

Steel column failure is generally characterized by inelastic buckling and, as a consequence, is a function of inelastic material behavior (i.e., yielding) and local and/or global instability. The strength of a column is related to the properties of the steel (in this case, possibly at elevated temperatures), the shape of the cross section, and the unbraced length (i.e., the distance between points of lateral support). In a building frame, a column is considered to be braced where each floor frames into the column and, thus, the unbraced length would be the floor-to-floor height. Since a column's cross section is not likely to change, a column subject to fire could fail (1) if its material properties are diminished by fire exposure sufficient to result in column instability, or (2) if failures of floor framing increase the unbraced length sufficient to result in column instability. Both of these possible hypotheses were investigated.

8.4.1 Column Failure by Heating

Heating of a column could occur as a result of a building contents fire, or as had been suggested, from a diesel fire resulting from rupture of a fuel line supplying one of several emergency generators in the building. Prediction of growth and spread of building contents fires (Section 9.3.2) indicated that such fires moved from one location to the next (e.g., from one office cubicle to the next) and burned intensely in any one location for roughly 20 min to 30 min. However, the large floor area surrounding Column 79 would have had sufficient combustibles (i.e., cubicles) to support fires in that area for two to three hours. A diesel fuel fire could also have occurred in the vicinity of Column 79, but analyses have shown (Section 9.2) that the duration of such a fire would be limited to less than two hours.

A thermal analysis was conducted of Column 79, typical of the geometry found on lower floors, i.e., a W14x730 section with cover plates and thermal insulation (see Chapter 9). Based on the knowledge that the yield strength of steel is reduced to roughly 50 percent of its room temperature value at steel temperatures of around 500 °C to 600 °C, it was found that it would take roughly 6 h of continuous exposure from a fully developed fire (gas temperatures of around 1100 °C) to reach these temperatures. Therefore, it would not have been possible for a building contents fire to have heated a massive, insulated column such as Column 79 to the point of failure.

Sections 9.2 and 8.9.1 show that the worst-case scenarios associated with ruptured fuel lines generated fires that could not be sustained long enough, would have produced too little heat to raise the temperatures of the steel to the point of significant loss of strength, and/or would have led to the flowing of smoke out the ventilation louvers, which contradicts the visual evidence.

8.4.2 Column Failure by Loss of Lateral Support (increased unbraced length)

Floors that frame into a column provide lateral support to the column. If a building had a regular floor-to-floor height, h , then failure of one floor would result in an unbraced column length of $2h$. Likewise, failure of two floors would result in an unbraced column length of $3h$, and so on. If a sufficient number of floors were to fail, the column could buckle even if it were not weakened by heating. This simple explanation assumes that the load on a column remains constant. In reality, the load on a column can change as fires grow and spread and non-uniformly heat the steel frame. Such load redistribution is accounted for in the analyses conducted in this investigation. The possibility of floor failure in fire is explored in detail in later sections of this chapter.