

- In the fourth simulation, the building experienced no debris or fire-induced damage. A section of Column 79 between Floors 11 and 13 was removed. The purpose of this analysis was to determine the potential for a classic progressive collapse, i.e., disproportionate structural damage from a single failure, regardless of the cause of that failure.

The LS-DYNA model was initiated as follows to minimize any spurious dynamic effects associated with the loading sequence. First, gravity was applied slowly to the 47 floor structure, taking 4.5 s of elapsed simulation time. Then, the debris impact damage from the collapse of WTC 1 was applied to the structure instantaneously by removing from the model the damaged elements that were no longer capable of bearing their loads. The structure was then allowed to damp residual vibrations for 2 s. Over the next 2 s, the structural temperatures were ramped up to the levels from the ANSYS simulation. Last, the fire-induced damage obtained from the 16 story ANSYS analysis, including damage to floor beams, girders, and connections, was applied instantaneously. The damage was from the computation of Case B at 4 h after the initiation of the fires in FDS. The heated, damaged structure was then free to react. The time at which the east penthouse began to descend was defined as 0.0 s, i.e., the beginning of the collapse of WTC 7.

Figure 2-2 shows the structural response of WTC 7 to the fire-induced damage on the east side. Floor 13 collapsed onto the floors below, causing a cascade of floor failures down to Floor 5. The floor failures left Column 79 laterally unsupported and it buckled, which was quickly followed by the buckling of Columns 80 and 81. The buckling of Column 79 was the initiating event that led to the collapse of WTC 7, not the floor failures. If Column 79 had not buckled, due to a larger section or bracing, for instance, the floor failures would not have been sufficient to initiate a progression of failure that would result in global collapse.

The global analysis with fire-induced damage at 4.0 h most closely matched the observed collapse events, and the following discussion begins with the results from this analysis.

Figure 3–10 through Figure 3–14 depict the state of the WTC 7 structure at various times as the structure collapsed. The first four figures are views of the lowest 18 floors of the WTC 7 building core from the south. In these graphics, the exterior columns and some of the tenant floor structure spanning between the core and the exterior have been removed for an unobstructed view of the core. The scale on the right side shows the absolute (i.e., without any indication of direction) lateral displacement of each structural element. Displacements greater than 0.15 m (6 in.) are also shown in red.

Figure 3–10 shows the beginning of upper floor failures on the east side of the building at 0.5 s, following the buckling of Columns 79, 80, and 81. The east penthouse, which was supported by these three columns, had just begun to descend. About 2 s later, as shown in Figure 3–11, the collapse of all the east sections of all the floors had occurred, the upper floors had moved southward, Truss 2 had been damaged, and the westward progression of the building failure was underway. Figure 3–12 and Figure 3–13, only 2 s apart, indicate the speed with which the westward column failures proceeded between Floors 7 and 14.

In Figure 3-14, the total collapse of the building is underway. The two views cover the lower half of the building. The purple area at the bottom is the Con Edison substation. With no fires on the west side of Floors 10 through 14, the intact floor framing pulled the exterior columns inward as the interior columns fell downward. Loads from the buckled interior columns were redistributed to the exterior columns, which, in turn, buckled the exterior columns between Floors 7 and 14 within approximately 2 s. At that