Repair of Rigid Pavements Using Epoxy Resin Grouts, Mortars and Concretes

Course Number: GE-02-210

PDH: 2

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REPAIR OF RIGID PAVEMENTS USING EPOXY RESIN GROUTS, MORTARS, AND CONCRETES

1. Purpose. This course presents criteria, and procedures for rapid repair for 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. References. Appendix A contains a list of system. References used in this document.

3. Definitions. *a. Epoxy resin.* The resin component of a thermosetting polymer which contains epoxy groups principally responsible for its polymerization.

b. Epoxy resin system. The product resulting from the combination of all the components supplied for use as an epoxy resin system.

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

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

e. 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.

f. 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.

g. Epoxy resin mortar. The product obtained by combining a fine aggregate with the epoxy resin system.

h. Epoxy resin concrete. The product obtained by combining both fine and coarse aggregate with the epoxy resin system.

4. General.

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.

5. 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 course. 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.

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

a. 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.

b. Type II. Used as the adhesive for bonding freshly mixed port-land cement concrete (PCC) to hardened PCC. Grade 2 is preferred, but Grade 1 can be used.

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

7. Effective temperature and conditioning.

a. Pavements. Paragraph 5 presents the three classes of epoxy resins 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.

b. 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.

c. 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

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.

d. "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.

8. Aggregates for epoxy resin concretes and mortars. *a. Concretes.* The aggregates used for epoxy resin concretes should be clean, dry, washed gravel or crushed stone, 3/8-inch or ½-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.

b. 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 not exceed one-third of the thickness of the layer being placed nor one-third of the width of the opening being filled.

9. 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. The US Army Engineer Waterways Experiment Station and the South Pacific Division Laboratories, US Army Corps of Engineers, have been designated to conduct the required tests for acceptance of epoxy resins. The method of sampling, amount of sample required, and the test procedures are given in appendix B. 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 volume.

10. Trial batches. *a.* 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 aggregates 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 aggregates 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.

b. 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

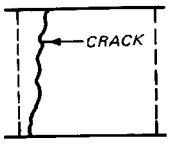
proportions specified by the producer without additional fillers and/or aggregate.

11. 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, strippers, mechanical abrasion, or burning will be necessary to remove the cured epoxies.

12. 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, and 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, flush with the pavement surface, using appropriate hand tools. Excess material shall be carefully removed and not thinly spread on the adjacent concrete.

13. Procedure for condition 3. Repair of this type of condition requires that the area within the broken corner (fig. 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.

a. 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

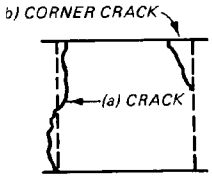


CONDITION 1

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

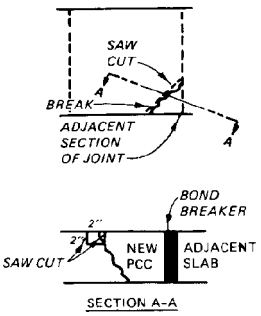
ROUT, CLEAN AND SEAL CRACK WITH JOINT-SEALING MATERIAL. FILL JOINT WITH EPOXY-RESIN MORTAR

LEGEND

——— LONGITUDINAL CONSTRUCTION JOINTS

– – – – CONTRACTION JOINTS

Figure 1. Approved methods for repair of uncontrolled cracks and spalls in rigid pavements.

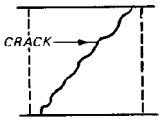


CONDITION 3

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

a. CRACK WITHIN SLAB, CRACK TIGHT AND NOT "WORKING"

b. CRACK WITHIN SLAB, CRACK OPEN AND "WORKING"

REPAIR METHOD

a. IF CRACK IS TIGHT AND NOT "WORKING," NO REPAIR IS REQUIRED

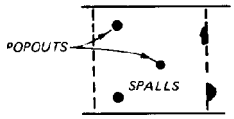
b. IF CRACK IS OPEN AND/OR "WORKING," ROUT, CLEAN, AND SEAL WITH JOINT SEALANT

LEGEND

——— LONGITUDINAL CONSTRUCTION JOINTS

– – – – CONTRACTION JOINTS

Figure 1. Approved methods for repair of uncontrolled cracks and spalls in rigid pavements—continued.

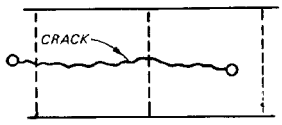


CONDITION 5

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

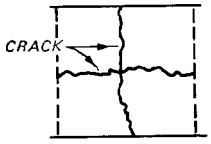
b. IF CRACK IS OPEN AND "WORKING": DRILL 4 TO 6 INCH DIAMETER CORE HOLES AT EACH END OF CRACK, FILL HOLES WITH EPOXY RESIN CONCRETE TO PREVENT PROGRESSION OF CRACK. ROUT, CLEAN, AND SEAL CRACK WITH JOINT SEALANT.

LEGEND

——— LONGITUDINAL CONSTRUCTION JOINTS

– – – – CONTRACTION JOINT

Figure 1. Approved methods for repair of uncontrolled cracks and spalls in rigid pavements—continued.



CONDITION 7

a. MULTIPLE CRACKS IN ONE SLAB. EITHER TRANSVERSE OR LONGITUDINAL CRACK OR BOTH, CRACKS NOT "WORKING"

b. MULTIPLE CRACKS IN ONE SLAB. ALL CRACKS "WORKING" AND FULL DEPTH OF PAVEMENT

REPAIR METHOD

a. IF CRACKS ARE TIGHT AND NOT "WORKING," NO REPAIR REQUIRED

b. REMOVE AND REPLACE FULL SLAB; AN INTERIM REPAIR METHOD IS TO ROUT AND SEAL CRACKS.

LEGEND

——— LONGITUDINAL CONSTRUCTION JOINT

– – – – CONTRACTION JOINT

Figure 1. Approved methods for repair of uncontrolled cracks and spalls in rigid pavements—continued.

Purchase this course to see the remainder of the technical materials.