



Above and right: Debris removal continues at the World Trade Center site two weeks after the buildings were destroyed.

SEEKING STRUCTURAL LESSONS

IN THE WORLD TRADE CENTER AND PENTAGON ATTACKS

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The attacks on New York's World Trade Center (WTC) and the Pentagon have forced us all to reconsider our usual ways of doing things. And just as experts in airline operations, intelligence gathering and border security are now examining their procedures to address a new reality, members of the structural engineering

profession will be looking at ways to improve the performance of buildings that might be the target of future attacks.

Within 24 hours of the attacks, the American Society of Civil Engineers (ASCE) had begun assembling a team of engineers to investigate the structural performance of the Trade Center and the Pentagon. Other sponsors of the team include the National Council

of Structural Engineers Associations (NCSEA), the American Institute of Steel Construction (AISC), American Concrete Institute (ACI) and the National Fire Protection Association (NFPA). Because of my service as principal investigator of the performance of the Murrah Building in the Oklahoma City bombing, I was asked to spearhead the effort. (Members of the WTC

and Pentagon teams are listed in an article under "Structural Columns" on page 11).

The investigative teams expect to be working over the next 12 to 18 months to collect and analyze data, document our findings and prepare reports. That timetable could be extended, however, depending on the course of the criminal investigation at the sites. If warranted by the results of the investigation, recommendations will be made for structural modifications that might increase the available evacuation time or reduce the likelihood of collapse in the event of similar attacks in future buildings. At this point, any such recommendations are expected to apply only to new buildings considered likely terrorist targets by virtue of their height, location or strategic or symbolic significance.

Trade Center Structure

The 110-story towers were designed as tube-in-tube structures, each supported and stiffened by closely spaced (3'-3" o.c.) steel exterior columns and a steel-columned interior core surrounding elevator, stairwell and service shafts. The buildings reportedly were designed to resist the impact of a Boeing 707, the most common commercial airliner at the time of their construction. In fact, they did remain standing after the considerably stronger impact of the hijacked 767s. The fires resulting from the plane crashes eventually heated the steel in the damaged buildings to the point that collapse occurred. While in no way minimizing the magnitude of the losses, it's important to remember that the towers survived long enough to evacuate as many as 25,000 people before the collapse.

Pentagon Structure

In contrast to the Trade Center towers, the Pentagon is an immense but relatively low building, and the damage, though severe, was confined to a relatively small portion of it. As it happens, the building had been undergoing a staged renovation at the time of the attack, and the plane hit at a point between renovated and unrenovated areas. For the Pentagon investigation, one of the key questions will be how well the renovated area performed and whether design modifications are called for in areas that remain to be upgraded.

Investigative Approach

The initial phase of the investigation will involve visual inspection of both sites, a careful review of existing photographs and video footage and creation of our own photos and video of the wreckage. At the Trade Center site, we've discovered pieces of structural steel that still bear identifying marks indicating



their original position within the building. Analysis of damage to critical structural elements will be helpful in understanding localized conditions and structural behavior following the attacks.

If possible, samples of structural members will be removed for detailed metallurgical testing, with particular attention paid to members that were actually impacted by the planes if they can be found. We hope to learn where and how far the planes may have penetrated and damaged the interior structural core by impact as well as by the resulting fire.

We've already begun and will continue to interview eyewitnesses to get their accounts of what happened to the buildings during and after the attacks.

A variety of computer modeling tools will help the team study the impact of the crashes

on the structures. One program will allow us to model the fire spread and temperature rise in different parts of the buildings over time. Another will show the effects of increasing temperatures on the steel columns to help determine how the collapse occurred. We also should be able to model the overall structure and predict how various modifications might have altered its behavior. These models will help predict both the relative effectiveness and cost of any changes to design or construction practice the team might recommend in its final report.

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