

MICHIGAN DEPARTMENT OF TRANSPORTATION
MDOT

CONCRETE PAVEMENT RESTORATION
Final Report

D. E. Branch

A State Planning and Research Project
by the Michigan Department of Transportation
in Cooperation with the
Federal Highway Administration

Research and Technology Section
Materials and Technology Division
Research Project 86 G-267
Research Report No. R-1327

Michigan Transportation Commission
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Lansing, January 1995

This report, authorized by the transportation director, has been prepared to provide technical information and guidance for personnel in the Michigan Department of Transportation, the FHWA, and other reciprocating agencies. The cost of publishing 60 copies of this report at \$2.37 per copy is \$142.02 and it is printed in accordance with Executive Directive 1991-6.



Action Plan

1. Engineering Operations Committee
 - A. Review report and approve.
2. R. A. Welke, Deputy Director, Bureau of Highways
 - A. Transmit report to FHWA.
3. Materials and Technology Division
 - A. Project complete; investigate any future improvements in materials and procedures for applications in areas identified as having problems.
 - B. Send copies of this report to Maintenance and Construction Divisions, and District Design Units to assist in job selection/maintenance operations.

Acknowledgments

The authors wish to acknowledge the help and cooperation of the many people who made the numerous phases of this project possible. Special acknowledgement is owed to J. E. Simonsen and the late A. W. Price for their development and management of the construction phases of this project, as well as their authorship of many of the department's related specifications. This report is a final version of their Construction Report published in August 1988.

Executive Summary

For the past 25 years, the Michigan Department of Transportation's Research Laboratory has conducted several studies to develop effective maintenance procedures for concrete pavement. The procedures were developed for daylight closures to minimize the inconvenience and hazard to motorists caused by maintenance operations. By 1982 (following evaluation of cast-in-place repairs, with and without dowelled joints), the department used dowelled repairs as a standard procedure. The dowels are loose fitting (1/16-in. clearance) in holes drilled in the adjacent slabs. The restoration work described in this report uses repair techniques previously developed in addition to new ones. The pavement selected for restoration was a 20 year-old, 9-in. reinforced concrete slab with 71-ft joint spacings, and joints sealed with preformed neoprene seals. Deteriorated joints were repaired using full-depth repairs having dowelled joints with the dowels grouted-in-place using an epoxy grout. Some mid-slab failures were repaired by tying the new concrete to the existing slab using grouted-in-place No. 10 deformed bars. The deteriorated intersections of the longitudinal and transverse joints were restored using 2-ft by 4-ft full-depth repairs tied in place with grout-in No. 5 deformed bars. Spalls along the joint grooves were repaired partial-depth with fast-set premixed mortar; the neoprene seals were replaced with silicone sealant; the longitudinal joints were resealed using a low-modulus hot-poured sealant; and surface pop-outs were fixed using fast-set premixed mortar. The performance of the various restoration techniques were evaluated for a five-year period.

INTRODUCTION

Since 1970, the Michigan Department of Transportation's concrete pavement maintenance program has included the use of full-depth repairs of distressed areas. The repair procedures developed by the Research Laboratory were designed to allow the repairs to be opened to traffic during daylight hours in order to limit possible hazards caused by overnight lane closures. Initially, precast slab repairs were used to avoid night closures. Subsequently, cast-in-place repairs were used with calcium chloride accelerator in the repair concrete. These cast-in-place repairs were developed primarily to reduce cost and increase daily production; they were undowelled and were intended to serve for an interim five-year period. By the late seventies, changes in available funding resulted in the need for alternative repair procedures with longer service lives. Our experimental work with dowels installed in machine-drilled holes, and the performance of 12-year old repairs with dowels in hand-drilled holes, indicated that the use of loose fitting dowels (1/16-in. hole clearance) would increase the repair's service life to 10 or more years. As specifications developed, grouted-in-place dowels using an epoxy grout were required. Dowelled repairs of this type are currently specified for concrete pavement maintenance.

In 1976, the department began a study aimed at developing a preventive maintenance program for reinforced concrete pavements having neoprene sealed transverse joints. The procedures developed were to be such that traffic could be maintained through the repair area and the work performed during daylight hours. Following laboratory testing to determine the most promising fast-set patching materials and development of repair procedures, a nine-mile section of I-69 in Calhoun County was selected as a field testing site. The experimental procedures applied on I-69 involved the use of five fast-set patching materials for joint groove spall repairs; removing damaged or malfunctioning contraction joint seals and resealing with new neoprene seals; and removing tight and frayed neoprene expansion joint seals, resawing the joint grooves, and resealing the joints with either a liquid sealant or a new neoprene seal. The work was done by MDOT Research and Maintenance forces.

Based on the I-69 field work experience and the performance of the spall repairs and resealed joints, specifications for experimental contract maintenance work were prepared. A first contract covering a section of I-75 in Arenac County was let in 1983 and a second contract was let in early 1984, which included an eight-mile section of M-47 in Saginaw County. In addition to joint groove spall repairs and resealing transverse joints, full-depth repairs were made at severely deteriorated joints and transverse cracks. Further, less severely deteriorated cracks underwent spall repair, routing, and sealing with a liquid sealant. Similar materials and procedures were also used to seal the resawed longitudinal joints.

The use of bars, cemented into drilled holes in hardened concrete using a polyester or epoxy grout, has been common for many years in some phases of construction work. However, only relatively recently has the use of grouted dowel bars been used in concrete pavement repairs, and its use has met with mixed success. The difficulty in obtaining reliable and consistent grout has been traced to problems in mixing and injecting the material into the horizontal holes.

To overcome these problems, the industry has introduced epoxy and polyester grouts that mix in the nozzle of the injection equipment. This has greatly reduced the mixing problem and the injection difficulty as well, since the nozzle can deposit the grout in the back of the hole. Thus, when the bar is inserted in the hole the grout flows out around the bar, ensuring proper embedment and bond. The injection tool can be calibrated to deposit the exact amount of epoxy needed to embed the bar.

In the spring of 1985, the Research Laboratory, in cooperation with the Maintenance Division, installed five full-depth lane repairs on northbound I-69 south of Charlotte, using the above described method of grouting the dowels into the predilled holes. This experimental work revealed that the use of the prepackaged two-component grout was a feasible method for grouting dowels in hardened concrete. Subsequent load-deflection tests confirmed that an increase in load transfer efficiency was obtained compared with repairs utilizing loose fitting dowels.

Based on the experimental work described above, an extensive restoration project was envisioned which used previously developed procedures, modified as needed, as well as new ones to restore the distressed or failed areas of a pavement. A proposal for this research project was submitted to the Federal Highway Administration to perform this work under the Highway Planning and Research (HPR) program. The proposal was approved in October 1986, and in 1987 the project was begun.

The restoration procedures outlined in the proposal were:

- 1) Full-depth lane repairs with grouted-in-place epoxy coated dowels.
- 2) Full-depth lane repairs with grouted-in-place epoxy coated No. 10 deformed bars.
- 3) Partial lane width full-depth repairs at the intersection of the transverse and longitudinal centerline joints.
- 4) Partial depth repair of pop-outs and spalls along the joint grooves.
- 5) Routing and sealing of transverse cracks.
- 6) Removing existing neoprene seals and resealing with a silicone sealant.
- 7) Resawing and resealing the longitudinal centerline joint.

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

Objectives

The experimental work was undertaken to evaluate the field performance of the various repair techniques and to determine the merit of restoring concrete pavements to substantially increase their service life.

Selecting a Candidate Restoration Project

Concrete pavements considered for restoration must meet certain criteria. One of the most important factors is that the underlying base is capable of providing adequate support and drainage. To correct base problems would require removing and replacing the existing slab which would be reconstruction rather than restoration of the pavement. Improving the drainage would, as a minimum, require installation of edge drains which would result in extensive work on the shoulders.

Some concrete pavements in Michigan that have been built in the last 25 years have exhibited severe base or drainage problems. These pavements were not considered as candidates for the restoration project. Therefore, the only remaining factors considered in selecting restoration candidates were aggregate quality and working joints. Experience has shown that partial-depth spall repairs along joint grooves and routing and sealing of cracks is not cost effective in pavements showing signs of extensive D-cracking. Pavements with this problem are best maintained by removing the affected D-cracked area full depth. In extreme cases, overlaying or reconstruction may be necessary.

Non-working joints, by restraining movement during contraction cycles, cause increased tension in the concrete. Consequently, the reinforcement eventually fractures at one or more cracks between the joints. These cracks now act as undowelled joints allowing unimpeded access for water and incompressibles into the pavement section. In time, faulting may occur at the cracks. To correct this problem a full-depth dowelled repair is necessary. On pavements where most movements occur at mid-slab cracks, a cost analysis would be required to determine if restoration costs would compare favorably with overlay or reconstruction costs. However, such mid-slab cracks are known to cause reflective cracking in bituminous overlays.

Existing Project Description

A 20-year old concrete pavement on I-69 in Calhoun County was selected for restoration work. Based on its surface condition D-cracking was not a problem; however, pop-outs caused by a few expansive aggregates included in the mix, were present in the pavement surface. Nearly all transverse joints appeared to be working. The main distress in the pavement was compression failure of most of the expansion joints and a few contraction joints. Open transverse cracks, acting as joints, were present in some slabs as well as cracks still held tight by the reinforcement. The 20-year old neoprene seals were no longer entirely effective and spalling of the joint grooves had occurred. The longitudinal centerline joint was originally sealed with a cold mastic sealant which was no longer effective, but the tie bars were still holding the slabs tightly together.

The selected pavement was a 4.2-mile section of I-69 located between the M-60 interchange and the overpass for J Drive South. It was constructed in 1967 and each roadway consists of two 12-ft, 9-in. reinforced concrete lanes. The dowelled joints were spaced at 71 ft and the contraction joint grooves were sawed 1/2 in. wide by 2-1/2 in. deep. Expansion joints were installed at every fifth joint on the southbound roadway and on the southern mile of the northbound roadway. The longitudinal centerline joint was sawed 1/8 by 2 in. deep. The pavement was placed on a 10-in. sand subbase overlain with a 4-in. aggregate base. Drainage was provided through the sand subbase by extending it to the foreslope. The 1986 total two-way average daily traffic (ADT) volume was 12,000 and the commercial volume was 2,400. No surface maintenance work, other than routine patching with cold patch bituminous material, had been done at the time the restoration work started.

Condition Survey

A condition survey was conducted to ascertain the amount of each distress type present in the pavement. Since all distressed areas must be repaired on a restoration project, the need for assigning distress levels to the problem areas is not necessary. Thus, the survey was done primarily to obtain quantities of the distressed items. It should be noted that coring at the intersection of the transverse and longitudinal joint was done prior to the surface condition survey to determine a minimum full-depth repair area needed to correct failures at this location. Previous experience had determined that most failures at these joint intersections resulted from full-depth deterioration of the concrete. Based on examination of the cores, it was decided that a 2-ft wide by 4-ft long full-depth repair would be the minimum size and would cover most failures.

The distress types for which quantities were obtained were:

- 1) Expansion and contraction joint compressive failures
- 2) Cracks with fractured reinforcement
- 3) Spalls along joint grooves
- 4) Surface pop-outs
- 5) Cracks still held tightly together by the reinforcement
- 6) Transverse joints to be resawed and resealed
- 7) Longitudinal joints to be resawed and resealed

The survey was conducted under traffic from the outside shoulder and the quantities were estimated values. Illustrations of the various distress types are shown in Appendix A.

Contract Repair Quantities

The repair quantities for contract bidding purposes were based on the condition survey results. Table 1 gives the quantity for each repair item and the unit bid price of the successful contractor.

TABLE 1 Repair Quantities and Costs			
Bid Item	Quantity	Unit	Unit Cost
Full-Depth Lane Repairs	2,622*	sq yd	\$75.77
Full-Depth Centerline Repairs	317*	sq yd	\$261.75
Partial-Depth Spall Repairs	1,103*	lin ft	\$28.24
Surface Pop-out Repairs	1,538	each	\$15.00
Miscellaneous Pavement Repairs	219	sq yd	\$64.20
Sawing and Sealing Cracks	4,112	lin ft	\$1.75
Sawing and Resealing Transverse Joints	13,854	lin ft	\$4.30
Sealing and Resealing Longitudinal Joints	47,400	lin ft	\$1.40

* Increased quantities for these repairs at the start of the restoration work caused an increase of 7 percent in the total contract cost.

The work to be done and the materials to be furnished by the contractor under each bid item shown above are described as follows:

Full-depth lane repair included furnishing all labor, equipment, and materials required to: saw and remove the distressed concrete; drill holes and grout the dowel bars; place the reinforcement and the concrete; finish and cure the concrete, and seal the joints.

Full-depth centerline repair included furnishing all labor, equipment, and materials required to: saw and remove the distressed concrete; drill holes and grout the tie bars; place, finish, and cure the concrete; and seal the perimeter.

Partial-depth spall repair included furnishing all labor, equipment, and material required to: saw the repair perimeter; chip out the unsound concrete and clean the area; reform the joint groove; and place, finish, and cure the fast-set mortar.

Surface pop-out repair included furnishing all labor, equipment, and materials required to: chip out the unsound concrete; sandblast and clean the area; and place, finish, and cure the fast-set mortar.

Miscellaneous pavement repair included furnishing all labor, equipment, and materials required to: saw and remove the distressed concrete; drill and grout dowel bars; place the reinforcement and load transfer assembly; place, finish, and cure the concrete, and seal the joints.

Sawing and sealing cracks included furnishing all labor, equipment, and materials required to: saw the groove, sandblast and clean the joint groove; and seal the groove with a hot-poured sealant.

Sawing and resealing transverse joints included furnishing all labor, equipment, and material required to: remove the existing seal; resaw the joint groove; sandblast and clean the joint groove; install the backer rod; and seal the joint groove with silicone sealant.

Sawing and resealing longitudinal joints included furnishing all labor, equipment, and materials required to: resaw the joint groove, clean the joint groove; and seal the joint groove with a hot-poured sealant.

Special provisions covering the above bid items were prepared for the contract work and copies are included in Appendix B.

CONSTRUCTION PROCEDURES

The experimental project (Michigan Project IR 13073, Job No. 25975A, Federal No. IR 69-1[061]24, Federal Item NP0787) was awarded to the low bidder, Kelcris Corporation of Williamston, Michigan, on June 10, 1987. Since most of the work was governed by special provisions, the department sponsored a pre-bid meeting at which the special provisions and suggested construction procedures were discussed and clarified. Pre-construction

meetings were also held with the department's supervisory construction personnel and with the contractor's personnel. In addition, Research Laboratory personnel who developed the repair procedures and prepared the special provisions were on the job site throughout the construction period to monitor the work and provide technical assistance.

Construction operation began in September and was completed in November of 1987. The work was completed without any major delays but minor delays caused by equipment breakdown and adverse weather were encountered.

Although the restoration work was designed to accommodate daylight closures with more stringent restrictions in reopening to traffic, on this project the contractor was permitted to use overnight closures. One lane closure per direction was allowed at any time except that no lane closures were allowed on holiday weekends. The contract also required the contractor to recast all full-depth repairs the same day that the distressed concrete section was removed. The traffic closures were accomplished with light plastic drums for barricades and lighted arrow-bar flashers at the beginning of a lane closure.

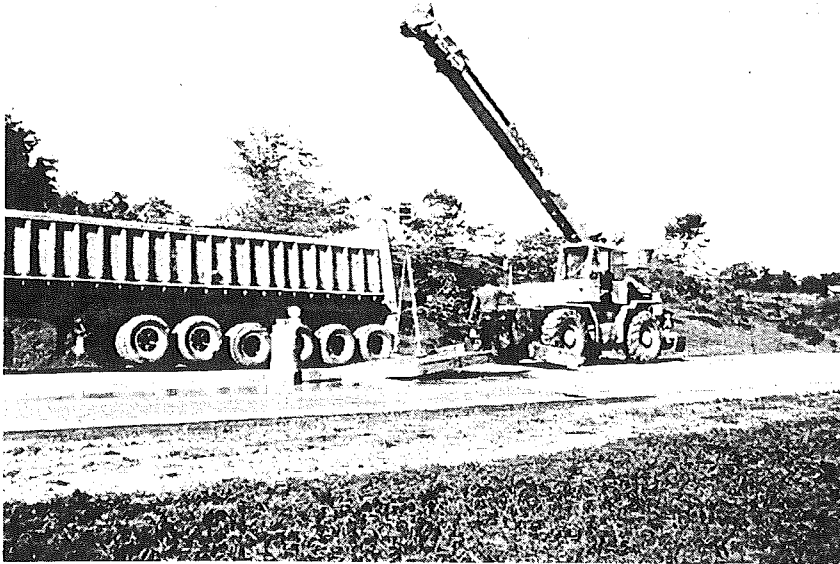
A brief description of each type of restoration work follows.

Full-Depth Repairs

The end limits of the repairs were sawed full-depth using a diamond segmented saw blade and the larger sections of the distressed concrete slab were lifted out without disturbing the base material (Fig. 1). After hand clean out of the repair area, the dowel holes were machine drilled. Two groups of five dowels, spaced 12 in. apart, are used in each end of a lane repair. Each dowel group is centered in each half-lane width, resulting in the first dowel being 12 in. from the lane edge and in a 24 in. spacing in the center of the 12-ft lane. The contractor used a five-gang drilling machine, hydraulically powered, to drill the holes. The dimensions of the holes were 1-3/8 in. diameter with a nominal depth of 7-1/2 in.

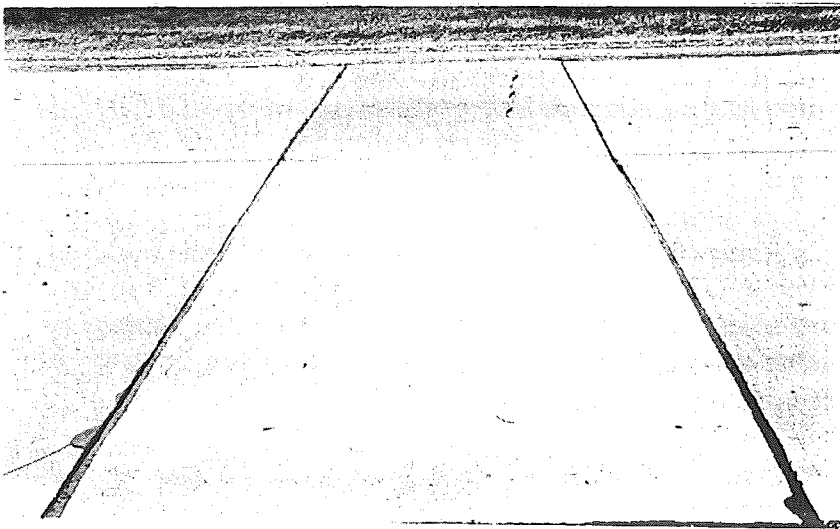
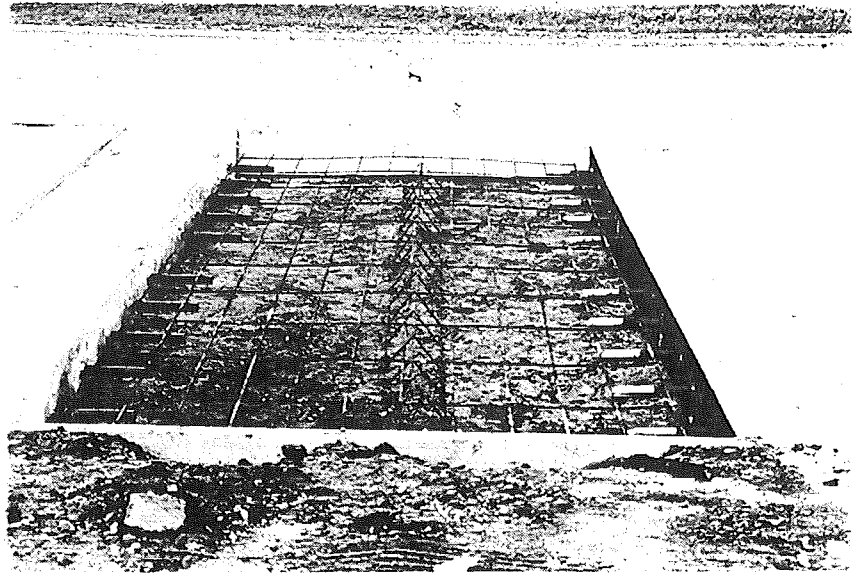
The drilled holes were cleaned using oil-free compressed air by inserting an air wand into the back of the hole. The contractor elected to use an epoxy grout to fasten the dowels into the holes. He also chose to use a dispensing pump utilizing five gallon containers of each grout component. The grout components were pumped through a mixing nozzle and deposited in the back of the holes. The epoxy coated dowel bars, 1-1/4 in. diameter by 16 in. long, were then inserted in the holes and forced to the back of the holes by hand pressure. Forcing in the dowels in this manner resulted in the grout flowing out around the bar which ensured proper grouting.

Considerable pressure was required to fully insert the bars. To alleviate the laborious task, the contractor built a pneumatic ram to force the dowels



◀ Figure 1. Removing distressed pavement section.

Figure 2. Repair area ready for concrete placement. (Contraction joint on the left, expansion joint on the right). ▶



◀ Figure 3. Finished concrete repair.

in place. This equipment worked well when properly aligned with the dowel bar being inserted. The contractor experienced frequent malfunction of the grout dispensing equipment and about half way through the job he switched to prepackaged cartridges. The two prepackaged epoxy components were extruded and mixed through the nozzle using an air-operated ram.

Three types of joints were used with the full-depth lane repairs: contraction, expansion, and fixed or tied joint. For contraction joints the free ends of the dowels were coated with an RC 250 asphalt. For expansion joints the filler board hole locations were marked on the filler board prior to grouting the dowels in place, and the holes were drilled by a hand-held drill. The board was then placed against the concrete end face and the dowel bars were grouted in place. The RC 250 asphalt coat was then applied and an expansion cap placed on each free dowel end. The construction of tied joints was the same as for contraction joints except that instead of dowels, No. 10 epoxy coated deformed bars were grouted into the drilled holes and the RC 250 asphalt coat was eliminated.

Once the treatment of the dowels or deformed bars was completed, the repair area was formed and the reinforcement installed (Fig. 2). A 9-sack ready mixed concrete was used and consolidated using a hand-held immersible vibrator, screeded off, floated, broomed, and a curing compound applied. The transverse joint grooves were formed using a 1 by 1-in. wood strip inserted in the fresh concrete just prior to screeding the concrete surface. The joint grooves were sandblasted and cleaned with oil-free compressed air just prior to sealing with a low-modulus hot-poured sealant. Figure 3 shows a typical finished repair.

Full-Depth Centerline Repairs

As previously mentioned, cores taken at the intersection of the transverse and longitudinal joints indicated that removal of a 2-ft wide by 4-ft long area of the slab would be sufficient to remove the deteriorated concrete. During construction it was found that in the majority of cases this area was adequate in size, but in a few cases it was necessary to increase the area by resawing to remove all the unsound concrete. Figure 4 shows a sawed deteriorated joint intersection.

Full-depth saw cuts were made parallel to and 12 in. on each side of the centerline, and 24 in. on each side of the transverse joints. On about half of the repairs the contractor was allowed to oversaw the corners whereas on the other half no overcuts were permitted. This variation in sawing the perimeter was made to determine if overcutting promoted crack propagation in the adjacent lane.

The overcut sections were lifted out without any problems utilizing lift pins (Fig. 5). On the sections that were not overcut, the contractor freed up the

bottom of the corners by drilling holes through the areas that were not sawed (due to inaccessibility of the saw blade) and then lifted out the section. In both cases, the debris in the repair area was cleaned out by hand (Fig. 6). The new concrete was tied into the existing concrete using 24-in. epoxy coated No. 5 deformed bars epoxy grouted into 3/4 in. diameter holes 6 in. deep (Fig. 7). The bars were located 4 in. from the surface of the slab. Four bars were used in the transverse direction and four in the longitudinal direction. The transverse bars were a nominal 10 in. from the ends of the repair and the longitudinal ones were 6 in. from each side. The holes were drilled by hand-held drills, downward at about a 20° angle to allow drilling in the confined space. Once the bars were in place, they were bent down so as to be approximately parallel to the surface. The dowels removed with the concrete were not replaced, but a 3/4 in. thick full-depth filler board was installed in line with the transverse joint to ensure that the new concrete would not be subjected to excessive compression. Figure 8 shows a finished repair before sealing.

The replacement concrete was a 9-sack ready mixed concrete (no chloride accelerator) which was placed, consolidated, finished, and cured in the normal manner. The repair perimeter was edged and an attempt was made to seal this groove with a low-modulus hot-poured sealant. The sealant, however, did not penetrate the very narrow and shallow groove so this sealing operation was discontinued after trying a few of the repairs. The overcuts were sealed with hot-poured sealant in all cases.

The research procedure outlined in the project proposal included full-depth repair of a substantial length of centerline where the tie bars had fractured and concrete deterioration had occurred. However, on this project the centerline joint was in excellent condition except at the intersection with transverse joints; thus the only centerline repairs performed were the 2 by 4 ft sections where the joints meet. Based on the experience gained by making these repairs, it is evident that full-depth repair of long sections of the centerline joints is possible from a construction point of view. It appears, however, that the cost would be prohibitive. Using the bid price for the 2 by 4 ft repairs, the cost would be \$58/lin ft for a 2-ft wide repair. This price could be reduced considerably if a substantial length of joint were to be repaired, but even reducing the price to that for the transverse joint repairs, the cost would still be high (\$17/lin ft).

Resealing Transverse Joints

All contraction joints and a few expansion joints were resealed using a silicone sealant meeting the requirements of Special Provision AWP2, located in Appendix B. The existing neoprene seals were removed by pulling them out by hand. The grooves were then sawed to a nominal 1 in. width and a 2-1/4 in. depth, so the final seal dimensions would accommodate the stresses anticipated by the movements occurring with a 71-ft slab length. Just prior to



Figure 5. Lifting out distressed concrete at joint intersection.

Figure 4. Sawed perimeter of a typical deteriorated joint intersection.

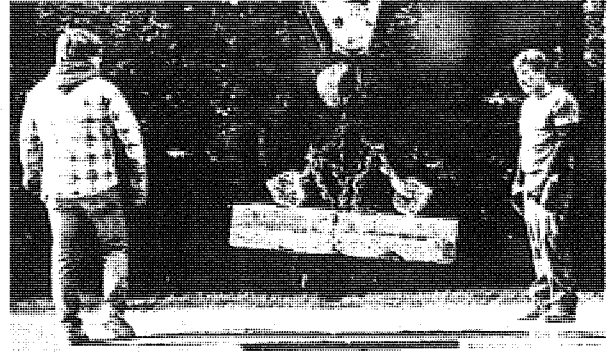


Figure 6. Deteriorated concrete in bottom of repair area.

Figure 7. Joint intersection ready for concrete placement.

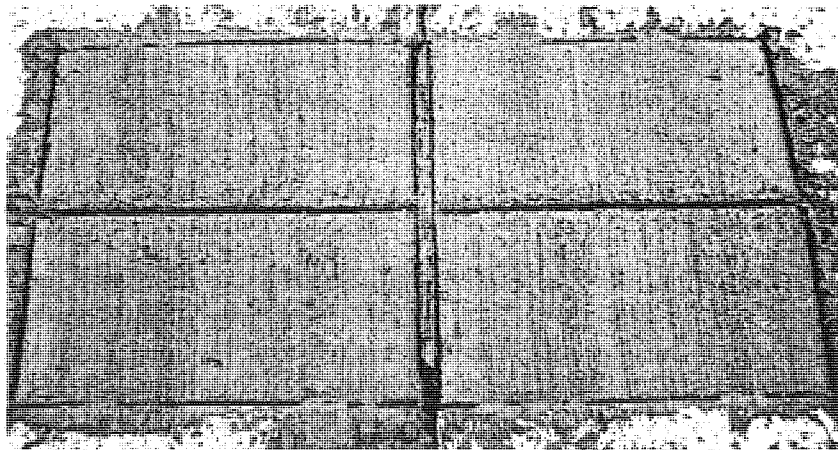
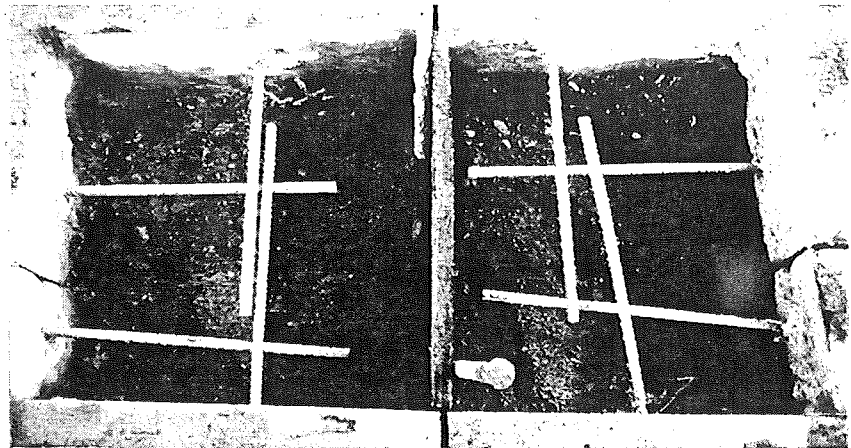


Figure 8. Finished repair before sealing joints.

sealing the joints, the grooves were sandblasted followed by a final cleaning with compressed air free of oil and water. Then a 1-1/4 in. diameter closed cell polyethylene foam rod was installed in the groove to the required depth (Fig. 9). The silicone sealant was pumped into the groove through a wand and the sealant tooled (Fig. 10) to ensure contact with the groove walls (Fig. 11). The specified seal depth was $7/16 \pm 1/8$ in.

Resealing Longitudinal Joints

The longitudinal centerline joint was originally sawed 1/8 in. wide by 2 in. deep and sealed with a cold-applied mastic sealant. This sealant was no longer effective and was replaced with a hot-poured low-modulus sealant. A new groove 3/8 in. wide by 1 in. deep was sawed over the original sawed groove (Fig. 12). To accomplish this, the contractor made two saw cuts; the first one removed the old hardened sealant and the second one sawed the groove. The groove was sandblasted and cleaned with oil-free compressed air prior to sealing the joint with a hot-poured sealant (Fig. 13).

Sealing Transverse Cracks

Transverse cracks with the reinforcement still functioning were sealed to retard the rate of corrosion of the steel. A groove 5/8 in. wide by 3/4 in. deep was sawed over the crack using a random crack saw equipped with a small diameter (8 in. or less) diamond blade (Fig. 14). Any spalls along the cracks were repaired using a fast-set mortar. The routed groove was sandblasted and cleaned with oil-free compressed air prior to sealing with a low-modulus hot-poured sealant (Figs. 15 and 16).

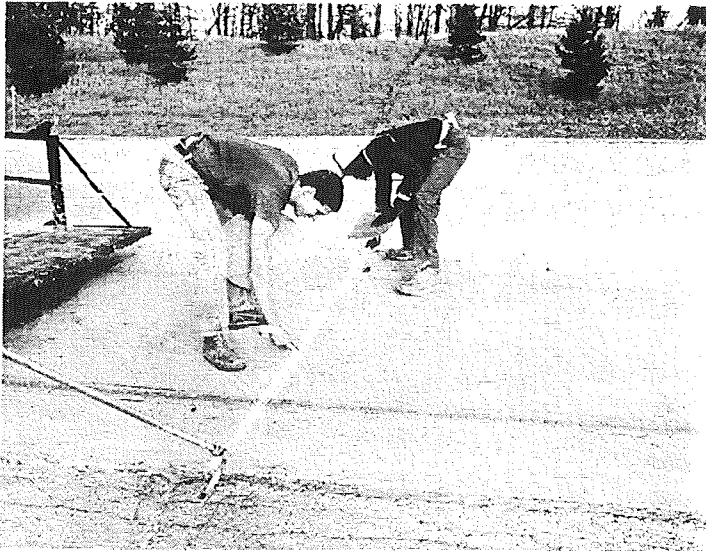
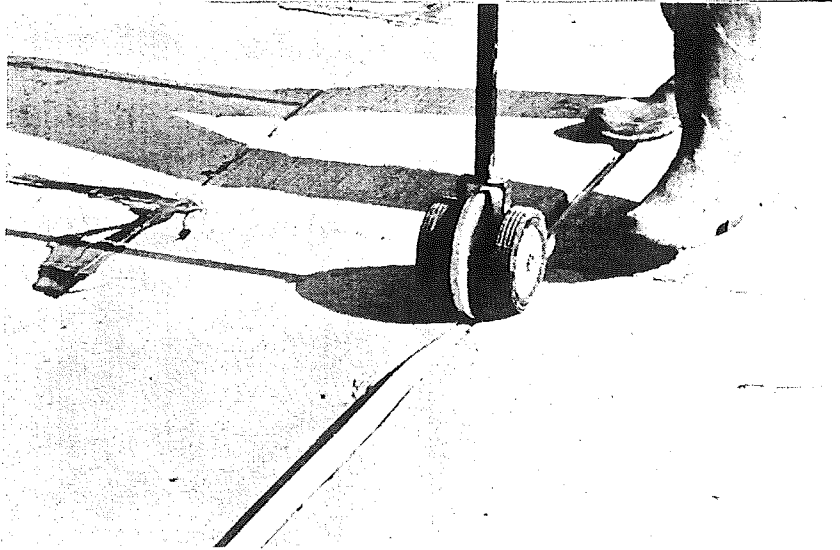
Surface Pop-Out Repairs

The coarse aggregate used in the original concrete contained a few expansive aggregates which had caused pop-outs in the pavement surface. The larger ones were selected to be repaired with the fast-set mortar used for spall repair. The pop-outs were prepared for repair by removing any unsound concrete or remaining expansive aggregate using an air hammer, then sandblasting followed by cleaning with oil-free compressed air. The mortar mix was placed, consolidated, and finished flush with the pavement surface by hand trowelling, as shown in Figures 17 and 18.

Partial-Depth Repairs

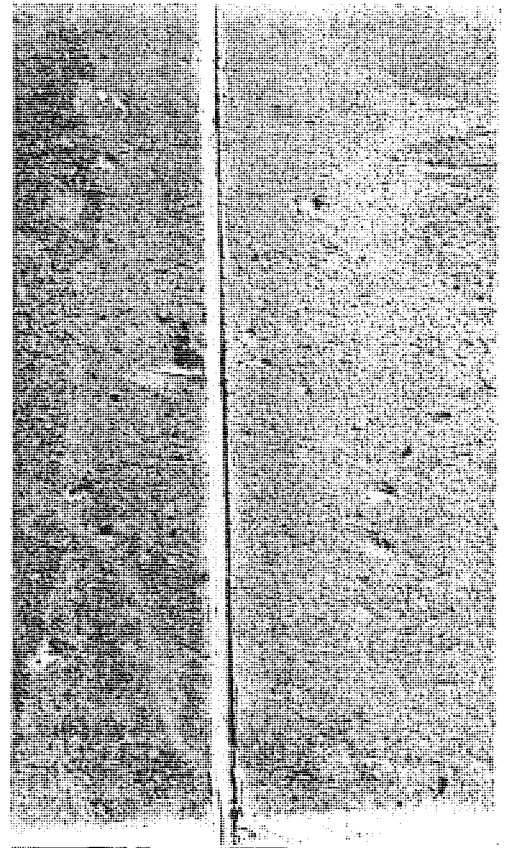
The perimeter of the spall repairs was located 2 in. beyond the distressed area with a minimum width and length of 6 in. specified. The perimeter saw cuts were made 1-3/4 in. deep and the concrete within the cuts was removed using a lightweight air hammer (Fig. 19). The joint groove through the repair area was formed to the proper width using styrofoam (Fig. 20). In cases where the depth of the repair extended beyond the groove bottom, the plane-

Figure 9. Installing
backer rod in re-
sawed joint groove. ▶



▶
Figure 10. Installing and tooling silicone sealant.

Figure 11. Finished silicone seal joint groove. ▶



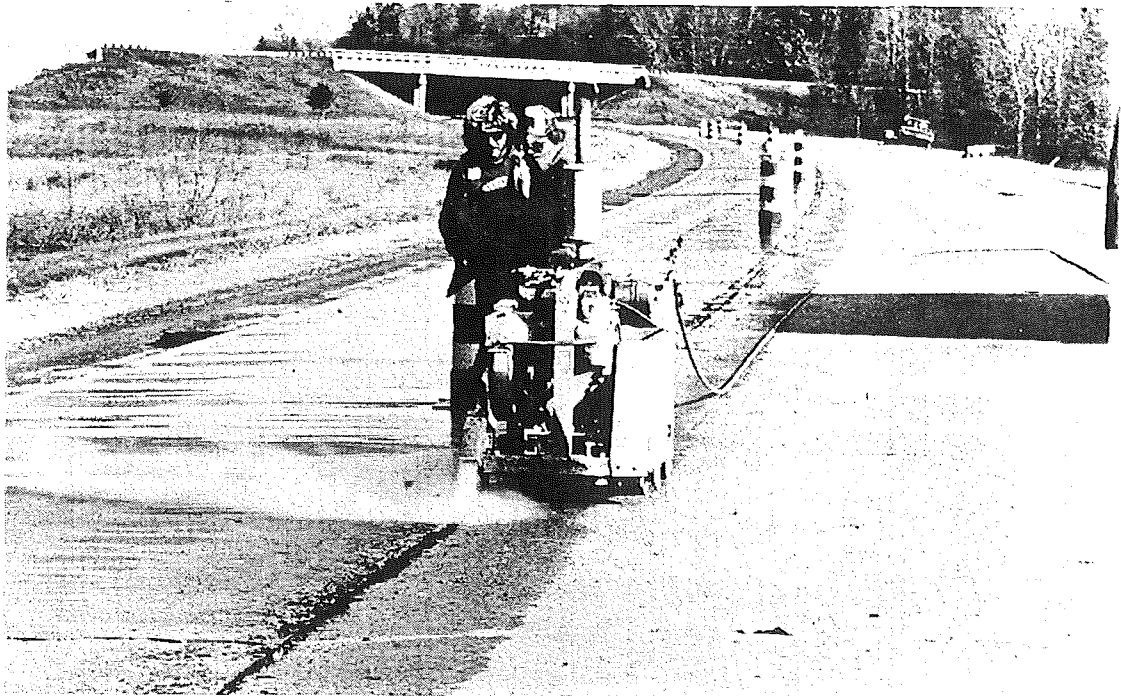


Figure 12. Resawing longitudinal joint groove.

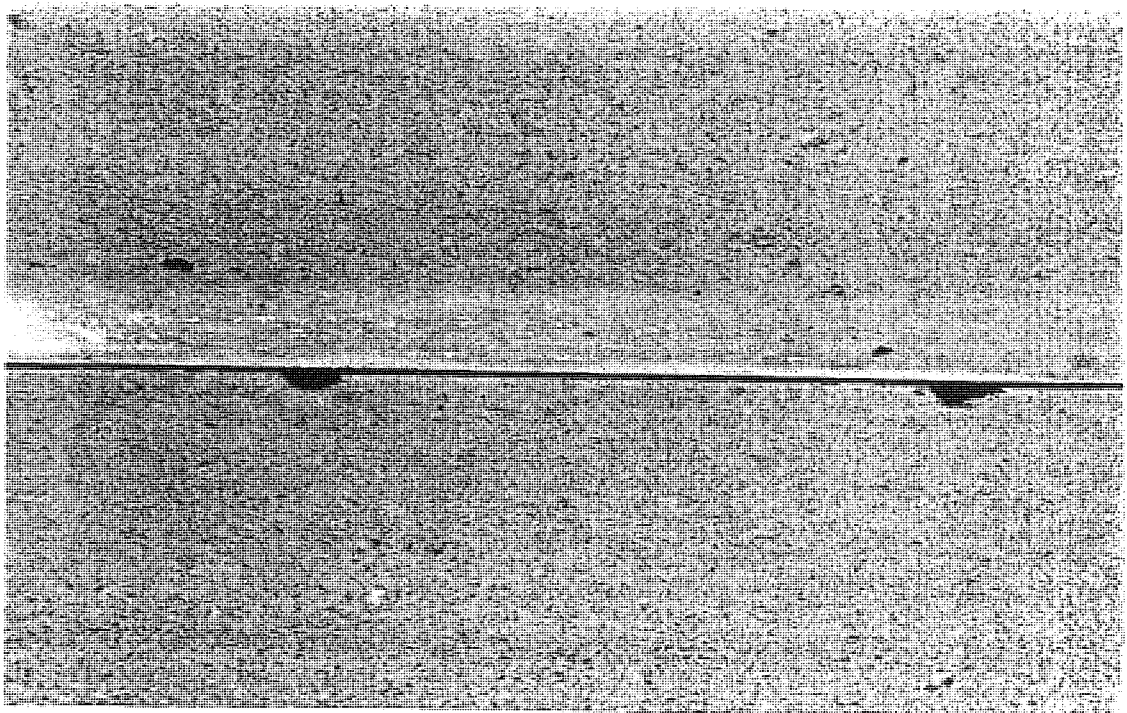


Figure 13. Longitudinal joint groove after resealing.

Figure 14. Sawing groove over transverse crack.



Figure 15. Sawed groove ready for sealant installation.

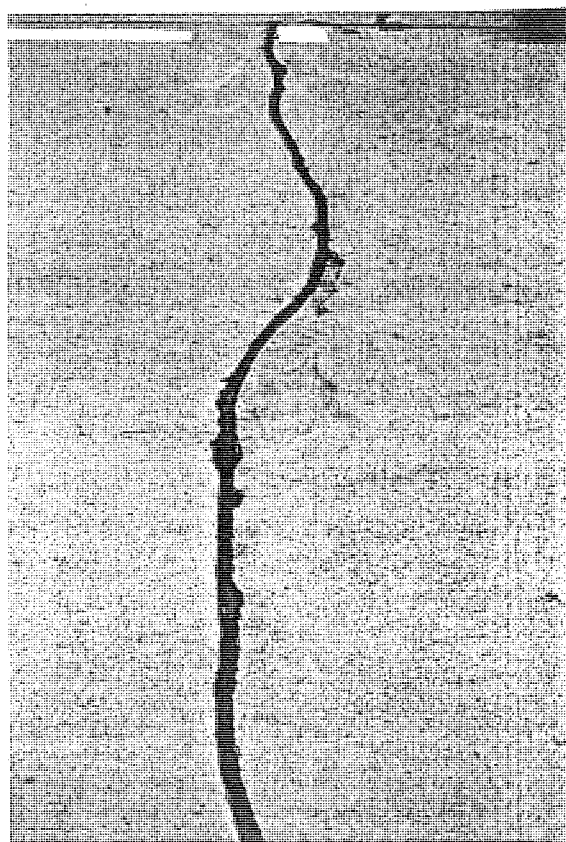


Figure 16. Sealed crack.



Figure 17. Placing fast-set mortar in pop-out.

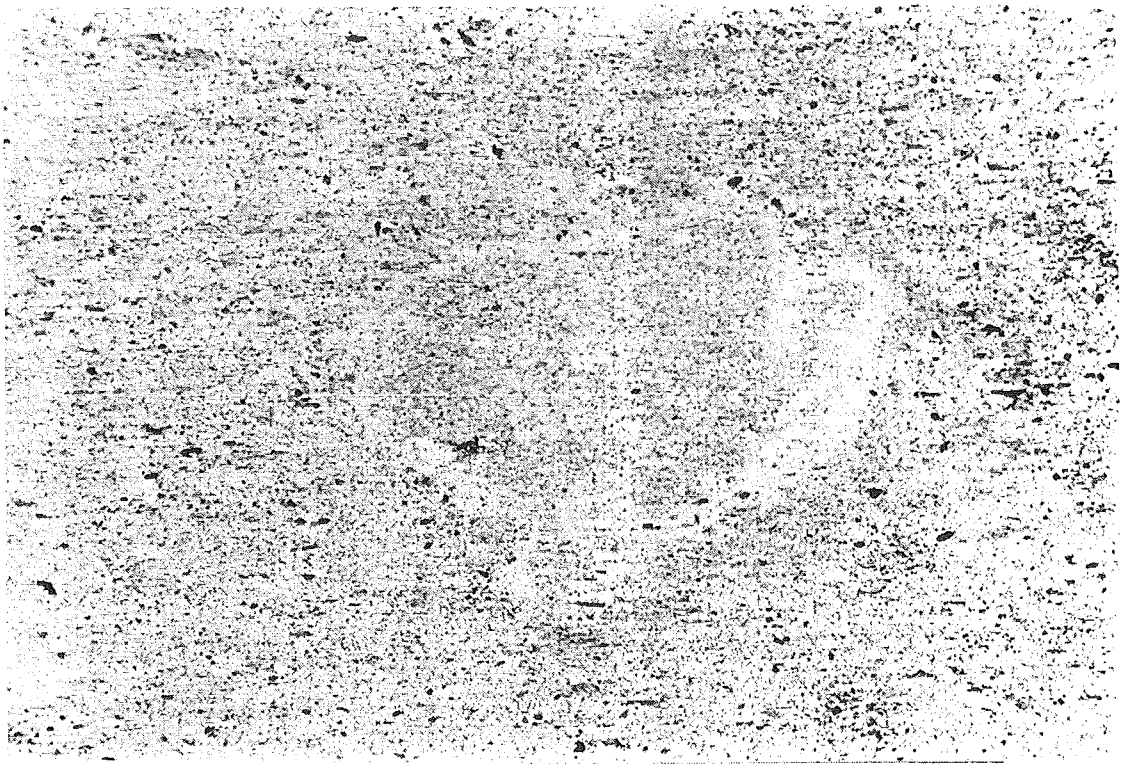
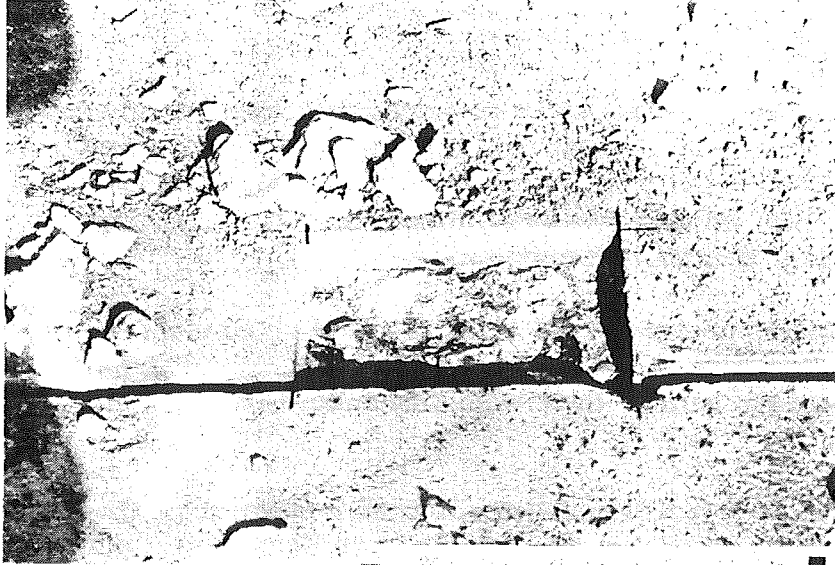
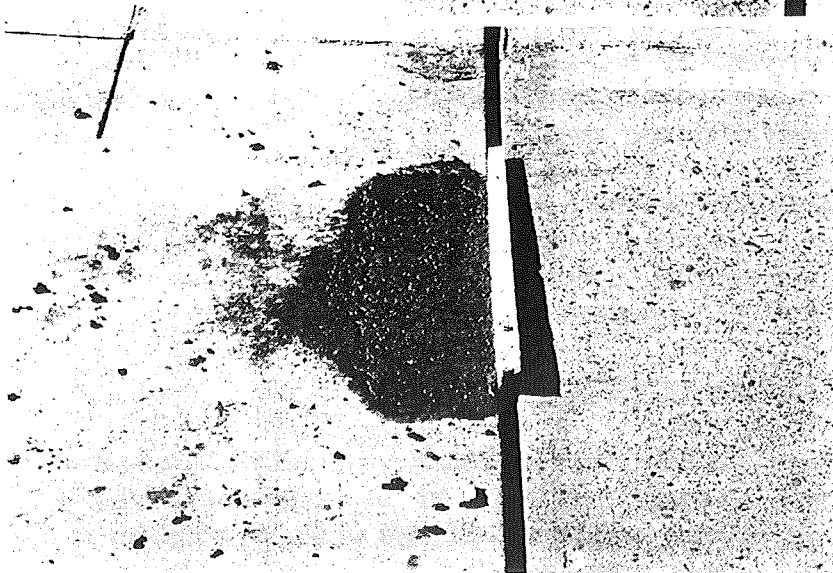
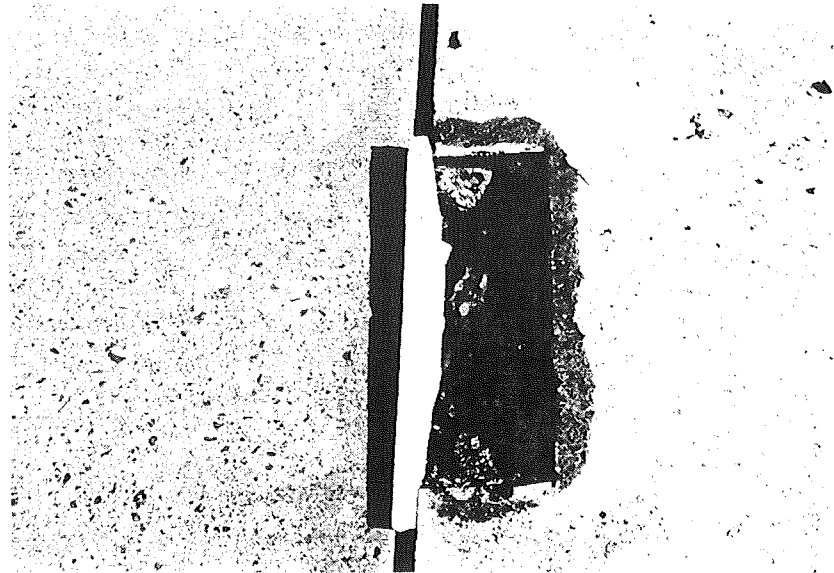


Figure 18. Finished pop-out repair.



◀ Figure 19. Partial-depth repair area with sawed perimeter and unsound concrete removed.

Figure 20. Repair area pre-wetted and groove forming material in place. ▶



◀ Figure 21. Finished repair before curing.

of-weakness crack was recreated by extending the styrofoam to the bottom of the repair area.

The repair area was cleaned with oil-free compressed air and prewetted just prior to placing the fast-set mortar. The mortar was mixed in small batches in a portable mixer at the repair site. The mortar was placed in the repair area and finished by hand trowelling (Fig. 21). Curing was accomplished by covering with burlap for two hours.

It was planned to experiment with partial-depth repairs on long sections of the centerline joint. However, this experiment was deleted from the primary project site because there were only minor isolated spalls along the joint.

Several thousand feet of partial-depth repair were made on the centerline joint in 1984 on a project on I-69 near M-71 in Shiawassee County. Both bituminous and concrete were used to replace the deteriorated concrete. First, the unsound concrete was removed to a depth of about 1-1/2 in. and a width of 12 in. using a cold milling wheel with carbide teeth. The resulting edges were badly ravelled. The area was cleaned with oil-free compressed air. For the concrete repairs, the 9-sack mix was placed and finished, and a plastic strip was inserted at the centerline location to form the plane-of-weakness joint. Bituminous repairs were made with a sand type mixture, placed and levelled by hand, and compacted with a roller. A recent inspection revealed that both repair types have cracked severely with separation and raveling along the edges. Figures 22 through 25 illustrate the condition of the repairs. This procedure is not satisfactory and better repair techniques are needed.

EVALUATION

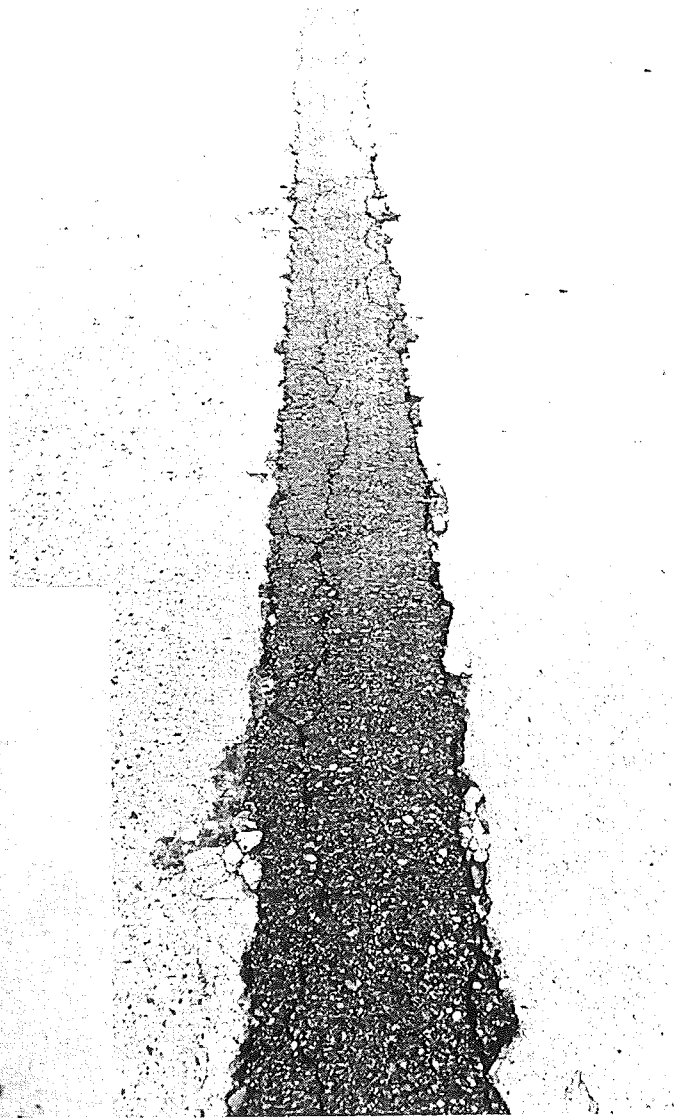
The performance of the restored pavement was to be monitored for a period of five years. The performance factors being evaluated were: horizontal movement of joints and cracks, faulting of joints, effectiveness of sealants, partial-depth repair and centerline repair performance, and load transfer efficiency of repair dowels.

A brief description of the evaluation procedures for each performance factor follows. Since the evaluation was conducted under traffic, the evaluators were required to operate from along the pavement shoulder. Thus only the traffic (right-hand) lane was evaluated.

Horizontal Movement of Joints and Cracks

Twelve transverse joints on each roadway resealed with silicone sealant, 14 repair joints on each roadway, and 14 transverse cracks scattered throughout both roadways were instrumented with gage plugs for measuring their opening and closure. Measurements were made summer and winter.

Figure 22. Typical 1988 condition of centerline joint on I 69 repaired with bituminous materials in 1984. ▶



◀ Figure 23. Ravelling along edges and cracking over plane-of-weakness crack--4 years of service.

Figure 24. Typical condition in 1988 of centerline joint repaired in 1984 on I 69 using concrete.

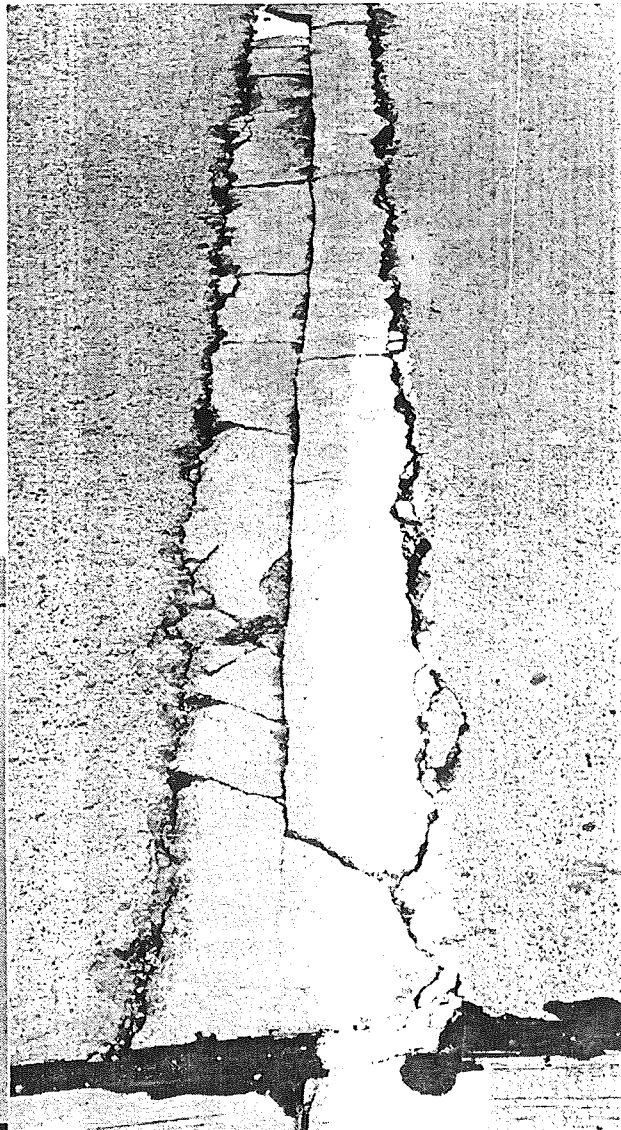
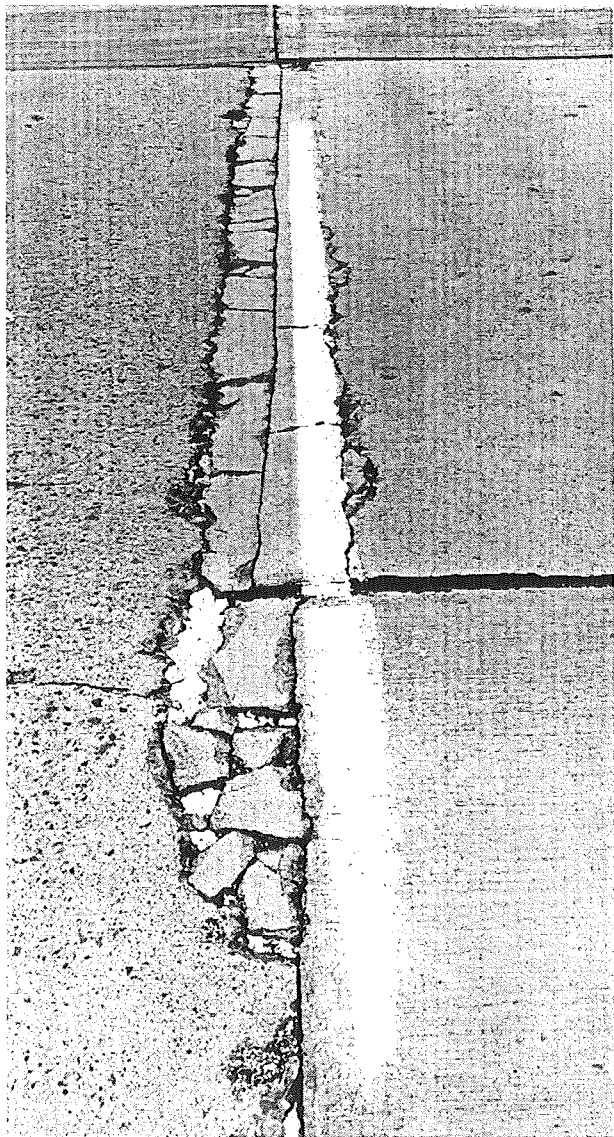


Figure 25. Severe cracking has occurred. Some of the concrete pieces are missing.

Faulting Measurements

The joints and cracks instrumented with gage plugs were measured for faulting once a year in the summertime.

Sealant Effectiveness

The instrumented joints and cracks plus 40 silicone sealed joints, 20 hot-poured sealed cracks, and four 200-ft sections (two each roadway) of the resealed centerline joint were evaluated using the rating system given in Table 2, which was developed by the Pennsylvania Department of Transportation. The evaluation was done once a year in the wintertime.

TABLE 2 - Performance Rating Levels			
	Rating	Degree	Description
	5	None	Seal is intact and in the condition as constructed.
	4	Slight	Seal has experienced adhesion, cohesion, and/or spalling defects in less than five percent of the joint area.
	3	Moderate	Seal has experienced adhesion, cohesion, and/or spalling defects in less than 25 percent, but more than five percent of the joint area.
	2	Severe	Seal has experienced adhesion, cohesion, and/or spalling defects in less than 50 percent, but more than 25 percent of the joint area.
	1	Deteriorated	Seal has experienced adhesion, cohesion, and/or spalling defects in more than 50 percent of the joint area.
	5	None	Seal is intact and in the condition as construction.
	4	Slight	Seal surface aged (oxidized).
	3	Moderate	Seal surface has weather checking.
	2	Severe	Seal surface has alligator cracking.
	1	Deteriorated	Seal surface has eroded.

TABLE 2 - Performance Rating Levels			
	Rating	Degree	Description
	5	None	Seal is intact and in the condition as constructed.
	4	Slight	Seal is intact and in the condition as constructed with debris accumulated, but no intrusion.
	3	Moderate	Seal (cavity) has accumulated debris with scattered intrusion (into reservoir).
	2	Severe	Seal (cavity) has accumulated debris with much intrusion.
	1	Deteriorated	Seal is broken and eroded by excessive intrusion of debris.

Partial-Depth and Pop-Out Repairs

Visual inspections were made in the wintertime to monitor any cracking, spalling, or fractures that may occur.

Load Transfer Efficiency

The department purchased a Falling Weight Deflectometer in 1989 and was planning to use this equipment to measure the load transfer capability of the grouted-in-place dowels. These measurements were to be scheduled for the early morning hours or on cool days when the upward curling of the slab is minimal. Unfortunately, scheduling conflicts for using the deflectometer prevented its use on the project.

CONSTRUCTION DISCUSSION

Observations of the repair procedures revealed no major problem in conducting the work as specified. Minor delays and some difficulties did occur as discussed below. The experience gained on this job will be valuable for improving specifications for future projects.

Most delays were caused by malfunction of the pump-injection system the contractor elected to use in mixing and injecting the epoxy grout into the predrilled holes. The problem resulted from the equipment dispensing incorrect proportions of the two components. In some instances, this forced shutdown of the full-depth repair work. About midway through the project the contractor switched to prepackaged cartridges, which worked very well.

To prevent delays in the grouting process on future jobs, the contractor should be required to have back-up equipment on standby.

The full-depth centerline repairs could be an effective repair treatment where the deterioration is confined to the joint intersections or relatively short sections of roadway. It was determined on this project that by overcutting the corners the distressed concrete could be lifted out quickly, whereas when overcutting was not permitted, substantial air hammer work was necessary in the unsawed corners.

On these repairs, a groove was edged around the repair perimeter with the intention that the groove would be sealed. It was determined that sealing the very narrow groove was not feasible, and thus the edging of the repair would not be required on future projects. Re-establishing the centerline joint groove through the repairs was not required, but the contractor did saw grooves through some which were sealed when the centerline joint was resealed. Though probably not affecting performance, the establishment and sealing of the joint greatly improved the appearance of the repair and should be specified on future projects.

The completion date of the project was scheduled for November 1, 1987 to avoid cold weather conditions. However, due to delays, the contract was not completed before November 8. On some days the temperature and moisture conditions were not very conducive to working with epoxy and joint sealants. On cold days the epoxy was preheated or stored in heated quarters to make it workable, and on damp mornings the joint grooves could not be sealed before the concrete was surface dry later in the day. It is obvious that this type of work is best suitable for warmer weather and consideration should be given to set the completion date early enough to ensure that materials are only utilized within recommended temperature limits.

At certain times during the construction operation it was necessary that the traffic use part of the outside shoulder to allow room for the equipment. This resulted in the shoulders failing in some areas, requiring repair. On this contract, these shoulder repairs were made by the department's Maintenance personnel. On future contracts the repair of shoulders should be the contractor's responsibility and repair quantities included as a bid item in the project proposal.

Based on the information recorded during the construction period, it appeared that the joint repairs with tied joints were equal in performance to dowelled ones and it is suggested that they be used for mid-slab repairs and also used on one end of a repair at the joints. This eliminates a substantial number of joints, which reduces tire noise effects.

From a construction standpoint, the use of silicone sealants in resealing joints demonstrated an advantage over using hot-poured sealants. Silicones

eliminate the need for a double boiler kettle for heating the sealer and can be used in small quantities at a time without wasting much material. Silicones were observed to be somewhat more sensitive to installation procedures, however; especially regarding joint reservoir surface preparation and tooling techniques. The performance of both sealant types is included in the post-evaluation period discussion.

The partial-depth repair techniques were labor intensive. Considerable care and patience was required to ensure that all unsound concrete was removed, the repair surface clean, the joint properly formed, and the fast set material properly proportioned, mixed, and placed within its working time. The construction phase of this repair technique proved to be failure prone and contributed to performance problems discussed later in this report.

POST-EVALUATION PERIOD DISCUSSION

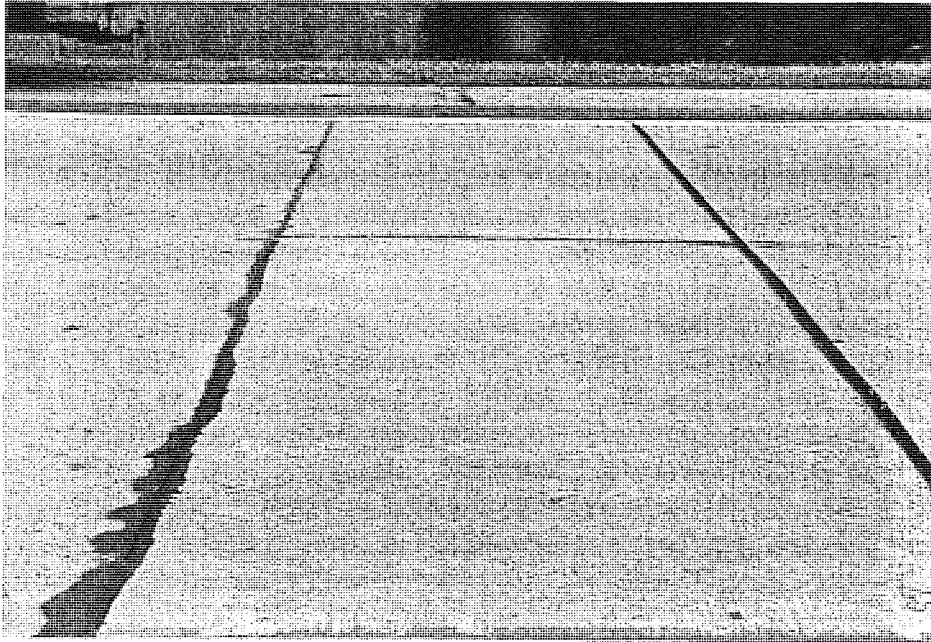
A five-year evaluation schedule was initially planned, with a completion date of November 1992. However, delays in issuing a final report have allowed the opportunity for a six-year evaluation.

Full-Depth Repairs

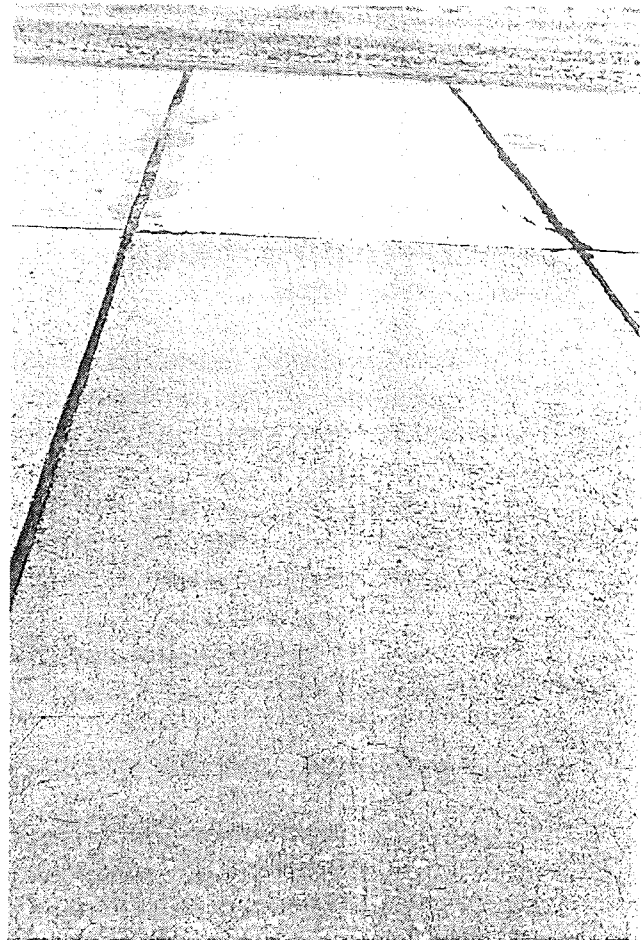
Most of the full-depth lane repair procedures as outlined in this research project have been incorporated into the department's present pavement repair standards. An additional development from this project was the recognition of a need for a more uniform rating system for pavements. The "Concrete Pavement Condition Survey Manual" (Appendix C) that was first developed in 1983, was updated in May of 1991 to better meet that need. This manual provides information to assist the designer and engineer in laying out the restoration work. Its use has provided more statewide uniformity in treating projects and has reduced the amount of cost overruns.

After six years of service, all full-depth repairs remain structurally sound with a minimum of spalling (Figure 26). It had been planned to use a Falling Weight Deflectometer to measure the load transfer capability of the grouted-in-place dowels. However, the unit was not available in time for this project. Vertical measurements do indicate that the load transfer has been achieved. Vertical differences (faulting) of only 0-1/8 in. were recorded. This small amount allows for acceptable levels of traffic noise and ride quality.

The problem most frequently observed was the presence of severe map cracking. This condition is described on page ten of the "Condition Survey Manual" and is rated as Severity Level 2 for previous repair distress. A less severely map cracked repair is shown in Figure 27. This problem is associated with shrinkage due to the heat generated from rapidly curing concrete. The problem is exacerbated by the addition of more chloride to accelerate hydration in cold weather. Unless slower cures can be tolerated, this problem,



▲
Figure 26. Full-depth repair
in good condition.



▶
Figure 27. Moderate level
of map cracking.

at least to some degree, appears to be unavoidable. Surface spalling and scaling over the next few years can be expected requiring some maintenance repairs.

Early appearances indicated that tied repairs would perform as well as dowelled repairs, while eliminating a substantial number of moving joints. The final evaluation has substantiated this observation. However, since becoming a departmental standard, two potential problem areas with full-depth repairs have been observed. The first area is the need for an accurate initial inspection of the pavement to ensure that working and non-working joints and cracks are identified. Tied repairs should not be specified at the expense of limiting adequate movement capability. The second potential problem area occurs when a large number of repairs are scheduled or when additional repairs are performed in a previously repaired pavement. Additional expansion space must be provided to avoid damage to newly placed repairs. Constructing repairs in cold weather places an additional need for expansion. The department's repair standards are presently being revised to address these needs.

The final evaluation phases for full-depth repairs included horizontal movement and sealant effectiveness. Movements were determined utilizing gage plugs and conducting readings in both warm and cold weather.

Contraction movements were as expected, with readings ranging from less than 1/64 in. to 5/64 in. The low modulus hot-poured sealant performance was rated according to the system shown in Table 2. Ratings averaged a three (moderate) in sealing ability, while weathering and debris intrusion were at similar levels.

Expansion movement readings were more variable, due in part to the proximity of non-working joints and/or working cracks. As repairs were constructed, the expansion joints tended to take most of their closure (up to 39/64 inch) during the first six months. The pavement pressures tended to stabilize after that time, reducing closures to approximately one third of their initial movements. The hot-pour performed more variably in the expansion repair joints, with ratings from one to four after five years.

Tied joints, as expected, had negligible movements with sealant ratings averaging at the four level.

Full-Depth Centerline Repairs

A few full-depth centerline repairs experienced uniform settling throughout the patch area to depths of 1/4 - 3/4 in. within the first six months. This problem was most prevalent in locations such as horizontal curves where truck traffic tended to more frequently impact the repairs. Cores taken in June 1988 showed visible evidence that the concrete patch was crushing

around the reinforcing bar. Damage to the rebar's epoxy coating was also observed.

By February 1989, 12 percent of southbound and 23 percent of northbound repairs had developed settling of 1/4 - 1 1/2 in. The percentages of settled repairs were basically the same for both the break-out and lift-out removal methods. Additional cores taken in December 1993 showed that the crushed concrete had allowed the No. 5 deformed bars to bend under traffic impact. The epoxy coating at the juncture of the old to new concretes was virtually worn away. Considerable corrosion of the rebar with a corresponding decrease in cross-sectional area contributed further to the settling problem.

In addition to a rough ride, detrimental impact forces were generated by traffic impacting the settled repairs. Patches frequently developed edge ravelling, spalling, and cracking (Figure 28), and contributed to damage of the adjacent roadway (Figure 29). Repairs that are badly map cracked from shrinkage (Figure 30) appear to be near the end of their serviceable lives and will require yearly maintenance. This maintenance has been in the form of bituminous patching over all (Figure 31) or part of the repair.

The finished repair, as shown in Figure 8, utilized perimeter and centerline joints that were too narrow to be effectively sealed. Eliminating "edging" of the repair perimeter and sawing the centerline joint through the repair area would improve its appearance and decrease ravelling. There was an initial concern that oversawing to more easily facilitate removal of the old deteriorated concrete might cause crack propagation. Minimal cracking was observed due to the oversawing technique. Since this procedure saves considerable time, it should be employed as the technique of choice.

The data clearly indicate a need to modify the procedure for full-depth centerline repairs. A longer patch area to accommodate two rebars longitudinally per quadrant should decrease the tendency to settle. Additionally, No. 5 deformed epoxy-coated rebars should be replaced by No. 9 rebars. While creating a more structurally sound repair, these modifications would further increase an already prohibitive cost for such repairs. The modified procedure would be more time consuming and labor intensive, and therefore more suited to limited selected areas. For large scale production repairs the standard (full lane width) full-depth repair should be utilized.

Resealing Transverse Joints

Effective resealing of pavement joints is viewed as one of the more critical goals in rehabilitation. It also continues to be one of the most difficult goals to achieve. The silicone sealant used to reseal the formerly neoprene-sealed contraction joints was evaluated using the performance rating system described in Table 2. The twice yearly ratings are summarized in Graph 1 for the final years ratings. Most of the sealants fall within the slight to moderate rating

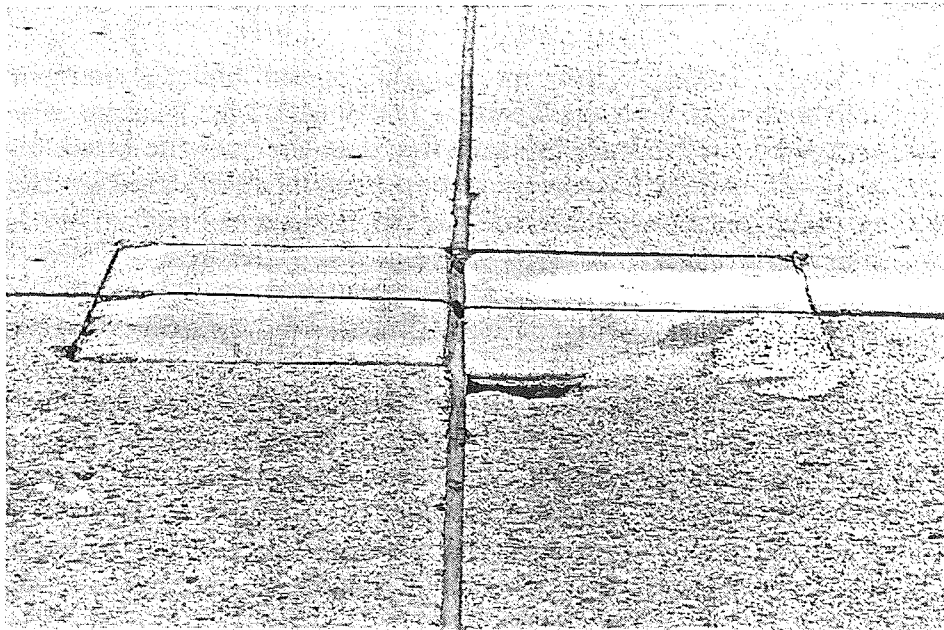


Figure 28. Settled full-depth centerline repair with spalling and cracking.

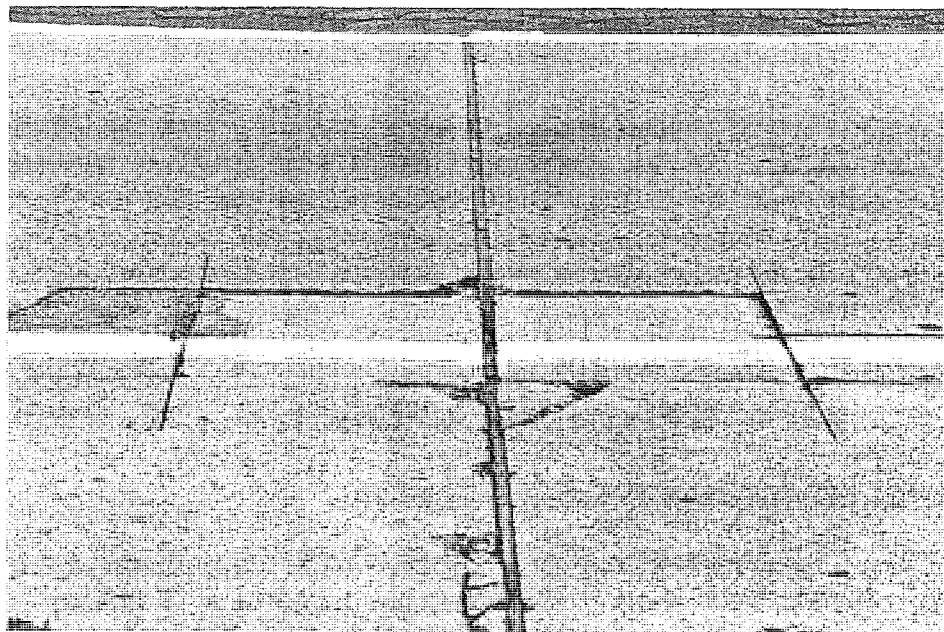


Figure 29. Damage to roadway concrete adjacent to patch.

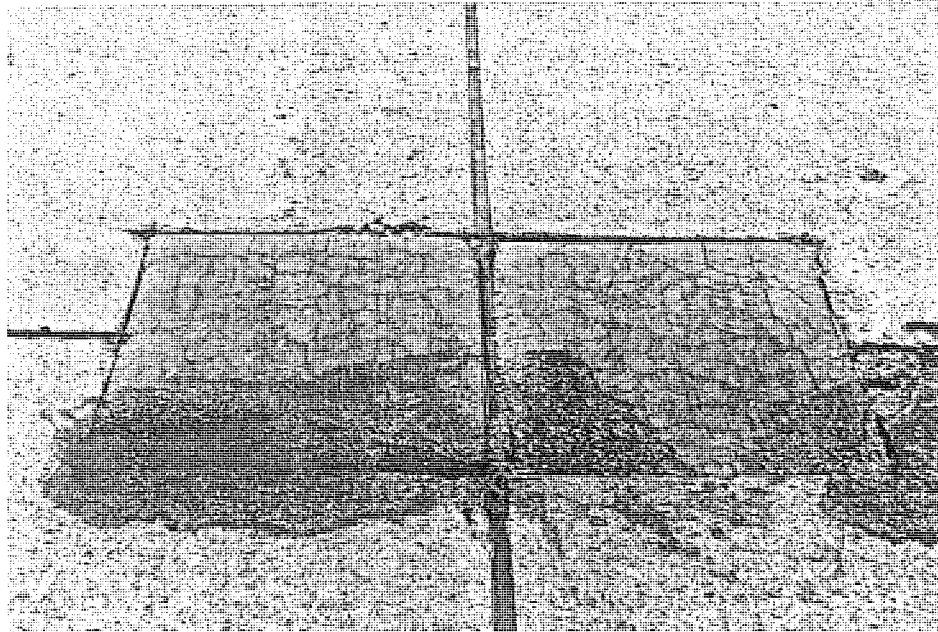


Figure 30. Severe map cracking.

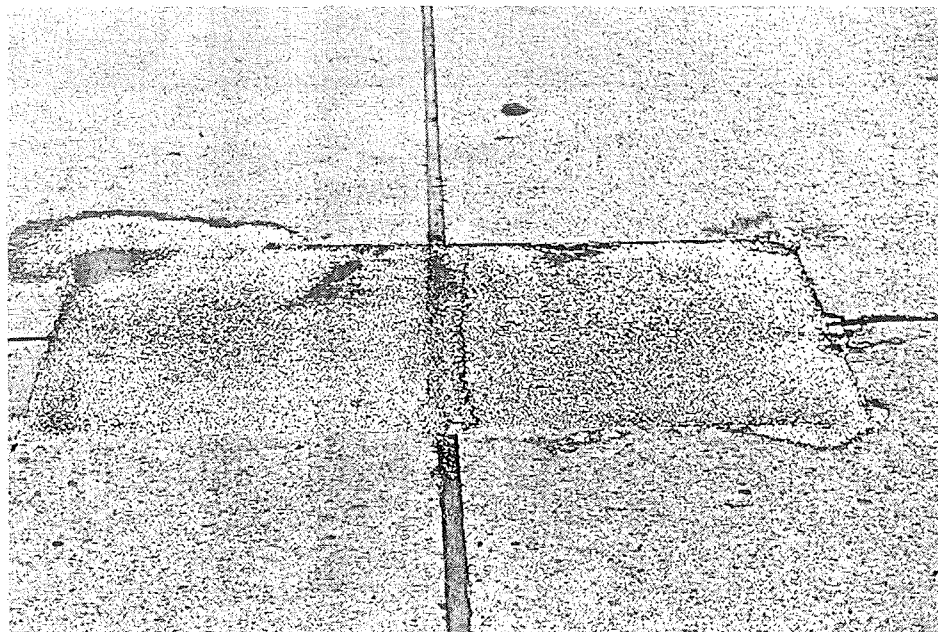
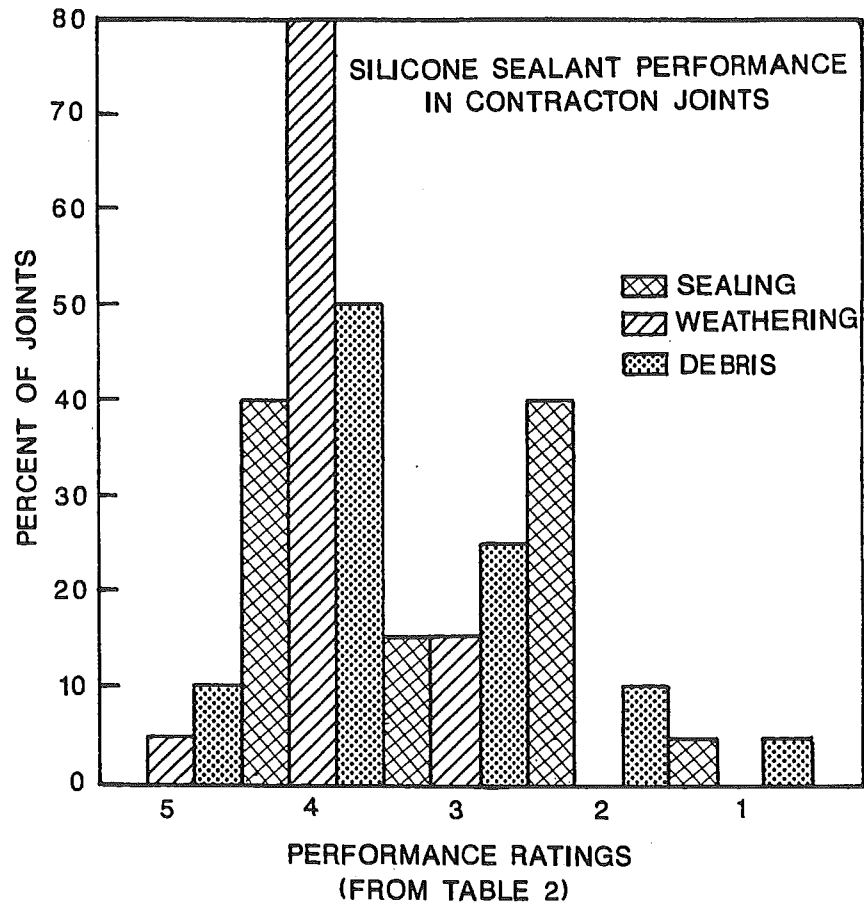


Figure 31. Bituminous repair of full-depth centerline repair.

levels for the evaluation categories of sealing, weathering, and debris intrusion (Figure 32).

GRAPH 1



The few expansion joints resealed with silicone are performing somewhat better than the contraction joint sealants. The number of expansion joints sealed was too few to include them in a graph.

Early in the project a question was raised with regard to being able to obtain an adequate bond between the silicone sealant and the spall repairs along the transverse joints. Inspections did not reveal a problem though.

The one inch wide joint groove was also discussed in regard to ride quality. No noticeable change in the ride quality was detected however. Joint groove width movements, as monitored for warm and cold temperature differentials, fell well within design guidelines for 71 ft joint spacings.

Joint sealants, whether pourable or preformed, are highly dependent upon joint groove preparation, weather conditions, and installation techniques. Groove faces to receive a silicone sealant must be very clean and dry to allow for proper adhesion and performance. Though close inspection and conscientious effort was maintained by the contractor, this remains to be the problem area for sealants. Installation mistakes were observed that affected sealant performance, such as inadequate sandblasting and omitting the air cleaning prior to sealing. Continued research into new methods and materials (ultra low-modulus and self-leveling products, for example) to help increase performance, is presently underway. The performance of the silicone on this project must be viewed as typical of most joint resealing projects.

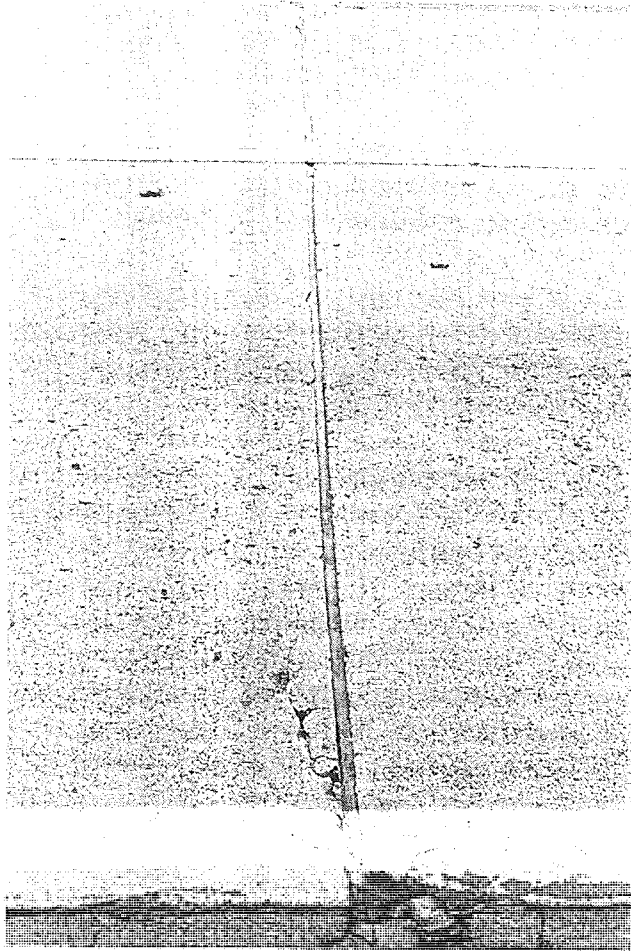
Resealing Longitudinal Joints

The low-modulus hot-poured joint sealant used to reseat the longitudinal joints has performed very well. Performance ratings of 4 to 5 (problems observed are slight to none) were typical. Since the centerline joint is subjected to such small amounts of movement, the hot-pour was an excellent choice. The sealant has the added advantage of flowing well into the narrow 3/8 inch wide groove. This material has become the department's standard for longitudinal joint sealing.

Sealing Transverse Cracks

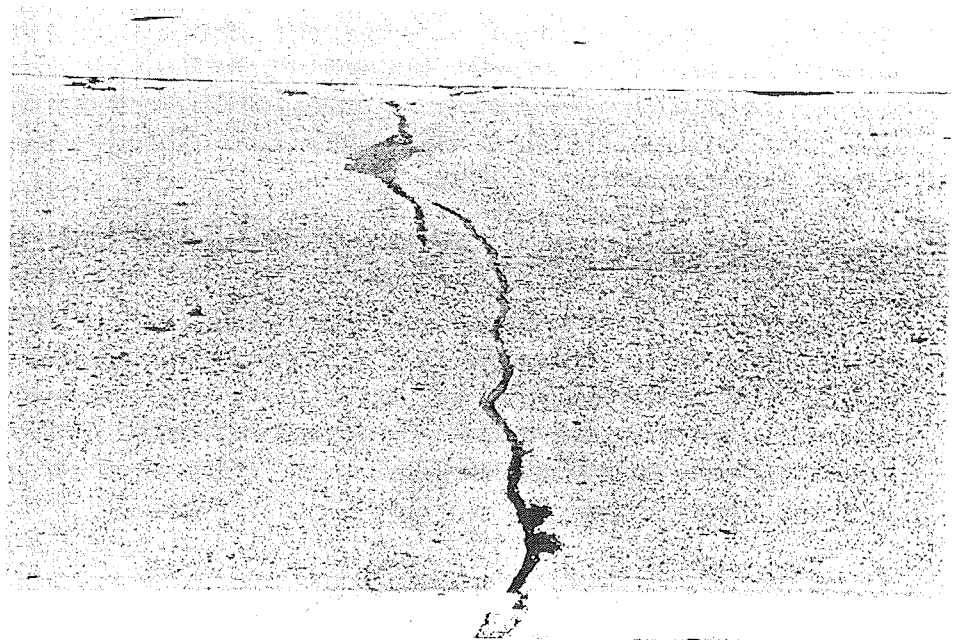
Transverse cracks with reinforcement still functioning were sealed to retard the corrosion rate of the steel. The work plan specified the use of a low-modulus hot-poured sealant. A few joints were also evaluated using silicone as the sealant material. Horizontal movement of the cracks was monitored using gage plugs, even though the cracks were considered to be "non-working".

Performance of the low-modulus hot pour was highly variable. Cracks that were basically "fixed" (less than 0.01 inches of movement) were rated a four since only slight problems were observed (Figure 33). As the measured crack



◀ Figure 32. Transverse joint resealed with silicone is rated as having slight problems.

Figure 33. Low-modulus hot-pour sealed crack with a 4 rating.



movements increased towards 0.06 inches, the ratings decreased to a one or two (deteriorated or severe problems observed). These results are consistent with results from many other projects utilizing a low-modulus hot pour. The sealant consistently failed in adhesion whenever movements in sealed cracks or joints exceeded the 5-10 percent range.

The need, however, does remain for an effective pourable sealant. Research is currently underway to more tightly control "low-modulus" properties through specification changes. Ultra low-modulus hot pours are also being examined.

Silicone was also used to seal several fixed cracks. As with the hot-poured sealant, results were variable. Ratings of two (severe problems) to four (slight problems) were observed. No correlation was found between crack movement and sealant performance. In fact, some cracks that were determined to have basically no movement actually had the worst performance. Figure 34 shows a moderately (three rating) performing silicone sealed crack.

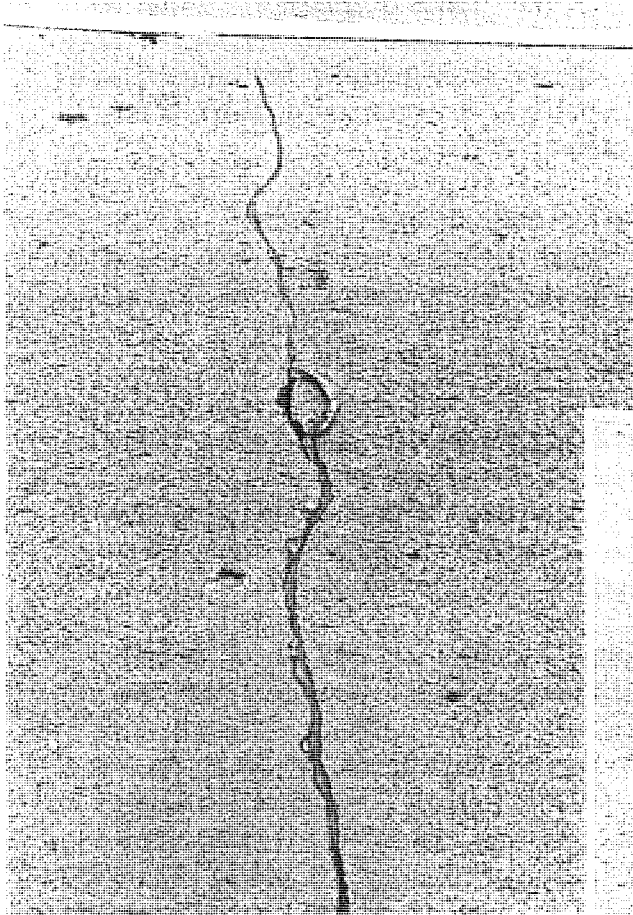
One of the complications in rating sealants in sawed cracks is the development of secondary cracks and additional spalling after sealing. Some small size spalls that developed after sealing can be seen in Figure 34. The "sealing" portion of the performance rating system addresses the development of spalling defects of this nature. However, Figure 35 illustrates a sealed crack with major spalling and concrete loss along its faces. This crack was apparently close to losing its reinforcement integrity at the time of sealing. The rebar corroded through subsequent to sealing and the crack opened beyond the ability of any sealant to perform. This points out the difficulty in choosing appropriate locations for this type of restoration technique, and also points out the necessity to do such work early after the crack occurs.

The stated purpose of crack sealing was to "retard the rate of corrosion of the steel". This was accomplished to some extent by slowing the rate of water intrusion. The materials and techniques used need to be refined and improved to be much more effective in protecting the steel and decreasing additional spalling. Generally, such spalling is due to differential vertical movement, which means the steel has stretched and the crack opened somewhat.

Surface Pop-Out Repairs

The restoration technique for repairing large size surface pop-outs, caused by expansive coarse aggregate, was very successful. Figure 36 shows a typical repair looking the same now as when repaired. The success of these repairs was something of a surprise for two reasons.

Partial depth repairs with mortar mixes are normally required to have a sawed perimeter to increase the mortar thickness and to increase support.



◀ Figure 34. Moderately performing silicone crack sealant.

Figure 35. Crack has developed into a "moving crack" with severe spalling.

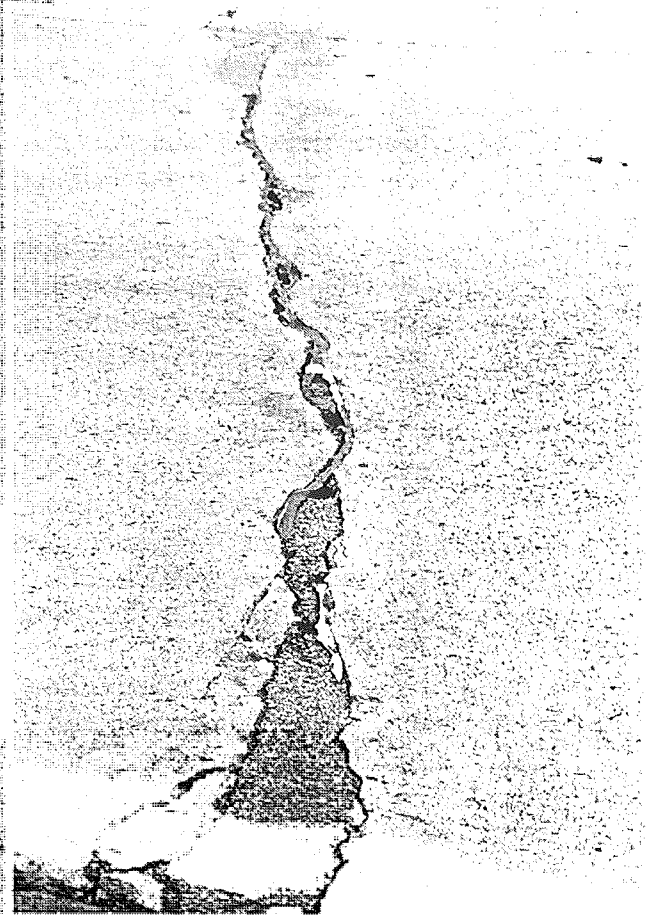
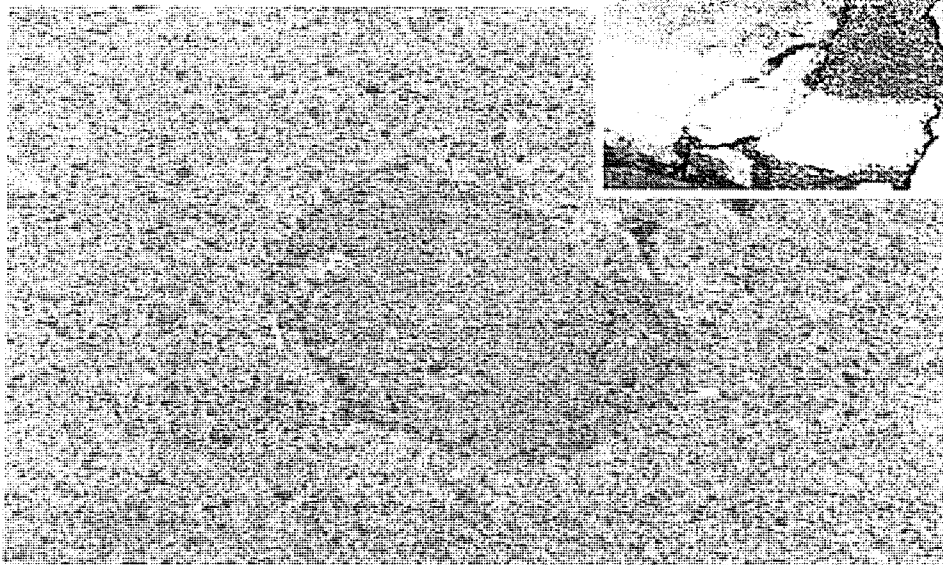


Figure 36. Surface pop-out repair is in excellent condition.



The pop-out repairs, however, were basically "feather edged". The perimeter band has remained intact and ravelling is practically nonexistent.

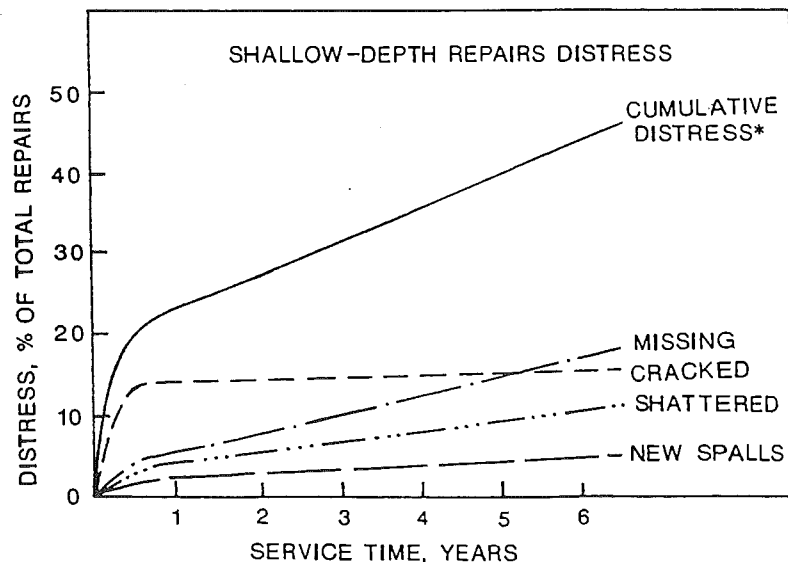
Secondly, the mass of adjacent roadway concrete surrounding the repairs tends to act as a sponge to remove moisture from the mortar mix. Yet even though no effort was made to cure or retard moisture loss, the repairs remain sound and adhered. The slow cure and small volume of material with a corresponding minimum of heat generation probably prevented shrinkage cracks from forming.

This repair technique is worthwhile when incorporated into a larger restoration program. It would not be cost effective to perform only this repair technique as a contract item.

Partial-Depth Repairs

In evaluating the performance of the partial-depth repairs at joints, it became necessary to define the objective of the restoration work in more specific terms. The stated objective, to substantially increase the pavement's service life, was probably not accomplished through this restoration technique. An analysis of the shallow-depth repairs is summarized in Graph 2. After five years of service, approximately 37 percent of shallow-depth repairs exhibited distress. There was additionally four percent new spalls. While the distress rate is high, there is a dual benefit gained from these repairs. This benefit includes slowing the rate of development of new spalls and also lowering the severity level of distresses that do develop. Achieving these benefits, given current material options, may be a more realistic objective.

GRAPH 2



* INCLUDES CRACKED, SHATTERED, AND MISSING REPAIRS.

As seen from this graph, the rate of new spall development was limited to only about one percent per year. This rate would undoubtedly be higher if repairs had not been made to adjacent joint distresses. The detrimental effect of traffic crossing distressed concrete as it impacts adjacent sound concrete is well recognized. Providing a smoother ride by performing shallow depth repairs will therefore lessen the development of new distresses. Figure 37 illustrates two shallow-depth joint repairs in good condition after six years, with no evidence of additional joint distresses.

The second benefit, that of decreasing the severity level of distress, can also be illustrated. Figure 38 shows a contraction joint that developed cracks shortly after the repair work was completed. The cracks were not repaired and they developed into a significant level of distress requiring cold bituminous patching.

In comparison, Figure 39 shows that a contraction joint with several partial-depth repairs has developed only low levels of distress. The repair in the lower left portion of the figure has developed narrow spalling and ravelling along the joint face, while in the upper left portion the development of an edge spall is evident.

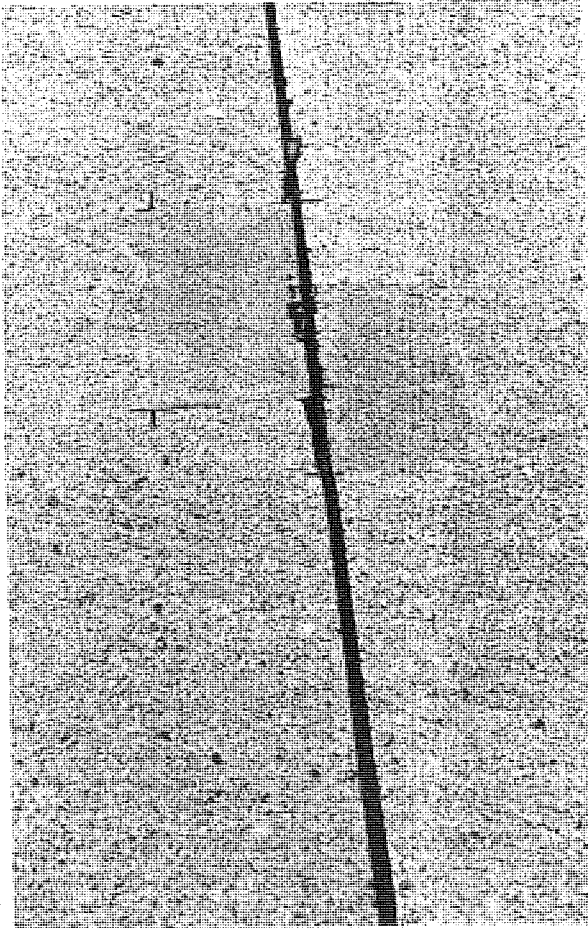
One type of distress was observed to develop at an initial rate considerably faster than other types of distress. Partial-depth repairs that crack tend to do so within the first months (or during the first significant temperature change period). After that time, the amount of additional cracking develops at about one percent per year. These cracks develop in the repair mortar because the original pavement crack is still present in the underlying concrete. The cracks may be too fine to be visible during the chipping hammer removal procedure. As the concrete expands and contracts, the crack propagates up through the repair mortar. A simple, reliable technique to identify these fine fractures is not available.

A small amount of yearly maintenance (bituminous patching to fill missing patches) was required for the partial-depth repairs. In general, the overall performance of this phase of the restoration work was beneficial in decreasing the amount and severity of pavement joint deterioration. However, this labor intensive and somewhat failure prone technique provides a short services life.

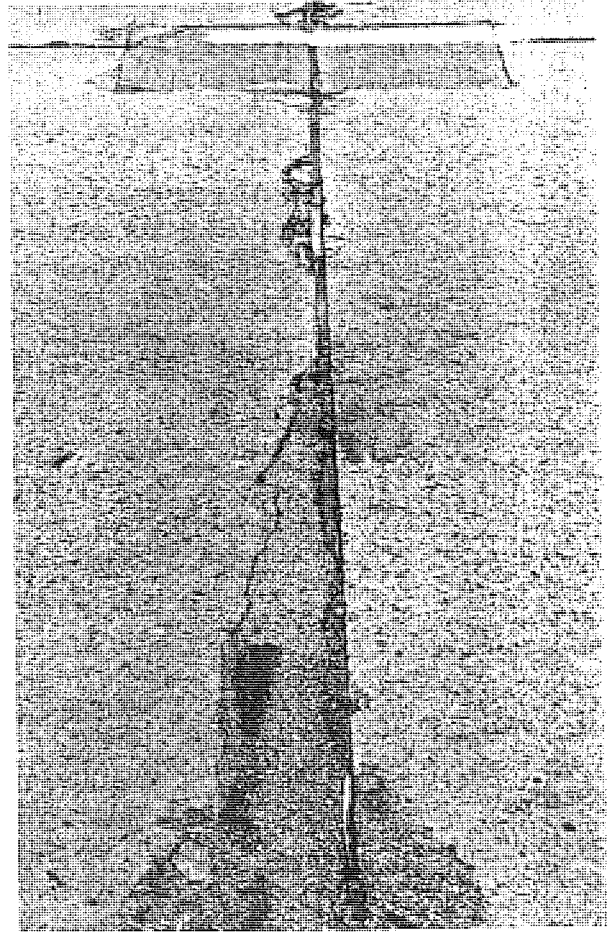
CONCLUSIONS

Several of the repair procedures, with varying degrees of modifications, have been adopted as standards by the department. Others are either not cost effective without improvements in procedures, materials, or equipment, or need to be incorporated into a continuing maintenance program.

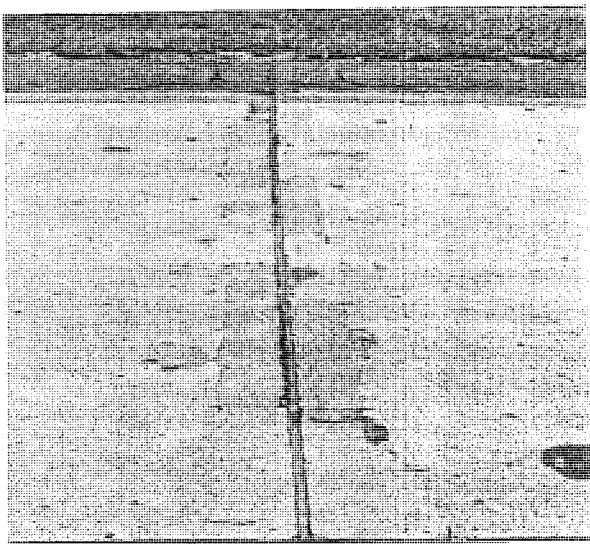
Conclusions for each restoration procedure evaluated are summarized below. These conclusions reflect the knowledge gained from this research



▲
Figure 37. Shallow-depth joint spall repairs in good condition after 6 years of service.



▲
Figure 38. Cracks along joint faces developed into significant distress.



◀
Figure 39. Level of distress along transverse joint with partial-depth repairs has remained low.

project, as well as several subsequent contract and maintenance projects utilizing these restoration procedures.

1) Full-depth lane repairs with grouted-in-place epoxy coated dowels.

This procedure is a department standard. It is a cost-effective restoration technique, but additional benefit could be achieved from improved curing methods or materials to reduce shrinkage cracking. Ten year plus life spans for the full-depth repairs should be expected. However, areas of pavement distresses that may not have been severe enough to be included in an earlier restoration project may later require repairs. When that occurs, a coordinated maintenance program (that analyzes the net effect of both old and new repairs), would decrease problems that might occur from inadequate expansion provisions. Such problems are much less likely when cold weather placement restrictions are enforced, proper distribution of new expansion space is accomplished, and joints are promptly sealed.

2) Full-depth lane repairs with grouted-in-place coated No. 10 deformed bars.

This tied repair procedure is also a department standard. It effectively reduces the number of additional moving pavement joints in locations where additional movement capability is not required. If surface map cracking is controlled, this type of repair should require no maintenance while substantially increasing the pavement service life.

3) Partial lane width full-depth repairs at the intersection of the transverse and longitudinal centerline joints.

The length of the repair and the size of the reinforcing bars were found to be inadequate in providing enough load transfer. This procedure is very labor intensive and costly. Changes believed needed in this repair procedure to make it effective would include a considerable enlargement of the repair area. Full lane width full-depth repairs are a better alternative.

Constructing full-depth repairs also requires that traffic be run on the shoulder. This resulted in shoulder damage. Any modified future projects should incorporate bid items to cover shoulder maintenance and rehabilitation.

4) Partial depth repair of pop-outs and spalls along the joint grooves.

Since these repairs reach a 40 percent failure rate within five years, this procedure is questionable as to its benefit in substantially increasing pavement service life. The procedure is effective in reducing the quantity and level of distress however. Its most cost effective use would appear to be as part of a continuing maintenance program and when incorporated as part of comprehensive restoration projects.

5) Routing and sealing of transverse cracks.

This procedure is effective in retarding the rate of steel reinforcement corrosion, which causes crack movement to accelerate. Crack sealing also helps reduce the infiltration of incompressibles that cause spalls and reduce the effectiveness of pavement joints and open cracks to accommodate pavement movement. Both low-modulus hot pour and silicone are moderately effective as sealants in cracks with very low movements. The procedure would be more effective with improved sealant adhesion and earlier maintenance of failed sealants.

6) Removing existing neoprene seals and sealing with a silicone sealant.

Joint resealing should be an integral part of any pavement restoration project. A properly resealed joint, with the adjacent pavement concrete in sound condition, joint should fully restore sealing integrity and increase service life for 10 or more years. However, our evaluation of sealant performance showed only moderate success in achieving this goal.

The sealant's performance is highly dependent upon preparation and installation techniques, and as a result frequently fails to provide the degree of service life desired. Improvements in inspection, installation techniques, and materials are needed to meet the full potential of the restoration procedure. To this end, efforts are underway to insure proper training of both contractors and inspectors. Statewide training at the district level, as well as on-site assistance, is being provided. Inspection equipment is under development that may provide very early (within a week after resealing) indication as to the effectiveness of resealed joints. Research is also underway to find improved materials to be used in reconstructing a sound joint reservoir, as well as materials to seal that reservoir.

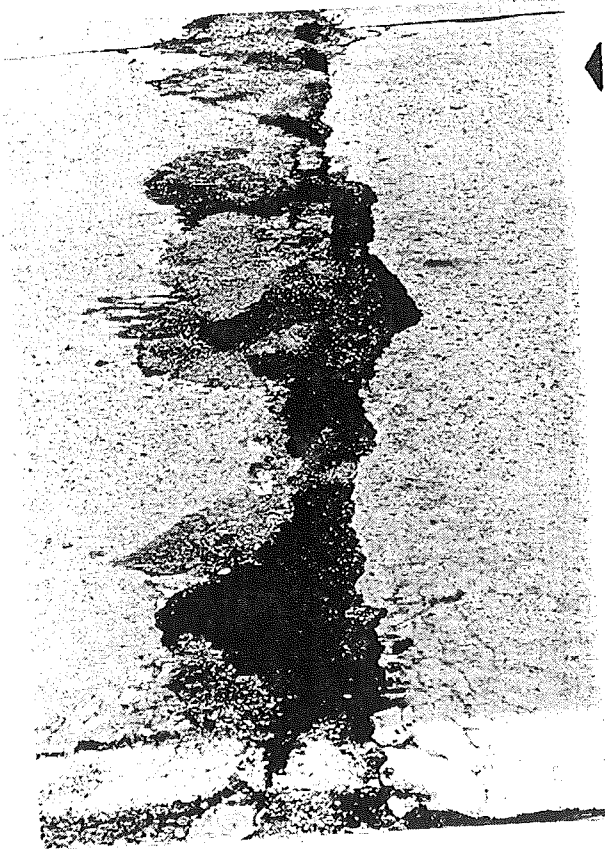
7) Resawing and resealing the longitudinal centerline joint.

The materials and procedures utilized are effective as performed in this research project. Shallow depth repairs along the centerline joint (if needed) followed by resealing with low-modulus hot pour will restore the joint and thus decrease the potential for spalling.

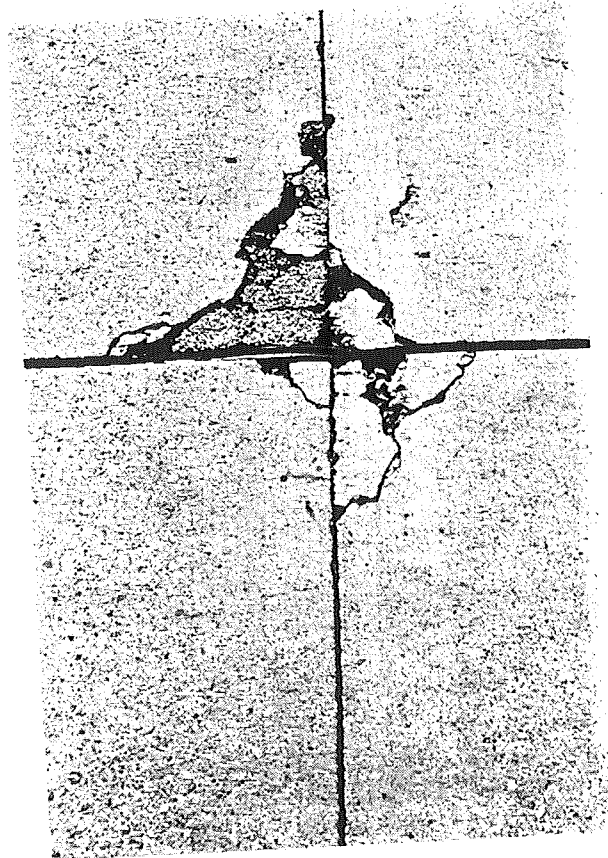
8) Surface pop-out repair.

Deleterious (expansive) aggregates used in the original concrete had caused unusually large surface pop-outs. The technique used to repair these pop-outs was very successful. My opinion is that a cost benefit relating to increased service life does not exist. The primary benefits gained were improved appearance and slightly better ride.

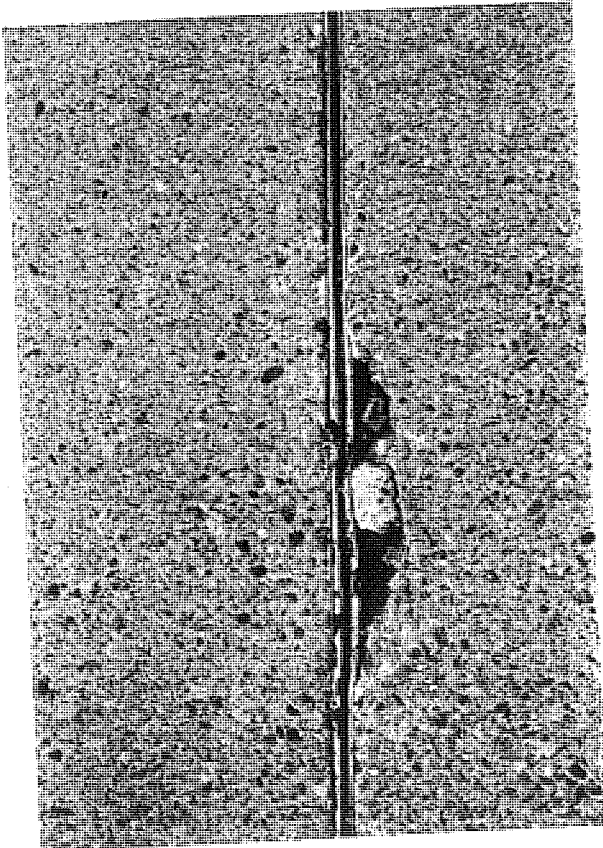
APPENDIX A



◀ Figure 1A. Transverse joint compression failure.



▲ Figure 2A. Failure at intersection of the transverse and longitudinal joint.



◀ Figure 3A. Joint groove spall.

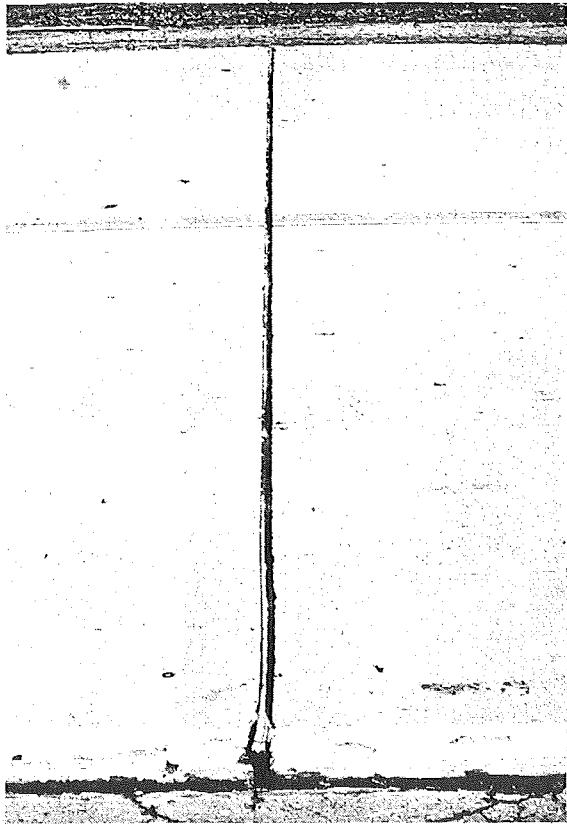


Figure 5A. Transverse crack with fractured steel.

Figure 4A. Ineffective neoprene seal.

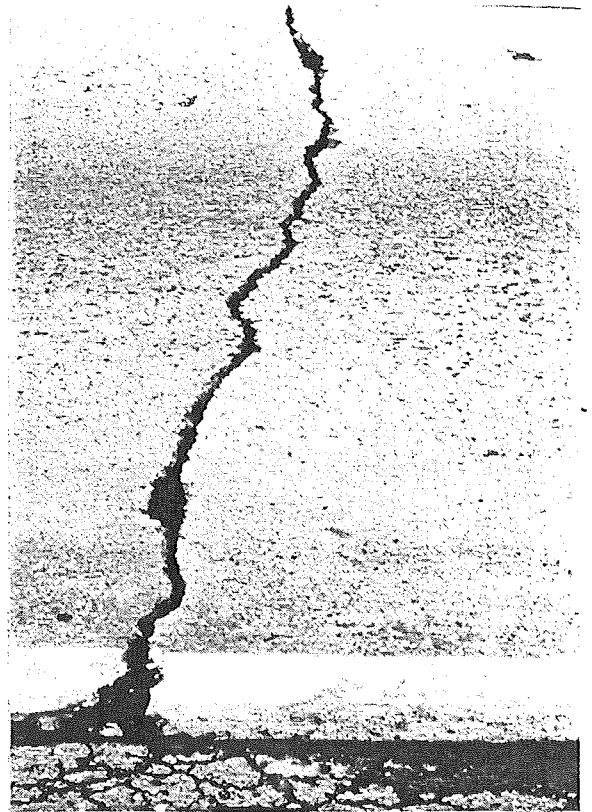


Figure 6A. Transverse crack with reinforcement intact.

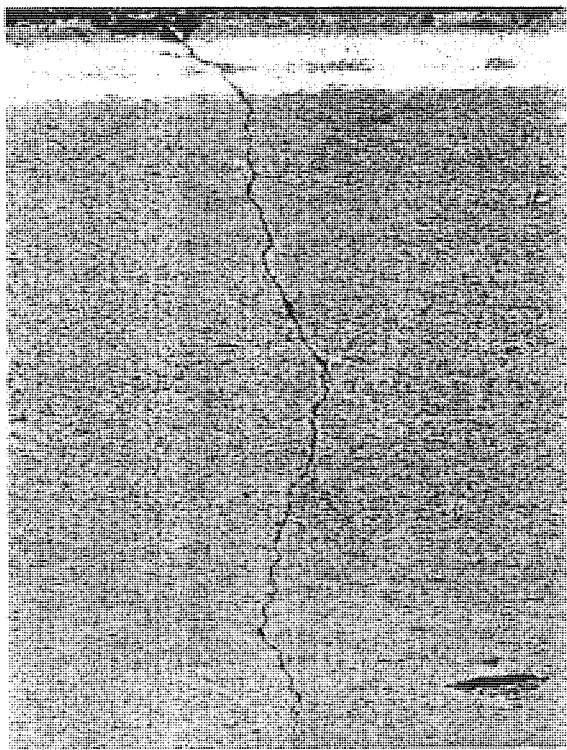


Figure 7A. Surface pop-out due to absorbent coarse aggregate.

APPENDIX B

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION
FOR
DOWELLED OR TIED CONCRETE PAVEMENT REPAIR

M&T:JES8

1 of 2

02-27-87

a. Description.-This special provision covers concrete pavement repairs utilizing 1-1/4 inch by 16-inch long, epoxy coated dowel bars or No. 10 deformed epoxy coated bars 18 inches long, both to be grouted-in-place in drilled holes with a polyester or epoxy grout.

All work and materials shall be in accordance with the 1984 Standard Specifications (primarily Section 4.52 Concrete Pavement Repair), with the exceptions and additions specified herein.

b. Materials.

Dowel Bars.-The dowel bars shall be 1-1/4 inch diameter by 16 inches long (both ends sawed) and shall be epoxy coated in accordance with Subsection 8.16.08-a (Type B coating).

Tie Bars.-The tie bars shall be No. 10 deformed bars 18 inches long and shall meet the requirements of Subsection 8.16.10-a. The bars shall be epoxy coated for their entire length, and shall have at least one sawed end.

Debonding Coat.-Type B coated dowels shall be coated with a bituminous material meeting the requirements of RC-250, as specified in Section 8.04. The RC-250 coat shall be applied after the dowels are installed in the field.

Grout.-The polyester or epoxy grout shall be selected from the list of Qualified Products for Grouting Dowel Bars and Tie Bars attached to this special provision.

Joint Sealant.-The hot-poured sealant shall be in accordance with the Special Provision for Low-Modulus Hot-Poured Joint Sealant contained in this proposal.

Equipment.

Drill.-The depth of the drilled holes specified in Subsection 4.52.03-e shall be 7-1/2 inches \pm 1/2 inch.

Grout Dispenser.-The grout dispensing equipment shall be capable of properly proportioning the components and mixing them while they are extruded through a nozzle. The nozzle shall be of sufficient length to deposit the grout in the back of the hole.

c. Construction.-The construction shall be in accordance with Construction Methods as specified in 4.52 Concrete Pavement Repair with the following exceptions:

Once the dowel bar or tie bar holes have been cleaned with oil-free compressed air (the air wand shall be inserted into the back of the hole), and just prior to inserting the bars in the holes, the approved grout material shall be deposited in the back of the holes. The amount of grout in each hole shall be of sufficient quantity to completely fill the space around the bar as it is inserted into the hole using hand pressure. The grout extruded during the bar insertion shall be wiped around the bar at the joint face with a gloved hand or hand trowel. Excess grout on the concrete joint face and the bar shall be wiped off.

After the grout has set, the portion of all dowels extending into the repair area shall be uniformly coated with liquid asphalt meeting the requirements of RC-250. For expansion joints, the filler material shall be in place prior to applying the RC-250 asphalt, and an expansion cap shall be placed on the end of each protruding dowel after the RC-250 coat has been applied. The alternate procedure of using a cylindrical plug inserted in the holes in lieu of an expansion cap will not be permitted. Tie bars shall not be coated with RC-250. Transverse joint grooves at tied joints shall be 1/4 inch wide by 1/2 inch deep and formed by edging the repair and shall be sealed with a hot-poured sealant.

d. Measurement and Payment.-The completed work as measured for DOWELLED OR TIED CONCRETE PAVEMENT REPAIR will be paid for at the contract unit prices for the following contract items (pay items).

<u>Pay Item</u>	<u>Pay Unit</u>
Contraction Joint Cr (Modified).....	Linear Foot
Expansion Joint Er (Modified).....	Linear Foot
Grouted-In-Place Tied Joint.....	Linear Foot

The payment for Contraction Joint Cr (Modified) and Expansion Joint Er (Modified) includes all the work for Contraction Joint Cr and Expansion Joint Er and in addition includes furnishing and installing the grout material, furnishing epoxy coated dowels, furnishing and applying the RC-250 asphalt coating, and furnishing and installing the expansion caps.

The Pay Item for Grouted-In-Place Tied Joint will be Lineal Feet and the Pay Item will include the cost of drilling and cleaning the holes, furnishing the tie bars, the grout material, injecting the grout in the hole, installing the bars, and edging and sealing the transverse repair edges.

QUALIFIED PRODUCTS
FOR
GROUTING DOWEL BARS AND TIE BARS

Product Name	Manufacturer & Representative	Grout Type
Hilti C-10	Hilti Fastening Systems 1431 Opus Place, Suite 522 Downers Grove, Illinois 60515 Michael Casey (312) 971-2556	Polyester
Mark 198	Poly-Carb 33095 Brainbridge Road Cleveland, Ohio 44139 Hormus Irani (216) 248-1223	Epoxy
Solid Bond 200	Adhesive Technology Corp. 21850 88th Place South Kent, Washington 98031 Dennis Fogh (206) 872-2240	Epoxy

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION
FOR
FULL-DEPTH CENTERLINE JOINT REPAIR

M&T:JES5

1 of 3

02-27-87

a. Description.-This special provision covers full-depth repair at the intersection of the longitudinal centerline joint and the transverse joints in concrete pavement.

All work and material shall be in accordance with the 1984 Standard Specifications (primarily Section 4.52 Concrete Pavement Repair), with the exceptions and additions specified herein.

b. Materials.

Tie Bars.-Straight tie bars shall meet the requirements of Subsection 8.16.10-a. The bars shall be No. 5 Grade 40 deformed, 24 inches long and epoxy coated for the entire length.

Grout.-A polyester or epoxy grout for fastening the tie bars in drilled holes shall be selected from the list of Qualified Products for Grouting Dowel Bars and Tie Bars attached to this special provision.

Joint Sealant.-The hot-poured sealant shall be in accordance with the Special Provision for Low-Modulus Hot-Poured Joint Sealant contained in this proposal.

Equipment.

Drill.-At the Contractor's option, tie bar holes 3/4 inch in diameter by 6 inches deep may be drilled with a hand-held drill.

Grout Dispenser.-The grout dispensing equipment shall be capable of properly proportioning the components and mixing them while they are extruded through a nozzle. The nozzle shall be of sufficient length to deposit the grout in the back of the holes.

c. Construction Methods.

General.-Unless otherwise directed by the Engineer, the repairs shall be 2 feet wide and 4 feet long.

Removing Pavement (Lift Out Method).-The perimeter of the repairs shall be sawed full-depth with overcuts at each corner required. The distressed area of concrete shall be removed by lifting it out. Any concrete rubble left in the repair area shall be removed by use of hand tools. Disturbance of the base material will not be permitted.

Removing Pavement (Break Out Method).-The perimeter of the repairs shall be sawed full-depth, but overcuts at the corners will not be permitted. The concrete within the sawed limits shall be removed by use of hand-held air hammers and hand tools. Care shall be exercised to prevent undercutting at each corner of the removal area. The disturbed base material shall be recompacted by use of a hand-held air operated tamper.

Tie Bar Installation.-Tie bar holes shall be drilled at the locations and to the diameter, depth, and angle shown on the Detail for Full-Depth Centerline Joint Repair attached to this special provision. The drilled holes shall be cleaned with oil-free compressed air just prior to installing the bars. The air wand shall be inserted into the back of the hole to ensure proper cleaning. Once the holes are cleaned, a sufficient quantity of grout shall be deposited in the

back of the holes to completely fill the space around the bar when it is inserted. The tie bars shall be inserted by hand using sufficient pressure to ensure the bars are embedded for the full depth. Excess grout extruded from the hole shall be wiped around the bar at the hole opening with a gloved hand or hand trowel. After the grout has hardened, the tie bars shall be bent downward until they are parallel to the pavement surface. At the Contractor's option, the tie bars may be bent prior to grouting them in place.

Joint Construction.-At the existing transverse joint location, a 3/4 inch bituminous filler board shall be installed in line with the existing joint as shown on the attached detail. The longitudinal joint shall not be extended through the repair area. A groove, approximately 1/4 inch wide by 1/2 inch deep, shall be edged around the perimeter of the repair.

Joint Sealing.-The perimeter joint, including sawed overcuts, shall be sealed with hot-poured joint sealant.

d. Measurement and Payment.-Measurement and payment for the completed work as measured for FULL-DEPTH CENTERLINE JOINT REPAIR will be paid for at the contract unit prices for the following contract items (pay items).

<u>Pay Item</u>	<u>Pay Unit</u>
Removing Pavement (Lift Out Method).....	Square Yard
Removing Pavement (Break Out Method).....	Square Yard
Concrete Pavement Repair _____ in.,	
Non-reinforced (Special).....	Square Yard
Grouted-In-Place Tie Bars.....	Each

The item Removing Pavement (Lift Out Method) includes the cost of sawing the perimeter, lifting out the distressed concrete without disturbing the base, and loading, hauling, and disposing of the material removed.

The item Removing Pavement (Break Out Method) includes the cost of sawing the perimeter, breaking and removing the distressed concrete, and loading, hauling and disposing of the material removed, and recompacting the base.

Concrete Pavement Repair, Non-reinforced (Special), of the thickness specified, will be measured by area in square yards. Longitudinal and transverse measurements for area will be made along the actual surface of the roadway. Payment for Concrete Pavement Repair, Non-reinforced (Special) includes payment for furnishing, placing, consolidating, finishing, and curing the concrete, furnishing and placing the bituminous filler board, and edging and sealing the joint groove around the repair perimeter.

Payment for Grouted-In-Place Tie Bars includes drilling and cleaning the holes, furnishing the tie bars and the grout material, injecting the grout in the holes, and installing the bars.

QUALIFIED PRODUCTS
FOR
GROUTING DOWEL BARS AND TIE BARS

Product Name	Manufacturer & Representative	Grout Type
Hilti C-10	Hilti Fastening Systems 1431 Opus Place, Suite 522 Downers Grove, Illinois 60515 Michael Casey (312) 971-2556	Polyester
Mark 198	Poly-Carb 33095 Brainbridge Road Cleveland, Ohio 44139 Hormus Irani (216) 248-1223	Epoxy
Solid Bond 200	Adhesive Technology Corp. 21850 88th Place South Kent, Washington 98031 Dennis Fogh (206) 872-2240	Epoxy

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION
FOR
RESEALING TRANSVERSE JOINTS WITH SILICONE

M&T:AWP2

1 of 3

02-27-87

a. Description.-This work consists of removing existing neoprene or hot-poured sealant, resawing the joint groove, cleaning the joint, and sealing the joint with a silicone sealant.

The location of the joints to be resealed shall be as shown in the proposal or as directed by the Engineer.

All work and materials shall be in accordance with the 1984 Standard Specifications with exceptions and additions specified herein.

b. Materials.-The silicone sealant shall be a low-modulus sealant having a one part formulation which does not require a primer for proper bonding to portland cement concrete. The sealant shall meet the following requirements:

<u>Property</u>	<u>Value</u>	<u>Test Method</u>
Shelf Life, months	6 min (from date of shipment)	
Flow, inches	0.3 max	ASTM C 639
Extrusion Rate, grams/minute	90-300	MIL S 8802
Tack Free Time, minutes	35-75	MIL S 8802
Specific Gravity	1.010-1.515	ASTM D 792 (Method A)

Tests on Sealant Cured 7 Days at 75 F and 50% RH

Durometer Hardness, Shore A	5-25	*ASTM D 2240
Tensile Stress at 150% Elongation, psi	45 max	*ASTM D 412 (Die C)
Elongation, %	700 min	*ASTM D 412 (Die C)

Bond test, -20 F, 100% Elongation, 3 cycles

Non-Immersed	Pass	**Departmental
Water-Immersed, 96 hours	Pass	**Departmental

*The hardness, tensile stress, and elongation specimens shall be prepared from a sheet of material 1/8" to 3/16" thick which has been cast and cured on a sheet of polyethylene.

**Bond tests shall be run in triplicate on sealant sections 1/2"W x 3/8"D x 2"L, poured and tooled between sawed concrete blocks. A cycle shall consist of 100% extension at -20 F at a rate of 1/8 inch per hour. The specimens shall be allowed to recover at laboratory temperature for four hours, then conditioned for a minimum of four hours at -20 F before starting a cycle. Failure is determined by one or more of the three specimens exhibiting 10% or more adhesion or cohesion failure after three cycles.

The containers of the sealant shall be plainly marked with the manufacturer's name or trade name, color, lot number, and date of manufacture. The sealant will be sampled by a representative of the Department and tested by the Department. A minimum of three weeks will be required for testing from the time the sample is received.

c. Construction.

Seal Removal.-All existing neoprene joint seals shall be removed from the joint grooves. The portion of the neoprene seal in the vertical joint groove at the edges of the pavement need not be removed. For joint grooves that have closed beyond their design limits, it may be necessary to run a single saw cut through the length and depth of the joint seal to relieve the pressure and facilitate removal. Hot-poured sealant shall be removed by plowing or sawing.

Spall Repair.-Spalls along the joint groove which are directed to be repaired by the Engineer, shall be repaired as specified in the Special Provision for Joint Spall Repair contained in this proposal. Spalls shall be repaired prior to sawing the joint groove.

Joint Sawing.-The joint groove shall be resawed to dimensions shown on the Detail for Resealing Transverse Joints with Silicone attached to this special provision. The joint groove shall extend across concrete widening and concrete ramps, but shall not extend down the edge of the concrete. The new saw cut shall be centered over the old joint groove to produce a finished joint with two freshly sawed faces. Immediately after sawing the joint, the joint groove shall be flushed with water having sufficient pressure to remove all slurry and debris from the joint faces and reservoir.

Joint Preparation.-Immediately prior to sealing, the joint shall be cleaned to remove all dust and contamination from the joint faces and reservoir.

Cleaning shall consist of sandblasting followed by a final cleaning with compressed air free of oil and water and having a minimum pressure of 90 psi. After the final cleaning, the closed cell polyethylene backer rod shall be inserted into the transverse joint groove to the depth shown on the Detail for Resealing Transverse Joints with Silicone.

Joint Sealing.-The joint groove shall be sealed after the insertion of the backer rod and prior to becoming contaminated. At the time of sealing, the joint groove faces shall be dry and dust free. The silicone shall be pumped into the joint groove in a continuous operation to properly fill and seal the joint groove. A list of recommended pumps for this procedure can be obtained from the supplier of the sealant. In conjunction with or immediately after placement, the sealant shall be tooled to force it against the joint faces and to obtain the correct depth.

A temporary dike (consisting of a piece of the backer rod inserted vertically in the joint groove) shall be installed near the centerline to terminate the sealant. The dike shall be removed when the adjacent lane is sealed and the newly placed sealant shall be tooled to force it against the end of the previously placed sealant. In the event the adjacent lane has not been resawed prior to sealing the first lane, the dike shall be placed in the first lane a minimum of 12 inches from the unsawed area to permit sawing the adjacent lane without damaging the sealant.

The joint faces and pavement surface shall be dry at the time of sealing. The joints shall not be sealed when the air or pavement temperature is below 40 F. Traffic shall not be allowed on the sealed joints for a minimum of three hours after tooling, unless otherwise directed by the Engineer.

d. Measurement and Payment.-The completed work as measured for RESEALING TRANSVERSE JOINTS WITH SILICONE will be paid for at the contract unit price for the following contract unit (pay item).

<u>Pay Item</u>	<u>Pay Unit</u>
Resealing Transverse Joints with Silicone.....	Linear Foot

Payment for Resealing Transverse Joints with Silicone includes all labor, equipment, and materials required to remove all existing sealants and resaw, clean, and seal the joints, with the exception of spall repair which will be paid for separately as provided for in the Special Provision for Joint Spall Repair contained in this proposal.

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION
FOR
RESAWING AND SEALING LONGITUDINAL
PAVEMENT JOINTS

M&T:AWP4

1 of 1

02-27-87

a. Description.-This work includes all labor, equipment, and material required to resaw and seal existing longitudinal concrete pavement joints.

All work and materials shall be in accordance with the 1984 Standard Specifications with the exceptions and additions specified herein.

The longitudinal joints shall be resawed to the dimensions specified, cleaned, and sealed with a low-modulus hot-poured joint sealant as directed by the Engineer.

b. Materials.-The joint sealant shall be in accordance with the Special Provision for Low-Modulus Hot-Poured Joint Sealant contained in this proposal.

c. Construction.-The joints shall be sealed with the hot-poured sealant as specified in Subsection 4.50.22-c of the 1984 Standard Specifications with the following exceptions and additions:

1. All spalls along the longitudinal joint which are directed by the Engineer to be repaired, shall be repaired as specified under the Special Provision for Joint Spall Repair contained in this proposal. The spalls shall be repaired prior to resawing the longitudinal joint.
2. The existing longitudinal joints shall be resawed to a depth of 1 inch to 1-1/4 inch and a width of 3/8 inch to 1/2 inch. Immediately following the sawing operation, the joint groove shall be flushed with water of sufficient pressure to remove the slurry and debris from the joint groove. The longitudinal joints shall be sawed prior to resealing the intersecting transverse joints.
3. The joints shall receive a final cleaning, just prior to sealing, as specified in Subsection 4.50.21 of the 1984 Standard Specifications.
4. The joint groove shall be sealed flush to 1/8 inch (after cooling) below the surface of the pavement. The faces of the joint groove and the pavement surface shall be dry at the time of sealing.

d. Measurement and Payment.-The completed work as measured for RESAWING AND SEALING LONGITUDINAL PAVEMENT JOINTS will be paid for at the contract unit price for the following contract item (pay item).

<u>Pay Item</u>	<u>Pay Unit</u>
Resawing and Sealing Longitudinal Pavement Joints.....	Linear Foot

Payment for Resawing and Sealing Longitudinal Pavement Joints includes all labor, equipment, and materials required to saw, clean, and seal the joints, with the exception of spall repair, which will be paid for separately as provided in the Special Provision for Joint Spall Repair contained in this proposal.

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION
FOR
REPAIR OF CONCRETE PAVEMENT SURFACE POP-OUTS

M&T:AWP3

1 of 1

02-27-87

a. Description.-This work shall consist of cleaning and repairing pop-out areas in the surface of the concrete pavement with a fast set mortar.

The areas to be cleaned and repaired shall be as shown in the proposal or as directed by the Engineer.

All work and materials shall be in accordance with the 1984 Standard Specifications with the following exceptions and additions.

b. Materials.-The fast set repair mortar shall be in accordance with the Special Provision for Prepackaged Fast Set Mortar contained in this proposal.

c. Equipment.-The chipping hammers used to prepare the repair area shall be light weight (15 pound class maximum), unless otherwise approved by the Engineer.

d. Construction.

Repair Area Preparation.-All unsound concrete and bituminous patching material shall be removed from the repair area with chipping hammers. All surfaces of the repair area shall be sandblasted to remove all contamination, followed by a final cleaning with oil-free compressed air having a minimum pressure of 90 psi.

Mortar Placement.-The mortar shall be mixed, placed, consolidated, finished, and cured as specified in the Special Provision for Prepackaged Fast Set Mortars as contained in this proposal.

e. Measurement and Payment.-The completed work as measured for REPAIR OF CONCRETE PAVEMENT SURFACE POP-OUTS will be paid for at the contract unit price for the following contract item (pay item).

<u>Pay Item</u>	<u>Pay Unit</u>
Repair of Concrete Pavement Surface Pop-outs.....	Each

Payment for Repair of Concrete Pavement Surface Pop-outs includes all labor, equipment, and materials required to prepare the repair area and place, consolidate, finish, and cure the patching mortar, with the exception of furnishing and mixing the repair mortar which will be paid for separately as provided in the Special Provision for Prepackaged Fast Set Mortar contained in this proposal.

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION
FOR
PREPACKAGED FAST SET MORTAR

M&T:AWP7

1 of 2

02-27-87

a. Description.-This special provision covers prepackaged fast set mortars for use as a concrete repair material.

All work and material shall be in accordance with the 1984 Standard Specifications with the exceptions and additions specified herein.

b. Materials.-The prepackaged fast set mortar shall be one of the materials listed in Table 1 (Prepackaged Mortar) attached to this special provision.

The aggregate used to extend the mortar shall be natural, clean, surface dry pea stone of the size and gradation recommended by the manufacturer of the prepackaged mortar material.

c. Surface Preparation.-The surface of the repair area shall be clean and free of contamination at the time of placing the repair material. The surface shall be dry or damp (free of standing water) at the time of placement as specified in Table 1.

d. Mixing.-The water, prepackaged mortar mix, and aggregate shall be mixed together in a paddle type mortar mixer for a minimum of two minutes or until the mixture is of a uniform consistency.

e. Placement.-Immediately after mixing, the material shall be placed in the repair area, consolidated, and finished. Caution! In warm weather, the working time (after mixing and prior to initial set) may be 5 minutes or less. Retempering or remixing of the material will not be permitted. The material shall be firmly worked into the bottom and sides of the repair area to insure good bond and consolidation. The repair area shall be completely filled before any portion of the material has taken an initial set. Immediately after placing and consolidating the material, it shall be trowelled off to produce a surface flush to 1/16 inch below the existing surface.

f. Curing.-Immediately after the initial set, the material shall be cured as specified in Table 1.

g. Temperature Limitations.-The repair material shall not be placed when the air temperature is above 90 F or below 40 F.

When the air temperature is less than 50 F, the components of the repair material (water, prepackaged mortar, and aggregate) shall be heated to 75-85 F prior to mixing. In addition, the concrete at the repair area shall be slowly heated until it is warm to the touch prior to placing the material.

When the air temperature is greater than 80 F, the prepackaged mortar and aggregate shall be kept cool and ice water shall be used as the mix water.

h. Opening to Traffic.-Traffic shall not be allowed on the completed repair for at least 2 hours after the material has been finished, unless otherwise approved by the Engineer.

i. Measurement and Payment.—PREPACKAGED FAST SET MORTAR will be measured in cubic feet as determined by multiplying the number of units used by the yield per extended unit factor (Table 1) and will be paid for at the contract unit price for the contract item (pay item).

<u>Pay Item</u>	<u>Pay Unit</u>
Prepackaged Fast Set Mortar.....	Cubic Foot

Payment for Prepackaged Fast Set Mortar includes all labor, equipment, and material required to furnish and mix all components of the material.

TABLE 1
PREPACKAGED MORTAR

Product Name	Manufacturer	Prepackaged Weight (Pounds) per Unit	Aggregate Extension (Pounds) per Unit	*Mix Water (Quarts) per Extended Unit	Yield (cu ft) per Extended Unit	Cure Type & Length	Bonding Surface Condition
Burke Fast Patch 928	Burke Company P.O. Box 5818 San Mateo, CA 94402 (415) 349-7700	50	25	3.25 to 3.75	0.52	Wet Burlap 2 hr.	Clean & Damp
Durapatch Hi Way	L & M Construction Chemicals, Inc. 8316 Blondo St. Omaha, NE 68134 (402) 393-3371	50	25	3.00 to 3.75	0.52	Wet Burlap 2 hr.	Clean & Damp
Five Star Highway Patch	US Highway Products 405 Stillson Rd. Fairfield, CT 06430 (203) 336-7930	50	30	3.00 to 3.50	0.58	Wet Burlap 2 hr.	Clean & Damp

*The mix water used shall be the minimum amount within this range which produces a mix that is basically self-consolidating and self-leveling.

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION
FOR
LOW-MODULUS HOT-POURED JOINT SEALANT

M&T:AWP

1 of 1

02-27-87

a. Description.-This special provision covers a low-modulus hot-poured joint sealant used to seal joints and cracks.

b. Material.-The low-modulus hot-poured sealant shall meet the requirements of the 1984 Standard Specifications, Subsection 8.16.04-a with the following exceptions and additions:

1. Bond.-The sealant shall be tested at -20F for 3 complete cycles at 100 percent extension. The fine aggregate incorporated into the concrete mixture used to make the bond blocks shall be 2NS sand.
2. Penetration at 77F.-The penetration at 77F shall be 120+20.
3. Penetration at 0F.-The penetration at 0F shall be not less than 40. Two specimens shall be prepared and tested after being conditioned for 24 hours at 0F. The test shall be completed within 20 seconds after removal from the freezer.
4. Packaging and Marking.-The containers in which the material is packaged shall be legibly marked with a non-fading weather-resistant type of ink or paint. The markings shall include the manufacturer's name, or trade name, batch number, recommended pouring temperature, and the maximum safe heating temperature.
5. Sampling and Testing.-The sealant will be sampled by a representative of the Department. A minimum of two weeks will be required for testing from the time the sample is received.

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION
FOR
SAWING AND SEALING PAVEMENT CRACKS

M&T:AWP5

1 of 1

02-27-87

a. Description.-This work includes all labor, equipment, and material required to saw, repair spalls, clean, and seal cracks with hot-poured joint sealant.

All work and materials shall be in accordance with the 1984 Standard Specifications with the exceptions and additions specified herein.

The location of the cracks to be sealed will be as shown in the proposal, on the plans, or as directed by the Engineer.

b. Materials.-The joint sealant shall be in accordance with the Special Provision for Low-Modulus Hot-Poured Joint Sealant contained in this proposal.

c. Equipment.-The cracks shall be sawed with a random crack saw designed to follow the path of the crack. The saw shall be equipped with a diamond blade with a maximum diameter of 8 inches.

d. Construction.

Spall Repair.-All spalls along the crack which are directed by the Engineer to be repaired, shall be repaired as specified in the Special Provision for Joint Spall Repair contained in this proposal. The spalls shall be repaired prior to sawing the crack.

Sawing.-The cracks shall be sawed to a width of 5/8 inch to 3/4 inch and a depth of 3/4 inch to 7/8 inch. Immediately following the sawing operation, the crack shall be flushed with water of sufficient pressure to remove the slurry and debris from the sawed groove.

Cleaning.-Immediately prior to sealing, both faces of the sawed groove shall be sandblasted followed by a final cleaning with oil-free compressed air having a minimum pressure of 90 psi.

Sealing.-The sawed groove shall be sealed flush to 1/8 inch (after cooling) below the surface of the pavement. The faces of the sawed groove and the pavement surface shall be dry at the time of sealing.

e. Measurement and Payment.-The completed work as measured for SAWING AND SEALING PAVEMENT CRACKS will be paid for at the contract unit price for the following contract item (pay item).

<u>Pay Item</u>	<u>Pay Unit</u>
Sawing and Sealing Pavement Cracks.....	Linear Foot

Sawing and Sealing Pavement Cracks will be measured in a straight line from end of crack to end of crack in linear feet.

Payment for Sawing and Sealing Pavement Cracks includes all labor, equipment, and materials required to saw, clean, and seal the cracks, with the exception of spall repair which will be paid for separately as provided in the Special Provision for Joint Spall Repair contained in this proposal.

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION
FOR
JOINT SPALL REPAIR

M&T:AWP1

1 of 2

02-27-87

a. Description.-This work includes furnishing all labor, equipment, and materials necessary to remove all unsound concrete, reform the joint groove, and patch the spall area with a prepackaged fast set mortar.

All work and material shall be in accordance with the 1984 Standard Specifications with the exceptions and additions specified herein.

The size and location of the repair areas will be as shown in the proposal or as determined by the Engineer. The total length of spall and volume of material for bidding purposes has been increased from that shown on the log to allow for increase in spalls since the initial survey and to include the increase in area due to the repair procedure.

b. Material.-The fast set repair mortar shall be in accordance with the Special Provision for Prepackaged Fast Set Mortar contained in this proposal.

Fiber joint filler shall conform to Subsection 8.16.03 of the 1984 Standard Specifications.

c. Equipment.-Chipping hammers for the removal of the unsound concrete shall be light weight (15 pound class maximum), unless otherwise approved by the Engineer.

Concrete saws for sawing the perimeter of the repair area shall be equipped with a diamond blade or blades with a maximum diameter of 12 inches.

d. Construction.

Repair Area Preparation.-Unless otherwise approved by the Engineer, the repair limits shall be constructed by sawing. The depth of the saw cut shall be 1-3/4 inch \pm 1/4 inch. The saw cut to control the width of the repair area shall be 2 inches beyond the widest portion of the spall (6-inch minimum width) and approximately parallel to the joint groove. The saw cuts to control the length of the repair shall be 2 inches beyond the length of the spall (minimum of 6 inches apart) and approximately perpendicular to the joint groove. Additional saw cuts may be made within the repair area to facilitate the removal of the unsound concrete.

The unsound concrete shall be removed by hand chipping with a light weight chipping hammer. The slope of the bottom of the repair area shall not exceed 1 vertical to 4 horizontal, unless otherwise approved by the Engineer.

All areas of the existing concrete which must bond to the patching material shall be freshly sawed or chipped to remove all unsound concrete and contamination.

The repair area shall be cleaned with oil-free compressed air or high pressure water, and any other tools required to remove all slurry and debris.

All waste material and debris shall be disposed of by the Contractor as directed by the Engineer.

Joint Groove Forming.-When the spall repair area is along a transverse joint, a temporary joint groove shall be formed 1/2 inch wide and to the depth of the existing joint groove adjacent to the repair area. The form material shall be 1/2 inch thick and shall be either styrofoam or fiber joint filler. In the

event that the repair area extends below the bottom of the joint groove, the plane of weakness crack shall be recreated by extending the form material to the bottom of the repair area or by positioning a piece of 1/4 inch thick polyethylene foam sheet against the existing concrete between the bottom of the form material and the bottom of the repair area.

All dowel bars exposed in the repair area shall be coated with a heavy grease to prevent a bond between the dowel bar and the repair mortar.

When the spall repair area is along a longitudinal joint, a temporary joint groove shall be formed 1/4 inch wide. The temporary form material shall be 1/4 inch thick styrofoam or fiber joint filler. The form material shall extend to the bottom of the repair area.

When the spall repair area is along a crack, a temporary joint groove 1/4 inch wide shall be formed along the path of the crack. The form material shall be 1/4 inch thick polyethylene foam sheet material and shall extend the full depth of the repair area.

Repair Mortar Placement.-The repair mortar shall be placed, consolidated, finished, and cured as specified in the Special Provision for Prepackaged Fast Set Mortar contained in this proposal.

Joint Sawing and Opening to Traffic.-The repair mortar shall be cured for a minimum of 2 hours prior to sawing the joint groove or opening to traffic, unless otherwise approved by the Engineer.

e. Measurement and Payment.-The completed work as measured for JOINT SPALL REPAIR will be paid for at the contract unit price for the following contract unit (pay item).

<u>Pay Item</u>	<u>Pay Unit</u>
Joint Spall Repair.....	Linear Foot

Payment for Joint Spall Repair includes all labor and materials required to saw the repair limits, remove the unsound concrete, form the temporary joint groove, and to place, consolidate, finish, and cure the repair mortar, with the exception of furnishing and mixing the repair mortar which will be paid for separately as provided for in the Special Provision for Prepackaged Fast Set Mortar contained in this proposal.

APPENDIX C

CONCRETE PAVEMENT
**CONDITION
SURVEY
MANUAL**

1991



CONCRETE PAVEMENT CONDITION SURVEY MANUAL

Research Laboratory Section
Materials and Technology Division

Michigan Transportation Commission
Barton LaBelle, Chairman;
Charles Yob, Vice-Chairman;
William C. Marshall, Hannes Meyers, Jr.,
Irving Rubin, Richard White
Partick Nowak, Director
Lansing, May 1991

INTRODUCTION

This manual has been designed to make the job of the survey team as simple as possible, but still provide all the information the designer needs to design the project, and for the project engineer to lay out and supervise the work. Proper use of this manual will provide a uniform treatment for each project and greatly reduce or eliminate cost overruns.

The manual has been set up for jointed concrete pavements only and does not apply to continuously reinforced concrete pavements.

Suggested changes or additions to this manual, requests for additional manuals, or requests for Pavement Condition Survey Data Sheets (Form No. 1023) should be addressed to the Engineer of Research, Research Laboratory Section, Materials and Technology Division, P.O. Box 30049, Lansing, Michigan 48909.

PAVEMENT SURVEY INSTRUCTIONS

1. Conduct the survey from a vehicle driven on the shoulder in the same direction as the traffic is moving. On multi-lane pavements, it may be necessary to survey half the lanes from each shoulder. Normally a two-person crew is the most efficient. On a multi-lane pavement, however, or a pavement with high ADT, a third person may be required.
2. Occasionally it may be necessary to walk onto the pavement to ascertain the extent of distress or to locate station numbers.
3. Required safety precautions must be followed.
4. The stationing for each distress occurrence and the POBs and POEs of ramps shall be determined by the use of a vehicle mounted electronic distance measuring device. Periodically, the measured stations shall be tied into stenciled stationing and adjusted as needed.
5. All distress items will be recorded on the provided data sheets either by letter or number code. Definitions of distress types, the severity level for each distress type, codings, and a sample data sheet are included herein.
6. Indicate on the data sheet which lane is represented by lane number 1, 2, and 3. It is suggested that lane number 1 be the outside lane (right hand lane when looking in the direction of the traffic flow). On multi-lane two-way pavements, the numbering of the lanes should be continuous across the pavement, and should start with the right hand lane (looking in the direction of increasing stationing) as lane number 1.
7. On multi-lane pavements, note which lanes were constructed in the same pour. In general, on the older pavements the longitudinal joint between lanes poured at the same time will be sawed and sealed and the longitudinal joint between lanes poured separately will be a non-sealed bulkhead joint. This information will be helpful to the designer if the project is set up to seal the longitudinal joints.
8. Any unusual pavement distress which does not fit the data sheet but would assist the Design Division should be recorded separately and submitted with the data sheets.

REPAIR PLAN

The following repair plans shall be used to determine the type of repair required, the quantity of repairs needed, and the priority of the repairs.

The first repair plan (Repair Plan 1) covers full depth dowelled concrete repairs constructed on pavements that are not being prepared for a bituminous overlay.

REPAIR PLAN 1

Distress Severity Levels	Repair Priority Levels		
	1 (highest)	2	3 (lowest)
1 (highest)	Joints Cracks General Slab Deterioration Previous Repairs	*Relief Joints	
2	Joints Cracks Previous Repairs	General Slab Deterioration	*Relief Joints
3		Joints Cracks Previous Repairs	
4 (lowest)			Joints Cracks Previous Repairs

*In case of relief joints with just filler missing and no other associated distress, only the filler will be replaced.

All undowelled repairs shall be classified in repair priority level 1, regardless of the distress severity level.

The second repair plan (Repair Plan 2) shall be used when a concrete pavement is being prepared for a bituminous overlay.

REPAIR PLAN 2

Traffic Volume, ADT (each roadway)	Distress Type	Distress Severity	Repair Type	Comments
0 - 5,000	Joints & Cracks	1	Detail 8	For UDRs faulted more than 3/4 inch cold milling is optional
		2	Detail 7	
		3 & 4	Detail 7	
5,000-10,000	Joints, Cracks, UDRs, and existing DRs	1	DR	*Cold mill all UDRs faulted more than 1/2 inch
		2	Detail 7	
		3 & 4	Detail 7	
10,000 - up	Joints, Cracks, UDRs, and existing DRs	1	DR	*Cold mill all UDRs faulted more than 1/2 inch
		2	DR	
		3 & 4	Detail 7	

NOTES:

UDR = Undowelled Repair

DR = Dowelled Repair

*Refer to Design Division IM #361-R for alternate to milling and additional data.

DISTRESS TYPE DEFINITIONS

Name of Distress -
Transverse Joint Failure

Description:

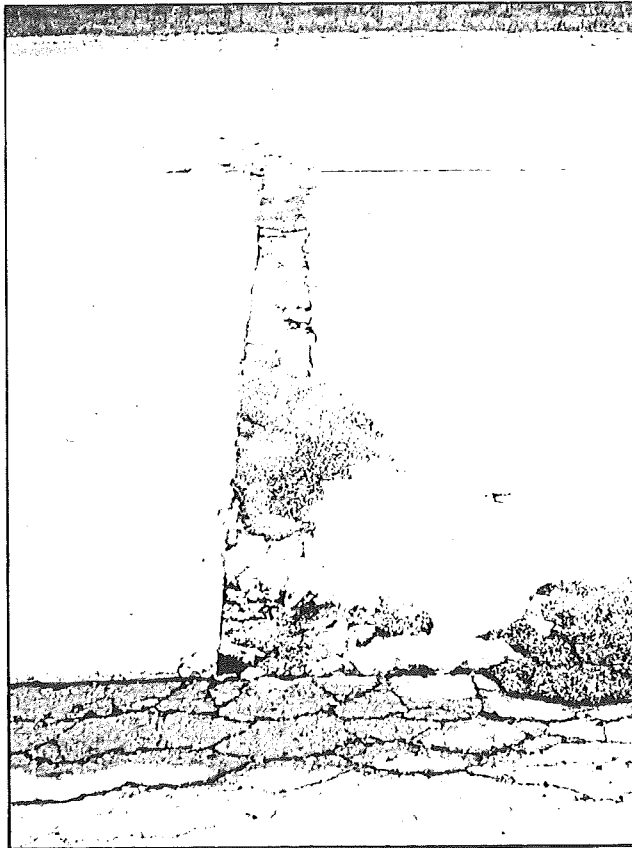
Failure of the transverse joints are the spalling, breaking, or buckling of the concrete along one or both edges of the joint groove for a total width of 4 in. or more. Failures normally occur gradually and are maintained by temporary bituminous patching.

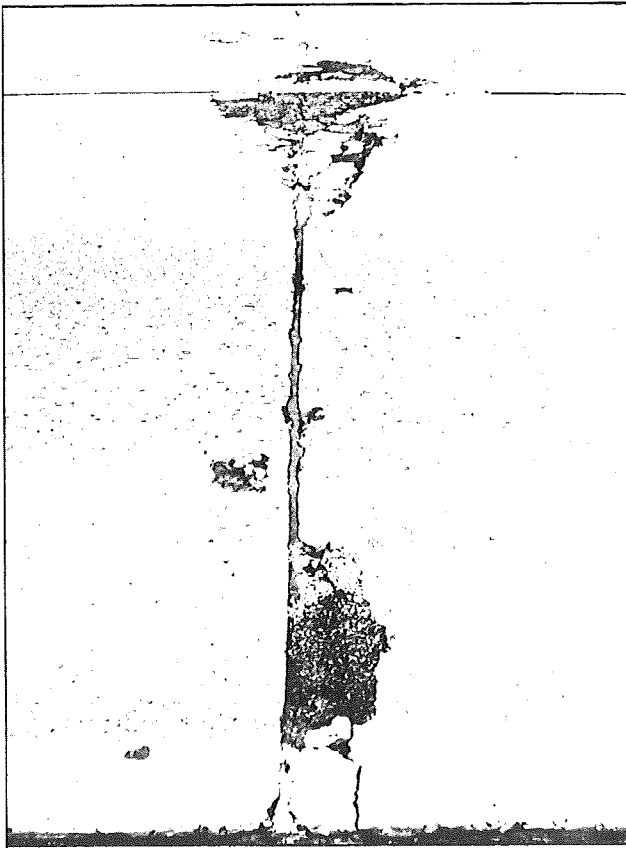
Rating Procedure:

- A. Determine severity level.
- B. Estimate width of distress in ft (to nearest ft).
- C. Estimate length of required repair in ft (6 ft Minimum).

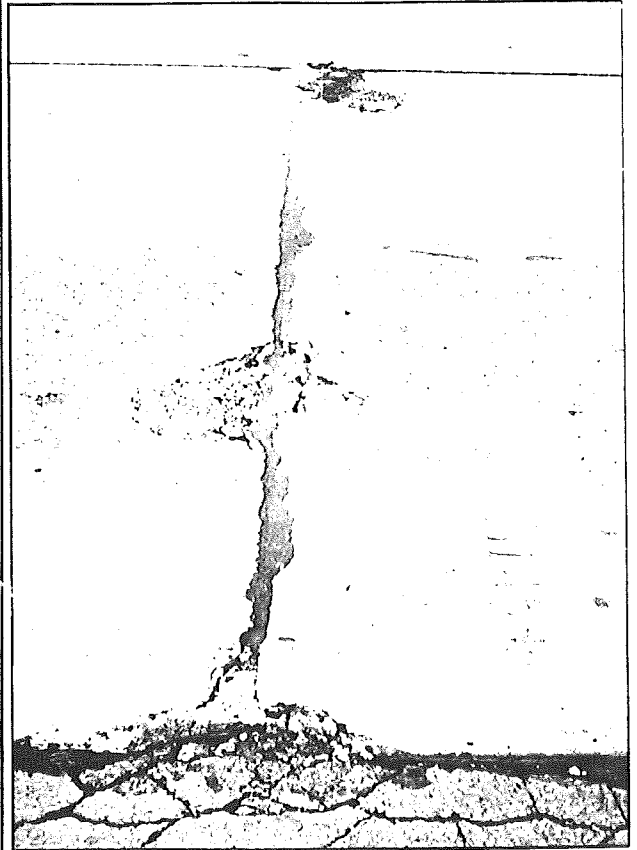
Severity Level 1

From 6 to 12 ft of spall or
bituminous patching.

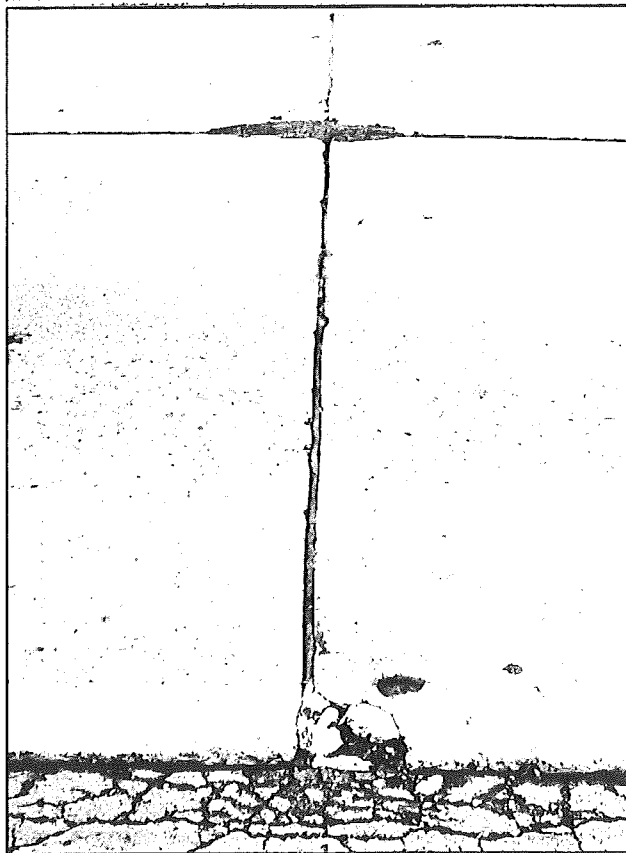




Severity Level 2
From 3 to 6 ft of spall or bituminous patching.



Severity Level 3
From 1 to 3 ft of spall or bituminous patching.



Severity Level 4
From 0 to 1 ft of spall or bituminous patching.

Name of Distress -
Open Transverse Crack

Description:

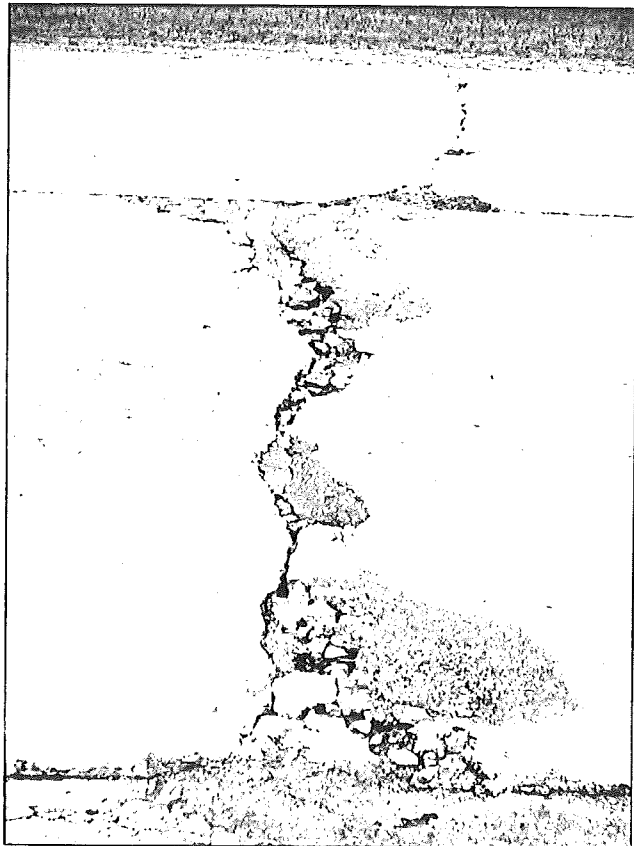
An open transverse crack is a small gap in the pavement slab between joints. The reinforcement has fractured and the crack acts as a joint. Normally the width of the crack must be 1/4 in. or more to be considered open. Spalling, bituminous patching, and faulting may have occurred.

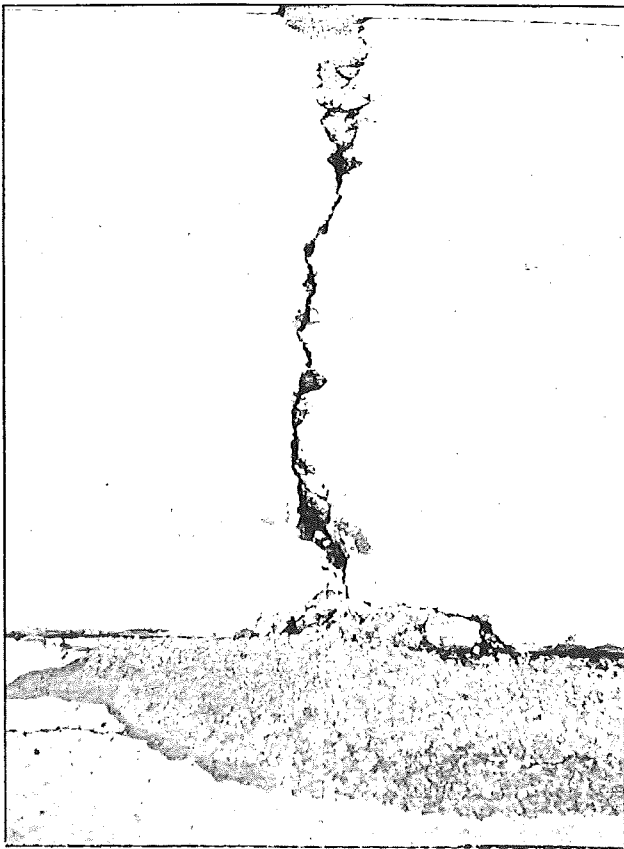
Rating Procedure:

- A. Determine severity level.
- B. Estimate width of distress in ft.
- C. Estimate length of required repair in ft (6 ft minimum).
- D. Estimate amount of faulting (for faulting greater than 1/2 in.).

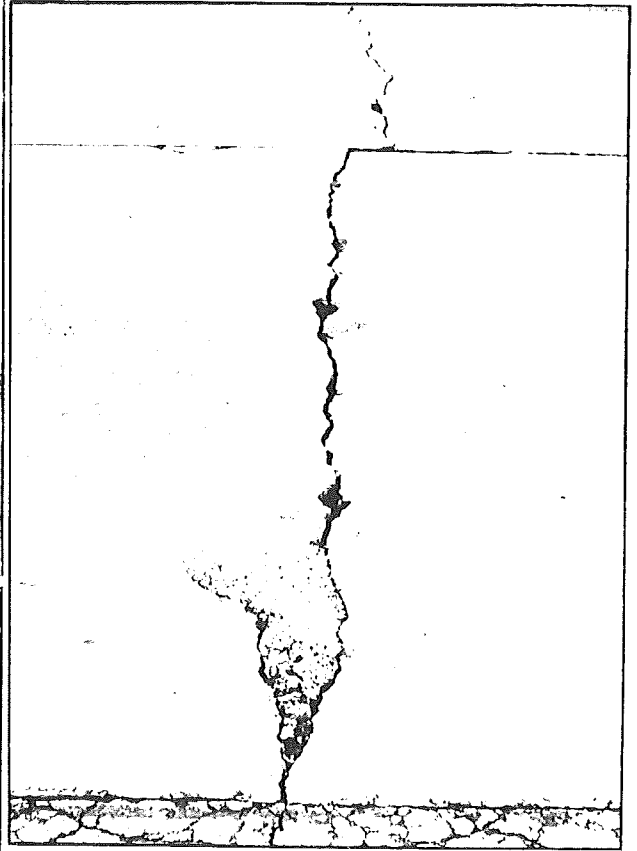
Severity Level 1

From 6 to 12 ft of spall or
bituminous patching.
Faulting may have occurred.

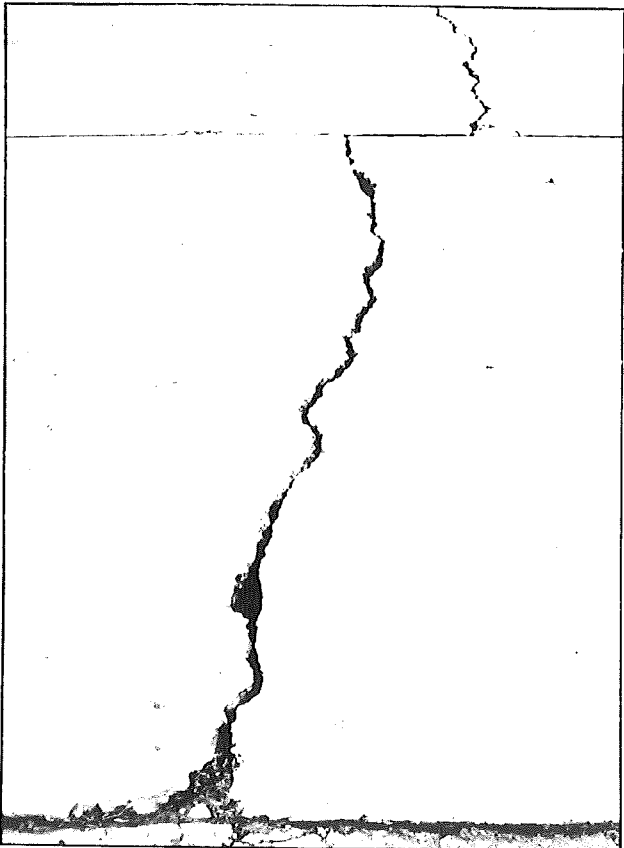




Severity Level 2
From 3 to 6 ft of spall or bituminous patching.
Faulting may have occurred.



Severity Level 3
From 1 to 3 ft of spall or bituminous patching.
Faulting may have occurred.



Severity Level 4
From 0 to 1 ft of spall or bituminous patching.
Faulting may have occurred.

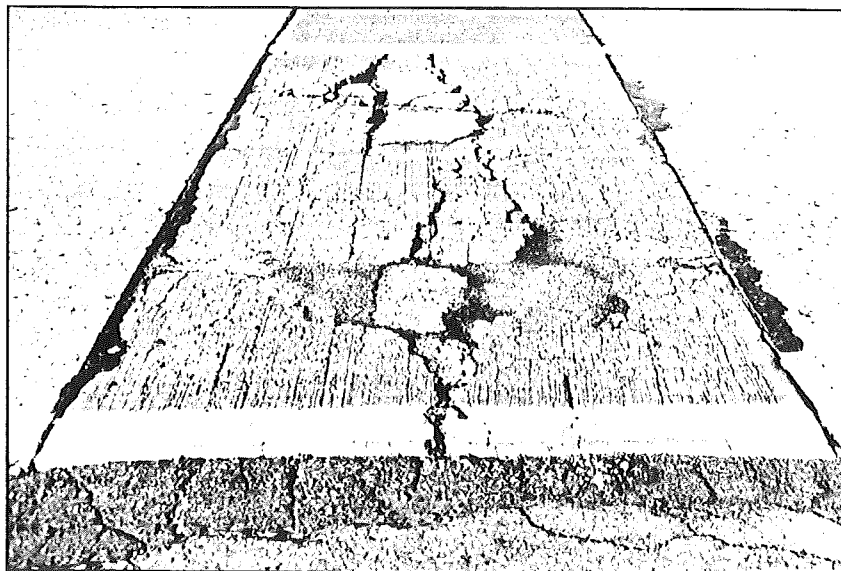
Name of Distress -
Previous Repair

Description:

A previous repair is the replacement of a section of the original pavement. Repairs may be located at the joint or between the joints. Spalling, cracking, patching, and/or faulting of the repairs may have occurred.

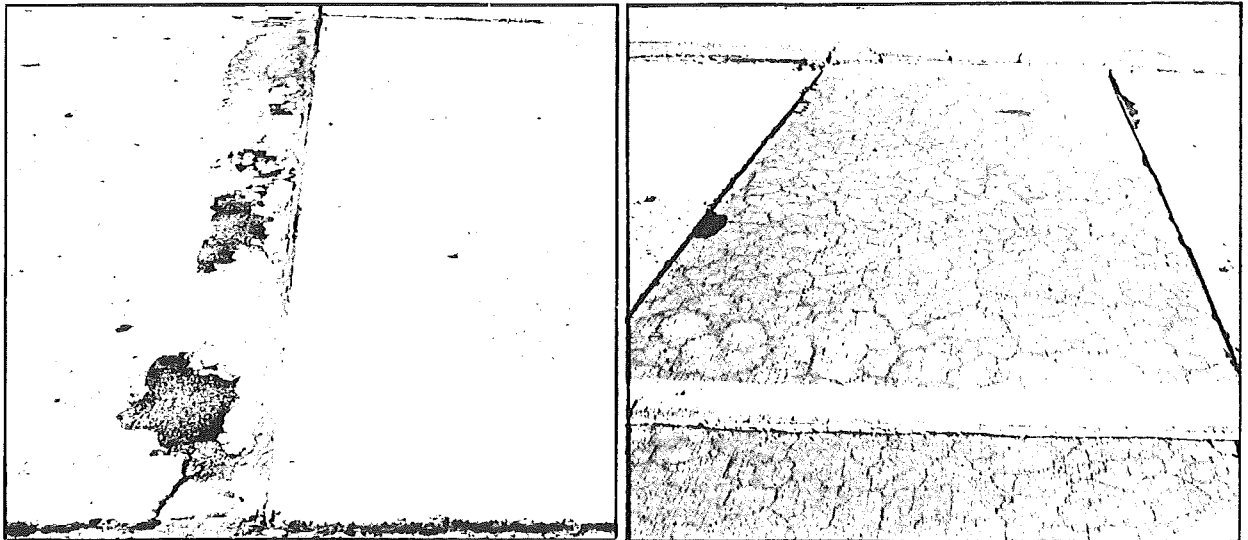
Rating Procedure:

- A. Determine severity level by visual inspection of the repair slab.
- B. Estimate length of repair required in ft (6 ft minimum). To compensate for resawing, the length of the new repair should be 1 ft greater than that of the existing undowelled repair, and 2 ft greater than that of an existing dowelled repair.
- C. Estimate amount of faulting (for faulting greater than 1/2 in.).
- D. Determine if the existing repair is dowelled. In general, dowelled repairs will have minimal faulting and have been constructed after 1983.



Severity Level 1

Severely cracked slab--faulting may have occurred.

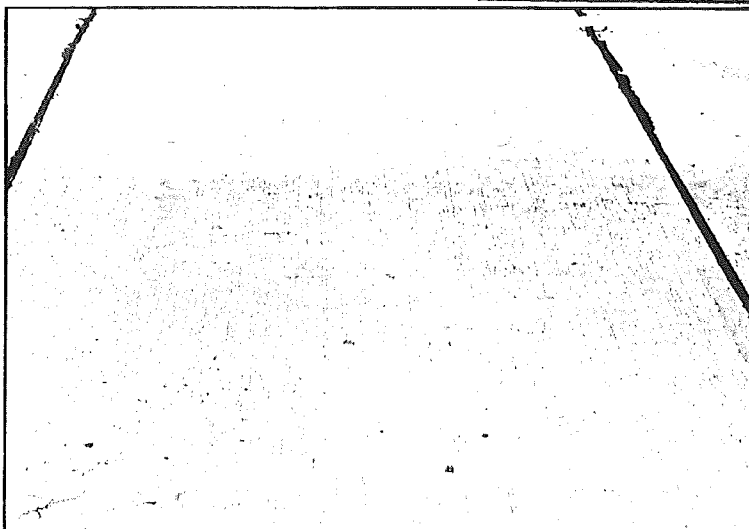
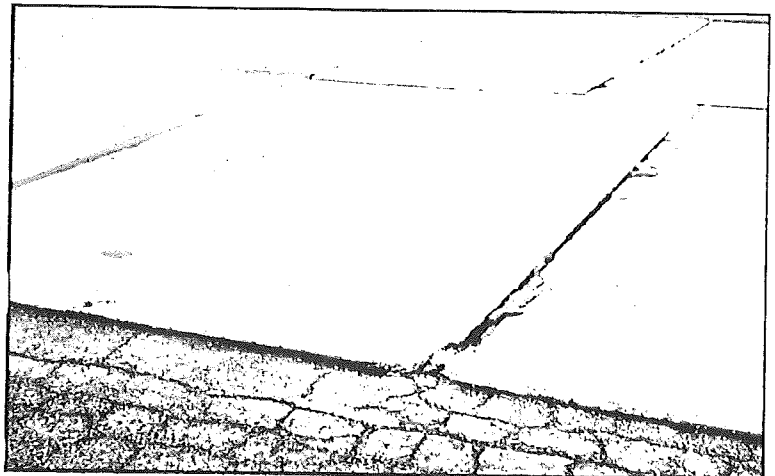


Severity Level 2

Spalling along the joints in either the old or new slab have developed--faulting may have occurred, or repair is severely map cracked.

Severity Level 3

Good repair but faulting over 1/2 in. has developed, minor map cracking may be present.



Severity Level 4

Good repair faulted less than 1/2 in., very minor map cracking may be present.

Name of Distress -
Pressure Relief Joints

Description:

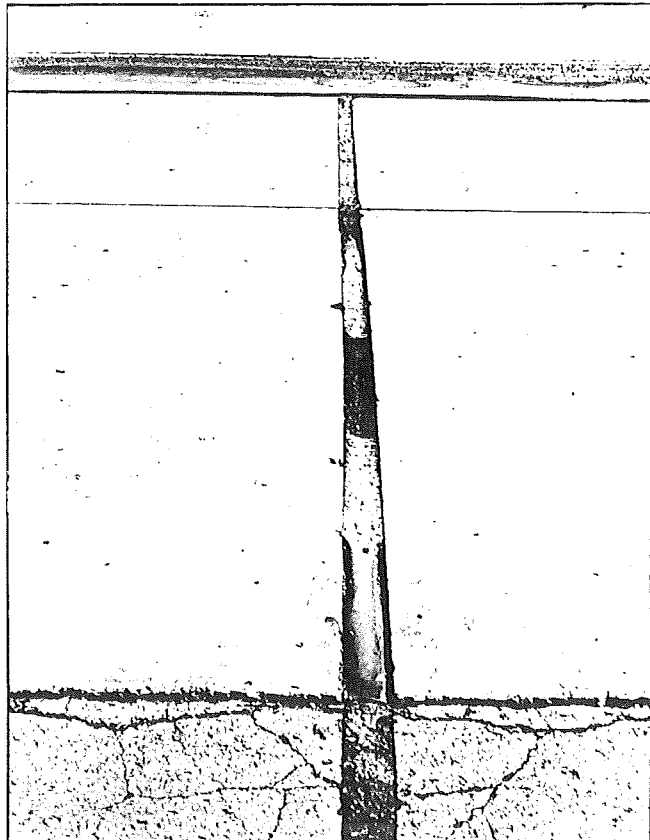
A pressure relief joint is an undowelled expansion joint, originally 4 in. wide when installed in the pavement. Normal location is in the interior portion of a slab. Spalling and/or faulting may have developed. The amount of expansion space available varies from 0 in. and up. The filler material may be missing in some joints.

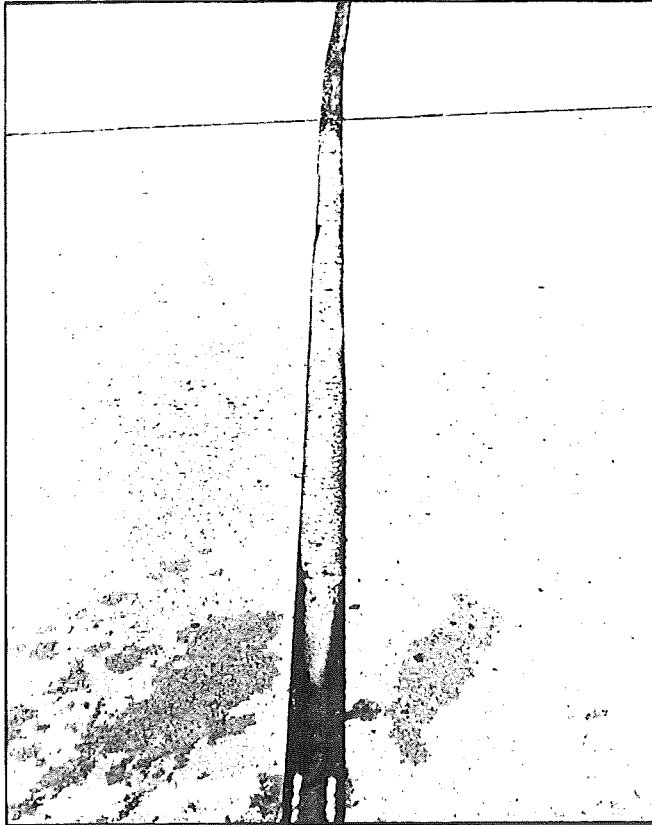
Rating Procedure:

- A. Determine severity level by visual inspection of the joint.
- B. Estimate the width of spalling in ft.
- C. Estimate the length of repair (if required) in ft.
- D. Estimate the amount of faulting (for faulting greater than 1/2 in.).
- E. Estimate length of spall in ft.
- F. Note if any filler is missing.
- G. Estimate width of joint groove in inches (if missing filler).

Severity Level 1

Spalls may have developed, faulted over 1/2 in., and filler may be partially or entirely missing.





Severity Level 2

Good joint--no spalling,
faulted less than 1/2 in.,
and filler intact.

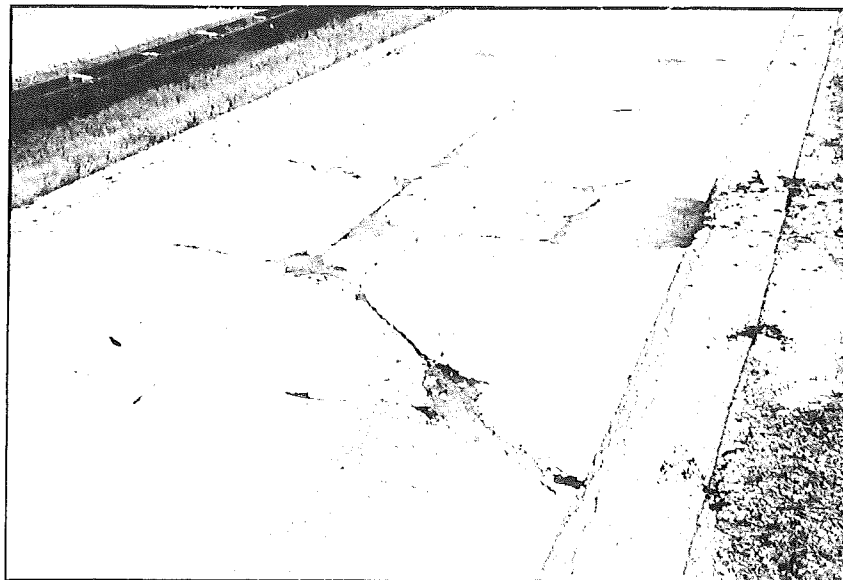
Name of Distress -
General Slab Deterioration

Description:

General slab deterioration is characterized by both severe transverse and longitudinal cracking and/or disintegration of the slab surface. Areas have normally been heavily patched with bituminous material and/or mud jacked.

Rating Procedure:

- A. Determine severity level of area by visual inspection and make judgment as to whether or not the area needs replacement.
- B. Estimate the length of repair (if required) in ft.



Severity Level 1

Long lane sections severely cracked in both directions--individual slab pieces may have faulted--settlement may have occurred. Area is difficult to maintain with routine bituminous patching. (In areas where long sections of concrete pavement have failed because of base problems, an analysis should be made to determine if a bituminous overlay would be a better performing and less expensive repair method than a concrete repair.)



Severity Level 2

Area deteriorated to a lesser degree than previously described and is judged to be maintainable using normal maintenance procedures.

RECORDING PROCEDURE

The five types of distress are coded as follows:

- J = Transverse Joint
- C = Open Transverse Crack
- R = Previous Repair
- P = Pressure Relief Joint
- G = General Slab Deterioration

Instructions and examples for recording each of the five distress types are as follows.

Transverse Joint

1. Record the location by stationing.
2. Record the following for the appropriate lanes.
 - A. Distress type.
 - B. Severity level.
 - C. Distress width (in feet).
 - D. Required repair length in feet (6 ft min.).

Example: A joint at Station 762+46 (Lane No. 1) has 9 ft of distress, 3 ft wide, and requires a 6-ft repair. Lane No. 2 has 10 ft of distress, 2 ft wide, and requires a 6-ft repair.

Construction Project No. : _____ Sheet No. : _____
 Route: _____

Station Tie-Ins and Comments	Joint No.	Lane Number																	
		1 (RIGHT)							2					3					
		Distress Type	Severity Level	Distress Width	Repair Length	Faulting	Spall Length Filler	Distress Type	Severity Level	Distress Width	Repair Length	Faulting	Spall Length Filler	Distress Type	Severity Level	Distress Width	Repair Length	Faulting	Spall Length Filler
762+46		J	1	3	6			J	1	2	6								

Open Transverse Crack

1. Record the location by stationing.
2. Record the following for the appropriate lanes.
 - A. Distress type.
 - B. Severity level.
 - C. Distress width in feet.
 - D. Required repair length in feet (6 ft min.).
 - E. Faulting if greater than 1/2 in. (record to nearest 1/4 in.).

Example: Lane No. 1 has a crack at Station 762+86. The crack has 5 ft of distress 1 ft wide, requires an 8-ft repair, and has 1 in. of faulting.

Construction Project No.: _____ Sheet No.: _____
Route: _____

Station Tie-Ins and Comments	Joint No.	Lane Number																	
		1 (RIGHT)						2						3					
		Distress Type	Severity Level	Distress Width	Repair Length	Faulting	Spall Length Filler	Distress Type	Severity Level	Distress Width	Repair Length	Faulting	Spall Length Filler	Distress Type	Severity Level	Distress Width	Repair Length	Faulting	Spall Length Filler
762+86		C	2	1	8	1													

Previous Repair

1. Record location by stationing.
2. Record the following for the appropriate lanes.
 - A. Distress type.
 - B. Severity level.
 - C. Required repair length in feet (6 ft min.).
 - D. Faulting if greater than 1/2 in. (record to nearest 1/4 in.).
 - E. If the existing repair is dowelled place a "D" in the spall length/filler column.

Example: At Station 763+45 there is an existing shattered repair in Lane No. 1, which will require an 8-ft repair, and the faulting is 3/4 in. Lane No., 2 has an existing repair which is in good condition except that it is faulted 3/4 in.

Construction Project No.: _____ Sheet No.: _____
Route: _____

Station Tie-Ins and Comments	Joint No.	Lane Number																	
		1 (RIGHT)						2						3					
		Distress Type	Severity Level	Distress Width	Repair Length	Faulting	Spall Length Filler	Distress Type	Severity Level	Distress Width	Repair Length	Faulting	Spall Length Filler	Distress Type	Severity Level	Distress Width	Repair Length	Faulting	Spall Length Filler
763+45		R	1		8	3/4		R	3		8	3/4							

Pressure Relief Joints

1. Record the location by stationing.
2. Record the following for the appropriate lanes.
 - A. Distress type.
 - B. Severity level.
 - C. Distress width in feet (width of spall).
 - D. Required repair length in feet (6 ft min.).
 - E. Faulting if greater than 1/2 in. (record to nearest 1/4 in.).
 - F. Length of spalling in feet.
 - G. Missing filler (M).
 - H. Width of joint (if filler is missing) in inches. Record in Comments Column.

Example: A pressure relief joint is located at Station 763+60. The joint in Lane No. 1 has spalling 1 ft in width, requires a 6-ft repair, has faulted 3/4 in., the spall totals 6 ft, some filler is missing, and the joint is 2-3/4 in. wide. In Lane No. 2 the only problem is that the joint has faulted 3/4 in.

Construction Project No.: _____ Sheet No.: _____

Route: _____

Station Tie-Ins and Comments	Joint No.	Lane Number																	
		1 (RIGHT)						2						3					
		Distress Type	Severity Level	Distress Width	Repair Length	Faulting	Spall Length Filler	Distress Type	Severity Level	Distress Width	Repair Length	Faulting	Spall Length Filler	Distress Type	Severity Level	Distress Width	Repair Length	Faulting	Spall Length Filler
763+60 (2 3/4")		P	1	1	6	3/4	6-M	P	1	-	6	3/4	-						

General Slab Deterioration

1. Record the location by stationing.
2. Record the following for the appropriate lanes.
 - A. Distress type.
 - B. Severity level.
 - C. Length of repair required in feet.

Example: Starting at Station 775+65 the slab in Lane No. 1 is severely deteriorated for 125 ft.

Construction Project No.: _____ Sheet No.: _____

Route: _____

Station Tie-Ins and Comments	Joint No.	Lane Number																	
		1 (RIGHT)						2						3					
		Distress Type	Severity Level	Distress Width	Repair Length	Faulting	Spall Length Filler	Distress Type	Severity Level	Distress Width	Repair Length	Faulting	Spall Length Filler	Distress Type	Severity Level	Distress Width	Repair Length	Faulting	Spall Length Filler
775+65		G	1		125														

