www.foxind.com
email address: info@foxind.com
Toll Free: (888) 760-0369 in USA

3100 Falls Cliff Rd.
Baltimore, MD 21211
Phone: (410) 243-8856
Fax: (410) 243-2701

Prepared By:
H. Michael Simpson
Technology & Application Specialist
Fox Industries, Inc.

CONCRETE REPAIR IN AGGRESSIVE ENVIRONMENTS

ABSTRACT
Generally speaking concrete structures will deteriorate over time from exposure to wetting and drying cycles, freeze thaw cycles, abrasion, chloride intrusion, chemical attack, etc. Concrete structures in the water and waste water industry are under constant attack from the very processes they are built to serve. Combine these specific processes with the exposures listed above, and the fact that many of our water and waste water plants are beyond their designed life and capacity you have a unique set of circumstances that must be addressed on a regular basis to provide protection, repair, and rehabilitation of these concrete structures.

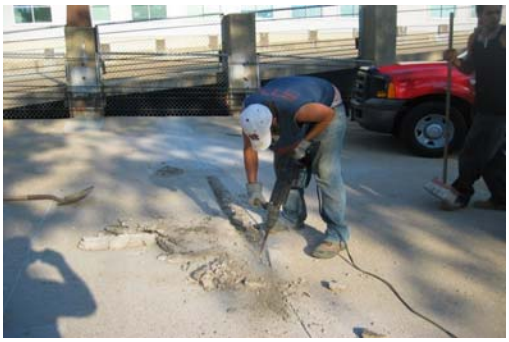
Many of these structures have been in place for 30 plus years, exposed to harsh chemicals and treatment materials for much of that time. Over the last five years, many wastewater treatment plants have begun to use more environmentally friendly (green) chemicals and treatment materials. Even with greener treatment methods being used today, damage to the structures from harsher treatments of the past, must be addressed to prevent additional deterioration that could lead to loss of structural integrity.

The structures we are referring to are clarifiers; sludge thickener tanks; filtration structures; sludge digesters; aeration tanks; outfalls; waste water process support structures; and water treatment tanks. Concrete buildings and structures that are in the general confines of the treatment plants that are exposed to the by-products of the water and waste water process are also in need of repair. This paper will address the methods and materials that have a proven track record in the repair and rehabilitation of concrete that may be utilized by owners, engineers/architects, and contractors.

SURFACE PREPARATION OF CONCRETE
Two of the best resources for information regarding surface preparation of concrete surfaces are SSPC SP 13/NACE No. 6 Surface Preparation of Concrete, and ICRI Technical Guideline No. 310.2

Factors relating to surface preparation and repair of deteriorated concrete will include:

- Type of concrete deterioration (spalls, cracks, abrasion, chemical attack, etc.)
- Size and depth of area to be repaired or restored
- Treatment of exposed reinforcing steel
- Location of deteriorated area
- Temperature or climatic conditions
- Time restraints
- Safety factors
- Accessibility
- Type of material best suited for the repair or restoration



Determining the extent of the area to be repaired is very important and will be a major factor in the overall outcome of the finished job. Most of the time, a visual assessment of concrete deterioration is not enough to determine the extent of the area that must be repaired. Many times the extent of the repair is not determined until the surface preparation has been completed. Hollow, spalled, loose, or cracked concrete visible to the eye is usually only a portion of the true area in need of repair. Sounding and or chipping may be required to determine the true extent of the area to be repaired. Once the area has been determined, a perimeter saw cut should be created to define the area of repair as well as provide a straight edge around the area. The saw cut perimeter can be accomplished before or after chipping of deteriorated concrete has been done. The fewer corners you create in the saw cut perimeter the better. This will provide a lower chance of cracking after the repair work is completed.

Determining the amount of concrete to be removed is always a crucial factor in selecting the exact repair scenario. Depth of repair will determine what type of repair methods and materials that should be used to insure a successful repair.

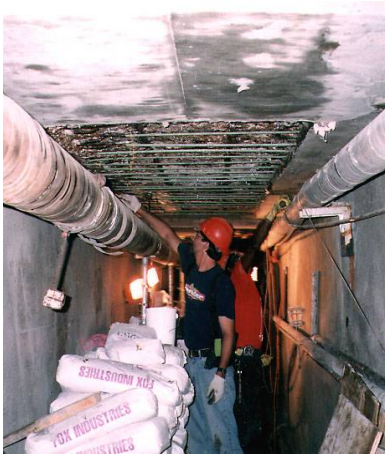
EXPOSED REINFORCING STEEL
Removal of deteriorated concrete will often involve exposing reinforcing steel. In fact many concrete problems arise because the reinforcing steel was placed too close to the surface of the concrete. Inadequate concrete coverage of reinforcing steel will often result in surface cracking, which can expose reinforcing steel to air and moisture, causing oxidation of the steel. The resulting rust will not only deteriorate the steel, but

cause damage to the surrounding concrete. Exposed reinforcing steel must be dealt with to facilitate a successful repair outcome. Exposure of the reinforcing steel is usually accomplished by chipping out and removing the surrounding deteriorated concrete down to sound concrete. This does not always mean that the exposed steel must be void of all surrounding concrete. In many cases, partial exposure of the steel will be sufficient, because hard, sound concrete is covering a portion of the exposed steel. If the exposed steel does not have significant section loss, cleaning the steel to remove rust and debris will be the first step in treating the exposed steel. This may be accomplished using one of the following SSPC surface preparation standards:

SSPC-SP 1 Solvent Cleaning
SSPC-SP 2 Hand Tool Cleaning
SSPC-SP 3 Power Tool Cleaning
SSPC-SP 6 Commercial Blast Cleaning
SSPC-SP 11-87T Power Tool Cleaning to Bare Metal

The specific standard will be selected based on accessibility, size and amount of steel to be prepared, location of steel, time restraints, weather, etc.


Cleaning Reinforcing Steel


Priming Reinforcing Steel

Once the steel has been cleaned the next step will be to prime the steel as soon as possible to prevent rust blooms from appearing on the cleaned steel. Two of the most common types of steel primers used in concrete repair and restoration are:

Non-Immersion Applications:

- **FX-406 Organic Zinc Rich Primer**
- A one component pre-mixed liquid organic zinc which provides sacrificial protection against steel corrosion
- Meets the SSPC-PS 20, Type II Organic Zinc Rich Primer

Immersion Applications:

- **FX-408 Epoxy Organic Zinc Rich Primer**
- A two component epoxy organic rich primer which provides both barrier and sacrificial protection against steel corrosion
- Meets the SSPC-PS No. 20 Type II. This type of steel primer is generally used in immersion applications

REPAIR SCENARIOS AND SELECTION OF REPAIR MATERIALS

Repair of Concrete Cracks:

The first step in a successful crack repair job is to try and determine why the concrete cracked in the first place. This is important because if the cracks were a result of movement and insufficient expansion joints, repairing the cracks with a rigid, hard repair material would more than likely result in future cracking, in or adjacent to the repaired areas. This may also indicate improper reinforcing steel and support of the area that has cracked. Once you have determined the reason for the cracking you can proceed to selecting the proper repair method and materials. In the water and waste water industry, many cracks appear as a result of settlement of new structures, or loading and unloading of structures that is consistent with the operation of the particular structure. For example, a large clarifier that is at full capacity will be emptied for inspection or scheduled maintenance, and then re-loaded to capacity. Other factors contributing to concrete cracking are:

- Extreme temperature fluctuations (freeze thaw cycles)
- Impact
- Erosion of the ground that is supporting the structures


A Crack Being Repaired

Once a determination is made regarding the cause of cracking, selection of a repair method and repair materials can begin. One of the most common repair methods for non-moving cracks is epoxy pressure injection. This method ranges from using a hand held caulking gun to inject a low viscosity epoxy resin into the cracks, in a low pressure application, to a plural component automatic metering pressure injection machine that mixes the plural component epoxy at the injection head, at pressures up to 300 psi. For crack repair work in temperatures between below 32°F - 50°F, a low temperature, fast setting, low viscosity epoxy can be used.

The selection of hand held process or injection by machine will be determined by several factors:

- Size and amount of cracks
- Location of cracks
- Accessibility to area
- Who is doing the work
- Time restraints

The materials for crack repair will generally be a sealer epoxy material to adhere the surface mounted injection ports, and seal crack opening between ports, and a low viscosity epoxy resin to pump into the cracks.

Examples of these materials are:

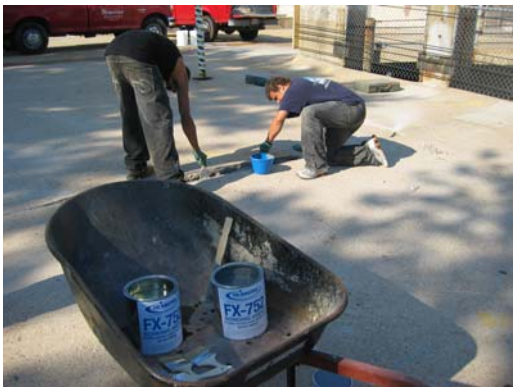
- **FX-763 Low Modulus Hydro-Ester Trowel Grade Epoxy, meeting ASTM C-881-99 Types I,II and V, Grade 3, Class B and C for sealer epoxy**
- **FX-751 LV Hydro-Ester Epoxy, meeting ASTM C-881-02 Types I,II, and IV, Grade 1 , class B for normal temperatures**
- **FX-741 Fast Set LV Epoxy, meeting ASTM C-881-90, Type I, Grade 1, Class A for cold weather**

If it is determined that the cracks are moving cracks it may be necessary to create new, or additional, expansion joints to compensate for the movement. These joints would be sealed with a flexible joint sealant material. Fox Industries manufactures a joint sealant specifically for use in the water and waste water industry, **FX-572 Self Leveling Polymeric Joint Sealant** or **FX-573 Non- Sag Polymeric Joint Sealant**. The high polysulfide polymer content allows resistance to many chemicals and bioactivity, shrinkage, aging, and thermal stress effects of outdoor exposure including UV and weather. This material provides a durable elastomeric, weather tight seal and retains flexibility even with substrate movement.

CONCRETE REPAIRS REQUIRING RAPID RETURN TO SERVICE

Bonding Agents:

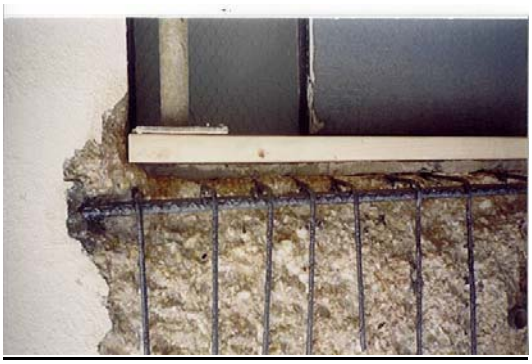
The bond between the existing concrete and the repair material may be achieved in various ways. Bonding agents have evolved from a basic wetting of concrete prior to application of repair materials, to placement of a cement slurry coat, to basic latex bonding agents, to acrylic latex bonding agents, to epoxy bonding agents. For these applications, latex and epoxy bonding agents are most commonly used. For the utmost bond strength between the existing concrete surface and the new repair material an epoxy bonding agent such as **FX-752 Hydro-Ester All Purpose Epoxy Bonding Agent** is recommended. For very thin applications from 1/8" to ¼" thick, a latex bonding agent such as **FX-Bond Crete** is more compatible because epoxy bonding agents will tend to bleed through thin applications.



Application of FX-752 Bonding Agent

Spall Repair:
When repairing small concrete spalls, surface preparation will be the same as discussed in Surface Preparation and Treatment of Exposed Reinforcing Steel. Once the surface preparation and treatment of the exposed reinforcing steel has been accomplished, the next step is to select the repair materials.

Usually in water and waste water repair and restoration projects, down time is a major factor in material selection. The repair materials must be rapid setting and be able to receive top coat systems within hours of their placement.


View of a Small Vertical Spall

Small Spall Repairs:
Small spalls are defined as areas that are less than 10 square feet in size and less than 4 inches in thickness. These repairs are usually on overhead or vertical surfaces. The most common method to repair these areas involves hand patching or troweling. The best repair material for these types of repair is a fiber reinforced rapid curing polymer modified cement based material containing a migratory corrosion inhibitor. Fox's most popular material, **FX-263 Rapid Hardening Trowelable Mortar**, is single component and only requires the addition of water to activate. These materials are very basic for contractors to work with.

Large Spall Repairs:
When repairing large spall areas surface prep will be the same as discussed in Surface Preparation and Treatment of Exposed Reinforcing Steel. Once the surface preparation and treatment of exposed reinforcing steel has been accomplished the selection of the repair materials will be the next step. Since we are talking about large areas that could range from hundreds of square feet to thousands of square feet there are many factors to consider before selecting the repair materials.

Beyond fast return to service, other important factors include:

- Weather conditions at time of placement
- Application technique (hand applied or spray applied)
- Thickness of repair areas
- What kind of coating or membrane system will be applied over the repair material
- Amount of curing time before top coating or membrane system will be applied
- If no top coating of repair material will be done, what will the repair material be exposed to.

Close-up View of Large Spall

Larger View of Repair Area

If the repair materials will be hand applied, they must have a long enough pot life and working time to allow for mixing of full bags or units of the material to be applied. On vertical or overhead repair areas of less than 3 inches in thickness on which there is enough time to allow for hand placement, a polymer modified fiber reinforced cement mortar containing a migratory corrosion inhibitor, and silica fume, with a 30-45 minute working time, such as **FX-262 Repair Mortar** is an ideal material.

Before and After Application of FX-262

Read for Top Coat

This same type of material can be utilized if there is a time restraint condition, because this material can be spray applied for large applications if necessary. If the material is spray applied, the surface of the material can be troweled or floated to create the desired finish. Different coating systems require different types of finishes for adhesion or aesthetic purposes.

In special situations where the repair material will be exposed to high levels of hydrogen sulfide and no top coatings will be applied, a calcium aluminate repair mortar such as **FX-293 Calcium Aluminate Repair Mortar** shall be used. These mortars can be hand or sprayed applied in lifts up to 2” thick.

After Application of FX-293, no Top Coat Required.

PARTIAL OR FULL DEPTH HORIZONTAL REPAIRS

When deep partial depth or full depth repairs are required, and ready mix concrete is not an option because of accessibility or time restraints, surface preparation and treatment of exposed reinforcing steel will be as discussed in Surface Preparation and Treatment of Exposed Reinforcement Steel.

In this kind of repair some additional treatments may be required such as:

- Replacing or adding to the reinforcing steel
- Special formwork
- Cribbing or shoring of the structure being repaired
- Curing of the repair materials

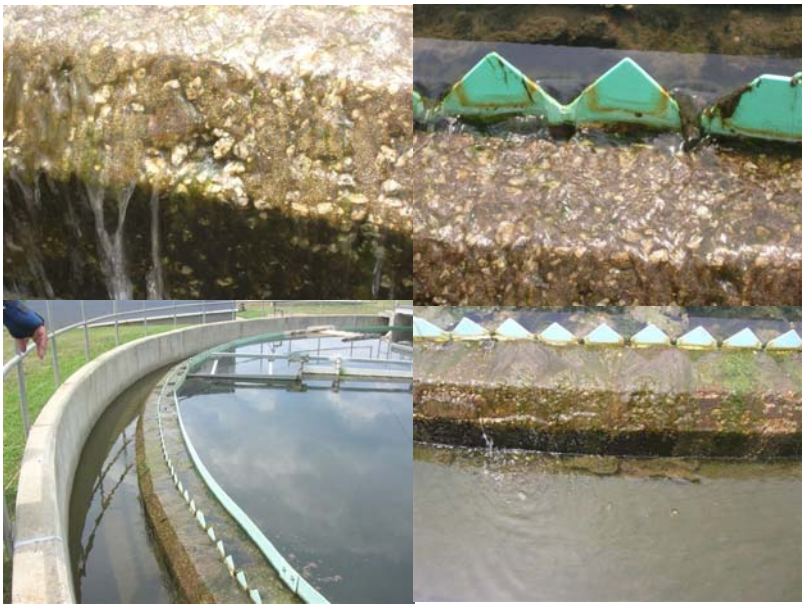
Deep pour repairs will require mixing equipment that will allow the applicator to mix 6 cubic feet or more of the material at one time to facilitate the repair. These materials are usually packaged in bags and are loaded on pallets for transport to the job site. These type of repairs will usually require more labor because of the need to move bagged materials from the storage areas to the application site, form work that will be involved, mixing and placement of 6 cubic feet or more of mixed material from the mixer to the placement areas, and the set up and clean up of the equipment and material packaging. Curing of the material being placed is also a consideration in these types of repairs. Most materials utilized for these types of repairs will be cement based materials containing admixtures to achieve 12 to 24 hour high early strengths, air entrainment for resistance to freeze thaw cycles, and will contain fibers, and extender materials such as pea gravel or stone. These pre-bagged materials will also be formulated to inhibit Alkali Silica Reaction. These types of materials will usually have to cure for longer periods of time than the rapid hardening mortars previously mentioned. Curing shall be in accordance with ACI standards regarding the curing of concrete materials depending on the temperature at time of placement. This could involve wet curing, curing compounds, or in cold weather heat blankets and protection from low temperatures. These materials are most often used in conjunction with epoxy bonding agents, like **FX-752 Hydro-Ester® All Purpose Epoxy Bonding Agent** to help prevent separation from the remaining concrete substrates. An example of this type material is **FX-32 Concrete Mix AE Air Entrained Concrete with Corrosion Inhibitor.**

CONCRETE RESURFACERS

Before coating and waterproofing systems can be applied to concrete surfaces the concrete surface must first be prepared by sandblasting, water blasting, grinding, scarifying, or other method that would yield a similar result. These surface preparation techniques often result in opening bug holes, tie wire holes, form marks, honey combs, and other voids in the surface of the concrete. Before a coating or waterproofing system can be applied to this surface, a resurfacer material must be applied to provide a smooth uniform coating surface. This type of material can be hand applied for small and medium areas and spray applied for large areas. These materials will also cure rapidly, allowing them to be over coated in 6 hours at 72°F. These materials must be able to cover areas from skim coat to ½ inches thick in one application without sagging.

Examples of these materials are:

- **FX-472 Epoxy Resurfacer (May be spray applied)**
- **FX-473 Trowelable Epoxy Resurfacer**
- **FX-262 Repair Mortar**



Erosion of Concrete, Resulting in Exposed Aggregate

FX-472 Is Used to Fill in Bug Holes

FX-262 Parge Coat ¼" to ½" Thick

Thank you for your interest in our products. If you would like any additional information, please visit us at www.foxind.com, or call us toll free at 1-888-760-0369.