

One principal step was the determination of those variables that most affected the outcome of the various computer simulations. Sensitivity studies and examination of components and subsystems were carried out for the modeling of the aircraft impact, the fires, and the structural response to impact damage and fires. For each of the most influential variables, a central or middle value and reasonable high and low values were identified. Further computations refined the selection of these values. The computations also were improved to include physical processes that could play a significant role in the structural degradation of the towers.

The Investigation Team then defined three cases for each building by combining the middle, less severe, and more severe values of the influential variables. Upon a preliminary examination of the middle cases, it became clear that the towers would likely remain standing. The less severe cases were discarded after the aircraft impact results were compared to observed events. The middle cases (which became Case A for WTC 1 and Case C for WTC 2) were discarded after the structural response analysis of major subsystems were compared to observed events. The more severe case (which became Case B for WTC 1 and Case D for WTC 2) was used for the global analysis of each tower.

Complete sets of simulations were then performed for Cases B and D. To the extent that the simulations deviated from the photographic evidence or eyewitness reports, the investigators adjusted the input, but only within the range of physical reality. Thus, for instance, the observed window breakage was an input to the fire simulations and the pulling forces on the perimeter columns by the sagging floors were adjusted within the range of values derived from the subsystem computations.

The results were a simulation of the structural deterioration of each tower from the time of aircraft impact to the time at which the building became unstable, i.e., was poised for collapse. Cases B and D accomplished this in a manner that was consistent with the principal observables and the governing physics.

6.14.2 Results of Global Analysis of WTC 1

After the aircraft impact, gravity loads that were previously carried by severed columns were redistributed to other columns. The north wall lost about 7 percent of its loads after impact. Most of the load was transferred by the hat truss, and the rest was redistributed to the adjacent exterior walls by spandrels. Due to the impact damage and the tilting of the building to the north after impact, the south wall also lost gravity load, and about 7 percent was transferred by the hat truss. As a result, the east and west walls and the core gained the redistributed loads through the hat truss.

Structural steel and concrete expand when heated. In the early stages of the fire, temperatures of structural members in the core rose, and the resulting thermal expansion of the core columns was greater than the thermal expansion of the (cooler) exterior walls. The floors also thermally expanded in the early stages of the fires. About 20 min after the aircraft impact, the difference in the thermal expansion between the core and exterior walls, which was resisted by the hat truss, caused the core columns' loads to increase. As floor temperatures increased, the floors sagged and began to pull inward on the exterior wall. As the fires continued to heat areas of the core that were without insulation, the columns weakened and shortened and began to transfer their loads to the exterior walls through the hat truss until the south wall started to bow inward due to the inward pull of the sagging floors. At about 100 min, approximately 20 percent of the core loads had been transferred by the hat truss to the exterior walls due to weakening of