

- The first was based on the best estimate of both the debris impact damage from the collapse of WTC 1 and the fire-induced damage based on the ANSYS analyses (Case B at 4 h).
- The second simulation differed only in the input of an earlier state of fire-induced damage with Case B at 3.5 h. The purpose of this LS-DYNA simulation was to determine whether a lesser degree of fire-induced damage could lead to the collapse of WTC 7.
- The third simulation was the same as the first, except that no debris impact damage was included. The purpose of this analysis was to determine the contribution of debris impact to the WTC 7 global collapse sequence and whether WTC 7 would have collapsed solely due to the effects of the fires.
- 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.

Section 12.2 provides a description of the global 47 story model, including material constitutive models, floor framing, truss and column transfers, penthouse structures on the roof, and modeling of floor system connections. Section 12.3 describes the model boundary conditions and loading sequence applied during the execution of the model. Section 12.4 presents the three simulations and their outcomes. Section 12.5 compares the simulation outcomes with the photographic and videographic observations and the calculated time of descent of WTC 7 with an estimate of the hypothetical free fall time.

12.2 GLOBAL LS-DYNA 47 STORY MODEL

12.2.1 Material Constitutive models

The structural materials in the WTC 7 global model were the steels used in the framing of WTC 7 and the concrete floor slabs. Brief descriptions of the constitutive models for the steels and concrete slabs are provided (see Chapter 2 of NIST NCSTAR 1-9A for further details).

Structural Steel Constitutive Models

The primary constitutive model used for modeling the steel in the framing of WTC 7 was the Piecewise Linear Plasticity model (material type 24 in LS-DYNA). This model captured the nonlinear behavior and failure of steel, with an effective stress versus effective strain curve and a pre-defined strain to failure to simulate fracture.

The constitutive models for the WTC 7 steels were based on those developed for the WTC tower steels. (Appendix E and NIST NCSTAR 1-3D). The steels used to construct WTC 7 were ASTM A36 (nominal yield strength $F_y = 36$ ksi), A572 grade 50 ($F_y = 50$ ksi), and steel plates produced by Algoma (CSA G40.21-44W, $F_y = 44$ ksi) for the fabrication of all shear connections in the floor framing. The Algoma steel had not been used in the WTC towers, and a stress-strain curve was developed for the analysis of WTC 7. The true stress-strain curves for these grades of steel at room temperature are shown in Figure 12-1.