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Bubble Deck Slab Using Recycled Polypropylene Spheres

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Abstract: *This study presents a detailed experimental investigation of Bubble Deck slab technology using polypropylene (PP) spheres as void formers. The primary objective of the study is to reduce the self-weight and material consumption of reinforced concrete slabs without compromising structural performance. In this system, the non-structural concrete present in the neutral axis is replaced with hollow spherical voids, which results in a reduction in dead load and improvement in material efficiency (Lai & Veneziano, 2010). A slab specimen of dimensions 600 mm × 600 mm × 150 mm was cast using M35 grade Ready Mix Concrete (RMC) and reinforced with Fe550 steel. Polypropylene spheres of 50 mm diameter were used as void formers and placed within the neutral axis. The slab was subjected to loading tests and compared with a conventional solid slab of identical dimensions. The results indicated that the Bubble Deck slab retained approximately 90% of the load-carrying capacity of the conventional slab while achieving nearly 30% reduction in concrete volume and self-weight. Although a slight increase in deflection was observed, the values remained within acceptable limits. The study concludes that the Bubble Deck slab using PP spheres is a structurally efficient and sustainable alternative for modern construction applications.*

Keywords: *Bubble Deck slab*

I. INTRODUCTION

In conventional reinforced concrete construction, slabs are generally designed as solid sections even though a significant portion of the concrete in the central region contributes minimally to structural performance under bending conditions (Phalke et al., 2019). This inefficient use of concrete increases the dead load acting on the structure, leading to higher material consumption, increased cost, and greater demand on supporting structural elements such as beams, columns, and foundations.

To address these inefficiencies, Bubble Deck slab technology has been developed as an innovative solution. In this system, the non-load-bearing concrete present in the neutral axis is replaced with hollow spherical void formers, thereby reducing the overall self-weight of the slab while maintaining its structural integrity (Lai & Veneziano, 2010). The outer layers of concrete continue to resist tensile and compressive stresses, ensuring that the structural performance is not significantly affected (Nor Ashikin et al., 2020).

In recent years, sustainability has become a major concern in the construction industry due to the environmental impact of excessive cement usage and plastic waste generation. Conventional Bubble Deck systems typically utilize high-density polyethylene (HDPE) spheres as void formers. However, this study proposes the use of polypropylene (PP) spheres as an alternative due to their availability, recyclability, and suitable mechanical properties. The present study focuses on evaluating the structural performance and sustainability benefits of Bubble Deck slabs using PP spheres through experimental investigation.

II. LITERATURE REVIEW

Several researchers have studied the performance of Bubble Deck slab systems and have highlighted their advantages in terms of material efficiency and structural behavior. It has been reported that the incorporation of voids in the neutral axis can reduce concrete consumption by approximately 30–50 percent, which significantly lowers the dead load acting on the structure (Lai & Veneziano, 2010). This reduction in weight allows for longer spans and improved overall efficiency of the structural system.

Experimental studies have also demonstrated that the flexural behavior of Bubble Deck slabs is comparable to that of conventional solid slabs. This is because the tensile and compressive stresses are primarily resisted by the outer concrete layers, while the concrete in the neutral axis contributes very little to bending resistance (Phalke et al., 2019). Further research indicates that slabs with a void ratio of 20–30 percent can retain more than 90 percent of the load-carrying capacity of conventional slabs (Nor Ashikin et al., 2020).

Despite these advantages, certain limitations have been identified in previous studies. The presence of voids near column–slab junctions leads to a reduction in punching shear capacity, which requires careful design and additional reinforcement (Pulke, 2019). Additionally, the reliance on plastic void formers raises concerns regarding environmental sustainability and long-term recyclability. The lack of standardized design provisions, particularly in countries like India, further limits the widespread adoption of this technology (Francis, 2019). These challenges highlight the need for experimental studies using alternative materials such as polypropylene, which can improve sustainability while maintaining structural performance.

III. METHODOLOGY

The methodology adopted in this study is based on experimental investigation and comparative analysis of a Bubble Deck slab and a conventional solid slab. A slab specimen of dimensions 600 mm × 600 mm × 150 mm was designed to represent a scaled structural element suitable for laboratory testing. The specimen was cast using M35 grade Ready Mix Concrete to ensure uniform quality and consistent strength.

Setting of reinforcement in formwork while providing cover (25mm)

High-strength reinforcement steel of grade Fe550 was used to provide adequate tensile resistance. Two layers of reinforcement were arranged within the slab, with the bottom layer designed to resist tensile stresses and the top layer to resist compressive and shear stresses. Polypropylene spheres of 50 mm diameter were used as void formers and were placed within the neutral axis of the slab between the two reinforcement layers.

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The casting process involved preparation of formwork, placement of bottom reinforcement, positioning of the polypropylene spheres in a uniform grid pattern, and installation of the top reinforcement layer. Concrete was then poured and properly compacted to eliminate air voids and ensure uniform distribution. The specimen was cured under controlled conditions for the required duration to achieve the desired strength.

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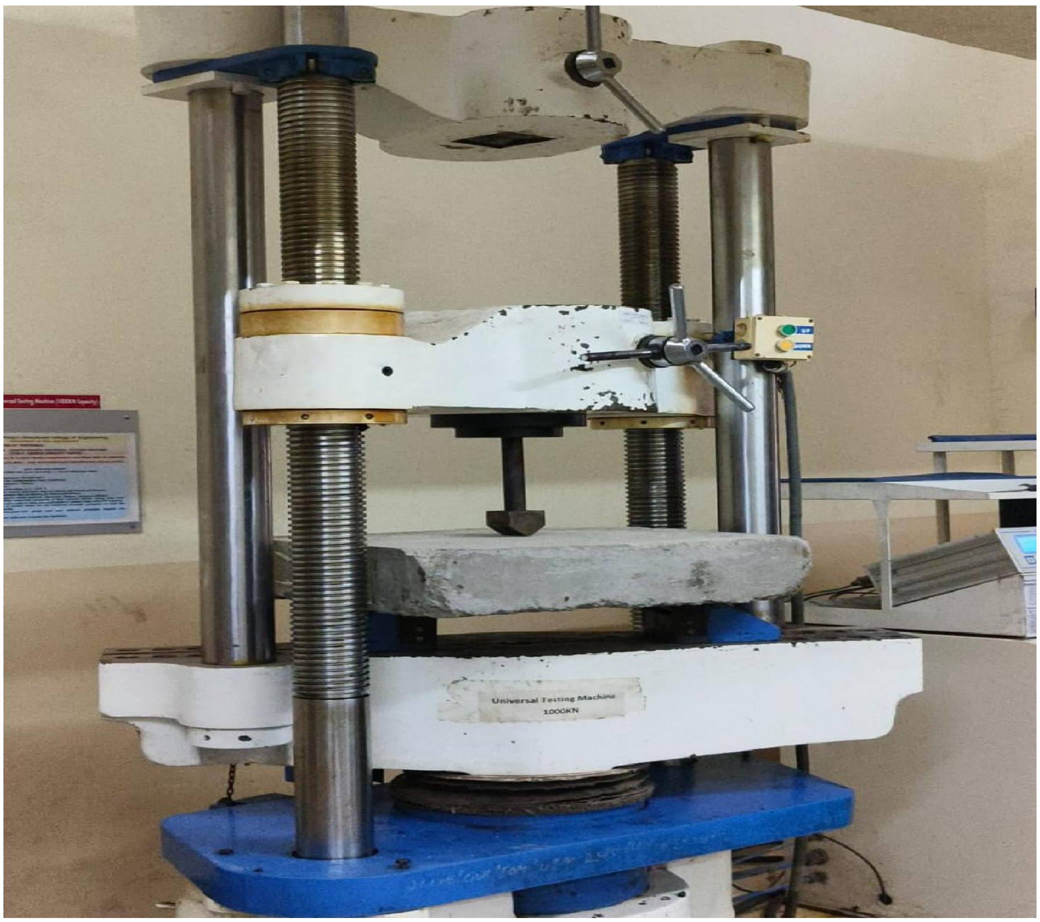
After curing, the slab was subjected to loading tests using appropriate testing equipment. The applied load and corresponding deflection were recorded throughout the test. A conventional solid slab of identical dimensions and material properties was also tested under similar conditions for comparison.

IV. RESULTS AND DISCUSSION

The experimental results obtained from the Bubble Deck slab were compared with those of the conventional solid slab to evaluate structural performance. The Bubble Deck slab achieved an ultimate load of 105.61 kN with a corresponding deflection of 8.89 mm, whereas the conventional slab exhibited a higher ultimate load of 118.40 kN and a lower deflection of 7.35 mm.



The results indicate that the Bubble Deck slab retained approximately 90 percent of the load-carrying capacity of the conventional slab. The slight reduction in ultimate load can be attributed to the presence of voids, which reduce the effective concrete area and stiffness of the slab. However, the load–deflection behavior of the Bubble Deck slab was smooth and continuous, indicating stable structural performance without any sudden or brittle failure.

The increase in deflection observed in the Bubble Deck slab is primarily due to reduced stiffness resulting from the voids. Despite this, the deflection values remained within permissible limits, confirming satisfactory serviceability performance. These findings validate the fundamental concept that the concrete in the neutral axis contributes minimally to flexural strength and can be replaced without significantly affecting structural behavior.

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Pimpri Chinchwad College Of Engineering
Nigdi Pradhikaran
Compression Test Report

Machine Model	: TUE-C-1000	Test File Name	: pcet_2026.Utm
Machine Serial No	: 2014 /110	Date	: 02-03-2026
Customer Name	: Pimpri Chinchwad College of Engg.	Customer Address	: Sector no 26, Nigdi pradhikaran
Lot Number	:	Test Type	: Compression
Order No.	:	Heat Number	:
Item	:		

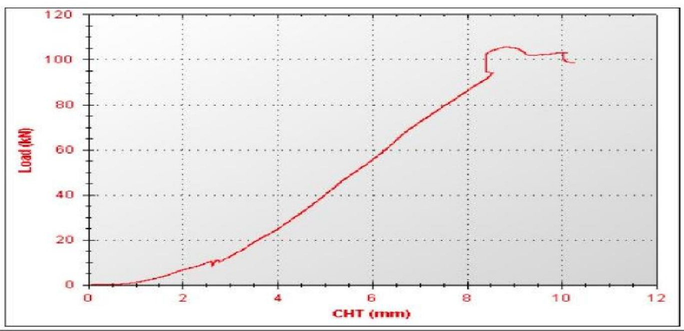
Input Data

Specimen Shape	: Concrete cube	
SpecimenType	: Concrete Cube	
Specimen Description	:	
Specimen Width	: 600	mm
Specimen Thickness	: 150	mm
Beam Span	: 0	mm
Pre Load Value	: 0	kN
Max. Load	: 1000	kN
Max. Elongation	: 250	mm
Specimen Cross Section Area	: 90000	mm2

Output Data

Load at Peak	: 105.610	kN
Elongation at Peak	: 8.890	mm
Compression Strength	: 1.173	N/mm2
Loat at 0 mm is	: 0	kN
Elongation at 0 kN is	: 0	mm

Load Vs. Elongation



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In addition to structural performance, the Bubble Deck slab achieved approximately 30 percent reduction in concrete usage and self-weight. This reduction can lead to decreased loads on supporting elements and improved efficiency in structural design, particularly in multi-storey and long-span constructions.

Bubble Deck Slab Performance

Characteristic	Flexural Behavior	Punching Shear Behavior	Serviceability Performance
Bubble Deck Slab	Comparable strength, outer layers resist stress	Reduced capacity, requires careful design	Slightly higher deflection, similar crack patterns
Conventional Slab	Standard flexural strength	Standard punching shear resistance	Standard deflection, standard crack patterns

V. CONCLUSION

The present study demonstrates that the Bubble Deck slab using polypropylene spheres is a structurally efficient and sustainable alternative to conventional reinforced concrete slabs. The system effectively reduces concrete consumption and self-weight while maintaining approximately 90 percent of the load-carrying capacity of a conventional slab.

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Although a slight increase in deflection is observed due to reduced stiffness, the values remain within acceptable limits, ensuring that serviceability requirements are satisfied. The experimental results confirm that the removal of non-structural concrete from the neutral axis does not significantly affect flexural performance.

Furthermore, the use of polypropylene spheres contributes to sustainability by promoting the reuse of plastic materials and reducing the carbon footprint associated with cement production. Overall, the Bubble Deck slab system provides an effective balance between structural performance, material efficiency, and environmental sustainability, making it suitable for modern construction practices.

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