ANALYSIS OF THE UTILISATION OF HIGH-DENSITY POLYETHYLENE BUBBLES IN DECK SLAB

Md. Sharuf Ali[1], Mr. Mohammed Jalaluddin[2]

[1] PG Student, Structural Engineering, Department of Civil Engineering, Lords Institute of Engineering and Technology, Himayath Sagar, Hyderabad, Telangana, India.
[2]Assistant Professor, Department of Civil Engineering, Lords Institute of Engineering and Technology, Himayath Sagar, Hyderabad, Telangana, India.

Abstract: *Bubble Deck technology is a revolutionary approach in the field of construction that incorporates the use of high-density polyethylene (HDPE) bubbles within deck slabs. This innovative method significantly alters the traditional composition of deck slabs, replacing the concrete in the middle of the slab with HDPE balls. The Bubble Deck slab is a biaxial hollow core slab where the concrete placed in the central portion of the slab acts as a filler material and does not carry structural load. The diameter of the HDPE ball depends upon the depth of the slab, and the ratio of bubble diameter to the depth of the slab plays a vital role in the structural integrity of the slab. One of the key advantages of this technology is the reduction in the slab's self-weight. The use of spherical balls to fill the voids in the middle of a flat slab reduces 35% of a slab's self-weight compared to a solid slab of the same thickness. This reduction in weight does not affect the slab's deflection behaviour and bending strength, maintaining the structural integrity of the slab*

Key words: Deck slab, HDPE bubble, Structural Integrity, Spherical balls, Fill the Voids.

1.INTRODUCTION

1.1 Introduction to Bubble Deck Slab

Bubble deck slab is an innovative and environmentally friendly building technology that integrates hollow plastic spheres, or "bubbles," into the structure of a reinforced concrete slab, transforming its shape. This method reduces the slab's total weight while maintaining structural integrity and load-bearing capability. Bubble deck slabs are an alternative to standard solid slab construction that addresses major concerns like as material consumption, construction time, and environmental effect.

Bubble deck slabs operate by replacing non-structural concrete in the centre of the slab with high-density polyethylene (HDPE) spheres, creating a network of hollow holes. These perforations successfully lower the slab's self-weight while yet providing adequate strength to withstand applied stresses. This breakthrough method not only conserves materials, but also allows for longer spans and superior thermal

. Bubble deck slabs operate by replacing non-structural concrete in the centre of the slab with high-density polyethylene (HDPE) spheres, creating a network of hollow holes. These perforations successfully lower the slab's self-weight while yet providing adequate strength to withstand applied stresses. This groundbreaking method not only saves materials, but also allows for longer spans, better thermal performance, and higher building efficiency.

The reduction in dead load obtained using bubble deck technology has a variety of advantages. First, longer clear spans are achievable without the need for additional supporting columns or beams, resulting in more adaptable interior spaces and simpler architectural solutions. Second, the lowered weight of the slab decreases foundation requirements, which can lead to cost savings and a lower environmental impact.

Furthermore, the air gaps within the spheres provide better thermal insulation, resulting in enhanced energy efficiency and occupant comfort. This function is especially beneficial in locations with frequent temperature variations.

While the concept of voided slabs is not new, using HDPE bubbles in bubble deck slabs offers a lightweight and easy approach that addresses some of the limitations of prior voided slab systems. The technology has been successfully applied in several building projects, including residential, commercial, and industrial structures, demonstrating its practicality and potential of transforming our approach to slab design and construction.

1.2 Invention of Bubble Deck Technology

In the 1990s, Jorgen Breuning developed a method for connecting air space and steel within a voided biaxial concrete slab. Bubble Deck technology creates air holes with recycled industrial plastic spheres while giving strength through arch action.

The concept of voided or bubble deck slabs dates back several decades, with different iterations and modifications leading to the revolutionary construction approach we know today. The concept of inserting voids into concrete slabs to reduce weight and increase efficiency dates back to the mid-twentieth century. Here's a quick history of bubble deck slabs

i) Early Experiments (1950s-1960s): The notion of voided slabs, also known as biaxial slabs, gained popularity throughout the 1950s and 1960s. Researchers and engineers experimented with making slabs with gaps created by inserting various objects, such as polystyrene cubes or clay pots, into the concrete. These voids sought to minimize the slabs' self-weight while retaining their load-carrying capability. However, problems with construction and material availability hampered practical execution and widespread adoption.

ii) Hollow Spheres and Bubble Deck (1990s-2000s): The Bubble Deck method, developed in the 1990s, was a significant advancement in the contemporary bubble deck idea. Jorgen Breuning, a Danish engineer, developed the use of hollow plastic spheres, commonly composed of high-density polyethylene (HDPE), to substitute concrete in specified portions of the slab. This technology enabled greater voids and more flexible structure.

iii) Refinement and Application (2000s-Present): The Bubble Deck system gained popularity in Europe in the early 2000s due to its improvements over previous voided slab systems. The method was improved to improve the structural performance of the slabs while maintaining correct load distribution and fracture management. Bubble deck slabs were used in a variety of architectural projects, demonstrating their advantages in terms of material efficiency, speedier construction, and increased thermal qualities

Global Adoption and Innovations: Over time, bubble deck slabs have been used in many regions of the world, with engineers and architects exploring new design possibilities and adapting the concept to local building procedures. Innovations include merging heating and cooling systems, increasing fire resistance, and using sustainable materials.

Fig.1. Placing of Balls

Fig.2. Casting Bubbles on Building

2. LITREATURE REVIEW

M.Surendar, et al. (2016), completed a computational and experimental study on Bubble Deck Slab with the primary goal of decreasing the concrete in the centre of the slab utilizing recycled balls. Plastic hollow spherical balls were utilized to replace the ineffective concrete in the slab's centre, reducing dead weight and enhancing floor efficiency, as well as improving the performance of the bubble deck slab in places with moderate and severe seismic vulnerability. To investigate the structural behaviour of the slab, finite element analysis (FEA) was performed using the FEA program ANSYS. The conventional and bubble deck slabs were subjected to uniform loads. The ultimate load, stress, and deformation were all measured analytically. By applying a UDL load of roughly 340kN to a conventional slab, the stress was approximately 30.98MPa, resulting in a 12.822mm deflection. The bubble deck slab carries a stress of approximately 30.8MPa when a dull load of around 320kN is applied, resulting in a 14.303mm deflection. When compared to ordinary slabs, the bubble deck slab can bear 80% more stress. The deformation varies slightly when compared to a typical slab. The stress and deformation outcomes of bubble deck slabs were assessed and compared to conventional slabs using finite element analysis. According to the results, Bubble Deck Slab outperforms ordinary slabs.

Arati Shetkar & Nagesh Hanche (2015) undertook an experimental investigation on the Bubble Deck Slab System with Elliptical Balls; the behaviour of Bubble Deck slabs is determined by the ratio of bubble diameter to slab thickness. The bubbles were created using high density polypropylene materials. The bubble diameter ranges from 180mm to 450mm, with a slab depth of 230mm to 600mm. The gaps have notional diameters of 180, 225, 270, and 315. In this experiment, the force is applied from the bottom to the top of the slab until fractures form and the failure modes are recorded. Results collected demonstrate the better load bearing capability of the Bubble Deck may be reached by employing hollow elliptical balls, which reduces material consumption, speeds up construction, and lowers total costs. Aside from that, the study's results demonstrate a reduction in deadweight of up to 50%, allowing for reduced foundation sizes.

Mr. Muhammad Shafiq Mushfiq An experimental study on Bubble Deck Slab concluded that while bubble deck slabs were not as efficient as conventional slabs (having less loadbearing capacity), they are very satisfactory in slab construction due to the negligible difference in load bearing capacity between them and the conventional. It is worth noting, however, that the weight of the bubble deck slabs is reduced by 10.55% and 17% when compared to the standard slab, which is an extra benefit for the bubble deck slabs, particularly in constructions where load is a problem

Sankalp k. Sabale & Dr. N. K. Gupta the structural behaviour of a Bubble Deck Slab was investigated using spherical and elliptical balls of grades M25 and M30, and an analysis was done on the bubble deck slab. The results showed that bubble deck slabs with elliptical balls had a higher load bearing capability than bubble deck slabs with spherical balls. Bubble deck slab with spherical and elliptical balls of M30 grade conducted an experimental investigation on bubble deck flat slab and concluded. Concrete usage was decreased, resulting in lower material consumption. It reduced dead load by up to 10.07%. The deflection of bubble deck flat slabs was found to be greater than that of conventional slabs. The ultimate load bearing capability of the bubble deck flat slab was lowered by 11.22 percent. The bottom cracks are both longitudinal and diagonal. The majority of the cracks are longitudinal and comparable in both situations. In comparison to standard concrete, the cost was lowered by 13.39%.

Samantha Konuri & Dr. T. V. S. Varalakshmi Review of Bubble deck technology and their uses the slab BD analysis of the project showed to be the most appropriate and cost-effective when the findings were compared to others. The slab made using such technology had a lower steel consumption, a lower concrete consumption, and a lower maximum deflection, which disqualified the use of an 18cm smooth slab. Importantly, in addition to economic aspects, BD capitalizes on the user's comfort, which has been validated by recognized organizations and lived in various buildings throughout the world

3. METHODLOGY

3.1 Collection of Data

Collect the data about bubble deck slab with help to Lecturer and from different research papers. From that data we have study about the difference between the bubble deck slab and conventional slab. From that study we make a model on it by step by step

3.1.1 Selection of Materials

1. Ordinary Portland Cement of 53 grade

2. Maximum Nominal size of Coarse Aggregate: 20mm

3. River sand is used as fine aggregate.

4. High strength deformed steel of grade fe500 is used.

5.HDPE balls of 42mm & 90mm Dia is used.

3.1.2 Method

Cubes and slab are casted with the materials with a mix design of M25.The casted specimens are tested on UTM for comparative analysis between Convectional and HDPE Bubbles in deck slab.

3.2 Mix proportion

1.STIPULATIONS FOR PROPORTIONING a) Grade designation : M25 RCC b) Type of cement :53 grade Ordinary Portland Cement conforming IS 12269 c) Maximum nominal size of coarse aggregate : 20 mm d) Minimum amount of cement : 300 kg/m^3 as per IS 456:2000 e) Maximum water-cement ratio : 0.50 as per Table 5 of IS 456:2000 f) Workability : 100 – 125 mm slump g) Exposure condition : Moderate (For Reinforced Concrete) h) Method of concrete placing : Pumping j) Degree of supervision : Good k) Type of aggregate : Crushed Angular Aggregates

2.TEST DATA FOR MATERIALS

a) Cement used : 53 grade Ordinary Portland cement conforming IS 12269. b) Specific gravity of cement :3. 15 c) Chemical admixture: Super Plasticizer conforming to IS 9103. d) Specific gravity of 1) Coarse aggregate 20 mm: 2.799 2) Coarse aggregate 10 mm: 2.789 3) Combined Specific Gravity of aggregate (20 mm -45% & 10 mm - 55%) =2.79

4) Fine aggregate: 2.517

e) Water absorption: 1) Coarse aggregate 20 mm: 0.41 % 2) Coarse aggregate 10 mm: 0.59 % 3) Fine aggregate: 1.87 % f) Aggregate Impact Value: 20.52 % g) Combined Flakiness & Elongation Index: 27.57 % h) Sieve analysis: 1) Coarse aggregate: Confirming to all in aggregates of Table 2 of IS 383 2) Fine aggregate: Confirming to Grading Zone III of Table 4 of IS 383.

3 TARGET STRENGTH FOR MIX PROPORTIONING

$$f'ck = fck + 1.65\, s$$

where f’ck = average target compressive strength of concrete at 28 days, fck = characteristics compressive strength of concrete at 28 days, and s = standard deviation. From table 1 of IS 10262 assumed Standard

Deviation, s = 4 N/mm^2. Therefore, target strength of concrete

= 25 + 1.65 x 4 = 31.6 N/mm^2

4. SELECTION OF WATER - CEMENT RATIO

Based on the trial, adopted water cement ratio 0.38 From the Table 5 of IS 456 maximum Water Cement Ratio is 0.50 0.38 < 0.50 Hence ok.

5. SELECTION OF WATER CONTENT

From Table 2 of IS 10262:2009, maximum water content for 20 mm aggregate = 186 liter for 25 to 50 mm slump range but for an increase by about 3 percent for every additional 25 mm slump so here estimated water content for 125 mm slump = 186+(9/100) x 186 = 202 liter. Water requirement if we are considering cement 360 kg & w/c ratio o.38 for concrete mix design; calculated water will be 138.42

6. CALCULATION OF CEMENT CONTENT

Adopted w/c Ratio = 0.38 then Cement Content = 138.42/0.38 = 360 kg/m^3, from Table 5 of IS 456, minimum cement content for 'moderate' exposure conditions is 300 kg/m^3 but taken 360 kg/m^3 > 300 kg/m^3 hence ok.

7. CALCULATION OF COARSE AGGREGATE AND FINE AGGREGATE PROPORTION

From Table 3 of (IS 10262:2009) Volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone III) for water-cement ratio of 0.50 =0.64 (a) In the present case water-cement ratio is 0.38 therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water cement ratio is lower by 0.12, the proportion of volume of coarse aggregate is increased by= (0.12/0.05) = 2.4 times of 0.01, so 0.01 x 2.4= 0.024 (b) Net required water cement ratio= a+b = 0.64 + 0.024 =0.66(at the rate of -/+ 0.01 for every ± 0.05 change in water-cement ratio) therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.38 = 0.66

8. MIX CALCULATIONS

Determination of mix calculation will be as under: a)Volume of concrete = 1 m^3 b)Volume of cement = [Mass of cement] / {[Specific Gravity of Cement] x 1000} = 360/{3.15 x 1000} = 0.115 m^3 c)Volume of water = [Mass of water] / {[Specific Gravity of water] x 1000} = 138.42/{1 x 1000} = 0.138.42 m^3 d)Volume of all in aggregate = [a-(b+c+d)] = [1-(0.115+0.134+0.00149)] = 0.750 m^3 e)Mass of coarse aggregate= e x Volume of Coarse Aggregate x Specific Gravity of coarse Aggregate x 1000 = 0.750 x 0.59 x 2.792 x 1000 = 1235.46 kg/m^3 f)Mass of fine aggregate= e x Volume of Fine Aggregate x Specific Gravity of Fine Aggregate x 1000 = 0.750 x 0.41 x 2.517 x 1000 = 773.98 kg/m^3 9. MIX PROPORTIONS Cement = 360 kg/m^3 Water = 138.42 l/m^3 Fine aggregate = 834 kg/m^3 Coarse aggregate 20 mm = 1235.46 x 45 %= 555.96 kg/m^3 Coarse aggregate 12 mm = 1235.46 x 55%= 679.50 kg/m^3 Water-cement ratio = 0.38.

4. TEST ANALYSIS

4.1 Compression Test of Cubes Comparison of Compressive Strength of Convectional and Bubble Deck Slab comparative compressive test between a bubble deck slab and a conventional solid slab involves subjecting both types of specimens to axial loading until failure. This test allows for a direct comparison of the compressive strength and performance between the two slab designs Materials and Machines Used

• A mould of Dimensions 150 X 150 X 150 mm are used for casting of cubes.

• OPC 53 Graded cement, M25 Graded Concrete, and 42 mm HDPE Balls

• A Universal Testing Machine (UTM) are used for Compression testing

Casting Specimen

• The 150 x 150 x 150 mm specimen was used for compressive strength test. Totally 6 no's of cubes were casted.

• 3 cubes are using for Normal convectional slab and another 3 cubes for Bubble slab specimen are casted.

• The materials were taken as per M25 (1:1:3:0.38) and mixed well in dry condition. The required amount of water is added gradually. 150mm mould were greased well.

• The concrete was placed in three layers. At the end of each layer, the polyethylene balls were placed. Each layer has 9 polyethylene balls.

• The Moulds are opened after 24 hours of time and the cubes are placed in water tank or sump for curing

The curing period is Settled for 7, 14, 28 days and used for compression test.

Procedure

1.Specimens are taken out from Curing tank or sump after curing period

2.The specimen is dried and cleaned with cloth.

3.Specimen is placed at UTM and tighten the screw.

4.Load is applied and noted the load at which the specimen is failed the compression strength of the Convectional slab and bubble slab specimen by formula

Compressive Strength (F) = Load applied/ Area of the cube. (P/A)

The Compressive strength of convectional Slab Specimen is for 7, 14, 28 Days.

The Compressive Strength of Bubble Slab Specimen For 7, 14, 28 Day.

Fig.3 42mm Dia Plastic Sphere.

Fig.4 Placing of Bubbles and Casting

Fig.5 Curing of Cubes

Fig.6 Cube Testing

Fig.7. UTM Reading

4.2 Compression Test of Convectional Slab and HDPE Balls introduced Slab. Comparison of Compressive Strength of Convectional and Bubble Deck Slab with Reinforcement.

Comparative compressive test between a bubble deck slab and a conventional solid slab with reinforcement involves subjecting both types of specimens to axial loading until failure. This test allows for a direct comparison of the compressive strength and performance between the two slab designs.

Materials and Machines Used

• A mould of Dimensions 700 X 700 X 150 mm are used for casting of Slabs

• OPC 53 Graded cement, M25 Graded Concrete and 90 mm HDPE Balls

• Fe 500 10mm Dia Bars

• A Universal Testing Machine (UTM) are used for Compression testing. 23 Casting Specimen

• The 700 x 700 x 150 mm specimen was used for compressive strength test. Totally 2 nos of Slabs were casted.

• 1 Slab is using for Normal convectional slab and another 1 Slab for Bubble slab specimen are casted.

• The materials were taken as per M25 (1:1:3:0.38) and mixed well in dry condition. The required amount of water is added gradually. Mould was greased well.

• Reinforcement is made by Fe500 Steel of 10 mm Dia and placed 240mm spacing from c/c.

• The concrete was placed with the polyethylene balls were placed between the spaces in the reinforcement and use 16 HDPE balls

• Moulds are opened after 24 hours of time and the cubes are placed in water tank or sump for curing

• The curing period is Settled for 28 days and used for compression test.

Fig.8 Fe 500 Bar 10mm Dia @ 240mm Spacing from Centre to Centre in 0.7m X 0.7m X 0.15m Mould

Fig.9 Using 90mm Balls and placed for casting in a Grid form

Fig.10. Testing slabs

5.RESULTS AND CONCLUSION.

5.1 Results

The result of the compression test of comparison between convectional cube and HDPE balls cubes after curing of 7,14,28 days.

Fig. 11. Cracks of Cube

DAYS	CONVECTIONAL CUBE		HDPE BALL CUBE	
	KN	MPA	KN	MPA
7	320	14.22	336	14.93
14	417	18.53	429	19.06
28	520	23.11	526	23.37

Table 1 Test Results

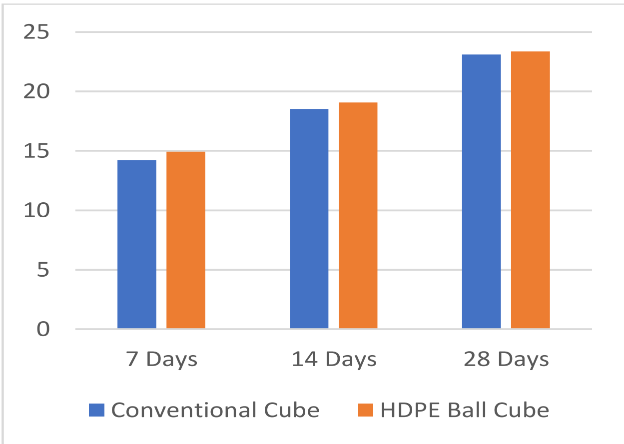

Fig.12. Graphical Representation of Comparison between the compression test of Convectional Cube & HDPE balls Cube.

The Result of Compressive test of Comparison between Convectional Slab and HdPE Slab with deflection on every load

Fig.13. Slab Failure at maximum Load.

Convectional Slab		HDPE Ball Slab	
Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
0	0	0	0
47	0.9	45	1.2
96	1.45	87	2.03
155	2.06	136	2.6
210	3.8	198	3.9
306	4.5	286	4.8
398	5.2	353	5.6
512	5.8	492	6.2

Table.2 Deflection as per Load of Convectional Slab and HDPE Ball Slab

5.2 Conclusion

1. Load bearing capacity of Bubble Deck slab is high compared to conventional slab

2. Bubble deck slab can be lesser (30% to 50%) to the weight of conventional slab

3. The construction of Bubble deck slab can economically compare to Conventional Slab

4. The deflection of Bubble deck slab under load is higher compared to Conventional Slab

5. The Emission of the CO2 is lesser compared to Conventional Slab

6. REFERENCES

1.Nizamud Doulah and Md.Ahsanul Kabir, "Nonlinear finite element analysis of reinforced concrete rectangular and skew slabs," Journal of Civil Engineering, 29(1). Pp.1-1, 2001.

2.Martina Schnellenbach Held, "Punching behaviour of biaxial hollow slab, Journal of Cement and Concrete Composites," Vol.24, Pp 551 -556, 2002.

3.C. Marais, J.M Robberts and B.W.J van Rensburg, "Spherical void formers in solid slab," Journal of the South African Institution of Civil Engineering, Vol.52, pp2-11, 2010.

4.Sergiu Calin and Sergiu Baetu, "Nonlinear finite element modelling of spherical voided bi-axial concrete floor slabs," International Symposium Computational Civil Engineering, Vol.08, pp. 81-92, 2011.

5.P. PrabhuTeja, S.Anusha and C.H Mounika, "Structural behaviour of bubble deck slab," IEEEInternational Conference on Advances in Engineering, Science and Management (ICAESM), Vol.20, pp.21-41, 2012.

6. A.N Prakash (2011), "The revolutionary concept in voided slabs", Dimensions - A Journal of a N Prakash CPMC Pvt. Ltd., Issue No.10, March 2011.

7. Amer M. Ibrahim, Nazar K. Ali, Wissam D. Salman. (June 2013). "Flexural capacities of reinforced concrete two-way bubble deck slabs of plastic spherical voids", Diyala Journal of Engineering Sciences, ISSN 1999-8716, Vol. 06, No. 02, June 2013.

8.Arati Shetkar and Nagesh Hanche. (2015). "An experimental study on bubble deck slab system with elliptical balls". ISSN: 0976-2876 4

9.Bhagyashri G. Bhade and S.M Barelikar AN EXPERIMENTAL STUDY ON TWO WAY BUBBL E DECK SLAB WITH SPHERICAL HOLLOW BALLS International Journal of Recent Scientific Researc h Vol. 7, Issue, 6, pp. 11621-11626, 2016

10.Calin S, and Asavoaie C (2010). Experimental program regarding "Bubble Deck" concrete slab with spherical gaps Intersections/Intersectii, 4(7)-1, pp. 34-40.

11. AarathiShethkar, Nagesh Bhanche. (2015). An Experimental Study on Bubble Deck Slab System with Elliptical Balls. Volume 12. Issue 1. Pages 21 -27.

12.Annamiya, Anup Willson, Khadeehga, Mithoon, Mohammed Sheebili, Nincy C.K. (2018). Bubble deck slab. International Journal of Advance Engineering and Research Development (IJAERD). Volume 5. Issue 4. April 2018. Pages 2012-2015.

13. Aron Maake, MeenaksiKhadao. (2018). Experimental study on bubble deck slab by using HDPE balls. International Journal of Advanced Innovative Technology in 31 Engineering (IJAITE). Volume 3. Issue 2. March 2018. Pages 96-100.

14. Bhagyasree Bade, Barelikhar. (2016). An Experimental Study on Two Way Bubble Deck Slab with Spherical Hollow Balls. International Journal of Recent

Scientific Research (IJRSR). Volume 7. Issue 6. June 2016. Pages 11621-11626.

15. Bhagyasree Bade, Suryavanshi. (2017). Structural Behaviour on Two Way Bubble Deck Slab Using Hollow Spherical Balls. Vishwakarma Journal of Engineering Research (VJER). Volume 1. Issue 2. June 2017. Pages 116-124.