Study of mechanical performance of a new type of fabricated composite floors

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Abstract. Mechanical performance of a new type of fabricated composite floors was studied. It was concluded that the local buckling of the upper flange of the thin-walled steel beams occurred along the whole upper flange of the thin-walled steel beams of the composite floors presented here, which showed that properly strengthening the upper flange of the main steel beams was necessary. It was also seen that the boundary condition at end of the main steel beam had no evident effect on vertical displacements of the specimens. Distribution of strains along height of the steel beam agrees with the plan cross-section assumption, which may be used as foundation of determining the formula of bearing capacity of the composite floor.

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 properties 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 in the paper. 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 researched [4], in which the thin-walled steel truss was considered, but there were still some deficiencies for engineering application. A new type of composite floors was put forward in paper [5], and the fundamental mechanical property was studied. It follows that the research on 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 and construction
The construction of composite floor specimens is shown in Figure 1. It is indicated that the composite floor specimen consists of the thin-walled steel skeleton which contains a set of H-type main steel beams and steel channels as secondary beams, the lightweight aggregate concrete precast panels and the post-pouring concrete layer. It was specially denoted that each main beam was made of two thin-walled steel channels by dot welding at upper and lower flanges.
It is denoted that the main steel beams and the secondary beams of the specimens are supported at the support beam. The specimens are denoted as SB1, SB2 and SB3, of which the constraint condition and the height of secondary beam are different. Especially, two ends of main steel beam of specimen SB1 and SB3 are all fixed supported, while the ends of main steel beam of specimen SB2 are simply supported.

As shown in Fig. 2, the height of secondary beams of specimen SB1 is 20mm, which is only half of those of specimen SB2 and SB3. It is noted that the thickness of steel plate of the main steel beams and the secondary beams of SB2~SB3 is 0.6mm, the value of secondary beam of SB1 is 1.2mm, and the height of the precast panels is 40mm. The depth of the post-pouring concrete layer is 20mm.

The mechanical properties of the materials used here are taken as: the Young’s modulus of steel and the yield strength are $2.04 \times 10^5 \text{MPa}$ and 149MPa, respectively, and the cube strength standard value and elastic modulus of the lightweight concrete are $\sigma_c = 40.8\text{MPa}$ and $E_c=2.12 \times 10^4\text{MPa}$, 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 measuring points of vertical displacements is set, and denoted as 1–4. The loading point is set at the centre of the specimen.

![Diagram of loading point distribution and measuring points](image)

(a) Key points and sections  
(b) Strain measuring points of main beam  

Fig.3 Distribution of the measuring points of specimens

3.1. Experimental phenomena
It is seen that all the specimens presented here have better entirety and larger deformation ability, and the damage of the composite slab specimen includes the local buckling of thin-walled steel beam and cracks in concrete. It is shown that there are obvious local buckling in upper flange of the main steel beam shown in Fig.4a and the evident cracks on upper surface of the concrete panel shown in Fig.4b.

![Damage of the composite floor specimens](image)

(a) Local buckling of steel beam  
(b) Crack in concrete  

Fig.4 Damage of the composite floor specimens

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 along all the upper flange of the thin-walled steel beam, which means that properly strengthening the upper flange of the main steel beam is necessary.

3.2. Displacements and strains of the composite floor specimens
The curves of load-vertical displacements of three specimens are shown in Fig.5.
It is seen that the relation of load $P$ and vertical displacement $\Delta$ of the composite slab specimens has evident nonlinearity, but the deflection $\Delta$ varies linearly with load $P$ for the load less than 8kN for all the specimens, which means that the composite slabs are elastic when the load $P$ is less than 8kN. It is also seen that the maximum value of deflections of the specimens presented here is much less than $L/400$ for 20kN, which show that the composite floor specimens presented here has larger stiffness for that the equivalent uniformly distributed load is 10kN/m$^2$.

It is also seen from Fig.6 that the boundary condition at end of the main steel beam has no evident effect on displacements of the specimens. However it is seen from the results shown in Fig.6 that three of the composite slab specimens have obvious plasticity and larger deformation ability. The specimens SB1 and SB2 have larger elasticity than the specimen SB3, but the later one has the greatest deformation ability and plasticity ability.
It is also seen from Fig. 6 that the slip displacement at end of the composite slab specimens is very small, and the value of SB2 is lest. It is denoted that the boundary condition at end of the main steel beam has effect on slip of the end of the specimen in a degree. The results also showed that the thickness of steel plate of secondary has no effect on slip of the specimens.

It is seen from the results shown in Fig. 7 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. It is also seen that the strain distribution of main steel beam of specimen SB1 is close to that of specimen SB3, but the later has larger limit load than the former.

The variation of strains along height of the main steel beam is shown in Fig. 8. It is seen from the results shown in Fig. 8 that distribution of strains along height of the steel beam agrees with plan cross-section assumption which lays the foundation of obtaining the formula of the bearing capacity and deflection of the composite slabs which may used in engineering. It is also seen that P1 and P2 shown in Fig. 8 stands for yielding load and limit load, respectively. The results also show that the maximum strain of main beam of specimen SB1 is larger than that of specimen SB2.
4. Conclusions
It is concluded that the composite slab has higher bearing capacity and larger stiffness. The position in which the local buckling of upper flange of the thin-walled steel beam occurred is located along all the upper flange of the thin-walled steel beam, which means that properly strengthening the upper flange of the main steel beam is necessary. The boundary condition at end of the main steel beam has no evident effect on the vertical displacements of the specimens. It is seen that distribution of strains along height of the steel beam well agrees with the plan cross-section assumption, which may be used as basis of determining the formula of the bearing capacity and deflection of the composite slabs.

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