EXPERIMENTAL STUDY ON BUBBLE DECK SLAB

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Abstract – *Bubble deck, which is another name for slabs whose core is embedded with spherical balls that can be of various shapes and sizes is a technology that is currently gaining awareness around the world as a result of its tremendous positive effects on an entire structure; this include its light weight, economy and flexibility in terms of slab span. This research work focused on the use of bubble deck in construction. M30 Grade of concrete was used. Three slabs were casted, two with spherical bubbles and the other without bubbles. The slab without bubbles (conventional slab) was casted with (183.35 kg) of concrete. In The slabs with bubbles, one has spherical balls of size 90 mm in which (164 kg) of concrete was used and the other has spherical balls of size 120mm in which (151.54 kg) of concrete was used and B/H ratios of 0.60 & 0.80 having 35 and 16 spherical balls respectively. Experimental tests results indicate that the conventional slab carried a load of 424.95KN and cause 12.1 mm deflection with crack occurring after a load of 164KN. The bubble deck slab with B/H ratio 0.60, carried load of 350 KN and cause 12.64 mm deflection with crack occurring after a load of 168 KN. The last Bubble Deck slab with B/H ratio 0.80, carried a load of 398.2KN and causes 13.3mm deflection with crack occurring after a load of 300KN. A total of 10.55% of concrete was saved in the first Bubble Deck slab and 17% of concrete saved in the second one. This means that the bubble deck slabs have less load carrying capacity compared to the conventional slab*.

Key Words: **Bubble deck, Slabs, Conventional, concrete.**

1. INTRODUCTION

In any Engineering structure, slabs constitute the most important part, used for berthing purpose and also used to transmit the loading to other structural members. In general, slabs are classified as being one-way or two-way. Slabs that primarily deflect in one direction are referred to as one-way slabs. When slabs are supported by columns arranged generally in rows so that the slabs can deflect in two directions they are usually referred to as two-way slabs. This study is performed on bubble deck slabs, invented by Jorgen Bruenig in 1990's (who developed the first biaxial hollow slab in Denmark), the slab is constructed using void formers which merely create voids commonly referred to as bubbles and the slab, as bubble deck (also known as voided slab). Bubble deck system is a new construction technology using recycled spherical balls in slabs to reduce self-weight of the structure as part of the concrete is replaced by the bubbles. The use of spherical balls to fill the voids in the middle of a flat slab eliminates 35% of a slab self-weight compared to solid slab having same thickness without affecting its deflection behavior & bending strength.

2. OBJECTIVES OF PAPER

1. To determine the loadbearing capacity of bubble deck slab and compare with conventional slab with different B/H ratio.

2. To estimate the amount of concrete saved as a result of spherical balls introduction into the core of the slab.

3. LITERATURE REVIEW

M.Surendar, et al. (2016), did a numerical and experimental Study on Bubble Deck Slab with the sole aim of reducing the concrete in the center of the slab by using recycled balls. Plastic hollow spheres balls were used to replace the in-effective concrete in the center of the slab, thus decreasing the dead weight and increasing the efficiency of the floor and to enhance the performance of the bubble deck slab in moderate and severe seismic susceptibility areas. Finite element analysis (FEA) was carried out by using the FEA software ANSYS to study structural behaviour on the slab. The slab of Conventional and Bubble deck slab were subjected to uniformly distributed load. The ultimate load, stress, deformation were measured by analytically. Conventional slab carried the stress of about 30.98MPa by applying the UDL load of about 340kN and causes deflection of 12.822mm.The bubble deck slab carried the stress of about 30.8MPa by applying the udl load of about 320kN and causes deflection of 14.303mm. The bubble deck slab can withstand 80% of stress when compared with conventional slab. Slight variation occurs in the deformation when compared to conventional slab. The stress and deformation results of bubble deck slabs were evaluated and compared with conventional slab, using finite element analysis. From the evaluation of these results, Bubble Deck Slab gives better performance than that of the conventional slab.

Arati Shetkar & Nagesh Hanche (2015) did an experimental study on Bubble Deck Slab System with Elliptical Balls, the behaviour of Bubble Deck slabs is influenced by the ratio of bubble diameter to slab thickness. The bubbles were made using high density polypropylene materials. Bubble diameter varies between 180mm to 450mm and the slab depth is 230mm to 600mm. The nominal diameter of the gaps are of sizes: 180, 225, 270, 315. In this experiment, the applied force is from the bottom to the top of the slab, until the cracks occur in the slabs and the failure modes were recorded. Results obtained shows tha better load bearing capacity in Bubble Deck can be achieved using the hollow elliptical balls, thereby Reducing material consumption make the construction time faster, and to reduce the overall costs. Besides that, result of the study also shows a reduction in deadweight up to 50%, which allow creating foundation sizes smaller.

Diyala Journal of Engineering Sciences Volume 6 No.2, June (2013) studied the stiffness values of BubbleDeck slabs in comparison with solid slabs. The (BD2-bu80 and BD3- bu100) plastic spheres in reinforced concrete slabs of size (B/H=0.51, 0.64 and 0.80), were subjected to a flexure test in which they results show some one-way flexural cracks and lower stiffness indicating that their flexural capacities were good enough to use. The results were compared with reference solid slabs (without plastic spheres), (100%, 100% and 90%) applying the ultimate load of a similar reference solid slab but only (76%, 75% and 70%) of the concrete volume due to plastic spheres, respectively. Results obtained gives the deflections under service load of BubbleDeck specimens to be a little higher than those of an equivalent solid slab. The concrete compressive strain of BubbleDeck specimens is greater than that of an equivalent solid specimen.

Calin S, and Asavoaie C (2010) carried out an experimental program on the effects of concrete strength on the shape and diameter of plastic balls on the overall behavior of bubbledeck. Concrete slabs with spherical balls and implied the realization of a monolithic slab element at a scale of 1:1 were used. The BubbleDeck slab sample was subjected to static loadings. The results showed deformation, cracking and failing characteristics of slabs subjected to static gravitational loadings. Results also suggest that performance can be improved by traditional spherical ball's shape by using hollow elliptical balls for better load-bearing capacity in BubbleDeck.

C Marais et.al. (2010) studied the economic value of internal spherical void formers (SVF) slabs in South Africa and compared the direct construction cost to those of two other large span slab systems, namely coffer and post-tensioned slabs. They concluded that the stiffness of SVF slab areas should be reduced by approximately 10% compared to that of a solid slab with same thickness.

BubbleDeck-UK (2008) studied traditional BubbleDeck technology using spheres made of recycled industrial plastic to create air voids while providing strength through arch action. Results show a dramatic reduction of dead weight by as much as 50% allowing much longer spans and less supporting structure than traditional solutions. Therefore, the BubbleDeck has many advantages as compare to traditional concrete slab, such as: lower total cost, reduced material use, enhanced structural efficiency, decreased construction time, and is a green technology. It gains much of attention from engineers and researchers from the world.

Guðmundur B, (2003) studied the BubbleDeck based upon the patented integration technique. The direct way of linking air and steel The BubbleDeck is a two-way hollow deck in which plastic balls serves the purpose of eliminating concrete that has no carrying effect By adapting the geometry of the ball and the mesh width, an optimized concrete construction is obtained, with simultaneous maximum utility of both moment and shear zones. Results obtained showed the basic effect of the bubbles in the weight reduction of the deck. Results also show the dead load of the BubbleDeck to be 1/3 lesser than a solid deck with the same thickness – and that without effecting the bending strength and the deflection behavior of the deck.

4. MATERIALS AND METHOD

Cement: Ordinary Portland cement as a hydrated paste is the binder of concrete. The binder, often called the cement gel, governs in large part most of the properties of the concrete. Ordinary Portland cement of grade 43 confirming to IS 8112-1989 is being used. The specific gravity of cement calculated by the use of Specific Gravity Bottle was found out to be 3.14.

Fine Aggregate. Natural River sand size 4.75mm and below confirming to zone 3 of IS 383-1970 is being used as the fine aggregate.

Coarse aggregate. Natural crushed stone with size 20mm is being used as coarse aggregate.

Plastic Hollow Spheres (Recycled Plastic Balls). The plastic hollow spheres used in this project are manufactured in Sadar bazar Delhi, India at (popli enterprises factory), from recycled plastic with diameter of (90mm and 120mm). The purpose of using recycled material is to curb consumption of finite natural resources such as oil and minimize the burden on the environment through the cyclical use of resources, therefore the recycling martial reduces inputs of new resources and limits the burden on the environment and reduces the risks to human health.

Steel Reinforcement. High grade steel of Fe 500 is generally used. The same grade of steel is used in both in top and bottom steel reinforcement. Here 8mm diameter steel bar is used for main reinforcement and distributor reinforcement. Reinforcement provided in both transverse and longitudinal direction. 4mm diameter steel was welded to keep distance B/W top and bottom reinforcement

Fig. NO. 1: steel reinforcement

Water. Potable water was being used in this investigation for both mixing and curing. The amount of water in concrete controls many fresh and hardened properties of concrete including workability, compressive strength, permeability, water tightness, durability and weathering, drying shrinkage and potential for cracking. For these reasons, limiting and controlling the amount of water in concrete in important for more constructability and service life.

5. LAYOUT OF EXPERIMENTAL TESTS

Table- 1: three slabs were tested, one without bubbles (conventional) and two with bubbles

Table 1

N 0	Specimen name	length (mm)	width (mm)	Slab thickness H (mm)	Bubble diameter B (mm)	B/H	No. of plastic spheres	Fc (Mpa)	Fy (Mpa)
1	Conventional slab				-	-	-		
2	BD1	700	700	150	90	0.60	35	33.6	500
3	BD2				120	0.80	16		

BD1. Bubble Deck 1
BD2. Bubble Deck 2

6. STIFFNESS MODIFICATION FACTOR AND WEIGHT REDUCTION. (Dr. K. B. Parikh (2014).

The second moment of inertia is a key variable when performing structural analysis of slab. The un-racked moment of inertia is dependent on the thickness and width of the flat plate slab and the contribution made by steel can be ignored since steel is not taking part prior to cracking. In addition, the values in Cobiax Technology Handbook are taken by calculating second moment of inertia in State-1 (uncracked) and in State-2 (cracked). The results have revealed that the stiffness reduction factor in state-1 is the determining factor. The stiffness reduction factor can be derived from the calculation of second moment of inertia of voided slab and solid slab. With the help of this reduction factor and taking into account the reduced self-weight of voided slab deflection of voided slab can be calculated.

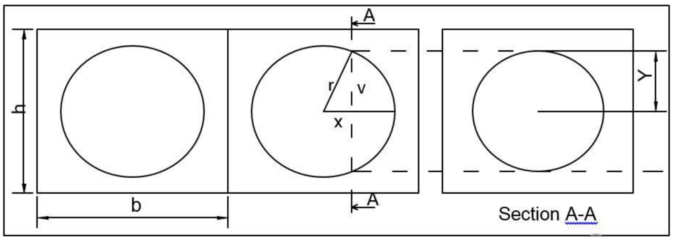

Fig. No. 2: voided slab stiffness calculation method

To find out stiffness reduction factor first find out second moment of inertia of conventional slab without void former. And this can be calculated with:

$$I_c = bh^3/12$$

Where,
b = Width of conventional section surrounding a single sphere.
h = Total thickness of the slab
Second moment of inertia of circle can find out with following equation by considering average void area with radius r.

$$I_v = \pi r^4/4$$

stiffness reduction factor is given by $(I_s - I_v)/I_s$ In this study for moment of inertia and weight saving, slab thickness taken 150mm with respective ball diameter from 90 mm to 120 mm. detail dimensions and value of stiffness reduction factor are shown in table 3.

Weight reduction is calculated using $\frac{(W_s - W_v)}{W_s} x100$

Where,
W_s = total weight of conventional slab
W_v = total weight of voided slab

Table- 2: Stiffness modification factor and weight reduction

Table 2 Stiffness modification factor and weight reduction					
Slab thickness (h)mm	Ball diameter (d)mm	Moment of inertia of solid section Is	Moment of inertia of voided section Iv	Stiffness reduction	% weight saving
150	90	2.98×10^7	3.2×10^6	0.891	10.55
	120	4.5×10^7	1.07×10^7	0.773	17.43

Experimental test

Fig. No. 3: BD1

Fig. No. 4: BD2 and Conventional

The conventional slab carried a load of 429.2 KN and cause 12.26 mm deflection with crack occurring after a load of 164 KN.as shown in fig. 5. Bubble deck slab with B/H ratio of 0.6 carried a total load of 350.78 KN and caused 12.6mm deflection; with crack occurring after a load of 158KN, the other bubble deck slab with B/H ratio of 0.8 carried a total load of 398.2 KN and causes 13.2mm deflection; with crack occurring after a load of 123 KN.

Fig.NO. 5: conventional slab placed on UT

Fig. No. 6: conventional slab on UTM after testing

Fig. No. 7: BD2 on UTM

Fig. No. 8: BD2 fail after testing

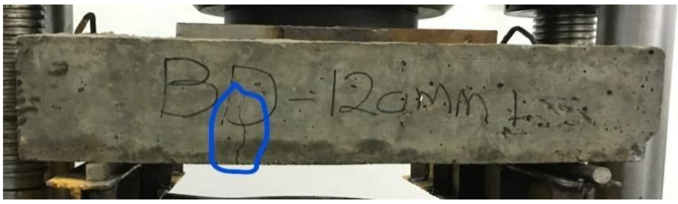

Fig. No. 9: crack occur during test

Load Vs deflection

Table- 3 Conventional slab

Load (KN)	Displacement (mm)
0	0
50	0.9
100	1.55
157	2
214.2	4
324.9	8
371.4	9.3
424.9	12.26
378.5	13.15
373.2	13.46
300	15.15

Table- 4 BD1 slab(0.6)

Load (KN)	Displacement (mm)
0	0
42.8	2.5
59.95	3.36
100	4.49
120	5.1
149.92	6.08
200	7.6
254.2	9.22
350.78	12.6
331.4	12.8
258.52	14.67

Table -5: BD2 slab(0.8)

Load (KN)	Displacement (mm)
0	0
42.8	1.3
58.92	2
100	3.6
133.92	4
192.85	6
235.7	8
317.14	10
398.2	13.3
389.28	13.7
355.35	14.6

From fig. 10 conventional slab carried more load compare to that of bubble deck slab and causes less deflection to bubble deck slab. Results shows bubble deck slab with B/H ratio 0.60 carried a load 350 KN and causes 12.65mm deflection while the other Bubble Deck slab carried load of 398.2KN and causes 13.3mm deflection. The conventional slab carried 424KN and causes 12.26mm deflection. It can be seen from the results, bubble deck slab carried less load due to its stiffness reduction because of plastic balls introduce in to the slab.

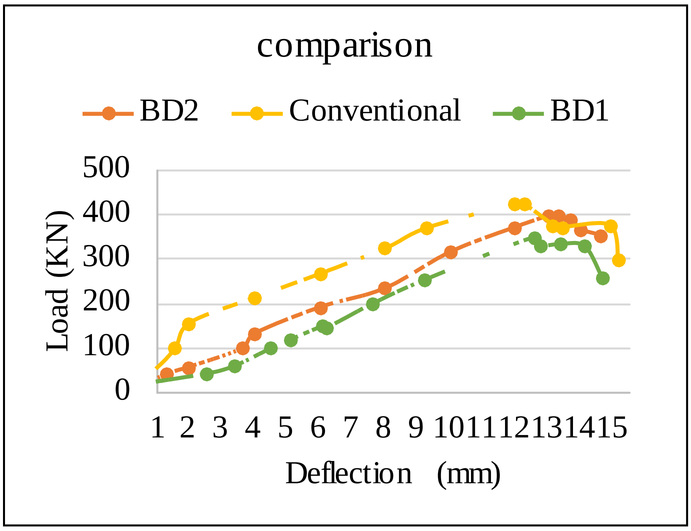

Fig.NO. 10: Load vs Deflection curves for comparison

6. CONCLUSION

From the foregoing it was evident from tests conducted that though the bubble deck slabs were not as efficient as the conventional slab, (having lesser loadbearing capacity), they are very much satisfactory in slab construction considering the negligible difference in load bearing capacity between them and the conventional. It is however interesting to note a weight reduction of 10.55% & 17% in the bubble deck slabs compared to the conventional slab which is an added advantage for the bubble deck slabs especially in structures where load is an issue.

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