APPLICATOR

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FEATURE

Figure 1. Marquette building constructed in 1895 with a one bay addition in 1905. View following completion of repair work.

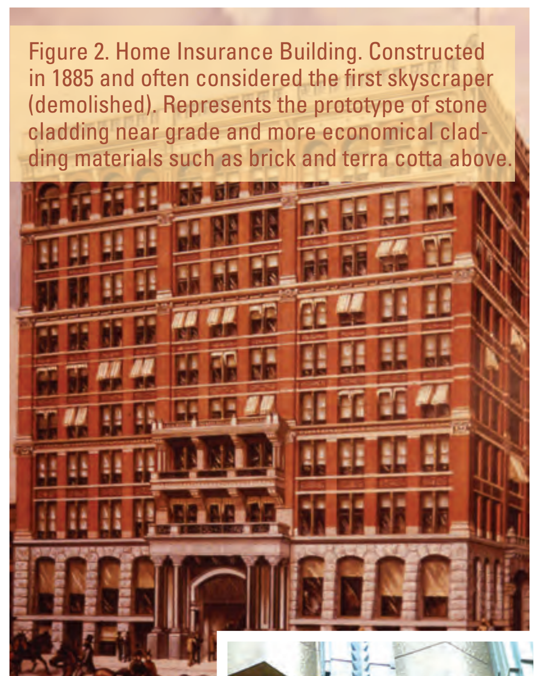

Figure 2. Home Insurance Building. Constructed in 1885 and often considered the first skyscraper (demolished). Represents the prototype of stone cladding near grade and more economical cladding materials such as brick and terra cotta above.

Terra Cotta Skyscrapers

By Edward Gerns and Anita Simon

Following the 1871 Chicago Fire, building construction changed dramatically as a result of several factors including availability of inexpensive rolled metal shapes, improved elevator technology, increased urban density, and the desire to develop “fireproof” buildings. Stone and brick had been used extensively for centuries to construct buildings. The development of the skeleton frame structural system was possible due to the increased availability of structural metals in the mid-19th century. The skeleton frame enabled cladding systems to be lighter, resulting in the decreased necessity for mass masonry solely for structural support. Several new uses of metal framing components, both for the primary building structure and for cladding systems, were developed. With this evolution came new flexibility for veneer cladding options, particularly for use of architectural terra cotta.

Figured 3. Representative example of polychrome and metallic glazed terra cotta popularized in the 1920s.

Figure 4. Repairs in pregress at the Marquette building.

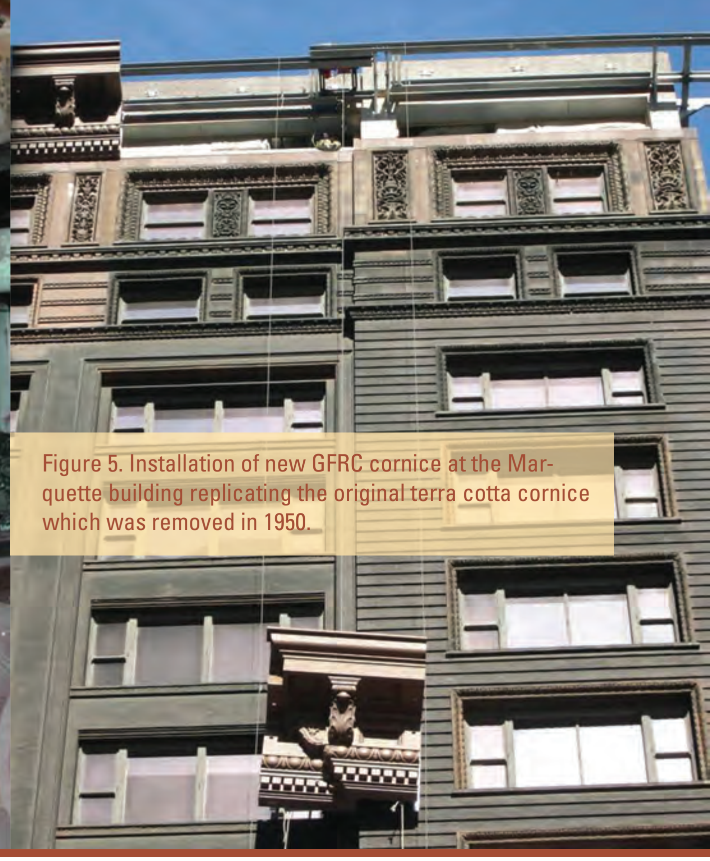

Figure 5. Installation of new GFRC cornice at the Marquette building replicating the original terra cotta cornice which was removed in 1950.

The use of terra cotta for cladding was generally limited in the United States until around 1890. Around this time, terra cotta became favored as a cost effective alternative to stone for its fire resistance, durability, aesthetic appearance, and lightweight properties. Chicago experienced rapid growth during this time period and subsequently developed the reputation as the origin city of today's skyscraper, many of which incorporated terra cotta cladding. In the Midwest, there were 10 terra cotta manufacturing companies that were founded between 1868 and 1912. Chicago therefore provides excellent examples of the evolution of skyscraper technology and use of terra cotta cladding for nearly 150 years. The design evolution and long-term performance characteristics of terra cotta will be reviewed with representative Chicago buildings constructed in the 1890s through the 1920s.

Prior to the 1930s, Chicago skyscrapers were typically clad with a combination of masonry materials including stone, brick, and terra cotta. Since one of the early uses of terra cotta was an economical alternative for stone, the glaze developed during its manufacture was intended to replicate stone. Terra cotta was now being used on the upper floors of the new taller building (Figure 2). Visually, the terra cotta had the same appearance as stone, but was more economical to produce and the lightweight characteristic of terra cotta made for easier installation. A system of metal dowels, J-hooks, wire ties, and shelf angles enabled terra cotta veneers to be attached to the primary building structure with its own independent system. Stylistically, enhancing the appearance of facades was simplified through the selection of ornamental motifs that were available in company catalogs of mass produced terra cotta units.

As the popularity of terra cotta increased, vitrified (i.e. having the appearance of smooth glass, similar to fired ceramics) glazes were used to create more dramatic architectural expressions with white glazed units. The zenith of terra cotta corresponded to the increased popularity of Art Deco and the increased use of polychrome (i.e. containing more than one color; either with speckles of one or more colors over a solid base color; or color applied to areas of high relief to accentuate ornamental pieces on units; or a blending of multiple individually-colored units throughout entire facades) and metallic finishes (Figure 3) (metallic finishes incorporated elements such as silver and gold in the firing process, creating an appearance similar to gilding). Dramatic colors used in combination with Art Deco motifs created innovative architectural expressions. However, by around 1930, construction of terra cotta-clad skyscrapers in Chicago was very limited. While numerous terra cotta manufacturers existed in the Chicago area prior to 1930, by 1950 almost all were out of business.

As these early skyscrapers began to age, the need to maintain and repair these buildings became important for the survival of this archetype. Beginning around 1950, deterioration of some elements of the terra cotta cladding assembly became inevitable. The deleterious effects of time emerged in the confluence of the carbonation of the mortar within the wall system, the consumption of the zinc coating on galvanized steel components, the deterioration of lead primer after 60 years of service life, and effects of expansive forces of corrosion by-product due to the proximity of terra cotta in relation to supporting steel elements. In addition, ornamental terra cotta units often have recessed mortar joints that are difficult to access for pointing maintenance, or necessary overall maintenance was simply deferred. Consequently, water intrusion through joints became a common threat to the integrity of the cladding systems. In combination, these conditions were directly related to the increased and

Figure 6. Santa Fe building constructed in 1904.

irreversible corrosion of embedded steel members and anchors due to exposure to moisture. The resulting corrosion led to corrosion scale build-up and forces that caused damage to the terra cotta and other masonry adjacent to metal anchorage or support materials. These mechanisms, in combination with the increase popularity of the modern architectural aesthetic by world renowned architects such as Mies Van Der Rohe, led to the demise of many of the early masonry clad skyscrapers in Chicago. If the buildings weren't demolished in the name of progress, many had significant decorative elements such as cornices and watertables which were removed due to falling masonry. The following buildings represent the range of conditions and repair approaches which are frequently encountered when repairing historic masonry skyscrapers in Chicago and elsewhere.

1890S SLIP GLAZED TERRA COTTA SKYSCRAPER

One of the earliest of the masonry-clad skyscrapers was designed by architects Holabird and Roche in 1894. The 17-story Marquette building is considered one of the first high-rise buildings constructed with a steel frame structural system and a classic example of the Chicago School aesthetic (Figure 1). The facade of the building is notable for its expression of the underlying steel frame structure. Large window openings extend across nearly the entire width of the structural bays and at typical floors. Continuous projecting brick piers and recessed brick spandrels further emphasize the structural grid. The ornamental street-facing facades of the building include the exterior perimeter walls of the entire south and east facades and a portion of the north facade at the northeast corner of the building. These ornamental facades are clad with a slip glazed (a glaze made mostly or entirely from clays and low fusion paint which has a limited color palette of tan, browns, and black) brown terra cotta at the 1st through 3rd, 15th and 16th floors and are clad with brickwork at the 4th through 14th floors. The masonry cladding is supported vertically by the shelf angles at each floor level. Terra cotta masonry above windows is supported by horizontal steel dowels that are threaded through holes in the webs of the terra cotta units and through J-hooks that are hung from the steel shelf angles above.

The 17th floor of the main facades of the building was originally clad with a large, projecting terra cotta cornice. In 1950, this cornice was removed and replaced with a fl at brick wall. Investigations of the facade found that with the exception of the distress resulting from the removal of the cornice and subsequent poor detailing at the new 17th floor cladding, the majority of the embedded steel was in remarkably good condition. In many instances the original lead based primer remained intact. Many possible explanations could explain the lack of distress. Mortar joints were typically less than 1/8 inch wide, known as butter joints, and the steel which supported the terra cotta tended to be embedded deeper in the wall and typically encapsulated within the backup brickwork, resulting in a configuration that was less problematic relative to areas with greater exposure to cyclic moisture.

Over the course of a 10 year process, numerous exterior restoration projects have been performed on the building. The most significant distress was found at the interface between the reconstructed 17th floor wall system and the original terra cotta cladding at the 16th floor. The reconfiguration of this interface detail resulted in increased moisture infiltration and subsequent corrosion of the embedded steel and distress to the terra cotta. Repairs have included: cleaning the brickwork and terra cotta, selected terra cotta replacement (Figure 4), repointing, and the installation of a new GFRC

Figure 7. View of terra cotta cladding on Santa Fe building.

(glass fiber reinforced concrete which is sometimes used as a substitute material to replicate terra cotta) cornice which replicated the original cornice which had been removed (Figure 5), and restoration of the original wood windows.

1900S VITRIFIED GLAZED TERRA COTTA SKYSCRAPER

Designed by architect Daniel Burnham and constructed in 1904, the Santa Fe building represents an example of a white vitrified glazed building (Figure 6). The building is 16-stories tall and the two street facades are clad with ornate vitrified white glazed terra cotta and aluminum frame replacement windows. The terra cotta facade of the building was constructed with numerous decorative elements including a cornice at the roof level and water tables and belt courses at the 3rd and 14th floors. The terra cotta is supported vertically by the shelf angles at each floor level. Lateral support is provided by metal wall ties that are embedded into the masonry and laid contiguous with the brick masonry backup. Terra cotta masonry above windows in the fl at areas is supported by horizontal steel dowels that are threaded through holes in the webs of the terra cotta units and through J-hooks that are hung from the steel shelf angles above. Terra cotta masonry above the bay windows is notched to accommodate and bear on the horizontal leg of the shelf angle (Figure 7).

Investigation revealed that while corrosion of the embedded steel was not significant, deterioration had occurred including cracking and displacements as a result of the expansive forces of corrosion by-product. The combination of initial moisture expansion, thermal cycles and frame shrinkage resulted in significant accumulation of compression stresses within the cladding system. These stresses resulted in cracking and localized displacements of the terra cotta.

To relieve compressive stresses within the terra cotta cladding, horizontal joints were cut within the piers immediately below the shelf angle at each floor. Subsequent repairs included replacement of significantly deteriorated terra cotta with new terra cotta units. Selected salvageable units were removed, repaired and reinstalled, and through-wall anchors were installed at some of the cracked units for stabilization purposes. Finally, due to a combination of conditions, all of the terra cotta units at one of the corners were removed, the embedded steel repaired, and the corner was reconstructed with a combination of new and salvaged units.

Subsequent phases involved disassembly and reconstruction of the terra cotta cornice that extended along the major facades of the building. Previous evaluations revealed corrosion of the supporting steel components as well as complications resulting from backfilling of portions of the cornice with concrete. The repair scope included replacement of the dentils of which the majority had all previously been stabilized, replacement of the ornamental profile units due to damage resulting from previous facade work, and salvaging and reinstallation of the decorative cap units. In addition, a new roofing and fl ashing system was installed to improve water management at the roof, cornice and parapet interface.

1910S MATT GLAZED TERRA COTTA SKYSCRAPER

The 1200 North Lake Shore Drive building, designed by Marshall and Fox Architects, is thirteen story building that was constructed circa 1914 (Figure 8). The exterior facade of the building is clad with limestone, brick, and terra cotta. One of the most distinctive features of the facade is the L'Orangerie (rounded bay) centered on the east facade. The first two floors of the three street facades are clad with limestone, ornamented with fluted pilasters and festoons above the windows. Levels above the first floor are

Figure 8. View southeast corner of the 1200 North Lake Shore Drive building.

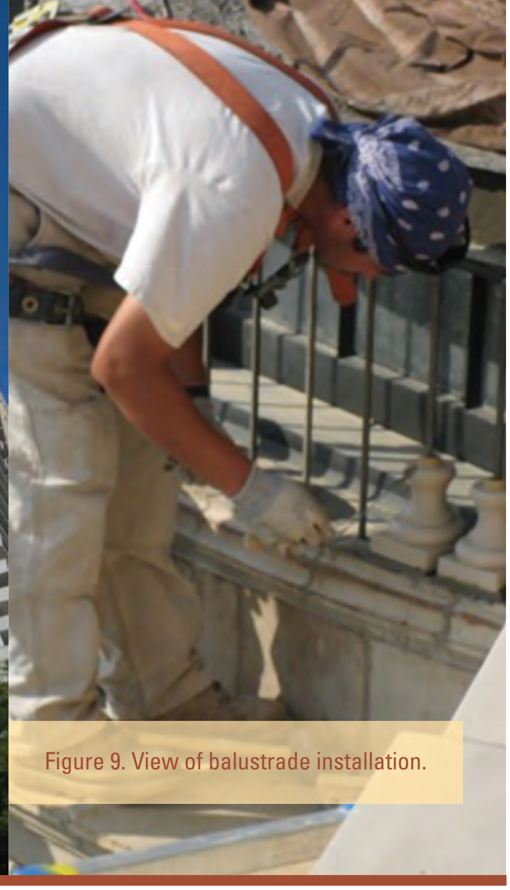

Figure 9. View of balustrade installation.

clad with ornate taupe-colored glazed terra cotta, matching brick, and Indiana limestone. The exterior cladding of floor three through 11 consists of buff colored brick and terra cotta window heads, jambs, and sills. The brick and terra cotta facades of the building were constructed with numerous decorative elements including a parapet with a balustrade that is capped with terra cotta coping units. The balustrades sit on a base just above the projecting water table (Figure 9).

Investigation revealed that deferred maintenance had resulted in significant water infiltration and subsequent deterioration at the parapet, projecting bays including the L'Orangerie, window lintels, and the corners of the building. These areas are naturally more prone to water infiltration and with the lack of maintenance, significant deterioration of the embedded steel structure had occurred. At many locations corrosion of the steel was so significant that members had lost significant structural capacity. While the underlying steel was significantly deteriorated, in many instances the terra cotta cladding was relatively undamaged because corrosion of the lateral anchorage for the terra cotta had corroded completely with no significant corrosion scale accumulation. As a result the units had shifted as the structural elements corroded but the units themselves had not been damaged.

Repairs included rebuilding the corners of the building from the 12th floor to the roof and the southeast corner was rebuilt from the third floor upward. Additional shelf angles were installed to provide continuous support of the masonry and the exposed portions of the existing steel framing was cleaned and painted (Figure 10). The cracked terra cotta mullion units at the three projecting bays, including the L'Orangerie, were removed and replaced with new matching terra cotta units. The mullions were anchored using stainless steel brick veneer ties modified to support the terra cotta back to the existing structural tees. The visibly cracked terra cotta units at the spandrels of the projecting bays were replaced with terra cotta units to match. Displaced but intact salvageable terra cotta units were repaired and reinstalled; however, when units could not be repaired, replacement terra cotta units were fabricated to match existing. Upon removal of the terra cotta mullions it was discovered that many of the terra cotta spandrel units showing no signs of visible distress had experienced face shearing and concealed cracking because of the support condition of the existing steel as well as the weight of the cast iron railings bearing on the terra cotta. As a result, the terra cotta units were replaced to match existing and additional lateral stainless steel anchorages were installed to help alleviate this condition in the future. All of the exposed steel curved spandrel beams and supplemental steel were cleaned and painted after the removal of the existing terra cotta units. The cracked terra cotta units and adjacent deteriorated brick masonry were removed to repair, clean, and paint the exposed corroded steel lintels. In addition, supplemental steel plates were fastened to the existing steel angles to provide adequate support for the replacement terra cotta and brick masonry. Upon completion of the steel repairs, new terra cotta units and brick masonry were installed to match the existing.

1920S POLYCHROME GLAZED TERRA COTTA SKYSCRAPER

The 38-story polychrome terra cotta clad Carbide and Carbon building was designed by Daniel and Hubert Burnham, sons of architect Daniel Burnham and constructed in 1929. The exterior of the building is clad with dark green vitrified glazed terra cotta. The tower of the building also incorporates gold terra cotta accents (Figures 10 and 11). According to popular legend, architects Daniel and Hubert Burnham designed the building to resemble a dark green champagne bottle with gold foil. The terra cotta cladding was supported at each floor as described in the previous examples.

Investigation revealed significant corrosion of the embedded terra cotta lateral anchorage resulting in significant deterioration of terra cotta units including cracking and displacements from the accumulation of corrosion scale. The steel plates which were riveted to the horizontal leg of the support angle for the terra cotta at each floor were typically severely corroded. These conditions were further exacerbated by the stresses due to initial moisture expansion, thermal cycles and frame shrinkage.

Repairs included cleaning the terra cotta and cutting horizontal joints at regular vertical intervals. New plates were bolted

Figure 10. View of portion of corner repair of reconstruction.

Figure 11. View of portion of of the Carbide and Carbon building.

to the existing steel angles to reestablish support for the cladding. Salvageable units were removed, repaired and reinstalled and significantly deteriorated units were replaced. Terra cotta units which exhibited minor cracking and were not displaced were stabilized in-situ using stainless steel anchors.

CONCLUSION

A review of the construction, investigation, and repairs of these four Chicago buildings demonstrates the representative challenges involved with preserving and maintaining historic terra cotta clad structures. The integration of metal anchorage systems with terra cotta veneers was perhaps as equally innovative to the advancement and popularity of the material as it was detrimental to its long term durability. Maintaining watertight joints in terra cotta assemblies is integral to its successful performance, regardless of the unit's configuration or type of glaze. Similarly, water penetration through cracks or glaze spalls can be equally as damaging. As discussed in the examples above, exploratory openings are critical to determine the condition and configuration of concealed metal anchorage and supporting members. Repairs can vary from replacement of badly damaged units, in situ stabilization, crack and spall repairs, or facade cleaning. The extent and type of repair is often dictated by economic constraints and the level of damage or distress. While four Chicago terra cotta skyscrapers were presented, it should be noted that the performance of this cladding is similar elsewhere, with somewhat varying impacts of climatic forces that can be severe or mild in other geographic areas.

Figure 12. Close up view of gold glazed terra cotta on the Carbide and Carbon Building.

Preserving the existing stock of terra cotta skyscrapers involves diligent and appropriate maintenance coupled with an understanding the material behavior of terra cotta, the complex and sometimes unique support system, and the building's structural frame. With this fundamental knowledge, one can proceed with the evaluation of distress, the development of various treatment options, and the implementation of appropriate levels of corrective repairs.

The success for a long-term repair campaign typically depends on a combination of several factors. Once a clear understanding of existing conditions is established, construction documents are developed to identify the extent of repairs required with details illustrating the repair of existing conditions, the approach for repairing and reinstalling salvageable units, or the installation of new terra cotta. Specifications are critical to define contractor and manufacturer qualifications, mock-ups, submittals, quality control processes, and the requirements for all materials and their installation, including anchorage, coatings, mortar, and new steel with associated accessories. Masonry restoration contractors experienced in the repair of historic terra cotta are aware of the critical phases of repair campaigns and place value on engaging manufacturers, obtaining approval of highly detailed shop drawings, and the importance of mock-ups to verify appropriateness of specified approaches, materials, and to demonstrate aesthetic effects.

Various factors have contributed to the increased use of substitute materials and innovative alternate approaches to preserving these masonry facades. Some substitute materials used to replicate full-size units include glass fiber reinforced concrete or plaster, composite polymers, and cast stone. While well-established preservation efforts coupled with appropriate maintenance have demonstrated the ability to prolong the useful life of terra cotta, the implementation of cathodic protection is perceived by some to offer increased insurance to minimize further corrosion of substrate steel and limit associated distress. Utilizing substitute materials or technologies to rehabilitate terra cotta facades should be implemented only after research considers appropriateness to historic fabric, compatibility, irreversibility, long-term performance, and maintenance considerations.

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