COVER STORY

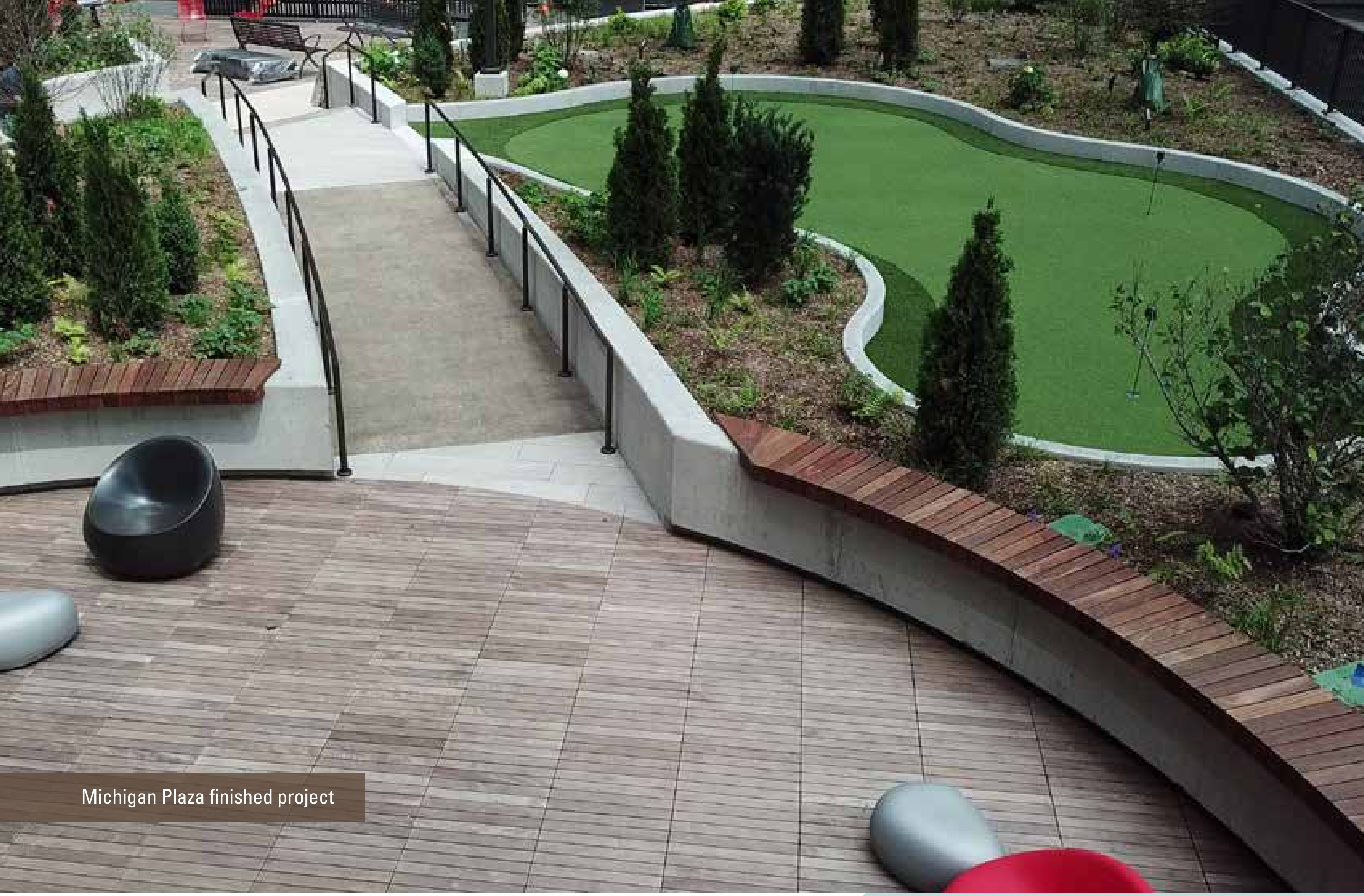
Rehabilitation of Michigan Plaza

TESTIMONY TO TEAM WORK

Michigan Plaza finished project

BY KAMI FARAHMANDPOUR AND MAGGIE LANE

Michigan Plaza is a twin-tower office building located in Chicago. The two buildings, 205 and 225 North Michigan Avenue, were constructed in 1984 and 1981, respectively. There is an outdoor plaza on the east side of the two buildings. That plaza is contiguous with an adjacent plaza to the north.



Michigan Plaza finished project

The plaza was constructed over occupied spaces below, including a television studio and other commercial spaces.

Water leakage had been reported below the plaza deck over the years. In addition, the plaza's access and other features did not serve to provide sufficient functionality for the plaza deck and building occupants.

The owner retained a well-respected architectural firm to evaluate the layout, access, and functionality of the plaza deck. As a result, the architect developed a new plan for the plaza that consisted of several new outdoor spaces, planters, and access from an adjacent street. The renovations also consisted of adding access points from within the buildings.

As part of the renovations, the plaza waterproofing system was to be replaced, and an existing large skylight with prior chronic water leakage history was to be covered with a conventional roofing system.

The architect-of-record retained several subconsultants with specific expertise to design the renovation.

Three views of Michigan Plaza prior to renovations

INVESTIGATION OF EXISTING CONDITIONS

An important aspect of designing a new waterproofing system for an outdoor plaza is investigating the existing conditions of the concrete deck, configuration of the existing plaza assembly, and evaluating subsurface drainage characteristics.

Before the design phase could begin, exploratory openings (*Image 1*) were made through the waterproofing assembly at the locations where leaks had been reported. This allowed the consultant to verify the waterproofing assembly as well as review the condition of the cast-in-place (CIP) concrete slab supporting the plaza assembly. In order to avoid disturbing the television studio, the investigation was scheduled around the studio's recording times.

IMAGE 1: Exploratory openings made in the existing waterproofing at locations of previously reported leaks

The exploratory openings confirmed that the construction of the plaza assembly was consistent with the original design drawings. The existing system consisted of a CIP concrete topping slab with exposed aggregate, a layer of rigid insulation, and a fluid-applied waterproofing membrane over a CIP concrete slab. The existing waterproofing membrane was confirmed to be an adhered rubberized membrane. The concrete slab was found to be in good condition and would not need significant repairs.

Drainage was achieved using several two-tier drain assemblies placed at various locations. The placement of the drains did not follow a regular grid pattern.

The openings also served to verify the overall thickness of the plaza assembly. This information was important to evaluate how the new assembly could accommodate the code-prescribed insulation thickness.

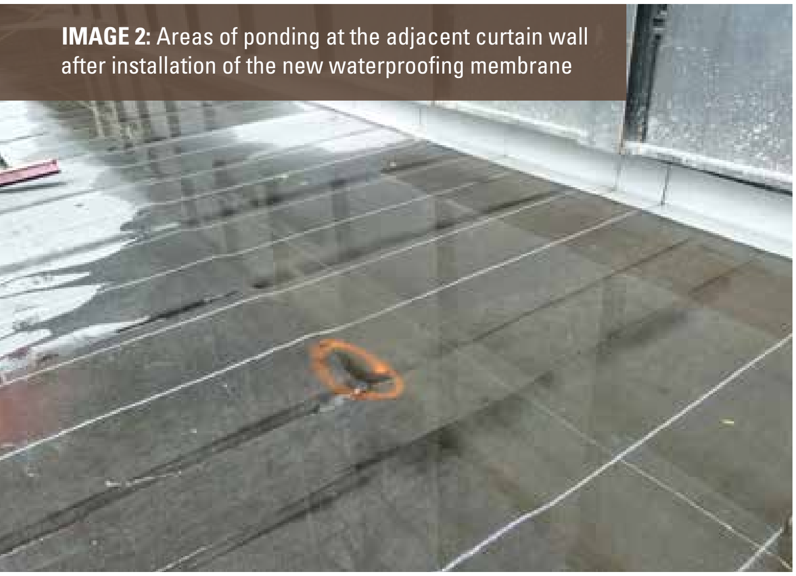


IMAGE 2: Areas of ponding at the adjacent curtain wall after installation of the new waterproofing membrane

DESIGN

Design Challenges

Drainage Slope

An important aspect of design for a plaza deck is to understand subsurface drainage characteristics of the existing concrete deck. The existing concrete deck had not been constructed with adequate drainage slope. Ideally, a bonded cementitious sloped topping would be provided to create a positive drainage slope towards the drains. However, this proved to be impractical due to dead load limitations of the supporting structural slab and the height limitations imposed by the existing curtain wall along the interface between the plaza and the buildings.

With creating slopes towards drains off the table, it was determined that additional drains would be added based on an elevation survey. Immediately after the removal of the existing plaza finishes but prior to removal of the existing waterproofing system, all existing drains were located on a site plan. Concrete slab elevations were measured on a four-foot grid in order to determine an elevation plan and locate areas that may experience ponding. Based on the findings of the survey, additional drains were added to the site plan.

Waterproofing Membrane

As with every waterproofing project, choosing a suitable waterproofing membrane is an essential part of a successful project. When evaluating various options for a waterproofing membrane, many factors including application requirements, site conditions, etc. should be considered.

Several waterproofing membrane options were considered, including a hot rubberized asphalt, a loose-laid single-ply membrane, and a 2-ply modified bitumen membrane.

Once the existing membrane was removed, a new membrane would need to be installed quickly to provide protection over the occupied spaces below. As mentioned previously, the pre-design investigation confirmed that the existing concrete deck would not need any significant repairs. While this was a positive finding that would make it easier to

IMAGE 3: Installation of two-ply modified bitumen membrane in progress

expedite protection of the occupied spaces below, the most significant concern was the presence of excessive moisture in the concrete slab which would inhibit the bond of a hot rubberized asphalt membrane to the substrate. (*Image 2*) In addition, consideration was to be given to numerous reinforcing steel and MEP penetrations through the membrane. Sealing such penetrations with a single-ply membrane system would be more challenging than with an asphaltic membrane. For reliability purposes, the consultants preferred the use of a PMMA flashing system for such penetrations. PMMA flashing systems are more compatible with many asphaltic membranes than with some single-ply loose-laid systems.

After much consideration, a two-ply modified bitumen sheet waterproofing membrane was selected. (*Image 3*) Although modified bitumen membranes are typically fully bonded to the concrete substrate, they do not rely on their bond to form a continuous waterproofing system as they are prefabricated with a reinforcing scrim. Therefore, they are not prone to formation of blisters resulting from excessive substrate moisture or any other related issues. Many modified bitumen waterproofing membrane manufacturers also supply PMMA liquid-applied flashing as part of their system and include those flashings in their warranty coverage.

Insulation Requirements

Another design challenge was ensuring that insulation requirements of the applicable energy code would be met. The applicable energy code prescriptive requirements mandated a continuous insulation R Value of R-30 (R-30ci). Using an extruded polystyrene insulation (XPS), approximately six inches of insulation would be needed to meet this requirement. However, the existing plaza

IMAGE 4: A full six inches of insulation would cause the pavers to sit too high against the curtain wall

assembly did not include such insulation. Where the plaza deck abutted the adjacent plaza deck and buildings, six inches of insulation could not be accommodated without major modifications. (*Image 4)* In order to meet the energy code requirements, consideration was given to adding insulation below the structural slab. However, due to extensive interior finishes and the sensitive nature of the occupancy, that approach was deemed impractical.

Due to these limitations, the consultants opted to meet energy code requirements through the equivalent U-Factor method allowed by the energy code (U-Factor is the inverse of R-Value). When using the equivalent U-Factor method, the consultants could specify far thicker insulation in some areas, such as within planters, to compensate for less insulation in paved areas where existing dimensions limited the new plaza assembly insulation thickness to a maximum of three inches (Approximately R-15).

Based on the applicable code requirements, for insulation entirely above the roof deck in Climate Zone 5, the maximum allowable U-factor is U-0.032. Based on U-factor method calculations and the landscaping plan of the plaza, it was determined that the perimeter of the plaza where it interfaced with the existing buildings' curtain wall system would require three inches of insulation, the walkways would require six inches of insulation, the sloped access ramps would have an average of four inches of insulation (sloping from six inches to two inches), the raised planters would have 10 inches of insulation, and the raised terraces would have 18 inches of insulation.

IMAGE 5: Existing Skylight in the background

Existing Skylight

The plaza included a large skylight area, which was comprised of several sloped glazed systems in parallel configuration. (*Image 5*) The interface between the parallel sections had formed narrow gutters which had caused prior leaks. Based on the configuration of the narrow gutters, it was determined that repair or re-waterproofing the gutters would pose a challenge to workers, and that such repairs would not be reliable. (*Images 6 and 7*)

Several options to address the existing skylight were considered. These included the following:

1. The first option included removing the skylight completely. Once the skylight was removed, it would be either capped or covered with a single, high performance sloped glazing system.

2. The second option was similar to the first option, but would include installation of a new structural deck and capping the skylight opening with a conventional roofing system.

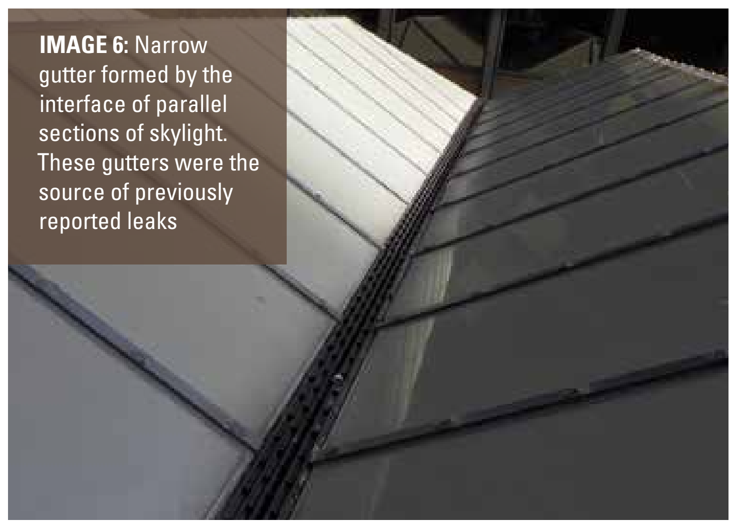


IMAGE 6: Narrow gutter formed by the interface of parallel sections of skylight. These gutters were the source of previously reported leaks

IMAGE 7: Narrow gutter formed by the interface of parallel sections of skylight. These gutters were previously repaired with limited success

IMAGE 8: New Steel deck being installed over the skylight prior to placement of concrete

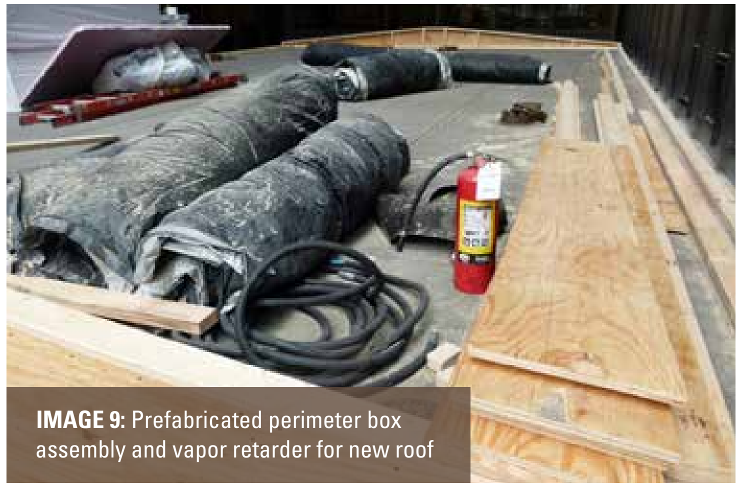


IMAGE 9: Prefabricated perimeter box assembly and vapor retarder for new roof

3. The third option involved repairing the skylight and its gutters, and isolating the skylight area from the remainder of the waterproofing system, so that any future leaks would not affect the new waterproofing system and its warranty coverage.

In order to provide for best reliability and long-term performance, the owners decided to select option two above. (*Images 8 and 9*)

As shown in *Figure 1*, the area was to be capped with a composite steel and concrete deck and topped with a new standing seam metal roofing system.

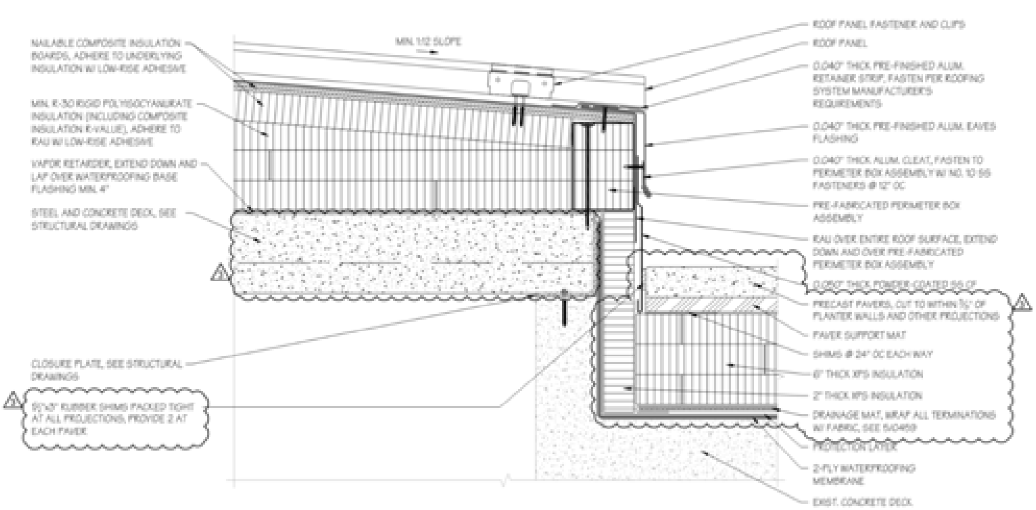
New Plaza Wearing Surface

There were two options under consideration for a new wearing surface for the plaza deck. The first option that was considered was a closed system consisting of a CIP concrete topping placed on top of the waterproofing membrane, insulation, and drainage mat. This option had several potential issues. First, concrete trucks would be required to navigate through the city to the site location, and the concrete was to be placed using large conveyors or concrete pumps. Since placing the concrete topping would likely occur during cold temperatures, casting the concrete would be limited by the weather conditions at site, and cold weather concrete placement procedures recommended by ACI 306 would have to be implemented during the placement and curing process. Additionally, CIP concrete topping slabs would be prone to cracking. Control joints would need to be saw-cut to control cracking due to drying shrinkage. Since CIP concrete topping slabs are a closed system, the topping would also need to be sloped towards the roof drains to ensure proper surface drainage. Finally, the closed system would pose potential challenges towards maintaining the waterproofing system below in the event any leaks developed over time.

The option that was ultimately chosen was an open system constructed of precast concrete pavers and modular Ipe wood panels installed over supports. (*Figure 2*) With this system, the pavers would be constructed off-site in a controlled environment. The pavers also provided unlimited choices in sizes and finishes. The pavers could be placed across the roof drains for improved aesthetics and concealment of the drains, while providing the owner the ability to service the drains by simply removing the pavers. Since the pavers are an open system where water drains between individual pavers to the waterproofing system below, the wearing surface could be installed on a flat and level plain as it would not need to slope towards the drains.

One concern with using pavers was the design team's preference to specify long, narrow pavers, which could be susceptible to cracking if only supported on four corners by conventional pedestals. Providing intermediate pedestals would also be costly. The solution was that the long pavers would be continuously

FIGURE 1: New Roof Detail



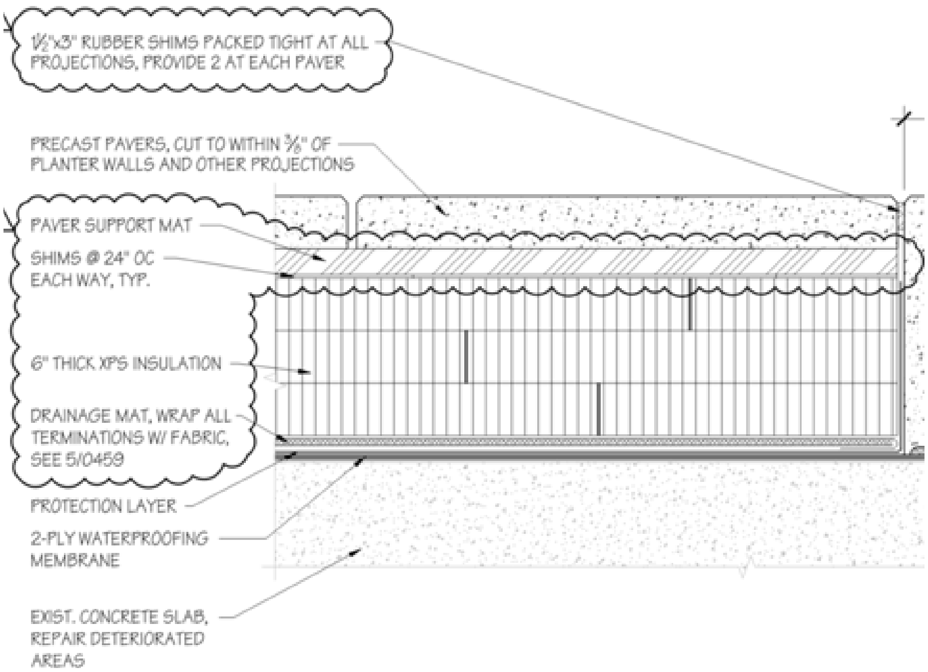


FIGURE 2: Pavers with support mats

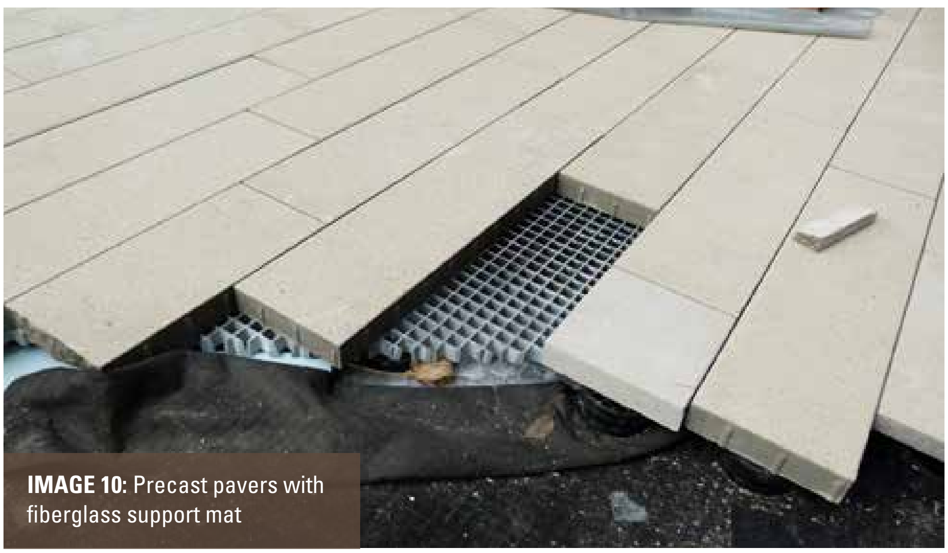


IMAGE 10: Precast pavers with fiberglass support mat

supported by a fiberglass paver support grating system. (*Figure 2 and Image 10*) This would eliminate the need for numerous support pedestals and provide a more uniform support for the pavers.

Expansion Joints

There were two expansion joints located on opposite ends of the plaza: the expansion joint to the south separating the property from an adjacent elevated public sidewalk and the one to the north separating the plaza from the neighboring property's plaza. Both posed their own unique challenges.

North Expansion Joint

The north expansion joint separated the subject plaza from a neighboring plaza which was contiguous with Michigan Plaza. The challenge with this was that at the time of design, the existing conditions on the neighboring plaza were largely unknown. The design process required much revision and collaboration with the neighboring property and its waterproofing consultants to ensure that the needs of both properties were being met. All work had to be coordinated with the adjacent property's owner. The initial design included an expansion joint assembly with rubber flanges that would tie into the existing waterproofing to the north.

Exploratory openings at the north expansion joint revealed some significant information. The existing waterproofing system consisted of a rubberized asphalt membrane, protection layer, drainage mat, and a granular bed supporting precast concrete pavers. Most significantly, the exploratory openings revealed that the expansion joint did not follow a straight line between the properties. As such, the new expansion joint would have to follow the existing 90 degree turns.

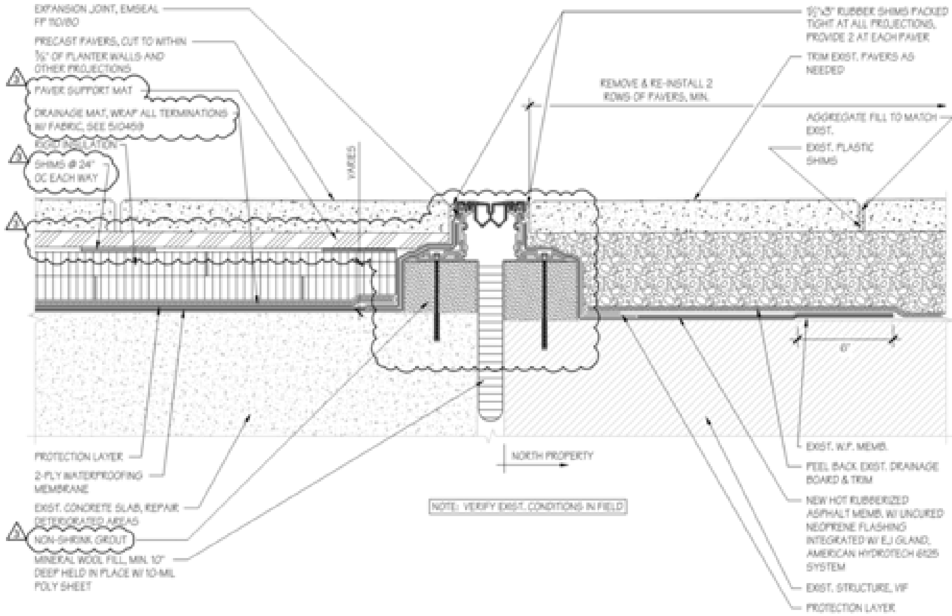


FIGURE 3: Detail for north expansion joint

Due to the high level of anticipated foot traffic and potential damage by snow removal equipment, an expansion joint assembly with metal cover plates was originally preferred. However, after much consideration to potential damage to the metal cover plates, the owners and design team decided to utilize an integrated expansion joint assembly from an SWR Institute member company. The expansion joint assembly included rubber flanges on both sides of the expansion joints to be integrated with the waterproofing systems. The selected expansion joint assembly also incorporated extruded aluminum supports with adjustable height, and stainless steel shoulders to resist damage from snow removal equipment.

IMAGE 11: Location of water leakage at the west end of the north expansion joint to the street below

IMAGE 12: Joint between precast wall panels on the west end of the north expansion joint to the street below

As shown in *Figure 3*, on the north side, the existing drainage mat and protection board would be peeled back and the rubber flange of the expansion joint assembly would be tied into the existing waterproofing membrane with a hot rubberized asphalt membrane.

Additional exploratory openings were still required for the east and west ends of the plaza before they could be detailed properly. The occupied areas below the west end of the expansion joint had previously reported issues of water leakage, evidence of which could be seen from failed expansion joints between the panels of the wall below. As such, it was important to detail these areas appropriately so as to mitigate future water infiltration. (*Images 11 and 12*)

Exploratory openings at the ends of the north expansion joint included removing portions of guardrails on the northern property, requiring further coordination with the northern property's owner. This also introduced a new complication of having to develop such details during construction phase to minimize disruptions to both properties. (*Figure 4*)

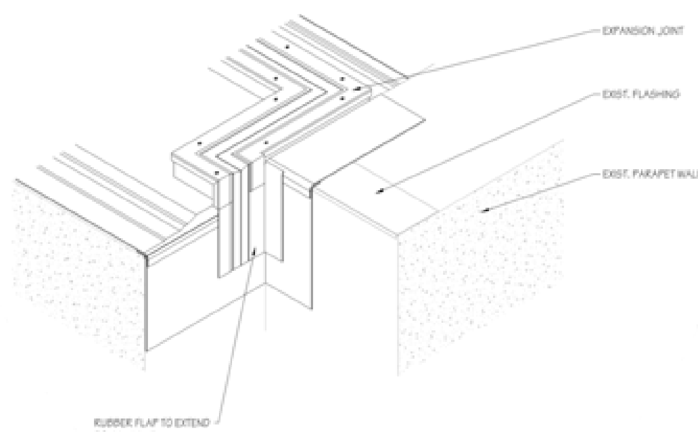


FIGURE 4: East end of north expansion joint termination detail

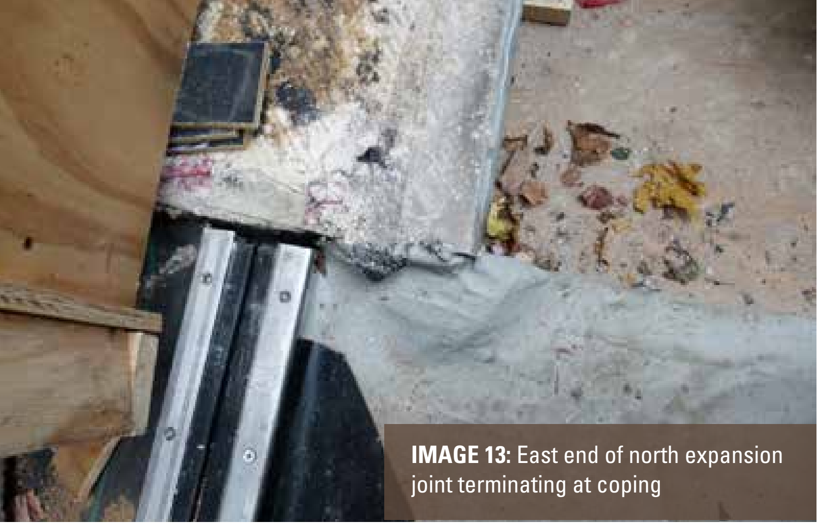


IMAGE 13: East end of north expansion joint terminating at coping

IMAGE 14: East end of north expansion joint termination

IMAGE 15: West end of north expansion joint

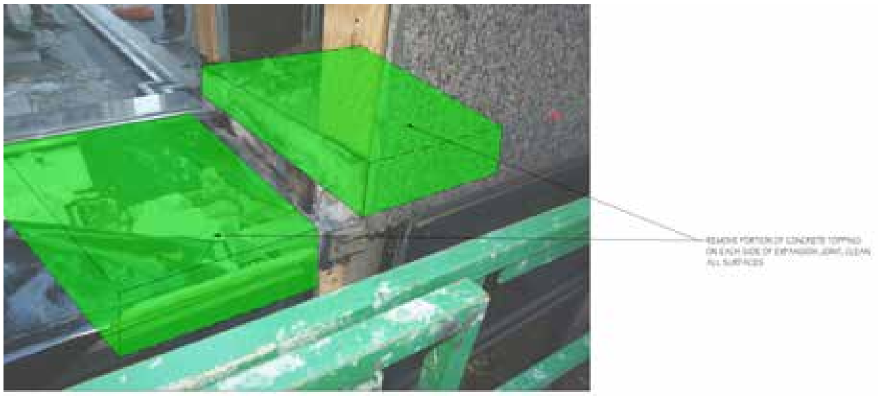


FIGURE 5: Uneven side elevations of west end of north expansion joint

As shown in *Image 13*, it was discovered that the detail at the east (*Image 14*) would require two 90-degree turns before ending and extending down the parapet wall. (*Image 15*)

At the west end, the expansion joint would be required to make a 90-degree vertical step onto the existing curb of the parapet wall. Additionally, as shown in *Figure 5*, the concrete topping on either side of the expansion joint where the rubber flaps would tie into the existing waterproofing were at different elevations. (*Figure 5*) Ultimately, the east and west ends of the expansion joint had to be cut in-field to fit the existing conditions.

South Expansion Joint
The initial design for the south expansion joint was similar to that of the north expansion joint. However, this design would have required removing sections of an elevated public sidewalk in order to perform the installation, and tie-in the waterproofing into the sidewalk area. Although no information was available on the construction of the sidewalk, inspection indicated that the sidewalk area was likely constructed of a solid slab with no waterproofing system. This would have potentially required an extensive process of obtaining permits and approval from the city, which would have taken time while construction was already underway. As indicated in *Figure 6*, the design team and owners decided to utilize a precompressed expansion joint assembly with a metal cover plate, also manufactured by an SWR Institute member company. The system chosen featured a center-mounted coverplate, which would reduce the potential for tripping hazards and misalignments as a side-mounted coverplate might experience.

FIGURE 6: East end of north expansion joint termination detail

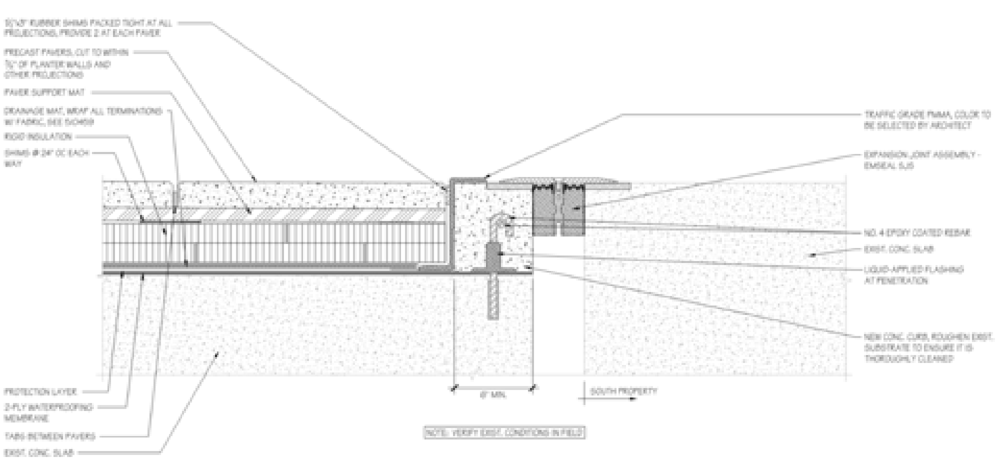


IMAGE 16: Corroded steel angle on the plaza side of the south expansion joint

IMAGE 17: New concrete curb placed on the plaza side of the expansion joint

After the existing expansion joint was removed, it was revealed an existing steel angle exhibiting corrosion existed on the plaza side of the joint. (*Image 16*) It was decided that the angle would have to be removed due to the possibility of the joint coverplate impacting the steel angle, resulting in noise under traffic. (*Image 17*)

CONSTRUCTION

Scheduling and Sequencing

The construction phase of this project brought unique challenges, the first of which was the schedule and timing of the project. As mentioned previously, some areas of the plaza are located above a television studio, which would be impacted by construction noise and vibration. There were times when work around the studio was limited to certain times of the day to minimize interruption of its recording schedule.

Work was to begin in fall of 2020 with a target completion date of early summer of 2021. This would require working through the winter months in the Chicago climate, including snow and subfreezing temperatures. As such, arrangements had to be made to protect construction materials from the elements and keep materials stored at the appropriate temperatures. Certain portions of the work which were temperature sensitive had to be scheduled to avoid colder months of the project schedule.

Site Acess

The plaza was situated approximately 40 feet above a vacant lot to the east. Arrangements were made with that property owner to utilize the lot as a staging area during construction. However, commitments were only provide for the staging area to be available during the initial stages of construction.

The staging area could be accessed via the lower level streets of the city, providing parking and area for storage. Additionally, cranes were able to access this area to lift materials to the plaza level. For workers, the plaza was accessible from the lower levels via a temporary stairway. (*Image 18 and 19*)

Having access to this location was not a permanent guarantee, however. At any time, plans for a building could be set into motion for this property, taking away this valuable staging area for the Michigan Plaza project. As such, this added an additional layer of importance to keeping the schedule and completing portions of the work which involved extensive material handling procedures.

Planter and Bench Construction

A major consideration for construction was erection of the planters and benches for the plaza. Although the original concept included precast concrete planters and benches that could be tied into the new waterproofing system, it was decided early in the design process that these components would be constructed of CIP concrete. (*Image 20*) This decision was primarily based on advice from the general contractor who had expressed concerns regarding logistical complications of lifting and locating heavy precast members onto the plaza. Due to the complicated geometry of the benches, the design team expressed hesitation regarding consistency in appearance and quality of CIP concrete benches. However, the general contractor convinced all team members that high quality benches could be properly formed and cast through a mock-up.

One complication posed by using CIP concrete benches and planter walls was that they would have to be tied to the existing structural slab using numerous dowels installed through the waterproofing membrane. To provide for reliable penetration flashing, the design team specified a PMMA flashing system around each penetration.

Another challenge was to ensure proper water drainage through the CIP concrete planter walls. This challenge was addressed using large flow-through openings along the base of all planter walls and benches. (*Image 21*)

As mentioned previously, another concern with a CIP method was weather constraints. To address this, the sequence of the work was modified to provide for casting of

IMAGE 18: Stairway from vacant lot to plaza level

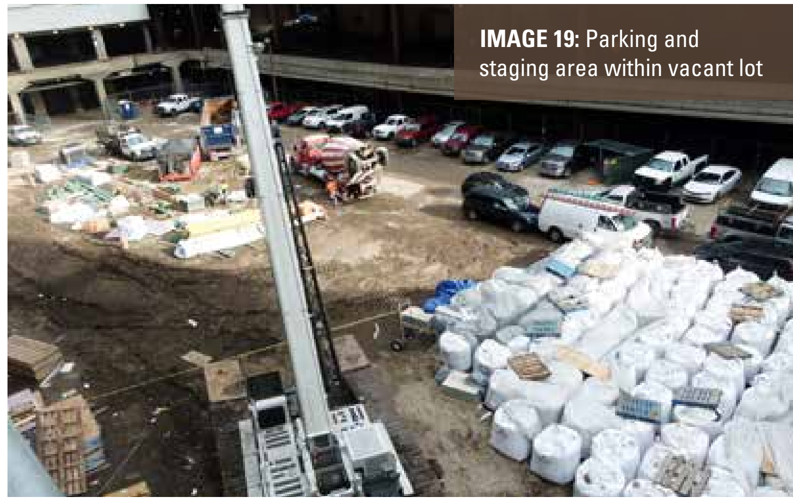


IMAGE 19: Parking and staging area within vacant lot

IMAGE 20: CIP bench mockup

IMAGE 21: Flow-through opening at base of CIP concrete planter

IMAGE 22: Crane lifting concrete to plaza level

IMAGE 23: Concrete being poured into forms for planters

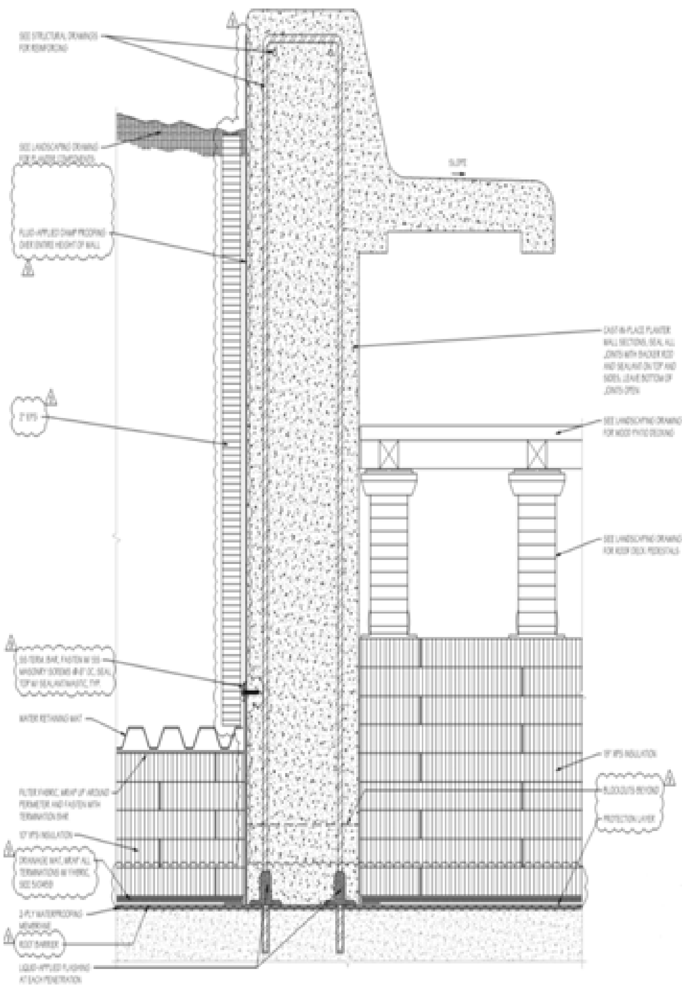


FIGURE 7: CIP planter detail

IMAGE 24: Newly poured planter wall covered with tarp and insulating blankets

the planter walls and benches during the early stages of the project when probability of cold temperatures was less. In addition, the forms were covered with tarp and insulating blankets to protect the freshly placed concrete against cold temperatures as required by ACI 306.

Another concern with CIP concrete was the potential for cracking due to shrinkage of the concrete. This was accounted for in a few ways. Within 48 hours of the concrete being placed, control joints were saw-cut to control cracking. In addition, epoxy-coated reinforcing steel was specified to provide protection against corrosion when water would penetrate through inevitable cracks. To reduce potential for staining through control joints and cracks, the control joints were filled with a sealant, and the inner face of all planter walls were treated with a damp proofing material. (*Images 22, 23, and 24*)

Waterproofing Quality Control

With the main issues surrounding CIP concrete addressed, there was one last issue remaining. The concrete for the planters would be poured after the new waterproofing system had been installed. This would mean that steel reinforcement for the planters would penetrate the new membrane, potentially impacting watertightness of the system. As shown in the *Image 25* , this was partially solved by providing liquid-applied flashing at each penetration of the epoxy-coated steel reinforcement. (*Figure 7*)

Quality and watertightness of the waterproofing membrane as a whole was also checked via electric field vector mapping (EFVM) in accordance with ASTM D7877.

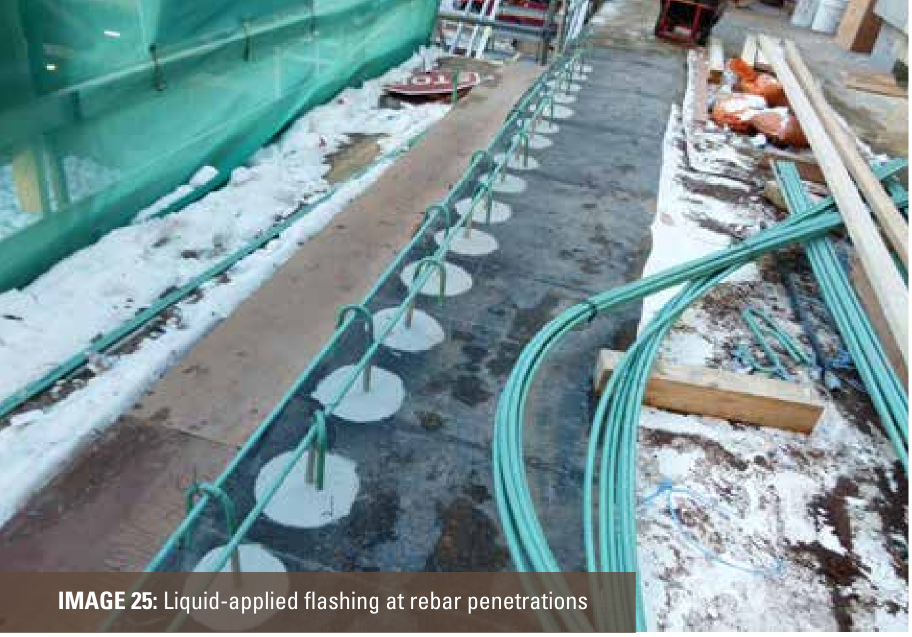


IMAGE 25: Liquid-applied flashing at rebar penetrations

IMAGE 26: Wetting the area to receive EFVM testing

IMAGE 27: Technician following the induced electrical field

Each section of the installed waterproofing membrane was tested twice, once after installation of the membrane, and again after placement of the cast-in-place walls and bench reinforcing steel penetrations. (*Images 25, 26, and 27*)

Ultimately, no water infiltration issues were reported during the construction phase. It is common to experience water leakage during such large waterproofing project. Lack of any reported water leakage during such a complicated project shows that the construction team went to great length to ensure water tightness during construction.

Project Completion

The project was substantially completed on time and within the owner's budget. As previously mentioned, no water leakage issues were reported during construction. Thanks to the creative minds of the architect-of-record and other team members, the rehabilitated Michigan Plaza has transformed the outdoor environment of its surrounding buildings into a new and inviting space. (*Image 28*)

CONCLUSION

When designing a new waterproofing system for an existing plaza deck, it is vital to consider all existing conditions when entering the design phase. It is also important to coordinate constructability of the repairs with an experienced contractor. Selection of materials including waterproofing membrane, wearing surfaces and planter walls should be based on site specific condition, not the preferences of the design team.

Since exploratory openings cannot expose every feature of a plaza assembly, most waterproofing rehabilitation projects will involve addressing unforeseen conditions during construction. For this reason, coordination between the design and construction teams is paramount. Ultimately, an adequate solution to any challenge will require input from the owner, design team, general contractor, and various subcontractors.

IMAGE 28: Finished Michigan Plaza outdoor space

Finished Michigan Plaza outdoor space

About the Authors

Kami Farahmandpour, F-IIBEC, REWC, RRC, RWC, RBEC, PE, CCS CCA, is the principal of Building Technology Consultants, Inc., a forensic engineering firm in Arlington Heights, Illinois. Kami has been involved in the evaluation, testing and repair of construction materials and building enclosure performance since 1984. He has managed over 600 projects involving multiple disciplines and complex building enclosure issues. His involvement with the building enclosure industry has earned him several awards, both for his contributions to the industry, and for his work on several projects. Kami is a Fellow of International Institute of Building Enclosure Consultants (IIBEC) and a Fellow of National Academy of Forensic Engineers (NAFE).

Maddie Lane , EIT, joined the team at Building Technology Consultants, Inc. as an Engineering Consultant Intern in 2019. She holds a Bachelor of Science degree in Architectural Engineering and a Master of Engineering Degree in Structural Engineering from Illinois Institute of Technology. She is currently an Associate Engineering Consultant at BTC. During her time at BTC, she has contributed to several projects related to the design and evaluation of waterproofing systems, building facades, and roofing systems. She has had experience in construction administration as we has destructive and nondestructive testing.

ACKNOWLEDGMENTS

The authors acknowledge that the successful outcome of this project was entirely dependent on the talents and cooperation of the project team members which include the following:

1. MD Real Estate, Owner
2. CannonDesign: Project Architect, Structural Consultant, and MEP Engineer
3. Pepper Construction: General Contractor
4. TGDA Landscape Architecture: Landscape Architect
5. CCI Code Consultants, Inc.: Code Consulting
6. Lerch Bates: Vertical Transportation Consultant
7. Soprema: Waterproofing Membrane Manufacturer
8. Kedmont Waterproofing: Waterproofing Subcontractor
9. Emseal: Expansion Joint Manufacturer