

connections' tensile strength. The failure most likely began on the 8th floor and progressed downward, because the 9th floor did not collapse. The 4th floor and those below remained intact.

- f. The 7th floor framing was shop-coated. In some locations, the paint appeared to be in good condition and not discolored by the fire. Paint usually blisters and chars when heated to temperatures of about 100 °C (212 °F). This indicates that the fire protection material remained on the steel during the early phase of the fire and may have fallen off relatively later in the fire as the beams twisted, deflected, and buckled. Additional measures for proper adhesion may be required when applying spray-on fire protection to painted steel.
- g. On the lower floors, the steel beams appeared to have heat damage from direct fire impact and there was little or no evidence of shop painting, indicating that fireproofing material was either missing before the fire or delaminated early in the fire exposure.
- h. In general, the buildings responded as expected to the impact loadings. Collapse was often localized, although half of WTC 4 and most of the central part of WTC 6 suffered collapse on all floors. The damage was consistent with the observed impact load.
- i. Reinforced web openings in steel beams performed well, as no damage or local buckling was observed at these locations.
- j. The automatic sprinkler system did not control the fires. Some sprinkler heads fused, but there was no evidence of significant water damage, due to a lack of water. This is consistent with the lack of water damage in the bookstore on the lower level and the complete burnout of the upper floors.

8.2.4.2 Recommendations

The scope of this study and the limited time allotted prevented in-depth analysis of many issues that should be explored before final conclusions are reached. Additional studies of the performance of WTC 4, 5, and 6 during the events of September 11, 2001, and related building performance issues should be conducted. These include the following:

- a. There is insufficient understanding of the performance of connections and their adequacy under real fire exposures as discussed in Appendix A. This is an area that needs further study. The samples discussed in Section 4.3.2 should be useful in such a study.
- b. A determination of the combined structural and fire properties of the critical structural connections should be made to permit prediction of their behavior under overload conditions. This can be accomplished with a combination of thermal transfer modeling, structural finite element modeling (FEM), and full-scale physical testing.

8.2.5 Chapter 5: WTC 7

8.2.5.1 Observations and Findings

- a. This office building was built over an electrical substation and a power plant, comparable in size to that operated by a small commercial utility. It also stored a significant amount of diesel oil and had a structural system with numerous horizontal transfers for gravity and lateral loads.
- b. The loss of the east penthouse on the videotape suggests that the collapse event was initiated by the loss of structural integrity in one of the transfer systems. Loss of structural integrity was likely a result of weakening caused by fires on the 5th to 7th floors. The specifics of the fires in WTC 7 and how they caused the building to collapse remain unknown at this time. Although the total diesel fuel on the premises contained massive potential energy, the best hypothesis has only a low probability of occurrence. Further research, investigation, and analyses are needed to resolve this issue.