Integrating Terra Cotta Window Mullion Repair with Leaded Stained Glass Window Restoration

at St. Dominic's Church, San Francisco

by Lex F. Campbell; Simpson, Gumpertz, and Heger

Introduction

St. Dominic's Church in San Francisco, CA, is in the process of completing a multi-phased terra cotta and leaded stained glass window restoration project. With the ambitious objective of restoring more than 90% of the window openings and leaded glass window panels in the Church, the project encompasses more than 70 openings, including windows as large as the 21 x 31 ft. *Christ in Glory* tracery window to smaller 3 x 5 ft. arched amber glass windows. Nearly all of the windows were experiencing deterioration of terra cotta mullions that frame the lancet openings and support the Gothic tracery. Concurrently, much of the leaded glass was experiencing significant problems with lead and glazing deterioration.

Remarkable in scale for a parish of its size, the restoration project provides valuable lessons in some of the complex issues encountered in integrated terra cotta cladding and leaded glass window restoration. This paper will identify typical problems of deterioration encountered in terra cotta window tracery systems. Furthermore, it will emphasize the importance of integrating the terra cotta and stained glass setting in order to provide a watertight system. Understanding the nature of terra cotta construction; identifying underlying causes of deterioration; designing effective repairs; and planning and close coordination between trades have all contributed to a successful restoration that is now nearly complete.

Terra Cotta and Gothic Revival Architecture

Architectural terra cotta was a common construction material in the United States during the first half of the twentieth century. Made from fired clay typically with a ceramic finish, terra cotta formed a durable facing material with unique functional and ornamental potential. At the functional level, terra cotta blocks were commonly used as wall facing and on cornices to provide durable weather protection. Aesthetically, buildings were visually enhanced by the unique colors formed by glazes. Terra cotta offered countless numbers of shapes and was able to articulate any number of architectural styles.

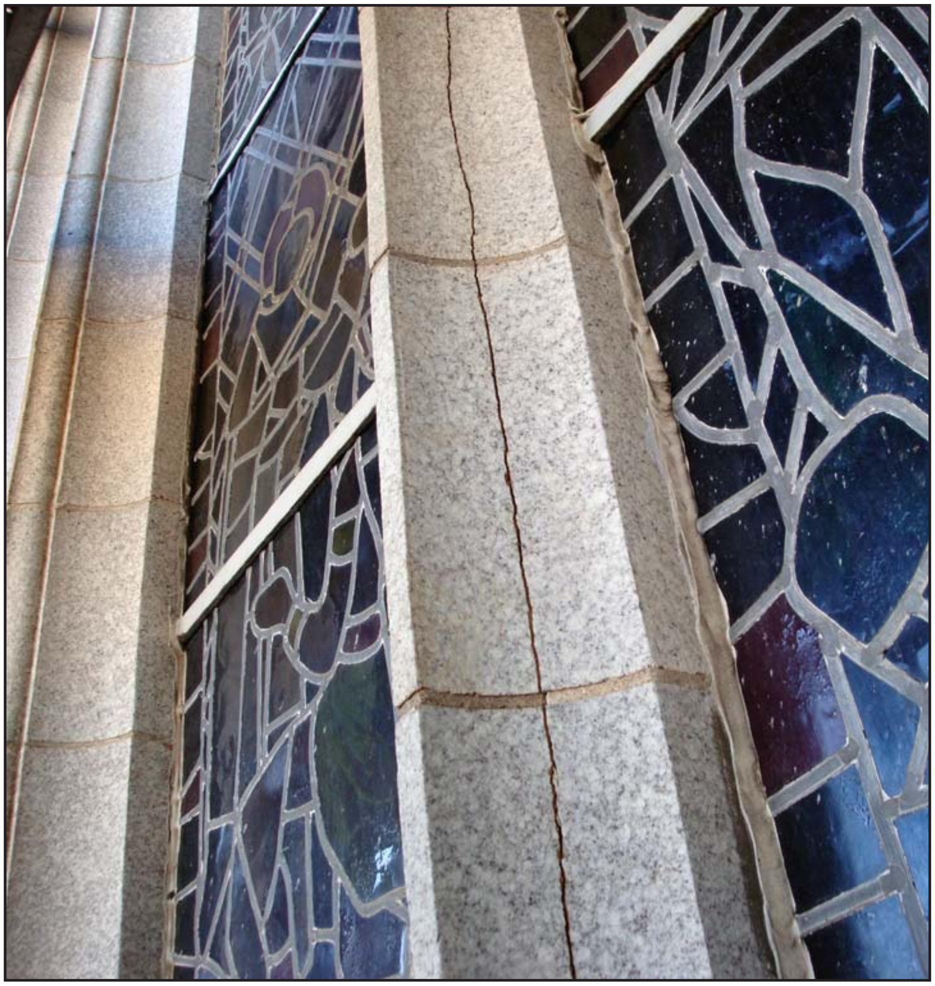
Perhaps best known for its utilization as ornamentation and facing on commercial buildings, terra cotta was also especially applicable to church construction. The highly sculptural clay material, which was formed from sculpted molds, made it ideal for the intricate ornamentation and sculpture of Gothic Revival churches in particular. Tracery windows were no exception, with terra cotta used to form jambs, mullions, and elaborate tracery work.

In some ways, the simple configuration of terra cotta block window construction is similar to traditional masonry coursing. The sill supports stacked mullion or jamb blocks, which, in turn, support a spring stone and tracery blocks within an arch. However, the nature of terra cotta is different from stone in several important ways. Primarily, terra cotta blocks are hollow and require structural reinforcing most often comprised of steel and grout fill. Terra cotta, which is not load bearing, generally is anchored to the structural frame. The exterior and interior wall facings, often of different materials leave a groove (or rebate) in between for the window placement. Grout fill is often installed in the terra cotta cavities to form solid blocks as well as to provide additional structural stability.

The east and south elevations of St. Dominic's Church.

A typical Gothic pointed arch window.

As opposed to monolithic stone block coursing, terra cotta construction is



A vertical crack in a terra cotta mullion.

instead an assembly of components each with specific function and potential problems and rehabilitation issues to address. As we will see, these factors may significantly impact restoration approaches to tracery window restoration from restoration sequencing and window removal to the final setting and the configuration of the support matrix.

St. Dominic's Tracery Windows

Designed by Arnold S. Constable in conjunction with the Beezer Brothers, the current St. Dominic's Church (there were two other buildings) was built in 1928. The Gothic Revival building is constructed with a reinforced cast-in-place concrete frame and walls and architectural terra cotta cladding on the exterior. The interior walls are finished with cast stone. A seismic retrofit in the early 1990s added a concrete ring beam around the roofline and a series of flying buttresses along its perimeter. The main building forms a cruciform plan characterized by a long nave crossed by a transept.

The Gothic Revival style of the church is primarily characterized by a series of large arched tracery window openings with multiple lancets in the nave clerestory, transepts, and apse. A series of multi-paneled and single arched foil and simple lancet windows are found on other walls of the building, including in the Sacristy and Confessionals.

In multi-lancet windows, terra cotta window mullions separate the lancets and support the corresponding tracery or quatrefoils. The window mullions range from seven to 14 inches wide and rise three to 20 feet high, where they meet the tracery spring stone. There are a total of 76 window openings, 41 with at least one or more mullions. Installed within the window openings are stained glass windows by the Connick, Ingrand, and Cummings studios and some amber glass windows of unknown origin.

Cracked Window Mullions

In 2001, the engineers Simpson, Gumpertz & Heger were hired by the church to investigate the conditions of the walls and windows, with a particular emphasis on the window mullions. Open vertical cracks were visible on select window mullions. Deterioration was also noted in the leaded glass windows, which, according to church records, had never been serviced since their installation.

SGH conducted a ground-level binocular survey of the terra cotta walls, window mullions, and window openings. In their initial findings, SGH observed that a substantial number of terra cotta mullions were cracked, with varying levels of severity. In some windows, an open vertical crack extended the height of all the mullion blocks. Some of the more severe cracks were open with rust staining evident on the surface of the terra cotta. A select group of mullions on the north elevation were less damaged, with single blocks being cracked if at all. SGH suspected that corroded structural steel embedded in the mullions was the cause of cracking. Severely cracked terra cotta potentially can lead to loose spalls, pieces which can fall from the building. The poor condition of the window mullions was also an obvious threat to the condition of the leaded glass windows and tracery matrix.

Physical investigations of cracked mullions and structural reinforcement by removing terra cotta blocks confirmed that corroded steel mullions were the problem. Pressure from flaking and expanding corroded steel caused the mullions to expand and crack. A likely cause of the corrosion was water leaking into the mullions from deteriorated window

A window reglet or groove in poor condition.

The installation of a new stainless steel "T" mullion and terra cotta blocks.

perimeter mortar and sealant/glazing putty joints. The steel mullions also lacked sufficient anchorage back to the structure and were typically embedded into the surrounding concrete or brick masonry substrate. Many of the embedded connections were now cracked around the masonry substrate due to the corrosion. In some windows, the tracery framework did not permit the extension of a mullion up to the lintel, creating a cantilevered mullion potentially with inadequate lateral support to resist wind and seismic loads.

Concurrent with the terra cotta survey, the leaded stained glass windows were surveyed by a conservator. Common problems included weakened, broken, and deflected lead cames, lead corrosion, insufficient and poorly applied support bars, hard-setting putty inhibiting movement of the panel within the frame, deteriorated glazing compound, broken glass, and built-up dirt.[1] The setting detail in the frame or reglet was in poor condition. The hard cement and glazing putty used to set the windows were cracked and deteriorated, allowing water into the window frame and wall. Finally, all the setting materials, including some sealants, tested positive for the presence of asbestos fragments.

A complete body of schematic design information included a comprehensive visual survey and evaluation, invasive investigation of the terra cotta substrate, a conservator's report, and hazardous-material report. SGH engineers and architects effectively used this information to design and plan a phased restoration.

Innovative Repairs & Project Planning

The large scale of the project and potential overall costs presented a dilemma for the church, that, like most organizations, had a limited set of funds available on a yearly fiscal cycle. Therefore, in order to spread out costs, it was evident from the very beginning that the project would be phased over a number of years. Furthermore, priorities would need to be set to address some of the more severe deterioration and potential life safety issues first.

During their overall survey, SGH noted the severity and extent of cracking at window mullions that ranged from all mullions being cracked at an individual window to none at all. The cracked window mullions could further be classified into blocks that contained open cracks and visible spalls, indicating more advanced deterioration. In the end, blocks that contained severe deterioration (*i.e.* open cracks and spalls) and mullions with all (or nearly all) the blocks cracked were assigned a high priority or Priority I. Windows that contained some severe cracking that was limited to less than five mullion blocks were assigned to Priority II. Windows with minor cracking in individual mullion blocks or no cracking were assigned a low priority, or Priority III.

A stainless steel cross bar provides additional structural support.

A lancet window with a new perimeter sealant joint.

The condition of the leaded glass windows provided additional direction as to project priorities, phasing, and planning. Windows were classified according to windows that immediately need re-leading (as directed by the glass conservator) and windows that should be re-leaded within the next 10 years and 20 years.

When mullion and window conditions were compared together, high-priority repairs were immediately evident in windows that contained Priority I mullions with glass that needed immediate re-leading. Window mullions with little or no mullion replacement and longer releading cycles were scheduled for work later in the repair phasing. This system was used effectively to prioritize and divide window repairs into phases that were manageable and affordable to the church, while addressing high-priority repairs first. Project delivery initially included the production of construction drawings and specifications for pricing and could be adjusted as needed to fit the church's budget for the year.

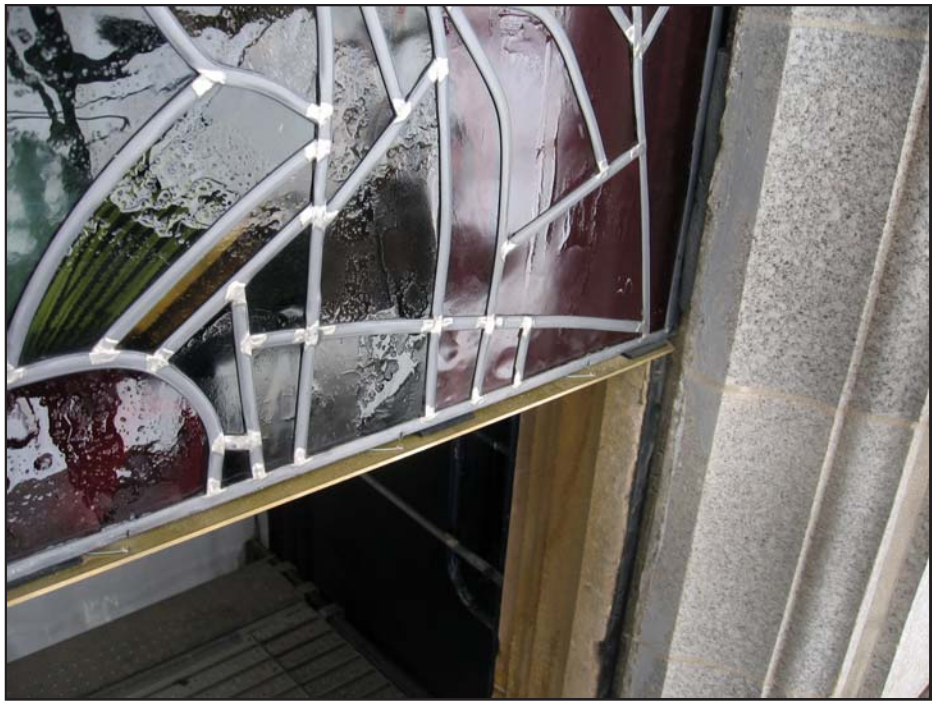
Work proceeded at the south Nave clerestory first, followed by the south transept, apse, triforium gallery, east and north elevations, respectively. While all the windows and terra cotta on each elevation had unique requirements, various themes were consistently repeated throughout the project, revealing issues that are perhaps common to terra cotta tracery window openings.

Abatement

The existing leaded glass windows originally were set in a mortar-filled reglet finished with a sealant fillet on the exterior and glazing putty on the interior. As is standard practice, the sealants and glazing were tested for hazardous materials.

All of the tested windows contained asbestos fragments within the exterior sealants. Due to its hazardous content, an abatement contractor that specializes in the removal and disposal of hazardous materials was required to remove the sealant. As part of this work, the abatement removal needed to be contained within a conditioned enclosure to prevent dust and materials from entering the outside air. Special training, protection, and certification were required to enter the enclosures during work. Due to the proximity of the work to the leaded glass and special access conditions, the question was raised as to how the abatement work would be accomplished, supervised, and coordinated with the glass removal.

For this project, which lacked a general contractor, the best solution was to specify that the abatement work be included as part of the stained glass restoration studio's work. This meant that the stained glass sub-contractor would be responsible for supervising the removal of all materials around the glass, as well as removal of the glass, and the condition of the glass upon removal. In practice, the stained glass restoration sub-contractor brought in a hygienist to establish and supervise procedure as well as to provide the required training for being in enclosures. The stained glass sub-contractor also contracted the abatement contractor for removal of the hazardous material. The abatement contractor was closely supervised by the stained glass restoration sub-contractor to limit damage to the glass.

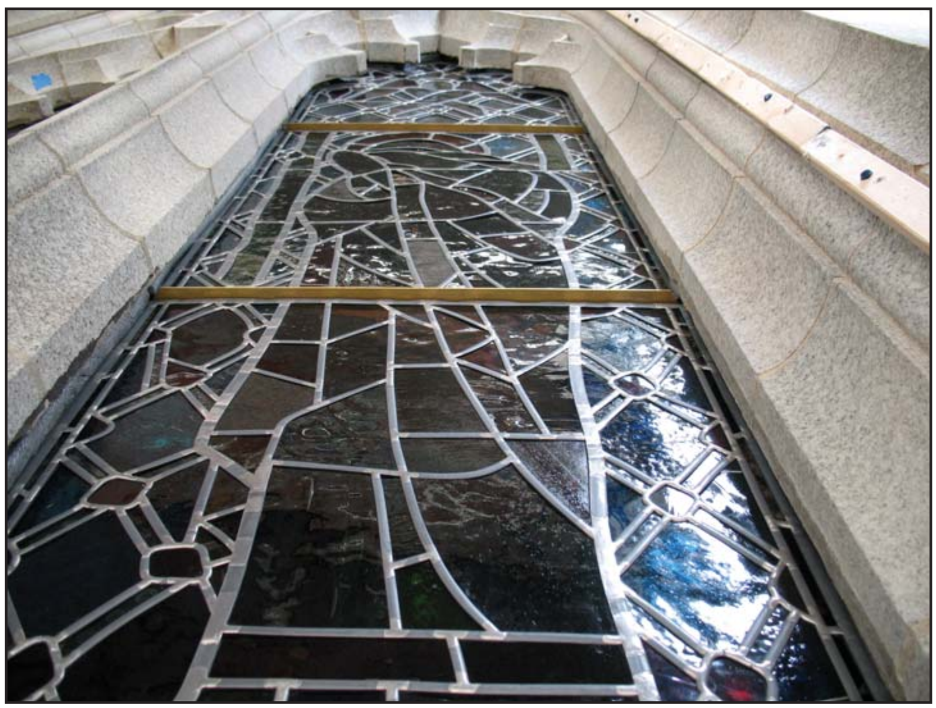


Exterior detail of new tee bar installation.

Mullion Repair

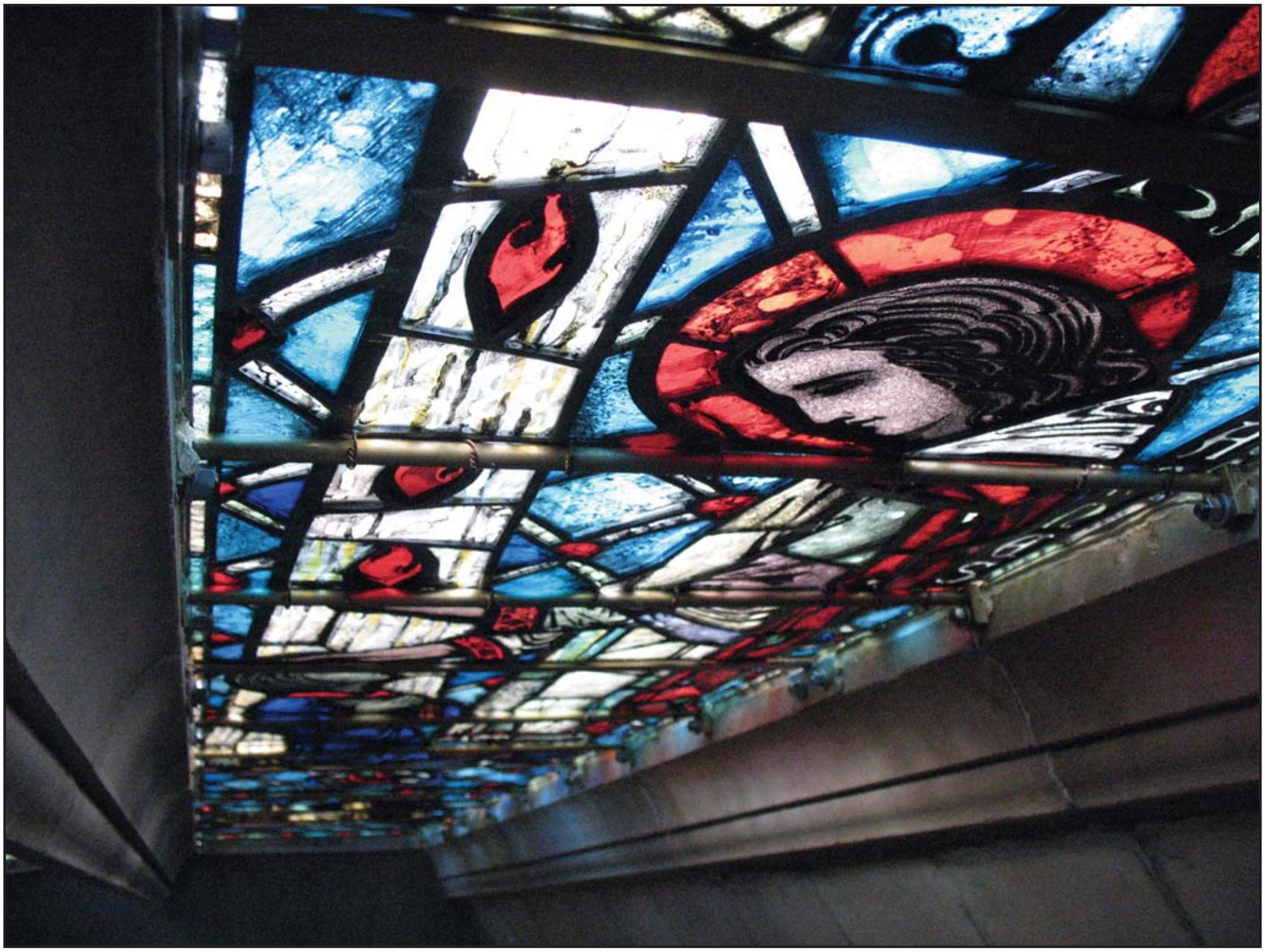
Following the removal of the leaded glass windows for restoration, the terra cotta mullions were repaired. The terra cotta mullions are formed by stacked individual hollow terra cotta blocks filled with grout and supported by steel "tees." To repair the mullions, the terra cotta mullion blocks were disassembled, and cracked mullions were replaced. Where possible, intact mullion blocks were salvaged and reinstalled. The corroded supporting steel tees were removed and replaced with new stainless steel support tees and anchoring.

Generally shaped in paired cavetto or cyma reversa profiles, the mullions varied in size from window type to window type. An inventory was developed identifying the different types of blocks and quantities to be replaced. The final replacement inventory was subsequently used for pricing and placing orders with the terra cotta manufacturer for reproduction. New blocks were manufactured to be identical in size, profile, texture, and color to the existing blocks.



A lancet window with new brass tee bars.

The design of new steel tees and anchoring had to contend with the size of the terra cotta mullion blocks, overall size of the window openings, and the existing conditions of the mullion connections to the concrete structure. Unique sets of details were developed for each window type; however, various aspects of the designs were conceptually similar. In general, to compensate for wind loads, the new stainless steel tees increased slightly in thickness from the original tees. Where



Interior of lancet panel showing brass round bars.

possible, stainless steel anchor plates were used to connect the ends of the steel mullions to the concrete wall structure. In other locations, the ends were embedded in grout-filled notches cut into the concrete wall opening at the sill or lintel. Stainless steel wires wound through the webbing connected the terra cotta mullion blocks to the steel tees. The entire mullion cavity finally was filled with masonry grout to provide additional structural stability.

In some cases, such as on some larger windows, the steel mullion was not sufficient to meet code requirements in order to withstand wind loads. At these windows, an H-shaped steel cross bar was used to connect the mullion to the window jambs, providing additional lateral support. Because the cross bar was exposed, there was a visual impact on the window with the introduction of a horizontal element. To minimize the impact, the horizontal bar was located between the leaded glass panels in individual lancets, replacing the bronze tee that would normally provide horizontal support. Because the cross bar was thicker than a typical tee bar, adjustments were necessary in the overall vertical alignment of the lancet panels. The panel located above the horizontal bar was raised slightly to maximize the visibility of the glass design.

The terra cotta work was completed with the preparation of the groove between the terra cotta cladding and inside stone to accommodate the leaded glass setting. Much of the work required leveling out existing bumps in the grout fill and filling in gaps to create a consistent one-inch deep groove or reglet. With the completion of this work, the window openings would be ready for the leaded glass to be installed.

Leaded Glass Setting and Support

In the new design for the window setting, two primary issues needed to be addressed: waterproofing and adequate vertical support for the restored leaded glass panels. Both of these problems previously contributed to the deterioration of the windows as well as the mullions.

Originally, the leaded glass windows were set in a mortar-filled reglet. At some locations, sealant (on the outside) and glazing (on the inside) fillet joints were installed to provide added weather protection. The failure of these joints allowed