Below-Grade Blindside Waterproofing Membrane Systems:

A STATE-OF-THE-ART REPORT

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Blindside waterproofing is a system in which the below-grade waterproofing membrane is temporarily attached to the soil-retention system facing the excavation, prior to casting the concrete foundation against it. It is required where the exterior faces of foundation walls will be inaccessible. A common situation dictating blindside waterproofing is the proximity of adjacent property lines or other abutting structures that preclude excavation outside the foundation walls (*Photo 1*).

Strictly defined, it is positive-side waterproofing, but a blindside waterproofing problem is sometimes solved by negative-side or integral waterproofing.[1] Waterproofing under pressure slabs on grade is also a form of blindside waterproofing.

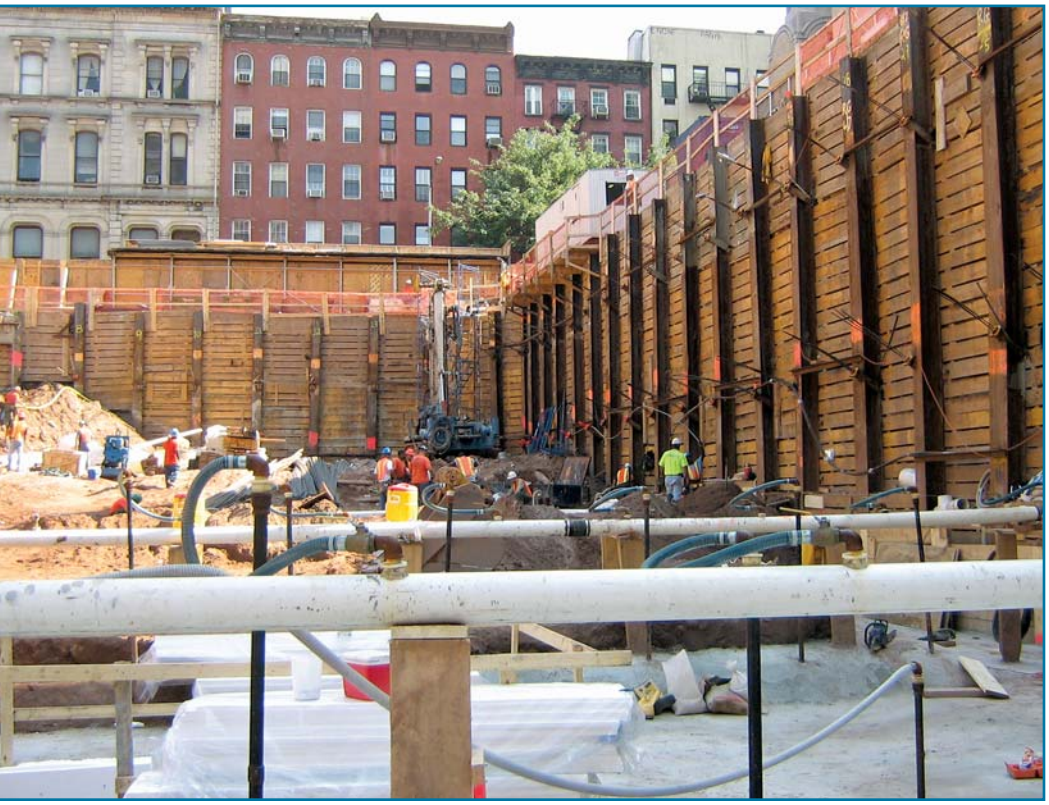

Photo 1 – Soil retention system to receive blindside waterproofing at zero lot line foundation.

This paper discusses blindside waterproofing and the pros and cons of the various types of membranes that are currently marketed in the United States for that use. It does not include those products manufactured for use on plazas and similar locations where the waterproofing system is not subjected to hydrostatic pressure. Nor does it include crystalline and similar coatings applied to the negative side of foundations and additives to cast-in-place concrete.

HISTORICAL BACKGROUND

Below-grade occupied spaces traditionally were provided to house heating systems and served as storage areas.[2] They were rarely deeper than one story. However, in the past 50 years, deeper basements were required for below-grade automobile parking and air-conditioning equipment, which became popular after World War II.

Buildings in large cities were being built out to lot lines and fronted on streets crowded with below-ground utilities. Thus, applying waterproofing to the outboard side of foundations became impractical.

Today's foundations are typically reinforced concrete. But prior to the turn of the nineteenth century, foundations were primarily constructed of stone several feet thick and frequently parged with cement on the inboard side. The water resistance of the parging was increased by adding iron filings and an oxidizing catalyst, which caused the iron to corrode and swell, compacting the parging.

Limited moisture infiltration in these

stone foundations often occurred[3] but was not considered critical since the equipment located in the basement could tolerate dampness. However, when basements were constructed in areas with high water tables, more water-resistant construction was required to satisfy the demands of moisture-sensitive occupancies. The choice was either to construct a watertight basement with walls and slabs sufficiently strong to resist hydrostatic pressure or to provide a drainage system of sumps and pumps in order to reduce the water pressure. The proponents of the drainage system contended that the "interest on the increased cost of constructing a hydrostatic pressure-resistant basement was greater than the cost of providing sumps and operating the pumps."

Frequently, the below-ground waterproofing system consisted of adding chemicals to the concrete to densify it by filling the voids. These additives consisted of finely ground sand, colloidal clays, or hydrated lime. Some additives, such as stearates and oil, were intended to repel the water. In 1910, the *Engineering News* reported, "Oil in the amount of 10% by weight of the cement gives very satisfactory results" and is economical, "since oil costs about 6 to 7 cents per gallon or about 60 to 70 cents more per cubic yard of concrete."[4]

The use of additives did not find unqualified acceptance. Kidder-Parker, in its 1945 *Handbook*, recounts a report published by ASTM Committee D08, circa 1927, regarding the permeability of concrete and methods used to render it waterproof. The committee report discusses the results of laboratory testing and information obtained from the field. It evaluates the "addition of foreign substances" and "external treatments." The committee concluded that additives to concrete were of doubtful benefit, whereas protective coatings–both bituminous, applied to the exterior faces of the concrete, and cementitious, applied to the interior face–had proven to be efficacious.

At the turn of the twentieth century, popular blindside waterproofing applications on zero lot line basements consisted of erecting drainage tiles against a brick soil-retaining system, then covering them with bricks dipped in hot coal-tar pitch. (Asphalt bricks were also used and dipped in hot [unblown] asphalt.) Alternately, multiple layers of burlap or felt swabbed with hot pitch or asphalt would be applied over the tile and covered with bricks. The concrete foundation wall was then cast against it

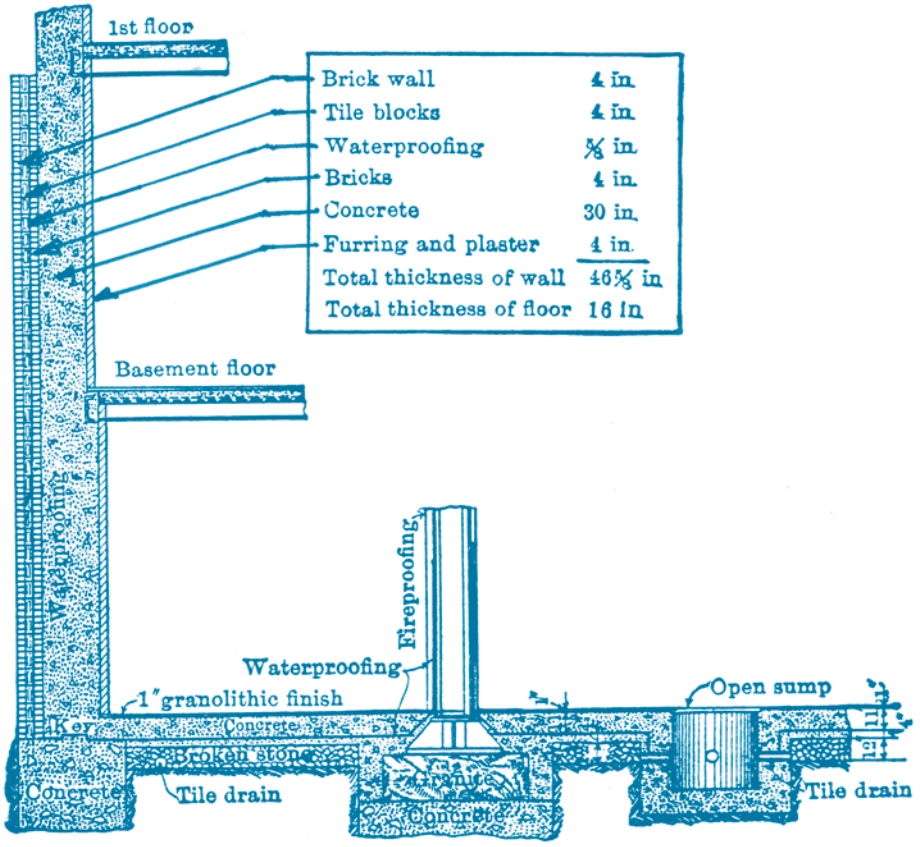

Figure 1 – Historical blindside waterproofing system.

(*Figure 1*). The boilers, which were located in the basement, kept the foundation walls warm enough to keep the coal-tar pitch soft and enable it to reseal when shifting soils caused seams to open.

Good workmanship was critical to the successful waterproofing envelope, but perfection was not always achieved. Consequently, the prudent designer did not solely rely on the waterproofing system, but installed a drainage system under the waterproofed slab that conducted infiltrating water to a sump from which it was pumped to a sewer. Unfortunately, most municipal sewage treatment plants refuse to accept the discharge of subsurface water, or they accept it on a limited basis.

BLINDSIDE WATERPROOFING MEMBRANES

Generally, blindside membranes can be divided into two categories:

- Attached
- Nonattached

Attached types are those that are intended to bond mechanically or adhesively to the concrete after it is cast against them. Nonattached types are those that are faced with a granular bentonite[6] compound or a hydrophilic polymer, which is intended to swell when in contact with water and form an impermeable watertight gel between the soil and the concrete or a loose-laid thermoplastic sheet.

Prior to 2000, there were only a handful of manufacturers that produced membranes specifically aimed at the blindside waterproofing market. Most of these products were either bentonite-clay systems or one-ply or built-up membranes designed to adhere to the concrete cast against them. Adhesion was obtained chemically or by concrete mechanically engaging fibers.

The use of blindside waterproofing increased as more buildings were constructed in heavily populated areas that precluded the luxury of extending the soil retention system sufficiently beyond the foundation to permit application on the positive side of foundation walls. This prompted manufacturers of positive-side waterproofing membranes to enter the field and established blindside waterproofing manufacturers to develop new products. Currently, these include bentonite clay-based compounds and hydrophilic polymers laminated to EIP, HDPE, and geotextiles; a self-adhering SBS laminated to a polyester fleece; an adhesive-surfaced HDPE; a polymer-modified asphalt emulsion; and a butyl alloy laminated to TPO.

Current producers of blindside water-

proofing market one or more of these:

- A sheet applied to the soil retention system consisting completely or in part of bentonite that will create a water-impermeable gel between it and the concrete that is cast against it.
- A water-impermeable sheet applied to the soil retention system that will reattach itself to concrete cast against it and thus prevent leak water migration.
- A sheet applied to the soil retention system that is both water-impermeable and contains bentonite or hydrophilic polymer-based compounds and will prevent leak water from reaching the concrete. The sheet may or may not be designed to reattach itself to the concrete cast against it.
- A cold-applied, two-component polymer-modified asphalt emulsion.

All of these systems are intended to facilitate leak detection by limiting the migration of leak water between the membrane and the concrete.

BENTONITE-BASED MEMBRANES

Older bentonite clay systems, such as sprayed and trowelled-on applications and clay-filled kraft paperboard panels, have generally been abandoned by their producers in favor of bentonite encapsulated in geotextiles or bentonite laminated to thermoplastic sheets.

These were introduced to overcome the disadvantages of the panels and sprayed-on applications that failed when the bentonite was washed away by flowing water. However, the newer products did not completely solve the problem of failure when the soil retention assembly developed voids and neglected to provide the requisite confinement.

BENTONITE/THERMOPLASTIC LAMINATED MEMBRANES

The thermoplastic laminated products sought to correct bentonite clay erosion by introducing a sheet membrane as a first line of defense and utilizing the gel-forming bentonite bonded to it to prevent water that infiltrated the seams from coming in contact with the concrete.

The thermoplastic sheets alone did not qualify as a satisfactory blindside waterproofing membrane because they lacked the ability to prevent leaking water from migrating laterally between the concrete and the membrane. This was to be accomplished by the bentonite, but it was only effective when sufficient pressure was permanently maintained between the substrate and the membrane to confine the bentonite gel. Karim Allana reported on a HDPE/bentonite failure that resulted from moisture that deformed wood lagging.[7]

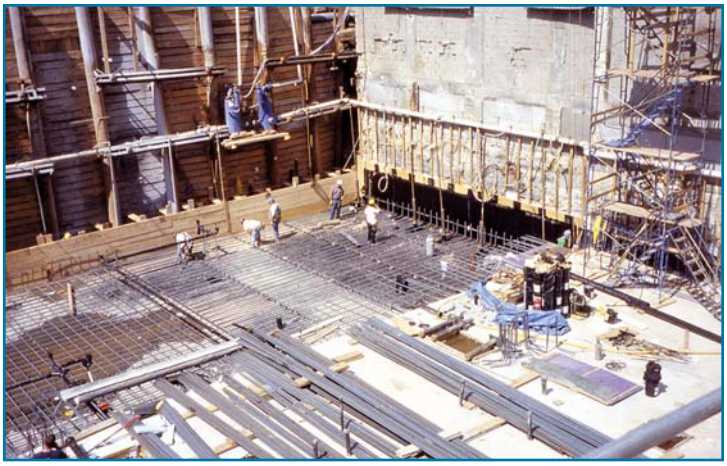

Photo 2 – Bituminous membrane installed under pressure slab and boarded-out lagging.

Currently, granular bentonite compounds laminated to HDPE thermoplastic sheets are being marketed, one with an additional geotextile facing the concrete, which is intended to resist hydration on vertically applied installations but not to bond to concrete.

BENTONITE/GEOTEXTILE MEMBRANES

These products encapsulate bentonite between layers of woven and nonwoven polypropylene. The bentonite is intended to swell when hydrated, and one product is faced with a geotextile that is reported to form a mechanical bond with the concrete cast against it.

With the exception of the products faced with geotextiles, the bentonite membranes rely on the principle that watertightness can be obtained by maintaining permanent compression between the soil retention system and the concrete foundation. This enables the swelling clay to develop sufficient pressure to prevent water from reaching the concrete and migrating laterally. Critical to this is the effectiveness of the soil retention system to provide solid, void-free backing. Such is not always the case in the real world, where settlement, intermittent pressures, corrosion, and rot exist and combine to erode the structural integrity of the substrate. This may reduce the confining pressure below that is required to ensure watertightness. The fact that this is not easily achieved is noted by Gibbons and Towle,[8] who point out that the West Coast practice of using shot-crete as a soil retention system "does not provide the necessary confining pressure to allow bentonite platelets to…create a waterproof layer."

BITUMINOUS MEMBRANES

The use of multiple-ply coal-tar pitch membranes has been so restricted by VOC regulations that their use today is virtually nonexistent. They have been replaced by a two-ply, chloroprene-modified asphalt membrane and an SBS-modified asphalt sheet surfaced with a polyester fleece. The older chloroprene-modified membrane is reported to bond to the concrete as it is softened by the heat of hydration of the cement when the concrete is cast against it. The newer membranes–consisting of polyester fleece or nonwoven fabric laminated to a modified asphalt–are also intended to mechanically bond to the concrete cast against them. One manufacturer markets a spray-applied, two-component, modified-asphalt emulsion that is claimed to chemically bond to concrete cast against it. The membrane is marketed as a gas vapor barrier system (*Photo 2*).

The older, two-ply membrane has a 45-year track record, whereas the newer, SBS membranes have yet to establish one. The asphalt emulsion has a somewhat limited resistance to hydrostatic pressure, compared with the other two.

THERMOPLASTIC AND HDPE ADHESIVE-SURFACED MEMBRANES

One of the oldest single-ply blindside waterproofing membranes consists of an HDPE sheet surfaced with an adhesive. A recently introduced system consists of a TPO membrane surfaced with a butyl adhesive. Both membranes are intended to chemically bond to the concrete cast against them. Seams are sealed with pressure-sensitive tape.

The HDPE/adhesive sheet manufacturer does not recommend it for use in a blind-

side application where the adhesive face will receive shotcrete.[9]

The HDPE sheet is thick and does not easily conform to changes in plane. The manufacturer recommends using a self-adhering rubberized asphalt sheet; a two-component, trowel-applied, asphalt-modified urethane; and tapes. This transition has proven to be the most vulnerable part of the system and must be carefully designed and installed (*Photo 3*).

The TPO/butyl sheet is a self-adhered 22- and 30-mil TPO that is more flexible. The seams are lapped and sealed with factory-applied adhesive. It is yet to be demonstrated whether this seam performs satisfactorily when the 30-mil sheet is turned up the foundation and concrete is cast against it.

Photo 3 – HDPE sheet membrane on mud slab and lagging.

SEAMS

As with all sheet membranes, seams are the Achilles heel at which water infiltration is most likely to occur. Movement of the substrate can open so-called bentonite pressure seams that are simply lapped or mechanically fastened and depend on soil compression to keep them watertight. Taped seams improve the integrity of the seam since they are better able to resist the shrinkage that is common with HDPE. Heat-fused seams are far superior but more costly. Nevertheless, heat-fused seams offer the greatest resistance to seam failure caused by differential movement between the concrete and the substrate.

Probably the one location where seams become critical is the transition from the horizontal to vertical and the vertical re-entrant angle. The thermoplastic sheets are usually thick and can be quite stiff in colder climates. They are often thicker for use under pressure slabs than those applied to the lagging. At the horizontal/vertical reentrant angle, most manufacturers' details suggest that the horizontal membrane be turned up the wall a certain distance and lapped by the vertically applied membrane. This often results in tenting because the sheet is too stiff to conform to the right angle. The adhered seam is also turned up. When the concrete foundation wall is cast against the coved corner, the seams are susceptible to rupture or disbonding. This is exacerbated at the transitions where the slab meets the interior and exterior corners of the foundation, columns, and pile caps. With sheet thicknesses that exceed 60 mils, good, tight corners are virtually impossible to fabricate in one piece.

Joints of thermoplastic sheets that are welded or that use a combination of more flexible sheets and tapes and with a liquid component usually perform better than those that rely on adhesives or bentonite pressure laps.

Photo 4 – Boarded-out lagging.

ATTACHMENT TO SUBSTRATE

A basic premise of blindside waterproofing is that the membrane must be installed securely, albeit temporarily, to the soil retention system. It should resist displacement from sagging wet concrete and be capable of spanning small voids, step-offs, and other surface irregularities with rupturing or disbanding seams. It should not be secured so tenaciously that displacement of the soil-retention system tears it away from the cured concrete foundation. Seismic events, corrosion, erosion warping, and decay must be taken into consideration. Moreover, it should provide uniform support free of voids that can localize pressures and rupture the membrane.

Soil-retention systems usually consist of lagging or shotcrete but also may include sheet piling. Lagging is usually installed with 1-in or greater joints between timbers and must be overlaid to form a smooth,

solid surface to receive the blindside membrane. This is the role of plywood sheathing, drainage composites, protection boards, and rigid insulation (*Photo 4*).

The attachment of the membrane to the soil retention system must be assumed to be temporary and that the fasteners will corrode and/or the substrate into which they are driven will rot away or disintegrate. Eventually, the lagging will no longer provide a uniform, structurally sound support. If the retention system shifts, rots away, twists, cups, or disintegrates, the membrane may be vertically or laterally displaced or the resultant voids may fail to provide the requisite pressure required by bentonite, and its watertight integrity will be threatened.[10]

All three systems rely on watertight seams. Sheets containing bentonite depend on the initial and continuing integrity of the soil retention system to maintain void-free solid surfaces that will be capable of resisting water infiltration.

Blindside membranes that depend on adhesion to the concrete share this problem of unstable substrates but not to the same degree. Shifting, settlement, or similar lateral movement of the soil-retention system can shear the tenuous bond between the membrane and the concrete, tearing it at fasteners or open seams between the sheets. Often, this can be minimized by introducing several layers of materials between the membrane and the lagging. Common components are plywood, protection boards, drainage composites, and low-density expanded polystyrene, which have been used separately or in combinations. Differential movement between the membrane and lagging can be absorbed by adhering these components rather than mechanically fastening them or allowing the low-density expanded polystyrene to shear internally. However, some fasteners may be required to resist the shear forces that result from placing concrete.

MEMBRANES UNDER PRESSURE SLABS

Membranes for use under pressure slabs are similar to those used for blindside waterproofing on foundations — a blindside waterproofed foundation rotated 90 degrees. They are intended to bond to the underside of the pressure slab cast over them mechanically or adhesively or to swell in contact with water to form a water-impermeable gel.

Photo 5 – Bentonite membrane under pressure slab.

The membranes are installed over a compacted gravel subgrade or an unreinforced concrete mud slab. The gravel must be well compacted and free of voids or pockets that would permit the membrane to bridge. The mud slab must also be free of voids, ridges, or surface irregularities that would not provide uniform support (*Photo 5*).

Neither the mud slab nor compacted gravel is intended to provide support for the membrane for the life of the building. The gravel will eventually settle or be washed away, and the mud slab will disintegrate. When this occurs, the membrane must remain firmly adhered to the pressure slab or the bentonite remain in compression. In this respect, the bonded membrane offers superior water resistance.

However, the ability to provide a satisfactory mechanical or adhesive bond can be compromised during the normal course of construction. Sheets that depend on mechanically engaging the concrete with the geotextile fibers can have those fibers compressed by construction traffic and material storage to the extent that they can no longer provide a satisfactory bond. Sheets that depend on chemical adhesion can lose their adhesion when coated with a film of dirt that concentrates in puddles over the surface.

Both problems can often be avoided by casting a 2- to 3-in layer of concrete over the membrane as soon as possible after each section is completed. This will protect the membrane, and its surface can then be raked to bond to the pressure slab. This has the added advantage that reinforcing chairs, pipe supports, and the like will be supported on the concrete fill rather than directly on the membrane.

THE DESIGNER'S DILEMMA

Unlike roofing, below-grade waterproofing is intended to perform satisfactorily for the life of the building. Once concrete is cast against the membrane, it is essentially inaccessible for repairs. This poses a challenge for the designer who is interested in exploring some of the newer blindside waterproofing systems but lacks the comfort of a long track record. Note that warranties do not provide for removal and replacement of overburden should the membrane fail. Moreover, the physical and logistical

Photo 6 – Grout injection.

restraints of removing 3 to 5 ft of concrete to access the membrane make this procedure impractical.

How, then, can the prudent designer venture into the unknown world of new blindside waterproofing systems or even older proven systems that are dressed up in new clothes? Since it is as unrealistic to select a waterproofing membrane that will perform for an infinite life as it is to select one for zero probability of failure, a certain amount of risk must be accepted as inevitable. There is always cause for concern when specifying newer systems that lack a reasonably long track record, both in membrane performance and the installer's familiarity with installation procedures. The selection and application of the wrong waterproofing system can result in leaks and substantial financial consequences.

Fortunately, there are some well-developed methods of remediation when water begins to flow down the foundation walls or bubble up through the joints in the floor slab. Reverting back to negative-side waterproofing systems is a tried-and-true method of halting infiltration. Today there are crystalline waterproofing compounds that have proven to be effective for face grouting. They can be applied to large areas of prepared concrete or used to fill cracks and joints. However, this remedy may be defeated by inaccessibility where equipment is installed against a foundation wall or at intersecting partitions (*Photo 6*).

Alternately, when large areas of concrete walls and floor slabs are inaccessible, cracks and joints can be injected with hydrophilic urethane or acrylates. Hydrophobic urethane can also be injected behind the walls or under the slab to create a chemical grout curtain. Bentonite slurry (Bentogrout®) can also be injected behind foundation walls and is particularly appropriate where bentonite-based membranes were installed.

Having these methods of remediation available should allay some of the concerns about using one of the newer blindside waterproofing systems.

Additional protection can be provided by other methods that will minimize water infiltration. Since most basement leaks occur at construction joints, the use of hydrophilic waterstops at these locations should be mandatory wherever hydrostatic pressure exists. Where occupancies are particularly sensitive to leakage, reinjectable hoses should also be provided in joints. Avoiding horizontal construction joints is also desirable whenever possible since it is difficult to ensure that the intersection of horizontal and vertical waterstops can be made watertight.

Finally, nothing is as good as quality assurance during the installation. The membrane manufacturer should be intimately involved with every step of the installation, beginning with the initial product selection. Following prewaterproofing meetings, he should conduct a class *in situ* to instruct the applicators and work out the details. Treatment of tie-back heads, form spreaders, well points, and other penetrations should be detailed on the shop drawings and means and methods resolved in the field prior to beginning work.

RECOMMENDATIONS

Failures in blindside waterproofing applications may not be avoided by using one of the products introduced to the market in the last ten years, but the prudent designer can take precautions to reduce the risks and provide a long-term watertight basement.

- Select products from producers who have experience in manufacturing

and installing blindside waterproofing systems.

- Involve the manufacturer's technical forces early and throughout the initial phases of the installation.
- Don't rely on stock details. Prepare exhaustively detailed construction and shop drawings that will address penetrations, plane changes, tiebacks, walers, rakers' footblocks, pile caps, construction joints, and other allied issues.
- Hold mandatory preconstruction meetings with the excavation contractor to explore all the means and methods of soil retention. This includes the location of well points. (Well points are never indicated on drawings; but if they are located too close to the foundation walls, adequate flashing becomes extremely difficult.)
- Provide waterstops at all construction joints in foundation walls and pressure slabs on grade. Hydrophilic rubbers, with or without bentonite fillers, have mostly replaced PVC and other glands. Consider adding reinjectable hoses where pressures are high and occupancies are sensitive to moisture.
- Advise the owner that some leaking cannot always be prevented but that there are established means and methods to stop the water infiltration, should it occur.
- Where dampness threatens applied finishes, consider applications of coatings specifically designed to reduce the emissivity to acceptable levels.
- Use a mud slab under pressure slabs rather than compacted gravel.
- Carefully detail sheet plane transitions. Use cants or an assembly of sheets, tape, and the liquid component of the system rather than relying on the manufacturer's details.
- Since lathers erecting reinforcing and form spreaders often damage in-place waterproofing, the waterproofing contractor's superintendent should inspect the membrane prior to casting each lift of concrete.

ENDNOTES

1. Some of the pitfalls to using negative-side waterproofing are the lack of positive water vapor control and the discontinuities that occur at intersecting shear walls and intermediate suspended slabs.
2. Kidder-Parker, *Architects' and Builders' Handbook, 18th Edition*, 1945, John Wiley & Sons, New York, NY.
3. *Ibid.*
4. *Ibid.*
5. Properties of membranes have been obtained from the latest literature published by W.R. Grace, Carlisle Coatings and Waterproofing, Tremco, Soprema, Cetco, W.R. Meadows, and Laurenco.
6. The term "bentonite," used throughout this paper, refers to sodium bentonite clay and polymer-modified compounds thereof.
7. Karim Allana, "Bentonite Composite Waterproofing System Below-Grade Applications, Failures, and Solutions," Sealant, Waterproofing, and Restoration Institute, 2010 Winter Technical Meeting, South Beach Miami, FL, Feb. 21-24, 2010.
8. Daniel G. Gibbons and Jason L. Towle, "Waterproofing Below-Grade Shotcrete Walls," *The Construction Specifier*, March 2009.
9. For shotcrete applications, the HDPE/adhesives manufacturer markets a system consisting of a sheet membrane coupled with a polymer-mesh reinforced cavity covered with a geotextile that is post-filled through injection ports with hydrophilic grout.
10. *Ibid.*

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