1. Experimental sections of continuously reinforced concrete overlays.

(3-mm) per foot slope across the entire width with the intention that it ultimately would serve as part of a four-lane facility with a raised median. The other two lanes, however, never were constructed. The existing pavement was resurfaced in 1952 and again in 1962 with approximately [illegible] inches of bituminous concrete each time.

To obtain background information, various sampling and testing were carried out on the existing pavement and roadbed soil along with a detailed field survey of the observed condition of the existing pavement surface.

Present Serviceability Index of the existing pavement was determined using the following relationship:

$$PSI = 10.01 - [illegible] - 0.01 \sqrt{C+P} - [illegible]$$

Where:

PSI = present serviceability index

RI = Roughness index in inches per mile [illegible] by Illinois Roadometer

C = Square feet of alligator-type cracking per 1000 square feet of pavement area

P = Square feet of patching per 1000 square feet of pavement area

RD = the depth of rutting in wheelpaths in inches, and

C' = lineal feet of open or spalled cracks per 1000 square feet of pavement area.

The above equation represents the AASHO Road Test flexible pavement PSI equation as modified for use with the Illinois Roadometer with the addition of the rigid pavement cracking term $(-0.09\sqrt{C'})$, and was developed for computing the Present Serviceability Index of resurfaced PCC pavements in Illinois.

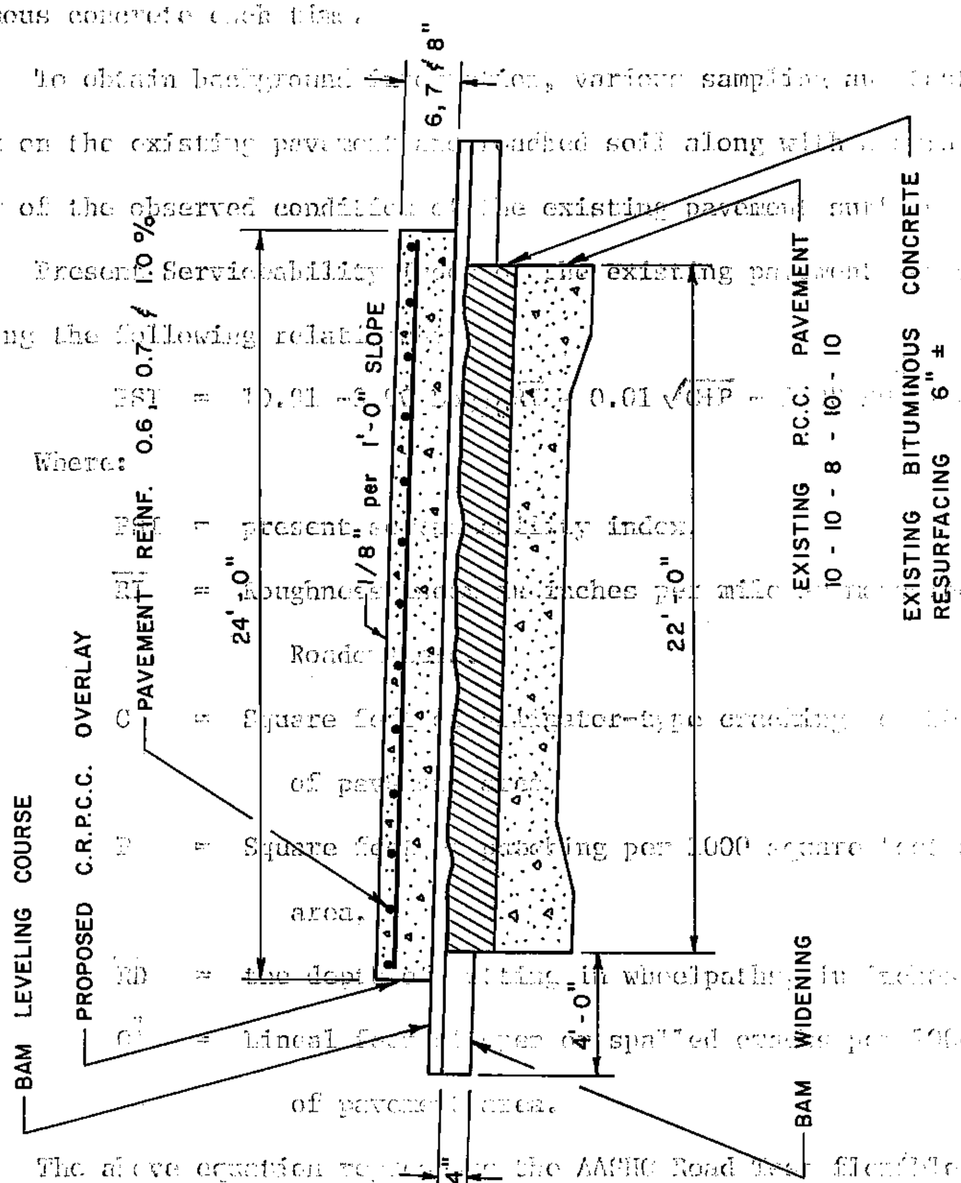


Figure 2. Typical cross-section of the continuously reinforced concrete overlay.

The Present Serviceability Index of the existing pavement was computed to be 3.26, being 3.20 for the eastbound lane and 3.32 for the westbound. The pavement generally was in good condition. A typical closeup of the existing pavement surface is shown in Figure 3. There were a few joints in the PCC pavement where distress was relatively severe. A typical distressed location is shown in Figure 4.

Prior to paving, a minimum of two cores, based on random selection, were taken from each test section for compressive strength determination of the portland cement concrete. No testing except thickness measurements was made for the portion of core which contained the bituminous concrete overlay. The compressive strength tests for the PCC portions varied from 3690 psi (25,442 KPa) to 9330 psi (64,328 KPa), and averaged 6220 psi (42,886 KPa) for six tests.

Undisturbed subgrade samples to a depth of approximately 3 feet (0.9 m) were taken after the PCC coring operation for soil classification, moisture content and density determinations. The soils were classified as A-4, A-6, and A-7-6. Test results on the samples from the upper 12 inches (305 mm) of embankment were fairly evenly distributed with 31 percent classified as A-4, 38 percent as A-6, and 31 percent as A-7-6. The moisture content in the top 12 inches (305 mm) ranged from 17.9 to 29.2 percent, and averaged 24.9 percent; the in-place wet density ranged between 119 and 128 pcf, and averaged 124 pcf.

DESIGN DETAILS OF CRC OVERLAY

The CRC overlay was designed to be 24 feet (7 m) wide. The plans called for the existing 22-foot-wide (6.7-m) pavement to be widened 4 feet (1.2 m) on each side with 4 inches (102 mm) of the bituminous aggregate mixture (BAM), which currently is being used in Illinois as stabilized subbase under rigid

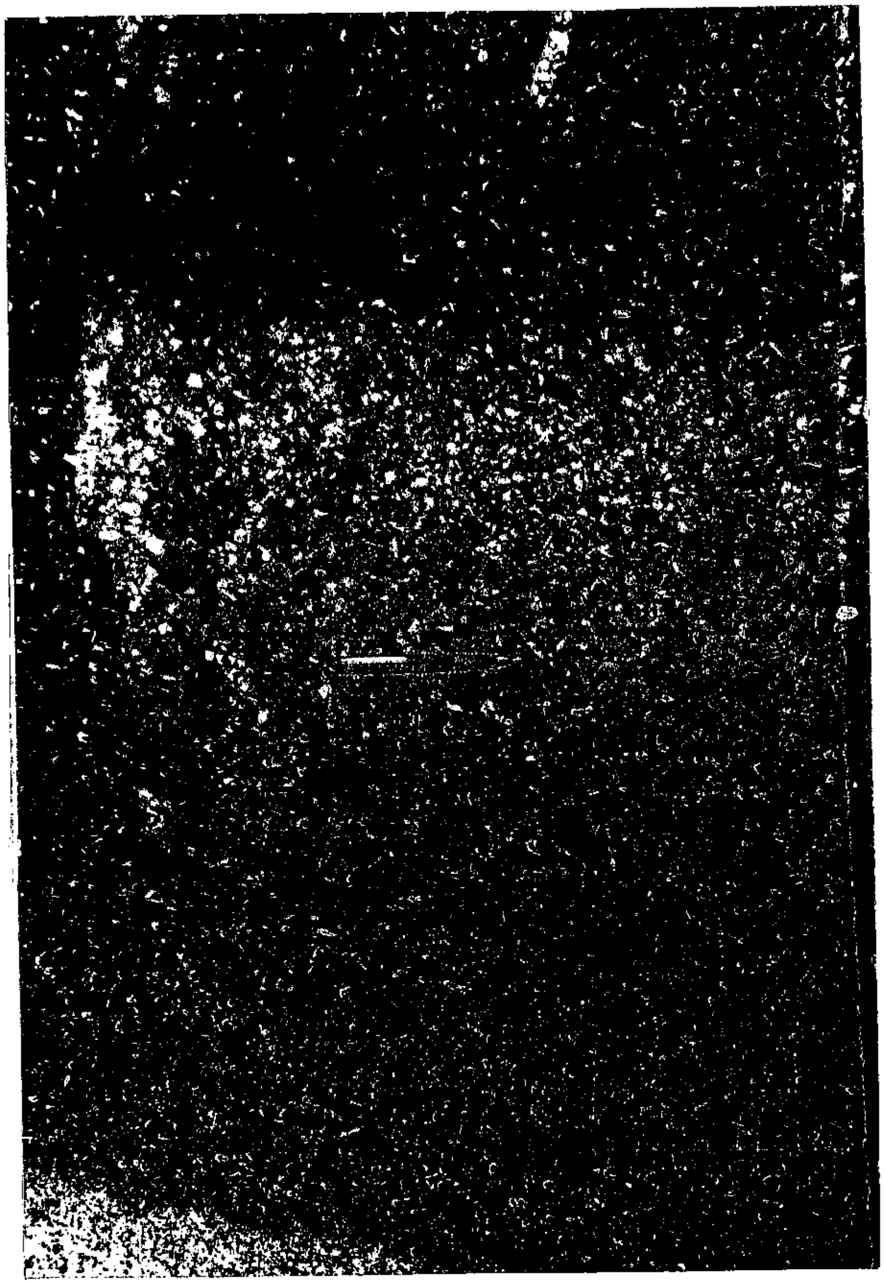


Figure 3. Typical close-up of the existing pavement surface.

Figure 4. Typical distressed area.

pavements. BAM is a hot-plant-mix bituminous concrete. On this particular project, the BAM was composed of a granular material of 1½-inch (38-mm) maximum size (35-55 passing the No. 4 sieve and 4-12% passing the No. 200 sieve), with 3-6% asphalt cement by weight. The particular mix used on this job included a blend of 78% gravel and 22% stone, with 5% by weight of 150-200 penetration grade asphalt cement.

Cold-drawn deformed welded steel fabric meeting the requirement of ASTM A497-64 was used for the concrete reinforcement. The deformed steel used in the manufacturing of the fabric met the requirement of ASTM A496-64. Transverse wires of the fabric sheets were fabricated and placed in the concrete in such a way that when they overlapped at the centerline of the pavement, they met the tie bar requirement. Various details of the test sections, including the size and spacing of the steel reinforcement, are given in Table 1.

In the early planning stages it was considered that some method of preventing bond between the CRC overlay and the existing jointed pavement probably would be necessary to prevent possible overstressing of the steel in the CRC overlay at joints and faulted cracks in the existing slab. However, it was believed that the existing bituminous concrete resurfacing over old PCC pavement would be satisfactory for this purpose, and no special treatment was included in the plans. It was realized that some adjustment in grade would be required at certain locations to provide satisfactory riding quality, and that the new CRC overlay would be somewhat thicker than specified at these locations. This was not thought to be a serious problem, however, and the construction control specified for the overlay was the same as that used in new pavement construction. This specification established penalty clauses for a thin slab, but did not provide a control governing thick construction.

TABLE 1

TEST SECTION DETAILS

Section No.	Slab Thickness (in.)	Percent Reinforcement	Longitudinal Deformed Wire Size No.	Lap (in.)	Spacing (in.)
1	6	0.7	D-18	17	4-5/16
2	6	1.0	D-26	20	4-5/16
3	7	0.7	D-21	18	4-5/16
4	7	1.0	D-26	20	3-5/8
5	8	0.6	D-21	18	4-5/16

1 in. = 25.4 mm

Note: Transverse deformed wire for all test sections was of size No. D-4.7 and was spaced at 14-inch centers.

The plans further established transitions to be constructed between experimental sections of pavement, such that changes in thickness of CRC overlay would be accomplished at the rate of 1 inch (25 mm) to 40 lineal feet (12 m) of slab.

CONSTRUCTION

A contract for the construction of this section of Interstate Route 70 was awarded in 1966. Work during that year included the grading and paving for the construction of the new pavement to serve eastbound traffic. The construction plan provided for Route US 40 traffic to be carried by the existing pavement until the new pavement was completed, following which the traffic would be transferred to the new pavement to permit construction of the continuously reinforced concrete overlay over the existing pavement.

Prior to construction of the overlay, elevations of the existing pavement surface were taken at 50-foot (15-m) intervals to assist in establishing the finished grade line. Transverse sections plotted from the elevations indicated that some crown had been placed in each lane of the sloped pavement during resurfacing, and that rutting had occurred in the bituminous concrete. Longitudinal profiles established from the elevations indicated considerable deviations from true grade. At some locations the thickness of the continuously reinforced overlay would have to be increased over plan thickness by as much as 3 inches (76 mm) to provide a smooth grade for the finished surface. At other locations it would be necessary to increase the overlay thickness appreciably on one edge to maintain a uniform cross section with the 1/8-inch (3-mm) per foot slope.

The specifications did not permit less than plan thickness. It was felt, however, that a control was needed on excessive thickness created by filling low areas in the existing pavement to prevent too much reduction in the effective percentage of longitudinal reinforcement. For example, increasing the 8-inch (203-mm) thickness by as much as 3 inches (76 mm), which would be required at some locations to establish a smooth grade, would reduce the effective reinforcement from 0.6 percent to about 0.4 percent, a value which is considered too small for continuously reinforced pavement in the Illinois environment. This control finally was set so that maximum overlay thickness would not exceed plan thickness by more than 1 inch (25 mm). This would limit the reduction in effective reinforcement at all locations to no more than about 0.1 percent less than plan quantity, or provide a minimum effective reinforcement of 0.5 percent which previously had been established as a minimum value for use in Illinois (4).

To accomplish the above and to provide a smooth grade and uniform cross section, it was decided to use a leveling course of the BAM material over the existing pavement.

To accomplish a smooth grade and at the same time minimize the amount of BAM needed for the levelling course, the grade was established from the high side of the existing pavement, transferred to the low side, checked and adjusted as necessary so that the CRC overlay would not be less than plan thickness at any location, and then adjusted longitudinally to provide satisfactory grade.

The 4-foot (1.2-m) BAM widening on each side of the existing pavement was placed prior to constructing the levelling course. The BAM levelling course then was placed for the full 30-foot (9-m) width using an autograde with electronic controls operating off a stringline. Compaction was accomplished with two steel-wheel rollers. A trimming pass was attempted, but proved to be unnecessary. Thickness of the levelling course over the existing pavement varied from a scratch-coat at high areas to a maximum of about 3 inches (76 mm) at deepest depressions.

The concrete was designed for a 3-inch (76-mm) slump and a cement factor of 1.50. Crushed stone having a maximum size of 1½ inches (38 mm) was blended with two other types of aggregates to obtain the required gradation. On the average, the modulus of rupture, for the concrete beams tested at the age of 14 days, was 933 psi (6433 KPa). Concrete was hauled from a central mix plant located near the midpoint of the project and placed by readymix trucks. The concrete was placed and struck off full depth between the forms. Pavement reinforcement, consisting of cold-drawn deformed welded fabric in sheets approximately 30 feet (9 m) long and 4 feet (1.2 m) wide, were positioned by hand on the surface of the concrete in a staggered pattern, and mechanically depressed into place to provide 2 to 2½ inches (64 m) concrete cover over the steel. A conventional paving train consisting of a spreader, a mesh depresser, two finishing machines, and a panfloat, was used. Final finish of the pavement surface was obtained by the use of two separate double-thickness burlap drags. Concrete of the experimental overlay was cured by covering with polyethylene sheets. The longitudinal joint was formed by sawing the concrete after expiration of the required curing period.

Paving was started on May 4, 1967, and the 3.8 miles (6.1 km) of overlay was completed on May 23, requiring a total of ten working days. The average low temperature was 50°F (10°C), and the average high was 71°F (22°C). No rain occurred during this period.

Paving operation progressed with little difficulty. The only problem encountered of any consequence was depressing the fabric to the required depth at laps in the 6-inch (152-mm) overlay. It was very difficult to depress the fabric at the laps as the two layers of fabric and the 1½-inch (38-mm) maximum size aggregate in the concrete utilized most of the slab thickness. Overlapping of the fabric at these locations resulted in the steel being about 1½ inches (38 mm) below the pavement surface. A smaller size coarse aggregate will be beneficial in eliminating this problem.

PRESENTATION OF DATA AND DISCUSSION

Transverse Cracking

Data from the various postconstruction condition surveys, after ten years of service, showed only a small increase in transverse cracking with an increase in the amount of reinforcing steel and no significant relationship between transverse cracking and overlay thickness.

The results of six condition surveys made to determine the frequency of transverse cracks are shown in Table 2. For the purpose of comparison, frequency is calculated in terms of the average interval between transverse cracks instead of the number of cracks for a given length. Transverse crack development in the overlay has followed the same general pattern as is occurring in regular CRC pavements in Illinois. Ten years after construction, the average interval between transverse cracks ranges from 2.5 to 3.1 feet (0.76 - 0.94 m) for the various experimental sections, and does not appear to be associated with overlay thickness. A small decrease in average crack interval occurred with and increase in amount of longitudinal reinforcement for the two thinner pavements.

As is typical for CRC pavements, transverse cracking in the overlay developed at a rapid rate in the first 15 months following construction and during initial traffic loadings. After 15 months, transverse cracking reached a point of relative stability. Transverse cracking has continued with age, but at a very, very slow rate since the first year after construction.

TABLE 2

DEVELOPMENT OF TRANSVERSE CRACKS

Overlay Thickness (in.)	Longitudinal Steel (%)	Average Crack Interval (Feet)					
		June* 1967	July 1967	September 1968	August 1970	June 1974	August 1977
6	0.7	38.8	24.9	4.2	3.9	3.3	2.9
	1.0	50.0	27.6	4.4	4.0	3.2	2.5
7	0.7	30.8	18.4	4.8	4.6	3.6	3.1
	1.0	110.0	69.5	4.2	4.0	3.0	2.5
8	0.6	53.2	35.6	5.1	4.5	3.3	2.9

* Overlay constructed in May 4-23, 1967

1 in. = 25.4 mm
1 ft. = 0.0929m

No concentration of transverse cracking or relatively wide cracking at the location of joints or faulted cracks in the base pavement was found. This situation suggests that the bituminous concrete (BAM) surfacing over old PCC is acting as a good bond breaker and is preventing the overstressing of the steel in the CRC overlay at joints and faulted cracks in the base slab.

Longitudinal Cracking

Even though all five overlay sections were constructed with the conventional sawed centerline joint, variable amounts of longitudinal cracking have developed in the traffic lanes of all the sections. The amount of longitudinal cracking is inversely proportional to the thickness of the CRC overlay. The cracks have remained tight, are not readily visible when travelling over the pavement at normal traffic speeds, and as yet have not shown any indications of causing undesirable or adverse effects on the overlay behavior.

The projected centerline length of the longitudinal cracks in each section observed during several condition surveys is given in Table 3 as percent of the total length of the section. As can be seen, the amount of longitudinal cracking was greatest in the thinnest overlay section and least in the thickest. Also, at a few isolated locations in the 6-inch (152-mm) thick sections, a pair of longitudinal cracks developed in the traffic lane. These cracks follow an irregular course, meandering from 6 to 9 feet (1.8 to 2.7 m) from the centerline of the pavement. This cracking was first noted and recorded during the conduct of the pavement condition survey in 1970, after the pavement had been in service for approximately three years. The cause of the longitudinal cracking has not been determined. A possible explanation could be that the overlay is 2 feet (0.61 m) wider than the existing pavement, resulting in less support along the outer edge and development of longitudinal cracking during edge

TABLE 3

LONGITUDINAL CRACKING IN TEST SECTIONS

Overlay Thickness (in.)	Longitudinal Steel (%)	Longitudinal Cracking (%)					
		1970*		1974		1977	
		Single	Double	Single	Double	Single	Double
6	0.7	4.2	0	17.5	1.3	35.7	1.3
	1.0	25.0	0.8	29.6	2.0	32.9	2.0
7	0.7	1.4	0	13.6	0	24.4	0
	1.0	0	0	2.3	0	14.5	0
8	0.6	0	0	0	0	4.0	0

1 in. = 25.4 mm

* Longitudinal cracking was detected first time since the overlay was constructed in May 1967.

loadings with heavy trucks. The locations of the longitudinal cracks are about where one would expect them to be if this phenomenon did occur. Further support to the phenomenon is offered by the fact that the cracking developed much earlier and to a greater extent in the thinnest overlay than in the thicker ones.

The apparent surface width and condition of these longitudinal cracks are about the same as those of transverse cracks on this project. A typical longitudinal crack is shown in Figure 5. No maintenance has been carried out or required.

Width of Transverse Cracks

Table 4 includes the results of crack width measurements taken at the surface of the pavement in the summer and winter during the first years of service. The measurements were made with a Whittemore strain gage and reference plugs set in the pavement surface on each side of the selected cracks. Cracks which first became apparent immediately after construction were selected because these cracks usually undergo the greatest amount of opening. The initial crack opening was measured with a microscope by peering down into the crack in an effort to obtain the crack width near the surface. A change in the position of the microscope will give a different reading. Thus, it is considered that it is not possible to accurately determine the actual crack width. The change in width from summer to winter determined from the reference plug measurements, however, can be replicated. As shown in the table, the average measured crack width change at the pavement surface was smallest for 8-inch (203-mm) overlay, and greatest for 6-inch (152-mm) overlay. The change for 7-inch (178-mm) overlay was intermediate between the two. The change in the crack width from summer to winter for all different trial designs was very small, and the differences between

Figure 5. A typical longitudinal crack (7-inch CRC overlay with 0.7 percent steel).

TABLE 4

CRACK WIDTH MEASUREMENTS AT OVERLAY SURFACE

Overlay Thickness (in.)	Longitudinal Steel (%)	Station	Date	Average Crack Width (in.)			
				Winter	Summer	Change	Average Change
6	0.7	1970+27	1968	0.0254	0.0268	0.0014	
			1969	0.0261	0.0289	0.0028	
			1970	0.0289	0.0299	0.0010	
			1971	0.0300	0.0316	0.0016	
		1968+17	1968	0.0181	0.0177	0.0004	
			1969	0.0183	0.0187	0.0004	
			1970	0.0196	0.0189	0.0007	
			1971	0.0200	0.0196	0.0004	
							0.0011
	1.0	1980+85	1968	0.0274	0.0257	0.0007	
			1969	0.0256	0.0268	0.0012	
			1970	0.0263	0.0260	0.0003	
			1971	0.0271	0.0266	0.0005	
		1976+80	1968	0.0110	0.0093	0.0017	
			1969	0.0101	0.0092	0.0009	
			1970	0.0093	0.0079	0.0014	
			1971	0.0089	0.0076	0.0013	
							0.0010
7	0.7	2004+78	1968	0.0132	0.0123	0.0009	
			1969	0.0128	0.0129	0.0001	
			1970	0.0130	0.0122	0.0008	
			1971	0.0132	0.0124	0.0008	
		2001+64	1968	0.0075	0.0081	0.0006	
			1969	0.0080	0.0089	0.0009	
			1970	0.0090	0.0089	0.0001	
			1971	0.0094	0.0097	0.0003	
							0.0006
	1.0	2015+43	1968	0.0081	0.0071	0.0010	
			1969	0.0086	0.0085	0.0001	
			1970	0.0089	0.0080	0.0009	
			1971	0.0088	0.0075	0.0013	
		2013+71	1968	0.0089	0.0075	0.0014	
			1969	0.0087	0.0086	0.0001	
			1970	0.0094	0.0089	0.0005	
			1971	0.0106	0.0101	0.0005	
							0.0007
8	0.6	2025+50	1968	0.0069	0.0069	0.0000	
			1969	0.0085	0.0090	0.0005	
			1970	0.0098	0.0088	0.0010	
			1971	0.0097	0.0096	0.0001	
		1952+39	1968	0.0243	0.0238	0.0005	
			1969	0.0240	0.0247	0.0007	
			1970	0.0249	0.0250	0.0001	
			1971	0.0250	0.0258	0.0008	
							0.0005

1 in. = 25.4 mm

the various designs were also small. As indicated by the data, no permanent progression of transverse crack opening took place in any of the overlay designs.

Although the changes in crack opening from summer to winter were small for all overlay designs, the total amount appears to be inversely proportioned to overlay thickness but not affected by the percent of longitudinal reinforcement in the overlay.

Deflection

The structural response of CRC overlay to load as measured by pavement edge deflection has been investigated in Illinois. It was anticipated that some consistent trend of deflection with overlay thickness would be observed. However, such was not the case, and the total edge deflections taken four years after construction were small for all overlay designs.

The change in transverse crack widths taken under the deflection test load also were small, and no trend was found which could be associated with any overlay design variable.

The deflections at the transverse cracks were taken by positioning a Benkelman Beam on the shoulders of the roadway at an angle of 30 degrees (0.5 rad.) to the longitudinal edge of the pavement slab with the probe positioned on the pavement about one inch (25 mm) from the pavement edge pointing toward the truck. Before taking deflection readings, the pavement at each test location was "ironed out" by making four passes with the test truck. The truck was a single-axle type and was loaded with a rear-axle loading of 18,000 lbs (80,068 N). The tire inflation pressure was 75 psi (517 MPa). The center of the dual tires on the right side of the truck was kept 20 inches (508 mm) from the edge of the pavement. Five readings per test section were taken. Two out of five readings were taken in conjunction with transverse crack-width measurements. The measurements of crack width were made with a Whittemore strain gage and reference plugs set in the pavement surface on each side of selected cracks. All readings were taken in the morning of April 29, 1971.

The average deflection for each test section is shown in Table 5. As can be seen, the average deflections for all sections were small, and no apparent trend exists which can be associated with overlay thickness or amount of longitudinal steel. The AASHO Road Test findings (2) indicated that the life of a rigid pavement subjected to repeated application of the same load can be satisfactorily predicted from the static edge deflection of the pavement before visible deterioration has taken place. It was found that the frequency of pavement survival increased as deflection decreased. If these overlay sections had been exposed to the Road Test traffic their frequency of survival would have been very close to 100 percent. This low deflection is an indication of long service life.

Reduction in transverse crack width at the pavement surface and deflection due to test load are shown in Table 6. The change in the crack width caused by 18,000-lb (80,068-N) loading was measured successfully, but no trend was found that could be associated with overlay thickness or the amount of longitudinal reinforcing steel. Also, no relationship was found between deflection and reduction in the crack width. The change in crack width caused by the test loading was very small for all test sections.

<u>Riding Quality and Traffic</u>

The riding quality of the overlay sections was measured with the Illinois BPR-type Road Roughness Indicator in the years 1968, 1970, and 1974. A summary of the results is given in Table 7. The values of the Roughness Index (RI) shown

TABLE 5

SUMMARY OF DEFLECTIONS

FOR

EXPERIMENTAL CONTINUOUSLY REINFORCED OVERLAYS

Overlays Thickness (in.)	Longitudinal Steel (%)	No. of Tests	Deflection ($\times 10^{-3}$ in.) Average	Range
6	0.7	5	6.4	4-8
	1.0	5	6.4	6-8
7	0.7	5	6.0	4-8
	1.0	5	4.8	2-6
8	0.6	10	6.7	4-10

Tested on April 29, 1971 between 9:30 to 10:55 A.M. The air temperature range was between 48 and 54°F (-9 and 12°C).

1 in. = 25.4 mm

TABLE 6

REDUCTION IN CRACK WIDTH DUE TO
TEST LOAD

Overlays Thickness (in.)	Longitudinal Steel (%)	Station	Deflection in* thousandth of inches	Reduction in* Crack Width (in.)
6	0.7	1968+77	6	.0003
		1970+27	4	.0002
	1.0	1976+80	6	.0000
		1980+85	8	.0003
7	0.7	2001+64	8	.0002
		2004+78	4	.0003
	1.0	2013+71	6	.0002
		2015+43	6	.0002
8	0.6	1952+39	6	.0004
		2025+50	4	.0002

1 in. = 25.4 mm

* The test load was applied by a single axle type truck with 18,000-pound (80,068 N) rear axle load.

TABLE 7

ROUGHNESS INDEXES FOR EXPERIMENTAL
CRC OVERLAY

Overlay Thickness (in.)	Steel Content (%)	Roughness Index (in. per mi.)		
		1968	1970	1974
6	0.7	89	108	95
	1.0	95	111	82
7	0.7	91	104	91
	1.0	80	87	78
8	0.6	76	93	84

1 in. = 25.4 mm

are the averages for measurements made in each of the four wheelpaths of the two-lane overlay sections. As can be seen, the RI values varied for the individual experimental sections during each period of testing. The values for the individual sections also fluctuated during the three test periods. The RI values determined in 1970 after three years of service showed an increase from the initial measurements taken in 1968 for all sections, ranging from 7 to 19 inches per mile. The RI values determined in 1974 after 7 years of service went down, and indicated a change from the original readings ranging from an increase of 8 inches per mile for the 8-inch-thick (203-mm) overlay, with 0.6 percent reinforcement to a decrease of 13 inches per mile for the 6-inch-thick (152-mm) overlay, with 1.0 percent reinforcement. The fluctuation in RI values for individual sections obtained from one test year to another is typical of the values obtained on many research studies, including those obtained on the AASHO Test Road pavements. In comparing the change in RI during the 7-year test period, the results are being interpreted as indicative of little-to-no change in the level of service being provided by the CRC overlay sections. The interpretation is further strengthened by the crack survey and deflection data, and by the fact that no deterioration or structural maintenance had been required on any of the test sections during the 7-year period, and even further through 1977 at the end of the 10-year evaluation period.

The traffic that the experimental overlay sections have carried through the years is typical in volume and composition of the traffic on many interstate highways in Illinois serving a high percentage of truck traffic. Traffic data for the representative years 1968, 1972, and 1976, during which separate counts were obtained for single- and multiple-unit trucks, are shown in Table 8. As will be noted, the total ADT increased from 8,800 in 1968 to 13,300 in 1976.

TABLE 8

VOLUME AND COMPOSITION OF TRAFFIC ON EXPERIMENTAL OVERLAY

Vehicle Type	Average Daily Traffic 1968	1972	1976
Passenger Cars	5900	8700	8400
Single-Unit trucks[1]	700	1100	1300
Multiple-Unit trucks[2]	2200	3000	3600
Total ADT	8800	12,800	13,300
Total Cumulative Equivalent 18K Single-Axle Load Application Through 1977		7,060,000	

[1]Two-axle and three-axle single-unit trucks

[2]Tractor semitrailers and combinations

During this same period the single-unit trucks increased from 700 to 1,300, and the multiple-unit trucks from 2,200 to 3,600. The total equivalent 18,000-lb. single-axle load applications generated by this traffic and carried by the overlay pavements during the 10-year analysis period through 1977, as computed by the Illinois procedure (3), amounted to 7,060,000.

SUMMARY OF PRINCIPAL FINDINGS

This experimental project represented an initial attempt on the part of the Illinois Department of Transportation to rehabilitate an existing resurfaced PCC pavement by overlaying it with continuously reinforced concrete. Construction of the experimental overlays was performed in 1967, and observations and measurements on the behavior of the overlays continued for a 10-year period following construction. While this time period has not been sufficient to relate the design variables of the overlay sections to total performance of the experimental overlays, analysis of the collected data has provided some useful information relative to the construction and behavior of the experimental overlay sections. The following conclusions have been drawn:

(1) The initial plan to place the CRC overlay directly over the existing resurfaced pavement to serve both as leveling course and to structurally strengthen the existing slab proved not to be feasible due to channeling that had developed in the wheelpaths of the existing resurfaced pavement, other variations in the transverse cross section, and appreciable deviations in the longitudinal profile from a reasonably true grade. The modified construction plan of using a hot-mix bituminous aggregate mixture over the existing pavement to correct the transverse cross section and to level the existing pavement such that

the experimental overlays could be placed without deviating from the design thickness by more than plus one inch produced a good end result.

(2) In general, paving operations progressed with little difficulty. The only problem encountered of any consequence was depressing the cold-drawn deformed steel reinforcement to the proper depth in the 6-inch (152-mm) overlay. The utilization of a smaller size coarse aggregate in the concrete undoubtedly would have reduced the problem.

(3) Performance of the overlay pavement sections during the 10-year study period has been very good. During this time the pavements have carried in excess of 7,000,000 equivalent 18,000-lb. single-axle load applications with very little change in riding quality or level of service. No structural maintenance has been performed, and none of the experimental sections exhibit any signs indicating that structural maintenance will be required in the near future.

(4) The only structural discrepancy that has shown up is a variable amount of random longitudinal cracking that has developed from the centerline to the outer wheelpath in the traffic lanes of all the experimental overlay sections. The amount is greatest for the thinner sections, with only a token amount (4% of the length) showing up in the thickest section. The reason for the longitudinal cracking has not been determined, but it is suspected that it may have been caused by the fact that the CRC overlays were one foot wider on each side than the existing pavement. Longitudinal cracking was first noted after the pavements had been in service for approximately three years, and has continued to develop throughout the entire 10-year study period. All cracks, however, have remained tight, are not readily visible when traveling over the

pavement at normal traffic speeds, and as yet have not shown any indications of causing undesirable or adverse effects on the overlay behavior.

(5) Transverse crack development in the CRC overlay sections followed the same general pattern as is typical for regular CRC pavements in Illinois. Transverse cracking does not appear to be related to overlay thickness. A small increase in transverse cracking was associated with an increase in the amount of longitudinal reinforcement, although the differences in cracking were less than would normally be anticipated in Illinois in new CRC pavement (4).

(6) The initial crack opening and changes in crack width from summer to winter were small for all overlay designs. The change in crack-width opening from summer to winter decreased as the overlay thickness increased, but did not appear to be affected by the percent of longitudinal reinforcement in the overlay.

(7) The pavement-edge deflections for all test sections were small, and no apparent trend existed which can be associated with either overlay thickness or the amount of longitudinal reinforcement.

(8) The reduction in transverse crack widths at the pavement surface taken in conjunction with deflection testing and caused by the test load was very small for all test sections. No trend was found that could be associated with either overlay thickness or the amount of longitudinal reinforcement in the slabs. Also, no relationship was apparent between pavement-edge deflection and the reduction in crack widths due to the test load.

RECOMMENDATIONS

BAsed on the information gained from this study, combined with the experience of others (5, 6, 7), the following recommendations are made relative to the design and construction of CRC overlays in Illinois:

(1) In rehabilitating an existing PCC pavement by overlay, the overlay normally performs two functions. It increases the structural capability of the existing slab and levels the existing pavement and restores its riding quality or level of service. In the case of overlaying with continuously reinforced concrete, it is recommended that the overlay be considered primarily for the purpose of increasing the structural capability of the pavement. Leveling of the existing pavement should be performed prior to placement of the CRC overlay. Any leveling with the CRC overlay should be kept to a minimum such that the increase in thickness does not exceed 3/4 to 1 inch (19 to 25 mm). Increases in the plan thickness of the overlay beyond these limits, which will occur if the overlay is also used to level the pavement, can result in reducing the effective percent of longitudinal reinforcement at extra-thick locations beyond a level which can be expected to provide satisfactory performance. Early research (4) has suggested that the minimum longitudinal reinforcement for satisfactory performance under the Illinois environmental conditions is 0.5%. Later experience has indicated that the minimum level may even be somewhat higher than this value. The specifications should include a control on the constructed thickness of the CRC overlay, requiring it to be not less than plan thickness to assure adequate structural capability and to not exceed plan thickness by more

than 1 inch (25 mm) to prevent excessive reduction in the effective percent of longitudinal reinforcement.

(2) Prior to construction of a CRC overlay, a bituminous concrete leveling course should be placed over the existing pavement to true up the cross section and level the pavement, and to function as a bond breaker between the existing slab and new CRC overlay. A possible exception to this requirement could be in the case of placing a CRC overlay over an existing CRC pavement. Generally, it is recommended that a scratch coat be placed over an existing pavement prior to constructing a CRC overlay, even if the pavement previously had been resurfaced. In most instances it will be needed to correct the profile of the pavement and to correct for any faulting and spalling that may have occurred at transverse reflection cracks. Faulting or spalling at transverse cracks in a resurfaced pavement can cause mechanical bonding of the CRC overlay which can result in overstressing the steel and failure in a form of wide cracks at these locations.

(3) Longitudinal reinforcement in the amount of 0.6% of the cross sectional area of the CRC overlay appears to be adequate. It is recommended that this percentage be considered as a minimum for design purposes.

(4) It is recommended that the minimum thickness for CRC overlay over existing concrete pavement be 7 inches (178 mm). Although all thicknesses of experimental CRC overlays are still performing satisfactorily, difficulty was encountered in placing the steel in the 6-inch (152-mm) thickness. In addition, variations in steel placement that can be tolerated in a 6-inch (152-mm) thickness and still provide adequate concrete cover over the steel and prevent the steel from being placed

too deep in the pavement, are much tighter than can be obtained under normal construction practices, most especially with mechanical placement of the steel. A 7-inch (178-mm) minimum thickness will greatly minimize this problem while at the same time provide additional assurance of structural adequacy of the overlay at a nominal increase in total cost. The added cost of increasing the slab thickness from 6 to 7 inches (152 to 178 mm) on this experimental project was 15¢ per square yard as bid in 1966.

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