IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified ⁜ Impact Factor 7.105 ⁜ Vol. 9, Issue 8, August 2022
DOI: 10.17148/IARJSET.2022.9814

THE STUDY OF BUBBLE DECK SLAB USING HIGH DENSITY POLYETHYLENE BALLS - A REVIEW

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Abstract: Construction field requires new technique in order to enhance the construction procedure. As the traditional method of building construction require huge consumption of materials and the time as well. Thus, it becomes necessary to search new approach in construction. Slab is one of the important elements of the building consuming large amount of concrete. The load transmitted on the slab is more and the clear span between the columns is large which results in usage of massive amount of concrete and steel. Due to this, the dead weight and the cost of construction increases so to minimize the above issues, Bubble deck technology can be used. Bubble deck slab is a biaxial hollow core slab. In this method concrete in the mid span of the slab is replaced by high density polyethylene balls (HDPE). HDPE balls are recycled materials derived from gasoline products under controlled temperature and prove to be eco-friendly. The diameter of the ball depends upon the depth of the slab. The ratio of bubble diameter to the depth of the slab plays a vital role. The concrete placed in the central portion of the slab acts as a filler material and it does not carry structural load. In this thesis the theoretical, analytical and experimental study has been done. Flexural test is carried out on the slab in order to check the strength. 24 specimens of slabs are casted, 12 specimens of conventional slab and 12 specimens of Bubble Deck slab. The grade of concrete used in casting the slab is M25. The approach includes making of moulds, forming the reinforcement mesh, placing the HDPE balls between the mesh, concreting, curing and testing. The test is performed on UTM and the results are analyzed. From the results it is obtained that the volume of concrete is reduced by 28.8% in bubble deck slab as compared to conventional slab and Bubble deck slab is lighter by 25% as compared to conventional slab also. The load bearing capacity of bubble deck slab is also increased by 11.68%.

Keywords: Bubble Deck slab, HDPE, conventional slab, flexure, comparison.

I. INTRODUCTION

This study is performed on bubble deck slabs, invented by Jorgen Bruenig in 1990's who developed the first bi-axial hollow slab in Denmark, the slab is constructed using void former's which merely create voids commonly referred to as bubbles and the slab, as bubble deck also known as voided slab. The use of spherical balls to fill the voids in the middle of a flat slab reduces 35% of a slab self-weight compared to solid slab having same thickness without affecting its deflection behaviour & bending strength. The behaviour of Bubble Deck slabs is influenced by the ratio of bubble diameter to slab thickness. These bubble deck slabs have many advantages over a conventional slab. The total cost is lower, material is reduced, structural efficiency is enhanced, and construction time is decreased and is a green technology. The slabs are designed as biaxial flat slabs. The spheres are not placed at the edges of the slab where the shear forces acting are more. About one third of the thickness is reduced when spheres are introduced and thus provides more head room and thushelps in construction of many stories. The structure constructed thus has overall less self-weight and thus the seismic performance of the structure is also increased. The spheres also act in better acoustic performance of the structure. Bubble Deck slab is a unique method in which concrete is eliminated in the middle part of the slab which does not contribute to the structural self-weight and also leads up to 50 % lighter slab which reduces the loads on the columns, walls and foundation, and of course of the entire building. According to the Bubble Deck, 100 kg of concrete is replaced by 1 kg of recycled plastic. The reductionin dead load makes the long-term response more economical for the building. Since resistance is directly related to the depth of concrete, the shear and punching shear resistance of the bubble deck floor is significantly less than a solid deck. This weight reduction creates many benefits that should be considered by engineers determining the structural system of the building. Plastic voided slabs remove concrete from non- critical areas and replace the removed concrete with hollow plastic void formers whileachieving similar load capacity as solid slabs. Voided slab principles have beenapplied in different applications dating back to the

DOI: 10.17148/IARJSET.2022.9814

early 1900s.Similarly the reduction of concrete in bridge deck modal (light weight Pedestrian Bridge). In this thesis work our main focus on the reduction of concrete.

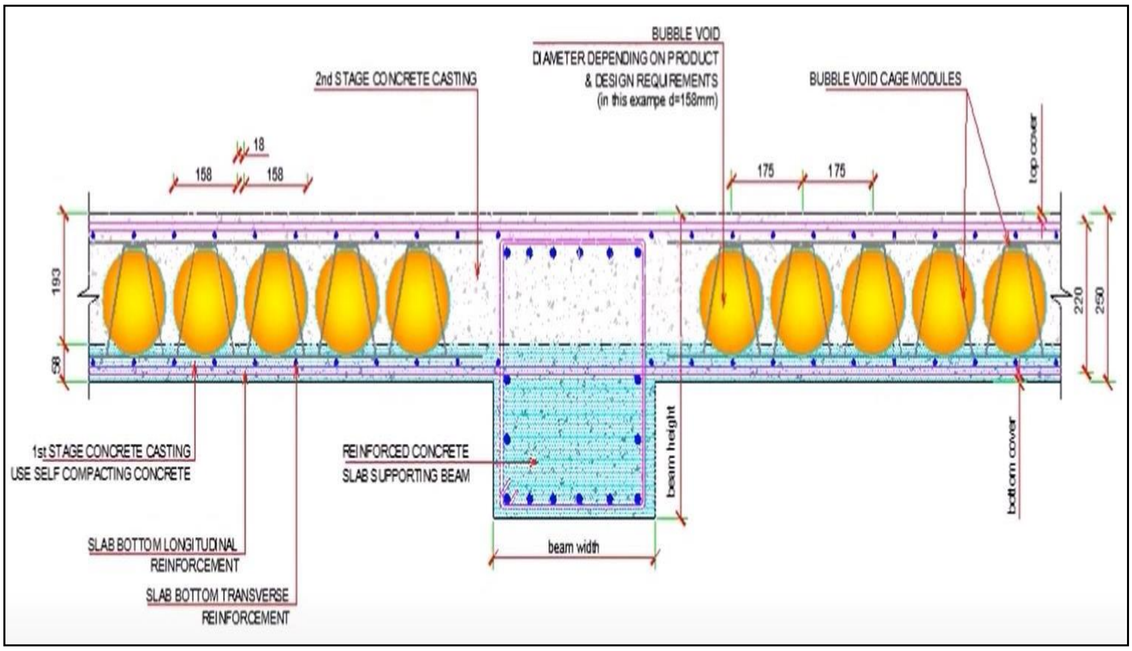

Figure 1: - Cross Section of Bubble Deck Slab

II. LITERATURE REVIEW

Pfeffer et.al [1] investigated the influence of the cavities on the punching behavior. In addition to these tests nonlinear computations using the Finite Element Method were performed. The computations allowed parametric studies to get a better understanding of the structural behavior without doing further expensive tests. Finally, necessary modifications of existing design recommendations according to the German design code DIN 1045 were developed. To investigate the punching shear capacity of the biaxial hollow slabs, three specimens with a thickness of 24 cm and three specimens with a thickness of 45 cm were produced and tested. The slabs were produced withB25 concrete of nominal compressive strength 25 N/mm^2 and average compression strength 30 N/mm^2. The B35 concrete having nominal compressive strength 35 N/mm2 and average compression strength of 40 N/mm^2 respectively. The maximum aggregate size used was 16 mm. The mode of failure of biaxial hollow slabs was similar to the one of solid slabs. To specify the punching shear capacity proposal of a modification of available design rules has been made. The angle between the horizontal and internal crack was in between 30^o and 40^o. The value of the punching shear is smaller than the one of a solid slab.

Experimental and analytical investigations were carried by **Sagadevan et.al [2]** to study the behavior of biaxial voided slab under one-way flexure. Voided slab specimens were prepared and tested with two different shapes of voids namely sphere and cuboid, which were manufactured using recycled polypropylene. Comparison of experimental and analytical studies showed that the ultimate load-carrying capacity of voided slabs was higher or similar to that of solid slab. An analytical study was carriedout using the yield line analysis in conjunction with Indian Standards. It was foundthat the capacity of voided slab can be estimated by yield line analysis. The flexural stiffness of voided specimen was approximately 50% lesser in comparison with solid slab of identical dimensions and reinforcement at yield stage. The reduction in flexuralstiffness was mainly due to the presence of void former and the maximum void ratio ata section defines the flexural stiffness of the voided slab, the deflection was under serviceable limit for both the specimens for 75% of ultimate load. Ultimately, it was found that the behavior of voided slabs under one-way flexure can be predicted by provisions of Indian Standards with necessary correction for loss of cross-section caused by voids. The ultimate load-carrying capacity of specimens with sphere- and cuboid-shaped voids was equal to that of the solid slab. The theoretical load-carrying capacity of voided and solid slabs using the yield line theory was the same. The presence of void formers did not influence the reinforcement behavior in longitudinal and transverse directions.

Saini et.al [3] carried out experimental and analytical study has been performed to compare the flexural strength of the normal slab and voided slab. For analytical study, ANSYS 18.1 software has been used. The slab specimens were of dimension 500 x 500 x 90/100/110 mm with similar boundary condition. The diameter of voids has been taken as 55

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mm and 40 mm with a spacing of 25 mm between each void. Theaim of this paper is to discuss and compare flexure behavior of normal slab and voidedslab and reduction in weight of the slab by void formation. For slab of 500 x 500 x 90 mm, experimental result showed that the loads taken by normal slab and voided slab of 40 mm void were equal. But analytically, load carrying capacity of voided slab was 11.11% more than normal slab. For slab of 500 x 500 x 100 mm, experimental result showed that the loads taken by normal slab and voided slab of 40 mm void were equalbut, load carrying capacity of voided slab of 55 mm void decreased by 10.71%. Analytically, load carrying capacity of voided slab of 40 mm void decreased by 7.4% and voided slab of 55 mm void decreased by 25.92% as compared to normal slab. For slab of 500 x 500 x 110 mm, experimental result showed that the load carrying capacity of voided slab of 55 mm void decreased by 9.6% and load carrying capacity of voided slab of 40 mm void decreased by 6.4% as compared to normal slab. Analytically, load carrying capacity of voided slab of 40 mm void was same as normalslab; but load carrying capacity of voided slab of 55 mm void decreased by 6.6% as compared to normal slab. It was found that load carrying capacity decreased marginally when the size of void was increased. Maximum reduction in weight was observed in slab 500 x 500 x 100 having voids of 55 mm diameter.

Mahdi et.al [4] studied reinforced concrete slabs under the effect of harmonic load. Tow-way Bubble deck slab of 2500 mm × 2500mm × 200mm dimensions and uniformly distributed bubbles of 120 mm diameter and 160 mm spacing c/c was testedexperimentally under the effect of harmonic load. Numerical analysis was also performed with the ABAQUS software. After comparing the experimental and theoretical studies to ensure that the Bubble deck slab's modeling was adequate, nonlinear finite element analysis was carried out using the ABAQUS/Standard 2019 toanalyze the Bubble deck slabs adopted in the current study. The constituent materials, the element type for concrete and reinforcing steel, and the modeling of the connectionbetween the specimen parts and the support adopted in the numerical analysis are in good agreement with the experimental work. According to the considered parametric study, the bubbles distribution was highly affected upon the dynamic response of the Bubble deck slab. The volume reduction for Model 1 was 15.6 % and for Model 2 and Model 3 was 15%. Then model 2 shows the better results as the response for the natural frequency was greater by 1 to 2 % than the model 2 and model 3.

The effective hollow slab systems that dramatically reduce the slab weight by 30 - 50%. Moreover, concrete usage was reduced as 1 kg of recycled plastic replaces 100 kg of concrete.

Quraisyah et.al [5] discuss the significance and various properties of bubble deck slab against conventional reinforced concrete slab based on various studies and researches that had been done. Two slabs were casted and tested BD1 and BD2 of size 700 mm x 700 mm x 150 mm. In BD1 the HDPE balls of diameter 90 mm had been used of 0.6 b/h ratio and 35 balls were placed in BD1. In BD1 the HDPE balls of diameter 120 mm had been used of 0.8 b/h ratio and 16 balls were placed in BD2. The load and deflection give better result for bubble deck slab as compared to conventionalslab. Flexural capacity, stiffness and shear capacity of at least 70% When the same amount of concrete and the same reinforcement is used as in the solid slab, realizing 30-50% concrete economy, in comparison with the solid slab.
The concrete in the middle of solid slabs about 80% perform no structural function andis structurally ineffective.

Francis V. [6] compares the stiffness between bubble deck and traditional slab, under conditions of same strength, bending stiffness, and concrete volume. The result shows that under the same strength, bubble deck slab has 87% of the solid slab's bending stiffness, but using only 66% concrete. This implies that the resulting deflection was be higher in bubble deck slab than in solid slab.

Laxmikanth et.al [7] reviewed analytical and experimental studies on bubble deck slabs under general loading to know the structural behavior has been presented in this article. The structural behavior of the bubble deck slab has been assessed through flexural strength, shear strength, punching shear, anchoring, crack pattern, fire resistance, creep, and crack pattern. From the review of literature, it has been concluded that the bubble deck slabs are more economical and efficient with respect tostructural integrity.

N. Lakshmipriya et.al [8] covey's that by using Bubble deck method, the objectiveof this paper is to convey the recent advancements in civil construction and implementing the new technique of using high density polyethylene hollow spheresin the construction field. The quantity of concrete and cement is reduced by 30 to 50% for the same built surface compared with the classical slabs, fact that gives an important reduced quantity of carbon emitted. The result identified that 1 m^3 of concrete replaced by high density polyethylene hollow sphere with 27% cost reductionin total amount of concrete. Bubble Deck will distribute the forces in a better way thanany other hollow floor structures. Because of the three-dimensional structure and the gentle graduated force flow the hollow areas will have no negative influence and causeno loss of strength. All tests, statements and engineering experience confirm theobvious fact that Bubble deck in any way act as a solid deck and consequently will follow the same rules/regulations as a solid deck

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Mr. Muhammad [9] studied that light weight, economy and flexibility in terms of slab span also 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 i.e., conventional slab was casted with (183.35 kg) of concrete. Tests conducted that though the bubble deck slabswere not asefficient as the conventional slab because of having lesser load bearing capacity, they are very much satisfactory in slab construction considering the negligible difference in load bearing capacity between them and the conventional. It was however interesting to note a weight reduction of 10.55% & 17% in the bubble deck slabs compared to the conventional slab which was an added advantage for the bubble deck slabs especially in structures where load is an issue.
Discussion of Bubble Deck Slab against Conventional Slab based on the various studies. This provides a wide range of cost and construction benefits.

Banerjee [10] studied the practicality by using hollow spherical plastic balls in reinforced concrete slab, which is called as bubble deck slab. To present a procedure for comparison of all parameters between solid conventional slab & bubble deck slab and also study the bending (deflection) behavior of conventional slab & bubble deck slab. The comparison for sound insulation was made between Bubble Deck and conventionalone way prefabricated hollow deck of similar height. They found that the noise reduction with Bubble Deck was 1db higher than the one way prefabricated hollow deck.

Dheepan K. et.al [11] states that the diameter of the ball and the thickness of the slab play a major role. 100 kg of concrete is replaced by 1 kg of HDPE balls, which are recycled ball in Bubble deck slab. This leads to reduction in dead weight but along with that there was slight increase in deflection in the slab. This paper also contains theinformation about different types of Bubble deck slab. There are three types of Bubble deck slab – 1) TYPE A-Filigree Element, 2) TYPE B – Reinforcement Modules, 3) TYPE C – Finished Planks. From this paper, the experimental details are as follows, they constructed the Bubble deck slab by varying the diameter of the ball and altering the spacing. The diameter of the balls is 60 mm and 75 mm diameter and the spacing are of 20 mm and 30 mm. The grade of cement is OPC 53 and the concrete used for testing is of M30. They performed two-point loading test under UTM. The results concluded that as the diameter of the ball decreases the strength of the slab increases. And as the spacing increases, the strength of the slab increases. It is also observed that the flexural strength of the slab in 60mm ball diameter is higher by 2% to 3 %than the flexural strength of slab in 75mm ball diameter for both 20mm and 30mm spacing of the balls.

Jain D. et.al [12] studied that Plastic voided slabs provide similar load carryingcapacity to traditional flat plate concrete slabs but weigh significantly less. This weightreduction creates many benefits that should be considered by engineers determiningthe structural system of the building. Plastic voided slabs remove concrete from non- critical areas and replace the removed concrete with hollow plastic void formers while achieving similar load capacity as solid slabs. Voided slab principles have been appliedin different applications dating back to the early 1900s.Similary the reduction of concrete in bridge deck modal.

Bhade .et.al [13] casted and tested 4 specimens of slab in which 1 slab is conventional slab and other 3 slabs are bubble deck slab with different arrangements. He found that the bubble deck (continuous) was reduced the volume of concrete so that weight of slab ultimately decreases. Simultaneously the load carrying capacity has also increase as compare to conventional slab. But the arrangement of the bubbles is effect on the load carrying capacity of the slab. The load carrying capacity of continuous bubble deck slab was 18.75% more than the conventional slab.

Radha S. et.al [14] the principal characteristic was that hollow plastic spheres are incorporated in the floor, Clamped in a factory-made reinforcement structure. This reinforcement structure constitutes at the same as the upper and lower reinforcement ofthe concrete floor. Properties of Bubble deck slab. In flexural strength, the moments of resistance are the same as for solid slabs provided this compression depth was checked during design so that it does not encroach significantly into the ball. In shear resistanceof Bubble deck slab is 0.6 times the shear resistance of a solid slab of the same thickness. The shear capacity is measured for two ratios of a/d which is distance from imposed force to support divided by deck thickness. If the resistance is still greater than the solid slab resistance and less than the maximum allowed, we provide shear reinforcement.

Joseph et.al [15] conducts trial on varying diameter of balls. Experimental results of the above project shows that there was no much reduction in strength and various aspects compared to normal reinforced concrete slab The Indian Standard Code was used for the design of two-way slab and bubbles were implemented into it the results of the project show that there was only comparable difference in properties compared to normal RCC slab which concludes that Bubble Deck slab can be implemented usingthe Indian Standard code (IS 456: 2000). On overall comparison, slab with full ball of 60 mm (S60) was concluded good as there was proportionality between the decrease inultimate load and decrease in dead

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weight while all the other characteristics and properties remained almost same. This slab can be implemented in case where the loadbearing capacity is less and where the dead weight needs to be reduced.

Tiwari et.al [16] analyzed that HDPE sphere ball act the purpose of reducing concrete that has no carrying effect. By adapting the mesh width & the geometry of the sphere,a unique and optimized concrete construction is obtained, with regular maximum useof both moment and shear zones. The reinforcement mesh catches, distributes & fixes the spheres at exact position point, while the spheres shape the air volume it controls the level of reinforcement mesh and also stabilizes the spatial lattice. Currently, this innovation technology has been applied to a few hundred residential high-rise buildings, and industrial floor slab due to limited understandings. The models of the slabs created for the analysis verifies the prior analysis & experiments. However, the performance of bubble slab was not as successful in pedestrian deck. This does not reduce the use of bubble deck in bridge deck, but requires more studies to completely analyze the feasibility of slab in bridge.

III. CONCLUSION

By using this technique, the sizes of foundation will reduce since the structural dead-weight is reduced. Time savings as on-site construction time can be shortened since Bubble Deck slabs can be precast. Hence the time for construction will be reduced. The size of the HDPE balls depends upon the depth of the slab. The stiffness of the bubble deck slab increases as the spacing between the HDPE balls increases.

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