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SEALANT, WATERPROOFING & RESTORATION INSTITUTE • FALL 2021 • 43.4

FEATURE

The Terra Cotta Industry

THE FUTURE IS BRIGHT

BY BRETT LAUREYS

Project: One Vanderbuilt / Photoghaper: Raimund Koch

Terra cotta is ceramic material that has been used for architectural purposes since ancient Roman times. After the fall of the Roman Empire, terra cotta was abandoned until the fourteenth or fifteenth century, when it was revived in Northern Italy. In the early nineteenth century, terra cotta flourished in England first as a material used for pipes and pottery, and then as an architectural material used to embellish brick buildings. Architectural terra cotta has been used throughout the world as a cladding material. Its unique characteristics make the approach to assessment and restoration different than that used for many other cladding materials.

History of Terra Cotta in the United States

Terra cotta production began in the United States around 1850 and primarily included units used for fireproofing on steel frame buildings. In 1868, Chicago Terra Cotta Company began production of architectural terra cotta. Terra cotta particularly gained favor as a fireproof building material after the 1871 Chicago Fire. In the late 1800s, terra cotta was primarily used as accents on masonry clad buildings but by the early 1900s it gained widespread use as an anchored exterior cladding material due to the opportunities it provided for new forms and ornament and its relatively low cost and speed of production as compared to carved stone.

Another benefit to architectural terra cotta cladding installed over a steel frame was the speed and height at which the building could be constructed. As an architectural cladding, terra cotta cladding was originally a cost-effective alternative to mass masonry and natural stone. Many of the glaze finishes applied to the exterior of the terra cotta units mimic granite, marble, brownstone, and other natural materials. By the 1920s, polychrome ceramic glazes gained popularity with some architects. These multi-colored units were typically designed to be incorporated into a building facade as accents.

With the difficult economic times of the 1930s and changes in architectural style, the demand for and use of architectural terra cotta significantly decreased. By 1945, only seven of the original 28 American manufacturers were still producing architectural terra cotta. Today, architectural

Project: Corbin Building
Photoghaper: Chris Payne

terra cotta is still manufactured by a few firms in the United States and England, and it is experiencing a resurgence in use on both new and existing building facades.

Attributes of Terra Cotta

Fired clay terra cotta units are made from moist pliable clay that can be formed into shapes and designs, limited to the imagination of the designer. Durable ceramic glazes can be developed to mimic the aesthetics of common stones. This glass-like glaze is durable and impervious to moisture penetration. Most glazed surfaces are very dense and do not attract dirt and/or atmospheric deposits, resulting in a nearly self-cleaning surface. The fired clay material is fireproof. It can be used as a load bearing material or cladding material that can be hung on the exterior of a high-rise facade. In general, terra cotta is an excellent building material that is extremely durable. Terra cotta cladding materials have more recently had some negative attention since portions of historic terra cotta clad buildings have been found with severe distress and in some cases units have fallen. In nearly all cases, these buildings are distressed due to lack of proper maintenance, lack of accommodation for thermal and moisture movements within the assembly, and the limitations of support materials (unprotected mild steel ties and anchorage) used when these buildings were constructed over 90 years ago.

Project: Miami-Dade Courthouse
Photoghaper: Brett Laureys, WJE

Modern Terra Cotta Restoration

Typical Mechanisms of Terra Cotta Deterioration

In order to properly assess and restore a terra cotta clad building, it is very important to understand the sources that cause distress in this exterior cladding material. Similar to most clay masonry clad buildings, the most common sources of distress in terra cotta clad buildings are moisture penetration (and associated material deterioration and corrosion of underlying steel support elements), moisture expansion, thermal movements, and building movement due to gravity, wind, or earthquake.

Common to most terra cotta clad buildings are ornate parapet walls, projecting cornices and water tables, balustrades, and deep window sills. These elements are susceptible to severe weathering because they are exposed to standing water or are exposed to the elements on multiple faces. This accelerated weathering allows more moisture penetration into the exterior wall assembly, which in turn causes distress to the underlying building structure and supports for the terra cotta cladding material.

Replacement of Terra Cotta

To maintain the historic appearance of a building and prevent differential movement between dissimilar alternative materials used for restoring terra cotta facades, it is recommended to replace with in-kind materials. The Secretary of the Interior Standards for the Treatment of Historic Properties provides the industry guidelines for preserving, rehabilitating, restoring, and reconstructing historic buildings. Terra cotta is very durable material that lasts at least 100 years in service if integrated into a properly designed and constructed wall assembly, with appropriate maintenance. With any terra cotta restoration project, the following must be considered:

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Accommodation of Building

Movements: Historically, terra cotta units were assembled within a mass of masonry, commonly installed around a high-rise steel framed structure. When designed and constructed, building movements and thermal/moisture movements in the cladding materials were not well known and typically not accommodated. In modern restoration, the introduction of vertical and horizontal movement joints should be considered to accommodate these movements.

Typical distress of terra cotta cladding systems includes the following:

DETERIORATION OF MORTAR JOINTS: The mortar joints between the terra cotta units will deteriorate over time due to weathering and freeze-thaw cycling that occur in northern climates. This deterioration is generally accelerated in locations with severe weather exposure such as parapets, cornices, sills, etc. Since these mortar joints are critical in minimizing the amount of water that penetrates the terra cotta wall assembly, maintaining the integrity of the mortar joints in a terra cotta facade is one of the most effective long-term repair solutions.

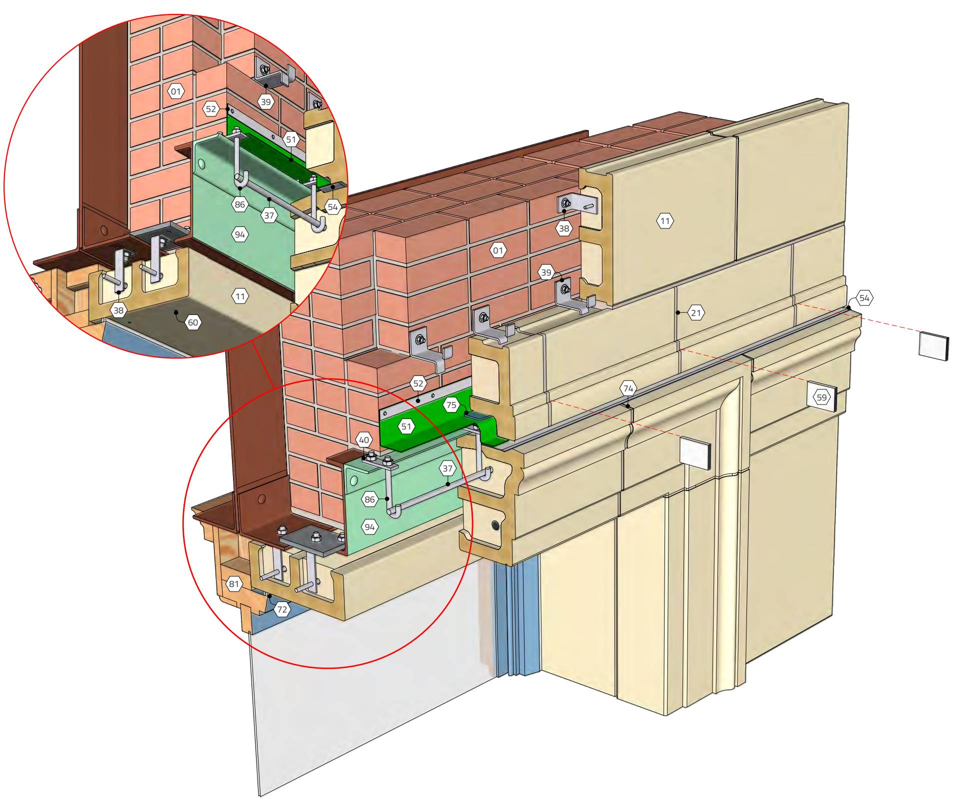
CRACKING: Cracking is usually caused by corrosion of supporting metal elements and anchorages, unaccommodated expansion of the cladding assembly, and/or building movements. The most common type of cracking is easily observed on the surface of the terra cotta cladding and may include some displacement. The type of cracking that presents the most significant safety concern is the cracking that cannot be seen on the building exterior. In-plane cracks typically extend through the vertical height of the terra cotta units in line with the back of the face shell of the unit. These cracks are typically due to vertical stresses (caused by unaccommodated expansion) within the cladding material.

SPALLING: There are two types of surface spalls common to terra cotta cladding. Glaze spalls (loss of glaze) are typically caused by several factors, which may include differential movement between the glaze and the bisque (clay body), cyclic freezing and thawing of entrapped moisture, biological growth, moisture movement through the terra cotta unit, and/or mechanical damage to the units. Bisque spalls are deeper than glaze spalls and extend into the clay body of the terra cotta unit. Causes of bisque spalls are freeze-thaw cycling due to water infiltration and saturation, expansive impurities in the clay, impact, and/or corrosion of supports.

CRAZING: A pattern of fine hairline cracks within the glaze is known as crazing. Crazing occurs when the stresses caused by moisture expansion of the clay body exceed the tensile capacity of the glaze, and may be a natural result of firing of the terra cotta. Typically, this fine cracking does not allow water penetration into the unit and the durability of the terra cotta material is not greatly affected and does not need to be repaired.

GLAZE SHIVERING: When glaze formulation is not compatible or "fit" with the clay body shrinkage ratio during firing. The glaze will be in tension without complete adhesion of glaze to the clay body. This can result in glaze peeling from the clay body. This can be recognized by no or minimum clay retained on the underside of the glaze shard.

INAPPROPRIATE REPAIRS: Improper repair techniques typically cause the most severe subsequent deterioration to a terra cotta facade (cladding material and underlying structure). Some examples include: Complete replacement of all joint mortar with sealant on a terra cotta facade can be very detrimental due to entrapment of moisture within the exterior wall system. Other inappropriate repairs include the use of aggressive cleaners, expansive grouts, incompatible patching compounds, and non-breathable coatings.



Detail exhibiting rebuild strategies with hand pressed architectural terra cotta.
Diagram provided By: IMI and WJE

KEY NOTES

- 01 (E) Masonry backup, multi-wythe construction
- 11 Architectural terra cotta, hand pressed
- 21 Mortar
- 37 Stainless steel rod
- 38 Stainless steel strap and pin anchor
- 39 Stainless steel split tail anchor
- 40 Stainless steel strap anchor
- 51 Flashing system with end dams as required
- 52 Termination bar with continuous sealant
- 54 Stainless steel drip edge; seal and adhere to substrate
- 59 Weep vent
- 60 Weep hole at underside of each overhanging TC unit
- 72 Sealant and backer rod
- 74 Sealant or lead T-caps at all horizontal skyward-facing joints
- 75 Plastic setting shims as required
- 81 (E) Window assembly
- 86 Stainless steel J-bolt
- 94 (E) Structural steel treated with corrosion-inhibiting coating

GENERAL NOTES

This drawing references Lintel-Original Plate 36.

Where anchors penetrate flashing, seal with compatible sealant.

DELIMITATION

This detail exhibits rebuild strategies with hand pressed architectural terra cotta (TC). Other options may be appropriate. It is best to consult a professional team of engineers, architects, and architectural conservators when crafting a repair or rebuild scenario for historic architectural TC.

CONSIDERATIONS

- Architect/engineer to verify condition and soundness of existing (E) masonry backup. Perform testing as necessary.
- Rebuild or replace backup as necessary.
- Replacing anchors requires performing anchorage pull-testing.
- Accessible existing sound steel that is to remain, requires cleaning and coating with a corrosion inhibitor.
- Corroded steel to be evaluated and painted, repaired, or replaced with stainless steel based on condition
- Original TC units are to be replaced in-kind or removed, repaired, and reinstalled and not filled.
- Install new TC units not filled.
- Weep holes in units must be kept clear and free of mortar and debris to prevent trapping of moisture after installation.
- Design considerations include:
  - Tolerances
  - Shims
  - Shoring
  - Modifications to units
  - (E) Anchor removal

KEYWORDS

Terra cotta, Rebuild, Pressed, Hand pressed, Lintel, Brick, Restoration, Anchor, Repair, Window, Flashing, 10.030.0632

Anchorage/Structural Support: Restoring and improving the structural and lateral support systems on a historic terra cotta clad building are critical and can be very challenging. Each project is unique; however, common anchorage techniques include using modern corrosion resistant anchorage (i.e. stainless steel), using high-performance coating systems over existing structural supports, and improving structural support systems to accommodate horizontal and vertical movements within the cladding system.

Technology and Methods of Fabrication: To remain competitive with alternate replacement materials, terra cotta has advanced in more recent times to use extrusion techniques to improve timeliness and production cost. Extruded units are strong high-quality units, but they can create challenges with hanging supports and lateral anchorage. With a clear understanding of the material and terra cotta unit limitations, these challenges are easily overcome.

Understanding Material Behaviors and Durability: Advancements/improvements in clay and glaze materials will continue as terra cotta is a natural material that continues to be used in new ways. As clay quality has advanced over time, the interface between the clay body and glaze coating can be critical in the durability and performance of the terra cotta units. Ceramic engineers play a key role in reviewing the clay components and understanding the effects on the durability of the fired clay material.

Integrating with Modern Wall Assemblies: With any historic building, the challenge is to restore damaged or failed portions of the facade while maintaining the original appearance. With historic terra cotta facades, most of the damage is due to failure of concealed wall components (anchors, supports, lack of water management, etc.) and these failed components are commonly replaced with more modern/durable materials. Integration of these modern materials and wall systems can be critical to the long-term performance of the restored assembly. As guidance for the industry, the International Masonry Institute (IMI) with cooperation from Wiss, Janney, Elstner Associates, Inc. (WJE) has developed a great resource for modern terra cotta restoration detailing on their website (https://www.imiweb.org/masonry-detailing-series-3). This includes several typical details for using modern materials when restoring various components of a terra cotta clad building.

Project: Fulton County Courthouse
Photoghaper: Brett Laureys, WJE

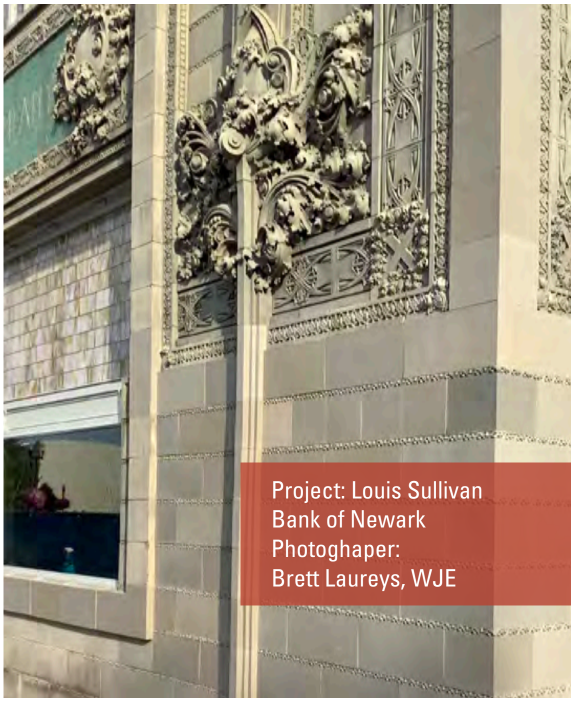
Project: HOK/Permastelelisa/TriPyramid
Photoghaper: Patrick Bernard

The Future of the Terra Cotta Industry

Over the past 10 years, the terra cotta industry has made a resurgence as a modern cladding material due to its resilience, sustainability and durability. This material can last hundreds of years and is lightweight, versatile and fire resistant making it ideal for skyscrapers. As architects become more creative and technology allows for more involved designs, terra cotta keeps up in that it is malleable and can adhere to almost any shape and the glaze color pallet is endless. As for impact on our planet, terra cotta leaves behind a low carbon footprint and can be 100 percent recycled. Dr. William Carty (Former Professor

Project: Miami-Dade Courthouse
Photoghaper: Jeffery Ross, Ross Creative Works

Project: 847 W. Jackson
Photoghaper: Brett Laureys, WJE



Project: Louis Sullivan Bank of Newark
Photoghaper: Brett Laureys, WJE

Project: St. Mary of the Angels Church
Photoghaper: Joseph Zale, WJE

and Chair of Ceramic Engineering at Alfred University) has published that many building materials can require over 100 gigajoules of embodied energy per ton, terra cotta requires somewhere between 2 and 7 gigajoules of embodied energy per ton, making it one of the most environmentally friendly building materials.

Though terra cotta has been used successfully as a building material for hundreds of years, to be competitive in today's marketplace the manufacturers have developed means of using modern equipment and processes to save cost. For example, a modern terra cotta rainscreen system is fabricated using a cost-effective extrusion process and these extruded panels are dried in a roller dryer and fired in a roll kiln. This allows for faster production and overall reduced cost. For replication of historic terra cotta blocks, extrusion and ram pressing techniques are used to recreate more common block styles to reduce cost and expedite delivery times. More and more of the historically labor driven industry is moving into the digital world. Computerized dryers and kilns produce more consistent high-quality terra cotta replications. While 3D scanning and 5-axis CNC equipment is being used to improve exact replication of historic units

Project: Todd Williams Billie Tsien Architecture
Photoghaper: Patrick Bernard

and also improve the manufacturing process by being more efficient with less error.

Advancements in Ceramic Assemblies

In 2016, Boston Valley Terra Cotta and the University of Buffalo (School of Architecture and Planning) developed the Architectural Ceramics Assemblies Workshop (ACAW). This workshop was developed to bring together teams of architects, artists, designers, and engineers to address the untapped potential for ceramic component system development. Each of the multi-disciplinary teams is allowed to experiment with ceramic materials and is challenged with assembling their creation over the one-week long workshop.

As part of ACAW, facade and material experts from around the world also present on their experience in using terra cotta as a unique cladding material. ACAW then gives back to the architectural community by raising awareness of the capabilities, strengths, and limitations of terra cotta and presenting the findings from their ACAW experience. The goal of all participants in the workshop is to raise awareness in the industry and to get students interested in an architectural or ceramics related career.

Over the past five years, I am honored to have been given the opportunity to be involved with ACAW from the team-based workshops to participating in a panel discussion on facade engineering. The experience of working with other facade engineers, architects, ceramic artists, and students is one of a kind. I have now seen some of the ideas developed during this workshop be used in new construction and further development of the terra cotta and ceramics industry.

Summary

Terra cotta has many great qualities (fire rated, lightweight, malleable, sustainable and an endless color pallet) and it has proven to be a durable building material. Historic terra cotta

Project: Todd Williams Billie Tsien Architecture
Photoghaper: Patrick Bernard

has been seen negatively due to its failures on facades throughout the United States; however, from my experience, the common failure mechanism for terra cotta failure is related to lack of maintenance and failure of the underlying steel structural attachments, not the terra cotta material itself. Knowledge and advancements in terra cotta restoration have addressed many of the past failures; however, terra cotta is a natural material, and we must be cautious as we advance and expand the use of this material in different ways.

Costs and timelines continue to challenge the industry, which has advanced the use of technology to improve production techniques and product quality. Continued advancements in both historic restoration and new construction will be critical in terra cotta being a cost-effective building material in the future. Overall, I am very encouraged by the recent advancements in both the restoration and new construction market. With the more recent renewed interest in further developing terra cotta as a cladding material, I look forward to seeing future advancements and the endless possibilities of how this material can be used in the building industry.

About the Author

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Project: 150th Avenue
Photoghaper: Alan Schindler

Project: Fulton County Courthouse
Photoghaper: Jeffery Ross, Ross Creative Works