ACI RAP 1
STRUCTURAL CRACK REPAIR BY EPOXY INJECTION

OCTOBER 16, 2018

SCOTT DISTEFANO

BUILDING TRUST

AGENDA

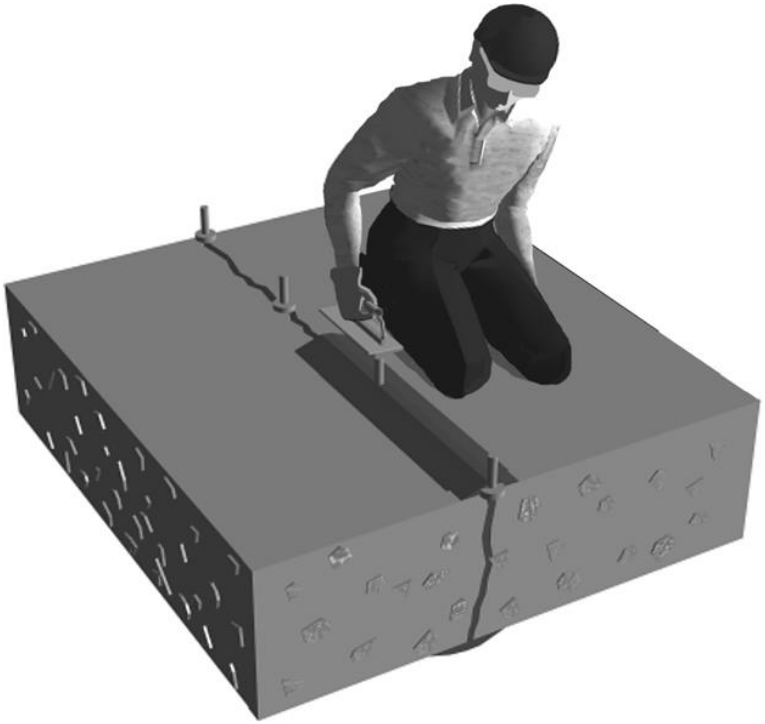
- Introduction
- Purpose of Repair
- When to Use
- Proper Preparation
- Selecting Materials
- Equipment
- Safety
- Repair Procedure
- Evaluation

INTRODUCTION

- Life, Death, Taxes and Cracks!

FIELD GUIDE TO
CONCRETE REPAIR
APPLICATION PROCEDURES

Structural Crack Repair by Epoxy Injection

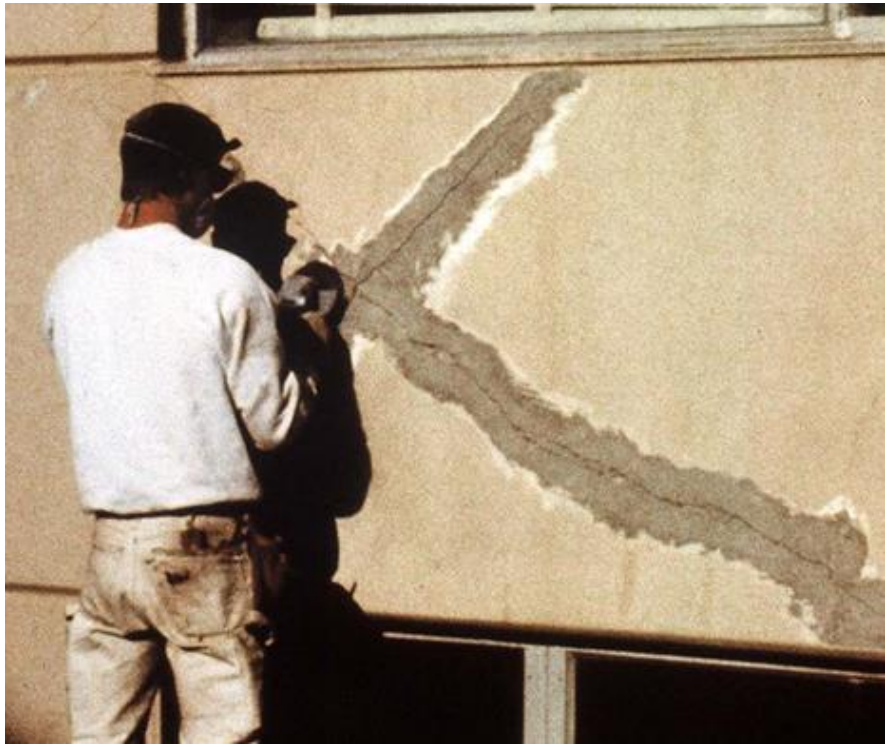


INTRODUCTION

- Causes may include:
  - Drying shrinkage;
  - Thermal contraction or expansion;
  - Settlement;
  - Lack of appropriate control joints;
  - Overload conditions that produce flexural, tensile, or
  - Shear cracks in concrete
  - Restraint of movement

PURPOSE OF REPAIR

- Restore structural integrity
- Resist moisture penetration (0.002 in. width and greater)



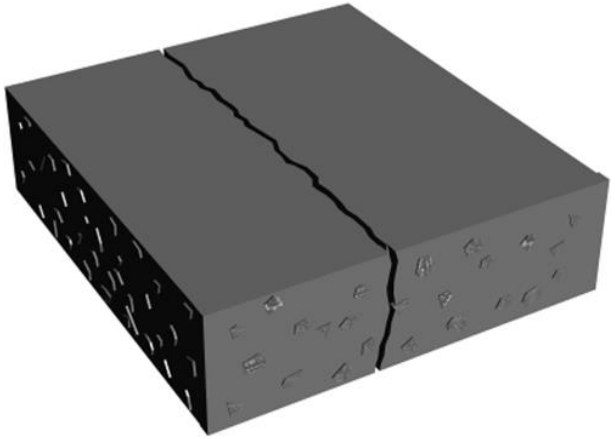
WHEN TO USE INJECTION METHOD

- Horizontal, Vertical & Overhead
- Must determine:
  - Cause
  - Need

Vertical Cracks

Horizontal Cracks

PROPER SURFACE PREPARATION



- ½” wide on each side
- Wire brush
  - Grinders may fill crack with dust
- Pressure washer
  - Allow to dry
  - Moisture tolerant epoxy
- Compressed Air (oil free)
- Power Vacuums

- “V” groove or notch

PROPER SURFACE PREPARATION

SELECTING THE CORRECT MATERIALS

- Viscosity is very important
  - Width 0.010” or smaller = 500 cps or less
    - Water = 1 cps
    - Syrup = 3000 cps
  - Larger cracks may use higher medium to gel viscosity

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SELECTING THE CORRECT MATERIALS

- ASTM C881 identifies basic criteria
- Concrete >12” may require
  - Increased working time
  - Lower viscosity
  - Depending on width
- Other considerations include:
  - Modulus of elasticity (rigidity);
  - Working life;
  - Moisture tolerance;
  - Color
  - Compressive, flexural, and tensile strengths.

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.

PROPER EQUIPMENT

- High & Low pressure is acceptable
  - Injection ports
  - Wire brush
  - Air guns;
  - Hand-actuated delivery systems;
  - Spring-actuated capsules
  - Balloon-actuated capsules.

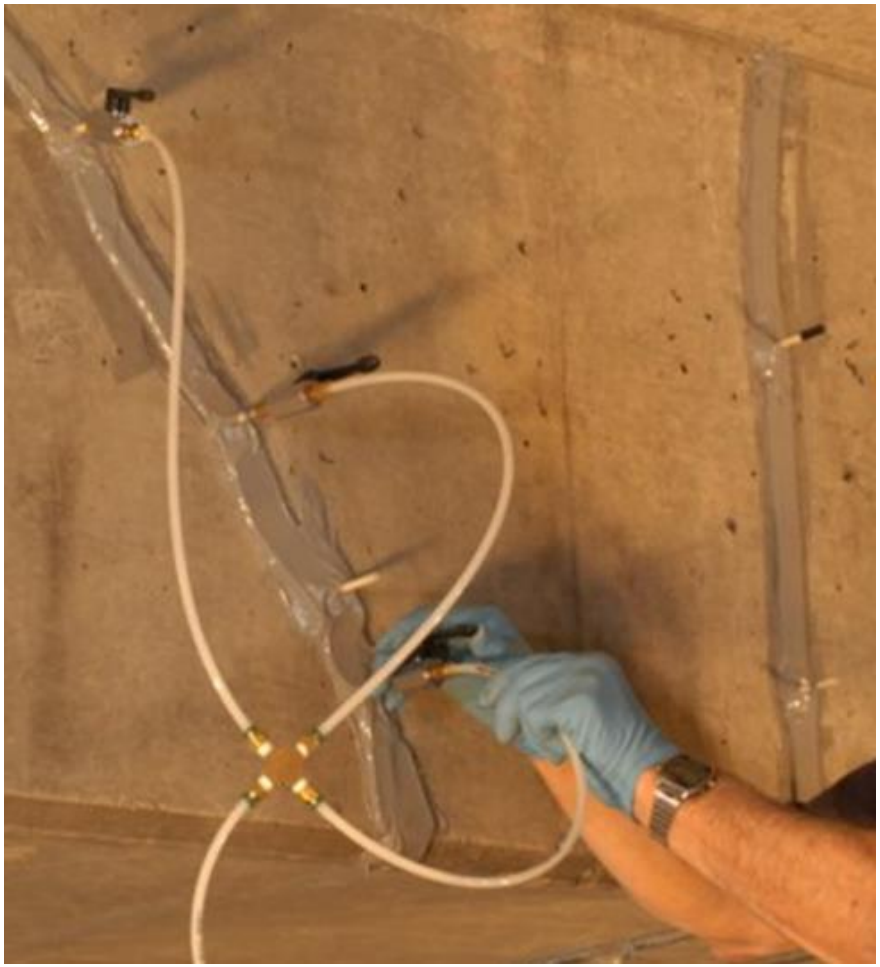
SAFETY CONSIDERATION

- User must document safety practices:
  - Having Material Safety Data Sheets (MSDS) available on site;
  - Wearing protective clothing and protective eyewear
  - 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.

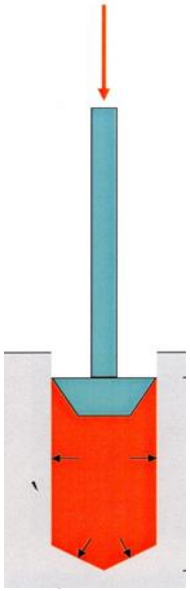
REPAIR PROCEDURE

1. Port Installation

- Surface mounter or Socket
- May be connected with manifold

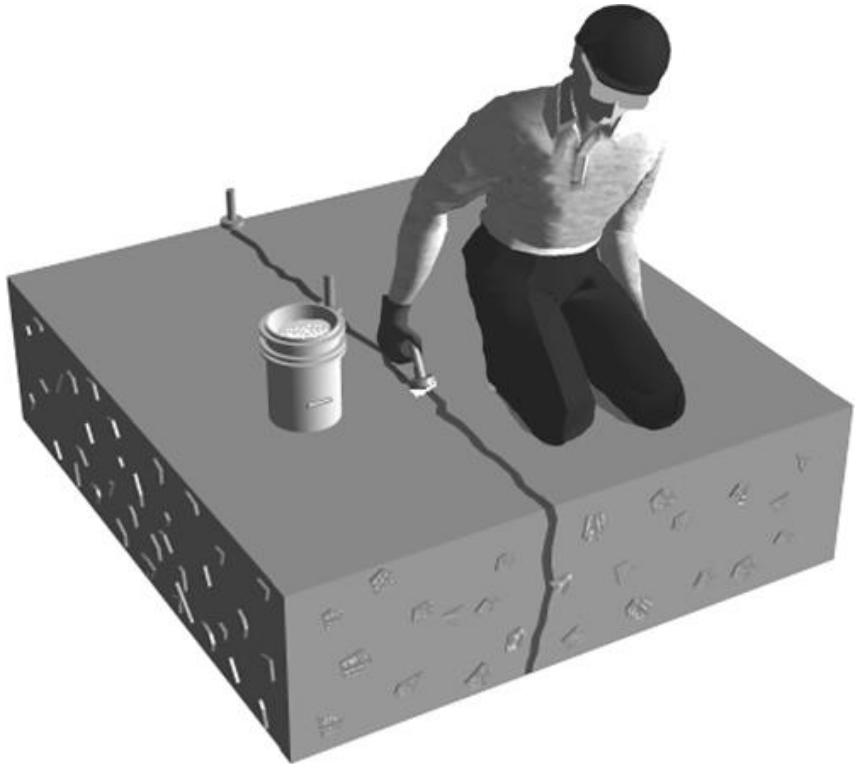


- How far apart do we space ports?



REPAIR PROCEDURE

1. Port Installation



- Surface mounter or Socket
- May be connected with manifold

- How far apart do we space ports?

As far apart as possible

but no closer than 6”

(we can assume a 3” travel of resin in direction).

On Average 8”

Thinned slabs may allow for 12”

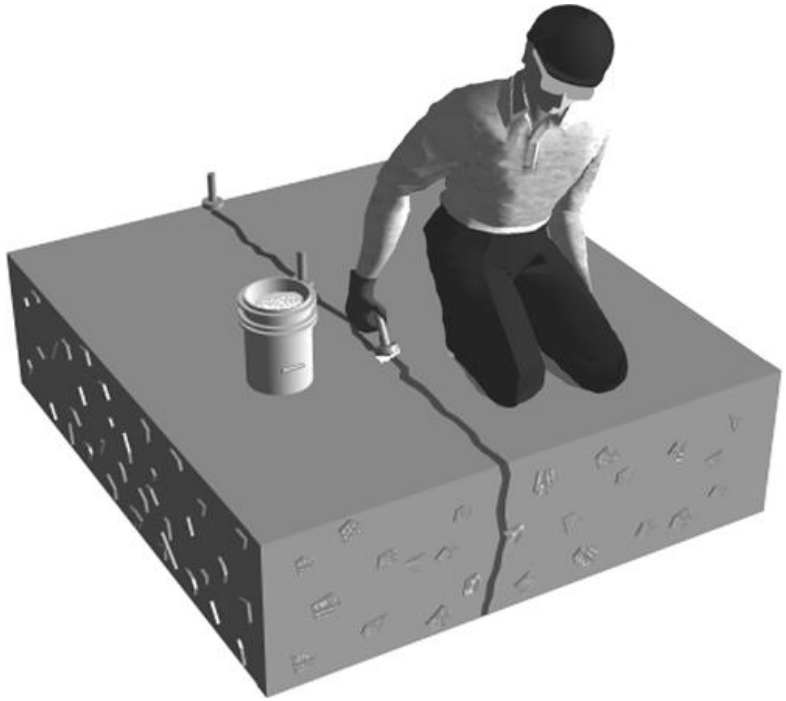
REPAIR PROCEDURE

1. Port Installation

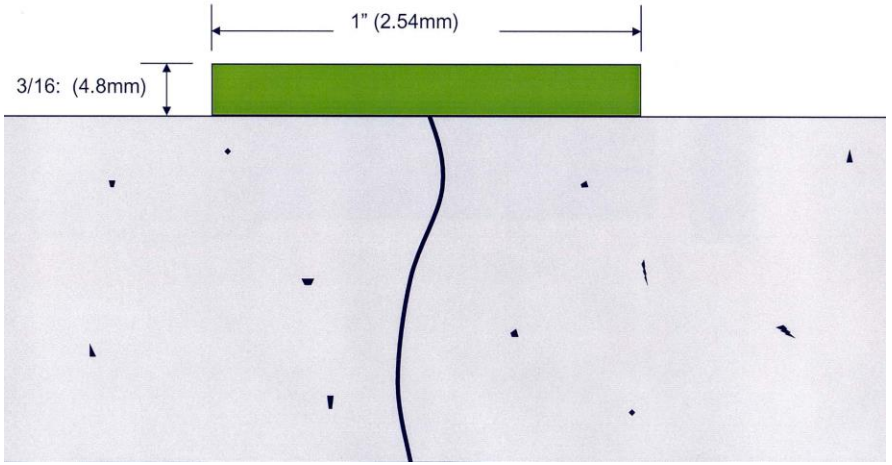
REPAIR PROCEDURE

2. Install the Capseal

- Must install on both sides of crack
- “More is better”
- Material Selection Criteria:
  - Non-sag consistency (for vertical or overhead)
  - Moisture-tolerance
  - Working life
  - Rigidity (modulus of elasticity).



The ideal cap profile.



REPAIR PROCEDURE

2. Install the Capseal

- Mark largest portion of crack
- Pay close attention to:
  - 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
  - Consistent application of the material (1 in. wide x 3/16 in. thick [25 x 5 mm]) over the length of the crack.

REPAIR PROCEDURE

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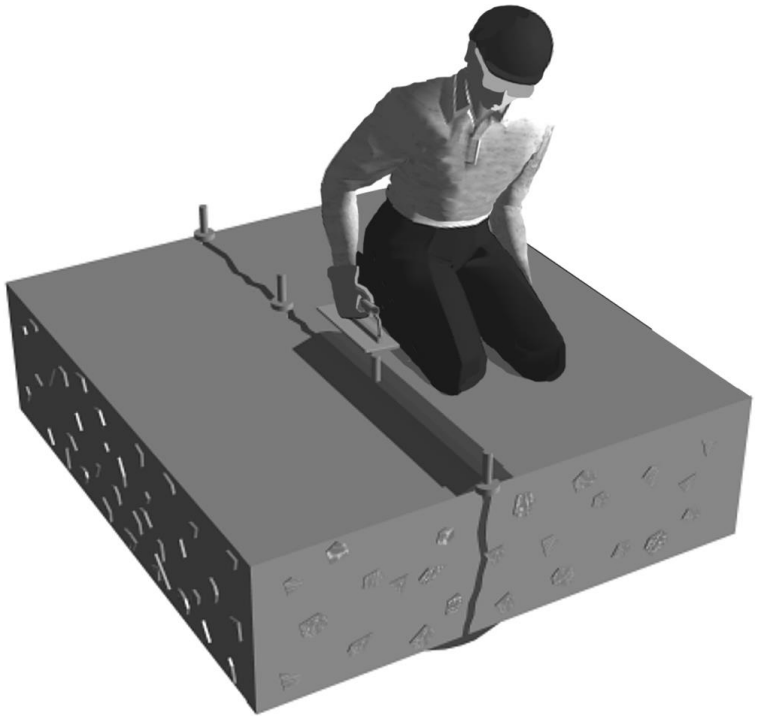

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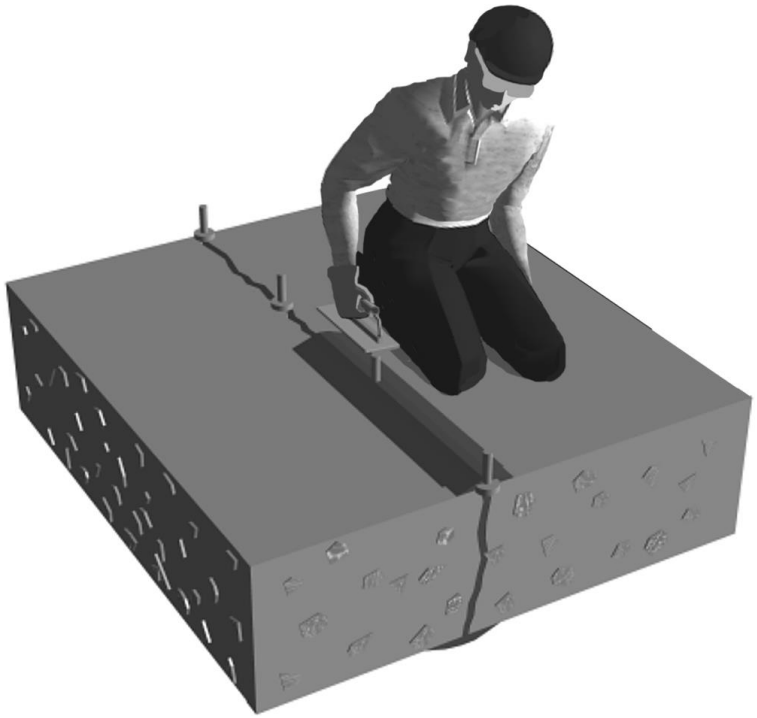
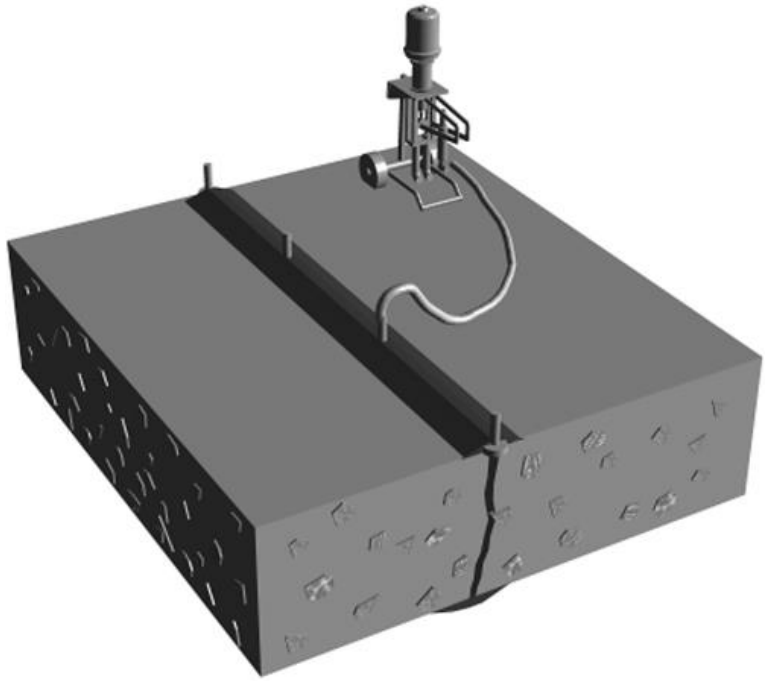
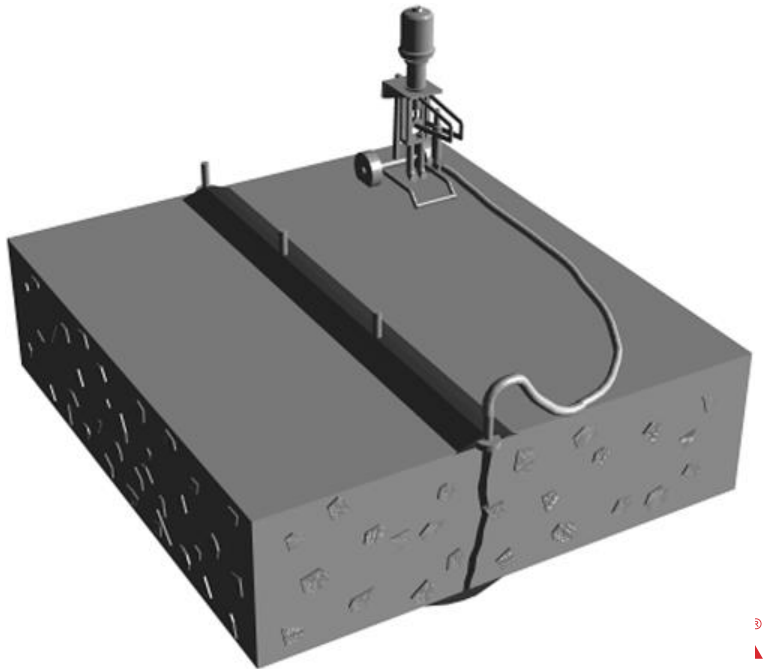


REPAIR PROCEDURE

3. Inject the Epoxy

- Double check cap seal and ports
- Mix epoxy according to manufacturer
- For horizontal – start at widest point
- For vertical – start from bottom
- Continue until refusal, cap immediately





REPAIR PROCEDURE

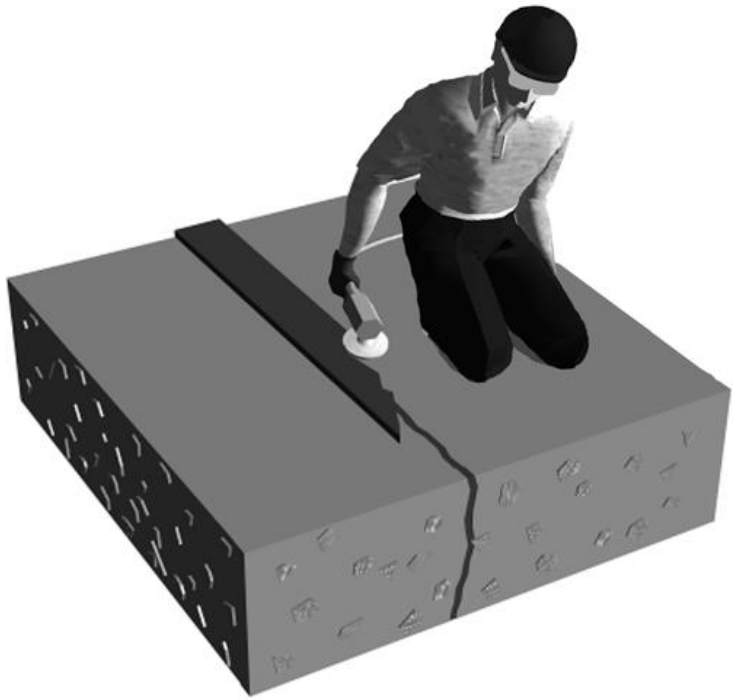
3. Inject the Epoxy

- Double check cap seal and ports
- Mix epoxy according to manufacturer
- For horizontal – start at widest point
- For vertical – start from bottom
- Continue until refusal, cap immediately
- If hairline crack, try increasing pressure to 200 psi for 5 min. (must be managed to prevent blowout)

REPAIR PROCEDURE

4. Remove Ports & Capseal

- Optional step
- May use:
  - Heat
  - Chipping
  - Grinding
  - Other mechanical means



REPAIR PROCEDURE

4. Remove Ports & Capseal

HOW TO CHECK THE REPAIR

1. Test cores
   - Engineer should determine location to avoid high stress areas
   - ASTM C42 – compressive & split tensile
   - Visual evaluation for penetration depth
   - Must patch with expansive high strength grout (epoxy or cement based)

HOW TO CHECK THE REPAIR

1. Test cores

HOW TO CHECK THE REPAIR

2. Nondestructive evaluation
   - Impact Echo
   - Ultrasonic pulse velocity
   - Spectral analysis of surface waves

SOURCES

ACI Committee 224, 1993, "Causes, Evaluation, and Repairs of Cracks in Concrete Structures (224.1R-93)," American Concrete Institute, Farmington Hills, Mich., 22 pp.

ACI Committee 364, 1994, "Guide for Evaluation of Concrete Structures Prior to Rehabilitation (364.1R-94)," American Concrete Institute, Farmington Hills, Mich., 22 pp.

ACI Committee 503, 1998, "Use of Epoxy Compounds with Concrete (ACI 503R-93 (Reapproved 1998))," American Concrete Institute, Farmington Hills, Mich., 28 pp.

ACI Committee 546, 1988, "Guide for Repair of Concrete Bridge Structures (546.1R-80 (Reapproved 1988))," American Concrete Institute, Farmington Hills, Mich., 20 pp.

ACI Committee 546, 1996, "Concrete Repair Guide (546R-96)," American Concrete Institute, Farmington Hills, Mich., 41 pp.

ASTM C 881-90, 1990, "Standard Specification for Epoxy-Resin Based Bonding Systems for Concrete," ASTM International, West Conshohocken, Pa., 5 pp.

Emmons, P. H., 1994, *Concrete Repair and Maintenance Illustrated,* R. S. Means Co., Inc., Kingston, Mass., 300 pp.

"Guide for Verifying Performance of Epoxy Injection of Concrete Cracks," 1998, *ICRI Technical Guideline* No. 03734.

Murray, M. A., 1987, "Epoxy Injection Welds Cracks Back Together," *Concrete Repair*, V. 3.

Promboon; Y.; Olsen, L. D.; and Lund, J., 2002, "Nondestructive Evaluation (NDE) Methods for Quality Assurance," *ICRI Bulletin*, V. 15, No. 1, Jan.-Feb., pp. 12-16.

"State-of-the-Art Adhesives for Concrete Construction," 1998, *Construction Canada Magazine*, May-June.

Trout, J. F., 1998, *Epoxy Injection in Construction,* The Aberdeen Group, 80 pp.

THANK YOU FOR YOUR ATTENTION!

QUESTIONS?

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