Structural strengthening of historic chapel: extensive repairs and restoration return the Seton Hall University icon to its original grandeur

Harald Greve

The Chapel of the Immaculate Conception is the centerpiece of the Seton Hall University campus in South Orange, N.J. This historic structure was built during the civil war era of local brownstone and lime mortar. Architect J. O'Rourke and Builder Moran & O'Rourke created the original building in 1863; a sacristy was added in 1887. Brilliantly colored stained glass windows were later commissioned and artist F. Mayer of Munich, Germany, produced the stunning results between 1903 and 1908.

The building is constructed of stone bearing walls stiffened with stone buttresses at the ornamental timber roof truss support locations. Walls are 12-in. thick masonry stone bearing walls with rubble filled cores. A 6-in. sandstone veneer facade is constructed with solid stone buttresses at every setback corner. The Chapel is the signature building of the Roman Catholic university campus.

There is a canvas painting of flying angels decorating the arched stone bearing wall that vignettes the main altar. A cloverleaf-shaped window was constructed at the top of the arch. This window was covered by soot from many years of candle illumination and had been forgotten until this renovation. After the restoration, sunlight streams into the chapel from this window, which is named "The Eye of God."

Numerous problems

During the work, it was discovered that the main arch had serious structural cracking that required strengthening. Old masonry arch cracks were concealed behind multiple layers of wall plaster. Exterior stone buttresses had moved outward causing the arch wall to crack.

Applied Engineering & Technology designed the temporary support system for holding the rubble masonry arch wall while removing and replacing the buttresses. Controlled sequential facade stone replacement was performed simultaneously, with this work adhering to a tight construction schedule.

Original mortar samples were tested for aggregate and lime proportions. New replacement mortar was engineered and the mix was specified to account for stone and mortar strength requirements. Elite Restoration was selected as the prime masonry contractor.

Elite Restoration tested the mortar design for workability and prepared mockup samples for approval. The ribbon joint was selected for highlighting the stone and a mortar color was developed with batch plant mixed dye.

Femenella & Associates was retained to restore the historic stained glass windows as the masonry stone contractor provided structural repairs to the buttresses, main arch, and facade walls. Efficient work by skilled masons and prompt stone delivery were essential in order to meet the work schedule.

Mortar joints were raked out at the beginning of the project as the pressure washing of the existing facade took place. Many pre-existing patches were removed to expose the surface conditions of hidden stones. A final engineer's count of problem stone

conditions was established and compared with the previously estimated repair quantities. The original contract-specified stone replacement quantities turned out to be quite accurate.

Stone delivery and fabrication were performed by Old World Stone Co. Stones with two different hues were interchanged to replicate the original sandstone color. Original stone was removed from the O'Rourke's Quarry located on the face of Orange Mountain near Seton Hall.

A stone fabricator detailed shop drawings from site measurements of existing ornamental stones. Craftsmen carved and delivered brownstone as 4-in. and 6-in. veneer stones. Special replica roof crosses and ornamental window edge coin stones were hand-chiseled to match the original artwork.

Mortar concerns

A special mortar mix was designed for tooling a high relief ribbon joint and to accommodate the compressive strength properties required to protect the existing stone from outside edge spalling. ASTM C270 permitted designers to either specify the mortar mix ratios or the final mortar properties.

It was decided to specify the mortar mix and perform quality assurance sample mix analysis during the construction. The mix included a color dye for the desired earthy appearance. The designed mortar mix was relatively soft in comparison with the facade stones. The new mortar had a compressive strength of 750 psi, while the original stone was 5000 psi, and new replacement stones varied from 6000-9000 psi.

An engineering evaluation study of the stone delaminations showed that many original sandstones were exfoliating their outer layers because there was a prior application of surface sealer on the stone. Water subfusion caused delaminations of sandstone around corners and at stone surfaces. The naturally porous sandstone (quarto-felspathic arenite) composition permitted quick absorption of water.

The surface applied repellant, however, created a barrier that trapped the water where freeze-thaw could cause delaminations. Construction Materials Consultants Inc. assisted in the laboratory analysis of the mortar and stone waterproofing properties. It is believed that the presence of a non-breathable surface sealer prevented evaporation of absorbed moisture in the stone.

This condition increased the degree of saturation and the potential for freezing-related expansion and scaling during cyclic freezing and thawing. Cylindrically-shaped, curved delaminations were observed, which supported this theory of water repellant-induced scaling at various carved stones throughout the building.

Over time, the building gradually deteriorated from exposure. New copper flashing details were developed in combination with new coping stone anchorages. The masonry restoration contractor replaced deteriorated buttresses, field-cut facade replacement stones, restored the window arch stones, and coordinated installation of copper flashing and coping stones.

Masonry arch restoration

Many years of exposure caused the original stone wall buttresses to lean outwards and separate from the building bearing walls. The two main stone buttresses that support the main stone arch over the altar were beyond repair. These two buttresses were removed and replaced with reinforced concrete retaining buttresses concealed with facade stones to match the original construction.

The new concrete buttresses were designed larger than the originals for structural masons. Prior to removing buttresses, an

arch support system and a temporary lateral tie system were engineered to stabilize the stone masonry arch wall. These temporary supports were designed to hold the thin 12-in. thick arched wall together so that it did not expand during the reconstruction work.

At the main arch, serious structural cracking was discovered behind the canvas painting depicting angels. It became evident after removing the painting from the arched masonry wall that the plaster behind the canvas was cracked. Removal of the plaster revealed even larger cracks in the structural rubble stone masonry arch itself. This prominent arched wall required strengthening to stabilize it from further movements.

The stone arch is composed of a clay brick formwork concealed within painted ornamental plaster molding. The stone arch is constructed on top of the clay brick arch. Fortunately, the brick arch remained intact, but the stone wall was severely cracked. Stainless steel grouted anchors up to 25-ft. long were installed within cored holes along the width and radially within the arch wall.

Applied Engineering & Technology designed the strengthening configuration to tie together existing open wall cracks. After installing these post-tensioning grouted anchors, the wall cracks were repaired and plastered. The mural wall painting was cleaned and re-installed.

Stone facade repairs

At the start of the project, the worn stone surfaces made it difficult to establish a true building face line during the initial work. The irregular wavy stone surfaces were adjusted so that a new face line was established and the remaining stones now appear to be worn (even though they were the best stones of the original facade).

Ice damaged buttresses were repaired so that they were once again bracing the building bearing walls. Interior rubble stone within the bearing walls were water washed from exposure and voids were found as stones were removed for replacement. The interior rubble fill was repaired as stones were removed for replacement, but further work will be required to tie the exterior veneer stones together with the interior face stones. The extent of this work is not known because the interior walls are concealed with plaster.

There were so many individual stone replacements that it became necessary to sequence the repair clusters to limited areas at a time so that the work was performed in a checkerboard pattern. The work areas changed as the mortar cured.

New stones and re-used old stones were installed throughout the work to provide an original looking finish. It was important not to replace all surface damaged stones in the building. The charm and historical appearance of the 150-year-old building had to be maintained by keeping some of the stone imperfections built into the building facade.

Problems Galore

The years had taken a heavy toll on the Chapel of the Immaculate Conception. A detailed examination of the building revealed that the stone buttresses had moved away from the building (A) and caused serious cracking in the main masonry arch. Old masonry cracks were concealed behind several layers of wall plaster (B), and the soft rubble mortar literally crumbled to the touch (C). Many of the damaged stones required repair or replacement (D), some because of delamination resulting from earlier waterproofing efforts (E). Interior rubble fill within the bearing walls were water washed from exposure and voids were found as stones were removed for replacement (F).

To counteract the many problems discovered, the masonry restoration contractor replaced deteriorated buttresses, field-cut

facade replacement stones, restored the window arch stones, and coordinated installation of copper flashing.

[ILLUSTRATIONS OMITTED]

Harald Greve, PE, SECB, is a principal of Applied Engineering & Technology, Princeton, N.J. The firm provides structural and masonry consulting services for historic and modern structures. The author is a member of The Masonry Society, American Concrete Institute, and other professional societies.

Mr. Harald Greve can be reached at Harald@aetpc.com.