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# Testing of composite steel top-and-seat-and-web angle joints at ambient and elevated temperatures, Part 1: Ambient tests

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ABSTRACT

This paper presents six ambient tests on composite steel top-and-seat-and-web (TSW) angle joint specimens subject to monotonic loading. It is well known that the inherent strength and stiffness of composite semi-rigid joints can improve the structural behaviour of steel frame structures. However, experimental works on the composite steel TSW angle joints are very limited. The main objective of this study is to ascertain the ambient moment–rotation characteristics of composite steel TSW angle joints and to validate the authors' mechanical model. The test results are presented and the joint failure modes are described. The effects of some parameters on the overall joint behaviour, such as longitudinal shear strengths of RC slabs, steel beam depths and tightening torques of bolts are investigated. With the development of a new joint component to represent the RC slab in tension, the authors' mechanical model proves to be able to produce accurate and consistent predictions of the moment–rotation characteristics of composite steel TSW angle joints. The analytical results are compared with the test results and good agreement is achieved.



## 1. Introduction

In the area of composite steel framed structures, the importance of semi-rigid beam-to-column joints for the satisfactory structural performance under gravity and lateral loads has been well established. The use of continuous reinforcement in slabs around steel columns to provide for composite action at the joints was first proposed by Barnard [1] in 1970. It is clear that the inherent stiffness, strength and rotation capacity of semi-rigid joints can result in a more balanced redistribution of sagging and hogging moment in continuous structural members and a reduction in beam sizes. Therefore, the overall building height and the construction costs can be reduced as a result. Since then, extensive research works have been focused on the design of semi-rigid joints in building structures. The moment–rotation characteristic of the semi-rigid composite joints was first investigated by Johnson and Hope-Gill [2] in 1972. It was shown that the semi-rigid composite joints had the advantages of large rotation capacity and predictable flexural capacity and no site welding in comparison with rigid beam-to-column joints. Since 1972, numerous experimental works have been carried out on composite semi-rigid joints and the major works have been summarised by Zandonini [3], Simões da Silva et al. [4] and Gil and Bayo [5]. The test results illustrated that the composite action greatly improved the strength and stiffness of composite joints which could also sustain large rotation. As for the whole frame behaviour, the end restraint provided by joints can reduce the effective lengths of columns in semi-rigid frames, which will result in reduced lateral drifts and reduced beam deflections under wind or seismic loads. 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.

However, despite voluminous experimental data of composite semi-rigid joints, most of the experimental works conducted were focused on the behaviour of composite joints with flush or extended end-plates, or flange or web cleats [3,4,6–9]. The experimental works on the composite steel TSW angle joints are relatively limited to 1994 [10–13]. Composite steel top-and-seat-and-web (TSW) angle joints are very popular in composite constructions in seismic-active countries (USA, Japan) because of its large strength and high stiffness, sufficient rotation capacity, high energy-dissipation capacity and relatively low construction cost. Since 1994, there have been few more experimental studies carried out on the behaviour of composite steel TSW angle joints at ambient temperature, let alone their structural behaviour at elevated temperature. Hence, there is an urgent need to carry out further experimental study on this form of composite joints at both ambient and elevated temperatures.

Due to the diversity and complexity of joints, it is impractical to develop a comprehensive database of moment–rotation

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