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Numerical modelling of restrained structural subassemblies of steel beam and CFT columns connected using reverse channels in fire

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ABSTRACT

This paper employs the general finite element software ABAQUS to numerically model the behaviour of restrained structural subassemblies of steel beam to concrete filled tubular (CFT) columns and their joints in fire. The simulations were conducted using 3-D brick elements to enable detailed structural behaviour to be obtained. For validation, this paper compares the simulation and test results for the three fire tests using reverse channel connection recently conducted at the University of Manchester. This comparison demonstrates that the 3-D finite element model is able to successfully simulate the fire tests. Afterwards, the validated finite element model was used to conduct a preliminary numerical study to investigate the feasibility of changing some of the connection details to enhance survivability of the structure in fire. Specifically, this investigation concentrated on developing connection methods to enable catenary action in the connected beam to be more fully developed. An example is to develop a hybrid flush/extended endplate and flexible endplate connection in which the tension part of the connection uses a flush/extended endplate for increased tensile resistance but the compression part of the connection uses a flexible endplate for improved ductility. It has been found that, without additional cost, using a hybrid extended/flexible endplate connection to replace a flush endplate connection has the potential to enable the connected beam to survive significantly increased temperature.

1. Introduction

The collapse of World Trade Center buildings [1,2] and the results of the Cardington full-scale eight storey steel framed building fire tests in the UK [3] have demonstrated that steel joints are particularly vulnerable during the heating and cooling phases of fire. Joint behaviour in fire is currently one of the most important topics of research in structural fire resistance.

As with any other aspects of structural behaviour, ideally, understanding the behaviour of steel beam-to-column connections in fire should always start from observations of the behaviour of physical models. However, due to the cost of conducting physical fire tests, experimental research alone will not be able to provide sufficient information for a thorough understanding of connection performance in a fire. Using numerical modelling provides an attractive alternative means provided the numerical model is adequately validated. Such an approach has been implemented by a number of researchers. For example, Liu [4] developed a finite element model for the study of the behaviour of steel and steel/concrete composite connections at elevated temperatures. El-Houssieny et al. [5] conducted an extensive parametric study to investigate the influence of varying connection behaviour at normal and elevated temperatures. Al-Jabri et al. [6] studied the behaviour of flush endplate bare-steel connections at elevated temperatures using ABAQUS. Sarraj et al. [7] developed a three-dimensional (3-D) FE model of fin plate connection using the ABAQUS software in order to analyse and understand the behaviour of such a connection at ambient and elevated temperatures. Hu et al. [8] created a three dimensional numerical model for flexible end plate connection with cohesive elements, using the ABAQUS finite element code, in order to investigate its resistance and ductility at ambient and elevated temperatures. Mao et al. [9] investigated the fire response of steel semi-rigid beam–column moment connections made with H-shape beams and H-shape columns using the general purpose finite element software ANSYS. Yu et al. [10] used the general-purpose program ABAQUS to model web cleat connections under tying force in fire. However, so far, all these existing numerical simulations of joint behaviour have considered statically determinate structures in which the joint forces do not change with time and the effects of large deformation in the connected beam (if any) are not included.

In contrast, the recent publication by Dai et al. [11] appears to be the only one to have included the behaviour of realistic steel beam/column joints in structures in which the connected beams would experience large deformations and the joints would have variable forces in fire. The study is based on 10 fire tests on

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