Below-Grade Waterproofing in Urban Areas

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Abstract

Building construction in urban areas with high water tables and/or mandated flood plains presents design teams and contractors with unique logistical issues. Difficulties can include site access, material delivery, construction of the structural framing system, cladding, roofing, below-grade waterproofing, and governmental regulations. In an urban environment, where buildings may be constructed with zero lot lines, the basement must be formed by excavating and installing a soil retention system. When below-grade site conditions include excavating through rock or a high water table, the cost of the work escalates rapidly. The presenter will offer case studies of three buildings with basements located in urban areas and how the support of excavation and waterproofing systems evolved.

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Below-Grade Waterproofing in Urban Areas

Waterproofing failures can occur from one or all of the following: design errors, construction practices, or materials that are defective or improperly selected by the designer. Design errors can include the selection of an inappropriate membrane.

The owner and general contractor can also contribute to the failure of the waterproofing system. The owner’s misguided insistence on cost savings can extend to the waterproofing system: “Out of sight is out of mind.” When it comes time to cut costs, value engineering has a tendency to focus on the roof, exterior wall weatherproofing, and the below-grade and plaza waterproofing. And why not? No one sees these elements, so why spend money on something that is hidden from view? The funds from these cost savings can be better spent on other building elements.

Other factors can cause a waterproofing failure. Building construction in urban areas with high water tables and/or mandated flood plains presents the designer and contractor with unique logistical requirements and restrictions, including those imposed by state or municipal environmental agencies.

In locations where space is unlimited, basements can be formed by simply excavating a hole in the soil and erecting foundation walls. This luxury does not exist in urban areas, where a building will often be constructed with zero lot lines. In these cases, installing a soil retention system is mandatory. Excavating through rock or in the presence of a high water table can cause the cost of construction to escalate rapidly.

The following case studies illustrate some of the problems that may be encountered and how they affect the ultimate design and construction process.

CASE STUDY 1: MUSEUM, NEW YORK CITY

Background

In 2010, the board of trustees for a prominent museum in New York City that supports American art made a decision to relocate from their current location on the Upper East Side of Manhattan. The new building would be located in the Meatpacking District, which has been categorized as one of New York’s most vibrant neighborhoods. The building would be bordered by the Highline to the east and the Hudson River to the west.

The new building would be nine stories high, with a two-level basement, and would include 50,000 square feet of indoor galleries and 13,000 square feet of rooftop exhibition space. The basement would house the electrical rooms, mechanical spaces, pre-exhibit storage area, shipping and receiving, and other ancillary support facility areas (Figure 1).

The new building would be built on a landfill created during New York City’s explosive growth of 1836. As demand for land grew, the city began selling water lots along the shore, where daring entrepreneurs could create their own plots. Engineers would sometimes sink entire ships to create a solid foundation for the landfill. By 1900, the original footprint of the island had expanded approximately 1000 feet into the Hudson and East Rivers.

Over time, these landfill areas became the dumping ground for a host of materials that rendered the land unsuitable for construction. These included toxic waste materials, abandoned fuel oil tanks, organic materials, and construction debris with limited load-bearing capacity. The water table remained high, but was now contaminated with aggressive chemicals, many of which were harmful to both human occupancy and below-grade waterproofing materials.

Site Conditions

When the board of trustees decided to relocate the museum to the proposed location, they were unaware of the below-grade issues they would need to address from adjacent properties and the government regulations that would dictate the design of the below-grade waterproofing system.

The original below-grade structure was designed as a cast-in-place concrete foundation. The support-of-excavation (SOE)
was projected to be a piles and lagging. As the project progressed, the general contractor/construction manager (GC/CM) began pricing the cost of the proposed changes to the foundation design.

One change that the GC/CM proposed to the owner was to utilize the SOE system as the building foundation to maximize cost savings. The system selected by the GC/CM was a secant wall system (SWS). A secant pile wall is formed by constructing intersecting reinforced concrete piles. The piles are reinforced with either steel rebar or steel beams, and are constructed by either drilling under mud or augering. The cost savings for this change was reported to be slightly over $1 million. Since the joints between the alternating piles are not resistant to water infiltration, the wall required waterproofing.

As designers for the below-grade waterproofing system, we presented two alternate solutions if the SWS were to be utilized as a foundation. These were:

**Proposed System No. 1 (Figure 2)**
- Securing wood blocking to the unreinforced piles
- Installing plywood over the wood blocking
- Applying a drainage composite panel on the plywood substrate
- Adding a waterproofing membrane
- Laying reinforced shotcrete over the membrane

**Proposed System No. 2 (Figure 3)**
- Placing a flowable fill over the secant piles (the fill would be placed between the secant piles and temporary formwork)
- Installing a drainage composite panel over the fill
- Adding a waterproofing membrane
- Casting a 6-in. reinforced concrete wall over the membrane

Each solution required the pressure slab to be engaged into the secant piles by raking or notching out the bottom of the piles to the face of the steel beam (column). The waterproofing below the pressure slab would turn up onto the piles approximately 6 in. (150 mm). A waterstop and two injection tubes would be installed between the face of the piles and slab edge (Figure 4).

During the design, the architect decided to add a 1.5-ft. (457-mm) gravel base over the pressure slab, which would then be covered with a filter sheet and a 6-in. (150-mm) reinforced concrete wearing slab. The space between the concrete slab would be utilized as a conduit for sanitary and storm piping without the need to trench down below the mud mat.
Since the museum was being built on landfill, and although the site did not contain contaminants, adjacent sites did contain varying levels of petroleum byproducts and aggressive chemicals. The New York City Department of Environmental Protection (NYC DEP) ruled that there was potential for these contaminated fluids to infiltrate at the joints of the secant piles and into the basement, where the fumes could be harmful to human occupancy. They directed the owner to provide a system to seal them off.

System Revision
Time was now of the essence, since the secant pile wall or support of excavation was being installed on the southwest and west sides of the property (Figure 5), and a revised foundation/waterproofing system needed to be designed to meet the NYC DEP directives, which were to eliminate the passage of chemicals through the secant wall and into the building interior. The design was to construct a concrete foundation on the basement pressure slab where the secant wall was constructed. The wall would be located approximately 3 ft. (1.0 m) from the secant wall to allow for installation of the waterproofing membrane. Where the SOE changed to piles and wood lagging, blindside waterproofing would be applied. The project was further complicated by the use of walers and diagonal bracing and cross lot bracing (Figure 6). The walers and bracing would extend into the basement walls in some locations that required or necessitated extremely difficult flashing.

Since the building was to be occupied as a museum, a hydrophilic waterstop and an injection hose waterstop were specified in all horizontal and vertical pour stops in the basement construction to provide added protection against future leaks.

With a directive from the NYC DEP and a revised foundation/waterproofing design, the project could move forward. A pre-waterproofing meeting was scheduled as was specified. The only issue was the fact that the GC/CM had already directed the waterproofing trade contractor to commence installing the below-grade waterproofing. Not only had the waterproofing commenced, but also 65% of the waterproofing had been installed prior to the meeting. The project was now deemed to be a renovation, since most of the installed work was contrary to the contract documents.

As the building was rising from grade, Super Storm Sandy hit the Northeast. The 20-ft.- (6-m-) deep basement flooded, destroying the mechanical and electrical systems and other services that had been installed in the basement.

Figure 5 – Partial plan for support of excavation.

Figure 6 – Site conditions showing support of excavation, rakers, and cross bracing.
As the project was nearing completion, little notice was given by the construction team to discoloration of the foundation walls and floor slab (Figures 7 and 8). As the consultants to the design architect and executive architect, we were requested to investigate. After conducting a walkthrough to observe the reported leaks and interviewing several persons from the GC/CM, the following was ascertained:

- The hydrophilic waterstops were omitted at the pour stops and other construction joints.
- The injection hose waterstop was also omitted.

The reason given for the omission: cost and time savings.

**Conclusion**

The project, although problematic during the design phase, was one in which a watertight solution and installation were achievable. The lack of reviewing contract documents and adhering to them was an issue that continued throughout the project.

Some of the unilateral decisions made by both the GC/CM and trade contractor during construction may have resulted in cost savings, but at the expense of the watertight integrity of the building.

The addition of flood proofing did not contribute to the waterproofing failure, but enhanced the watertightness of the building at grade and plaza levels.

**CASE STUDY 2: MEDICAL/HIGHER EDUCATION FACILITY**

**Background**

In May 2011, the New York City Economic Development Corporation (NYCEDC), on behalf of the New York City Department...
of Sanitation (DSNY), issued a request for proposals (RFP) to redevelop the lot of land at East 73rd and East 74th Streets along the FDR Drive. The RFP explicitly required that the site be redeveloped to create or expand a health care, educational, or scientific research facility.

The City University of NY (CUNY) and a major and well-respected medical hospital/research facility responded to the RFP with a joint proposal to develop two buildings that would include an outpatient cancer care facility for the medical facility and a science and health professions building for the university.

In August 2012, Mayor Michael Bloomberg announced that the medical facility and CUNY had been designated to develop the site west of the East River (Figure 9).

The successful team jointly proposed to develop two separate but interconnected buildings for a total of 1,150,000 sq. ft. (106,840 m²). The lot size is approximately 66,111 sq. ft. (6,141 m²).

Site Conditions

The site was originally used by the NYC Department of Sanitation as a garage and repair facility. The building size for the medical/research facility would be approximately 747,000 sq. ft. (69,398 m²). The university building would be approximately 403,000 sq. ft. (37,440 m²). Each building would include a basement that would be located 30 ft. below grade. The basement for the medical facility would house the garage, fuel tank room, stormwater tank rooms, solid waste rooms, electrical feeder rooms, and storage rooms. The university basement would include an auditorium, classrooms, and ancillary spaces.

The site is located south of a designated masonry-clad historic building, north of a 65-story residential building clad with a curtainwall, and east of two three-story masonry buildings constructed on a rubble foundation and built circa-1940s.

The geotechnical report for the site indicated a 6- to 7-ft.- (1.82- to 2.1-m-) deep layer of mixed soil and gravel and other debris. The remaining stratum was bedrock. Removal of the mixed soil layer would pose no issues. Excavating through bedrock would present a challenge. Blasting through the bedrock was not feasible, as the city restricted its use to a small area in the center of the site due to the location of the historic building to the north and the residential high-rise to the south. The only way to remove the bedrock was to use an excavator-mounted hydraulic jackhammer (Figure 10).

The geotechnical report further indicated an extremely high water table.

SOE/Foundation Systems

The upper portion of the site that contained the mixed soil on the north, east, and south sides would be supported with steel piles and wood lagging. The lower portion (bedrock) would be self-supporting on the same sides. The west side of the site against the existing circa-1940s buildings would be an 8-in. concrete retaining wall with the actual foundation pinned to the 8-in. retaining wall. The bedrock below the mixed soil-gravel layer would function as its own retaining system.

The slab-on-ground was designed as a 6-ft. (1.82-m) reinforced concrete pressure slab to counter the buoyancy of the high water table (Figure 11). The dewatering system was to be maintained until the building superstructure reached the 17th floor. This would place sufficient downward forces to counter the upward pressures due to the high water table.

Designed Waterproofing System

The designed system would consist of:
- ¾-in. (19-mm) plywood over the wood lagging (for boarding out)
- 1½-in.- (38-mm-) thick XPS insulation
- Drainage composite panel
- Waterproofing membrane

The identical components would be utilized, with the exception of the plywood, over the surface of the bedrock and at the west 8-in. (200-mm) concrete wall.

The horizontal waterproofing would be installed over a 3-in. (75-mm) unreinforced concrete mud mat. A 4-in. (100-mm) concrete protection slab would be placed over the membrane.

The joint between the pressure slab and foundation wall would include a hydrophilic waterstop, as well as an injection hose waterstop. Since the CUNY auditorium would be located in the basement, injection hose waterstops would be installed in all pour stops, both vertical and horizontal.
The reinforced foundation wall was to be secured to the bedrock with rock anchors. The concrete specifications included a crystalline additive to the concrete mix as integral waterproofing.

**System Revision**

As the project progressed through bidding and, as always, the value-engineering phase, changes were presented for the below-grade waterproofing to reduce cost and expedite construction. One change, although minor, was to remove the drainage composite panel.

The other change was to eliminate the insulation over the vertical rock surface and install a 3-in.- (75-mm-) wide sand wall. Over the sand wall, the insulation and membrane would be installed.

What was not presented at the time was the concrete trade contractor's method of supporting the reinforcing bar cage for the concrete wall. The cage as it was being constructed would be held in place with horizontal steel dowels. The dowels would be installed after the waterproofing membrane was installed. Flashing the dowels became extremely difficult since it would need to be executed through the reinforcing cage (Figure 12).

Waterstops and injection hose waterstops were to remain as part of the original design.

**Conclusion**

As the waterproofing membrane was being installed, it became apparent that issues would be forthcoming regarding its ability to provide a watertight system. Excavation continued during the installation of the waterproofing membrane. The dowels to support the reinforcing cage were becoming difficult to make watertight. Installation of the hydrophilic waterstop became questionable.

These concerns became fact when one of the dewatering pumps failed. The result was extensive leakage. Leaks were not limited to the foundation wall, but occurred through the 6-ft. (1.82-meter) concrete pressure slab.

A survey was performed that indicated leaks were occurring at pour stops, both vertical and horizontal in the slab and walls, and at penetrations through foundation walls.

When the dewatering system was back on-line, remediation of the leaks commenced through the use of urethane injection grouting. The efficacy of the repairs will not be known for at least two years, as the owner has directed that the dewatering system remain functioning until the building is completed.
**Case Study 3: 135 East 79th Street, New York, NY**

**Background**

In the early 2000s, a respected high-end developer purchased an older, outdated building located on the north side of East 79th Street, between Park Avenue and Lexington Avenue in New York City, with the intention of a complete demolition and construction of a new luxury condominium building. The area was considered the old-money Upper East Side, home of the Astors, Rockefellers, and Roosevelts. The developer understood that the neighborhood residents wanted to maintain the area pretty much as it was in terms of real estate, and knew a glassy condominium building would not be welcomed in the neighborhood.

The developer retained a known and respected architect to design the new building. What resulted was a 20-story reinforced concrete structure clad with carved stone, custom-manufactured hand-laid brick, hand-cast ironwork, and customized windows that created a façade that ranks among the finest in New York (Figure 13).

Building amenities include landscaped private gardens, a fitness center with a private training studio, a residents’ lounge with a separate catering kitchen, a family club/game room overlooking the garden, and private wine cellars.

**Site Conditions**

In 2009, the developer decided to move forward with the plan for a new condominium building. The site was located between three existing buildings on the north, east, and west sides, and is approximately 96 x 96 ft. (29 x 29 m). The existing building was slated for demolition in the early part of 2011. The basement was designed to extend north of the existing basement to accommodate the fitness center, lounge, and game room that were being located below-grade and below the north garden/terrace area.

The geotechnical report for the site indicated a stratum of bedrock. The use of explosives to break through the bedrock was rejected due to the location of adjacent buildings. Excavation would be by hydraulic hammers (Figure 14). The geotechnical report also indicated a below-grade stream (Figure 15).

During demolition, cost estimates for the new building began to escalate. The developer began to look for ways to decrease construction costs. The architect and engineer explored various options, including retaining portions of the existing foundation.

The owner, after reviewing the various cost-saving options, made a fatal decision to retain portions of the foundation with the intention of integrating the new and existing foundation walls.

**Designed Waterproofing System**

The decision to keep portions of the existing foundation walls in place created difficult, if not impossible, waterproofing solutions. This was in addition to the underpinning required for the existing buildings on the east and west sides of the site.

The waterproofing system would require a hybrid design, incorporating both blind-side and a negative-side waterproofing on the interior face of the existing foundation.

*Figure 13 – Elevation rendering of building façade.*

*Figure 14 – Site excavation utilizing hydraulic hammers.*

*Figure 15 – Below-grade stream.*
Figure 16 – Plan view between existing and new foundations.

The developer turned his attention to the contractor to seek recommendations to reduce the cost of waterproofing. The waterproofing contractor was more than eager to give value-engineering counsel to reduce cost and further expedite the construction schedule. Some of these suggestions included:

- Parging the adjacent building foundation walls and eliminating the EPS insulation
- Eliminating the application of crystalline waterproofing on the interior face of the existing foundation walls
- Eliminating waterstops

With the basic decision to salvage portions of the existing building foundation and the revisions indicated above, the only recourse was to wait until the dewatering system was turned off. Once dewatering ceased, leaks began to appear within six months of the building’s completion as reported by the developer’s representative. Leaking started along the south foundation and continued to the east foundation wall. Leaking occurred predominately at the joints between the new and existing foundation walls. The interior of the walls were cleaned, scarified, and coated with a crystalline waterproofing, according to the developer. This remediation appeared to have stopped the leaks, until the spring of 2016.

One of the owners of a first-floor duplex unit located on the west side had just completed a $2,000,000-plus renovation. Almost immediately after the renovation, leaking appeared along the north side of the west wall. Probes were made through the interior walls to determine the exact location of the water infiltration (Figure 19). The building owner on the west side agreed to allow access for the purpose of additional investigation.

The developer, who was still responsible for maintaining the building, rejected our recommendation to utilize an injection grout to remediate the leak because of the higher cost. What they opted for was to trench along the west foundation walls. Where new foundation walls occur, the system would consist of (Figure 16):

- Foundations of the existing north, east, and west buildings
- 1 ½ in.- (37 mm-) EPS insulation
- ¾ in.- (18.75 mm-) plywood
- Drainage composite panel
- Waterproofing membrane
- Reinforced concrete

The horizontal waterproofing would be installed over a 3-in. unreinforced mud mat (Figure 17). The membrane would extend up vertically where new foundation walls would be cast. At existing foundation walls, the membrane would terminate approximately 8 in. and be secured to the wall.

The surfaces of the existing foundation walls would be scarified, and two applications of crystalline waterproofing would be made.

Hydrophilic waterstops were specified to be installed between the vertical face of the pressure slab and the existing foundation walls, as well as the vertical joint between the new and existing walls (Figure 18). The blindside waterproofing for the new foundation walls would also return onto the vertical face of the existing walls.

System Revision

The developer wanted to further control the construction cost and looked towards the below-grade waterproofing. The age-old saying “out of sight is out of mind” was beginning to appear at project design meetings.

Figure 17 – Waterproofing membrane applied over mud mat.
approximately 2-3 ft. below grade and to install a perforated pipe surrounded by crushed gravel and a filter sheet. The pipe was extended to discharge to a drained areaway. Presently, this solution has relieved the water pressure along the foundation and maintained a dry interior.

**Conclusion**

The owner’s initial decision to retain portions of the existing foundation wall was a fatal flaw that continued with ill-advised recommendations. The removal of the different components of the waterproofing system (i.e., crystalline waterproofing, waterstops, etc.) compounded the problems.

As leaks appeared, the designed system was slowly incorporated and the leaking stopped, with the exception of the west leak. The owner did not want to expend funds for any type of grouting remediation because of logistics and cost. Their decision to install a perforated pipe has provided relief, but the long-term effectiveness of this solution is yet to be determined.

**LESSONS LEARNED FROM EACH PROJECT**

Like the five blind men encountering different parts of an elephant, each of the participants in the process of planning, designing, financing, constructing, and operating physical facilities has a different perspective of any project. It behooves all participants in the process to heed the interests of owners because, in the end, it is the owners who provide the resources and call the shots. Therefore:

- Right or wrong, the building owner is the final decision-maker for any project, even when they are uneducated about the decisions they may be making. Owners tend to get their information from suppliers, contractors and subcontractors, or associates that may not have a full understanding of the building design considerations.
- Inexperienced contractors, or even contractors who have been in business for years, may be ignorant about new technology or trends. Decisions that the design professional has made regarding the waterproofing system can be negated by the contractor, even though the contractor may not fully understand the basis of the design professional’s decisions.
- Value engineering should not exclude the design professional. Value engineering should not include the elimination or modification of elements that are essential to successful performance of the material or system selected and their required functions.
- Changes or revisions made to the building design may equate to a reduction in immediate construction cost, but can increase future maintenance or repair costs.

The phrase “out of sight, out of mind” was originally translated by a computer as “invisible idiot,” “blind and insane,” etc. When decisions are made to reduce construction cost at the expense of roofing, exterior wall weatherproofing, or below-grade/plaza waterproofing, the results can only lean towards possible catastrophic failure. This is especially true of below-grade or plaza waterproofing.

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**Figure 18 – Detail of waterstop locations.**

**Figure 19 – Water testing perforated pipe installation.**