

11.2.5 Modeling Connections

As illustrated in Chapter 8, the simple floor framing connections and shear studs are critical to the behavior of a structure subject to the effects of fire. The modeling of connection failure modes is covered in this section.

User-defined connection models were developed with break elements for each connection type. These connection models used the various temperature dependent failure modes described in Section 11.2.4. Failure in connections was determined by exceedance of either a limiting force or a deformation limit (for example, “walking off” the seat). The inclusion of contact elements in the connection models allowed for slip and construction clearances (gaps) to be taken into account and for a different response in horizontal tension and compression.

The temperature of connections and shear stud connectors was taken as the average of the temperature between two components (e.g., a girder and a column). Shear stud temperatures were modeled as the average of the slab temperature at mid-depth and the floor beam temperature. Connection and shear stud capacity at elevated temperature were modeled using room temperature capacity and the tensile strength reduction factor for steel. The temperature dependent strength reduction of the shear studs was applied when temperatures became greater than 300 °C. At this temperature in the shear studs, differential thermal expansion of the floor beams and floor slab resulted in significant shear force in the shear studs and caused them to fail. The temperatures assigned to shear studs did not significantly affect the time and sequence of shear stud failures.

Modeling Failure with Break Elements

User-defined finite elements, or break elements, were developed to capture complex modes of failure in connections, including temperature-dependence, with relatively few degrees of freedom. A user-defined break element is a multi-degree of freedom elastic spring element with the capability of turning “off” once its capacity is reached. The stiffness of the element in the off mode was reduced to a predefined post-failure stiffness, which was set to a significantly small value, 10^{-6} to 10^{-9} times the initial stiffness. The force and moment capacity of the element were defined as temperature-dependent properties. Different tension and compression force capacities were assigned where appropriate.

Connections with multiple failure modes required use of several break elements connected in series and/or parallel. To model independent failure modes, that is, one failure mode that did not cause other failures, break elements were connected in parallel so that when one break element turned “off”, the other break elements remained “on”. For example, in a seated connection, failure of the bolts in shear did not lead to vertical failure of the connection. To model dependent failure modes, break elements were connected in series so that when one break element turned off, all elements turned off. For example, bolt shear and tear-out were modeled as two break elements in series, where failure by either bolt shear or tear-out caused a disconnect. A list of break element types developed in ANSYS is summarized in Table 11-5.