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Punching Shear Strength of Lightweight Self-Consolidating Flat Slabs

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ABSTRACT: In this research, the punching shear strength of flat plate lightweight self-consolidating concrete and lightweight concrete slabs is studied. The experimental work consisted of 9 rectangular slab specimens with either 100 or 150 mm depth, 1000 mm length and 1000 mm width. The type of concrete, strength of concrete and reinforcement varied in different tests. The slab dimensions and the area of reinforcing bars in slabs have been carefully designed so that the slabs failed due to punching shear. In a test, load and displacement were measured using a data acquisition system. Using the results, the behavior of slabs, cracking pattern and the slab stiffness were studied. The experimental results have been compared with the provisions of different codes. The comparison showed that the BS-8110 code estimates the punching shear of lightweight slabs most accurately. The slabs made by leca lightweight aggregates can be used in structures providing that they have a good mix concrete design.

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1- Introduction

Punching shear occurs in concrete slab structures exposed to high bending moment and concentrated shear stress loads that are either supported on a column or subjected to a point load. Use of smaller cross sections of structural members and reduction in dead loads in massive civil structures have become important topics in recent years. Slabs are often densely packed with steel reinforcing bars and the concrete is required to possess high strength, lightweight and self-consolidating.

2- Methodology

In the experimental part of the study, nine specimens of rectangular lightweight self-consolidating concrete, lightweight concrete and normal concrete slabs have been manufactured and tested. The main variables considered were the type of concrete, strength of concrete, slabs depth and the steel bar reinforcement ratio. The reinforcement ratio of the slabs were either 0.8% or 1.6%. The concrete mixtures were casted using ordinary portland cement with a water-cement ratio of 0.3, 0.39 and 0.38. After 28 days of curing, all the specimens were tested. Punching shear strength and displacement of each specimen were measured by a Linear Variable Displacement Transducer (LVDT). During the punching shear tests, the load and the maximum deflection were recorded by a data acquisition system, as a result the load-displacement curves were drawn. The tests were conducted using a testing machine so that the load is applied at an average rate of 10 kg/sec. Table 1 shows the concrete mix proportions.

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Table 1. Concrete mix proportions

Super plasticizer (kg/m^3)	Sand (kg/m^3)	Leca (kg/m^3)	Silica fume (kg/m^3)	cement (kg/m^3)	w/c
2.92	765	300.0	50	450	0.30
5.00	805	390.4	50	450	0.39
4.00	805	290.4	50	450	0.38

Details of a typical test slab specimen are shown in Figure 1.

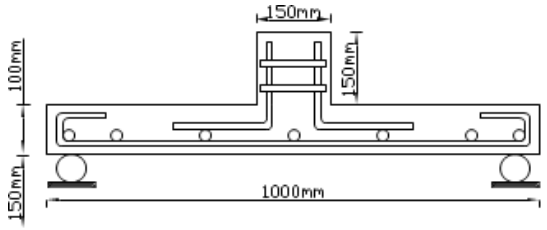

Figure 1. Typical test slab specimen

A hydraulic jack was fixed to the frame and used to apply the concentric load on the column stub. The hydraulic jack has a maximum capacity of 1500 kN (Figure 2).

3- Results and Discussions

Table 2 shows the load and the corresponding deflection values at the ultimate load.

Figure 2. Testing machine

Table 2. Deflection characteristics of tested slabs

Slab specimens*	Load (kN)	Displacement (mm)
R0.8-N-10	184.6	6.6
R1.6-N-10	225.0	6.7
R0.8-LWSCC-10	189.0	7.0
R1.6-LWSCC-10-1	202.6	6.7
R1.6-LWSCC-10-2	223.7	6.0
R0.8-LWSCC-15	311.4	5.2
R1.6-LWSCC-15	368.4	4.2
R0.8-LW-10	182.0	7.0
R1.6-LW-10	210.9	5.9

*(R: reinforcement ratio, N: normal concrete, LWSCC: lightweight self-consolidating concrete, LW: lightweight concrete)

4- Conclusions

In this paper the punching shear strength of flat plate lightweight self-consolidating concrete and lightweight concrete was studied. The main parameters of the test were type of concrete, strength of concrete, slab depth and steel bar reinforcement ratio. The structural behavior and characteristics of self-consolidating concrete slabs were examined by load-deflection, capacity, and crack profile at failure. The following conclusions can be drawn from the present research:

1. The American Code (ACI 318-11) [1] gives safe predictions of the capacity of the lightweight self-consolidating concrete and lightweight concrete slabs.
2. The British Code (BS8110-97) [2] is able to reasonably predict the structural behavior of either normal concrete or lightweight concrete slabs.
3. Increasing the ratio of reinforcement from 0.8% to 1.6% led to enhancement of punching shear strength and improved toughness for all types of concrete slabs.
4. Lightweight concrete slabs using leca aggregates can by safely used in reinforced concrete structures.
5. No significant different was seen between punching shear strength in different types of concrete.

References

[1] ACI Committee 318, Building Code Requirements for Structural Concrete (ACI 318M-11) and Commentary", American Concrete Institute, 2011.

[2] B.S. Institution, Structural Use of Concrete, Standard BS-8110, 1997.

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