

dependent mechanical properties of the steels, welds, and bolts used in the construction of WTC 7, including elastic, plastic, and creep properties. The description of the building structure was based on architectural and structural drawings of the original building and subsequent building alterations, as well as erection and shop fabrication drawings.

Component structural analyses were conducted to identify critical behavior and failure mechanisms that could have contributed to the global structural response of the building. These component analyses included (1) buckling of a core column, (2) beam-to-girder connections under thermal loading, and (3) girder-to-column connections under thermal loading. Subsystem analyses were then performed that incorporated the behavior and failure mechanisms identified in the component studies. The subsystems analyses included (1) the northeast corner of a typical floor and (2) a full tenant floor, both under gravity and fire loads. Modifications were made to reduce the model size and complexity and to enhance computational performance, but without adversely affecting the accuracy of the results. Whenever modeling modifications were used, they were validated against the detailed component model results.

Due to the nonlinearities in the analysis, as well as fire-induced damage, a 30 min analysis could take a few weeks to complete. Due to the range of time steps that were required to reach equilibrium (e.g., from 10^{-6} seconds to 10s of seconds), a complete ANSYS analysis for a given thermal case took approximately six months to complete on a 64 bit workstation with quad-core, 3.0 gigahertz (GHz) processor, and 64 gigabyte (GB) of Random Access Memory (RAM). The use of user-defined elements prevented the use of parallel processing on a Linux cluster.

The three different thermal response cases (A, B, and C) were used in the ANSYS analysis. Based on the ANSYS model results, it became apparent that the calculated fire-induced damage to connections and beams were occurring at essentially the same locations and with similar failure mechanisms, but shifted in time. (Case C failures occurred at a later time than the same failures in Case A, and Case A failures occurred at a later time than Case B failures.) As a result, only the fire-induced damage produced by Case B temperatures was carried forward as the initial condition for the building collapse analysis, since the damage occurred in the least computational time (i.e., 6 months).

Figure 3-9 shows an example of the extent of structural damage from the fires, in this case for the 13th floor. At both 3.5 h and 4.0 h, connections, floor beams, and girders were damaged or had failed at steel temperatures that were approximately 400 °C (750 °F) or less, primarily due to the effects of thermal expansion. After 4.0 h of heating, there was substantially more damage and failures in the WTC 7 structural floor systems than at 3.5 h of heating.

The ANSYS results were input to the LS-DYNA analysis when it appeared that an initial failure event might be imminent. Damage diagrams for the 16 floors modeled in ANSYS, such as those shown in Figure 3–9, indicated some degree of uncertainty in selecting the time and damage state for the transition. However, it appeared likely the critical damage state occurred between 3.5 h and 4 h. Accordingly, as shown in the next section, LS-DYNA analyses were performed for both of these damage states.