Architecture Image Studies
AIS Scientific Journal

Vol.5 , Issue 1, Ubiquity, 2024

Experimental Study on Behaviour of Reinforced Concrete-Bubbled Beam

Mr. Shubham S. Zanwar[1], Mr. Sandeep B. Javheri[2], Dr. Mahesh G. Kalyanshetti[3]
[1]*PG Student, Dept, of Civil Engineering, Walchand Institute of Technology, Solapur, Maharashtra, India.*
[2]*Asst. Professor, Dept. of Civil Engineering, Walchand Institute of Technology, Solapur, Maharashtra, India.*
[3]*Associate Professor, Dept. of Civil Engineering, Walchand Institute of Technology, Solapur, Maharashtra, India.*

Abstract:
The construction industry constantly seeks innovative solutions to improve the efficiency and sustainability of building structures. One such advancement is the Bubble Deck Beam, which revolutionizes conventional beam design by incorporating air-filled plastic spheres into reinforced concrete beams. This study investigates the effect on displacement and flexural strength after introducing voids in beam by addition of HDPE balls in different numbers for different amount of volumetric reduction. Beams of size 150mm x 200mm x 1200mm were casted having concrete grade M25. Three number of beams were casted each for conventional beam with zero concrete replacement, BB1 having 2% volumetric reduction, BB2 having 4% volumetric reduction. BB3 having 6% volumetric reduction. BB4 having 8% volumetric reduction. The casted beams are cured for 28 days then this beam were tested for flexural strength. Simply supported beam with two equal point load acting at top surface of beam will be tested up to failure in well-equipped heavy structural laboratory. The behaviour of beam studied in concern with crack and ultimate load. Experimental findings suggest that 2% volumetric reduction is more optimal in usage.

Keywords:
High Density Polyethylene(HDPE) balls, volumetric reduction, Deflection,Flexural Strength.

1. Introduction

The Bubble Deck beam is a revolutionary construction technology that offers significant advantages in terms of efficiency, cost-effectiveness, and sustainability. It is an innovative system that enhances the traditional reinforced concrete beam by eliminating unnecessary concrete material, thereby reducing the weight of the structure without compromising its strength and integrity.

The Bubble Deck system was developed as a solution to address the challenges associated with conventional solid concrete slabs and beams. Traditional reinforced concrete structures often suffer from excessive dead load, which leads to higher material consumption, longer construction times, and increased costs. The Bubble Deck beam system aims to overcome these limitations by introducing hollow plastic spheres or "bubbles" into the concrete beams.

These plastic bubbles replace the non-structural concrete that is typically found in the center of reinforced concrete beams. By doing so, the system reduces the weight of the beam while maintaining its load-carrying capacity. The result is a structure that is not only lighter but also requires fewer raw materials, which contributes to sustainability and environmental friendliness.

The design and construction of Bubble Deck beams involve placing the plastic bubbles within the formwork and then pouring the concrete around them. The bubbles are arranged in a predetermined pattern, ensuring that the load distribution remains uniform throughout the beam. Once the concrete has cured, the bubbles within the beam create voids, reducing the overall weight of the structure without compromising its strength.

Advantages of Bubble Deck beams include:

a.Reduced Dead Load:- The system significantly reduces the weight of the structure, leading to cost savings in terms of materials and transportation.

b.Speedy in Construction: The lighter weight of Bubble Deck beams makes speedy in handling and installation and more efficient, potentially shortening construction schedules.

c.Cost-Effectiveness: The reduced material consumption and faster construction can lead to cost savings for both the initial construction and the lifetime maintenance of the structure.

d.Sustainability: The use of fewer raw materials and the potential for shorter construction times contribute to a smaller environmental footprint. Additionally, the voids created by the bubbles can be used to install services such as electrical and plumbing systems, further optimizing space utilization.

e.Architectural Flexibility: Bubble Deck technology allows for longer spans and more open layouts, providing architects with greater design freedom.

While Bubble Deck beams offer several advantages, it's important to note that proper engineering and construction practices are essential to ensure the structural integrity and safety of the building. The system's adoption may vary based on local building codes, construction practices, and project-specific requirements. Always consult with qualified structural engineers and construction professionals when considering innovative construction technologies like Bubble Deck beams.

2. Research Significance

Research on bubble deck beams holds substantial significance in the construction industry, offering potential benefits in terms of lightweight construction, structural efficiency, sustainability, cost savings, and innovation. Understanding the structural performance of bubble deck beams and their environmental impact contributes to more sustainable construction practices and informs economic decisions for builders and developers. Investigating their applications and limitations can guide design choices, while research data and case studies provide practical insights into performance and maintenance. Additionally, this research contributes to the broader context of modern construction technology and engineering practices, encouraging innovation in the field and driving the adoption of more environmentally friendly and cost-effective building solutions.

3. Experimental Work

Materials and Properties –

A. An Ordinary Portland Cement (OPC) - OPC is a widely used type of cement in construction and is considered the most common and essential variety of cement. It forms the foundation of many concrete mixes and is integral to various construction applications due to its versatile properties. OPC comes in different strength grades, categorized by their compressive strength at a specified age. Common types include OPC 33, OPC 43, and OPC 53, with the numbers denoting the approximate compressive strength in megapascals (MPa). We have used OPC 53 grade of cement.

B. Fine Aggregates - We use M-sand of size 4.75mm and below confirming to zone 3 of IS 383-1970 is being used as the fine aggregate.

C. Coarse Aggregates - We used Natural crushed stone of size between 10mm to 20 mm.

D. Hollow Plastic Spherical Bubbles - The hollow plastic spherical bubbles used in this project are manufactured from recycled plastic of diameter 60 mm. The purpose of using recycled material is to curb consumption of finite natural resources such as oil and minimize the burden on the environment through the cyclical use of resources, therefore the recycling martial reduces inputs of new resources and limits the burden on the environment and reduces the risks to human health.

E. High Density Polyethylene (HDPE) balls - HDPE balls are spherical objects made from a type of thermoplastic polymer called high-density polyethylene. HDPE is a versatile material known for its durability, chemical resistance, and low moisture absorption. HDPE balls find applications in various industries due to their unique combination of properties. High-Density Polyethylene (HDPE) balls, composed of high-density polyethylene polymer, are known for their exceptional chemical resistance, durability, low friction properties, low moisture absorption, electrical insulation capabilities, and lightweight nature. HDPE's high molecular weight and density provide mechanical strength, while its resistance to various chemicals makes it suitable for diverse applications. Its durability, impact resistance, and low friction coefficient make it ideal for environments with wear and tear, such as ball bearings. Additionally, its low moisture absorption ensures dimensional stability, and its electrical insulation properties are beneficial in applications requiring minimized electrical conductivity. Moreover, HDPE's lightweight quality is advantageous in weight-sensitive applications. Collectively, these characteristics make HDPE balls a versatile and reliable choice for a wide range of industrial and commercial uses.

F. Water - The essential component is water, which when combined with cement creates a paste that holds the aggregate together. Concrete hydrates, or hardens, as a result of the water. The importance of water is due to the fact that the water to cement ratio is the most crucial component in the creation of "perfect" concrete. Concrete-making water should have a PH value more than 6 and be potable.

G. Steel Reinforcement - Steel is an alloy of iron and carbon and other elements. High grade steel of Fe 500 is generally used. The same grade of steel is used in both in top and bottom steel reinforcement. We used 2 no.of Fe 500 steel bar of 12mm diameter as main reinforcement & 2 no.10 mm diameter steel bar as hanger bar to hold shear reinforcement bar of 8mm diameter at 180mm center to center spacing.

4. Research Methodology

1. Concrete mix design -

Mix design of M25 grade concrete using IS10262:2019 is carried out.

Cement = 395.83 kg/m^3

Fine aggregate = 770.19 kg/m^3

Coarse aggregate = 1169.83 kg/m^3

Water = 223.18 kg/m^3.

Mix design ratio = 1 : 1.945 : 2.955 .

2. Form work of mould and beam casting - A wooden mould of dimension 150mm wide, 200mm deep and 1200mm length was used to cast the beam (as shown in figure 1). Two numbers of 12mm diameter Fe500 steel reinforcement were used in the tension zone and 2 numbers of 10mm diameter Fe415 steel reinforcement were used in compression zone as hanger bar. The stirrups having diameter 6mm are provided at 180 mm center to center spacing for the entire length (as shown in figure 2).

3. Different percentage of volume reduction is done by replacing concrete by different no. of balls placed equidistant from each other in tension zone. It can be calculated as follows -

Beam size is 150mm x 200mm x 1200mm so volume of beam is 0.036 m^3 .

A) For 65mm diameter of ball, Volume of one ball of 65mm diameter is $1.438*10^{(-4)}$ m^3.

B) For 75 mm diameter of ball, Volume of one ball of 75mm diameter is $2.209*10^{(-4)}$ m^3.

So for 2%, 4%, 6% and 8% volume reduction calculations are as follows -

Figure.1 Mould preparation for casting of beam.

Figure.2. Reinforcement of beam specimen.

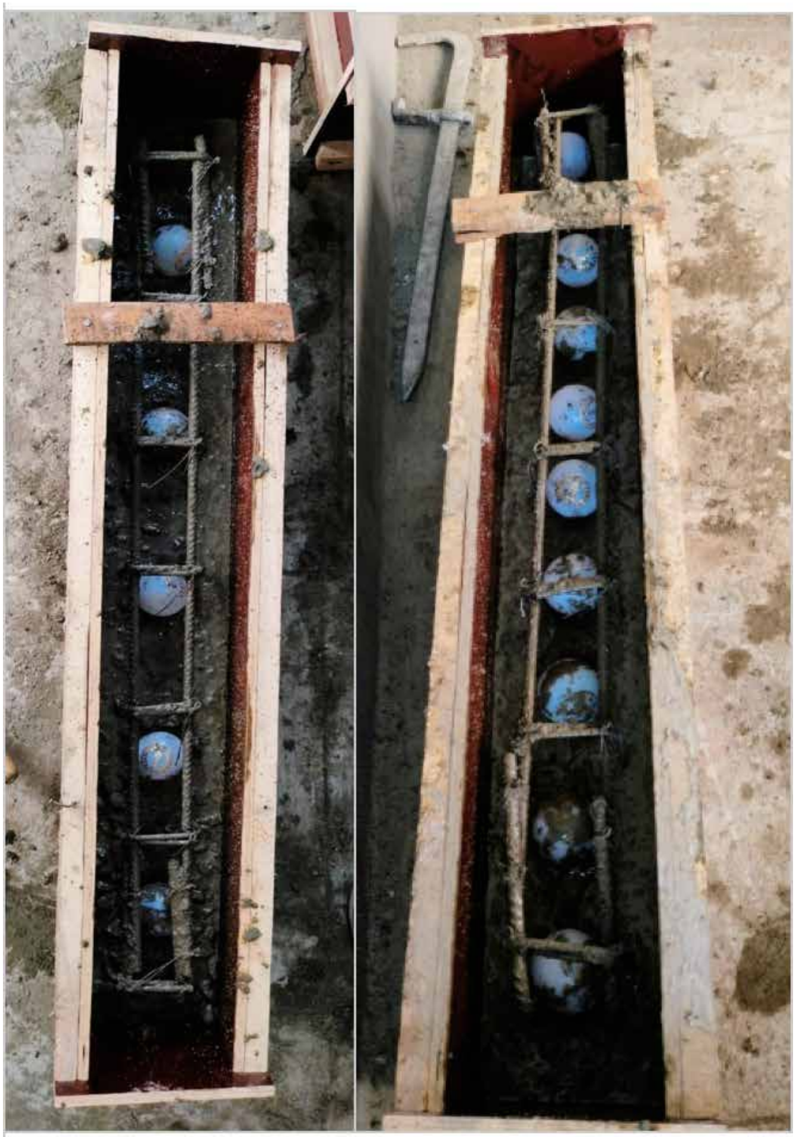

Figure.3 Placing of HDPE balls for different percentage of Volume reduction.

1) For 2% reduction in total volume of beam - 5 balls of 65mm diameter is used.
Volume reduction by 5 balls is (0.000719) / (0.036) = 2% reduction in total volume of beam.

2) For 4% reduction in total volume of beam - 10 balls of 65mm diameter is used.
As volume of 10 balls of 65mm diameter is 0.001438 m^3.
Volume reduction by 10 balls is (0.001438) / (0.036) = 4% reduction in total volume of beam.

3) For 6% Reduction in total volume of beam - 15 balls of 65mm diameter is used.
Volume reduction by 15 balls is (0.002157) / (0.036) = 6% reduction total volume of beam.
4) For 8% Reduction in total volume of beam - 13 balls of 75mm diameter is used.
As volume of 13 balls of 75mm diameter is 0.0028717 m^3.
Volume reduction by 13 balls is (0.0028717) / (0.036) = 8% reduction in volume of beam.

Figure.4 Casting and Curing of beam specimen.

4. Testing of specimens

The flexural beam test specimens were designed as reinforced section and consisted of 2 numbers of 12mm diameter bars in tension and 2 numbers of 10mm diameter bars in compression as hanger bars. 2 legged stirrups of 6mm diameter at a spacing of 180mm provided throughout the section. The reinforcement detail of beams tested for flexure is shown in Figure.5. A total of 15 concrete beams specimens of size 150 mm x 200mm x 1200mm were casted.Three for each 2%, 4%, 6%, 8% volumetric reduction. Three beam without any voulmetric reduction were kept as control beam (CB).

The beam specimens were cast and curing was done for 28 days. After curing, the specimens were kept dry for 24 hours. The grid lines and loading point lines are marked on the specimen before testing. The loading pattern is two points loading system. The loading points are 150mm from the centre on the either side. The point load is applied through a hydraulic jack. Test setup for beams under flexural behavior is shown in Figure. 6. For every increment of 5KN load the strains and deflections readings are taken down. The first flexure crack is marked and the corresponding load is noted. The loading is done until the beam fails due to yielding of steel.

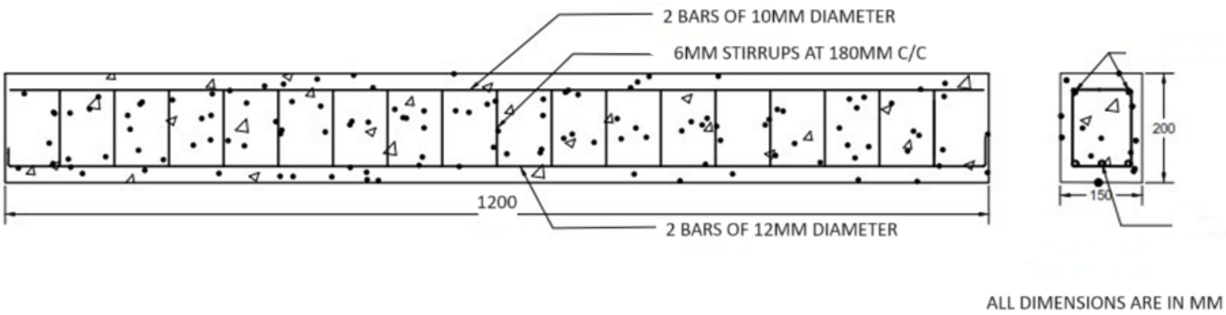

Figure.5 - Reinforcement details of beam specimen.

Figure.6 - Loading arrangement.

Table. No.1 Load vs Deflection

Sr. No.	Load in kN	Deflection CB(mm)	Deflection BB 1(mm)	Deflecton BB2 (mm)	Deflection BB3(mm)	Deflection BB4(mm)
1	5	0.073836	0.003989	0.106133	0.02888	0.021144
2	10	0.421971	0.114666	0.350368	0.17152	0.088227
3	15	0.50587	0.291144	0.410657	0.512348	0.62001
4	20	1.110053	0.523992	0.649538	0.924919	1.346174
5	25	1.380832	0.783569	0.667472	0.88464	1.430949
6	30	1.42102	0.811458	0.737729	1.056565	1.542794
7	35	1.47181	0.866103	0.794063	1.06142	1.629344
8	40	1.53566	0.881914	0.824023	1.17139	1.717004
9	45	1.61729	0.994608	0.811146	1.23033	1.767369
10	50	1.779027	1.016351	0.97902	1.38896	1.970211
11	55	1.925277	1.169585	1.073587	1.543115	2.03336
12	60	2.129437	1.34977	1.278323	1.743815	2.299245
13	65	2.280137	1.52808	1.445664	1.97325	2.423645
14	70	2.41564	1.63058	1.629033	2.213325	2.55601
15	75	2.625387	1.773595	1.847764	2.40976	2.72711
16	80	2.876297	1.93452	2.058865	2.687625	3.08978
17	85	3.015583	2.182555	2.229125	2.98172	3.45178
18	90	3.220647	2.284995	2.57593	3.45856	3.58313
19	95	3.424237	2.53507	2.849995	3.54704	3.73368
20	100	3.59176	2.744655	3.08079	3.89462	4.18322
21	105	3.865933	3.001605	3.48671	4.27717	4.360755
22	110	4.08245	3.12955	3.63735	4.50382	4.78671
23	115	4.4158	3.257375	3.9058	4.785335	4.997495
24	120	4.541493	3.556395	4.238195	5.24986	5.14732
25	125	4.645103	3.768765	4.73321	5.3871	5.366785
26	130	4.876683	3.99902	4.98349	5.534685	5.67382
27	135	5.569453	4.09809	5.10785	5.61836	5.82657
28	140	5.30834	4.37125	5.198895	6.06221	5.932925
29	145	5.56828	4.44039	5.55896	6.209815	6.23503
30	150	5.438145	4.67733	5.809495	6.657625	8.02922

5. Result and Dissussion

1.Behavior of beams in Deflection - The test results for the beam specimens casted are tested for flexure behavior and deflection at the age of 28 days. Table 1. Shows load vs deflection behaviour of conventional beam and bubbled beam.

Comparison of deflection for conventional beam with bubbled beam is done in order to study deviation of bubbled beam deflection compared with conventional beam. Load vs Deflection graph is plotted for all bubbled beam with different amount of volumetric reduction. Load is taken on y-axis and corresponding deflection is noted on x-axis.

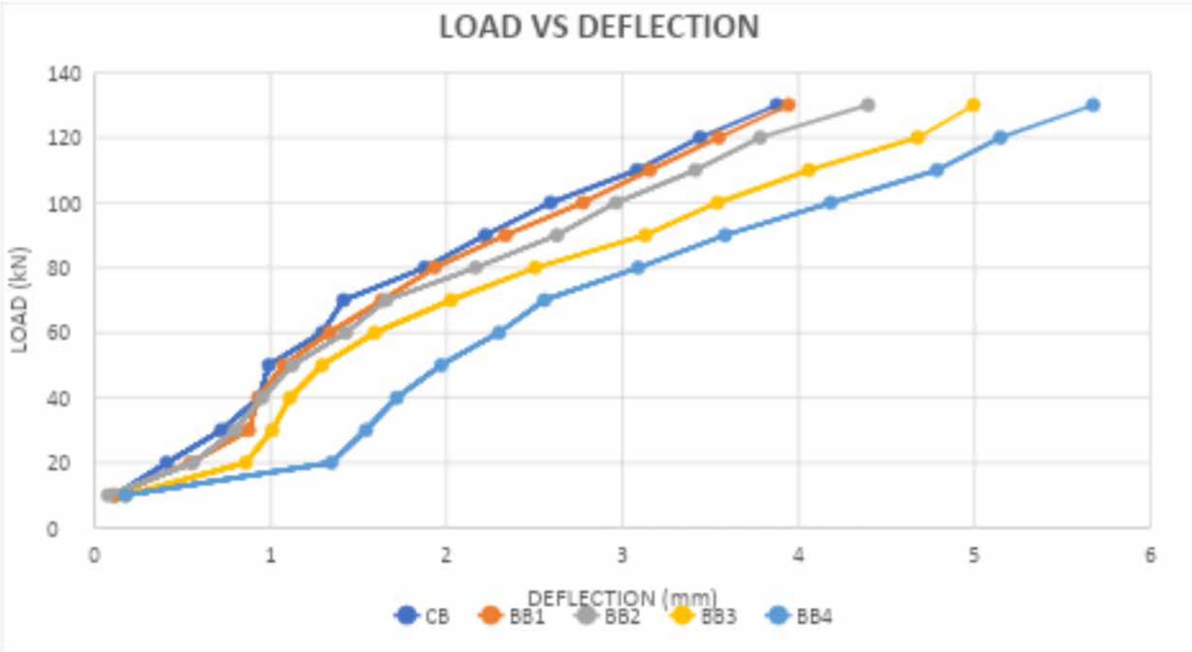

Figure.7 - Load vs Deflection behavior of Conventional Beam(CB) and Bubbled Beam(BB)

It is observed that at 2% volumetric reduction of concrete BB1 beams showed reduced deflection of to the extent of 44.66 % in comparison with conventional beams, at the same stress. This is because the inclusion of HDPE balls somewhat increased tension carrying capacity after addition in tension zone results in the increase in the stiffness of deep beams at the same load level.Study of 4% volumetric reduction of concrete BB2 beams showed deflection pattern similar to conventional beam till 100kN of load but after that deflection in bubbled beam increased exponentially in comparison with conventional beams, at the same stress.It is observed that at 6% volumetric reduction of concrete BB3 beams showed increase in deflection to the extent of 39 % in comparison with conventional beams, at the same stress. At initial till load of 20kN there was very less difference but as load increase beyond 20kN deflection increased exponentially.It is observed that at 8% volumetric reduction of concrete BB4 beams showed increase in deflection to the extent of 61 % in comparison with conventional beams, at the same stress. As soon as loading is started the deflection was more in case of BB4. Due to more reduction of concrete from tension zone which decreased tension carrying capacity of beam which lead to increase in deflection which make it not feasible for actual use.

2.Behavior of beams in flexure -

Based on bending stress equation M/I=f/y=E/R, Flexural strength of the beam was calculated by using the expression PL/BD^2, where cross section of the beam (BXD in mm^2), length of the beam (L in m), ultimate load (P in kN).From the Table No.2 , the flexural strength of the all specimens shows reducing trend as compared with conventional beam specimen.

BB1 showed 1.7% of reduction in flexural strength compared to conventional beam. While BB2 showed 3.5% of flexural strength reduction. BB3 and BB4 had flexural strength of 33MPa and 28MPa which is 12.30% and 25.6% less than conventional beam which is not feasible.

Table. No.2 Flexural Strength

Sr.No.	Description	Specimen	Initial Crack Load (kN)	Ultimate Load (kN)	Flexural Strength (PL/BD2) (MPa)	Average Flexural Strength (MPa)	Percentage reduction in Flexural Strength
1)	Conventional Beam	CB-1	75	190	38	37.67	
		CB-2	70	190	38		
		CB-3	75	185	37		
2)	Bubbled Beam	BB1-1	70	180	36	37	1.70%
		BB1-2	70	190	38		
		BB1-3	65	185	37		
		BB2-1	70	185	37	36.33	3.50%
		BB2-2	60	175	35		
		BB2-3	65	180	36		
		BB3-1	60	165	33	33	12.30%
		BB3-2	70	170	34		
		BB3-3	55	160	32		
		BB4-1	55	140	28	28	25.60%
		BB4-2	60	145	29		
		BB4-3	50	135	27		

6. Conclusion

The study bubbled with different percentage of volume reduction were carried out and compared with convebtional beam.The following conclusions are observed from this study:

1.Deflection in bubbled beam BB1 decreased by amount nearly 44% compared with conventional beam while BB2 somewhat behaved as conventional beam. In case of BB3 and BB4 ,deflection increased by significant amount which made it not usable for actual use.

2.Due to introduction of HDPE balls in cube there was not much difference for 28days of compressive strength.

3.Bubbled beam having 2% volumetric reduction (BB1) showed 3% cost reduction for 4% volumetric reduction (BB2) showed 6% reduction in cost for 6% volumetric reduction (BB3) showed 9% reduction in cost and for 8% volumetric reduction (BB4) showed cost reduction of 10% compared with conventional beam.

4.Optimum reduction was found out to be BB1 which had 2% of volumetric reduction because in BB1 showed less deviation from flexural strength also was having less deflection compared with other bubbled beams having more percentage of volume reduction.

5.BB3 and BB4 which had 6% and 8% of volume reduction was showing more deviation in flexural strength as well as more deflection compared to conventional beam, hence it is not feasible for actual use.

References

1. Shaikh Nadeem Ashraf Nawazoddin[1] , Prof. Shete G.N.[2] "Experimental Study on Bubble Deck Beam", *Journal of Research in Engineering and Science (IJRES)* Volume 9 Issue 8 2021 PP. 72-77

2.Krupadan Samayya Jangam[1], Karan Sunil Biswas[2], Roshan Laxman Gaikwad[3], Ratan Sunil Sarkar[4] Investigation on Durability Parameters of Concrete adopting Bubble Deck Technology *International Journal Of Advanced Innovative Technology In Engineering* Special Issue 2(1), PP 233-238

3.S.Pradeep Kumar & Koppal Shiva, "Strength Investigation Report on Bubble Deck" Beam Reinforced Concrete Beam. Volume 7 Issue 7 – JULY 2021 PP 464-470

4.Prof. Shraddha Asalkar[1], Mr. Laxmankumar Solanki[2], Mr. Shubham Jaiswal[3]. "Experimental investigation: Bubbled Beam", | Volume 6, Issue 2 April 2018 PP 501-503

5. P. Prabhu Teja, P. Vijay Kumar, S. Anusha, C. Mounika and P. Saha, "Structural behavior of bubble deck slab," *IEEE-International Conference On Advances In Engineering, Science And Management (ICAESM -2012)*, Nagapattinam, India, 2012, pp. 383-388.

6. Joy, J., & Rajeev, R. (2014). "Effect of reinforced concrete beam with hollow neutral axis." *International Journal for Scientific Research & Development*, *2*(10), 2321-0613.

7. Ali, S., & Kumar, M. (2017). Analytical study of conventional slab and bubble deck slab under various support and loading conditions using Ansys Workbench 14.0. *International Research Journal of Engineering and Technology*, *4*(05), 1467-1472.

8. Mushfiq, M. S., Saini, S., & Rajoria, N. (2017). "Experimental study on bubble deck slab." *Int. Res. J. Eng. Technol*, *4*, 1000-1004.