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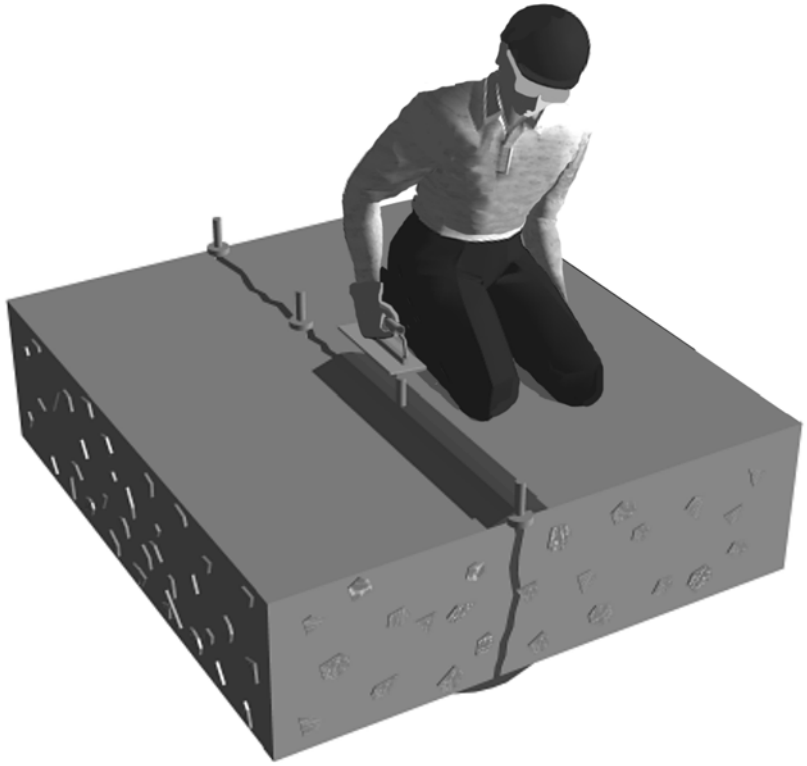
*ACI RAP Bulletin 1*

FIELD GUIDE TO
CONCRETE REPAIR
APPLICATION PROCEDURES

# Structural Crack Repair by Epoxy Injection



**ACI RAP Bulletin 1**
**(Reapproved 2009)**

# Field Guide to Concrete Repair Application Procedures

# Structural Crack Repair by Epoxy Injection

Reported by ACI Committee E706

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ACI Repair Application Procedure 1.

## Introduction

Certain things in life are inevitable. Some are said to include death, taxes, and concrete cracks! The latter is subject to volumes of literature on causes and cures. Some of the more typical causes for concrete cracking include:

- Drying shrinkage;
- Thermal contraction or expansion;
- Settlement;
- Lack of appropriate control joints;
- Overload conditions that produce flexural, tensile, or shear cracks in concrete; and
- Restraint of movement

One of the potentially effective repair procedures is to inject epoxy under pressure into the cracks. The injection procedure will vary, subject to the application and location of the crack(s), with horizontal, vertical, and overhead cracks requiring somewhat different approaches. The approach used must also consider accessibility to the cracked surface and the size of the crack.

Cracks can be injected from one or both sides of a concrete member. If access is limited to only one side, installation procedures may include variations in epoxy viscosities, injection equipment, injection pressure, and port spacing to ensure full penetration of epoxy into the crack.

Depending on the specific requirements of the job, crack repair by epoxy injection can restore structural integrity and reduce moisture penetration through concrete cracks 0.002 in. (0.05 mm) in width and greater. However, before any concrete repair is carried out, the cause of the damage must be assessed and corrected and the objective of the repair understood. If the crack is subject to subsequent movement, an epoxy repair may not be applicable.

**Note:** Horizontal cracks of sufficient width can be filled by gravity-fed epoxies where suitable for the repair (See Crack Repair by Gravity Feed with Resin, RAP-2).

## What is the purpose of this repair?

The primary objective for this type of repair is to restore the structural integrity and the resistance to moisture penetration of the concrete element.

## When do I use this method?

Injection is typically used on horizontal, vertical, and overhead cracks where conventional repair methods cannot penetrate and deliver the specific repair product into the crack.

Prior to proceeding with a crack repair by epoxy injection, the cause of the crack and the need for a structural repair must be determined. If the crack does not compromise the structural integrity of the structure, injection with polyurethane grouts or other nonstructural materials may be a more suitable choice to fill the crack. When a structural repair is required, conditions that cause the crack must be corrected prior to proceeding with the epoxy injection. If the crack is damp and cannot be dried out, an epoxy tolerant to moisture should be considered. Cracks caused by corroding reinforcing steel should not be repaired by epoxy injection because continuing corrosion will cause new cracks to appear.

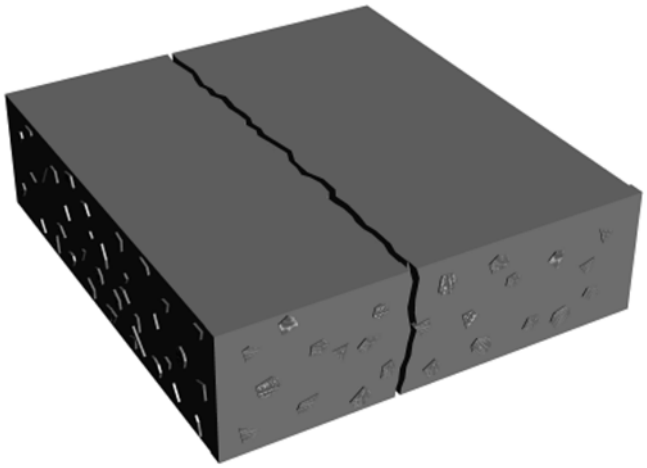

*Fig. 1—Cracks must be clean and free of debris.*

## How do I prepare the surface? (see Fig. 1)

Clean the surface area about 1/2 in. (13 mm) wide on each side of the crack. This is done to ensure that materials used to seal the top of the crack (the cap seal) will bond properly to the concrete. Wire brushing is recommended because mechanical grinders may fill the cracks with unwanted dust. Contaminants can also be removed by high-pressure water, "oil-free" compressed air, or power vacuums. When using water to clean out the crack, blow out the crack with oil-free, compressed or heated air to accelerate drying. Otherwise, allow enough time for natural drying to occur before injecting moisture-sensitive epoxies.

Where concrete surfaces adjacent to the crack are deteriorated, "V"-groove the crack until sound concrete is reached. "V" grooves can also be used when high injection pressures require a stronger cap seal.

## How do I select the right material?

The appropriate viscosity of the epoxy will depend on the crack size, thickness of the concrete section, and injection access. For crack widths 0.010 in. (0.3 mm) or smaller, use a low-viscosity epoxy (500 cps or less). For wider cracks, or where injection access is limited to one side, a medium to gel viscosity material may be more suitable.

ASTM C 881, "Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete," identifies the basic criteria for selecting the grade and class of epoxies (see Table 1).

For concrete sections greater than 12 in. (305 mm), the working time may need to be increased, and the viscosity decreased, as the crack gets smaller.

In addition to the criteria used in Table 1 for epoxy selection, the following product characteristics may also have to be considered:

- Modulus of elasticity (rigidity);
- Working life;
- Moisture tolerance;
- Color; and
- Compressive, flexural, and tensile strengths.

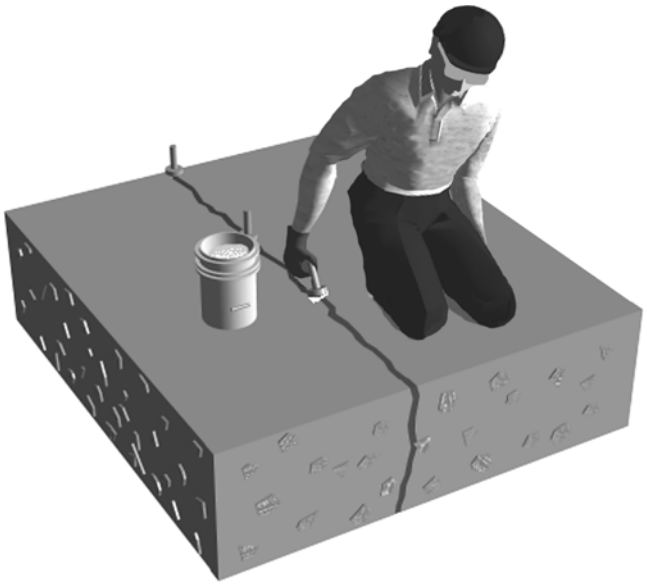

*Fig. 2—Installation of entry ports.*

## What equipment do I need?

Equipment for epoxy injection by high-pressure or low-pressure systems includes:

- Air guns;
- Hand-actuated delivery systems;
- Spring-actuated capsules; and
- Balloon-actuated capsules.

Determine the delivery method that will best suit the repair requirements by considering the size and complexity of the injection repair and the economic limitations of the project.

## What are the safety considerations?

Epoxy resins are hazardous materials and must be treated as such. Job-site safety practices should include, but not necessarily be limited to, the following:

- Having Material Safety Data Sheets (MSDS) available on site;
- Wearing protective clothing and protective eyewear where required;
- Wearing rubber gloves or barrier creams for hand protection;
- Having eye wash facilities available;
- Wearing respirators where needed;
- Providing ventilation of closed spaces;
- Secured storage of hazardous materials;
- Having necessary cleaning materials on hand; and
- Notifying occupants of pending repair procedures.

It is the responsibility of the user of this document to establish health and safety practices appropriate to the specific circumstances involved with its use. ACI does not make any representations with regard to health and safety issues and the use of this document. The user must determine the applicability of all regulatory limitations before applying the document and must comply with all applicable laws and regulations, including but not limited to, United States Occupational Safety and Health Administration (OSHA) health and safety standards.

**Table 1—ASTM C 881 requirements for epoxy resins that are used to bond hardened concrete to hardened concrete**

| | Type I* | Type IV† |
|---|---|---|
| Viscosity, centipoise | | |
| Grade 1 (low-viscosity), maximum | 2000 | 2000 |
| Grade 2 (medium-viscosity), minimum | 2000 | 2000 |
| Maximum | 10,000 | 10,000 |
| Consistency, in. | | |
| Grade 3 (non-sagging), maximum | 1/4 | 1/4 |
| Gel time, min. | 30 | 30 |
| Bond strength, minimum, psi | | |
| 2 days, moist cure‡ | 1000 | 1000 |
| 14 days, moist cure | 1500 | 1500 |
| Absorption, 24 h maximum, % | 1 | 1 |
| Heat deflection temperature | | |
| 7 days minimum, °F | — | 120 |
| Linear coefficient of shrinkage | | |
| On cure, maximum | 0.005 | 0.005 |
| Compressive yield strength | | |
| 7 days minimum, psi | 8000 | 10,000 |
| Compression modulus, minimum, psi | 150,000 | 200,000 |
| Tensile strength, 7 days minimum, psi | 5000 | 7000 |
| Elongation at break, minimum, % | 1 | 1 |

*Type I: for use in non-load-bearing applications.

†Type IV: for use in load-bearing applications.

Source: ASTM C 881, Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete.

‡Moist-cured systems should be tested by assembling the sections to be bonded before immersing in water.

## Preconstruction meeting

Prior to proceeding with the repair, a preconstruction meeting is recommended. The meeting should include representatives from all participating parties (owner, engineer, contractor, materials manufacturer, etc.) and specifically address the parameters, means, methods, final appearance, and materials necessary to achieve the repair objectives.

## Repair procedure

*1. Port installation (see Fig. 2).*

Install the entry ports only after proper surface preparation. Two types of entry ports are available for the injection process:

- Surface-mounted; or
- Socket-mounted.

Entry ports (also called port adapters) can be any tubelike device that provides for the successful transfer of the epoxy resin under pressure into the crack. Proprietary injection guns with special gasketed nozzles are also available for use without port adaptors. Port spacing is typically 8 in. (40 mm) on center, with increased spacing at wider cracks. Port spacing may also be a function of the thickness of the concrete element. Surface-mounted entry ports are normally adequate for most cracks, but socket-mounted ports are used when cracks are blocked, such as when calcified concrete is encountered. Entry ports can also be connected by a manifold system when simultaneous injection of multiple port locations is advantageous.

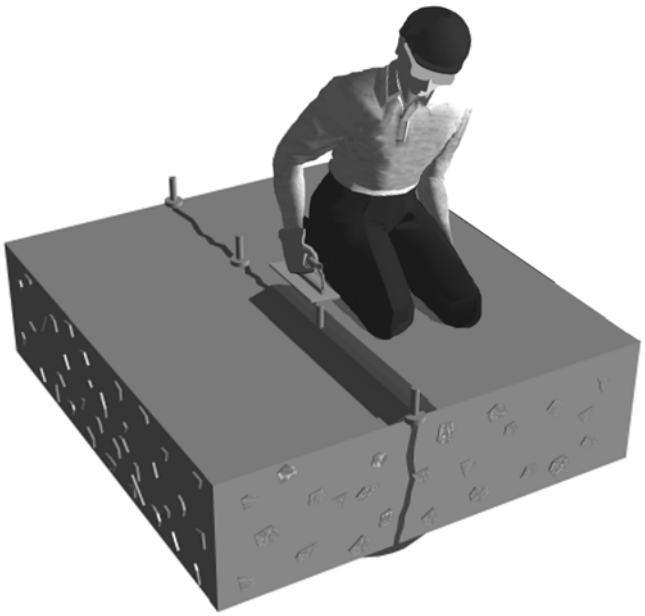

*Fig. 3—Installation of seal cap.*

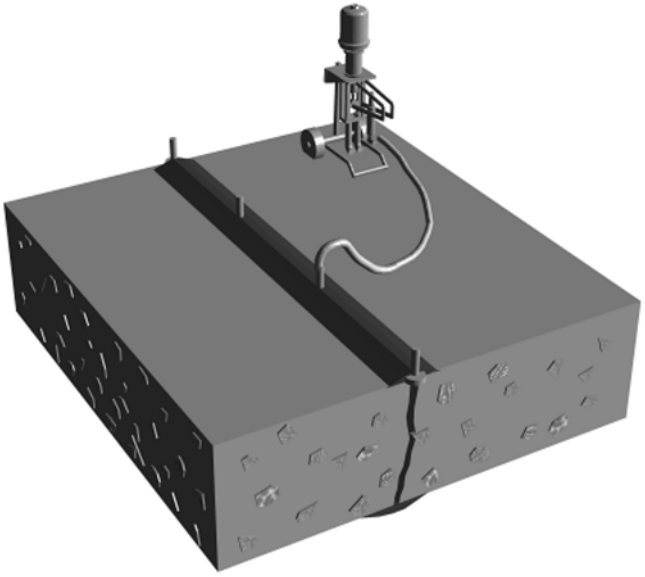

*Fig. 4—Start injection at widest segment of the crack.*

*2. Install the cap seal (see Fig. 3).*

Properly installed, the cap seal contains the epoxy as it is injected under pressure into the crack. When cracks penetrate completely through a section, cap seals perform best when installed on both sides of the cracked element, ensuring containment of the epoxy. Cap seals have been successfully installed using epoxies, polyesters, paraffin wax, and silicone caulk. The selection of the cap seal material should consider the following criteria, subject to the type of crack to be repaired:

- Non-sag consistency (for vertical or overhead);
- Moisture-tolerance;
- Working life; and
- Rigidity (modulus of elasticity).

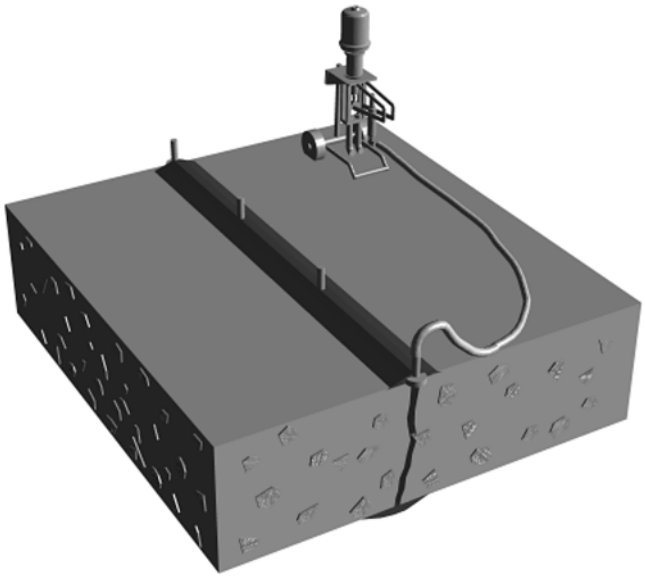

*Fig. 5—Continue injection until refusal.*

Concrete temperature changes after installation of the cap seal but prior to injection may cause the cap seal to crack. If this occurs, the cap seal must be repaired prior to resin injection.

Prior to proceeding with installation of the cap seal, mark the location of the widest portion of the crack and pay close attention to the following:

- Use only materials that haven't exceeded their shelf life;
- Accurate batching of components;
- Small batches to keep material fresh, and dissipate heat;
- Port spacing; and
- Consistent application of the material (1 in. wide x 3/16 in. thick [25 x 5 mm]) over the length of the crack.

*3. Inject the epoxy (see Fig. 4 and 5).*

For a successful epoxy injection, start with the proper batching and mixing of the epoxy components in strict accordance with the manufacturer's requirements. Prior to starting the actual injection, be sure that the cap seal and port adapter adhesive have properly cured so they can sustain the injection pressures.

Start the injection at the widest section of a horizontal crack. (Be sure to locate and mark these areas before installing the cap seal.) Vertical cracks are typically injected from the bottom up.

Continue the injection until refusal. If an adjacent port starts bleeding, cap the port being injected and continue injection at the furthest bleeding port. Hairline cracks are sometimes not well suited to "pumping to refusal." In those cases, try injecting the epoxy at increased pressure (approximately 200 psi [1.3 MPa]) for 5 min. Closer port spacing can also be considered. When injection into a port is complete, cap it immediately. Higher pressure can be used for injecting very narrow cracks or increasing the rate of injection. However, the use of higher pressure should be managed with care to prevent a blowout of the cap seal or ports.

*4. Remove ports and cap seal (see Fig. 6).*

Upon completion of the injection process, remove the ports and cap seal by heat, chipping, or grinding. If the appearance is not objectionable to the client, the cap seal can

*Fig. 6—Remove seal cap.*

be left in place. If complete removal is required for a subsequent application of a cosmetic coating, prepare the concrete surface by grinding.

### How do I check the repair?

To ensure that the injection has been successful, quality assurance measures may include test cores or nondestructive evaluation (NDE).

*1. Test cores:*

- Core locations should be chosen to avoid cutting reinforcing steel, drilling cores in areas of high stress, or creating core holes below the waterline. The engineer should determine core locations when these types of conditions exist;
- Be sure the epoxy has set before extracting a core;
- Take cores (normally 2 in. [50 mm] diameter) to check that the penetration of the epoxy is adequate;
- Inspect the core visually to determine the penetration of the epoxy into the crack;
- Cores can be further tested for compressive and split tensile strength per ASTM C 42; and
- Subsequently, patch the removed-core area (after proper surface preparation) with an expansive cementitious or epoxy grout compatible with the existing substrate concrete and the surrounding environment.

*2. Methods for nondestructive evaluation:*

- Impact echo (IE);
- Ultrasonic pulse velocity (UPV); and
- Spectral analysis of surface waves (SASW).

### Sources for additional information


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