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Testing of composite steel top-and-seat-and-web angle joints at ambient and elevated temperatures: Part 2 — Elevated-temperature tests

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ABSTRACT

An experimental programme of eight elevated-temperature tests on composite steel top-and-seat-and-web (TSW) angle joints was carried out to investigate the behaviour of this form of joints under fire conditions. It is found that the inherent strength and stiffness of composite joints can significantly improve the structural behaviour of steel framed structures under fire conditions. However, experimental works on composite steel TSW angle joints under fire conditions have not been published yet. To develop a versatile model to predict the joint moment-rotation characteristics, the authors have developed a component-based mechanical model for this form of joints. The objectives of this study are to ascertain the moment-rotation characteristic for this form of joint at elevated temperatures and to validate the authors' mechanical model. The effects of some parameters on the overall joint behaviour, such as elevated temperatures, longitudinal shear strength of RC slabs, steel beam depth and bolt behaviour were observed and investigated. The mechanical model predictions are compared with the test results and showed good agreement.

1. Introduction

Extensive research has been carried out on composite beam-to-column joints at ambient temperature since the 1970s [1,2]. The structural behaviour of beam-to-column joints is found to be neither "purely pinned" nor "fully fixed". The actual joint behaviour lies between these two extreme cases and is denoted as "semi-rigid". The flexural behaviour of semi-rigid joints is generally defined by the relationship between the joint moment and the relative rotations of the connecting member at the joint, as shown in Fig. 1. The initial gradient of the moment–rotation curve defines the initial rotational stiffness of a joint.

By now it is well established that composite joints can yield a significant influence on satisfactory structural performance of steel framed structures under gravity and lateral loads. Composite action between steel joints and concrete slabs can greatly improve the stiffness and strength of beam-to-column joints and result in better redistribution of sagging and hogging moments on beams in the event of extreme loading such as a fire.

The current design practice of steel frames for the fire limit state is mostly based on prescriptive-based approaches by limiting the critical temperature of members under fire conditions for a prescribed period. For most steel members, additional fire protection is required and the associated cost can constitute up to 20%–30% of the total construction cost of steelworks [3]. Clearly, this represents a significant portion of the construction cost. Therefore, many research works have been carried out to demonstrate the inherent strength of unprotected steel members and the economy of reducing the cost of fire protection. Some research studies have been conducted to understand the effect of fire on steel structures [4–6] and isolated members [7–10]. But only a few experimental studies have been conducted on limited types of joints at elevated temperatures [11,12,3,13–15].

Composite steel top-and-seat-and-web (TSW) angle joints are very popular in composite constructions in seismic zones like USA and Japan because of their significant strength and stiffness, large rotation capacity, and high energy-dissipation capacity [16]. However, despite numerous test data on composite semi-rigid joints, most of the experimental works were conducted on limited types of composite joints with flush or extended end-plates, or flange or web cleats [17,18]. Before 1994, there were relatively few experimental works on composite steel top-and-seat-and-web (TSW) angle joints [16,19–21]. Since 1994, there have only been a few published experimental studies on this form of joint in ambient conditions, let alone its structural behaviour at elevated temperatures. Therefore, there is an urgent need to carry out further experimental study on this form of joint at both ambient and elevated temperatures. An experimental programme of six ambient tests on composite steel TSW angle joints has been presented in the companion paper [22]. As a continuation of this research work, an experimental programme of eight elevated-temperature tests on this form of joint is presented in this paper.

However, due to the diversity and complexity of semi-rigid joints, it is impractical to develop a comprehensive test database

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