

# Redundancy in Subgrade Waterproofing

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Each subgrade waterproofing membrane system and application method has advantages and disadvantages that need to be considered and carefully evaluated prior to specifying a system for a particular use.

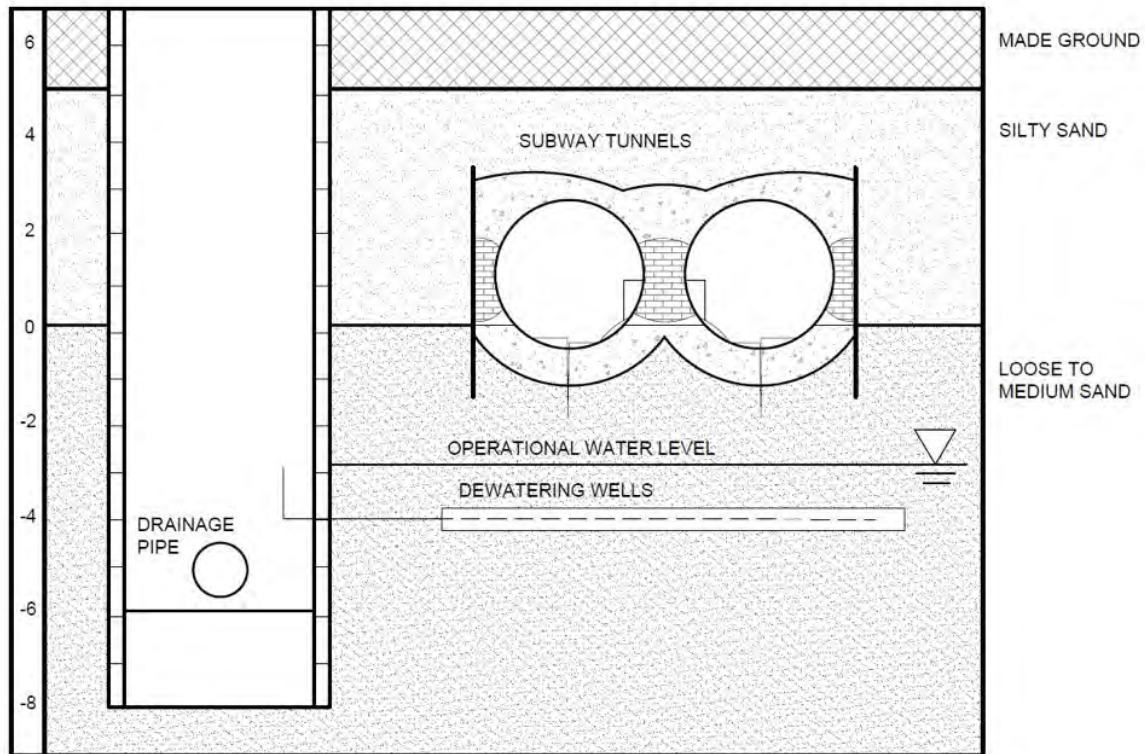
Issues that must be considered include, but are not limited to:

- Clearance to install the waterproofing;
- Blindside vs. post-construction application of the membrane;
- Fully adhered vs. loose-laid systems;
- Concrete cure times;
- Application of concrete cast-in-place vs. pneumatically sprayed;
- Number of joints in sheet products;
- Difficult details;
- Proposed phasing;
- Penetrations; and
- Proposed “tie-ins” to existing waterproofing systems.

No one product or system is without limitations.

## **A ‘BELT AND SUSPENDERS’ APPROACH**

It is extremely difficult for even the most skilled applicator to be perfect in membrane application. Additionally, one cannot assume that follow-on contractors of different trades will not damage the completed waterproofing. Therefore, some subgrade structures introduce supplementary measures to divert and/or control water that may bypass the membrane or even mitigate the amount of hydrostatic pressure the membrane experiences (at the exterior).



**Diagram of permanent dewatering system.** PHOTOS COURTESY OF WISS, JANNEY, ELSTNER ASSOCIATES INC. UNLESS OTHERWISE SPECIFIED

This redundancy creates an alternative system to augment the waterproofing strategy of the structure. Such redundant systems may include, but are not limited to, a combination of external dewatering and waterproofing, compartmentalizing and grouting, or interior water collection systems used in conjunction with a waterproofing membrane.

The term “belt and suspenders” is commonly used to describe the presence of independent but complementary waterproofing systems. This idiom has been used for as long as we can remember. What people tend to mean when using this expression is redundancy: a system that has a backup plan if failure in the primary system were to happen. So when your belt fails to hold up your pants because of the new diet you’re on, your pants have a secondary support system in the form of suspenders.

Redundant approaches can only be done during initial construction and are difficult if not impossible to install once concealed. However, other systems can be introduced even after completion of initial construction.

## PLAN TO DOUBLE-UP EARLY

When a redundant method is utilized in subgrade waterproofing design, it can mean having an additional safety system in place to eliminate or mitigate water leaks into the structure if there is a breach in the primary waterproofing system. This redundant

design approach should always be considered and carefully evaluated when specifying waterproofing systems during the design of a new structure.



**Blindside waterproofing membrane with integral compartmentalizing system and injection ports for grouting after concrete placement.**

If not considered during the initial design phase or implemented during construction, owners are usually left to rely on crack-injecting leaky joints or applying a negative-side waterproofing to the areas of moisture intrusion. Remediation attempts like these can be difficult and may cause disruptions to the building operations.

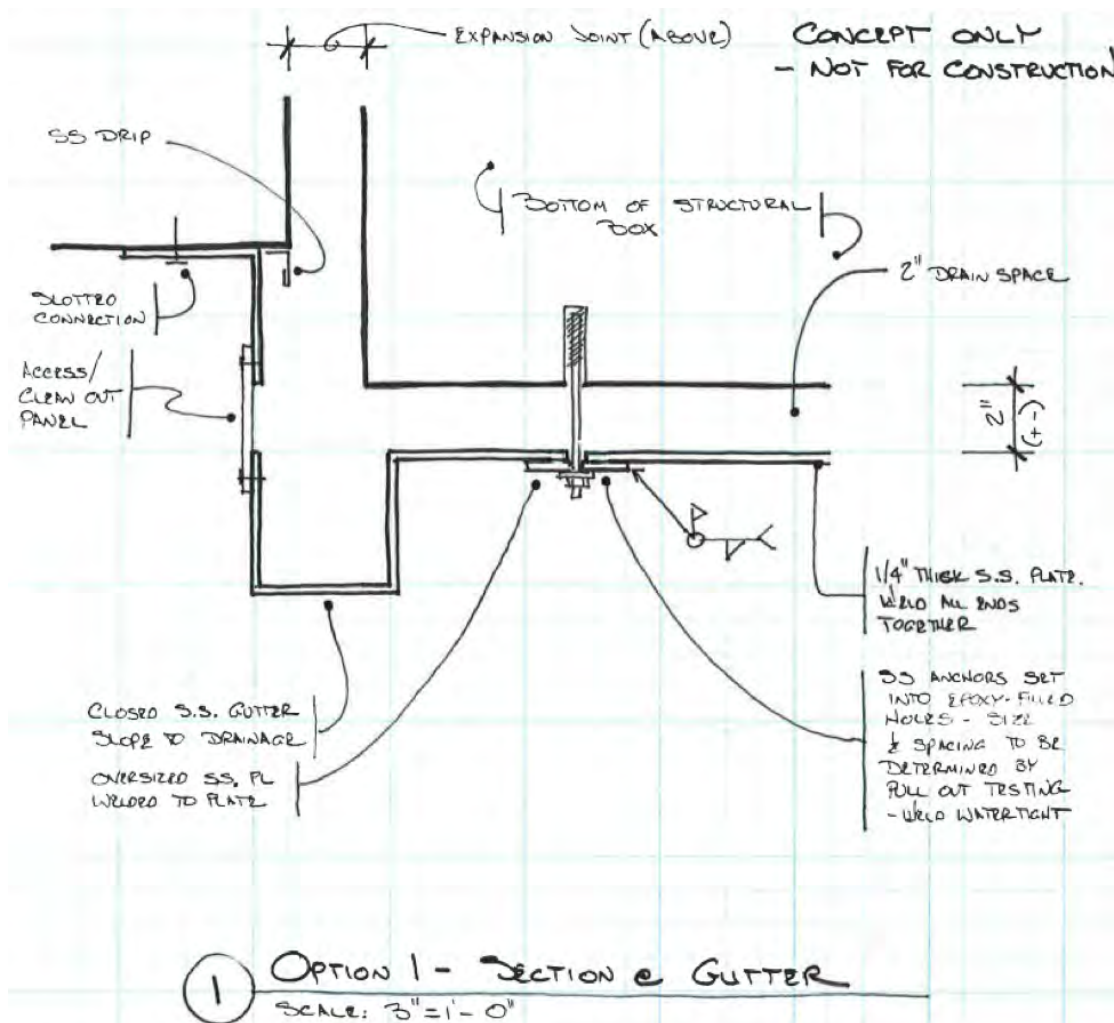
It is also usually very difficult and expensive to repair a subgrade waterproofing system from the outside of the structure, after construction. In our experience, rarely will the exterior of a foundation wall be exposed to repair a breached waterproofing membrane. These repairs tend to be expensive and may exceed the costs of a redundant system during initial construction. With this reactionary approach, the cost implications may go beyond just the waterproofing systems — for example, the leak may damage mechanical or electrical systems or interior finishes.

You get one chance to properly install the waterproofing before the building is completed, which is why multiple levels of redundancy should be evaluated during the design.

## ANTICIPATE THE CHALLENGES

There are many challenges to the design and installation of a subgrade waterproofing system. The soil and hydrostatic pressure on the structure must be accommodated in the structural design and are components to consider during the selection of a waterproofing system. The site is usually dirty, wet and may be congested. There may be contaminants in the soil and/or the water that can degrade the waterproofing, concrete and/or reinforcing steel.

The logistics of construction, particularly in an urban site, will have a significant impact on the schedule and on the overall cost of the project. The waterproofing design and installation will be impacted by the contractor's means and methods of construction, and the waterproofing design and installation must accommodate the proposed construction sequencing.



Sketch of internal drainage collection system designed to collect water that infiltrates through the expansion joint.

The owner needs to make this determination with the help of the architect and waterproofing consultant. This will be the fundamental principle in determining the levels of redundancy to incorporate into the design — that is, the owner's level of acceptable exposure risk given the planned use or occupancy of the below-grade space. Remember, there are multiple levels of exposure risks that go hand in hand with redundant system components. High-risk structures are less tolerant of water and require more levels of redundancy, which should be incorporated into the waterproofing design.

The use of the structure will influence the importance of the subgrade waterproofing. Some occupancy conditions within the structures have little tolerance for water leaks, like laboratories or museum spaces, and every effort should be made to prevent water infiltration. Other conditions or uses — say, for example, a below-grade parking garage, may have more tolerance for water infiltration — and subsequently the costs and effort associated with waterproofing these spaces can be reduced.

The site should be analyzed for any contaminants in the soil and/or water that will impact the proposed waterproofing system for the structure. Asphalt products may degrade in the presence of hydrocarbons, such as oil and gasoline, and bentonite waterproofing is impacted by saltwater. Water-soluble sulphates can degrade concrete. The geotechnical report with a soil and water analysis should be approved by the waterproofing materials manufacturer in the design phase and prior to the selection of a waterproofing system. This phase will determine what types of membranes are suitable for your project.

## **DIVERTING WATER**

The questions now turn to the location of the water table in relation to the lowest level of the planned construction. This information is usually provided within the geotechnical report and provides the waterproofing designer with the level of hydrostatic pressure the structure may see in its service life and what type of systems would be necessary to mitigate water intrusion.

If the water table is low and relatively close to or within the lowest level of the structure, one of the redundant waterproofing concepts the designer can institute, along with the membrane component, is a dewatering or subsurface drainage system. The purpose of a dewatering system is to reduce water pressure in the soils around the site excavation during construction and, if left permanently, to reduce and possibly prevent hydrostatic pressure against the structure throughout the life of the building.



Subslab drainage system being installed as part of a water leakage repair project.

These systems are usually composed of wells, drainage pipes and pumps designed to collect the underlying site water and discharge it to a location away from the construction site. This redundant system is very effective in preventing leaks, as underground site water around the structure is controlled and is ideally prevented from getting to the structure. However, there will be costs to maintain any dewatering system. The water also needs to be tested, as most municipalities will not allow contaminated water to be pumped into their storm water or sewer systems.

Another method to prevent hydrostatic pressure from getting to the membrane level of the structure is to provide a drainage composite panel on the exterior side of the wall. This component is typically constructed of a synthetic geotextile filter fabric material and a rigid drainage core. The filter fabric is oriented outwards to accept the water and to prevent the drainage core from clogging with silt, debris or dirt. The drainage composite panel can be connected to a subsurface drainage system to drain water away from the structure.



Drainage composite.

The premise in using this component is that the water is never allowed to build up pressure against the membrane and is drained away, thus providing a form of redundancy. The drainage composite panels also may act as membrane protection during backfill and can limit the membrane's exposure to damage from ultraviolet light and nearby construction activity prior to backfill.

## **CONSTRUCTION LOGISTICS**

How the structure will be constructed, site logistics, and proposed support of excavation structures become the next item to consider during the design phase. The logistics of construction, particularly in an urban site, will have a significant impact on the waterproofing design and what effective redundancies can be incorporated. Installation will be impacted by the contractor's means and methods of construction, and the waterproofing design should consider probable methods of installation and sequencing while not diminishing the quality of the design. It is usually during the determination of these basic items that the building's subgrade waterproofing system begins to take shape and the various redundant waterproofing system components get narrowed down.

The waterproofing membrane can be installed either on the exterior or “positive side” of the structure, the interior or “negative side” of the structure, or a combination of both. Positive-side subgrade waterproofing is generally more effective since the force of the soil and water compresses the waterproofing membrane against the structure and limits lateral water migration. Negative-side waterproofing does not have this same advantage but can be effective in certain conditions. However, for negative-side waterproofing, you must also consider that the water is allowed to migrate through the construction before it gets to the waterproofing, exposing the substrate (and structure) to elevated moisture levels. This approach is typically used in leak remediation or difficult construction conditions where a positive-side system cannot be used.



Application of crystalline, cement-based negative-side waterproofing.

The construction conditions will dictate if the site can be over-excavated for a positive-side waterproofing membrane to be post-applied or if the membrane will be pre-applied to the support of excavation in a blind-side method. Blind-side waterproofing is a type of positive-side waterproofing in which the waterproofing membrane is installed against the excavation support and then the structure is built against the waterproofing.



## MEMBRANE SYSTEMS

There are several types of membranes on the market to consider for each application method, with some having their own integral redundancy features. Each application method of the membrane system is another consideration to evaluate during the design. The detailing or ease of flashing conditions of penetrations through the membrane should also be thought out when selecting a membrane system for the construction application. Wide open spaces where the site can be over-excavated tend to allow for the membrane to be post-applied. These systems can be either sheet goods, spray-applied or a combination of both. The self-adhered membranes, commonly referred to as “peel-and-stick,” can be installed on a prepared substrate in multiple layers for a level of redundancy.

Pre-applied systems are usually used in urban construction sites where the excavation is limited to the building footprint and you’re building your structure adjacent to other existing buildings. Pre-applied membranes are usually placed against the support of excavation or ground until the concrete is formed and poured.

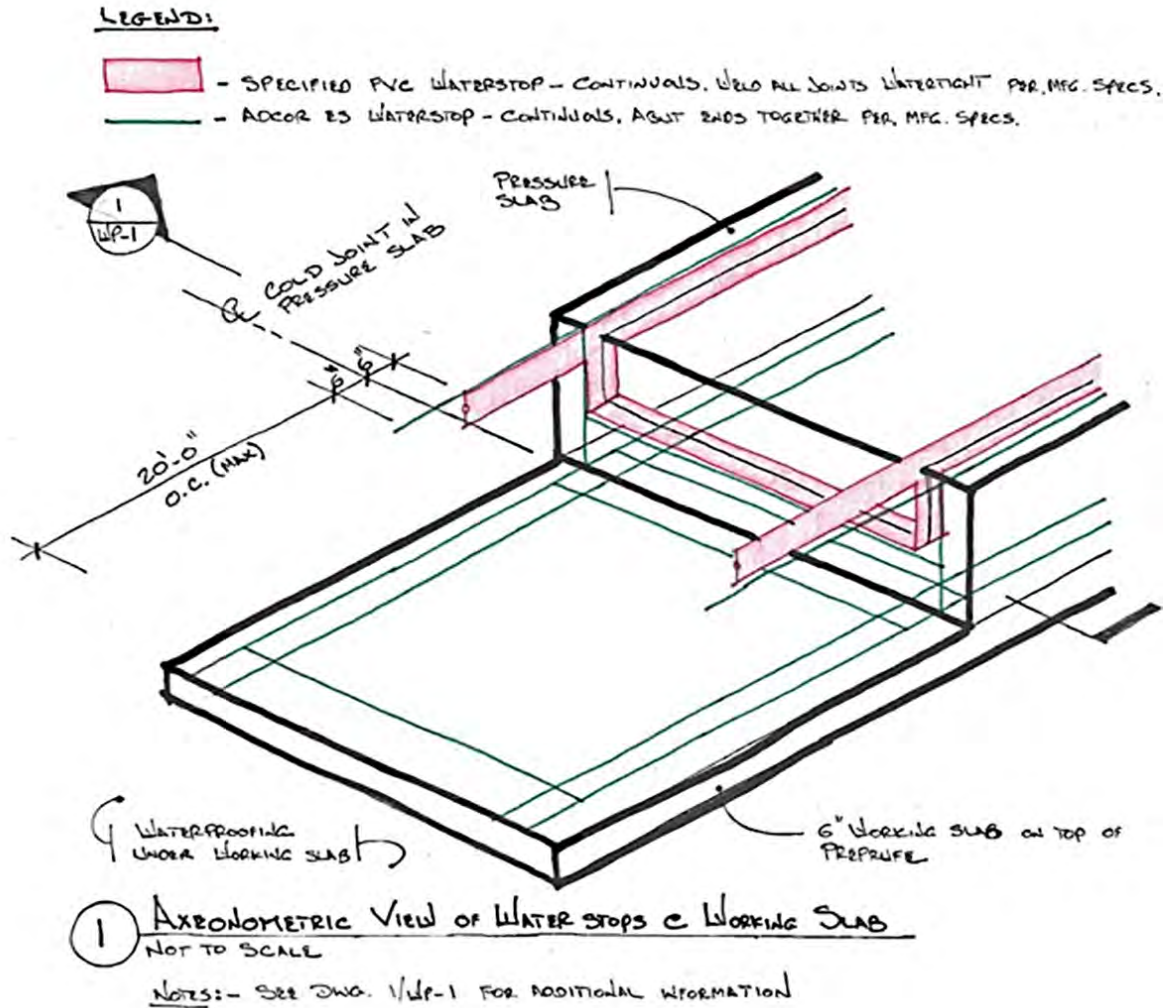
The membrane’s characteristics on how it will interface or adhere to the concrete should be studied because, similar to the post-applied membranes, some pre-applied systems on the market have redundant features within the membrane itself. Waterproofing systems that are adhered to the structure mitigate the potential for water to travel between the waterproofing membrane and the structure. Concrete walls can also be pneumatically sprayed, commonly referred to as “shotcrete.” However, this method of concrete placement should be determined prior to the design of the waterproofing. Not all pre-applied membrane systems can be used for this particular concrete application, and full consolidation of the shotcrete is difficult to verify — that is, voids may exist that prevent a fully adhered pre-applied membrane system from performing as intended.

Speaking of concrete, the next consideration is the use of waterproofing admixtures within the concrete that prevent moisture migration. These systems can add a level of redundancy to the overall system; however, they should be used in conjunction with a primary waterproofing system and not relied upon as the primary protection. The advantages and disadvantages of using an admixture should be considered along with compatibility between the admixture and the primary waterproofing membrane. The concrete mixture should be approved by the structural engineer and the waterproofing materials manufacturer. These waterproofing admixtures are proven to seal static cracks; however, the size of the crack is limited, which is why you should not rely on this as a primary system.

## INTEGRAL SYSTEMS

Working our way from the exterior toward the interior, we now are within the concrete structure. Integral systems within the concrete are another line of defense that should be considered. These integral systems are typically installed at construction joints and vertical-to-horizontal transitions and include, but are not limited to, water stops and

injection tubes. Water stops are an important component of any below-grade waterproofing project. They are used to restrict the passage of water through construction joints and come in multiple varieties that include swellable and polyvinyl chloride (PVC).



**Combination of swellable and PVC water stops.**

The swellable variety of water stops are usually conformable synthetic water-stop strips that are placed within cold joints of concrete after the first section is cast and prior to placement of the next. They are typically held in place with adhesives and mechanical fasteners to prevent displacement during the second concrete pour. When placed within the construction joint and water interacts with the strip, the water-stop material increases in size or swells to seal the joint and prevent the passage of water. Therefore, the material should be kept dry during construction to prevent hydration (swelling) prior to the second concrete pour. If it swells prior to the second concrete pour, it should be replaced.

PVC water stops are preformed strips with flanges that are placed within the concrete forms. They are cast in to each pour of the concrete to bridge across cold joints and act as a continuous barrier within the construction joint. Joints between sections of the PVC water stop are heat-welded together. Difficulties can arise if the concrete is not properly consolidated around the flange of the water stop, if it displaces during the concrete pour or if the joints are not properly welded together.



Injection grout tube at construction joint. PHOTO COURTESY OF GCP APPLIED TECHNOLOGIES

Injection tubes can also be used within the construction joint. These systems consist of permeable tubes, injection ports and chemical grout. These permeable tubes are installed before the concrete pour with the injection ports placed at interior locations for future use. Chemical grout is usually not injected in the ports until after the concrete has cured and/or leaks have occurred in the construction joint. Redundant water stops can also be specified.

## **WATER MANAGEMENT**

On some rare occasions, even after redundancy has been designed into the waterproofing system, water can bypass these systems and enter the structure. Once inside the structure, a method of water collection can be utilized as another means of protection. This internal drainage system can be in the form of troughs, gutters, drainage mats, cavity walls or pipes that collect leakage and direct the water to an

internal drainage system. This can be an effective water management system when leaks have bypassed primary waterproofing systems.

## DESIGNING REDUNDANCY

Now that we've discussed some of the components to a waterproofing system design to consider and the level of exposure risks, it's time to actually design for the system. Depending on the owner's level of risk, multiple layers of redundancy can and should be utilized and incorporated into the waterproofing design.

The endless combinations of these various components should be considered and carefully evaluated during the design phase of a critical structure. The degree to which water is tolerable will vary from site to site and from owner to owner. Providing redundancy in the waterproofing system can come in multiple levels that include all of the component systems noted above.

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### ABOUT THE AUTHORS



**Jesse Torres** joined WJE in 2007 and is primarily experienced in the investigation and rehabilitation of roofing and waterproofing systems. Prior to joining WJE, he worked for NTH Consultants Ltd., a multidisciplinary engineering firm in Exton, Pennsylvania, and with Systematic Roofing Analysis Inc., a roof consulting firm in West Lawn, Pennsylvania. Torres has more than 12 years of experience in roofing and waterproofing projects, including condition surveys, core sampling, roof moisture surveys, construction document preparation, and construction administration services. He has experience with all major low- and steep-slope roofing systems, including built-up roofing, single-ply membrane, modified bitumen, liquid-applied, polyurethane foam, sheet metal, asphalt shingle and slate shingle.



**Douglas Stieve** is a building envelope consultant with a specialization in roof and waterproofing consulting, as well as masonry construction. Since joining WJE in 1991, he has provided professional services for over 800 buildings and other structures, predominantly in the northeast United States. Stieve has experience with many types of materials, including low- and steep-slope roofing as well as plaza deck, green roof and subgrade waterproofing systems. He also has experience with brick, concrete masonry, glazed curtain walls, natural stone, and exterior insulation and finish systems (EIFS). His work includes some of the largest and most complicated waterproofing projects in the New York metropolitan area.