Study of post-fire mechanical behaviours of the light prefabricated composite floors after fire

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Abstract. The post-fire mechanical properties of a prefabricated composite slabs consisting of thin-walled steel members and lightweight aggregate concrete was experimentally studied, and the displacements of the composite floor specimens was discussed. The experimental results showed that the ultimate load of the composite slab specimens after fire with using the stud shearing connectors was greater than that with using the new type shear keys made with thin-walled steel plate. The global stiffness and load-bearing capacity of the composite slabs after suffering hydrocarbon fire can be effectively improved by increasing the wall thickness of transverse sub-members appropriately.

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 thin-walled steel member-lightweight concrete composite floor was presented and the mechanical performance of it had been experimentally studied, and the combined action of the thin-walled steel beams and the ceramsite concrete had been studied [2]. Wang [3] emphatically studied the fire response and post-fire bearing capacity of a group of profiled steel sheet-ceramsite concrete composite slabs with different structural characteristics through experiments, and the results show that the lightweight composite slabs have good fire behavior and bearing capacity. Wellman[4] carried out an experimental study on the structural response of thin composite slab system (composed of a group of steel beams, ribbed steel plates and light concrete) under load-bearing and fire, and the results showed that thinner lightweight concrete plays an important role in load transfer between steel beams. Nguyen [5] carried out study on post-fire performance of flat decking composite slabs and analytical model for predicting the load–deflection curve of post-fire reinforced-concrete slab, respectively. However, the lightweight concrete is not used and prefabricated concrete sheet is also not involved. Therefore, the post-fire bearing capacity test of a group of new composite slab specimens after suffering hydrocarbon fire was carried out, and the residual bearing capacity of it was presented and studied based on the test results.

2. Geometrical dimensions and mechanical parameters of specimens

The geometrical dimensions and construction of the composite slab specimens was shown in Fig.1. It is noted that there are two thin-walled steel components with openings (named as main member) and two channel side beams longitudinally for each slab specimen; nine short thin-walled steel channels (named as sub-members) are connected horizontally. The construction and dimensions of the main
member noted as MB is shown in Fig.2 (symmetrical to the left part). It is noted that all the main components are welded by two crimped channels to form the section shown in Fig.2, and have the section dimension of 72mm×40mm×20mm×1.0mm (Fig.2c).

![Fig.1 Geometrical dimensions of the slab specimens](image)

![Fig.2 Dimension and construction of the thin-walled steel member (MB1)](image)

The transverse sub-components SB1-A/B is made of the thin-walled steel channels, and the cross-section specifications is 80mm×20mm×0.6mm and placement direction is shown in Fig.1. All side members as shown in Fig.1 are made of thin-walled steel plates with thickness of 1.5mm, and the cross-sectional specifications are 120mm×20mm×1.5mm. 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 160MPa, respectively, and the cube strength standard value and elastic modulus of the lightweight concrete are σc = 32.5MPa and Ec=2.17×10^4MPa, respectively.

3. Test result and discussion
The post-fire static load tests for four composite slab specimens as shown in Table 1 are finished here. The loading point (denoted as LP) distribution is shown in Fig.1. It is noted that the static load test of post-fire mechanical performance of a group of specimens is finished in situ after fire test. The furnace
temperature used the heating curve of hydrocarbon fire, which has the maximum temperature of 700℃ and duration of 90min.

3.1. Test phenomena

Table 1 Main parameters of the composite floor

| No | Main members | Sub members | Post-poured layer | Type of Shearing keys | Connection ways |
|----|--------------|-------------|-------------------|-----------------------|-----------------|
| AS1 | MB1          | SB1-A (B)   | C-m               | SI                    | N-GJ            |
| AS2 | MB1          | SB1-A (B)   | C-c               | SI                    | N-GJ            |
| AS3 | MB1          | SB1-A (B)   | C-m               | SII                   | N-GT            |
| AS4 | MB1          | SB2-A (B)   | C-m               | SII                   | N-GT            |

Note: N-GJ is U-shaped tie piece made of steel rod and not connected to the shear keys denoted as SI; N-GT is shown in Figure 4b; The shear keys SI is traditional studs with height of 40mm and diameter of 10mm, the shear keys SII is made of thin-walled steel with thickness of 2mm; C-m means that post-poured layer is cement mortar and C-c ceramsite concrete with thickness of 20mm.

In the static load test after fire, the specimens show different characteristics and phenomena, and the common phenomena and characteristics are mainly as follows: (1) After yielding, two main cracks extend to the end of the specimen; (2) The longitudinal thin-walled steel members are obviously distorted and the free end is seriously damaged (Figure 3); (3) Local buckling and overall plastic bending of steel members were observed for all specimens; (4) There was clear separation of transverse members from concrete slabs.

3.2. Distribution of vertical displacement of specimens

The post-fire distribution of deflection along the longitudinal direction of the slab specimens after fire are shown in Fig.4, respectively for ultimate load and final failure, which indicted the deformation of the composite slab under static load.

It is seen that the deformation forms of two states are quite different for all specimens. For the specimens presented in Table 1, deformation forms of specimen AS1 and specimen AS2 is similar and deformation of AS1 became greater than that of AS2 with approaching the final failure, and deformation of AS3 are quite close to that of AS4 and finally coincide with each other and the deflection is in apparent asymmetry.
3.3. Strains of specimens

The distribution of strains along the height of the cross-section at mid span of the main steel member of all specimens is shown in Fig. 5, respectively for three load levels (that is $q=2\text{kN/m}^2$, $q=3\text{kN/m}^2$, $q=4\text{kN/m}^2$), and the corresponding measuring points of strains can be seen in Figure 2c.

It can be seen from Fig. 5 that the normal strain distribution along the section height of the thin-walled main members of the specimens presented in Table 1 basically conforms to the assumption of plane section, and presents concave distribution which is large at both ends and small in the middle. The main reasons for this distribution are: (1) The thin-walled steel plate used for main steel members has obvious non-linear stress-strain characteristics, and the strain increases rapidly with the increase of...
stress (such as tension stress of lower flange); (2) Thin-walled steel members are composed of two channel steels by pressing and welding webs, and the welding joints are located near the cross-section axis. Therefore, one channel steel will restrain the other channel steel to a certain extent, which will reduce the strain at center of the cross-section of steel members while the steel members is bended by bending moment; (3) The stress concentration caused by the opening of the web of steel members also has some influence on the strain distribution of the section.

The results show that the tensile strain of the lower flange is much larger than the compressive strain of the upper flange. In order to compare the strain characteristics of the specimens, the ratio \( \varepsilon_c/\varepsilon_l \) of compressive strain of flange \( \varepsilon_c \) to tensile strain of lower flange \( \varepsilon_l \) in the mid-span section of the main steel member of each specimens for the equivalent uniform load of 3kN/m\(^2\) are obtained as 0.14, 0.30, 0.38, 0.15 respectively for specimens AS1, AS2, AS3 and AS4. The ratio \( h_c/h_t \) (herein after referred to as \( \rho \)) of the height of compression zone \( h_c \) to the height of tension zone \( h_t \) at the same load level are obtained as 0.5, 1.18, 0.75 and 0.97 for the four slab specimens.

![Curves of load-strain of typical points of the specimens](image)

**Fig.6** Curves of load-strain of typical points of the specimens

It can be seen from Fig.6 that the strains at three measuring points of concrete slabs of the specimen presented in Table 1 are all tensile strains except point C3 of specimen AS4 during loading. Comparing the results of specimens AS1 and AS2, it is shown that the strain of specimens AS2 is much larger than that of specimens AS1 when the load is less than 2kN/m\(^2\), which shows that the concrete slab of specimen AS2 has large deformation at the joint of the upper surface, and its integrity is weak. This is due to the fact that the post-poured layer of specimen AS2 is ceramsite concrete, and its bonding performance and self-strength are lower than those of cement mortar.

From the results of specimen AS3 and AS4, it can be seen that the strain of test point C3 of specimen AS3 is tensile strain, while that of specimen AS4 is compressive strain. It shows that the increase of wall thickness of transverse members is beneficial to improve the integrity of composite slabs after fire, and can change the stress state at the joint of concrete slabs, effectively prevent or delay the cracking of concrete slabs.

**4. Conclusions**

It is concluded that increase of wall thickness of transverse members is beneficial to improve the integrity of composite slabs after fire, and can change the stress state at the joint of concrete slabs,
effectively prevent or delay the cracking of concrete slabs. The post-fire performance of composite floor after fire with using the ordinary bolt (SI-type) as shear keys are better than that with using the new type of shear keys (SII-type) made of thin-walled steel. The results showed that the concrete slab of specimen AS2 has large deformation at the joint of the upper surface, and its integrity is weak.

Acknowledgments
This work was financially supported by the national natural science foundation of China (No.51678312).

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