PCC PAVEMENT JOINT RESTORATION AND REHABILITATION
(Federal Highway Administration NEEP Project 27)
Construction Report

MICHIGAN DEPARTMENT OF TRANSPORTATION

TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION

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PCC pavement joint
restoration and
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J. E. Simonsen
F. J. Bashore
A. W. Price

Research Laboratory Section
Testing and Research Division
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Introduction

Since the late sixties, much research has been devoted to developing methods for repairing transverse joints in concrete pavements. Because of the nature of joint distress experienced on Michigan's concrete pavements, repairs have consisted of replacing the deteriorated joint area with a new full-depth section. Thus, our research work has mostly involved the development of methods for joining an existing slab to a new one utilizing either fixed or movable-type joints.

The methods experimented with include: tying the slabs together either by using self-drilling expansion anchors with hookbolts or by saving a sufficient length of the existing reinforcement so that it can be lapped with the replacement slab steel to form a fixed joint, or by drilling holes and installing dowel bars to form a movable-type joint. Although these methods can be used to construct a joint between a new and old slab that will perform reasonably well, they are all very labor intensive and time consuming to construct, and consequently, quite costly. For these reasons, only a limited number of repairs using these joint types have been constructed.

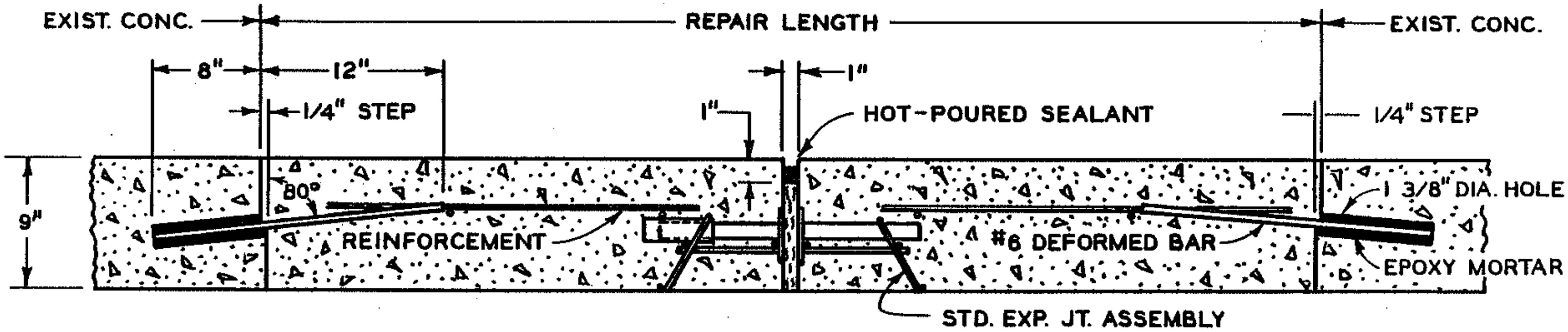
The objective of this project is to develop a tied joint for use between existing and new concrete pavement slabs that can be constructed rapidly without extensive hand labor, which when used in conjunction with a doweled joint in the repair center will provide necessary load transfer and eliminate faulting.

The project, as outlined in the Work Plan for PCC Pavement Joint Restoration and Rehabilitation (FHWA NEEP Project 27), May 1981, is planned to be completed in three stages with each succeeding one to be initiated only if the prior one proves successful. Briefly, each stage will involve the following work:

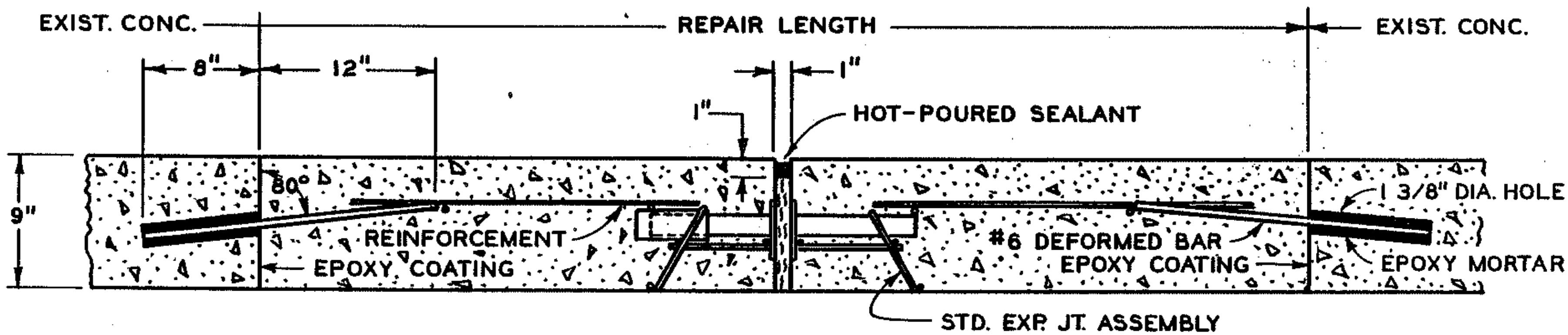
Stage 1. Installation of a few repairs using two types of tied joints on a roadway with light commercial traffic, primarily to determine the feasibility of construction and evaluate their performance under light traffic loads.

Stage 2. A limited number of the experimental repairs will be installed on a major roadway carrying a heavy commercial traffic volume, to evaluate their performance under such loading.

Stage 3. A contract to construct a large number of the repairs will be let to determine their suitability for use on a production type project and to obtain cost information when large quantities are involved.



a. Repair with step-cut end limits.



b. Repair with epoxy coated end limits.

Figure 1. Experimental types of repairs.

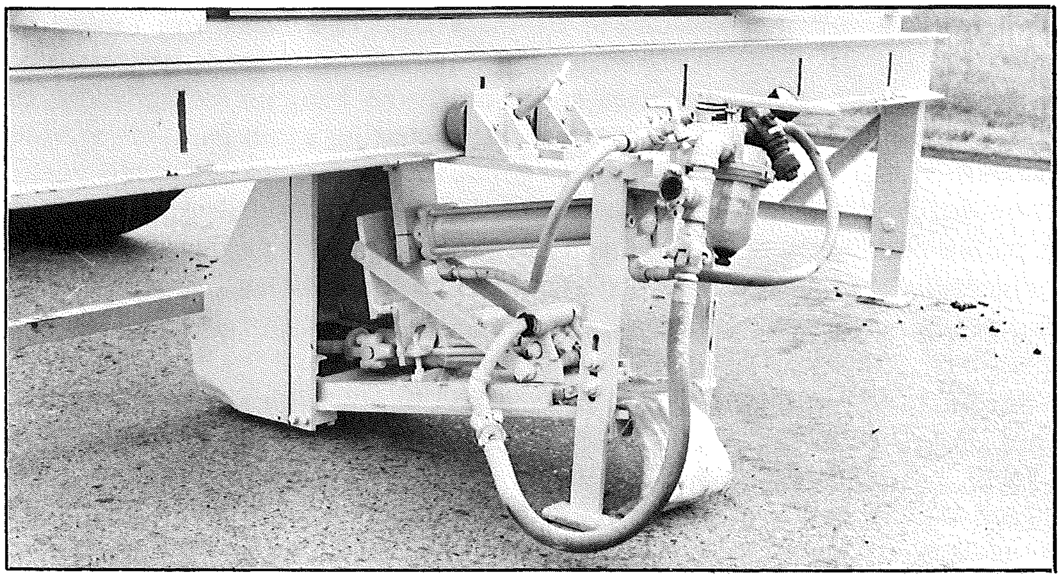


Figure 2. Machine for drilling holes in vertical end faces of concrete pavement. The drill is mounted on rollers on back-to-back channels to allow positioning of holes across the pavement width. An air cylinder provides pressure for forward and backward movement of the drill.

Stage 1 is now completed and this report describes the experimental features involved and the construction methods used to repair four pavement joints. On the basis of the data obtained, recommendations are made for proceeding with Stage 2 of the project.

Experimental Features

On the basis of laboratory test results on different types of tied joints, two types were selected for field testing (Fig. 1). Both types utilize No. 6 deformed tie bars set in a 1-3/8 in. diameter by 8 in. deep hole with Type II epoxy mortar. This epoxy conformed to the low temperature grade in MDOT Standard Specifications, Section 8.16.05, and was used to obtain early strength.

To provide necessary shear strength, one of the tied joint types utilized a 1/4-in. (approximate) step sawed into the vertical end limit faces at about mid-slab depth. On the other type of joint, the vertical end faces were coated with the epoxy binder used for hole grouting immediately prior to placing the concrete.

A special drilling rig (Fig. 2) was made in the Laboratory's Machine Shop to eliminate the use of handheld drills, and to increase the speed of drilling holes in the hardened concrete. It consists of back-to-back 12 ft long channels with slip brackets to fit the bucket of a front end loader. A sinker drill (30 lb class) along with an air cylinder to provide pressure for both forward and backward motion of the drill was hung on rollers from the bottom flanges of the channels. The roller mounting arrangement provided for transverse movement of the drill across the 12 ft wide slab. To reduce friction during drilling, drill movement was facilitated using a slide plate with roller bearings. The drill was positioned on a 10 degree angle above a horizontal plane, which was done to both aid the drilling process and the filling of the holes with the epoxy mortar.

Seven tie bars were installed in each end face of a repair at the following spacing: 12-18-18-24-24-18-18-12 in. (that is, the first and last bars are 12 in. from a lane edge). The number of tie bars at each repair end was selected on the basis of laboratory test results which showed that seven bars used in conjunction with either a step cut or an epoxy coat should develop close to the same shear strength as a tied construction joint used in new pavement construction.

Repair Locations and Description

The pavement on which the construction feasibility work was done is located on US 127 between I 96 and M 36 south of Lansing. It is 15 years old and consists of two 24 ft roadways of reinforced concrete 9 in. thick. The joints are spaced 71 ft apart and contain 1-1/4 in. diameter dowels, 18 in. long, on 12-in. centers. The joint grooves were sawed, and preformed neoprene seals were used to seal the joints. The pavement was placed on a clay subgrade, 10 in. of sand subbase, and 4 in. of aggregate base. The 1977 ADT volume is reported to be 5,500 with the commercial volume estimated at approximately 9 percent.

Four joints were selected for repair, two on the southbound roadway at Sta. 728+55 and 745+35 and two on the northbound at Sta. 449+10 and 590+60. Three repairs were 6 ft long and one 8 ft in length. One repair on each roadway was constructed with the 1/4 in. step saw cut and one with epoxy coated joint faces. As previously mentioned, No. 6 deformed tie bars, set in 8 in. deep holes with epoxy mortar and embedded 12 in. into the new concrete, were used at all repairs. A standard expansion joint assembly was placed in the center of each repair and the concrete was a 9 sack per cu yd mix. Calcium chloride was added to the concrete mix at the job site to provide early concrete strength so that the repairs could be opened to traffic four to six hours after pouring. The repairs were reinforced with 6 by 12 in. plain welded wire mesh, W9 and W4 wires with the W9 wires transverse to the pavement.

Construction Operations

The repairs were done during the week of July 13-17, 1981, except for sawing of the repair limits which was done during April. The field work was a cooperative effort of Maintenance personnel from the Mason garage and personnel from the Research Laboratory.

Sawing - The end limits of the repairs and interior cuts were sawed full depth using a 26 in. diameter diamond blade. The cut was made in two passes: the first one about 5 in. deep and the last one about 4 in. deep. Care was taken to ensure that the blade did not cut into the base material. At the repairs where a step was required, the second pass was made with 18 in. diameter blades mounted next to the 26 in. blade. This resulted in a step at about mid-slab depth.

On the first step cut repair, one 18 in. blade with a spacer between it and the 26 in. blade was tried. However, the flexibility of the 18 in. blade outside the spacer support resulted in difficult sawing and a step of approximately 1/8 in. in width. Therefore, on the second repair, two 18 in. blades were mounted next to the larger blade. This set-up resulted in a step slightly over 1/4 in. wide and did not interfere appreciably with the normal operation of the saw. Figure 3 shows the blade mounting arrangement used for the second repair and Figure 4 shows the step after concrete removal.

Concrete Removal - The distressed concrete was lifted out by attaching chains to lift pins installed in holes drilled through the slab and using a front end loader. First a narrow strip of concrete—about 18 in. wide at the shoulder tapering to 12 in. at the pavement centerline—was lifted out to relieve any pressure present in the slab. Then the remaining portion of the failed area was lifted out and final clean out of the repair area was done by use of hand tools.

Tie Bar Installation - Once the repair area was cleaned out, the drilling operation began. Timing of the actual drilling of holes showed that the average time to drill one hole was 45 seconds, resulting in a total time of about 10 minutes to drill the 14 holes required on each lane repair. With the time needed to move and position the drill at each hole location and time lost due to occasional sticking of the drill bit, about 17 minutes was used to complete the drilling at a repair. Although the positioning of the drill rig at each end limit was not timed, it is estimated that about three to five minutes was consumed during this part of the drilling work. Thus, a total time of about 20 to 22 minutes would be needed to drill the 14 tie bar holes.

Figure 3. Saw blade mounting arrangement to make step saw cut--one 26-in. blade with two 18-in. blades next to it.

Figure 4. View of step saw cut after concrete removal. Cut made with blade arrangement shown in Figure 3.

The installation of the tie bars required about 11 minutes per lane repair. First, the holes were blown clean using compressed air. Then, one man would hand fill the holes with the mortar and another one would insert the bar and smooth off the mortar around the bar. Figures 5 through 7 show the drilling and tie bar installation operations. Following the bar placement, the repair was formed and an expansion joint assembly installed in the center of the repair (Fig. 8). The reinforcement was then placed (Fig. 9) and at the epoxy coated repair locations, the epoxy was brushed on the end faces just prior to concrete placement.

The 9-sack concrete mix was delivered to the site in ready mix trucks. Calcium chloride was added to the mix at the job site. The concrete placing and finishing operations followed normal procedures used for this type of work. Figure 10 shows a finished repair before the curing compound was applied and before sealing the joint.

All repairs were done one lane at a time while traffic was maintained in the other lane. The repairs were opened to traffic four to five hours after concrete placement was completed.

Performance Evaluation

The most critical factors in the performance of the tied joints are their ability to resist slab contraction restraint and provide adequate load transfer capacity during the first 24-hr period while the concrete is still developing strength. To evaluate these factors, cores were taken through one tied joint at each repair in the traffic lane about 24 hours after pour and gage plugs were installed at all joints to monitor joint width variation.

Joint width measurements taken the morning following the pour and one week later showed that at three repair locations the expansion joints were open about 0.10 in. in the morning, and the tied joints had openings ranging from 0.001 to 0.020 in. The measurements taken at the fourth joint repair show the expansion joint closing (0.06 in. after one week), one tied joint opened 0.03 in., and the other one opened 0.006 in.

Examination of the cores revealed no evidence of failure from the step cut joints (Figs. 11 and 12). One core from an epoxy coated joint showed that the new concrete was well bonded to the existing concrete (Fig. 13) but the other core showed bond failure (Fig. 14). It appeared the epoxy did not bond to the fresh concrete. This core was taken from the tied joint that had opened 0.03 in. and it is apparent that the epoxy bond and tie bar bond resistance to the new concrete was less than the adjoining expansion joint

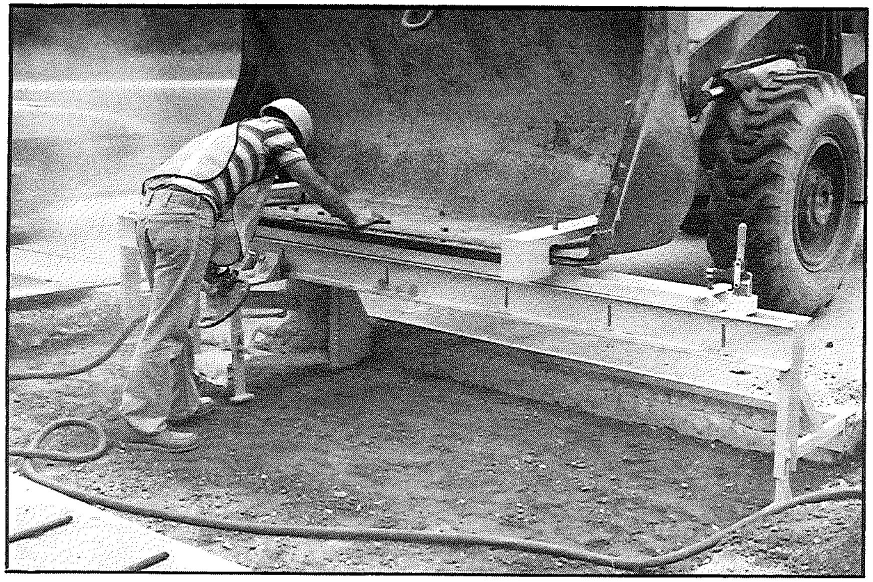


Figure 5. Drilling holes for tie bar installation. Dark lines on support channel indicate hole locations.

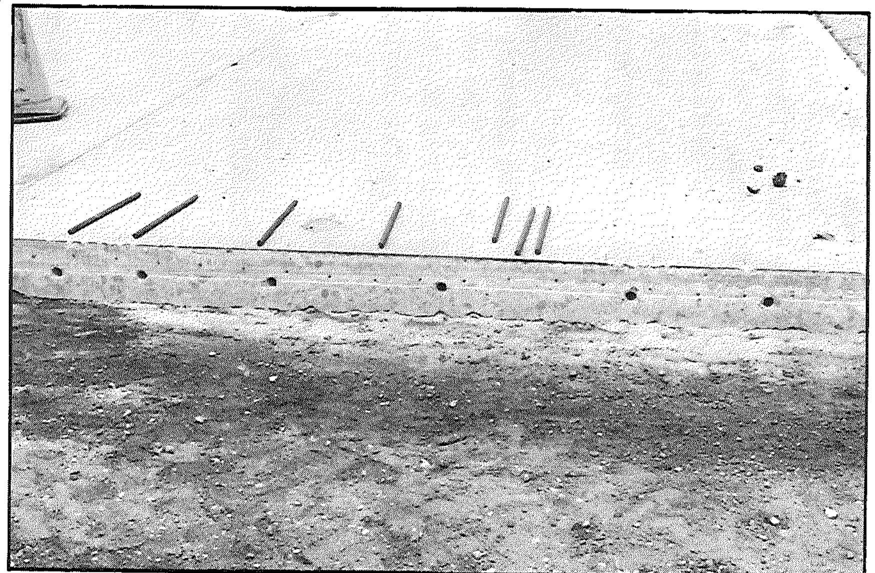


Figure 6. End face of repair showing part of the transverse 12-18-18-24-24-18-18-12-12 in. spacing of tie bars. Vertically, the holes are at mid-slab depth.

Figure 7. Hand placing of tie bars in end face of pavement slab.

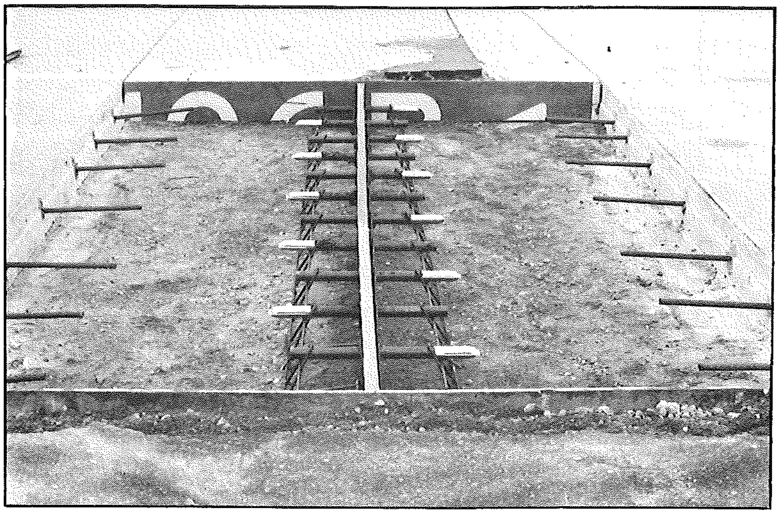
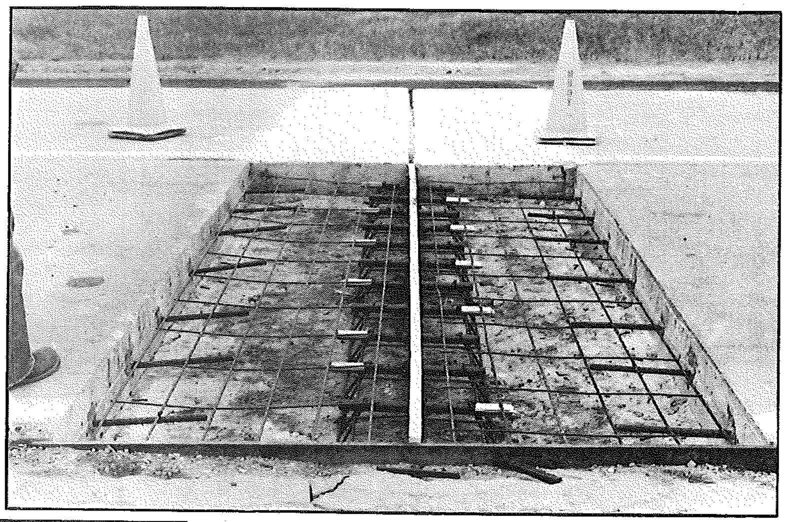


Figure 8. Repair area with tie bars, forms, and expansion joint assembly in place.

Figure 9. Repair area just before placing concrete. On short length repairs the reinforcement is placed with heavy wires in the transverse direction.



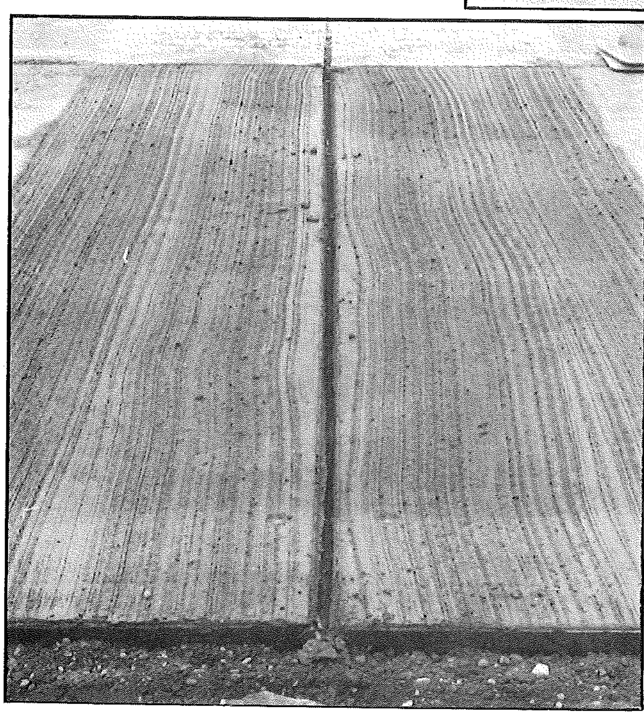


Figure 10. Appearance of finished repair before applying curing compound and joint sealant.

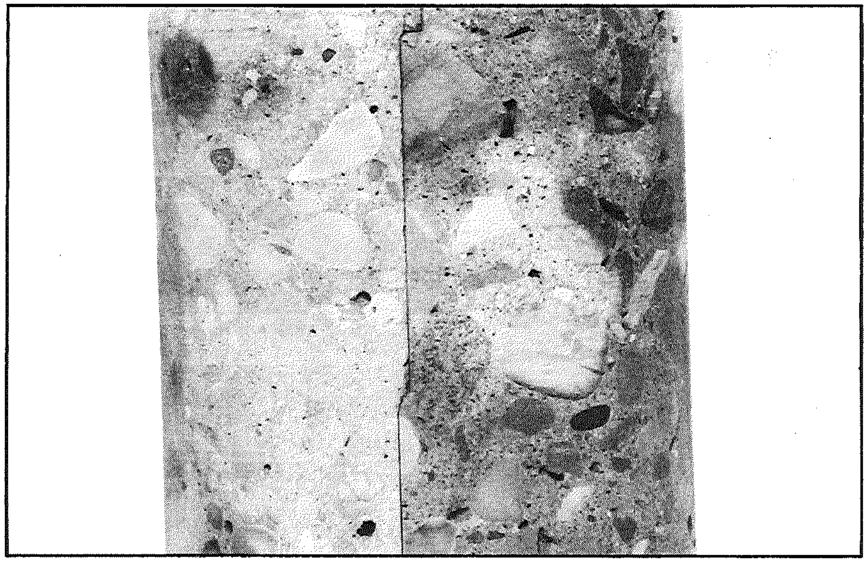


Figure 11. Condition of step cut (about 1/8 in. wide) joint after 24 hours service. No failure cracks are noticeable.

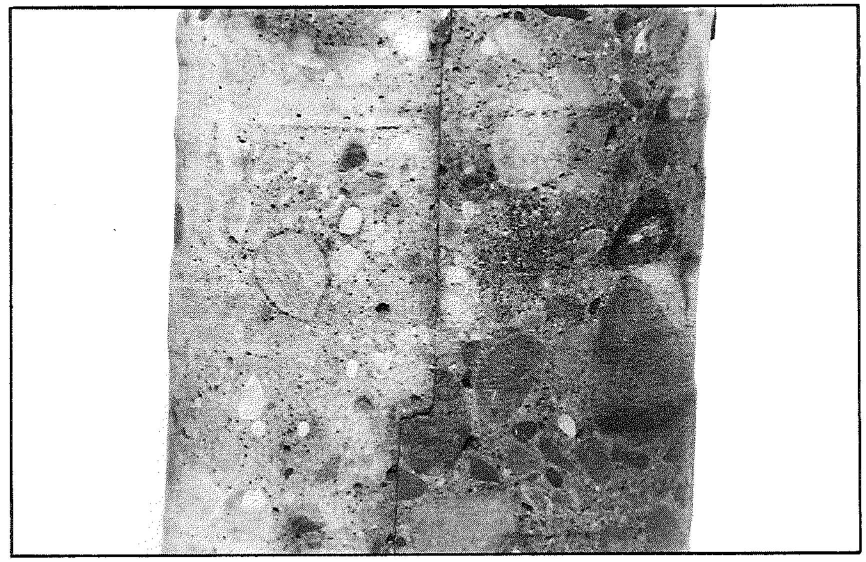


Figure 12. Condition of step cut (about 1/4 in. wide) joint after 24 hours service. No failure cracks are noticeable.

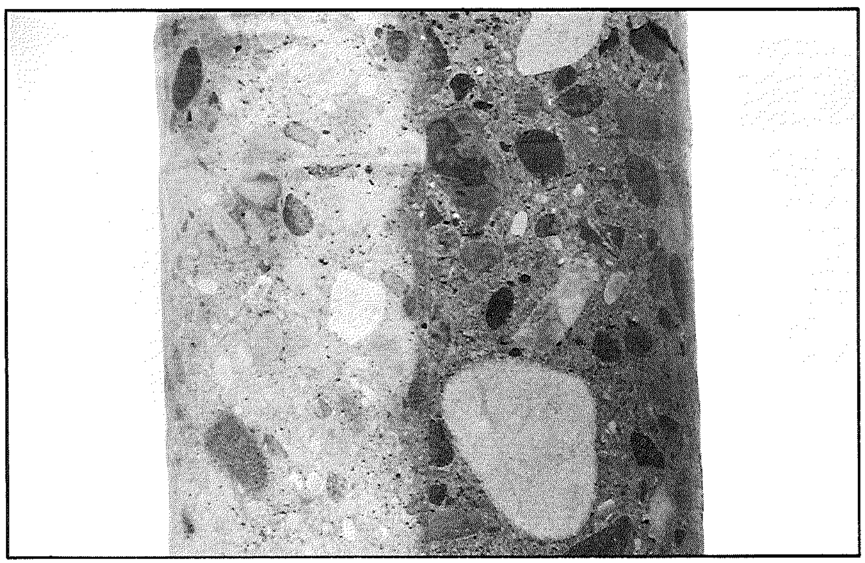


Figure 13. Condition of epoxy coated joint after about 24 hours service.

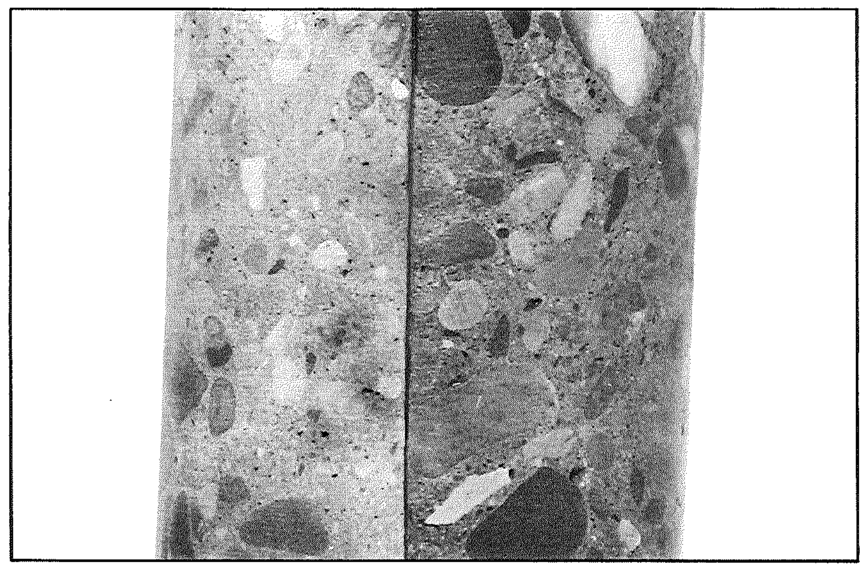


Figure 14. Condition of failed epoxy coated joint.

restraint in resisting the tensile forces during the first night's cooling period.

Since later joint width measurements revealed the closing of the expansion joint rather than opening, an inspection of the repair area was made. This showed an open transverse crack at about the mid-length of an adjacent slab. This is indicative of progressive contraction joint restraint in the original pavement. Thus the pavement is, in effect, tied together at these joints effecting long continuous slab behavior.

Conclusions

On the basis of the results of this construction feasibility study, it is concluded that the use of tied joints constructed by grouting tie bars into drilled holes in the existing concrete is a practical way of preventing faulting of repair slabs.

The equipment fabricated for drilling the tie bar holes eliminates the hand labor normally involved in this type of drilling operation. The time required to drill the holes and install the bars at a lane repair is about 30 minutes using two men. This is less than half the time it takes two men to save the steel for tying onto an existing slab.

Early performance data indicates sufficient strength of the joints during the first 24-hr critical period while the concrete is still below the 3,500 psi compressive design strength. The one epoxy bond failure, as previously mentioned, apparently was caused by the expansion joint dowel restraint.

It is estimated that the tied joints should give satisfactory performance—retain their smoothness—for at least 10 years. It is also estimated that this important improvement in our joint repair performance will add approximately $150 to the cost of a lane repair, which is a relatively small price to pay for the benefits gained.

Recommendations

It is recommended that Stage 2 of the project, the installation of a few tied joint repairs on a route carrying heavy commercial traffic to test their performance under heavy loading, be approved.

It is proposed that six repairs, three with step cut joints and three with epoxy coated joints, be done this fall. This would allow several months' performance, which should provide additional data on which to determine whether the project should be continued next year with a larger number of repairs to be constructed on a contract basis.

It is suggested that the Stage 2 repairs be made on I 94 between Jackson and Battle Creek where the 24-hr truck volume on each roadway is about 2,200. The repair work would be a cooperative effort between the Maintenance Division and the Research Laboratory. The Maintenance Division would furnish the material, equipment, and personnel to remove and replace the failed joints, and the Research Laboratory would help with the tie bar installation as well as concrete placement.