WATERPROOFING IS *NOT* BELOW-GRADE ROOFING

By David Campbell, RWC, AIA

When a person is unfamiliar with something, it's human nature to relate it to something similar with which he or she is more familiar. Unfortunately, this can result in minimizing or even ignoring subtle but important distinctions between the two. Such is the tendency with many architects and other design professionals today with respect to waterproofing and roofing. Though this tendency is less common than in years past, there are still an alarming number of design professionals who assume that roofing and waterproofing are very similar. The truth is, even though they both have the common goal of keeping water out of the building, their similarities end there.

As one who has been employed by a roof design firm for over 16 years, I have a deep appreciation for the level of expertise necessary to design a roof system for long-term performance. However, imagine what would happen if a well-designed, 20-year, conventional roof were to be placed below ground. All of a sudden, issues such as hydrostatic pressure, leak localization, high static loading, subdrainage, sheet metal corrosion, and repair accessibility (to name a few) are all introduced, turning your 20-year roof into something altogether different.

As *Diagram A* illustrates, waterproofing and roofing have far less in common than many people may think. In fact, only ten out of 29 major design considerations are common to both.

WHY WATERPROOFING SHOULD PERFORM FOR THE LIFE OF THE BUILDING

A below-grade waterproofing system that is either poorly designed, poorly installed, or both can be a financial time bomb to an unsuspecting building owner if the system fails within the lifetime of the building. This is usually not due to the cost of repairing or replacing the waterproofing membrane itself but, rather, to the disproportionately high costs related to reaccessing and exposing the membrane.

When a roof develops a leak, locating and repairing the failure can be relatively straightforward. The materials are accessible, and any standing water can be easily swept or drained away. Or, when a masonry wall has to be tuck-pointed, scaffolding can be erected, and the accessible brick veneer can be repaired. However, it is far

Diagram A: Major Design Considerations Common to Both Waterproofing and Roofing

	Major Design Considerations	Roofing	Waterproofing
1.	Prevent water from entering the building	☐	☐
2.	Vertical installations		☐
3.	Horizontal installations	☐	☐
4.	Hydrostatic pressure		☐
5.	Wind uplift	☐	
6.	Geological influences		☐
7.	Easy visual inspection	☐	
8.	Accessible for repair or maintenance	☐	
9.	Building use disruption during repair		☐
10.	Thermal protection	☐	☐
11.	High static loading		☐
12.	Dynamic loading		☐
13.	Subject to damage by maintenance	☐	☐
14.	De-icing chemicals		☐
15.	Dew point considerations	☐	☐
16.	Temporary site dewatering		☐
17.	Surface drainage	☐	☐
18.	Subdrainage provisions		☐
19.	Foot traffic	☐	
20.	Ground water contaminants		☐
21.	Assembly certifications (i.e. Factory Mutual)	☐	
22.	Substrate testing	☐	☐
23.	Ultraviolet exposure	☐	
24.	15 - 30 yr. life expectancy is acceptable	☐	
25.	Initial cost	☐	☐
26.	Horizontal flood testing		☐
27.	Membrane shrinkage	☐	☐
28.	Leak localization		☐
29.	Warranty	☐	☐

Note that only 10 out of 29 (those shaded in yellow) are common to both roofing and waterproofing.

Photo 1

more time consuming and expensive to reaccess and to expose a failed waterproofing membrane for the following reasons:

- **Removal and replacement of unrelated site features:** This can include such things as plant materials, wearing slabs and pavements, lighting, retaining walls, stairways and ramps, bollards, signage, etc. If the waterproofing that needs repair or replacement is on a foundation wall, then, depending on the foundation depth, the excavation angle can affect a very large surface area and thereby a great many existing site features. If the foundation of the building in *Photo 1* were to be rewaterproofed, the excavation would affect existing retaining walls, mature plantings, wearing pavement with granite feature strips, and other site features that are not directly related to the waterproofing work itself.
- **Excavation and recompaction of backfill:** In addition to the obvious additional cost of excavating and backfilling, there are the related costs of compaction testing and the inconvenience of stockpiling.
- **Existing hydrostatic conditions:** Such existing conditions cannot only add the additional cost of temporary site dewatering, but can also delay the construction schedule by making it necessary to allow the substrates to properly dry before installing the new waterproofing.
- **Warranty exclusions for damage of interior finish and contents:** Depending on the use of the interior space, the damage to finishes, furniture, and other contents caused by the water infiltration can sometimes match and even exceed the entire cost of the project, especially if computer equipment is affected. These costs would be assumed by the owner, since this author currently knows of no waterproofing manufacturer or installer who has ever included such consequential damages in its warranty.
- **Structural capacity limitations:** In the case of a waterproofed plaza, the removal of the overburden can be more time consuming and expensive if the structural capacity of the existing deck cannot support the dynamic loading of large construction equipment, thereby compelling the contractor to use smaller, more time-consuming equipment.
- **Disruption of building access/egress:** During foundation excavation, required building access and egress must by maintained by means of temporary code-compliant bridges, stairs, handicap ramps, walkways, etc. Obviously, the design, construction, and removal of these temporary items can add considerable cost to the project.

To further reveal how disproportionate the waterproofing repair/replacement costs can be to the overall project cost, we have provided those cost breakdowns on six completed waterproofing projects that we have designed (*Diagram B*). Note that the remedial waterproofing cost averages 17% of the total cost of the entire project. This means that 83% of the project cost was related to things that have nothing directly to do with the waterproofing repair/replacement itself.

DYNAMIC AND HIGH STATIC LOADING

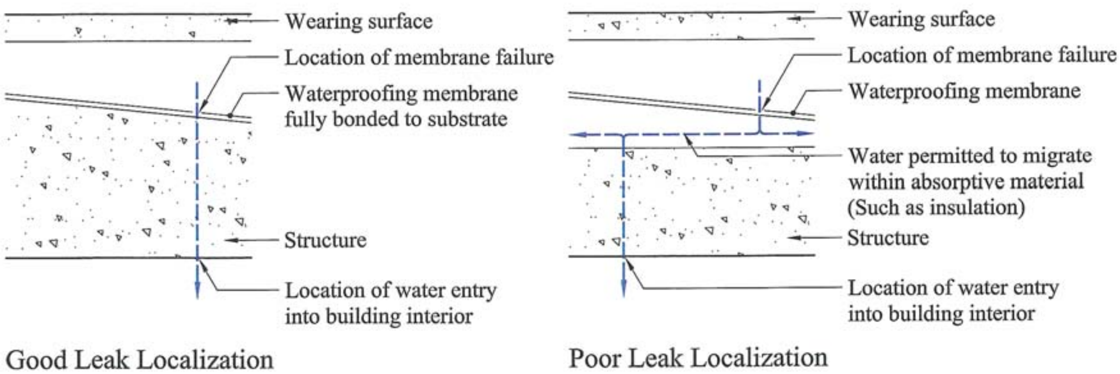
Generally, whenever large static loads such as mechanical equipment are superimposed on a roof, the load is transferred directly to the structure by means of curbs, pipes, or other methods of support rather than simply resting the load directly on the roofing membrane. Typically, the membrane is then flashed around these penetrating supports. However, it is not unusual for a waterproofing system to have to bear the high static loads of such overburden as thick concrete wearing slabs, large quantities of earth, free-standing planter boxes, retaining walls, and other permanent structures. Under these static load conditions, the designer has to make sure that all of the waterproofing-related materials will not be damaged initially or over a long period of time as the result of what's referred to as compression "creep."

Dynamic loading is another design consideration that differentiates roofing from waterproofing. Obviously, a roof does not have to be designed to withstand moving vehicular or other similar loads. However, it is not at all uncommon for a plaza or tunnel waterproofing system to be subjected to the types of dynamic loading associated with roadways, parking areas, delivery/loading areas and even airport runways. The long-term deleterious effects of a given static load are far less than that same given load applied dynamically over time, and this has to be provided for by selecting materials with appropriate densities and by distributing the concentrated dynamic loads over larger areas. When designing the waterproofing system for an underground pedestrian tunnel that has Boeing 747s taxiing overhead many times every day, unique challenges are encountered that have to be properly addressed if the system is to continue to perform for a long time.

Diagram B

Inspec Project	Total Remedial Construction Cost	Remedial Waterproofing Cost Only	Waterproofing Cost as a Percent of Total
Assisted living facility	$165,000	$24,000	15%
Office/computer facility	$147,000	$31,000	21%
Medical research facility	$116,000	$12,000	10%
Classroom building	$550,000	$60,000	11%
Classroom/library facility	$510,000	$110,000	22%
Bookstore/administration facility	$225,000	$46,000	20%
Average			17%

Diagram C: Importance of Waterproofing Leak Localization



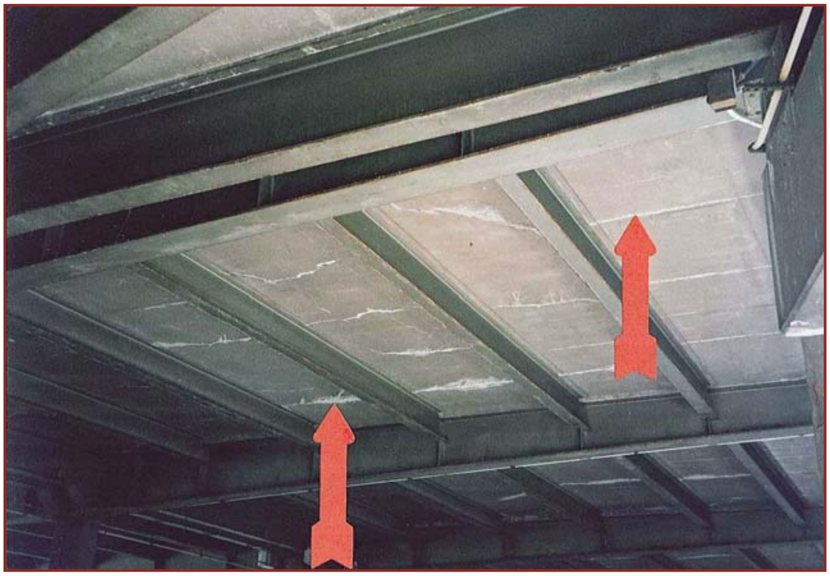


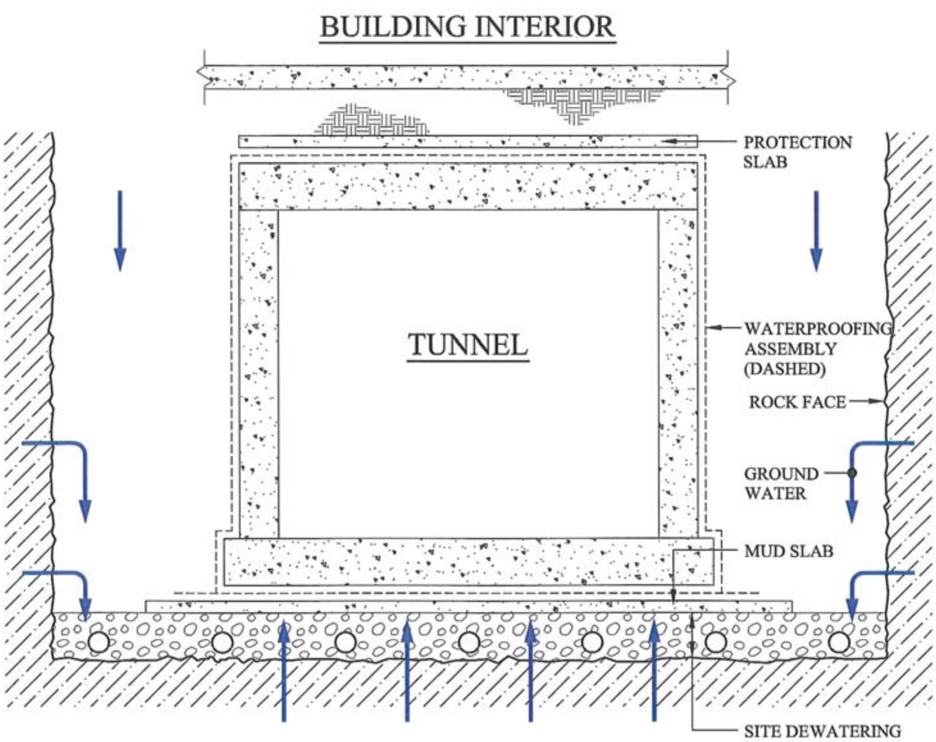
Photo 2

LEAK LOCALIZATION

Leak localization is achieved when the system assembly maintains a relationship between the location of the membrane failure and the location of the water entry into the interior space below. This relationship allows a localized repair of the membrane directly above the point of water entry through the structure, thereby avoiding having to replace the entire system.

Since a roofing membrane is rarely subjected to the type of hydrostatic pressure that would "drive" water through a failure and since roofing membranes are easily accessible, allowing relatively inexpensive repairs, such leak localization is not a critical characteristic of roofing assemblies. However, this is not the case with waterproofing. If a waterproofing membrane should develop a failure and the substrate is such that water is allowed to migrate laterally below the membrane, water could travel a considerable distance before it shows up in the interior space below, due to hydrostatic pressure. Without being able to identify the exact location of the membrane failure, the owner would have no recourse but to replace the entire waterproofing assembly. *Diagram C* illustrates this concept, and *Photo 2* shows how one waterproofing failure can result in multiple leaks through otherwise innocent shrinkage cracks when water is allowed to migrate below the membrane.

Diagram D: Permanent and/or Temporary Subdrainage Dewatering



SUBDRAINAGE PROVISIONS

Unlike roofing, which drains only at the surface, waterproofing assemblies should include "subdrainage provisions," which lower or remove the hydrostatic pressure to which the waterproofing membrane would otherwise be subjected. Not only can subdrainage extend the performance life of the membrane, but in the event of a membrane failure, it can also greatly reduce the amount of water that enters the building, since the water is not under pressure.

Subdrainage, in a horizontal application, allows moisture that has penetrated the wearing surface to percolate down to the membrane level, where it is "encouraged" to migrate laterally through either a composite drainage sheet or an aggregate layer. Since the membrane is sloped, the migrating water is then discharged by means of either bilevel interior drains or at the perimeter edge condition. In a vertical application such as a foundation wall, water either drops down

Photo 3

within the cores of the composite drainage sheet or percolates down through a free-draining aggregate backfill. At the base of the foundation, this water is then carried away and discharged by means of a perforated drainage system or "drain tile."

In addition to extending the performance life of the membrane, subdrainage, in a horizontal or plaza application, can also extend the life of concrete, brick pavers, or other hard-wearing surface materials in freezing climates. By preventing water from accumulating under the wearing surface, the movement caused by repeated freeze-thaw cycles is minimized, thereby greatly reducing the heaving, spalling, and cracking of the wearing surface (*Photo 3*).

Sometimes waterproofing design must take existing conditions into account such as geology, groundwater, and even groundwater contaminants, which are obviously not a concern in roofing design. *Diagram D* illustrates the elaborate measures that sometimes must be taken in order to properly manage existing groundwater in a particular geological condition, both during and after waterproofing installation. The volume of groundwater that was expected to enter the excavation through cracks and fissures in the bedrock at this airport site was such that full-time site dewatering, as shown in the diagram, had to be maintained. In addition, tests revealed that the groundwater was contaminated with hydrocarbons and ethylene glycol, which are capable of chemically "melting" most waterproofing-related products over time. Consequently, special care was taken in specifying products that were compatible with this witch's brew of contaminants.

SUBSTRATE TESTING

In roof design, the materials that serve as the substrate directly in contact with roofing membranes are usually not of the type that require testing prior to the membrane application (i.e., ballasted EPDM membrane on expanded polystyrene). However, this is not the case with waterproofing.

As previously discussed, the waterproofing membrane must be completely and permanently bonded to the substrate in order to achieve good leak-localization characteristics. Most waterproofing substrates are some form of concrete (CMU, CIP, or precast), which can vary in moisture content, surface texture, and applied surface coatings, thereby affecting the membrane bond. This is why rigorous onsite substrate testing for adhesion and moisture content is recommended in order to achieve a permanent, long-term bond between membrane and substrate.

Photo 4 shows one method of testing the

Photo 4

Photo 5

adhesion of a hot, fluid-applied, rubberized asphalt membrane. The adhesion test reveals adequate bond by virtue of the fact that the rubberized asphalt separated from itself rather than separating from the substrate. *Photo 5* shows the same type of waterproofing membrane completely debonding from the substrate due to a combination of excessive primer and an extremely smooth substrate surface. *Photo 6* shows the type of debonding that can occur when a cold, fluid-applied membrane is incompatible with the liquid curing agent that was applied to the substrate.

Testing the substrate for moisture content is also critical. *Photo 7* shows what can happen when hot rubberized asphalt is applied to a concrete substrate that has too high a moisture content. The moisture in the concrete vaporizes when the hot, 375-degree material hits it, creating water-filled blisters, which can break open and cause membrane failure.

LEAK TESTING

Since leak localization characteristics are not typically built into roofing assemblies for reasons discussed earlier, it is not typical to conduct leak testing on a newly installed roof for fear of inadvertently introducing moisture into the insulation and other absorptive materials located between the membrane and the structural system. However, since it is so expensive to dig up and reaccess a failing waterproofing membrane, it is prudent to conduct such testing on newly installed waterproofing mem-

Photo 6

Photo 8

Photo 7

branes prior to the installation of subsequent overburden materials. In fact, many membrane manufacturers require it for certain warranties. Such leak testing can include flooding and seam pressurization.

As shown in *Photo 8*, flood testing is accomplished by simply exposing an installed waterproofing membrane to standing water (usually two to four inches) for a specified period of time (usually 24 to 48 hours) prior to the installation of any protection course or other overburden materials. One exception to this would be hot rubberized asphalt, which requires that the protection course be installed and bonded to the membrane prior to the flooding. At the end of the specified period of time, the interior is inspected for moisture infiltration, the water is drained away, and any membrane failures that were discovered are repaired.

Our firm has developed a variation on the flood test described above. When the overburden materials provide adequate containment weight, we will design the assembly with a 3/8-in layer of inexpensive granular bentonite directly beneath the primary sheet membrane. Not only does the bentonite component act as a backup waterproofing system and prevent moisture migration under the primary membrane, but it also enables us to locate leaks during flood testing by free swelling or hydrating directly underneath any failures in the primary membrane. At these bulging locations, the primary membrane is opened up, the hydrated bentonite is replaced with dry product, and the membrane is repaired.

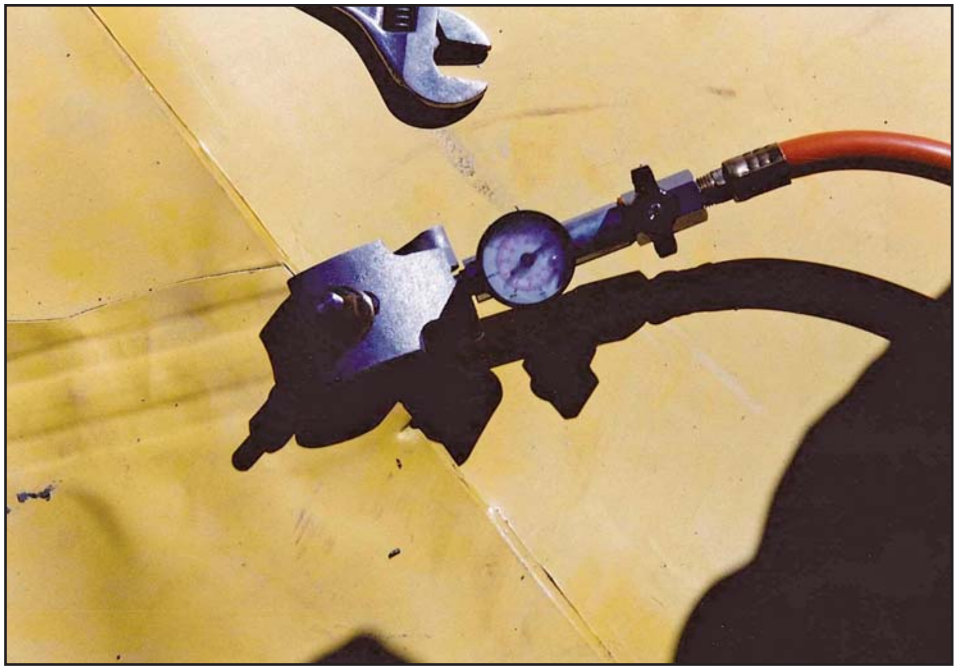


Photo 9

One leak-testing method that is being used more and more in vegetated roof applications, as well as in plaza waterproofing, is electric field vector mapping (EFVM). EFVM technology is a nondestructive, low-voltage testing method that creates an electrical potential difference between a nonconductive membrane surface and a conductive structural deck or substrate. An electric field is created by applying water to the membrane surface, which then acts as a conductive medium. A breach in the membrane creates a ground fault connection or vector, which can then be measured and plotted by a technician.

Since vertical waterproofing installations cannot be flood tested, at least one manufacturer has developed a way of "pocket seaming" its PVC membrane, which enables testing of the seams by pressurizing them with air and then watching for a pressure drop on a gauge attached to one end of the seam (*Photo 9*) This method does not test the entire vertical field membrane, but it does at least test the seam, which is the most susceptible to failure.

SUMMATION

Because of their many dissimilarities, roofing design and waterproofing design represent different areas of expertise altogether, as recognized by RCI-developed credentials for RRCs (Registered Roof Consultants) and RWCs (Registered Waterproofing Consultants). With the ever-increasing demands society continues to place on the performance of our buildings, resulting in an increased complexity of all building components, it is becoming even more necessary to select qualified people who have the expertise and experience necessary to design these components for long-term performance.

As a wise man once said, "There is never enough money to do it right the first time, but there always seems to be enough money to do it over again."

David Campbell, RWC, AIA

David Campbell, RWC, AIA, has been employed with Inspec since 1994. He is a licensed architect and an associate with the firm. His primary areas of expertise at Inspec include below-grade waterproofing, subdrainage, vegetative "green" roofs, and exterior walls. While at Inspec, he has received awards for his work in forensic investigation and design. He also provides continuing education presentations, writes technical articles, and provides expert testimony. Inspec is an award-winning engineering/architectural consulting firm founded in 1973 with offices in Minneapolis, Milwaukee, and Chicago.