PROCEEDINGS

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Innovative Façade Repair Solutions: 3-D Laser Scanning and Project Team Collaboration

Matthew Kutzler, PE, CDT

Facility Engineering Associates

12701 Fair Lakes Circle, Suite 101, Fairfax, VA 22033

Phone: 703-591-4855 • Fax: 703-591-4855 • E-mail: matt.kutzler@feapc.com

Abstract

Design and implementation of building repairs can present challenges when dealing with existing conditions. Access difficulties, time and budget constraints, etc. hinder observation and understanding of conditions. This session will share project-related experiences that led to innovative approaches in two specific instances. Participants will learn how 3-D laser scanning technology was used to render models of elevation planes for detection of brick movement in consideration of retrofit masonry ties. The speaker will also explore the collaborative team process used to address an atypical brick-support and flashing issue that was a persistent source of water infiltration.

Speaker

Matthew Kutzler, PE, CDT — Facility Engineering Associates - Fairfax, VA

MATTHEW KUTZLER is a project manager who has participated in over 200 projects while at Facility Engineering Associates in Fairfax, VA. His experience with existing facilities includes evaluation and repair of waterproofing, masonry and stucco building enclosures, balconies, roofing systems, parking garages, and asphalt and concrete pavements. His primary focus has been working with property managers and owners to develop and implement repair and maintenance plans that make sense for the life cycle of each facility. Kutzler has authored several articles related to construction contract administration, façade and parking garage maintenance and restoration, and hazardous materials testing.

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Have you ever passed by a building and wondered, "How was that ever constructed?" Your mind wanders through all of the planning and coordination, equipment and materials, labor force, and leadership required to accomplish this feat. You stand in awe at the architectural elements and detailing or sheer magnitude of size. If you're like me, these thoughts have crossed your mind many times.

Inevitably, all of those structures will need some sort of repair, restoration, and maintenance as they move through their service lives and materials deteriorate. Now think about another question: How often have you wondered how a building will be accessed for repairs? A busy sidewalk shut down for overhead work? A large cooling tower replaced on the roof? I'm guessing this isn't thought about nearly as much as original construction accomplishments.

Restoration contractors and consultants are routinely challenged with these questions. The presence of finishes, access difficulties, time and budget constraints, etc. all hinder observations and understanding of potential repair conditions of existing buildings. In order to overcome these hurdles, all members of a project team must work in unison. Owners, property managers, contractors, consultants, and others have specific roles that overlap in many areas. No ideas on how to accomplish goals should be off the table.

A recent repair project performed at an urban office building highlighted the use of an atypical assessment approach (three-dimensional laser scanning technology) and the importance of project team collaboration in addressing a challenging through-wall flashing repair.

JUST THE (BACKGROUND) FACTS

In keeping with several other metropolitan areas and jurisdictions, Philadelphia had adopted an ordinance for scheduled façade inspections to be performed by a Pennsylvania-licensed professional engineer or registered architect. The intent was to document building wall components that were in need of repair or potentially unsafe conditions, what those conditions were, and how/when they should be addressed to consider the building façade to be in "safe" condition.

Based on the specified ordinance schedule and age of the building, the façade had to be inspected and commented upon no later than the end of June 2012. To comply with the ordinance, it was thought that a building façade assessment could be performed and recommended repairs completed prior to the specified deadline—a plan that building owners were determined to follow.

The aforementioned property was a 20-story commercial office building that was constructed in 1970 in the center city of Philadelphia (see *Photo 1*). The rectangular structure consisted of a concrete frame-and-brick veneer at each of the four elevations. Vertical mechanical chases of alternating depths projected outward from the building, creating a recessed appearance at narrow window bays between chases (*Photo 2*). The building was uniform throughout its height, terminating at its peak with a wall around the perimeter that sloped toward

Photo 1 – Typical façade overview of subject building.

Photo 2 – Top of mechanical chase projections and sloped wall.

the main roof. There was a large mechanical penthouse near the center of the roof.

WE NEED TO ADD WALL TIES THROUGHOUT THE FAÇADE?

According to original construction drawings, corrugated galvanized metal ties were to be installed every three to four brick courses vertically. The specified horizontal spacing was unclear at window bays but was to be one tie into each side of the projections (two at the front of the larger projections).

In the early 1990s, a repair project was undertaken to address various conditions related to deterioration and water infiltration. During this project, large areas of brick were removed at the top of the mechanical chases. Photographic documentation and past reporting indicated that wall ties were largely absent at areas where brick was removed. While ties were installed at these repair areas, no additional ties appear to have been installed elsewhere.

There was speculation from past consultants that a perceived lack of wall ties necessitated widespread installation of retrofit masonry ties. Based on the height of the building and a perimeter length approaching 400 linear feet, performing such repairs would be costly, disruptive, and time-consuming. As a result, one of the central goals to the façade assessment was to assess the potential need for additional masonry ties; but what was the best way to accomplish this?

WHEN IS ENOUGH ENOUGH?

Façade assessments can include a variety of aspects such as past document review, visual observations, and exploratory openings. Visual observations are typically performed from swing stages or other lifts, terraces or balconies, roofs, and surrounding grounds—perhaps with binoculars. These methods all have two things in common: human observation and perception. Two people viewing the same conditions can have differing opinions on what they've seen, based on past experience or knowledge, not to mention weather conditions, fatigue, etc. Without a definitive way to measure or calculate a deficiency, there is the potential for human error.

Another aspect to consider is the level of assessment performed. How many swing-stage drops or exploratory openings are appropriate? At what point can an assessor be comfortable with his or her findings? Conditions can vary widely, and what is observed in one area may not necessarily be the same condition present at another.

In the case of assessing the state of masonry ties at the subject building, visual observations from the ground, roof, and several swing-stage drops were performed to gain an initial understanding of conditions. The masonry elements and mortar joints were generally in fair condition. Evidence of bulging or other movement of the brick veneer was not observed below the top floor. However, it appeared that the brick veneer at mechanical chase projections had shifted outward at the top floor in some locations. The movement was minimal in this area, but visually apparent.

Exploratory openings indicated a lack of brick ties, but the openings were quite small compared to the overall façade area. A bore scope was able to indicate that some ties were employed, but use of the instrument was difficult due to mortar droppings within the cavity, which is common in masonry walls.

Considering the age and service life of the building, observed conditions, and no reports of falling brick, initial indications were that the apparent lack of ties had not adversely affected the brick façade. However, there was enough information to show that ties were likely needed in select areas. Determining which areas were candidates for retrofit masonry ties would be the challenge.

THE TECHNOLOGY OF THE FUTURE

It was apparent that visual observations alone would not be sufficient for the project requirements related to masonry wall ties. While an educated estimate could be provided for the number of wall ties to be installed, it had the potential to be somewhat or even largely inaccurate, and the owner's budget could be exceeded. This wouldn't be confirmed until the project had already started and a swing stage was erected at each façade drop. Also, the construction schedule could be adversely affected with an unexpected increase in quantity, leading to unhappy tenants and extended closure of facility areas and public sidewalks. Finally, the contractor would have little to no direction as to where to install the ties; it would ultimately be left, in large part, to his judgment.

Accessing all areas of the façade during the assessment phase did not make sense financially, as it would cost far more to refine the number of expected ties than it would to actually install them. Even with unparalleled access, the quantity of ties would be subjective, based on the assessor's opinion. A finite, quantitative assessment was sought to alleviate these possible issues.

Photo 3 – Typical scanner set up on tripod.

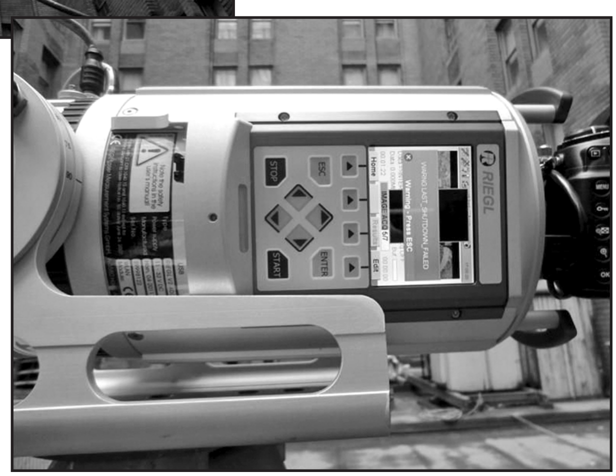

Photo 4 – Typical scanner keypad and display screen.

The answer was found in three-dimensional laser scanning.

Laser scanning involves the gathering of millions of data points from the surface under consideration (the brick façade) in order to manifest the data into lines and planes for documentation of as-built conditions. The process is similar to traditional surveying, with a laser-scanning device taking the place of the theodolite.

Using traditional surveyors' methods, a baseline of reference is established. This baseline (or control) can be the sidewalk at the base of the building, a nearby benchmark, or another set point that will have a high likelihood of remaining fixed for future scans. The baseline is linked to a global positioning system (GPS), so that all points are linked to the global reference. Once the baseline is set, the scanning device is set up on a tripod, attached to a computer, and takes a 360-degree view of the items around it (*Photos 3* and *4*). Everything is captured, including trees, pedestrians, cars, and even steam in the air. After data acquisition is complete, the usable point data must be sorted from the noise. The device measures the "time of flight" of the laser from the time it leaves the device to the time it bounces off of a surface. With the speed of light being a known constant, the time of flight is then converted to a distance; that distance is then referenced to the baseline and, in turn, given a GPS position for every point on the surface. Accuracy of the scan will depend on line of sight, angle of incidence, and the density of the scan.

The electronic data output can be catered for the desired use, such as production of a highly detailed elevation drawing in CAD, and is accurate within a thousandth of a foot. The data can be used for comparative analysis from year to year to look for trends in movement. Some scanners even have the ability to link high-resolution digital photographs to the point cloud data.

In the case of the subject building, the scanning was used to establish a uniform plane at each elevation. Once a base plane was established, limits could be placed on the point data to determine their location relative to the plane. For example, an analysis could be performed to identify any point that is more than ½ inch away from the base plane. These points, gathered together, would represent brick movement away from the building and a possible area where retrofit masonry wall ties should be installed (*Photo 5*).

With this data in hand, locations where brick movement had occurred were identified on elevation drawings and included in the construction documents for repair. Detailing related to spacing for retrofit masonry ties was also included, providing clear direction to the contractor as to where the ties should be installed. Ties were not unilaterally installed everywhere at unneeded locations, and a contracted quantity of ties was established that was largely adhered to during the course of work.

It should be noted that the laser scanning was not intended to be a replacement for professional engineering judgment, but rather supplemental to it. Several areas of potential concern were identified during the scanning and were subsequently reviewed in conjunction with the contractor during the project. Repairs were intelligently, not blindly, performed at these areas.

Laser scanning provides a safe and effective way for gathering repeatable data for future comparisons. Beyond the façade repair project, the point data could be used as a baseline for movement detection in the future. When a follow-up assessment is required to fulfill the local façade ordinance in five years, scanning can again be performed to assess increased movement at previously identified areas or new deviations at others.

While there are added costs associated with laser scanning, these could be offset in reduced up-front assessment fees through less required staging and fewer professional hours. In addition, as future repairs are recommended, the point data comparisons could result in more accurate construction documents, concentrated repairs where needed, and cost savings to the owner in avoiding unnecessary repairs and possible change orders.

HOW DOES WATER ALWAYS FIND A WAY IN?

While the issue related to masonry ties had been resolved, a second challenge awaited with the waterproofing detail at the top of the building. The mechanical chase projections that extended the height of the building were terminated with waterproofing membrane and precast concrete caps. A

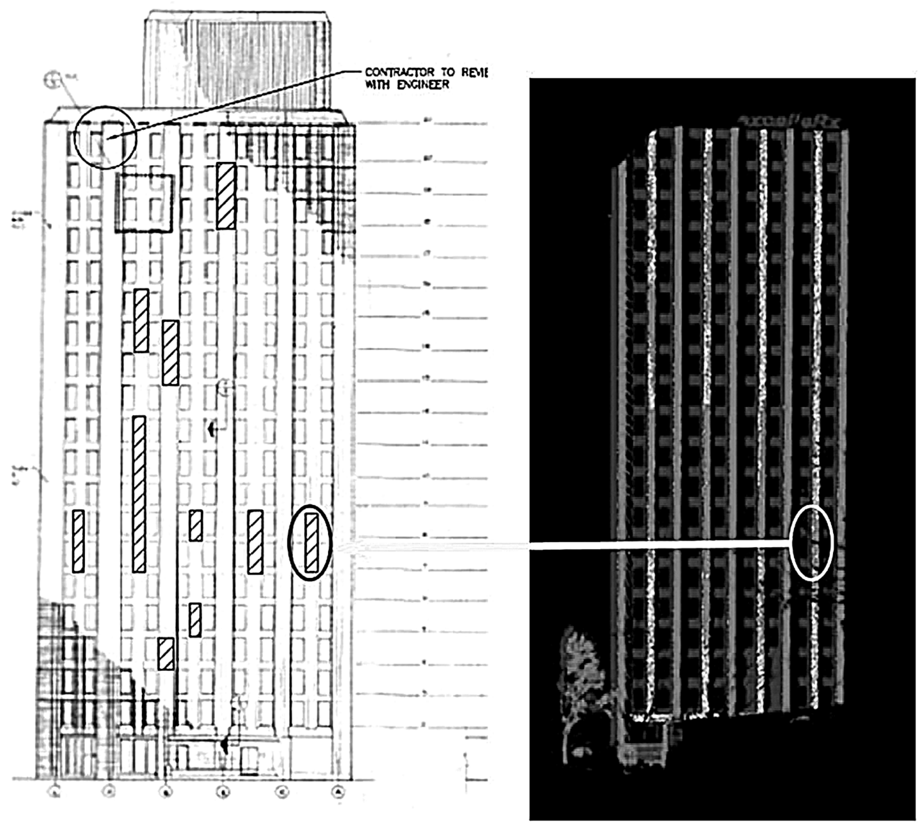

Photo 5 – Drawing provided to contractor (left) depicting retrofit tie installation locations (superimposed on original building elevation drawing). Scan image (right) showing variation from analysis plane. The circled area is just one example of locations that were out of plane and then transposed to the bid documents.

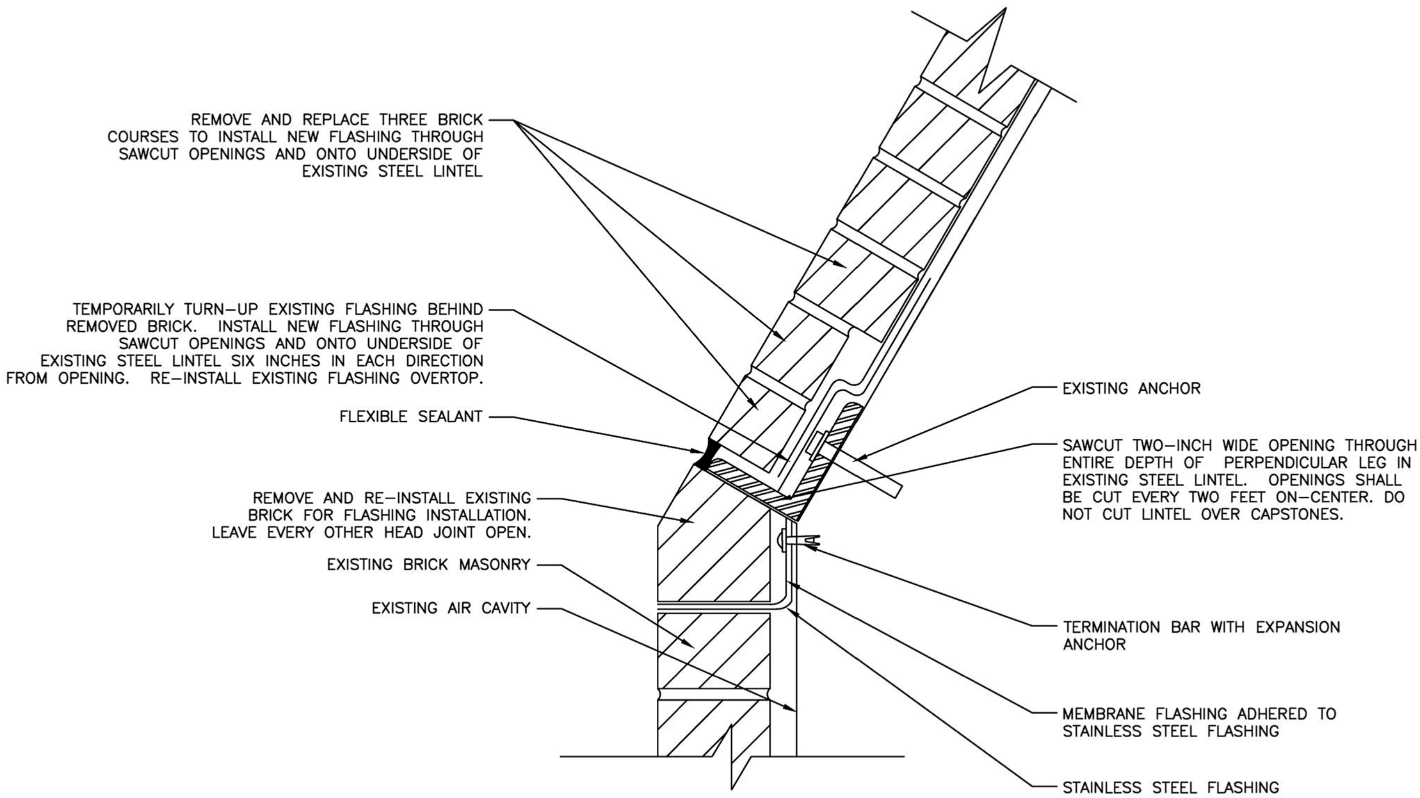

Photo 6 – Through-wall flashing detail at base of sloped wall.

sloped brick parapet wall extended from the caps toward the penthouse at the main roof. A wood wall was constructed on the backside of the sloped wall, creating a triangular-shaped cavity around the perimeter of the main roof. A shelf angle supported the sloped brick at the bottom of the inclined surface.

Over time, water infiltration and efflorescence issues arose at the top floor of the building. As part of the aforementioned repair project performed in the early 1990s, the lower eight brick courses of the sloped wall were removed above the shelf angle to install through-wall flashings. Flashing was also installed at a five-sided brick wall where the sloped wall transitioned to the vertical façade. Weep tubes were installed at this lower flashing. A similar detail was employed at projections, with the flashing extending below the setting bed and precast concrete caps.

Follow-up repairs were completed in 2000 at the north elevation only and consisted of masonry work at the sloped wall and further repairs at the precast caps. A similar scope of planned repairs was slated for the south elevation, but it was later deemed unnecessary and canceled. However, water and efflorescence issues continued to plague the top floor.

INFORMATION JUST OUT OF REACH

Due to the configuration of the building and projected areas, access to the sloped wall proved difficult. The swing stage was several feet away from the area in question, and observations were limited to visual only, not exploratory. Even if this area could have been accessed effectively, the swing stage was positioned nearly 270 feet in the air above crowded urban streets and an adjacent school. Removal of brick in a sufficient quantity for observation under these conditions could potentially be unsafe without overhead protection or closure of areas below, which was an undesirable scenario for the assessment. Putting these measures in place could result in double or triple the cost of the assessment.

Based on detail drawings available from original construction and past repairs, it appeared that sufficient information was available to specify waterproofing details to address ongoing water infiltration. The past scope of work was used as a starting point, as it appeared to be reasonably effective at the north elevation, though some issues remained.

Both the former and new designs called for removal and replacement of through-wall flashing at the base of the sloped wall, both on the steel angle and directly below at the five-sided transition brick. Several improvements in the design were made (*Photo 6*). Cell vents replaced weep tubes (which had frequently clogged), and were spaced at a greater frequency. A stainless steel flashing with a drip edge was specified for the transition brick in an effort to keep water away from the brick face below and address the presently unsupported, sagging condition of the membrane flashing within the brick cavity. Lastly, the shelf angle at the base of the sloped wall was tilted back such that any water traveling down the flashing behind the wall was effectively trapped at the lowest point of the angle. Holes were to be drilled into the base of the shelf angle to allow moisture behind the brick veneer to follow the new flashing down to the stainless steel termination below.

Constructability was of some concern, though previous repairs were completed in a similar setting. While multiple flashing sections and terminations were not ideal (including sealing each hole in the angle), options appeared limited due to existing conditions.

Photo 7 – Conditions at the base of the sloped wall created difficulties in addressing lintels and installing new through-wall flashing.

TWO HEADS ARE BETTER THAN ONE

As design gave way to bidding, contracting, and preconstruction activities, the time had come to put the specified detail into practice. Work began at the initial swing-stage drops, and the contractor naturally had questions related to work as points were clarified and expectations set in the field.

The repairs proceeded through a mock-up process but at a slower-than-desired pace due to a few issues (*Photo 7*). To maintain support for the sloped brick face above, through-wall flashing was being installed in short runs. The condition of the shelf angles was slightly worse than anticipated, with some loss of cross section, necessitating removal of several angle sections for replacement. The lintels that could remain were cleaned, primed, and painted in place, but drilling of holes for water to pass through was difficult for the crew to achieve under the circumstances.

Though the specified detail could be achieved, it became apparent that improvements could be made to speed production and create a better end result with fewer points of water entry. Collaboration with the contractor was going to be important for an effective solution.

Working as a team, an exchange of ideas led to several changes in the flashing approach and creation of a new mock-up. Since several angles required removal for replacement, a method to support the brick above was required. After removal of three courses of brick and the existing flashing and angle, the contractor placed small, temporary steel angles at the bottom of the remaining brick, which were in turn supported with clips fabricated to slide onto the shelf angle fasteners and abut the temporary angle above (*Photo 8*). The steel angle could now more easily be prepared, primed, and painted at the roof rather than in place.

With removal of the shelf angles, it became apparent that a one-piece flashing could be installed at the base of the sloped wall and extended below the five-sided brick and precast caps at the top of the mechanical chase projections (*Photo 9*). This was more ideal than the detailed two-piece flashing. Doing so also removed the need for holes in the bottom of the shelf angles and the associated waterproofing that would need to be performed at each opening. The amount of termination detailing was substantially

Photo 8 – Sloped brick supported with temporary steel and fabricated clips at angle fasteners.

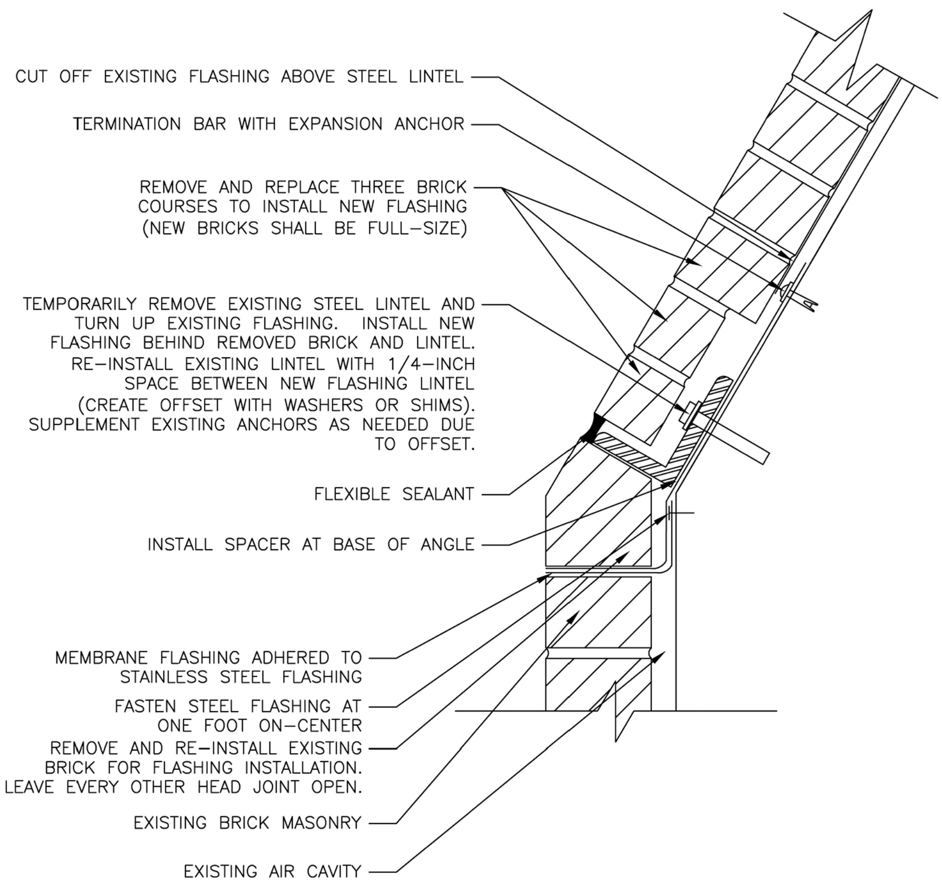

Photo 9 – Revised through-wall flashing detail following collaboration with contractor.

Photo 10 – Completed appearance at sloped wall, five-sided brick, and capstone. Contrast with soiled, unrepaired appearance below.

reduced, minimizing future risk for waterproofing failures.

Installing the through-wall flashing behind the shelf angles as opposed to over top maintained the previous dam condition, as water traveling down the flashing would encounter the top of the steel and eventually settle at the low point of the tilted angle. To address this, an offset was created between the flashing and angles by placing two washers on the fasteners prior to reinstallation of the angles. The minimal space could accommodate water flow behind the angle but was slender enough to prevent angle rotation.

END OF THE ROAD

Despite the issues encountered related to retrofit masonry ties and installation of an effective waterproofing detail at a problematic area, the project was completed successfully (*Photo 10*). Three-dimensional laser scanning led to a cost-effective effort for concentrated installation of retrofit masonry ties, and project team collaboration enhanced a difficult waterproofing detail while improving efficiency of installation. The project was completed in October of 2011, and there has been no reported water infiltration or the return of efflorescence at the areas addressed.