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Experimental Research of the Lightweight Concrete-Profiled Sheeting Composite Floor Supported by Light Gauge Steel Tubes

[Mengli Song, Zhijun Wang, Lanying Zhu, Weichao Kong]

Abstract—**In this paper, the lightweight concrete-profiled sheeting composite floor supported by Light Gauge Steel (LGS) square tubes was studied through static experiment using the vertical load. The influence of profiled sheeting and lightweight concrete-profiled sheeting to the bearing capacity and flexural rigidity of the composite floor was discussed. Then the failure mode of the square tube was investigated, and the positive effects of lightweight concrete on the bearing capacity of LGS square tube is discussed, then a suggestion for the calculation of load bearing capacity of the composite floor was proposed.**

Keywords—**experimental, research, FEM analysis, light-weight concrete-profiled sheeting, mechanical performance**

I. Introduction

Residential system consists of light gauge steel (LGS) or Cold-formed steel has been applied all over the world [1,2]. The composite floor composites of floor slab and girders or joists, concrete-profiled sheeting often applied as floor plate, and for buildings with a large span, solid webs (C-shaped section) or Light Gauge Steel (LGS) truss girders were used, but for small houses, LGS square tube is more economical and easier to carry out in construction. Recently, research on concrete-profiled sheeting composite floor supported by LGS joists have been conducted [3,4,5], and lightweight concrete was often used as floor slab in timber structure[6], but only a few experimental researches were carried out to apply lightweight concrete in cold-formed steel residential system. And the present researches are concentrating more on C-shaped joists [7-10]. Thus, more experimental programs should be carried out to investigate the mechanical property of composite floor supported by LGS square tubes. Through analyzing the performance of the lightweight concrete-profiled sheeting composite floor supported by Light Gauge Steel (LGS) truss girder and applying them in real residential construction, lightweight concrete with dry apparent density varies from 800 kg/m^3 to 1600 kg/m^3 and compressive strength varies from 5 MPa to 10 MPa have a good mechanical performance in floor system. In detail, it not only has a light weight, but can enhance the flexural rigidity and bearing capacity of truss girders. Moreover, it can meet the basic requirements of building physics (acoustic, fire, vibration etc). In order to accelerate the application of lightweight concrete in LGS residential system, it is necessary to study the mechanical property, failure mode, and factors that can influence the mechanical performance of the composite floor. This paper will provide useful references for practical engineering application and experimental basis to further research on the lightweight concrete-profiled sheeting composite floor supported by other form of girders or joists.

Mengli Song, Zhijun Wang (Corresponding author), Lanying Zhu, Weicao Kong
Civil Engineering/ Chongqing University
P.R. China

II. Experimental Program

A. Test Specimens

Three specimens of composite floor supported by LGS tubes, including one with lightweight concrete-profiled sheeting and two with profiled steel sheeting were tested. The dimension of the floors is: $2.47m \times 1.0m$, the distance between the two square tubes is $500mm$, the profiled sheet and LGS square tubes was connected together by ST 4.8 self-tapping screws. The lengthwise direction of the ribs of profiled sheet is perpendicular to that of LGS square tubes. The parameter of the specimens and the layout of the specimens were listed in Table I.

B. Loading Scheme and Experimental Setting

The composite floor was simply supported at both ends, the arrangement of the specimen, strain gauges, dial meters were showed in Fig. 1, and 1-1 section view shows the arrangement of strain gauges of LGS tube. The uniformed load was applied through bagged-iron sands, the weight of each bag is $10Kg$.

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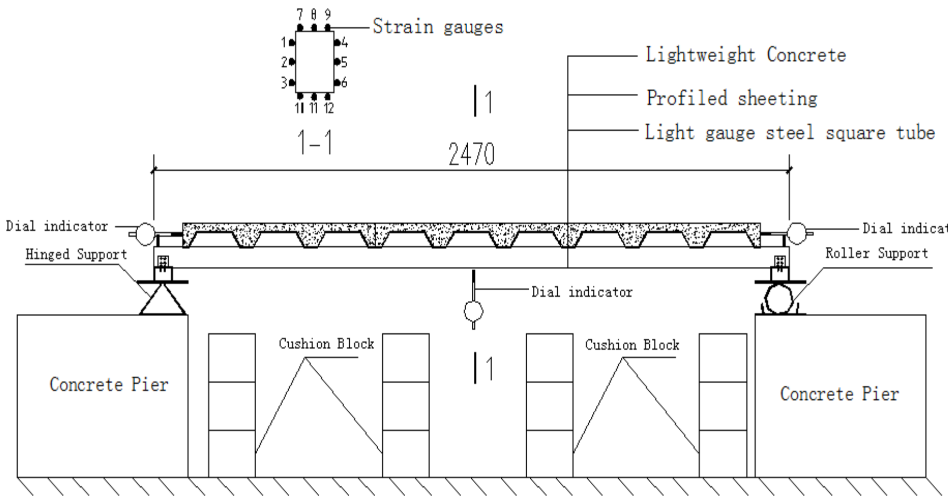

Figure 1. Layout of the specimen and arrangement of strain gauges and dial meters

TABLE I. LAYOUT OF THE SPECIMENS

Parameters of Specimen	**Specimen**		
	LG1	***LG2***	***LG3***
Section dimension of square tube (mm)	50×70×1.0	50×70×1.0	50×70×1.2
Screw spacing (mm)	250	250	250
Number of screws between the ribs	2	6	6
Unit weight of lightweight concrete (kg/m3)	—	—	1347
Thickness of lightweight concrete (mm)	—	—	32.2

When the value of load is near to the value given by theoretical calculation at the serviceability limit state and ultimate limit state, change the one load step into two steps, so that, we can get more accurate data. Moreover, strain gauges were applied mainly on LGS square tubes, profiled sheeting and lightweight concrete at the mid-span; dial indicators were arranged at both ends and mid-span of the composite floor, as shown in Fig. 1.

III. Test Results

a. Failure Mode

The ultimate load, failure position and failure mode are shown in Table II. For specimen RLG1 and TLG2, when the specimen was broken, the square tubes occur lateral corrugation; while for RLG3, diagonal cracks caused by shear force occurred on lightweight concrete, and at that time, the tubes did not buckling, as shown in Fig. 2.

TABLE II. FAILURE INFORMATION

Specimen number	**Ultimate load (KN)**	**Failure position**	**Failure mode**
RLG1	10.0	Mid-span	Local buckling
RLG2	11.0	Mid-span	Local buckling
RLG3	22.6	Mid-span between two ribs	Longitudinal shear failure

(a) RLG1

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(b) RLG2

(c) RLG3

Figure 2. Failure mode of the three specimens

b. Stress and Deflection at Mid-span

The stress of upper and bottom surfaces of square tube and the deflection at mid-span of every specimen were shown in Fig. 3. According to material characteristic test, the yield strength of square tube is 395 N/mm^2.

In Fig. 3, Local buckling of the top surface of the square tube induced the broken of RLG1 and RLG2, and the bottom surface of the tube is unwounded; While both upper and bottom surfaces of square tube of RLG3 did not occur buckling, and the stress of upper and bottom surfaces are less than that of specimen RLG1 and RLG2 under the same load. Moreover, the limit load of RLG3 is larger than that of RLG1 and RLG2. In Fig. 4, the deflection at mid-span of RLG1 is smaller than that of RLG2 and RLG3 under the same load.

Thus, it is clear that lightweight concrete-profiled sheeting can improve the bearing capacity and flexural rigidity of the square tube; Furthermore, comparing to RLG1 and RLG2, it can be known that the amount of screws have little influence on the bearing capacity and flexural rigidity of the composite floor.

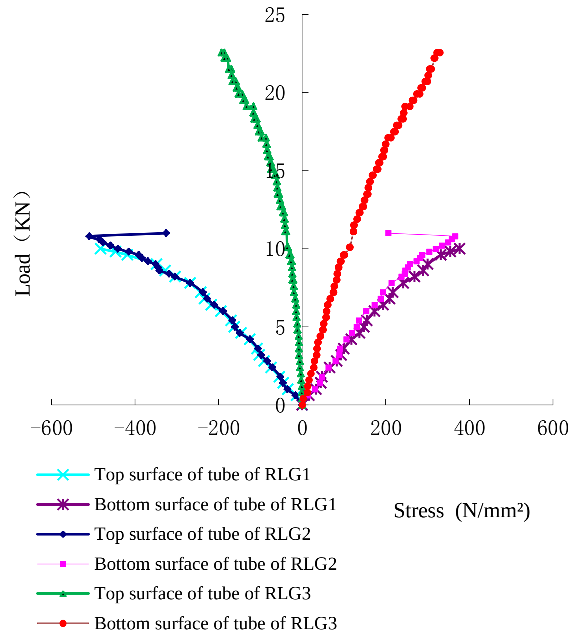

Figure 3. Load-stress curve

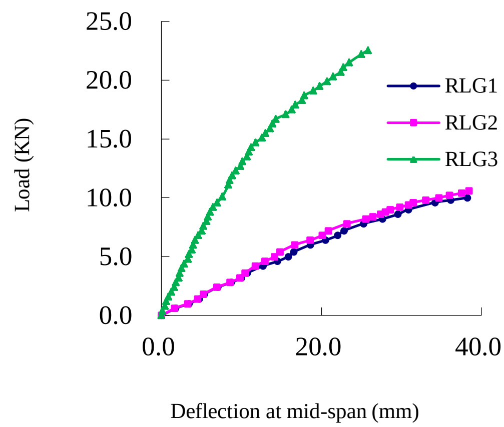

Figure. 4. Load-deflection curve

IV. Comparison and Discussion

Considering the low flexural rigidity of the profiled steel sheet, the effect of profiled sheet to the composite floor was ignored when calculating the bearing capacity of RLG1 and RLG2. Because the failure modes of RLG1 and RLG2 are local buckling, the ultimate bearing capacity of them will be the smaller value of the two values calculated based on Plate Interactive Buckling and Plate Monolithic Buckling, according to Technical Specification for Web Steel Building System (DBJ/CT045-2008) [11]. For RLG3, the lightweight concrete increases the flexural rigidity of the profiled sheeting, and restrains the deformation of the profiled sheet, so the influence of the composite floor should not be neglected, and we considered the influence under two conditions: 1. The lightweight concrete-profiled

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Table III. ULTIMATE LOAD CAPACITY OF THE THREE SPECIMENS

Specimen	P_u (kN)	P_f (kN)	P_{ut} (kN)	P_{ft} (kN)	P_u/ P_{ut}	P_f/ P_{ft}
RLG1	10.0	2.4	10.96	2.53	0.91	0.95
RLG2	11.0	2.4	10.96	2.53	1.003	0.95
RLG3	22.6	9.6	17.86(60.67)	3.62(29.03)	1.26(0.37)	2.65(0.33)

a. Pu denotes experiment results of ultimate load; P_f denotes experiment results of ultimate load when the deflection of mid-span is L/360.
b. P_{ut} denotes theoretical results of ultimate load; P_{ft} denotes theoretical results of ultimate load when the deflection of mid-span is L/360.

sheeting and the square tubes combined completely; 2. They did not combined together, as shown in Table III. For RLG3, values in bracket denote that the results was calculated based on complete combination of tube and lightweight concrete-profiled sheeting; values without bracket denotes the influence of combination is neglected.

Through comparing P_u and P_f of the three specimens, the positive effects of lightweight concrete-profiled sheeting to the composite floor is apparent, especially at serviceability limit state, the bearing capacity can be enhanced by 105%. But the experimental value of the bearing capacity only equals to 1/3 of the value calculated according to the condition 1, which indicates that the lightweight concrete-profiled sheeting and the square tubes are not combined completely. The main reason is that the screws are not strong enough to resist the sheer force between the profiled sheeting and the square tubes, then relative slippage between the two members occurred.

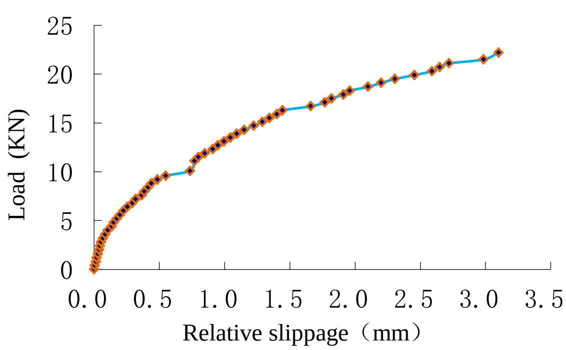

Figure 5. Load-relative slippage curve of RLG3

In Fig. 5, the relationship between load and relative slippage obeyed quadric curve approximately, which means the increase of relative slippage is larger than that of load. As a result, when RLG3 reach its serviceability limit state, the relative slippage is 0.47 *mm*; While at ultimate limit state, the relative slippage is 2.8 *mm* , which is not ignorable. Thus, further research on composite floor comprising of lightweight concrete-profiled sheeting and LGS tubes should take this influence into consideration.

V. Conclusion

(1) The failure mode of LGS square tube composite floor with profiled sheeting (RLG1 and RLG2) is local buckling of the tubes; while the failure mode of the lightweight concrete-profiled sheeting composite floor supported by Light Gauge Steel (LGS) square tubes (RLG3) is shear destruction of lightweight concrete.

(2) Lightweight concrete-profiled sheeting can enhance the flexural rigidity and the ultimate capacity of LGS tubes and the composite floor. However, the amount of screws has little influence on mechanical performance of the composite floor.

(3) Through theoretical calculation and experimental data, the LGS tubes and lightweight concrete-profiled sheeting are not combined completely, and the relative slippage should be considered when calculating the bearing capacity of the composite floor.

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