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Solving Interior Water Leakage Problems Below-Grade

Five Classic Approaches

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In the design of concrete structures, where concrete slabs and walls are used as the environmental barrier, water leakage is a concern. In well consolidated, normal weight concrete, high pH components within the cement/gel paste react with iron on the steel surface and resist corrosion from actively occurring around the steel. This is called "passivation." However, concrete cracking, due to high stress and associated strain defects in the element, allows leakage and lateral migration of water, and effectively introduces all of the necessary components – oxygen, water, and an electrolyte – needed for uncontrolled corrosion of the steel reinforcement. Groundwater leakage through concrete continues to bring water with dissolved oxygen and enhances the electrolytic environment, and salt water exacerbates the problem dramatically.

To help control leakage into a concrete element, it is important to understand the best water control solution is generally to provide a new, exterior membrane to a structure. However, initial cost, accessibility, public nuisance, or other circumstances, may dictate that such a solution is prohibitive. In such cases, other methods of water control must be explored.

When solving a water leakage problem around a building foundation or civil structure (tunnels, tanks, vaults, pipes, bridges and docks), approaches can be applied either exterior (positive side) or interior (negative side). Positive side solutions are in direct contact with hydrostatic water, and therefore resist water penetration at the interface. Negative side solutions are not in direct contact with water. It is common to use a combination of solutions, or perhaps different solutions on various parts of a structure, to control water migration.

After a leakage problem has been diagnosed, five classic approaches to an acceptable resolution can be explored:

1) Crack/Joint Routing, Caulking, and/or Dry-packing
2) Crack/Joint Injection, Chemical Grouting
3) Water Management & Drainage
4) Coatings, Sealers, Reactants, Sheet Liners
5) Electro-Osmotic Pulse (EOP) Technology

There is not always one right answer to the problem and there are exceptions to any water control solution, so blended approaches are very common.

Crack/Joint Routing, Caulking, and/or Dry-packing

A simplistic, first attempt is to paste over a leaking crack/joint with a high viscosity compound. This paste should extend over the crack/joint one inch and the paste should be ⅛-inch thick; sometimes it is reinforced. On rare occasions, this may temporarily resolve the leakage problem in the long term, provided cracks are static. Costs vary; $5.00 per linear foot is common, plus mobilization.

A slightly more robust solution would be to grind-out or rout-out the crack in a "U" or "V" shape, and fill with a high viscosity, low modulus filler. The performance of this solution depends upon slot depth and width, use of bond breaker, and adhesion to concrete sides. Slots ranging from ⅜ x ⅜ inches, to ¾ x ¾ inches, are common. Fillers ranging from elastomeric (low modulus) sealants, to high modulus epoxies are used. Costs vary, $25.00 per linear foot is common, plus mobilization.

Similar to using polymeric compounds in saw-cut or routed-out concrete slots, it is possible to fill the slot with a Portland cement based compound/mortar. The most common technique is to use a crystalline growth mortar. Similar to using high modulus epoxy fillers, the crack needs to be relatively static. Routing out slots in concrete for crystalline mortar filling generally requires a 1- x 1-inch slot, up to 1.5 x 1.5 inches; larger slots are also common. Costs vary; $45.00 per linear foot is common, plus mobilization.

Crack/Joint Injection, Chemical Grouting

There are three basic approaches for sealing water leaks at concrete wall/floor defects (cracks and joints). These approaches are as follows:

1) Backside Injection (curtain grouting), whereby a grout material is deposited behind the wall/floor crack/joint or into the earth backfill (permeation grouting or soil solidification). The grout material solidifies soil and plugs leaking water points of origin.
2) Internal Injection (interception grouting), whereby a grout material is deposited into the internal concrete crack/joint at mid-depth. The internal injected grout fills the crack/joint from internal to external face.
3) Surface Mounted Injection, whereby a grout material is applied to the surface of the leaking crack/joint, or is partially routed and plugged with a water impedance material prior to pressure injection.

Typical resinous injection and generic grout types available in the industry include:

- Epoxies
- Bentonites
- Hydrophobic Urethanes
- Hydrophilic Urethanes
- Two-Component Structural Urethanes
- Acrylamides
- Acrylic Resins
- Rubberized Mastic or Gels
- Micro-Fine Portland Cement

This injection process involves placement of a resinous polymer, and/or non-reactive gel or paste, into a crack zone or behind it. Most chemical grouting within the crack zone involves placement of a low viscosity, reactive, epoxy, urethane, or acrylic-based polymer. These reactive polymers fill the cracked section and theoretically plug the void. They bond to the crack sidewalls in various degrees depending upon crack cleanliness. These various reactive polymers exhibit different degrees of elongation. The grout selection must consider crack width, movement, orientation, age, and sequence.

The cost of injection grouting varies considerably based on mobilization and access, quantity of work, security requirements, time duration per shift, and material used. Rough cost ranges may be as follows:

1) Backside Injection (curtain grouting); variable cost range = $35.00 to $100.00 per square foot
2) Internal Injection (interception grouting); variable cost range = $75.00 to $485.00 per linear foot
3) Surface Mounted Injection; variable cost range = $20.00 to $70.00 per linear foot

Water Management and Drainage

This concept can be very simple to complex. Simple water management solutions may involve cutting a slot into a floor slab adjacent to leakage area(s) and channeling it to a nearby drain. Slot depths and widths vary based on water flow rates. Costs vary, but $25.00 per linear foot, plus mobilization, is common.

A more comprehensive solution may involve cutting out a much wider and deeper slot into or under the floor slab (may include soil removal), adjacent to leakage areas, and installing perforated drain pipe or a manufactured drainage mechanism that collects water and channels it to a sump collection area. Costs vary from $25.00 to $100.00 per linear foot, plus mobilization.

The next water management and drainage step up involves placement of a drainage media to move water from the leakage area to a collection point. Collected water is either pumped to the surface or drained. Water management materials usually consist of some type of deformed plastic sheeting attached to the wet substrate that collects, channels and deposits water to centralized locations. Concrete, masonry, or gypsum sheeting often cover these systems for aesthetics and fire protection. Costs vary from $75.00 to $400.00 per linear foot, plus mobilization.

Coatings, Sealers, Mortar Reactants

This process involves placement of a bonded layer, or chemically reactive mortar agent, on the concrete interior surface experiencing water leakage (negative side treatment). All coatings and reactive agents require the substrate to be free of permeating water prior to installation. Thus, chemical grouting may be first performed to alleviant active water leakage prior to coating or reactive mortar agent installation.

Interior coatings generally come from the same generic family of polymers as used for pressure injection, i.e., epoxy, urethane, acrylics and/or latex. Interior coatings must resist both the effects of negative side water and water-vapor pressure. These coatings can be "breathable" (vapor permeable) or "non-breathable" (vapor retarders). Interior coatings depend upon adhesion to the concrete substrate exceeding liquid and water vapor pressures. Further, they must be flexible to accommodate substrate movement. Costs vary from $5.00 to $20.00 per square foot, plus mobilization.

Some coatings may be chemical reactive agents, commonly referred to as crystalline growth slurrys or mortar treatments. These are surface applied mortars with reactive chemistries to the concrete substrate, meaning that they react with cement hydration by-product(s). Calcium hydroxide is a high pH, soluble salt by-product, contained within the micro voids and pores of the concrete gel matrix.

Surface-applied reactive treatments to a damp concrete substrate can be formulated to react with un-hydrated cement, free calcium oxide and calcium hydroxide, thus creating silicate based crystal growth in pore spaces and micro voids within the concrete gel matrix. These crystal growth by-products can plug micro voids and pores, and very fine cracks in the concrete matrix, thus creating a water resistant barrier. Costs vary from $4.00 to $12.00 per square foot, plus mobilization.

Electro-Osmotic Pulse (EOP) Technology

This technology is an electrical solution for drying out concrete and is capable of protecting reinforcing steel in concrete. EOP systems fundamentally consist of a power supply and two oppositely charged electrodes. The power supply charges an anode (+) terminal at one end of a concrete element and a cathode (-) terminal at the other end. Low voltage (24 to 28 volts) output from the power supply, across the terminals, is created through the concrete element via the water containing micro-voids. Current flows from cathode to anode and electrons flow from anode to cathode. EOP installations are designed to create low intensity electric field(s) within wet concrete element(s) and adjacent soil.

Fundamentally, the design places oppositely charged electrodes on each side of a wet concrete element or area. If the concrete element and adjacent soil is conductive (wet), and the micro-voids are partially filled with water, ions can move from electrode terminal to electrode terminal because an electric field was created in the damp concrete between said terminals. Over time, water moves from anode to cathode and dries the concrete out.

Wet concrete is more conductive than dry concrete, thus high internal moisture content concrete is more conductive than dry concrete. Lower strength concrete is usually more conductive as well. The highest electrical conductivity is at water leakage locations because the concrete micro-structure is close to saturation.

EOP system design depends on many factors. Placement of anodes is either in a grid system or at wet locations where defects in the concrete element exist. Cathodes are spaced in a manner whereby the electric fields are relatively uniform across the concrete element. Because this is an electrical solution, the designer needs to ensure that outside electric field(s) will not interfere with the EOP system. The cost of EOP installations vary considerably, however a range of $400.00 to $1,200.00 per linear foot of wall length is common. Slabs may be in the range of $25.00 to $80.00 per square foot.

Conclusions

Facility owners tend to approach water leakage problems in a systematic way. They tend to explore solutions on a lowest-to-most-costly basis, coupled by spot location-focused to a broad-based scope repair. Engineers and contractors, with input from a facility owner, generally will take a similar approach. Consider further that each water control approach can use a vast array of products with material properties that seem similar; however, they can have quite different results. Be mindful that the contractor's experience may be more important than the design approach selected.

When engineers and consultants are involved with the water control process, they typically want to determine leakage root cause prior to design. A systematic engineering approach for identifying and solving moisture problems could be outlined as follows:

1) Gather history of problem,
2) Understand the design,
3) Search for the leak path,
4) Perform proper tests,
5) Discover the root cause, and
6) Determine solution approach.

After the water leakage problem root cause is determined, the engineer/consultant and/or contractor must match a cost effective solution with the budgetary criteria that provides the longest service life. This requirement involves considerable experience and knowledge about the concrete structure, materials and tradesmen capabilities.▪