
Introduction to Repair of Rigid Pavements

Course No: C03-031

Credit: 3 PDH

J. Paul Guyer, P.E., R.A., Fellow ASCE, Fellow AEI



Continuing Education and Development, Inc.
22 Stonewall Court
Woodcliff Lake, NJ 07677

P: (877) 322-5800
info@cedengineering.com

An Introduction to Repair of Rigid Pavements



GUYER PARTNERS

44240 Clubhouse Drive
El Macero, CA 95618
(530) 758-6637
jpguyer@pacbell.net

J. PAUL GUYER, P.E., R.A.

Paul Guyer is a registered civil engineer, mechanical engineer, fire protection engineer and architect with over 35 years experience designing all types of buildings and related infrastructure. For an additional 9 years he was a public policy advisor on the staff of the California Legislature dealing with infrastructure issues. He is a graduate of Stanford University and has held numerous local, state and national offices with the American Society of Civil Engineers and National Society of Professional Engineers. He is a Fellow of the American Society of Civil Engineers and the Architectural Engineering Institute.

CONTENTS

1. PURPOSE
2. DEFINITIONS
3. GENERAL PROVISIONS
4. APPROVED EPOXY MATERIALS
5. APPLICATIONS
6. EFFECTIVE TEMPERATURE AND CONDITIONING
7. AGGREGATES FOR EPOXY RESIN CONCRETES AND MORTARS
8. SAMPLING AND TESTING EPOXY RESINS
9. TRIAL BATCHES
10. FIELD MIXING AND BATCH SIZE
11. PROCEDURES FOR CONDITIONS 1 AND 2
12. PROCEDURE FOR CONDITION 3
13. PROCEDURE FOR CONDITION 4
14. PROCEDURE FOR CONDITION 5
15. PROCEDURE FOR CONDITION 6
16. PROCEDURE FOR CONDITION 7
17. PROTECTION OF REPAIRED AREAS FROM WEATHER AND TRAFFIC
18. CLEANING OF EQUIPMENT AND TOOLS
19. SAFETY AND HEALTH PRECAUTIONS

This course is adapted from the *Unified Facilities Criteria* of the United States government, which is in the public domain, is authorized for unlimited distribution and is not copyrighted.

1. PURPOSE.

This course presents an introduction to materials, criteria, and procedures for rapid repair of uncontrolled cracks and spalls in rigid pavements by using epoxy resin grouts, mortars, and concretes. This guidance is applicable to the repair of rigid pavements on roads and airfields.

2. DEFINITIONS.

2.1 EPOXY RESIN. The resin component of a thermosetting polymer which contains epoxy groups principally responsible for its polymerization.

2.2 EPOXY RESIN SYSTEM. The product resulting from the combination of all the components supplied for use as an epoxy resin system.

2.3 BINDER. The cementitious part of a grout, mortar, or concrete that binds the aggregate or filler into a cohesive mass.

2.4 COMPONENT. A constituent that is intended to be combined with one or more other constituents to form the epoxy resin system.

2.5 FILLER. A finely divided solid, predominantly passing the No. 200 sieve, which is used to improve certain properties of the epoxy resin system or to reduce cost.

2.6 EPOXY RESIN GROUT. The product obtained by combining a filler with the epoxy resin system. The filler and the epoxy resin system are obtained from the formulator.

2.7 EPOXY RESIN MORTAR. The product obtained by combining a fine aggregate with the epoxy resin system.

2.8 EPOXY RESIN CONCRETE. The product obtained by combining both fine and coarse aggregate with the epoxy resin system.

3. GENERAL PROVISIONS.

Expedient methods of repairing uncontrolled cracks and spalls in rigid pavements are often required to minimize the time a pavement is closed to traffic. Approved epoxy resins described herein, provide binding agents particularly suitable for use in this type of work where a high degree of bond in a short period of time is needed. The high strengths obtainable in a short curing time usually permit regular traffic on the pavements within 24 to 48 hours after the repair, depending upon temperature conditions. The epoxy resins specified react most favorably when air and surface temperatures are in the range of 70 degrees F to 100 degrees F, but satisfactory results can be obtained at temperatures as low as 40 degrees F, if proper conditions are provided as described herein. Generally pavement repairs with epoxy materials shall not be initiated unless the air and pavement temperatures are above 40 degrees F and rising. Class A epoxy resin shall be used if the temperature is below 40 degrees F.

4. APPROVED EPOXY MATERIALS.

Many epoxy resins for repairing rigid pavement are available under a variety of trade names. Selection of the proper epoxy resin is required to obtain satisfactory results for the work described in this manual. Epoxy resins shall conform to the American Society for Testing and Materials (ASTM) C 881. This ASTM specification designates three types, grades, and classes of epoxy resins. Type I is used to bond hardened concrete and other materials to hardened concrete; Type II is used to bond freshly mixed concrete to hardened concrete; Type III is used to bond skid-resistant materials to hardened concrete, and as a binder in epoxy resin mortars or epoxy resin concretes. A bond strength of 1,400 pounds per square inch (psi) shall be used for Type III in lieu of the 300 psi shown in Table 1 of ASTM C 881. The three grades are defined according to viscosity: Grade 1-low viscosity, Grade 2-medium viscosity, Grade 3-nonsagging

consistency or high viscosity. Grade 3 is used primarily on vertical faces. The three classes are defined according to the range of temperatures for which they are suitable: Class A for use below 40 degrees F, Class B for use between 40 and 60 degrees F, and Class C for use above 60 degrees F.

5. APPLICATIONS.

The general applications or intended uses of the materials are as follows:

5.1 TYPE I. Used for cementing dowels in drilled and preformed holes and for pressure grouting of nonworking cracks. Grade 1 shall be used for pressure grouting.

5.2 TYPE II. Used as the adhesive for bonding freshly mixed portland cement concrete (PCC) to hardened PCC. Grade 2 is preferred but Grade 1 can be used.

5.3 TYPE III. Used as a binder in epoxy resin mortars or epoxy resin concretes for repairing spalls and for filling nonworking joints.

6. EFFECTIVE TEMPERATURE AND CONDITIONING.

6.1 PAVEMENTS. Three classes of epoxy resins are defined according to temperature. If pavement and atmospheric temperatures are less than 70 degrees F but not below 50 degrees F, satisfactory repairs can be obtained without creating an artificial environment, provided the slightly increased cure time can be tolerated. The artificial environment can be a suitable temporary structure designed to provide the minimum specified temperature for repairs. If seasonal air temperatures are above 90 degrees F, repairs should be scheduled in early morning or the areas should be protected from direct sunlight prior to initiating repair operations. High air temperature (90 degrees F and above) will decrease the working time for placement of epoxy resin mortars and epoxy resin concretes. When pavement temperatures are less than 50 degrees F, infrared heat lamps or other suitable heat sources should be placed over the

area to be repaired for approximately 3 hours prior to placement operations. Gentle winds can make the heat lamps ineffective; therefore, temporary windbreaks should be used as necessary. The raising of the pavement temperature by the use of heat lamps reduces the heat loss into the pavement and permits a desirable moderate heat buildup from the exothermic reaction which occurs when the two components of the epoxy system are combined. Although a satisfactory repair can be obtained if this moderate heat buildup does not occur, the lack of moderate heat buildup may prolong a satisfactory cure-out or hardening and thereby delay reopening to traffic. Similarly, the cure-out or hardening period for epoxy resin concretes and mortars can be accelerated during cool weather by the use of heated enclosures over the repaired area. The method of attaining the desired air temperature in the enclosure must avoid creating localized hot spots which may cause bubbling of the liquid epoxies and also induce cracking. The best method for heating an enclosed area is to circulate heated air with added precautions to ensure surface temperatures in the repaired areas do not exceed 100 degrees F during the hardening stage.

6.2 CONDITIONING OF AGGREGATES. In the preparation of epoxy resin concretes and mortars, aggregates should be dry and conditioned to a temperature of 70 to 85 degrees F. The moisture content of the aggregates should not exceed 1.0 percent by weight of the aggregates. The addition of epoxy material to cold aggregates will result in increased viscosity and decreased stability of the mixture. Low temperatures of the final mixture will be conducive to a reduced hardening rate. If the aggregates are too hot, the epoxy-curing agent reaction will be accelerated; making placement and finishing difficult and possibly resulting in cracking.

6.3 CONDITIONING OF EPOXY RESIN COMPONENTS. The viscosity of the two components of an epoxy resin increases as temperatures decrease. In order to readily obtain a homogeneous mixture of the two components, the materials should be conditioned to a range of 60 to 100 degrees F prior to mixing with a mechanical stirring device. Although adequate uniformity of the mixture might be obtained at lower temperatures by a prolonged mixing time when epoxy resin concretes or mortars are

being prepared, an overly “rich” mixture (a mixture containing excess epoxy resin) could occur due to the reduced wetting capability.

6.4 “TRIGGERING” CURING CHEMICAL REACTION. To expedite resumption of traffic over a repair area for low pavement and atmospheric temperature conditions, the early hardening rate of the epoxy binders can be appreciably accelerated. This may be accomplished by warming the aggregates before the aggregates are added to the epoxy resin. Aggregates may be warmed by storing in a heated building, by burners, or by radiation. Care must be taken not to heat aggregates excessively because such heating can limit the working life of the epoxy mortars and epoxy concretes. Aggregate temperatures above 120 degrees F shall be avoided.

7. AGGREGATES FOR EPOXY RESIN CONCRETES AND MORTARS.

7.1 CONCRETES. The aggregates used for epoxy resin concretes should be clean, dry, washed gravel or crushed stone, 3/8-inch or 1/2-inch maximum size, well graded from coarse to fine, and of the same quality as those used for PCC and bituminous mixtures. Fine aggregate and coarse aggregate of indicated sizes meeting the requirements of ASTM C 33 should be specified for epoxy resin concrete mixtures.

7.2 MORTARS. The fine aggregate used for epoxy resin mortars is required to conform to either ASTM C 144 or ASTM C 33. The aggregate should be well graded from coarse to fine with a minimum amount of material passing the No. 100 sieve. The maximum size required will depend on the intended use of the mortar. For example, in the filling of saw kerfs, the normal width of the cut requires the use of an aggregate with 100 percent passing the No. 8 sieve. In general, for both epoxy resin concrete and mortar, the maximum size aggregate should neither exceed one-third of the thickness of the layer being placed nor one-third of the width of the opening being filled.

8. SAMPLING AND TESTING EPOXY RESINS.

All epoxy resins proposed for use should be tested for compliance with the requirements of the applicable specification. The manufacturer's certificates of compliance with the requirements will not be accepted in lieu of tests for large jobs. If epoxy resin concretes are to be used, samples of fine aggregate and coarse aggregate should be submitted for testing. The contractor is required to supply the testing laboratory the proportions of aggregate used by weight or by volume.

9. TRIAL BATCHES.

9.1 EPOXY RESIN MORTARS AND EPOXY RESIN CONCRETES. Variations in aggregate grading and particle shape may affect the proportions required to obtain an economical mixture that has satisfactory placing and finishing characteristics. Small laboratory trial batches shall be prepared and tested prior to the start of field placement operations. The quantity of epoxy resin system prepared for use in these trial batches should be at least 300 grams. The labels on the shipping containers will specify the manufacturer's recommended mixing proportions. A polyethylene container having a hemispherical (convex) bottom should be used as the mixing vessel. The recommended proportions of the two components are added to the mixing vessel and mixed until a uniform mixture is obtained. The rate of stirring should be such that the amount of entrapped air is minimized. Hand-mixing is usually unsatisfactory and a power-driven (air or spark-proof), propeller-type blade should be used. The mixed epoxy resin system must be uniform and homogeneous. Mixing may require 2 to 5 minutes depending on the viscosity and density of the epoxy resin. Epoxy resin concrete proportions by weight may vary from 6 to 10 parts aggregate to 1 part epoxy resin binder, which is equivalent to a ratio of approximately 4 to 7 parts aggregate to 1 part epoxy resin binder by volume. The aggregate mixture (fine and coarse aggregate) should contain 55 ± 5 percent fine aggregate by weight. The epoxy resin mortars may vary from 4 to 7 parts aggregate by weight to 1 part epoxy resin binder, which is equivalent to a ratio of approximately 3 to 5 parts aggregate to 1 part epoxy resin binder by volume. The proportions suggested are applicable only to aggregates in the 2.60 to 2.80 specific

gravity range. Aggregates having specific gravities above or below these values will probably require adjustment of the suggested proportions. The trial batch procedure will assist field personnel in obtaining the proper proportions of aggregate and binder in preparing the larger field batches.

9.2 EPOXY RESIN SYSTEM AND EPOXY RESIN GROUT. Trial batches are not required when using an epoxy resin system as a bonding medium between plastic and hardened PCC or when using epoxy resin grout for filling cracks and/or placing dowels. The two components of a grout will usually be mixed in the proportions specified by the producer without additional fillers and/or aggregate.

10. FIELD MIXING AND BATCH SIZE.

Small mechanical mixers of the drum type and mortar mixers have been used successfully for mixing epoxy resin concrete and mortars. Small batches of approximately 0.1 cubic foot (1 gallon) can be hand-mixed using a spatula or trowel. The maximum batch size will be limited by the ability to thoroughly mix the epoxy resin system and aggregate. Experience has demonstrated that the maximum batch size will range from 200 to 300 pounds (1.5 to 2.0 cubic feet). Prior to starting operations, the immediate on-site availability of all materials and the suitability and adequacy of the mixing and placing tools shall be carefully checked. Several 2- to 5-gallon plastic graduated buckets have been found to be satisfactory for proportioning by volume. The mixing procedure of an epoxy resin system must produce a uniform and homogeneous mix. The components of the epoxy resin system are mixed by stirring or agitation to effectively put them into solution. For mixing epoxy resin systems in small containers (1 quart), a spatula, palette knife, or similar device can be used. For larger volumes, the epoxy resin system shall be mechanically mixed in plastic buckets. A paint mixing paddle driven by a low-speed electric drill may be used for the mixing. After mixing the epoxy components, the mixture should be immediately transferred to the mixing pan (small mixes) or the mechanical mixer (large mixes) and the aggregates immediately added. Delays in adding the aggregate to the mixed epoxy resin system can result in a

loss of the binder due to the accelerated chemical reaction. In mixing epoxy resin concrete, the large aggregate should be added to the mixed epoxy resin binder first, followed by the fine aggregate. This order of addition will help prevent the tendency of the mix to “ball.” The mechanical mixers should be cleaned immediately after usage to prevent the epoxy compounds from curing in the mixers. High-pressure water can be used to remove the uncured epoxy if used shortly after the application. The most widely used cleaning method is to immerse the tools and wash the mixers with solvents such as methyl-ethyl-ketone or methylene chloride. Mineral spirits or toluene may also be used with greater safety although they are not as efficient as the previously mentioned solvents. If the epoxy resins have hardened on the tools or mixers, then strippers, mechanical abrasion, or burning will be necessary to remove the cured epoxies.

11. PROCEDURES FOR CONDITIONS 1 AND 2.

Conditions of pavements, as described in this course, are shown in Figure 1. Conditions 1 and 2 require that the random crack be widened with a rotary-type grooving tool and sealed with a joint sealer so as to function as the working joint, while the existing nonworking joint be filled with an epoxy resin mortar. The vertical faces of the joint groove should be free of oils, greases, residual fines from sawing operation, or other coatings. All fillers and joint sealant material should be removed from the joint. Oils and greases will rarely be present, but if inspection indicates areas of even minor traces of oil and grease, these areas shall be cleaned by sandblasting. Inspection of joints or other small openings can be facilitated by using a small mirror to reflect light into the opening. Residual fines from sawing operations or sandblasting should be removed by the use of high-pressure water jet followed by an air jet to dry the concrete before applying the epoxy resin system. A moderately rich epoxy resin mortar should be used for filling joint grooves and other small openings where it may be difficult to hand-fill and compact a lean mix. However, care should be exercised to ensure that the epoxy resin mortar is not so rich that the material flows. The epoxy resin mortar batch size should be adjusted so that the personnel available can complete all placing and finishing operations before the epoxy resin mortar starts to gel. The batching operations will

follow the same sequence as that for trial batches. The epoxy resin system is prepared first and the fine aggregate gradually added while continuing mixing until all particles are coated. After the joint or crack has been filled with the epoxy mortar, the surface should be neatly finished and flush with the pavement surface, using appropriate hand tools. Excess material shall be carefully removed and not thinly spread on the adjacent concrete.

12. PROCEDURE FOR CONDITION 3.

Repair of this type of condition requires that the area within the broken corner (Figure 1) be removed and replaced with new PCC. The new concrete will be bonded to the old concrete with an epoxy resin system at the prepared vertical faces of the patch area. The vertical face of the joint must be maintained to prevent the new PCC from bonding to the adjacent slab. If the joint is not properly maintained, the concrete patch will break loose due to slab movement caused by variations in temperature.

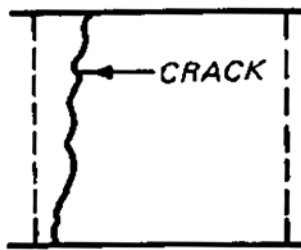
12.1 PREPARATION OF REPAIR AREA. The area to be repaired should be outlined using a concrete saw. The saw cut lines should be located at least 2 inches outside the crack in sound concrete, and not extend past the joint into the adjacent slab. The depth of the saw cut should be at least 2 inches. Remove the broken corner and the remaining concrete inside the saw cut to the full depth of the slab using air hammers. All joint sealant material inside the repair area should also be removed. All exposed vertical faces within the repair area should be cleaned. Prior to the placement of the new concrete, the exposed subgrade should be reconditioned to comply with the specified requirements.

12.2 MAINTAINING THE JOINT. To prevent bonding the new concrete to adjacent slabs at the joints, the vertical faces should be protected with a bond-breaking medium. The existing contraction joint may be maintained by the use of temporary inserts of appropriate dimensions or by sawing the required kerf. Sawing must be done early enough to prevent development of a random crack at the joint.

12.3 PLACEMENT OF NEW CONCRETE. After removing the concrete and preparing the subgrade, the cleaned vertical surfaces should be coated with at least a 20-mu film of the epoxy resin system, using a stiff bristle brush or roller to ensure thorough wetting of the concrete. Placement of the new concrete should be delayed until some degree of tack has developed (30 minutes to 1 hour). When vibrators are used, it is essential to allow the epoxy bond coat to reach a tacky state since vibration can displace the epoxy from the existing concrete by emulsifying the fluid epoxy bond coat. Vibrators should not come in contact with the epoxy coating. If the concrete placement is delayed until the epoxy coating reaches a soft rubberlike stage, a second application of epoxy bond coat equal to the amount of the first coat should be applied to the existing bond coat. If the concrete placement is delayed until the epoxy coating is no longer tacky, the epoxy coating will have to be removed or abraded by sandblasting and a fresh coat applied. Forms, if needed, should be placed after the concrete pavement has been properly prepared. The forms should be lined with polyethylene sheets or waxed paper to prevent any adhesion to the form that may result from the override of epoxy onto the form. The use of form oil will not be permitted. The concrete mixture should be relatively dry and the slump of the concrete should not exceed 2 inches. The repair is to be finished so as to match the texture of the surrounding concrete. After the concrete has cured, the reconstructed joints should be sealed in the conventional manner.

13. PROCEDURE FOR CONDITION 4.

The repairs required under condition 4 do not use epoxy resin grouts, mortars, or concrete.

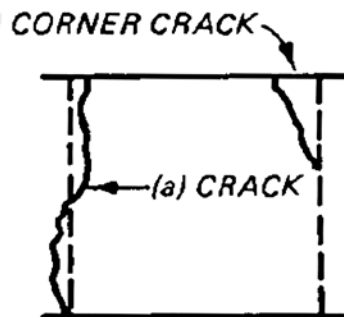


CONDITION 1

CRACK ENTIRELY WITHIN SLAB AND FULL DEPTH OF PAVEMENT. IF CRACK DEVELOPS PRIOR TO SAWING, DO NOT SAW JOINT.

REPAIR METHOD

ROUT, CLEAN AND SEAL CRACK WITH JOINT-SEALING MATERIAL. FILL JOINT WITH EPOXY-RESIN MORTAR IF SAWED ALREADY.



CONDITION 2

- a. CRACK CROSSES NORMALLY SPACED TRANSVERSE CONTRACTION JOINT.
- b. CORNER CRACK FULL DEPTH OF SLAB AND NORMAL JOINT NOT "WORKING" IN SECTION ADJACENT TO CRACK.

REPAIR METHOD

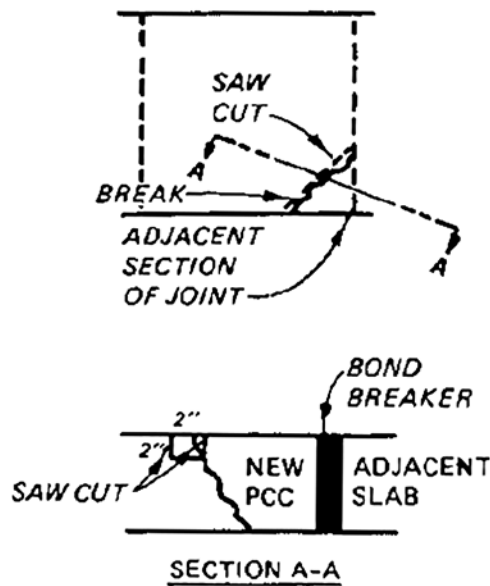
ROUT, CLEAN AND SEAL CRACK WITH JOINT-SEALING MATERIAL. FILL JOINT WITH EPOXY-RESIN MORTAR

LEGEND

- LONGITUDINAL CONSTRUCTION JOINTS
 - - - - - CONTRACTION JOINTS

Figure 1

Approved methods for repair of uncontrolled cracks and spalls in rigid pavements

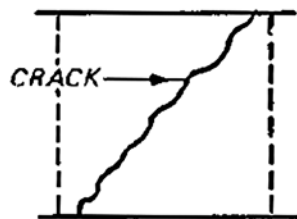


CONDITION 3

CORNER BREAK AND ADJACENT CONTRACTION JOINT BOTH CRACKED FULL DEPTH OF SLAB

REPAIR METHOD

MAKE SAW CUT 2 INCHES DEEP AND 2 INCHES FROM CRACK IN SOUND MATERIAL. AFTER REMOVAL OF BROKEN CONCRETE, THE PATCH AREA SHOULD BE SANDBLASTED. APPLY THIN COAT TO EPOXY RESIN GROUT TO CLEANED FACE. PLACE INSERT IN JOINT TO PREVENT PATCHING MATERIAL FROM INFILTRATING INTO JOINT. PLACE CONCRETE IN SECTION AND RESTORE JOINTS



CONDITION 4

- CRACK WITHIN SLAB, CRACK TIGHT AND NOT "WORKING"
- CRACK WITHIN SLAB, CRACK OPEN AND "WORKING"

REPAIR METHOD

- IF CRACK IS TIGHT AND NOT "WORKING," NO REPAIR IS REQUIRED
- IF CRACK IS OPEN AND/OR "WORKING," ROUT, CLEAN, AND SEAL WITH JOINT SEALANT

LEGEND

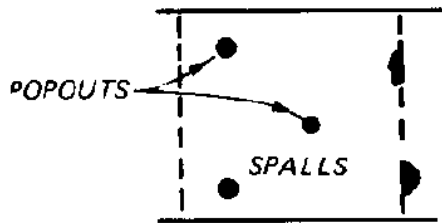
- LONGITUDINAL CONSTRUCTION JOINTS
 - - - - - CONTRACTION JOINTS

Figure 1 (continued)

Approved methods for repair of uncontrolled cracks and spalls in rigid pavements

CONDITION 5

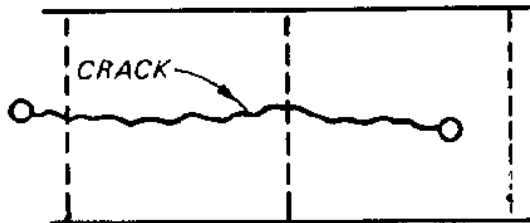
SPALLING ALONG JOINTS.
SMALL SURFACE SPALLS OR "POPOUTS".



REPAIR METHOD

REMOVE LOOSE CONCRETE AND PATCH WITH
EPOXY-RESIN CONCRETE
IF SPALL IS PART OF THE "WORKING" JOINT,
ROUT, CLEAN, AND SEAL WITH JOINT
SEALING MATERIAL

CONDITION 6



- a. CRACK ACROSS ONE OR MORE
SLABS, CRACK TIGHT AND
NOT "WORKING"
- b. CRACK ACROSS ONE OR MORE
SLABS, CRACK OPEN AND
"WORKING"

REPAIR METHOD

- a. IF CRACK IS TIGHT AND NOT
"WORKING", NO REPAIR REQUIRED
- b. IF CRACK IS OPEN AND "WORKING":
DRILL 4 TO 6 INCH DIAMETER CORE
HOLES AT EACH END OF CRACK, FILL
HOLES WITH EPOXY RESIN CONCRETE
TO PREVENT PROGRESSION OF CRACK.
ROUT, CLEAN, AND SEAL CRACK
WITH JOINT SEALANT.

LEGEND

- LONGITUDINAL CONSTRUCTION JOINTS
- - - - - CONTRACTION JOINT

Figure 1 (continued)

Approved methods for repair of uncontrolled cracks and spalls in rigid pavements

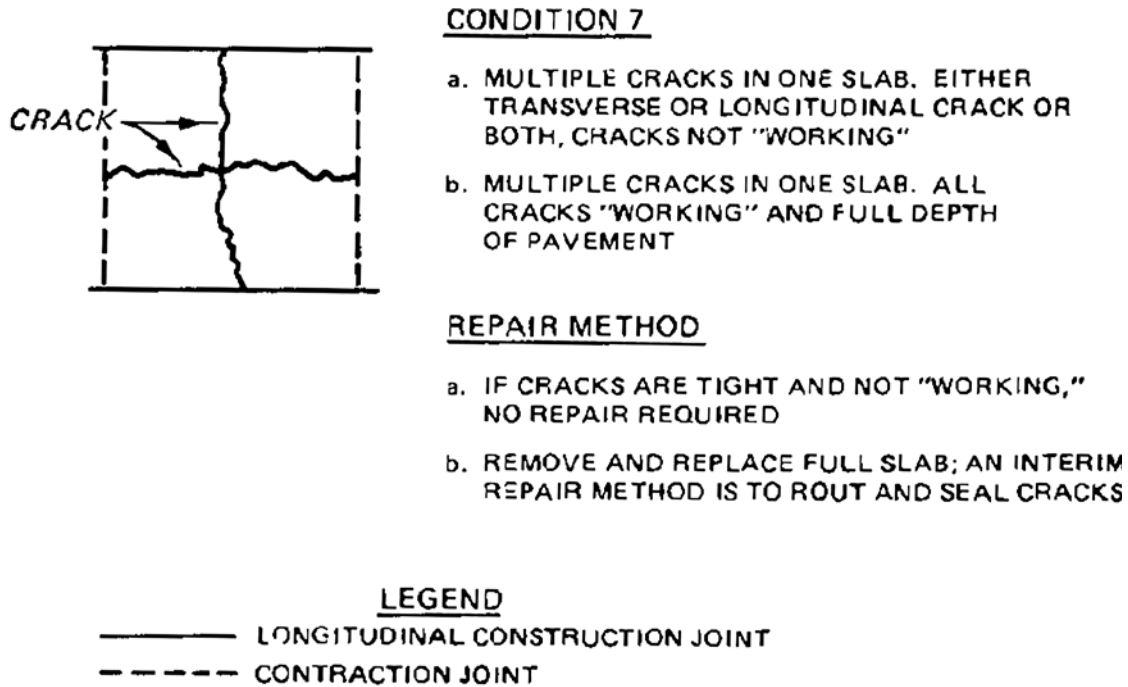


Figure 1 (continued)

Approved methods for repair of uncontrolled cracks and spalls in rigid pavements

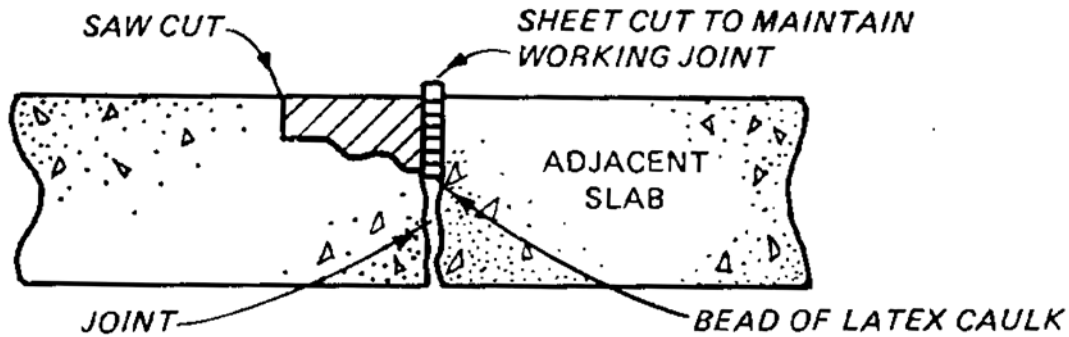
14. PROCEDURE FOR CONDITION 5.

The repairs required under condition 5 (Figure 1) include all spalls which occur along joints and along working cracks. The same general procedures as mentioned for condition 3 are used for the repair of isolated small surface spalls or pop-outs. The repair of all spalls consists of removing unsound or damaged concrete, modifying the spall cavity dimensions as necessary to prevent further breakout, taking precautions in the repair procedure to ensure freedom of movement at working joints, and taking appropriate measures to properly seal the joint. Large spall areas should be repaired using PCC bonded with the proper epoxy resin system. "Pop-outs" are not normally repaired unless hazardous to tires. If they are determined to be hazardous to tires, repair with epoxy resin systems.

14.1 REMOVING UNSOUND OR DAMAGED CONCRETE. All unsound or damaged concrete must be removed prior to repairs. The defective areas to be removed can be determined by tapping with a hammer or steel rod throughout the area and listening for dull or hollow sounds. The Schmidt hammer can be used by those experienced with this test. A tensile test that can be used in the field to check the soundness of the substrate concrete has been suggested in the American Concrete Institute (ACI) Committee Report 503. The test is designated as a “Field Test for Surface Soundness and Adhesions.” The periphery of the area required to be removed should be sawed to a depth consistent with the type of repair. Saw cutting delineates the repair area and serves to essentially eliminate edge spalling and weakness that might be introduced by outlining the repair area with other types of equipment. The saw cut lines should be located outside the defective area and in sound concrete. The saw cut should not be extended across the joint into the adjacent slab unless that area is also spalled. The depth of the saw cut should be at least ½ inch for epoxy resin mortar repairs and 2 inches for epoxy resin concretes and epoxy resin bonded PCC. In preparing cutouts for pop-outs or small spalls wholly within a structural component and not involving joints, edges, or corners, feather-edging is permissible. The feather-edge should be at least ¼ inch deep to provide a shoulder of sufficient depth to obtain a smooth finish. High-frequency chipping hammers can be used to make cutouts for this type of repair in lieu of saw cuts. Concrete removal inside the saw cut should be accomplished using medium to lightweight air hammers. The bottom of the cutout should be smooth in order to reduce the surface area and therefore reduce the quantity of epoxy resin concrete needed for the patch. Also, in edge or joint replacement areas, such as concrete removal working cracks, the cracks must be maintained such that their bottom slope does not exceed 30 degrees. The minimum depth of the concrete removal will depend on the maximum depth of the spalled or damaged area. The concrete should be removed to a sufficient depth to expose sound concrete in the entire patching area. The removal depth should be at least 2 inches, except where interior slab spalls such as pop-outs, are to be repaired. In this case, the minimum depth should be 1 inch.

14.2 SURFACE PREPARATION. All newly exposed surfaces are to be cleaned by sandblasting. Dust and other debris resulting from the removal of deteriorated surfaces or contaminants must be removed. Cleaning may be accomplished by jetting the surface with compressed air, thorough washing with high-pressure water jets, or by use of a high-suction vacuum. The vacuum method should only be used when other procedures cannot be employed. All equipment for providing compressed air must have oil and water traps in the air supply lines.

14.3 MAINTAINING THE WORKING JOINT. The regular working joint may be maintained by the use of a fiberboard coated with a polyethylene film, polyethylene foam strips, or other suitable material. The separating medium should be approximately ½ inch thick cut to closely fit the pattern of the cavity along the adjacent slab (Figure 2). If fiberboard is used, it should be coated with a polyvinyl film or vinyl duct tape to prevent epoxy from binding to the board. If necessary, the irregular surface treated at the crack of the pavement joint should be coated with a suitable bond-breaking medium. A flexible latex caulking compound may be used to fill any voids underneath the sheet material. The insert should be removed after the epoxy resin concrete hardens, or it may be cut out with a concrete saw to form the joint sealant reservoir. The formed joint is later sealed with an acceptable joint-sealant material. Oils, waxes, greases, or silicones should not be used on the insert since these substances prevent bonding of the joint-sealant materials.



NOTE: USE COMPRESSIBLE SEPARATING MEDIUM WITH A MINIMUM THICKNESS OF 1/2" IN JOINT TO MAINTAIN AND PROTECT JOINT DURING PLACEMENT OF THE FRESH CONCRETE.

PARTIAL DEPTH REPAIR AT JOINTS

Figure 2

Use of sheet material to maintain working joint during repairs

14.4 SPALLS ALONG WORKING CRACKS. For spalls along working cracks, the cracks must be maintained like a working joint. A different approach is required because rigid temporary inserts cannot be used. In this case a bond-breaking medium must be used to prevent bonding the epoxy concrete to the concrete adjacent to the spall area which could possibly result in further spalling. One bond-breaking medium uses polyethylene foam strips cut to fit the entire working face adjacent to the spall and an appropriately sized flexible polyethylene backing rod which is temporarily embedded to provide a groove for the joint-sealing material. Another bond breaking medium involves coating the working face adjacent to the spall area with a bond-breaking medium, such as grease, and temporarily embedding a backing rod for groove-forming as in the previous case. With either of the suggested methods, the backing rod must be removed after the epoxy concrete hardens.

14.5 REPAIR OF SPALLS WITHIN WORKING CRACKS. Where a working crack continues through an area to be patched, the crack should be maintained as a joint

through the freshly placed epoxy resin concrete. After removal of the unsound concrete and cleaning of the prepared spall area, a polyethylene foam sheet should be cut to fit along the alignment of the crack within the prepared cavity. The concrete surface along the alignment of the crack should not be excessively irregular which would produce voids greater than $\frac{1}{4}$ inch deep below the sheet when placed over the crack. A small chipping hammer equipped with a $\frac{1}{2}$ - to 1-inch-wide blade may be used to remove high spots along the crack to form a regular surface. When placing the epoxy resin concrete, placements need to be carefully made around the joint filler sheet to prevent tilting or misalignment of the sheet. Maintaining an active crack through an area being repaired is shown in Figures 3 and 4.

14.6 PLACEMENT OF EPOXY RESIN CONCRETES AND MORTARS. In scheduling the placement of epoxy resin concretes and/or mortars, the correct type and classification of epoxy resin system should be procured, pavement and materials temperatures should be carefully considered, and appropriate operational conditions and procedures established.

14.6.1 Prior to the placement of epoxy resin concrete or mortars, the surface of the cavity (except for the face of the working joint) shall be primed with the binder. The primer should be applied in a relatively thin coat (15 to 20 mils) and briskly scrubbed into the concrete surface with a stiff bristle brush or roller. Placement of the epoxy resin concrete or mortar should begin immediately after the application of the prime coat.



Figure 3

Placement of joint filler sheet to maintain active crack through area to be patched.



Figure 4

Finishing a patch containing an active crack

14.6.2 The size of the batch to be prepared at one time will vary with the area to be repaired. In cases where the depth of the area being repaired is greater than 2 inches, a multiple-course procedure will be followed. It has been found that the heat buildup in courses thicker than 2 inches sometimes is sufficient to cause cracking. The placement of an additional course or courses, if required, should be delayed until the peak temperature has been reached and the temperature of the previously placed material is decreasing. In most instances, large patches (typically those requiring more than 5 gallons of an epoxy resin system) should be made with PCC unless the repaired area has to be opened to traffic within 48 hours.

14.6.3 The methods for epoxy resin concrete or mortar placement including consolidation, screeding, and finishing will generally follow normal small area PCC operations, except that delays cannot be tolerated. Because of the relatively thin layers of courses necessary, the use of internal spud-type vibrators to properly consolidate the mixtures is difficult. The use of a mechanical plate, screed, and float or float vibrators has proven satisfactory. In many instances, because of dimensional and shape restrictions, consolidation by hand tampers will be necessary.

14.6.4 In the final finishing operations, the surface shall not be left slick due to excess epoxy resin bleeding to the top. Fine aggregate can be broadcast on top of slick areas before the epoxy resin hardens to improve the surface texture. The final surface should be left even with the surrounding pavement. Excess mortar or binder should be removed since feather-edge finishing usually will form a weak bond resulting in chipping under traffic.

14.6.5 The formed joint should be sealed in a conventional manner. This work can usually be initiated about 24 hours after epoxy resin concrete or mortar placement, unless low temperatures have appreciably retarded the hardening of the epoxy resin binder.

15. PROCEDURE FOR CONDITION 6.

Repair of the type of failure in condition 6 (Figure 1) involves remedial measures to stop progression of the longitudinal crack in both directions. The procedure for this is similar to the repair of spalled areas. The full length of the crack should be routed with a rotary grooving tool after the pavement surface is carefully examined to locate the ends of the crack. Since the crack termination points may be almost indiscernible, sandblasting and high-pressure air jets should be used near the apparent ends to remove fines embedded in the crevices. Also, laitance beyond the apparent ends should be removed by sandblasting to make identification of the actual ends of the crack more accurate. Core holes, 4 to 6 inches in diameter, should be drilled at each end of the crack. These core holes should be centered on the ends of the crack to assure complete crack removal. After removal of the core, all residual fines on the core hole wall should be removed by scrubbing the walls with a stiff bristle brush, followed by washing and removal of excess water from the core hole. The removal of the residual fines is necessary to ensure that the required bond of the epoxy resin concrete to the PCC is obtained. The application of primer to the core hole wall and placement of the epoxy resin concrete to fill the core hole should be similar to the procedures for the repair of spalls. Because the FCC mass is much greater than that of the epoxy resin concrete, the heat generated by the epoxy binder will be diffused rapidly and the thickness of the courses placed may be increased to 6 inches. In some climatic areas or under certain weather conditions where pavement temperatures may be relatively high, it may be advisable to place thinner courses to avoid cracking. The thickness of courses and time interval between courses should be such that the temperature of the epoxy resin concrete never exceeds 140 degrees F during hardening. The peak temperature of the epoxy resin concrete can be determined by placing the epoxy resin concrete into a container, such as a can or pail approximately the same diameter as the core hole, and measuring the temperature with a thermometer. The groove formed in the routing operation will be sealed with an appropriate type of joint sealant in accordance with accepted methods for sealing pavements.

16. PROCEDURE FOR CONDITION 7.

The repairs required under condition 7 do not use epoxy resin grouts, mortars, or concretes.

17. PROTECTION OF REPAIRED AREAS FROM WEATHER AND TRAFFIC.

Repaired areas should be protected as follows:

17.1 TEMPERATURE. Pavement repairs made when ambient temperatures during the following 24 hours may be 60 degrees F or lower, require limited protection to maintain the epoxy concrete or mortar at temperatures which will provide a normal hardening rate. The use of tarpaulins supported several inches above the surface of the repaired area will help maintain the desired conditions, provided the temperature difference or drop is not too great. Heated enclosures may also be used to provide effective temperature conditions.

17.2 WATER. The epoxy resin grout and binder will bond to a damp concrete surface, but greater bond strengths are obtained when the surface is dry. The epoxy resin systems should not be applied to a concrete surface containing excessive moisture. Excessive moisture may be detected by tightly covering the surface with a transparent plastic film. If no moisture has accumulated under the film after 24 hours, capillary moisture may be considered insufficient to adversely affect the bond. During the early hardening stages, which may vary from 2 to 12 hours depending upon weather conditions, the epoxy resin mortars and concrete should be protected from rain.

17.3 TRAFFIC. The repaired areas should be barricaded to prohibit traffic of all types until the epoxy resin concrete or mortar has hardened. The time interval over which protection against traffic is to be maintained will vary with weather conditions, but will usually be less than 24 hours.

18. CLEANING OF EQUIPMENT AND TOOLS.

Because of the nature of the hardened epoxy resin systems, all tools and equipment must be thoroughly cleaned before the epoxy materials set. Toluene, xylene, or other aromatic petroleum solvents must be used with proper precautions concerning the fire and/or explosion hazard. During cleaning operations, the workers must wear solvent-resistant gloves and aprons, and the use of protective creams is desirable. Cleaning should be done in a well ventilated area or respirators should be used in a closed area.

19. SAFETY AND HEALTH PRECAUTIONS.

19.1 GENERAL PRECAUTIONS. The materials used in the two epoxy systems and the solvents used for cleanup do not ordinarily present a serious health hazard except to hypersensitive individuals. Materials can be handled safely if adequate precautionary measures, such as the following, are observed:

19.1.1 Handle only in well ventilated areas.

19.1.2 Prevent skin contact.

19.1.3 Wear neoprene or other suitable impervious gloves whenever the possibility of skin contact occurs. When gloves become contaminated, they should be discarded or reconditioned by washing with soap and water; preferably while they are still on the hands of the operator. Gloves should be dried and kept in a clean place. Powdering the inside of the gloves with talcum is recommended. Contaminated gloves, aprons, sleeves, clothing and working tools shall not be removed from the work area except for discarding or cleaning.

19.1.4 Apply protective ointments or proprietary creams to exposed skin surfaces before beginning work and remove by washing after the work is completed.

19.1.5 Wear full face shields or goggles during the blending and mixing operations.

WARNING: *Goggles must be worn to protect eyes from the epoxy resin system. Goggles are mandatory for persons doing the blending and mixing operations, but the hazard is reduced for persons engaged in the placing operations.*

19.1.6 Restrict blending and mixing operations to the open areas, or if in a building, near an operating hood ventilating system. Use disposable paper coverings in the work area where drips or contamination may be expected.

19.1.7 Maintain good housekeeping and personal hygiene standards.

DANGER: *Solvents are fire hazards.*

19.1.8 Provide thorough instruction to the inspectors concerning the danger of working with exposure to the epoxy resin. This includes advising foremen of the epoxy system constituents; of the removal of individuals who develop sensitivity to any resins and hardeners; and of the nature of skin irritation. Recommend measures to be taken to avoid skin irritation.

19.1.9 Work rooms should be provided with new or unused cleaning rags.

19.2 PERSONAL SENSITIVITY. Historically, few individuals have developed dermatitis from skin contact of epoxy resin components and cleaning solvents (toluene, xylene, and other aromatic petroleum solvents); therefore, adequate precautionary measures should be exercised. Epoxy resin systems containing polysulfide curing agents have an obnoxious odor from the polysulfide constituent which may nauseate some individuals. Inhalation of the vapors should be avoided or kept to an absolute minimum. The amine-type curing agents incorporated in the epoxy resin systems are caustic and may cause tissue damage upon direct contact with the skin. Contamination

of the eye by the curing agent component can cause severe damage, and exposure to high vapor concentrations may also irritate the eyes and mucous membranes.

19.3 FIRST AID. Provide necessities for prompt treatment of accidental skin or eye contact.

19.3.1 EYES. In cases of accidental skin contamination, immediately and thoroughly flush the affected eye for at least 15 minutes with running water, bathe the eye with a normal saline solution, and see a physician if there is any possibility of potential eye damage.

19.3.2 SKIN. Cleanse all areas thoroughly with soap and water following accidental skin contact. If necessary, fresh alcohol, acetone, toluene or methyl-ethyl-ketone may be used as a solvent, but the use of such solvents should be kept to a minimum. In cases of spills, contaminated clothing should be immediately removed and decontaminated in the manner described for gloves.

19.4 REMOVING SOURCE OF CONTACT. If a worker develops dermatitis, the source of contact should be determined and eliminated. Treatment of such a condition should be handled by a competent physician or dermatologist with full information being furnished as to the probable cause of the problem.

19.5 MOVING SENSITIZED PERSONS. Remove from exposure individuals who develop sensitivity to any of the epoxy system constituents. The limiting or removal of subsequent contact with materials will be made by a competent physician or dermatologist.