Building Envelope Technology Symposium

Addressing Roof Leaks by Fixing a Wall Problem

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ABSTRACT

Sources of water infiltration can be extremely difficult to locate and repair without thorough inspections of both roof and façade systems. At the Dillon County Courthouse in Florence, South Carolina, water infiltration, structural deterioration, façade distress, and leaks were reported and thought to be associated with a defective roof system. Façade systems consisted of load-bearing brick, terra cotta, and carved stone masonry; and the roof system consisted of a two-ply modified bitumen membrane applied over a well-sloped wood plank deck. Structural deterioration was observed, specifically at the bearing points of the wood rafters in the brick masonry walls. The backside of the multiwythe brick masonry parapet wall had been covered with roof membrane and an aluminized coating. The building owners were considering roof replacement in kind. Through a concerted effort of client education and relationship development, the contractor and engineer worked together with the owners to explain the building science of what was occurring at the roof parapet. The solution was a revision in project approach, moving away from in-kind replacement toward a more holistic project that addressed through-wall flashings, sealants, terra cotta, roof membrane systems, wood structural repairs, and a metal panel rainscreen at the parapet wall.

SPEAKERS

Steven P. Bentz, RRC, PE — Facility Engineering Associates, P.C.

Steve Bentz is a registered professional engineer in five states and the District of Columbia and a Registered Roof Consultant. With a degree in architectural engineering from Pennsylvania State University, he has been involved in over 100 projects with Facility Engineering Associates, P.C. (FEA) over the past ten years, including in-field investigation, testing, and evaluation; preparation of construction documents; bidding; and construction administration of roof replacement, façade repair, and historic rehabilitation projects. He is currently a senior engineer specializing in building envelope repair and assessment at the Fairfax, VA, office of FEA and an associate member of the Sealant, Waterproofing, and Restoration Institute Board of Directors.

Mark Howell — Structural Group

Mark Howell is a recognized leader in the building envelope repair industry with specific experience in historic preservation, exterior façade maintenance, and waterproofing. Howell is currently a member of the SWRI Board of Directors, an active member of the American Society of Testing Materials, the Association for Preservation Technology International, and RCI. From the lessons learned by solving problems as well as the information gathered through organization involvement, Howell publishes articles in national industry publications and makes presentations to many organizations, including education programs for the AIA. Howell is the national consultant for Building Envelope Solutions and provides support services to architects, engineers, and owners for investigation of structure, forensic, and waterproofing conditions on existing structures.

Addressing Roof Leaks by Fixing a Wall Problem

Photo 1 – Overview of building façade.

INTRODUCTION

The Dillon County Courthouse is located in Florence, SC, and was built in 1911 and expanded with a small addition at the rear of the building in the mid-1990s. The structure is four stories tall, with the first floor roughly half a level below grade. It measures approximately 110-ft by 60-ft, giving a total square footage, allowing for the two-story courtroom, of approximately 22,000 sq ft. The building façade systems (*Photo 1*) consist of brick-masonry, carved-stone features, including columns, pilasters, water tables, pediments, cornices, balusters, and entablatures, and terra cotta coping stones. The courthouse is built in the Beaux-Arts style of architecture with raked-back mortar joints and traditional brick quoins at the corners. It is a historic landmark in South Carolina and part of the historic district of Dillon, SC.

The roof system at the property consisted of modified bitumen membranes applied over a sloping wood roof-deck system. The facility managers had been dealing for many years with water infiltration at the upper floors of the building. The roof system had reportedly been replaced several times, yet the leaks continued. In 2008, the contractor was asked to review the façade and roof system. The contractor requested that the engineer assist in developing repair construction documents and in reviewing the installed work.

During the initial fieldwork, façade distress was noted at numerous locations, mainly associated with the parapet wall. The roof membrane had been extended up the back side of the masonry parapet wall. No through-wall flashings were installed at the parapet. Numerous blisters and other deficiencies were noted in the roof system, and leaking drains and gutters were also evident. The contractor and engineer determined that the source of the leaks was mainly related to deficiencies at the parapet wall. The following is a summary of the repair scope, implementation, and challenges encountered.

Photo 2 – Overview of existing roof systems. Note vertical wall flashings at back side of parapet.

ROOF REPLACEMENT

The existing roof system at the property consisted of a two-ply modified bitumen roof set in hot asphalt over a 1-in-thick layer of polyisocyanurate insulation (*Photo 2*). The insulation was set in hot asphalt over the wood plank deck. The roof structural system consisted of sloped wood rafters supported by the exterior load-bearing masonry walls and internal concrete beams at the long span over the main courtroom. The wood rafters were rotted at locations of bearing pockets in the masonry wall system. An interstitial attic space existed between the wood deck and the concrete ceiling system. The attic was only partially ventilated. Roof debris from the previous roof projects was found inside the attic space, apparently discarded there rather than being properly disposed of by the previous contractors. The roof was primarily drained by perimeter built-in sheet-metal gutters stripped into the roof system. The gutters had minimal slope-to-drain, and the discharge openings to the downspouts were partially obstructed.

The vertical flashings of the roof system extended to the top of the parapet wall in most locations, with no cant at the base of the wall, some of which were over 6 ft in height. The flashings and the top of the parapet coping had been coated with an aluminized coating. The vertical flashings were delaminated from the masonry substrate.

The engineer designed a replacement roof system that incorporated a cold-adhesive-applied modified bitumen membrane; mechanically fastened polyisocyanurate insulation; steep-sloped, wood-framed crickets (*Photos 3* and *4*); cants; and sumped drains. The design eliminated the stripped-in sheet-metal gutter, a chronic leak issue, and directed water to the drains,

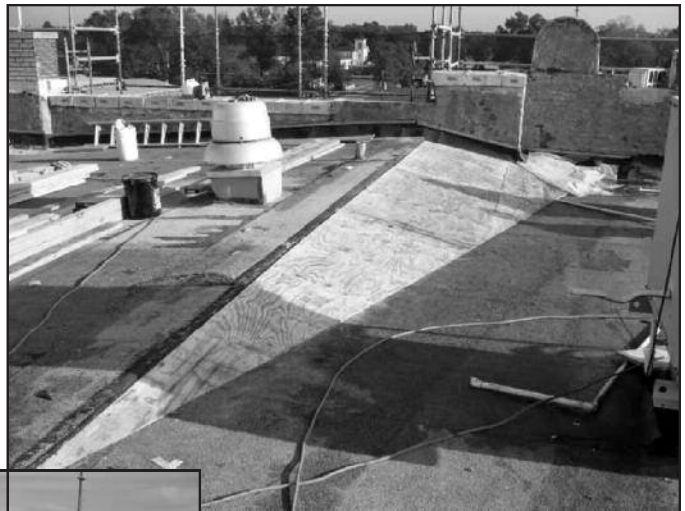

Photo 3 – Steep-slope cricket at existing transition in roof slope.

Photo 4 – Steep-slope cricket at parapet wall.

facilitating efficient drainage. As part of the roof design, new mechanical ventilation was installed to increase airflow through the attic space.

Due to the historic nature of the building, no overflow scuppers or drains were added during the roof replacement. Additionally, it should be noted that minimal insulation beneath the modified bitumen membrane was used due to the nature of the ventilated attic space beneath the roof. The concrete ceiling of the building was determined to provide a sufficient thermal and air barrier between the attic and the habitable space. The additional attic ventilation was deemed necessary to reduce the thermal load across the membrane from the attic space to the exterior.

Once the roof replacement was completed, all debris was removed from the site and properly disposed of, including the existing debris found in the attic space, leaving the owner with a potentially open attic space for storage, mechanical equipment, or other uses.

STRUCTURAL REPAIRS

As part of the repair project, nearly all of the roof rafters were addressed at the bearing pockets where the wood was in contact with the masonry wall. Many of the rafters were already rotted beyond salvaging (*Photo 5*), while others were repaired with a pressure-treated sistered member to provide a measure of protection against future rot. Pressure-treated lumber was used at the repairs, and both sistering (attaching new members to the face of existing remaining members) as well as full replacement were performed (*Photo 6*). Many of the primary rafters had been decreased in cross section at the bearing points due to a boxed-out frame for the built-in gutter. These were replaced as part of the wood structural repairs with full-depth members.

At some locations, construction of a secondary masonry knee wall approximately five courses high was necessary within the attic space to support the repaired rafters (*Photo 7*). This approach was selected by the contractor to minimize the unknown com-

Photo 7 – View of sistered rafters from beneath after deck reinstallation. Note masonry knee wall.

Photo 5 – Rotted wood rafter at bearing end, note box out for gutter.

Photo 6 – View of sistered rafters from above prior to deck reinstallation.

ponent chipping into the existing remaining masonry to create bearing pockets. By constructing this knee wall within 3 to 4 in of the face of the existing wall, load transfer to the existing bearing points was accomplished within the concrete slab cross section.

In addition to wood structural repairs, concrete slab replacement was also necessary at the ceiling over the main entrance portico. This entrance had originally included a plaster suspended ceiling that had deteriorated and been removed as a safety concern years before. The unprotected and exposed concrete ceiling had deteriorated to the point of spalling; and exposed, corroded reinforcing was observed at the start of the project (*Photo 8*).

Photo 8 – Underside of portico ceiling at start of project.

The portico ceiling was replaced with a cast-in-place concrete slab, similar to the original construction (*Photo 9*).

Photo 9 – New portico ceiling slab.

PARAPET WALL REPAIRS

Upon removal of the vertical wall flashings, the suspicions of the contractor and engineer were confirmed that the masonry parapet had been saturated with moisture due to the flashings preventing drying. The uncovered masonry was found to be previously painted and parged as well, which may have also contributed to additional moisture retention in the masonry. Once the walls were uncovered (*Photo 10*), they were allowed to dry, and the masonry was verified to be sound.

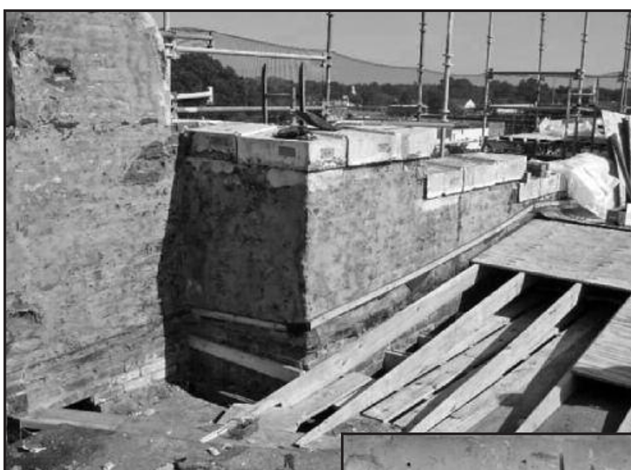

Photo 10 – Backside of exposed brick masonry parapet.

The terra-cotta coping was removed from the entire perimeter of the building, and a new continuous copper through-wall flashing was installed beneath the terra-cotta. Each section of terra-cotta was numbered, stored, cleaned, and then reinstalled over the new flashings. New stainless-steel cleats (*Photo 11*) were installed by using traditional dovetail stone anchors in a horizontal application. Openings were made in the sides of the terra-cotta sections to install the cleats. The installation of the cleats was necessary to prevent sliding of the terra-cotta on the flashings.

Photo 11 – Stainless-steel cleat at terra-cotta attachment.

Once the terra-cotta was reset, the skyward-facing joints were sealed with caulking over backer rod. The sealant joints were protected with an embedded lead cap (*Photo 12*).

Photo 12 – Installation of lead cap at terra-cotta sealant joints.

When the addition to the building was constructed in the 1990s, a portion of the original parapet was left in its original posi-

Photo 14– Rear elevation of addition after restoration of parapet.

Photo 13 – Rear elevation of addition before restoration of parapet.

tion, in turn obscuring it from view (*Photo 13*). As part of the parapet wall work, this ornamental detail was relocated to the exterior wall of the addition (*Photo 14*) to allow for the parapet to appear continuous from the exterior and the roof level. This additional step not only was an aesthetic improvement but also allowed for improved waterproofing details at the transition from the addition to the original building at the parapet level.

RAINSCREEN CLADDING

As a counterflashing for the roof system, protection for the masonry, and drying time for the masonry, a metal rainscreen was installed on the back side of the parapet (*Photo 15*).

A 30-pound building felt was installed over the wall as a drainage plane behind the metal panels. Then steel hat channels were attached to the masonry using nail-in expansion anchors. The metal panels were secured to the hat channels using standing-seam metal roof system clips. The installation of the rainscreen allowed the parapet to dry out while keeping the driving rain from saturating the masonry. Because of the intricate nature of the parapet wall, numerous transitions and various panel sizes were necessary. A patina green copper finish was chosen to maintain an historic appearance consistent with this building's age. Once the rainscreen was installed, the new through-wall flashing beneath the terra-cotta coping was used as a counterflashing for the top of the rainscreen, capping off the system.

SUCCESS WITH MOCK-UPS

Mock-ups—a detailed, full-scale sample of part of a project to be completed—were an important part of the construction process. In this case, mock-ups were not just part of the submittal process to verify the contractor's ability to install a given product in accordance with the specifications; they also provided the owners with a sample of the final product so that they could understand what they would eventually be purchasing. For the purposes of this project, the mock-up was an essential part of client education in how the wall and roof system functioned.

In most cases, the process of developing a mock-up begins with a need to demonstrate how a portion of the building will be assembled. This need may be outlined in the engineer's specifications, identified by the owner, or insisted on by the contractor. Consultants specify mock-ups as a means of quantifying items in the design that may

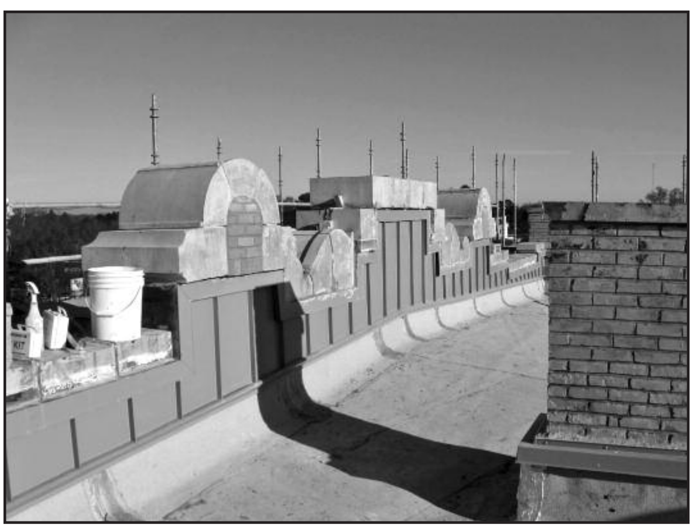

Photo 15 – Installed rainscreen at back side of parapet wall.

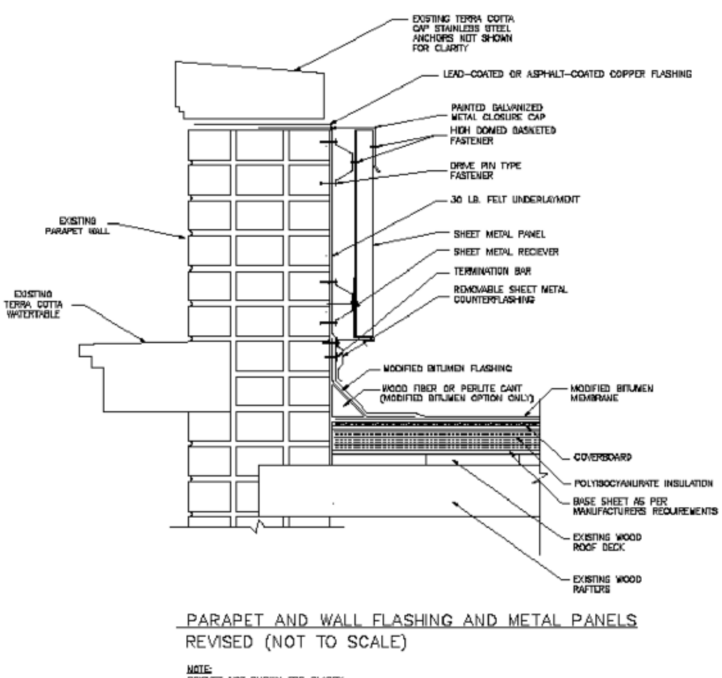

Figure 1 – Cross-sectional detail of rainscreen parapet wall.

Photograph 16 – Rainscreen mock-up.

not be easily submitted or approved by means of a paper submittal. In this case, the contractor insisted on mock-ups being installed for a variety of reasons. The contractor wanted to verify that what was shown in the drawings could actually be constructed. The contractor also needed to train its less-experienced personnel in the installation of certain products. Additionally, the contractor wanted to install the mock-ups as comparison samples to have a basis for determining the acceptability of installed work.

In many cases, the mock-up must be expanded to include a series of mock-ups: a prototype. A prototype typically includes a mock-up of several items and their interaction with each other representative of the project and is used to solve a problem or provide answers to questions before the building process begins. Prototypes help to identify challenges with regard to constructability as well as to better determine how all the components will work together. In essence, a prototype allows for testing the way in which a system will physically work. In this case, a prototype of the rainscreen system was installed (*Photo 16*).

Mock-ups and prototypes help minimize risk because the contractor has been exposed to information from the first stages of the building process; and the owner has been given a tangible, measurable basis of comparison. Although some believe mock-ups slow the construction process, this project proved that they contributed to the project's success, especially since they were used early in the design process to demonstrate to the owner what would be installed. Additionally, as will be noted in review of the photographs, the contractor had assumed the use of a corrugated steel panel for the wall panels; however, a standing-seam panel was specified. The mock-up allowed the engineer and owner to see the contractor's intent and to clear up this confusion prior to the ordering of materials.

CHALLENGES AND UNFORESEEN CONDITIONS

As with any restoration project, numerous challenges and unforeseen conditions presented themselves throughout the course of the work.

The structural repairs beneath the main roof deck needed to be completed quickly to minimize the time the roof deck was open to the elements. In many instances, due to the complex nature of the repairs, it was necessary to temporarily waterproof the roof to return to it the next day. In some cases, the roof was left open in the evenings when forecasts called for clear weather. This is contrary to good roofing practice, but this relatively low-risk exception led to a savings in time in the overall project.

The complexity of the roof cricket layout presented challenges for the roof carpenters. The cricket layout, while simple in plan view, became complicated to install due to the compound angles of the steep-sloped roof. The engineer worked closely with the contractor to lay out the crickets and develop framing plans in the field that would address support of the roof system, proper slope, and proper attachment.

Removal of the aluminized coating from the terra-cotta coping was accomplished carefully, using specialized cleaning products that were initially tested in discrete areas. The contractor encountered difficulties in cleaning the coping quickly, leading to an extended period where the coping was left off the wall. This led to the unexpected benefit of testing the through-wall flashings under direct rain exposure. Although not recommended, this testing proved the efficacy of the flashings.

During the assessment of the property, it was noted that there were many honeybees present at the ornamental stone carvings and terra-cotta at the parapet level (*Photo 17*). Although it was expected that the bees would affect construction, it was not expected that a complete hive structure, including honeycomb, would be found within the terra-cotta coping (*Photos 18* and *19*).

The contractor contacted a local apiarist to remove the bees safely and humanely.

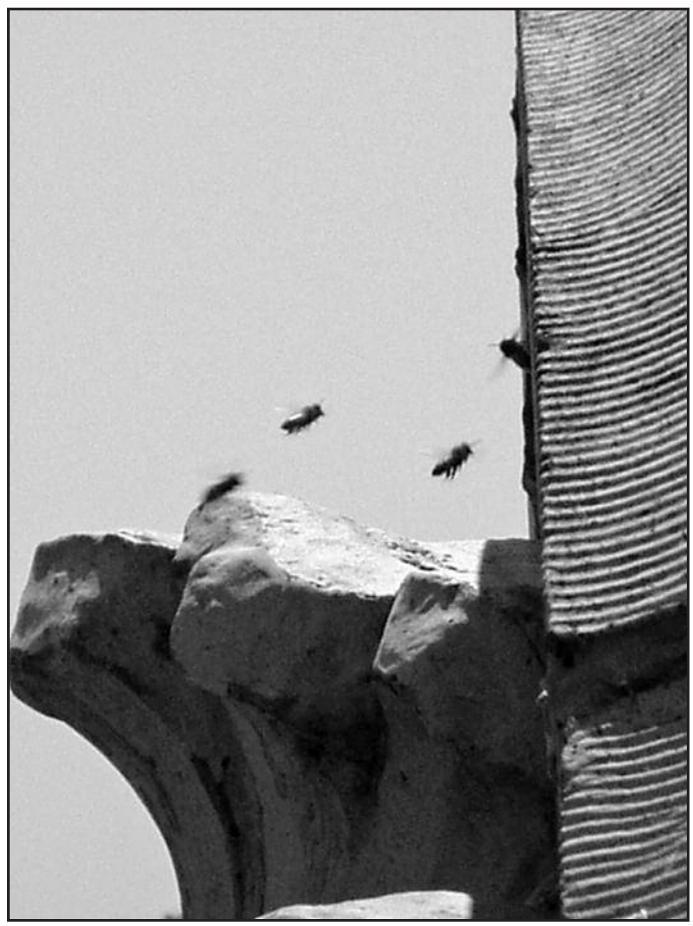

Photo 17 – Honey bees at stone ornament prior to construction.

Photo 18 – Honeybees swarming as terra cotta is removed.

Photo 19 – Terra cotta void filled with honeycomb.

The bees and their honeycomb were extracted from the terra-cotta, which was then cleaned and reinstalled as planned. This process added a few days to construction but successfully preserved the hive structure of a large honeybee colony.

CONCLUSIONS

The Dillon County Courthouse project was completed in January of 2010. The project that took nearly two years to plan took only about four months to complete, including the mock-up process. By working as a design-build team, the engineer and contractor expedited the process by removing a bidding stage and addressing uncovered conditions as a team during construction. The result of the project included the replacement of a roof system (*Photo 20*); however, the replacement of the roof alone would not have addressed the problem.

Photo 20 – Completed roof system.

The parapet wall repairs and the installation of the rainscreen were critical components of the project. The team effort by the engineer and the contractor convinced the owner to proceed with this repair. Detailed explanations of the building science behind the repairs enhanced the owner's education about the project. The team approach of the engineer and contractor, both delivering the same message to the owner, resulted in a product that addressed the issue and restored the facility to a watertight condition. As of the writing of this paper, no roof or parapet wall leaks have been reported, and the system appears to be functioning as intended.