World Trade Center Plaza

Taking a Closer Look at Masonry and the World Trade Center Disaster

By David T. Biggs, P.E.

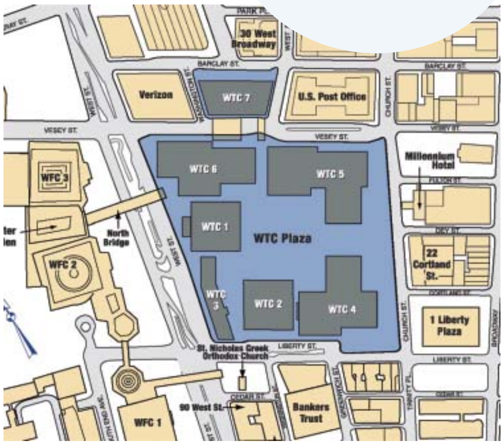

Figure 1 – World Trade Center Plaza and surrounding buildings

While few will ever design or construct a 110-story office tower, every disaster provides information of value to all structural engineers. One particular aspect of the disaster worth studying is the performance of the masonry construction because many of the buildings that surrounded the plaza survived, in some part, due to the use of masonry. *Figure 1* shows the 16-acre site of the World Trade Center Plaza (in blue) prior to September 11, 2001; all seven buildings were steel framed. The north tower was WTC 1; the south was WTC 2. WTC 7, a 47-story building, collapsed under fire approximately 6 hours after the towers came down; WTC 3 was crushed. WTC 4, 5 and 6 were damaged by both fire and the collapses.

> *"…buildings that surrounded the plaza survived, in some part, due to the use of masonry."*

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The seven plaza buildings did not survive. In addition, St. Nicholas Greek Orthodox Church, a small masonry structure at the southwest corner of the site, was also crushed by WTC 2. The surrounding buildings suffered damage from a combination of:

- impact of plane wreckage
- impact of building structure debris from the towers and WTC 7
- fire from the towers debris, and
- impact of wind-borne debris and the air concussion created by the collapses.

The following is derived from personal observations or from information provided in the building evaluations by LZA/Thornton-Thomasetti and members of the Structural Engineering Association of New York (SEAoNY). Their assessments were performed in conjunction with the New York City Department of Design and Construction (DDC) and Department of Buildings (DoB). The masonry performance can be summarized as:

- Older framed buildings with exterior masonry walls generally performed better than the newer buildings with lightweight curtain wall construction. As an example, *Figure 2* shows the east wall of 140 West Street that faces WTC 7. Even though large portions of the exterior wall were damaged by impact, the exterior wall and the structure remained intact. In comparison, *Figure 3* shows the north elevation of the more modern 130 Liberty Street. A column section from WTC 2 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. However, in general, the masonry elements of buildings that were impacted absorbed the energy and kept the damage to the structural framing more localized.
- 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 collapse of portions of several buildings. *Figure 4* shows a damaged steel column where the load was taken by the infill and collapse was prevented so shoring could be installed.
- The performance of masonry veneers and panelized masonry systems was dependent upon the type of veneer and the anchorage system used. *Figure 5* shows brick veneer damaged by impact and air-borne debris. The brick ties were inadequate, yet damage was limited primarily to areas of impact. Panelized wall systems were removed and rebuilt.
- Interior masonry partition walls provided redundant lateral stiffness and added fire protection in the older buildings.

Figure 2 – East elevation of 140 West Street

Figure 3 – North elevation of 130 Liberty Street

> *"A column section from WTC 2 sliced through the curtain wall system…"*

Figure 4 – Column Infill

> *"…most were destroyed by physical impact or overpressure from the explosion of the jet fuel."*

- The masonry flat arches floors of 90 West Street performed better under fire than the newer steel framed plaza buildings. *Figure 6* shows a section of floor in 90 West Street adjacent to an impact area; it was built to 1906 standards and remained intact under the fire. *Figure 7* shows a section of distorted steel framing in WTC 5; it was designed and fireproofed using 1970 standards. Both areas experienced a full fire burn.
- In the towers, egress enclosures were fire-rated using gypsum wallboard products. At the floors of aircraft impact, most were destroyed by physical impact or overpressure from the explosion of the jet fuel. Only 18 people from WTC 2 escaped above the floors of impact. More durable enclosure walls might have been able to better resist the blast of the jet fuel explosions.
- Research to evaluate and set structural standards for fire-rated egress enclosures for high-rise buildings is part of the overall National Institute of Standards & Technology (NIST) program. Concrete and reinforced masonry offer two effective solutions without further development. Low weight systems include reinforced autoclaved aerated concrete (AAC) and post-tensioned lightweight concrete masonry.

Summary Comments

The benefits of structural redundancy were evident in the performance of the surrounding buildings. Masonry infill provided that redundancy.

The added fire protection of masonry encasement performed better than modern methods of spray-on fireproofing and gypsum products.

Durable egress enclosures are essential in modern buildings.■

Figure 5 – Southeast corner of 30 West Broadway

Figure 6 – Flat arch tile floors in 90 West Street

Figure 7 – Floor framing in WTC5

Where to Get Information on the World Trade Center Study

The Federal Emergency Management Agency (FEMA) and the Structural Engineering Institute of the American Society for Civil Engineers (SEI-ASCE) released the report "World Trade Center Building Performance Study: Data Collection, Preliminary Observations, and Recommendations" in May 2002. That report was prepared by the Building Performance Assessment Team (BPAT) that was comprised of civil, structural, and fire protection engineers assembled by SEI-ASCE. It is available as a free on-line at **www.house.gov/science/hot/wtc/wtcreport.htm**.

Several of the buildings that surrounded the World Trade Center plaza are addressed in Chapter 7, "Peripheral Buildings", of the BPAT report. The Masonry Society of Boulder, Colorado later released a publication, "Masonry Aspects of the World Trade Center Disaster", that supplements Chapter 7 and takes an in-depth look at the buildings with masonry construction. The full report is available at **www.masonrysociety.org**

While the FEMA-SEI study was an initial assessment, the definitive report on the disaster will be based upon an on-going study being conducted by The National Institute of Standards and Technology (NIST), an agency of the Commerce Department. Their activities can be found on-line at **www.wtc.nist.gov**.

David T. Biggs is a structural engineer with Ryan-Biggs Associates, Troy, New York. He represented both SEI-ASCE and The Masonry Society on the Building Performance Assessment Team (BPAT) and co-authored Chapter 7. The opinions stated are the author's and do not necessarily reflect those of the BPAT.

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