

significant additional load. However, the structures were subjected to a second, simultaneous severe loading event in the form of the fires caused by the aircraft impacts.

The large quantity of jet fuel carried by each aircraft ignited upon impact into each building. A significant portion of this fuel was consumed immediately in the ensuing fireballs. The remaining fuel is believed either to have flowed down through the buildings or to have burned off within a few minutes of the aircraft impact. The heat produced by this burning jet fuel does not by itself appear to have been sufficient to initiate the structural collapses. However, as the burning jet fuel spread across several floors of the buildings, it ignited much of the buildings' contents, causing simultaneous fires across several floors of both buildings. The heat output from these fires is estimated to have been comparable to the power produced by a large commercial power generating station. Over a period of many minutes, this heat induced additional stresses into the damaged structural frames while simultaneously softening and weakening these frames. This additional loading and the resulting damage were sufficient to induce the collapse of both structures.

Because the aircraft impacts into the two buildings are not believed to have been sufficient to cause collapse without the ensuing fires, the obvious question is whether the fires alone, without the damage from the aircraft impact, would have been sufficient to cause such a collapse. The capabilities of the fire protection systems make it extremely unlikely that such fires would develop without some unusual triggering event like the aircraft impact. For all other cases, the fire protection for the tower buildings provided in-depth protection. The first line of defense was the automatic sprinkler protection. The sprinkler system was intended to respond quickly and automatically to extinguish or confine a fire. The second line of defense consisted of the manual (FDNY/Port Authority Fire Brigade) firefighting capabilities, which were supported by the building standpipe system, emergency fire department use elevators, smoke control system, and other features. Manual suppression by FDNY was the principal fire protection mechanism that controlled a large fire that occurred in the buildings in 1975. Finally, the last line of defense was the structural fire resistance. The fire resistance capabilities would not be called upon unless both the automatic and manual suppression systems just described failed. In the incident of September 11, not only did the aircraft impacts disable the first two lines of defense, they also are believed to have dislodged fireproofing and imposed major additional stresses on the structural system.

Had some other event disabled both the automatic and manual suppression capabilities and a fire of major proportions occurred while the structural framing system and its fireproofing remained intact, the third line of defense, structural fireproofing, would have become critical. The thickness and quality of the fireproofing materials would have been key factors in the rate and extent of temperature rise in the floor trusses and other structural members. In the preparation of this report, there has not been sufficient analysis to predict the temperature and resulting change in strength of the individual structural members in order to approximate the overall response of the structure. Given the redundancy in the framing system and the capability of that system to redistribute load from a weakened member to other parts of the structural system, it is impossible, without extensive modeling and other analysis, to make a credible prediction of how the buildings would have responded to an extremely severe fire in a situation where there was no prior structural damage. Such simulations were not performed within the scope of this study, but should be performed in the future.

Buildings are designed to withstand loading events that are deemed credible hazards and to protect the public safety in the event such credible hazards are experienced. Buildings are not designed to withstand any event that could ever conceivably occur, and any building can collapse if subjected to a sufficiently extreme loading event. Communities adopt building codes to help building designers