AUTHENTICITY vs. STABILITY:
CHALLENGES in RESTORING THE SUN BUILDING

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ABSTRACT

The Lowell Sun Building is a landmark in Lowell, MA, and currently serves as an elderly residential building. It was the former Lowell Sun headquarters, a newspaper agency founded in 1878. The 10-story, steel-framed, exterior masonry wall building was built in 1914. Thornton Tomasetti, Inc. (TT) will present the challenges of restoring the historic masonry façade, satisfying the local landmarks commission, and repairing the deteriorated structural framing that was embedded within the masonry. We will also discuss our investigation strategy, surprises uncovered during the investigation, and how to manage the client’s expectations—especially when the extent of the structural framing deterioration is unknown prior to masonry removal.

SPEAKERS

Charu Chaudhry, LEED AP — Thornton Tomasetti, Inc.

Charu Chaudhry, senior project director at TT, graduated as an architect and earned her MS in historic preservation from the University of Pennsylvania. She is a member of the International Scientific Committee on Earthen Architectural Heritage (ICOMOS-ISCEAH) and of the Sustainable Preservation Technical Committee of the Association of Preservation Technology International. She was awarded a Charles Wallace Conservation Fellowship for conservation training in advanced applications of lime technology and stone conservation in the UK and a US-ICOMOS internship in the U.S.

Lisa Davey, PE — Thornton Tomasetti, Inc.

Lisa Davey, vice president of TT, applies her 18 years of experience in structural engineering analysis, design, investigation, and litigation support services to a myriad of project types. She is equally at ease with the renovation and expansion of historic structures as with the design of new structures. Davey is especially adept at forensic investigations and has provided litigation support for delay, standard of care, and failure claims, as well as for the largest construction claim in UK legal history.
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ABSTRACT

The steel skeleton frame was introduced in masonry buildings in the United States in the late 1800s. Steel members and the connections were generally not protected against moisture, and most times, the outer finish of the building envelope provided the sole protection against water infiltration and the electrochemical process of corrosion. Prolonged water infiltration through the veneer, in the absence of flashings or waterproof coatings, triggered corrosion of the steel members, leading to heavy rust buildup and section loss. As the rust builds up, it pushes against large portions of masonry elements wrapping the steel member. Due to this considerable pressure, cracks and spalls result in the exterior masonry, threatening the life and safety of the public at large.

This paper will present the challenges in the restoration and structural stabilization of the Sun Building in Lowell, Massachusetts. The building is a local landmark, and the project team worked with the City of Lowell Landmark Commission to preserve the intent and aesthetics of the original design. The project team identified bulging and loose masonry areas due to corrosion of underlying steel that required immediate stabilization, and developed construction documents for complete restoration. The restoration included repair and replacement of cracked masonry, replacement of lintels and slate window-sills, reinforcement of masonry piers, and full repointing. The structural rehabilitation required the reinforcement of several spandrel beams and exterior columns due to years of water infiltration.

INTRODUCTION

The nineteenth century witnessed the introduction of steel in the construction industry in the United States. This led to the development of new structural schemes to support taller buildings. As a type, steel-framed building evolved over many decades, from the 1880s through World War I.\(^1\)

The transition from traditional load-bearing masonry and wood joist floors or vaults to independent steel frames took from approximately 1870 to 1905.\(^2\)

However, even up to the 1940s, the combination of steel frames and masonry remained the most common solution for urban buildings. The virtual disappearance of masonry-bearing wall construction for tall buildings and the dominance of masonry-clad steel-frame construction for most low- to high-rise construction from the 1880s through the 1930s is testament to the seeming success of the evolving designs for masonry-clad, steel-framed buildings. But the design refinements that enabled the cladding of those buildings with thinner wall assemblies also introduced issues with long-term consequences for the structural steel.

The stylistic expressions of the building form, materials, and construction methods were also constantly changing, but one aspect remained mostly unchanged: the standard practice of packing masonry tightly around the columns so that the steel would be completely encased in a monolithic masonry mass. Although the alkaline environment of the Portland cement provided the passivation to the embedded steel members, which acted as a natural barrier against corrosion, it is not realistic to expect zero water intrusion within the brick masonry. Therefore, the steel will eventually experience the electrochemical processes of corrosion. Another reason for practicing this type of construction was to achieve fireproofing of the steel members.\(^3\)

The potential scale of the issues associated with masonry-clad, steel-frame buildings is daunting because there is growing evidence that steel and its masonry cladding are inherently incompatible and the source of many façade issues.

THE SUN BUILDING

The Lowell Sun building was designed by architect Clarence Blackhall and constructed in 1914 in Lowell, Massachusetts. Located at the corner of Merrimack and Prescott Streets, it is a 10-story, steel-framed building with 4-inch-thick concrete floor slabs and exterior masonry walls. The building served as the headquarters for the Lowell Sun newspaper operation from 1914 to 2001.
1914 to 1976. When constructed, the Sun building was the tallest building in the city of Lowell, standing at 114 feet tall, and was nicknamed “the skyscraper.” It remained the tallest building in the city until an 18-story dormitory built for the Lowell Technology Institute stole the title in 1972. The city of Lowell became known as the cradle of the American Industrial Revolution, and many of the city’s historic sites have been preserved by the National Park Service. In 1976, the building was sold and converted to a senior residential building.

The building exterior consists primarily of a brick masonry façade with wood-framed punched windows (Photo 1). The lower two stories are accentuated with stone cladding, and storefronts are provided on the first floor. Stone cornice fronts accent the punched windows of the second-floor and tenth-floor levels. The primary structure of the building is steel framing embedded in three-wythe brick masonry. The exterior wythe is generally self-supporting with minimal header courses bonding it back to the backup brick. All primary steel framing members are 4 to 8 inches from the exterior face of the masonry.Lintels are hung at every level from tabs riveted to the bottom flange of the spandrel beam, which support the exterior wythe. The lintels and relieving angles are within 1 inch of the exterior surface. The two interior wythes of brick sit on the concrete slab and spandrel beam, and the exterior wythe is supported by the hung lintel. The masonry is tight to the underside of the spandrel beam, and loads from the masonry above the beam are passed through to the masonry wall section below. In other words, the interior wythes of brick are load-bearing and support their own weight as well as a portion of the perimeter floor slab loads. Additionally, a fire escape staircase fronts the Prescott Street elevation.

IDENTIFYING THE PROBLEM
The current exterior restoration project was prompted by water leakage and the deterioration of elements of the façade, including the masonry walls. A critical requirement in any preservation project is the need to establish and assess the structural condition, as well as determine the existing condition of the building exterior. This assessment determines the need, type, and extent of the repair.

The masonry condition was assessed by visual and hands-on inspection. Probes were conducted at localized areas to view the condition of the columns, spandrels, lintels, sills, and the general construction of
the exterior wall prior to the preparation of contract documents. Probe locations were identified at areas with the most severe masonry conditions, such as at those with cracking or bulging (Photos 2, 3, and 4).

The assessment revealed that the primary types of distress were related to large-scale cracking, bulging, and detachment of brick and stone masonry and mortar deterioration. The masonry deterioration in turn contributed to the structural steel corrosion of the columns and spandrel beams. The lintels were corroded and deformed, and there was significant section loss. There was no evidence of flashing or a waterproof membrane within this assembly. The most severely deteriorated masonry was predominately on the Merrimack and Prescott Street elevations. The northwest corner of the Merrimack Street elevation had large vertical cracks and bulging masonry between the tenth floor and the roof level. The northeast corner of the Merrimack Street elevation also had a large vertical crack through the stone at the base of the building and continued several stories into the brick masonry above. The wooden window frames were original to the building, and many had advanced wood decay. Slate windowsills were loose and slipping out from under the decaying windows, as there was no mechanical anchorage between the sills and the masonry or window frame. The fire escape staircase was severely corroded as well, and its anchors were pulling out of the masonry.

The condition of the steel structure behind the masonry varied, depending on the condition of the masonry. We discovered that many of the lintels had been sealed with sealant, cutting off the natural exit point of any moisture within the wall. The water remained trapped on the lintel, flowed to the ends of the lintels, and ran down the columns, causing corrosion of the lintels and the steel columns. Rust is an iron oxide that forms on steel when it corrodes, due to exposure to air and water over a long period of time. As the steel rusts, it expands to approximately six times the volume of the base material. This means that ¼ inch of steel is equivalent to approximately ¾-inch-thick rust scale.

The iron oxide expansion applies pressure on the surrounding masonry, causing it to crack and displace away from the supporting structure (Photos 5 and 6). This phenomenon is commonly referred to as rust jacking. This process is a vicious cycle because the cracked masonry allows greater water infiltration, which accelerates corrosion, increases pressure on the masonry, and further widens cracks. Although this process is slow, it is not self-limiting; and
without intervention, it can continue until the steel is completely corroded and the masonry is completely detached. The challenge was to develop new details within the historic masonry to stop the vicious cycle of deterioration.

Thornton Tomasetti, Inc. (TT) observed cracked and displaced masonry in the masonry panels above the lintels. This cracking caused water to seep to the spandrel beams, corroding these members as well.

THE CHALLENGE

A preservation professional is frequently faced with the problem of balancing the structural stability and the operating requirements of the historic masonry within the framework of the guidelines established by the National Parks Service. The guidelines suggest that the modifications to the historic masonry should be minimal, and choosing the most appropriate treatment for a building requires careful decision-making about a building’s historical significance and service conditions. Authenticity criteria are often misunderstood in the field by creating exact replicas of the original construction. The materials, construction methods and systems, and the requirements to achieve stability need to be understood to create durability within the historic masonry system. The challenge of the project was to execute the repair that would perform well and match the appearance of the original, existing materials.

To achieve that, the preservation professional must understand the strength of the existing masonry and steel in order to assess compatibility of repair materials with the original materials. Chemical and strength testing can be used to determine the composition of the masonry, mortar, and steel, as well as the compressive and yield strengths of these materials. Since the impact of intervention on the authenticity and stability of a structure can vary from minor to drastic, knowledge of the existing material properties helps to ensure proper repair materials and methods are selected. The primary objective of the repairs was to use materials and techniques that would be sympathetic to the existing façade and perform well. Finally, repair design needed to meet the installation tolerances used in the original construction. The repair philosophy was to maintain the authenticity of the original construction methods and to improve the performance by repairing and replacing steel while introducing flashings, brick ties, and expansion joints to accommodate for thermal movement of the building.

INTERVENTION

The primary agent causing the rust formation was water entering through the joints and cresting across the top of the spandrel beams. Once the water breached the cresting, some was channeled down the columns because of the beam-to-column connections. It was clear that the build-
ing structure and envelope both required significant corrective and mitigative interventions. The goal of the project was to repair the exterior masonry, address the deterioration of other exterior elements of the façade, and reduce the rate of future deterioration of exterior elements by reducing the rate of moisture infiltration into the façade.

**STRUCTURAL COLUMNS**

The perimeter building columns were either rolled I-sections or riveted built-up sections with a center web plate and angles used as the flanges. The perimeter columns were generally spaced 11 to 13 feet on center. The spandrel beams were 8- to 10-in.-deep channel sections with riveted seat connections to the web of the exterior columns.

The northwest and northeast corner columns on the Merrimack Street elevation exhibited the most severe corrosion of the entire building. The northwest corner was a built-up steel column 8 inches deep. The web plate was originally between ¼ and ⅜ in. thick, with a web thickness of approximately ¼ in. thick. The exterior flange of the column was corroded to the point that it was paper-thin and, in many areas, crumbled (Photos 7 and 8). The web also had extensive corrosion and section loss. The interior column flange, which was still tightly packed within the interior masonry, was relatively intact, with only minor rust scaling. The column required reinforcement from the roof level to just below the fifth-floor level. The main goal of the column repair was to replace the area of steel lost to rust corrosion such that the column is able to support the intended load and prevent further oxidation of the steel. The rust scale was removed down to bare, sound steel and painted with a corrosion-inhibiting coating.

The west side of the northwest column flange was so severely corroded that most of the flange was missing or too thin to weld any type of flange reinforcement plate (Photos 9 and 10). The web of the column also had substantial section loss, making much of it not viable for welding, and the riveting of the angle flanges further complicated access for welding.

A repair detail was developed that placed a 1½-in.-thick steel plate with a yield strength of 50 ksi (original steel has a yield strength of 36 ksi) on either side of the web (Figure 1). Along the east side of the column, the reinforcement plate was welded to the front and back flange of the column. The plate was interrupted at each spandrel beam location. The reinforcement plate on the west side of the column was welded to the rear flange and to a new angle welded directly to the existing column web. The plate ran continuous the entire length of the column because no beams framed into this side of the column. A 1-in.-diameter A490 slip-critical bolt was drilled through the two new reinforcement plates and the existing column web at 3½ ft. o.c. The bolt was threaded through the
plates and fully tensioned against a 2-in.-diameter, double, extra-strong pipe between the reinforcement plates. The clamping action of the bolts helped the entire cross-section work together and transfer shear into the new reinforcement.

The northeast column on the Merrimack Street elevation was a built-up section 8 in. deep between the ninth floor and roof. The column changed to a rolled wide-flange section—also 8 in. deep—below the ninth-floor level (Photo 11). Similar to the northwest corner column, this particular column exhibited extensive rust scale, delamination, and section loss. Spandrel beams framed into the web of the column parallel to Merrimack Street and into the flange parallel to Prescott Street.

The decision was made to remove and replace the existing column from just below the roof spandrel beam to approximately 5 ft. above the fifth floor due to the extent of section loss and severity of the corrosion (Photo 12). The new column was a W8x35 with a yield strength of 50 ksi. Shoring was placed on the interior of the building under the spandrel beams from the roof to the basement level. The spandrel beams were cut free from the existing column, and the existing column was removed and replaced in sections. A cover plate was welded to the outside flange of the column from the fifth to the third floors and the column. The existing spandrel beams were reattached to the new column with welded shear-tab connections. The remaining portions of the existing column and any section of the spandrel beams that were exposed during the work were

Figure 1 – Northwest column reinforcement detail.
cleaned of rust and painted with a corrosion-inhibiting coating.

Several spandrel beams adjacent to the northwest and northeast columns, along the Merrimack Street elevation, were found to have significant corrosion and section loss. As the lintels rusted, it caused rust jacking and cracking of the masonry around the spandrel beams (Photo 13). This allowed water to infiltrate the masonry and reach the spandrel beam. The spandrel beams exhibited corrosion of the bottom flange and the lower part of the web. Reinforcement of these beams included welding a custom built-up channel section to the web of the existing spandrel beam. Hang tabs for the new lintels were then connected to the new channel flange.

BUILDING ENVELOPE

Unit Masonry and Stone Assemblies

The original wall assembly did not include any metal anchors or ties to attach the masonry back to steel. The inner wythes of masonry formed a solid masonry mass around the steel columns. The exterior wythe ran past the face of the spandrel beams with minimal header courses connecting it back to the backup brick. Large sections of brick at the column locations throughout the façades were bulging and completely detached.

These full-height sections of brick needed to be removed and rebuilt. All the replacement brick received stainless-steel masonry repair anchors to compensate for the lack of header courses. The column locations received screen-tube-type repair-adhesive anchors. Other locations that needed stabilization of the brick veneer (driven-in anchors designed to be installed in drilled holes and reliance on screw effect rather than adhesive) were used to secure anchors to backup and veneer.

The walls were to be rebuilt using new brick selected and blended to match the original as closely as possible. Finding the
right combination of the veneer and backup brick was a challenge and required numerous sample panels from the mason. The best match of the brick had to be cut in the field to match the original size. Though not an ideal solution, this route was chosen to stay within the dimensional tolerances of the historic masonry brick coursing. The rebuilding of brick masonry matched the original profiles’ coursing but incorporated brick ties to attach the brick to backup steel or brick.

**Provision of Thermal Movement**

There were no provisions in the original construction for relief of thermal or lateral stresses in the masonry cladding. The building exhibited vertical cracks at the corner column locations. In order to provide the allowance for thermal movement, all the rebuilt masonry at the corner column locations received expansion joints at the intersection of the new and historic brick masonry.

**Flashings and Trim**

The original construction of the building envelope was reasonably well-detailed and executed for its period of construction and the materials available at that time, but it was clear that a waterproofing and flashing system was needed between the cresting and the steel beams and lintels to eliminate the primary entry of water as much as possible. It is unrealistic to think that the restoration of the building would lead to elimination of moisture from the masonry. Moisture management became an important aspect of the restoration work. A copper-laminated flashing was deemed suitable for the masonry. Copper sheets, bonded with asphalt between two layers of glass-fiber cloth set in adhesive, were used where flashing was fully concealed in masonry; only the metal drip edge was made visible at the mortar joints (*Photo 14*). At lintels and shelf angles inside the masonry, flashing was extended a minimum of 6 inches into masonry at each end to form end dams.

**CONCLUSIONS**

Although the strategy of masonry removal, steel cleaning, and reinstallation of masonry has been a common practice for many years, there remains a lingering question as to whether the system where masonry tightly packed to the steel members is flawed. Pre-war buildings have inherent problems of a larger scale and larger quantity than any buildings of an earlier era. The façade failures and distresses observed in those buildings are characteristic of the way they were built.¹

The late nineteenth and early twentieth centuries were marked by the changing function of masonry. The transition period from masonry-bearing wall buildings to steel-framed curtain wall buildings left a legacy of buildings with widely varying conditions for both masonry attachment and steel-member corrosion protection that pose durability, maintenance, and repair challenges.

Regular maintenance to keep water out and regular inspections under municipal laws or owner direction are important actions for building longevity and public safety. Where repairs are required, creative solutions can be cost-effective compared to other approaches. ²

**REFERENCES**