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Using terra cotta in an expanding urban world

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by Christian Lehmann

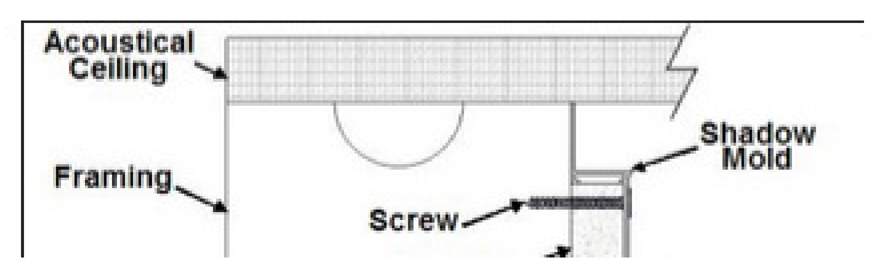
Photos © Ashley Streff

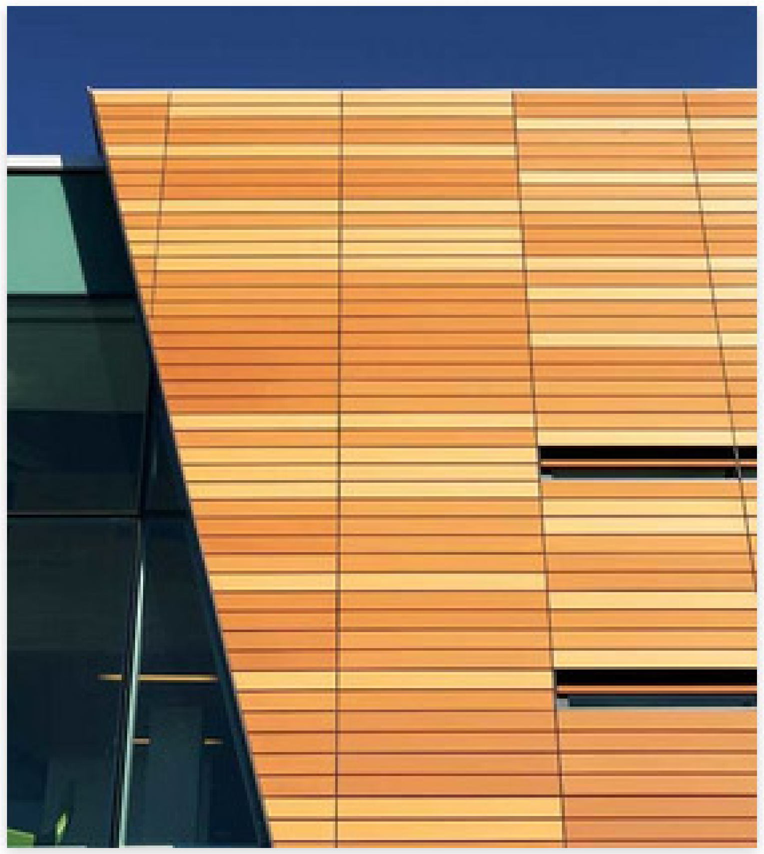
In the United States, 82.5 percent of the population is urban—a number translating to more than 268 million people in 2016. (This number was obtained from the United Nations [UN] Populations Division's *World Population Prospects: The 2015 Revision*.) This creates a need for increasingly dense housing, along with investment in commercial offices, transportation facilities, government complexes, and schools. In some urban areas, this growth is being accommodated by the construction of taller buildings.

Terra cotta, a construction material with a lengthy history, offers some of the most versatile solutions to meet the demands of modern tall building design (generally described as buildings of 14 stories or more, although not limited specifically by height). This natural, lightweight, cost-effective material offers many options for attractive exteriors with a vast palette of colors and textures, and can enhance the energy performance of virtually any building. The 'chameleon' among exterior building materials, terra cotta can take on appearances ranging from sleek and modern to intricate and historical.

Skylines across the country feature a broad array of construction styles, chronicling decades of design trends and accompanying shifts in building elements. For these structures, versatile materials that meet current standards, deliver comfort and safety, and decrease energy demand must be selected. Considered from the perspective of material performance alone, this is an enormous task.

When aesthetic aspirations are also taken into account, few materials support the expansion of existing structures, allow options for restoring and refacing buildings, and exhibit the required performance values. The durability, natural manufacturing, and attractive color and texture of terra cotta place it on this list.





Designed by Gould Evans, the renovation and expansion of the Lawrence Public Library has transformed it into a 21st-century civic space—from book repository to multimedia community hub. Located in Lawrence, Kansas, the library was upgraded to address challenges in thermal performance, daylighting, and openness. Its striking renovated terra cotta façade provides a high-performance thermal envelope engineered to harvest daylight and reduce energy usage.

Terra cotta spans the centuries
Since the earliest periods of construction, terra cotta has been used for diverse structural and decorative elements, including roof tiles, drain pipes, and façades. Commonly translated as 'fired clay' or 'baked earth,' terra cotta is created using high-grade aged clay, which is formed and then fired at high temperatures. This causes it to yield a hardness and compactness unobtainable with brick. Both glazed and unglazed tiles and panels made using state-of-the-art techniques can, with very little maintenance, keep consistent appearance and structural integrity.

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The clip and panel system allows for installation in any weather conditions, meaning terra cotta is much faster to install than both brick and stone systems. Terra cotta façades also incur minimal maintenance costs, especially compared to brick façades, which require costly repointing due to the inevitable degradation of the mortar and silicone joints.

In addition to its exceptional durability, terra cotta features numerous desirable properties.

Aesthetics and reusability
Terra cotta provides the beauty of a natural material at a much lower price than stone, based on the cost of materials, shipping weight, and ease of handling. When glazed, it can accommodate a wide range of colors and surface qualities, from matte pastels to iridescent metallics to earth tones. Surface textures may also be custom-designed to add rhythm and interest to building exteriors or blend into the existing fabric of the neighborhood.

As a completely natural material, terra cotta can be recycled after use to produce new building products or be used for road base.

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Performance

In rainscreen applications, terra cotta has a natural capacity for cooling. In fact, it has been used as protection against hot climates in many cultures and civilizations throughout history. In cold weather, its high thermal inertia can also help contain heat loss when it is installed as part of a ventilated rainscreen system. The back ventilation assists in maintaining a dry cavity and negates the buildup of hot air in the cavity.

The State of Alaska Library Archives Museum (SLAM) was developed to collect, manage, and care for objects representing the people and history of Alaska. The building features terra cotta tiles in a custom finish.

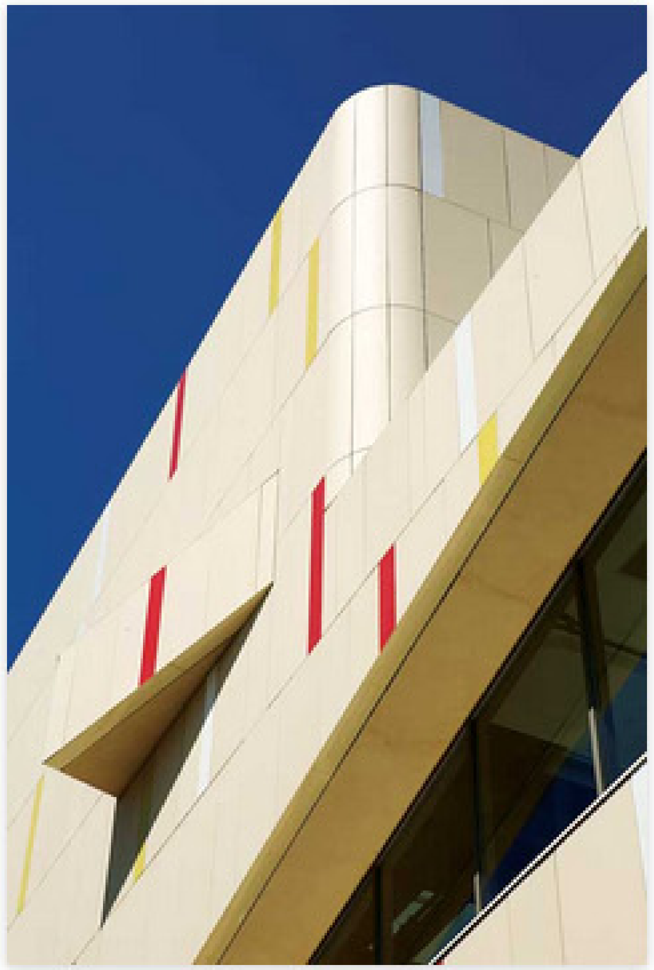
Terra cotta is also known for reducing sound transmission. During the manufacturing process, terra cotta becomes denser as the temperature increases and silicates melt. In many designs, the addition of a glaze to the exterior facing surface creates a smooth, reflective plane. These combined properties provide sound deflection, which helps reduce the intrusion of outdoor noise into interior spaces. Terra cotta tiles with more natural or deliberately textured surfaces also disperse sound waves, and those panels produced for exterior cladding are designed with a hollow air chamber in each panel or tile to further suspend the transmission of sound.

Resistances

Terra cotta has been recognized as an important material in fireproof commercial construction in the United States for more than a century, as its clay-based composition renders it naturally fireproof. These properties, along with the denseness of the clay, result in minimal thermal transmission, making terra cotta virtually impervious to the effects of ultraviolet (UV) light. This in turn provides natural resistance to both heat and light—elements commonly causing deterioration in other façade materials. Modern glazing and firing techniques can also make terra cotta resistant to water, eliminating the damaging effects of water infiltration in addition to the deterioration experienced in most cladding materials subjected to heat and frost cycles.

History and use of terra cotta in Chicago

Terra cotta's fireproof properties led to its incorporation in an important building trend beginning in the United States nearly 100 years ago. Chicago is credited as the origin point of many of the stylistic and technical advances associated with tall buildings—elements of the modern skyscraper. In the years following the 1871 Chicago fire, design and construction teams developed techniques to build safer structures with greater fire resistance. In 1873, architect John M. Van Osdel designed the Kendall Building, the first fireproofed building in the United States. The structure included terra cotta tiles to protect its structural elements. Such fireproofing properties make it an appealing construction material to this day. (From the Infrastructure Protection and Disaster Management Division of the Advanced and High-Performance Materials Program's winter 2011 *Journal of Advanced and High-Performance Materials*, a publication of the National Institute of Building Sciences (NIBS) Advanced Materials Council.)



Designed by John Friedman Alice Kimm Architects, Claremont McKenna College's Roberts Pavilion (Claremont, California) features white glazed terra cotta tile accented with red and yellow glazed tile. This project showcases the rich color glazed terra cotta can deliver to enhance an application's aesthetics.

In the 20th century, the Windy City was a hotbed of architectural talent, with architects of the Chicago School venturing into new construction techniques such as the design of the city's first skyscraper. In 1920, Graham, Anderson, Probst & White designed the Wrigley Building to serve as headquarters for the chewing gum manufacturer. Completed in 1921 and 1924 respectively, the 130-m (425-ft) south tower and 137-m (450-ft) north tower took inspiration from the Giralda tower of the Seville Cathedral in Andalusia, Spain. Both towers of the building façade comprise more than 250,000 glazed white terra cotta tiles. Almost a century later, these tiles maintain their attractive appearance.

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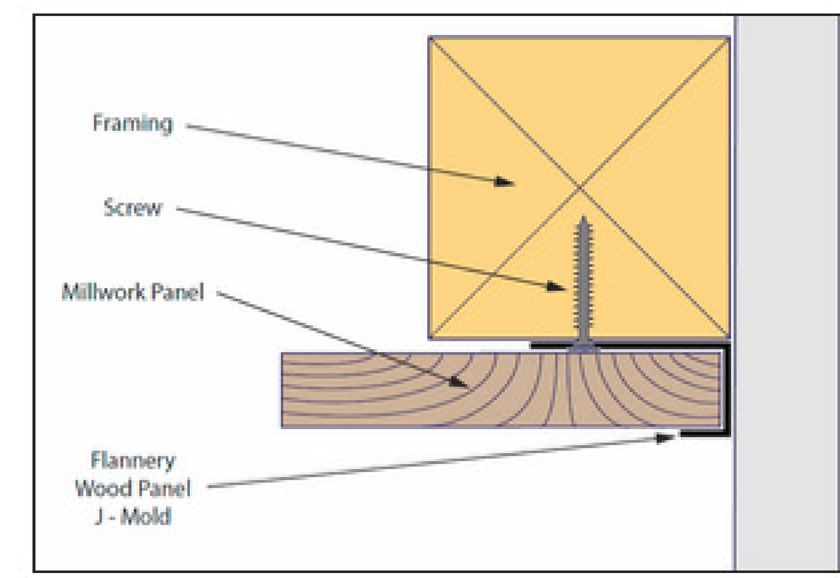
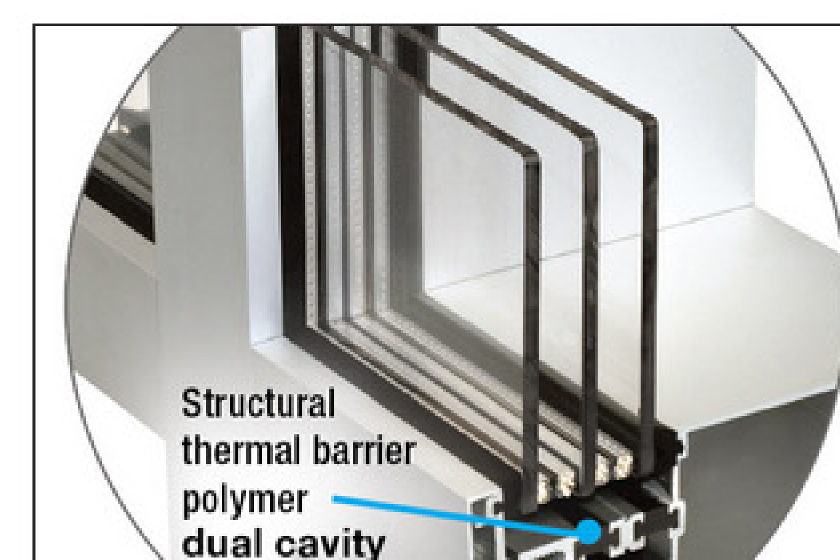
Another important feature of terra cotta is its versatility, which allows manufacturers to customize tiles and panels to create unique shapes, colors, textures, and glazes for expressive and individual design solutions. Terra cotta's material adaptability also makes it a suitable choice for repairing or adding to structures designed decades ago. Custom-designed terra cotta can reference Beaux Arts aesthetics, provide continuity with a historic district, integrate into regional construction and design techniques, or support modern sleek and minimal design statements.

A project in progress at 111 West 57th Street in New York City demonstrates the versatile design possibilities of custom terra cotta. Inspired by the terra cotta façade of Manhattan's Woolworth Building, this unique structure has the smallest footprint of any skyscraper worldwide. Designed by SHoP Architects, it tops out at more than 426 m (1400 ft), and will be among the tallest towers in the city. The structure represents a commitment to the quality of craft, history, and thinking behind New York City's classic skyscrapers.

Intended to be a reinvention of the landmark Steinway building designed in 1925 by Warren & Wetmore, this building is being restored and refurbished. Its terra cotta façades, combined with bronze filigree, are meant to bring back the quality, materiality, and details of historic New York towers while taking advantage of the latest technology to push the limits of engineering and fabrication. The tower's form multiplies the setback to present a feathered profile, rather than a stepped profile. As with the Wrigley Building, this structure's façade will be constructed of white, glazed terra cotta tiles.





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CityCenterDC brings in a mix of condominiums, apartments, offices, retail, and restaurants to a 4-ha (10-acre) site in the heart of downtown Washington. The exterior of the apartments features more than 7432 m2 (80,000 sf) of textured terra cotta in a palette of natural tones. Most of the project was installed as terra cotta in precast, making this the largest terra cotta in precast application in the country.

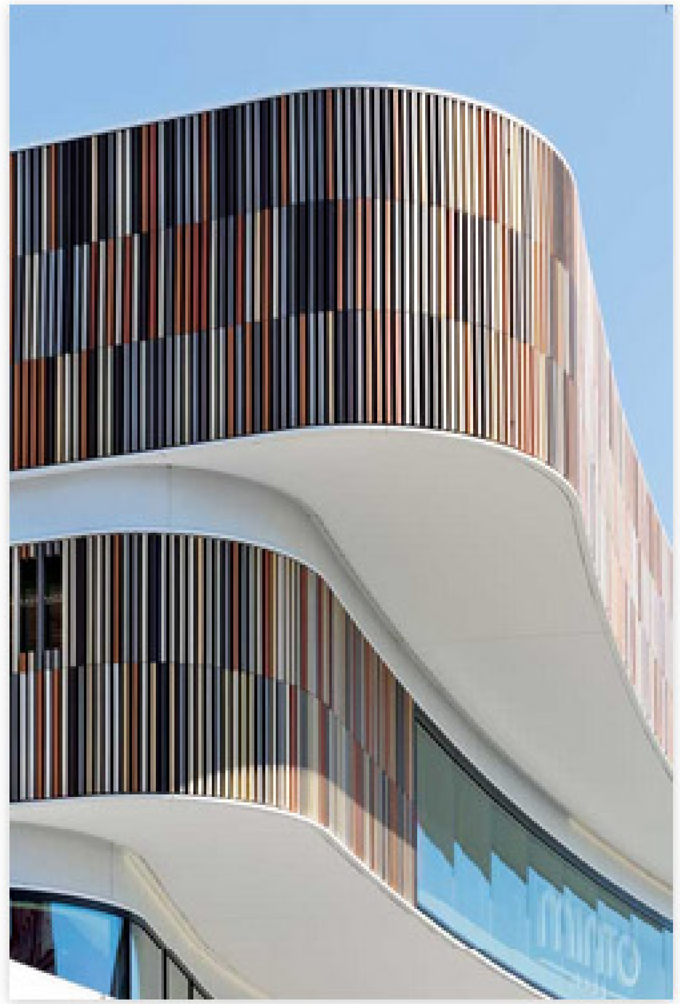
Heat transfer and energy use

In June, the American Society of Civil Engineers (ASCE) published a study that addresses methods for designing high-performance façades from the perspective of heat transfer and associated energy usage. (Aksamija and Peters published their study, "Heat Transfer in Façade Systems and Energy Use Comparative Study of Different Exterior Wall Types," in the *Journal of Architectural Engineering* in June 2016.) It compares the thermal performance of four exterior façades:

- a brick cavity wall with metal framing;
- a rainscreen with terra cotta cladding;
- another rainscreen with glass fiber-reinforced concrete (GFRC) cladding; and
- a curtain wall assembly.

In addition to these basic systems, the study also evaluated three thermally improved systems, including curtain walls with thermal breaks, terra cotta and GFRC rainscreen façades with thermal spacers, and terra cotta rainscreen façades with thermal isolators. Using software that provided two-dimensional, steady-state heat-transfer simulation, the study assessed the systems using thermal and energy modeling. (The software used was THERM 6.3 by Lawrence Berkeley National Laboratory in Berkeley, California.)

The systems were studied in conditions that modeled different climate zones across the United States, including climate extremes, with representative exterior temperatures of 32 C (90 F), 16 C (60 F), –1 C (30 F), and –17 C (0 F), and with constant interior temperatures of 22 C (72 F). U-values (*i.e.* heat-transfer coefficients) were calculated for each system using heat-transfer simulation software. In all configurations, rainscreens using terra cotta cladding with thermal spacers and those using terra cotta cladding with thermal isolators exhibited the lowest U-values, outperforming all other façade systems in the study.



Located in Mönchengladbach, Germany, Minto is a vibrant shopping mall. Designed by Kadawittfeldarchitektur, the project consists of vertically installed baguettes in a variety of natural terra cotta colors.

Energy use

The study also analyzed these systems for energy use. (To do this, the U.S. Department of Energy's EnergyPlus 8.3 software was used.) It was designed to determine the best performance for whole-year total energy use for a defined office space, featuring examinations of five opaque walls. However, since typical office walls are seldom opaque, configurations of opaque walls with window-to-wall ratios of both 20 and 40 percent were modeled in each of the studied cladding systems. Parameters were evaluated for whole-year energy use and included heating, cooling, and lighting. The study also incorporated a range of building orientations, including 12 different orientations at 30-degree increments, using climate models for 15 different U.S. cities.

The study demonstrated wall types with the lowest U-values typically provided better whole-year energy performance in all climates and at all orientations. Again, terra cotta rainscreens with thermal spacers and those with thermal isolators—including both terra cotta and GRFC cladding systems—outperformed all wall assemblies studied, with the lowest heating energy demand and highest thermal resistance. Terra cotta and GRFC cladding systems also exceeded other systems' performances when it came to cooling energy demand, likely because of terra cotta's high thermal resistance. Curtain walls outpaced brick cavity walls in terms of energy demand, but performed worse than any system when evaluated for cooling energy consumption and whole-year energy performance.

Compared to other façade cladding solutions, the initial costs for terra cotta façades begin in the mid-range. This type of cladding outperforms other products in both lifetime expectancy and maintenance costs.

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Other forces

Buildings must be engineered to sustain gravity loads—as architects reach for loftier heights, gravity loads, along with lateral loads such as seismic forces and wind, increase the challenges of design. The dead load of terra cotta tiles and systems is approximately 5 to 6.5 kg/m^2 (11 to 14 lb/sf).

Both curtain walls and terra cotta rainscreen systems—including curtain wall assemblies with infills combining glass and terra cotta—are commonly fabricated with aluminum framing. Aluminum framing construction is relatively lighter than steel, and is less susceptible to the brittle fractures experienced with materials such as iron (used in the early days of skyscraper design). Aluminum framing does not carry floor or roof loads, but transfers them to the building. Wind and gravity loads of the curtain wall or rainscreen system are also transferred to the building structure, typically at the floor line. (For more information, access Vigener and Brown's *Building Envelope Design Guide* at www.wbdg.org/design/env_fenestration_cw.php.)

Further demonstrating the versatility of this material, architectural terra cotta tiles have been used on this T-Mobile storefront with embedded lights to bring texture and differentiation to the building.

Façades are engineered to reduce any movement and sway caused by wind and seismic activity. Custom-designed systems can be engineered to accommodate a project's anticipated amount of movement. This allows the system to adapt to differences in movement between the structure and the thermal movement of the metal frame. Additionally, rainscreen systems can transfer lateral outside pressure from wind load to the inside cavity. When installed properly, terra cotta rainscreens can reduce wind loads by equalizing the pressure on both sides of the cladding. However, the specific performance of such assemblies varies according to the materials and construction methods used.

Conclusion

Ongoing urbanization will continue to feed the trend of building upward. (Ali's *Art of the Skyscraper: The Genius of Fazlur Khan* can provide further reading on this subject.) Design trends for tall buildings will continue to reflect the need for both structural efficiency and dynamic performance, and for accommodating the ever-evolving aesthetic goals of the design industry. In this environment of urbanization, one of the most versatile materials available to the architect and designer is terra cotta. Proven by its use over more than two millennia, terra cotta meets the changing physical challenges of construction while providing innovative options for forward-looking architecture, setting the stage for compelling urban environments.