Westmoreland County Courthouse, Greensburg, Pennsylvania, USA: reconstruction of an historic dome in a substitute material

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ABSTRACT

Westmoreland County Courthouse, designed by Pittsburgh architect William Kauffman, was constructed in 1906-1907. The Courthouse is constructed with granite-clad walls and a central dome. The dome rises 175 feet above the ground and, together with the rotunda drum, is supported by a steel truss system. The original dome was clad with gold and cream-colored glazed terra cotta. After a partial structural failure of the dome in 1977, the terra cotta of the dome was replaced with new terra cotta that did not match the original color scheme. The new terra cotta soon exhibited signs of severe deterioration. Wiss, Janney, Elstner Associates, Inc. (WJE) was asked to investigate the dome in the late 1980s. This investigation determined that the replacement terra cotta on the dome was in poor condition and could not be salvaged.

The goals of the dome reconstruction were to restore the historic appearance of the dome, provide a durable and serviceable exterior cladding, and integrate the new system with the existing structure. A number of replacement materials were evaluated and cast aluminum was selected for the new dome cladding. Cast aluminum was selected because it is durable, can readily be formed to recreate original ornamental features, is light in weight, is easily maintained, and can be painted to match original color schemes. Cast metals also have a history of use in dome construction. In order to confirm the durability of the paint coating, an extensive laboratory test program was implemented. Construction drawings and specifications were
prepared for removal of the existing dome cladding and reconstruction of the dome in cast aluminum.

The paper focuses on the criteria used in the selection of cast aluminum as a replacement material, and on the design developed for retrofit of the dome structure and the fabrication and installation of the new cast aluminum.

INTRODUCTION AND HISTORY

The Westmoreland County Courthouse stands prominently on a hilltop in the city of Greensburg, Pennsylvania, approximately 30 miles southeast of Pittsburgh. The ornately carved granite courthouse building was designed by Pittsburgh architect William Kauffman, and was constructed in 1906-1907. The decorative central dome rises to a height of 175 feet above the ground, and is surmounted by an aluminum-clad decorative cupola. The dome was originally clad with glazed terra cotta: the background of the terra cotta units was gold, while the raised decorative elements were cream colored. The dome and cylindrical drum level enclose an unfinished space that provides protection for an interior decorative plaster dome below.

In early 1977 the original dome cladding suffered a partial structural failure when a section of the terra cotta collapsed. Soon after the collapse, the entire dome was reclad with new terra cotta units. The new terra cotta cladding was glazed with a single, mustard yellow color that did not match either of the colors on the original dome. The cavity between the waterproof membrane and the back of the terra cotta units was filled with a high slump grout, connecting the cladding units together monolithically and eliminating the air cavity. The new cladding soon exhibited signs of severe deterioration including spalling of the glaze and terra cotta body. The hollow clay tile of the inner dome layer and the waterproof membrane were removed from the interior of the dome in an attempt to release water trapped in the system and halt the deterioration of the terra cotta. The deterioration of the terra cotta continued.

In the late 1980s, Wiss, Janney, Elstner Associates, Inc. (WJE) was asked to investigate the terra cotta dome to evaluate the design of the existing cladding system and the condition of the existing materials. The investigation included research into standards of dome construction and terra cotta cladding of domes, as well as laboratory tests of the materials used in the existing dome cladding. The investigation determined that deterioration of the existing dome cladding would continue, and that the terra cotta cladding was not salvageable and required replacement.
REPLACEMENT MATERIAL SELECTION

The goals of the design for replacement of the dome cladding system were to restore the historic appearance of the original dome, provide a durable and serviceable exterior cladding, and integrate the new system with the existing structure. Replacement materials considered for the new cladding included terra cotta, precast concrete, cast stone, glass fiber-reinforced concrete (GFRC), fiber-reinforced polymers (FRP), cast metals (in particular, aluminum), and stamped or formed sheet metals.
A research program was initiated to evaluate the candidate materials. Samples and material data were obtained for the substitute materials. Criteria were developed for selection of the new dome cladding material. It was important that the new dome match the original dome as closely as possible in size, shape, color and reflectivity. Since the original dome no longer existed, these characteristics were determined through research and available photographs and drawings. The replacement material products were required to have a proven track record of durability in a similar climate to that in Greensburg. The materials and detailing selected were required to have been successfully used in the past to construct similar decorative domes. The installation design required that the material have a proven ability to keep out water. The materials and design were also required to be compatible with the capacity, movement, and detailing of the existing system of radiating steel ribs. It was also important that firms and contractors be available to manufacture and install each material to the specifications required for the new dome, and the methods for installation were required to be relatively simple. Maintenance requirements were also taken into consideration. Finally, the cost of producing, installing, and maintaining each material was evaluated.

Based upon these criteria, and research performed, the selection was narrowed down to new terra cotta and cast aluminum. Cast aluminum was selected because it is durable and corrosion resistant, can readily be formed to recreate the original ornamental features of the dome, can be produced rapidly and with consistency, is light in weight, is easily maintained, and can be painted to match the two-color scheme of the original dome. Cast metals also have a history of use in dome construction. Terra cotta also met the criteria for selection. However, installation of terra cotta under the existing conditions at the dome was difficult due to weight of material, number of units, and transport and handling to the high dome site. Also, a limited number of fabricators were available to produce a high-quality, consistent product in large quantities, and a strict quality control program was more difficult to implement than for cast aluminum.

DESIGN OF CLADDING

The design of the new cast aluminum cladding system was organized around the following criteria: close cooperation with fabricators and installers of cast aluminum systems in order to provide a buildable solution; an understanding of the characteristics of aluminum, including a high coefficient of thermal expansion and a potential for galvanic corrosion; and research and testing of potential paint coatings to provide a durable coating system that meets the design and color requirements for the dome.
During the design phase, the architects visited facilities where patterns for new cast aluminum pieces are made. Patterns, the positive models for the pieces to be cast, are used to form the sand molds into which the molten aluminum is cast. Foundries were visited to observe the molding and casting process. Cast aluminum fabricators were consulted on aspects of the casting process, including the design of patterns and molds, and how these limit the size and shape of the cast aluminum panels. These visits, as well as the cooperation between the trades at this early stage in the design, helped immensely in the development of the design. In particular, this process led to the design of proper panel sizes and configurations that could be easily molded, cast, shipped, and installed on the dome.

Since aluminum has a higher coefficient of thermal expansion than other traditional building materials, the design was based on providing connections that would allow the aluminum panels to expand and contract freely in response to temperature variations without binding with the back-up steel framing. This was accomplished by using steel arms and connection angles with multi-directional slotted holes in a sliding connection. Joints between aluminum panels were sized to allow for proper expansion and contraction of sealant. Also, due to the potential for galvanic corrosion between the new cast aluminum panels and the existing steel back-up frame, connections were designed to incorporate material separators between all dissimilar metals.

As part of the research and quality control programs, paint coatings for the new cast aluminum units were investigated and tested. The systems tested included several proprietary fluoropolymer-based coatings containing Kynar resin, factory-applied with primer, topcoat, and clear coat. In order to provide for field touchups after installation and in the future, air-dry fluoropolymer topcoats were also evaluated. The laboratory test program utilized samples formed by the cast aluminum fabricator, and prepared, shop-coated, and selectively touched-up by the coating applicator. The samples were subjected to a series of weathering, adhesion, and durability tests to confirm their serviceability. Several systems were tested, and one factory-applied and one field touch-up product by a single manufacturer were selected based on the laboratory studies and research.

The initial schematic design for the new cladding included the replacement of the inner dome layer and the use of a cavity system similar to the original dome construction, with a waterproof membrane on the face of the inner dome layer. The new steel connection armature was to be attached to the existing steel ribs of the frame, penetrating the membrane layer and supporting the new cast aluminum panels. However, the numerous penetrations of the steel connection arms through the waterproof membrane posed potential sources of leakage to the interior. The inner dome layer and
cavity construction did not allow for easy access to the connections during construction, or after construction for maintenance.

In the revised design, the inner dome layer was deleted and a new floor level was added at the interior of the dome. The waterproof membrane level was moved to this floor level, sloping downward from the center of the dome to the perimeter at the springline of the dome where weep holes were provided. The back sides of the cast aluminum panels and their connections were exposed to the interior of the dome. Vents were provided in the floor and cupola of the dome for air circulation inside of the dome to minimize condensation. This design dramatically reduced the number of penetrations though the waterproof membrane, and allowed for easy access to the panel connection from all sides while simplifying installation of the panels. This design also exposed panels to the interior, permitting regular maintenance and observation. This will greatly simplify future repairs to the aluminum panels, panel connections, existing steel framing, and the waterproof membrane.

Figure 2. Elevation/section through the dome and drum, showing design for the reconstruction.
The steel connection armature was refined to a T-shaped configuration. The armature consists of seat angles rigidly connected to the existing steel frame. Extension angles are connected to the seat angles and extend to the back side of the cast aluminum panels. The extension angles are connected to the seat angles with slotted bolt holes to allow for installation adjustments and for construction tolerance. Once the angles are properly located, the bolts are tightened to form a rigid connection. Finally, cross angles are attached perpendicular to the extension angles. Clip angles connect the cast aluminum panels to the cross angles with multidirectional slotted holes in sliding connections to allow for the expansion and contraction of the cast aluminum panels. This typical armature is repeated at almost every panel connection, thus simplifying the construction sequence.

![Diagram of new steel connection armature](image)

**Figure 3.** Plan of new steel connection armature, showing structural connection of aluminum cladding to existing steel frame.

**CONSTRUCTION**

After the final design was completed and a contractor and fabricator were selected, the cast aluminum fabricator visited the site to make rubber molds from the existing terra cotta dome. The measurements and molds were used in the development of shop drawings for the new panels. During the preparation and review of shop drawings, the architect and fabricator worked together to refine the panel design to achieve the desired appearance of the new dome, while providing proper structural connections and joint conditions.
Portions of the dome were modelled at full scale by the fabricator to test proper fit and alignment of the new panels and connection arms. The rubber molds made at the site were used to make the patterns for the new panels. Patterns were constructed of wood and plastic. Sand molds were cast around these patterns, which were then removed from the sand molds leaving a hollow void in the shape of the panel to be cast. Molten aluminum was poured into the sand molds, and once cooled the molds were broken apart and the new cast aluminum panels were ready to be cleaned and finished. The panels were then sent to the coating applicator for final preparation and application of the two-color paint coating system. Finally, the panels were packaged and shipped to the jobsite for installation.

While fabrication of the cast aluminum panels was in progress, work at the dome was started. The new waterproof membrane was installed at the new floor level prior to the demolition of the dome in order to protect the decorative plaster dome below from water damage during construction. The existing terra cotta cladding and grout back-up were then removed. The existing steel framing was inspected, cleaned, and given a new paint coating in preparation for installation of the new cast aluminum panels.

Once the new panels arrived, the new steel connections were attached to the existing steel frame and the panels were installed on the dome. Installation of the panels began at the base of the dome and proceeded upward to the cupola. During the installation, the architects performed regular site visits to observe construction. Constant communication between the architects, the fabricator, and the installer during construction helped assure proper installation of the cast aluminum panels. Correct installation of the panels and steel connections was very important to the performance of the dome cladding to provide adequate anchorage for the panels, while allowing for the movement capability of the designed system during thermal expansion of the cast aluminum panels. The final step of the dome construction was the application of a field-applied coating to the existing aluminum cupola cover to match the color scheme of the new dome. The paint coating used at the cupola was an air-dried system of the same paint coating specified for field touch-up of the shop-coated cast aluminum panels.
Figure 4. Installation of the new cast aluminum cladding units was simplified because access was available from the interior of the dome, and the cladding units were relatively light in weight.

CONCLUSION

The Westmoreland County Courthouse dome reconstruction provided a unique application of substitute materials to successfully replicate the historical appearance of a building. The courthouse had seen the failure of two terra cotta clad domes. With the new design, the appearance of the original two-colored decorative dome was restored, while the best possible material, cast aluminum, was used to satisfy durability, finish, and installation requirements for the special conditions of the dome.