

Two timing reference frames are used when discussing global model results: a calculation reference frame and a collapse reference frame. The LS-DYNA calculation reference frame is described in Section 12.3.2. The collapse reference frame is based on observation times from photographic and videographic records (Chapter 5). The collapse reference time of 0.0 s starts when a kink was observed in the roofline of the east penthouse, as viewed from the north. In the global analysis results, the kink in the roofline of the east penthouse occurred at 16.0 s in the calculation reference time. In the following graphics, when both times are quoted, the syntax used is “collapse reference frame (calculation reference frame).”

A series of snapshots of the interior columns and floor systems up to Floor 18 taken, viewed from the southwest (see Figure 12–42, Figure 12–48, Figure 12–49, and Figure 12–52 to Figure 12–55) illustrates the progression of failures in the floors and interior columns of WTC 7. Exterior columns and some of the tenant floor structure spanning between the core and the exterior have been removed from the views to illustrate the damage to the interior of the building. In each figure, contours of resultant lateral displacements are shown. For comparison between snapshots, a constant range of 0 in. to 6 in. (0 m to 0.15 m) was used. Since a resultant lateral displacement is presented, negative and positive values can not be distinguished, and only absolute values are displayed. Any value greater than 6 in. (0.15 m) remains red in the figure.

The following sequence of events was observed in the analysis, after the application of the loads and damage, which led to the global collapse of WTC 7. For each step, an overview highlighting the major events is presented first, followed by a discussion detailing these events. For further details on the global analysis results, see Chapter 4 of NIST NCSTAR 1-9A.

Initial Local Failure for Collapse Initiation

The global collapse analysis calculated a sequence of events that resulted in the buckling of critical Column 79.

The floor framing structure was thermally weakened at Floors 8 to 14, with the most substantial fire-induced damage occurring in the east region of Floors 12, 13, and 14. Even though each floor had been weakened over hours of exposure to separate and independent fires, it was not until there was substantial damage to the long span floors in the northeast region of Floor 13 that the initial failure event, i.e., buckling of Column 79, was triggered.

After the fire-induced ANSYS damage was applied, floor sections surrounding Columns 79 to 81 on Floors 13 and 14 collapsed to the floors below, as shown in Figure 12–42. The LS-DYNA analysis calculated the dynamic response of the structure to the floor failures and resulting debris impact loads on the surrounding structure. The thermally weakened floors below Floors 13 and 14 could not withstand the impact from the collapsing floors, resulting in sequential floor collapses. The floor systems progressively failed down to Floor 5, where the debris accumulated, as shown in Figure 12–43.

Figure 12–43 shows a cutaway view that illustrates the structural condition surrounding Column 79 as it buckled to the east. Figure 12–43 includes resultant lateral displacements and column axial stress histories for Columns 79 to 81. The plots show that Column 79 buckled 1.3 s before the kink was observed in the east penthouse roof framing (which occurred at 0 s (16.0 s) in the analysis). The rapid increase in lateral displacement indicates column buckling. Likewise, the axial column stresses indicated a rapid loss of stress at the time, signifying column buckling. Column 79 was laterally unsupported in the