

specified thickness of the insulation was adequate to delay heating of the trusses; the amount of insulation dislodged by the aircraft impact, however, was sufficient to cause the structural steel to be heated to critical levels.

- Based on four standard fire resistance tests that were conducted under a range of insulation and test conditions, NIST found the fire rating of the floor system to vary between 3/4 hour and 2 hours; in all cases, the floors continued to support the full design load without collapse for over 2 hours.
- The wind loads used for the WTC towers, which governed the structural design of the external columns and provided the baseline capacity of the structures to withstand abnormal events such as major fires or impact damage, significantly exceeded the requirements of the New York City Building Code and other building codes of the day that were reviewed by NIST. Two sets of wind load estimates for the towers obtained by independent commercial consultants in 2002, however, differed by as much as 40 percent. These estimates were based on wind tunnel tests conducted as part of insurance litigation unrelated to the Investigation.

E.4 RECOMMENDATIONS

The tragic consequences of the September 11, 2001, attacks were directly attributable to the fact that terrorists flew large jet-fuel laden commercial airliners into the WTC towers. Buildings for use by the general population are not designed to withstand attacks of such severity; building regulations do not require building designs to consider aircraft impact. In our cities, there has been no experience with a disaster of such magnitude, nor has there been any in which the total collapse of a high-rise building occurred so rapidly and with little warning.

While there were unique aspects to the design of the WTC towers and the terrorist attacks of September 11, 2001, NIST has compiled a list of recommendations to improve the safety of tall buildings, occupants, and emergency responders based on its investigation of the procedures and practices that were used for the WTC towers; these procedures and practices are commonly used in the design, construction, operation, and maintenance of buildings under normal conditions. Public officials and building owners will need to determine appropriate performance requirements for those tall buildings, and selected other buildings, that are at higher risk due to their iconic status, critical function, or design.

The topics of the recommendations in eight groups are listed in Table E-1. The ordering does not reflect any priority.

The eight major groups of recommendations are:

- Increased Structural Integrity: The standards for estimating the load effects of potential hazards (e.g., progressive collapse, wind) and the design of structural systems to mitigate the effects of those hazards should be improved to enhance structural integrity.
- Enhanced Fire Endurance of Structures: The procedures and practices used to ensure the fire endurance of structures should be enhanced by improving the technical basis for construction classifications and fire resistance ratings, improving the technical basis for standard fire resistance testing methods, use of the “structural frame” approach to fire resistance ratings,