An Experimental Analysis of Flexural Behaviour of the Bubble Deck Slab in Comparison with Conventional Concrete Slab

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Abstract— Reinforced concrete slabs are one of the most common components in modern building construction. Efforts are being continued from past decades to reduce the dead weight and to improve the performance of the slab. Bubble deck slab system are a new and innovative type of structural concrete slab system developed to allow for lighter self-weight of the structure while maintaining similar load carrying capacity of a solid slab. In these slabs shear and punching shear resistance of the BubbleDeck floor is significantly less than a solid deck since resistance is directly related to the depth of concrete. In this work efforts are made to understand the load deflection behaviour of bubble deck in compersion with the conventional slab system. Quantity estimation results showned that there was a considerable reduction in the weight of concrete in case of bubble deck slab. A scaled down models are tested under nine point loading system to determine the load and deflection behaviour of both the slabs. Test results have proven that the bubble deck slab system is more efficient in carrrying more load and undergo more deflection compared to conventional rcc slab system.

Key words: Bubble Deck Slab, Conventional Concrete Slab

I. Introduction

Reinforced concrete slabs are components commonly used in floors, cielings, garages, and outdoor wearing surfaces. Reinforced concrete has many advantages for floor systems – it provides resistance to high compressive stresses and to bending stresses; it is relatively cheap to produce and construct; and it can be molded into virtually any shape and size. Disadvantges include a high weight to strength ratio and difficulty in structural health monitoring. Efforts are being done done to reduce the self-weight of the structure, aim is to achieve a higher performance level than would have been the case had the two materials functioned separately. Consequently, the design must identify inherent differences in properties and ensure that the structural system properly accommodates them. As a result, some form of connection is clearly necessary. The reduction in self-weight of composite elements has an important effect in reducing the forces in those components supporting them, such as the foundations (01). Bubble deck technology, a way to link air space and steel within voided biaxial concrete slab. The Bubble Deck technology uses spheres made of recycled industrial plastics to create air voids while providing strength through arch action. As a result, this allows the hollow slab to act as normal monolithic two-way spanning concrete slab. These bubbles can decrease the dead weight up to 35% and can increase the capacity by almost 100% with the same thickness. As a result, BubbleDeck slabs can be lighter, stronger, and thinner than regular reinforced concrete slabs. Bubble Deck was proven to be superior to the traditional solid concrete slab. The reduced dead load makes long term response more economical for the building while offsetting the slightly increased deflection of the slab (02). A typical bubble deck slab is as shown in figure 1.1.

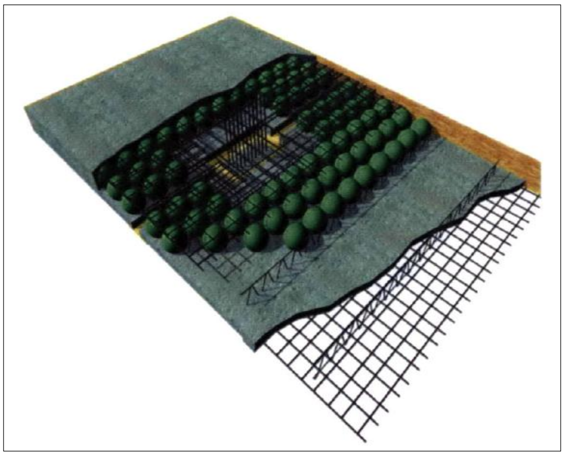

Fig. 1.1: Cut through section of Bubble Deck

II. Methodology

However, in bubble deck slab shear and punching shear resistance of the Bubble Deck floor is significantly less than a solid deck since resistance is directly related to the depth of concrete. Bubble Deck is a revolutionary biaxial concrete floor system developed in Europe. High density polyethylene hollow spheres replace the ineffective concrete in the centre of the slab, thus decreasing the dead weight and increasing the efficiency of the floor. These biaxial slabs have many advantages over a conventional solid concrete slab: lower total cost, reduced material usage, enhanced structural efficiency, decreased construction time, and is a green technology (05).

For the present study, flexural behaviours of two-way Bubble Deck slab such as ultimate load capacity and service load deflections were studied for the scaled down prototype of 1m x 1m x 0.07m was casted in the laboratory to simulate a 9m x 9m x 0.45m slab. 35mm diameter plastic balls were placed to remove and/or replace the concrete from the centre of the slab and create voids. Minimum reinforcement of 0.15 percent of the total cross sectional area is provided in the either direction in slabs and on the tension and compression face of the slab using chicken mesh as shown in fig 2.1. The slabs as simply supported on four sides were tested on the loading frame. Details of the Model is as shown in table 2.1 below:

SN	Description	Dimension (mm)
1	S: Spacing between balls, also edge distance of ball	10
2	Ø: Diameter of ball	35

3	X: Centre to Centre spacing of balls	45
4	Total slab depth	70

Table 2.1: List of parameters used in current study of bubble deck slab

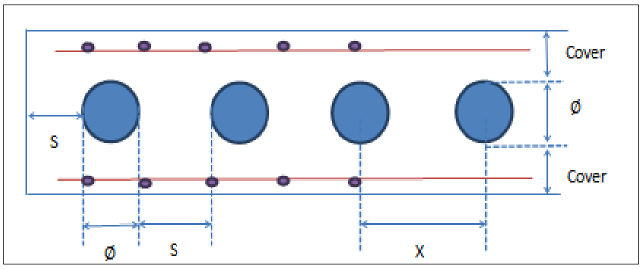

Fig. 2.1: Typical cross section of bubble deck slab used in current study

III. PARAMETRIC STUDIES

The experimental studies are carried out to understand the flexural behaviour of two-way Bubble Deck slab. To simulate 9m x 9m x 0.45m slab, the slab dimensions of 1m x 1m x 0.07m slab with the scaling factor of 1:8.05 is casted in the laboratory. Flexural tests are carried between conventional slab and bubble deck slab with the minimum reinforcement of 0.15% of total cross-sectional area for a period of 28 days. The test results are compared with conventional solid concrete slab of same dimension. Size of the specimen: 1000mm x 1000mm (925mm effective span) and 70mm (depth) which is simply supported on all four edges of the slab. Grade of concrete used is M25, diameter of the plastic balls used in 35mm and curing of the specimen was done up to 28days. To determine the load deflection behaviour, Nine-point load was applied at the centre of the slab. The concentrated load from the hydraulic jack is distributed over the nine-steel balls placed over an area of 320mm x 320mm as shown in figure 3.1.

In this study efforts are done to know the difference in load deflection behaviour of conventional slab with bubble deck slab system. It was found that, with the introduction of bubbles (balls) at a spacing of 10mm face to face the balls; there was a reduction in 14.4% by volume of concrete used with respect to the conventional concrete slab. Reinforcement in provided using a chicken mesh of diameter 2mm Top and bottom reinforcement is made up chicken mesh of diameter 2mm @ 30mm c/c and an middle layer reinforcement with bars of diameter 2mm @ 150mm c/c placed in-between the balls for all Bubble Deck slabs with 10mm spacing of the balls, as shown in figure 3.2 and table 3.1 shows reduction in the volume of concrete between conventional and bubble deck slab and number of balls used.

Fig. 3.1: Arrangement of Nine-point Load at the centre of the slab

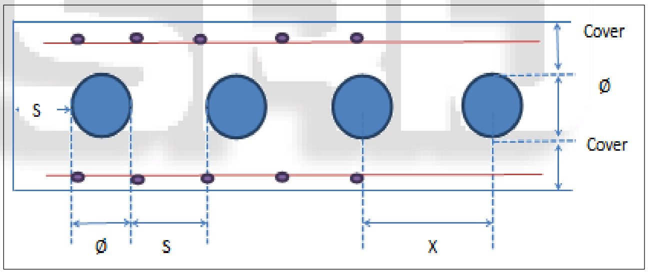

Fig. 3.2: Typical cross section of slab with top and bottom reinforcement

Sl No.	Slab designation	Description of Slab	% Volume reduction	No. Of plastic balls	Reinforcement		
					Top	Middle	Bottom
1	S	Solid Slab	0	0	2mm @ 30mm c/c	-	2mm @ 30mm c/c
2	S_{10}	Bubble Deck slab with 10mm spacing of plastic balls	14.14	441	2mm @ 30mm c/c	-	2mm @ 30mm c/c

Table 3.1: Details of the specimen

IV. MATERIAL TEST RESULTS:

A. Cement:

In the present work, ordinary Portland cement of 43 grade Coromandel King conforming to IS 8112:1989 has been used.

The physical properties of cement obtained on conducting appropriate test and the requirements as per IS 4031:1968 are given in table 4.1 below.

Sl No.	Material Properties	Cement	
		Obtained Values	Requirement as per IS 8112: 1989
Coromandel King 43 grade			
1	Fineness	2.56%	Not more than 10%
2	Initial Setting time	65 minutes	Not less than 30 minutes
	Final Setting time	425 minutes	Not more than 600 minutes

3	Compressive strength	43.5 N/mm^2	Not less than 43 N/mm^2
4	Standard Consistency	31%	
5	Specific gravity	3.04	

Table 4.1: Physical properties of Cement

B. *Fine aggregate:*

Locally available clean river sand is used. The physical properties of natural sand are carried out and the test results of tests are tabulated in table 4.2

Sl No.	Particulars of the test	Results
1	Fineness Modulus	3.06
2	Specific Gravity	2.64
3	Water absorption	1.0%
4	Zone	II

Table 4.2: Physical properties of fine aggregate.

C. *Course aggregate:*

Course aggregate used is crushed granite of 10mm maximum size and retained on IS480 sieves have been used. Results of tests conducted on coarse aggregate are tabulated in table 4.3.

Sl No	Particulars of the test	Results
1	Fineness Modulus	6.88
2	Specific Gravity	2.6

Table 4.3: Physical properties of course aggregate

D. *Compressive Strength*

The test results of compressive strength of M25 grade concrete for different curing periods of 7 and 28 days are tabulated in table (). The compressive strength of concrete, of standard cube size 150mm is calculated using formula.

$$f = P/A \quad N/mm^2$$

Where,

f = compressive strength of concrete in, N/mm^2

P = ultimate load resisted by concrete in, N

A = cross sectional area of cube specimens in, mm^2

Concrete Grade	Mix proportion				Compressive Strength (N/mm^2) (Curing period in days)	
	Cement	Fine Aggregate	Coarse Aggregate	Water	7	28
M25	1	2.05	1.72	0.5	16.3	25.1

Table 4.4: Compressive strength of concrete

From the table(), it is observed that the compressive strength of concrete cubes after 7 days curing period is 16.3 N/mm2 which is approximately 65% of 25N/mm2, the strength of concrete at 28 days for M25 grade.

V. CASTING OF SLABS:

A. *Casting of Conventional Slab:*

Concrete was poured into the mould in two layers. After placing the bottom reinforcement cage over the wodden cover blocks the first layer of concrete is poured into the mould. To remove the air voids, concrete is compacted using a custom made tamping road attached to a plate of 10cm x 10cm. After compaction, the concrete is poured till the level where the top reinforcement is to be placed; top reinforcement cage is placed and the remaining concrete is poured over the top reinforcement cage till the depth of the slab reaches 70mm. After each pour of concrete the slab were subjected to compaction using a custom made tamping rod. Figure 5.1 shows casting of conventional concrete-slab.

Fig. 5.1: Casting of conventional slab

B. *Casting of bubble deck slabs:*

Concrete was poured into the moulds in two layers. First layer of concreting is done upto the level where the plastic balls needs to be placed. After achieving this level, the layer of concrete is compacted using a custom made tamping rod attached to a plate of 10cm x 10cm. After compaction the plastic balls were placed with face to face spacing between the balls at 10mm to achieve the desired reduction in volume of the slab. Later on top reinforcement cage is placed over the balls, so as to make sure that plastic balls do not move while pouring the next layer of concrete and also to make sure that plastic balls do not float during the concreting. Once the reinforcement cage is in place, the next layer of concrete is poured till the depth of slab reaches 70mm and it is subjected to a compaction using custom made tamping rod. The top surface of the slab was finished using trowel. Figure 5.1 shows casting of bubble deck slab.

Fig. 5.2: Arrangements of plastic balls and casting of bubble deck slab

VI. RESULTS AND DISCUSSION:

A. Sound test:

The hand held sound measuring device was placed just below the slab to record the impact noise created when a 1kg weight is dropped from 1 feet height. Maximum hold option was used to record the reading. Maximum hold option gives us the impact noise only; it does not give any noise dissipated due to the surroundings.

Sl No.	Specimen	Slab Designation	Trial 1 (db)	Trial 2 (db)	Trail 3 (db)	Average Sound (db)
1	Solid slab	S	106.8	106.6	112.6	108.7
2	10mm spacing slab	S_{10}	106.9	107.1	110.2	108.1

Table: 5.1 Impact noises of solid slab and bubble deck slab

It is observed that the impact noise created varies from 106 decibels to 112 decibels. From the average values for each slab it is noted that the slab S10 has recorded the low value of 108.1 decibels and the solid slab S has recorded the highest value of 108.7 decibels.

B. Reduction in volume and weight:

It is observed that the solid slab (S) with 70mm thickness consisted of 0.07 m3 of volume and weighed about 172 kg. Whereas the Bubble Deck slab of thickness 70mm consisting of 35mm diameter plastic balls spaced at 10 mm there is a reduction in volume by 14.29% when compared to solid slab. Table 5.2 shows the complete details of reduction in volume and weight of concrete in bubble deck slab.

Sl No.	Specimen	Slab Designation	Volume (m3)	% Reduction in volume	Weight (kg)	% Reduction in weight
1	Solid slab	S	0.07	0.00	172	0.00
2	10mm spacing slab	S_{10}	0.06	14.29	148	13.95

Table 5.3: Reduction in volume % and weight %

C. Load and Deflection at Ultimate load:

It is observed that ultimate load of solid slab (S) is 4.44kN, whereas the bubble deck slabs is 4.93kN, above results shown that bubble deck slab can take loads 11% more load when compared with a solid slab. The maximum deflection of solid slab (S) is 11.64mm, where as in case of bubble deck slab is 16.83 mm. It is observed that bubble deck slabs have shown 44% more deflection in comparison with solid slab as shown in bale 5.3 below.

Sl No.	Specimen	Slab Designation	Ultimate load (kN)	Deflection (mm) @ ultimate load
1	Solid slab	S	4.44	11.64
2	10mm spacing slab	S_{10}	4.93	16.83

Table: 5.3 Ultimate load carrying capacity and corresponding deflection

D. Load versus deflection:

The figure 5.1 shows the plot of load versus deflection of all the slabs. The table 5.4 presents the values of load and its corresponding deflection of all slabs. From the graph, it is observed that the maximum deflection of solid slab (S) is 11.640mm and an ultimate load of solid slab (S) is 4.44kN. Whereas the deflection and ultimate load values are considerably higher for Bubble Deck slabs. Maximum deflection of Bubble Deck slab S10 is 16.825mm for an ultimate load of 4.93kN. It is observed from the figure below, that the solid slab has shown sudden rise in deflection with increase in applied load, whereas the bubble deck slabs have shown gradual increase in deflection with increase in applied load. In comparison with solid slab, the bubble deck slabs behaviour of gradual increase in deflection is advantageous as we can observe the sufficient warning before the structure collapse and also slabs being capable of taking more loads before collapse in comparison with solid slab

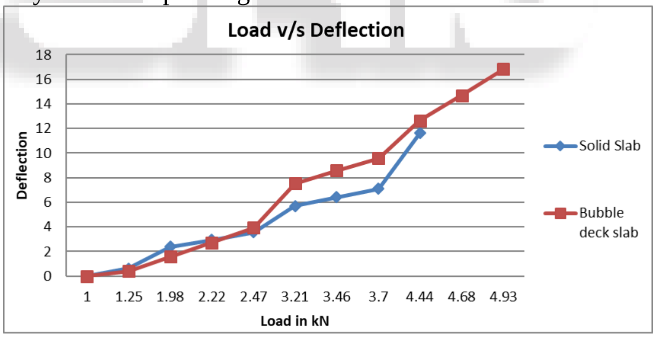

Fig. 5.1: Load deflection curve of solid and bubble deck slab.

	Deflection in mm	
Load in kN	Solid slab	Bubble deck slab
1	0.000	0.000
1.25	0.625	0.402
1.98	2.378	1.575
2.22	2.955	2.739
2.47	3.555	3.951
3.21	5.694	7.540
3.46	6.416	8.581
3.7	7.110	9.580
4.44	11.640	12.660
4.68		14.700
4.93		16.825

Table 5.4: Shows load deflection values under nine point loading conditions

VII. CONCLUSION:

1) The structural behaviour of the Bubble Deck slab is considerably good in comparison to the Solid Slab
2) Bubble deck slabs have shown reduction in volume and weight when compared with solid slab resulting in reduction in dead load of the slabs by 11%.
3) Reduction in dead load can be advantageous in larger spans without beams, larger open floor areas, and lower floor to floor heights.
4) During an earthquake event the accelerated mass of the building creates seismic forces that have to be absorbed by the vertical elements of the structure.
5) The reduced dead weight results in lower force demands on the structure, with associated savings in detailing and constructability requirements, resource efficiency and benefits of direct and indirect cost savings due to reduced volume, lower transportation.
6) Bubble deck slabs have shown reduced noise levels in comparison with solid slab.
7) The ultimate load of Bubble deck slabs have shown that it can take loads 11% more when compared to solid slab. Bubble deck slabs have shown the maximum deflection of 44% more than maximum deflection of solid slab. This indicates that insertion of plastic balls in the centre of the slab has increased the slab capacity in comparison with solid slab.

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