TECHNICAL BULLETIN 11

EPOXY INJECTION

INTRODUCTION
The intent of this bulletin is to familiarize the reader with the concepts and general uses of epoxy injection. In general, epoxy injection is used to re-establish the continuity of various elements or components. Epoxy injection can also restore the original physical properties of an element as well as protect reinforcing steel from harmful exposures, anchor dowels, rebond overlays and fill voids. Although epoxy injection is used on many substrates such as wood, marble, granite, concrete, masonry and terra cotta, this bulletin focuses primarily on the injection of cracks and/or voids in concrete.

DEFINITIONS
Epoxy: Resin, usually thermosetting, capable of forming tight cross-linked structures characterized by, strong adhesion, high compressive strengths, and high corrosion and chemical resistance.

Inspection port: A porting adapter used to visually confirm penetration or travel of an injected resin through a structure.

Modulus of elasticity: The ratio of the unit stress to the corresponding strain. An indicator of the flexibility of a material.

Port: An opening for the passage of a gas or fluid.

Surface Port / Porting adapter: A device bonded to the face of a crack or inserted into a void to facilitate the injection of an epoxy resin.

Surface Seal: An application of an epoxy, sealant, mortar or other material to contain an injected resin within a fissure or void.

BACKGROUND
While the term 'epoxy injection' commonly refers to many chemical crack injection products, the purpose of this technical bulletin is to familiarize all readers with the process of injecting two-part epoxy resin products into concrete cracks for the purpose of structural repairs. Refer to to Technical Bulletin 10 Urethane Grout Injection for details on water leakage control injection techniques.

FEATURES & BENEFITS
1. Properly performed, epoxy injection results in a long-lasting and water-tight repair.
2. Epoxy injection can be significantly less expensive than replacement of damaged substrate materials. This technique offers the possibility of saving valuable original materials.
3. Epoxy injection materials are readily available, so repairs can be made more rapidly than replacement stones can be made for specialty applications.

LIMITATIONS
1. It is difficult to inject damaged substrates when leaks are active. The leakage must be addressed prior to injection.
2. Epoxies are much harder than most building materials. Overstressing of substrate material due to thermal movement or loading can result in failure of the repair.
3. Injection should not be used where continuous or periodic movement is expected. If stresses that need relief are present, epoxy injection may result in a larger structural failure.
4. Filling large voids with epoxy material can result in excessive heat build-up as epoxy cures. This heat build-up can damage substrate as well as the resin.
5. Injection pressure can sometimes cause failure of materials. For example: When injecting a partially delaminated area of concrete, the injection pressure can result in delamination.

DESIGN CONSIDERATIONS
Prior to commencing with the epoxy injection of a structure, many factors that could affect the success or failure of the application must be considered. These include:
1. Understanding the cause of the condition being considered for repair, and the suitability of injection.
2. Some resins have odors considered noxious. In many locations, due to poor ventilation or personal preferences, less noxious resins should be selected.
3. Selection of a surface seal material to minimize staining of the substrate yet strong enough to contain injection pressures. Injection repairs are seldom invisible.
4. Accessibility issues during injection. If only one side of the damaged area is accessible, resin may drain from the unsealed side, resulting in a starved cavity as well as excessive resin consumption.
5. Surface and ambient temperatures at the time of injection. Epoxy materials are more viscous in colder weather, and frost can inhibit bond. In hot weather, the pot life of most resins is shorter, often necessitating special precautions. Most epoxy resins require a minimum temperature of 40F for curing.
6. Special considerations should be given when injecting voids that are wet. Moisture in a void affects the bond strength of most epoxy resins, and can actually dilute very low viscosity resins.
7. Special consideration should be given when injecting older voids and cracks. Typically, older voids and cracks include deposits and external debris than can inhibit the proper filling of the void or cracks by the resin.

APPLICATION
Ideal epoxy injection environments are dry, poured concrete, structural applications. The use of epoxy injection techniques is wide-ranging to concrete, brick, block, and specialty masonry applications such as architectural elements that are cracked from aging or stress.

SURFACE PREPARATION
Prior to injecting a void or crack, the substrate surface must be sealed to contain the injected resin. All surface sealant products require a clean surface to bond, and therefore the surface must be prepared. There are a variety of surface preparation methods:
1. Grinding is the most common method. An abrasive or diamond blade or stone is used to grind away any loose or friable material including paint, dust, cement paste,

form release agents and curing compounds. Vacuum attachments are available to control dust.

2. Abrasive blasting is also popular. This method uses an abrasive, most commonly sand or slag that is discharged from a pressurized tank impacting the surface, removing the contaminants. Abrasive blasting is generally used on large open areas where dust and noise are not a problem and speed is of essence.
3. Hydro blasting is another option, using water sprayed at very high pressure against the surface. Although a high production method, the contractor will often have to wait for the surface and void to dry prior to sealing. Hydro blasting is often a very loud and messy procedure.
4. For smaller projects, many cracks can be prepared with a simple hand wire brush. This method can be used when the surface is in generally good condition and the injection pressures will not be excessive.
5. Crack chasing or routing is also used.This procedure entails the use of a power grinder or saw and a "V" shaped diamond blade. The crack is routed to a depth of approximately ½". This method does not, often, require the removal of the surface seal at the end of the project. Although it does, almost always, require hydro blasting or vacuum drilling to get beyond the impacted dust from the routing procedure.

PORTING

Porting is the step that allows access to the void at prescribed locations. These access points are where the injected resin is forced into the void. They are also used to monitor the progress of the injected resin. Porting adapters are devices that allow for the mechanical connection to the void. There are a variety of porting adapters:

1. Surface mounted porting adapters are the most common. These devises usually have a flat bottom or foot that is placed over an opening of a void and then glued into place by the surface seal. Surface mounted porting adapters can only be used when a clean open passage to the void is available. Where crack widths allow, a common procedure is to place a nail through the surface port and into the crack. This will ensure an open passage into the crack after surface seal. The nail is removed prior to resin injection, but after surface seal.
2. Drilled or socket mounted porting adapters are utilized when access to a void is impeded by efflorescence, dirt or other contaminants. Holes are drilled through the blockage using hydro or vacuum bits to evacuate the fines and contaminants. The socket porting adapters are then driven or fitted into the hole and sealed.
3. Insertion porting adapters may be used when access to a void is large and clear. These items are normally a length of tubing, straw or other devise capable of handling the injection pressures, inserted into the void. The void is then sealed leaving an end of the adapter exposed.

Master ports are generally a single 2" diameter hole drilled on a crack in a large monolithic concrete pour. This hole is then filled with clean stone particles, sealed and injected.

The injected resin is forced out to the extremities, filling every void it may encounter.

Spacing of the porting adapters will vary depending upon the project. Commonly porting adapters are placed eight to twenty- four inches apart along the length of the crack. However, it is not uncommon for them to be placed as close as three inches apart and some master ports to be the only one in a massive structure.

The thickness of the member to be injected often influences the porting adapter spacing. Many contractors place the adapters as far apart as the member is thick. Hairline cracks often have adapters placed closer and larger fissures, further.

Inspection ports are placed at the extremities, and in critical areas. They are used for a visual confirmation that the injected resin has reached that location. Often they are placed on the opposite side of a wall to confirm through wall penetration. Rarely are they injected.

Multiple port setups are available with the use of in-line nylon tubing, t-connectors, and shut off valves. It should be noted that multiple port systems decrease the output pressure at each port.

CLEANING

The effectiveness of cleaning cracks prior to epoxy injection has been debated for many years. Cracks have been flushed with compressed air, acids, detergents, water and even solvents. Some believe that flushing the cracks with the catalyzed injection resin until it flows clean is a better way. A third group is inclined to do nothing. Most feel that the introduction of any foreign material is more detrimental than beneficial. In all cases a thorough understanding of the positives and negatives of each option is required before proceeding.

SURFACE SEAL

The surface sealing of a void or crack is critical. If this application fails, the injection process will fail. The seal must contain the injection pressures long enough for the injected resin to be forced into the smallest and most remote faults. When the surface seal fails the injection process comes to a halt. If the process cannot be reinitiated before the injection resin within the crack gels it becomes very difficult if not impossible to re-inject the fault. Also, if the seal leaks the structure being injected will become stained by the leaking resin and require additional clean-up.

The surface seal material can be almost anything as long as it will contain the injection resin at the required pressure and duration. The most commonly used sealing material is a paste consistency epoxy resin. Epoxy pastes bond well to most materials and have very good strengths allowing for higher injection pressures than would *not* be available with most other materials. Fast and normal setting resins are available.

Urethane and silicone sealants are also utilized as surface seals. These materials are generally used for low-pressure injection. They often require longer cure times than the epoxies prior to injection. The advantages of these materials are that they are less likely to stain the injected element and do not require aggressive removal methods that mar the substrate. Another plus, is that they are often one component and therefore do not require mixing.

When large voids are encountered a cementitious based seal can be used. Generally injecting these voids will not require high injection pressures. At times this material can be made to match the existing substrate, hiding the repair.

Some contractors have used automobile body putty or "bondo". This product can be used for lower pressure injection applications, as it does not have extraordinary strengths.

INJECTION RESIN SELECTION
Selection of an injection resin depends upon the project. Most injection today uses a low viscosity or "thin" material. These forms of resin flow easily into small voids and allow for faster injection rates.

Many resin manufacturers are now making what are called super low viscosity resins. These resins are almost water-like. Care should be used when using these resins. On porous substrates these resins can be absorbed, resulting in a starved glue line.

Medium and gel viscosity resins are popular for medium or large sized cracks where the backside of the repair is inaccessible. If a low viscosity resin is used it often drains resulting in an empty crack. The heavier resins will "hang" in the crack until they cure.

No matter what the viscosity of resin that is selected it should have good lubricity. In other words, it should not be sticky or heavy with course fillers. These types of materials make injection difficult if not impossible.

The pot life of a resin should also be considered. A resin that sets too fast may shorten the injection time, limiting the depth of penetration. When injecting at low pressures, longer than normal pot life resins should be selected, allowing the resin more time to penetrate deeper.

Epoxy injection resin reaction times are temperature and moisture dependent. A good quality control measure is to always react a small cup sample on-site prior to beginning injection. Cure times, specific to that environment, should be noted.

INJECTION EQUIPMENT
Injection equipment or pumps as they are often called are broken into two categories, high pressure and low pressure.

High-pressure units are capable of dispensing the resins at pressures greater than 50 p.s.i.:

1. Plural component machines are used for most construction applications. This equipment takes the catalyst and bases resins from a supply source, often pressurized tanks or gravity feed hoppers, meters them at the prescribed ratio and thoroughly mixes the resin prior to injecting. These units are commonly electrically or pneumatically operated.

   The advantage of this equipment is ease of cleaning, accuracy of ratio and thoroughness of mixing. The disadvantage is cost. The plural component dispensers can cost many thousands of dollars. Plural component equipment is generally piston displacement or gear driven.

2. Single component pumps are also used. This equipment dispenses the already measured and mixed resins. The downside of this equipment is that a very long pot life resin must be used and frequent cleaning is required. Accuracy of metering and mixing depends upon the conscientiousness of the operator. If great care is not taken and the resin gels in the equipment, the unit may be a total loss.

3. The pneumatic coaxial gun has two side by side cylinders filled with the two components of resin. Two plungers in the gun push the resin through a static mixer into the void. This system is often relatively costly and slow. Clean up involves simply throwing the empty cartridges away. This form of injection is often the choice for small, non-critical injection jobs. This system also falls into the low-pressure category as well.

Low-pressure dispensers rarely exceed 50 p.s.i. injection pressures:

1. Pressure pots were the first injection equipment used. The resin is measured, premixed and placed into a pressurized pot. From there, hoses take the resin to the point of injection. Often the resin would cure in the pot and hoses. This method proved to be slow and expensive. Today, with long pot lives and very low viscosities, this method is popular again. Disposable pots and hoses and the ability to inject an entire crack at once make this system cost effective.

2. Individual spring-loaded capsules and elastic balloons are also used. With these systems the resin is premixed and the delivery device charged with the resin. Each porting location has a delivery device attached to the porting adapter. The balloons rely on the stretching of the bladder for delivery of the resin. The capsules are powered by the compression of a spring. Although, fairly reliable these devises are rarely used today. Spring-loaded or balloon pressurized ports must be constantly monitored for best results. If filled, and abandoned, ports are often not filled to refusal as there is limited resin supply to each port.

3. Gravity feed is the simplest form of low-pressure injection. This method is simply mixing the resin, pouring it over a horizontal crack and allowing it to penetrate. It is often messy and often requires numerous applications to completely fill the void.

INJECTION PROCEDURES
Often, prior to injection the surface seal is tested by capping all of the porting adapters on a crack and pressurizing it with air. This will reveal any gaps in the seal. These flaws can then be sealed and injection can proceed with confidence.

Many in the industry ask that injection begin at the lowest porting adapter or at an end of the crack. After resin appears at the adjacent port, the original port is capped and the injection process moved to the leaking porting adapter. This process assumes that the crack is uniform, throughout. One porting adapter is injected at a time with this method.

Another view is to inject from the widest part of the crack until the void is filled (ACI RAP-1 guideline recommends this technique). When resin appears at an adjacent porting adapter, it is capped and injection continues. This method assures complete satisfaction of the smallest voids. Manifolding, the injection of several porting adapters at once, is common when using this approach.

CLEAN-UP
Removal of the surface seal and any resin that may have leaked from the void may begin after the injection resin has cured. Commonly, this procedure is skipped when aesthetics is not a concern i.e.: wastewater treatment facilities, tunnels, and electrical vaults.

The most common method to remove the epoxy seal is by grinding. This method is dusty and loud, but often leaves the best final finish. Chipping hammers are also used, resulting in a rough finish that is rarely better than leaving the epoxy in place.

On projects where aesthetics are not crucial and speed is essential, burning off the seal is popular. The seal is heated with a torch until soft and then scraped off with a sharp blade. This method often leaves burn marks and small popouts of concrete. Chemical strippers have been used as well. This method is often costly, slow and unpopular.

For low pressure injection applications strippable seals are used. These materials can be peeled from the substrate leaving a clean, attractive substrate. Strippable seals are very popular for use on architectural concrete and decorative stone.

Most surface seal materials once removed from the substrate may be disposed of in a landfill. Check with the manufacturer of the product for proper disposal methods.

QUALITY CONTROL
To insure a successful injection project, quality control is essential. If an uncatalized resin is injected into a crack it is almost impossible to re-inject. If a crack is only partially filled it may recrack. There are several quality control steps:

1. Checking ratio. It is critical that the equipment and/or method being used insures that the resin is properly proportioned and mixed. Propriety equipment must be tested as recommended by the manufacturer. Non-propriety equipment should be required to pass rigorous testing.

2. Samples of the mixed resin should be taken randomly throughout the injection process. The cure rate of these samples should be compared to the resin manufacturer's data sheets.

3. Resin delivered to the site should have the batch numbers recorded and samples from each batch retained. Temperature and other environmental conditions should also be recorded.

4. The most effective quality control device is the requiring of cores. Cores of the injected void should be taken randomly and often to confirm that the required results are being met. Cracks should be 90% filled and well bonded. Generally, three cores are taken in the first fifty feet of injected crack and then one for every one hundred feet thereafter. If cores fail to meet the minimum requirements the injection should stop until new procedures are agreed upon and confirmed by cores.

SAFETY
Epoxy resins, pressurized hoses and equipment can be hazardous. All personnel participating in an injection project should be fully aware of the hazards and knowledgeable on the proper safety precautions. S.D.S., manufacturer's Safety Data Sheets and equipment owners' manual safety procedures should be on site at all times.

Protective eyewear and clothing should be worn at all times. A contractor safety program should be in place and enforced.

SPECIAL CONSIDERATIONS
Epoxy Injection applications often have structural implications for load-bearing elements. Any use of structural repair products should be approved and/or recommended by a licensed structural engineer or qualified design professional. Unauthorized contractors, manufacturers, or home-owners should not make ultimate decisions on equipment, repair methods, and/or product selection when repairing structural elements.

If there is any question in the identification of, or repair method for, a structural element, please consult said qualified professional.