IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

The Bubble deck technology

Parth Pandey , Ms.Deepti Hazari , Dr.sindhu J. Nair

M.tech, Assistant Professor, Head Of Civil Department B.I.T

Department of Civil Engineering, Chhattisgarh Swami Vivekanand Technical University, Bhilai Institute Of Technology, Durg, Chhattisgarh

Abstract

The Bubble Deck slab system represents an innovative structural technology designed to reduce the self-weight of reinforced concrete slabs without compromising their load-bearing performance. By replacing non-functional concrete in the slab's neutral zone with recycled high-density polyethylene (HDPE) spheres, this method decreases dead load, material consumption, and carbon emissions while promoting sustainable construction practices. In this study, experimental investigations were carried out on M30-grade concrete cubes embedded with 1-ball and 5-ball Bubble Deck configurations. Standard tests—including slump tests for workability and compressive strength tests at 7, 14, and 28 days—were conducted in accordance with IS codes. Results indicated that Bubble Deck specimens achieved a compressive strength of up to 47 MPa at 28 days, satisfying the requirements for structural application, while reducing slab volume by approximately 23–28%. The slump values (80–90 mm) confirmed medium workability suitable for slab casting. Findings further highlight cost reductions of up to 30% and significant environmental benefits through reduced cement usage and incorporation of supplementary materials such as fly ash. However, limitations such as increased deflection and reduced punching shear capacity were observed, suggesting the need for optimized reinforcement strategies. Overall, this study validates Bubble Deck technology as a structurally efficient, eco-friendly, and economically viable alternative to conventional solid slabs, with strong potential for adoption in high-rise, long-span, and sustainable construction projects.

Introduction

In modern construction, reducing the self-weight of structural elements without compromising strength and performance is a key goal, especially in high-rise and long-span buildings. The Bubble deck cube system is an innovative structural technology that addresses this challenge by incorporating hollow plastic spheres into reinforced concrete slabs. These spheres, made from recycled materials, replace non-functional concrete in the slab's centre, significantly reducing the slab's dead weight by up to 50%. This not only lowers the overall load on columns, beams, and foundations but also reduces material usage and construction costs.

Originally developed in Denmark, the Bubble Deck system combines the benefits of two-way slabs with enhanced environmental and structural efficiency. It offers improved flexural performance and rigidity compared to conventional solid slabs while being more sustainable. However, the introduction of voids can reduce shear strength, especially in slab-column connections, making shear reinforcement a critical design consideration. This research focuses on analyzing the structural behaviour and performance of Bubble Deck slabs, aiming to optimize their application in modern construction while addressing their limitations in punching shear resistance.

1.2 Background:-

The Bubble Deck slab is an innovative structural system developed to reduce the self-weight of reinforced concrete slabs without compromising their strength or load-bearing capacity. This technology incorporates hollow spherical voids—usually made from recycled plastic—strategically placed within the slab to replace non-functional concrete in the central zone, where concrete primarily acts as filler rather than contributing to structural performance. By removing unnecessary concrete, the Bubble Deck system significantly decreases the dead load, which in turn reduces the size of columns, beams, and foundations required for a structure. This results in material savings, faster construction, and improved cost efficiency. The reduced concrete volume also leads to lower carbon emissions, making it a more sustainable alternative to traditional solid slabs.

Initially developed in Europe, the concept has gained global attention in recent years due to its structural efficiency, environmental benefits, and adaptability to various architectural designs. Today, Bubble Deck slabs are used in a range of applications, from commercial and residential buildings to large-scale infrastructure projects, offering a balance between strength, economy, and sustainability.

1.3 Scope of the bubble deck technology :-

Bubble Deck slab technology has broad applications in modern construction, offering the advantage of reduced weight, material savings, and enhanced sustainability without compromising structural performance. By significantly lowering slab weight, it reduces the overall load on a structure, enabling the construction of taller buildings with lighter foundations. Its suitability for large-span projects makes it ideal for applications such as airports, auditoriums, bridges, and industrial facilities where wide, open spaces are essential. The incorporation of recycled plastic spheres supports eco-friendly construction practices and helps minimize carbon emissions by reducing cement usage. Additionally, the system offers economic benefits through material efficiency and faster installation, which together lower overall project costs and timelines. Its versatility also allows architects greater design freedom, enabling spacious layouts with fewer columns and thinner slabs while maintaining the required strength and durability.

1.4 Challenges for bubble deck technology:-

A key barrier to the adoption of Bubble Deck slab technology in India is the absence of dedicated guidelines within the Indian Standards (IS codes) for its design, construction, and evaluation. Being a relatively recent innovation in the country, its application often requires engineers to depend on international standards or manufacturer recommendations, which may not fully correspond with local construction conditions, available materials, or regulatory requirements. This gap in codal provisions leads to uncertainties during structural approvals, necessitates additional testing, and can slow down project timelines. Consequently, many professionals opt for conventional slab systems that are already well-supported by IS codes. The inclusion of specific design and execution criteria for Bubble Deck slabs in national standards would significantly encourage its acceptance and use in India.

1.4.1 Skilled Workforce Requirement

Installation demands trained personnel familiar with the system, which is limited in the Indian construction sector.

1.4.2 Conservative Industry Approach

Many stakeholders prefer tried-and-tested conventional slab systems over newer methods due to concerns about performance and risk.

1.5 Advantages of bubble deck slab technology:-

- Reduces self-weight by 10–35% compared to solid slabs.
- Saves materials (less concrete and steel needed).
- Allows longer spans without increasing thickness.
- Reduces foundation size and cost due to lighter load.
- Speeds up construction with prefabricated panels.
- Eco-friendly – uses recycled plastic balls and lowers CO_2 emissions.
- Improves seismic performance by reducing mass.
- Maintains **fire** resistance and durability similar to solid slabs.
- Flexible **in** design for irregular layouts.

1.6 Application of bubble deck slab technology:-

- **High-rise buildings** – Reduces dead load, allowing taller structures with smaller foundations.
- **Long-span structures** – Suitable for auditoriums, airports, and exhibition halls.
- **Office buildings & commercial complexes** – Provides open floor space with fewer columns.
- **Parking garages** – Enables wide spans and open layouts for vehicle movement.
- **Residential projects** – Reduces structural weight in multi-storey apartments.
- **Hospitals & educational institutions** – Allows flexible interior planning and large open areas.

- **Industrial buildings** – Supports heavy service loads with efficient structural design.

- **Renovation & retrofitting** – Ideal where reducing structural weight is critical without compromising strength.

Fig. 1 Bubble deck slab

Fig. 2 Cube of bubble deck

Objective of the work

The primary objective of this research is to investigate the efficiency and performance of the Bubble Deck system as a modern and sustainable alternative to conventional reinforced concrete slab designs. This study aims to evaluate the structural behaviour of Bubble Deck cube, focusing on their load-bearing capacity, deflection characteristics, and overall strength under various loading conditions. It also seeks to analyze the material efficiency and cost-effectiveness of the system by assessing the reduction in concrete usage and overall construction costs. In addition, the research will explore the environmental benefits of Bubble Deck technology, such as reduced material waste, and cost during the construction process. Furthermore, the study intends to develop practical design guidelines for the application of Bubble Deck slabs in diverse structural scenarios and propose optimization strategies for their integration into modern construction practices. Ultimately, this research aims to provide valuable insights into the advantages and limitations of Bubble Deck systems, encouraging their broader adoption in both residential and commercial projects.

Literature Review

2.1) Case study

1) Experimental Study on Bubble Deck Technology Ranjeet Chandre, Pratik Gotake, Atharv Chavan, Sumit Bhalke, Prof. R. B. Kesarkar Department of Civil Engineering, JSPM's Imperial College of Engineering and Research Wagholi, Pune, Maharashtra, India.

The results of these studies have typically shown that Bubble Deck slabs may provide structural performance that is equivalent to or even superior than that of conventional solid slab structures while utilizing less concrete. Furthermore, it has been shown that using Bubble Deck slabs reduces a building's total weight, resulting in decreased foundation and structural expenses. Overall, the results of the experimental tests point to the Bubble deck cube as a viable and ground-breaking innovation with the potential to completely alter the way slabs made of concrete are conceived of and built.

Based on the results of this experiment, it has been determined that:
1) Typical compressive strength of a normal slab with a thickness of 100 mm is 32 N/mm2 for specimens with 20 mm ball spacing.
2) The average compressive strength of the slab for a bubble deck cube with a thickness of 100 mm is 27.06 N/mm2 for specimens with balls spaced at 20 mm apart, respectively.

A decrease in the self-weight of the slab with the same compressive strength as the traditional slab results from an 11–12% reduction in the amount of concrete used. Compared to a traditional slab, this option has a lower overall cost, a shorter building period, and green technologies?
1) The consumption of materials was decreased by using less concrete. Dead load was reduced by up to 10.07% as a result.
2) It was found that the deflection of a flat bubble deck cube is greater than that of a traditional slab.
3) The bubble deck flat slab's maximum load bearing capacity was decreased by 11.22%.
4) The bottom fractures are both diagonal and longitudinal. In both situations, the majority of the fractures are longitudinal and identical.
5) Compared to standard concrete, costs were lowered by 13.39%.

2)Punching shear behaviour of LWA bubble deck cube with different types of shear reinforcement Maha Habeeb , Adel A. Al-Azzawi, Faiq M.S. Al-Zwainy Al-Nahrain University, Baghdad, Iraq.

1. In general, for lightweight aggregate concrete slab shear reinforcement existence leads to reduce the deflection at ultimate load by at least 35% with respect to slab without shear reinforcement
2. All specimens with shear reinforcement before reaching failure
Load showed lesser deflection at the same load level compared to the control specimen without shear reinforcement.
3. For the same void ratio, the existence of hook or stud shear reinforcement decreases the amount of absorbed energy by at least 50%. While for slab with inclined shear reinforcement, the absorb energy is increased to reach (107.2%) with respect to energy of slab without shear reinforcement.
4. The inclined shear reinforcement has the most positive effect on lightweight voided slab behaviour in terms of ultimate load, deflection, and slab toughness because the inclined reinforcement located perpendicular to the potential shear crack path. This causes a clear reduction in the effect of shear stresses on the column-slab connection region.
5. The punching shear capacity for lightweight aggregate concrete may be significantly improved by using devolved reinforced concrete shear reinforcement rather than using traditional one.

3)Building energy and exergy analysis of the light-weight roofs compared with the traditional ones in different climates Mohammad Hossein Jahangir , Saheb Ghanbari Motlagh Renewable Energies and Environmental Department, Faculty of New Sciences and Technologies, University of Tehran, Tehran, Iran.

During winter, analysis shows that a waffle slab roof can reduce heat loss in buildings by around 17% compared to a traditional cement block roof across all three studied regions. In contrast, the bubble deck roof demonstrates a significantly higher thermal performance, reducing heat loss by nearly 76%. Among the locations, Valencia recorded the lowest heat loss, while Denver experienced the highest.

However, during the summer months, the performance trend shifts. On July 15th, typically one of the warmest days of the year, the waffle slab roof actually resulted in approximately a 60% increase in heat gain, making it less effective than the cement block roof. The bubble deck roof, however, maintained superior performance, reducing heat gain by about 41% on average. The lowest heat gain in summer was recorded in Denver, due to its cooler summer temperatures.

Reducing heat transfer whether loss in winter or gain in summer plays a key role in lowering energy demand. When comparing the overall heating energy consumption, both the waffle slab and cement block roofs showed comparable results. However, the bubble deck roof offered an average reduction of 6.8% in heating energy usage across all regions.

In terms of cooling energy demand during summer, the bubble deck roof again outperformed the others, showing the lowest energy consumption. The waffle slab roof, on the other hand, led to an increase in cooling energy usage in all locations.

The enhanced thermal insulation of the bubble deck roof can be attributed to the trapped air pockets and the layered concrete-mesh structure, which limits heat transfer effectively.

Finally, an analysis of natural gas and electricity consumption during January and July was conducted to evaluate the economic and environmental impacts of energy use. Lower consumption of these resources directly results in reduced fossil fuel dependency and a decline in greenhouse gas emissions, owing to the decreased need for electricity generation.

4)Experimental studies for comparing Conventional concrete with Bubble deck concrete Samantha Konuri, T.V.S. Vara lakshmi Department of Civil Engineering, Dr.Y.S.R.A.N.U. College of Engineering & Technology, Acharya Nagarjuna University, Nagarjuna Nagar.

The test specimens of BDCC, BDFACC cubes are compared with CCC, & CFACC in terms of Compression Strength, percentage of Weight Reduction & Volume of Concrete. In every grade of concrete the in-active concrete is replaced by PP hollow ball in three different sizes i.e.30 mm, 60 mm & 90 mm ball. The results vary for the concrete with different size of ball for 28 days, 90 days, 180 days and 360 days .
In this review, it was found that the % of weight Reduction is increases then the Compressive Strength of the concrete is decrease by 0 to 0.09 %. Using the same Water/Cement ratio of different grades M20, M25 and M30 grades, the Weight reduction of M20 grade is 7.49 % using 90 mm PP hollow ball compared to Conventional Concrete (CC). The other two sizes of 30 mm, 60 mm polypropylene hollow balls are less % of weight Reduction in M20 grade. Using 90 mm polypropylene hollow ball the percentage of Weight reduction is more compared to conventional concrete cubes (CCC), Conventional Fly ash concrete cubes (CFACC),and Bubble Deck concrete cubes (BDCC),Bubble Deck fly ash concrete cubes using 30 mm,60 mm polypropylene hollow balls. The Fly ash cubes are slowly increasing their Compressive strength compared to conventional cubes (CCC) and Bubble deck concrete cubes (BDCC). The conventional concrete cube (CCC) weight should be compared to the Bubble Deck Concrete weight is reduced 2 to 8 % based on that the cost of the Bubble Deck concrete is reduced to 10 to 30 %. And also the Compressive strength of Conventional concrete cubes and Bubble Deck concrete cubes are almost same. Finally I concluded that, the Bubble Deck constructions are light weight, low cost, eco-friendly

2.2) Inferences Drawn from Literature Review

a) Structural Efficiency and Material Optimization.

Research has consistently demonstrated that Bubble deck cube systems can notably decrease the self-weight of a structure—ranging from 10% to 50%, depending on the size of the voids and the type of concrete used. This weight reduction translates into:Up to 12% less concrete usage, A decrease in dead loads transferred to columns and foundations, Overall construction cost reductions between 10% and 30%, and Comparable or slightly reduced compressive strength when measured against traditional solid concrete slabs.

b) Environmental and Economic Advantages.

The use of hollow plastic spheres made from recycled materials, combined with lower concrete usage, enhances the environmental sustainability of Bubble Deck systems. Key benefits include: A reduced carbon footprint during construction, Enhanced building energy performance due to better insulation properties, and Lower consumption of electricity and natural gas—especially in cooler climates—which helps reduce greenhouse gas emissions.

c) Design Challenges and Reinforcement Considerations

Despite their benefits, Bubble Deck slabs have some structural limitations: The presence of voids decreases the punching shear resistance, Flat slab configurations may experience greater deflection under load, and Additional shear reinforcement is essential, particularly in lightweight aggregate concrete systems, to prevent shear failure and improve structural integrity.

d) Role of Shear Reinforcement.

Experimental findings highlight the importance of proper reinforcement design: Inclined shear reinforcement has proven to be the most effective, as it aligns with the typical direction of shear cracks, thereby improving performance, Slabs with shear reinforcement show up to 35% lower deflection and over twice the energy absorption capacity compared to slabs without such reinforcement.

e) Thermal Efficiency and Energy Reduction.

Bubble Deck slabs also offer thermal performance advantages: In both hot and cold climates, they outperform waffle and cement block roofs by retaining heat in winter and reducing cooling loads in summer, These thermal properties contribute to an approximate 6.8% reduction in energy use for heating, offering both economic and environmental benefits.

f) Durability and Long-Term Performance.

In terms of long-term strength: The compressive strength of Bubble Deck slabs remains stable over extended curing periods (up to 360 days), Fly ash-based Bubble Deck variants exhibit gradual but consistent strength development, making them a viable option for sustainable construction projects.

Methodology

Material use

3.1.1) Concrete:- M30 concrete is a design mix concrete with a characteristic compressive strength of 30MPa (megapascals) after 28 days of curing. The term "M30" is derived from the mix's compressive strength, where “M” stands for Mix and “30” indicates the strength in MPa. Unlike nominal mixes (like M5 to M20), M30 is a design mix, meaning the mix proportions are determined based on specific engineering requirements, not fixed ratios.

Material	Source	Wt (Kg/cum)	Sp .Gravity	Wt/Sp. Gravity
Cement	Utratech OPC 43	318	3.15	0.101

3.1.2) HDPE Ball:-HDPE balls are used in bubble deck slabs to reduce the self-weight of concrete by replacing non-load-bearing concrete with hollow plastic spheres. Placed between reinforcement layers, they help lower material usage without affecting structural strength. This results in lighter, cost-effective, and environmentally friendly slabs, ideal for long span and sustainable development.

Fig.3 HDPE ball

3.1.3) FLY Ash:-A byproduct of coal combustion in power plants, is used in concrete as a supplementary cementitious material. Its pozzolanic properties enhance workability, durability, and long-term strength, while reducing heat of hydration and cement usage. This makes concrete more economical, sustainable, and suitable for mass structures and harsh environments

Material	Source	Wt.(Kg/cum)	Sp. Gravity	Wt./Sp. Gravity
Fly ash	NSPCL, Bhilai	80	2.2	0.036

.

3.1.4) Admixture:- STP Shaliplast PCE 300 is an advanced polycarboxylate ether (PCE)-basedsuperplasticizer developed for contemporary concrete needs. It is engineered to deliver improved work ability, rapid early strength development**,** and significant water reduction in concrete mixtures. As a third-generation admixture, it enhances the flow-ability of concrete without increasing the water-to-cement ratio, making it ideal for high-performance, high-strength, and-self-compacting concrete (SCC)**.**This admixture is widely applied in ready-mix concrete**,** precast components, tall structures, and large infrastructure works, where consistent strength, durability, and ease of placement are essential. Additionally, it supports sustainable construction practicesby allowing for lower cement usage while maintaining or enhancing overall concrete quality.

Material	Wt.(Kg/cum)	Sp. Gravity	Wt/Sp. Gravity
STP Shaliplast PCE 300	3.957	1.070	0.004

3.1.5) Aggregate:-

a) Fine aggregate:-Fine aggregate, often referred to as sand, is a key component in concrete that fills spaces between larger aggregates and enhances the mix's workability. Comprising particles smaller than 4.75 mm, it contributes to the concrete's strength, durability, and surface finish by creating a dense and well-packed mixture. The quality and proper grading of fine aggregate are important to ensure strong, workable, and long-lasting concrete used in construction projects like buildings and pavements.

i) Source of fine aggregate:- Mudpar, Chhattisgarh

b)Coarse aggregate:- Coarse aggregate consists of larger particles, typically greater than 4.75 mm in size, such as gravel, crushed stone, or recycled concrete. It forms the bulk of the concrete mix and provides the necessary strength and stability to the structure. By creating a solid framework within the concrete, coarse aggregate reduces shrinkage and helps resist compressive forces. Its size, shape, and quality significantly influence the workability, strength, and durability of concrete. Proper selection and grading of coarse aggregates are essential to achieve a well-balanced mix suitable for various construction applications, including foundations, beams, slabs, and pavements.

ii)Source of aggregate:- Mahanadi., Chhattisgarh

3.1.6) Specific gravity:-Specific gravity of aggregates is a key physical property that indicates the ratio of the density of the aggregate to the density of water. It reflects the quality and strength of the aggregates used in concrete. Knowing the specific gravity helps in mix design calculations, ensuring the right proportion of materials for a durable and strong concrete mix. Accurate measurement of specific gravity assists engineers in determining the aggregate's density and void content, which directly affect the concrete's strength and durability. Aggregates with higher specific gravity usually indicate denser and stronger material suitable for construction purposes.

1) **Specific gravity of 20mm aggregate:-** 2.176
2) **Specific gravity of 10mm aggregate:-** 2.697

3.1.7) Sieve analysis:- Sieve Analysis is a laboratory or field test used to determine the particle size distribution of granular material—most commonly soil, aggregates, or sediments. It's essential in fields like civil engineering, geology, and materials science.

Figure 3

i)Coarse aggregate:- Conforming of table-7 of IS code 383:2016

ii) Fine aggregate:- Conforming to grade zone-II of table-9 of IS code 383:2016

3.1) Mix design for M30 according to IS:10262:2009 :-

Step 1- Determine the target mean strength of concrete:

Ft = fck + k.s

Where, FT = Target mean strength at 28 days.

fck = Characteristic compressive strength of concrete at 28 days.

k = 1.65 as per IS 456:2000.

s = Standard deviation as per IS 456:2000

Table 1 Assumed Standard Deviation
(*Clauses* 3.2.1.2, A-3 *and* B-3)

Sl No. (1)	Grade of Concrete (2)	Assumed Standard Deviation N/mm² (3)
i)	M 10	3.5
ii)	M 15	
iii)	M 20	4.0
iv)	M 25	
v)	M 30	5.0
vi)	M 35	
vii)	M 40	
viii)	M 45	
ix)	M 50	
x)	M 55	

Step 2 – Choosing water/cement ratio

Volume of water = (mass of water / specific gravity of water)*1/1000

From the given Table-5 of IS 456, select the preliminary water–cement ratio corresponding to the required exposure condition. This value should then be verified against the limiting value to ensure the desired durability.

Table 5 Minimum Cement Content, Maximum Water-Cement Ratio and Minimum Grade of Concrete for Different Exposures with Normal Weight Aggregates of 20 mm Nominal Maximum Size

(*Clauses* 6.1.2, 8.2.4.1 *and* 9.1.2)

Sl No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum Cement Content kg/m³	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete	Minimum Cement Content kg/m³	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete
1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Mild	220	0.60	-	300	0.55	M 20
iii)	Moderate	240	0.60	M 15	300	0.50	M 25
iii)	Severe	250	0.50	M 20	320	0.45	M 30
iv)	Very severe	260	0.45	M 20	340	0.45	M 35
v)	Extreme	280	0.40	M 25	360	0.40	M 40

Step 3 – Calculation of cement content

$$\textbf{Volume of cement} = \frac{\text{weight of cement}}{\text{Specific gravity of cement}} \times \frac{1}{1000}$$

Step 4 – Estimation of proportion of coarse aggregate

Table 5 Minimum Cement Content, Maximum Water-Cement Ratio and Minimum Grade of Concrete for Different Exposures with Normal Weight Aggregates of 20 mm Nominal Maximum Size

(Clauses 6.1.2, 8.2.4.1 and 9.1.2)

Sl No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum Cement Content kg/m³	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete	Minimum Cement Content kg/m³	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete
1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Mild	220	0.60	-	300	0.55	M 20
iii)	Moderate	240	0.60	M 15	300	0.50	M 25
iii)	Severe	250	0.50	M 20	320	0.45	M 30
iv)	Very severe	260	0.45	M 20	340	0.45	M 35
v)	Extreme	280	0.40	M 25	360	0.40	M 40

3.2.2) Calculation for mix design

a) Volume of concrete mix = 1.0 M^3

b) Volume of Entrapped air in wet concrete = 0.010 M^3

c) Volume of cement -(mass of cement /sp.gr of water)×(1/1000) = 0.101 M^3

d) Volume of water – (mass of water /sp.gr of water)×(1/1000) = 0.166 M^3

e) Volume of fly ash – (mass of flyash/ sp.gr of fly ash)×(1/1000) = 0.0364 M^3

f) Volume of admixture –(mass of admixture/ sp.gr of admixture)×(1/1000) = 0.004 M^3

g) Volume of aggregate = {(a-b)-(c+d+e+f)} = 0.683 M^3

h) Mass of CA (20mm) = g×vol of CA-2×sp.gr CA-1×1000 = 557 Kg

i) Mass of CA(10mm) = g× vol of CA-2×sp.gr of CA-2×1000 = 553 Kg

j) Mass of FA (river sand) = g× vol of FA-1×sp.gr of FA-1×1000 = 694 Kg

Mix proportion for trail weight (saturated surface dry)

Cement	318 Kg/M^3
Fly ash	80 Kg/M^3
CA2(20mm)	557 Kg/M^3
CA1(10mm)	553 Kg/M^3
FA1(river sand)	694 Kg/M^3
Water	166 Kg/M^3
Admixture @1.0% by weight of cement	3.975 Kg/M^3
Density of mix	2372 Kg/M^3

3.3) Test on concrete

3.3.1) Slump test:- The slump test is a straightforward on-site method used to assess the consistency and workability of fresh concrete. It serves as a quick quality control tool to ensure that each batch of concrete meets the required specifications before pouring. Conducting slump tests across multiple batches also helps detect variations in the mix, allowing for timely adjustments if needed.

The main goal of the slump test is to evaluate the water-to-cement ratio and the workability of the concrete. A higher slump generally indicates greater workability, which may suggest too much water in the mix — potentially compromising strength and durability.

Slump observation (mm)	Unit	Trail no-1	Trail no-2	Trail no-3	Average at 90 min
Initial	mm	185	180	180	100
After 60min	mm	140	135	140	100
After 90min	mm	100	95	105	100

Type of slump

i) Shear Slump

The top portion of the concrete slides off to one side, showing a lack of cohesion in the mix. This result typically means the sample isn't valid, and a retest is needed.

ii) Collapse Slump

The concrete completely collapses and spreads out. This suggests excessive water—making the mix overly fluid and potentially weak.

iii) True Slump

The concrete subsides uniformly, preserving much of the cone's original shape. This is the ideal result—indicative of good consistency and workability.

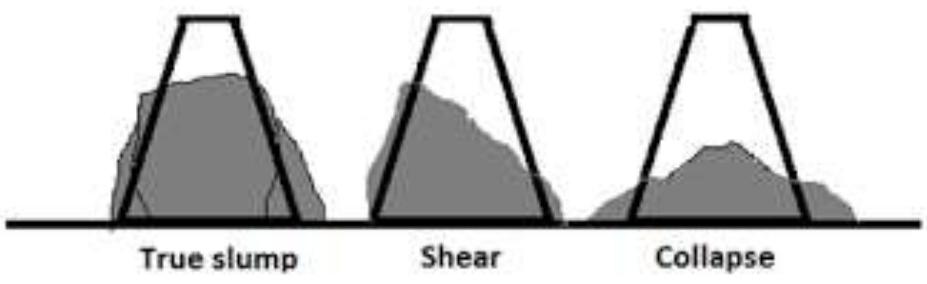


Fig.5 Different type of slump

3.4) Procedure (IS 1199:2018)

1. **Scoop:**

The mould is filled in three layers, each containing the same volume of concrete, though not the same depth. To achieve equal volumes, the first layer should reach a depth of approximately 2 5/8 inches (70 mm), and the second layer should be filled up to about 6 1/8 inches (160 mm). While placing the concrete, move the scoop around the edge of the cone's opening to ensure even distribution. The third and final layer should be overfilled slightly, allowing for any necessary additions during the Rodding process.

Figure 4

2. **Consolidate:**

Using a tamping rod with the correct size and a rounded (hemispherical) tip is essential for accurate test results. Substituting it with materials like rebar, which lack the proper tip shape, can displace the aggregate rather than evenly compact the concrete. Additionally, a rod that is too short may be hard to handle and could prevent proper Roding through the full depth of each layer Each layer should be compacted with 25 evenly spaced strokes, distributed uniformly throughout the layer's depth. For the first layer, insert the rod without striking the base or base plate aggressively. In the following layers, the rod should penetrate approximately 1 inch (25 mm) into the layer below to ensure proper bonding. Begin the Roding process slightly angled near the perimeter to achieve even compaction at the edges, then proceed in a spiral pattern toward the centre using vertical strokes.

3. **Strike-Off:**

Once Roding is finished, use only the tamping rod to level the concrete with the top edge of the cone. Achieve a smooth, even surface by applying a horizontal screening motion while simultaneously rolling the rod. This technique ensures a clean strike-off without further compacting the concrete sample.

4. **Lift:**

Secure the cone by holding one handle and use your other hand to remove any excess concrete around its base. Then, either lift your foot off the opposite foot tab or disengage the clamping mechanism. While keeping the cone steady, switch hands and repeat the cleanup on the other side. With both hands gripping the handles, slowly and steadily lift the cone straight upward in a vertical motion—avoiding any twisting. The lift should be completed within 5 ± 2 seconds.

Figure 5

3.5) Measure:

Once the slump cone is lifted, the concrete will settle—or in the case of high-slump mixes, may collapse entirely. To determine the slump value, measure the vertical distance between the top edge of the mould and the highest point at the center of the subsided concrete. This measurement should be taken to the nearest 1/4 inch (5 mm). If part of the concrete breaks or shears off during the test, the results are invalid, and the procedure must be repeated with a fresh sample.

Fig.8 performing slump test

3.6) Workability of concrete (IS 456:2000)

It refers to how easily freshly mixed concrete can be mixed, placed, compacted, and finished without segregation or bleeding.

- It determines ease of handling in construction.
- A workable concrete mix flows smoothly and fills formwork properly.
- It must allow proper compaction to avoid voids and ensure strength.

Factors Affecting Workability:

1. **Water content** – More water increases workability (but too much reduces strength).
2. **Aggregate shape and size** – Rounded aggregates improve workability.
3. **Cement content** – More cement usually means better lubrication.

Placing condition	Degree of workability	Slump (mm)
1) Trench fill, In-situ pilling Tremie concrete	**High**	100-150(mm)
2) Heavily reinforced slab section ,Beam ,Column ,Wall	**Medium**	50-100 (mm)

4. **Admixtures –**	**3)** Lightly reinforced section, Beam, column	**Low**	25-75 (mm)

Plasticizers and superplasticizer can improve workability without increasing water.
Table no.1

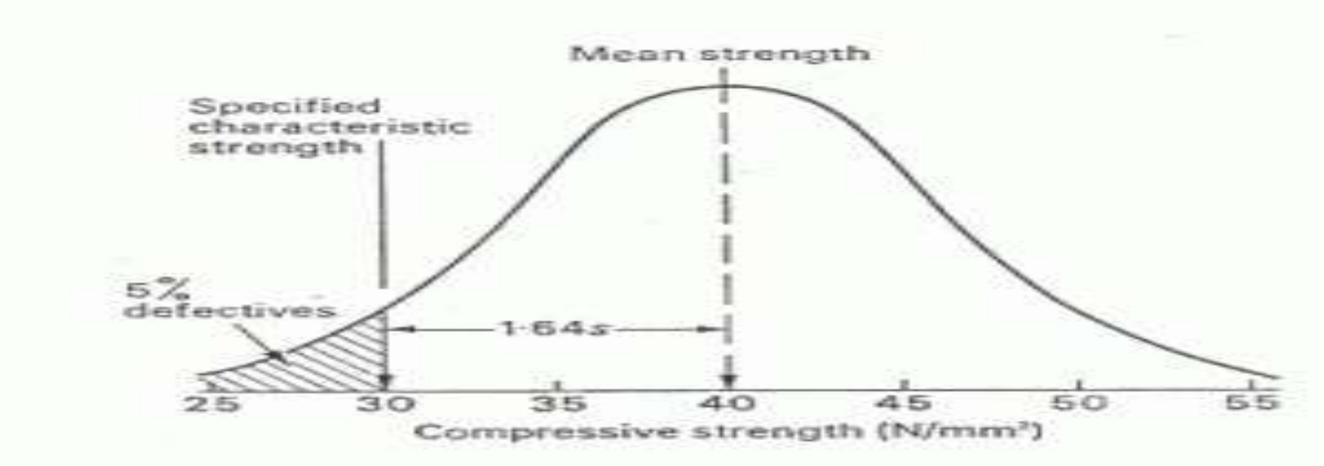
Fig.9 Taking slump test measurement

3.7) Test on concrete cube

1. Compressive strength: Concrete is one of the most widely used construction materials in the world, valued for its strength, durability, versatility, and cost-effectiveness. Among its various mechanical properties, compressive strength stands as the most critical and commonly measured parameter, serving as a primary indicator of the material's structural capacity and performance. Compressive strength refers to the ability of a material to withstand axial loads that tend to reduce its size. In concrete, it is the resistance offered to the crushing or compressive forces, and it is fundamentally influenced by a range of factors including the quality and proportion of constituent materials, water-cement ratio, curing conditions, compaction, and age.

Understanding and accurately determining the compressive strength of concrete is essential for structural design, quality control, and safety assessment. It directly impacts the design of foundations, beams, columns, slabs, and other load-bearing components in buildings, bridges, and infrastructure projects. Typically measured in megapascals (MPa) or pounds per square inch (psi), compressive strength is evaluated by crushing standard cylindrical or cubical specimens under controlled conditions, as outlined in various codes and standards such as ASTM C39 or IS 516.

Concrete Grade	Compressive Strength at 28 Days (MPa)	Typical Use Cases
M5	5	Non-structural works, levelling courses
M7.5	7.5	Blinding concrete, pathways
M10	10	Curbing, flooring (non-structural)
M15	15	Plain concrete, footpaths
M20	20	Residential slabs, beams, footings
M25	25	Reinforced concrete structures
M30	30	Commercial buildings, high-rise structures
M35	35	Industrial structures, bridge piers



Normal Distribution curve on test specimens for determining compressive strength

2. Equipment Required:

The test has been conducted using a compression testing machine that complies with the specifications outlined in IS 14858. It is essential that the machine is properly calibrated at the time of testing. Calibration should be performed at a minimum frequency of once every year.

i) CTM machine:-A Compression Testing Machine (CTM**)** is a specialized mechanical testing device used to evaluate the compressive strength of materials. Compressive strength is the capacity of a material or structure to withstand axial compressive forces—that is, forces that pushes or squeezes it together.

Figure 6

Compression testing machine

3. Reference:

This testing method is based on the specifications outlined in **IS 516 (Part 1/Section 1): 2021**, titled *"Hardened Concrete – Methods of Test"*. This standard offers comprehensive instructions and recommendations for evaluating the strength properties of hardened concrete. It includes the following key testing procedures:

- **Compressive Strength Test**: Describes the process for casting, curing, and testing concrete specimens to determine their ability to withstand axial loads using properly calibrated equipment.
- **Flexural Strength Test**: Provides a method to assess the concrete's resistance to bending by specifying specimen size, support arrangements, loading methods, and result interpretation.
- **Split Tensile Strength Test**: Details a procedure in which a cylindrical concrete specimen is loaded along its diameter to evaluate its tensile strength.

These standardized procedures promote consistency, accuracy, and dependability in test outcomes, which are essential for ensuring construction quality, structural performance, and adherence to regulatory standards.

3.8) Test Specimen (5 ball specimen cube)

3.8.1) the test specimen shall be a cube or a cylinder meeting the requirements of IS: 1199 (Part 5) and IS: 516 (Part 4) for concrete cores. The standard cube and cylinder specimen shall not be tested if they are badly honeycombed as this is an indication of poor specimen making. When such specimens are tested, the test report shall include the fact that the specimen was honeycombed.

Figure 7

3.8.2) Age at Test: 7, 14and 28 days Tests have been done as recognized ages of the test specimens, the most usual being 7 and 28 days.

3.8.3) Number of Specimens: 3 **(As per IS 516 (Part 1/Sec 1): 2021**

a) Size of HDPE ball: - we have used HDPE ball of diameter range from 36mm to 37mm, As there is no IS code standardization prescription for the use of ball in bubble deck cube, the IS code is under development, the purpose of HDPE ball is make it cost effective and efficient we have use procured the material from local available source which make it reliable to use.

Figure 8

3.9.) Procedure

3.9.1) Preparation and Placement of Test Specimens:

Before testing, it's important to properly prepare the concrete specimens to ensure accurate and reliable results. If the specimens have been stored in water for curing, any excess surface moisture must be gently removed—this helps prevent slipping or interference during testing.

Figure 9

The **dimensions of each specimen** should be measured accurately to the nearest **0.2 mm**, and their **weight must be recorded**. These measurements are necessary for calculating parameters like density and verifying compliance with size specifications.

Once the specimen is taken out of the curing tank, **testing should be done as soon as possible**, ideally within **2 hours**. This time limit is crucial because the properties of the specimen can change due to moisture loss or temperature variation. To avoid drying out, the specimen should be **kept covered with a wet cloth** until it is tested.

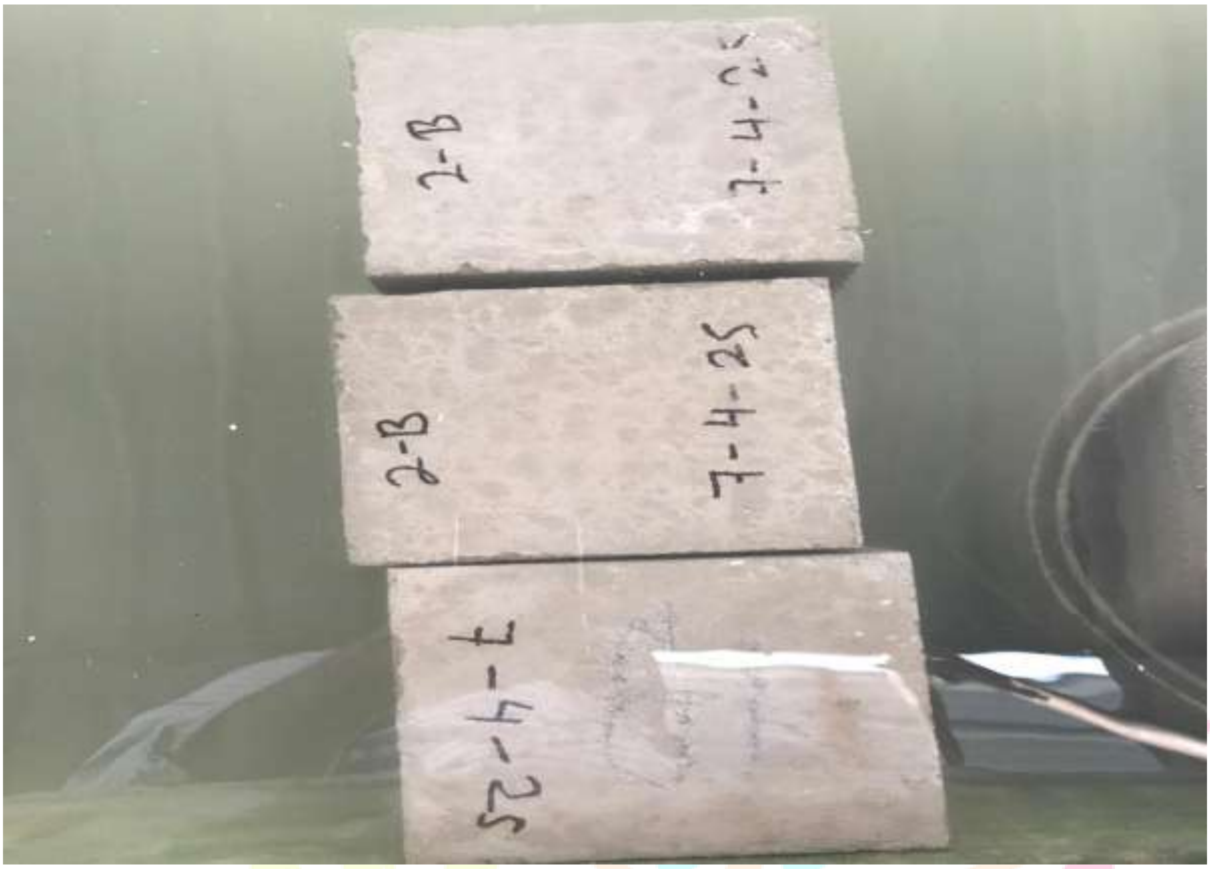
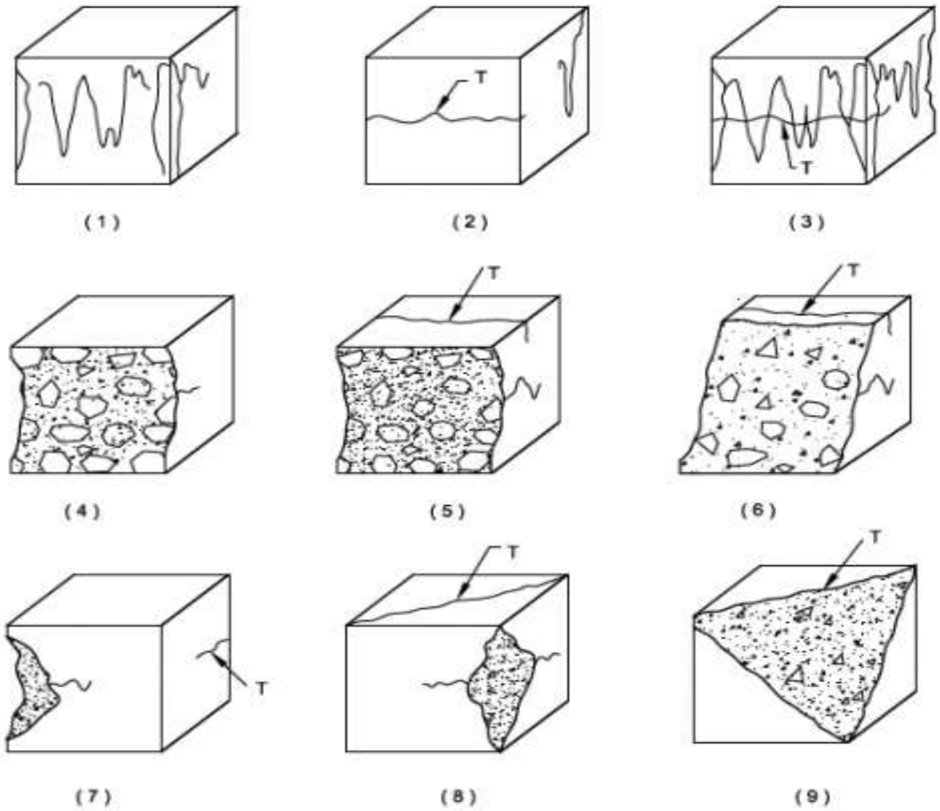


Fig.14 Curing of bubble deck cube

Before placing the specimen in the testing machine, **the bearing surfaces of the machine must be cleaned** to remove any dust, grit, or loose materials. Likewise, the contact surfaces of the specimen should also be cleaned. This step is essential to ensure proper contact between the specimen and the platens, which helps maintain even load distribution during testing and avoids inaccurate readings.

Fig.15 under compression testing machine



NOTE: T = TENSILE CRACK
FIG. 2 UNSATISFACTORY FAILURE OF CUBE SPECIMENS

Fig.16 placing bubble deck cube in CTM

3.10) Test specimens (1 Ball):-

Fig.17 placing HDPE ball in cube

The test specimen must be either a cube or a cylinder and should comply with the specifications outlined in IS: 1199 (Part 5) and IS: 516 (Part 4) concerning concrete cores. Specimens that are significantly honeycombed, indicating improper preparation, should not be used for standard testing. If such defective specimens are tested, the test report must clearly state that the specimen exhibited honeycombing.

3.10.1) Age at Test: 7, 14and 28 days Tests have been done as recognized ages of the test specimens, the most usual being 7 and 28 days.

3.10.2) Number of Specimens: 3 **(As per IS 516 (Part 1/Sec 1): 2021**

a)Size of ball use:- We have use HDPE ball of diameter between 57mm to 58mm, there is no IS code standardization on the diameter of ball as it a developing area under the shadow of civil engineering scope.

(We have HDEP ball which are available in the market for the purpose of game and decoration this makes the use of HDEP ball more efficient in terms of use and availability)

Fig.18 Taking diameter using venire calliper

3.11) Procedure

3.11.1) Preparation and Placement of Test Specimens:

Before testing, it's important to properly prepare the concrete specimens to ensure accurate and reliable results. If the specimens have been stored in water for curing, any excess surface moisture must be gently removed—this helps prevent slipping or interference during testing. The dimensions of each specimen should be measured accurately to the neares**t** 0.2 mm**, and their** weight must be recorded**.** These measurements are necessary for calculating parameters like density and verifying compliance with size specifications. Once the specimen is taken out of the curing tank, **testing should be done as soon as possible**, ideally within **2 hours**. This time limit is crucial because the properties of the specimen can change due to moisture loss or temperature variation. To avoid drying out, the specimen should be **kept covered with a wet cloth** until it is tested. Concrete cube specimens should be tested with the load applied perpendicular to the casting direction. During testing, the specimen must be accurately centered on the lower platen within 1% of its designated size (for cubes) or diameter (for cylinders). The compressive load should be applied steadily and without shock, at a uniform rate of 14 N/mm^2 per minute, until the specimen can no longer sustain an increasing load. The highest load achieved during the test must be documented.

Following the test, the failure mode has been assessed. The failure corresponds to an acceptable pattern (as illustrated) this have been noted. In cases where the failure pattern deviates from acceptable modes, the type of failure must be identified and recorded according to the closest matching pattern shown

Figure 10

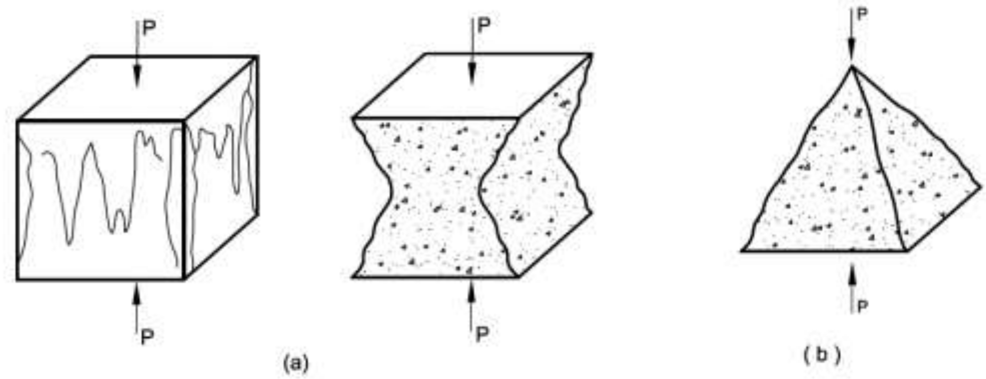


FIG. 1 SATISFACTORY FAILURE OF CUBE SPECIMENS
2

Chapter-4
Result and Discussion

4.1) Fineness of cement

$$\text{Fineness} = \frac{\text{Residual cement on sieve in gm}}{\text{Initially taken sample}}$$

$$= \frac{0.001}{0.1} \times 100$$

$$= 1\%$$

4.2) Aggregate use

Source: - Mudpar and Mahanadi

sp.gr of 20mm aggregate (SSD)	2.176
Sp.gr of 10mm aggregate (SSD)	2.697
Sp.gr of natural sand	2.539
Water absorption 20mm aggregate	0.45%
Water absorption 10mm aggregate	0.53%
Water absorption of natural sand	1.41%
	2.710 (MORTH section1008, limit2.0-3.5)
	20.8% (IS 383:2016)
	22.4% (MORTH section 1007, max-35%)
Sieve analysis	
Coarse aggregate	Conforming table 7 of IS 383-2016
Fine aggregate	Conforming of grading zone-II of table-9 of IS383-2016

4.3) Water cement ratio

a) Selection of water content

i) Maximum water content for 20mm nominal size aggregate (for50mm slump)
= 186 Kg (clause 5.3 of IS 10262)

ii) Increase in water/cement ratio for 125mm slump = 9.00% (clause 5.3 of IS10262)

iii) Estimate water content for 125mm slump = 203 Kg

b) As super-plasticizer admixture is use the water content can be reduce
= 18%

i) Reduced water content = 166Kg

4.4) Cement content

a) Water/cement ratio = 0.460

b) Water content = 166

Hence cement content = 361 Kg/M^3

It is proposed to add 20% fly ash in the mix in such situation increased in cementitious material content may be warranted. The decision on increase in cementitious material content and its percentage may be based on experience and trial.

c) Increasing cementitious content by mass of cement = 10% as per clause 5.4 of IS 10262:2019

d) The cementitious content = 398.00 Kg/M^3

e) Fly ash @ 20% by weight of cementitious material as per MORTH clause 1715-2 = 80 Kg/M^3

f) Cement content = 318 Kg/M^3

g) Revised W/C ratio = 0.418

Minimum cementitious content, 340 Kg/Cum and we achieved 387 Kg/cum Hence OK
Maximum cement (OPC) content, 450Kg/M^3 and we achieve 309Kg Hence OK

4.5) Result of slump test

The result of the slump test in our experimental procedure is around 80-90mm, therefore it comes under the category of medium workability of concrete which is suitable for slab casting on industrial as well as residential building as per IS code 456-2000.

7 WORKABILITY OF CONCRETE

7.1 The concrete mix proportions chosen should be such that the concrete is of adequate workability for the placing conditions of the concrete and can properly be compacted with the means available. Suggested ranges of workability of concrete measured in accordance with IS 1199 are given below:

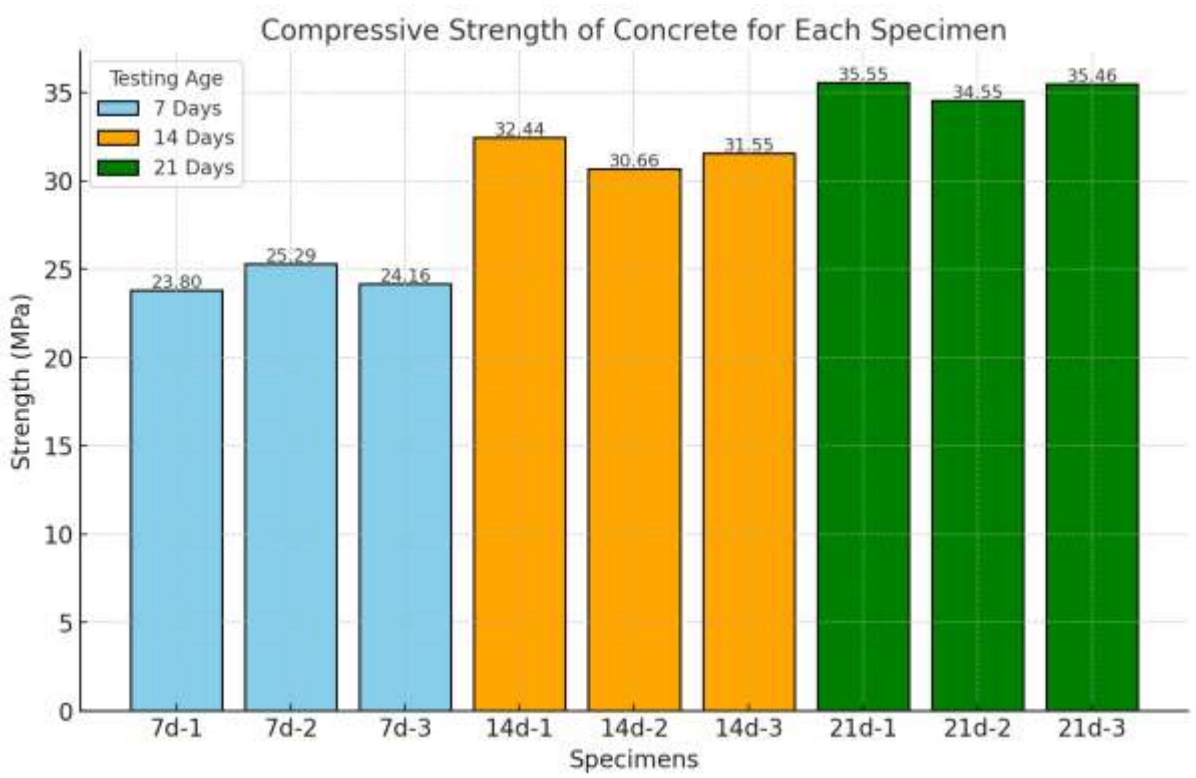
Placing Conditions	*Degree of Workability*	*Slump* (mm)
(1)	(2)	(3)
Blinding concrete; Shallow sections; Pavements using pavers	Very low	*See* **7.1.1**
Mass concrete; Lightly reinforced sections in slabs, beams, walls, columns; Floors; Hand placed pavements; Canal lining; Strip footings	Low	25-75
Heavily reinforced sections in slabs, beams, walls, columns;	Medium	50-100
Slipform work; Pumped concrete		75-100
Trench fill; *In-situ* piling	High	100-150
Tremie concrete	Very high	*See* **7.1.2**

NOTE—For most of the placing conditions, internal vibrators (needle vibrators) are suitable. The diameter of the needle shall be determined based on the density and spacing of reinforcement bars and thickness of sections. For tremie concrete, vibrators are not required to be used (*see also* 13.3).

4.6) 1 Ball specimen compression test.

S .no	Date of casting	Date of testing	Weight of specimen(gm.)	Load (kN)	Specimen strength (MPa)
1.(7day)	7-04-2025	14-04-2025	8160	535.50	23.80
2.			8035	569.0	25.29
3.			8125	543.60	24.16
1.(14day)	7-04-2025	21-04-2025	8150	730	32.44
2.			8013	690	30.66
3.			7961	710	31.55
1.(21day)	7-04-2025	05-05-2025	8060	862	35.55
2.			8170	777	34.55

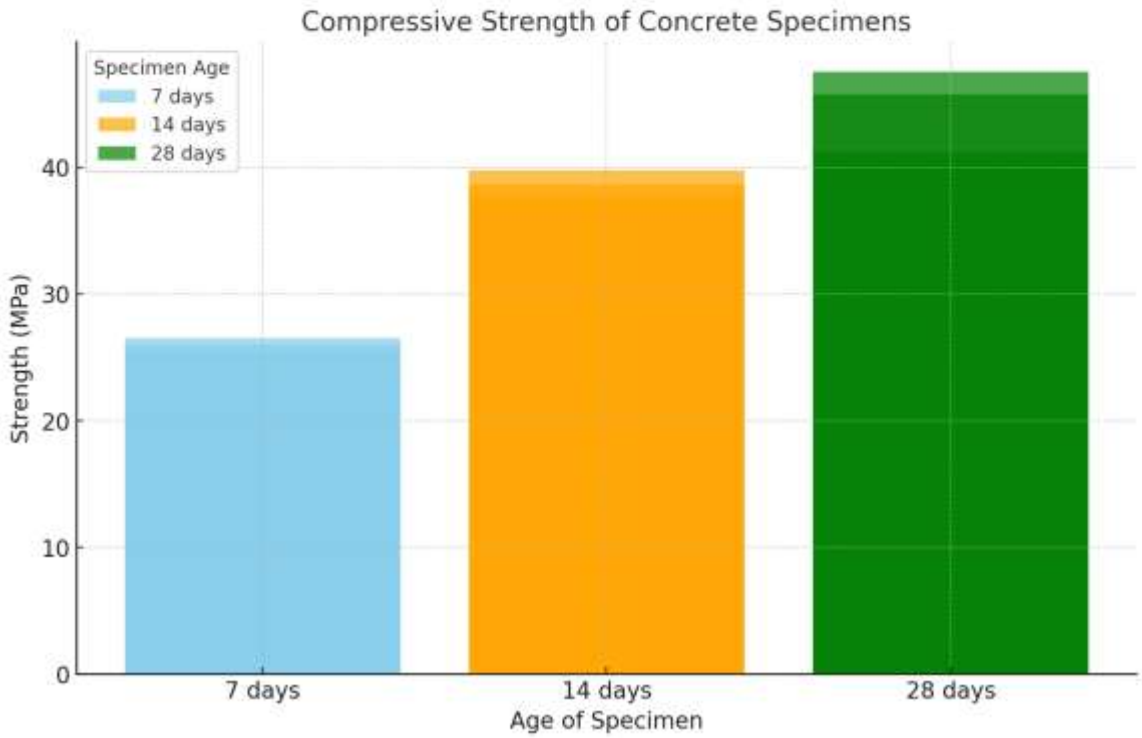
3.			**8120**	**798**	**35.46**



The graph represent the gain in strength in 7 day , 14 day , and 28 day of 1 ball specimen having a mix design of M30, the gain in strength is satisfactory according to the IS code 456:2000.

4.7) 5 Ball specimen compression test result

S no. (age of specimen)	Date of casting	Date of testing	Weight of cube (Kg)	Size of cube(cm)	Load (kN)	Strength of specimen(MPa)
1.(7 days)	7-04-2025	14-04-2025	8.049	15*15*15	597.5	26.55
2.			8.00		585.9	26.04
3.			8.34		569.2	25.29
1.(14days)	7-04-2025	21-04-2025	8.050		895	39.78
2.			8.100		846	37.6
3.			8.020		870	38.66
1.(28days)	7-04-2025	05-05-2025	8.115		927	41.21
			8.127		1030.3	45.79
			8.110		1070	47.55



The graph represent the gain in strength in 7 day , 14 day , and 28 day of 5 ball specimen having a mix design of M30, the gain in strength is satisfactory according to the IS code 456:2000.

4.8) Reduction of volume

a) 1 ball specimen

Volume of cube = 150*150*150
= 3375 cm^3

Volume of sphere $= \frac{4}{3} \times \pi \times r^3$ **(r for one ball specimen is 57mm)**

$$= \frac{4}{3} \times \pi \times 57^3$$

= 775.73 cm^3

So, reducing the area of volume of sphere by volume of cube which is 23% reduction in the volume of the cube

i.e. 3375-775.73 cm3

= 2599.27 cm^3

b) 5 ball specimen

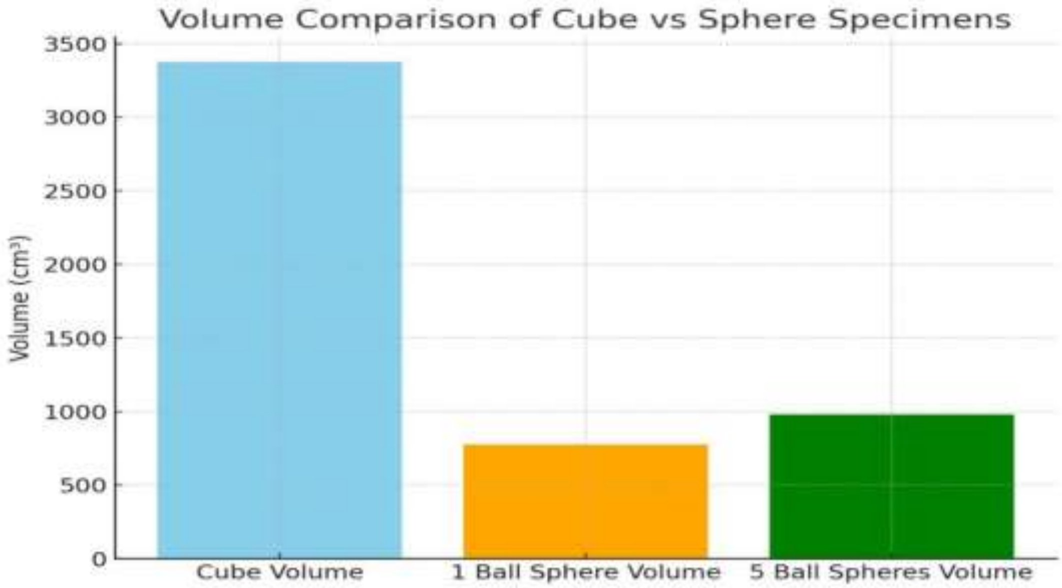
Volume of cube = 150*150*150
= 3375 cm^3

Volume of sphere $= \frac{4}{3} \times \pi \times r^3$ **(r for one ball specimen is 36mm)**

$$= \frac{4}{3} \times \pi \times 36^3$$

$= 195.43 cm^3$

So, as we use 5 ball of size 36mm which has the total volume of 195.43×5 which is $977.15 cm^3$ this reduces the volume of cube by 28%



Conclusion

The present experimental analysis validates the Bubble Deck slab system as a practical, eco-friendly, and structurally viable alternative to traditional solid concrete slabs. By incorporating lightweight HDPE spheres in place of non-structural concrete, a significant reduction in the slab's dead weight and concrete consumption was achieved—without compromising its load-bearing capabilities.

Compression tests conducted on concrete cubes with both 5-ball and 1-ball Bubble Deck configurations demonstrated a consistent increase in strength over time. By the 28th day, the compressive strength values were found to be well-aligned with the requirements for M30 grade concrete, indicating the system's suitability for conventional structural use.

Slump test results, ranging between 80 to 90 mm, indicated moderate workability, making the mix suitable for both residential and industrial slab applications. The system also demonstrated clear environmental advantages such as lower carbon emissions, reduced dependency on raw materials, and improved thermal insulation properties—contributing to energy savings over the building's life cycle. From a cost perspective, savings of approximately 10% to 30% were observed due to less material usage and reduced structural load requirements. However, the study also brought attention to some structural drawbacks, such as slightly increased deflection and reduced punching shear strength. These issues can be addressed effectively through the use of appropriate reinforcement strategies—particularly inclined shear reinforcement.

1. Reduced Structural Weight: Bubble Deck slabs achieved a 10–12% reduction in self-weight, which helps minimize the load transferred to supporting columns and foundations.

2. Cost Reduction: Overall construction expenses decreased by up to 30%, attributed to lower concrete consumption and improved construction speed.

3.Eco-Friendly Materials: The integration of recycled HDPE balls and fly ash led to decreased carbon emissions and promoted environmentally sustainable construction.

4. Compressive Strength Performance: After 28 days of curing, the slabs demonstrated compressive strength values reaching approximately 47 MPa, meeting the performance expectations for M30-grade concrete, despite minor reductions compared to traditional solid slabs

Reference

1) Experimental studies for comparing Conventional concrete with Bubble deck concrete Samantha Konuri, T.V.S. Vara lakshmi Department of Civil Engineering, Dr.Y.S.R.A.N.U. College of Engineering & Technology, Acharya Nagarjuna University, Nagarjuna Nagar, Guntur Dist, Andhra Pradesh 522510, India, Materials Today: Proceedings 80 (2023) 464–476

2) Punching shear behaviour of LWA bubble deck slab with different types of shear reinforcement Maha Habeeb , Adel A. Al-Azzawi, Faiq M.S. Al-Zwainy Al-Nahrain University, Baghdad, Iraq Journal of King Saud University – Engineering Sciences

3) Building energy and exergy analysis of the light-weight roofs compared with the traditional ones in different climates Mohammad Hossein Jahangir ∗, Saheb Ghanbari Motlagh Renewable Energies and Environmental Department, Faculty of New Sciences and Technologies, University of Tehran, Tehran, Iran, July 2023, Energy Reports 10 (2023) 1069–1090.
DOI: 10.1016/j.egyr.2023.07.043

4) Experimental Study on Bubble Deck Technology Ranjeet Chandre, Pratik Gotake, Atharv Chavan, Sumit Bhalke, Prof. R. B. Kesarkar
DOI: https://doi.org/10.56025/IJARESM.2023.114231467

5) IS 456:2000; Amendment no 1 June 2001 to IS456:2000 plain and reinforce concrete code of practice (fourth revision)

6) IS 10262:2009; Indian standard – concrete mix proportioning – Guideline (first revision) ICS91.100.30

7) IS 1199:2018; French concrete-Method of sampling, Testing and Analysis part 2determination of consistency of French concrete (first revision)

8) **Book:-** Recent trend in civil engineering byBibhuti Bhushan Das , Anil.k.Patnaik, Neena Shekhar , SPRINGER Publication

9) **Book:-** Mechanics of material by B.C Punamia, Er. Ashok kumar jain, Dr. Arun Kumar Jain, VISIONIAS (1 January 2024); VISIONIAS ltd.