

Bubble Deck Slab Construction and it's Applications

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Abstract - Invented in Denmark the Bubble Deck slabs, is imposed for the two directions reinforced composite concrete slab with gaps, it is licensed and is conceived to achieve the saving of concrete and energy in buildings' construction. Bubble Deck, a revolutionary method which follows virtually eliminating non-functioning concrete i.e. not performing any structural function from the middle of the conventional concrete slab, hence achieving reduction in structural dead weight of 35% by linking air and steel directly via hollow spherical or elliptical balls made by recycled plastic (High Density Poly Ethylene). Additionally, it does not react chemically with concrete or the reinforcement. It consists of a two-dimensional arrangement of voids placed between the reinforcement mesh arranged as per the project to reduce self-weight. Its behavior is governed by the ratio of bubble diameter to slab thickness. It has no porosity and has enough rigidity and strength to take-up small loads such as from pouring of concrete and the subsequent phases of this process. It is effective and feasible thus removes constraints of high dead loads and short spans (gives 50% longer spans without any beams). Thus provides a wide range of cost and construction benefits. Usually, the Bubble Deck system combines the benefits of the factory- manufactured elements in controlled conditions along with on-site completion with the final monolithic concrete, resulting in a completed floor slab.

Keywords: Bubble Deck, Long Span, Bi-axial Slab, Savings, Monolithic, H.D.P.E.

1. INTRODUCTION

With virtually no framework, no downturn beams or drop heads, and fast coverage of typically 350 ft² per panel, using Bubble deck means floor cycles up to 20% faster than traditional construction methods. Regardless of project stretch, pattern or complexity, ease of assembling, and pour to quickly install concrete decks. There are a ciphers of green attributes including conquest in total construction materials, use of reclaimed materials, minor energy consumption and trimmed the Structural Behaviour of Bubble deck Slab CO₂ emissions, lower carriage and crane lifts which make Bubble deck more environmentally benign than auxiliary concrete construction techniques.

Bubble deck can acquire bulkier spans in comparison to a site cast concrete structure without the charge for post-tensioning or pre-stressed sections. The entire construction time for the structure was reduced and allows the consultants to fast-track the design without the interior

design finalized. The total time from design inception to completion of the structure was less than 12 months. The contractor was able to set over 60,000ft² in a month.

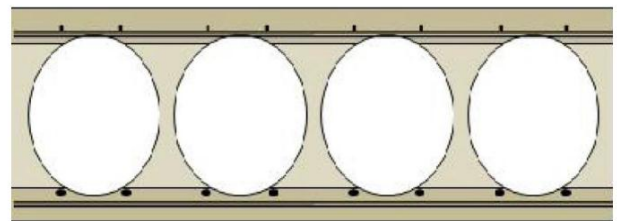


Fig. 1: Section of Bubble deck slab

One notable deviation of Bubble deck technology is that it allows for muscular, and often husky, slabs of concrete that span larger areas, as well as the opportunity to architecturally design larger cantilevers. According to the Bubble deck Group, the hollow spheres at the core of this technology allow for a roughly 35% cutback of the dead weight from the building's concrete slabs. These muscular slabs cover a larger area, also there isn't any requirement for supports. Instead, it can generate limitations for the architects, not granting them to design liberal, unblocked spaces with basic supporting features.

The Bubble deck slab floor rule can be used for storey, roof and ground floors slabs'. A Bubble deck slab floor is throughout flat and, therefore without beams and column heads. The leading characteristic being that hollow plastic spheres are incorporated in the floor, clamped in a factory-made reinforcement structure. This reinforcement structure constitutes at the same time as the upper and lower reinforcement of the concrete floor.

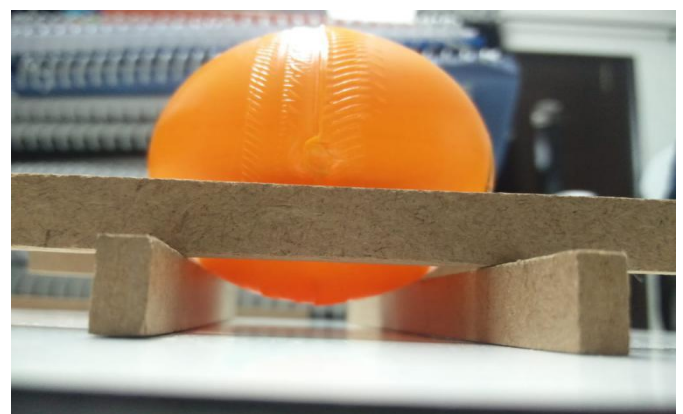


Fig. 2: Section of Bubble deck slab

The reinforcement structure with a spherical aspect and a thin concrete shell as precast slab floor are outfitted to the construction site in factory-made units with a utmost width of 3 meters; they are initiated on site and are assembled by installing fusing rods and by discharging concrete. After the concrete has set, the floor is apt to be used. The scale of the diameter of the plastic spheres to the thickness of the floor is such that a 35 % saving is procured on the material or concrete expenditure for the floor in comparison with a solid concrete floor of the twin thickness.

The preserving on weight obtained results that the Bubble deck slab floor can provide the vital load-bearing capacity at a lesser thickness which leads to the further advantage, saving 40 to 50 % of the material expenditure in the floor construction. More remarkably, since, the Bubble Deck slab floor system has lower weight within, the supporting constructions such as columns and foundations will be of lesser weight.



Fig. 3: Pre-Cast Bubble Deck Slab Setup

This eventually resulted in gains in building construction of up to 50 % due to total weight and material savings. Also, it will experience reduced earthquake damage.

2. RELATED WORK

In 1990's, Jorgen Breuning [2] invented a way to link the air-space and steel within a void bi-axial concrete slab. The Bubble Deck technology uses spheres made of recycled industrial plastic to create air voids while providing strength through arch action. As a result, this allows the hollow slab to act as a 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, Bubble Deck slabs can be lighter, stronger, and thinner than regular reinforced concrete slabs. Corey J Midriff [3] has studied "Plastic Voided Slab Systems: Applications and Design investigated the Reinforced concrete slabs are one of the most common components in modern building construction. Reinforced concrete slabs with plastic voids slabs 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. The design processor plastic voided slabs is directly compared with traditional two-way flat plate reinforced concrete slabs through a design comparison of typical bays of 20' by 20' (6m by 6m), 25' by 25' (7.6m by 7.6m), 30' by 30' (9m by 9m) and 35' by 35' (10.7m by 10.7m). The traditional slab design process follows the ACI 318-11 Building Code Requirements for Structural Concrete. Gilani A and Juntunen [4] studied about "Spherical Void Former in concrete slabs" investigated the Large span concrete flat-slab systems with internal spherical void former (SVF) have been used in Europe for over a decade. This paper addresses three issues associated with SVF slab systems: their shear resistance, their short-term elastic deflections and their economic value in a South African context.

Ibrahim, Nazar Ali, and Salman [5] on the flexural capacities of reinforced two way Bubble deck slabs. To verify the flexural behaviour of Bubble deck slabs such as ultimate load, deflection, concrete compression strain and crack pattern, two-dimensional flexural tests were tested by using special loading frame. Results have shown that the crack pattern and flexural behaviour depend on the void diameter to slab thickness ratio. The ultimate load capacities for Bubble deck slabs having bubble diameter to slab thickness of 0.01 to 0.64 were the same of solid slabs, the ultimate capacities were reduced to about 10%. Calin and Dascalu [6] on the tests of Bubble deck slab inferred that Bubble deck slab is conceived to omit a significant volume of concrete in the central core where the slab is principally un-stressed in flexure. Teja and Kumar [7] studied the durability of Bubble deck slab and is explained on the basis of creep and shrinkage. The influence of carbonation shrinkage can be neglected in the design of concrete structures with Bubble deck system because only a small part of the concrete cross-section is exposed to this kind of shrinkage. Mounika and Purnachandra [8] conducted studies on the fire resistance of Bubble deck slabs. The analysis was first done on a hollow core slab without fire, for two charges one that leads to elastic dynamic response and the other that causes plastic behaviour and severe concrete cracking. Vijay Kumar [9] studied the "Structural Behaviour of Bubble Deck Slab" investigated the Bubble deck slab is a method of virtually eliminating all concrete from the middle of a floor slab, which is not performing any structural function, thereby dramatically reducing structural dead weight.

3. COMPARISON BETWEEN CONVENTIONAL AND PROPOSED SLAB

3.1 Volume Reduction

Total thickness of slab = 120mm

Diameter of the hollow sphere= 67mm

Width of solid sec. around hollow sphere = 87mm

Vol. of slab without void former (v_1) = $0.087 \times 0.087 \times 0.12 = 9.0828 \times 10^{-4} \text{ m}^3$

Weight of corresponding section = $v_1 \times \rho_c = 2.2707 \text{ Kg}$

Vol. of 67 mm diameter sphere (v_2) = $\frac{4}{3} \times 3.14 \times \frac{0.067^3}{8} = 1.5748 \times 10^{-4} \text{ m}^3$

Volume of material saving (v_3) = ($v_1 - v_2$)
 = $(9.0828 - 1.5748) \times 10^{-4} \text{ m}^3 = 7.508 \times 10^{-4} \text{ m}^3$

Weight of material saved (w) = $v_3 \times \rho_c = 1.8770 \text{ Kg}$

Percentage of weight saving per ball = 82.66%

3.2 GRAPHICAL COMPARISON

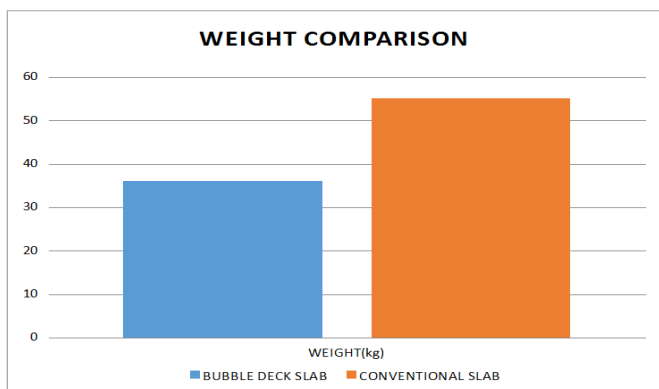


Fig. 4: Weight Comparison

Weight of bubble deck slab: 38kg
 Weight of conventional slab: 54kg
 % weight reduction: 29.6%

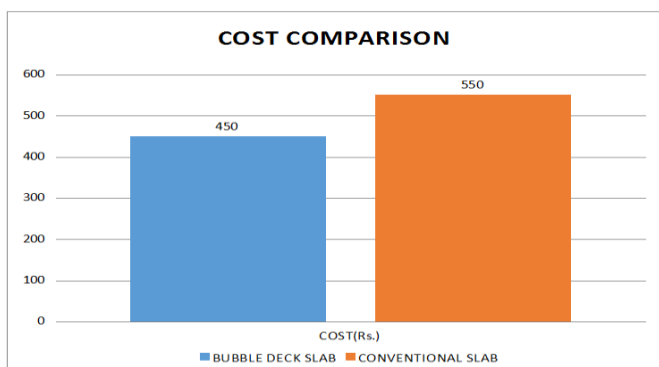


Fig. 5: Cost Comparison

Cost of bubble deck slab: Rs. 450
 Cost of conventional slab: Rs. 550
 % Cost reduction: 18.18%

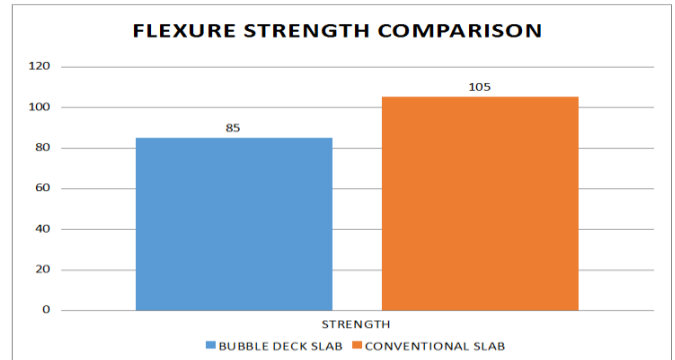


Fig. 6: Strength Comparison

Strength of bubble deck slab: 85 N/mm²
 Strength of conventional slab: 105 N/mm²
 % Flexural strength reduction: 19.047%

4. BUBBLE DECK SLAB CASTING AND TESTING

➤ **Step 1:** Initially, we gathered all the materials and made a practical drawing on a plain smooth wooden plank that would serve as the base for binding the bars. The drawing helped us in multiple instances to check the orientation of the reinforcement mesh. Next, the bars were placed and they were bound together with the help of binding wire as shown in figure 7.

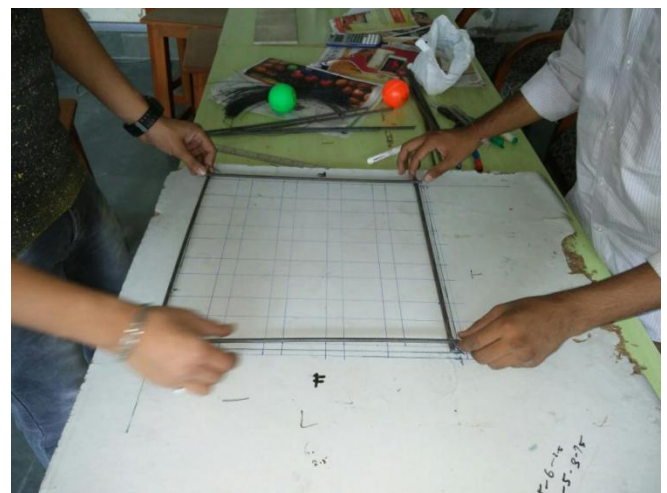


Fig. 7: Bar Binding

➤ **Step 2:** After preparing the whole mesh, the balls were placed and the orientation was checked. Later, spacing and the support condition of the balls were checked and corrected as shown in figure 8.



Fig. 8: Placing the Balls

- **Step 3:** The second mesh was made, placed and the orientation was checked as shown in figure 9.



Fig. 9: Complete Mesh consisting Balls and Wires

- **Step 5:** Oiling of the finished moulds with oil in order to keep off the concrete form being stick to the base as shown in figure 10.



Fig. 10: Oiling Of Mold

- **Step 6:** Placing the concrete cover before placing the mesh and the balls as shown in figure 11.



Fig. 11: Placing Of 1st Layer of R.C.C. 20mm Thick

- **Step 7:** We will place the mesh and the balls after pouring this cover. After the balls and the mesh was placed, the concrete was poured, then the top mesh was placed and the cover was provided. The top finish was given and the slab was left for drying. Timely curing was done till 7 days while it was in the moulds as shown in figure 12.



Fig. 12: Mixture Filling In Mould

- **Step 8:** The finished slab with the top surface was given a surface level for aesthetic appearance as shown in figure 13.



Fig. 13: Green Slab Just After Finishing

- **Step 10:** The second slab was prepared in the same way as the previous one. Only difference was there were no balls in the second sample. Slab after 7 days after the mould was removed as shown in figure 14.



Fig. 14: Slab after 14 Days

- **Step 11:** After 14 days the strength was to be measured. The machine used was universal testing machine made by Heico ltd. A premier company in manufacturing of these machines. The model used was HL590.20 with capacity 600 KN as shown in figure 15.



Fig. 15: Universal Testing Machine (UTM)

- **Step 12:** The specimen was placed centrally in the machine with supports near the end the distance from the ends of the slab to the supports was kept as per the standards to get optimum results as shown in figure 16.



Fig. 16: Testing Of Specimen

- **Step 13:** The load was increased gradually and the gentle cracking was observed. Some unbounded coarse aggregated fell first then followed by gentle cracks appearing then the cracks widened in no time. This clearly depicted the failure of the slab specimen as shown in figure 17.



Fig. 17: Crack Formations after Loading

- **Step 14:** The specimen after testing was observed and then the specimen was carefully disposed and the apparatus was cleaned and put off. The specimen was dismantled and then disposed carefully as shown in figure 18.



Fig. 18: Specimen after Testing

5. CONCLUSIONS

- A. Concrete usage is reduced as 1 kg of recycled plastic replaces 100 kg of concrete. This avoids the cement production and allows reduction in global CO₂ emissions. Hence this technology is environmentally green and sustainable.
- B. Reducing material consumption made it possible to make the construction time faster, to reduce the overall costs. It not only led to outfit dead weight up to 50% but also created smaller sized foundation.
- C. The Bubble Deck configuration gives much improved extramural 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.
- D. By using the hollow elliptical balls, the better load bearing capacity in Bubble Deck can be achieved.
- E. Advantage of Bubble Deck system is the significant cost saving, because of the possibility of obtaining great spans with less support elements.

Thus, the Bubble Deck technology is more efficient and useful than conventional slab construction techniques.

Generally, for every 500 m² of Bubble Deck floor slab, the owner can save:

- 100 m² of on-site concrete
- 16 concrete truck trips

- 180 tones of foundation load, or 2 piles lesser
- 174.5 GJ of energy used in concrete production and transportation
- 27 tons of CO₂ emissions

6. BENEFITS, LIMITATIONS AND FUTURE SCOPE

Advantages

- I. It allows architectural freedom of design with non-rectilinear plan forms. Instead of rectangular and square old shape slabs we got the liberty to design any shape as per our desire thus enhancing the aesthetic view of the structure.
- II. Due to its less weight, we can build large span slabs up to 20-25m in case of simply supported support and also there is no necessity of any kind of bottom support like beams to hold the slab weight, thus reducing the cost and concrete for beams.
- III. Since the structural dead-weight is reduced by 50%, the foundation depth and hence the excavation is minimized. The whole weight of building can be easily be supported on the Foundation of low depth.
- IV. Cross-bracing and intermediate supports are eliminated.
- V. Concrete usage is significantly reduced; 1kg of recycled plastic replaces 100kg of concrete. It is, therefore, environmentally friendly and a step towards Green Building and due to less consumption of concrete, CO₂ emission will be reduced.

Limitations

1. Punching shear capacity is low.
2. Skilled labor is required.
3. Not applicable to slabs having limited thickness.

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