Journal of Constructional Steel Research 106 (2015) 329–346

Contents lists available at ScienceDirect

Journal of Constructional Steel Research

Flexural behavior of shallow cellular composite floor beams with innovative shear connections

Shiming Chen *, Toi Limazie, Jianyao Tan

School of Civil Engineering, Tongji University, Shanghai 200092, China

ARTICLE INFO

Article history:
Received 7 September 2014
Accepted 24 December 2014
Available online 4 February 2015

Keywords:
Shear connection
Shear transfer
Shallow cellular composite beam
Slim floor
Tie-bar element
Infill concrete

ABSTRACT

This paper presents an experimental study of the flexural behavior and shear transfer mechanisms of shallow cellular composite beams where the concrete passing through the steel web opening is combined with a steel tie-bar element to form the shear connection. Four full-scale flexural tests were undertaken aiming to provide information on their flexural behaviors, and to assess the shear resisting properties and the failure mechanisms of the proposed shear connections. The tested composite beams showed satisfactory composite behavior and satisfactory horizontal shear resistance. It is demonstrated that combining the tie-bar with the concrete significantly increases the shear resistance, slip capacity and ductility of the shear connections. Based on the test findings, design procedures of shallow cellular floor beams which are in accordance with the stress method presented in EC4 and BS5950-3.1 and of the shear connection were developed. The design procedures were verified against the test results and were found to be consistent.

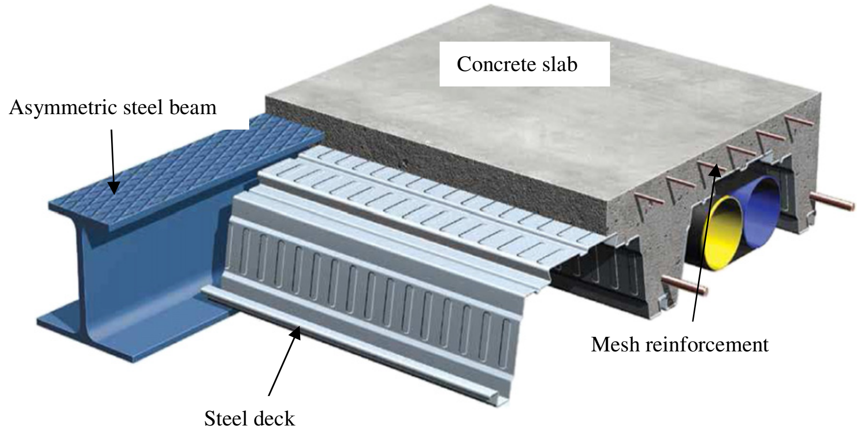
1. Introduction

In modern building constructions, the increasing demands of long span floors but with shallow floor depth have led to the development of various composite floor systems. In conventional composite floor systems, the depth of beam section normally increases with the length that the floor spans over and it results in the steel sections of the ordinary down stand composite beams being heavier and deeper than expected. The shallow cellular composite floor system has been developed to overcome this problem, and it consists of an asymmetric steel beam embedded within the concrete slab and therefore minimizes the overall floor depth (Fig. 1). The use of shallow cellular composite floor offers vital benefits in terms of cost such as long spanning capability without or with fewer secondary beams, shallow floor depth, and inherent fire resistance, as well as the advantages offered by the ordinary composite beam construction [1–3,4]. To reduce the overall depth of the composite floor, the steel profiles are normally encased within the slab depth. The shallow cellular floor beam can be constructed by an asymmetric I-section beam or can be fabricated by welding different plate sections together, with regularly spaced openings formed on the web post (Fig. 1).

The composite slim floor systems have been studied in terms of the integrated composite beam [1,2,5,6,7]. Experimental studies on integrated slim beams were conducted by researchers of the Helsinki University of Technology; and also, the influence of parameters such as reinforcement ratios and types of loading on the behavior of composite slim beams was investigated [8]. Mullett [9] proposed a design guidance for Slimflor beams using the hollow core precast units. The design guidance outlined was in accordance with the BS5950: Part 1: 1990 [10]. Slimflor beams using the profiled deep decking were also investigated by Mullett and Lawson [11] and design tables and worked examples were given. A full-scale slim-floor beam test was presented by Mullett [5], and in the study the shear transfer between the steel section and the concrete was provided by the shear bond at the interface between the two components. Wang et al. [7] presented an experimental investigation of flexural behavior of slim floor beams using deep decking with fixed end connection to a column frame. Also, four full-scale tests carried out on two span continuous composite floor systems (6 m × 10 m) were experimentally studied by Hegger et al. [12]. However, the structural mechanism of this integrated composite beam is not yet well understood. The roles that the shear connections and the shear transfer play in the overall behavior of the composite slim floor system have been overlooked. The shear connections in composite slim floor beams are different from that in ordinary down-stand composite beams, where headed shear studs are usually welded on the top flange of steel beam, playing the role to transfer the longitudinal shear forces between the concrete slab and steel beam. For slim floor beams, the shear transfer is usually assumed by the bonding effect at the interface between concrete and steel beam. This adhesive strength is very small and is prone to shear failure under small loads. It is essential to assure the effective interaction between the two materials and also to take advantage of the benefits offered by its structural configuration. For this purpose and to enable an effective and innovative shear connection for the composite slim floor

* Corresponding author: Tel.: +86 21 65986183; fax: +86 21 65982668.
E-mail address: chensm@tongji.edu.cn (S. Chen).

http://dx.doi.org/10.1016/j.jcsr.2014.12.021
0143-974X/



(a) Ordinary slim floor

(b) Shallow cellular floor

Fig. 1. Typical configuration of ordinary slim floor and shallow cellular floor.

beams, a row of circular openings are performed within the steel web, which provide passage for concrete cast in place. The infill concrete combines with the additional steel reinforcing bar, as shown in Fig. 2, to form the shear connection which is able to transfer the longitudinal shear force between the concrete slab and the encased steel beam.

The shear transfer mechanism on perfobond shear connections (similar but not the same as that proposed herein) was studied by Jeong et al. [13], Oguejiofor and Hosain [14,15] etc…, however, research of the composite action on shallow cellular composite beam with the proposed perfobond-like shear connection is still very rare in the literatures. To promote its design application, the mechanism of this perfobond-like shear connection system should be well understood. Huo and D'Mello [16] presented 24 full-scale push-out tests to investigate four types of shear connections for shallow cellular beams, under direct longitudinal shear force.

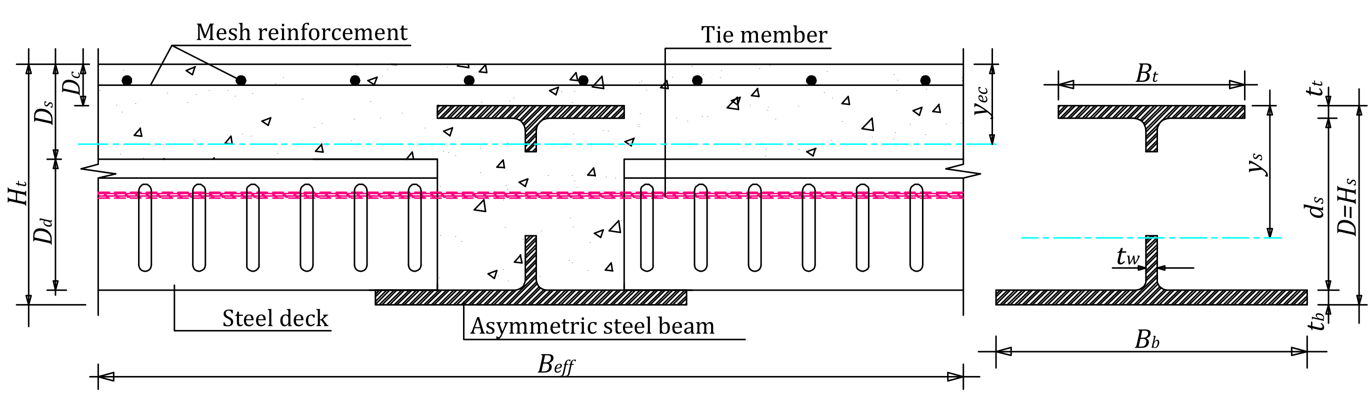


Fig. 2. Geometrical configuration of shallow cellular beam with shear connection arrangement.