INTRODUCTION

Connections are usually the weakest points in steel and composite structures. In particular, when the floor structure is affected by fire, connections can be subjected to extremely large forces in both directions, often with very large rotations. The disproportionate collapse of WTC 7, on 11 September 2001, has now been traced to connection failures arising from these forces. Each practical approach to integrating the behaviour – and failure - of connections into whole-structure modelling used in performance-based design of steel structures is the component-based method. In this research, the behaviour of fin-plate connections at elevated temperatures is being investigated with a view to integrating these characteristics into the finite element analysis software VULCAN.

FIN-PLATE COMPONENT MODEL

A mechanical model is formed based on identification of individual components, following the load path through this kind of joint. The model divides the joint into zones of fundamental behaviour which are called components. The lap joint component model consists of three fundamental Components (“springs”) in series: (i) Fin-plate in bearing, (ii) Bolt in shear, (iii) Beam web in bearing.

FIN-PLATE CONNECTIONS IN FIRE

When the fin-plate connections, which come into the category of shear connections, consist of a single plate welded to the column, and attached to the beam using two or more bolts through its web. This simple connection is intended primarily to transfer vertical shear, and is assumed not to transmit significant moment from the beam to the column.

EXPERIMENTAL VALIDATION OF COMPONENT MODEL

The Sheffield group has conducted fire tests to investigate the capacity and ductility of flush endplates, flexible endplates, fin-plates and web cleats, under combinations of tensile force, shear and rotation. The electric furnace has a 3.0m³ internal volume with strain gauges and digital cameras to measure the forces and deformations of the specimen. To allow free movement of the furnace bar, the column was tilted by 25° in the furnace.

The responses of the component model during the loading phase agree well with the test results, up to the point at which the lower beam-flange spring was activated. When the model is loaded, the geometry changes, causing a discontinuous relationship between the forces and rotational displacements. Subsequently, the second-order geometric effects are taken into account in the VULCAN analysis, which creates increased internal moments caused by additional bending of the column member. At elevated temperatures, the predicted maximum resistance is higher than was observed in the tests. This is to be expected, as it is mainly caused by successive failures of the bolts beyond their maximum nominal resistance.

CURRENT & FUTURE WORK

The newly developed component model has now been incorporated into VULCAN. A more comprehensive understanding of the joint behaviour can be achieved by carrying out further work:

• Unloading of the connection model using the classical Mason Rule to consider cyclic behaviour at elevated temperatures. A modification to Mason's rule is applied to account of the initial slip phase, which only allows force transition into the opposite quadrant when contact is re-established.
• Application of connection element in sub-frame modelling as a parametric study.
• Influence of combined forces (horizontal and vertical forces). Complexities in modelling the fin-plate connection arise from the combined action of horizontal and vertical bolt forces.

CONCLUSION

At elevated temperature, failure of fin-plates is dominated by bolt shear failure, but significant bearing deformations to the bolt holes may be caused before the bolts shear. On the basis of numerical modelling, the force-deflection-temperature component model for the fin-plate components have been derived, and have been embedded in VULCAN. This is intended to enable comprehensive analysis of whole structures or large substructures, up to failure, including the interaction between members, via realistic connection behaviour.