

Exterior Wall

Exterior wall models were developed for the south face of WTC 1 (floors 89 to 106) and the east face of WTC 2 (floors 73 to 90). These sections were selected based on photographic evidence of column bowing.

Many of the simulation conditions were similar to those for the isolated core modeling: removal of aircraft-damaged structural components, representation of lower floors by springs, temperature-varying steel properties, gravity loads applied at each floor, post-impact column forces applied at the 106th floor, and temperature histories applied at 10 min intervals with linear ramping between time intervals.

The analysis results showed that:

- Inward pull forces were required to produce inward bowing consistent with the displacements measured from photographs. The inward pull was caused by sagging of the floors. Heating of the inside faces of the exterior columns also contributed to inward bowing.
- Exterior wall sections bowed outward in a pushdown analysis when several consecutive floors were disconnected, the interior face of the columns was heated, and column gravity loads increased (e.g., due to load redistribution from the core and hat truss). At lower temperatures, thermal expansion of the inside face was insufficient to result in inward bowing of the entire exterior column. At higher temperatures, outward bowing resulted from the combined effects of reduced steel strength on the heated inside face, which shortened first under column gravity loads, and the lack of lateral restraint from the floors.
- The observed inward bowing of the exterior wall indicated that most of the floor connections must have been intact to cause the observed bowing.
- The extent of floor sagging observed at each floor was greater than that predicted by the full floor models. The estimates of the extent of sagging at each floor was governed by the combined effects of insulation damage and fire; insulation damage estimates were limited to areas subject to direct debris impact. Other sources of floor and insulation damage from the aircraft impact and fires (e.g., insulation damage due to shock and subsequent vibrations as a result of aircraft impact or concrete slab cracking and spalling as a result of thermal effects) were not included in the floor models.
- Case B impact damage and thermal loads for the WTC 1 south wall, combined with pull-in forces from floor sagging, resulted in an inward bowing of the south face that reasonably matched the observed bowing. The lack of floor sagging for the Case A impact damage and thermal loads resulted in no inward bowing for the south face.
- Cases D impact damage and thermal loads for the WTC 2 east wall, combined with pull-in forces from floor sagging, resulted in an inward bowing of the east face that reasonably matched the observed bowing.