Masonry Performance and the World Trade Center Disaster

by David T. Biggs, P.E.

September 11, 2001, is a date that has become synonymous with terrorism in the U.S. The attacks on the World Trade Center in New York City and the Pentagon in Washington, D.C., resulted in the unprecedented collapse of buildings from structural and fire damage. In May 2002, the Federal Emergency Management Agency (FEMA) and the Structural Engineering Institute of the American Society of Civil Engineers (SEI-ASCE) released the report, "World Trade Center Building Performance Study: Data Collection, Preliminary Observations, and Recommendations." The findings came from the Building Performance Assessment Team (BPAT) of civil, structural and fire protection engineers assembled by SEI-ASCE.

The primary emphasis of the BPAT report was the collapse of the two 110-story office towers and a third 47-story office building (#7 building) at the World Trade Center Plaza (Figure 1). The towers collapsed within two hours of being attacked, and the third building collapsed later that afternoon as an apparent result of fire damage. The BPAT report was intended as an initial assessment and was not expected to serve as the definitive analysis. The National Institute of Standards and Technology (NIST) is in the process of extending the study.

While the collapsed buildings had few or no masonry components, many of the buildings surrounding the plaza survived, due to some extent to the use of masonry. As one of the sponsoring societies of the BPAT report, The Masonry Society (TMS) has released a publication entitled "Masonry Aspects of the World Trade Center Disaster" that supplements Chapter 7 of the BPAT report ('Peripheral Buildings') by taking an in-depth look at the performance of surrounding buildings with masonry construction.

World Trade Center Plaza

None of the seven steel-framed buildings in the World Trade Center Plaza survived the disaster unscathed. The surrounding buildings suffered damage from the falling debris and fires caused by the collapse of the north and south towers and #7 building. The collapse of the south tower also crushed St. Nicholas Greek Orthodox Church, a small masonry structure at the southwest

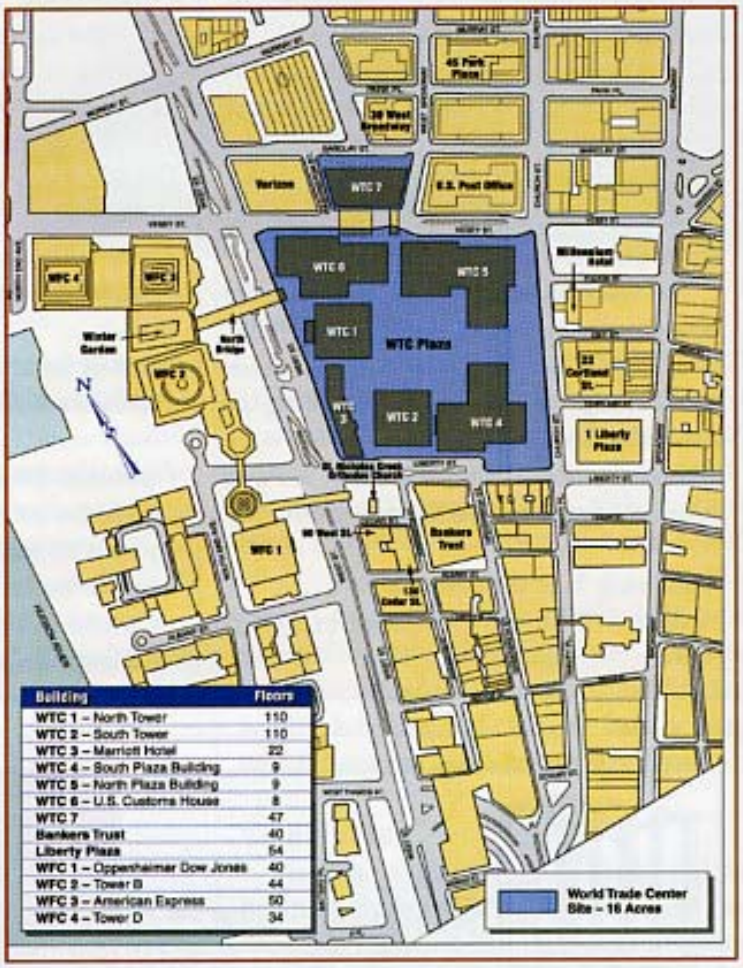

Figure 1. World Trade Center Plaza and surrounding buildings.

corner of the site. Many surrounding buildings not seriously impacted were still affected by wind-borne debris and the air concussions created by the collapses.

Credit for the structural assessment of the surrounding buildings goes to LZA/Thornton-Tomasetti and members of the Structural Engineering Association of New York. It was performed in conjunction with the New York City Department of Design and Construction and Department of Buildings using a modified version of the Applied Technology Council's (ATC) ATC-20 methodology—a post-earthquake rapid visual evaluation system originally developed on behalf of FEMA.

Masonry-related lessons, derived from information provided by the building evaluations or personal observations, can be summarized as follows.

- Framed buildings with exterior masonry walls generally performed better than newer buildings with lightweight curtain-wall construction. Figure 2 shows the east wall of 140 West Street, which faces #7

building. Large portions of the exterior wall were damaged, but the damage remained confined to the area of impact. Figure 3 shows the Banker's Trust building. A column tree from the south tower sliced through the curtain wall system and structure from the 15th floor down to the 8th floor. It is not fair to assume both buildings experienced the same loading. In general, however, the masonry elements of buildings that were impacted absorbed the impact energy and limited the damage.

Figure 2. East elevation of 140 West Street.

- Masonry infill for walls and beams functioned as fireproofing and provided significant structural redundancy. The infill provided an alternate load path to transfer gravity loads from damaged steel columns and prevented the collapse of portions of several buildings. Figure 2 is also an example of this.
- Interior masonry partition walls provided redundant lateral stiffness and added fire protection in the older buildings.
- The performance of masonry veneers and panelized masonry systems was dependent upon the type of veneer and the anchorage system used. Figure 4 shows where damaged wall panels with granite facing were removed and later rebuilt.
- The masonry flat arch floors of 90 West Street performed better under fire conditions than the newer steel-framed plaza buildings that could be examined. Figure 5 shows a section of floor in 90 West Street adjacent to an impact area. Built to 1906 standards, it remained intact after the fire. Figure 6 shows a section of distorted steel framing in plaza #5 building, which was designed and fireproofed using 1970 standards. While both areas experienced a full fire burn, the masonry construction performed better.

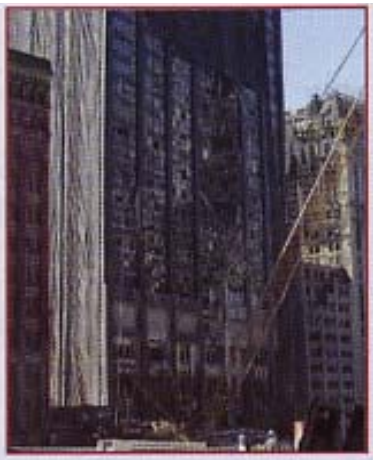

Figure 3. North elevation of 130 Liberty Street, Bankers Trust.

Figure 4. Southeast corner of #3 World Financial Center.

Figure 5. Flat arch tile floors in 90 West Street.

Figure 6. Floor framing in #5 World Trade Center Plaza.

Tower Egress

The egress enclosures of the World Trade Center towers were fire rated using gypsum wallboard products; data indicates that most were destroyed in the attacks. More durable wall systems might have been able to better resist the blast of the jet fuel explosions, but we don't know whether there may have been more survivors. Although research to evaluate and develop durable, fire-rated egress enclosures for high-rise buildings is part of the overall NIST program, reinforced masonry and concrete are two effective solutions that can be used now without further development. If minimizing weight is a concern, systems such as reinforced, autoclaved, aerated concrete and post-tensioned lightweight concrete masonry are available. ◆

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For more information on masonry design, construction, evaluation and repair, phone TMS at (303) 939-9700 or direct your web browser to *www.masonrysociety.org*.