Repairing cracks

A summary of repair methods for active and dormant cracks

This summary of crack repair methods tells what kind of cracks can be repaired with each of the following procedures:

- Epoxy injection
- Routing and sealing
- Stitching
- Adding reinforcement
- Drilling and plugging
- Flexible sealing
- Grouting
- Polymer impregnation
- Overlays and surface treatments
- High-molecular-weight methacrylates

To be successful, crack repair procedures must be based on the cause of the cracking and the present condition of the crack. If the cracking was primarily due to drying shrinkage, then it is likely that the cracks will eventually stabilize. However, if the cracks are due to continuing foundation settlement or other structural changes, they will continue to grow. Some of the following repair procedures will work with "active" or moving cracks. Others are recommended only for "dormant" cracks.

Epoxy injection

Epoxy injection can be used to restore structural soundness of buildings, bridges, and dams where cracks are dormant or can be prevented from moving further. Cracks as narrow as 0.002 inch can be bonded by the injection of epoxy. The technique generally involves drilling holes at close intervals along the cracks, in some cases installing entry ports, and injecting the epoxy under pressure.

Except for certain specialized epoxies, the method cannot be used if the cracks are leaking. While moist cracks can be injected, water or other contaminants in the crack will reduce the effectiveness of the epoxy repair. The basic steps needed in epoxy injection are:

1. **Clean the cracks.** Remove any contamination by flushing with water or a special solvent. Then blow out the solvent with compressed air, or allow adequate time for air-drying.

2. **Seal the surface.** This keeps the epoxy from leaking out before it has gelled. A surface can be sealed by brushing an epoxy over the surface of the crack and allowing it to harden. If extremely high injection pressures are needed, cut out the crack in a V shape, fill with an epoxy, and strike off flush with the surface.

3. **Install the entry ports.** There are three ways to do this:

- *Fittings inserted in drilled holes* — Drill a hole into the crack, penetrating below the bottom of the V-grooved section. Insert a fitting such as a pipe nipple or tire valve stem into the hole and bond with an epoxy adhesive. A vacuum chuck and bits will help keep the cracks from being plugged with drilling dust.
- *Bonded flush fitting* — When the cracks are not V-grooved, a common method of providing an entry port is to bond a fitting flush with the concrete face over the crack.
- *Interruption in seal* — Another way to allow entry is to omit the seal from part of the crack. This method uses special gasket devices that cover the unsealed portion of the crack and allow injection of the adhesive directly into the crack.

4. **Mix the epoxy.** In batch mixing, the adhesive components are premixed according to the manufacturer's instructions, usually with a mechanical stirrer like a paint mixing paddle. In the continuous mixing system, the two liquid adhesive components pass through metering and driving pumps before passing through an automatic mixing head. The continuous method allows the use of fast-setting adhesives that have a short working life.

5. **Inject the epoxy.** Hydraulic pumps, paint pressure pots, or air-actuated caulking guns can be used. Select the pressure carefully because too much pressure can

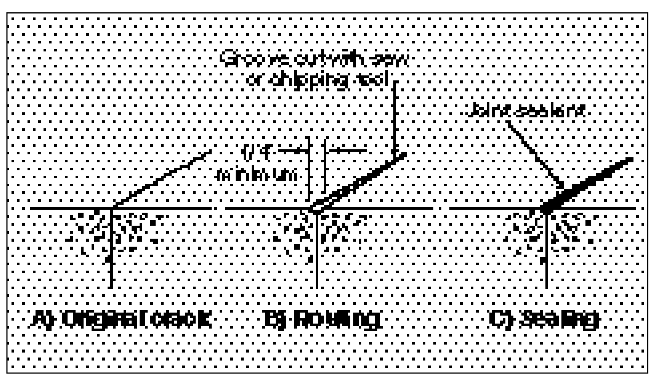

Figure 1. *Routing and sealing is a suitable repair method for cracks that are dormant and not structurally significant. Routing and cleaning before installing the sealant add significantly to the life of the repair.*

extend the existing cracks and cause more damage.

For vertical cracks, start by pumping epoxy into the entry port at the lowest elevation until the epoxy level reaches the entry port above. Then cap the lower injection port and repeat the process at successively higher ports until the crack has been completely filled. For horizontal cracks, go from one end of the crack to the other in the same way. When the pressure can be maintained, you will know the crack is full.

6. **Remove the surface seal.** After the injected epoxy has cured, remove the surface seal by grinding or some other appropriate means. Fittings and holes at entry ports should be painted with an epoxy patching compound.

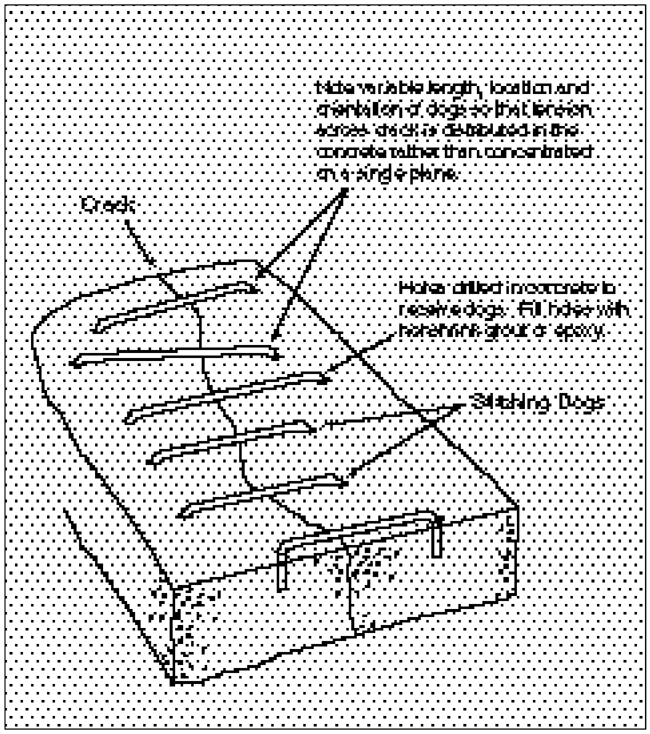

Figure 2. *Stitching restores tensile strength across major cracks. Where there is a water problem, cracks should be made watertight first to protect the stitching dogs from corrosion.*

Routing and sealing

The simplest and most common crack repair—routing and sealing—works on cracks that are dormant and of no structural significance. This method involves enlarging the crack along its exposed face and filling and sealing it with a suitable joint sealant (Figure 1). The routing may be omitted, but the repair won't last as long. Relatively untrained workers can handle this method, and it is good for sealing both fine pattern cracks and larger isolated defects.

Don't expect routing and sealing to work on active cracks or cracks subject to strong hydrostatic pressure, except when sealing the pressure face, in which case some reduction in the flow can be obtained.

Clean the surface of the routed joint with an air jet and let it dry before placing the sealant. The purpose of the sealant is to keep water from reaching the reinforcing steel; to stop hydrostatic pressure from developing within the joint; or to prevent staining the concrete surface and get rid of moisture problems on the far side of the member.

Choice of sealant depends on how tight or permanent a seal is desired. Epoxy compounds are often used. Hot-poured joint sealants work well when thorough water tightness of the joint is not required and appearance is not important. Urethanes, which remain flexible through large temperature variations, have been used successfully in cracks up to ¾ inch wide and of considerable depth.

Stitching

This method involves drilling holes on both sides of the crack and grouting in U-shaped metal units with short legs (called *stitching dogs*) that span the crack (Figure 2). Stitching is suitable when tensile strength must be reestablished across major cracks. Use either a shrinkage-compensating grout or an epoxy resin-based bonding system to anchor the legs of the dogs.

Stitching will not close a crack but can prevent it from spreading. Where there is a water problem, the crack should be sealed watertight before stitching to protect the dogs from corrosion.

Adding reinforcement

Conventional reinforcement— Cracked reinforced concrete bridge girders have been successfully repaired by inserting reinforcing bars to supplement epoxy injection. First the crack is sealed, then holes are drilled across the crack plane at about 90 degrees (Figure 3). Both the holes and crack planes are filled with epoxy pumped under low pressure (50 to 80 psi), and reinforcing bars are placed in the drilled holes. The epoxy bonds the cracked surfaces back together and anchors the bars.

This method calls for a temporary elastic exterior crack sealant. Gel-type epoxy crack sealants work well within their elastic limits. Silicone rubber gap sealants also work well and are especially attractive in cold weather or when time is short.

The epoxy used to rebond the crack should have a very low viscosity and a high modulus of elasticity. It should be able to bond to concrete in the presence of moisture, and it should be 100% reactive.

External prestressing—Post-tensioning is often a good solution when a major portion of a member must be straightened or when cracks must be closed (Figure 4). Prestressing strands or bars are used to apply compressive force to the ailing

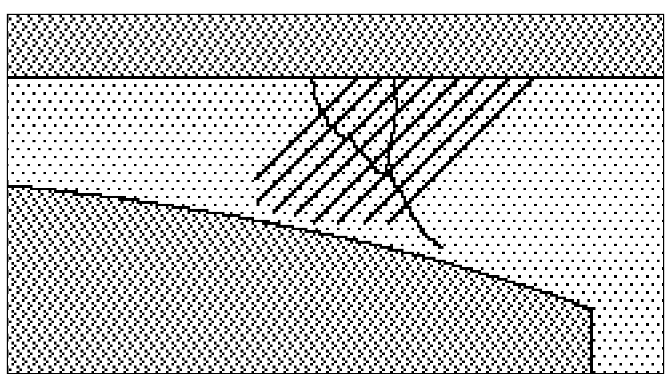

Figure 3. *Reinforcement added to strengthen member. Holes are drilled at right angles to the crack, then filled with epoxy before bars are inserted.*

member. This calls for adequate anchorage for the prestressing steel, and analysis of the effect of the tensioning force and eccentricity of stresses in the structure.

Drilling and plugging

Drilling and plugging is a method useful for vertical cracks in retaining walls. It consists of drilling down the length of the crack and grouting it to form a key (Figure 5). This can be done only when cracks run in reasonably straight lines and are accessible at one end. The hole must be large enough to intersect the crack along its full length and provide enough repair material to structurally resist shear loads on the key. The key will also reduce heavy leakage through the crack and loss of soil from behind a leaking wall.

Flexible sealing

Active cracks can be routed out; cleaned by sandblast, air-water jet, or both; and filled with a suitable field-molded flexible sealant. The slot or groove for the sealant should have a suitable width and shape factor for the expected movement. Follow the ACI recommendations for joints (Ref. 1) to select a suitable sealant and installation method.

Where appearance is not important, active cracks not subject to traffic or mechanical abuse may be sealed with a flexible surface seal (Figure 6). Using a bond breaker over the crack permits movement, and the flexible joint sealant is troweled on top, bonding to adjoining concrete.

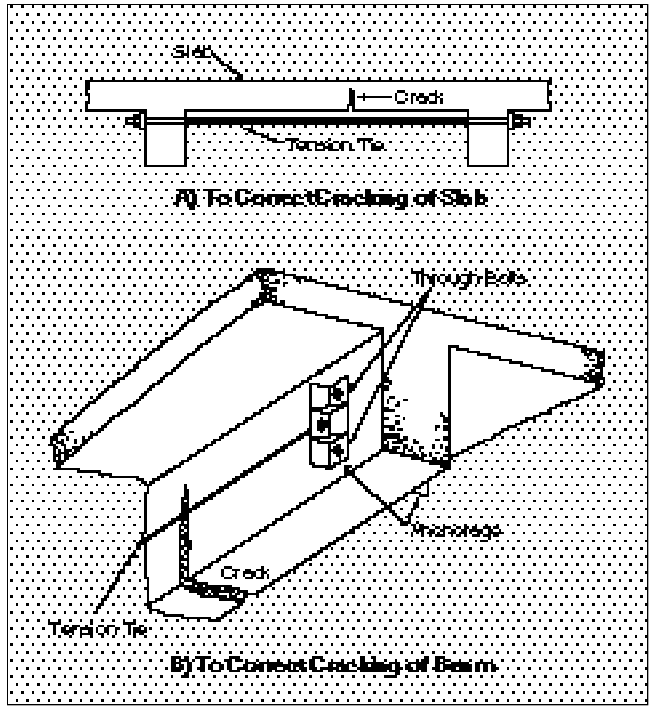

Figure 4. *External prestressing can close cracks and restore structural strength. Careful analysis of the effects of the tensioning force must be made or the crack may migrate to another position.*

Portland cement or chemical grouting

Wide cracks, particularly in gravity dams and thick concrete walls, may be filled with portland cement grout. The procedure consists of cleaning the concrete along the crack; installing grout nipples at intervals and sealing the crack between the nipples with a cement paint, sealant, or grout; flushing the grout to clean it and test the seal; and then pumping the grout. The grout is a mixture of cement and water or cement plus sand and water, depending on the width of the crack. Water reducers or other admixtures may be used to improve the properties of the grout. After the crack is filled, the pump pressure should be maintained for several minutes to ensure good penetration.

Narrow cracks may be filled with chemical grouts consisting of solutions of chemicals that combine to form a gel, a solid precipitate, or a foam. Concrete cracks as narrow as 0.002 inch have been filled with chemical grout.

Chemical grouts can be used in very fine fractures, in moist environments, with wide limits of control of gel time. However, they have disadvantages: the high degree of skill needed for satisfactory use, their lack of strength, and the requirement that the grout does not dry out in service.

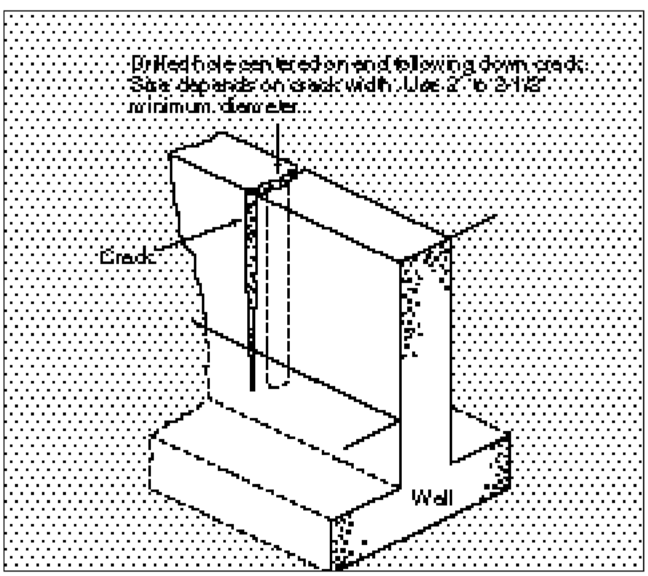

Figure 5. *Drilling and plugging is a repair method well suited to vertical cracks in retaining walls. The repair material becomes a structural key to resist loads and prevent leakage through the crack.*

Polymer impregnation

A monomer system is a liquid that consists of small organic molecules capable of combining to form a solid plastic. These monomers vary in volatility, toxicity, and flammability, and they do not mix with water. However, they are very fluid and will soak into dry concrete, filling cracks much the same way as water does.

Monomer systems used for impregnation contain a catalyst or initiator and the basic monomer (or combination of monomers). They may also contain a cross-linking agent. When heated, the monomers join together, or polymerize, becoming a tough, strong, durable plastic that greatly enhances a number of concrete properties.

If a cracked concrete surface is dried, flooded with the monomer, and polymerized in place, the cracks will

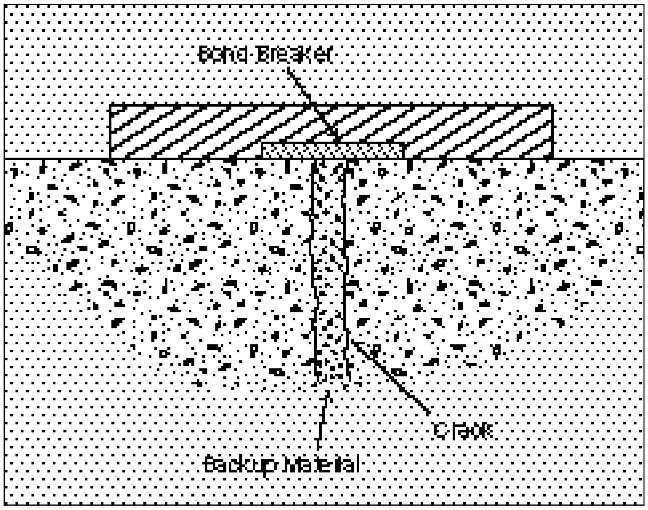

Figure 6. *Flexible surface sealant can be used over narrow cracks subject to movement, if appearance is not a consideration. Note bond breaker over the crack itself.*

be filled and structurally repaired. However, if the cracks contain moisture, the monomer will not soak into the concrete at each crack face, and consequently the repair will be unsatisfactory. If a volatile monomer evaporates before polymerization, it will be ineffective. Polymer impregnation has not been successful in repairing fine cracks.

Badly fractured beams have been repaired using polymer impregnation by drying the fracture, temporarily encasing it in a watertight, monomer-proof band of sheet metal, soaking the fracture with monomer, and polymerizing the monomer. Large voids or broken areas in compression zones can be filled with fine and coarse aggregate before doing a polymer repair. For a more detailed discussion of polymers, see Ref. 2.

Overlays

Most cracks in slabs are subject to movement caused by variations in loading, temperature, and moisture. These cracks will reflect through any *bonded* overlay, defeating the purpose insofar as crack repair is concerned. *Unbonded* overlays can be used to cover slabs with moving cracks.

Slabs and decks containing fine dormant cracks can be repaired by applying a bonded overlay of latex-modified portland cement concrete or mortar. In highway bridge applications, a minimum overlay thickness of 1½ inches has been used successfully.

Prior to overlay application, the surface should be cleaned to remove laitance, carbonation, or contaminants such as grease or oil. A bond coat of broomed latex mortar or an epoxy adhesive should be applied immediately before placing the overlay. Since latex mixtures normally solidify rapidly, continuous batching and mixing equipment is needed.

Surface treatments

Slabs on grade in freezing climates should never receive a surface treatment that acts as a vapor barrier. This would cause moisture passing from the subgrade to condense under the barrier, leading to critical saturation of the concrete and rapid disintegration by freezing and thawing.

Bridge and parking decks and interior slabs (not on-grade) may be effectively coated using a heavy coat of epoxy resin. This treatment should include broadcasting of aggregate on the uncured resin as specified in ACI 503.3 (Ref. 3). Suitable epoxy resin systems are covered by ASTM C 881 Type III, viscosity Grade I or II (Ref. 4). This method will close dormant fine cracks. Even if the skid-resistant aggregate is abraded away, traffic cannot abrade the resin that has penetrated the cracks.

High-molecular-weight methacrylates

Horizontal concrete surfaces can be sealed and tight cracks repaired by soaking them with a high-molecular-weight catalyzed methacrylate monomer. When in solution, this material has a viscosity slightly greater than water. It is absorbed into pores and penetrates fine cracks. The procedure, while effective for dry concrete, has reduced effectiveness for wet concrete.

Wait until the concrete has cured at least a week and has had a chance to air-dry before applying the material. Air-drying is also necessary after rainfall. Using a broom and squeegee, apply enough material to absorb into the cracks and surface, but not to leave an excess on the surface where it may polymerize into shiny splotchy areas. But if they do appear, these areas can be removed later by sanding or grinding, if necessary.

Time, heat, and ultraviolet radiation affect the rate of polymerization. In shaded areas at 70° F, most monomer formulations become tack-free in about a day. Gel time and rate of polymerization can be adjusted somewhat by adjusting the promoter and initiator quantity.

References

1. "Guide to Joint Sealants for Concrete Structures (ACI 504R-90)," American Concrete Institute, Box 19150, Detroit, MI 48219.

2. "Guide for the Use of Polymers in Concrete (ACI 548.1R-86)," ACI.

3. "Standard Specification for Producing a Skid-resistant Surface on Concrete by the Use of a Multi-component Epoxy System (ACI 503.3-79)," ACI.

4. "Standard Specification for Epoxy-resin-base Bonding Systems for Concrete (ASTM C881-90)," ASTM, 1916 Race Street, Philadelphia, PA 19103.

Acknowledgment

This article is condensed from "Causes, Evaluation, and Repair of Cracks in Concrete Structures," reported by ACI Committee 224 in the *ACI Manual of Concrete Practice,* 1991. The reader is referred to the complete report for a more detailed explanation of crack repair methods.

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