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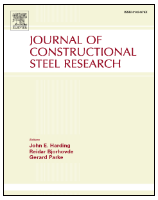

Experimental study on long spanning composite cellular beam under flexure and shear

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ABSTRACT

This paper describes a sequence of experiments on a long-span asymmetric composite cellular beam. This type of beam has become very popular, combining the composite action between the steel and concrete with the increased section depth, compared with more commonly used solid-web I sections. Openings in the steel web also reduce the self-weight and can accommodate the passage of service ducts. Eurocode 4 recommends a high degree of shear connection for asymmetric composite beams despite the practical difficulties in achieving this. Recent research suggests that the required degree of shear connection could be reduced, particularly for beams that are unpropped during construction. However, little test data exists to verify the behaviour of unpropped composite cellular beams. Therefore two series of tests were conducted on a 15.26 m long asymmetric composite cellular beam with regular circular openings and an elongated opening at the mid-span. The degree of shear connection was 36%, less than half of that recommended in Eurocode 4, and the beam was unpropped during construction. The beam was subjected to uniformly distributed loading and shear load during the tests. The end-slip, mid-span vertical deflection, shear connector capacity and strain distribution were examined. The beam failed at an applied uniform load of 17.2 kN/m^2 (3.4× design working load 5.0 kN/m^2). The member withstood an applied shear load that was 45% higher than predicted, and exhibited a Vierendeel mechanism at the elongated opening. Overall, these tests demonstrated the potential of unpropped composite cellular beams with low degrees of shear connection.

1. Introduction

Composite beams, consisting of steel I-beams connected to concrete slabs, are a popular choice in structures around the world. The composite action is achieved between the components through the use of shear connectors, increasing the member stiffness and loading-bearing capacity and enabling the member to span long distances between supports. Cellular beams, consisting of regular circular openings in the web, are also widely used for long spans. These are formed by cutting and re-welding two steel I-sections, typically providing a beam with a greater cross-section depth than the parent members. This is a highly efficient system that combines an increase in bending resistance with a reduction in material and member self-weight. The web-openings are aesthetically pleasing and enable the passage of service ducts to reduce the structural zone.

In recent years this relatively new form of asymmetric steel-concrete composite cellular beam has been used extensively in construction practice. Since the top flange acts compositely with the slab, the bottom part of the cellular beam is cut from a heavier section than the top part to improve the design efficiency. The ratio of the bottom to top flange areas is usually in the range of 1.5 to 2.5. Extensive research has been conducted to date on composite beams and cellular beams. Ranzi et al. [1] carried out full scale tests on composite beams with deep trapezoidal decking. Lam [2] examined the resistance of headed shear studs when used in composite beams in conjunction with precast hollow core slabs. Erdal and Saka [3] carried out laboratory tests to establish the load-carrying capacity of non-composite cellular steel beams. Chung et al. [4] conducted an analytical study of non-composite cellular beams, focussing on the Vierendeel mechanism that occurred at the web opening. Research has also been carried out in recent years on the new type of composite cellular beam. Lawson et al. [5] considered the design rules for composite asymmetric cellular beams and verified

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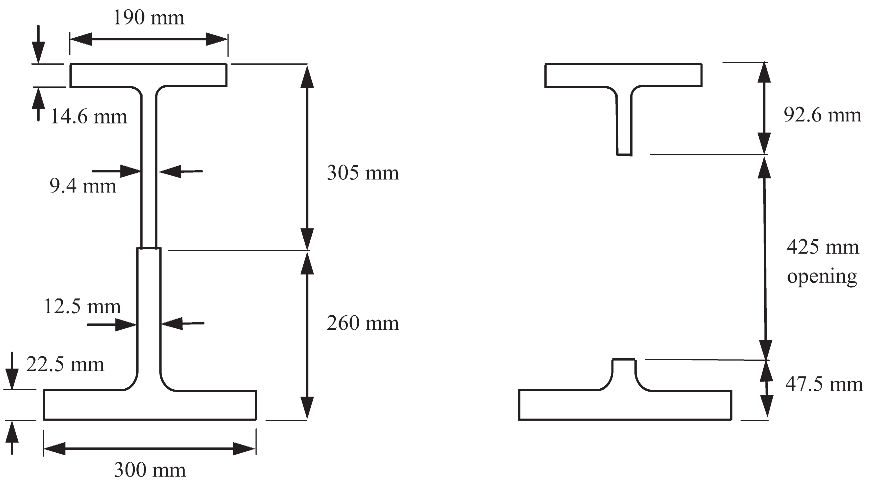


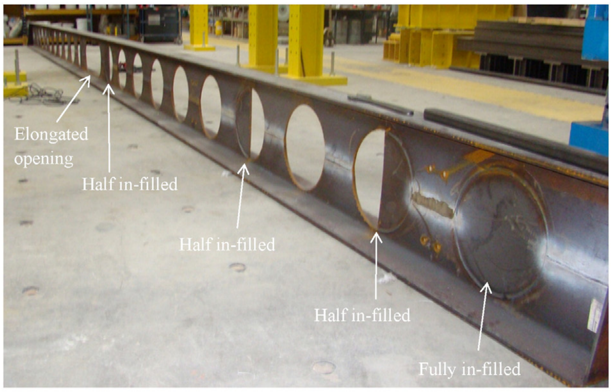
Cross-section in solid web region

Cross-section at the centre of web opening

Fig. 1. Cross-section dimensions of the asymmetric cellular beam.

these rules using finite element analysis. However, very little test data currently exists to support the design of asymmetric composite cellular beams, in particular longer span composite cellular beams. A European research project called "LWO" [6] included 3 tests on composite cellular beams spanning 7.2 m but only one of these beams was asymmetric. In Eurocode 4 [7], a higher degree of shear connection is required for asymmetric beams than for symmetric beams. If is often impossible to achieve the desired degree of shear connection (nearly 100%), since this is limited by the spacing of the deck ribs (usually 300 mm for trapezoidal decking). Furthermore, the development of deeper deck profiles has increased the spacing between beams from 3 m to 4.5 m, increasing the potential load to be transferred by shear studs. Hence design is often governed by achieving the minimum degree of shear connection.

Composite beams may be constructed with or without the use of temporary props. If props are used, the weight of the steel beam and fresh concrete of the slab is supported by the props. Once the slab concrete has gained sufficient strength, the props are removed and the composite section bears the self-weight. Without the use of props during the concrete slab casting, the self-weight of the beam and the wet concrete is supported by the steel beam alone, since the concrete does not have adequate strength at this stage. Unpropped construction is popular since it reduces the time and operational cost during construction, but as suggested by Lawson and Saverirajan [8] and Banfi [9], there are differences in response between propped and unpropped beams. Unpropped beams experience a lower degree of end-slip and require a lower degree of shear connection. However, the advantages of unpropped beams are not currently exploited in Eurocode 4.



(a) prior to installing decking and shear studs

(b) after installation of profile decking and shear studs

Fig. 2. Set up of the cellular steel beam.

Fig. 3. "Wing" system used to support wet concrete slab weight.