STUDY ON FLEXURAL BEHAVIOR OF BUBBLE DECK SLAB STRENGTHENED WITH FRP

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ABSTRACT: Bubble deck sheets are a technique to remove all the concrete from the center of the floor sheet, thus reducing structural dead weight. Inefficient concrete in the center of the slab replaces the high-density hollow spheres (HDPE). The weight decreases and increases efficiency in the plane. Because the bubble deck slab consumes less material, it reduces greenhouse gas emissions into the atmosphere, enabling us to achieve green construction. The benefits include reduced energy consumption - both in production and transportation - and emissions - from production and transportation, mainly CO2 - as well as material, load, and value reduction. It is also a green technology. Reduce the volume of concrete in the bubble deck technology by substituting locally available spherical bubbles. This implies that the monolithic slab element is used to determine load carrying, deformation (deformation), crack, and failure properties in the plant and is subjected to static gravity loads. The resulting conclusions will be used to define the failure mechanisms, and the benefits of the bubble deck slab will be highlighted.

Keywords: Bubble Deck slab, CFRP Strengthening, concrete technology, slab, CO2

1. INTRODUCTION
In building construction, the slab is a critical structural member that consumes the most concrete. Jorgen Bruenig invented the first biaxial hollow slab (now called a bubble deck slab) in Denmark in the 1990s. Bubble deck is a more sustainable construction method than traditional concrete floor systems because it uses less concrete and emits less CO2 during the manufacturing process. It complies with sustainability standards by utilizing recycled plastic spheres [1]. The spheres may be recycled even if the building is demolished or renovated in the future. By virtually eliminating the substantial portion of the conventional slab in the center, it results in a 30 to 50% lighter slab, which reduces the loads on the columns, walls, and foundations, and ultimately on the entire structure. The slab is a critical structural member in the construction of buildings because it forms the space [2].

A slab is a critical component of building construction. It is a significant structural member that consumes concrete. The primary impediment to concrete constructions, particularly horizontal slabs, is their high weight, restricting their span. Thus, it is necessary to concentrate on the span's weakness, reduce the load, or overcome concrete's inherent tension weakness [3]. In general, as the span increases, the deflection of the slab increases as well. As a result, the thickness of the slab should be increased. Increased slab thickness results in heavier slabs and can result in increased column and foundation size. As a result, buildings become...
uneconomical. To circumvent the disadvantages associated with increasing the self-weight of slabs, the voided slab system is used.

2. LITERATURE REVIEW
Based on the literature study following.

Shaimaa Tariq Sakin (2014) – Shaimaa Tariq Sakin is one of the leading European countries to participate. SCC has been shown to improve the punching shear power and reduce the deflection in the mid-span. We are increasing the box strength of the steel fiber in the crucial zone and reducing the angle of box failure. The 1% volume fiber ratio was more effective than the 0.8% volume ratio. The crack pattern of the punching shear was reduced by the SCC use and the empty SCC use, but the empty SCC was increased by 1% by volume fraction, particularly by steel fiber [4]

Reshma Mathew, Binu (2016) – In this study GFRP strengthening system is used. Strengthened deck plates have a higher capacity of punch compared to a deck control. Increased load capacity carries up to 20% due to reinforcement of a GFRP bubble cover. A strengthened bubble deck has low deflection compared to an unstrengthen bubble deck slab. 8% of global carbon dioxide is due to cement production. One ton of cement causes the emission of about 800 kg of carbon dioxide. One m3 of concrete causes carbon dioxide emission close to 300 kg. By inserting 180 mm diameter HDPE balls into a flat 230 mm diameter label, we save up to 23.62% on one ball [5]

Shikha Saini and Nishant Rajoria Muhammad Shafiq Mushfiq (2017), In this study (with less load capacity), the bubble deck platforms were not as efficient as the conventional plating, and in slab construction are very satisfactory, as the load-bearing capacity difference between them and the conventional is negligible. However, it is worth noting that the weight in bubble deck sheets is 10.5%–17% lower than in conventional decks, which benefits the bubble deck sheets, particularly in structures with a load problem. This is an added benefit [6].

S. Aswini (2017) – R.S. Dheepan, S.Saranya In this study, the bending strength of the plates increases when the spacing between the balls increases, regardless of the change in the thickness of the plates. The bending force of the plate in a diameter of 60mm balls are also observed to be higher than the bending strength of the plate in a diameter of 75mm balls for both 20mm and 30mm distance between balls. Finally, it is concluded that 60mm and 30mm can be the ideal diameter for the hollow balls used in the slab for a common purpose. The use of concrete is reduced by 35 – 50 percent, reducing the self-weight of the lath with equal bending strength compared to the conventional lath. It has an excellent thermal insulating property because of the vacuum in the plate. Lower total cost, lower building time, and green technology than conventional plates. The following inferences are noted. The load-bearing capacity of the bubble deck slab is mostly less than the conventional slab. The load-bearing capacity of the bubble deck slab depends on the arrangement of the slab, ball size, and ball diameter. The punching shear of the bubble deck slab is low. The self-compacting concrete increases the punching shear [7].

3. STAGES INVOLVED IN BUBBLE DECK SLAB
Bottom reinforcement placement - The first step is to lay the reinforcement on the underside. It puts the ball in a straight line and aligns it. Two directionally welded reinforcement meshes are bottom reinforcements.

Foot concrete laying - Concrete at the bottom of the assembly line is supplied. It acts as a material for ball connection because the ball is attached to the concrete. Hollow ball placing - the hollow ball is located rather than the concrete between the reinforcement.

Top enhancement - Top enhancement netting is supplied on the top of the sphere after placing the balls. It places the ball and also serves as the ball's cover. After placing the spheres in places, the two meshes are connected to make the shell rigid [8].
4. CFRP STRENGTHENING

Because of the material to enhance the cutting capacity of concrete plates, CFRP sheets were used. The CFRP increased bending rigidity and improved the punching shear strength of the sheets. It was observed. The increase in bending capacity has altered the failure from pure bending to a combined bending shaking mode or pure bending shaving mode [9]. The bending resistance of the two-way layer can be improved by binding the CFRP layers effectively to the tightening face of the laths. The flexural consolidation method offers several advantages: minimizing structural expansion and weight, easy on-site handling, and excellent corrosion resistance. The interface link between concrete and CFRP composite strengthening is of decisive importance for the overall performance of the strengthened framework since the CFRP sheets are linked to the concrete framework.

5. MATERIAL TESTING:

5.1 Cement
Cement is a binder material used in concrete shown in table 1. In this project work, cement of OPC 53 grade is used. The preliminary test is conducted based on IS codes [10].

| TEST                        | RESULT | As per IS standard |
|-----------------------------|--------|--------------------|
| Consistency                 | 29%    | 25-30%             |
| Initial setting time        | 32min  | Not less than 30min|
| Final setting time          | 259min | Not more than 600min|
| Specific gravity            | 3.06   | 2.5-3.15           |

5.2 Fine Aggregate:
Fine aggregates are usually sand or crushed stone. The preliminary test is based on IS 2386 Part 3 (1963) observed in table 2

| TEST                        | VALUE | As per IS standards |
|-----------------------------|-------|---------------------|
| Specific gravity            | 2.75  | 2.6 – 2.8           |

5.3 Coarse Aggregate:
The ground compound is one of the essential elements of cement and occupies the most significant volume in the blend. The test is based on part 3 of the IS 2386 (1963). Properties of coarse aggregates shown in table 3 [11]

| Test                        | Value | As per IS standards |
|-----------------------------|-------|---------------------|
| Specific gravity            | 2.60  | 2.6 – 2.85          |
| Impact test                 | 28.57%| not more than 30%   |

6. Experimental Description:
Cement: FA: CA was 1:1.5:2.8, and the M30 grade concrete was used in the design mix. As per the literature study and as per IS codal provision, the size of the slab is decided. The ball of size 75mm is placed between the top and bottom reinforcement. Since Flexural behavior is
done, so two-point loading condition is adopted. The length of the slab is 700mm, and depth is 125 mm, and width is 300 mm. The mouth was placed on a smooth surface and arranged properly. The sides of the mold exposed to cement are oiled well, so the side walls of the mold do not absorb that water from the concrete, and the specimen can be easily removed. The cages were placed in the mould, and the cage and the shaped cover were kept to 20 mm. The materials in concrete, including concrete, cement, sand, aggregation, and water, have been precisely weighted and combined. Firstly, the bottom reinforcement is placed over the cover, and the hollow plastic balls were placed on the bottom reinforcement, and the top reinforcement was placed over the hollow balls. Immediately after mixing and well compacting, the concrete was placed into the mould [12]. At the end of 24 hours of casting, the test specimens were removed. On specimens, marks of identification were marked. For 28 days, they were healed in water. Three types of slabs are cast with variations in material properties along with cubes to find out the compressive strength. One specimen for the CFRP wrapping is a carbon fiber polymer laminate used to strengthen structural elements in load-bearing structures. CFRP sheet of bi-directional is used in the specimen. Surface preparation, including cleaning, one layer epoxy polyamine base, and a layer epoxy putty was made before the jacketing with CFRP sheets; then epoxy adhesive was used for binding CFRP sheets to the specimen [13]. Figure 1,2,3 and 4 shows casting of specimens. Table 4 depicts parameter of the specimens.

| SL.no | Specimen Description                          | Dimension (mm³) |
|-------|-----------------------------------------------|-----------------|
| 1.    | S1 (Conventional Slab)                        | 700X300X125     |
| 2.    | BD2 (Bubble Deck Slab)                        | 700X300X125     |
| 3.    | BD3 (Bubble Deck Slab strengthened with cfrp)  | 700X300X125     |

**Table 4 Specimen Parameters**

![Fig 1 Top and Bottom reinforcement](image1)

![Fig 2 Mould for Specimen](image2)
Testing of Specimen
The slabs are tested on a two-point load setup with support at the bottom. The distance between the end of the slab to support is 70mm, and the distance from support to the load point is 167mm. The load is applied in the proportion of L/3. Jack used for the beam is of 50-ton capacity. Flexural behavior beam is calculated after 28 days of curing, which consists of maximum load, deflection properties. The load was applied using a 50-ton jack in the total order of 2 kN, and deflection was observed using a digital dial gauge [14]. Load is applied till the ultimate point, and deflection is noted. Figure 5 and 6 shows testing of specimens.
8. RESULT AND DISCUSSION

The three specimens' ultimate load and bending strength are shown in Table 5 for a dimension of 700mmx300mx125mm. The hollow balls used are 75mm in diameter.

| SL.NO | Slab Specimen | Ultimate Load (kN) | Deflection (mm) | Flexural Strength (N/mm²) |
|-------|---------------|---------------------|-----------------|---------------------------|
| 1.    | S1            | 55                  | 4.59            | 8.66                      |
| 2.    | BD2           | 50                  | 3.43            | 7.61                      |
| 3.    | BD3           | 84                  | 9.32            | 12.5                      |

8.1 Load – Deflection Relationship

Figure 7,8 and 9 depicts relationship between load and deflections for conventional, bubble deck and bubble deck with CFRP [15].
Fig 7 Load Vs. Deflection of Conventional Slab

Fig 8 Load vs. Deflection for Bubble Deck slab

Fig 9 Load vs Deflection for bubble deck slab strengthened with CFRP

8.2 Crack Pattern:
Crack pattern observed in the three specimens are shown in the figure 10, 11 and 12.
CONCLUSION:

1. As a result of the preceding, it was determined through testing that while bubble deck slabs were not as efficient as conventional slabs.
2. The load-bearing capacity of a bubble deck slab reinforced with CFRP is 18% greater than that of a conventional slab and 32% greater than that of the bubble deck slab alone.
3. The experiment discovered that the bubble deck slab weighs less than the bubble deck slab.

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