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Effect of Polyvinyl Alcohol on Flexural Behavior of RC Bubble Slabs under Linear Load

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Abstract: The enhancing of flexural strength provided from using Polyvinyl Alcohol (PVA) as internal curing in concrete mix will be studied in this researcher. PVA constitute an adhesive gel attached concrete components. Thickness of concrete layer which modified with PVA was the first variable of this research (25 and 50% of total thickness of slab). Also, the comparison between solid slab and bubble slab was considered the second variable of this study. The linear load was applied on two lines perpendicular on supports. The slabs were supported by two opposite simple support. The results were obtained by testing six slabs (87×87×6 cm) of 70 cm supported length and measuring the maximum load and mid span deflection. PVA increased the load capacity of 47.4 and 55.6% and decreased the maximum deflection of 28.6 and 50.3% for solid slabs while PVA increased the load capacity of 34.7 and 35.6% and decreased the maximum deflection of 18.6 and 25.7% for bubble slabs.

Key words: RC slabs, polyvinyl alcohol, bubble slabs, flexural, experimental, maximum

INTRODUCTION

Using PVA in concrete enhanced the physical properties of concrete as proved in recent researches. Allahverdi *et al*. (2010) studied the effect W/C ratio Polyvinyl alcohol-to-Cement (P/C) ratio on flexural capacity of cement paste. The maximum increase in flexural strength occurred when W/C ratio is 30% and P/C ratio is 0.016%.

Contrafatto (2013) comprehended of the mechanical properties of concrete and mortar modified with of polyvinyl-alcohol. Based on the experimental results obtained from Contrafatto (2013), it can be noticed that the effect of PVA was depend on several variables such as type of cement, chemical components in sand and water.

Comparing with Allahverdi *et al*. (2010) and Contrafatto (2013), 3% of P/C ratio were investigated in this research (0.01, 0.015 and 0.02%) to choice the optimum one by estimating the compressive strength with constant W/C ratio of 50%.

Many researches deal with voided slabs of different conditions. Bhade and Barelikar (2016) discussed the effect of voids arrangements on the behavior of slabs under point load. The voids were arranged with three different patterns as shown in Fig. 1. The alternative arrangement of the voids increased the load carrying capacity of the slab than the conventional arrangement of voids but less than continuous voids deck slab. Ibrahim *et al*. (2013) presented the effect of diameter of void to thickness of slab with 3% of 0.51, 0.64 and 0.80. The two way slabs were tested under five-points load with simply supported edges. The percents 0.51 and 0.64 have the same load capacity as compared with solid slab but the 0.80% decreased the load capacity about

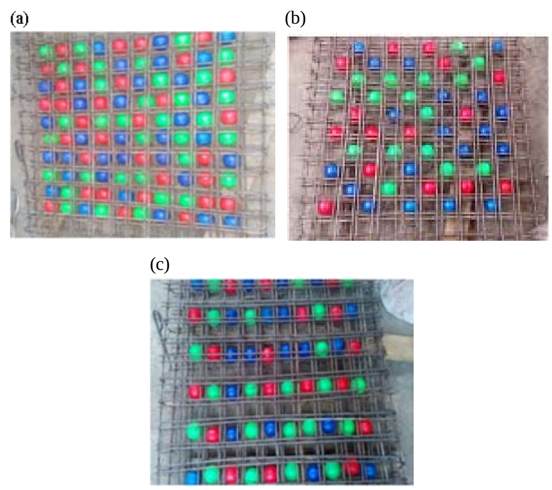

Fig. 1: Experimental variables of Bhade and Barelikar (2016): a) Continuous bubble deck slab; b) Alternative bubble deck slab (type 1) and c) Alternative bubble deck slab (type 2)

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10%. Marais *et al*. (2010) studied experimentally and theoretically the shear behavior of spherical void formers in concrete slabs. The condition of one way slabs was investigated under point load. The suggestion of obtained from experimental and theoretical date was the shear resistance of the voided areas can be taken as 85% of that of a solid slab with the same thickness. Nowadays using bubble slab was wide speared and the partitions were constructed along this slabs, so that, the special loading technique was developed to simulate this loading condition as distributed load along the slab.

MATERIALS AND METHODS

Experimental program: Six simply supported RC slabs were set and tested under two lines of distributed load as shown in Fig. 2. Three samples were solid and the others were voided. The information of each slab were listed in Table 1. The study comprehended load capacity and midspan deflection of slabs.

Slabs information: The slabs were 87×87×6 cm dimensions with bottom reinforcement only ϕ6 mm @ 60 mm in both directions as shown in Fig. 3a. The bubbles were spherical plastic balls of 40 mm radius that resulted the void to thickness of slab ratio about 0.67 and 60 mm spacing c/c. The balls were fixed to the glass base of the mold with plastic piece of 1 cm height and arranged at 52×52 cm at middle of slab to keep away from critical position of shear as shown in Fig. 3b. Additional 85×85 cm fiber wire mesh was applied on the upper face of slabs to prevent shrinkage cracks.

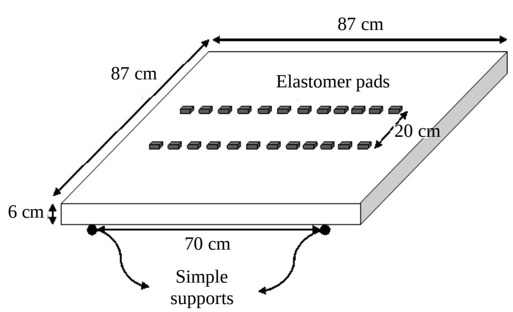

Fig. 2: Geometric details of tested slabs

Table 1: Slabs appellation

Slab specifics	Slab denotation
Voided slabs	
Normal concrete	B
Concrete improved with PVA of 15 mm thickness	B15
Concrete improved with PVA of 30 mm thickness	B30
Solid slabs	
Normal concrete	C
Concrete improved with PVA of 15 mm thickness	H15
Concrete improved with PVA of 30 mm thickness	H30

Reinforcement and concrete: Only ϕ6 mm diameter steel bar used. Average yield stress was obtained from testing three specimens about 520 MPa. In order to determine the optimum P/C ratio which resulted high compressive strength and good workability three of P/C ratios 0.1, 0.15 and 0.2 were examined. Others components of concrete mix were constant as shown in Table 2. The tests indicated that optimum P/C ratio was 0.15 and the compressive strengths of concrete were 31 Mpa for normal concrete and 46 MPa for concrete modified with PVA.

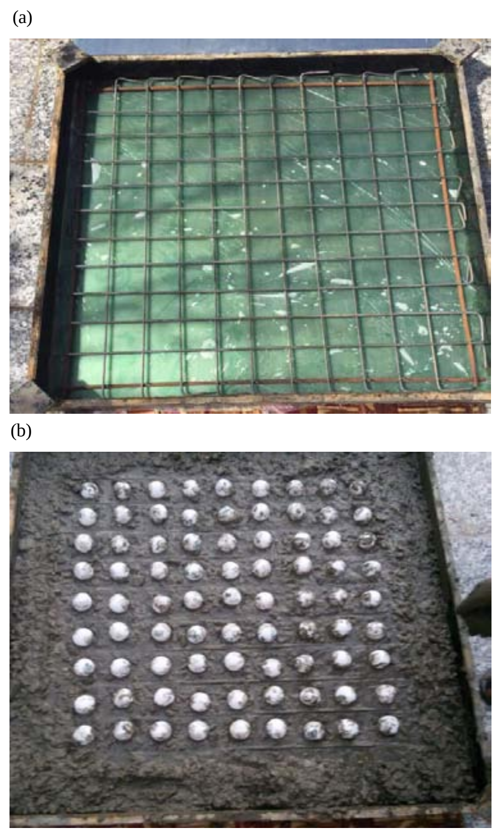

Fig. 3: Steel reinforcement and ball distributions: a) Mold and steel reinforcement and b) Balls distribution

Table 2: Amount of concrete components

Materials	Amount	PVA/cement ratio	Compressive strength (MPa)
Water/cement ratio	0.53	0.00	32
Water (kg/m^3)	242.00	0.10	41
Cement (kg/m^3)	456.00	0.15	45
Fine aggregate (kg/m^3)	675.00	0.20	46
Coarse aggregate (kg/m^3)	1090.00		

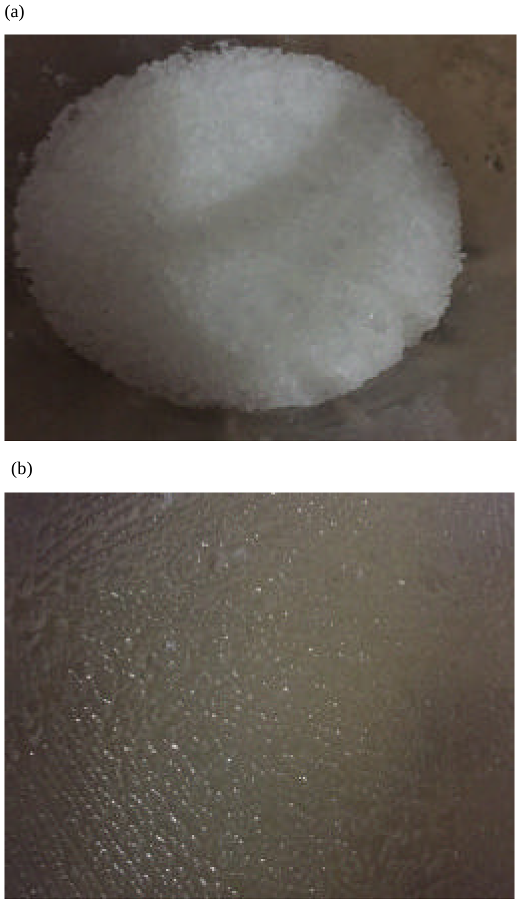

Fig. 4: a) Polyvinyl alcohol PVA as powder and b) Soluble in water

Polyvinyl alcohol PVA: PVA is a granular powder white or cream color. It is soluble in water to constitute a liquid gel as shown in Fig. 4 and 5. For slabs with PVA concrete layer (H15, H30, B15 and B30), the dry curing was used (slabs were covered with rag only for 3 days) while the others two slabs curing with water for 28 days).

Loading technique: The load was applied in to lines of 20 cm spacing between them. Each line constitute from 12 load points. Each point was (20×20×8 mm) elastomer pads. Every two elastomer pads were fixed to small steel plate (80×80×8 mm). An axial spring connected the small steel plate with another large steel plate (350×350×20 mm) as shown in Fig. 5a. Two large steel plates were used in test placed along the slab perpendicular to the supports. Each large steel plate connected to 6 axial springs of the same axial stiffness (3 in each side) as shown in Fig. 5b. The main advantage of these springs was to keep contact between slab and large steel plate at all the time of test, especially, when the deflection was increased. Above each large steel plate two steel shaft of 30 mm diameter and 300 mm long were welded at 150 mm spacing as shown in Fig. 5c. The overall loading system is shown in Fig. 6. The two point loads of testing machine applied on the middle of the two steel shafts. Meanwhile the testing, it can be noticed that the axial springs maintained the same compression as shown in Fig. 7.

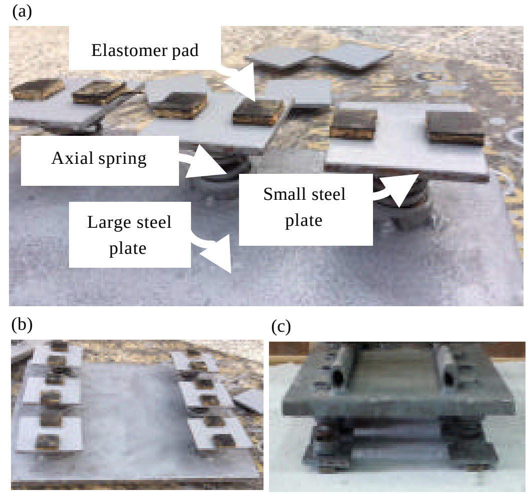

Fig. 5: Load system accessories: a) Connection parts between slab and large steel plate; b) Load points for large steel and c) Two steel shaft on large steel plate

Fig. 6: Overall loading system

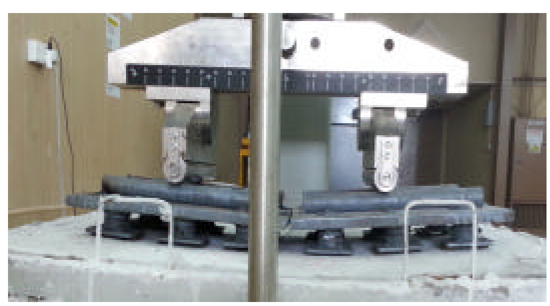

Fig. 7: Loading system during test

RESULTS AND DISCUSSION

The deflection at midspan was recorded using one dial gage at the middle as shown in Fig. 8 and 9 showed all tested slabs after testing. The test results of slabs were investigated regarding ultimate load and deflection corresponding to it as listed in Table 3 and Fig. 10-18. Adding PVA to concrete improved behavior of slabs as shown in Fig. 10-18.

Fig. 8: Tested specimen

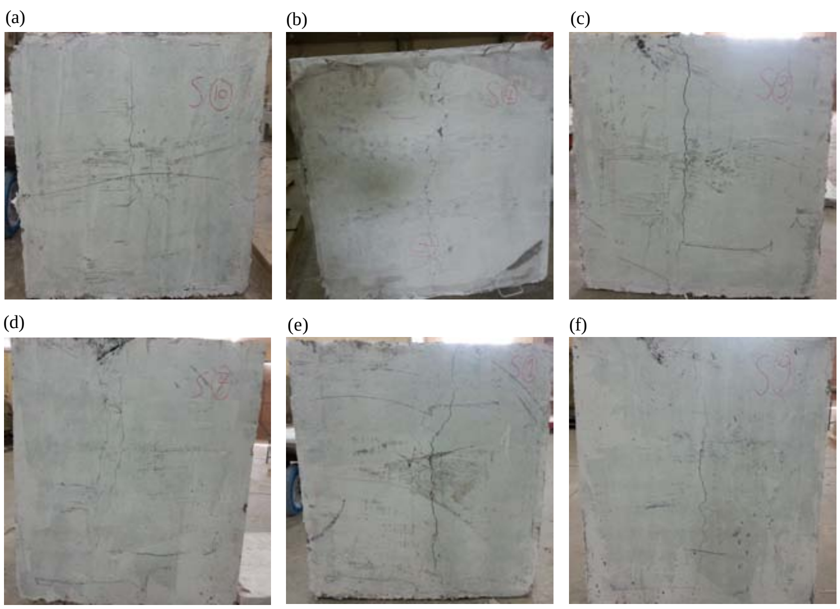

Fig. 9: Tested RC slabs: a) C; b) B: c) H15: d) B15; e) H30 and f) B30

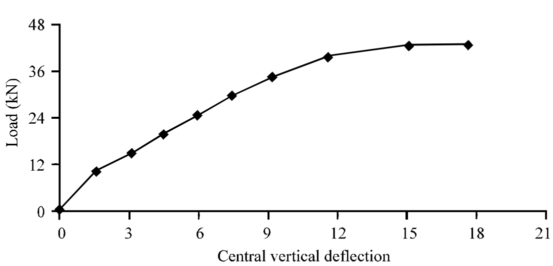

Fig. 10: Load vs. central vertical deflection of slab C

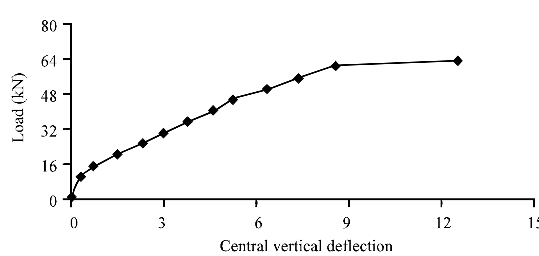

Fig. 11: Load vs. central vertical deflection of slab H15

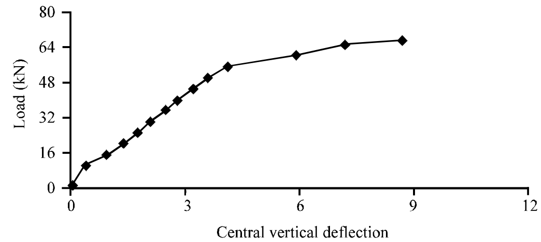

Fig. 12: Load vs. central vertical deflection of slab H30

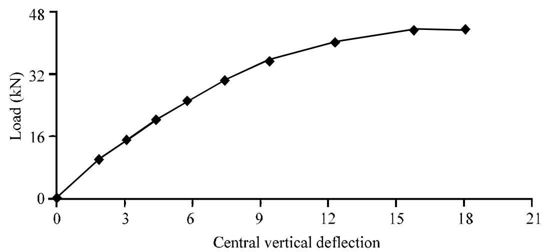

Fig. 13: Load vs. central vertical deflection of slab B

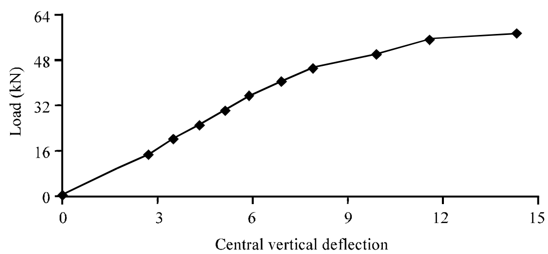

Fig. 14: Load vs. central vertical deflection of slab B15

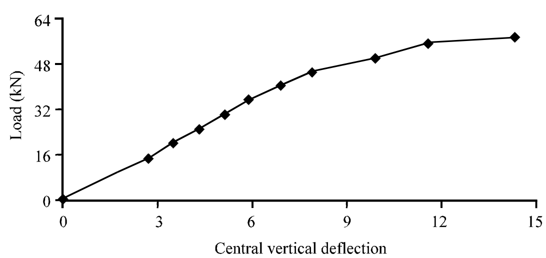

Fig. 15: Load vs. central vertical deflection of slab B30

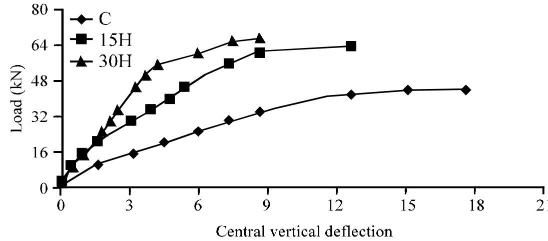

Fig. 16: Load vs. central vertical deflection of solid slabs C, H15 and H30

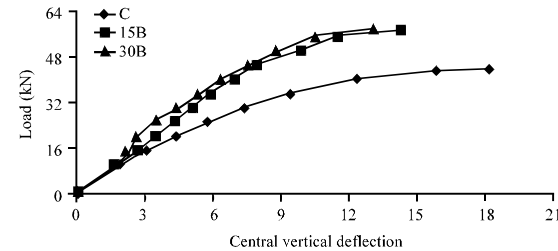

Fig. 17: Load vs. central vertical deflection of voided slabs B, B15 and B30

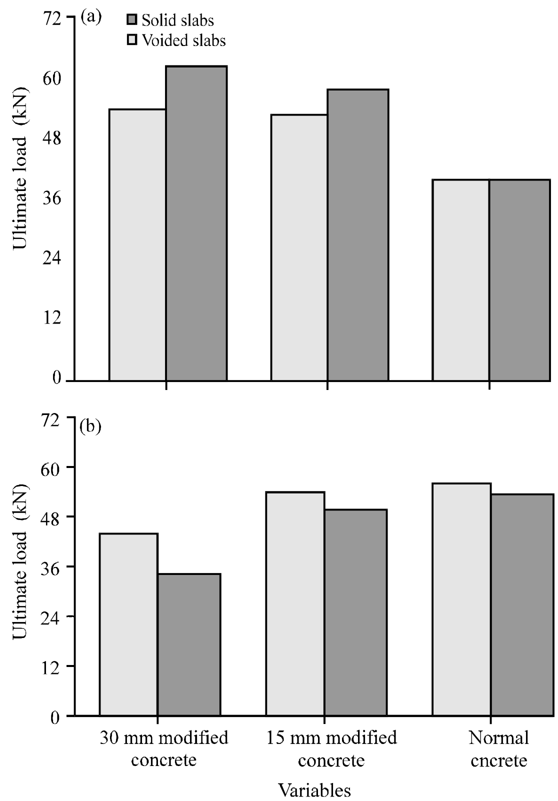

Fig. 18: Effect of PVA concrete layer on ultimate load and its deflection

Table 3: Synopsis of test results

Sample code	Ultimate load (kN)	Deflection at maximum load (mm)
C	43.0	17.50
H_{15}	63.4	12.50
H_{30}	66.9	8.70
B	43.0	18.00
B_{15}	57.9	14.25
B_{30}	58.3	13.00

CONCLUSION

The important points were noticed from tested slabs are PVA concrete layer of solid slabs increased the ultimate load with respect to Control slab (C) about 47.4 and 55.6% while maximum deflection decreased 28.6 and 50.3% for slabs H15 and H30, respectively. PVA concrete layer of voided slabs increased the ultimate load with respect to Control slab (C) bout 34.7 and 35.6% while maximum deflection decreased 18.6 and 25.7% for slabs B15 and B30, respectively. At 0.67 void to thickness of slab ratio, the load capacity did not affected but the maximum deflection was inferior increased about 2.9%. The effect of PVA concrete layer was obviously in the behavior of solid slabs as compared with voided slabs in both load capacity and maximum deflection. Comparison between the 2% of PVA concrete layer to thickness of slab (0.5 and 0.25) indicates that the increase when in ultimate load (with respect to 0.25%) about 5.5% for solid slabs and 1.7% for voided slabs. It can say that 0.25% of PVA concrete layer to thickness of slab is the optimum percent when the cost of PVA was considered.

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