Test study of mechanical properties of composite floors of thin-walled steel and ceramsite concrete

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Abstract. The mechanical property of the lightweight composite slabs consisting of ceramsite concrete and thin-walled steel beams was experimentally studied. The test results showed that the composite floors had larger stiffness and better entirety, the relation of load P and vertical displacement of the composite slab specimens had evident nonlinearity, but the deflection $\Delta$ varied linearly with load $P$ for the load less than 12kN for all the lightweight composite floor specimens. It was seen that distribution of strains of cross section of main steel beams basically agreed with the plan cross-section assumption.

1. Introduction
In order to reduce the floor quality, it can be replaced by lightweight concrete instead of the commonly used concrete with gravels as coarse aggregate to form the profiled steel plate-lightweight aggregate concrete composite floors [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 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 the composite floor specimens
The geometrical dimensions and construction of the composite floor specimen is 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 noted that the geometrical dimensions of the cross-section of thin-walled steel beams, 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 except for specimen SB3, 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 fixed supported at the support beam as shown in Fig.1. Each secondary beam (steel channel) is connected with the main steel beam and supported at the support beam at the other end.

![Diagram of specimens and construction](image)

Fig.1 Geometrical dimensions of specimens and construction

![Cross section of main beam and precast panel](image)

(a) Cross section of main beam   (b) Precast panel

Fig.2 Geometrical dimensions of the main elements of composite floor specimens

The mechanical properties of the materials used here are taken as: the Young’s modulus of steel and the yield strength are $2.02 \times 10^5$MPa and 148MPa, respectively, and the cube strength standard value and elastic modulus of the lightweight concrete are $\sigma_c = 41.5$MPa and $E_c=2.13\times10^4$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.
3.1. Description of specimens
The specimens are denoted as SJ1, SJ2 and SJ3, for which the constraint conditions for them are the same. In particularly, two ends of the main steel beam of three specimens are all fixed supported.

3.2. Displacements and strains of specimens
The curves of load-vertical displacements of three specimens are shown in Fig.4. It is seen that three of the composite floor specimens has better deformation ability and plasticity, and deformation of specimen SJ2 and SJ3 is larger than specimen SJ1, the largest deflection is L/130.
It is also seen that the relation of load P and vertical displacement of the specimens has evident nonlinearity, but the deflection $\Delta$ varies linearly with load P for the load less than 12kN for all specimens, which means that the composite slabs are elastic when the load P is less than 12kN. It is also seen that the maximum value of deflections of the specimens presented here is much less than $L/400$ for 8kN/m$^2$ of equivalent uniform load, which means that the composite slab specimens presented here has larger stiffness.

![Comparison of S-P curves of specimens](image1)

Fig. 5 Comparison of S-P curves of specimens

It is seen from Fig.5 that slip displacement between concrete and steel beam at the end of the specimens is quite small and slip of specimen SJ1 is less than that of the other specimens, which show that the coordination of steel beam and concrete is better. It is seen from the results shown in Fig.5 that the slip displacement at limit load is just less than 1mm for specimen SJ2 and SJ3, and slip of specimen SJ1 is less than 1.5mm.

![Strains of specimen SJ1 at different cross-section](image2)

Fig. 6 Strains of specimen SJ1 at different cross-section
Fig. 7 Strains of measuring points of SJ2

Fig. 8 Strains of measuring points of SJ3

It is seen from the results shown in Fig. 6–Fig. 8 that the whole section of the main steel beam is in tension, which show that the coordination of steel beams and concrete panel is better. It is also seen from Fig. 6 that the variation of strain in section I-I of SJ1 is quite similar with that in section II-II.

Fig. 9 Variation of strains along height of cross section of steel beam of SJ2

Fig. 10 Variation of strain on upper surface of concrete panel
It is specially noted that PJ and PH in Fig.9 stand for limit load and yielding load, respectively. It is seen from the curves as shown in Fig.9 that variation of strains along height of the cross-section of the main steel beam is linear before the load of 10kN, which showed that variation of strain for the specimen coincide plan cross-section assumption, which may be used as basis of getting formula of deflection of the composite slab. However, it is seen that as the load is close to limit load and yielding load the variation of strain along height of the cross-section of the main steel beam is nonlinear which means that part of the cross section is in the stage of elastoplasticity.

It is seen from the variation of strains shown in Fig.10 that the upper surface of concrete is in compression and the value at end of the specimen is zero. The results show that variation of the strains along span of the specimen SJ1 is larger than that of SJ2, and there is larger difference between the strains of the four measuring set on upper surface of the specimen SJ1.

4. Conclusions
It is concluded that the composite floor specimens has larger stiffness and higher bearing capacity. The relation of load P and vertical displacement of the specimens has evident nonlinearity, but the deflection $\Delta$ varies linearly with load $P$ for the load less than 12kN for all specimens. The results presented here also show that the coordination of steel beams and concrete panel is better and distribution of strains along height of cross-section of the main beam basically coincide the plan cross-section assumption.

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