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An experimental study on the behaviour and design of shear connectors embedded in solid slabs at elevated temperatures

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ABSTRACT

This paper presents an extensive experimental investigation carried out to evaluate the thermo-structural response of shear connectors embedded in solid slabs. For this purpose, seven push-out tests have been performed at different levels of temperature. Considering the limited experimental data available in the literature on the behaviour of shear connectors at elevated temperatures, these results are expected to provide useful benchmarking measurements for the calibration and validation of numerical models. Comparisons between test data (also reported by other authors) and numerical predictions obtained applying European guidelines have been presented, which highlighted the adequacy of the EC4 design equation format and the fact that, when the stud resistance is governed by the concrete component for temperatures lower than 400 °C, further research needs to be carried out (because available push-out test results do not fall in this range) to better define the reference temperature for the concrete to be used in design.

1. Introduction

Composite steel-concrete beams are a popular form of construction used for buildings and bridges. The composite action between the steel joist and concrete slab is provided by means of mechanical devices, the most popular being welded headed shear connectors [1–3], which significantly influence the strength and ductility of composite beams. Push-out tests are commonly used to determine the resistance and load-slip behaviour of shear connectors [4] and extensive experimental work has been carried out to date to determine their behaviour at ambient temperature when embedded in both solid slabs and composite slabs with profiled steel sheeting, e.g. [5–8]. The experimental activities have been complemented by the development of 2D and 3D finite element models to gain better insight into their ambient response [9–14]. Despite the extensive work carried out to investigate the performance of shear connectors at ambient temperature, only limited studies are currently available in the literature on their performance at elevated temperatures. In particular, Zhao and Kruppa [15] performed 47 push-out tests to study the behaviour of shear studs and angle connectors embedded in both solid and composite slabs exposed to ISO standard fire conditions. Their specimens were initially loaded at ambient temperature, after which the fire was applied. During the tests, temperature changes and slip measurements between the steel and the concrete were recorded. All solid slab samples exhibited shear failure of the connectors above the weld collar. Based on these experiments, Zhao and Kruppa [15] proposed design equations for the prediction of the resistance for shear connectors and for their load-slip curves at elevated temperatures. Choi et al. [16] carried out a number of push-out tests under ISO standard fire using a modified push-out set-up. Only one slab was included in each specimen with the other side of the push-out sample replaced with an electric furnace. Specimens were then loaded up to failure after being exposed to a specified fire duration. Temperatures recorded at different locations in the steel joist, shear connector and concrete over the duration of the fire were reported together with measured load versus slip relationships. Fracture of the stud shank just above the weld collar was observed in all experiments.

Table 1
Summary of the specimens and temperature specified in the ultimate tests.

Specimen ID	Nominal temperature at 10 mm from the shear connectors' base at the ultimate tests (°C)
SP-T1	20
SP-T2A	400
SP-T2B	400
SP-T3A	500
SP-T3B	500
SP-T4A	600
SP-T4B	600

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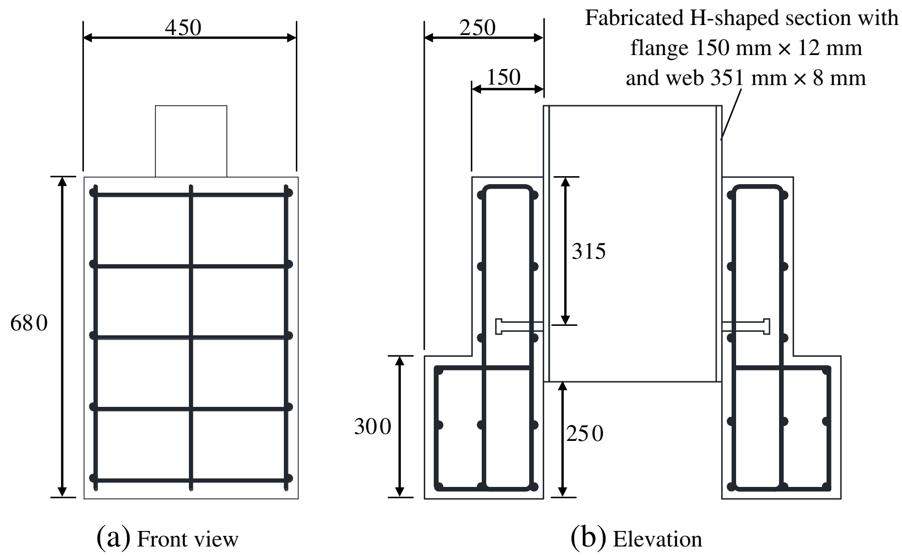

Fig. 1. Geometry and detailing of the push-out specimens (all dimensions in mm).

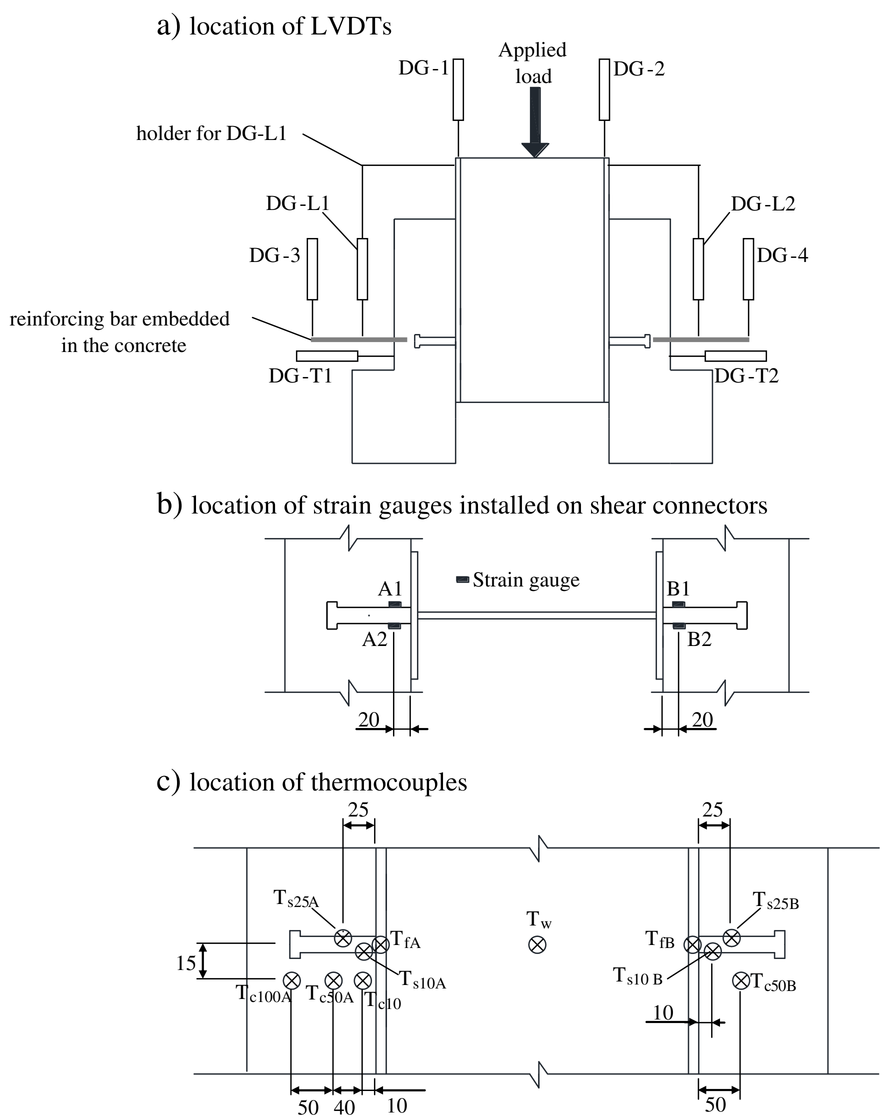

Fig. 2. Layout of the instrumentation for displacement, slip and temperature measurements: (a) location of LVDTs; (b) location of strain gauges installed on shear connectors; (c) location of thermocouples.