Building Envelope Solutions for the South Tower of the Milwaukee City Hall

Part 3


Figure 1: Milwaukee City Hall South Tower before construction.

By Peter M. Babaian, P.E., S.E., Francesco J. Spagna, P.E., and Brent A. Gabby, P.E.

This article is the final in a three-part series on the rehabilitation of the South Tower of the historic Milwaukee City Hall. Part 1, published in the November 2010 issue of this magazine, addressed the investigation of significant masonry cracking in the structure. Part 2, published in the January 2011 issue of this magazine, described the design of structural repairs to rectify this distress. Part 3 discusses the design for durability of the reconstructed masonry.

As discussed in Parts 1 and 2 of this series on the rehabilitation of Milwaukee City Hall's South Tower *(Figure 1)*, investigation uncovered significant structural problems in the masonry walls and piers related to gravity, moisture, and thermal effects, as well as significant structural steel corrosion. The design team developed a number of repairs to the structure including:

- A new concrete ring beam to resolve horizontal stresses at the 13th level.
- Cintec™ anchors to provide additional resistance to tensile stresses within the masonry.
- Pier reconstruction with composite masonry.
- Clock gable reconstruction.

Repair Philosophy

The analysis and design of the new structure for the South Tower presented an opportunity to change the existing mass masonry wall of the South Tower into a cavity wall from the 13th level to the lantern at the top of the building. Mass masonry buildings generally do not include backup waterproofing and generally do not include flashings. Instead, they rely on their mass to absorb water and store it within the masonry of the exterior walls where it can later dry after rainstorms cease. Contemporary cavity wall systems function on the principal that water will bypass the exterior cladding. The water is then managed via backup waterproofing and drained from the building envelope system with flashings that protrude from the exterior face of the building.

The introduction of protruding flashings on historic buildings is always met with controversy. Milwaukee City Hall is a National Registered Landmark, and repairs could not alter the original appearance of the building. This presented challenges in rebuilding the masonry to match the original aesthetic and locating flashings where they would be concealed in shadow lines or other inconspicuous locations. Another major challenge was designing supports for large, ornate terra cotta pieces.

The decision to convert to a cavity wall system provided several benefits:

- Recladding allowed for a conversion of the mass masonry wall system to a cavity wall system, which handles water more efficiently. The introduction of a reliable waterproofing membrane behind the masonry veneer with flashings at multiple levels and locations provided a means to continuously drain water from the walls; this provided better protection to the structural steel from moisture migration and subsequently eliminated the risk of corrosion of steel due to prolonged exposure to moisture.
- Prior to repairs, the building had a history of falling hazards resulting from masonry spalls. Elimination of the solid masonry wall also significantly reduced the long-term risk of potential falling hazards by decreasing the size of the masonry "reservoir" that could absorb water. In a cavity wall system, only the veneer can absorb water; the masonry behind the waterproofing layer remains dry. Therefore, the conversion to a cavity wall system reduces the overall absorption of the wall. In addition, the veneer has a greater ability to dry out in comparison to a mass

masonry wall. All of these factors reduce the likelihood of freeze-thaw damage and resultant masonry spalls.

- The large gravity loads from the clock gables caused significant cracking in the masonry. Converting from mass masonry walls to cavity walls reduced the overall gravity load on the upper levels of the South Tower and eliminated the potential for cracking.

Exterior Wall Details

Design Intent

To change the wall system from load-bearing masonry to cavity wall construction, the design team carefully located new, epoxy-anchored relieving angles on the South Tower facades, typically at locations where the masonry stepped out of plane. The location of relieving angles is shown in *Figure 2*. In cavity wall systems, flashings are typically used at relieving angle locations to drain water from the wall system. By locating the relieving angles at steps in the masonry, the flashing drip edge was typically hidden in a shadow line and difficult to detect. This allowed the design team to introduce the flashings without altering the appearance of the building.

The design team developed extensive details for the reconstruction of the load-bearing masonry walls as cavity walls. Among others, these details included anchorage for the relieving angles, gravity support anchor systems for large pieces of terra cotta (large lion heads weighed upwards of 300 lbs each), lateral load anchors for individual terra cotta pieces, reinforcement for new masonry, backup waterproofing, and metal flashings. Through such detailing, the design team was able to convey to the contractor how to integrate the flashing and anchorage to prevent water from penetrating into the backup structure. *Figure 3* shows one such detail at the top of the clock gable where the terra cotta is curved. The design detail shows how each terra cotta piece is anchored and flashed. This was common throughout the design documents and necessary to clearly define the design intent.

The design team included performance specifications, requiring the contractor to engage an engineer to provide final design details for terra cotta anchorage. This recognized that the contractor may not reconstruct the exterior walls in the same sequence that the design team assumed, which turned out to be the case on this project. The design team required all anchorage shop drawings to also show the required

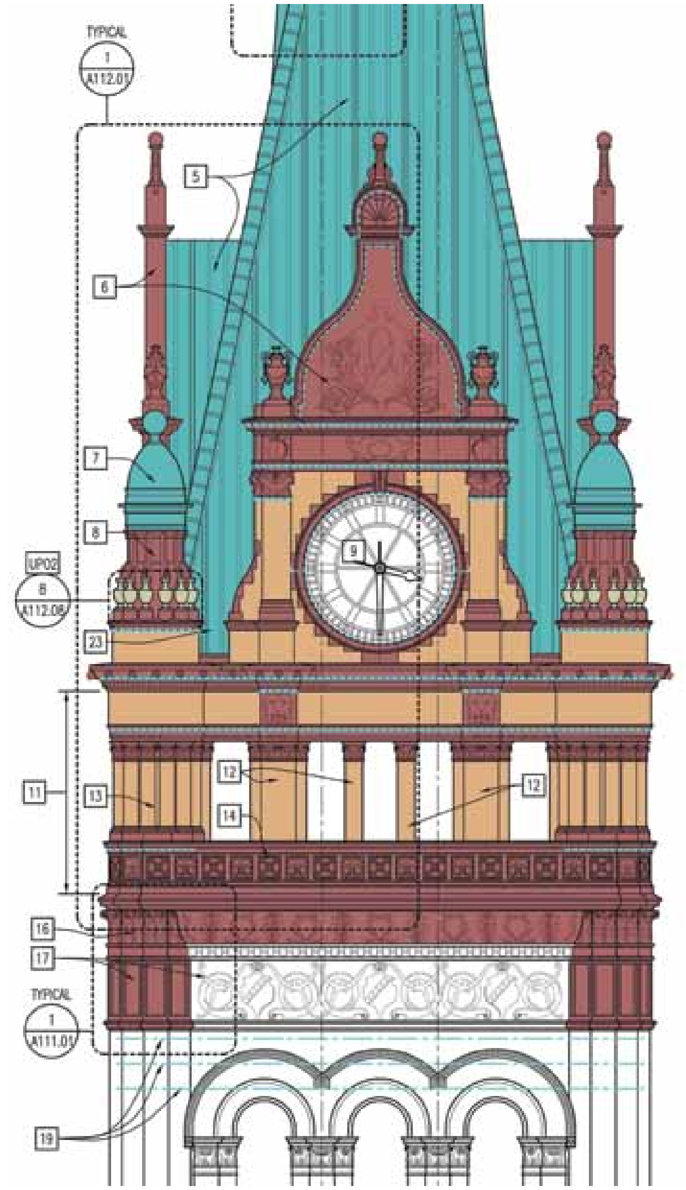

Figure 2: Scope of work elevation for the South Tower. New relieving angles are located at all new flashing locations (shown as horizontal blue dashed lines).

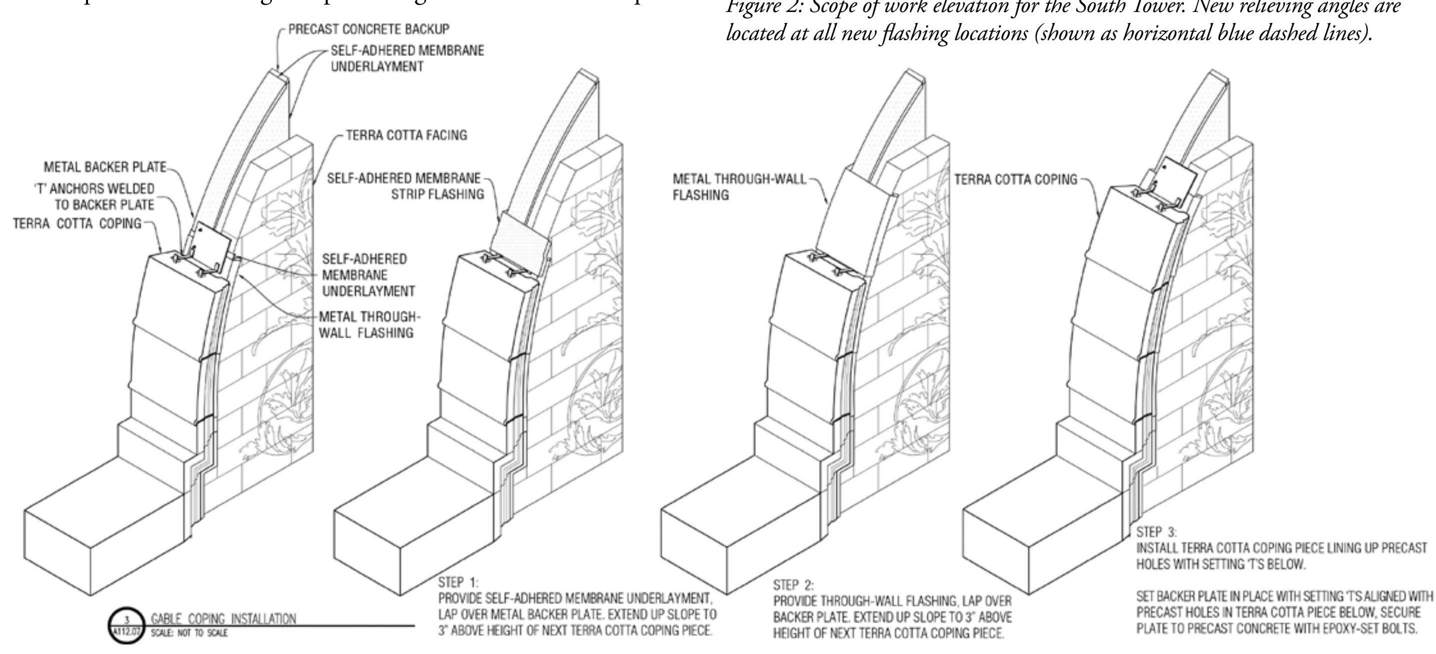

Figure 3: Sequence for installation of waterproofing, flashing, and terra cotta cladding.

Figure 4: Typical terra cotta cladding with roll caps found throughout the structure.

backup waterproofing and flashing, to verify that the end condition would meet the design intent and provide the appropriate protection to the backup structure.

Materials

The masonry at the South Tower is a mix of brick and terra cotta. The terra cotta proved to be a very difficult material to match for a variety of reasons, including color, texture, strength, durability, and complexity of shapes. Extensive use of mockups allowed the design team to continuously evaluate the quality of the materials and the ability to match the existing shapes and sizes. Terra cotta manufacturing is a time-consuming and labor-intensive process. Lead times on the terra cotta were upwards of six months. To further complicate the process, most of the existing terra cotta had roll caps that needed to be replicated. Roll caps are a raised profile along the edge of one piece of terra cotta that extends over the adjacent piece of terra cotta, thus hiding the skyward facing mortar joint between two terra cotta pieces *(Figure 4)*. The most common manufacturing process for terra cotta is to extrude pieces along their length. Due to the presence of the roll caps, most of the non-decorative terra cotta on the project could not be extruded. Instead, almost all terra cotta on the South Tower needed to be cast into molds by hand.

Quality control for the terra cotta was maintained for the remainder of the project. Recognizing that the terra cotta would be more exposed to the weather than most of the other masonry features, due to its prominence on the facade and its constant projecting, the design team carefully inspected the terra cotta for cracks and other defects that might compromise its long-term durability. This inspection was in addition to the quality control completed by the manufacturer before shipping. The increased quality control effort often resulted in discussions over whether a crack was repairable, too wide, or compromised the quality of the piece. Questionable pieces were either remade or repaired, until the concerns of the design team and the owner were completely addressed.

Milwaukee City Hall South Tower after construction. Courtesty of Eric Oxendorf.

Construction Administration

Engberg Anderson, the lead architect, was the point of contact for the contractor. All submittals, product information, and shop drawings were directed through Engberg Anderson. However, almost all submittals required reviews by multiple members of the design team. Before construction started, the design team developed a list of expected submittals and identified primary, secondary, and tertiary reviewers for them. Submittals could not be returned until comments from all reviewers had been supplied. The design team selected this approach because the details on this project required integrated shop drawings that often included structural and architectural elements in one drawing. The process forced the contractor to think through the complete construction process and verify that the submitted details would meet the design intent. The design team went through the same process when reviewing the submittals. The result was identifying potential problems and correcting them before they were constructed on the building, which saved time and money for all involved.

As with any large project, constant field supervision was critical. All members of the design team had a significant presence onsite to verify construction in accordance with the construction documents. This onsite presence allowed many issues to be resolved rather quickly in the job trailer rather than languishing in correspondence. Twice per month, the design team conducted project walkthroughs together so all aspects of construction were reviewed at once and any cross-disciplinary issues could be identified. This provided engineers and architects with the opportunity to look beyond their specialized area and understand the impact of the decisions they make on the other disciplines. As the project progressed, this walkthrough was reduced to once per month. Site visit reports kept a running list of work items to be addressed by the contractor and were reviewed onsite with each site visit to track progress. This significantly simplified the punch list process at the end of the project.

Conclusion

The Milwaukee City Hall reconstruction project provided the opportunity to restore one of America's finest examples of German Revival Renaissance architecture from over 100 years ago. The decisions made by the design team, especially the decoupling of the envelope from structure at the South Tower, were critical to provide the basis of successful performance for the next 100 years.▪

*Peter M. Babaian, P.E., S.E., is a Senior Project Manager at Simpson Gumpertz & Heger Inc. He can be reached at **pmbabaian@sgh.com**.*

*Francesco J. Spagna, P.E., is a Senior Project Manager at Simpson Gumpertz & Heger Inc. He can be reached at **fjspagna@sgh.com**.*

*Brent Gabby, P.E., is a Senior Principal at Simpson Gumpertz & Heger Inc. He can be reached at **bagabby@sgh.com**.*

Figures 1-4 courtesy of Simpson Gumpertz & Heger Inc. (SGH)