CONCRETE 102

REPAIR CRACKS IN CONCRETE THROUGH INJECTION

UNDERSTANDING WHY CONCRETE CRACKS AND REPAIRING CRACKS

CONCRETE 102 - CRACKS

CHAPTER 1 - INTRODUCTION

1. PURPOSE

Concrete 102 - Cracks is one of a series of Basic Education seminars developed by General Polymers to support the Company's Perfect Choice™ Contractors in their quest to be the best they can be.

This paper is to focus on the nature of cracks in concrete and how to repair them.

2. HOW THE REPORT WAS DEVELOPED

The scope of this report includes: The review of why concrete cracks and the different methods or treatment(s) of cracks, from epoxy injection to bridging with elastomeric stretch coats to ignoring of them.

The detailed repair procedures listed in this paper were originally developed for and presented to the PCI Quality Control Committee as the recommended repair procedures for concrete elements.

The following publications of the American Concrete Institute (ACI) and American Standards Testing Material (ASTM) will provide guidance in the use of epoxy compounds:

ACI 224
ACI 318
ACI 503
ACI 503.1
ACI 503.2
ACI 503.3
ACI 503.4
ACI 547
ASTM C 881
ASTM C 882

EPOXY RESIN ADHESIVES FOR BONDING CONCRETE

The principal characteristics of epoxy resins used with concrete in the construction industry include:

- **a. High strength adhesion to most building materials**
- **b. Very low shrinkage during and after cure**
- **c. Outstanding dimensional stability**
- **d. Void filling qualities**
- **e. Thermosetting - resistance to softening**
- **f. Optimum chemical resistance**
- **g. Fatigue resistance**

h. Creep resistance
i. Ability to withstand thermocycling
j. Good electrical insulation

There are many reasons why epoxies make good adhesives. Among these are:

a. Compounds are in liquid or paste form and contain no volatile solid
b. They adhere to most properly prepared construction materials
c. There are no hazardous by-products during the curing period
d. There is limited shrinkage during and after cure
e. Cured epoxies have dimensional stability
f. Cured epoxies have tensile strengths and compressive strengths as high, and higher than, concrete

Structures built of Portland Cement Concrete have an undesirable tendency to crack, even though proper provisions are made for expansion and contraction by engineered joint design. On horizontal slabs, cracking may develop because of a number of reasons, even though expansion joints have been provided at minimal centers.

On vertical placements, severe stresses and strains will inevitably result in cracking.

Therefore, the most commonly used method of structurally repairing cracks in concrete is by injection of epoxy adhesives. Liquid epoxy resin systems of low viscosity are utilized for this purpose. Since the material is 100% solids, it develops very little shrinkage in curing, thus the entire crack is filled.

Should further stress be place in the concrete member, cracking will inevitably occur at another location and seldom if ever at the epoxy-repaired point.

CHAPTER 2 DEFINITIONS

Active Cracks — **A crack that moves (opens and closes) periodically from loading or thermal cycling**

Crack — **A visible separation at the surface of the concrete, which may penetrate just below the surface to all the way through.**

Dormant Crack — **A crack that does not move (open or closes), because it is not exposed to loading or thermally induced movement.**

Hairline Crack — **A separation in the mass of the concrete with a displacement measuring less than 0.004 inch (0.1 mm).**

Surface Seal — **A material that is applied to the face of the crack (both faces for through cracks), between the entry ports, which after cure will be capable of preventing the epoxy injection adhesive from leaking out of the crack.**

CHAPTER 3 METHODS OF CRACK REPAIR

3.1.1.0 **Prior to repairing cracked Portland Cement Concrete and evaluation of the factors contributing to the cause of the cracking should be determined. Once the cause has been identified and eliminated the crack can be repaired.**

This chapter provides a survey of crack repair methods

Epoxy adhesive repair

Injection of epoxy adhesives

Sealant

Sealers

Penetrating sealers

Film sealer

CHAPTER 4 CRACK REPAIR - EPOXY INJECTION

4.0.0.0 CRACK REPAIR

4.1.0.0 CRACK REPAIR with EPOXY INJECTION ADHESIVES

4.1.0.1 INVESTIGATION OF MECHANISM THAT INDUCED THE CRACK

Prior to injecting an epoxy adhesive into a crack the cause of the crack should be determined. It is important that the cause of the cracking is eliminated.

Both working and non-working cracks can be repaired with epoxy injection adhesives. However, there is word of caution when repairing active or working cracks. Working cracks open and close due to changes in temperature and/or moisture content and/or as a response to loading. The injection of epoxy adhesives will make the concrete behave monolithocally and if the repaired concrete can not restrain the movement the member will crack again.

If the cause of the movement can not be eliminated a qualified engineer should be consulted. It may be necessary in his opinion to restrain the crack by retrofitting the member with internal or external steel reinforcement or V-notch 1/2" wide by 1/2" deep and fill the crack with a flexible sealant allowing it to behave as an expansion or control joint (See ACI 504).

4.1.1.0 Cleaning of Crack

The introduction of cleaning or flushing* compounds into the crack can be helpful; however, there is always a chance that the compound will not exit the concrete element after it is installed. Therefore, to facilitate cleaning of the crack and minimize the risk of entrapped cleaner purge with clean air and then flush with the injection epoxy. The best crack cleaner is the epoxy injection adhesive itself. To clean the crack excessive material should be pumped into the crack until the epoxy injection adhesive vacating it is clean and free of contaminants.

*** If flushing is required use water only. Acid flushing should not be allowed.**
**** The compressed air equipment and lines must be free of oil, water, or other contaminants.**

4.1.1.1 Contaminated Cracks

Cracks contaminated by dirt, dust, efflorescence, oils, grease, fine particles or other chemicals present special problems. In addition, dirt, or fine particles of concrete may also prevent injection resin penetration. Except in severe instances of contamination, the contaminants may be removed by flushing with epoxy injection adhesive. The material should be injected until the discharged epoxy injection adhesive is free of particulate contaminants and returns to the color and consistency of the original epoxy injection adhesive. Other contaminants, such as petroleum products may or may not be fully removed through this process (or any other process for that matter). Note: a risk of low adhesive strength always exists when attempting to repair contaminated cracks.

4.1.1.2 Cleaning new cracks

New cracks are usually free of foreign substance contamination and seldom require cleaning.

4.1.1.3 Cleaning surface area adjacent to crack face

The surface area adjacent to the crack face should be grit blasted or wire brushed to provide a clean sound surface for the adhesion of the non-sag epoxy paste surface seal.

4.1.2.0 Entry Ports

Entry ports are employed to provide an injection avenue for the epoxy adhesive to flow into the crack through the surface seal. They serve as the gateway to allow for the placement of epoxy injection adhesives, Several types of physical entry ports can be utilized, ranging from prefabricated plastic or metal fittings to nothing (gasket seals). Entry ports are usually placed prior to or during the placement of the surface seal.

4.1.2.1 Entry Ports

At designated intervals along the crack face, entry ports are made during or after the crack is sealed. Entry ports should be provided along the crack at intervals equal to or greater than the thickness of the concrete member at that location.

4.1.2.2 Gasket Seal

A special gasket seal allows for the repair of most cracks without the need for prefabricated fittings. The gasket attaches to the end of the injection nozzle and is pressed directly against the crack opening. Predetermined and pre-measured gaps (usually about 1/4") in the surface seal are required. To ensure leak free injection, the surface should be flat and smooth for proper gasket compression seat.

4.1.2.3 Metal Pipe Nipples, Plastic Tubing and Zerk Type Grease Fittings

Dry drill and wet core drill methods are employed for setting these mechanical entry ports. Prefabricated entry ports are usually anchored in a non-sag epoxy paste adhesive or

cementitious hydraulic cement. The fitting should be set no deeper than the first 1/3 of the drilled hole depth, with care being taken to avoid overfilling with the anchoring adhesive. The drill hole into the crack is slightly larger than the outside diameter of the metal fitting (a snug fit is desirable).

4.1.2.4 Plastic Flush Fittings

Plastic Flush fittings "stand off" the crack (slightly). The fitting is usually bonded in place using the same non-sag epoxy surface seal material. The fitting looks like a hollow upside down 'T'. The shoe or the top of the 'T' is held in place by the surface seal adhesive prior to and after cure.

4.1.3.0 Surface Seals

The crack surface is sealed on each exposed face with a fast-setting non-sag epoxy adhesive paste to prevent the loss of the epoxy injection adhesive during the injection process.

4.1.3.1 Surface Seal Application

A temporary surface seal is placed over each face of the crack, after the entry ports have been placed. A non-sag epoxy adhesive paste is usually used to provide the temporary surface seal. The seal must be capable of withstanding the hydraulic pressures exerted during the injection process and confine the low viscosity epoxy injection resin in the crack until it has cured.

4.1.3.2 Removal of the Surface Seal

In most cases the surface seal material will be removed by grinding after the epoxy injection resin has cured. The surface seal should be removed leaving the face of the crack finished flush with adjacent concrete showing no indentations or protrusions caused by the placement of the surface seal, injection adhesive runs, or the entry port fittings. Also, epoxy paste adhesives are specifically designed to be pulled off after injection.

4.1.4.0 Mixing of Epoxy Injection Adhesive

The epoxy injection adhesive may be mixed in small batches or meter mixed at the mix head or nozzle when using plural component meter mixing injection equipment. Epoxy injection adhesives are two component materials consisting of a resin and a hardener. Accurate proportioning and complete mixing are extremely critical with all epoxy materials.

It is even more critical with injection products, because once the material is placed in the cracked concrete it can not be removed, therefore extreme care must be placed in proportioning and mixing to avoid costly errors.

4.1.4.1 Batch Mixing (Plural Component Injection Adhesives)

Batch mix the epoxy injection adhesives in accordance with the manufacturer's instructions. Batch mixing should be limited to small quantities (one quart), using an electric drill and paddle mixer that minimizes the introduction of air during the mixing process. Batch size should be limited to only the material that can be used during its working life.

(For best results, a long pot life material is recommended for this method. It should be noted that long pot life materials have a corresponding slow rate of cure).

4.1.4.2 Plural Component (Continuous Mixing)

Plural component meter mixing pumps provide continuous supply of the epoxy injection adhesive. Usually the plural component mixer provides a continuous flow of material from two separate containers through separate fluid feed lines, which are mixed in a single automatic mixing head.

(Continuous mixing equipment allows the use of fast setting epoxy injection adhesives, with a corresponding short rate of cure).

4.1.5.0 Placement of the Epoxy Injection Adhesive

Pressure injection (pumping) of the epoxy adhesive is the most reliable method of installation.

Some cracks as narrow as .002 inch)0.05mm) can be bonded by the injection of a low viscosity epoxy adhesive. Narrow cracks and wide cracks require different epoxy injection adhesives during the repair sequences.

4.1.5.1 Pressure Injection Limitation

Listed below are several types of injection equipment. The equipment must be capable of providing and maintaining adequate pressure during placement of the epoxy injection adhesive while meeting the material flow demands.

4.1.5.2 Hydraulic Pumps

Hydraulic or fluid pump method drives the epoxy injection adhesive through mechanical driven gears or air-piston pumps which draw the adhesive from reservoirs. The adhesive material can be either gravity-fed or force-fed to the drive pump. Plural component pumps are the most desirable delivery equipment, because they reduce waste and, under normal working conditions, they provide accurate proportioning and mixing of the material.

It is extremely important that the equipment is field quality controlled or "ratio-checked" before and during its use to minimize the chance of mix error.

4.1.5.3 Pressure Pot

A single component standard painter's pressure pot requires batch mixing of the injection epoxy adhesive prior to filling the equipment. The material travels under air pressure through a single fluid hose to the entry port.

Pressure Pots that allow for the use of disposable internal containers are the most desirable since it reduces clean up requirements. Long pot life epoxy injection adhesive should be used with this equipment. In addition, extra fluid lines mix heads and nozzles should be readily available in the event that the injection adhesive sets up prematurely.

4.1.5.4 Caulking Gun (Air or manual Actuated)

Most caulking guns are single chambered and come with or without disposable insert cartridges. Long pot life epoxy injection adhesive should be used with this equipment. In addition, extra guns and/or cartridges and nozzles should be readily available in the event that the injection adhesive sets up prematurely.

4.1.6.0 Injection of the Epoxy Adhesive

Mixed epoxy injection adhesive is pumped under pressure into the crack through an entry port. Injection continues until the material shows at the adjacent entry port. This method is repeated until the entire crack is filled. When clean material shows at the next adjacent entry port, the first port should be plugged or capped and the injection process is continued at the next entry port. This process is continued until the entire crack is filled.

4.1.6.1 Entry Port Spacing

Entry ports should be spaced at intervals approximately the thickness of the member being repaired or at a 1:1 ratio equal in the rare occasion when the desired depth of penetration is less than full depth.

4.1.6.2 Vertical Surfaces

On vertical surfaces the epoxy adhesive is injected into the lowest entry port until it appears at the next adjacent entry port. The lower port is then sealed and the procedure is carried out repeatedly until the full length of the crack is filled. Filling from the lowest or bottom entry port reduces the likelihood of air entrapment.

4.1.6.3 Vertical Surfaces without access to both Crack Faces

On vertical surfaces, such as a wall that has been back filled and one side of the crack face is inaccessible, the back fill material makes accessing both sides of the crack impractical. Therefore, only the exposed crack face can be surface sealed. Multi-passes of epoxy injection adhesive will be required to fill the crack void.* The entry ports should be left unplugged (or plugged with a removable plug) to allow for easy repeat access to the crack through the same entry port.

*** The use of a non-sag epoxy injection paste adhesives should also be considered.**

4.1.6.4 Horizontal Surface

On horizontal surfaces the epoxy adhesive should be injected from the underside (bottom side) whenever possible. The injection procedure should start at the first entry port at one end and continue from port to port until the entire crack is filled.

4.1.6.5 Horizontal Surface without Access to both Crack Faces

Horizontal surfaces, such as slabs on grade deny access to both sides of the crack face, therefore the crack can be surface sealed only on the top surface. Multi-passes of epoxy injection adhesive will be required to fill the crack void. The entry ports should be left unplugged (or plugged with a removable plug) to allow for easy repeat access to the crack through the same entry port.

4.1.7.0 Quality Control

Field quality control by experienced applicators and inspectors is very important. There are no proven test methods for verifying that the crack has been properly filled, other than destructive test methods, such as full depth coring. Therefore, proper placement techniques are essential to a successful application.

4.1.7.1 Field quality control is dependent on a number of criteria:

- **a. Experienced epoxy injection personnel following the approved application techniques**
- **b. The use if the proper injection material that has been proportioned and mixed correctly (prior to injection)**
- **c. Properly functioning placement equipment**
- **d. Temperature at the internal bond line must be within the recommended guidelines for proper cure**
- **e. Clean and durable crack faces**
- **f. And many other items**

4.1.7.2 Core Sample

Core samples required to verify that the crack has been filled can be taken after the epoxy injection adhesive has cured.

4.1.7.3 The core should be visually inspected to determine if the crack has been filled

4.1.7.4 In addition, the core sample can be tested in compression to verify that the epoxy injection adhesives has fully cured. Samples tested in compression should not fail cohesively. The failure mode should be in the concrete and/or travel across the epoxy bond line. Cohesive failure should not be exhibited.

4.1.7.5 Should cohesive failure occur in the epoxy, the attempt to repair the crack must be considered to be non-structural. The filled crack may be water tight, but will not be capable of transferring loads uniformly form one element to another and the repair is considered unsatisfactory, for structural reasons.

4.1.8.0 Physical Properties (Choosing the right adhesive)

The epoxy injection adhesive should have been formulated especially for repair or cracked and delaminated concrete. The material should have a successful track record on previous applications that are similar to the application it is intended to be used for.

4.1.8.1 Low Viscosity

For most applications, the material should be a low viscosity, pumpable material possessing excellent concrete "wetting" characteristics.

4.1.8.2 Medium Viscosity

Medium viscosity material is acceptable when the crack is designated very wide and when it can not be surface sealed on all faces of the crack.

4.1.8.3 Other Considerations

The material must be designated 100% solids (no solvents) and it must be capable of bonding to saturated or dry concrete at the lowest concrete surface temperature that will be subjected to during placement and cure.

4.1.8.4 Selection of Materials

Materials selected for use must comply with ASTM C 881. The manufacturer of the surface seal and the injection material is to provide a certificate of compliance to the Type, Grade and Class as listed on the next page.

4.1.8.5 Epoxy surface seal non-sag epoxy adhesive paste:

ASTM C 881-87
Type IV or (Type I)
Grade 3
Class A or Class B or Class C

4.1.8.6 Low Viscosity Epoxy Injection Adhesive

ASTM C 881-87
Type IV
Grade 1
Class B or Class C

4.1.8.7 Non-Sag Epoxy Injection Adhesive

ASTM C 881-87
Type IV
Grade 3
Class A or Class B or Class C

4.1.9.0 Workmen Qualifications

Workmen engaged in the epoxy injection procedure must have satisfactorily completed a program of instruction in the methods of restoring cracked concrete members, utilizing the specific injection practices employed. The instruction must include materials, equipment use and trouble shooting and application technique.