# First Line of Defense – Plaza Waterproofing Replacement


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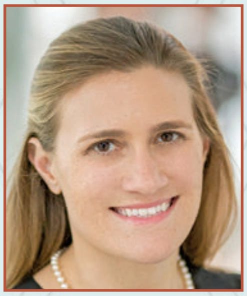
# ABSTRACT

Outdoor plazas are ubiquitous on the urban landscape, providing access to otherwise limited outdoor space. Due to tight urban space demands, plazas are often located above occupied spaces, which complicates their design and maintenance. In addition, as plaza systems age, plantings and trees can become overgrown, hardscapes worn and deteriorated, and failing waterproofing can result in interior leakage and damage. Maintenance and repairs are generally difficult because of the overburden and multi-layer systems, and so frequently the systems are either partially or completely replaced. Replacement is often complicated given perimeter constraints, changed code requirements, and constructability issues. In addition, the plaza system selection must consider life expectancy, durability, maintenance, and cost.

This presentation will provide strategies to evaluate plaza system replacement options within project-specific restrictions through a series of case studies. It reviews investigation strategies to evaluate existing plaza conditions and the field information critical for making design decisions. A range of replacement plaza waterproofing options and their advantages and disadvantages, including durability, constructability, and cost implications, will be discussed. Key design considerations such as drainage, overburden selection and setting, and building code requirements that can impact the material selection and overall system detailing will be presented.

# SPEAKER



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# First Line of Defense – Plaza Waterproofing Replacement

## INTRODUCTION

Plazas provide unique outdoor access in urban areas and are often located over occupied space in order to maximize usable space. Plaza systems and waterproofing are subject to a constantly damp environment, a challenging condition for any waterproofing system. As plazas age, materials deteriorate, leaks develop, and maintenance and repairs are difficult because of multiple layers and overburden, so systems are often fully replaced. Developing a replacement plaza system design is a balancing act of competing factors, but it is essential to consider life expectancy, durability, maintenance, and cost.

## REASONS FOR REPLACEMENT

Motivation for plaza system replacement can often come from worn and deteriorated hardscapes, overgrown plantings, and an outdated appearance. Typical surface damage can be unsightly, and it often suggests overall system durability issues. Common deterioration includes freeze-thaw damage to overburden materials such as stone, cast-in-place concrete, or brick pavers, which results in spalling or delamination of the surface. Heaving of the overburden, most common with unit pavers, is due to water trapped in the setting bed material freezing and thawing, which can cause trip hazards. Efflorescence and staining can also mar finish surfaces, creating an unattractive appearance.

These issues are commonly due to poor drainage through the system and at the membrane level. While not necessarily related to the waterproofing functionality, drainage provisions may be a deciding factor to choose plaza system replacement instead of repair. Adequate drainage is essential, as it prevents water from ponding on the membrane surface, and ponded water can cause degradation of membrane materials.

Plaza waterproofing system replacement can become a necessity if defects in the existing waterproofing membrane cause leaks into interior spaces or other damage. While repair of defects may be an option, addressing underlying issues that caused the defects may not be possible as part of a repair. Additionally, it is good practice to match the expected life of the waterproofing membrane with the system components.

## DESIGN PARAMETERS

Successful waterproofing designs take into account numerous considerations that vary, depending on the project's existing conditions, budget constraints, and client preference and risk tolerance. Risk tolerance should be discussed early on during design and can be evaluated based on tolerance for leakage, consequence of leakage, ability to make repairs, and expected service life.

Adequate drainage is essential, as it prevents water from ponding on the membrane surface, and ponded water can cause degradation of membrane materials.

The following parameters impact overall system design and plaza waterproofing membrane selection, and they must be evaluated for their potential impact and relative importance on a project-specific basis:

- **Drainage –** Drainage is affected by the selected wearing surface and its supports or setting bed. For example, open paver joints allow water to flow through, resulting in only membrane-level drainage, while a closed-joint system allows for bulk surface drainage with drainage at the membrane level. Proper drainage requires slope to drain at the surface level and waterproofing membrane level, and integration with the drains. As a rule of thumb for adequate slope to drain, provide ¼-in.-per-ft. minimum slope at the waterproofing level (consistent with International Building Code [IBC] 2018 roof drainage slope requirements for low-slope roofs), and ⅛-in.-per-ft. minimum slope at the surface. While not required by all waterproofing manufacturers, it is good practice to provide a drainage layer or gap at the membrane level such that water has an unrestricted path of travel to the drains that will not be impeded with fines while in service. Standing water on the membrane may reduce performance of the waterproofing membrane and contribute to premature failure. Bi-level drains, which provide drainage at both the waterproofing and finished surface, are also common for plazas.
  Modifying the existing slope with a sloped topping or tapered insulation can result in system pinch points at the plaza perimeter or door thresholds. Adding drain locations will help improve slope to drain while limiting the overall system thickness buildup. The additional material can also add weight to the system, and a sloped concrete topping must be allowed to cure, which can add time to the construction schedule.
- **Building Code Requirements –** Present-day building codes typically require more insulation than past building codes to improve energy performance, which often necessitates thicker insulation to achieve

required R-values in replacement systems. For comparable regions in New England, the 1998 International Energy Conservation Code (IECC) required R-14 continuous insulation above a roof deck, while the International Existing Building Code (IEBC) 2018 required R-30 for the same condition. This equates approximately to a 3-in. increase in required insulation over the past 20 years.

ADA requirements can impact possible modifications at door thresholds, as they do not allow an elevation change greater than ½ in. Due to these requirements, replacement plaza waterproofing system thickness may be limited at threshold locations, thereby dictating the overall system design.

The past editions of the IBC have required provisions for secondary drainage, either with a secondary drainage system including redundant stormwater piping, or by overflow scuppers. Adding secondary drainage can drive up project costs and result in finicky details at scuppers. An alternative approach to satisfy secondary drainage requirements is to verify that the structure can support ponding water resulting from the primary drainage system becoming clogged. In 2018, the IBC removed the requirement to provide secondary drainage when reroofing (or replacing a plaza waterproofing system). The designer must confirm applicable local building codes and secondary drainage requirements. A prudent designer may still confirm the structural capacity to support ponding loads or provide secondary drainage, or, at a minimum, encourage clients to regularly maintain primary drains and apprise them of associated risks.

- **Structural Considerations –** As part of the waterproofing replacement, the existing structure must be evaluated for deterioration and damage and be repaired. Designers can begin to access the structure during an investigation, but they are able to more holistically review and confirm design assumptions during construction. In addition to evaluating structural deterioration, structural review is needed to evaluate for changes in loads due to the replacement plaza system (dead loads), changes in access or use of the outdoor plaza space that can result in increased live loads, and construction loads. The IEBC dictates the extent of the full project scope (repair or alteration), change of use, or increased loads that may trigger structural upgrades. Careful review is required on a project-specific basis.
- **Constructability Concerns –** During design, project-specific conditions that impact construction, such as access for materials and equipment, odor control, and difficult-to-execute details should be considered to ensure a successful waterproofing replacement project.
- **Maintenance –** Plaza waterproofing is typically buried, difficult to access after installation, and nearly impossible to maintain. Pavers on pedestals provide the most serviceable wearing surface since individual pavers may be individually removed. Plaza maintenance is typically otherwise limited to cleaning drains and repairing paving, as more invasive maintenance and repairs are disruptive and costly. Designers must help clients and building maintenance staff understand the expected life of the selected waterproofing membrane and other system components, as well as future maintenance challenges.
- **Overburden and Setting Bed Selection –** Continuous paving (concrete or asphalt) typically allows less water through the paving system than unit paving (brick, stone, or precast concrete pavers). Setting bed options (sand, mortar, asphalt, or pedestals) should also be carefully considered as part of the overall design and match the owner's maintenance expectations. Apart from aesthetic considerations, overburden and paving selection can impact the performance of the plaza waterproofing membrane system. Pavers on pedestals impose bearing pressure on the waterproofing membrane (or insulation layer) which must be designed not to exceed the compressive strength of the substrate material. Overburden must accommodate the anticipated pedestrian and vehicular loads. Soils and plantings require special consideration as fines tend to block drainage and irrigation can introduce additional water.

## WATERPROOFING REPLACEMENT OPTIONS

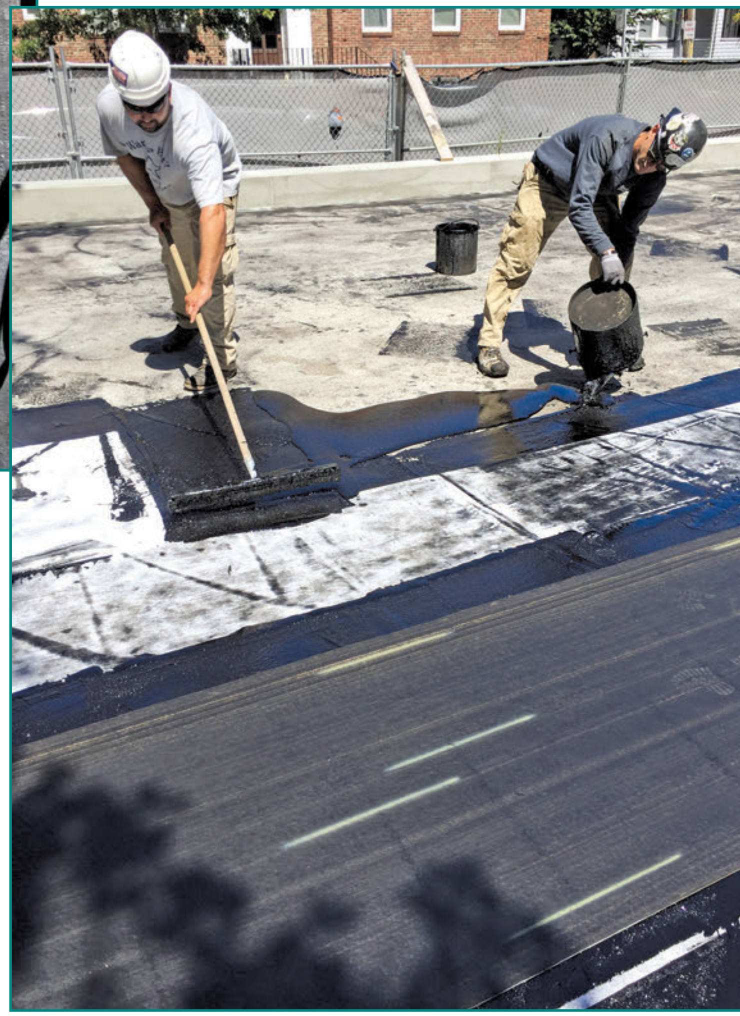
When designing a replacement plaza waterproofing system, selecting an appropriate waterproofing membrane is a critical decision to be balanced with other design parameters, risk tolerance for leakage, and expected service life. Since it is both difficult and costly to locate sources of leaks and complete repairs, it is important to select a reliable and durable product that meets the project constraints and can be subject to constant moisture. Waterproofing membranes must have sufficient puncture and tear resistance to withstand construction and traffic while in service, and they must have sufficient elongation to accommodate expected movements. Durable waterproofing membranes typically have low water absorption and low moisture vapor permeability. Commonly used plaza waterproofing membranes are discussed below.

### Sheet Membranes

Loose-laid or adhered sheet membranes are common options for plaza waterproofing replacement membranes. These membranes benefit from quality control during the manufacturing process and have consistent thickness but also have seams, which are an inherent vulnerability. Loose-laid membranes are isolated from the substrate and less vulnerable to damage due to cracks or joints in the substrate. Loose-laid membranes are less dependent on weather and site conditions to install successfully. Finding and repairing defects in a loose-laid membrane can be challenging because water can travel below the membrane to cracks or penetrations. Alternatively, adhered sheet membranes are more vulnerable at cracks and joint movement, which can translate through and damage the membrane, but which limit water from traveling below the membrane.

Figure 1 – Aged self-adhered sheet membrane exposed in plaza waterproofing system.

Figure 2 – Hot-applied rubberized asphalt installation.



In plaza waterproofing applications, single-ply thermoplastic membranes (such as polyvinyl chloride, or PVC) with heat-welded seams are commonly used as a loose-laid or mechanically attached membrane. Heat-welded seams are durable and generally preferable to adhered seams. Although originally used in building deck applications with non-removable overburden, such as a concrete topping slab, some manufacturers no longer allow their use in buried applications.

Self-adhered membranes (such as bituminous sheets with polyethylene facers, *Figure 1*) have been widely used for plaza waterproofing and, although less widely used today, are still available. These membranes have numerous seams due to available membrane roll sizes. Membrane seams are weak points since ponded water can lead to premature failure of self-adhered membrane seams and degradation of membrane materials. To improve self-adhered sheet membrane performance, careful surface preparation is necessary to ensure long-term adhesion, and this can be time consuming and costly. Some manufacturers recommend a robust adhesive or fluid-applied membrane layer below the self-adhered membrane to prepare the substrate and improve membrane adhesion, while some manufacturers require mastic at the seams to improve durability and watertightness. Mastic buildup, however, can impede membrane drainage.

## Liquid-Applied Membranes

Fully adhered to the substrate, liquid-applied membranes are applied monolithically to the substrate, and their performance is dependent on surface preparation, field condition, weather, and workmanship. Liquid-applied membranes suitable for plaza waterproofing are reinforced, which limits cracking of the membrane due to movements in the substrate. Liquid-applied membranes do not have seams, eliminating the potential for water penetration at seam defects, and they are also typically thicker than sheet membranes, providing improved penetration resistance and redundancy against damage. Should water bypass the membrane at a defect, fully adhered membranes have the benefit of isolating defects and limiting water from migrating below the membrane, which can result in fewer leaks. Because leakage is isolated, it may also be easier to find the source of the leaks and perform targeted repairs. Liquid-applied membranes are also typically easier to detail around penetrations. These materials can have a strong, objectionable odor, which can result in logistical issues for certain projects, requiring off-hours work or alternative ventilation for occupants.

Hot-applied liquid membranes–such as hot-applied rubberized asphalt (*Figure 2*)–require kettles or melters to warm the material and must be close to the work area, so access can be an issue at raised plaza areas. Concerns for possible fire hazards, dangerous working conditions, and odors

*Figure 3 – Exploratory opening at plaza drain.*

may also limit use of this material, depending on project restrictions. Installation is highly dependent on a clean, dry substrate, as well as the installer's ability to maintain the liquid membrane temperature and provide consistent membrane thickness. Hot-applied membranes can be especially challenging to install on vertical surfaces at rising walls and planters.

Cold-applied liquid membranes rely on chemical reactions to cure and have solvents that may also have an odor. Successful installations of these membranes are similarly dependent on adequate surface preparation and the installers' abilities.

## EVALUATING EXISTING PLAZA WATERPROOFING SYSTEMS

To understand sources of leakage and causes of damage, designers must complete a thorough investigation of the existing conditions to determine if repair, partial replacement, or full replacement of a plaza waterproofing system is warranted. At a minimum, investigations should include review of available background documents, such as original construction documents, past reports or repair documents, and maintenance logs; survey of interior and exterior conditions documenting damage such as cracks, displaced pavers, and signs of leakage; interviews with building maintenance staff and occupants to help identify where and when leakage occurs; water testing to identify sources of leakage; and exploratory openings or test pits to confirm existing conditions (*Figure 3*). A designer should take samples, as needed, to confirm the existing material composition, and engage a testing firm to collect and test samples to confirm whether hazardous materials are present. A level survey can also be invaluable to understand the existing plaza slope, identify low points and high points, and inform options during design.

A designer should approach an investigation with an open mind in order to gain a full understanding of various issues and causes of damage, deterioration, and leakage to inform a reasoned and successful repair approach. A designer should strive to gather sufficient field information to develop possible repair or replacement options that consider the design parameters discussed above. While the final recommendation may be for replacement, a designer should gather information to evaluate possible repair options that may better suit the client's project goals.

An investigation should answer the following questions related to the plaza waterproofing to help develop a design approach and avoid surprises during construction:

- What are the existing system components and their condition? What is the waterproofing material (hazardous materials and compatibility with replacement materials) and its age?
- What is the system thickness, including heights at drains, door thresholds, and other perimeter conditions?
- How do the existing waterproofing and overburden drain? Is the slope to drain achieved by a sloped structural slab, topping slab, or other? Is the stormwater collection system functioning?
- Where are the sources of leakage? Is leakage related to defects in the existing waterproofing membrane or surrounding conditions?
- What are the operating conditions on the plaza? Is it open to pedestrian and/or vehicular traffic? How is snow removed or treated during winter?
- What is the condition of the substrate below the waterproofing? Will the substrate require repair if waterproofing is replaced?
- How does the existing system accommodate movement (expansion joints), and is this sufficient?

## CASE STUDIES

The following case studies demonstrate how the design of a plaza waterproofing project can evolve based on project-specific conditions, client preference, and budget. Each case study details the project's existing conditions and issues, investigative techniques, and critical design parameters that drove the plaza waterproofing membrane selection and overall design.

### Case Study 1 – Let There Be Drainage

This existing plaza with concrete paving surface surrounds an apartment building located over an unconditioned parking garage (*Figure 4*). The plaza wraps around the building with stairs leading to lower slabs-on-grade, and a ramp leading from the sidewalk level to the building's primary entry. As part of a full-building renovation project, the owner wished to improve the plaza aesthetics and usability for residents, as well as addressing ongoing leakage into the parking garage—which was both unsightly and restricting parking—so that vehicles were not damaged by water leakage.

Our investigation consisted of an interior and exterior visual survey and exploratory openings. The existing system consisted of an unreinforced concrete topping slab with pedestrian traffic coating, bentonite waterproofing system, and structural concrete deck. The concrete topping slab had limited slope to drain and was cracked, allowing water to bypass the paving. The plaza drains provided only surface-level drainage and did not allow for waterproofing-level drainage. The waterproofing simply abutted the rising wall, which also had limited flashing height, and was held back from the plaza edge. Our openings also revealed delamination and spalling of the concrete structural slab. The existing plaza waterproofing system was not functioning, causing leakage into the interior.

Due to the systemic problems relating to drainage, perimeter conditions, and structural deck deterioration, we recommended removing the existing topping slab and waterproofing to allow for structural deck repairs and a new waterproofing system with integrated perimeter flashing to provide a reliable and durable system. Although the budget was a concern, the owner agreed with this approach and also elected to change the overburden, integrating landscaping for aesthetic improvements, and precast concrete pavers on pedestals, preferring pavers to other paving options for cost and maintenance reasons. The removal of the existing concrete topping slab provided a significant reduction of the system dead load, and provided flexibility for overburden material selection.

The following conditions and design parameters dictated the waterproofing selection for this project:

*Figure 4 – Case Study 1 plaza with cracked and unsightly concrete paving surface.*

- **Drainage –** Based on a level survey and exploratory openings during our investigation, we determined the existing structural slab and waterproofing level had no appreciable slope to drain, which was later confirmed during construction (*Figure 5*). Knowing that our new system would rely on drainage at the waterproofing layer because of open joints at the pavers and plaza landscaping, we recommended providing a sloped concrete topping on the existing structural slab to improve the slope to drain and adding drain locations to limit the sloped topping height buildup. Additionally, we recommended replacing drains with bi-level drains and providing a drainage layer directly at the waterproofing surface. The client decided against the sloped topping, based on their assessment of relative costs and construction schedule impacts vs. risk of possible premature membrane deterioration if it is saturated. This decision greatly impacted the waterproofing membrane selection, which must be durable, redundant, and ideally adhere to the substrate to be successful in this application.

*Figure 5 – Concrete structural slab lacks slope to drain and water ponds on the surface.*

*Figure 6 – Case Study 2 ninth-floor terrace with quarry tile pavers.*

- **Perimeter Conditions –** The building's rising wall had limited flashing height, a deteriorated concrete curb, and an existing through-wall flashing below brick masonry veneer. For a comprehensive repair, we recommended integrating the plaza waterproofing with the through-wall flashing. Because of budget restrictions, the client preferred to provide a reglet-set metal flashing to protect the waterproofing termination, though the flashing height was limited. To limit water that could travel behind the waterproofing membrane at the rising wall, we again favored an adhered waterproofing membrane for improved durability.
- **Penetration Details –** Although the field of the plaza is generally free from penetrations, we had numerous pin penetration locations to anchor a new precast concrete curb and prevent movement of cast-in-place concrete at the stairs. As a result, we prioritized a liquid-applied waterproofing system for more reliable penetration details.

As a result of these project constraints, we selected a hot rubberized-asphalt waterproofing, which the manufacturer allows to be installed on a flat deck. Should water bypass a defect in the waterproofing, the fully adhered waterproofing should limit leakage from traveling below the membrane to cracks in the concrete slab and leaking into the garage below. Hot rubberized-asphalt waterproofing also provides flexibility when dealing with unique geometries and penetration details, and has a long track record of successful performance in buried applications.

## Case Study 2 – To Roof or Not to Roof

This ninth-floor terrace provides unique outdoor space for an office building with sensitive occupied space below, although the space is currently unused due to interior leakage (*Figure 6*). The existing walking surface is spalled, cracked, and heaved, ponds water, and has vegetative growth at paver joints. The terrace is aged and has failed. The existing plaza system consists of quarry tiles on a reinforced mortar setting bed over a polyethylene sheet bond break, a reinforced concrete protection slab, neoprene waterproofing, insulation, sloped concrete topping (⅛ in. per ft.), and the structural concrete slab. A remedial coating was applied to the tile surface in some areas as an attempt to limit ongoing water infiltration, though this was unsuccessful and the coating was blistered.

Because of the plaza system's age,

failed repair attempts, and continued leakage, the client was committed to replacing the existing terrace system. Early on in design, however, the client was unsure of the desired appearance and whether they would allow future public access to the terrace. They were searching for a balance of long-term durability, ease of maintenance and repair, reliability, and redundancy. Of these criteria, ease of maintenance and repair became the primary driver for the system selection. As a result, both inverted roof membrane assemblies (IRMAs) and more traditional roof systems with an exposed membrane were considered during design.

An exposed membrane in this application is more vulnerable to impact but available for inspection and repair. Pavers on pedestals provide a walking surface and protection for the membrane, but limit maintenance. Alternatively, in an IRMA system, the waterproofing membrane is adhered directly to the concrete deck, with insulation and drainage layers on top of the waterproofing membrane. This configuration protects the membrane and uses the overburden as ballast to meet wind uplift requirements, but the membrane is hidden from visual inspection and maintenance. Because the membrane is directly adhered to the roof deck, water infiltration through a defect in the membrane is limited from traveling through the assembly. Because of the client's strong preference to have the membrane accessible for repair, we approached the design assuming the waterproofing membrane would be located at the top of the assembly, similar to a traditional roof system, with the option to include pavers set on pedestals, if desired by the client.

All plaza waterproofing design options for this project included removing the existing plaza waterproofing system to the structural concrete deck and tapered concrete topping and providing a vapor retarder, tapered insulation with ¼-in.-per-foot slope to drain, coverboard, and roofing membrane. We considered the following roofing membrane material options:

- **Single-Ply Membrane –** Single-ply membranes can be mechanically attached or fully adhered to the coverboard and insulation below. A single-ply roofing system lacks redundancy, making it more prone to damage from abrasion and foot traffic. Heavier membrane thicknesses are available to give greater resistance to tears and punctures. Thermoplastic membranes with heat-welded seams, which are easier to inspect and generally more reliable, are preferable to membranes with adhered seams.
- **Modified-Bitumen Roofing –** This system consists of two or three layers of modified-bitumen sheet membranes, which are either set in hot asphalt; set in cold, modified-asphalt-based adhesive; or torch applied. For this project, only cold-applied systems were considered due to construction limitations of getting a kettle to the project area. Multiple plies provided redundancy against damage or penetration. This system is durable and low maintenance, and the mineral surface cap sheet can withstand foot traffic. If used below pavers set on pedestals, manufacturers typically require using a non-granulated cap sheet, which is UV-sensitive, and a drainage mat to promote drainage and UV protection for the cap sheet.
- **Cold Fluid-Applied Waterproofing –** At the client's request, we considered a cold fluid-applied waterproofing system, although it is an atypical application for this project since it is more commonly installed directly onto a concrete deck. This waterproofing system is applied in multiple layers to form a monolithic waterproofing membrane. The reinforcing fabric is integrally installed in the membrane to improve performance at joints and flashing conditions. Similar to single-ply membranes, this option lacks redundancy, but it is typically more durable. Lack of redundancy is less critical when applied to a roof deck, as a fully adhered system limits water's ability to travel and leak into the building, but fully adhered systems may instead be installed as the top layer of the system. In this application, the system and waterproofing membrane must accommodate differential movement between the coverboard and insulation (typically requiring additional reinforcement at joints) and lacks the benefits of the fully-adhered waterproofing system.

Although not driving factors of the waterproofing membrane material selection, several code requirements significantly impacted the plaza system design.

- **Insulation Thickness –** Applicable building codes at the time of original construction required less insulation thickness than modern building codes do. To meet current code requirements, insulation increased from 2 in. to approximately 5 in. The existing plaza system thickness could accommodate this change and did not require modification of the rising wall details, door thresholds, stairs, and curbs to accommodate the increased insulation thickness.
- **Secondary Drainage –** The applicable building code for this project required that the existing structural slab be evaluated for ponding water, and/or that secondary drainage be provided to limit the risk of ponding water should the primary drains become clogged. A structural analysis of the existing structural slab showed that it did not have sufficient capacity, despite the

> Designers need to be flexible when developing plaza waterproofing replacement options, since each plaza is unique and will require a unique solution.

*Figure 7 – Case Study 3 raised granite plaza with large planters.*

*Figure 8 – Staining and efflorescence at stairs.*

overall reduction of plaza system weight, to support ponded water if the primary drains were to fail. We designed scuppers through the parapet wall, which was a challenging waterproofing detail and added significant cost to the project.

- **Wind Uplift –** Due to the height of the ninth-floor terrace, the plaza waterproofing system was required to resist higher wind uplift loads than more typical systems. Although the uplift design did not significantly impact the waterproofing material selection, the client again felt more comfortable with a traditional roof system with mechanically attached insulation and coverboard and an adhered exposed membrane designed and tested to withstand the uplift loads instead of an IRMA system that relies on the weight of the overburden to resist uplift. Additionally, the wind uplift loads dictated the paver selection.

## Case Study 3 – What Happens Below Stays Below

This raised granite plaza tucked into the building creates a courtyard with large planters on either side (*Figure 7*). A multi-flight granite staircase descends from the plaza to a lawn area with secondary building access to occupied spaces below the plaza. Granite balustrades line the plaza edge and staircase. The client reported leakage into the spaces below the plaza and was concerned that some of the leaks might be related to failed planter waterproofing and heavy spring rains. Additionally, the plaza trench drain was a maintenance problem and was seemingly perpetually clogged, and the stairs, which are a focal point facing the street, were heavily stained (*Figure 8*).

The investigation to understand the various issues related to the plaza, planters, and staircase was complex and involved document research, detailed mapping and scoping of the antiquated stormwater drainage system, exploratory openings and test pits in the planter, and water testing. The existing waterproofing system incorporated a waterproofing membrane, a drainage layer, and generally good slope to drain; however, we noted freeze/thaw deterioration of the mortar setting bed and ponded water on the plaza. The plaza trench drains at the planter walls were simply ineffective at surface drainage, despite the plaza's adequate slope to drain. As constructed, a large portion of the plaza slopes toward the stairs and balustrades. As water drains, it picks up soluble salts from the mortar bed below, which are transported to the stone surface and accumulate and stain the stone. Further, the balustrades and stair walls lack through-wall flashing, allowing water to travel through stone head joints, again picking up soluble salts and exacerbating the staining at the walls.

At the planter areas, we observed several deficiencies, including poor rising wall terminations and lack of drains at the membrane level (allowing water to pond on the membrane surface). The planter concrete slab was also deteriorated, suggesting that water is bypassing the waterproofing. While the water that collected in the planter and infill below the planter slab likely contributed to the reported interior leakage, our investigation determined that this was not the primary source. The stormwater drainage system is a complicated configuration of various aged components. Clogged stormwater pipes allowed water to back up into the system and leak below the floor in the spring during high ground water levels and intense rains. The clogged pipe was cleaned during our investigation, and no further leakage in this area has been reported.

To address the other leakage areas, planter waterproofing deficiencies, and causes of staining, we concluded that the planter waterproofing required replacement. Correcting the plaza drainage issues required eliminating the trench drains and reconfiguring the plaza drainage, including rebuilding the balustrade to provide a through-wall flashing below. Since this work would significantly disrupt the plaza, we recommended replacing the plaza waterproofing so that the plaza and planter systems would have a similar life expectancy, and also for improved detailing between the two areas, at perimeter conditions and drains. We also recommended providing a drainage layer, similar to the existing construction, and adjusting the paver setting detail to limit mortar setting (and soluble salts, which cause staining).

During design, we wanted to select a membrane suitable for both the planter and plaza conditions. Due to the client's need for long-term durability and redundancy with limited maintenance, numerous pin penetration locations, and inaccessibility in the planter for repairs, we favored a hot rubberized-asphalt waterproofing system. At the planter rising walls, we considered a self-adhered sheet membrane for ease of installation on the vertical surface, and because seams in the membrane would not be in ponded water. We had some constructability concerns for locating a kettle on the raised plaza but felt that it could be lifted into place with the same equipment used to remove and reinstall larger balustrade and stair stones.

We proceeded with this material selection, but raised potential odor concerns to the client during construction within the courtyard plaza area. Knowing that several air intakes were located around the work area with sensitive occupants in floors above, the client considered requiring off-hours waterproofing installation but eventually decided to change the plaza and planter waterproofing materials to a cold fluid-applied system, despite higher material cost.

To improve planter drainage, we included a sloped concrete topping slab to direct water toward the drains, as well as a drainage mat to limit water ponding on the waterproofing. On the plaza, using the existing structural concrete slab slope to drain, we sought to eliminate the trench drains at the plaza perimeter and improve drainage at the stairs to limit staining, which proved more challenging that initially anticipated.

Since the plaza sloped toward the planters, we first considered draining the plaza below the planter walls at the drainage layer level. The existing plaza trench drains output into the planter drains, so this would not alter the stormwater management intent. We were concerned, however, that the drainage layer below the planter wall would become clogged with sediment over time, obstructing the plaza drainage and reducing the longevity of the system. Providing internal bilevel drains and using a sloped concrete topping to rework, and even increasing slope to drain on the plaza, provided the best drainage outcome for the plaza (*Figure 9*). Designing the interior pipe layout was challenging and required further field verification, but it was ultimately successful, and modifications could be hidden within an existing dropped ceiling.

At the stairs, we studied numerous options to limit the amount of water draining from the plaza down the stairs, but were not successful in re-sloping this area of the plaza without also negatively impacting the perimeter conditions. This area and concern for future staining became a tipping point in the granite paver setting decision to choose either mortar-set pavers on drainage mat (similar to the existing construction), or pavers with open joints

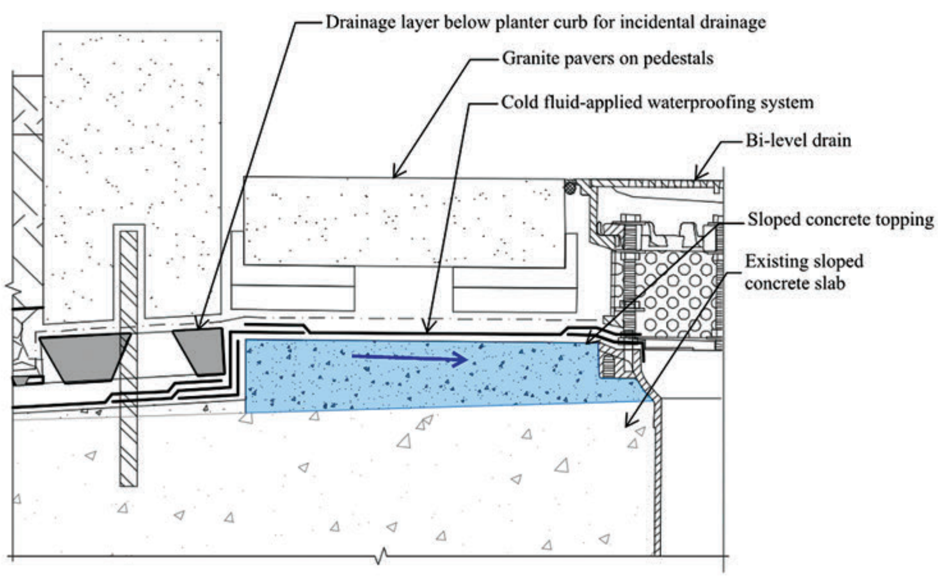



***Figure 9 – Plaza drain detail.***

set on pedestals with the addition of internal drains at stair landings. The client ultimately opted for the pavers set on pedestals throughout the plaza to limit future staining, with the added benefit of allowing for easier maintenance since pavers could more easily be removed and reinstalled to address problem areas. This paver setting selection informed the stair drainage, since water bypassing the paver joints drains on the waterproofing membrane surface, down the stairs under the treads, where it is collected by new internal drains at the stair landings.

## CONCLUSIONS

Plaza waterproofing replacement projects are dictated by a wide array of variables, including durability, construction, and cost implications. Design considerations such as drainage, overburden selection and setting, and building code requirements impact the waterproofing material selection and overall replacement system to work within the existing conditions.

Designers need to be flexible when developing plaza waterproofing replacement options, since each plaza is unique and will require a unique solution. Completing a thorough investigation provides invaluable information to help define critical design parameters. Identifying and understanding clients' priorities and goals helps narrow repair or replacement options. Realize that priorities can change during the design process, and that designers have a responsibility to react to these changes, educate clients on risks/rewards of the design options, and develop budget-conscious, yet reliable solutions.