RECENT DEVELOPMENTS IN THE BEHAVIOUR OF STEEL AND COMPOSITE CONNECTIONS IN FIRE

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Abstract: This paper summarises current developments in the behaviour of bare-steel and composite connections at elevated temperature. This includes both experimental and analytical work. The paper also reviews the progress occurred in the numerical modelling of connections at elevated temperature. The paper highlights the influence of the structural continuity on the connection behaviour.

1. INTRODUCTION

It is well known that steel is seriously affected by fire, losing strength and stiffness leading to large deformations and often collapse. Using applied fire protection remains the most common way of satisfying structural fire resistance requirements, despite its cost. Alternative approaches which account for steel's inherent fire resistance are beginning to develop, based on experimental and analytical studies of structural behaviour. A number of researchers have demonstrated the potential significance of connections in fire. However, because of a lack of experimental data this is inadequately addressed in current design codes and the effective use of numerical models is limited. Some recent work on the behaviour of bare-steel and composite connections in fire conditions is presented here. This includes both experimental and analytical work, with particular reference to beam-to-column connections.

2. EXPERIMENTAL STUDIES ON CONNECTION BEHAVIOUR IN FIRE

Modern steel and composite framed buildings are normally designed with simple shear resisting connections. Recent fire tests on the Cardington full-scale test frame[1] and observations from real fires have demonstrated that complete buildings behave very differently from individual elements. This is partly because of the finite stiffness of such connections, and the result can be a significant improvement in the survival time of the structure. However only very limited quantitative data is available for connections at elevated temperature. The most valuable work was performed by Leston-Jones using a specially developed portable junction furnace[2] to study the moment-rotation characteristics of small scale connections at elevated temperatures. The same experimental arrangement is used in the present work to investigate connections of more practical proportions (Fig. 1).

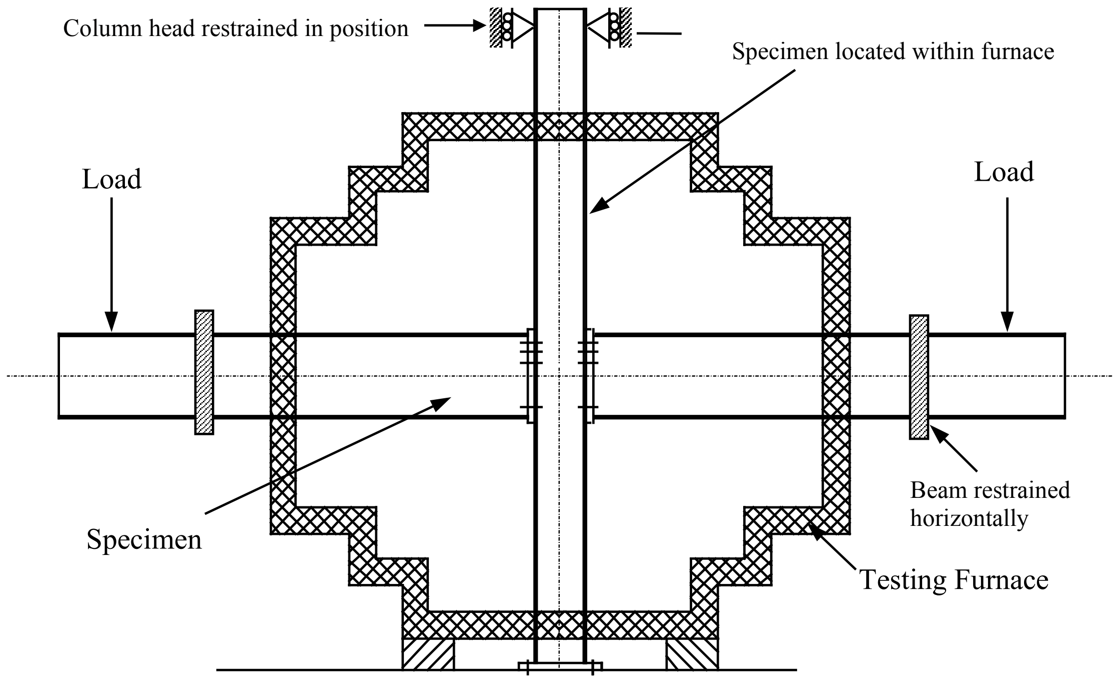

Figure 1: Typical Elevated Temperature Test Arrangement

A series of elevated temperature connection tests was conducted to study the influence of parameters such as member size, and end-plate type and thickness on the connection response in fire. Five different configurations were considered. For each configuration a series of tests were conducted, each at a different load level; in total twenty tests were performed. The configurations tested included three which were typical of those used in the composite-framed test building at Cardington in which a series of large-scale fire tests were performed between 1995 and 1996. From each group of tests a family of moment-rotation-temperature curves was derived as shown in Fig. 2. Similar results were found for other connection details[3]

The results provide valuable data for other researchers, especially those developing numerical modelling approaches to the behaviour of steel and composite structures in fire. They also provided the basis for developing a simple approach for estimating high temperature connection characteristics in relation to ambient temperature data.

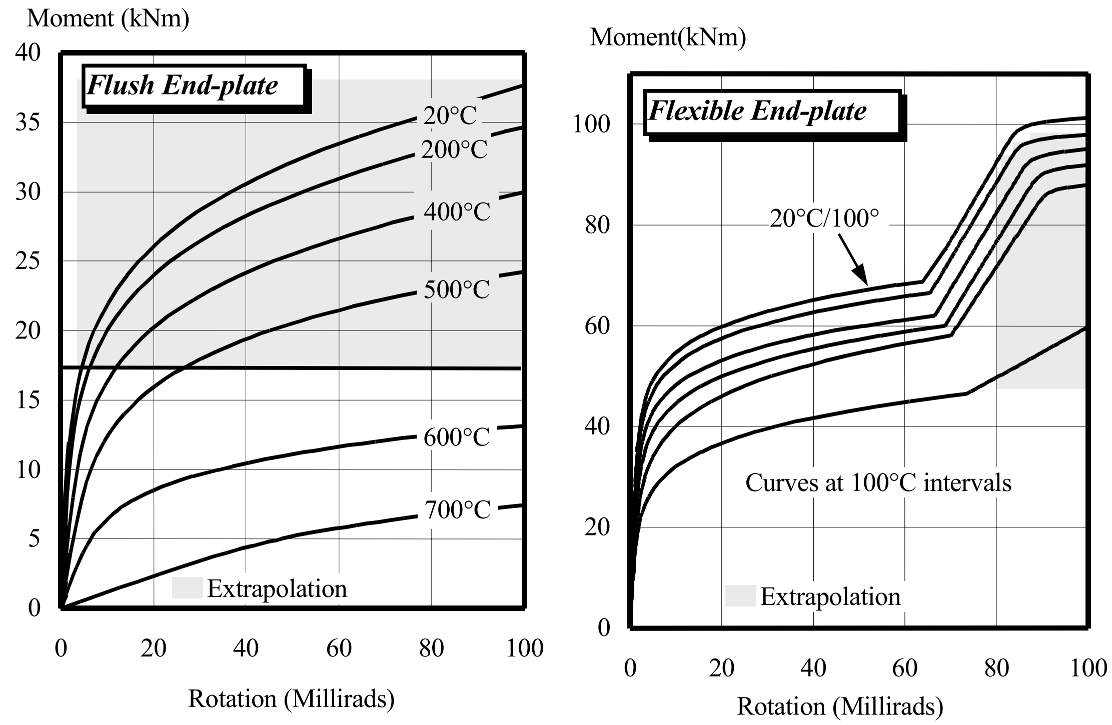

Figure 2: Moment-Rotation-Temperature Curves for Typical Connections

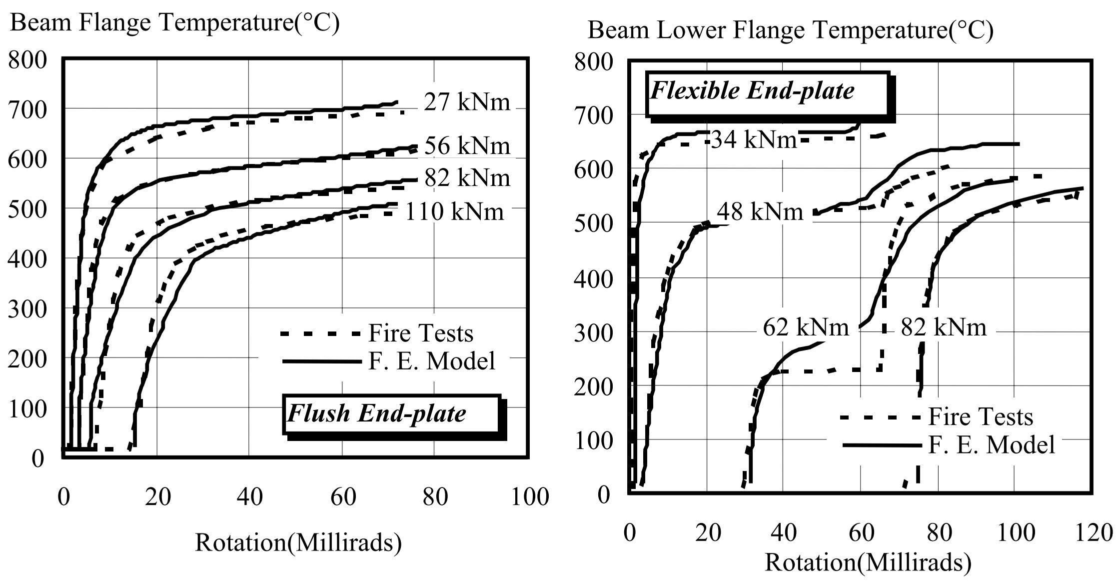

Figure 3: Finite Element Modelling of Connections in Fire

3. FINITE ELEMENT MODELING OF CONNECTIONS IN FIRE

Finite element analysis is a powerful tool but although a number of such studies have been made for connection behaviour at ambient temperature, very little has been done in relation to modelling connections in fire. Recently, Liu[4] has developed sophisticated three-dimensional finite element models for this purpose simulate the response of various types of connection in the event of fire. Liu's model, “FEAST”, was further developed to include composite connections, and compares well with the present experimental results as shown in Fig. 3.

4 ELEVATED TEMPERATURE COMPONENT-BASED MODELS

Component-based models for representing connection behaviour are attractive because of their relative simplicity and their capability to provide a reasonable representation of the full range of connection response. They are based on a consideration of individual components representing the principal parts of the connection as a set of rigid and deformable elements. The response of the connection is obtained by superimposing the

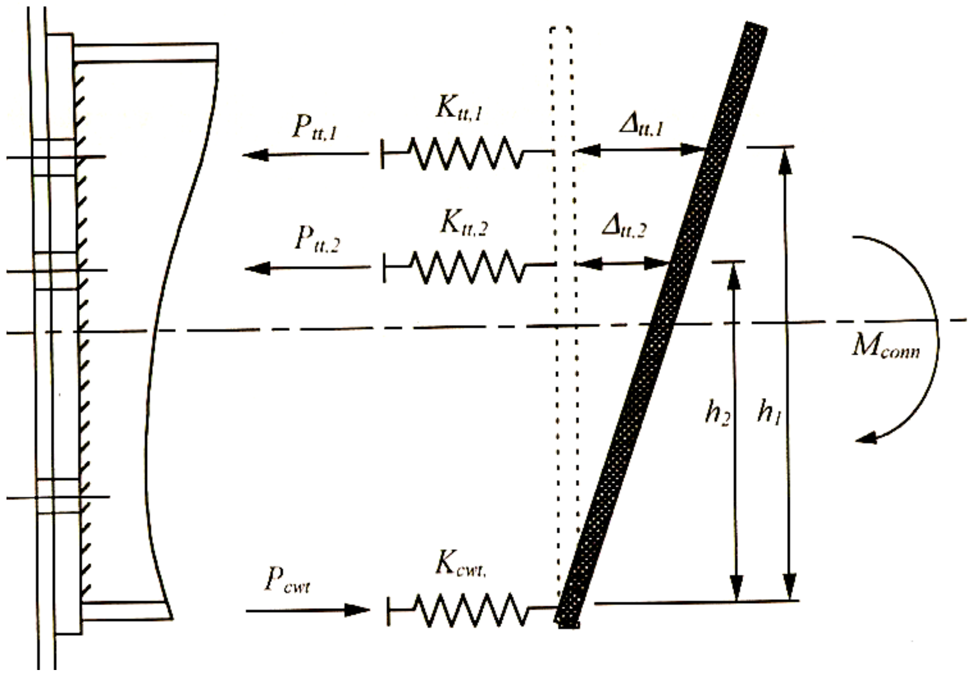

Figure 4: Component-based Model for Flush End-plate Connections

stiffnesses of individual components in the compression and tension zones. Elevated temperature component-based models are rare probably due to the lack of experimental data. Leston-Jones[2] proposed a component-based model for flush end-plate connections, as both bare-steel and composite (Fig. 4). This comprises a tension zone (bolts, end-plate and column flange) and compression zone (column web), with rotation assumed to be about the beam lower flange. The stiffness and capacity of these elements are degraded with temperature to model the connection behaviour in fire.

In the present work a similar approach has been adopted to model the behaviour of bare-steel and composite flexible end-plate connections. Comparison of the bare-steel component models with existing test data generated good results especially in the elastic zone, and accurately predicted failure modes as illustrated in Fig. 5. Also the predicted rate of degradation of the connection stiffness and capacity compares well with the experimental results.

For composite connections the predicted and the measured responses compared well for ambient temperature. Results were also encouraging for elevated temperatures, but in some respects more experimental data is required to draw positive conclusions. The use of component-based models proved desirable due to their simplicity and efficiency and the advantage of this form of model to be easily modified to account for alternative arrangements.

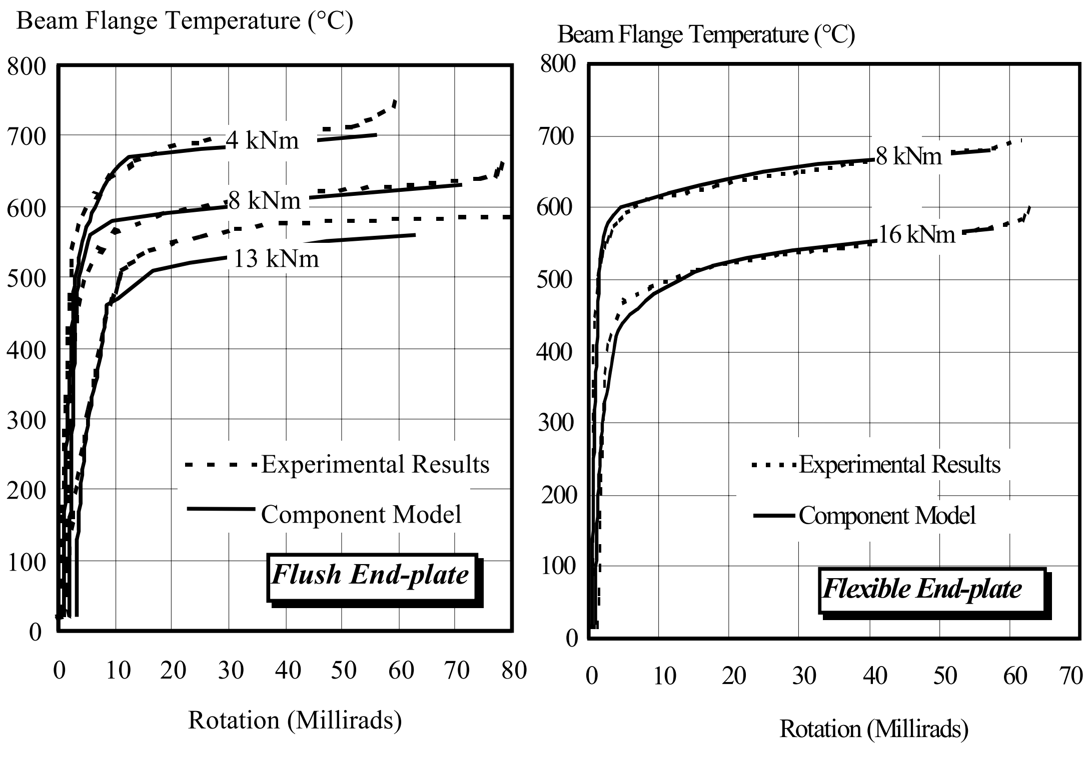

Figure 5 Comparison between experimental and component based connection characteristics at high temperature.

6. CONCLUSIONS

This paper presents recent developments in the behaviour of connections in fire. The experimental tests conducted to investigate the degradation characteristics of bare-steel and composite connections and the general outcomes from such tests are reviewed. The progress in the finite element and component based modelling of connections in fire is highlighted. The influence of the structural continuity on the behaviour of connections is discussed with the emphasis that the absence of such configuration may change the behaviour considerably in the context of a complete framed building.

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