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A Review of Sustainable Construction Practices with Bubble Deck Slabs and Their Environmental Benefits

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***Abstract*—This review compiles and critically examines twenty exploration studies on Bubble Deck slab technology, a voided biaxial reinforced concrete slab system designed to replace non-structural concrete in the slab core with recycled plastic spheres. Originating in Denmark in the 1990s, this invention has been shown to reduce slab self-weight by 25–50% while maintaining adequate structural performance. The substantiated studies explore various aspects of the technology, including structural behaviour under static and dynamic loading, seismic and fire resistance, effects of void geometry and materials, integration with sustainable concrete mixes, prefabrication methods, and optimisation strategies. Key findings across the literature indicate significant reductions in material consumption, foundation loads, and CO_2 emissions, along with faster construction cycles and cost savings. While limitations such as lower punching shear capacity and increased deflection have been noted, many works present effective design modifications to mitigate these issues. The collective evidence positions Bubble Deck slabs as a sustainable, economical, and technically viable alternative to conventional solid slabs, with broad applicability in modern construction, especially suitable for long-span, lightweight, and environmentally conscious designs.**

***Index Terms*—Bubble Deck slab, lightweight concrete., recycled plastic spheres, voided biaxial slab.**

I. INTRODUCTION

Bubble Deck slab technology is an advanced voided biaxial reinforced concrete system first developed in Denmark in the 1990s, designed to replace the non-structural concrete in the central portion of a slab, incorporating hollow plastic spheres, usually made of HDPE or polypropylene, positioned between the upper and lower reinforcement meshes. This innovative approach achieves a self-weight reduction of approximately 25–50%, enabling longer spans without intermediate beams, smaller foundation sizes, and significant material savings, all while retaining 60–90% of the bending and shear capacity of conventional slabs. The twenty studies reviewed in this paper span experimental testing, finite element simulations, and comparative analyses, covering structural aspects such as flexural behaviour, punching shear resistance, deformation patterns, seismic performance, fire resistance, and the influence of void geometry, ball size, and reinforcement spacing. Researchers consistently report environmental benefits, with reductions of up to 40 kg CO_2 per square meter of slab, decreased energy consumption during production and transport, and the reuse of waste plastics, which enhances the system's suitability for green building certification. Economically, the technology offers 10–40% cost savings through lower material usage, faster construction cycles—often 20% quicker—and reduced transportation demands. While some limitations have been identified, including lower punching shear capacity, slightly higher deflection, and the need for skilled labour, several studies propose solutions such as optimised void sizing, increased reinforcement in critical zones, the use of GFRP sheets, and prefabricated panel systems to enhance performance. Overall, the collective body of research positions Bubble Deck slabs as a sustainable, cost-effective, and structurally efficient alternative to traditional solid slabs, particularly suited to large-span structures, seismic zones, and projects with stringent environmental targets.

II. LITERATURE REVIEW SUMMARY

1. ARCHIT GARG ET AL. (2019):

The paper by Archit Garg provides an in-depth study of Bubble Deck slab construction. This innovative voided, bi-axial reinforced concrete slab system uses hollow recycled-plastic spheres to replace non-structural concrete in the central part of the slab. Developed in Denmark, this technology reduces the structural dead weight by approximately 35–50% while maintaining sufficient load-bearing capacity. The hollow HDPE spheres are placed between the top and bottom reinforcement meshes, allowing for longer spans without intermediate beams, thereby providing architectural flexibility and reducing the need for extensive support systems.

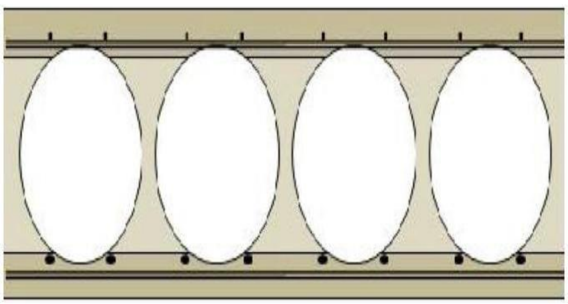

FIG. 1: SECTION OF BUBBLE DECK SLAB

As shown in Fig. 1, the Bubble Deck slab section demonstrates the placement of recycled plastic spheres. The study highlights several benefits, including reduced concrete use, lower CO_2 emissions, smaller foundation sizes, faster construction cycles (up to 20% quicker), and cost savings of about 18% compared to traditional slabs. Tests comparing Bubble Deck and conventional slabs showed a significant weight reduction of nearly 30%, with a small decrease in flexural strength of around 19%. The system offers substantial environmental benefits, with each kilogram of recycled plastic replacing up to 100 kilograms of concrete. For every 500 m^2 of floor area, it can save 100 m^3 of concrete, reduce CO_2 emissions by 27 tons, and decrease foundation loads by 180 tons. However, the technology has some limitations, such as lower punching shear capacity, the need for skilled labour, and unsuitability for slabs with limited thickness. Overall, Bubble Deck technology is a sustainable, cost-effective, and structurally efficient alternative to conventional slabs, aligning with modern green building goals and offering significant potential for future use in long-span and architecturally complex structures [1].

2. HARSHIT VARSHNEY ET AL. (2017):

The paper by Harshit Varshney provides an overview of Bubble Deck slab technology, a modern biaxial hollow slab system that reduces the self-weight of concrete structures by replacing the unused concrete in the slab's core is substituted with hollow spheres made from high-density polyethene (HDPE). This innovation, developed in Denmark in the 1990s, achieves a 30–50% weight reduction, which in turn decreases loads on columns, walls, and foundations, resulting in smaller foundation sizes and overall material savings. The study explains three main types of Bubble Deck slabs—filigree elements, reinforcement modules, and finished planks—each suited to different construction requirements. The technology offers multiple advantages: structurally, it eliminates the need for beams, allows longer spans, and maintains comparable flexural strength to solid slabs; environmentally, it uses recycled materials, reduces CO_2 emissions by up to 40 kg/m^2, and lowers energy and material consumption; economically, it cuts costs in transportation, materials, and construction time. Experimental studies cited in the paper show that Bubble Deck slabs can achieve up to 80% of the load-bearing capacity of conventional slabs while drastically reducing dead weight, with negligible differences in durability, shrinkage, and creep. Fire resistance ranges between 60 and 180 minutes, and thermal performance is slightly improved due to the air voids. Overall, the paper concludes that Bubble Deck is an efficient, sustainable, and cost-effective alternative to traditional concrete slabs, with strong potential for modern green building applications [2].

3. ZALENA ABDUL AZIZ ET AL. (2021):

The paper by Zalena Abdul Aziz reviews the design and performance of the Bubble Deck slab system, a biaxial hollow slab using recycled plastic balls to replace non-structural concrete. It reduces slab self-weight by about 30%, lowering loads on foundations and cutting material usage. The study outlines three variants: filigree elements, reinforcement modules, and finished planks. A PRISMA-based review analysed 18 studies from 2010–2021, focusing on void former size, shape, and material. HDPE and polypropylene are the most common materials for void formers due to their strength, durability, and recyclability. Spherical balls are widely used, but some studies suggest that elliptical shapes offer better load capacity, while other studies report contradictory results. Larger void formers reduce weight but increase deflection, requiring optimal sizing and spacing. Adding GFRP sheets can improve stiffness and reduce deflection by up to 75%. As shown in Fig. 2 and Table 1.

FIG 2. BUBBLE DECK SLAB SYSTEM UNDER CONSTRUCTION AT THE SITE.

TABLE I THE PARAMETERS OF THE BUBBLE SLAB SYSTEM

Type	Slab Thickness. (mm)	Balls diameter (mm)	Span (m)	Mass (kg/m2)	Concrete onsite (m^3/m^2)
BD230	230	Ø 180	7 – 10	370	0.10
BD285	280	Ø 225	8 – 12	460	0.14
BD340	330	Ø 270	9 – 14	550	0.18
BD395	380	Ø 315	10 – 16	640	0.20
BD450	420	Ø 360	11 – 18	730	0.25

Although slightly lower in load capacity than solid slabs, proper design can achieve similar performance. Overall, Bubble Deck slabs offer structural efficiency, cost savings, and environmental benefits, making them a sustainable alternative to conventional slabs [3].

4. VICTOR OSAZE FRANCIS (2019):
The paper by Victor Osaze Francis reviews the suitability and performance of Bubble Deck slab systems compared to conventional solid slabs. Bubble Deck slabs replace the structurally redundant middle concrete with high-density polyethene (HDPE) spheres, reducing dead weight by 35–50% and enabling longer spans without beams.

FIG 3. REINFORCEMENT MODULE

The study outlines three main installation methods—Filigree Element, Reinforcement Module, and Finished Plank—and describes key components including steel reinforcement, recycled plastic balls, and concrete. Performance analysis indicates that Bubble Deck slabs retain up to 87% of the bending stiffness of solid slabs while requiring only 66% of the concrete, and exhibit bending strength about 90% of conventional slabs, shear strength 60–80%, and punching shear around 90%. The system also demonstrates comparable fire resistance (60–180 minutes) and substantial environmental benefits, saving 1 kg of CO_2 for every 25 kg of concrete replaced. For every 5,000 m², it can reduce 1,798 tons of foundation load, 278 tons of CO_2 emissions, and 1,745 GJ of energy. Limitations include increased deflection and reduced shear capacity, but these can be mitigated with design adjustments such as shear reinforcements, increased slab depth in critical zones, or column heads. As shown in **Fig. 3** Overall, the paper concludes that Bubble Deck is a viable, sustainable alternative to conventional slabs, offering cost, material, and environmental savings while maintaining adequate structural performance [4].

5. DEEPAK CHAVHAN ET AL. (2022):
The paper by Deepak Chavhan presents a review and experimental study on the Bubble Deck slab system, a modern construction method that uses hollow high-density polyethene (HDPE) spheres to replace the non-structural concrete located in the central portion of a slab. This approach reduces the slab's dead weight by 30–50%, leading to smaller foundations, reduced material usage, and faster construction. The study examines the practicality, load-bearing capacity, and comparative performance of Bubble Deck slabs against conventional slabs. Literature reviewed in the paper indicates that the ratio of bubble diameter to slab thickness affects performance, with both spherical and elliptical balls improving efficiency depending on design needs. Experimental results using M30 grade concrete showed that Bubble Deck slabs can withstand about 80% of the stress capacity of conventional slabs while offering significant weight savings. Compressive strength tests yielded values up to 33.56 N/mm² at 28 days, and flexural strength tests showed that beams with Bubble Deck configuration performed close to conventional beams.

FIG 4. REINFORCEMENT

The ultrasonic pulse velocity (UPV) test confirmed good concrete quality and minimal internal defects. Key advantages identified include reduced concrete usage (1 kg of recycled plastic can replace 100 kg of concrete), higher load efficiency, and environmental benefits from recycling and reduced CO_2 emissions. As shown in **Fig. 4** Limitations noted include the need for skilled labour, lower punching shear capacity, and design considerations for optimum performance. Overall, the paper concludes that Bubble Deck technology is an effective, eco-friendly, and economical alternative to traditional slabs, suitable for applications in parking structures, commercial buildings, and auditoriums [5].

6. P. PRABHU TEJA ET AL. (2012):
P. Prabhu Teja et al. investigated an innovative flooring concept known as the Bubble Deck slab, in which the solid concrete portion in the middle of the slab is replaced with a grid of hollow plastic balls. This design change aims to remove non-structural concrete, thereby reducing weight without sacrificing strength. Their analytical comparison between Bubble Deck slabs and conventional solid slabs revealed that the Bubble Deck option is approximately 35% lighter. This weight reduction leads to a smaller dead load on the building structure. They observed that bending stresses in Bubble Deck slabs were about 6.43% lower than those in solid slabs, which suggests improved stress distribution. However, the slabs exhibited about 5.88% more deflection under load, indicating slightly increased flexibility. The shear strength was found to be 60% of the solid slab's capacity, which must be accounted for in design. Overall, the study recommended Bubble Deck technology as an efficient and innovative alternative to traditional heavy concrete floors, especially in projects prioritising weight reduction [6].

7. K. R. DHEEPAN ET AL. (2017):
K. R. Dheepan et al. carried out experimental research on Bubble Deck slabs incorporating polypropylene balls of different diameters (60 mm and 75 mm) with varying reinforcement spacing. Their results showed a clear trend — slabs with smaller balls achieved higher flexural strength than those with larger balls, regardless of the spacing between reinforcement bars. Interestingly, the study also found that increasing bar spacing could further enhance flexural strength in

certain configurations. Beyond structural performance, the slabs offered non-structural advantages: the voids created by the balls improved thermal insulation properties, making the slabs more energy-efficient in regulating indoor building temperatures. Moreover, this method demonstrated reduced construction time and cost, and since it requires less concrete and steel, it was classified as a "green technology" due to its environmental benefits [7].

8. SANKALP K. SABALE ET AL. (2019):
Sankalp K. Sabale et al. performed an experimental analysis of Bubble Deck flat slabs to assess material savings and cost-effectiveness. Their study confirmed that replacing a portion of concrete with hollow balls significantly lowered concrete consumption, resulting in a 13.39% reduction in total construction costs compared to conventional slabs. They also reported a reduction in dead load of up to 10.07%. However, these savings came with trade-offs — the slabs displayed greater deflection under load and had a lower ultimate load-carrying capacity. Cracks primarily developed diagonally on the underside of the slab, along with some longitudinal cracks. These findings suggest that while Bubble Deck slabs are lighter and cheaper, their reduced stiffness and lower load capacity must be addressed during structural design [8].

9. MIR SHAHED ALI ET AL. (2019):
Mir Shahed Ali et al. explored the mechanical performance of Bubble Deck slabs incorporating hollow polythene balls, comparing them directly to conventional solid slabs. Their research indicated superior performance in certain structural aspects — Bubble Deck slabs showed greater flexural strength, increased stiffness, and higher shear force capacity than their solid counterparts. The method proved to be significantly more economical, with the researchers estimating a 40% improvement in construction cost-efficiency. Weight reduction was another major benefit, as the hollow balls replaced a substantial volume of concrete. The team also examined slabs made from different concrete grades (M20 and M25), analysing their cracking behaviour and modes of failure. They concluded that Bubble Deck slabs not only save materials but can also be engineered to meet or exceed the strength requirements of traditional slabs [9].

10. M. SURENDAR ET AL. (2016):
M. Surendar et al. conducted both experimental tests and numerical simulations using Finite Element Analysis (FEA) to evaluate Bubble Deck slabs made with recycled sphere balls. Their findings revealed that these slabs were capable of withstanding 80% of the stress experienced by conventional solid slabs. In FEA simulations, Bubble Deck slabs showed better overall structural performance, particularly in terms of stress distribution and deformation patterns. The use of recycled balls also reinforced the system's environmental credentials, reducing the need for virgin materials and lowering the carbon footprint of the construction process. The researchers concluded that with proper design adjustments, Bubble Deck slabs can provide both sustainability and strength advantages over traditional systems [10].

11. RUSHIKESH U. KAMBLE ET AL. (2022):
Rushikesh U. Kamble et al. focused on the application of Bubble Deck technology in addressing seismic performance issues in large-span slabs. Heavy concrete structures tend to be less suitable in seismic zones due to their high inertia forces during earthquakes. The study found that Bubble Deck slabs could reduce structural weight by 25–50%, which directly decreases seismic forces. The hollow HDPE balls were positioned within reinforcement meshes, replacing the non-structural concrete. Using Ansys software, the team compared stress and deflection performance with conventional slabs, finding that Bubble Deck slabs to perform satisfactorily in both aspects. The method also provided significant environmental benefits, including reduced energy use and lower emissions during material production and transportation [11].

12. PURNACHANDRA SAHA ET AL. (2014):
Purnachandra Saha et al. examined the concept and benefits of Bubble Deck slabs with a focus on structural and environmental performance. They found that the slabs are 30–50% lighter than conventional slabs, reducing the load on columns and foundations and allowing for more efficient building designs. Environmentally, the reduced material usage translated to lower CO_2 emissions and less energy consumption during both production and transport. Structural characteristics such as moment, deflection, and stress distribution were analysed using Finite

Element Method (FEM) software SAP2000, confirming that Bubble Deck slabs perform well under practical loading conditions [12].

13. HARISHMA ET AL. (2015):
Harishma K. R. investigated the use of prefabricated Bubble Deck floor elements, which are manufactured under controlled factory conditions and then assembled on site. The approach combined two forms of reinforcement — a universal mesh layer for general slab strength and vertical supports placed at columns and beams for localised reinforcement. Prefabrication allowed for better quality control, faster installation, and reduced on-site labour, while retaining the benefits of Bubble Deck's weight and material savings [13].

14. CALIN S. ET AL. (2010):
Calin S. carried out experimental work to assess how concrete strength, along with the shape and diameter of hollow plastic balls, affected the behaviour of Bubble Deck slabs under gravitational loads. Their results demonstrated that these factors directly influence cracking patterns, deformation behaviour, and ultimate failure modes. They found that using hollow sphere balls generally improved the slab's load-bearing capacity, especially when combined with optimised concrete strength and ball geometry [14].

15. HASHEMI ET AL. (2018):
Hashemi assessed the ductility of reinforced concrete structures incorporating Bubble Deck slabs using nonlinear static analysis. While the detailed ductility metrics weren't specified in the available summary, their findings suggested that Bubble Deck-enabled structures can maintain adequate ductility under loading conditions. This implies reasonable deformation capacity before failure—crucial in seismic design—highlighting Bubble Deck slabs as viable options for buildings requiring ductile performance characteristics [15].

16. SAIFULLA ET AL. (2019):
Saifulla and Azeem (2019) compared the seismic behaviour of conventional slabs, flat slabs, and Bubble Deck slabs using SAP2000. The analysis considered displacement, bending moments, shell stresses, axial forces, and foundation reactions. Results showed that Bubble Deck slabs outperformed both conventional and flat slabs in seismic response, while using significantly less concrete due to weight reduction. The lightweight nature of Bubble Deck systems contributes to reduced base shear and foundation demands, improving overall seismic resilience while cutting materials and emissions [16].

17. ANSARI ET AL. (2023):
Ansari conducted a numerical study using Abaqus to examine the *fire resistance* of bidirectional Bubble Deck slabs under elevated temperatures. They modelled six simply supported slabs (1500 mm × 1500 mm × 150 mm), five incorporating plastic void spheres and one solid control. Their simulations revealed that, while Bubble Deck slabs perform comparably under normal conditions, exposure to high temperatures affects their structural behaviour. The foam spheres reduce mass but also impact thermal response; the study highlights the need to account for temperature-induced changes in stiffness and load capacity in design practices [17].

18. STASZAK ET AL. (2023):
Staszak presented a sensitivity analysis combined with numerical homogenization to identify which design parameters most influence the *load-bearing capacity* and weight of Bubble Deck slabs. Their results showed that slab height and void geometry (size, shape, and arrangement of the plastic balls) are the most critical factors. In contrast, concrete grade, steel type, and reinforcement quantity had only a minor effect on stiffness and weight. These insights can guide optimisation: by selecting void geometry and slab depth carefully, designers can maximise structural efficiency and minimise self-weight [18].

19. AHMED NISAR ET AL. (2024):
Ahmed Nisar explored the structural performance of Bubble Deck slabs incorporating *fly ash in the concrete mix*. Published in Materials Today: Proceedings, the study examined how partial cement replacement with fly ash affects flexural behaviour, sustainability, and mechanical properties. Although specific numerical results weren't detailed in the abstract, their work aims to combine lightweight design with green materials—further reducing carbon footprint while maintaining structural integrity [19].

20. ALI SABAH MAHDI ET AL. (2022):
Ali Sabah Mahdi and Shatha Dehyaa Mohammed conducted an experimental investigation into the structural behaviour of Bubble Deck slabs under static uniformly distributed loading. Their study involved five full-size (2.5 m × 2.5 m × 0.2 m) fixed-end supported two-way slabs—comparing solid concrete slabs to Bubble Deck variants incorporating hollow spheres of diameters 100 mm and 120 mm, which achieved concrete volume reductions of 15–18%. With identical concrete strength and reinforcement (Ø10 mm @ 164 mm), they systematically evaluated load-bearing behaviour, deflection patterns, bending stiffness, and crack propagation. The results showed that while the Bubble Deck slabs offered significant weight savings due to reduced concrete volume, their structural response under uniform load exhibited predictable differences in stiffness and performance. These findings provide valuable benchmarks for designing Bubble Deck systems in real-world applications, balancing self-weight reduction with acceptable load and deflection performance [20].

III. CONCLUSION

The review of twenty studies on Bubble Deck slab technology demonstrates its strong potential as a sustainable, cost-efficient, and structurally effective alternative to conventional solid slabs. By replacing non-structural concrete in the slab's core with recycled plastic spheres, this system reduces self-weight by 25–50%, enabling longer spans, smaller foundations, and faster construction while lowering material usage, CO_2 emissions, and transportation demands. Although limitations such as reduced punching shear capacity and slightly higher deflections exist, numerous design solutions—such as optimised void sizing, additional reinforcement in critical zones, and use of GFRP sheets—effectively address these concerns. The technology's adaptability to seismic zones, fire resistance, and compatibility with sustainable concrete mixes further enhances its application in modern construction. Overall, Bubble Deck slabs offer a viable path toward greener building practices, combining structural efficiency with significant environmental and economic benefits, making them well-suited for large-span, lightweight, and environmentally conscious designs.

IV. ACKNOWLEDGMENT

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V. DISCLAIMERS

The authors declare that the opinions and conclusions expressed in this paper are solely those of the authors and do not necessarily reflect the views of their affiliated institutions or sponsors.
The authors also confirm that there are no conflicts of interest regarding the publication of this paper.

VI. NOTATION LIST

The following symbols are used in this paper:

BD = Bubble Deck slab system;
HDPE = High-Density Polyethylene;
CO_2 = Carbon dioxide;
GFRP = Glass Fiber Reinforced Polymer;
M = Concrete grade (e.g., M25, M30);
UPV = Ultrasonic Pulse Velocity test.
Supplemental Materials

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