Specifying Below-Grade Waterproofing

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Waterproofing is the treatment of a structure's surface to prevent the passage of water under hydrostatic head or standing water conditions. It is used for foundation walls and sub-structures, slabs-on-grade, plaza decks, planters and green roofs, sumps and elevator pits, and between slabs or split slabs.

There are various options when designing waterproofing systems and specifying their components. However, selecting the correct products is dependent upon criteria and applications often beyond the design professional's control. Therefore, a full understanding of the properties and limitations of these materials is critical when designing waterproofing systems. This article focuses on vertically- and horizontally-applied membrane systems and typical auxiliary flashings and accessories.

Types of waterproofing applications

The first step in selecting the most appropriate waterproofing system involves determining when and where it is to be employed on the building. In standard construction projects, positive-side waterproofing is generally applied directly to the face of the structure exposed to water (or hydrostatic head of water). Negative-side waterproofing, on the other hand, is applied interior to the exposed structure, either in the wall or on the inside face of the wall—it has no direct exposure to ground water. Finally, blind-side waterproofing is affixed to an adjacent structure or soil retention feature (e.g. slurry wall), rather than the new structural wall. It is 'blind' because one cannot see the finished product sandwiched between the wall and the neighboring property.

Positive-side waterproofing

Positive-side waterproofing is installed during new construction on the exterior of the new structure or after removing the overburden for an existing one. It requires access to the outside face of the structure—when this is impossible, blind- or negative-side techniques are often necessary. Positive-side waterproofing can be seen as the least problematic and most successful method because, when installed and designed correctly, the water pressure forces it to work. The design team has the ability to inspect all the lap joints and defects in the membrane with full visibility. However, the major disadvantage with positive-side waterproofing is when there are leaks due to faulty installation or building movement, repairs can only be made through excavation or negative-side waterproofing techniques.

Negative-side waterproofing

Negative-side waterproofing is typically applied on existing construction in remedial applications when exterior access is unfeasible. This approach only protects inner surfaces. Generally, negative-side waterproofing is used more for problem-solving than problem prevention. It is not as effective as positive-side waterproofing because structures are subject to movement and cracking. When this happens subsequent to the initial installation, additional applications of negative-side products may be needed to close up the new gaps. However, ease of application often makes this type of waterproofing the preferred choice when exterior or positive-side techniques are not options.

Blind-side waterproofing

Blind-side waterproofing is used on new construction projects where property line encroachment or other space limitations prohibit the ability to excavate the site. It is also used for split- or mud-slab horizontal applications because the products are waterproofing the underside of the structural slab. While the various types of products mentioned in this article are available for blind-side waterproofing, the technique's installation typically involves using bentonite layers in sheet forms, with or without a protective membrane.[1] It is installed dry, activating as it becomes wet from either the newly poured in-place concrete, ground water, or water runoff. The bentonite layer of the sheet is applied against the concrete structure, with the expansive action of the clay filling voids or cracks in the structural concrete component. Confinement of the panels by backfilling or treatment of the lagging is critical to ensure the expanding clay is contained and gels or expands into the cracks, holes, and fissures of the structure, rather than escaping into a void.

Design selection criteria

The following paragraphs outline the various design aspects one must consider when it comes time to determine the best waterproofing system for a building.

Site conditions

Location can immediately dictate the need for blind-side techniques. When the building site is maximized to the property line, there is simply no opportunity to employ positive-side waterproofing since an installer will be unable to work between the new and existing structures.

Hydrostatic pressure

The hydrostatic pressure on-site also determines the type of system most suitable. Due to their relative tensile strength, bentonite products (blind-side or positive-side) and elastomeric sheets chemically or heat-welded to a monolithic condition are more likely to resist high hydrostatic pressures than peel-and-stick or fluid-applied systems. [2]

Temperature limitations

Temperature limitations should also be considered when selecting the membrane. Many waterproofing products are difficult to install properly when the temperature falls below 4 C (40 F). This is especially critical when solvents, adhesives, and sealants are necessary for a particular system. Manufacturer product requirements for cold- and hot-temperature storage and application limitations must be followed.

Drainage

Proper drainage is critical in both horizontal and vertical applications. Some membrane types, such as hot-rubberized asphalt (HRA), can be used on very low or no-slope plaza deck applications. However, HRA systems cannot be installed on lightweight concrete fill. The drainage of vertical waterproofing can be enhanced with larger cross-section drainage boards (e.g. base drain) and may be piped into weep tubes discharging into below-slab drainage media. The drains on plaza or terrace installations can be of the spot or trench variety, depending on the ability to develop slope in the structure or with tapered insulation (below the membrane). Single-ply membrane types, such as those made of polyvinyl chloride (PVC) or thermoplastic polyolefin (TPO), are typically used on sloped surfaces. In all cases, some type of drainage should be developed atop the membrane to efficiently remove the water from the surface.

Insulation

When necessary, the building's thermal performance can be enhanced by adding insulation to the system. When this insulation is to be in direct contact with water, such as below-grade on foundation walls or in a protected roofing assembly, it should be a product able to withstand absorption (e.g. extruded polystyrene [XPS]). Insulation beneath or above the waterproofing membrane can be designed in a manner consistent with roofing design practices.

Structural integrity

Generally, the structural integrity of the building is unaffected by waterproofing systems. However, green roofs, plazas with pavers, and other overburden materials need to be analyzed for dead load, snow conditions, live load, and construction loads in accordance with sound engineering principles. This article does not address the very important aspects associated with the structural requirements of roof, plaza, and foundation assemblies.

Building codes

Building codes in the region of the project (e.g. International Building Code [IBC] 1806.3.2, Building Officials & Code Administrators [BOCA] National Building Code 1813.4.2.2, Uniform Building Code [UBC] Chapter 18, and Southern Building Code [SBC] Section 1814) require a waterproofing membrane in areas where hydrostatic conditions exist. Each code defines the minimum required waterproofing system and allows the designer to select from four to seven choices that bridge non-structural cracks. Detailing and installation specifications are based on the designer's discretion and manufacturer's requirements, as well as code conformance.

Detailing

Proper detailing of penetrations, joints, and transitions is mandatory to satisfactorily address water intrusion regardless of the type of system. The locations of tie-backs, rakers, and walers in a blind-side system are likely the potential water entry areas, where cracks in the concrete often occur. Coincidentally, these areas are also the most difficult to install in the field due to requirements for sealing, stripping, and cutting off steel sections. Therefore, the designer should give special attention to the detailing and the owner or design team should consider using the services of a field monitor to carefully evaluate the application.

Penetrations, cracks, and construction joints

Although this point may seem fairly obvious, most leaks through foundation walls occur at penetrations, cracks, or construction joints in the concrete. Since the penetrations and joints are predetermined, waterstops and joint (i.e.link) seals at these areas are straightforward to specify. Cracks are more difficult to predict, so their treatment can be specified on positive-side applications and dealt with in the field. On blind-side applications, the bentonite gel should enter and close up the cracks. Grouting injections can also be made after fissure propagation to seal the concrete (these repairs become more of a negative-side application). Many positive-side products span minor cracks that develop in the curing concrete substrate. To prevent oxidation and further cracking, care should be exercised to protect the reinforcing steel in the concrete wall (i.e. the grout should be forced into the fissure and then extend through the wall past the steel).

Weighing the options

Each of the three application techniques are dependent on the design criteria discussed. Suitability of certain systems will have a greater or lesser impact depending on the limiting factors, such as hydrostatic pressure or application temperature. After the application technique is determined, the designer must weigh the important criteria to pare down the material choices to those most appropriate for the given conditions. For example, suppose the designer is given an accessible wall with hydrostatic head less than 15.2 m (50 ft) and cold weather considerations. The designer could specify a positively applied system of a fluid-applied membrane with minimum application temperature of about 7 C (20 F) – a good economic choice with acceptable performance expectations. However, when an application is to be made at a tunnel with tensile forces greater than 15 MPa (2175 psi), the designer would be advised to choose a high-strength material such as 2.5-mm (100-mil) PVC.

Products overview

The waterproofing system components are fairly basic with few accessories. Although the installation of the blind-side products begins at the outside of the structure, this article outlines the materials from the inside-out to accommodate the proper sequence of the positive-side application. Most product lines have applicability in either a vertical or a horizontal installation.

Primers (typically spray-applied) may be required on the concrete depending upon membrane type—they are appropriate for bitumen-based systems, as well as other liquid membranes. The membrane itself can be, as outlined above, any of the modified bitumen (mod-bit) pre-formed sheets or hot-/cold-applied rubberized asphalt products. The pre-formed sheets are adhered at the seams and the rubberized asphalt products are liquid-applied and seamlessly monolithic. PVC and TPO single-ply sheets are heat-welded at the seams and flashing areas. Adhesively seamed systems, on the other hand, exhibit poor performance characteristics under moist conditions. It is this author's opinion they are inappropriate for waterproofing applications. As stated in the Department of Defense (DoD) MIL-HDBK 1001/5A, Handbook on Roofing and Waterproofing, defective laps are vulnerable to rainwater ponding and freezing conditions that break down the performance of the adhesive.

Latex, asphaltic, and cementitious coatings are applied using a spray or a trowel. These systems, like the rubberized asphalt product, are monolithic in nature. Capillary products are crystalline materials mixed into the concrete or surface-applied. They are designed to penetrate the concrete to seal the capillaries. Metal oxide products are applied to the concrete surface as a slurry of cement, iron, and water—they swell upon rusting to form a protective coating over the concrete.

Bentonite waterproofing products are sheets of membrane with bentonite clay laminated to polyethylene sheets or woven into a geotextile core. The sheets are lapped and sealed or simply lapped. The expansion of the clay works as a protective cover for the concrete but also swells to fill small cracks and voids in the concrete. As described above, these products are used in blind-side applications, but can also be applied directly to cured concrete substrates using positive-side waterproofing techniques.

Drainage sheets are important to the system's anticipated service life and the structure's protection. The panels are typically three-dimensional, high-impact, dimpled plastic attached to a woven geotextile fabric. They channel water away from the membrane and relieve hydrostatic pressures against the waterproofing system.

Protection layers are sometimes incorporated into the waterproofing system to protect against traffic and backfilling operations. Depending on the membrane, the protection can be asphaltic boards, insulation, or even another layer of high-density polyethylene (HDPE). An insulation layer can also be used for thermal improvements to the structure.

Generally, a plaza deck waterproofing system includes an insulation layer, with XPS being the best choice when water is expected to come into contact with the insulation.

Depending on the system, accessories can range from sealants to adhesives and fasteners to flashing sheets and mastics. Each product is required to completely form a waterproof bond to the structure and deal with integral flashing components at terminations, penetrations, and transitions. The designer should attempt to stay within the same family of products by a manufacturer (or its sister companies) to maintain single-source responsibility for any warranty issues. These concerns even include products such as pavers for plaza deck waterproofing projects.

Waterstops are necessary to provide a final level of protection for the building. These products are within the concrete section, especially at construction joints and sometimes at control joints. The most common pre-manufactured joint seals are:

- PVC or chloroprene rubber that need to be welded or otherwise fused together;
- bentonite clay with/without butyl binders that expand when wet; and
- hydrophobic injectable expanding grouts.

The splices are critical to maintaining a watertight construction. There are also perforated hoses for injecting and re-injecting resins that allow for some joint movement (as do the rubber and PVC 'bulbed' waterstops). The waterstops should always be placed allowing for minimal cover in the concrete to prevent section blow-outs. They should be kept out of the keyway and outside the reinforcing steel to ensure dryness during installation while awaiting the concrete pour. This also provides a line of defense for the steel reinforcing in the wall. Trapping moisture in the wall beyond the steel may result in the unwanted deterioration of the alloy. It is critical to thoroughly coordinate all the trades (e.g. plumbers, electricians, concrete workers, waterproofers) to ensure correct placement of the appropriate waterstops and to reduce the potential for damage.

Conclusion

Waterproofing below-grade building elements is critical to keeping a facility watertight. While there are many excellent systems in the marketplace that can be specified and installed, the key point to success is understanding the benefits and limitations for any particular system. Proper design and inspection is well worth the effort, especially considering the cost of excavating and replacing a failed system. The guarantees/warranties for any particular system vary based on materials selected and details used. As they typically range from five to 20 years, the specifier should contact the material manufacturer for actual requirements. Proper design inspection is imperative for all systems no matter what guarantee or warranty is provided.

Notes

[1] For more information on blind-side waterproofing and bentonite systems, see "Specifying Bentonite Waterproofing" by Stacy Byrd, CDT (CS June 2004).

[2] Peel-and-stick products are single-ply membranes, generally comprising rubber or modified bitumen (mod-bit). They attach directly to the substrate, using adhesives that are factory-applied to the sheet beneath a release paper. The field membrane and the lap joints are pressed into place with wood or rubber-wheeled hand tools.

Abstract

Due to increased use of these below-grade structures for critical occupancies (e.g. electrical equipment), waterproofing is becoming much more prevalent (and necessary). This article addresses various systems, such as positive/negative side waterproofing, plaza deck assemblies, and garden roof designs, while analyzing pre-manufactured membranes, spray-on or brush-applied coatings, and expandable/injectable waterstops.