Experimental study of mechanical properties of lightweight composite floors

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Abstract. The mechanical performance of the fabricated composite floors consisting of thin-walled steel beams and lightweight aggregate concrete was experimentally studied and effect of some important factors on the mechanical properties of the composite floor specimens was discussed. The experimental results showed that the composite floors had better plastic deformation capacity, greater bearing capacity and better entirety, and effect of the geometrical construction of cross section of the main steel beams on the mechanical property of the floors was related with deformation of the floors in a degree.

1. Introduction
To reduce the floor quality, it can be replaced by ceramsite concrete instead of the commonly used concrete with gravel as coarse aggregate to form the profiled steel plate-lightweight aggregate concrete composite slabs [¹]. The lightweight steel truss-profiled steel sheet concrete composite floor was presented and the mechanical performance of it had been experimentally studied, and the combined action of the light steel trusses and the ceramsite concrete had been studied [²], but the lightweight precast concrete panel was not considered. The laminated composite floor was studied [³], in which the occlusal effect between the upper laminated plates and the precast panels was discussed to obtain the effective construction. Based on the existing papers, the mechanical property of thin-walled steel truss-ceramsite concrete composite slabs was studied [⁴], in which the thin-walled steel truss was considered, but there were still some deficiencies for practical engineering. A new type of composite floors was put forward in paper [⁵], and the fundamental mechanical property was studied. It follows that research on the lightweight prefabricated composite floor needs to be further studied. Hence, a new type of lightweight fabricated composite slab is presented, which consists of H-type thin-walled steel beams and the ceramsite concrete panels. The composite floors also have advantages of no formwork support, lighter weight and factory prefabrication, et al.

2. Geometrical dimensions of specimens
The geometrical dimensions and construction of the composite floor specimens was shown in Fig.1. It is denoted that the floor specimens consist of the thin-walled steel skeleton which is formed with a set of H-type thin-walled steel beams and steel channels, the lightweight precast panels located upon the steel skeleton, the shear keys connected to the main steel beams and the post-pouring concrete layer. It is especially denoted that the geometrical dimensions of the cross-section of thin-walled steel beams, steel channels and dimensions of the precast panels are shown in Fig.2. It is seen that the thickness of
steel plates of the main steel beam and steel channel is 0.6mm, and the thickness of the precast panels is 40mm, and the depth of groove of the precast panel is 10mm. It is specially denoted that the H-type steel beam consists of two thin-walled steel channels, which was formed by spot welding at outer flange. It is denoted that the main steel beams of three specimens are supported at the support beam as shown in Fig.1. Each secondary beam (steel channel) is connected with the main steel beam at one end and supported at the support beam at the other end.

![Diagram](image)

Fig.1 Geometrical dimensions of the specimens and construction

![Diagram](image)

Fig. 2 Geometrical dimensions of main elements of the specimens

The mechanical properties of the materials used here are taken as: the Young’s modulus of steel and the yield strength is 2.04×10^5MPa and 149MPa, respectively, and the cube strength standard value and elastic modulus of the lightweight concrete are σ_c = 40.8MPa and Ec=2.12×10^4MPa, respectively.

3. Test results and discussion
The static loading tests for three composite floor specimens as shown in Fig.1 are finished here. The loading point distribution is shown in Fig.3, in which four of the measuring points of vertical displacements is set, and denoted as number 1~4. The loading point is set at the centre of the specimen.

3.1. Description of specimens
The specimens are denoted as SP1, SP2 and SP3, for which the constraint conditions for them are different. In particularly, two ends of the main steel beam of specimen SP1 and SP2 are all simply
supported, and four corners of specimen SP2 are restrained in vertical direction, however two ends of the main steel beam of specimen SP3 are fixed support.

![Diagram of measuring points](image1)

![Diagram of strain measuring points](image2)

**(Fig. 3)** Distribution of measuring points of specimens

### 3.2. Test phenomena

It is seen that all the specimens presented here have better deformation ability and entirety, and the local failure of the specimens are shown in Fig. 4. It is shown that there are obvious local buckling in upper flange of the main steel beam and evident through cracks on top surface and bottom surface of the concrete panel shown in Fig. 5.

![Support end](image3)

![Midspan](image4)

**(Fig. 4)** Local buckling of the main steel beams

![Upper surface](image5)

![Lower surface](image6)

**(Fig. 5)** Cracks in the concrete panel
It is also seen from Fig.4 that the position in which the local buckling of upper flange of the thin-walled steel beam occurred is located near the support end of the beam and near midspan of the beam, it is concluded that strengthening the upper flange of end and midspan of the main steel beam is necessary.

3.3. Displacements and strains of specimens

The curves of load-vertical displacements of three specimens are shown in Fig.6.

![Fig.6 Comparison of ∆-P curves of specimens](image1)

![Fig.7 Comparison of S-P curves of specimens](image2)

It is seen that the relation of load P and vertical displacement of the specimens has evident nonlinearity, but the deflection ∆ varies linearly with load P for the load less than 10kN for all specimens, which means that the composite slabs are elastic when the load P is less than 10kN. It is also seen that the maximum value of deflections of the specimens presented here is much less than L/400 for 10kN/m² of equivalent uniform load.

It is also seen from Fig.7 that slip displacement between concrete and steel beam at the end of the specimens is quite small and slip of specimen SP1 is less than that of specimen SP2, which show that the coordination of steel beam and concrete is better.

![Fig.8 Strains of specimen SP1](image3)

(a) II- II  (b) upper flange of SP1
It is seen from the results shown in Fig. 8–Fig.10 that the whole section of main steel beam is in the state of tension, which also show that the coordination of steel beams and concrete panel is better. The strains at cross section III-III is quite small show that the right end of the beam is hinge joint which coincide with the restraint conditions.

4. Conclusions
It is concluded that the composite slab consisting of thin-walled steel beams and lightweight concrete panels has better plasticity and entirety. The composite slab has higher bearing capacity and larger stiffness. The results show that the maximum value of deflections of the specimens presented here is less than L/400 for 10kN/m² of equivalent uniform load.

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References
[1] Zhen Yi, Cheng Shuwei, et al. The caculation of shear slippage of light-weight aggregate concrete composite floor slabs [J]. Industrial Construction, 2007,37(s1):579-591(in Chinese).
[2] Kong Weichao. Experimental study of light steel truss beam-profiled sheet lightweight concrete composite slabs [D]. Chongqing: Chongqing University,2013:6-38 (in Chinese).
[3] Wu Fangbai, Liu Biao, et al. Analysis of the interlocking effect of the combined interface in a new type of composites floor [J]. Journal of Hunan University, 2014,41(2):1-7 (in Chinese).
[4] Wang Xintang, Yang Jin, et al. Experimental study of mechanical property of thin-walled steel truss–ceramsite concrete composite slabs [J]. Journal of Building Structures, 2016, 37(s1): 259-266 (in Chinese).
[5] Wang Xintang, Yang Jing, Wang Wanzhen. Experimental study of mechanical property of fabricated composite slabs of lightweight aggregate concrete and thin-walled steel beams with openings in web [J]. Journal of Building Structure, 2016, 37(5): 39-47(in Chinese)