Structural Repair of Concrete Cracks

A brief overview of epoxy injection tools, materials, and procedures

by Tom Murphy

Epoxy injection can be used for structural repair of cracks resulting from one-time events such as accidental overloads, vehicular impact, earthquake, restrained shrinkage, or large thermal differentials. The method is suitable for horizontal, vertical, and overhead application on cracks as narrow as 0.002 in. (0.05 mm).

While epoxy injection can be used to restore the integrity of a structure as well as provide resistance to moisture penetration, it should be conducted only after an engineering evaluation has shown that the crack is stable (will not recur due to ongoing effects) and there is no flowing water. This article provides a brief overview of the tools, materials, and procedures needed for successful application.

Tools and Materials

Tools and materials used for epoxy injection include:

- Capping paste;
- Injection ports;
- Injection equipment; and
- Injection resin.

Capping paste

Capping paste seals the surface of the crack as well as bonds the injection ports to the concrete. This material should have a high viscosity and adhere well to the surface to avoid sagging or flow. Ideally, the capping paste will also cure quickly, allowing an efficient repair process. A non-sag, high-modulus epoxy (Fig. 1) will exhibit good bond and fast curing, yet it will be easily removed after injection.

Injection ports

Injection ports are the means of delivering the epoxy resin to the cracks. They can be classified as surface mount ports or socket mount ports. Surface mount ports are available with straight tubes or reservoirs. Figure 2 illustrates the installation of a surface mount port. The base of this port has a circumferential rib inboard of periodic slots. These features both help to prevent capping paste from flowing to the center of the port (which would interfere with the flow of epoxy into the crack). The latter feature also helps bond the base to the concrete.

This port also includes a reservoir (Fig. 2(c)). Reservoir ports allow for more rapid material delivery, as they provide a constant, low-pressure injection until no more epoxy is accepted or the reservoir empties. Fast-setting resins can be problematic when using reservoir ports, however, as the material remaining in the reservoir may produce too much heat and cause the epoxy to set prematurely.
For large applications, a port manifold can be used to facilitate the epoxy delivery. Valves are used to control the sequential delivery of resin to the ports.

Resin

The epoxy injection resin is typically a low-viscosity (less than 400 centipoise [cP]), moisture-tolerant material that is slow setting and has a high modulus. For structural applications, the material should be a Type IV resin per ASTM C881/C881M, “Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete.” The application dictates the viscosity and other resin properties. While the maximum viscosity allowed for a low-viscosity Type IV resin is 2000 cP, very low-viscosity (less than 200 cP) resins are used for thin cracks less than 0.125 in. (3.2 mm) and where deep penetration is required for beams, columns, or thicker slabs. For blind side cracks, where the back side of the concrete member cannot be capped, a thixotropic resin is required to prevent loss of the injection resin through the crack. These resins are fluid when under pressure and thicken when the injection pressure is removed. Thixotropic resins will have relatively high viscosity (roughly, between 4000 and 5000 cP).

The Epoxy Injection Process

When preparing for the installation, an estimate is conducted for material use based on crack width, crack length, and slab depth. Tables 1 and 2 provide simple estimates for both cartridge and volume requirements for injection resin and capping paste.

Prior to epoxy injection, the surface is cleaned and prepared with a grinder or wire brush to ensure bond of the capping paste. When using socket mount ports, holes must be drilled to seat the port. Loose material and dust must be vacuumed or blown out of the crack. For socket mount ports, the ports are installed first, followed by the capping paste. Some manufacturers provide a “viewing window” that can be mounted over the crack every five ports to visually verify epoxy flow.

### Table 1: Estimated coverage (yield) for capping gel

<table>
<thead>
<tr>
<th>Crack width, in. (mm)</th>
<th>9 oz. (266 mL) cartridge (1:1), linear ft (m) of crack</th>
<th>Quart kit (946 mL), linear ft (m) of crack</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.002 (0.05)</td>
<td>7 (2.1)</td>
<td>25 (7.6)</td>
</tr>
<tr>
<td>0.125 (3.2)</td>
<td>6 (1.8)</td>
<td>22 (6.7)</td>
</tr>
</tbody>
</table>

### Table 2: Estimated coverage (yield) for epoxy crack injection into a 6 in. (152 mm) thick concrete member

<table>
<thead>
<tr>
<th>Crack width, in. (mm)</th>
<th>6 oz. (177 mL) cartridge (2:1), linear ft (m) of crack</th>
<th>16 oz. (473 mL) cartridge (2:1), linear ft (m) of crack</th>
<th>Gallon kit (3785 mL), linear ft (m) of crack</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.002 (0.05)</td>
<td>61 (18.6)</td>
<td>160 (48.8)</td>
<td>1280 (390)</td>
</tr>
<tr>
<td>0.005 (0.13)</td>
<td>31 (9.4)</td>
<td>80 (24.4)</td>
<td>640 (195)</td>
</tr>
<tr>
<td>0.016 (0.04)</td>
<td>10 (3.0)</td>
<td>26 (8.2)</td>
<td>200 (61)</td>
</tr>
<tr>
<td>0.030 (0.08)</td>
<td>5 (1.5)</td>
<td>13 (4.0)</td>
<td>100 (30)</td>
</tr>
<tr>
<td>0.060 (1.5)</td>
<td>2 (0.6)</td>
<td>6 (1.8)</td>
<td>50 (15.2)</td>
</tr>
<tr>
<td>0.125 (3.2)</td>
<td>1 (0.3)</td>
<td>3 (0.9)</td>
<td>25 (7.6)</td>
</tr>
<tr>
<td>0.250 (6.4)</td>
<td>—</td>
<td>2 (0.6)</td>
<td>12 (3.7)</td>
</tr>
</tbody>
</table>
Ports are placed about 6 to 10 in. (150 to 250 mm) apart—closer for thinner cracks and less frequent for wider cracks. Generally, port placement is roughly equal to the slab thickness.

The injection process begins at the lowest port for vertical applications and at the widest part of the crack for horizontal and overhead applications. When using tube ports, the epoxy is injected until material starts to flow out of the next port. The current port is capped and the process moves to the next port. When using reservoir ports, each reservoir can be filled in order and refilled as they empty (Fig. 3).

For large installations, pumps are required for efficient delivery of resin. Some pumps use only one reservoir and thus require the epoxy to be premixed. This hinders production efficiency because the amount of premixed epoxy must be limited to avoid exceeding the pot life of the resin in the pump reservoir. Dual reservoir pumps are designed to accurately meter the resin and hardener components, and because the epoxy is mixed only as needed, production efficiency is enhanced.

Most epoxies will not cure at very low temperatures and cure very slowly below 50°F (10°C). The injected epoxy needs to cure a minimum of 12 hours (temperature dependent) before removing the ports and grinding the capping paste from the surface. Depending upon the application, the surface can then be coated and no visual evidence of the crack will be apparent.

Verification
Inspectors can validate the injection process by either destructive testing or by nondestructive analysis. Destructive testing involves coring the crack and visually inspecting the depth of epoxy penetration. Further analysis can be conducted by testing the core for compressive and tensile strength per ASTM C42/C42M, “Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete.”

Impact echo, ultrasonic pulse velocity, and spectral analysis of surface waves are three nondestructive test methods that can be used to evaluate a concrete member after epoxy injection. If these methods are to be used to validate the structural repair, an initial (reference) test must be performed prior to the repair to quantify the results.

Summary
Epoxy crack injection is a reliable structural repair method when performed correctly. Selecting the appropriate capping paste, injection resin, injection ports, and delivery system all contribute to the successful and efficient process. For additional tips on epoxy resin injection, refer to Reference 4.

References
2. ACI Committee 224, “Causes, Evaluation, and Repair of Cracks in Concrete Structures (ACI 224.1R-07),” American Concrete Institute, Farmington Hills, MI, 2007, 22 pp.
3. ACI Committee E706, “Structural Crack Repair by Epoxy Injection (ACI RAP Bulletin 1),” American Concrete Institute, Farmington Hills, MI, 2003 (Reapproved 2009), 7 pp.

Note: Additional information on the ASTM standards discussed in this article can be found at www.astm.org.

Selected for reader interest by the editors.