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FIRE RESISTANCE ISSUES IN THE COLLAPSE OF THE WTC TOWERS

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Abstract

The twin towers of the World Trade Centre suffered significant damage from the impact of the planes, however, they withstood the impact. The severe fires that followed the impact brought down the twin towers, WTC 2 and WTC 1, at different intervals - 59 and 89 minutes respectively following the impact. Thus, fire issues played a major part in the collapse of the twin towers and the role of the various fire resistance issues is examined in this paper. The intense fires ignited by jet fuel, loss of fire defence mechanism, damaged fire proofing and the stressed state of the structural system were some of the key factors that contributed to the collapse of the towers.

Key words: WTC, Twin Towers, Collapse, September 11, Fire Resistance

Background

The twin towers, comprising WTC 1 (North Tower) and WTC 2 (South Tower), were the primary components of the seven building World Trade Center (WTC) Complex in Manhattan, New York City. These towers, built in the late 1960's were the world's tallest buildings for a while with the roof height of WTC 1 being 1368 feet and the roof height of WTC 2 being 1360 feet. The floor space at each storey level was about 40,000 sq. feet and in total, the twin towers provided more than 10 million square feet of office space. The full occupancy of the towers was about 50,000 people and the tenants included many prominent multinational financial service companies. Therefore, these towers were a major landmark and financial center in New York City.

The two towers, that encompassed 110 stories above grade and 7 stories below grade, had similar features in many respects. Each building had a square floor plate, 207 feet 2 inches long on each side, chamfered 7 feet at each corner. The WTC buildings were built as a unique structural system known as "tube tower", with stiff exterior walls and columns, and the gravity load-bearing frame at the central core, connected by deep spandrel beams to minimize horizontal deflection. In the center of each building a rectangular service core, measuring 87 feet by 137 feet, housed 3 exit stairways, nearly 100 elevators, and 16 escalators.

The fire protection features in each of the towers included sprinklers, smoke control systems, fire detection systems, notification systems and structural fire protection measures. Each tower had three emergency fire exit stairways located in the central core of each building. Full details of the various design features can be found elsewhere (FEMA 2002).

The Incident

On September 11, 2001 American Airlines Flight 11, enroute from Boston to Los Angeles was hijacked and slammed into the north tower of the World Trade Center at 8.46 a.m. Shortly thereafter, a second hijacked plane, United Airlines Flight 175, was slammed into the south tower of the WTC. Both airplanes that struck the towers were Boeing 767-200ER aircraft and were loaded with heavy amounts of jet fuel for transcontinental flights (FEMA 2002).

The first aircraft struck the north face of WTC 1 approximately between the 92nd and 96th floors, while the second aircraft struck the south face of WTC 2 between the 78th and 84th floors. The massive impacts from each of the aircraft resulted in severe structural damage at several floor levels in each tower. However, the structures remained standing, at least initially, despite

this heavy but localized damage. The subsequent, intense fires that followed further weakened the already damaged structure, resulting in the collapse of the floors, initiated at the floor with the worst fire conditions. The impact load of the collapsing floors on the structure below started a progressive collapse and resulted in the complete collapse of the towers.

The impact of the planes and the ensuing fires were the two most crucial factors that led to the collapse of the twin towers. An overview of the factors that led to the collapse of the twin towers and the collapse mechanism in each of the towers is detailed in report (FEMA 2002) and is based on the "building performance study" commissioned by the Federal Emergency Management Agency and the American Society of Civil Engineers.

Fire Resistance Issues

The effect of key fire resistance issues: state of the structural system, jet fuel, fire growth, fire defence systems, fire intensity, damaged fire proofing and the performance structural members under severe conditions, is examined in this section.

State of the structural system: The impact of aircraft caused massive damage to the structural system at impacted floors and left the structural members that withstood the impact in a highly-stressed state.

Jet fuel: The huge amount of jet fuel from the aircraft, though burned off within the first few minutes, ignited office and aircraft contents, that resulted in massive fires.

Fire growth: The fire intensity and heat output generated from these fires was much more severe than typical building fires; however, resulting fire temperatures were not significantly different from other building fires (FEMA 2002, Rehm et al. 2002, DeCicco et al. 1972).

Fire proofing: The damaged fire proofing, suffered as result of massive impact of planes, further contributed to weakening the structural members (Kodur and Harmathy 2002).

Active fire protection: The loss of fire defence mechanisms, including damaged fire proofing, further contributed to weakening the structural members.

Performance of Structural elements: The intense heat from the fires attacked the structural system and, over a period of time, resulted in sufficient additional damage to the structural system to initiate a progressive sequence of failures that eventually culminated in the total collapse of both towers (Bazant and Zhou, 2002; Quintiere et al, 2002)

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