

The model was subjected to several gravity loads and heating conditions, several combinations of disconnected floors, and pull-in from sagging floors until the point of instability. In one case, the simulation assumed three disconnected floors, and the top of the wall subsystem was subjected to “push-down” analysis, i.e., an increasing force to provide a measure of remaining capacity in the wall section.

The model captured possible failure modes due large lateral deformations, column buckling from loss of support at floor truss seats and diagonal straps, failure of column splice bolts, and failure of spandrel splice bolts or tearing of spandrel or splice plates at bolt holes. The model also showed:

- Large deformations and buckling of the spandrels could be expected at high temperatures, but they did not significantly affect the stability of the exterior columns and generally did not need to be precisely modeled in the tower models.
- Partial separations of the spandrel splices could be expected at elevated temperatures, but they also did not significantly affect the stability of the exterior columns.
- Exterior column splices could be expected to fail at elevated temperatures and needed to be accurately modeled.
- Plastic buckling of columns, with an ensuing rapid reduction of load, was to be expected at extremely high loads and at low temperatures.
- The sagging of trusses resulted in approximately 14 kip of inward pull per truss seat on the attached perimeter column.

Phase 2: Major Subsystem Analyses

Building on these results, ANSYS models were constructed of each of the three major structural subsystems (core framing, a single exterior wall, and full composite floors) for each of the towers. The models were subjected to the impact damage and elevated temperatures from the fire dynamics and thermal analyses to be described later in this chapter.

Core Framing

The two tower models included the core columns, the floor beams, and the concrete slabs from the impact and fire zones to the highest floor below the hat truss structure: from the 89th floor to the 106th floor for WTC 1 and from the 73rd floor to the 106th floor for WTC 2. Within these floors, aircraft-damaged structural components were removed. Below the lowest floors, springs were used to represent the stiffness of the columns. In the models, the properties of the steel varied with temperature, as described in Section 5.5.2. This allowed for realistic structural changes to occur, such as thermal expansion, buckling, and creep.

The forces applied to the models included gravity loads applied at each floor, post-impact column forces applied at the top of the model at the 106th floor, and temperature histories applied at 10 min intervals with linear ramping between time intervals.