

BUILDING ENVELOPE TECHNOLOGY SYMPOSIUM

EXTERIOR-STAIR WATERPROOFING: ASSEMBLING THE PUZZLE

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ABSTRACT

Proper design and construction of exterior-stair waterproofing is a challenging task. Structural, waterproofing, and architectural finish components must be integrated by different trades into a single assembly. Improperly detailed exterior-stair waterproofing assemblies often cause water penetration into interior spaces. In addition, nonleakage problems – such as unsightly efflorescence on exposed surfaces, deterioration of mortar-setting beds, and loss of anchorage of stone treads and risers – plague some installations. Due to the complex nature of exterior-stair construction, these problems are not easily or inexpensively remedied after construction is completed. Therefore, proper initial design and detailing of the entire stair assembly is essential to providing a reliable and durable waterproofing and overburden system at elevated stair slabs.

SPEAKER

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INTRODUCTION

The imagery invoked by ascending a stairway to an elevated entrance or plaza leaves little wonder as to why many architects include such features in their designs. Exterior stairways are complicated assemblies and often include complex geometries and ornate detailing that can make them awe-inspiring but also present numerous design and construction challenges. Many entrance stairways also border occupied or otherwise-usable interior space and further expand the number of puzzle pieces that must join together to successfully build this demanding assembly. Some challenges include careful arrangement of the assembly with reliable transitions to manage water (e.g., rising building walls, downturned foundation walls, horizontal plaza decks, etc.), restraint of overburden, and compliance with local building codes that strictly regulate important aspects of stair construction to address critical life-safety concerns.

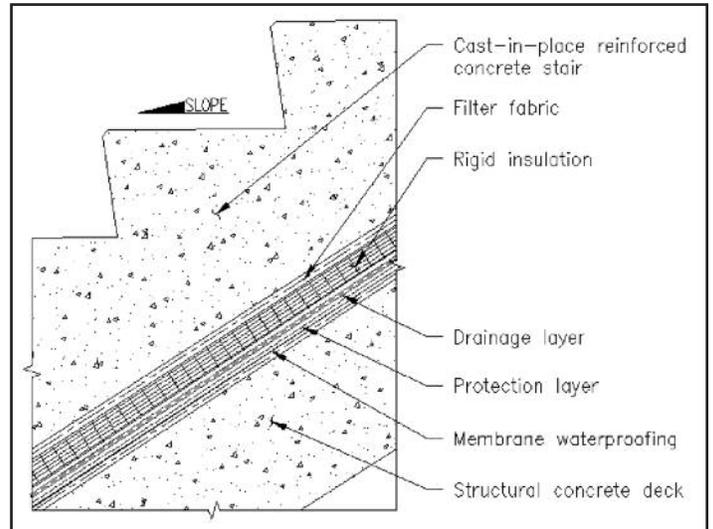
This paper reviews typical stair assembly components, provides insight and advice on design and construction in regard to each of these components, and discusses common deficiencies with stair assemblies. The paper will also briefly address some important code requirements and structural considerations for stair components that require additional forethought and planning

during design and construction.

ASSEMBLING THE PUZZLE

Stair waterproofing is a difficult task for even the most experienced engineer, architect, or contractor. Several different components must be arranged and assembled into a single waterproofing assembly in a confined space with limited tolerances. As with below-grade waterproofing, stair waterproofing assemblies are exposed to constantly wet conditions, heavy overburden, and occupant loads. Because of the below-grade nature of the assembly and the small tolerances for error, this condition is one of the toughest building locations to properly and successfully waterproof.

From start to finish, the pieces of a stair waterproofing puzzle must be assembled with great care. The engineer (or architect) must design the assembly properly, locating the pieces in a configuration to provide a reliable waterproofing membrane. The engineer must work with the contractor to ensure the latter understands the assembly through shop drawing and submittal reviews. Finally, the engineer should visit the site during waterproofing mock-ups and as the work progresses to review the components and verify that the configuration and installation comply with the contract documents. This paper focuses on



stair assemblies that consist of the following components, from interior to exterior (or from bottom to top). See *Detail 1*.

- Structural deck
- Waterproofing membrane with protection layer
- Drainage layer
- Insulation
- Filter fabric
- Overburden

We discuss each of these components herein. With proper design, some assemblies may vary the configuration of the components (e.g., placing insulation below the structural deck) or may even exclude some of these components. Such changes can provide successful stair waterproofing but they require rational analysis and careful consideration for the location of each component.

STRUCTURAL CONCRETE DECK

Elevated concrete stair decks are generally configured with either a uniformly sloped concrete slab (*Photo 1*) or a stepped concrete deck (*Photo 2*). Regardless of the deck configuration, the membrane should be applied to a reasonably smooth, dry, and properly sloped surface.





waterproofing system should include a membrane level slope of one-quarter in per ft to provide reliable membrane-level drainage (Photo 3). Slopes lower than one-quarter in per ft provide little margin for error in concrete placement or to accommodate long-term deflection, provide less-reliable drainage, and thereby reduce the durability of the waterproofing assembly. Stepped structural decks should include

slope at each individual stair tread, while sloped decks should slope across the entire length of the deck.

SUBSTRATE REPAIRS

Existing concrete decks often require structural repair and/or a new concrete topping slab to achieve a smooth surface. Repairs to a concrete structural deck must address unsound concrete and cracks that can contribute to failure of the waterproofing membrane and leakage into occupied spaces below. Typical crack repairs include routing and filling cracks with sealant and various injections (e.g., epoxy) to seal cracks. Placement of a concrete topping requires a clean but roughened substrate to achieve proper bond. Excessively smooth existing concrete or residue from prior membranes adhered to the deck will interfere with the bond of a concrete topping slab. Removal of membrane remnants may require sandblasting, shotblasting, scarification, or pressure washing (at significant risk of leakage to the interior) to clean the deck and can be tedious and difficult when done working in small areas such as stepped concrete decks. Some small well-bonded membrane remnants may not require removal, depending on the selected membrane type.

SLOPED SUBSTRATE

Regardless of the substrate configuration, the substrate must slope to direct water off of the membrane and out of the assembly. A durable low-slope

DECK PREPARATION

Regardless of the membrane selected, the concrete surface should be structurally sound and free of voids, spalled areas, loose aggregate, dirt, and sharp protrusions. The substrate should also be free of contaminants such as grease, wax, and oil that will inhibit the bond of adhered membranes and may cause deterioration of some membrane types. Each membrane also has specific deck preparation needs that are defined by the membrane manufacturer, that are critical to membrane performance, and that must be followed. Improper or poor preparation can

set a system up for premature failure. We provide some considerations specific to adhered membranes to illustrate our point below.

Adhered membranes rely on bond to the substrate to remain in place and prevent passage of water at conditions such as membrane seams. Surface water and excessive moisture within the concrete can inhibit bond between the substrate and the membrane. Membrane manufacturers typically offer guidance for the drying of concrete substrates such as a minimum 14-day cure prior to membrane installation. However, the drying of concrete substrates is highly dependent on environmental conditions during curing.

We recommend that the project team define an appropriately dry substrate with the aid of the membrane manufacturer and test for the presence of moisture at a minimum rate of one test per 500 sq ft of concrete or concrete repairs prior to membrane installation. Common test methods include ASTM D4263, Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method after a minimum 14-day cure; and ASTM F2170, Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using *in Situ* Probes. ASTM D4263 is a qualitative mea-



sure of concrete moisture that looks for condensation on the deck or a plastic sheet sealed to the deck (*Photo 4*), while ASTM F2170 is a quantitative measurement of the moisture within a concrete deck. The former is a rather unsophisticated measurement that is easy to perform in the field but may provide misleading results, while the latter is a more scientific test, but it requires specialized equipment to conduct.

COMMON PROBLEMS

We frequently encounter several challenges and problems with substrate repair and preparation. These challenges are not necessarily specific to stair assemblies, but instead apply to most waterproofing repairs and concrete substrate preparation below a variety of membranes.

Existing Membrane Removal. Before any repair or preparation is started, the removal of the existing membrane, such as coal-tar pitch, self-adhering rubberized-asphalt membranes, or existing hot-applied asphalt membrane can be difficult. Although workers will attempt many creative removal strategies, we have noted that the greatest success in removing these membranes is with heavy scraping bars, chisels, and physical effort.

Green Concrete/Moisture on Deck. Many membranes cannot be installed over wet surfaces or green concrete because the moisture will inhibit bond between the membrane and the structural deck and can ultimately cause failure of the membrane. Some membrane manufacturers, such as those of self-adhered rubberized-asphaltic membranes, allow installation of the membrane on green concrete if a specific primer is utilized. Given the short track record of these primers, we require a mock-up on site with the manufacturer's technical representative to review installation procedures and to test the bond between the new membrane and the substrate after installation.

After removal of any existing waterproofing membrane, after the repair of a structural concrete deck, and before the installation of a new waterproofing membrane, the waterproofing membrane manufacturer's representative should visit the site to provide additional guidance regarding the new membrane installation on the structural deck.

WATERPROOFING MEMBRANE

Waterproofing membranes perform the critical function of keeping water out of interior spaces and away from moisture-

sensitive building components. Successfully fulfilling this well-defined role for waterproofing requires careful membrane selection, a developed design, and meticulous construction practices. Several different membrane types can provide successful stair waterproofing, and a full discussion of membrane types and their differences is beyond the scope of this paper. However, all membranes for elevated stair assemblies above usable space share some common considerations. As such, in the sections below, we present general guidance for membrane selection and configuration with adjacent building components.

MEMBRANE OPTIONS

This paper addresses stair assemblies with the waterproofing membrane placed at the deck level and concealed by overburden. This configuration is analogous to a plaza deck assembly, and most membranes appropriate for plaza-deck waterproofing are appropriate for stair waterproofing. Common examples of appropriate stair waterproofing membranes include hot-applied rubberized asphalt, multiple plies of self-adhered waterproofing membrane, and some single-ply membranes (e.g., PVC or TPO). No one membrane is ideal for all conditions, and each of these materials has unique advantages and disadvantages that the project team must address throughout the design and construction processes. Several driving factors for membrane selection include the following:

Durability. Membranes installed on the structural deck below an overburden such as stone, concrete, or pavers experience large amounts of water, undergo frequent traffic, and require significant removal effort to access the membrane for maintenance or repairs. The selected membrane must be durable enough to resist damage during construction and provide a service life consistent with the owner's maintenance and service life expectations. Designers and installers should select products with a verified track record of performance in applications similar to the intended configuration.

Compatibility with Existing Construction. Restoration projects may have constraints associated with existing construction and wall configurations adjacent to the stairs. Examples include membrane tie-ins with existing below-grade, wall, and terrace-waterproofing membranes that are to remain; historic construction that must be reinstalled in its existing configuration;

and clearance limitations that will only allow a known maximum membrane thickness. In the end, the existing construction of a stair assembly may limit the choice in membranes from which the designer can choose.

Accessibility. Accessibility constraints may dictate appropriate membrane selection. Some elevated stair locations are easily accessible and may be conducive to an installation that requires space to accommodate support functions (e.g., a kettle for application of a hot, fluid-applied, rubberized-asphalt membrane), while other locations may be better suited to sheet membranes that can be carried through narrow passages to access the work area.

Local Availability. Commonly installed materials for a given geographic region tend to increase the applicator pool in terms of experience, ability, and availability. Conversely, selecting a material that is seldom installed in the project locale can reduce the size of the applicator pool, increase the time to procure an appropriate installer, and drive up the cost.

Cost. The bottom line is always on the owner's mind and must be a consideration in design and construction of a stair waterproofing system. In the end, the membrane will be buried under overburden and continuous waterproofing components that will be costly and difficult to remove, so only reliable membranes will be successful. We consider hot-applied, rubberized-asphalt, and heat-welded PVC membranes the most reliable for this type of application. While the above list is not a comprehensive list of factors that will drive membrane selection, an engineer or architect must at least weigh the above factors with the owner's project expectations to reach a consensus among the members of the project team regarding membrane selection.

MEMBRANE INSTALLATION AT DECK AND TRANSITIONS

The selected membrane must provide continuous waterproofing coverage that includes durable and correctly installed details to provide a successful stair waterproofing assembly. Stairs typically include numerous transitions and level changes that require a high degree of detailed construction. Generally, details are membrane-specific, and most manufacturers can provide a good starting point for many common stair details. Some manufacturers even provide preformed accessories that can help to simplify complex stair details. However,



a minimum of 8 in above the walking surface of the stairs to raise the transition out of the “wet zone” (*Photo 6*). Lower transitions can be damaged in service and may allow water to overtop and bypass the transition details. The installation of these transitions well above the “wet zone” of the stair assembly is critical to successful performance of the stair waterproofing. Stair membranes typically should terminate with a mechanical attachment to the rising wall to prevent detachment and require metal through-wall flashing integrated with the wall waterproofing to counterflash the top edge of the membrane and direct water onto the stair surface away from the membrane termination. Wall-to-stair transition details should also include provisions such as a removable metal skirt and protection plates to facilitate future membrane removal and replacement without requiring extensive removals or damage to the rising building walls.

stair conditions also frequently require many details to integrate at complex intersections that require development beyond most manufacturers’ details. Even with the membrane-specific differences, some stair details share common considerations. We offer suggestions applicable to numerous membrane types for common stair details below.

Internal Drains. Waterproofing membranes must be carefully detailed around internal drains so that water flows freely and efficiently into the drain bowls. We recommend bilevel drains that provide drain inlets at the membrane level for water flowing through the stair system, and at the surface level to collect water flowing on top of the stairs. To reduce the chances of stagnant water, the contractor should avoid building up the membrane around the drain.

Penetrations (i.e., Dowels, Handrails). Waterproofing membranes must be continuous to provide reliable performance. Stair assemblies frequently include numerous membrane penetrations, such as doweled anchors or handrails that anchor into the structural deck and challenge the continuity of the membrane (*Photo 5*). Each membrane penetration must be carefully detailed to provide membrane continuity and may include items such as stainless steel hose clamps installed to secure the top edge of the membrane against round penetrations.

Rising Walls and Curbs. Transitions between stair waterproofing and rising building walls or curbs are critical to provide a continuous and watertight building envelope. Reliable transitions should extend

attachment to the rising wall to prevent detachment and require metal through-wall flashing integrated with the wall waterproofing to counterflash the top edge of the membrane and direct water onto the stair surface away from the membrane termination. Wall-to-stair transition details should also include provisions such as a removable metal skirt and protection plates to facilitate future membrane removal and replacement without requiring extensive removals or damage to the rising building walls.

Below-Grade Transitions. Concealed stair membranes will allow water to flow to the base of the stairs and must integrate with below-grade or perimeter drainage provisions to maintain waterproofing continuity. Existing stairs may have the added challenge of integrating with a failed or debonded below-grade waterproofing membrane that requires repairs. Failed or debonded membrane should be removed until sound membrane is located to allow for a watertight transition detail. Membrane transitions should be secured with a termination bar and the fasteners, termination bar, and membrane laps set in the manufacturer’s recommended sealant.

A concealed membrane should always include a protection layer over the membrane to improve the

durability of the assembly. We often see failures due to membrane punctures unknowingly created during construction from dirt or debris in assemblies that omit a protection layer. Many manufacturers recognize the importance of a protection layer and require one for assemblies that place overburden on top of the membrane.

COMMON PROBLEMS

In addition to the items discussed above, we encounter many different issues during our investigations of existing stair assemblies. We discuss some of the most common problems we see below.

Surface-Applied Coatings. In an effort to avoid an intensive and expensive restoration project, owners often ask about the viability of a surface-applied coating to limit water penetration at existing stairs. We recommend against surface-applied coatings as remedial waterproofing for several reasons. Most coatings are designed to resist water penetration but will also prevent the substrate from drying out. This traps moisture between the existing waterproofing membrane and the remedial coating, a situation that can accelerate deterioration of the stair assembly. Surface-applied coatings in high-traffic areas are subject to rapid wear and require frequent maintenance and reinstallation to remain even partially effective. Finally, surface coatings fade, darken, or pick up dirt; become aesthetically unappealing; and lead to additional maintenance requirements.

Water Testing. Stair membranes are difficult to construct and can easily suffer damage during construction. The project team should always perform water testing





prior to installing drainage layer, insulation, filter fabric, and overburden components to locate and address any leaks. Leaks are much easier to address before the membrane is covered with overburden, which requires significant effort to remove in order to access and repair the membrane. Common water-testing strategies include standing-water and spray-rack tests.

Protection Layer. Stepped concrete substrates can create problems with the installation of protection layers and drainage board. The protection layer must be installed so that it does not deduct from the slope of the stairs and does not allow standing water at overlap sections (*Photo 7*).

DRAINAGE LAYER

Efficient drainage of water through the system is one of the most important characteristics of a well-designed stair waterproofing assembly. Water that has a chance to pond on the membrane can lead to a number of problems that we discuss further below.

Applied against the waterproofing membrane, the drainage layer plays a key role by providing a space to allow water to flow on top of the waterproofing membrane to reach internal drains or to exit the stair system. To be most effective, the drainage layer should be installed continuously and lapped over drainage composite on adjacent vertical below-grade walls. A premanufactured drainage layer (commonly known as drainage composite) is constructed of a rigid, high-density,

available in a variety of thicknesses and widths to meet many restrictions on the overall thickness of the waterproofing assembly.

DRAINAGE COMPOSITE VS. DRAINAGE CHANNELS

The configuration of the stair waterproofing assembly drives the recommended method of drainage. For example, a continuous-sloped structural deck lends itself to installation of a drainage composite, given the ease of installation and similar base-flashing detailing at the perimeter of the stairs. Alternately, installation of continuous-drainage composite on stepped structural decks is difficult and time consuming, since the drainage composite must conform to the configuration of each stair tread. To provide optimal drainage in these assemblies and reduce the risk for efflorescence



dimpled polystyrene core with an adhered polypropylene fabric. Some drainage composites have a polypropylene fabric adhered to both sides of the core to provide better protection for the waterproofing membrane. Some drainage composites are designed to withstand compressive loads of over 20,000 psf, which resist heavy overburden and high occupant loads on the stairs.

Drainage layers are

(see below), the mortar beds below the overburden should be spaced at approximately 12 in o.c. to provide a path for water to exit (*Photo 8*). Channels should run continuously on both the vertical and the horizontal surfaces of the concrete substrate. Where possible, we recommend the installation of a drainage layer in combination with drainage channels to provide optimal drainage and reduce the risk of efflorescence staining (see below).

INSULATION AND FILTER FABRIC

In order to improve occupant comfort, insulation is typically required in most stair assemblies that are in contact with building walls adjacent to occupied building space. The most common type of insulation, high-density extruded polystyrene (XPS), can withstand the continuously wet conditions in the assembly as well as the compressive loads of the overburden and high occupant load of a stairway. The International Energy Conservation Code (IECC) governs the required R-value for the stair assembly in most states. To provide optimal energy performance, insulation should be installed continuously against all surfaces adjacent to or over occupied space. The installation of a continuous thermal barrier reduces the risk for thermal bridges that can provide cold spots, discomfort to building occupants, and greater energy consumption.

Filter fabric installed between the insulation and overburden prevents the intrusion of soil, dirt, and debris into the waterproofing assembly. Soil, dirt, and debris can easily clog the joints between the insulation boards, block water drainage through the system to the drainage composite, or damage the waterproofing membrane. While this filter fabric is redundant with a proper drainage composite, we consider it good practice to provide this extra layer of defense to maintain a free-flowing and efficiently draining system. Filter fabric is made of a nonwoven mat of polypropylene fibers that is chemically inert and non-biodegradable. Filter fabrics should be lapped at all seams and installed continuously over the insulation in the stair assembly.

COMMON PROBLEMS

We have seen many problems associated with the installation of the drainage layer, insulation,



and filter fabric in stair assemblies we have investigated. We discuss a few in more detail below.

Staining and Efflorescence. On some recent field investigations, we noted significant efflorescence and staining on both the vertical and horizontal faces of the treads (*Photo 9*). Water travels through the mortar beds, dissolves soluble constituents, and deposits them on the exterior faces of the stairs as efflorescence. Drainage channels in the mortar-setting beds and drainage layers can provide a pathway for water flow and help prevent efflorescence or washout of the setting beds.

Freeze-Thaw Damage. Freeze-thaw damage from expansion of trapped water frequently plagues stone overburden assemblies with poor drainage. Water trapped within the assembly freezes and thaws with temperature cycles. This often leads to accelerated deterioration of the mortar bed.

Loss of Attachment of Treads and Risers. Lack of or loss of tread and riser attachment can create an unstable surface. Washout, deterioration, and freeze-thaw damage (described above) of the mortar bed are common causes of loose treads and pavers (*Photo 10*). The designer should provide mechanical anchors or dowels to attach the pavers to the structural deck to prevent this phenomenon.

Overtopping Waterproofing Transitions. Water penetration through improper



transition detailing is frequently a major cause of leakage in systems we have investigated. Bulk water that enters the system will generally follow the path of least resistance. If there is no dedicated drainage layer or channel, the water will tend to back up within the system, fill voids and gaps between components, and perhaps overtop improperly designed waterproofing transitions. Water in the system can lead to additional problems, including “floating pavers” and accelerated degradation of assembly components.

OVERBURDEN

Similar to a terrace paver system, the overburden in a stair assembly is composed of the walking surface

(treads and risers) along with their means of mechanical attachment. We have noted a variety of attachment configurations for various types of overburden. We describe the construction of the two most common overburden assemblies below.

Contractors frequently form and pour concrete stairs directly against the waterproofing assembly (*Photo 11*). The construction of concrete stairs is composed of one monolithic pour or several pours with limited cold joints. Limiting cold joints helps to limit opportunities for water to penetrate the wearing surface. The exposed face of the cast-in-place stairs becomes the walking surface. Concrete is available in a variety of colors and finishes. However, the aesthetic appearance of cast-in-place concrete tends to be less desirable for certain applications (i.e., stairs on a monumental structure). Concrete stairs must be designed by a structural engineer to resist anticipated loads, account for thermal and differential movement, and address other environmental factors and are often continuously reinforced.

Even though concrete is typically heavy enough to be held in place by gravity, concrete stairs need to be doweled into the underlying substrate or foundation walls. Dowel penetrations require careful detailing to provide waterproofing continuity.

Cracking and crack locations are another concern with concrete stairs. Concrete stairs require control joints where they turn a corner or change direction. Nosing reinforcing bars and stainless steel nosings are also prudent preventive measures to control cracking and spalling at the nose of the stair treads. Stairs in climates that may experience liberal use of deicing salts must consider this in the concrete mix design.





One major drawback to concrete stairs is if the system requires repair, the removal of concrete is time consuming and expensive.

The assembly for a stone or precast pavers system includes a preformed concrete step placed on top of the waterproofing assembly. Some stone pavers may provide a more appealing aesthetic than cast-in-place concrete. Paver designs must use a durable stone or well-manufactured precast paver with a track record of use in applications and climates similar to the project. Pavers are installed in smaller sections compared to concrete stairs and can be more easily removed for system maintenance or replacement. Pavers must be anchored to the existing substrate with dowels (*Photo 12*). Pavers are also frequently placed in a mortar-setting bed (*Photo 12*), although some large heavy pavers can be placed on shims without a mortar-setting bed to reduce the efflorescence potential. Joints between pavers should be filled with mortar to reduce bulk water intrusion. Designers sometimes specify backer rod and sealant to fill joints between pavers. Sealant requires regular maintenance to remain effective and prevent water infiltration. Sealant can also stain some paver materials.

Each of these overburden options, if well detailed and constructed, is a reasonable option to provide a durable stair walkway.

CODE REQUIREMENTS

Building codes often control stair dimensions and tolerances tightly, since most exterior stairways are often part of the building's emergency egress system.

used as egress pathways from a building have required widths that are governed by the code. The number of building occupants and use of the building must be considered when designing an exterior stair.

Stair Tread and Riser Dimensions.

Codes typically specify the minimum and maximum riser heights, minimum tread dimensions, and dimensional uniformity between stairs. Stair components (specifically, the stair overburden) must be designed with these requirements in mind.

Rise and Landing Dimensions. Building codes specify the maximum rise of a single flight of stairs between landings or terminations and the minimum dimensions of landings.

Handrails and Railings. Codes stipulate several handrail requirements. Handrails must be a specific height with a specific top-rail geometry. If a handrail is located along a parapet or vertical building wall, it may be classified as a railing with additional requirements related to the geometry of rail openings and structural demands. Handrail and railing placement must also consider stair widths to ensure proper egress pathways.

Additional stair requirements stipulated by building codes include minimum headroom, maximum slope, stair levelness, ponding

Therefore, stair assembly configurations require special considerations during the design phase. The majority of these considerations will ultimately affect the type, configuration, and dimensions of overburden used to create the stair-walking surface. An in-depth code review is beyond the scope of this paper; however, the following items must be considered:

on stair surfaces, stair texture, and stairway-material construction.

Existing buildings offer additional challenges related to stair renovations. Many existing stairs – and especially historic stairs – do not meet contemporary code requirements and may require modifications to meet code or variances. Restoration of an existing stair may also require construction of temporary stairs to address inaccessible stairs and maintain emergency egress during construction. As always, the designer must consult and follow the applicable building code during design and construction.

COMMON PROBLEMS WITH OVERBURDEN

Many problems with overburden in stair assemblies result from lack of forethought during the design phase and limited supervision by the contractor during the construction phase. We describe several overburden problems related to design and construction at one project below.

The project called for concrete stairs with an exposed aggregate finish. The contractor placed the stairs on a hot day during the summer. The concrete began to set rapidly while the contractor screeded and troweled the surface of the stairs. The contractor applied a retarder to the surface of the forms and the stair treads and returned to the site the following day to strip the forms and remove concrete paste to expose the aggregate. Due to the rapid set at the placement temperature, the paste was difficult to remove with a wire brush and low-pressure water as specified in the contract documents. The contractor decided to



remove the paste with a high-pressure power washer with the following results (see *Photo 13*):

- Washout of paste and aggregate from several stair nosings
- Washout of paste and aggregate from the face of several risers
- Washout of paste and aggregate from the face of several treads

The rapid set and finishing method utilized resulted in stair riser height variations that did not meet code requirements. The contractor removed and replaced the concrete stair overburden to meet code requirements and provide the specified finish. The time and expense of this overburden replacement could have been avoided with careful planning to place the concrete during conditions that would allow proper finishing.

OTHER THOUGHTS AND LESSONS LEARNED

A properly detailed and constructed stair assembly should include the following components throughout design and construction to provide:

- Review of existing documents (if repairing an existing structure)
- Field investigation (if repairing an existing structure) to understand the configuration and condition of existing components and the structural substrate
- Understanding of the intended use for any space below the stairs
- Understanding of the owner's expectations/risk for leakage
- Review of relative merits of waterproofing membrane options
- Meetings between the design team to coordinate details during the design phase
- Communication between the con-

tractor and designer during construction to resolve detailing at concealed conditions exposed by the construction

Considering the complexity of most stair waterproofing projects, the success of the project is highly dependent on a thorough and well-coordinated design, the experience and quality of the contractor performing the work, and the working relationship among the project team. We provide some ways to improve the design and construction phases below.

REPAIR VS. NEW DESIGN

The design for a typical stair-waterproofing assembly is similar for both new and existing stair assemblies. However, unlike new design, the repair of an existing stair assembly is dependent on the configuration and condition of the existing substrate. In addition to the components discussed above, existing stairs often require repairs to the existing structural deck, reuse of existing stone pavers, and restraints on overall height of the assembly. Review of existing design documents and a field investigation to verify the as-built conditions are necessary to identify such issues, where possible, prior to construction. Existing stair assemblies often require innovative design solutions to address such issues and should be coordinated with the membrane manufacturer's technical representative to ensure membrane continuity that meets the manufacturer's requirements.

CONSTRUCTION ADMINISTRATION AND GOOD COMMUNICATION

The key to constructing a successful stair assembly is open communication among the project team throughout the construction process. Prior to the start of construction, the design team, owner, and contractor should meet to review the expect-

tations for the project (i.e., submittals, schedules, job-site conditions, etc). The designers must review submittals early in the project schedule to prevent delays in the work. The submittals should include product data, material-safety data sheets, information on the contractor's quality control program, shop drawings, etc. Given the complex geometries of stair assemblies, shop drawings, prepared prior to construction, are important to convey the contractor's intentions and ensure that the contractor understands the construction documents as intended.

During construction, the engineer should visit the site to review mock-ups, observe the construction progress, and resolve detailing at hidden conditions. The designer should document these site visits and provide feedback to the owner/client through field reports and sketches that describe the construction progress, discussions in the field, and changes to the design for the project record.

SUMMARY

The proper design and construction of stair waterproofing, whether in new construction or as part of a repair program, make for a challenging puzzle. The project team faces a complex task when assembling the waterproofing and overburden, including drainage, structural load requirements, owner expectations, and building code requirements. Consequently, the careful arrangement of the components of a stair assembly requires intensive forethought by the designer, the knowledgeable hand of an experienced contractor during installation, and careful coordination between the designer and contractor throughout the construction process to provide a reliable and durable waterproofing and overburden system at elevated stair assemblies. 