

Chapter 11

STRUCTURAL ANALYSIS OF INITIAL FAILURE EVENT

11.1 OVERVIEW

Two global structural models of WTC 7 were developed to simulate the response of the building to debris impact damage from the collapse of WTC 1 and subsequent fire effects, and to evaluate the collapse hypothesis.

The first model, developed in ANSYS (2007), was used to determine how and where the building failure began, which is referred to as the initial failure event or collapse initiation event. The model accounted for nonlinear geometric effects, temperature dependent behavior of members and connections (including thermal expansion and stiffness and strength degradation), the sequential failure of structural framing and connections under fire conditions, and removal of failed elements (with user intervention). The ANSYS model estimated the structural response to elevated temperatures of the lower 16 stories of the building, where the fires grew and spread, until an initial failure event became imminent following a series of local structural failures in the floor systems. Since the spatial and temporal changes in the temperature of structural members were slow relative to the dynamic characteristics (i.e., natural frequencies) of the building, the structural response to thermal loads was static in nature. Thus, the ANSYS analysis used a non-linear static procedure with an implicit solution algorithm that guaranteed force equilibrium at each time step. The ANSYS analyses are presented in this chapter.

The second model, developed in LS-DYNA, analyzed the collapse propagation phase by accounting for the structural response of the full 47 story structure to the initial failure event due to fire (from the 16 story ANSYS model) up to the collapse of WTC 7, and is presented in Chapter 12. This model accounted for the possibility for the development of progressive collapse of the entire building, including buckling instability of columns due to loss of lateral support, dynamic effects associated with failure progression, and debris impact from falling floors. The fire-induced damage from the ANSYS model were input into the LS-DYNA model as initial conditions.

The floor framing geometry, member sizes, and gravity loads for both models were obtained from structural and architectural drawings, as well as erection and fabrication shop drawings of connections for the steel framing (Section 2.4.2). Mechanical properties of steel and concrete materials, which included room and elevated temperature behaviors, were based on the relevant information developed during the investigation of the WTC towers.

An important feature of the WTC 7 ANSYS model was the user-defined elements that were developed to model the behavior and failure of floor framing connections at elevated temperatures. The structural floor connections were analyzed for all possible failure modes. The failure modes and their associated capacities were modeled with user-defined connection elements, which are also referred to as break elements. Break elements were used on the east side of Floors 7 to 14, where the fires were dominant prior to collapse. Including break elements at every connection location on these floors would have