St. James' Church Bell Tower

By Mark W. Holmberg, P.E

A group of parishioners at St. James' Episcopal Church (Marietta, Georgia) approached the church proposing to install a set of English full-circle change ringing bells in the main bell tower. The church agreed to the proposal. Fund raising began in 1995 and successfully concluded in mid-1996.

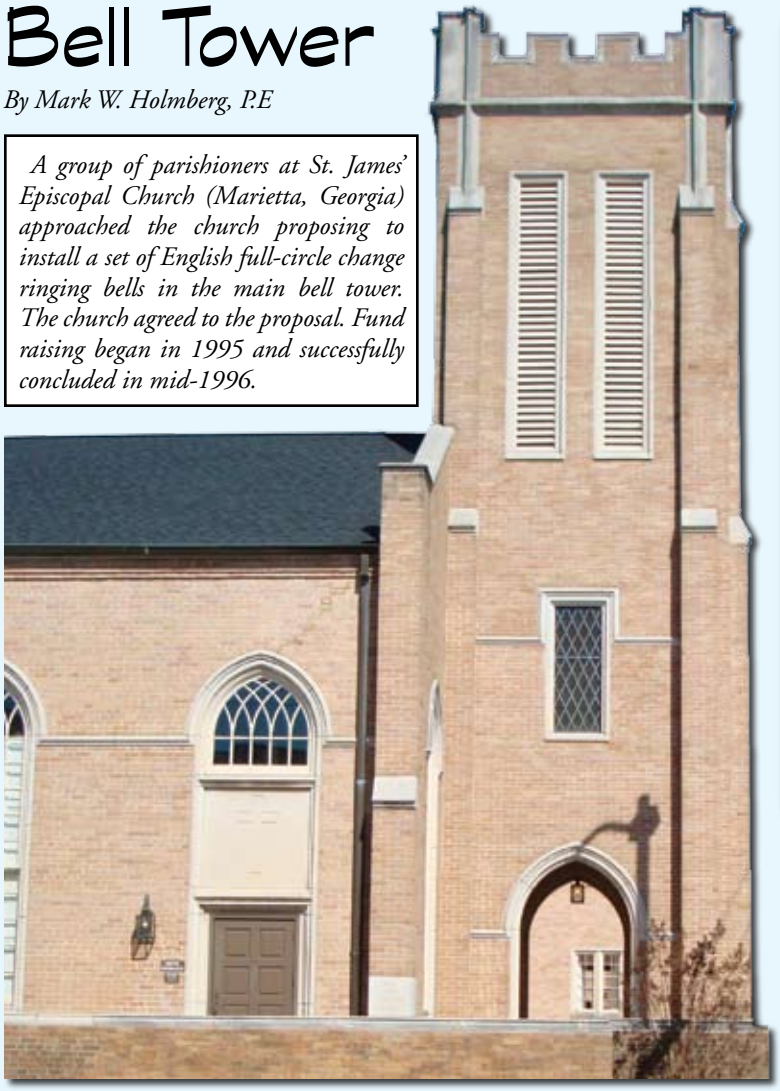

Figure 1: South Tower Elevation.

The St. James' bell tower construction is unreinforced brick masonry with limestone elements (*Figures 1 – 3*). The adjacent sanctuary also consists of unreinforced brick masonry walls supporting a steel truss and wood purlin roof framing system. The basic outside dimensions of the tower is 14 feet 10 inches square. Lower walls are 16 inches thick with large entry openings. The upper walls above the balcony/ringing chamber level are 12 inches thick. Concrete slabs with a depth of 5¼ inches are located at ringing chamber, bell chamber, and roof levels (*Figure 3*). The slabs are reinforced with #4 bars at 8 inches on center, 1-inch clear of the bottom, according to structural plans for the building.

The overall height of the tower is 59 feet 8 inches from top of footing to top of parapet. Assuming the main entry elevation at 100, top of footing elevation is 95 feet 4 inches, ringing chamber floor elevation is 113 feet 9 inches, bell chamber floor elevation is 127 feet 11½ inches, and roof elevation is 148 feet 10 inches. The maximum parapet height is 6 feet 2 inches.

In June 1995, the church requested that the author analyze the bell tower structure, recommend the total weight of bells for the tower, and design necessary structural modifications for the recommended weight of bells.

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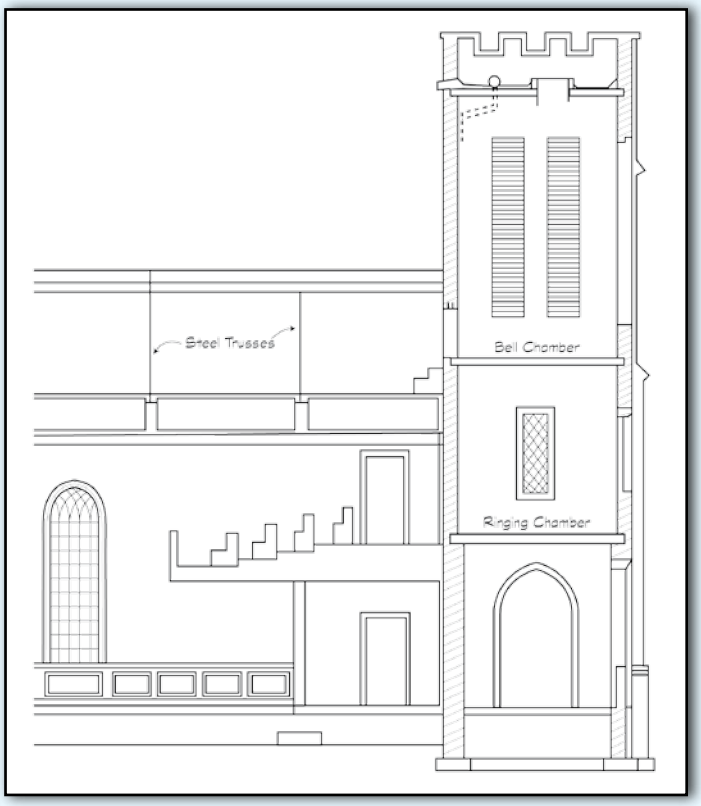

Figure 2: Tower Section from Original Plans.

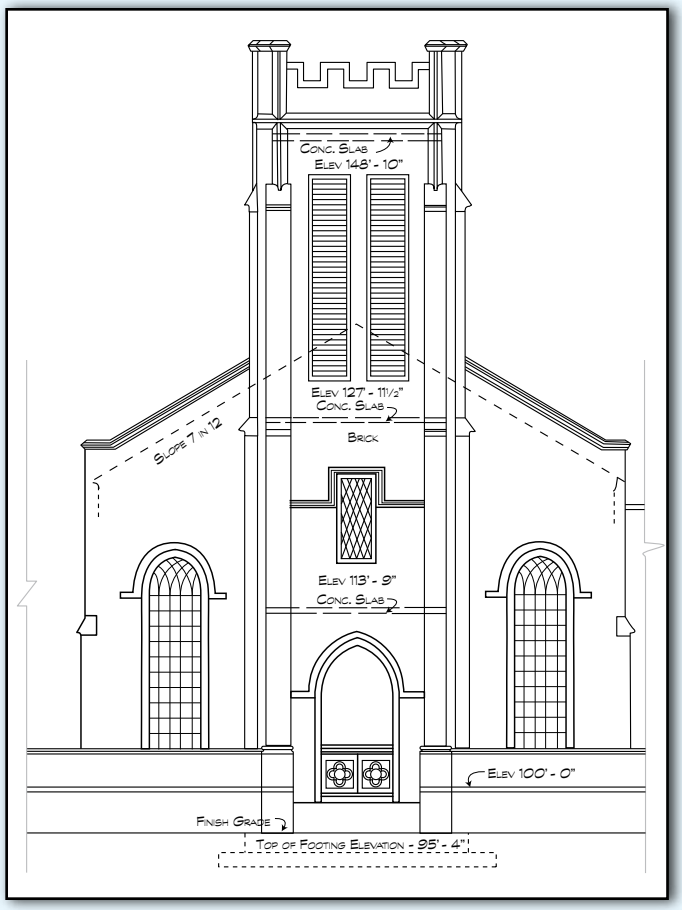

Figure 3: East Tower Elevation from Original Plans.

Change Ringing

Change ringing refers to ringing a set of tuned bells, hand bells, or large tower bells in patterns or *changes* based on mathematically varying the order of ringing them. The practice originated in England in the 17th century. The highest pitch or treble bell is number one, with the other bells numbered in order of pitch to the lowest or tenor bell. The treble is the lightest and the tenor is the heaviest weight bell. A set of change ringing bells consists of four to twelve bells. The majority of the 50 church towers with change ringing bells in the United States and Canada have sets of eight bells.

Figure 4: Bells in Down Position.

Change ringing bells swing full circle and sound when the clapper strikes the bell near the top of its swing (*Figure 4*). Individuals pulling on ropes control the bell swings. This type of bell ringing differs from carillon type bells that are typically stationary and rung by hammers to produce a melody.

Design Considerations

The proposed set of change ringing bells for the St. James' tower was eight. In addition, there was a pre-existing bell known as the Benedict-Schilling Sanctus bell. The Sanctus bell dates to 1882, and was recast and installed in the reconstructed tower in 1971.

Forces generated by swinging bells are approximately 4.25 times the deadweight in the vertical direction and 2.5 times the deadweight in the horizontal direction according to a 1914 book by Sir Arthur Haywood titled: *Bell Towers and Bell Hanging*, An Appeal to Architects. Haywood wrote the book, that includes research by EH Lewis of Trinity College, Cambridge, UK, in response to several bell tower failures attributed to designers failing to account for dynamic loads and lateral loads in particular.

Firing or simultaneously ringing all bells generates maximum lateral vertical loads. Peak forces are separated by approximately one half second in opposite directions. The St. James' change ringing bells are arranged with four oriented in an east-west direction and the four heaviest in a north-south direction. This arrangement produces torsional moments in addition to east-west/north-south forces on the tower.

The major concerns for installing change ringing bells in the St. James Church tower was: 1) the unreinforced brick construction, 2) large louver openings in the bell chamber, 3) large arched openings near the bade of the tower, and 4) unknown brick mortar strength.

Visual inspection of the tower and adjacent sanctuary structure indicated that the 1964 vintage brick structure was in good condition. The only sign of distress was a crack over one sanctuary window on the south face of the building that appeared related to thermal forces, and the lack of expansion and control joints in the structure.

According to the contract documents for the church, the specified mortar was Type M. The building code in use in the area at the time of construction was the Standard Building Code, which specifies a 2500-psi compressive strength for Type M mortar. The church opted not to test the in-place mortar due to the cost for testing. Therefore, Type S cement-lime mortar with compressive strength of 1500 psi and allowable shear stress of 38 psi (1.0 √f'm) was conservatively assumed.

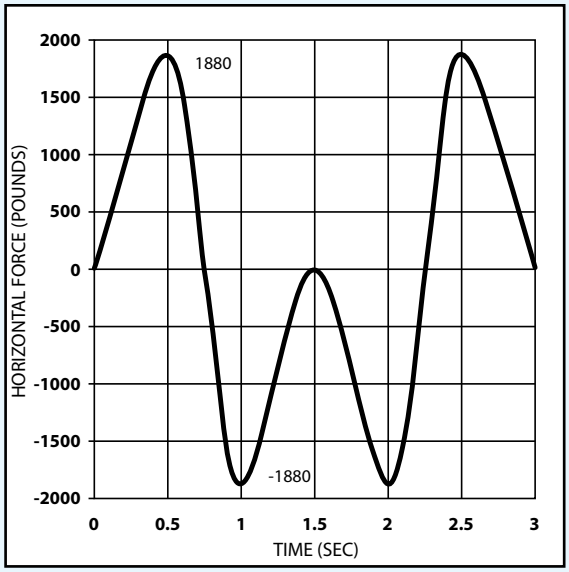

Figure 5: Tenor Bell Time Varying Horizontal Force.

Figure 6: East/West C12, W12, & Diagonal L3X3 Framing (Bell Frames Above).

Initially, the church proposed a set of change ringing bells weighing approximately 4000 pounds, plus the Sanctus bell weighing 406 pounds. The change ringing bells and the Sanctus bell are never rung simultaneously.

Analysis of the structure started with a dynamic analysis based on the set of eight bells noted above. With time versus maximum horizontal force of a half second (*Figure 5*) and the calculated frequencies of the tower, the maximum horizontal load amplification was estimated at 3.0 times the bell deadweight, 20% greater than the 2.5 factor suggested by Haywood. Based on the assumed mortar strength and resulting calculated stresses in the tower, the designers recommended a lighter 3000-pound maximum weight of eight bells.

Structural Modifications

Structural modification consisted of structural steel support framing located just above the bell chamber slab because the 5¼-inch slab was not capable of supporting the bells (plus 4.25 vertical amplification factor) and bell frames. Framing consisted of two C12X20.7 channels that were embedded eight inches into the brick walls at each end, and attached to the north and south walls with ¾-inch diameter Hilti epoxy anchors at two-feet on center. A C12X20.7 channel was attached to the north/south channels and Hilti anchored to the east wall. Two W12X19 beams span north/south and are located at third points of the ringing chamber. The W12s are bolted to the east wall channel and embedded eight inches in the west wall. Additional C12X20.7 sections span between the W12s and the north and south C12s, with Hilti bolts to the west wall. Diagonal L3X3X1/4 members brace the exterior bays (*Figure 6*). No center bay diagonal framing was installed in order to maintain access to a door to the attic space above the sanctuary. The framing system was

Figure 7: Bells in Up Position, Monorail System Above.

designed to uniformly transmit vertical and horizontal bell forces to the walls at an elevation near the bottom of the bell chamber and below the louver elevation.

To accommodate erection of steel framing and bells, 3-foot 6-inch square openings were saw cut in the ringing chamber and bell chamber slabs near the west wall of the tower. In addition, a monorail system (*Figure 7*) was installed above the bells that was used to hoist and move the bells and bell frames into position. The opening in the ringing chamber slab was repaired by drilling and epoxy-grouting six #4 bars in each direction prior to filling it with concrete. The new opening in the bell chamber floor was left open, and the existing access opening in this slab was filled similarly to the lower opening described above.

Completed Bell Installation

The structural modifications were completed and the eight change ringing bells installed in 1996. The bells ring twice on Sundays, as well as on special occasions. The total weight of the eight change ringing bells is 2773 pounds. Following are the bell names and weights:

- Dunstan (treble bell) 247-pounds
- Bridget 254-pounds
- Mary 282-pounds
- Catherine 281-pounds
- Margaret 326-pounds
- Michael 345-pounds
- James 445-pounds
- Scott (tenor bell) 593-pounds

  Total weight 2773-pounds
- Benedict-Schilling Sanctus Bell 406-pounds

These weights are bell material only, and do not include the moving wheel and headstock loads and dead load of the frames.▪

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