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Shear transferring mechanisms in a composite shallow cellular floor beam with web openings

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ABSTRACT

A new type of composite shallow floor beam has been developed to minimise the overall structural depth and provide service integration. The new composite shallow floor beam consists of an asymmetric steel section with regularly spaced web openings and a concrete slab incorporated between the top and bottom flanges. The web openings are filled with in-situ concrete when the floors are cast. The longitudinal shear force is transferred by the concrete plugs passing through the web openings, acting with or without reinforcing tie-bars. This paper presents an experimental investigation of the shear transferring mechanisms in a flexural bending test carried out on a full-scale composite shallow cellular floor beam prototype. The flexural test provided information on the slip behaviour and shear performance of the shear transferring mechanisms under a loading profile similar to uniformly distributed loading. The flexural test demonstrated significant composite action and that the flexural failure of the beam specimen was due to failure of the concrete plugs.

1. Introduction

The increasing demands on composite floor beams with shallow structural depth have led to the development of the Slimflor beam and Asymmetric Slimflor Beam (ASB). However, the thickness and width of the top flange increases with the increase of span; this often results in the steel sections being heavier than required [1]. A new type of floor beam, composite shallow cellular floor beam, has been commercially developed by ASD Westok Limited. The steel section is fabricated by welding two highly asymmetric cellular tees along the web. Regularly spaced openings are formed on the web post. The top and bottom tees are cut from different parent sections. In general, the top tee is cut from the universal column (UC) or universal beam (UB) and the bottom tee is cut from the UC. Typical proportion of the steel section is 190 to 350 mm deep for a span of 6 to 12 m. The weight of the steel section is reduced by having a smaller top tee. The moment resistance of the floor beam is optimized by having a bigger bottom tee. The hollowcore precast units or profiled steel decking sit on the bottom flange, as illustrated in Fig. 1 and the construction details are depicted in Fig. 2. This creates an encased section with only the bottom flange being exposed [1].

The shear transferring mechanisms of the composite shallow cellular floor beams are different to those with conventional headed shear studs. They are formed by incorporating concrete with the web openings of the steel section. The in-situ concrete fills the web openings when the floors are being cast. The concrete plugs, combined with or without reinforcing tie-bars, form the unique shear transferring mechanisms, as illustrated in Fig. 3. The concrete plugs passing through the web openings enable the steel section and concrete slab to interact with each other, hence transferring the longitudinal shear force. The shear transferring mechanisms allow the floor beam to behave compositely. The flexural test presented in this paper demonstrated a 50% increase in both moment resistance and flexural stiffness due to the composite action, compared to that of the bare steel section. Because of the significant increase in composite action achieved by the shear transferring mechanisms, the shallow cellular floor beam can therefore be designed as a composite section. This leads to reduction in the steel section sizes compared to the non-composite beam.

The web opening feature of the composite shallow cellular floor beam provides the passage for the concrete plugs and reinforcing tie-bars. The web openings can also be used for the passage of building services if it is required. This further minimises the overall floor depth and eliminates unwanted floor depth to accommodate the building services passing underneath the beam. Apart from the benefits of enhanced composite action and shallow floor construction, the composite shallow cellular floor beam also offers flexibility owing to the manufacture process of cutting and re-welding. The depth of the steel section is not fixed and can be designed in accordance with the required floor depth. The profile cutting or ribbon cutting technology allows the cellular tees to

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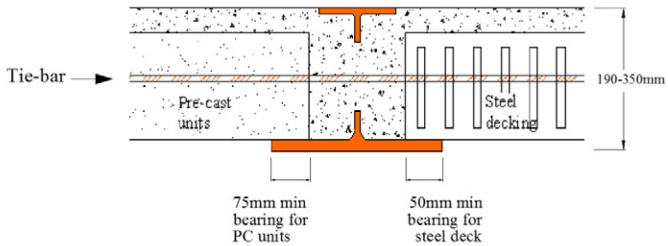

Fig. 1. Schematic cross section of the composite shallow floor beam with web openings [1].

be cut to the desired depth. Hence, the required beam depth can be obtained from two parent sections [2].

The authors have previously investigated the shear resisting properties and behaviour of the unique shear transferring mechanisms under the direct longitudinal shear force in a series of push-out tests [1,2]. In order to study the characteristics of the shear transferring mechanisms in flexural bending, a four-point bending test was performed on a composite cellular shallow floor beam prototype that has a 6 m span. The flexural test created a regions of constant bending moment and shear force. Loading points were 2.5 m from the supports. Two types of the shear transferring mechanisms were investigated in the flexural test. They were the concrete-infill-only and tie-bar shear connections. Half span of the test beam specimen had Ø16 mm tie-bar passing through alternative web openings. The overall behaviour and slip performance of both types of shear transferring mechanisms in the flexural test were studied and compared with that from the push-out tests [2]. The flexural behaviour and failure mechanism of the test beam specimen were investigated. The flexural test results were back analysed by using measured material properties to determine the degree of shear connection.

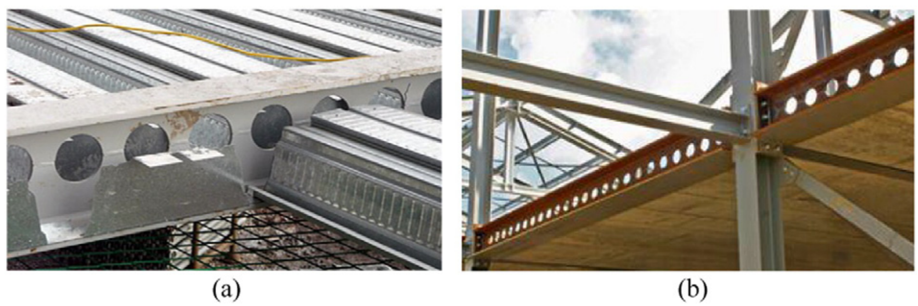

Fig. 2. Shallow cellular floor beam used with (a) profiled steel decking (b) precast floor units (courtesy of ASD Westok Limited).

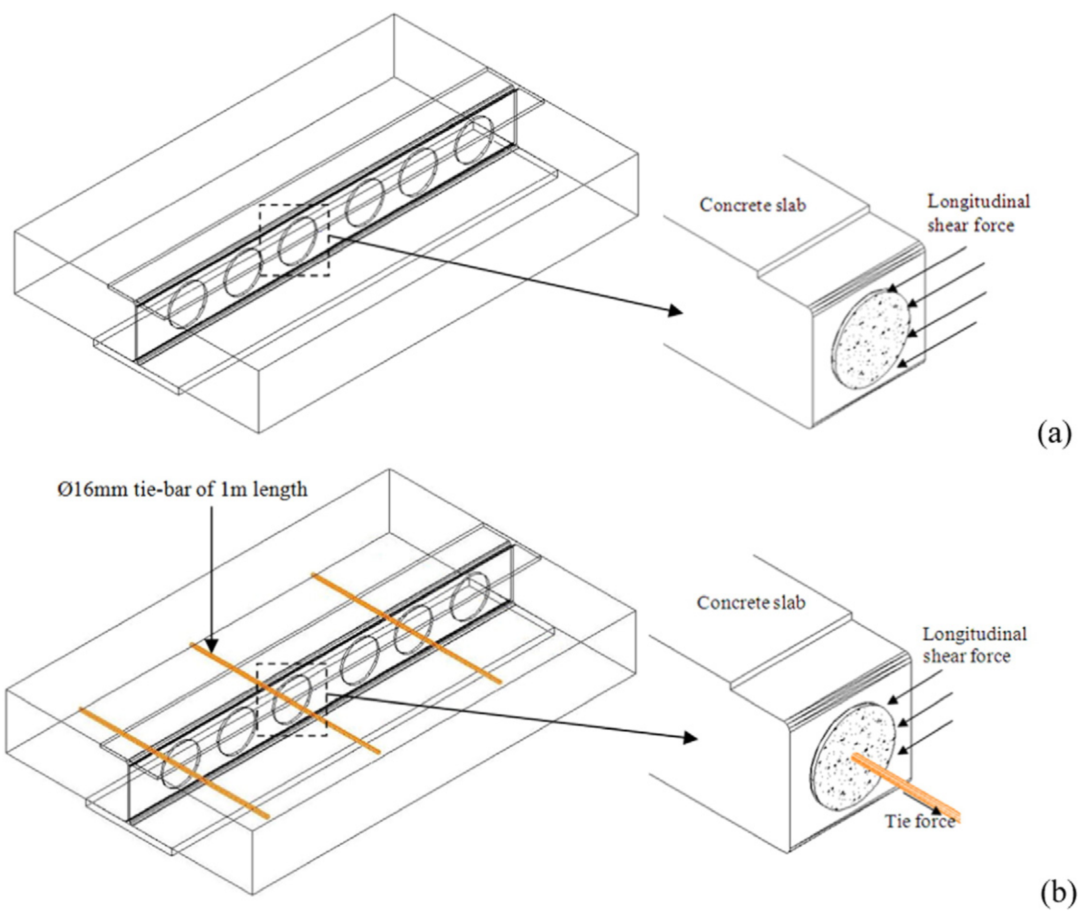

Fig. 3. Shear transferring mechanisms of (a) concrete-infill-only shear connection (b) tie-bar shear connection [2].