

**A DAY OF TERROR: THE BUILDINGS**

# *A DAY OF TERROR: THE BUILDINGS; Towers Believed to Be Safe Proved Vulnerable to an Intense Jet Fuel Fire, Experts Say*

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The cause of the twin collapse yesterday of the World Trade Center towers in downtown Manhattan was most likely the intense fire fed by thousands of gallons of jet fuel aboard the two jetliners that crashed into the buildings, experts on skyscraper design said.

The high temperatures, of perhaps 1,000 to 2,000 degrees, probably weakened the steel supports, the experts said, causing the external walls to buckle and allowing the floors above to fall almost straight down. That led to catastrophic failures of the rest of the buildings.

The towers were built to withstand the stresses of hurricane-force winds and to survive the heat of ordinary fires. After the 1993 trade center bombing, one of the engineers who worked on the towers' structural design in the 1960's even claimed that each one had been built to withstand the impact of a fully loaded, fully fueled Boeing 707, then the heaviest aircraft flying.

No engineer could have prepared for what happened yesterday, the experts said. "No structure could have sustained this kind of assault," said Richard M. Kielar, a spokesman for Tishman Realty and Construction Company, the construction manager for the original project.

The enormous heat from the jet fuel fire probably caused the steel trusses holding up concrete-slab floors and vertical steel columns to bend like soft plastic, said Jon Magnusson, chairman and chief executive of Skilling Ward Magnusson Barkshire in Seattle, a structural engineering firm that worked out the original design.

The skyscrapers had two means of defense against normal fire damage, Mr. Magnusson said. One, thick layers of insulation sprayed onto the steel beams, could have been breached by the initial crash, he said. Another, the building's sprinkler system, may have been disabled as well, or it may simply have been useless in the heat of the jet fuel fire.

Although they resisted collapse immediately after the planes' first impact, the hundreds of steel columns spaced around the outer facing of each tower eventually failed.

"They buckled outward and then the floors came down," said Mr. Magnusson, who warned that no conclusions could be reached yesterday since the information available was so sketchy.

Other experts agreed that the extreme conditions caused by the fire, and not unusual vulnerabilities of the buildings, were the likely causes of the collapse.

"There isn't anything particularly vulnerable about it," said Aine Brazil of Thornton-Tomasetti Engineers in New York, a structural engineering firm that worked on the Petronas Towers, the world's largest buildings, in Malaysia.

Buildings are simply not designed to withstand "the extreme levels of heat that would be found in the situation with the amount of jet fuel and the explosion that occurred," Ms. Brazil said.

Mr. Kielar, the Tishman spokesman, said it was too early to piece together a precise train of events, but he agreed that weakening by fire, followed by catastrophic collapse of the floors, was the most likely possibility. "As the structure warped and weakened at the top of each tower, it -- along with concrete slabs, furniture, file cabinets and other materials -- became an enormous consolidated weight that eventually, progressively crushed each tower below," he said in a statement.

The later collapse of the smaller 7 World Trade Center could have been caused by a combination of falling debris and a less intense fire -- one not accelerated by jet fuel -- lasting several hours, said Brian McIntyre, chief operating officer of Skilling Ward. Such a building

is "basically designed to resist heat buildup for three hours," he said.

The structural design of the two towers, fairly common now, was considered innovative in its day. Instead of the heavy internal bracing and heavy exterior masonry of, for example, the Empire State Building, the designers of the trade center towers chose a light glass-and-steel facing threaded by steel columns. Those columns, 61 on each side, gave the towers most of their stiffness and largely held them up, said John Schuring, a professor and chairman of civil engineering at the New Jersey Institute of Technology.

"The major strength of the building is in its skin," Dr. Schuring said.

There was also a cluster of columns in the center, supporting structures like the stairs and elevators, he said. A network of steel trusses ran between the two sets of columns, holding up each concrete floor and providing further strength to the buildings.

A special set of plates on each floor ran among the trusses, serving to dampen stresses on the buildings caused by winds of up to 200 miles per hour, said Jack Cermak, president of Cermak Peterka Peterson in Fort Collins, Colo., the firm that did the wind-tunnel testing for the design of the towers.

Dr. Cermak agreed that the impact of the crash itself probably could not have collapsed the massively reinforced building on its own.

"I presume, without knowing the details, that that collapse was caused by weakening of the structure due to the heat," Dr. Cermak said.

Matthys Levy, an architect at Weidlinger Associates and the author of "Why Buildings Fall Down" (Norton, 1992), watched the first tower collapse while standing at Seventh Avenue and Houston Street, some 20 blocks away.

"I saw the beginning of the top moving down, and the whole thing collapsed in a cloud of smoke," Mr. Levy said. "From what I saw, it seemed to come straight down."

Mr. Levy said the situation was much different from the one that occurred in 1945 when a much smaller plane slammed into the Empire State Building. That plane, a bomber with a smaller impact and less fuel, ripped a 20-foot hole in the structure, but the building remained standing.

There was some disagreement yesterday about whether, decades later, the trade center towers had been designed to withstand an impact from an airliner filled with fuel.

The engineer who said after the 1993 bombing that the towers could withstand a Boeing 707, Leslie Robertson, was not available for comment yesterday, a partner at his Manhattan firm said. The original 707 had a gross weight of 160,000 pounds, and the 767 a takeoff weight of

almost two and a half times that. The later plane carried about half again as much fuel, as well.

"We're going to hold off on speaking to the media," said the partner, Rick Zottola, at Leslie E. Robertson Associates. "We'd like to reserve our first comments to our national security systems, F.B.I. and so on."

But Anthony G. Cracchiolo, director of priority capital programs for the Port Authority of New York and New Jersey, which owned the buildings, said little thought had been given to the possibility of a plane crash into the towers.

"We never were asked to consider trying to protect the building from such a threat," said Mr. Cracchiolo, who was among those who coordinated the reconstruction after the 1993 bombing. "As structural engineers, there is nothing we could have done to protect the building from a direct impact from a plane as large as these."

Melvin Schweitzer, a member of the Port Authority board of commissioners from 1993 to 1999, said, however, that the board repeatedly inquired about that possibility. "We were just told that architects had explained that the building was designed to withstand a jet," Mr. Schweitzer said. "Frankly, when we raised that question, most of us were thinking of a small plane."

The architectural firm for the trade center, Minoru Yamasaki Associates of Rochester Hills, Mich., declined to answer specific questions about the collapse, and issued only a brief statement. "The company has been in contact with law enforcement authorities, and we will provide any assistance we can to aid the rescue efforts," the statement said.