# Truly Redeeming Qualities

Crisscrossing the nave with four large steel trusses provides an inspiring, open worship space.

BY ADAM CRYER, P.E.

**THE CONGREGATION** of Christ the Redeemer Catholic Church, located in northwest Houston, Texas, had a clear goal in mind when they first conceived of constructing a new 27,000-sq.-ft sanctuary adjacent to the existing worship space: to create a volume that would expand existing seating capacity while continuing to unite its parishioners. In order to limit costs while preserving the former sanctuary facility, the decision was made to re-task the existing church to expand the square footage of their existing chapel. To unite the new and existing spaces, the architects chose to connect the two volumes using a common glass wall, which includes an impressive stained glass feature.

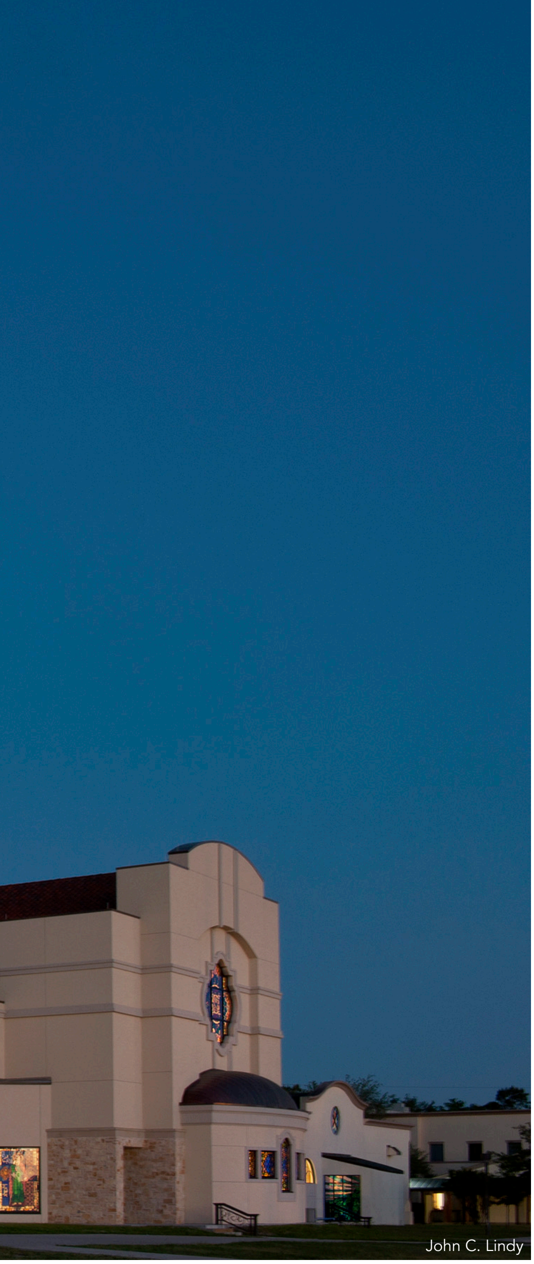
Because the essence of the church centers around a sense of community, the architects also wished to achieve an open nave floor plan with clear views of the sanctuary platform for all parishioners during services. This limitation meant there could be no interior columns within the nave. Furthermore, a significant amount of exterior light was important to the feel of the space. Early in the schematic design it became apparent that this unique combination of architectural requirements would necessitate development of a one-of-a-kind structural solution.

The footprint of the new church is a traditional cruciform shape but resting atop the intersection of the nave and the two transepts of the church is a 42-ft-diameter dome. Fabricated from fiberglass material, the dome is clad on the exterior with copper standing seam metal roofing and on the interior with hand-painted mosaic tiles. A cylindrical steel frame, using rolled HSS sections, supports the dome while accommodating vertical space for clerestory windows around the base of the dome. These windows illuminate the intricate mosaic of the dome while providing a central source of light for the sanctuary.

The primary roof structural system consists of a hybrid design using structural steel trusses and glulam beam framing. Four 54-in.-deep glulam ridge beams support a secondary glulam beam system topped with 3-in. (nominal thickness) tongue and groove wood decking. This combination of building materials serves as a testament to the versatility of steel and the beauty that can be achieved through its exceptional strength and compact section profiles.

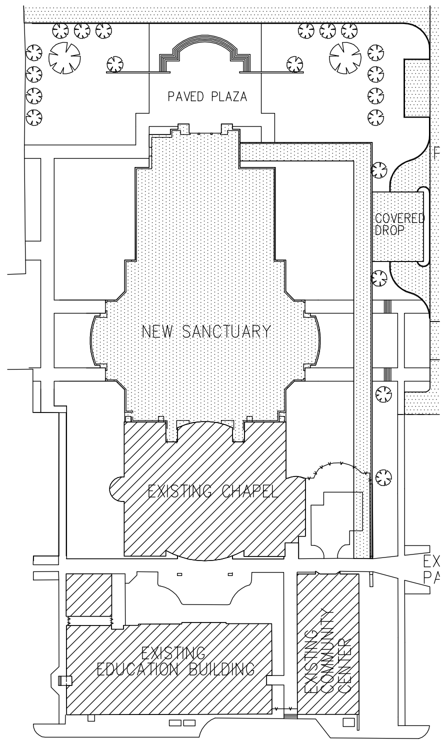
## Trusses

If there is a structural "heart" of the project it is without a doubt the four structural steel trusses that crisscross the nave, in pairs, and allow the main worship space to be column free. The trusses




◀ The 27,000-sq.-ft expansion of Christ the Redeemer Catholic Church, Houston, blends an expansive new sanctuary with the church's older facility, which now serves as a chapel.

▼ The new sanctuary is attached to the older structure, which is now used as a chapel, through a common glass wall.





▲ The 100-ft-tall bell tower at the entry to the new sanctuary features an architectural setback around the full perimeter at the 62-ft level, faciltated by fabricating the framework as two stacked segments.

▲ Partial cut-back rendering of truss node for convergence of eight wide-flange elements. Image created using RAM Elements.

span roughly 120 ft each and intersect each other in four locations just outside the perimeter of the dome. These intersections produce several nodes that consist of the convergence of eight wide-flange members to a single working point. These nodes are a prime example of how steel provided the design team the flexibility to meet the demanding geometric requirements of this project, while preserving the architects' original design intent for the space. Simply put, the geometric challenges of this project necessitated the use of structural steel.

More than a dozen truss configurations were examined to determine which would result in the most efficient overall design. Although the trusses were required to span 120 ft, the "pinch point," where the trusses transitioned from the clerestory region to supporting the dome (near mid-span) required that the trusses be reduced to just seven ft in depth at that location. This geometric constraint meant that the top chord of the truss would see a maximum factored axial load of nearly 700 kips. Standard wide-flange shapes were used for the entirety of the truss designs. The webs of the trusses were configured to accommodate the placement of all clerestory windows, located strategically by the architect to provide the sanctuary with natural light. Truss shapes were also configured to allow for coordination with a network of mechanical ductwork that conditions the space.

*Adam Cryer, P.E. is vice president and a founding principal of Pinnacle Structural Engineers and an AISC Professional Member. He has experience in structural design, detailing and project management for a variety of project types, including healthcare, worship, industrial and educational. He earned a Bachelor of Science in civil engineering from Rice University and a Master of Science in engineering from the University of Texas at Austin.*

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Interior views of the sanctuary's free interior roof corners, rose windows and glass wall shared with existing church building.

The first pair of primary trusses was field assembled and then lifted onto temporary erection towers. The second pair of trusses was then assembled between the first pair in three segments each. The trusses fit with minimal field work, which was particularly impressive given that 2½ in. of upward camber was built into all four trusses to reduce net deflections expected once all dead loads were applied to the structure.

## Construction Sequence

During the design phases, it became apparent that the sequence of erection for the primary trusses would have a significant impact on the design of the lateral braces located at the truss ends. If the trusses were fully welded into place prior to completion of the roof and installation of mechanical equipment, a significant set of forces would be permanently locked into the structure. The portion of construction occurring after erection of the trusses would include installation of terra cotta clay tile at the high roof, as well as four roof-mounted mechanical units at the low roofs that weigh roughly eight kips each. Welding up the trusses to the concentrically braced lateral steel frames would help relieve the truss elements of some axial load, but the economy gained by using these reduced truss member sizes would be lost back to the foundation design. This would occur because the permanent load would induce a large overturning force on the braced frames and the eight-ft-deep drilled and under-reamed piers supporting the back portion of the braces would have to be oversized to carry the associated pull-out forces.

The design team determined that it would be most economical to design the trusses for a simple span condition, where the trusses would not need to rely on any end restraint from the braced frames. Once all of the roof dead loads had been applied, the trusses would then be fully welded into place. Although this condition allows some transfer of roof live load from the trusses to the braces, it is minimal relative to the dead load forces.

## Coordination

The detailing of connections and design for reactions from the glulam beams to the steel trusses were closely coordinated between the structural engineer and glulam supplier on this project. The supplier's expertise in developing end connections for the beams was essential to finding effective details that would serve their purpose throughout the life of the structure.

One example of the supplier's insight relates to the tendency for large volume wood beams to shrink in continuously conditioned air, which can lead to "checking" of the wood laminations. This checking can cause delamination of the glulam beam which puts shear tab type connections at risk for failure. As a result, dapped bearing plates were incorporated into the connection designs to provide redundancy and supply protection from that particular limit state.

Beyond the sanctuary lies the adjacent renovated chapel space for the church. A curved steel wall with an inset rose window divides the sanctuary and the chapel, while still keeping the two spaces physically connected. The new and existing buildings were designed with an integral expansion joint to prevent any sharing of load between the two structures and their respective foundations. However, the challenge at the interface would lie in the geometry of the new wall above the joint.

The architects' design included a curved wall of stucco and glass that would terminate over the existing building, but could not be supported by it. Extensive field measurements by the general contractor, as well as careful coordination with the steel fabricator, led to a successful installation of these wall elements in the field.

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Steel framing at the interface between the new structure and the existing building, where a curved wall of stucco and glass terminates over the existing building but is not supported by it.

The design of the steel frames that form the face of the transept walls was controlled largely by serviceability requirements. Per the *International Building Code*, the 110-mph, three-second gust wind criteria paired with recommended deflection limitations resulted in frames consisting primarily of HSS members and miscellaneous steel angles to form the complex geometry around the windows. The walls were detailed to accept the intricate stained glass rose windows that serve as the focal point at the end walls of the church. The walls also support the half-domed apse that extends beyond the face of these exterior walls on either side of the church. Rolled tube steel beams were used in forming the eave of these architectural elements.

The architects also wished to conceal the substantial rooftop mechanical units that were sized to condition the entirety of the building interior. To do that, oversized parapets were employed

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▲ Primary trusses supported by erection towers at intersection points. The center portion of the lower chord shown here was for erection purposes only and was subsequently removed.

➤ Fiberglass dome being lifted into place atop the primary truss grid. The dome was erected using temporary steel hanger tabs.

to limit visibility of the units for parishioners standing at ground level. An HSS support structure, paired with bottom-flange bracing for the roof beams, was designed to be concealed within the parapets while providing necessary support to the stucco-clad walls.

The 100-ft-tall bell tower was designed as two stacked segments to allow for an architectural setback around the full perimeter at the 62-ft level. Economical, pre-tensioned steel plate x-bracing was used for the lateral force resisting system throughout the tower to reduce the cost of the structure. This system had to be carefully coordinated with the architectural details to ensure that the exterior studs could remain intact and impart no out-of-plane wind loading on the plate bracing. Eccentric HSS bracing was used at the top of the tower to allow for the openings through which the bells' tolling emanates.

### Schedule

Due to the congregation's wish to be moved into its new facility by the Christmas holiday, the project schedule was set to be fast track. Early in the design of the project, a collaborative approach was taken to the design and detailing of the project. Several goals were established to ensure that this schedule became a reality. To expedite the steel design process, the steel fabricator was brought onboard at the beginning of the design process to aid in decision making that ultimately would shave weeks off the detailing and fabrication time. As planned, the structural engineer was able to return the structural steel submittals to the general contractor at the first pre-construction meeting, which was months earlier than is typical for this type of project. Furthermore, the extensive involvement of the steel detailer in the design process resulted in fewer Requests for Information during the construction phase of the project and a quicker submittal review time by the design team, easily cutting an additional one to two weeks from the overall schedule.

From the start, the architectural design team aimed to create a new home for the church that not only united the church's worshipers but also reinforced the sense of pride associated with their existing facility. Fortunately, this project has the "wow" factor associated with a space that seems to defy the mind's basic concepts of geometric limitations of building construction and, in doing so, brings to light a special appreciation for its uniqueness and purpose.

In 2010, the project was awarded with the American General Contractors, Houston Chapter APEX Award in the project category of Liturgical/Church Over $5 Million, as well as a recent award from the publication *Texas Construction* for Best Worship Space. However, the greatest achievement for the design team has undoubtedly been the vehement praise from the parishioners themselves regarding their new 1,700-seat home. MSC

**Owner**
The Archdiocese of Galveston-Houston

**Architect**
Hall Barnum Lucchesi Architects, Houston

**Structural Engineer**
Pinnacle Structural Engineers, Inc., Houston

**Bender/Roller**
WhiteFab Inc., Birmingham, Ala. (AISC Member)

**General Contractor**
Fretz Construction Company, Houston

**Structural Software**
RAM Structural System, RAM Elements