

provisions for unusual circumstances and there is a limit to the events that can be handled and the strength capacities that can be provided. Defense facilities, nuclear power plants, and overseas embassies are just a few examples where special strengthening features are requested by building owners in the design and engineering of their facilities.

The WTC towers were the first structures outside of the military and the nuclear industries whose design considered the impact of a jet airliner, the Boeing 707. It was assumed in the 1960s design analysis for the WTC towers that an aircraft, lost in fog and seeking to land at a nearby airport, like the B-25 Mitchell bomber that struck the Empire State Building on July 28, 1945, might strike a WTC tower while low on fuel and at landing speeds. However, in the September 11 events, the Boeing 767-200ER aircraft that hit both towers were considerably larger with significantly higher weight, or mass, and traveling at substantially higher speeds. The Boeing 707 that was considered in the design of the towers was estimated to have a gross weight of 263,000 pounds and a flight speed of 180 mph as it approached an airport; the Boeing 767-200ER aircraft that were used to attack the towers had an estimated gross weight of 274,000 pounds and flight speeds of 470 to 590 mph upon impact.

Including aircraft impact as a design load requires selecting a design aircraft, as well as its speed, weight, fuel, and angle and elevation of impact. Figure 1-10 compares the design characteristics of several large aircraft that were in use or being planned for use during the life of the WTC towers. The maximum takeoff weight, fuel capacity, and cruise speed shown for each class of aircraft are presented for comparison of relative sizes and speeds. The larger square represents the floor plan area of the WTC towers (approximately 207 feet by 207 feet), and the smaller square represents a more typical size for a high-rise building. The likelihood of a building surviving an aircraft impact decreases as aircraft size and speed increase. The Airbus A380 is expected to be flying in 2006. Its weight and fuel capacity are approximately three times those of a 767-200ER. The security of aircraft is critical to the safety of high-rise and all other buildings; aircraft security measures should be commensurate with the size and potential risk posed by the aircraft.

The decision to include aircraft impact as a design parameter for a building would clearly result in a major change in the design, livability, usability, and cost of buildings. In addition, reliably designing a building to survive the impact of the largest aircraft available now or in the future may not be possible. These types of loads and analyses are not suitable for inclusion in minimum loads required for design of all buildings. Just as the possibility of a Boeing 707 impact was a consideration in the original design of WTC 1 and WTC 2, there may be situations where it is desirable to evaluate building survival for impact of an airplane of a specific size traveling at a specific speed. Although there is limited public information available on this topic (Bangash 1993, DOE 1996), interested building owners and design professionals would require further guidance for application to buildings.

1.5.3 Overview of Fire-Structure Interaction

Control of structural behavior under fire conditions has historically been based on highly prescriptive building code requirements. These requirements specify hourly fire resistance ratings. A popular misconception concerning fire resistance ratings for walls, columns, floors, and other building components is that the ratings imply the length of time that a building component will remain in place when exposed to an actual fire. For example, a 2-hour fire-resistant wall is often expected to remain standing for 2 hours if exposed to an actual fire. However, the time to collapse of such a wall in an actual fire may be greater or less than 2 hours. The standard method of test to evaluate fire resistance (ASTM E119) is a comparative test of relative specimen behavior under controlled conditions and is not intended to be predictive of actual behavior. Further, the results of the ASTM E119 test do not consider actual conditions such as member interactions, restraint, connections, or situations where damage to the structural assembly is present prior to initiation of the fire.