FULL-DEPTH REPAIR OF JOINTED PCC PAVEMENTS
CAST-IN-PLACE AND PRECAST PROCEDURES

by

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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SUMMARY

The deterioration of jointed portland cement concrete (PCC) pavements on the interstate system in Virginia has created a need for full-depth and partial-depth repairs. In this report, efforts related to full-depth repairs are described and discussed. Such repairs have utilized both cast-in-place and precast materials.

Rapid and permanent repairs have been achieved using procedures as stress relief, cast-in-place restoration, precast replacement, and cast-in-place replacement. It is recommended that these procedures be continued as warranted by pavement repair needs. They should be used with detailed guidance in both state force and contract work. In repair work, assurance should be made that the supervisors and inspectors are not only knowledgeable of the recommended procedures but also are aware of potential problems that can result from faulty applications.

Where poor drainage has contributed to pavement deterioration, improvement of drainage facilities and the use of pavement undersealing should be a part of the total rehabilitation effort to assure a satisfactory service life of both existing and repaired pavement segments.

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INTRODUCTION

The deterioration of portland cement concrete (PCC) pavements in Virginia has occurred almost exclusively at the transverse contraction joints. The deterioration of jointed PCC interstate pavement in Virginia has been discussed in a report that outlined the deterioration process, cited the major contributing factors, and described the resultant failure types.(1) Also, presented were criteria to be used with pavement condition surveys to aid the engineer in determining the time to initiate permanent repairs.

Depending upon the combinations of factors contributing to deterioration and the extent to which it has progressed, pavement distress may be identified as partial-depth, full-depth, or both at a single joint. Similarly, repair procedures may be specified as either partial-depth or full-depth. Both have been utilized in Virginia.

PURPOSE AND SCOPE

This report describes and discusses the full-depth PCC pavement repair procedures that have been used on interstate pavements in Virginia. Cast-in-place and precast materials are described along with the repair procedures in which they were used. Illustrated are permanent repairs at various locations, some of them installed by state work crews and others by contractors' crews.

A documentation of full-depth repair procedures would be incomplete without coverage of repair efforts that were not successful. Therefore, also illustrated are examples of jointed PCC pavement repairs that were not permanent but did serve to promote the understanding of the deterioration problem.

Partial-depth patches have been installed successfully using a selection of several concrete materials. Because of the specialized techniques and numerous materials involved, the partial depth repair procedures will be covered in a separate report.

BACKGROUND

The description of the various full-depth repair procedures that have been performed on the interstate pavements in Virginia should be preceded by a discussion of several items. Briefly, this treatment is intended to provide a framework within which the several repair procedures can be presented clearly to readers who may not be familiar with particular circumstances associated with such repairs.

Concretes

A factor enhancing any repair procedure is the early return of the repaired pavement to service. The concretes used in the full-depth repair of pavements have been both cast-in-place mixtures and precast units.

Cast-in-place mixtures have been produced in several ways, including the use of portable, manually charged mixers with capacities of 2 ft.^{3} (0.06 m^3) up to 0.5 yd.^{3} (0.4 m^3), ready-mix trucks, and a concrete mobile. Satisfactory batches can be obtained in each way and the selection of a method for concrete production depends primarily on the situation at hand.

Precast units for full-depth repairs have been produced in Virginia only by maintenance employees of the Virginia Department of Highways and Transportation. These normally reinforced slabs and the experimental repair procedure in which they were used were modeled after a study by the Michigan Department of State Highways.[2,3]

Work Crews

Repair activities on PCC pavements have been performed by maintenance crews of the Virginia Department of Highways and Transportation and by contractors performing maintenance work for the Department. Satisfactory repairs have been made by both types of crews. It has been noted that where full-depth repair procedures have been unsuccessful, the crews have acted rapidly to correct or modify their procedures.

Full-Depth Repairs

In a full-depth repair procedure the first consideration is that the concrete in the area to be repaired must be removed completely so as to expose the subbase. The repair material (concrete) may be placed on the existing subbase, or the subbase may be built up or undercut prior to placement. But in no case does a full-depth repair rest wholly on a layer of a previously existing pavement slab. A cast-in-place repair may have one or more sides cast directly against the old concrete. The interface between the old concrete and the repair concrete is nearly vertical, however, and the repair material clearly does not rest on an extensive layer of the old concrete. Precast slabs have been fabricated using vertical sides only, and no portions of these units rest on existing concrete.

Permanent Repairs

Permanent pavement repairs are installed to restore or replace the pavement structure and are intended to serve for the remaining life of the pavement. These are distinct from temporary bituminous patches because even though both are installed on PCC pavements to enable traffic to use the roadway efficiently and with safety the temporary patches have a relatively short service life and are not effective, as are permanent repairs, in halting the deterioration processes.[1]

An important part of the permanent rehabilitation of jointed pavements has been the installation of stress relief joints, with and without the replacement of existing transverse joints. Stress relief is, therefore, treated as a distinct full-depth rehabilitation procedure. In this report emphasis is given to the fact that pavement repairs have been required almost exclusively at the transverse joints. It is desirable to maintain a distinction between rehabilitation procedures in which the joint has been restored or rebuilt in its original location with load transfer dowels and those in which the original transverse joint has been replaced by two transverse joints, neither of which are in the same location or of the same design as the old joint.

From the foregoing, it can be seen that four full-depth pavement repair procedures — rehabilitation by stress relief, cast-in-place restoration, precast replacement, and cast-in-place replacement — have been employed on jointed PCC interstate pavements in Virginia. Descriptions of these procedures are given after a discussion of some earlier pavement repair activities.

EARLY FULL-DEPTH REPAIRS

In the report on deterioration of jointed PCC pavements in Virginia,[1] the installation of temporary bituminous patches was discussed. These patches have been and are installed by state crews as a part of routine maintenance.

Prior to the present study, state crews had placed numerous repairs of PCC concrete using Type II cement, Type III cement and Types II and III with C_aCl_2. The mix proportions associated with these repairs were recorded in some instances and have been found to be of good design. Other information such as the joint locations **and** dates of the repairs, their performance, and whether they were full-or partial-depth has not been documented.

Observations were made of such repairs that were still in service at the time this study was begun. Indications are that many failures of these early full-depth repairs resulted not from poor workmanship or inferior materials but from continued deterioration related to various factors that were not corrected. In Figure 1* a full-depth repair is shown that might have given good long-term service on this heavily trafficked roadway had it not been for the faulted condition that can be gauged by the beverage can and cigarette pack in the photograph. The area had been repaired by removing deteriorated concrete from 3 to 4 feet (0.9 to 1.3 m) on either side of the transverse joint and casting a good quality concrete adjacent to this restored joint. Pumping of subbase material from the underside of the forward slab to the underside of the leave slab due to traffic loadings is apparent. The role of pumping in the deterioration of jointed PCC pavements was explained with respect to joint sealants and subbase and shoulder materials in an earlier report.(1)

The enduring quality of some repairs installed by state crews is demonstrated in Figure 2. Repairs such as this, away from the transverse joints, are not typical. However, it is of interest to note that the light colored patch in the foreground, placed by a contract crew alongside the repair placed 2 years earlier by a state crew, failed at an age of 1 month. Aside from the fact that the second patch was not adequately consolidated, the problem with the initial repair was that it did not extend far enough to remove all of the unsound concrete.

Various other situations can lead to difficulty with full-depth repairs. In Figure 3 several of the dowels at the transverse joint have been removed with the unsound concrete. The risk with this incomplete restoration is that all of the dowels may not be properly aligned when the repair concrete is cast and the transverse joint may be prevented from functioning properly.

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*All figures are attached.

In Figure 4 the undoweled replacement joint in the near lane is not functioning. Since the lanes are in contact at the centerline and some bond strength must have developed along the lower face of the replacement joint, contraction has been accommodated in the repair concrete by a crack that formed in general alignment with the working joint in the far lane. The intended working joint should have been restored at the location of the original transverse joint.

Even though care was exercised to restore the doweled joint in Figure 5, transverse cracks formed at the repair limits. Shoulder material had been removed with the deteriorated concrete pavement so that casting of the repair concrete beyond the edge limit of the existing slab caused the repair to be keyed into the shoulder. The repair tended to remain stationary with the shoulder as the old pavement contracted longitudinally and pulled away.

Due to the several combinations of factors that may cause deterioration[1] some difficulty has been experienced in determining the severity of distress that has existed in some pavement locations that have been repaired. After the transverse joint in the near lane in Figure 6 received partial-depth repairs the far lane underwent full-depth restoration. Within a week of the full-depth repair, spalling was observed in the near lane. Full-depth removal of the concrete in the far lane relieved the compressive stresses that had not already been relieved in that lane through extensive deterioration of the concrete. Because the two lanes were connected by tie bars at the pavement centerline, the transverse joint of the near lane carried an increased compressive stress. This stress level and resultant strain was apparently sufficient to cause the additional spalling.

Unsound concrete was found in the area in the near lane to the left of the second partial-depth patch by hammer soundings. The core shown in Figure 7 was removed from the old pavement approximately two feet from the transverse joint. A nearly horizontal fracture plane was found at a depth of 5 inches (127 mm). This was not surprising because of the increased joint stresses. However, examination through X-ray diffraction techniques of material in the fracture plane revealed not only finely ground compacted concrete that was very unlikely to have been deposited during the wet drilling, but also an underlying thin coherent layer of calcite. This finding suggested that the fracture had existed prior to the time that the repairs were made at either joint since the calcite, formed by a reaction between $Ca(OH)_2$ in the concrete and CO_2 from the atmosphere, in the amount observed would have required a longer period of time to form than the 90-day period that elapsed between the initial repair installation and the coring operation. Identification of pavement distress by visual means only is obviously not sufficient.

Similar findings of unsound concrete were made using the hammer technique at other joints where no visual signs of distress existed. Unsound areas were verified by coring to reveal single and multiple fracture planes at varying depths. It was concluded that the hammer sounding technique is an effective means of locating pavement areas affected by full-depth distress of the subsurface fracture variety.

Conclusions

Early experiences with full-depth repairs on jointed PCC pavements have led to the conclusions given below.

1. Quality control and assurance of the concrete mixture and of the placing operations must be implemented.

2. The severity of pavement deterioration must be determined as early as possible to indicate the appropriate locations for full-depth repairs and removal of all unsound concrete.

3. Full-depth repairs should extend across a full lane width since subsurface damage is likely to have occurred across the full lane, even though such distress may not be visually detected.

4. Any factors, such as pumping, that have contributed to the deterioration of a transverse joint must be corrected or the service life of the repair will be shortened.

5. Repairs should be carefully formed at the shoulders to avoid abnormal restraint of slab movements.

6. Restored transverse joints must be aligned with transverse joints in adjacent lanes in order to function properly. If dowel assemblies are used for load transfer, the dowels must be accurately positioned.

CURRENT FULL-DEPTH REPAIR PROCEDURES

The four currently used full-depth pavement repair procedures — rehabilitation by stress relief, cast-in-place restoration, precast replacement, and cast-in-place replacement — are discussed in the following sections.

Stress Relief

The identification of advanced deterioration during some early repairs indicated the existence of quite high joint stresses. Some compressive stress in the concrete is desirable, because concrete is very strong in compression but comparatively weak in tension. In fact, in the development of jointed pavement design technology one important advancement was thought to be the omission of expansion joints. Aside from the savings in initial construction cost, this change was specifically directed toward providing better performance by reducing exposure of the concrete to tensile stresses.[4,5]

The presence of compressive stresses then is neither unplanned nor undesirable. However, these stresses can reach high levels, especially in localized areas of the contraction joints. The mechanisms by which transverse joint areas of concrete pavements become overstressed were described in a separate report.[1]

Installation and Performance

The identification of moderate or extensive pavement deterioration may indicate the need for stress relief prior to or along with the installation of other repairs to prevent damage to the repairs and continued deterioration of the pavement. The effectiveness of several 4-inch (100 mm) wide stress relief joints was indicated in a trial installation in the fall of 1973 in a pavement that had experienced extensive deterioration. The relief joint filler material was a preformed, cellular plastic meeting the requirements of ASTM Specification D 3204. At the present time it is felt that a spacing of 1,000 feet (305 m) for such relief joints will be sufficient for the typical relief requirement. An evaluation of the effectiveness of stress relief joints in protecting jointed PCC pavements from deterioration in certain circumstances is being made.[6]

A sample of the relief joint filler is shown in Figure 8 and a completed, and partially closed, relief joint is shown in Figure 9.

Conclusions

1. The use of expansion joints in jointed PCC pavements has been discontinued so as to avoid tensile stresses in the pavement by maintaining compressive stresses; however, jointed PCC pavements having only contraction joints can experience damaging compressive stresses in time due to the infiltration of incompressible materials.

2. Stress relief joints may be installed to reduce or prevent unwanted compressive stresses; however, their ultimate effectiveness has not been determined.

Cast-in-Place Restoration

Roadways experiencing only minor numbers of joint failures have been repaired by restoring the transverse joints along with the placement of cast-in-place concretes.

A project accomplished with state work forces in the Department's Richmond District was notable because of the special concrete mixture and batching procedure designed to meet the traffic requirements on that busy interstate pavement.

Traffic Considerations

Traffic demands on the Richmond District pavement made the most desirable work period a 7-hour span during daylight hours. Traffic control could normally not be set up for more than one repair on a given day because of the rather long distance of 1 mile (1.6 km) between repairs and the fact that some occurred in the travel lane and some in the passing lane. Therefore, the duration of the repair operation was critical and was shortened as much as possible.

Concrete Removal

Transverse saw cuts approximately 1.5 inches (40 mm) deep were made along the two limits of the repair parallel to the transverse joint. Jackhammers were used to remove the concrete to the full pavement depth. This procedure allowed ties to be made to the existing reinforcing fabric located at the 2-inch (50 mm) depth, and it further produced irregular faces against which the repair material could be cast to provide load transfer through aggregate interlock. All but 6 inches (150 mm) of the protruding steel fabric was cut away and the repair area was backfilled with bituminous material. The flexibility provided by this procedure is desirable because the scheduling of a ready-mix truck for the special batching procedure might not always be possible.

Repair Concrete

The concrete selected for this job was a high alumina cement (HAC) concrete which had been tested for strength development and durability at the Research Council. The mixture was capable of carrying traffic in this application only 5 hours after mixing with water. Strengths of approximately 5,000 psi (34.5 MPa) were anticipated.

Because contamination of the HAC with ordinary portland cement could cause flash setting, a ready-mix truck was prepared by washing with water and a load of aggregate to remove as much residual portland cement materials as possible. This aggregate was discharged and after fresh coarse and fine aggregates were charged the truck was dispatched to a location within 10 minutes of the job site. There the HAC and water were added and the final distance to the job site was traveled without the worry of delays due to city traffic. The mix was discharged within the desired mixing time of 30 minutes.

Installation

On the days tentatively selected for the permanent repair installations, the availability of the ready-mix truck and the weather were the final variables to be checked. In this operation, the setting up of traffic control and the removal of the bituminous material from the repair area were accomplished within an hour.

The precut steel fabric reinforcement and prefabricated dowel assembly used in the repair are shown in place in Figure 10. This reinforcement was tied to the existing reinforcement protruding from the slab. The dowel assembly was fixed to the subbase and included a bituminous impregnated felt strip to form the contraction joint through the full slab depth.

Placement of the cast-in-place concrete from the ready-mix truck included planned considerations for consolidation, finishing, and curing. Finished repairs were ready for opening to traffic considerably in advance of the imposed deadline. The darker colored repair concrete can be observed in Figure 11. Most of the repairs do not exceed 8 feet (2.5 m) in length and present an acceptable appearance from a moving vehicle.

Performance

Thirteen initial repairs of the type shown in Figure 11 have performed satisfactorily for more than 2 years. The functioning of the restored transverse joints and the proper tie-in at the construction joints between the repair concrete and existing pavement slabs were studied. Movements in several of the restored contraction joints and construction joints were instrumented with gage plugs and monitored to determine if they were functioning as they should. Deviations from expected behavior would have served as an early warning that the repair procedure needed modification.

Figure 12 shows typical data recorded during the joint monitoring. The ratio of the restored joint movement to the average of the two construction joint movements was 40 to 1, which shows that practically all of the slab movements were being accommodated by the transverse contraction joint. This was the desired behavior. The observed movement for the working joint was 0.2113 inch (5.367 mm), which compared quite well with the predicted value of 0.1800 inch (4.572 mm). The tightness of the construction joints can be attributed to the careful tie-in of reinforcement mesh between the old pavement and the repair concrete. The vertical section of a core drilled down through the construction joint reveals the overlapped transverse bars of the mesh in Figure 13. Excellent potential for load transfer can be seen in the mechanical interlock between concretes in that figure. The favorable irregular face in the old pavement was created by the concrete removal technique described earlier, and good bonding was achieved at the construction joint interface by adequate consolidation following the application of a bonding slurry made of HAC.

One other repair of this type is providing satisfactory service, however the joints are not functioning as planned. The ratio of the restored joint movement to the movement in one of the construction joints is approximately unity, so the construction joint required an additional sealing operation. A core through the steel reinforcement at the construction joint showed no tie-in between the mesh of the repair concrete and the existing pavement slab. The reason for this lack of tie-in was apparent since in the existing slab the mesh, having less than 1 inch (25 mm) of cover, had been severed by the transverse saw cut at the beginning of the repair operation.

Conclusions

On the basis of the data in the investigations, the following conclusions are made:

1. The cast-in-place restoration procedure can be used to produce permanent full-depth repairs;

2. the concrete removal technique produces an irregular construction joint face that effects good load transfer;

3. overlapping of reinforcement mesh between the old pavement and the repair concrete is needed to assure proper functioning of the transverse contraction joint; and

4. the use of rapid hardening HAC concrete makes this permanent repair procedure a rapid procedure as well.

Precast Replacement

In the fall of 1973, areas were identified in which pavement deterioration was extensive. The joints could not be restored permanently unless provisions were incorporated for stress relief. Because of the number of lane miles involved a pavement repair contract was being prepared. Meanwhile, state crews continued to be burdened with the task of installing and maintaining a large number of temporary repairs. The traffic control required for these activities was equivalent to that required for permanent repairs, although of shorter duration. Repeated lane closures that were neither accomplishing permanent repairs nor correcting deterioration factors were undesirable but necessary in order to maintain the roadway for traffic.

The use of precast slabs had been identified in 1972[7] as a possible alternative for full-depth pavement repairs in Virginia based on the experimentation reported by the Michigan State Highway Commission.[2,3] Cast-in-place repair procedures had been employed successfully through the use of rapid hardening HAC concrete as described in the preceding section of this report; however, in this case a more rapid repair procedure was desirable for use by state maintenance crews, and precast slabs appeared to have a good potential for being adapted to this situation. Therefore, a total of 12 experimental precast slab installations were planned.[8]

Precast Slab Fabrication

The greatest advantage of precast slabs over cast-in-place concrete is the elimination of curing time at the repair site. Additionally, the quality of the concrete is potentially greater since its acceptance and placement away from the repair site are subject to fewer variables. Ready-mix concrete was ordered after reinforcing steel and inserts were assembled for sets of three slabs. Delivery of ready-mix concrete in the small quantities required for pavement repair jobs cannot be expected to receive highest priority from producers without special arrangements being made; and while approximate delivery times were acceptable at the precasting yard, similar delays for cast-in-place repairs would have been added directly to the total lane closure times. Another advantage of the precast procedure, then, is the elimination of traffic interruptions attributable to delays in ready-mix concrete delivery.

The precast replacement procedure was developed and implemented completely using a state work crew in the Fredericksburg District. A casting bed, shown in Figure 14, was constructed for this project. A typical lifting insert is shown in Figure 15 and positions for the insert are indicated in the design drawing in Figure 16. Stockpiled slabs awaiting delivery to a repair site are pictured in Figure 17. Standard hardware for lifting the precast units is visible in the figure and is shown more clearly in Figure 18. Twelve experimental slabs measuring 6 feet x 12 feet x 8 inches (1.83 m x 3.67 m x 200 mm) and weighing approximately 7,200 lb. (3,300 kg) each were fabricated initially for installation. A second group of 12 slabs was fabricated and installed to allow a more reasonable assessment of cost data, and to date approximately 200 precast slabs have been placed. The slab dimensions are 6 feet x 12 feet x 8 inches, 8 feet x 12 feet x 8 inches and 12 feet x 12 feet x 8 inches (1.83 m x 3.67 m x 200 mm, 2.44 m x 3.67 m x 200 mm and 3.67 m x 3.67 m x 200 mm).

Pavement Removal

To achieve the minimal lane closure times, a refined technique for removing the deteriorated concrete was used for this repair procedure. Again information from the Michigan study proved to be valuable.

The limits of the pavement area to be removed were sawed in the transverse direction through the full 9-inch (225 mm) concrete depth. A centerline cut, shown in Figure 19, was made to sever the tie bars between lanes. A metal frame template was found useful for marking the pavement length to be removed. This total length included the precast slab length which was usually 6 ft. (1.83 m) plus the space selected for two transverse joints which had a combined width of 4.75 in. (120 mm). In Figure 19 the deteriorated area was longer than 6 ft. (1.83 m) so the removal of concrete was adjusted to accommodate two 6 ft. (1.83 m) precast slabs in series.

The steps for sawing the pavement included two passes of the saw at each cut location. On the first pass more than half of the concrete depth was sawed. During the full-depth cut the sawblade could be seized or clamped as the sawcut tended to close due to compressive stress in the slab. This problem, when observed, was avoided by placing into the sawcut, behind the blade, nails of sufficient diameter to resist the closure. Centerline cuts were made quickly and without difficulty.

Lift pin assemblies for removal of large sections of deteriorated pavement were fabricated in accordance with the details shown in Figure 20, which indicates the method for inserting and locking the pins in predrilled holes through the pavement. Two lift pins are shown in place for lifting in the left center of Figure 19.

Sawing of the repair limits was a major activity because the siliceous aggregates in this pavement were difficult to saw, both in terms of time and of wear to the saw blades. The cutting rate in this case was approximately 0.3 ft./min. (0.1 m/min.). The repair locations were sawed several days or more prior to a precast slab installation to add flexibility to the operation. These initial installations took place in cool to cold temperatures of late winter and early spring. In warmer weather, and with delays of more than one week between sawing and removal, some difficulty was experienced in removing the concrete due to increased joint stresses. Experience and judgement are needed to anticipate the occurrence of this problem at specific locations; and if stress levels will be high enough to restrict or prevent easy lifting of the damaged concrete, a third saw cut should be made initially so that stress relief may be accommodated by jackhammering an opening as in Figure 21.

Precast Slab Installation

The steps of the installation activity are described and illustrated in the following sections, since each step involves details that are somewhat unique and are quite important for the successful application of this repair procedure.

Slab Installation

The removal of the deteriorated pavement was the first step of the precast slab installation. Concrete was lifted from the repair area by a crane and placed in a dump truck. A mortar for bedding the precast slab was prepared concurrently and was placed on the existing subbase and screeded as shown in Figure 22. Details of the screed appear in Figure 23. The mortar was made flowable and contained 4% $CaCl_2$ to accelerate the set time. Information regarding the mortar is in Figure 24. It is important to note that only minor strength is required from this mortar and a slump of 8 inches (200 mm) was desirable for workability.

Precast slabs were transported to the repair site by truck (Figure 25), positioned over the mortar (Figure 26), and lowered into place (Figure 27). The sequence of operations from the time the crane was positioned on the pavement until the precast slab was placed (Figure 27) required 30 minutes. Traffic control setup and removal, along with other minor activities, resulted in a total of 1½ hours being required for a precast replacement. Because of the fixed times associated with the setup and removal of traffic control devices, an average time of 1 hour per installation was achieved for a series of installations in one period. Although the average time per installation can be reduced by making several repairs during a lane closure, the procedure was developed primarily to deal with single repairs on a priority basis. In practice, however, it has usually been possible to install two or more slabs with each lane closure.

Figure 28 summarizes the typical elements to be found in precast replacements. The precast slab shown is 6 ft (1.83 m) in length, though as stated earlier, lengths of 8 ft. (2.44 m) and 12 ft. (3.67 m) have also been used.

Joints

Stress relief joints were installed along with each precast slab because it was believed necessary to reduce the incidence of deterioration in this pavement. For clarification, the reader may wish to refer to the preceding section of this report where it was stated that a stress relief cut was <u>not</u> made to facilitate concrete pavement removal. However, in cases where replacement was not required in the lane adjacent to such installations, a stress relief cut was made in the adjacent lane on line with the typical relief joint shown in Figure 28. A preformed neoprene sealant was installed in the 3/4-inch (18 mm) joint.

Drainage

Pumping was a factor in the deterioration of this pavement. The precast slabs were installed without load transfer to the existing pavement, which made them particularly susceptible to the effects of pumping. Therefore, a drainage system was specified for each repair location.

Drains consisted of a graded crushed stone layer in the shoulder alongside the pavement slab and a perforated concrete pipe connecting this layer to a discharge point beyond the pavement shoulder limits. Figure 29 shows the general layout for the drainage components. A repair installation, complete with drainage, is shown in Figure 30.

Multiple Slabs

The 6-foot (1.83 m) precast slab dimension was initially selected because it was determined that most of the distressed pavement locations could be repaired by removing concrete from 2 to 3 feet (0.6 to 0.9 m) on either side of the affected transverse joint. Larger deteriorated areas were repaired by using up to four of the 6-foot (1.83 m) slabs in succession. Care was exercised to maintain grade; and as before, one stress relief joint was installed in the adjacent lane and in the repaired lane, and a single drain was installed through the shoulder.

Performance

Approximately 200 precast slabs have been placed and all are providing satisfactory service. From a moving vehicle the smoothness of the ride, the sound generated by the vehicle tires, and the appearance of the repair site are comparable to the effects associated with an ordinary contraction joint.

Because of the lack of load transfer between the precast slabs and the adjacent pavement slabs, it was felt that static load tests should be conducted to determine whether the precast slab movements were within an acceptable range. With an axle loading of 18,000 lb. (8,200 kg) deflections indicated by the Benkelman beam at the corners of a precast slab along the shoulder line were of the same order of magnitude as deflections of the adjacent corners of the existing pavement slabs, but were actually smaller by a factor of three. These measurements led to the conclusion that future problems would be most likely to occur first in the existing pavement where undermining had already taken place as a result of pumping. The undersealing of some existing pavements was therefore indicated, but was not incorporated in this study.

One precast slab was lifted from its location in the roadway after 3 months of service in order to examine the condition of the mortar base. The mortar, as expected, was not bonded to the underside of the slab since the precast slabs were very smooth, having been fabricated using a polyethylene sheet to line the form bottom, and because the bedding mortar, having been very workable, tended to bleed against the slab and inhibit bond formation. The mortar exhibited less shrinkage cracking than anticipated, and that observed was judged to be inconsequential with respect to the secondary function of the bedding mortar, which was to provide a subbase that would not erode under the action of significant quantities of water predicted to be trapped by the contiguous poorly draining subbase and shoulder materials.(1)

In Figure 31 patterns of fine subbase material can be seen on the bedding mortar. The fact that this quantity of material could infiltrate from the adjacent roadway in a short time period dramatized the need for improving the drainage of this roadway, and for undersealing to restore adequate structural support.

Conclusions

The precast replacement procedure has proven to be a rapid and effective means for maintaining jointed PCC pavements. The procedure is particularly advantageous for handling high priority or emergency repair situations where a single joint replacement warrants immediate attention.

Observations of the several steps developed for this procedure have led to the conclusions listed below.

1. The entire procedure can be handled satisfactorily by state maintenance crews with normal supervision.

2. Precast slabs can be fabricated, when convenient with available personnel, and stockpiled as the most efficient means of assuring availability at critical times.

3. The full-depth sawing operation for pavement removal can precede the installation activity by any practical time period, however slab movements (joint closures) may necessitate a third transverse saw cut and jackhammering for stress relief to facilitate concrete removal.

4. Removal of large sections of deteriorated pavement with lift pins inserted in predrilled holes is a key step to making the precast replacement a rapid procedure.

5. The bedding mortar should have a slump exceeding 8 inches (200 mm) to provide uniform seating of the precast slabs. In this application the low strengths and high shrinkage that result are not damaging.

6. Preformed neoprene and preformed cellular plastic sealants were successfully used in transverse joints adjacent to the precast slabs.

7. The performance of the precast slabs appears to have been enhanced by the installation of edge drains and by the presence of the stable mortar bedding layer, however the adjacent existing pavement in many cases needs improved drainage and undersealing.

8. Any practical precast slab length may be acceptable, however the 6-foot x 12-foot (1.83 m x 3.67 m) size is convenient for mass production and hauling. This size is large enough for most joint repairs, and up to four such slabs were successfully installed in series to repair large areas of deterioration.

Cast-in-Place Replacement

A cast-in-place replacement procedure has been used for full-depth repairs at transverse PCC pavement joints. The elements of this type of repair are depicted in Figure 32.

Load Transfer

It can be observed in Figure 32 that the traffic loadings for this repair situation are transmitted directly from the existing pavement slabs, on either end of the repair area, to the repair concrete through the inclusion of 6-inch (150 mm) undercuts in the subbase material. The volume of the undercuts is filled along with the volume created by removal of the deteriorated concrete and approximately 6 inches (150 mm) of the subbase material. The resultant monolithic mass of repair concrete not only serves to carry traffic loadings directly on its surface and from the adjacent slabs but also, because it is keyed into the subbase, probably provides a fixed location in the pavement system between structures from which to reference slab movements.

Concrete Removal

The 2-foot (0.6 m) minimum length for concrete removal on either side of the existing transverse joint indicated in Figure 32 is based on field experience. It has been observed that subsurface fractures of the joint face that may not be visually detected from the pavement surface can extend more than 1 foot (0.3 m) into the slab before intersecting the subbase interface.(1) It is, therefore, appropriate to designate minimum limits for pavement removal for this and other procedures for full-depth pavement repairs.

The pavement removal technique described earlier for the precast replacement procedure was also used in this procedure. Following removal of the subbase material no further preparation of the area was necessary since the cast-in-place concrete could conform to irregularities in the subbase.

Cast-in-place Concrete

The rapid hardening HAC concrete initially evaluated in the cast-in-place restoration procedure was determined to be the best material available to meet the lane closure limitations of this replacement procedure. For the smallest size repair area a concrete mobile proved satisfactory for timely production, while for the larger repair areas ready-mix production was utilized.

Transverse Joints

As indicated in Figure 32, the handling of the two transverse joints created in this repair procedure could be approached with some flexibility. If a stress relief joint is needed, the material shown in Figure 8 is installed prior to placement of the cast-in-place concrete. If no stress relief is required, as in the case where a stress relief joint has already been installed within approximately 1,000 ft. (300 m) of the repair area, both transverse joints are considered as cold-formed contraction joints and treated accordingly.

Performance

Repairs of this type number more than 200 and have been in service for periods up to 1 year. Their satisfactory installation requirements and good condition at this time warrant their classification, along with repairs from the other procedures described in this report, as rapid and permanent full-depth repairs.

Conclusions

The conclusions given below have resulted from observations of this replacement procedure.

1. Cast-in-place replacement of deteriorated transverse joints has been accomplished in Virginia as a rapid and permanent repair procedure.

2. The pavement removal technique and the rapid hardening concrete initially employed in other repair procedures were readily adapted to this procedure.

3. The direct load transfer incorporated in this procedure is easy to form by undercuts and should be effective in enhancing the performance of the repairs.

4. The two transverse joints that result from use of this procedure can be treated as cold-formed contraction joints, or one may be filled with a stress relief material.

RECOMMENDATIONS

The rehabilitation of transverse joints on jointed PCC interstate pavements in Virginia has involved the use of several maintenance procedures that require the full-depth removal of pavement segments. Conclusions resulting from observations of early repair efforts and from four recently used repair procedures have been listed in this report following descriptions and discussions of these repairs. On the basis of this information the following recommendations are made.

1. Full-depth repair procedures as stress relief, cast-in-place restoration, precast replacement, and cast-in-place replacement have been employed successfully in Virginia and should continue to be used where rapid and permanent repairs of PCC pavements are warranted.

2. Plans for pavement repairs should provide detailed guidance for state force and contract work.

3. Assurance should be made that supervisors and inspectors of repair work are not only knowledgeable of the recommended repair procedures but are also aware of potential problems that can result from faulty applications.

4. Where poor drainage has contributed to pavement deterioration, improvement of drainage facilities and the use of pavement undersealing should be a part of the total rehabilitative effort to assure a satisfactory service life of both existing and repaired pavement segments.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the cooperation of personnel in the Culpeper, Fredericksburg, and Richmond Districts of the Virginia Department of Highways and Transportation in the performance of the full-depth repair work.

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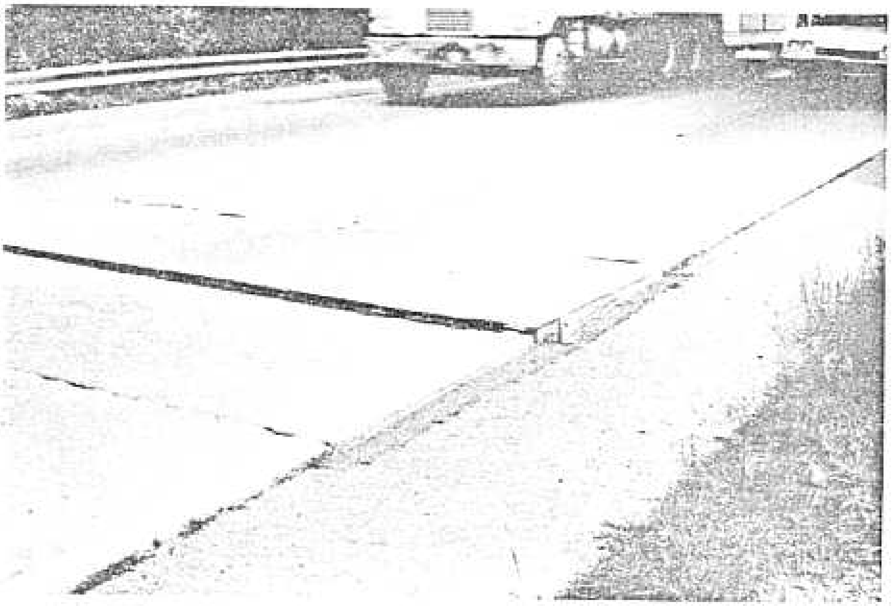


Figure 1. Faulting of repaired transverse joint due to pumping of subbase fines.

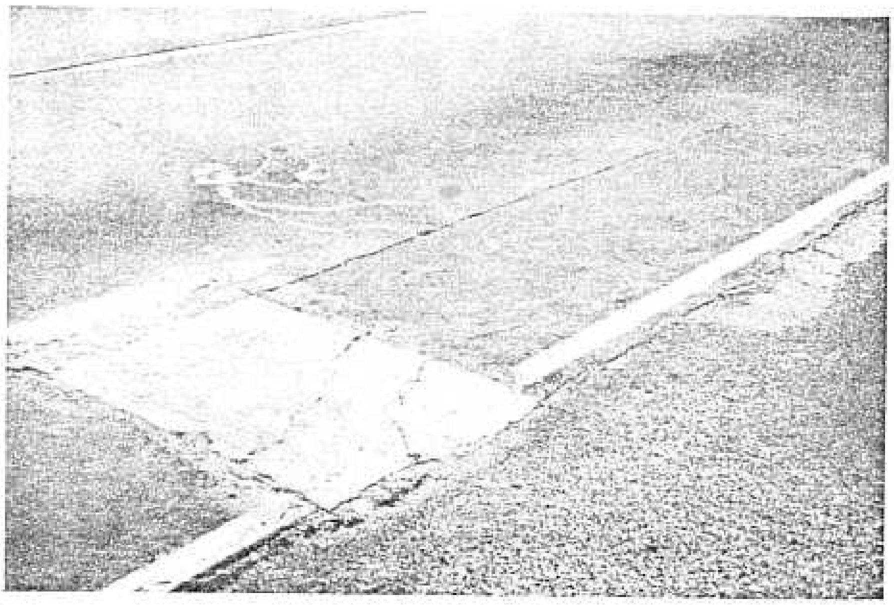


Figure 2. Initial full-depth repair in background did not remove all unsound concrete. Subsequent repair in foreground did not receive adequate consolidation.

Figure 3. Incomplete full-depth restoration presents difficulty with dowel alignment.

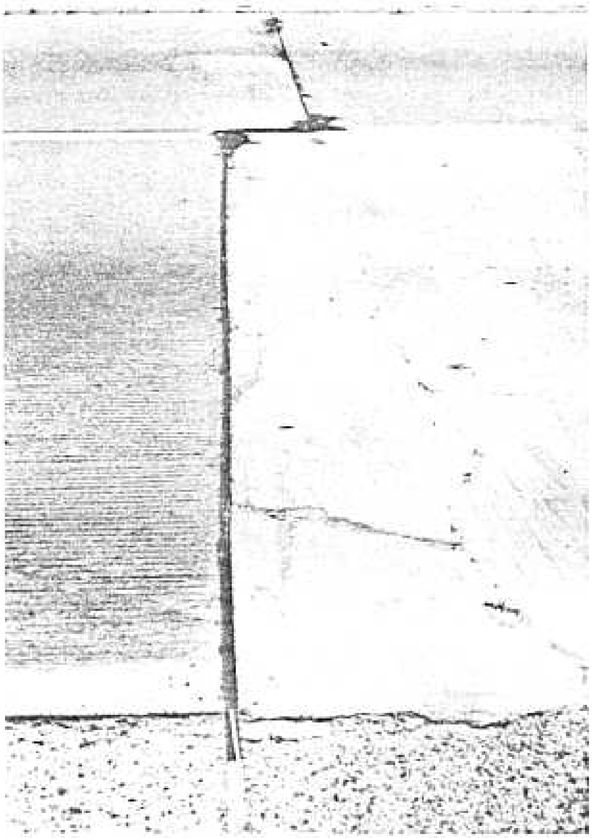


Figure 4. Full-depth replacement joint not functioning due to misalignment.

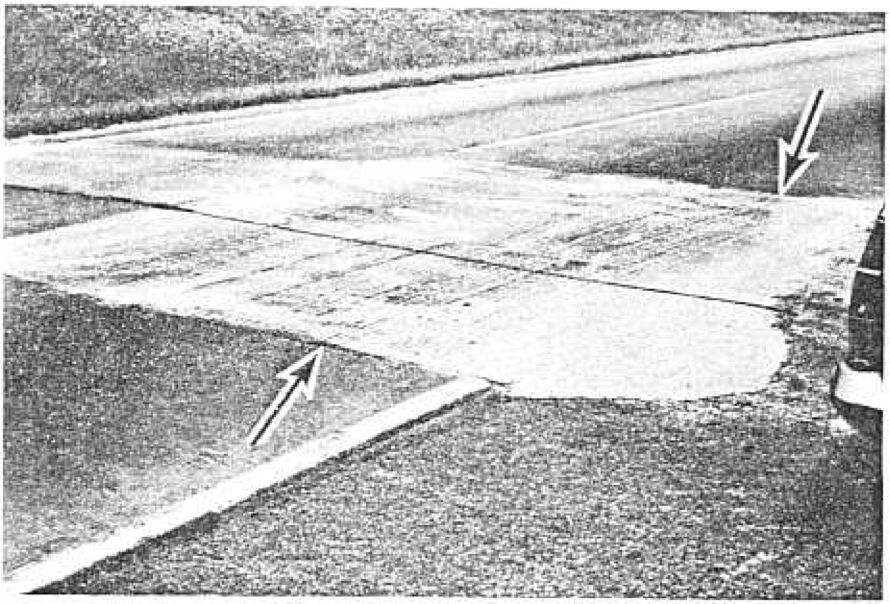


Figure 5. Full-depth restoration keyed into shoulder resulted in transverse cracks indicated by arrows.

Figure 6. Continued deterioration of concrete in foreground occurred after full-depth restoration of lane in background.

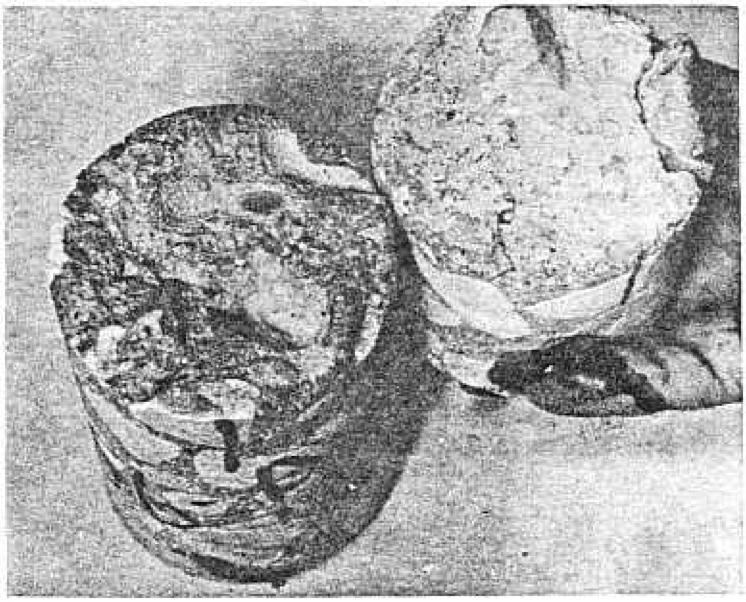


Figure 7. Fracture plane in old pavement containing compacted layer of finely ground concrete underlain by thin coherent layer of calcite.

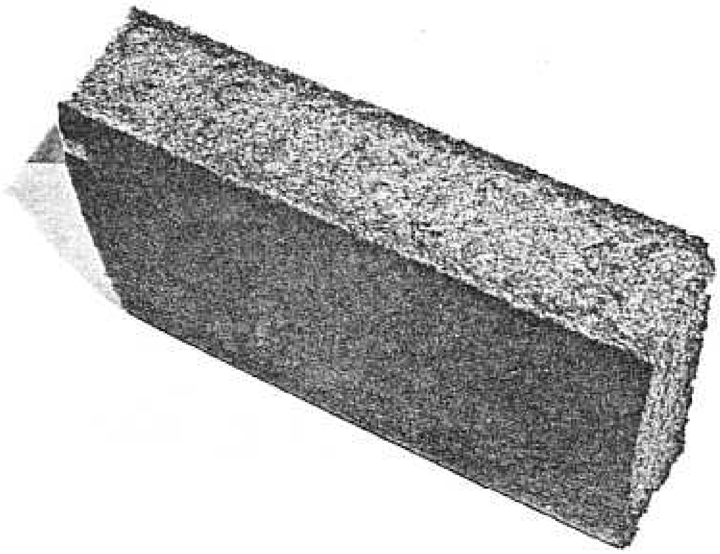


Figure 8. Preformed, cellular plastic stress relief joint filler material. (1 in. = 25 mm)

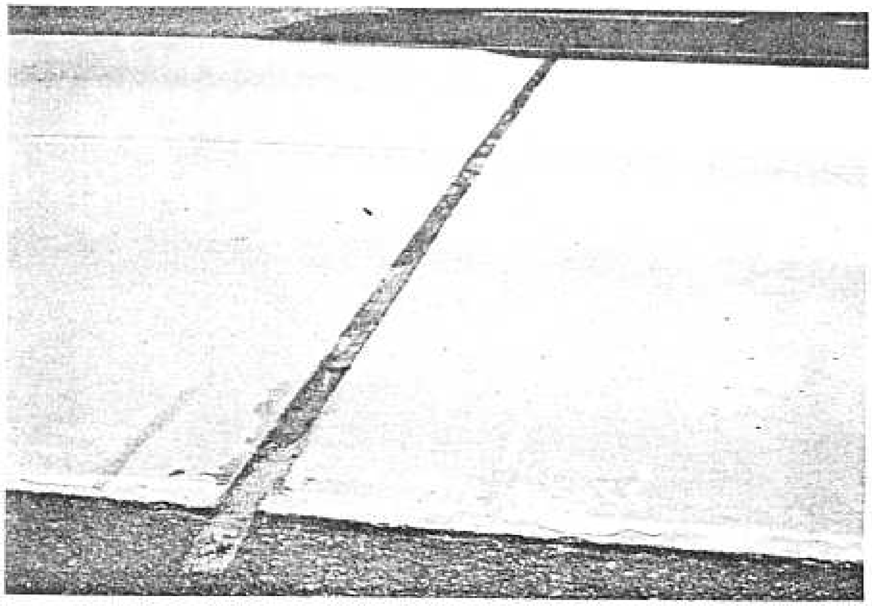


Figure 9. Stress relief joint and filler material in pavement.

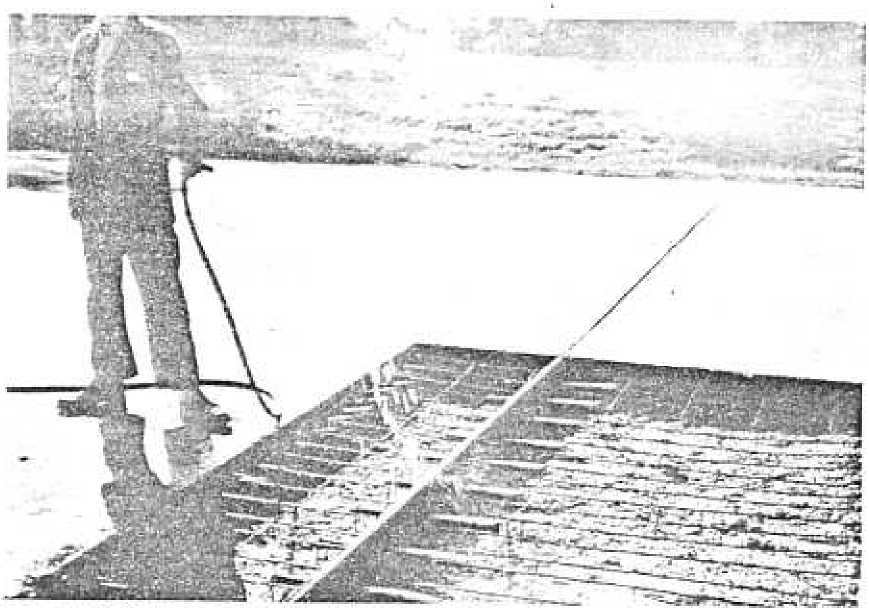


Figure 10. Precut steel fabric reinforcement and prefabricated dowel assembly in place.

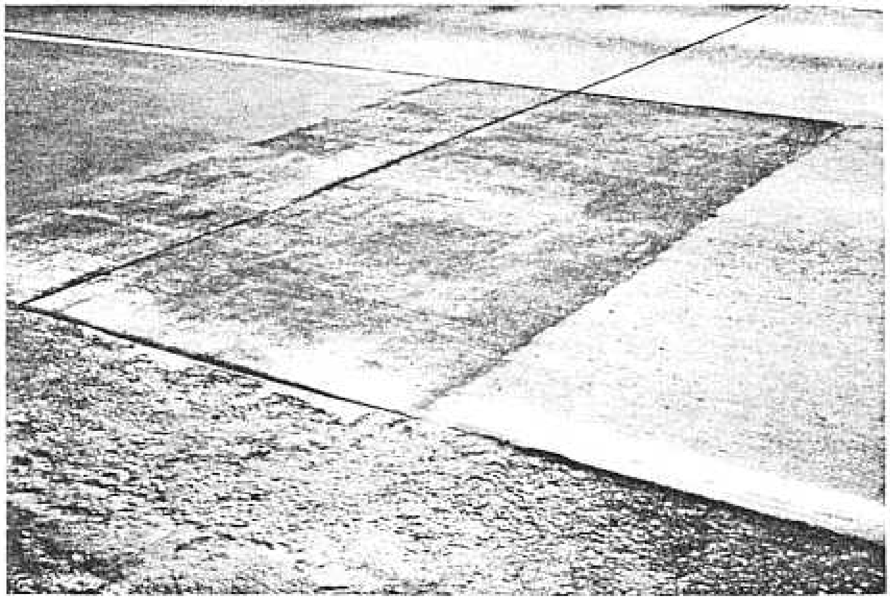


Figure 11. Hardened cast-in-place restoration made with HAC concrete.

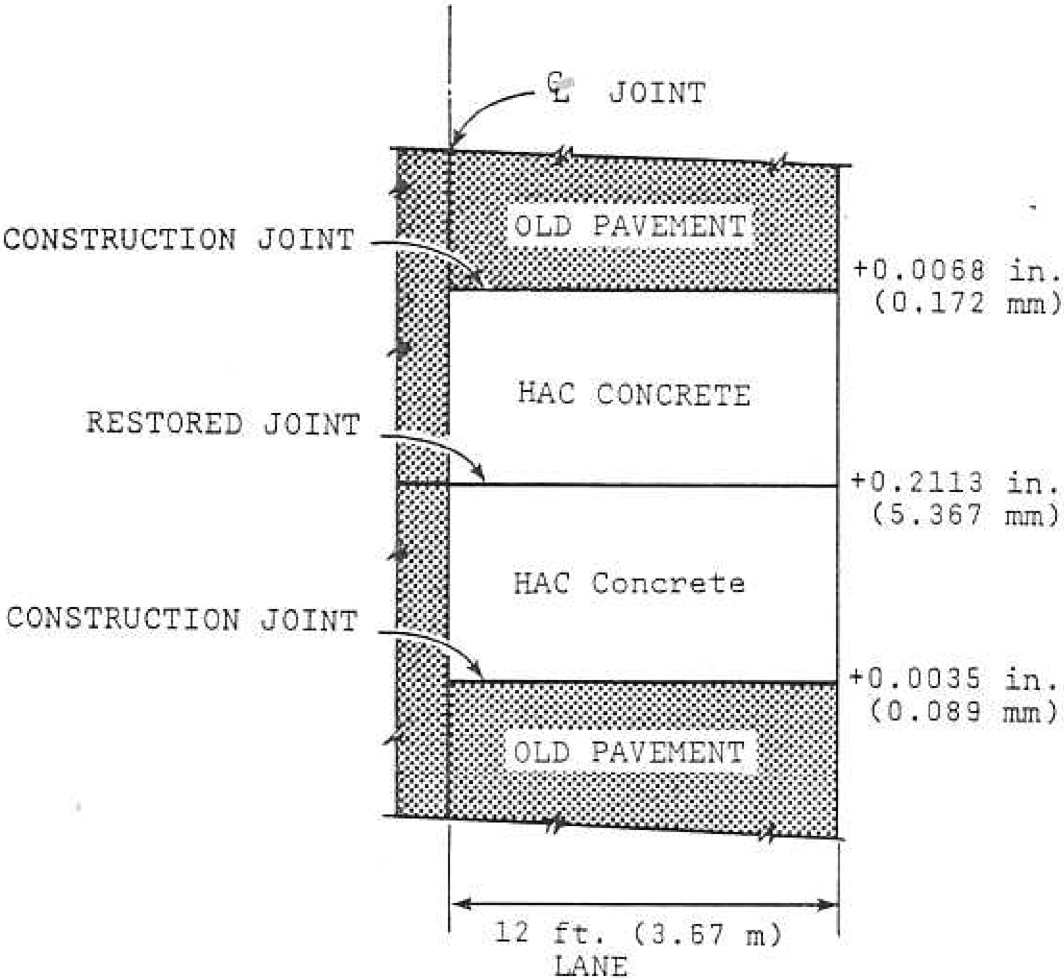


Figure 12. Joint movements (+ openings) occurring over a 17-hour period with an ambient temperature change from 75° F to 28° F (24° C to -2° C).

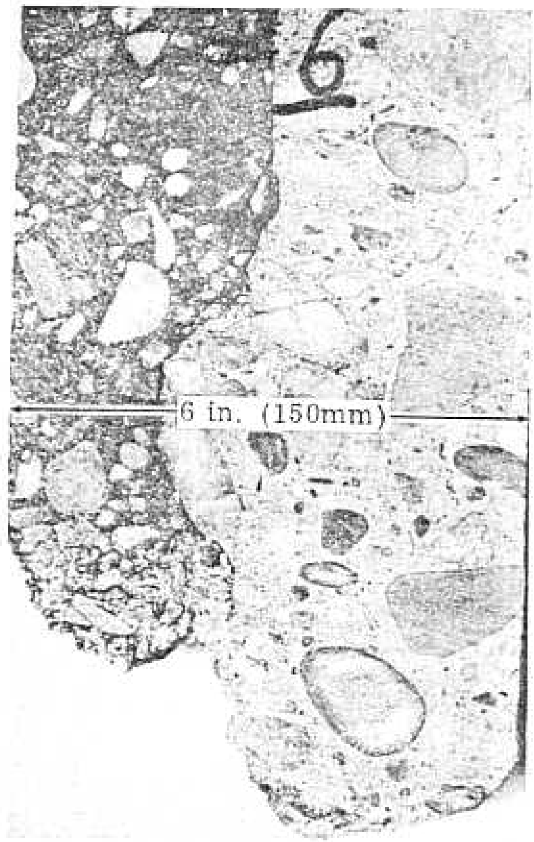


Figure 13. Core from construction joint between HAC repair concrete (left) and old pavement (right)

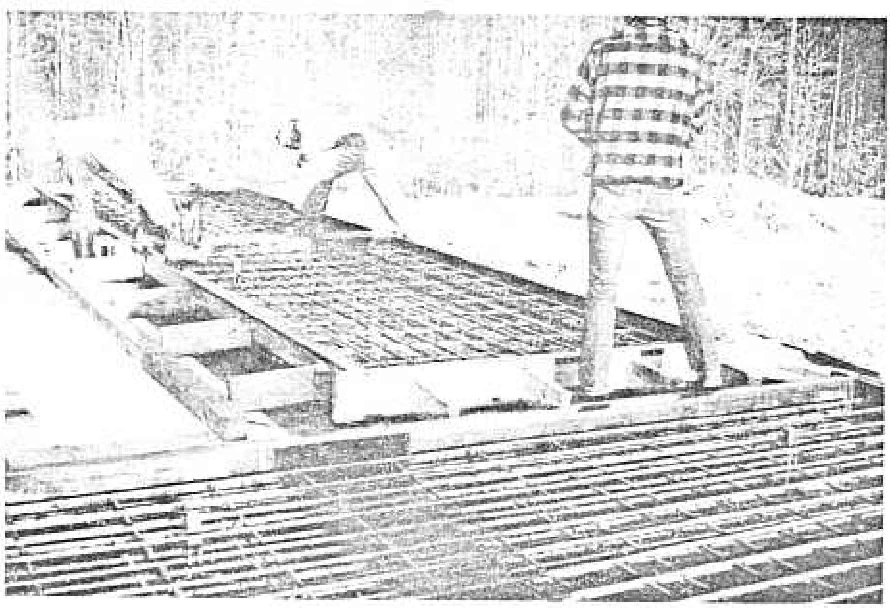


Figure 14. Assembly of reinforcing steel and lifting inserts at casting beds.

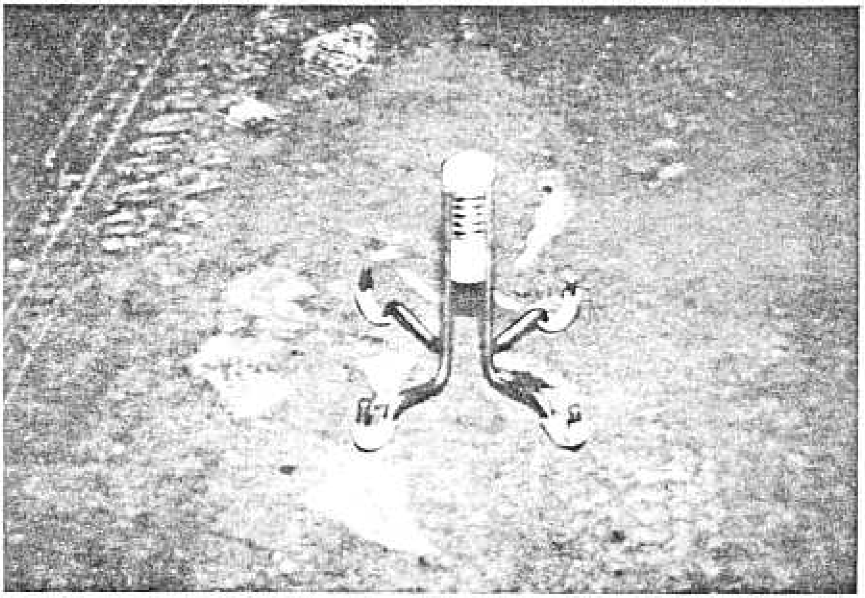


Figure 15. Typical lifting insert placed with reinforcing steel in precast slabs (Michigan photo).

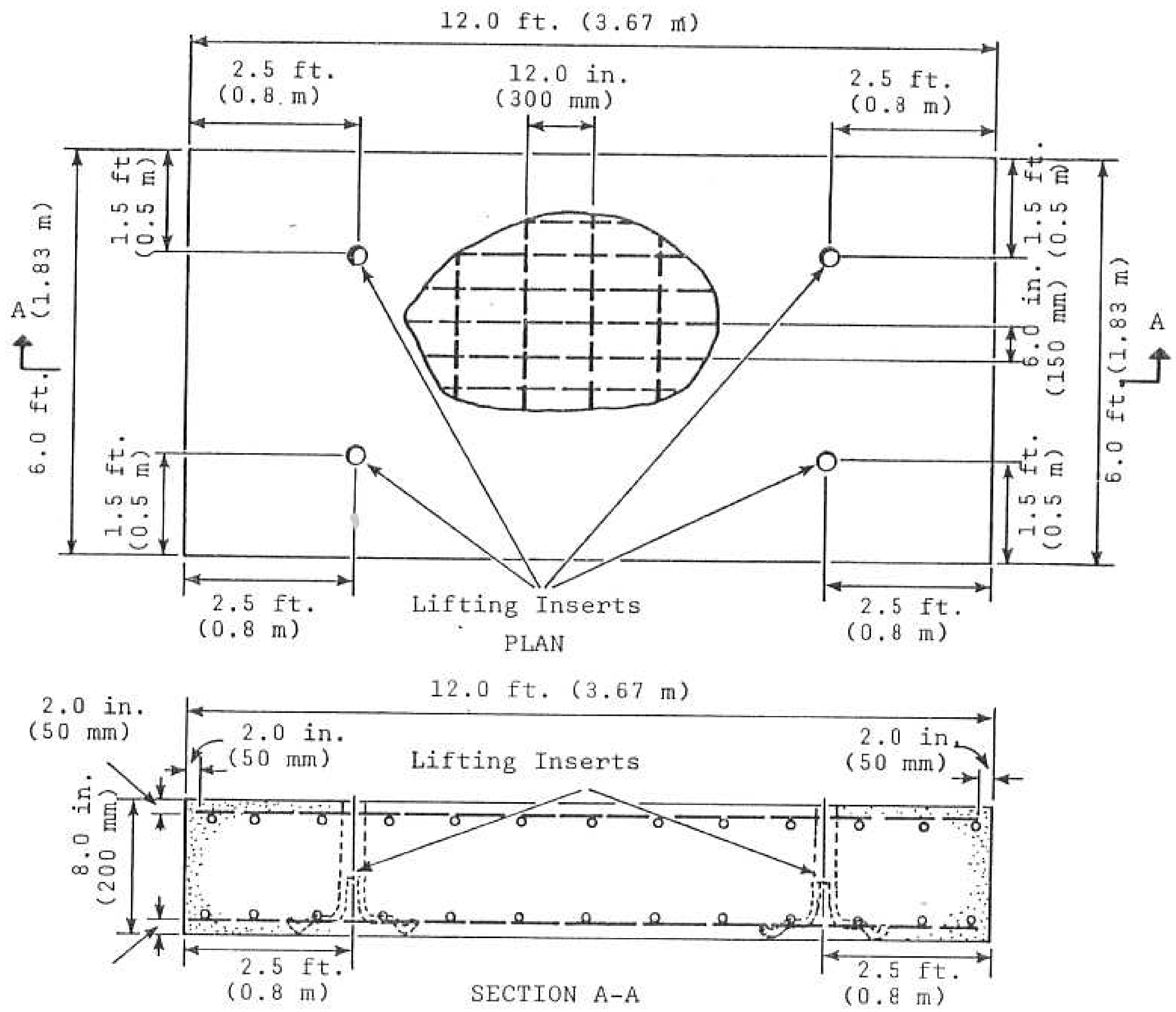


Figure 16. Precast slab for pavement repair.
(Note: All reinforcing bars are #4 (12.7 mm).)

Figure 17. Stockpiled precast slabs with dimensions of 6 feet x 12 feet x 8 inches (1.83 m x 3.67 m x 200 mm).

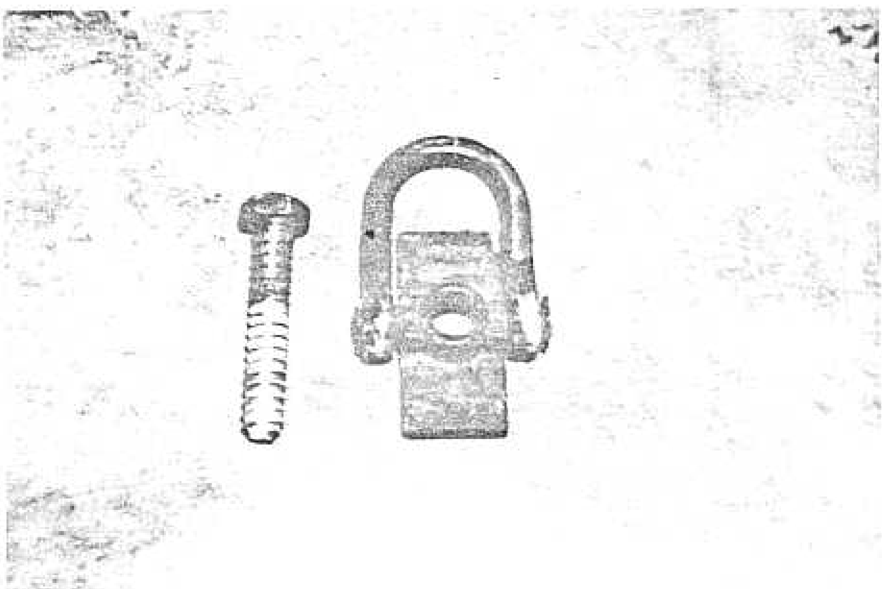


Figure 18. Swivel plate and bolt for attachment to lifting inserts in precast slabs (Michigan photo).

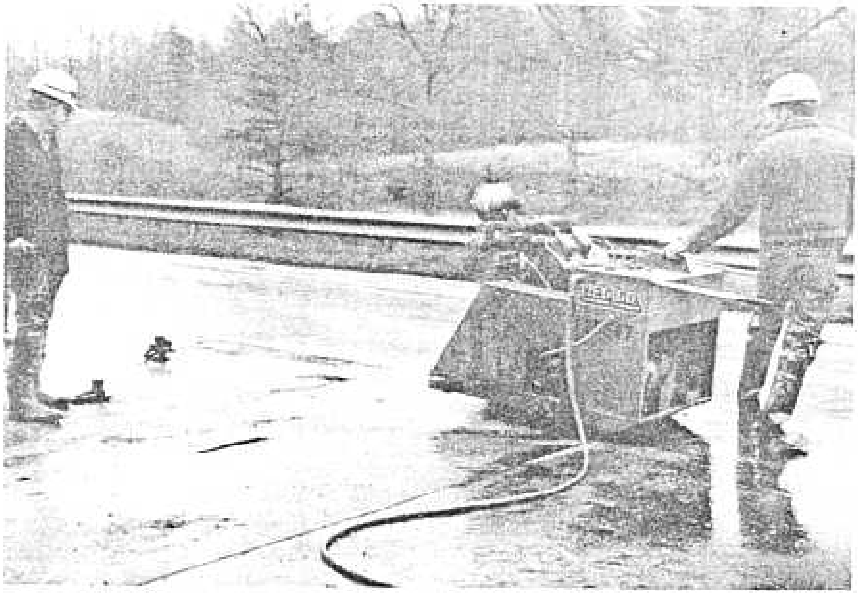


Figure 19. Full-depth sawing of repair limits.

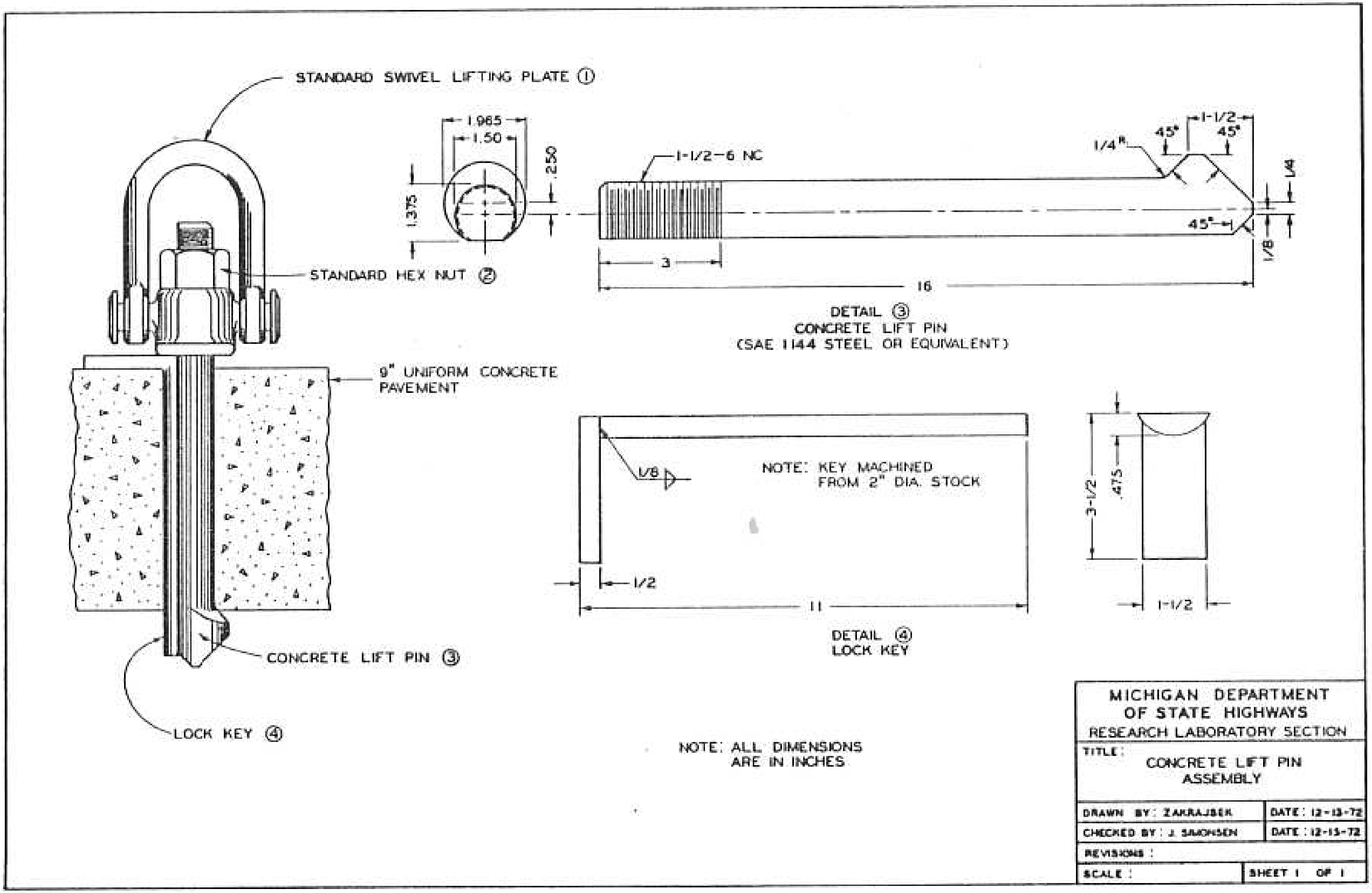


Figure 20. Lift pin assembly for concrete pavement removal. (1 in. = 25.4 mm).

Figure 21. Stress relief at one end of repair area requiring third transverse sawcut (Michigan photo).

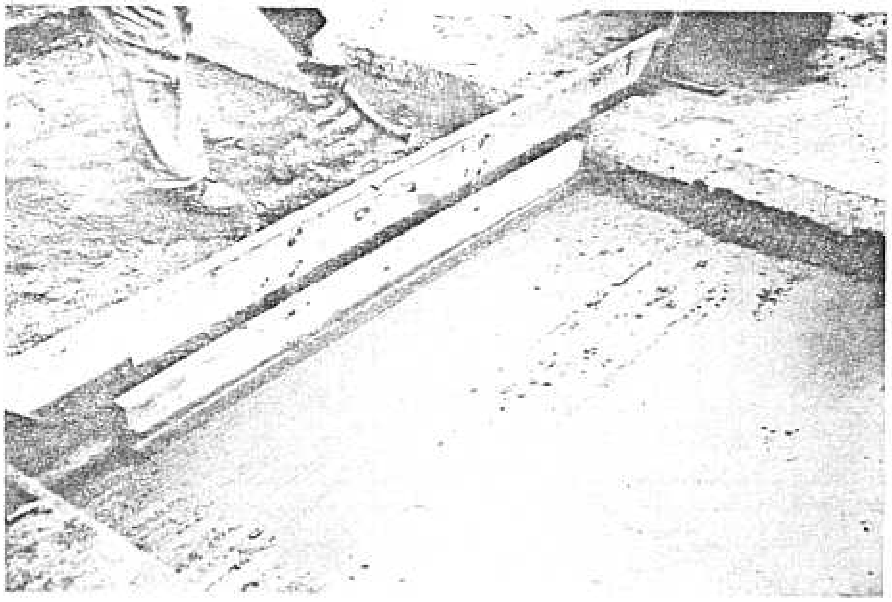


Figure 22. Bedding mortar layer being screeded to an elevation 8 inches (200 mm) below the pavement surface elevation.

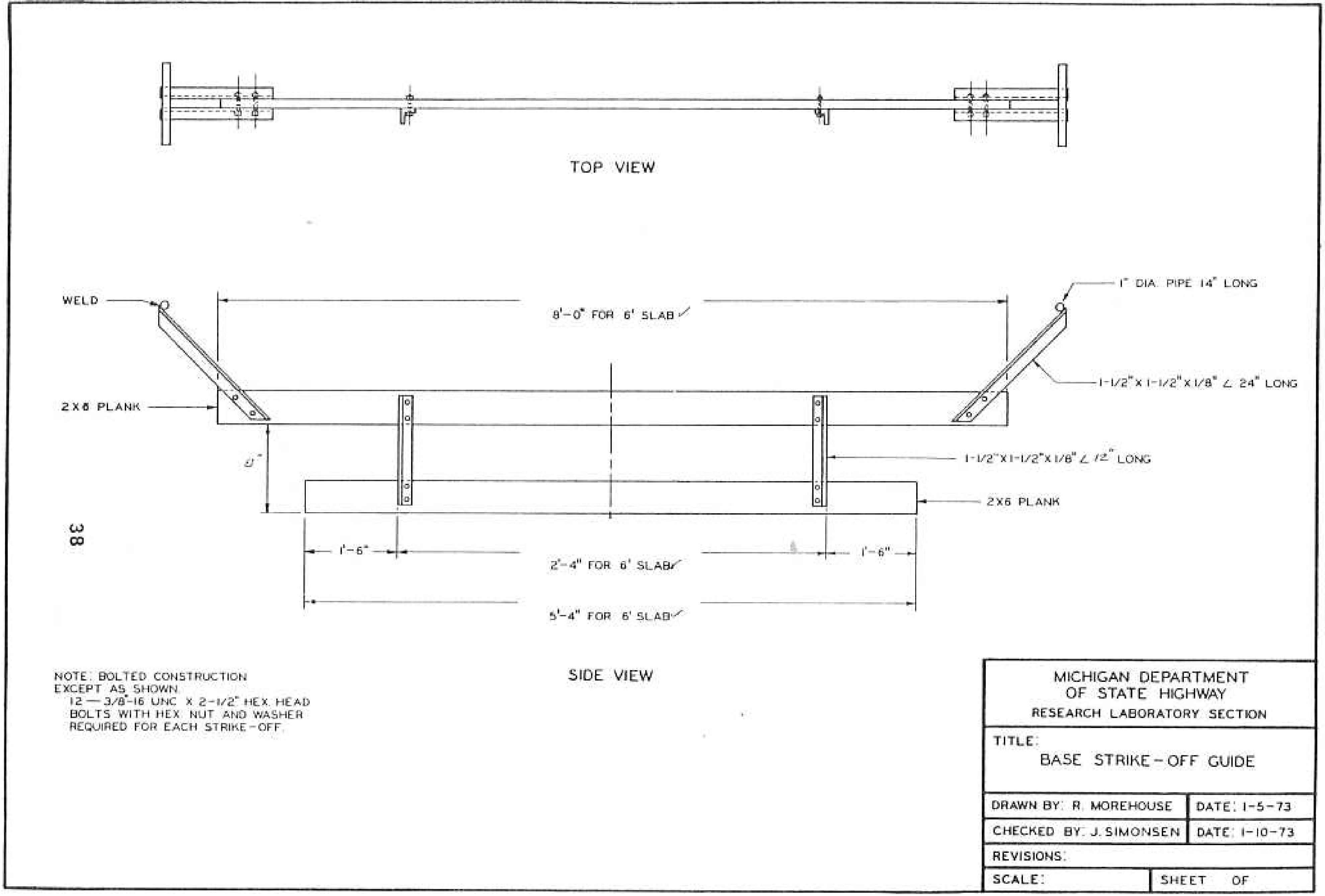


Figure 23. Base strike-off guide for precast slab installation.
(1 in. = 25 mm; 1 ft. = 0.305 m).

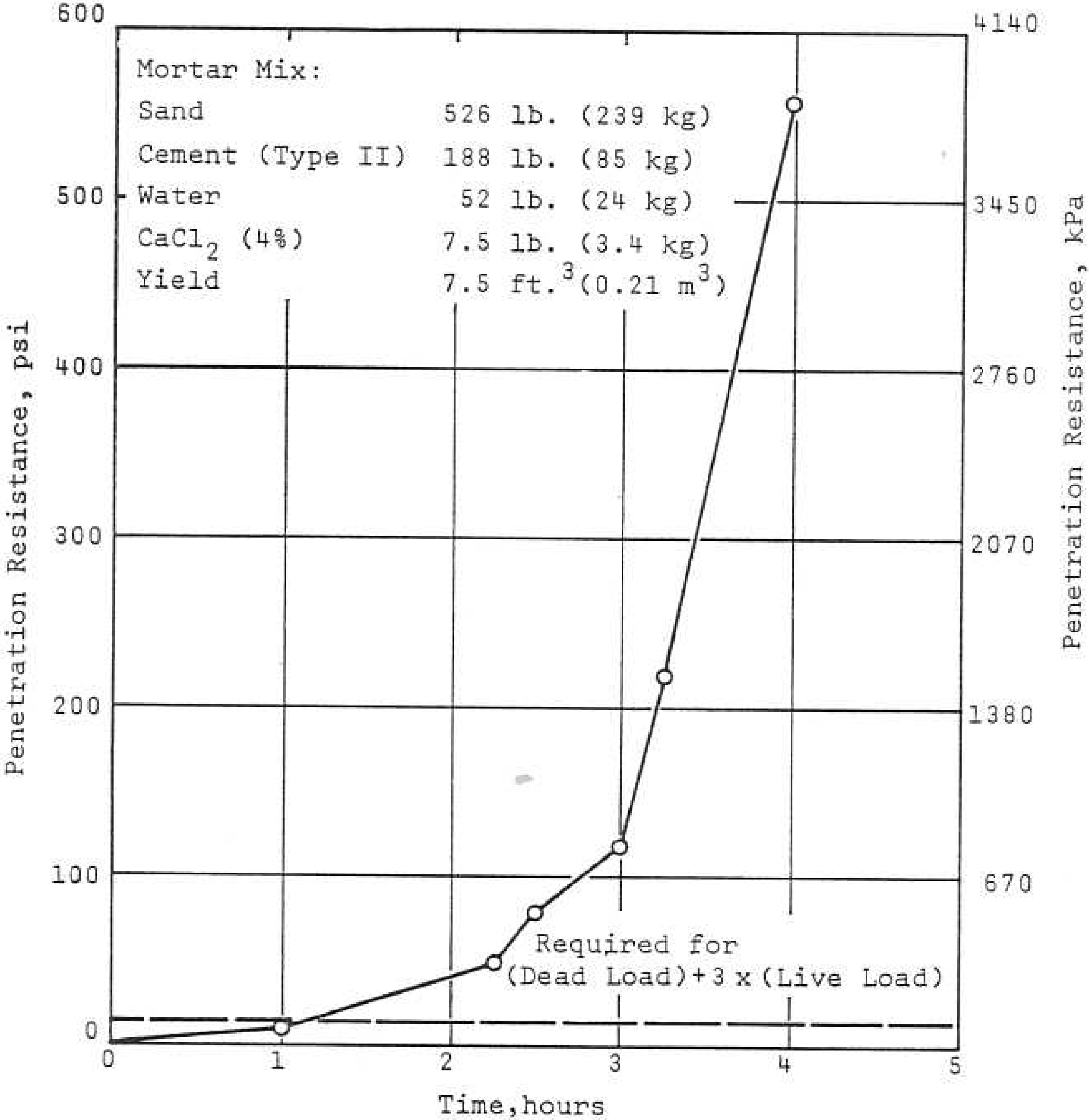


Figure 24. Bedding mortar for precast slab installation.

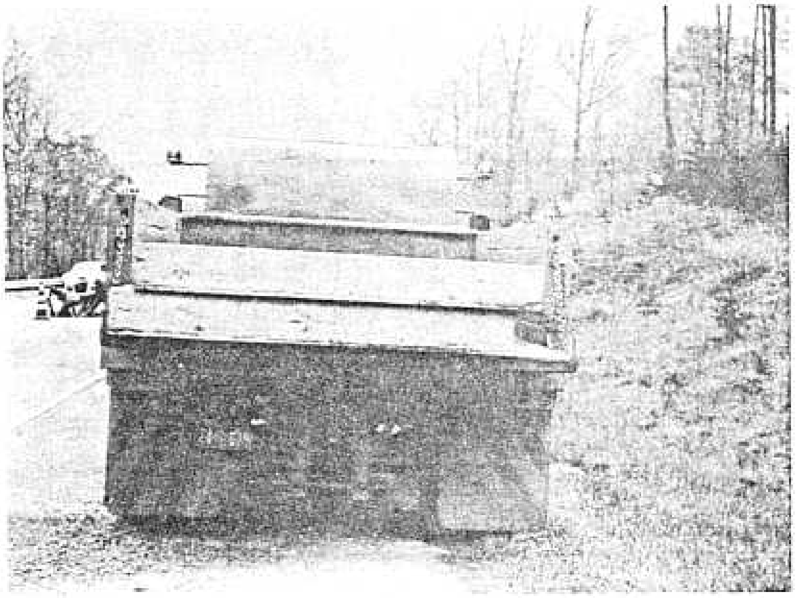


Figure 25. Precast slabs delivered to repair site.

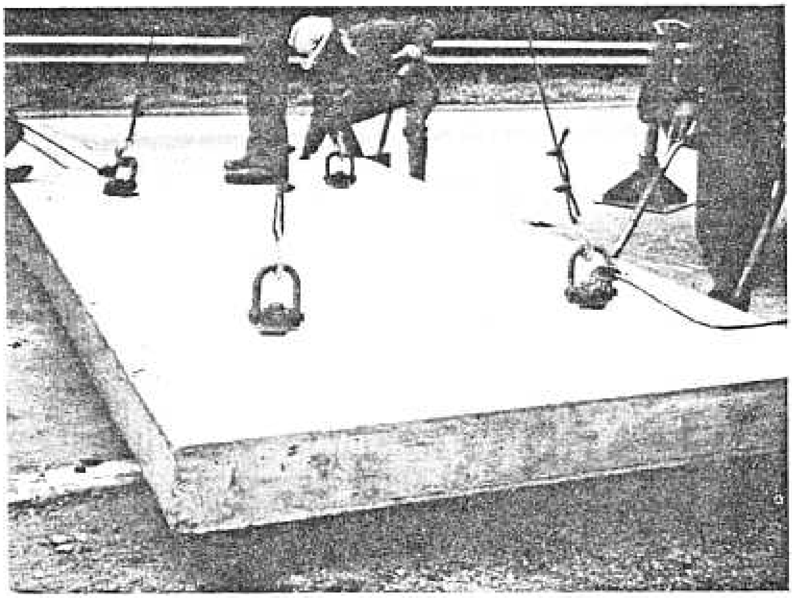
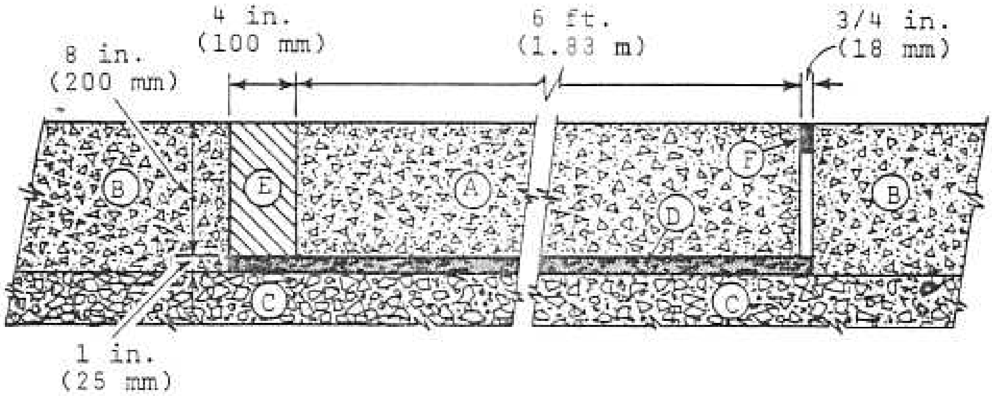


Figure 26. Precast slab being positioned over bedding mortar.

Figure 27. Precast slab in place.



A — Precast Slab
B — Existing Slabs
C — Subbase
D — Bedding Mortar
E — Stress Relief Material
F — Preformed Neoprene Sealant

Figure 28. Elements of a typical precast replacement installation (longitudinal section).

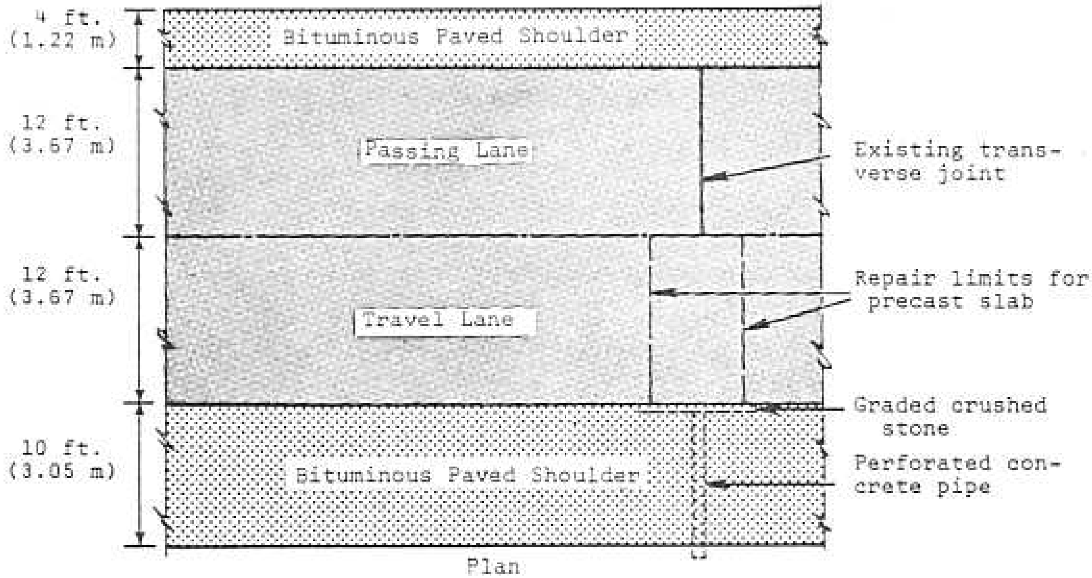


Figure 29. Drainage for full-depth PCC pavement repairs using precast slabs.

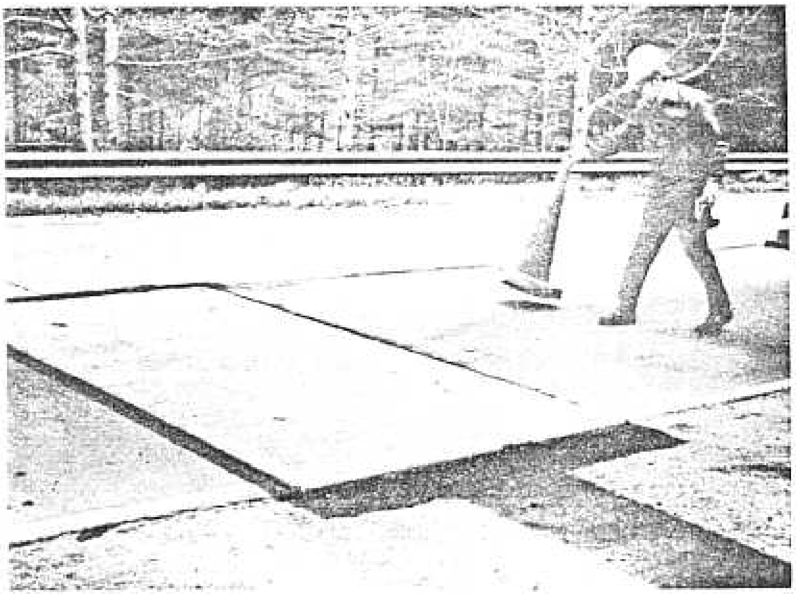


Figure 30. Precast replacement with completed drainage components.

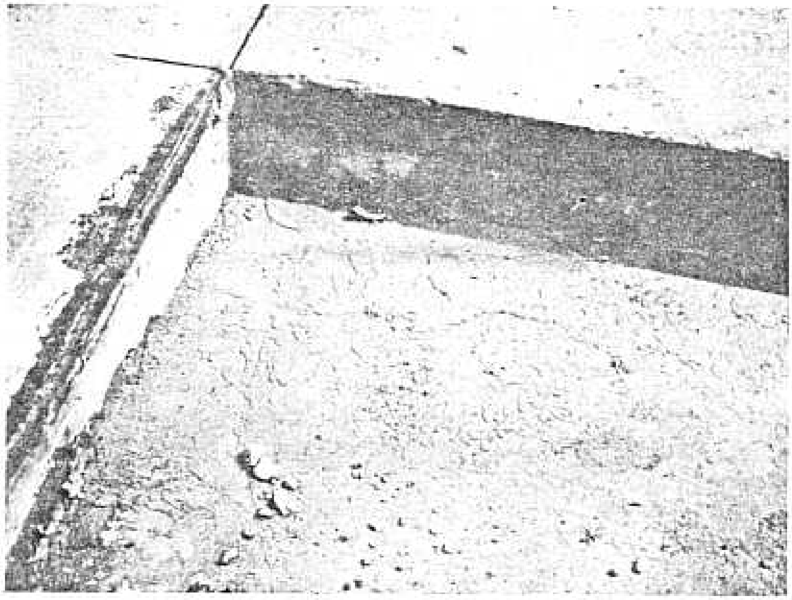
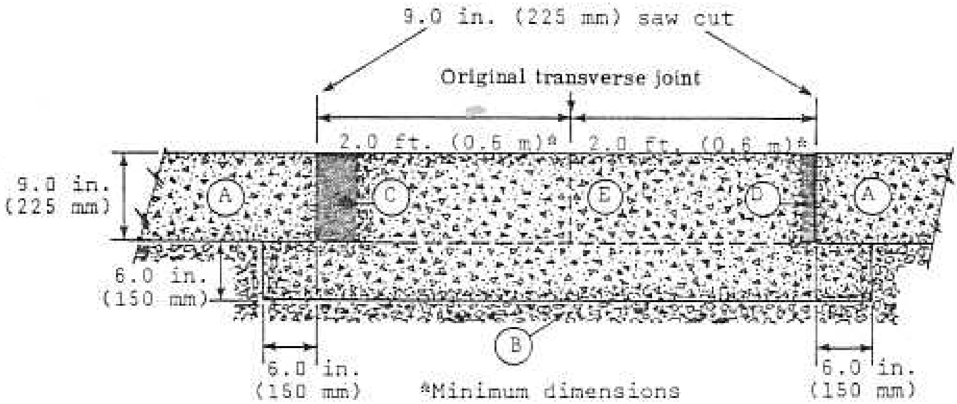


Figure 31. Fine subbase material infiltrated between mortar layer and precast slab from underneath adjacent roadway areas (roadway centerline on left).



LONGITUDINAL SECTION

A. Existing pavement slabs
B. Existing subbase
C. Stress relief joint (as needed)
D. Contraction joint
E. Cast-in-place repair concrete

Figure 32. Typical details of a cast-in-place replacement at a transverse joint.