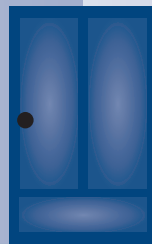


Pushing the Building Envelope...

Below Grade



By Phil Haisley, AIA

INTRODUCTION

This article summarizes a presentation for the RCI Region 6 Winter Symposium held in Honolulu, Hawaii on February 5 and 6, 2001. It touches on the history and basics of below-grade waterproofing systems, but focuses on leak remediation methods that are not typically covered in below-grade waterproofing books or manuals. Failures associated with termite damage and the potential health effects and liability of waterproofing failure are also briefly explored.

Designers and builders strive to be on the leading

edge of modern building technology, "pushing the envelope" of design, materials, and techniques. Highly visible building elements get the most attention, but unseen building elements may prove to have a greater impact on building performance. Because of a proliferation of below grade waterproofing products, designers may find themselves "behind the curve" in keeping up with changes. The risk of failure demands that unglamorous design elements receive as much (or more) attention as more visible elements of the building envelope.

Pushing the envelope below grade

Leaks have always led the list of common building defects and are one of the most common sources of claims in the construction industry. Push the leak underground, and the cost and difficulty of repair can increase substantially. Add the loss of use, property damage, and potential health risks associated with damp buildings and water-damaged materials, and a small mistake in judgment at the drafting board or slip in craftsmanship at the job site may turn into a dreadful liability.

Dampproofing and below-grade waterproofing are far from new. For 2,500 years, people have used bitumen and lead to keep water out of their homes. Coal tar pitch with fabric reinforcing came into use about 200 years ago, followed by hot-mopped bitumen in the mid nineteenth century and cementitious waterproofing around 1900. The past 50 years have seen an acceleration of

available products, with the introduction of crystalline coatings, rubberized asphalt sheets, single-ply butyl and PVC sheets, liquid-applied membranes, and bentonite clay. During the past ten years, VOC regulations have influenced the introduction of two-component, liquid-applied, cold-applied, and water-based systems.

New challenges

Today there is a variety of new products and choices for dampproofing and waterproofing below-grade walls and slabs, driven by technology, economics, and environmental regulation. Construction industry professionals faced with a wide range of products may become overly reliant on the experience and advice of manufacturers. Warranties for below grade systems are not as comprehensive as those in the roofing industry. For now, designers must take full responsibility for selection of appropri-

ate products, proper detailing of transitions and penetrations, and integration of waterproofing systems with surrounding building and soil components. Designers and builders must develop an understanding of the variety of materials, application techniques, and product attributes and limitations, while maintaining attention to changes in the industry.

Do it right...

Some things haven't changed much and aren't likely to. Future generations will still slope surface drainage away from building foundations and drain water from footings whenever possible. Anything that can be learned about site and soil conditions is useful in all situations and must never be overlooked. Test borings can help identify the nature and porosity of the soil, water table or a shelved water table location, and soil contaminants. Weather records can help put these conditions into historical context. The intended use of the space and the occupant's tolerance for humidity or moisture are important factors in the selection process, as is the owner's tolerance for the risk of failure. Many excellent references are available that can provide a foundation for sound practice in waterproofing fundamentals. These resources can also help sort out the variety of newer products. A short list of useful references is included at the end of this article.

...or do it over

Of course, if everyone designed and installed systems "by the book," roof consultants wouldn't have much to do. Usually, by the time we get involved, something has gone wrong. Access to the waterproofing is usually not feasible.

Although we occasionally must dig up a project and do it over, practical considerations usually dictate solutions from the interior of the affected space. "Negative-side" solutions have historically been limited to cementitious coatings containing metal filings, polymers, or other densifying agents. More recently, crystalline chemical coatings (which react with moisture) and portland cement or lime have become available. They grow crystals to fill pores and fine cracks in the concrete. Both of these negative-side solutions have a number of limitations:

- Neither will protect the building structure from contaminants or deterioration in the wall from the exterior side.
- Both are vapor permeable materials, and their use should be limited to humidity-tolerant occupancies.
- Neither is flexible or tolerant of building movement, though the crystalline chemicals are somewhat self-healing in fine cracks.
- Successful application usually requires continuous access to surfaces without interruptions at intersecting walls and floors.
- Treated surfaces are susceptible to damage from fasteners, wear, or abuse from the interior space.

The waterproofing manuals and references listed at the end of this article share useful infor-

mation on these negative-side waterproofing systems, but there are a couple of alternative negative-side solutions that are not discussed in most books or manuals on the subject. Crack injection can help overcome some of the limitations of other negative-side solutions, may address problems closer to the source, and might be more reliable in certain situations. In cases in which cracks and joints are not moving, many successful leak remediation projects use epoxy injection. Where movement might occur or leaks are heavy, chemical injection grouts can provide protection for below-grade walls either by forming a flexible gasket in cracks and joints, or by injecting a new positive-side membrane through the wall.

Epoxy Injection

Epoxy injection has proven to be an effective and practical way to stop leaks through concrete walls. It provides a strong but relatively inflexible seal at leaking cracks and joints and can restore the structural properties of the wall and protect reinforcing steel. The repair might be stronger than surrounding concrete, but any substantial movement will result in a new crack near the old one. In our experience, re-cracking is not ordinarily a problem for leak repair projects. Failed attempts at epoxy injection do not preclude a subsequent attempt using chemical gels and foams. Epoxy will not conduct moisture, so vapor permeability is reduced (at least to the limits of concrete wall or slab thickness). Injection epoxies cure chemically, are moisture tolerant, and are unaffected by freeze/thaw cycles. Epoxies are not a good choice for injecting against active, high-volume leaks, as it may be impossible to apply a seal on the surface of the crack and because the leak is likely to cause displacement of injection resin and result in incomplete penetration. The repair effort can be localized at problem cracks and joints, though it is not uncommon for leaks to find new paths after the easier paths are blocked. Additional injections at adjacent cracks are often required to solve leak problems.

The success of an epoxy injection project depends largely on the skill and experience of the injection contractor and the use of appropriate products of the right viscosity with the right



Epoxy Port Spacing

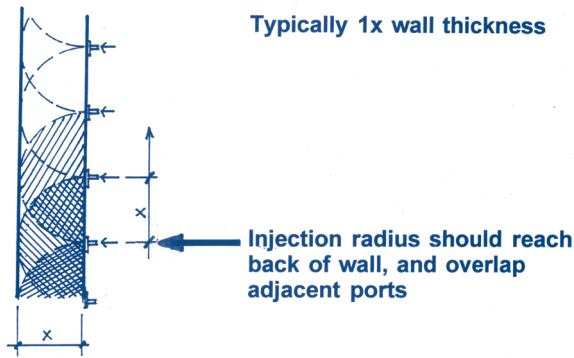


Figure 1: Epoxy Port Spacing. Wall thickness, crack size, and resin viscosity are considered when determining port spacing. Typically, ports are spaced one wall thickness apart to help assure full penetration without excessive loss of resin through the back of the wall.

injection pressure and timing. Much depends upon crack width, wall depth, and the presence of water or contaminants in the injection path. As a general rule, the best results on typical projects with narrow cracks are achieved by using a long pot life and 100% solids epoxy with a viscosity to match crack width.

Narrow cracks are injected relatively slowly at low pressures (20-40 psi), usually through all ports simultaneously. The lower pressures result in slower injection, which tends to provide better penetration and surface saturation. Cracks as small as 2 mils in width (.002") can be successfully injected, and equipment can be inexpensive (spring-loaded cartridge or bladder injection equipment). High pressures may be necessary for wide cracks, because of the volume of material required. High pressure injection typically proceeds from port to port, from the widest to narrowest portion of the crack, or lowest to highest for more consistent widths. Resins tend to flood the widest portion of the crack. If the crack is wider near the surface, the resin may appear at the next port before it has fully penetrated the wall. If there is a structural requirement for the repair, quality control can be mon-

Epoxy Injection Port

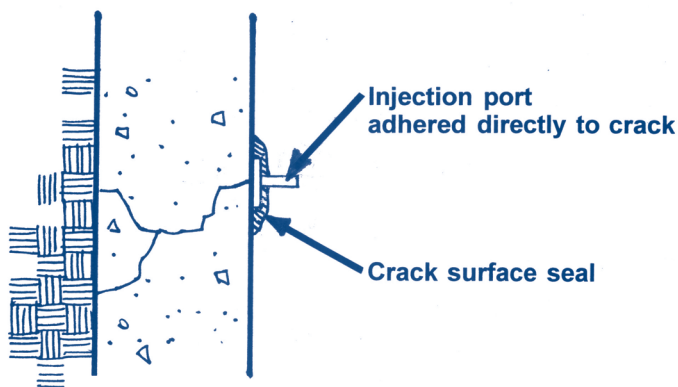


Figure 2: Epoxy Injection Port. Ports are glued to the face of the crack with epoxy, then the face of the exposed crack is sealed with epoxy between ports to force resin into the wall and prevent resin loss on the working side.

itored by taking cores at cracks to the desired depth of penetration to measure success (1 core per 100 LF of crack). For waterproofing work, the success of the injection work is apparent without coring.

Injection ports for epoxy are normally placed on the surface of the crack at a rule-of-thumb spacing of approximately 1x the wall thickness to help assure that resin will reach the back of the wall before reaching the next higher port (see Figure 1). Spacing may be closer for narrow cracks. The crack is then surface sealed with a paste epoxy (Figure 2). After injection, the surface seal and ports can be left in place if appearance is not important or they can be ground off and the surface smoothed and refinished.

There has been some debate about flushing cracks before injection. Most crack cleaning methods are of limited benefit and may create problems. Muriatic acid will etch the concrete without removing waxy or oily contaminants and can attack the bond of the surface seal. Acid is quickly neutralized by reaction with concrete and may leave salt or acid residue on reinforcing steel. Solvents and detergents remove some dirt and oil but produce no scouring action. Forced air removes only loose, dry particles. Water may become trapped in pockets, preventing resin penetration. If crack cleaning is required, the best approach is probably to flush cracks with the injection resin itself, until the "driool" at the next port looks clean. Cleaning is not usually required for leak repairs. Even a dirty crack can be sealed and typically will have shear and compressive strength restored by injection. Cleaning is required for a structural repair where adhesion is needed to restore tensile strength. Because concrete is inherently weak in tension anyway, the tensile strength of the injection is not usually a critical factor even for structural repairs.

Case study for epoxy injection

Parking for a high-rise condominium/office tower in downtown Honolulu was located entirely below grade with the lowest floor more than 20 feet below sea level. The original waterproofing was composed of bentonite panels applied directly to smoothed coral surfaces in the excavation without forms on the

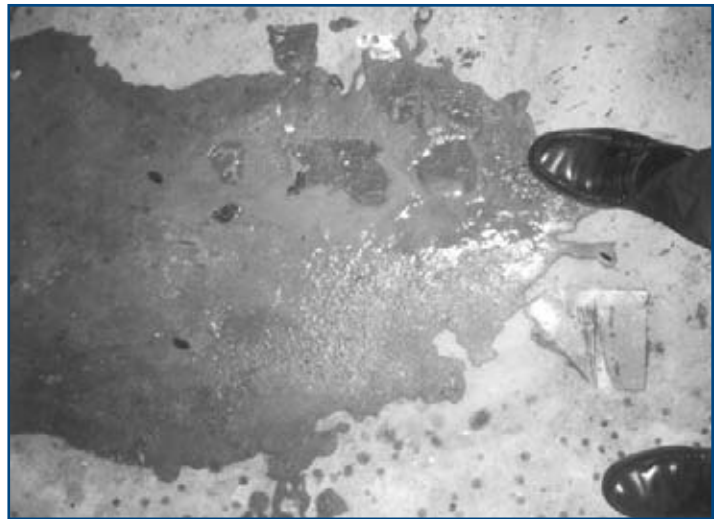


Figure 3: An underground, stream-washed bentonite waterproofing from the foundation wall and through cracks in below-grade walls of this Honolulu parking structure resulted in a slick slurry of clay on the parking deck. (Photo by Phil Haisley)

vide a flexible gasket that seals cracks and joints while tolerating limited building movement. These chemicals can even be injected through a problem wall or floor, saturating the soil or drainage course on the "blind side" to form a positive-side waterproofing membrane or to form a patch over an existing membrane (Figure 8). Failed attempts at polyurethane injection prevent subsequent attempts with epoxy, but gels or foams can be reapplied. Gels and foams are permeable, and though they will stop moisture, they do not act as a vapor barrier like epoxy. As with epoxy, the repair effort can be limited to the problem locations, though leaks should be expected to find new paths after the initial injection effort. Unlike epoxy, these materials can expand volumetrically upon reaction, so that large voids behind narrow cracks might be filled by relatively small quantities of low-viscosity injection chemicals.

Gels and foams normally fall into two broad categories: hydrophilic (loves water), and hydrophobic (fears water). Both types are actually mixed with water for the initial reaction. Hydrophilic products typically produce gels and flexible foams.



Figure 4: Above, hydrostatic pressure forced water through construction joints between the slab and foundation wall. This slab is approximately 15-20 feet below the water table. (Photo by Phil Haisley.)



Figure 5: Above, a constant stream of water down this ventilation shaft and through two levels of parking resulted from waterproofing failure at cracks through foundation walls. (Photo by Phil Haisley.)

exterior side. Persistent leaks developed and worsened over time, leaving slick streams and a slurry of bentonite clay on the decks (Figure 3). Water streamed in through joints in the foundation slab (Figure 4) and through cracks in walls (Figure 5). Investigation of subsurface conditions suggested that an intermittent sub-surface stream had scoured bentonite material from exterior surfaces, resulting in periodic leaks at upper levels and chronic leaks at lower levels. The injection contractor managed to alleviate the leak problems with two rounds of low-pressure epoxy injection, spaced one year apart, even though leaks were active and cracks were contaminated with bentonite. The second round of injection work was completed approximately two years ago, and formerly wet, treacherous areas are presently dry (Figures 6 and 7).

Chemical injection gels and foams

Polyurethane and acrylate injection chemicals cannot restore strength or structural integrity, but they can pro-



Figure 6: Above, left, epoxy injection sealed the leaking construction joint shown in Figure 4 against static pressure of the surrounding water table. Figure 7, above, right: Wet, treacherous areas around the base of the ventilation shaft shown in Figure 5 are dry after epoxy injection of wall cracks, although leaks were continuously active, and cracks were contaminated with bentonite. (Photos by Phil Haisley.)

Polyurethane Gel Soil Barrier

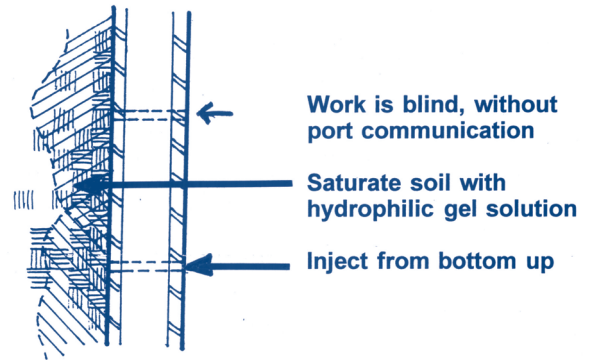


Figure 8: Gel injection through porous walls can fill voids and saturate back-fill materials, forming a flexible blind-side seal to repair breaks in existing waterproofing membranes.

Ports for Grouts & Gels

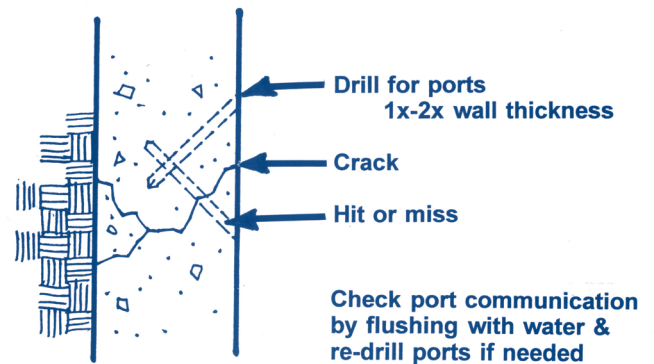


Figure 9: Injectors or "packers" are secured into drilled holes for chemical foam or gel injection. Holes are normally drilled at an angle designed to intersect the crack just beyond the mid-point of the wall thickness. Alternating ports on either side of the crack help ensure that ports will not miss cracks that are not perpendicular to the wall surface.

They are useful for injecting active, high-volume leaks, as the product generally cures better with added water. These are also useful for creating soil barriers on the positive side of the wall. They retain more water and tend to be more flexible than hydrophobic products but will shrink and expand when exposed to dry and wet cycles. Hydrophobic products are typically flexible or rigid foams, which don't need any additional water after the initial reaction. They cure more slowly and are more volumetrically stable under variable moisture conditions. Both types of products have been used in cold climates without problems, but specific project conditions should be discussed with the resin manufacturer before specifying hydrophilic products exposed to freezing temperatures.

Injection ports for gels and foams are usually drilled through cracks at an angle alternating from either side with the goal to intersect the crack just beyond the center of the wall or slab. Port spacing can start at a wider spacing than with epoxy injection (2x wall depth) if there is good communication between ports. Drilled injection holes are blown or vacuumed, and cracks



RCI, Inc.
800-828-1902
www.rci-online.org



Figure 10: Standing water in the Waikiki basement above came and went with the tide, through slab cracks, foundation walls, broken floor rains, and sump pits. (Photo by Structural Systems Inc.)



Figure 11: Above, the same basement slab shown in Figure 10 after a combination of gel and foam injection sealed slab cracks and created a soil barrier under the slab and around sump pits. (Photo by Structural Systems Inc)



Figure 12: Waterproofing was "value-engineered" out of this highway tunnel project! Injection chemicals solved subsequent water intrusion problems at cracks through the concrete vault. (Photo by Structural Systems Inc.)

can be flushed with lots of fresh water (150-750 psi) to clean cracks and check port communication. If cracks are "missed," (see Figure 9), the ports can be re-drilled at a closer spacing (1x depth).

The surfaces of cracks are typically left unsealed between ports (unless injecting overhead). Mechanical "packers" or plastic injectors are installed in the injection holes and include quick connect fittings for injection hose and sometimes one-way valves. Materials and equipment can be expensive.

Multi-ratio pumps to blend mix ratios precisely and inject chemicals at up to 10,000 psi may be required to solve high volume leaks, but it is possible to use small single piston pumps for smaller, low-pressure projects. The experience and skill of the injection contractor cannot be undervalued; injection timing and control of expansion pressures are critical to the success of the job.

Case study for chemical grouts

In Waikiki, the water table is just below grade elevation. Because land is at a premium and building heights are restricted, basements and basement leak problems are not unusual. Even half basements are prone to fluctuating hydrostatic pressures up to three feet above finished floor at high tide. The shallow basement of one such hotel was plagued for years by seepage through spreading slab cracks, broken floor drains, and persistent standing water

on floors (Figure 10). The injection contractor managed to bring leak problems under control by first filling cracks with polyurethane foam, then injecting through the slab to establish gel barriers behind leaking cracks. (Figure 11 shows slab after injection.)

Excavating two sump pits through sandy, water-logged soil to a depth of 16 feet below the basement floor elevation posed another challenge. The contractor injected a gel at various depths to form a tube shaped waterproof "curtain" with a "floor" at a depth of 16 feet. Loose soil in the center of the injection gel could then be excavated with almost no dewatering requirement. The owners are satisfied with success of the project, which was completed about eight years ago. They are currently expanding the injection work to cover areas where other repair procedures were less successful.



RCI, Inc.
 800-828-1902
www.rci-online.org

Vertical and overhead gel injection was required to stop leaks through a highway tunnel in the Koʻolau mountain range (Figure 12). Ordinarily, no crack seal is required; excess foam can simply be cleaned from exposed surfaces (Figure 13). In this case, surfaces were tiled after cleaning. The effectiveness of hydrophilic polyurethane in high volume leak conditions is demonstrated in waterproofing repair at tie-back anchor penetrations for a high-rise office tower in downtown Honolulu. The parking structure is entirely below grade with foundations extending well below the water table at sea level. The Pacific Ocean was determined to drain into the building excavation around and through casings for foundation tiebacks. The injection contractor stopped the flow by using fast-reacting mixture and stuffing openings with rags and oakum long enough to get the chemicals into the active leaks (Figure 14).



Figure 13: Surfaces of cracks are typically left unsealed for chemical injection. Ports are flushed with water to clean cracks and check communication between ports and are then injected until cracks are filled with chemical. Surface residues are easily cleaned after injection resins cure. (Photo by Structural Systems Inc.)

Case study for epoxy coating

What if the wall is not concrete? Many years before learning of injection gels, we struggled with sealing below-grade CMU block walls in a multi-story condominium project stepped up a hillside. After some frustrated demonstrations by a manufacturer to establish the worth of their cementitious and crystalline coatings, we ground interior surfaces

clean and soaked the block with multiple applications of epoxy, beginning with a very low viscosity and ending with medium-viscosity epoxy and veneer plaster to achieve a smooth wall finish. Although the positive-side membrane was not repaired, the epoxy worked where other methods failed. As might be expected, some leak chasing occurred initially as water wicked through the porous block, but the finished work has been in place for over 12 years with only one call-back; leaks were occurring periodically from the same spot on the wall, at about eye level...where a screw anchor had been drilled to hang artwork.



Figure 14: Water forces its way around casings for tie-back anchors and into a below sea-level excavation during construction of a Honolulu high-rise office tower. The injection contractor stemmed the flow with rags and oakum long enough to permit injection of fast-reacting chemicals around casings. Leaks were stopped and construction proceeded. (Photo by Structural Systems Inc.)

Case study for desperate solutions

If leaks cannot be stopped, a drained cavity wall might be created by installing a new wall over the leaking below-grade wall with furring strips to provide space for drainage and a sloping gutter in the base of the wall cavity to direct water to drain (see Figure 15). If drainage is to a sump, an emergency generator should be incorporated to handle storm water during power outages. There are some serious risks assumed when taking this approach: Problems are not corrected but concealed. Microbial contamination may proliferate in cavities. Corrosion can eat away at the structure, wall supports, or drainage system with damage going unobserved. If attempted, be sure to:

- Use only non-corrosive materials.
- Incorporate only mold-resistant materials.
- Don't allow standing water to accumulate.
- Ventilate the cavity if at all possible.
- Maintain drain lines to prevent blockage.
- Inspect problem locations and conditions periodically.

We resorted to this solution once at a cemented rubble stone retaining wall in the back of wet, rainy, Manoa Valley where a home with a lower level was plagued by an intermittent underground stream during periods of heavy rain. It was a last-resort

Cavity Wall drainage

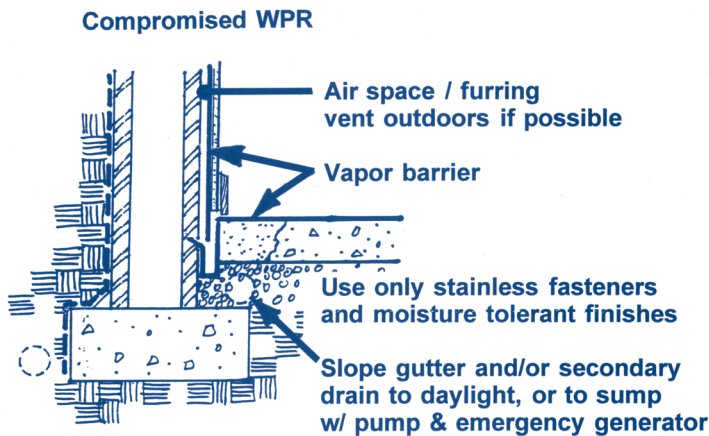


Figure 15: As a last resort, a drained cavity wall can intercept leaks and direct water away from occupied spaces. Careful design, construction, and maintenance, along with appropriate selection of materials are needed to limit the potential for microbial growth in concealed spaces.

solution, but it has functioned for the past eight years with only one call-back, which turned out to be unrelated to the repair. A washing machine receiver box in the wall had backed up.

Below grade bugs push back

Since our practice is located in Hawaii, we often encounter a secretive but voracious little pest that will not only compromise a waterproofing system but also eat a house. The Formosan termite (*Coptotermes formosanus*) has been in Hawaii as early as 1913. Over time, it has spread to cause an estimated \$100 million in damage each year in the islands. This species makes mainland U.S. varieties seem tame and is not just a Hawaii problem anymore. Formosan termites have started to spread throughout the southeastern U.S. and California. After Chlordane soil treatment was banned, we learned some painful lessons. Subterranean termites can enter the structure through, around, or behind the waterproofing system, not only compromising the waterproofing, but causing extensive damage to the structure.

Fully-adhered waterproofing systems can help limit termite access to structures, particularly when applied to concrete foundation walls. Although these little pests have been known to chew right through fluid-applied coatings, cracks can be resealed by epoxy injection if a breach occurs.

CMU block retaining walls are much more common in residential and light commercial construction and pose much more of a problem. CMU walls are like revolving doors for termites. Even fully-grouted cells offer a honeycomb of concealed passageways due to grout shrinkage and surface irregularities. Once termites have access to these walls, they will probably need to be excavated to isolate them from the soil.

Basaltic Termite Barrier

There is a simple but effective method to protect both the waterproofing and the structure using a product that was developed by Dr. Tamashiro, an entomology professor at the University of Hawaii. Basaltic Termite Barrier (BTB) can be used

as a backfill material to effectively keep termites away from waterproofing and below-grade walls. The material is like a coarse sand or fine gravel made from the local volcanic basalt rock. It works because it is too hard to chew and is evenly graded to a size that is small enough to prevent termite-sized gaps but large enough that termites cannot move within it or carry particles. The material is clean, drains well, and makes good backfill, but a few rules should be followed to assure termite protection:

- BTB should be maintained at a minimum 4" thickness.
- Granules must be in contact with smooth, clean concrete surfaces beyond any concealed edges of the waterproofing (may require grinding rough surfaces).
- The top surface must be protected from disturbance by plants, animals, gardening, and contamination with leaves and soil.
- Use a filter fabric that incorporates biocide tablets to prevent plant roots from providing a path into the barrier.

Case study for BTB

A hillside Honolulu home suffered severe termite damage at upper-level wood framing and water intrusion to lower levels due to termite entry through CMU retaining walls. The upslope side of foundation walls was completely excavated, and a new, fluid-applied coating, drainage course, and protection board were applied down to the edge of footings. The excavation was back-filled with BTB to protect waterproofing and its edges below grade. It has been more than six years since work was completed without a sign of termites. See Figure 16 for an illustration of a typical BTB application to protect below-grade waterproofing.

Health effects of damp buildings

During the past decade, people have become aware of health risks that are associated with exposure to damp buildings. Mold growth in buildings causes allergies, aggravates asthma, and may result in a variety of symptoms commonly known as "Sick Building Syndrome." Certain mold species produce toxins and may cause flu-like symptoms, respiratory problems, nerve damage, memory loss, and possibly even death in infants. Although much more rare, fungal infections can result from exposure of immune-compromised individuals, such as cancer or AIDS

BTB Drainage Course

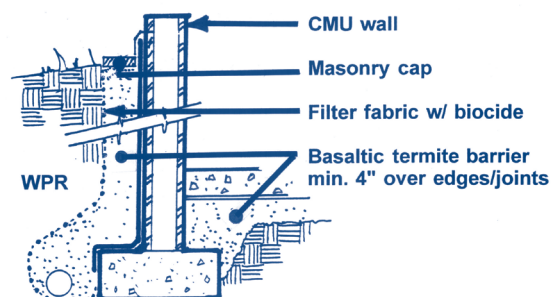


Figure 16: Subterranean termites can enter structures through, around, and behind waterproofing or foundation joints. Access can be blocked by use of Basaltic Termite Barrier as a backfill and drainage material, protecting both the waterproofing and the building.

patients, infants, elderly, or children with cystic fibrosis. Everyone involved in the design or construction of building envelopes should be made aware of the health implications of this work and the added risks associated with failure.

CONCLUSION

As choices for waterproofing systems continue to expand, it becomes necessary to understand the properties and limitations of a wide range of products. It is especially important that consultants develop an intimate familiarity with any products they specify or apply. Lack of attention to appropriate selection, detailing, and application of products is not only likely to result in leaks but in property damage, illness, or lawsuits.

Fortunately, these risks can be managed. Most leaks occur in localized areas as a result of design or application error.

Designers can:

- Focus on selecting an appropriate waterproofing for the intended use, geographic and climatic conditions, and skill of the local work force.
- Understand the implications of work by other members of the design team.
- Know the properties and requirements of products that are specified.
- Review products for compatibility with surrounding surfaces and conditions.
- Detail intersections, transitions, and penetrations carefully.
- Arrange for regular field inspections by qualified inspectors.

Applicators can:

- Prepare surfaces carefully.
- Assure proper use of primers.
- Avoid application of too little or too much material.
- Take special care with laps, seams, and terminations.
- Prevent damage to materials before or during backfill.

Selection of a qualified waterproofing consultant, an experienced contractor, and regular field inspections can help assure that a level of quality is maintained and that problems are minimized. Problems can still arise, but they should be manageable.

Just add a few tricks to the bag to help "push the building envelope . . . below grade." ■

Acknowledgments

Thanks to Justin Henshell, AIA, for his useful and concise manual and for his interest and support. Thanks also for input and assistance from two injection contractors: RCM Construction (Richard Malmgren) who has been responsible for the success of most of the case studies listed above; and to Structural Systems Inc. (Joe Enright, Al Wong) for the success of their chemical gel and foam injection projects and for project photos (Figures 10-14).

USEFUL REFERENCES

- Henshell, Justin, *The Manual of Below-Grade Waterproofing Systems*, John Wiley & Sons, New York, NY, 2000.
- Kubal, Michael T., *Construction Waterproofing Handbook*, McGraw Hill, New York, NY, 2000.
- Labs, K., Carmody, J., Sterling, R., Shen, L., Huang, Y.J., Parker, D. ORNL/Sub/86-72143/1: *Building Foundation Design Handbook* (May 1988).
- NRCA *Roofing and Waterproofing Manual*, National Roofing Contractors Association, Fourth Edition, Rosemont, IL, 1996.

ABOUT THE AUTHOR

Phil Haisley is a principal and vice president of Architectural Diagnostics Ltd. in Honolulu, Hawaii. As a forensic architect, he specializes in the investigation of construction-related defects and the remediation of building envelope problems. Phil can be reached by e-mail at haisley@architecturaldiagnostics.com



PHIL HAISLEY