Behavior of Experimental Continuously-Reinforced Concrete Pavements In Mississippi

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The first two continuously-reinforced concrete pavements constructed by the Mississippi State Highway Department have been designated as experimental sections and are being observed by the University of Mississippi Engineering Station. These pavements contain several design features that are relatively new in this type of construction. This paper describes the performance of the pavements to date.

A description of the design features and the construction methods used for both pavements is presented. Longitudinal movements of the pavement and crack width changes have been measured periodically. Crack surveys have been performed particularly in the early weeks after construction. Data on end movements, crack widths, crack frequency, and methods used for obtaining the data are presented and discussed.

Both pavements are in excellent condition. On the basis of the limited, but very satisfactory, performance of these pavements, several new projects using continuously-reinforced concrete pavement are being constructed and others are being planned.

•THE MISSISSIPPI State Highway Department, with the cooperation of the U.S. Bureau of Public Roads, has designed and constructed several sections of continuously-reinforced concrete pavement. The first two projects were designated as experimental sections and are being observed by the University of Mississippi Engineering Experiment Station. Both pavements contain some form of terminal anchorage and both have been placed on cement-treated bases. In the spring of 1961, the first pavement was completed in De Soto County. The second was completed in April 1962 in Jones County.

DE SOTO COUNTY PROJECT

The De Soto County project is 5.3 miles long and is that portion of I-55 extending from the Tennessee state line southward. It is a four-lane dual roadway facility consisting of ten individual continuously-reinforced concrete pavements, each terminating at a bridge or adjoining pavement. The pavement at the north terminus is a jointed concrete highway constructed by the Tennessee Highway Department. At the south terminus is an asphaltic-concrete pavement. A schematic plan of the project is shown in Figure 1. The lengths of the individual continuous sections, starting at the south end of the project, are 5,164 ft, 6,781 ft, 8,178 ft, 4,756 ft, and 724 ft, respectively, in the west pavement. For the east pavement, the lengths are 5,004 ft, 6,703 ft, 8,256 ft, 4,756 ft, and 724 ft, respectively, from south to north.

Experimental Features

The major experimental features incorporated in the De Soto County project were (a) the use of cast-in-place concrete piles as anchorages to inhibit the seasonal longi-

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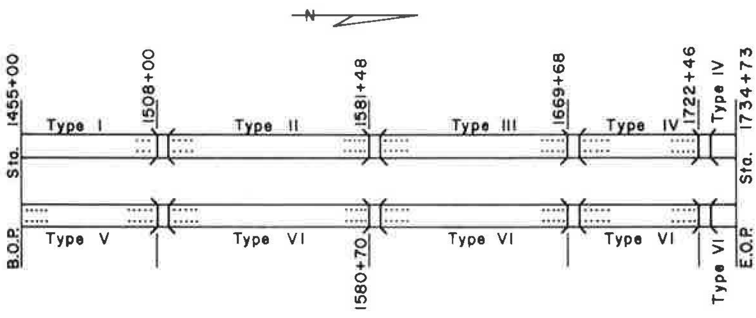

Figure 1. Plan of De Soto County project.

tudinal movements of the ends of the pavement, (b) a comparison of three combinations of pavement thickness and steel percentage, (c) a comparison of four sizes and spacings, of transverse reinforcement, and (d) the use of a cement-treated base.

Table 1 gives the significant characteristics of the various pavement sections. Details of the concrete anchor piles are shown in Figure 2. Ten piles were used at all pavement ends with the following exceptions: (a) eight piles were placed at the south end of the Type II pavement; (b) six piles were used at the north end of the Type I pavement; and (c) the south end of the Type I and the north end of the Type VI, at station 1734+73, were left without pile restraint. This arrangement was used to determine the effectiveness of the various sizes of pile groups.

At each pavement terminus where a pile anchorage was used, a series of eight 20-ft slabs separated by 1-in. doweled expansion joints was placed between the continuously-reinforced concrete pavement and the adjoining bridge or pavement. The slabs were individually reinforced with the same size, arrangement, and percentage of steel reinforcement as the adjoining continuous pavement. Figure 3 shows the arrangement of the pile groups and the terminal slabs. The diameter, depth, and configuration of the piles were originally suggested by Zuk (1) on the basis of model tests.

The spacing of the chair supported transverse rods was varied (Table 1). The transverse reinforcement serves to preserve the integrity of the longitudinal center joint and as a support platform for the longitudinal steel at the slab mid-depth during construction. The objective of field observations at the time of construction, and of subsequent measurements of behavior, was to evaluate the effect of the varied spacings and to determine, if possible, an optimum spacing.

This pavement is located a few miles east of the Mississippi River and roughly parallel to the floodplains bluffs. The surface soils on the bluffs are geologically classified as loess (a wind-blown, clayey silt). Underlying the loess is a layer of sandy gravel of undefined thickness. The loess thickness varies from about 20 ft to zero, depending on local erosion. Because lumping of the loessial subgrade has been a serious problem in this area, a cement-treated base was used.

In cross-section, the roadway consists of a 6-in. cement-treated subgrade, 13 or 14 in. of sand-gravel base, the upper 6 in. of which was cement-treated, and 7 or 8 in. of concrete slab. The total structure thickness, slab and base, is 21 in. All longitudinal reinforcement is No. 6 deformed bars, intermediate or hard grade, 40 ft - 0 in. long, placed at the mid-depth of the slab. Continuity of the reinforcement was obtained by overlapping successive bars 15 in. All overlaps were in line in the transverse direction. The steel was maintained continuous through all construction joints. All of the construction joints also contained a series of 15-in.

TABLE 1

PAVEMENT CHARACTERISTICS

Pavement Type	Thickness (in.)	Longitudinal Reinforcement (%)	Transverse Reinforcement
I	7	0.7	No. 4 bars at 24 in.
II	8	0.6	No. 4 bars at 24 in.
III	8	0.7	No. 3 bars at 18 in.
IV	8	0.7	No. 4 bars at 30 in.
V	8	0.7	No. 4 bars at 36 in.
VI	8	0.7	No. 4 bars at 24 in.

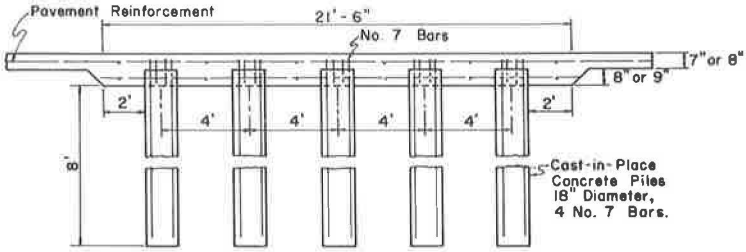

Figure 2. Typical detail of pile anchorage (De Soto County).

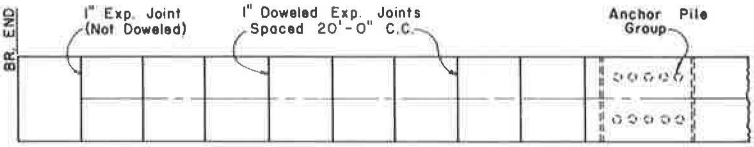

Figure 3. Typical plan of jointed slabs at pavement ends (De Soto County).

long, 1-in. diameter smooth dowel bars spaced 16 in. center-to-center in the plane of the continuous reinforcement. The construction specifications required that no construction joint could be placed within 5 ft of an overlap in the longitudinal steel.

Two layers of longitudinal reinforcement were used at the anchor pile caps (Fig. 2). The anchor pile reinforcement protruded above the piles and was tied to the pavement reinforcement steel.

Construction Methods and Materials

Cement treatment of the subgrade was started in the summer of 1960. Following the subgrade treatment, a sand-gravel base material was hauled into place. The lack of binder in the granular base was the source of a major construction difficulty. Haul trucks and other construction equipment traversed the unstabilized base only with great difficulty.

Paving was started in October 1960 at station 1628+91 of the west pavement. This point was nearest to the contractor's batch plant and base treatment was only partially completed. Paving proceeded southward in the normal manner, with two Koehring 34-E dual-drum pavers, one on each shoulder. Side forms, chair-supported transverse steel, and longitudinal steel were maintained 500 to 1,000 ft in advance of paving. The concrete was placed through the reinforcing steel to the full depth and full width of the slab. The finishing unit following the spreader provided full-width vibration to the fresh concrete. A split, wooden header board served to form the daily construction joint.

The poor trafficability condition existed until the base cement treatment was completed in the east pavement. The contractor then elected to stop paving at station 1554+07 and moved his operations to station 1455+00 of the west pavement. The two paving mixers were placed in tandem on the east base and the concrete was transported across the median in open buckets by crawler-mounted cranes operating on the shoulders. This method of construction (Fig. 4) was used throughout the remainder of the project.

On December 3, 1960, the project was closed down for the winter. Paving had been completed on the entire west pavement and had progressed from station 1456+60 to station 1491+82 of the east pavement. Work was started again on April 6, 1961, and was completed on May 2, 1961. A typical rate of paving for the major portion of the project was 150 to 180 lin ft per hr.

The anchor piles were emplaced in advance of construction. Holes were bored to

Figure 4. Method used for transport of concrete across median (De Soto County).

18-in. diameter and 8-ft depth by a truck-mounted earth auger. The four No. 7 reinforcing bars were formed in a cage by spiral windings at the top and bottom. The portion of each pile which was to extend into the 16-in. pavement section was formed by the use of a removable sheet metal form. Concrete for the piles was obtained from a local ready-mix concrete supplier and was delivered by mixer truck. Construction traffic was routed around the pile groups at all times. Where cement treatment of the base was not completed before anchor pile placement, mechanical mixing and compaction of the soil-cement were greatly hampered.

Two brands of portland cement were used for the concrete and the soil-cement—Marquette and Missouri Portland. The granular base was treated with 5% cement by volume and was compacted by a tractor-drawn steel-wheel vibratory roller followed by a rubber-tired roller. The concrete mix used was 1:2:3.75. Recorded slumps ranged from 1 to 2½ in. Fine and coarse aggregates were obtained from local borrow pits in the Mississippi River terrace deposits. A white liquid membrane was sprayed on the completed concrete surface for curing. The yield points for eight samples of the No. 6 reinforcing bars ranged from 50,200 to 56,100 psi.

Compression tests of soil-cement cylinders, made from the base material and tested at 28 days, typically ranged from 100 to 400 psi. Concrete cores taken from the pavement had compressive strengths ranging from 4,000 to 8,500 psi at an age of 270 days with an overall average of about 6,000 psi. The modulus of rupture for test beams at 28 days ranged from 550 psi to 800 psi.

Observations of Behavior

The major observations being made on the De Soto County pavement are (a) longitudinal movements, (b) crack widths, and (c) crack spacing.

The seasonal longitudinal movements of the ends of each pavement and of selected points in the interior of several sections are being measured to the nearest 0.01 in. Each measurement point consists of a 10-ft deep, concrete encased pipe monument placed 1 ft from the pavement edge and a pair of brass gage plugs imbedded in the pavement surface. A measurement device is located on the gage plugs and leveled. A movable arm from the device is extended out to a vertical extension inserted in the pipe monument. At the end of the movable arm is a cross bar to which a vernier caliper is attached. Longitudinal movements are recorded as the movement of the device, and of the pavement, relative to the monument.

Over 100 cracks in the entire project have been gaged for observation of seasonal changes in surface crack width. Gage plugs were imbedded in the pavement surface on each side of each designated crack in the manner prescribed in HRB Circular 372 (2) and measurements have been made with a Soiltest multi-position strain gage. All measurements are referenced to a standard invar steel bar. Initial, absolute crack widths have been measured at the surface with a microscope containing an etched objective lens.

Periodic crack surveys were started for each pavement section soon after its construction. The location of every crack in the entire project has been located to the nearest 0.1 ft at the outside pavement edge. As each new crack was located, it was marked with a small spot of traffic marking paint at the outside pavement edge, thereby removing the need for re-measurement in subsequent surveys.

Visible transverse cracks began appearing on the pavement surface and sides as soon as 3 days after construction of a slab section. In the west pavement (placed from October to December 1960), the average crack spacing ranged from 5 ft to 10 ft for the various sections. The east pavement (placed in spring 1961) showed a slower rate of cracking during the first few months after construction. This was undoubtedly due to the lack of cold weather. After two or more years in place, and two or three winter seasons, crack spacings have apparently stabilized so that the effect of placement season cannot be differentiated. Table 2 presents the results of a crack survey performed in the spring of 1963. With the possible exception of the zones within 1,000 ft from the pavement ends, all sections and pavement types show approximately the same average crack spacing.

For each pavement type, groups of four cracks were gaged (a) in the center of a day's pour near the center of a pavement section, (b) following a construction joint, and (c) 400 to 500 ft from an end. The first three cracks from each pavement end were also gaged. For the short (724-ft) sections at the north end of the project, six cracks were gaged near the center of the slab lengths.

The variation of crack width with temperature and time for the four gaged locations for the two southernmost sections in the east and west pavements is shown in Table 3. Values are for the average of the three or four gaged cracks at each location.

Each value (Table 3) is the result of two separate types of measurement: (a) establishment of the "true" surface crack width at one time by the use of a direct reading microscope, and (b) observation of changes in the "true" surface crack width by measurement of changes in distance between gage plugs on each side of the crack. Of the two measurements, the crack width change is by far the more reliable. The establishment of a "true" surface crack width was hampered by the indistinct surface edges and by the apparent lack of uniformity in width over even short lengths of each crack. Each microscope measurement used was the average of ten readings in the line of the gage plugs. Moreover, crack width is not uniform with depth. In several instances, observations of cores taken from cracks showed that the cracks extended downward only to the depth of the reinforcement. In most of the cores, however, the cracks extended the full depth of the slab.

Recognizing such limitations in the data, several tentative, general conclusions can be drawn regarding crack widths. All surface crack widths measured are reasonably small. No significant differences can be shown between the crack widths for the various experimental pavement designs. This is undoubtedly due, in great part, to the relatively small variation in the pavement design variables compared to the larger, normal variation in width of the individual cracks or groups of cracks. A variation in crack width occurs as a function of ambient temperature. However, there is also a distinct trend for the average crack widths to increase with time. The temperature effect may be seen, for example, by comparing the readings for January 1963 and March 1963. The time effect may easily be seen by comparing the width changes from August 1961 to August 1962 to June 1963, all of which were measured at about the same air temperature. Whether or not this trend will continue remains to be seen.

The effectiveness of the concrete piles as terminal anchorages is shown by the end movement measurements (Fig. 5). A comparison is made of the observed longitudinal movements of the ends of selected pavement sections. The air temperature recorded at the time of the individual measurements is also shown. All movements have been referenced to an initial "zero" reading in May 1961. The effect, or lack of effect, of the end movements on the crack pattern adjacent to the end is shown in Figure 6, in which the actual location of each visible crack has been plotted to scale for the first 300 ft of several pavement ends. No conclusions regarding the effect of end movement on cracking have been made.

TABLE 2

CRACK SURVEY RESULTS

Pavement Type	Station Limits	Date Paved	Paving Temperature (°F)	Avg. Crack Spacing (ft)	Avg. Crack Spacing for Type (ft)
I	1455+00 - 1459+19	10/29/60	42 - 64	4.1	
	1459+19 - 1468+22	10/31/60	40 - 62	4.0	
	1468+22 - 1482+14	11/ 1/60	45 - 72	4.0	
	1482+14 - 1495+82	11/ 2/60	45 - 72	4.6	
	1495+82 - 1506+64	11/ 3/60	45 - 65	4.7	4.3
II	1511+86 - 1526+22	11/ 4/60	40 - 65	5.8	
	1526+22 - 1530+44	11/ 5/60	40 - 60	5.0	
	1530+44 - 1541+90	11/ 7/60	44 - 60	5.6	
	1541+90 - 1554+07	11/ 8/60	40 - 58	3.9	
	1554+07 - 1564+44	10/24/60	45 - 78	5.6	
	1564+44 - 1575+86	10/22/60	40 - 71	4.6	
	1575+86 - 1579+68	10/21/60	40 - 63	7.5	5.1
III	1586+10 - 1592+58	10/20/60	40 - 54	5.0	
	1592+58 - 1599+78	10/18/60	55 - 83	5.3	
	1599+78 - 1613+22	10/17/60	58 - 78	4.6	
	1613+22 - 1621+08	10/15/60	68 - 77	5.1	
	1621+08 - 1625+00	10/13/60	75 - 82	4.9	
	1625+00 - 1628+91	10/12/60	68 - 78	6.4	
	1628+91 - 1639+76	11/14/60	50 - 62	5.3	
	1639+76 - 1655+60	11/15/60	47 - 70	5.1	
	1655+60 - 1663+98	11/16/60	42 - 64	4.9	
	1663+98 - 1667+88	11/17/60	50 - 77	5.8	5.1
IV	1673+11 - 1678+46	11/17/60	50 - 77	4.6	
	1678+46 - 1690+99	11/18/60	50 - 72	5.1	
	1690+99 - 1706+99	11/19/60	50 - 75	5.6	
	1706+99 - 1720+67	11/21/60	45 - 57	5.8	5.4
IV	1725+89 - 1733+13	11/22/60	50 - 72	5.8	5.8
V	1456+60 - 1463+50	11/25/60	45 - 63	7.4	
	1463+50 - 1475+44	11/26/60	41 - 59	5.4	
	1475+44 - 1480+22	12/ 2/60	45 - 52	7.5	
	1480+22 - 1491+82	12/ 3/60	50 - 61	5.0	
	1491+82 - 1495+48	4/ 6/61	45 - 55	3.8	
	1495+48 - 1503+07	4/ 7/61	44 - 64	5.0	
	1503+07 - 1506+64	4/ 8/61	45 - 55	10.8	5.5
VI	1511+86 - 1514+07	4/ 8/61	45 - 55	7.9	
	1514+07 - 1526+26	4/10/61	42 - 56	4.4	
	1526+26 - 1538+00	4/11/61	50 - 61	5.6	
	1538+00 - 1548+51	4/13/61	52 - 65	5.7	
	1548+51 - 1561+17	4/14/61	50 - 61	4.6	
	1561+17 - 1571+60	4/17/61	41 - 59	4.5	
	1571+60 - 1578+90	4/18/61	56 - 63	6.0	5.1
VI	1585+32 - 1587+70	4/18/61	56 - 63	4.9	
	1587+70 - 1603+56	4/19/61	60 - 75	5.3	
	1603+56 - 1621+56	4/20/61	58 - 78	5.0	
	1621+56 - 1640+06	4/21/61	59 - 78	6.1	
	1640+06 - 1657+06	4/24/61	54 - 78	8.5	
	1657+06 - 1667+88	4/25/61	58 - 82	5.8	5.9
VI	1673+11 - 1690+42	4/26/61	58 - 78	4.8	
	1690+42 - 1706+02	4/27/61	57 - 82	3.9	
	1706+02 - 1717+02	4/28/61	62 - 80	4.9	
	1717+02 - 1720+67	5/ 2/61	48 - 64	5.3	4.5
VI	1725+89 - 1733+13	5/ 2/61	48 - 64	6.0	6.0

The 1963 winter to summer movement for the unrestrained end of the short, Type VI section at the north end of the east pavement has been about 1.05 in. In all other respects, the movement pattern with time and temperature change has been the same as shown for station 1455+00 (west pavement, unrestrained south end of the Type I pavement). The difference in movement is probably due to the presence of the jointed concrete pavement at the north terminus as opposed to the asphalt pavement at the south end of the project. The movement patterns of all the pile restrained ends not shown in Figure 5 are quite similar in configuration and magnitude to those for the ends of the Type V pavement. The recorded end movements range from 0.30 to 0.75 in. In the overall pattern, there appears to be a trend toward a slight permanent elongation with time.

TABLE 3

CRACK WIDTH MEASUREMENTS, DE SOTO COUNTY

Pavement Type	Date and Air Temperature (°F)							
	Aug. 1961, 78-81	Nov. 1961, 45-50	Feb. 1962, 40-45	Aug. 1962, 76-89	Jan. 1963, 20-32	Mar. 1963, 67-74	June 1963, 88-90	Aug. 1963, 91-97
(a) Center of Day's Work in Center of Section (in.)								
I	0.016	0.016	0.012	0.008	0.020	0.015	0.014	0.018
II	0.010	0.008	-	0.006	0.014	0.011	0.012	0.012
V	0.011	-	-	0.013	0.024	0.017	0.016	0.017
VI	-	-	-	0.012	0.023	0.020	0.019	0.022
(b) Following a Construction Joint (in.)								
I	0.007	0.012	0.014	0.008	0.024	0.018	0.021	0.020
II	0.007	0.011	-	0.009	0.023	0.017	0.019	0.017
V	-	-	-	0.009	0.031	0.022	0.017	0.019
VI	-	-	-	0.008	0.015	0.012	0.013	0.010
(c) 400-500 Ft from End (in.)								
I	0.006	0.009	0.011	0.006	0.020	0.013	0.014	0.012
II	0.003	0.006	-	0.008	0.020	0.012	0.013	0.006
V	-	-	0.012	0.009	0.026	0.018	0.018	0.018
VI	-	-	-	0.008	0.022	0.016	0.016	0.020
(d) First Three Cracks from End (in.)								
I	-	-	-	0.011	0.023	0.018	0.024	0.023
II	0.007	0.009	-	0.010	0.020	0.016	0.024	0.019
V	0.006	-	0.011	0.006	0.020	0.013	0.018	0.014
VI	-	-	-	0.010	0.017	0.018	0.022	0.025
(e) Center of Short Sections at North End of Project (in.)								
IV	0.008	0.015	-	0.012	0.027	0.027	0.027	0.025
VI	-	-	-	0.011	0.022	0.024	0.023	0.019

All terminal joints appear to be functioning well except at station 1455+00 of the west pavement. Here the unrestrained pavement end occurs directly against an asphalt pavement with no joint filler or load transfer device used. Cold weather contraction causes the junction to open more than 1 ½ in. In the summer heat, the juncture space is completely closed. The long-term effect of this condition can only be surmised at this time.

At an age of three years, the De Soto County project appears in very good condition. No extra-large cracks or other failures directly attributable to the pavement design or behavior have occurred. A road roughness survey performed when the pavement was one year old showed a surface smoothness rated at very good to excellent for riding qualities.

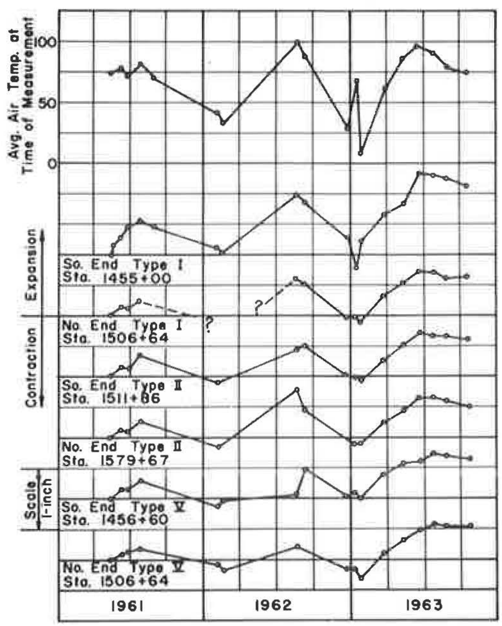

Figure 5. Measured longitudinal movements of various pavement ends (De Soto County).

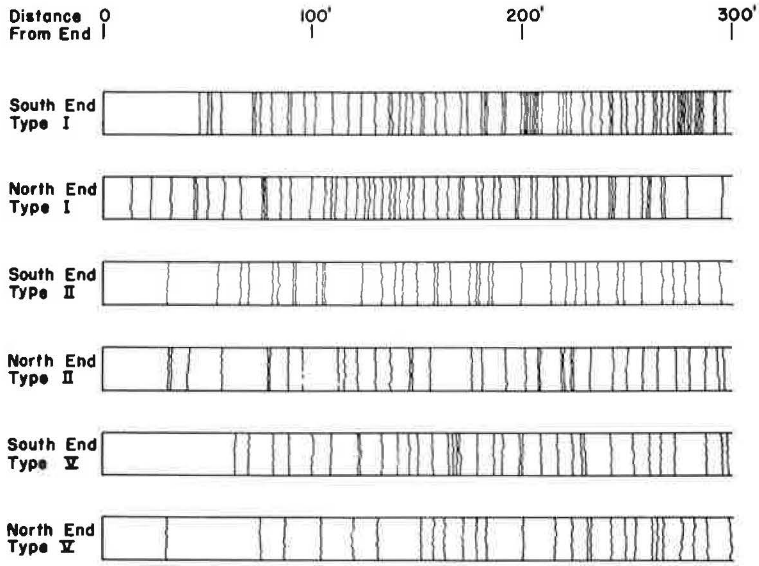

Figure 6. Crack pattern for first 300 ft for various pavement ends (De Soto County).

JONES COUNTY PROJECT

The second continuously-reinforced concrete pavement in Mississippi is in Jones County, in the south-central part of the State. This project is a 6.77-mi section of I-59 extending from Ellisville to Moselle. The project consists of two parallel, 24-ft pavements separated by a variable width median . Each pavement consists of two 12-ft wide traffic lanes. A uniform 8-in concrete thickness was used throughout the project. The experimental section begins at a jointed pavement at its south terminus and ends at a bridge at its north terminus. The pavement is continuous over the entire 6.77-mi length which, according to available information, makes this the longest section of unbroken, continuously-reinforced concrete pavement constructed to date.

Experimental Features

The major experimental features of the Jones County project were (a) use of concrete lug anchors as a means of terminal restraint; (b) a side-by-side comparison of wire-mesh and deformed-bar reinforcement, for each of three steel percentages; (c) use of a cement-treated base; and (d) use of a diagonal-lap configuration in the deformed-bar reinforcement.

The characteristics of the various pavement designs incorporated in the project are given in Table 4. The six pavement types are of equal lengths. A plan of the project is shown in Figure 7. The narrower median width was used where two local roads pass over the project.

TABLE 4

PAVEMENT CHARACTERISTICS, JONES COUNTY

Pavement Type	Long. Reinf. (%)	Long. Reinf. Type	Transverse Reinf.
I	0.5	No. 6 bars	No. 4 bars at 30 in.
II	0.6	No. 6 bars	No. 4 bars at 30 in.
III	0.7	No. 6 bars	No. 4 bars at 30 in.
IV	0.5	No. 5/0 wire mesh	No. 1 wire at 12 in.
V	0.6	No. 5/0 wire mesh	No. 1 wire at 12 in.
VI	0.7	No. 7/0 wire mesh	No. 00 wire at 12 in.

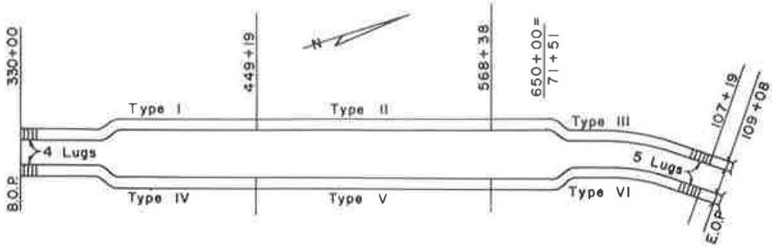

Figure 7. Plan of Jones County project.

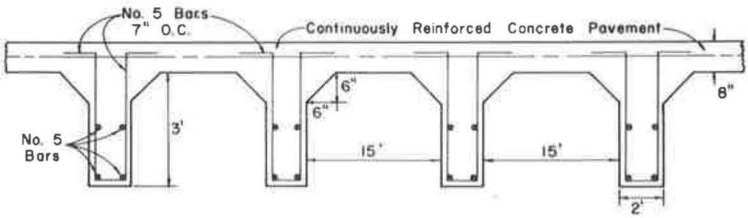

Figure 8. Typical detail of concrete lug anchors (Jones County).

The design of the full pavement-width lugs (Fig. 8) is very similar to that used (3) in several of Texas' continuously-reinforced concrete pavements. Four lugs were used at the south end of the project and five were used at the north, bridge end of both pavements. A series of eight 21-ft jointed slabs was placed between the bridge and the end of the continuously-reinforced concrete pavements at the north end of the project. The slabs were separated by 1-in. doweled expansion joints, had a uniform 9-in. thickness, and were reinforced with No. 00 ga. (longitudinal) and No. 4 ga. (transverse) wire mesh. The south end of the project abuts directly against a jointed concrete pavement. This pavement has the same thickness and reinforcement as the bridge-end terminal slabs except that the distance between the 1-in. doweled expansion joints is 63 ft 9 in. No contraction joints were provided. The slabs rest on a cement-treated base prepared in the same manner as that for the continuously-reinforced pavement. The arrangement of the anchor lugs at the pavement ends is shown in Figure 9.

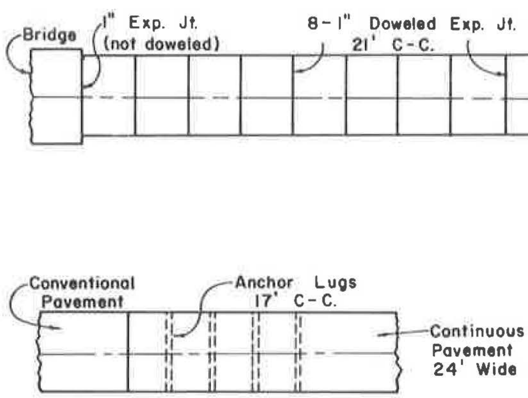

Figure 9. Typical plans at ends of pavement (Jones County).

In cross-section, the entire pavement consists of a uniform 8-in. concrete slab resting directly on a prepared subgrade, the upper six inches of which were cement-treated to form a base course. The west pavement is reinforced with No. 6 deformed bars, 40 ft 0 in. long, overlapped 15 in., and placed at the mid-depth of the slab. The wire mesh mats in the east pavement were 11 ft 6 in. wide and 24 ft 0 in. long, one in each traffic lane, overlapped 13 in., and placed 3 in. below the pavement surface. The effective overlap of the first cross-wires in the succeeding mats was 1 in.

Because of the possibility of failure at the overlaps in the bar reinforcement, the laps were formed at a 30° angle to the transverse steel rather than parallel to it as in the De Soto County project. The laps in the mesh reinforcement were in line across the pavement.

Construction Methods and Materials

The cement-treated base was mixed and compacted in fall 1961. Concrete paving was started on January 1, 1962, at the north end of the east pavement and proceeded southward until completion on February 27, 1962. The west pavement was placed (north to south) between March 5 and April 3, 1962.

The anchor lug trenches were dug by hand prior to concrete placement. After the lug reinforcing steel was in place, paving was started. Two concrete mixers were used in tandem. The forward paving mixer was a Koehring Tribatch, triple-drum mixer operating on the prepared base. The concrete was placed full width of the pavement and struck off 3 in. below the proposed pavement surface. A series of No. 4 deformed bars, 30 in. long, were spaced 30 in. apart across the centerline to tie the longitudinal joint. The rear mixer, operating on the shoulder, was a Koehring 34-E dual-drum unit used to place the remaining 3 in. of concrete. The combination spreader-finisher used on the project contained a series of submerged vibrators located on 3-ft centers.

The paving procedure for the bar-reinforced west pavement differed slightly from that used in the east pavement. The longitudinal reinforcement was tied to the chain-supported transverse bars and was maintained at least 500 ft in advance of concrete placement. The contractor's two paving mixers were operated simultaneously, in tandem, on the inside shoulder. As before, the anchor lugs were cast monolithically with the pavement. Placement of the reinforcing bars is shown in Figure 10. Concrete was placed in the full width of the pavement and to full depth through the reinforcement.

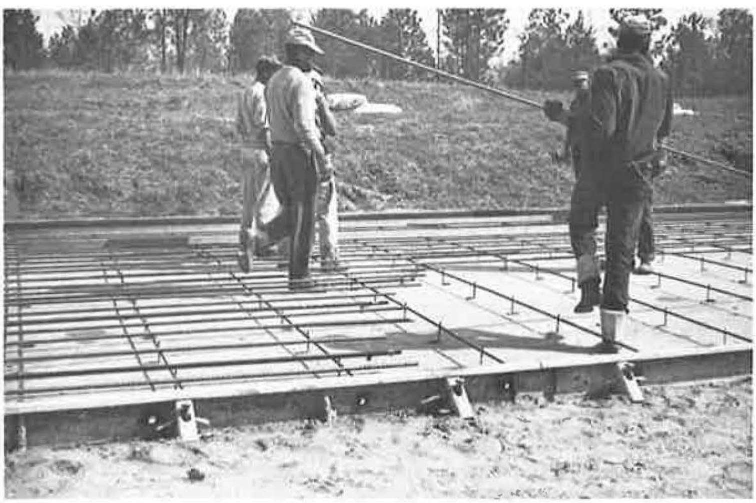

Figure 10. Placement of bar reinforcement in west pavement (Jones County).

Construction joints throughout the project were formed with a split, wooden header. No construction joint was allowed within 5 ft of any overlap in the longitudinal reinforcement. No additional longitudinal steel or load transfer devices were used at the construction joints.

The location of overlaps in the longitudinal reinforcement was measured and recorded for the entire project, for possible use in future studies of cracking tendencies at the laps.

The concrete mix used was 1:2.2:3.75. Recorded slumps ranged from 1 to 2½ in. Two brands of cement were used on the project—Ideal and Lone Star. Local sand and gravel were used as concrete aggregates. A white liquid membrane was sprayed on the completed concrete surface for curing.

The cement-treated base course was 28 ft wide and 6 in thick. Portland cement was added in the amount of 7 percent by volume. A mandatory 7-day curing period was used before traffic was allowed on the base. Curing was effected by a seal coat of asphalt emulsion.

Compression tests of concrete cores showed compressive strengths ranging from 6,000 psi to 10,500 psi at an age of 6 months. The overall average compressive strength was approximately 8,000 psi. The modulus of rupture for test beams at 28 days ranged from 750 psi to 1,150 psi.

Observations of Behavior

The field observations performed on this project are as follows: (a) longitudinal movements, (b) crack widths, and (c) crack spacing.

The measurement techniques and instrumentation are essentially the same as those used in the De Soto County project and were as previously described (2). The pavement ends and selected interior points are being measured for longitudinal, seasonal movements. Crack widths are being measured (a) 400 to 500 ft from each pavement end, (b) following a construction joint, and (c) in the center of a day's pour in the center of a test section for each of the six pavement designs. Cracks have been gaged in groups of four. Crack surveys are being performed on about 60 percent of the total project. Each individual survey section encompasses a complete day's pour.

Crack surveys were performed periodically for each designated section, starting immediately after construction. Visible cracks appeared in most sections within two or three days after construction. However, in the bar-reinforced west pavement, some sections did not show cracking for up to two weeks after construction. The west pavement was placed in warm, spring weather. Apparently, such shrinkage cracks as did form were so small as to be invisible to the naked eye. About 30 days after construction, most of the pavement sections showed crack spacings in the range of 8 to 15 ft for both pavements. Exceptions to this occurred at the pavement ends, the final 1,000 ft more-or-less, and at the north end of the mesh-reinforced pavement. This area was paved first, during an extremely cold winter. Several thousand feet of pavement in the interior of the Type VI showed almost no cracks even after 60 days.

By December 1963, the entire project had experienced at least one winter season. The results of a crack survey performed at this time are given in Table 5. The mesh-reinforced east pavement performed as expected; the crack frequency was greater for the higher steel percentage. On the other hand, the bar-reinforced west pavement showed average frequencies which indicate no effect of steel percentage. Whether this situation will persist with time remains to be seen.

Crack width measurements were accumulated in the same manner as for the De Soto County project. This information has not yet been developed to the point that definite trends can be established. The normal crack widths are, by visual inspection, of the same order of magnitude as those reported for the De Soto County project (Table 3).

The pattern and magnitude of longitudinal movements of the ends of the pavements are shown in Figure 11. The air temperatures were recorded at the time of the individual measurements. It is too early to estimate long-term trends. No reason can now be given for the difference in the behavior of the 4-lug and 5-lug ends. Possibly, the jointed concrete pavement at the 4-lug end offers a greater restraint than the bridge approach slabs and the bridge offer to the 5-lug end.

TABLE 5

JONES COUNTY CRACK SURVEY, DECEMBER 1963

Pavement Type	Station Limits	Date Paved	Paving Temp. (°F)	Avg. Crack Spacing (ft)	Avg. Crack Spacing for Type (ft)
I	330+00 - 334+53	4/ 3/62	50-55	6.0	
	334+53 - 347+70	4/ 2/62	50-63	4.9	
	364+53 - 381+97	3/29/62	66-85	8.3	
	381+97 - 400+39	3/28/62	58-82	5.9	
	400+39 - 420+90	3/27/62	50-76	6.0	
	420+90 - 440+60	3/26/62	56-73	6.6	6.2
II	440+16 - 464+32	3/23/62	52-75	7.8	
	464+32 - 484+05	3/22/62	54-65	5.2	
	484+05 - 508+13	3/21/62	60-80	6.4	
	524+46 - 540+54	3/19/62	52-75	8.6	6.7
III	560+69 - 571+36	3/14/62	48-51	5.0	
	589+05 - 606+10	3/12/62	45-68	6.5	
	606+10 - 622+88	3/ 9/62	64-78	7.4	
	644+35 - 86+88	3/ 7/62	39-56	6.6	
	100+09 - 107+19	3/ 5/62	42-51	5.1	6.2
IV	330+14 - 333+91	2/27/62	68-84	7.5	
	333+91 - 351+50	2/26/62	75-84	9.1	
	351+50 - 362+71	2/17/62	49-68	8.4	
	362+71 - 377+80	2/16/62	50-64	8.2	
	396+59 - 416+45	2/12/62	54-78	7.1	8.0
V	449+81 - 462+64	2/ 7/62	42-58	7.0	
	462+64 - 482+82	2/ 5/62	60-75	7.5	
	495+40 - 513+88	2/ 2/62	49-75	7.6	
	549+06 - 567+15	1/30/62	50-70	7.0	7.3
VI	587+35 - 601+05	1/24/62	50-70	6.0	
	607+67 - 621+44	1/17/62	40-53	6.4	
	621+44 - 626+93	1/ 9/62	35-47	5.1	
	626+93 - 639+52	1/ 8/62	42-57	3.0	
	77+42 - 91+94	1/ 3/62	26-58	7.3	
	97+00 - 103+65	1/ 2/62	26-51	4.1	
	103+65 - 107+19	1/ 1/62	37-42	3.3	4.9

With the exception of the extra-wide cracks, the entire project appears to be in excellent condition. No problems have been encountered in the bar-reinforced west pavement. Riding qualities of the project are very good to excellent on the basis of roughometer tests.

Extra-Wide Cracks

Soon after the construction of several sections of the mesh-reinforced east pavement, a series of ten abnormally wide cracks was located. Nine of the ten were located in the Type VI section which contains 0.7 percent steel. The other was found in the Type IV design, 0.5 percent steel. All of the cracks occurred at overlaps in the wire mesh and were typically ¼ in. or more wide. Repair of these sections was effected during the summer of 1962. In each instance, a 30-in. wide zone of concrete (full pavement width) was removed to the depth of the steel reinforcement. Half-inch deformed bars were welded to the mesh mats on both sides of the crack at each longitudinal wire. The entire opening, steel and concrete, was then coated with an epoxy cement and a high -early strength concrete was placed to fill the gap. After 1½ yr, all of the repairs appear to be in excellent condition.

No reason can be given at this time for the occurrence of the cracks. At first appearance, the blame should be laid on the very short overlap of the mesh sheets. With a 13-in. overlap and 24-ft lengths, approximately 4.75 percent of the pavement length contains overlapped wires. Yet, of all the cracks that had been located at the time of the failures, only 3.3 percent occurred in overlapped areas. Moreover, of all the overlaps in the surveyed zones, only 6.2 percent of the laps had visible cracks in their lengths. With the exception of the 10 extra-wide cracks, all other cracks at laps appeared to be of the same size as those in the other sections. This highly simplified analysis would tend to indicate that there is no greater tendency for cracks to occur at the overlaps than anywhere else in the pavement.

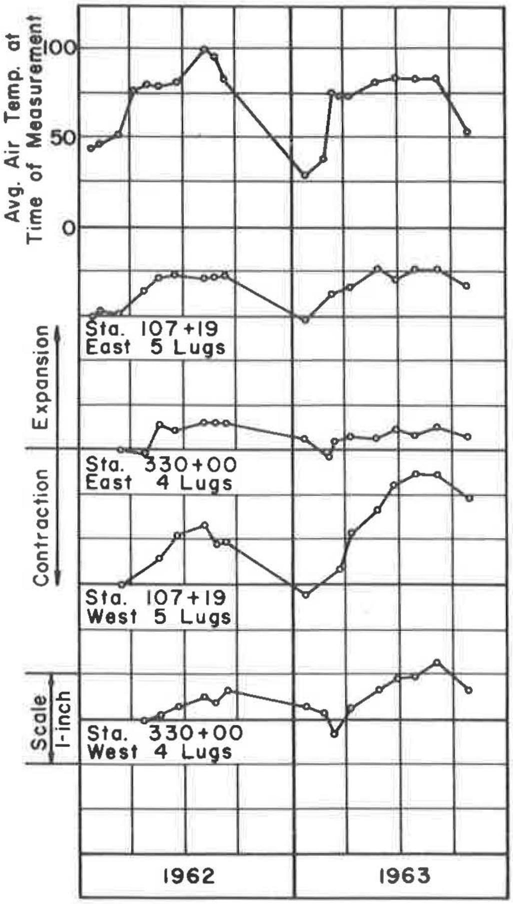

Figure 11. Measured longitudinal movements of pavement ends (Jones County).

GENERAL DISCUSSION

The results of the measurements and general observations concerning the long-term behavior of the two Mississippi projects are being recorded and reported to the U. S. Bureau of Public Roads by the Mississippi State Highway Department as part of a nationwide correlation study of continuously-reinforced concrete pavements. Although other such pavements have furnished much valuable information, there are many questions still remaining which can only be answered by additional experimental pavements of the type Mississippi has constructed. In addition to the primary experimental features, there are several characteristics of the Mississippi projects which do not lend themselves to direct measurement. During certain periods in the winter season, the De Soto County pavement experiences almost daily freeze-thaw cycles in contrast to the more northern states where only a few such cycles occur in any one year. The southern states, including Mississippi, have a winter construction season. Continuously-reinforced concrete pavements placed in cold weather should experience lower tensile stresses and higher compressive stresses due to temperature change than pavements placed in the summer. Further more, it is believed that the Mississippi pavements are the first to be placed on a soil-cement base, and in De Soto County, the first to use concrete piles as a means of end anchorage.

On the basis of the short-term, but satisfactory, performance of the two projects discussed in this report certain general statements can be made.

1. The steel percentages and pavement thicknesses used in these projects have given satisfactory performance. Although differences in crack frequency have occurred due to varied steel ratios, no detrimental behavior due to insufficient steel percentage or pavement thickness has been found.

2. Because of the satisfactory performance of the De Soto County project, no valid argument can be presented for the diagonal-lap configuration of the deformed-bar reinforcement. However, the diagonal arrangement is no more costly than the straight-across configuration.

3. In the De Soto County pavement, no clear evidence can be found for using smaller transverse bar spacings than 36 in. It is probable that even larger spacings could be used, perhaps limited only by that distance that would allow significant vertical movements of the longitudinal bars during concrete placement.

4. The concrete anchor piles used in De Soto County appear to be restraining the slab ends satisfactorily. On the basis of the limited data available, it would appear that pile groups of 6 or 8 piles are sufficient to maintain reasonable end restraint.

5. The concrete anchor lugs used in Jones County appear satisfactory as a means of terminal restraint.

6. The 7-in. pavement thickness used in De Soto County appears to be serving as satisfactorily as the 8-in. pavements. This may be due to the presence of the cement-treated base. There is a possibility that even thinner pavements may be used provided they are placed on a strong base.

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