

# Design and Performance Evaluation of Lightweight Voided Slab Using Recycled HDPE Spheres

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## ABSTRACT

In modern construction practice, reducing structural weight without compromising strength has become an important research area. Voided slab systems have emerged as an efficient solution by eliminating unnecessary concrete from the neutral axis of reinforced concrete slabs. One such innovative technology is the bubble deck slab system, which incorporates hollow plastic spheres inside the slab to reduce weight while maintaining structural performance. The present study investigates the structural behavior of a bubble deck slab constructed with high-density polyethylene (HDPE) balls and compares it with a conventional reinforced concrete slab. Both slabs were fabricated using M35 grade concrete and tested under three-point loading conditions. The experimental analysis focused on evaluating load carrying capacity, deflection characteristics, and concrete quality using ultrasonic pulse velocity testing. The results demonstrated that the voided slab achieved significant weight reduction while maintaining satisfactory structural performance. The bubble deck slab utilized approximately 22% less concrete compared to the conventional slab and exhibited comparable load carrying capacity with slightly higher but acceptable deflection values. These findings indicate that bubble deck technology can contribute to sustainable and economical construction by reducing material consumption and structural dead load.

**Keywords:** Bubble deck slab, voided slab, HDPE balls, lightweight concrete slabs, structural performance

## I. INTRODUCTION

Concrete structures are widely used in building construction due to their durability, versatility, and load carrying capability. Among structural components, slabs play a crucial role in transferring loads to beams, columns, and foundations [1]. However, a significant portion of the concrete in the central zone of a slab does not contribute effectively to structural strength because it lies near the neutral axis where stresses are minimal. In order to optimize material usage and reduce self-weight, modern construction technologies have introduced voided slab systems [2, 3]. Bubble deck slabs represent one of the most efficient forms of voided slab construction. In this system, hollow plastic spheres are embedded within the concrete slab, replacing the non-structural concrete in the middle region [4]. This technique decreases slab weight while maintaining structural rigidity and load distribution capability. The reduction in slab weight not only lowers the dead load acting on the structural framework but also decreases the load transmitted to columns and foundations. Consequently, the overall construction cost can be reduced due to lower material consumption and smaller structural elements. Additionally, the use of recycled plastic spheres contributes to environmental sustainability by reducing plastic waste and lowering carbon emissions associated with concrete production [5, 6].

## II. OBJECTIVES

The primary objective of this research is to investigate the structural performance of bubble deck slabs in comparison with conventional reinforced concrete slabs. The study focuses on analysing the load carrying capacity, deflection behaviour, and concrete quality through both destructive and non-destructive testing methods [7-9]. Another important aim of this study is to evaluate the material savings achieved by introducing HDPE spheres within the slab and to examine the potential economic benefits associated with this technology.

## III. MATERIALS USED

Ordinary Portland cement of grade 53 was used for the preparation of concrete mixes. This cement type was selected due to its high compressive strength and durability characteristics. The specific gravity of the cement was determined as 3.15. Locally available crushed sand passing through a 4.75 mm sieve was used as fine aggregate. The sand conformed to Zone II grading requirements according to IS 383 standards. The measured fineness modulus was 3.05, while the specific gravity was 2.65. Coarse aggregates with sizes ranging from 10 mm to 20 mm were used in the concrete mix. These aggregates provided adequate strength and improved bonding with the cement matrix. High-density polyethylene spheres with a diameter of 60 mm were used as void forming elements. These balls were lightweight, durable, and resistant to chemical reactions within concrete. Their placement within the slab replaced the non-structural concrete zone (Figure 1).



Figure 1. HDPE spheres used for void formation in slab

High yield strength deformed (HYSD) steel bars of Fe550 grade were used as reinforcement. Bars with diameters of 8 mm and 10 mm were arranged in grid form to provide tensile resistance in the slab. Waterproof plywood formwork of size 500 mm × 500 mm × 125 mm was fabricated to cast the slab specimens. The formwork ensured dimensional accuracy and prevented leakage of cement slurry during casting (Figure 2 and 3).

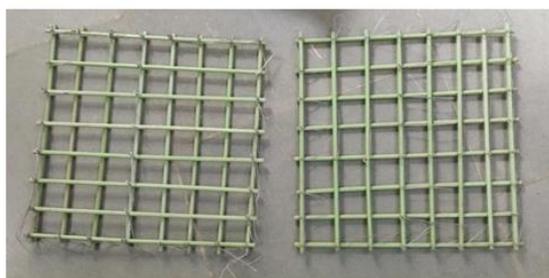


Figure 2. Steel reinforcement mesh used in slab casting



**Figure 3.** Formwork used for casting slab specimens

#### **IV. EXPERIMENTATION**

Two slab specimens were prepared for the experimental investigation: Conventional reinforced concrete slab and Bubble deck slab containing HDPE spheres. Both specimens had identical dimensions of 500 mm × 500 mm × 125 mm and were reinforced with identical reinforcement layouts. The bubble deck slab incorporated 48 HDPE balls arranged uniformly within the slab thickness. The specimens were cured for 28 days before testing

#### **V. TESTING METHODS**

The structural performance of the slabs was evaluated using a three-point loading test conducted on a Universal Testing Machine (UTM). The slabs were simply supported, and load was applied gradually until visible cracking occurred (Figure 4) and Concrete quality was assessed using the ultrasonic pulse velocity (UPV) test, which is a non-destructive testing method used to determine internal defects and overall concrete integrity (Figure 5).



**Figure 4.** Three-point load test on slab specimen



Figure 5. Ultrasonic pulse velocity testing

## VI. RESULTS AND DISCUSSION

### 6.1 Load Deflection Behavior

TABLE I LOAD-DEFLECTION VALUES FOR CONVENTIONAL SLAB AND BUBBLE DECK SLAB

Load (kN)	Deflection Conventional (mm)	Deflection Bubble Deck (mm)
0	0	0
8	0.32	0.35
14	0.49	0.53
20	0.78	1.21
26	0.96	1.38
32	1.15	1.47
38	1.29	1.60

The bubble deck slab showed slightly higher deflection values compared to the conventional slab due to the presence of voids. However, the deflection remained well within the allowable limits specified by design standards (table 1)

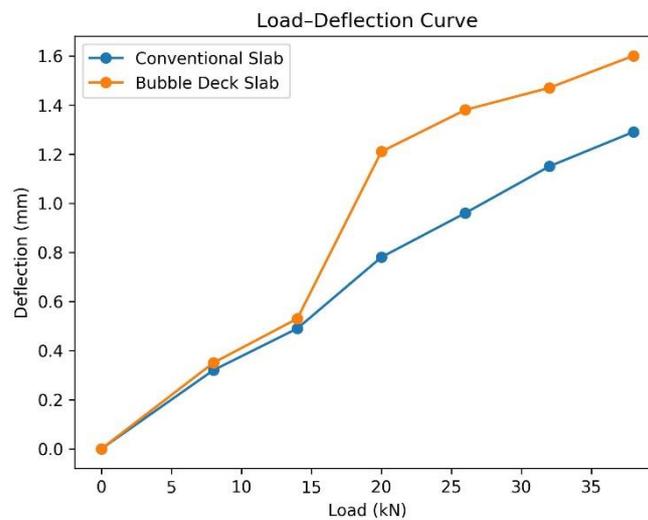


Figure 6. Load-Deflection Curve

### 6.2 Ultrasonic Pulse Velocity Results

Method	Conventional Slab (km/s)	Bubble Deck Slab (km/s)
Direct	4.48	4.31
Indirect	4.05	3.82

The UPV results indicate that both slabs fall within the good to excellent quality range, confirming adequate compaction and proper curing.

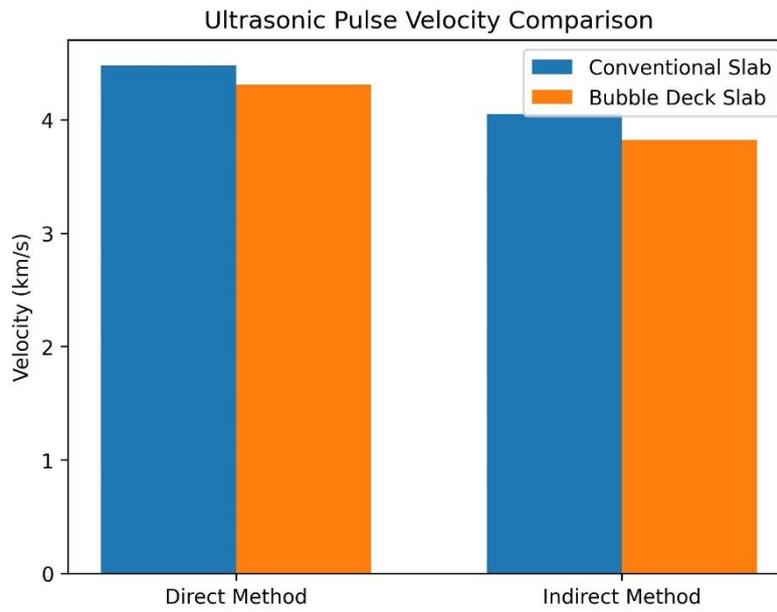


Figure 7. Ultrasonic Pulse Velocity Comparison Chart

### VII. CONCLUSION

The experimental study demonstrated that bubble deck slab technology can effectively reduce structural weight while maintaining satisfactory mechanical performance. The incorporation of HDPE spheres significantly decreased the volume of concrete used in the slab, resulting in approximately 22% material reduction compared to the conventional slab. Although the bubble deck slab exhibited slightly higher deflection under loading conditions, the values remained within permissible limits and did not compromise structural safety. The ultrasonic pulse velocity results confirmed that both slab types possessed good concrete quality. The reduction in slab self-weight contributes to lower loads on structural members such as beams, columns, and foundations, which can ultimately lead to economic savings in large-scale construction projects. Therefore, bubble deck slab technology can be considered a sustainable and efficient alternative for modern building construction.

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