

Failure Analysis of World Trade Center 5

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Abstract: *This research involves a failure analysis of the internal structural collapse that occurred in World Trade Center 5 due to fire exposure alone on September 11, 2001. It is hypothesized that the steel column-tree assembly failed during the heating phase of the fire. Abaqus/Standard was used to predict the structural performance of the assembly when exposed to the fire. Results from a finite element, thermal-stress model confirms this hypothesis, for it is concluded that the catastrophic, progressive structural collapse occurred approximately 2 hours into the fire exposure.*

Keywords: *Collapse, Coupled Analysis, Failure, Fire, Heat Transfer, Interface Friction, Structural, Thermal-Stress, World Trade Center (WTC)*

1. Background

World Trade Center 5 (WTC 5) was a nine-story building in the World Trade Center complex in New York City, NY (Figure 1). On September 11, 2001, flaming debris from the World Trade Center Tower collapses ignited fires in WTC 5. These fires burned unchecked, ultimately causing a localized interior collapse from the 8th floor to the 4th floor in the eastern section of the building (Figure 2). Debris impact was not a direct factor in this failure; the collapse was caused by fire alone.

The structural design of WTC 5 employed a common framing configuration, with steel column-tree assemblies that had beam stubs welded to the columns and cantilevering to support simple-span girders. The connections between the girders and the beam stubs were shear plates attached to the webs with bolts. The floor framing was topped with a concrete slab with welded wire fabric reinforcement.

Forensic evidence suggests that the collapse occurred during the heating phase of the fire. The columns remained straight and freestanding after the collapse (Figure 2), suggesting that the girders never developed catenary action that would have pulled columns inward, particularly as the girders cooled late in the fire. In general, the timing of this failure (early in the fire when occupants and firefighters could be in the building and therefore at great risk) is not typical for steel structures.