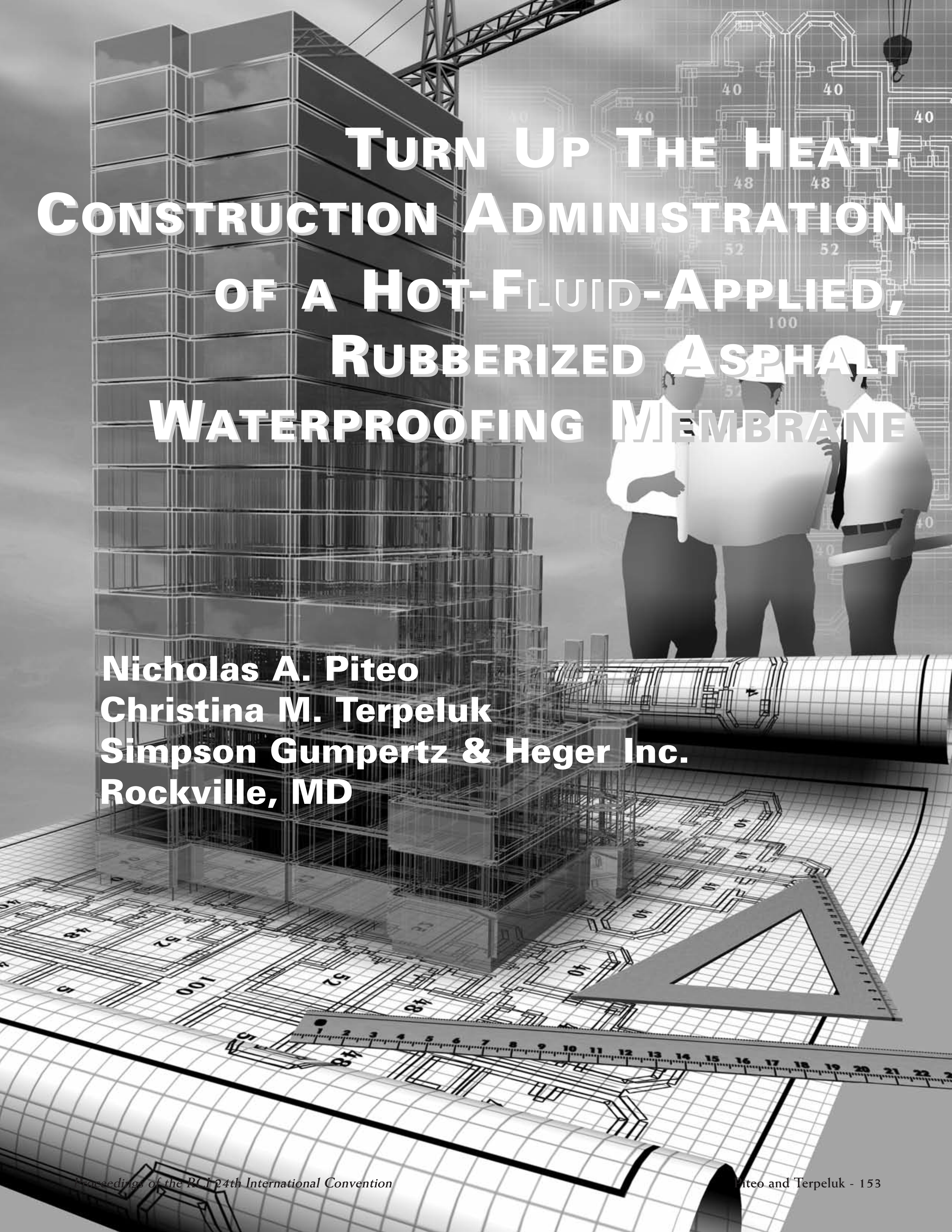

Turn Up The Heat! Construction Administration of a Hot-Fluid-Applied, Rubberized Asphalt Waterproofing Membrane

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ABSTRACT

Fluid-applied, rubberized asphalt membranes have a long track record of performance in many roofing and waterproofing systems. These membranes can provide reliable waterproofing protection for several decades, but poorly detailed or defectively constructed assemblies can be quickly destroyed in service and often require costly rehabilitation.

Achieving long-term performance requires diligent detailing, careful installation, and continued review to ensure that the designers' intents are constructible and accurately implemented in the field. This paper will present practical advice to assist in design and construction of fluid-applied, rubberized asphalt membrane systems, with case studies applicable to a variety of projects to illustrate successful details.

SPEAKER

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INTRODUCTION

Hot-fluid-applied rubberized asphalt waterproofing membranes have a long track record of performance in at-grade plaza waterproofing applications and are gaining popularity on roofs as designers increasingly strive to provide occupant-accessible rooftop plazas with green spaces. These membranes are durable and can provide reliable waterproofing protection for several decades. Achieving such durability, however, requires the appropriate system, diligent detailing, a quality-oriented waterproofing contractor, careful installation with a high level of quality control, and timely communication among the designer, manufacturer, and contractor to provide a reliable and durable waterproofing system.

Through our experience, we have found that active construction administration with frequent or even full-time field observation is critical to the success of hot-fluid-applied rubberized asphalt waterproofing membranes. This paper is intended as a primer to supplement the knowledge of designers, applicators, and quality assurance personnel for hot-fluid-applied, rubberized asphalt waterproofing systems and focuses on the authors' experiences during a recent project to illustrate challenges, successful construction phase detailing, and lessons learned.

THE PROJECT

The building, constructed in the 1920s, is a brick masonry structure. A large classical portico extends over the main entrance to the building. The portico is surrounded by eight freestanding masonry columns and two pilasters. The portico terrace is covered with limestone pavers and leads to a grand stair descending to a plaza courtyard. The stairs consist of limestone treads and are bound on either side by a brick masonry parapet wall. A plaza at the base of the portico is covered with flagstone pavers. The project included the replacement of the waterproofing system below the portico terrace and stairs. The existing portico terrace construction consisted of the following elements, from interior to exterior:

- Structural concrete deck
- Bituminous membrane
- Concrete topping slab; approximately ½- to 1-in thick
- Mortar setting bed; approximately 1- to 1½-in thick
- Limestone pavers; typically 2½-in thick with 5-in-thick pavers between portico columns

The existing stair construction consisted of the following elements, from interior to exterior:

- Stepped structural concrete deck
- Bituminous membrane
- Brick masonry; approximately two to three wythes thick
- Mortar setting bed; approximately 1- to 1½-in thick
- Limestone treads; typically 5-in thick

The owners reported that water leaked to the interior space below the portico terrace and stairs for many years. As a part of a comprehensive building renovation, the owner retained our firm to design the replacement of the portico terrace and stair waterproofing system.

During the design phase, we recognized that providing continuous waterproofing around the base of the large marble columns would be a challenge. The base of each column includes a continuous marble pedestal wrapped around a steel column concealed within the cement plaster columns. Each pedestal is supported by 5-in-thick limestone pavers. One design option proposed elevating the marble pedestals in place; another proposed cutting them and removing them in sections to turn base flashing up the steel columns.

We reviewed waterproofing options and limitations with the owner for each option. Considering the architectural significance of the building, portico, and columns, the owners decided that any efforts to move the fragile continuous marble pedestals could result in an unacceptable appearance change or irreversible damage; they selected the option

Photo 1 – Removal of concrete topping over concrete substrate. Note the existing roofing system consisted of (from interior to exterior): concrete deck, existing waterproofing membrane, concrete topping slab, mortar setting bed, and overburden (not shown).

to leave the pedestals in place during the waterproofing work.

Considering the existing portico terrace and stair configuration and column limitations, we recommended a hot-fluid-applied, rubberized asphalt membrane system to replace the existing portico terrace and stair waterproofing system. Although we based our waterproofing design on conditions exposed by our field investigation, we were not surprised that unanticipated existing conditions and unique details required some adjustments during construction to provide a reliable waterproofing system. Some of the challenges faced during the construction of the waterproofing system are described below.

SURFACE PREPARATION

Hot-fluid-applied, rubberized asphalt is commonly installed on both existing cast-in-place and post tensioned concrete, and less commonly, on precast concrete. Some hot-fluid-applied, rubberized asphalt membrane manufacturers also allow membrane installation over panelized substrates, such as plywood decks or metal decks covered with gypsum sheathing. The challenges of installation on panelized substrates are beyond the scope of this paper.

Surface preparation of the substrate is critical to the success of the waterproofing system. A poorly prepared surface can destroy the membrane bond, and ultimately, the membrane. This project included a previously covered cast-in-place concrete deck, which requires some additional time-consuming and costly surface preparation compared with a new concrete deck. Some of the key surface preparation steps for our existing plaza are described below.

Overburden Removal

Before installing a new waterproofing membrane, workers must first remove the existing overburden and waterproofing membrane to allow evaluation and repair of the underlying substrate (*Photo 1*). Removal of some existing membranes, such as coal-tar-pitch, self-adhering rubberized asphalt membranes, or

Photo 2 – Removal of existing waterproofing membrane on stairs using handheld-scrapers.

existing hot-applied asphalt, can be difficult. Workers often try creative solutions to remove hot-applied asphalt, but we have seen the greatest success with heavy scraping bars, shovels, chisels, and physical effort (P*hoto 2*). Designs should not require the installation of a new membrane over existing membrane because the existing substrate remains concealed, and recovering an existing leaky membrane is likely to trap moisture, which reduces the durability of the waterproofing system.

Provide a Smooth Surface to Receive the Membrane

Hot-fluid-applied, rubberized asphalt membranes should be applied to a reasonably smooth surface. Manufacturers generally recommend a wood float finish in accordance with ACI 301; a steel float or trowel finish is too smooth and compromises the bond of the membrane to the substrate. Both new and existing substrates often require grinding ridges smooth to avoid stress concentrations that damage the membrane; or filling depressions and bug holes, which can cause blistering, to provide an appropriate surface.

Existing or particularly rough substrates may require a concrete topping slab to provide an appropriate substrate. Proprietary concrete repair mortars that can be used to fill in voids or provide a concrete topping slab are available from several manufacturers. Concrete toppings require a clean but roughened substrate to achieve proper bond. Excessively smooth existing concrete decks or residue from prior membranes adhered to the deck will interfere with the bond of a concrete overlay and may require sandblasting, shotblasting, scarification, or pressure washing (at significant risk of leakage) to provide an appropriate substrate.

Consult with the concrete topping manufacturer to determine appropriate surface preparation requirements. We covered the existing deck at our project with a concrete topping to provide a smooth substrate for the new waterproofing membrane after expending considerable effort to scrape off residue from the previous waterproofing membrane.

Slope the Substrate

Waterproofing membranes should slope to direct water off of the membrane or to drains (*Photo 3*). Our project did not include drains, but existing drains (and overflow drains) should be reviewed for capacity based on rainfall data contained in the International Building Code or other locally applicable codes. Hot-fluid-applied, rubberized asphalt membranes bond directly to the substrate (i.e., tapered insulation is not appropriate), and therefore, the substrate must provide the membrane with slope. A durable, low-slope waterproofing system requires a slope of ¼ in/ft to provide reliable membrane level drainage. Slopes lower than ¼ in/ft provide little margin for error in concrete placement or long-term deflection, provide less reliable drainage, and thereby reduce the durability of the waterproofing assembly. Waterproofing slope can be provided by sloped structural framing with uniformly thick concrete, or with level formwork

Photo 3 – Level showing sloped surface at a stair tread. We added slope with a concrete topping at the stair treads to promote drainage.

and variable concrete thickness (adding significant weight). Waterproofing slopes in excess of approximately 2 in/ft require special considerations for overburden and membrane restraint because these slopes can create shear force on the membrane. Vertical surfaces that receive membrane are typically insulated from overburden shear forces by protection/drainage layers and frequently do not require special considerations for restraint.

The existing concrete substrate below the portico terrace for our project included slope towards the plaza stairs. We placed a uniform layer of concrete fill on top of the portico plaza and maintained the slope. The existing concrete substrate below the stairs did not include slope and we added slope towards the flagstone terrace, and a foundation drain at the bottom of the stairs, with concrete fill.

Cure and Dry the Concrete Substrate

Water on the surface and excessive moisture in the concrete results in poor bond and pinholes through the membrane as the vapor passes through the membrane. Foaming of the membrane during installation indicates a wet substrate. Manufacturers offer guidance for drying concrete substrates, including a minimum 14-day cure and a recommended minimum 28-day cure. The drying of concrete substrates is highly dependent on environmental conditions and we recommend testing the concrete deck and repairs for the presence of moisture.

ASTM D 4263 – Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method after a minimum 14-day cure provides one method to test the moisture levels in concrete. This test consists of sealing a piece of plastic sheeting (approximately 18 in. by 18 in.) to the concrete surface (*Photo 4*). After approximately 16 hours, the sheet is removed and both the sheet and concrete surface inspected. Moisture on either the plastic or concrete surface indicates wet concrete, which requires additional drying time prior to installation of a hot-fluid-applied, rubberized asphalt membrane.

Photo 4 – Moisture test according to ASTM D 4263 – Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method.

Photo 5 – Removal of dirt and debris from concrete surface using a hand-held blower.

Alternative test methods may also be selected to quantify the moisture levels of the concrete surfaces prior to membrane installation. Concrete surfaces should include at least one moisture test per 500 sq ft of concrete or concrete repairs. At our project, workers installed the concrete topping slab and covered it with a layer of wet burlap and tarps to cure the concrete. We performed moisture testing at several locations as outlined above until we determined that the concrete was sufficiently dry after 14 days.

Clean the Surface of the Substrate

During the construction process, debris and dirt will settle on the concrete substrate and interfere with the membrane bond. Debris and dirt must be removed from the substrate prior to the application of the membrane by sweeping and blowing the substrate clean with compressed air to (*Photo 5*).

PRIMER

Photo 6 – Primer application with a brush.

Photo 7 – Primer applied in field of the plaza. Note that the lighter-colored primer at the plaza perimeter is a water-based primer for locations that will receive self-adhered waterproofing membrane.

Manufacturers have long used an asphalt-based primer to bind dust and enhance the bond between the concrete surface and the waterproofing membrane. These primers must conform to ASTM D 41-85 – Standard Specification for Asphalt Primer Used in Roofing, Dampproofing, and Waterproofing. The primer is installed thinly over the concrete substrate (between 100 and 600 sq ft/gal depending on porosity and surface texture of the substrate and the selected primer) using a brush, roller, or spray equipment (*Photos 6* and *7*). Properly applied primers frequently dry within three hours. However, weather conditions, such as temperatures below 68°F and relative humidity higher than 50%, can increase the drying time.

On our project, the primer was not dry approximately 12 hours after application, due to the overly thick application and cold temperatures. Workers left the primer to dry overnight, contrary to manufacturer's recommendations. After consulting with the membrane manufacturer, we inspected the dry primer for moisture (dew) and blown dust prior to the application of the waterproofing membrane on the following day. Contaminated areas of primer require additional primer.

Solvent-based primers, such as the asphalt-based primer installed on our project, are highly volatile and emit strong odors. Solvent-based primers must be separated from open flames and other heat sources and occupants should be separated from the primer application to avoid complaints and occupant discomfort. With increasing awareness and regulation of solvents, manufacturers are starting to introduce a variety of alternative primers that are more "green." These alternative primers have a short track record and require careful evaluation, preferably through mock-ups, to evaluate their effectiveness and suitability prior to selection and wholesale installation.

Photo 8 – Placement of fabric reinforcement on top of the first coat of membrane.

MEMBRANE

Hot-fluid-applied, rubberized asphalt membranes are constructed in one or two coats, reinforced and unreinforced. We consider reinforced membranes more durable because the reinforcement increases puncture resistance, decreases cold flow (e.g., under-concentrated load), improves crack bridging (i.e. cracks, construction joints, and changes in planes) and provides a thickness gauge for the second coat. We recommend that reinforcement be spread across the first layer of membrane after initial cooling (*Photo 8*). If the reinforcement is installed too quickly prior to initial cool, the fabric will melt.

Photo 9 – Measurement of membrane thickness with pin tester. Note that the pin (not shown) is inserted into membrane and thickness is read off the top (arrow).

Photo 10 – Fabric embedded in membrane for adhesion test. After the membrane cured, workers pulled the fabric to observe the failure mechanism. The membrane failure occurred within the layers of the membrane.

A typical completed reinforced hot-fluid-applied, rubberized asphalt membrane is an average of 215 mils thick. The installed thickness is important to membrane durability and the construction observer, contractor, or manufacturer's representative should measure the membrane thickness in several locations to verify acceptable thickness prior to installation of the protection sheet. Membrane thickness may be measured with a pin tester or at test cuts in the membrane. Pin testing must be performed in close coordination with the installer so that the test area is immediately recoated to seal the test hole. Consistent with most manufacturers, we recommend one measurement per 100 sq ft (P*hoto 9*).

At our project, the contractor successfully mocked up the membrane within the expected thickness range while we were on site. The mock-up also included an adhesion test that consisted of embedding a piece of fabric with an exposed pull tab within the membrane (*Photo 10*). The fabric is pulled until membrane failure to examine the failure mode. Our mockup pull test failed cohesively within the membrane, which indicates that the adhesive bond to the deck is stronger than the cohesive bond between layers of the membrane, which is the desired result of the pull test. An adhesive failure between the membrane and substrate indicates insufficient bond that requires additional investigation to determine the source of poor adhesion. Different test methods may also be selected to measure numerical adhesion values for comparative purposes.

Following the mock-up, the contractor installed the membrane and a protection layer over the entire deck, but failed to install the membrane within the acceptable thickness range. We discovered the thin membrane by performing several pin tests during our next weekly site visit and provided the contractor with the following options to increase membrane thickness:

- Remove the membrane protection layer, install additional membrane to meet the specified thickness, and install a new protection layer. However, removal of a fully bonded protection layer is difficult under most circumstances and may not be possible in some applications (partial removal is not acceptable).
- Completely remove the existing waterproofing system and install new membrane at the specified thickness. Complete membrane removal can be difficult because the membrane aggressively bonds to the substrate, but may be necessary for applications with minimal clearances at waterproofing details.
- Install new membrane, reinforcement, and protection layer on top of the existing waterproofing assembly without removal. This option may be desirable for applications with sufficient clearance to accommodate the increased thickness of the membrane assembly, as long as the protection layer is otherwise well bonded.

At our project, the protection layer was well adhered to the first membrane application and the contractor installed additional membrane on top of the existing membrane without removal.

Photo 11 – Neoprene flashings installed at the base of a portico column prior to the application of waterproofing membrane.

MEMBRANE ACCESSORIES AND DETAILS

A hot-fluid-applied, waterproofing system requires several accessory materials to complete the assembly. Many difficult waterproofing details occur at transitions between the membrane and accessory materials. We discuss several difficulties we encountered on our project below.

Base flashings turn up and transition between the fluid-applied membrane and rising walls or other surfaces. Base flashings should be installed prior to wholesale deck membrane installation to facilitate seamless integration with the membrane. Base flashings may be installed with a manufacturer's recommended adhesive, may be hot-fluid-applied asphalt, or may be torch-applied. They must be installed without wrinkles or fishmouths. The base flashing should extend a minimum of 8 inches above the top surface of the waterproofing assembly (e.g., pavers, stair treads, etc.) and requires termination bars to secure the top of the base flashing in place. Some climates may require higher base flashing extension above the top surface to better resist drifting snow. Metal skirts, masonry or other protection may be necessary to cover base flashings in locations where exposed flashings are nondurable or undesirable. We specified uncured Neoprene base flashings at our project and the workers first attempted to adhere the base flashing with the membrane manufacturer's recommended Neoprene adhesive. We easily removed the base flashings adhered with Neoprene adhesive by hand. As an alternative, workers set the base flashings in hot-fluid-applied, rubberized asphalt, which resulted in well-adhered base flashings that we could not remove by hand (*Photo 11*). We also secured the top of the Neoprene flashing in place with continuous hook strips that also fastened copper protection plates over the Neoprene flashings.

At our project, the integration of the hot-fluid-applied, rubberized asphalt membrane with the self-adhered membrane applied to the below-grade wall at the bottom of the stairs was a significant challenge. Although the fluid-applied rubberized asphalt membrane and the asphalt in the self-adhered membrane are compatible, we learned on previous projects that the polyethylene facer on the self-adhered membrane inhibits bond between the hot rubber and the self-adhered sheet membrane. We worked with the membrane manufacturer and the contractor to extend the self-adhered membrane on the wall and approximately 6 inches onto the horizontal surface of the bottom stair tread. The contractor removed the polyethylene carrier sheet from the top surface of the self-adhered membrane with a torch and then applied the hot-applied rubberized asphalt over the self-adhered membrane (*Photo 12*). In doing so, we avoided the interference of the polyethylene layer with the bond between the hot-fluid-applied, asphalt and the self-adhered membrane.

Similar to base flashings, membrane penetrations, such as pipes and dowels, should be flashed prior to membrane installation and require carefully constructed details to provide durable waterproofing performance. Dowels are particularly difficult to waterproof, given the small size of the dowel, possible close dowel spacing, and the high temperature of membrane during installation. Although many details attempt to flash dowels by simply coating them with hot rubber, we have found it practical to create a higher flashing height with uncured Neoprene sheet flashing set in hot-fluid-applied, rubberized asphalt. At our project, workers first installed a Neoprene target patch set in hot-applied rubberized asphalt, tightly fixed around the dowel with an "X"-shaped hole (*Photo 13*). Next, the workers wrapped the dowel with a Neoprene sleeve. The workers first attempted to secure the Neoprene sleeve

Photo 12 (above) – Hot-fluid-applied, asphalt waterproofing membrane lapped over self-adhered waterproofing membrane at the vertical foundation wall. Workers removed the polyethylene carrier sheet from the surface of the self-adhered membrane to prevent bond interference between the hot-fluid-applied asphalt and self-adhered membrane.

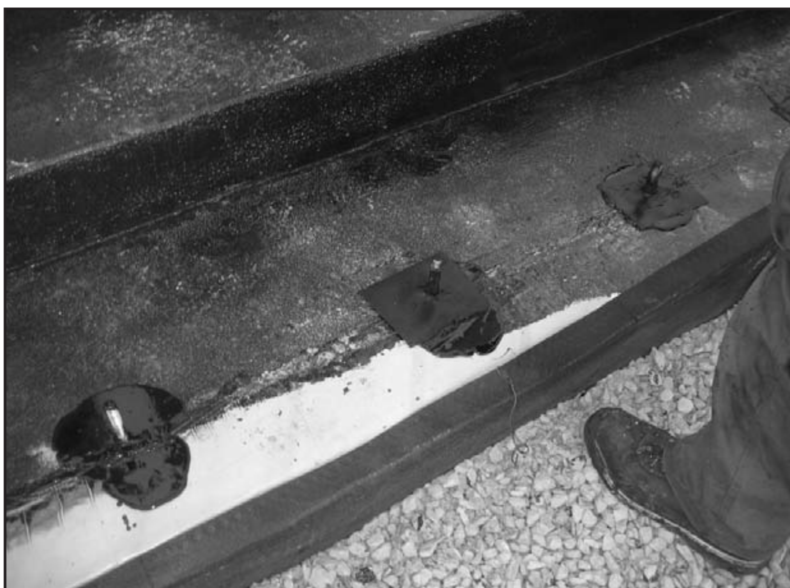

Photo 13 (left) – Neoprene test patch with "X"-shaped cut tightly fit around a dowel and set in hot-fluid-applied, asphalt waterproofing.

Photo 14 (below) – Neoprene sleeve flashing wrapped around dowel and secured with duct tape to prevent the membrane from unwrapping during placement of the hot-fluid-applied, rubberized asphalt.

Photo 15 – Placement of protection board over reinforced hot-fluid-applied, rubberized asphalt membrane.

to the dowel with the manufacturer's recommended adhesive prior to pouring hot-applied asphalt over the dowel, but the adhesive did not hold the sleeve together. We successfully secured the Neoprene wrap with tie wire and duct tape to prevent the membrane from unwrapping while workers installed the hot rubber at the dowels (*Photo 14*).

A protection sheet is required by most manufacturers and is placed over and bonded to the membrane while it is still aggressively tacky to complete the membrane application (*Photo 15*). Seams in the protection layer are lapped to provide continuity. We found that workers had difficulty applying the protection layer at some details, such as stair risers and treads. The ¼-in thick protection sheet is too stiff to bend and conform to the shape of the stairs (*Photo 16*). To solve the problem, the contractor cut the protection sheets into smaller and more manageable strips that covered several inches of the horizontal tread near the nose of the stair, the vertical riser below the tread, and the subsequent tread below the riser (*Photo 17*). We found that these smaller protection sheet strips were less susceptible to bowing at the vertical risers. We also made sure to shingle lap seams in the protection sheets and maintain slope to drain at each stair tread.

Photo 16 – Uncut protection board lapped over entire portion of stairs. Note that the protection board bulges at stair risers and does not conform to the shape of the stairs.

Photo 17 – Protection board cut into smaller and more manageable pieces that lap several inches onto each tread near the nose of the stair, over the vertical riser, and over the majority of the tread below the riser. Note that the protection board conforms to the shape of the stairs.

DRAINAGE LAYER

All membranes should include a membrane level drainage layer to improve system drainage. Drainage layers can range from an open space below a paver system to an engineered drainage

Photo 18 – Continuous layer of drainage board that conforms to the shape of the stairs.

board with integrally bonded geotextile fabric to prevent fine particles from clogging the drainage layer. A drainage layer should always be installed directly on top of the membrane protection layer to promote the flow of water at the membrane level. Although beyond the scope of this paper, some waterproofing systems may require multiple drainage layers for more reliable performance.

As described earlier, the stair treads and risers are a difficult waterproofing detail. The substrate below stair treads must slope to drain water and include a drainage layer to provide space for water to flow below the stairs. The dimpled drainage layer installed at our project was flexible enough to conform to the nose and heel of the stairs and provide a continuous drainage plane (*Photo 18*). However, the drainage layer must also integrate with the waterproofing above and below the stairs to conduct water into the intended drainage plane and resist unsightly stains and efflorescence at poorly integrated or missing drainage layers (*Photo 19*). In addition to the stair drainage layer, we installed the limestone stair treads on top of alternating 6-in-wide mortar-setting beds, spaced at 12 inches on center (*Photo 20*). The openings between the mortar setting beds promote drainage below the stairs.

INSULATION

Insulation, required by code for most buildings, improves the thermal efficiency of a building, helps to maintain occupant comfort, and is often included in plaza systems above occupied space. Plaza assemblies with hot-fluid-applied, rubberized asphalt waterproofing membranes typically include insulation on top of the membrane in a protected membrane roof (PMR). Our project did not include insulation above the plaza deck assembly because the additional system thickness would unacceptably alter detailing at the entrance and the base of the portico columns. Relocation of insulation below the deck or omission of insulation altogether is often acceptable in small areas and on historic buildings. We were not involved with the fit out of the interior space below the plaza, but note that the ceiling could be configured to include insulation below the membrane. Insulation installed below the waterproofing membrane is typically protected from moisture and is primarily concerned with insulation value (R-value). Insulation above the membrane must consider numerous items in addition to R-value, including the anticipated plaza traffic, overburden loads, long-term creep of the insulation, reduction of insulation value due to wet conditions, and separation between the insulation and membrane to prevent spot adhesion, which can damage the membrane if the insulation floats. All of these insulation issues are important, but none are specific to hot-fluid-applied, rubberized asphalt membranes and are beyond the scope of this paper.

Photo 19 – Stain at stairs installed over hot-fluid-applied, rubberized asphalt waterproofing with no drainage layer at a waterproofing project.

SURFACING AND BALLAST

Hot-fluid-applied, rubberized asphalt waterproofing systems require surfacing (paving, soil, etc.) and, in most applications, ballast. Surfacing provides a finished protective layer, while ballast provides weight to hold plaza components in place. Surfacing and ballast come in many shapes and sizes and may include stone, concrete pavers, a cast-in-place concrete slab, or growing media. The required surfacing or ballast depend on many factors which may include wind resistance, buoyancy resistance, durability as a wearing surface, UV resistance, and appearance. A comprehensive discussion of surfacing and ballast is beyond the scope of this paper; however, ANSI/SPRI RP-4, the Wind Design Standard for Ballasted Single-ply Roofing Systems, offers guidance for ballast selection.

Surfacing and ballast selection should also consider successful systems installed in the same locale as the building. Two important considerations for surfacing and ballast installed over hot-fluid-applied, rubberized asphalt membranes are:

- **Support:** Some surfacings and ballasts rely on continuous support from the substrate (e.g., mortar set pavers), and some ballasts rely on discrete points of support (e.g., pavers on pedestals). Continuously supported ballasts tend to evenly distribute loads through the membrane while discrete support points concentrate loads on the membrane. Concentrated loads can cause membrane squeeze out or damage and reduce durability.

Photo 20 – Alternating mortar-setting beds and drainage space installed below limestone stair treads.

- **Configuration:** Surfacing and ballast should not include sharp edges that can penetrate and damage the waterproofing membrane. Systems made up of many small elements (i.e., stone) should include a protection layer (e.g., protection sheets) to separate the surfacing or ballast from the membrane.

SUMMARY

Hot-fluid-applied, rubberized asphalt membranes have a long track record of performance in waterproofing applications, but often face considerable challenges during construction, such as unanticipated existing conditions and unique details. While construction challenges are not uncommon, their exact nature is difficult if not impossible to predict during design. Active construction administration, with frequent monitoring through site visits, along with a sophisticated quality control program orchestrated by a professional waterproofing contractor are critical to successfully address construction challenges in order to avoid conditions that can reduce the durability of the waterproofing system.

NOTES