Remediating Leaks in Below-Grade Structures and Plazas

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WATER INFILTRATION THROUGH a roofing or waterproofing membrane is problematic and can cause deterioration of structural building components that can adversely affect their performance. When water infiltrates a basement—whether through the foundation, the slab-on-grade, or the plaza above—the results can be catastrophic and render the basement space uninhabitable. Also, ascertaining the source or cause of these leaks can be difficult, and the repairs can be costly and disruptive to occupants.

For that reason, waterproofing membranes should ideally perform for the full life of the building. Durability is a principal consideration in selecting a waterproofing membrane. Notably, if waterproofing manufacturers offer warranties or guarantees, the usefulness of the warranty or guarantee tends to be severely limited for below-grade structures, for two reasons:

- Waterproofing for foundations and under slabs-on-ground are inaccessible.
- Replacing a waterproofing system under a plaza will require removal and replacement of the overburden, including vegetation, concrete slabs, pavers, and setting beds.

Relative to waterproofing, when roofs leak, the sources of water intrusion can usually be readily identified and repaired because most roof membranes are accessible. Even if those membranes are covered with aggregate, pavers, or protected membrane systems, it is not difficult to observe and expose the roofing membrane or flashing and then identify and repair the defect.

By comparison, remediating leaks in below-grade structures and plazas can be more challenging. This article addresses those challenges.

INVESTIGATION OF BELOW-GRADE OR PLAZA LEAKS

The methodology described in this section is intended to provide a systematic approach to evaluate leaks in below-grade structures or plazas. The investigation procedure of finding and stopping leaks in below-grade structures or plazas is similar to the process of resolving a roof leak.

Documentation Review

First, before a physical exploration is performed, the following should be acquired and reviewed:

- The geotechnical report (if one was issued)
- Construction documents to ascertain the type of waterproofing system installed, along with the thickness of the slabs and foundations
- The history of water infiltration, including locations
- A record of leak-related repairs
- Documentation showing whether sprinklers and lighting conduits were installed after application of the membrane
- Documentation regarding recent alterations of the structure to determine whether new below-grade penetrations were installed
- Reports from building personnel knowledgeable as to whether leaks are intermittent or continuous

Ascertaining the building area's flood zone, if applicable, can also provide invaluable information to the investigation.

Leak Survey and Observations of Existing Conditions

A basement plan of the premises should be obtained from the building owner. If they are not available, plans should be prepared to assist in recording all current leak sites and any inactive leak sites that have been repaired. The following items should be recorded:

- Areas where water is infiltrating from below (that is, through the slab/foundation joint)
- Locations of water infiltration through construction joints or cracks
- Flowing, dripping, or staining from water leaks at penetrations, plaza drains, piping, pipe hangers, or other penetrations in the suspended slab
- Leaking or staining near form-tie holes or rock pockets
- Staining under openings to window wells
- Volume of water infiltration or seepage
- Whether leaks appear only as damp spots
- Flood-level lines
- Whether stains on slab soffits and pipes are circular, indicating condensation

Additionally, not all damp spots on walls or puddles on floors are caused by water infiltration. These may be due to condensation or from overhead pipes that leak.

DETERMINING THE CAUSE OF A WATERPROOFING FAILURE

Leaks through below-grade concrete foundation walls and slabs-on-ground exhibit themselves at cracks, cold joints, expansion joints, and penetrations. On concrete masonry foundation walls leaking can extend over many mortar joints.

If leaking occurs after a period where the basement has been dry, it is usually caused by failure of either a structural element or one of the waterproofing components. These failures can be exacerbated by an unanticipated increase in hydrostatic pressure.

When structural failures occur, they exhibit as cracks or the opening of construction joints. These types of failures may be due to overloading, settlement, vibration, seismic

Figure 1. Absence of gutters can cause additional recharging of soil from roof runoff.

Figure 2. Oil (petroleum) infiltration can be identified by color and odor.

events, creep, shrinkage, or adjacent construction activities. Structural failures can also happen if a nearby construction site utilizes controlled blasting to minimize the over breakage of rock beyond the excavation site. Dewatering in nearby excavation sites can cause differential settlement from groundwater level drawdown.

When a below-grade or plaza waterproofing failure occurs, it can generally be traced to one or several of the following:

- Membrane rupture over voids or holes in the foundation from rock pockets or formwork spreaders
- Splitting or seam failure of waterproofing membrane at plane changes
- Cracking or disintegration of inadequately compacted soil or gravel
- Concrete cants at the footing/wall joint
- Membrane deterioration from aggressive soils, petroleum products, and other deleterious chemicals
- Membrane damage from root intrusion when vegetation is replaced or backfill settlement
- Loss of bentonite from rapidly moving water
- Improper or inadequate penetration flashing
- Ruptured flashing at plaza drains caused by traffic or wearing course movement
- Displacement or construction joint separation of waterstops
- Rupture of plaza expansion joints or separation of flanges from the membrane

Leaking in below-grade walls and slabs is frequently caused by an unanticipated increase in hydrostatic pressure due to a rise in the water table or from an overload of water in the soil surrounding the foundation. The latter may be caused by the following:

- Nearby construction of new below-grade structures or utilities diverting underground water tables toward the site
- Runoff from recently paved adjacent areas

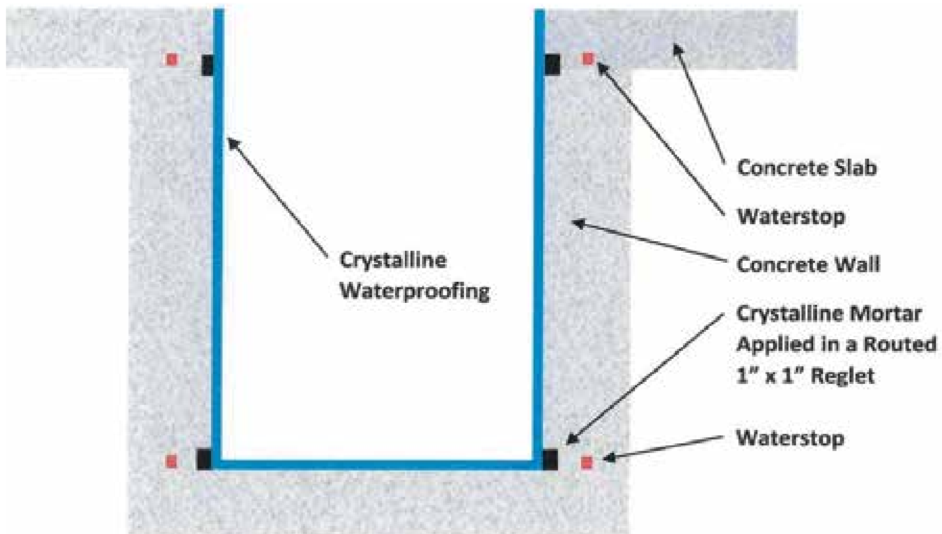

Figure 3. Diagram of crystalline waterproofing application.

- Regrading on neighboring lots that directs water toward the building
- Leaks from nearby area drains or sewers (storm or sanitary)
- Obstructed plaza drains
- Negative grading
- Dense shrubbery at the foundation preventing groundwater from evaporating
- Sprinkler heads that spray water under adjacent wall flashing
- Gutters that are undersized, absent (**Fig. 1**), too widely spaced, or clogged
- Lack of drainage or blocked drainage in areaways or window wells
- Relocation of underground water tables from their normal flow at nearby construction sites
- Abandoned or concealed catch basins

Leak sources from an increase in hydrostatic pressure can often be identified by observing the color or odor of the infiltrating water or from chemical tests. For example:

- Chlorine is indicative of a water line break.
- An unusually high level of bacteria is typically associated with a sewer line break; such breaks often go unreported because the leakage does not affect waste removal.
- Saltwater can be traced to a tidal flow from a nearby body of water.
- Bentonite or bitumen often indicates a failure of a bentonite or bituminous waterproofing system.
- Oil can originate from a ruptured fuel line or tank (**Fig. 2**).
- Rust stains on the interior of a concrete foundation can come from reinforcing bars attacked by aggressive soil chemicals.

REMEDIATION OPTIONS

After performing a leak survey, the consultant should complete a visual inspection of the building exterior. That inspection will help determine which remediation option is appropriate.

Figure 4. Crystalline waterproofing being applied by brush.

Depending on the specific variables associated with the repair project, a variety of remediation options may be pursued for leaks in below-grade structures and plazas. Each approach comes with its own advantages and limitations.

Crystalline Waterproofing and Hydraulic Cement

Crystalline waterproofing is a long-established method of remediating basement leaks. It is applied to moist surfaces. Construction joints and cracks are routed out, primed, and packed with a cementitious mortar (**Fig. 3**). Crystalline coatings are capable of limited self-healing of cracks that measure up to 0.012 in.(0.3 mm) wide. There are also many useful proprietary hydraulic cements marketed for emergency repairs of flowing water.

The application of negative-side waterproofing materials is a common remediation method. It is an efficacious approach in situations where water is infiltrating through many locations over a large or broad area.

Surfaces must be mechanically abraded to open the pores. Cracks and joints must be routed out at least 1 × 1 in. (25 × 25 mm) and a cementitious mortar forced into them. Surfaces to which the materials are to be applied must be kept moist for 36 to 48 hours after application, or as specified by the crystalline manufacturer. The material can be applied by brush or air spray (**Fig. 4**). Crystalline waterproofing is typically applied in two coats.

This approach is relatively inexpensive and easy to apply, and it is suitable for active leaks. A major disadvantage to crystalline coatings is that they are vapor permeable and should not be used in areas where high humidity must be controlled.

Some other disadvantages include:

- Vulnerability to substrate cracking
- Dependence on construction joint treatments
- Inability to protect against corrosive soils
- Impractical for structurally framed slabs and intersecting walls

Bentonite Grout

Sodium bentonite is a high-solids, clay-based remedial waterproofing material. When bentonite is injected at the foundation interface with the adjacent soil, it forms a dense, watertight material course. Bentonite grout is effective when injected behind heavy stone foundations or at least 6 in. (150 mm) thick reinforced concrete slabs.

Bentonite can be injected behind foundation walls from the interior, or it can be injected from the exterior of the building (**Fig. 5**). It can also be injected under basement slabs. Injecting from the interior requires the predrilling of holes through the foundation wall to pump grout through. Exterior injection does not require soil excavation and is accomplished by sinking a pipe into the soil adjacent to the foundation (**Fig. 6**). Pipes are spaced 2 ft (0.6 m) on center and used for shallow foundations that are less than 10 ft (3 m) deep. Maintaining proper pumping pressures is critical to ensure the structural integrity of walls and slabs, as high pressures can displace insufficiently reinforced concrete and masonry. It can fill large voids in the soil and is suitable for remediating failed foundation waterproofing.

Some installers state bentonite should not be used within 24 in. (600 mm) of the grade because of the difficulty of maintaining sufficient pressure and restraint. Without confinement, sodium bentonite cannot create sufficient pressure.

Bentonite is relatively inexpensive. It can fill large voids in the soil, and bentonite injection is suitable for remediating failed bentonite waterproofing. However, bentonite injections can be washed away by swiftly flowing water in well-drained soils.

Bentonite injections require the compression of the surrounding soil and construction components. Cracks wider than 0.125 in. (3 mm) must be sealed with mortar to maintain proper compression. Pumping must be monitored, as its force could displace insufficiently reinforced concrete or masonry walls.

When compared with urethane or acrylate esters, bentonite grout is less expensive and does not require the same level of application skills as other remediation methods.

Some of the advantages of sodium bentonite grout include the following:

- The product is a natural, inert mineral and contains no volatile organic compounds.
- It can fill both small and large voids around the foundation.
- It can be injected through the same drilled holes to provide greater coverage if the initial injection does not stop the leak.

Some disadvantages that should be considered:

- It may flow into footing drains and clog them.
- If the injection fails to stop the leaks, additional bentonite is the only option because it forms a bond breaker with alternative materials.

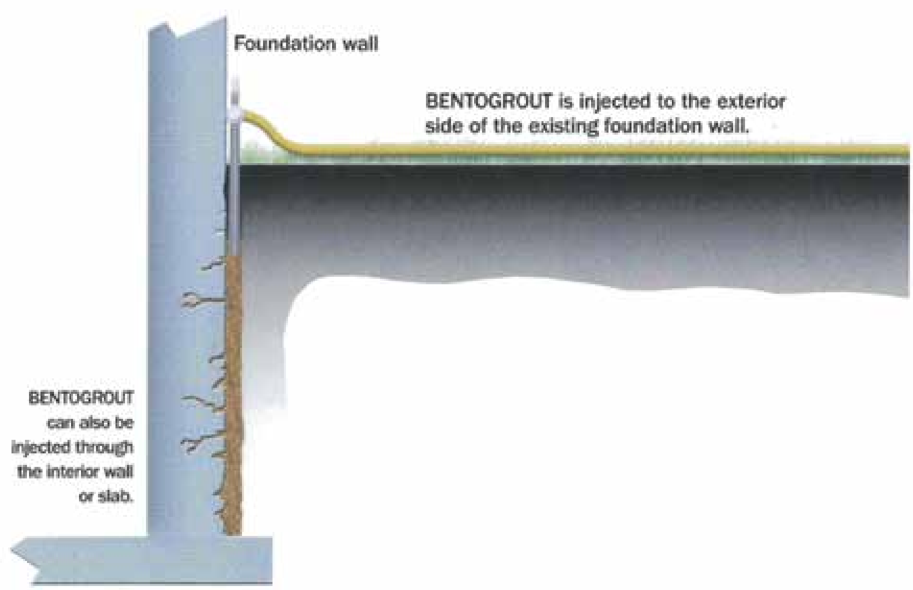

Figure 5. Diagram of bentonite injection on exterior of foundation (Diagram courtesy of CETCO.)

Figure 6. Bentonite injection on exterior side of foundation.

Figure 7. Port installation for epoxy injection.

Epoxy-Resin Bonding Systems

Epoxy-resin bonding systems are the preferred material for repairing structural damage in cracks or cold joints that are not subjected to movement from thermal changes or vibration. Injected into concrete cracks as narrow as 0.002 in. (0.05 mm), they can stop leaks; however, they are not as effective as chemical gel products. Epoxy-resin systems are two-component, consisting of modified epoxy resins and a curing agent of amine hardeners and modified fillers. They are specified under ASTM C881, *Specification for Epoxy-Resin-Base Bonding Systems for Concrete*.[1] These systems are classified according to type, grade, class, and color.

Epoxy-resin bonding systems cure chemically, are moisture tolerant, and are unaffected by cycles of freezing and thawing. They can cure under humid conditions and bond to damp surfaces. They adhere well, but they are relatively inflexible and do not tolerate movement. They are not recommended for high-volume leaks because it is difficult to keep the resin in position until it has cured. They are not as effective as urethanes for stopping leaks.

Since epoxy is inflexible and stronger than concrete, cracks may occur in the concrete near the site of the repair where stresses are transferred to adjacent areas. Additional injections at adjacent cracks with urethanes are often required to solve leak problems.

Epoxy injection requires workers who have the knowledge to select the most appropriate products with the correct viscosity and the skill to apply those products with the proper injection pressure and timing (**Fig. 7**). Cleaning cracks is crucial where epoxies are injected.

Epoxy-resin bonding systems are suitable for concrete, but not for masonry. Their use is inappropriate to repair dynamic joints or cracks that are actively leaking, as there is the possibility of re-cracking. Epoxy injections can be odorous. The use of an epoxy-resin bonding system does not preclude the subsequent application of other remediation materials such as gel foam or injection.

Figure 8. Urethane grout injection at a horizontal concrete slab.

Chemical Gels and Foams

Products in the category of chemical gels and foams are urethane, acrylate polymers, and similar hydrophobic and hydrophilic chemicals that are one- and two-component resins. The installed products can be flexible or rigid materials and/or open- or closed-cell foams, depending on the formulation and proportions. Chemical gels and foams function as a flexible gasket between surfaces. Chemical gels and foams generally stop leaks and permit limited joint movement, but they will not restore strength or structural integrity.

Hydrophilic urethane gels react with water and expand to form a flexible resin that maintains its watertight integrity even during limited concrete movement (**Fig. 8**).

Hydrophobic urethane foams react with small amounts of moisture and expand, forming a water-impermeable grout curtain. Their cured density is more predictable than that of hydrophilic foams. In their cured state, hydrophobic urethanes are not affected by changing moisture conditions.

Acrylate polymers have excellent adhesion and are very fluid, with viscosities approaching that of water. They do not expand upon reaction with water but exert less pressure than bentonite and most urethanes. As such, they are suitable for injection into thin cracks and joints in concrete and masonry, and for repairing deteriorated membranes in split-slab assemblies. They also form superior flexible grout curtains in moist environments.

Low-viscosity flexible urethane and acrylate polymer grouts are injected from the negative side into cracks or joints, and into soil behind leaking walls and slabs. The resins are installed by pumping them through holes drilled in the concrete from the interior. To create gel curtains, the holes are drilled through floor slabs spaced 12 to 24 in. (305 to 610 mm), and through foundations 12 to 24 in. (305 to 610 mm) each way. At cracks and joints, the holes are drilled at opposing angles on either side, generally spaced 12 to 24 in. (305 to 610 mm) apart. Packers are inserted in the hole and chemicals are injected under pressures ranging from 1 to 3000 psi (6.89 to 20,860 kPa) progressively from drill hole to drill hole. ASTM D8109, *Waterproofing Repair of Concrete by Chemical Grout Crack Injection*,[2] describes the selection of materials, installation methods, and inspection required for sealing leaks at cracks in concrete building walls and slabs.

Injected chemical gels and foams resist acids, alkalis, and organic solvents, but they are ineffective for structural repair and the strength of slabs and walls must be evaluated to ensure they can withstand the increase in hydrostatic pressure. Urethanes can be used to lift or stabilize floor slabs structurally by filling voids below the slabs. Other limitations with this technique include the fact that certain hydrophilic gels can shrink, and the application process can be messy and difficult to clean up.

Above-Ground Building Components

As noted earlier, the building enclosure consultant should complete a visual inspection of the building exterior before initiating

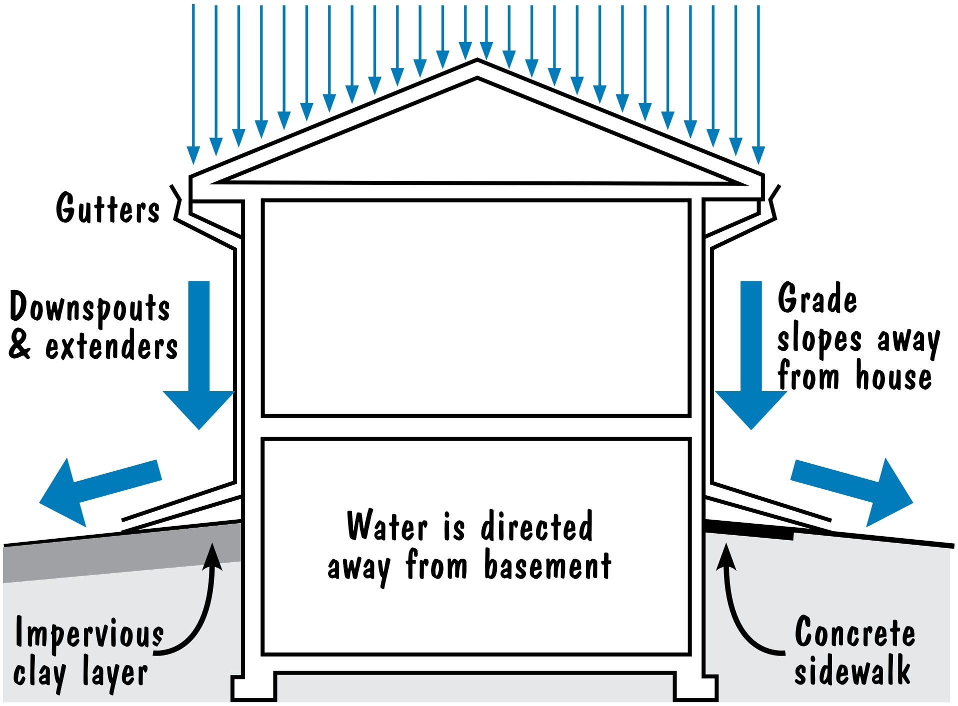

Figure 9. Leaks may be remediated by installing gutters and providing a positive slope away from the foundation.

remediation. In some situations, remediating a leak can be as simple as:

- installing gutters where they are absent and providing larger downspouts (**Fig. 9**);
- connecting downspouts to a storm water sewer or extending them to daylight at least 10 ft (3 m) from building:
- recontouring the grade to slope away from building;
- constructing swales to divert water around building;
- providing interceptor drains on uphill side of the site;
- installing a perforated pipe in gravel at the building perimeter and at the base of a metal and glass curtainwall to reduce hydrostatic pressure; or
- locating lawn sprinkler systems to avoid spraying water onto the building.

Other remediation methods may involve the following:

- Draining water within the basement by installing an interior perimeter gutter sloped to a sump so it can be pumped to a sewer
- Installing drainage panels on basement walls and floor slab and then covering them with watertight wall panels and 3 to 4 in. (75 mm to 100 mm) concrete slab; the water would be conducted to a sump and then removed by a pump

Repairing or replacing the waterproofing membrane on a concrete foundation can be costly but can be effective on shallow foundations where there is access.

CONCLUSION

The location and severity of the leaks will determine the appropriate method of remediation. Sometimes, more than one method is required. Factors that influence the selection process include the following:

- Access to the foundation and slab either from the interior or exterior
- The degree of disruption to the building occupants
- Budget limits imposed by the owner

In many cases, the best approach is to begin with the simplest and least expensive method and graduate to more complicated and costly remedies as required.

Causes of leaks in basements include the following:

- Failure or absence of a positive-side waterproofing system
- Movements that open cracks and joints
- Flashing failures of the waterproofing at penetrations
- Hydrostatic pressure absent at the time of construction

The building enclosure consultant should perform a thorough and systematic investigation to determine the source of water infiltration. The cause and building limitations should be determined before a remediation method is selected. Additionally, all options should be considered before a final decision is made as to which approach is best for the building.

REFERENCES

1. ASTM International. 2020. *Specification for Epoxy-Resin-Base Bonding Systems for Concrete.* ASTM C881/C881M-20a. West Conshohocken, PA: ASTM International.
2. ASTM International. 2017. *Waterproofing Repair of Concrete by Chemical Grout Crack Injection.* ASTM D8109-17. West Conshohocken, PA: ASTM International.

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