Continuously Reinforced Concrete Overlay of Existing Continuously Reinforced Concrete Pavement

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The design and construction of a 6-in. unbonded continuously reinforced concrete (CRC) overlay of a 20-yr-old continuously reinforced concrete pavement (CRCP) are described. This is the first time a CRC overlay has been placed over an existing CRCP. The existing CRCP was an experimental project when built and had several features that were being tried for the first time in Mississippi. One of these features, smooth wire fabric reinforcement, led to the need for the overlay. The CRC overlay project had several items new to Mississippi, including (a) a new, statistically oriented quality assurance specification for rigid pavement; (b) the closing of one side of an Interstate highway to traffic; and (c) plain concrete shoulders paved monolithically with CRC mainline overlay. The distress in the 20-yr-old pavement, design, and construction procedures, contract award provisions, traffic control features, and postconstruction evaluation are discussed, and some interim recommendations are presented.

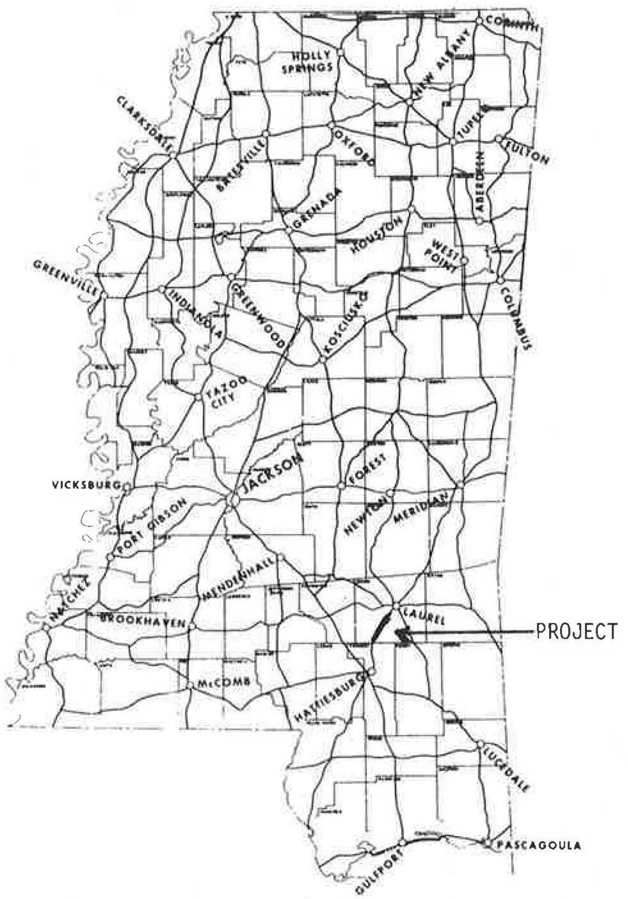
Since the late 1950s, more than 13,000 equivalent two-lane miles of continuously reinforced concrete pavement (CRCP) has been constructed. Even though various problems have arisen with this type of pavement, most of this mileage is giving acceptable performance.

Continuously reinforced concrete (CRC) has also been used as an overlay to rehabilitate existing roadways. The equivalent of 350 two-lane miles of CRC overlay has been constructed since its introduction in 1959; most of the overlays have been in service for less than 10 yr. Both flexible and rigid pavements have been given CRC overlays, but until recently no CRC overlay had been placed over an existing CRCP (1,2).

In January 1981, the Mississippi State Highway Department (MSHD) constructed a CRC overlay over an existing CRCP on I-59 in Jones County in southeast Mississippi. The pavement that was overlaid is located in the northbound lanes of I-59 in Jones County between Moselle and Ellisville. This is a divided highway with a depressed median. The location is shown in Figure 1, and a typical section is shown in Figure 2.

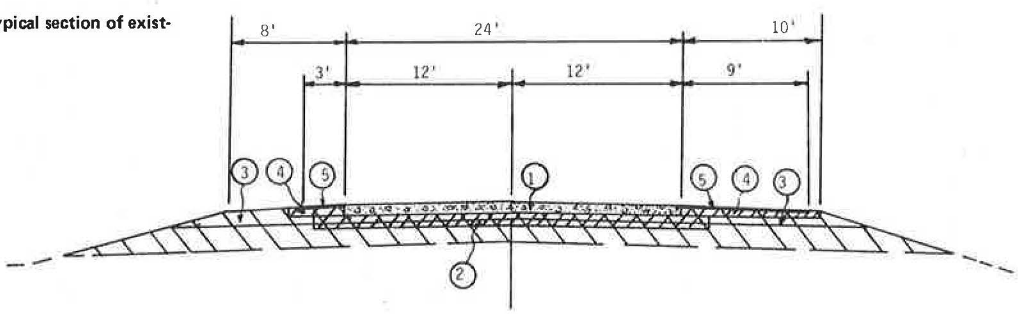
Between January and April 1962, the northbound and southbound lanes of this section of highway were constructed on a soil-cement base as an experimental project. Because this was only the second CRCP to be constructed in Mississippi, different schemes of reinforcement were incorporated into the project. In

Figure 1. Location of CRC overlay.



the southbound lanes, reinforcement was provided by using deformed steel bars with longitudinal steel percentages of 0.5, 0.6, and 0.7 in the southern, central, and northern thirds of the roadway, respec-

Figure 2. Typical section of existing CRCP.



Notes:

1. 8" Continuously reinforced cement concrete pavement (3/16"/' slope)
2. 6" Cement-treated base, 28' wide
3. Roadbed topping (sand-clay)
4. 6" Cement-treated shoulder (1/2"/' slope)
5. Double bituminous surface treatment

tively. In the northbound lanes, smooth welded wire mesh was used for reinforcement with the same longitudinal steel percentages as used in the southbound lanes. The welded wire mesh was fabricated in mats 11.5 ft wide and 24 ft long. Centerline tie bars were placed on 30-in. centers. The mats were overlapped 13 in. lengthwise and tied together by wire. It should be noted that smooth wire mesh is not typical of the reinforcement used in CRCPs constructed in the past 20 yr.

The southbound lanes have performed satisfactorily since construction. The northbound lanes, however, have developed some problems.

Over a period of approximately 3 months after placement, 10 abnormally wide cracks were noticed. Two additional cracks were found during the first year of pavement life. All of these wide cracks occurred at the laps of the welded wire mats. The typical repair performed by the contractor can be summarized as follows:

1. Make two saw cuts, each approximately 1 in. deep, from 30 to 40 in. apart, with the crack approximately centered between them;
2. Using a jackhammer, remove the concrete to the level of the reinforcement;
3. Weld 0.5- by 24-in. reinforcing bars to the adjacent mats at the ends;
4. Coat the entire zone, both concrete and steel, with epoxy glue; and
5. Place fresh concrete, incorporating high-early-strength cement to restore the section, and cure with wet burlap.

Almost all of these contractor-repaired joints were still performing well at the time of the overlay.

After the roadway was opened to traffic, many other wide cracks developed, again all at the laps of the welded wire fabric mats. These have been repaired by MSHD maintenance forces by using a variety of techniques. In some areas, the concrete was removed to the level of the reinforcement and replaced with a bituminous mix. In other areas, the full depth of concrete and reinforcement was removed and replaced with a bituminous mix, sometimes by using expansion material to create an expansion joint. Other techniques, involving both portland cement concrete (PCC) and bituminous concrete, were also used. Almost all of these repairs failed to correct the problem, and the problem areas became progressively worse with the spalling of the concrete.

There was also evidence of some pumping at the pavement edge due to roof water entering the edge joints. Little success had been achieved in sealing these edge joints, and most of them were sufficiently open to permit surface water to enter. By mid-1980, the condition of the pavement had deteriorated to the point where corrective action was essential.

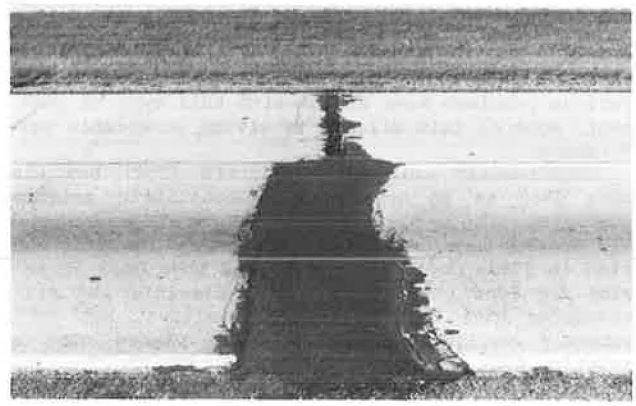
Reasons for Selecting CRC Overlay

The rideability and present serviceability index (PSI) of the northbound roadway diminished due to the unsuccessful repair operations previously discussed. This, coupled with the evidence that pumping at the pavement edge was beginning, indicated that effective rehabilitative work was needed to protect the investment made in this segment of the Interstate system and to restore the PSI to an acceptable level. An overlay would accomplish these objectives.

Mississippi had had success with an unbonded CRC overlay constructed in 1971 on I-20 near Vicksburg, which had given MSHD personnel valuable experience and expertise in this type of construction. In comparing the alternative of a CRC overlay with a bituminous overlay, attention should be directed to the roadway system involved and pavement life. Because the subject roadway is a segment of a busy Interstate highway and the rehabilitation disrupts the normal traffic flow and increases the likelihood of accidents, it is important that such rehabilitations be as infrequent as possible. Based on experience, a CRC overlay would provide a much longer pavement life than a bituminous overlay.

Figure 3. Extra-wide crack in existing CRCP.

Figure 4. Bituminous patch in existing CRCP.



An unbonded overlay was chosen primarily to eliminate or reduce the possibility of reflective cracking. To achieve a good bonded or partially bonded overlay would require reestablishing the continuity of the existing reinforcement in the numerous areas of distress. An unbonded overlay would allow much simpler patching of the 62 locations where the existing reinforcement was no longer continuous. A secondary reason for choosing an unbonded overlay was the need to correct some minor grade irregularities for which a bituminous leveling course would be ideal. Based on this reasoning, an unbonded overlay was selected.

Because this is the first CRC overlay of an existing CRCP (to our knowledge) to be constructed, the project should provide much valuable information that will advance the work of pavement rehabilitation. This information should be especially helpful in light of the fact that much of the Interstate system is approaching the end of its design life.

EVALUATION OF EXISTING CONDITION

Visual and Pictorial Evaluation

All patches and areas of distress were photographed just before construction of the overlay. Figures 3 and 4 show typical areas of distress. Minor to moderate spalling of the random cracks was evident in some areas, and the spalling was usually much worse in the passing lane than in the right lane. This type of spalling was also noticed in the southbound lanes. The spalling appears to be stabilized and is not considered to be a problem at this time.

Deflection, Roughness, and Skid Resistance

Before the overlay was constructed, deflection measurements were made with a Dynaflect. These measurements showed an average maximum deflection of 0.651 mil and a standard deviation of 0.235 mil. The measurements indicated that the pavement and subgrade were strong.

Mays Ride Meter testing was performed to determine pavement serviceability. The PSI, based entirely on the results of the Mays Ride Meter, was 2.6.

Skid resistance was determined by using the MSHD ASTM skid trailer. The average skid number for the pavement was 46.

Traffic Volume

The current average daily traffic (ADT) for the northbound roadway was 4,960, and the equivalent annual 18-kip single-axle loading was 317,000. The accumulated equivalent 18-kip single-axle loading was 4.5 million. The ADT for the design year (2000) is forecast to be 8,465.

Cracking

Two 1,000-ft sections were mapped for cracks before construction of the overlay. Typical cracking is shown in Figure 5. The average crack spacing was about 7 ft.

Shoulders

The 10-ft outside shoulder and the 4-ft inside shoulder appeared to be in good structural condition after a visual inspection. Some minor faulting was noticed in isolated areas. The longitudinal joint between pavement and shoulder was open in most areas. Minor staining was noticed at two locations near distressed areas in the CRCP, probably due to pumping of fines from under the pavement. Distressed areas were almost always confined to the CRCP, and the shoulders were maintained in good condition.

DESIGN

Selection of Rigid Overlay

In addition to the reasons listed earlier for selecting a rigid instead of a flexible overlay, another factor should be mentioned. Sixty-two distressed areas, as typified by those shown in Figures 3 and 4, needed repair before the overlay was placed. The repair method chosen was to remove the concrete, steel, and asphaltic concrete currently in the distressed area and replace them with hot-plant-mix asphaltic concrete. The resulting joints between the CRCP in place and the new asphalt concrete patch would be active due to longitudinal movement of the CRCP. If a bituminous overlay were placed, these joints would probably propagate through the overlay in a short period of time and would need regular maintenance to keep an effective sealant in place. It was thought that an unbonded rigid overlay would bridge the patched area and preclude the need for regular joint maintenance.

Basis of Overlay Design

The design of the CRC overlay was based more on experience than on any set design procedure, predominantly due to the rarity of this type of construction. The experience the MSHD gained in 1971 from the CRC overlay of a 9-in jointed reinforced concrete pavement on I-20 near Vicksburg was utilized in the design. The experiences of other states in constructing CRC overlays were also investigated and provided helpful information that was used as a guideline in the design (3).

The AASHTO Interim Guide for the Design of Pavement Structures (4) includes a procedure for designing PCC overlays for existing PCC pavements. The procedure was developed by the U.S. Army Corps of Engineers primarily for use in the design of runways and taxiways at airports. The design equation developed for an unbonded overlay was

$$h_o = (h_d^2 - ch^2)^{0.5} \quad (1)$$

where

- h_o = thickness of overlay slab (in.),
- h_d = thickness of new pavement from regular PCC pavement design analysis (in.),
- h = thickness of existing pavement (in.), and
- c = coefficient depending on the condition of the existing slab, ranging from 0.35 for badly cracked slabs to 1.0 for slabs in excellent condition.

Because this design equation would result in a slab thinner than the minimum being used by most states in placing unbonded CRC overlays (5-6 in.), it was not used in design.

Design of Pavement Overlay

The overlay design called for a 6-in. CRC overlay on the two 12-ft traffic lanes. Figure 6 shows a typical section of the overlay. Longitudinal steel consisted of No. 5 bars at 7.25-in. spacing, which provided a longitudinal steel percentage of 0.71. The first and last bars were spaced 2.62 in. from the outside edges of the traffic lanes. Transverse steel consisted of 30-in.-long No. 4 bars spaced 36 in. center to center and supported on chairs. There was 2.5 in. of concrete cover over the reinforcement. The contract provided that, if the contractor proposed a suitable method for placing the longitudinal steel through the paver, the transverse steel could be eliminated and replaced with tie bars. The longitudinal center joint was to be formed by inserting a strip of plastic material along the centerline of the pavement to induce longitudinal cracking along a controlled plane.

The shoulders were to be constructed of 6-in. plain PCC and were to be the first such shoulders constructed in Mississippi. The outside shoulder was to be 10 ft wide and the inside shoulder 4 ft wide. Transverse contraction joints with dimensions of 0.25x0.5 in. were specified at approximate 20-ft intervals. The shoulders were to be tied to the pavement with 30-in.-long No. 5 tie bars on 30-in. centers. Corrugated rumble strips were to be formed in the fresh concrete at approximately 60-ft intervals.

To provide end restraint for the CRC overlay, each end of the overlay was to be tied to the existing lug anchors, which were constructed monolithically with the original pavement. To do this, the existing pavement was to be removed down to the top of the lug anchors for a distance necessary to form a transition by which the grade would match the grade of the overlay at a rate of 2 in./100 ft (approximate transition distance of 300 ft). The concrete pavement in the transition was to be of varying thickness.

Surface Texture of Overlay

The two traffic lanes were to be given a transverse groove finish. After a burlap drag had been used, the final surface texture was to be produced by a metal tine finishing device. The texturing device was to produce uniform, transverse parallel grooves 0.5 in. on centers and 3/16 in. deep.

Repair of Failed Areas

The only repair work performed on the existing pave-

Figure 5. Section 1 mapped before CRC overlay.

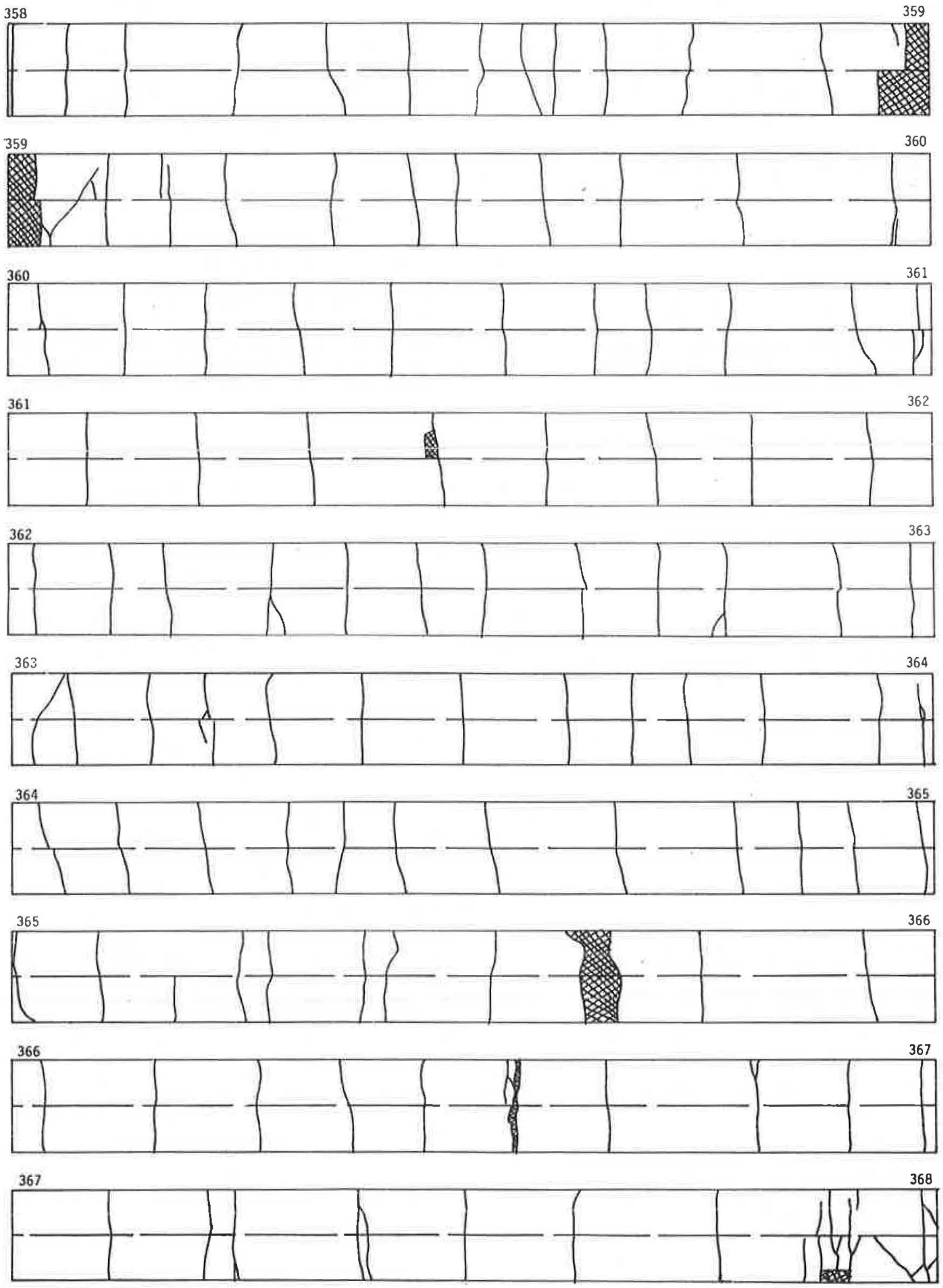
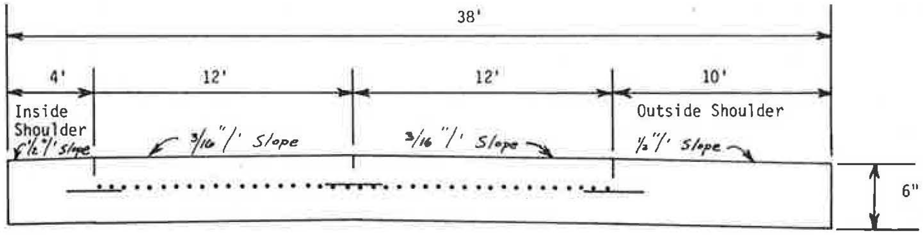


Figure 6. Typical section of CRC overlay.



Notes:

Longitudinal weakened plane joints may be formed by placement of a continuous strip of polyethylene or other approved material with a minimum thickness of 20 mils and a minimum depth of D/4, where D is the thickness of the pavement.

Above reinforcement detail is applicable only if the contractor has a suitable method of placing longitudinal reinforcement by machine. Otherwise, full length transverse reinforcement supported by chairs shall be used and the centerline tie bar eliminated.

ment was replacement of all of the failed areas. The full depth of the section was to be removed and replaced with hot bituminous mix. Before removal, neat saw cuts were to be made into sound concrete on each side of the failed area to define the limits of the patch.

Bond Breaker/Leveling Course

A hot bituminous leveling course was to be applied to the existing surface to correct slight irregularities in the grade and to serve as a bond breaker. The leveling course was 1.5 in. thick. This bituminous course extended across both traffic lanes and shoulders.

Traffic-Handling Procedures

The traffic control plan called for northbound traffic to be diverted to the southbound lanes during placement of the CRC overlay and subsequent curing time, which resulted in two-way traffic in the southbound lanes. All patching and placement of the bond breaker/leveling course was to be done under traffic. Crossovers were designed for each end of the project by using precast New Jersey-type barriers and impact attenuators in the reverse curves of the crossovers. Nighttime lighting through the crossover areas, trailer-mounted electric message boards located in advance of and throughout the project, and construction signing were to be used to alert motorists to the two-way traffic zone. In the southbound lanes, double 4-in. continuous yellow temporary stripe was used as centerline striping and 36-in. snapback delineators on 100-ft centers were used to prohibit passing. The two interchanges within the project limits were to be closed to both entrance and exit traffic during the time the southbound lanes were subject to two-way traffic.

Specifications

This CRC overlay marks the first time the MSHD has used these new specifications for concrete pavement. This type of specification is sometimes called a performance-related or end-result specification. Mix design, quality control, and much of the daily record keeping were to be the responsibility of the contractor, and the MSHD was to establish general guidelines and conduct random checks. Acceptance and payment were to be based on factors such as surface smoothness, pavement thickness, and the compressive strength of cores obtained from the pavement. Because of the disruption to traffic on a section of Interstate highway, it was imperative that this project be completed in the shortest time possible. It was decided that the award of contract would be based on a combination of bid prices and contract time. The MSHD established January 1, 1981, as the beginning of contract time and allowed bidders to propose their own completion dates. The bidder would then determine the number of calendar days between the beginning of contract time and his specified completion date and multiply this number by $7,000, the amount established by the MSHD as the average daily road-user cost associated with closing the northbound lanes and two interchanges to traffic. This product of calendar days multiplied by $7,000 was to be added to the total bid determined from bid prices. The sum of these two amounts was to be the amount used in the comparison of bids. Copies of special provisions describing this procedure are available from the MSHD.

Table 1. Comparison of bids.

Bidder	Total of Bid Items ($)	Contract Time (days)	Total[a] ($)
Denton Construction Company	4,721,539.83	151	5,778,539.83
Bush Construction Company and T. L. James and Company	4,544,930.41	250	6,294,930.41
Cook Construction Company	5,271,196.81	212	6,775,196.81
Eisenhour Construction Company	5,215,617.24	266	7,077,617.24

[a]Includes road-user delay costs of $7,000/calendar day.

CONSTRUCTION

Contract Award

Bids were opened in October 1980 after a 2-month advertisement period. Four bids were received. The lowest bid for construction items only was submitted by a joint venture of Bush Construction Company of Laurel, Mississippi, and T.L. James and Company of Ruston, Louisiana. When the amounts for road-user costs were added, however, the lowest total for comparison of bids was submitted by Denton Construction Company of Grosse Point Woods, Michigan. The contract was therefore awarded to Denton. Table 1 compares the bids submitted.

Mix Design and Quality Control

Denton Construction Company contracted with Ladner Testing Laboratories, Inc., of Jackson, Mississippi, to prepare the mix design and develop and coordinate a quality-control plan as required by the specifications. The mix design approved for the project was a five-bag, 4,000-psi mix containing an air-entraining agent and a water reducer. The quality-control plan submitted merely incorporated the minimum requirements set forth in the contract.

Diverting Traffic

The contractor requested and was granted permission to divert all traffic to the southbound lanes before performing any work on the northbound lanes. The traffic-control plan described earlier called for all patching and placement of the bond breaker/leveling course to be done under traffic. This was to have been done by performing the patching and asphalt placement one lane at a time while accommodating traffic in the other lane. The contractor reasoned that the time period during which all traffic would be forced to use the southbound lanes could be shortened by doing all the preliminary work on the northbound lanes after traffic had been diverted. Having the entire roadway open for construction activities would vastly improve efficiency and thus save time, and several operations could be carried out concurrently. Another advantage of this method was that it would eliminate the possibility of accidents between highway travelers and construction equipment.

Work began in mid-November 1980 on construction of the crossovers at each end of the project. Northbound traffic was diverted to the southbound lanes on December 12. Figures 7-9 show crossover barriers, traffic-control devices, impact attenuators, and lighting. Figure 10 shows a typical view of the southbound lanes, including the double yellow center stripe and snap-back delineators. Portable electric message-board signs were placed at four locations along the southbound lanes to remind motorists of the two-way traffic.

Repair of Distressed Areas

As soon as traffic was diverted from the northbound lanes, the work crew began removing concrete in the transition areas and in the distressed areas. Concrete saws were used in both areas. Numerous cuts were made in the transition areas at 10- to 20-ft intervals to facilitate removal of the concrete and steel. The depth of the saw cuts varied but always extended below the level of the steel reinforcement. Jackhammers and hydraulic rams were then used to break the concrete into pieces small enough to be picked up by a front-end loader. In the 62 distressed areas, saw cuts were made on each side of the distress into sound concrete. A hydraulic ram was then used to break the concrete and asphalt in the distressed area into small pieces for removal. The soil-cement base was generally in good condition and did not require removal. In areas where the soil-cement was unsuitable, it was removed and replaced with hot-plant-mix bituminous pavement.

Figure 7. Crossover barrier and attenuator.

Figure 8. Crossover directional arrow.

Figure 9. Crossover marking and lighting.

Figure 10. Typical section for two-way traffic on southbound lanes.

After the distressed areas were cleaned and a tack coat was applied to the edges of the existing concrete pavement, hot-plant-mix was placed in three lifts and compacted to complete the patch.

End Anchorage and Transition

Crews began work to provide end anchorage for the overlay as well as a smooth transition from the overlay to the adjoining pavement on each end of the project. The existing concrete pavement was removed over a distance of 375 ft at each end of the project. The existing lug anchors were left in place and prepared for use in anchoring the overlay. Approximately 75 ft of pavement removal exposed the four lug anchors, and the remaining 300 ft allowed for the grade transition. Hot-plant-mix bituminous pavement was placed in the 300-ft transition area.

Placing Bituminous Bond Breaker/Leveling Course

A combination bond breaker and leveling course with a 1.5-in. nominal thickness was placed across the entire width of the traffic lanes and shoulders for a width of 38 ft. The bituminous mixture conformed to MSHD specifications for hot-plant-mix surface course. The bond breaker/leveling course was placed in two lifts and conformed to the same cross-slope requirements as the CRC overlay. The thickness of the bond breaker/leveling course was variable to allow for the correction of minor grade problems.

Overlay Construction

The overlay construction began on January 5, 1981, at the northern end of the project. It should be remembered that the first 375 ft of pavement was of variable thickness and that transverse reinforcement, consisting of full-length No. 4 bars spaced 36 in. on center, was used. Thereafter, the longitudinal reinforcement was placed through tubes on the concrete spreader and the full-length transverse reinforcement was replaced with 30-in. tie bars.

The contractor used a modified concrete spreader (see Figure 11) to spread concrete about 8 in. thick across the two 12-ft-wide traffic lanes and to place both longitudinal reinforcement and the centerline tie bars. The longitudinal bars were fed through tubes and positioned at the proper height. Plans called for 2.5 in. of concrete cover above the reinforcement. To reduce the possibility of the deformed bars becoming stuck in the feeder tubes, a mechanical system was installed on the spreader to rotate the tubes slowly back and forth. The centerline tie bars were inserted by a reel-like device, and the shoulder tie bars were placed by hand. Steering of the spreader was controlled by an electronic sensor traveling on a string line. Concrete was delivered to the spreader in side dump trucks.

The slip-form paver used was modified to pave the entire 38-ft-wide roadway in one pass (see Figure 12). Twin augers on the front of the paver spread the extra-thick concrete placed by the spreader an additional 4 ft on one side and 10 ft on the other side to form the plain concrete shoulders. To increase production, concrete was also dumped directly in front of the paver on the 12-ft outside lane and on the 10-ft shoulder (see Figure 13). The paver inserted plastic crack initiators longitudinally into the 6-in.-thick slab along the centerline and along the joints between the traffic lanes and the shoulders. An oscillating belt and a burlap drag were used immediately behind the paver. Horizontal alignment of the paver was controlled by a string line. Vertical alignment was controlled by a rolling string line in tangent sections and by separate stationary string lines on each side of the roadway in the superelevated sections and in transitions.

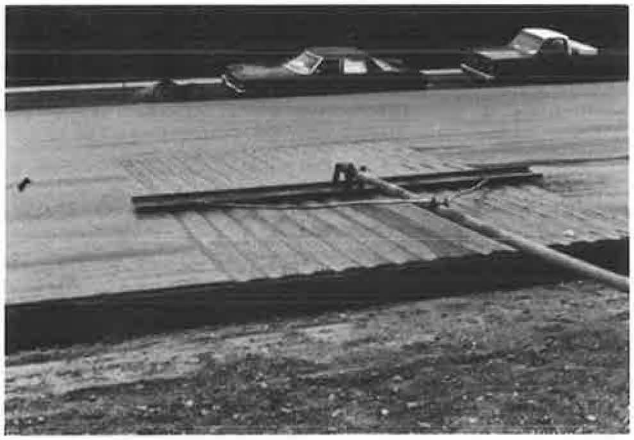
Concrete finishers standing on work bridges towed by the paver continued the finishing operation. A tube finisher followed the work bridges. Rumble strips were then formed in the concrete shoulders by hand with a special float (see Figure 14). The

Figure 11. Rear view of concrete spreader.

Figure 12. Front view of concrete paver.

Figure 13. Placing additional concrete on outside lane and shoulder.

Figure 14. Forming rumble strips in shoulder.



pavement was then given a transverse tined finish and sprayed with white pigmented curing compound at a rate of 1 gal/90 ft^2. If freezing temperatures were anticipated during the night, the pavement would be covered with plastic sheeting.

Transverse contraction joints were sawed into the plain concrete shoulders when the concrete was 1 day old. These joints were later cleaned with compressed air and sealed with grade AC-13 asphalt cement.

Construction joints were made at the end of each day's work. A piece of No. 5 reinforcing bar 5 ft in length was tied to each longitudinal bar so that half the length was in the current day's slab and the rest was in the next workday's slab to increase the bonding area across the cold joint. This is a standard practice for all CRCP construction by the MSHD.

Concrete for the project was produced in the contractor's double-drum plant located on property adjacent to the highway right-of-way and about 0.5 mile north of the beginning of the project. The maximum haul was about 6 miles. Batch size was 5.5 yd^3. The concrete was delivered to the site in side dump, standard dump, and agitator trucks.

In view of the fact that it was the middle of winter, the work progressed satisfactorily. The 6.7-mile project was paved in 14 workdays over a 3-week time span, and concrete placement was completed on January 24. The average maximum and minimum ambient temperatures for the month of January were 55.4°F and 28.5°F, respectively. The overall average ambient temperature was 42.0°F, which is 6.2°F below normal. One workday was lost due to low temperatures. The total precipitation (all rainfall) for January was 1.61 in., which is 3.23 in. below normal. One workday was also lost due to rainfall. Average daily production was 10,670 yd^2 or 2,527 linear ft of pavement and shoulders.

In conjunction with the CRC overlay, the exit and entrance ramps for the two interchanges located within the project limits were improved. Alignment and length changes were made to reflect current design standards. Grade changes were also made to match the new overlay grade. The 10-ft-wide outside concrete shoulder was deleted in the ramp areas, and asphalt pavement was used for the entire ramp.

After ramp improvements, striping, and signing had been completed, the northbound lanes were opened on February 11.

Shortly after the roadway was opened to traffic, excessive spalling of the concrete was noticed adjacent to the construction joint approximately 2.5 miles north of the beginning of the project. The concrete had deteriorated to an average depth of 1.5 in. Spalling was confined to only one side of the construction joint and was attributed to a bad batch of concrete used at the start of that day's construction. Only the traffic lanes were affected. Saw cuts were made on both sides of the spalled area across the traffic lanes. The 1.5-in.-deep cuts were approximately 2 ft apart, and one cut was directly above the construction joint. A jackhammer was used to remove the concrete between the saw cuts to an average depth of 1.5 in. After cleaning, the entire area was coated with epoxy cement and a rapid-setting concrete was used to restore the section. This repair was done one lane at a time while traffic was diverted to the other lane. Curing time for the patch was 2 hr.

POSTCONSTRUCTION EVALUATION

Performance Testing

Pavement performance testing was conducted on the completed overlay by using the MSHD skid trailer, the Mays Ride Meter, and the Dynaflect. The skid test resulted in a skid number of 51. The PSI rating of the pavement, based entirely on Mays Ride Meter measurements, was 3.1. Dynaflect deflections showed an average maximum deflection of 0.279 mil and a standard deviation of 0.078 mil.

Crack Pattern

The crack pattern of the CRC overlay was slow in developing. It is thought that the cool temperatures may be responsible for this. Also noteworthy is the fact that even on sunny days most of the pavement was shaded during most of the daylight hours. Both transverse cracks and longitudinal cracks at the centerline and at the edge between pavement and shoulder were not generally noticed until about 3 weeks after construction. It should be pointed out that the tight cracks were especially hard to see amid the transverse tining and the curing compound. Two 1,000-ft sections were mapped before placement of the overlay, and the corresponding sections of the overlay are to be mapped periodically. One section is near the south end of the project, and the other is approximately at midpoint of the project.

The first transverse cracks that were noticed extended across the pavement between the sawed contraction joints in the shoulders for a crack spacing of approximately 20 ft. The next transverse cracks generally appeared approximately midway between the contraction joints in the shoulders. In most cases, although these cracks remained tight, they extended through the plain concrete shoulders.

One of the mapped sections has two areas where five or six transverse cracks are closely spaced over a 10-ft section. It is interesting to note that these two areas are located above bituminous patches in the underlying CRCP. The method for constructing these bituminous patches was described earlier. In light of this finding, the entire project was examined. Eight additional areas of closely spaced cracks were found, six of which are directly above bituminous patches in the underlying CRCP. At the time this paper was prepared, all the cracks in these areas were tight and showed no spalling or other distress.

Longitudinal cracking has been found in three locations on the project. These longitudinal cracks are situated at about midpoint of each traffic lane and vary from about 50 to about 200 ft in length. All are tight at this time.

Specifications

No glaring deficiencies were noticed in the content of the new specifications dealing with rigid pavement. In our opinion, the specifications were not enforced as rigidly as they should have been. Quality assurance reporting, and possibly testing, were lax. Hereafter, an effort should be made to compel strict compliance with the requirements of the specifications.

Several factors probably affected the failure of the MSHD to follow the letter of the specifications:

1. Because few concrete highways are currently being built in Mississippi, MSHD personnel do not have extensive experience with this type of construction.
2. Because of the traffic-control situation, this project was built on a fast-track schedule, which made it difficult to keep up with all of the construction activities.
3. Because this was the first time these specifications had been used, various people involved were unfamiliar with their responsibilities.

One major factor of the construction directly attributable to these new specifications was the concrete mix design. The contractor submitted a mix design with a cement factor of 1.25, the minimum allowed. This mix design met MSHD criteria and was approved. Under the previous specifications, the MSHD would have used the aggregate and cement sources selected by the contractor in designing the mix and would probably have designed a mix with a cement factor of 1.45. This is one reason for the end-result type of specification. It allows the MSHD to set minimum criteria and frees contractors to meet the requirements in what they perceive to be the most economical way. Acceptance criteria spell out the penalties for noncompliance.

In this case, based on the asumption that a cement factor of 1.45 would have been used under the previous specifications, the contractor saved almost 1 bag of cement/yd^3 of concrete but was penalized for insufficient core strength on four lots, all located in the traffic lanes. Three lots were penalized 20 percent each, and one lot was penalized 5 percent for low compressive strengths on roadway cores. One of the lots that was penalized 20 percent for low compressive strength was also penalized 20 percent for deficient thickness. Because the contract price on which a penalty is calculated is also reduced by other penalties, this resulted in a penalty of 36 percent. A lot consisted of 1,500 linear ft of the two traffic lanes, or 3,000 linear ft of each shoulder. The shoulder pavement met all acceptance criteria.

An unusual aspect of the specifications used for this project was the method of determining contract time and contract award, which was discussed earlier. These provisions proved useful in limiting closure of the northbound lanes to the shortest time possible. In view of the rapid completion of this project, the use of such provisions should be strongly considered in future projects where lane closures are necessary.

CONCLUSIONS AND RECOMMENDATIONS

Based on observations made during and after construction, the following conclusions and recommendations are made:

1. The statistically oriented quality assurance specifications are sound, and strong consideration should be given to their implementation as the standard specifications for rigid pavement construction; however, measures need to be taken to ensure that the provisions of the specifications are rigidly followed.
2. Where traffic-control procedures permit, a less expensive leveling course/bond breaker should be used. Where a leveling course is required, sand asphalt is suitable if high skid resistance is not required. Where a leveling course is not necessary, some type of fabric or liquid membrane should be investigated for possible use as a bond breaker.
3. The use of specifications, such as those described in this paper that relate to contract time determination and contract award, should be considered when it is in the public interest to reduce construction time to the minimum.

The project will continue to be monitored, and the adequacy of the design and construction procedures will be assessed at the end of the study period.

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