International Journal of Advance Research in Science and Engineering
Volume No. 12, Issue No. 04, April 2023
www.ijarse.com
IJARSE
ISSN 2319 - 8354

AN INVESTIGATIONAL STUDY ON VARIABLE VOLUME BUBBLE SLAB UNDER STATIC LOADING AND COMPARISION WITH PACKED VOLUME SLAB

Sathya Devi S[1] , Mrithulaa R *[2], Mohamed Abu Gihath A[3], Selva Kumar S[4] , Yasar Ahamed Mydeen J S [5]

[1]*Asst Professor, sathyadevi.civil@gmail.com, Civil Engineering, F. X. Engineering College, India*
[*2]*Student, mrithulaa29@gmail.com, Civil Engineering, F. X. Engineering College, India*

[3]*Student, mohammedjihath094@gamil.com Civil Engineering, F. X. Engineering College, India*

[4]*Student, selvakumar66644@gmail.com Civil Engineering, F. X. Engineering College, India*

[5]*Student, yasarahamedmydeen081201@gmail.com Civil Engineering, F. X. Engineering College, India*

ABSTRACT

Concrete slab places a vital aspect component of every construction. Depending upon the nature of work, the cement, fine aggregates, coarse aggregates and water are mixed in specific proportions. Concrete slab consumes more concrete in the casting for providing flooring and roofing. Concrete is heavy in weight and more than 5% of CO_2 is created during the manufacturing of cement that goes into it. The usage of concrete is high in slab construction. It leads to additional usage of concrete though the load transfers from the structure only on the column portion not throughout the slab. Slab is largest member which consumes concrete and when load acting on the slab is large or clear span between columns is more, the slab thickness is increasing. It leads to consume more material such as concrete, steel and due to that, self-weight of slab is increased. To reduce this various studies are carried out and researchers suggest voided slab system. Reinforced concrete slab with plastic voids is a new and innovative type of structural, concrete slab system developed to allow for lighter self weight of the structure while maintaining similar load carrying capacity of a solid slab. So reduce the concrete in centre of the slab by using recycled balls. Plastic hollow spheres balls replace the in-effective concrete in the centre of the slab, thus decreasing the dead weight and increasing the efficiency of the floor this new technology is called Bubble deck slab. The main aim of this study to comparatively analysis of Bubble Deck slab over the solid conventional slab under load bearing capacity (i.e.) strength, efficiency and create awareness.The advantages of using this technique are less energy consumption - both in production, transport and carrying out, less emission - exhaust gases from production and transport. The slabs were then centrally loaded and the deformation and stress results output values were observed. The various parameters like flexural reinforcement, solid perimeter, moment *capacity of the voided slab and solid flat slab are calculated to compare both the systems and to suggest the economical slab system. The stress and deformation results were evaluated and compared the bubble deck slab with conventional slab were observed. The comparison has been made for Bubble Deck Slab with the Conventional slab over its self weight. From the evaluation of these results, Bubble Deck Slab gives better performance than that of the conventional slab.*

Keywords *Bubble deck slab, Static loading, Structural strength, Displacement, MiniTab,*

1 INTRODUCTION

In any Building structure, Concrete slab is the most important component of any building structure for transmitting the load to other structural members. A slab is the very important part of the structure which is to be effectively designed and mostly utilized. It should be optimized because it uses more quantity of concrete than the normal prerequisite. When large load acting on slab & span between two columns is more, then the thickness of slab goes on increasing. It contains more amount of stuff like steel & concrete than other components, so that slabs self-weight goes on increasing. Concrete is a heavier material & production of cement leads to 5% of world's co2 production. Bubble deck slab technology firstly invented in Denmark. Bubble Deck Slab is a unique way of reinforced concrete which contains spherical hollow plastic balls as replacement of ineffective concrete from middle of the slab which reduces the dead load of the slab. This type of bubble deck slab has been implemented in various parts of the world using their design codes of practice in construction and has found to be successful. This results in a dramatic reduction of dead weight by as much as 35-40% allowing much longer spans and less supporting structure than traditional solutions. Hence, the Bubble Deck has many advantages as compare to traditional concrete slab such as lowered total cost, reduced material use, enhanced structural efficiency, decreased construction time and is a green technology. It gains much of attention from engineers and researchers from the world.

By inserting the gaps leads to a 30 to 50% light weight slab which are minimize the loads on the columns, walls and foundations, and of Members of the entire building. "Bubble Deck" slab elements are plates with ribs on two directions made of reinforced concrete or precast concrete with spherical or circular shaped bubble (HDPE). These slabs consist of a bottom and an upper concrete part connected with vertical ribs that go around the gaps present in the slab. So that reduces the concrete from the middle/centre of the slab by using or inserting (HDPE) recycled balls in it. High density polyethylene (HDPE) hollow spheres/balls insert or place in-effective concrete in the middle portion or centre of the slab, thus reduce or decreasing the dead weight or load and increasing the efficiency of the floor. It ensures was conceived to achieve saving of concrete and energy in buildings construction. Plastic voided slabs remove concrete from non-critical areas and replace the removed concrete with hollow plastic void formers while achieving similar load capacity as solid slabs. There are three familiar types Partially Pre-casted slab, Assembly of bubbles and steel mesh and Fully Pre-casted bubble deck slab are in usage. The structural properties of bubble slabs are listed under Compressive strength and Flexural capacities, Durability, Fire Resistance, Shear Strength, Sound Insulation and Vibration.

2 LITERATURE REVIEW

The literature papers are reviewed related to our study. Arati Shetkar & Nagesh Hanche [1] presented their experimental Study on Bubble Deck Slab System with Elliptical Balls and revealed that the behaviour of Bubble Deck slabs is influenced by the ratio of bubble diameter to slab thickness, the effectiveness and feasibility of the application of Bubble Deck in the construction. Calin et al. [2] conducted study on bubble deck system to study the properties and compare the results with solid slab. The conclusion was made that the bubble deck slab will distribute the forces in a better way than any other hollow floor structures and lead to considerable savings. Ali and Kumar [3] conducted an investigative study of conventional slab with bubble deck slab under various support and loading conditions using ANSYS WORKBENCH 14.0. Through their investigation they have proved that the bubble deck concept is further competent than a solid conventional concrete slab. Bhowmik et al. [4] had evolved through a review study on bubble deck with spherical hollow balls towards the objective that the practicality and effects in using hollow spherical balls in reinforced concrete slab. They ended up with the conclusion that the concrete usage is significantly reduced in bubble deck slab than conventional slab. Fatma and Chandrakar [5] experimented on the bubble deck slab over the conventional solid slab. Finally it was concluded that load, deflection and weight parameters give better result for bubble deck slab as compared to conventional slab. Adenan et al. [6} conducted a comparative study on bubble deck slab and conventional reinforced concrete slab. The experimental work were conducted by casting and testing the conventional slab and bubble deck slab of size 700 mm x 700 mm x 150 mm. through the usage of recycled plastic balls of diameter 90 mm and 120 mm. the conclusions were the bubble deck configuration gave much improved flexural capacity, stiffness and shear capacity, concrete volume economy, avoiding CO_2 emissions which lead to more economical and environmentally green and sustainable. Ansari and Ahmad [7] conducted a test to study an improvement of structural behaviour of bubble slab by changing bubble thickness. The experimental works were conducted by casting and testing of conventional and bubble slab. The summary of the papers are reduction in concrete usage – 20 % to 30 %, reduction in self weight – 15 % to 25 %, reduction in initial cost - up to 12 %, Bubble deck slab with spherical balls have higher ultimate load capacity than the bubble deck slab with elliptical balls.

2.1 Problem statement

From the study of the literature the study conducted on the comparison variable volume Bubbled deck slabs have not yet been carried out. Research problem is to find out the relationship of the variable volume parameters on Bubbled deck slabs and its authority, thereafter to optimise the parameters for the required product quality level.

2.2 Objectives of the project

The main objective of this study is to practically using hollow spherical plastic balls in reinforced concrete slab which is called as bubble deck slab, determine the load bearing capacity of bubble deck slab by inserting plastic balls, the structural behaviour of bubble deck slab under static loading, comparing the strength between conventional slab and bubble deck slab and finding the volume of concrete reduction in bubble deck slab with conventional slab.

3 MATERIALS AND METHODOLOGY

The properties of all materials like cement, fine aggregate, coarse aggregate and water were studied. Then concrete mix design was computed followed by casting and testing of slab specimens.

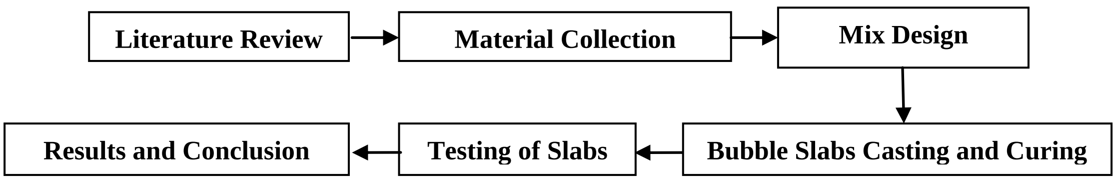

Fig 3.1 Flow chart of the methods

3.1 Materials

The substances that are used for making concrete were investigated before casting the samples according to the provisions of relevant Indian Standard codes.

Table 3.1 Cement Properties

Tests performed	Results	Tests performed	Results
Standard consistent value	31 percentage	Specific gravity	3.15
Beginning setting time	42 minutes	Fineness (<90 microns)	4 percentage
Terminal setting time	490 minutes	Standard consistent value	31 percentage

Ultra Tech 53 grade OPC has been used throughout the analysis and was utilized for making the samples. The important cement properties are given in Table 3.1. The optimal quality of fine aggregate to be used in concrete is mostly decided by its impact on water requirements than on physical stuffing. In order to create optimal compression strength with more cement substances and less w/c ratios, the largest dimensional coarse aggregate would be kept to 20 mm. Aggregate properties are listed through Table 3.2.

Table 3.2 Aggregate Properties

Characteristics	Fine aggregate Value	Coarse aggregate Value
Specific Gravity	2.62	2.78
Fineness Modulus	2.9	7.64
Water Absorption	0.55 %	0.35%
Density	1765 kg/m^3	1670 kg/m^3

3.2 Casting of slab specimen

8mm diameter Fe 500 steel has been used for reinforcement of 550 N/mm^2 yield strength, 620 N/mm^2 ultimate tensile stress and 12 % percentage elongation. 38mm diameter balls are used for the reinforcement bubble space as the cost of plastic ball is extremely low. The plastic balls don't react chemically with concrete or reinforcement. Mix design was done for M20 grade concrete using IS 10262: 2009 with water cement ratio 0.45.

Slabs of size 0.6 m x 0.45 m x 0.15 m were casted. The dimension of the slabs has been selected based on the accommodation capacity of the Leaf spring load testing machine which is available for the testing. Four specimens - solid slab, slab with 25, 30, 40 bubbles insertion were prepared for the conduction of this study. On completion of the bubbled slab casting the curing process is carried out for 28 days. For the solid slab specimen, placing reinforcement concrete was poured into three layers. Each layer was tamped by using tamping rods. Subsequently the bubble slabs are prepared. In the bubble slab the filler materials are placed below neutral axis based on the assumption there was no need of concrete below neutral axis. Table 3.3 reveals the volumetric calculation of the slab specimen.

Table 3.3 Volumetric Calculation of slab specimen

Slab type	Normal	25 Bubble slab	30 Bubble slab	40 Bubble slab
Slab volume, m^3	0.027	0.027	0.027	0.027
Balls volume, m^3	0	0.0005387	0.0006464	0.0008619
Rod volume, m^3	0.0008830	0.0008830	0.0008830	0.0008830
Concrete volume, m^3	0.0261170	0.0255783	0.0254705	0.0252551
% Saving of concrete	NA	5.27	5.66	6.46

Since the volume of the bubble space is playing a major role in this project, the selection of number of balls which are inserted in the bubble slabs is selected as the balls are inserted in a single plane in parallel arrangement. Balls are placed with equal spacing both column wise and row wise. 5 rows x 5 columns with the spacing row wise 0.075m column wise 0.1m for 25 bubbles, 5 rows x 6 columns with the spacing row wise 0.075m column wise 0.085m for 30 bubbles and 5 rows x 8 columns with the spacing row wise 0.075m column wise 0.065m for 40 bubbles. The void diameter to slab thickness ratios is 0.38.

The volume of the bubbles are 0.0005387 m^3 which saves the concrete volume as 5.27 % of total concrete used in 25 bubble stock slab, 0.0006464 m^3 saves the concrete volume as 5.66 % of total concrete used in 30 bubble stock slab and 0.0008619 m^3 saves the concrete volume as 6.46 % of total concrete used in 30 bubble stock slab. This is in order to find and analyse the strength of the slabs when the volume of bubbles are between marginal differences.

Cover block size is 0.0015 m, Concrete Ratio 1: 1.5: 3. Cement weight (1/5.5) x 0.027 x 1440 x 1.54 = 10.88 kg;

FA weight (1.5/5.5) x 0.027 x 1600 x 1.54 = 18.144 kg; CA weight (3/5.5) x 0.027 x 1800 x 1.54 = 40.824 kg;

Water (75/100) x 10.88 x 10^3 = 8160 ml.

Fig. 3.2 reveals the Formwork of slab casting with reinforcement, Fig. 3.3 represents Insertion of plastic balls (25) in slab casting, Fig. 3.4 denotes the Insertion of plastic balls (30) in slab casting, Fig. 3.5 shows the Insertion of plastic balls (40) in slab casting, Fig. 3.6 gives the Pouring concrete in plastic balls (25) slab casting and Fig. 3.7 reveals the Completion of Bubbled slab casting on the specimen casting.

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ISSN 2319 - 8354

Fig 3.2 Formwork of slab casting with reinforcement

Fig. 3.3 Insertion of plastic balls (25) in slab casting

Fig. 3.4 Insertion of plastic balls (30) in slab casting

Fig. 3.5 Insertion of plastic balls (40) in slab casting

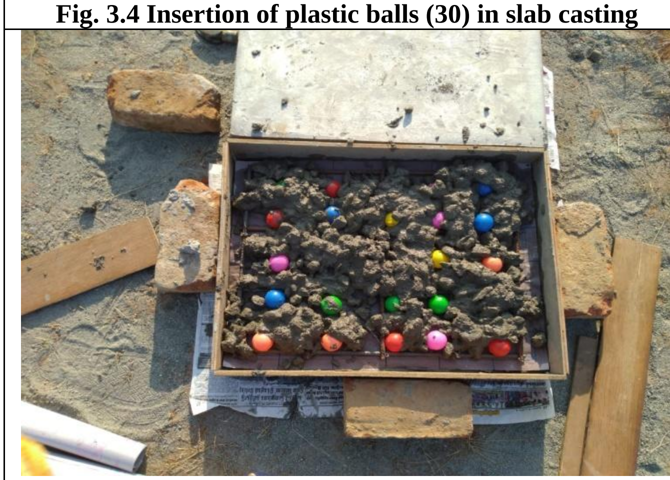

Fig. 3.6 Pouring concrete in plastic balls (25) slab casting

Fig. 3.7 Completion of Bubbled slab casting

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4 EXPERIMENTAL INVESTIGATION Subsequent to 28 days of curing of the slabs the specimens were tested for flexural strength under static loadings. The leaf spring machine testing is used to test the slabs under static loading.

Fig 4.1 Leaf spring testing machine with digital monitor

Fig. 4.2 Solid slab under static load test

Fig. 4.3 Bubble slab (25 balls) under static load test

Fig. 4.4 Crack propagation in 25 Bubble slab

Fig. 4.5 Crack propagation in 30 Bubble slab

Fig. 4.6 Crack propagation in 40 Bubble slab

The testing machine shown in Fig 4.1 has the 200 kN maximum capacity and a maximum straining speed of 200 mm/min. The slab has been simply supported throughout the breadth making the effective length as 500 mm and circular point load was applied at the centre of the slab. The loading setup along with the solid slab specimen is shown in Fig 4.2. Loading was done at a constant rate and the displacement pertaining to each 5 kN increment of load was measured until failure occurs. The solid slab, all the Bubble slabs with 25 balls, 30 balls and 40 balls were tested one by one and the load Vs displacement was recorded respectively. Fig 4.3 is representing the laod test while in progress. The crack propagation in Bubble slab of 25 balls, 30 balls and 40 balls are shown in the Fig 4.4, 4.5, 4.6 respectively. The load vs displacement observations are tabulated in the Table 4.1.

Table 4.1 Load Vs displacement of static load test – Normal slab, 25, 30, 40 Bubble slabs

Normal slab		Bubble slab (25 balls)		Bubble slab (30 balls)		Bubble slab (40 balls)	
Displacement (mm)	**Load (kN)**	**Displacement (mm)**	**Load (kN)**	**Displacement (mm)**	**Load (kN)**	**Displacement (mm)**	**Load (kN)**
1.0	31.71	1.0	22.18	1.0	20.60	1.0	10.27
1.2	33.91	1.2	22.28	1.2	21.51	1.2	10.33
1.4	35.96	1.4	22.49	1.4	26.58	1.4	11.30
1.6	38.05	1.6	22.64	1.6	29.10	1.6	14.20
1.8	40.21	1.8	26.82	1.8	30.40	1.8	16.81
2.0	42.29	2.0	31.13	2.0	37.60	2.0	19.12
2.2	43.76	2.2	33.88	2.2	38.26	2.2	21.40
2.4	45.30	2.4	33.38	2.4	39.50	2.4	23.61
2.6	47.37	2.6	34.71	2.6	40.20	2.6	26.10
2.8	49.03	2.8	36.40	2.8	41.16	2.8	28.42
3.0	50.17	3.0	31.11	3.0	41.90	3.0	31.07
3.2	50.64	3.2	35.22	3.2	42.54	3.2	33.80
3.4	50.18	3.4	37.86	3.4	42.88	3.4	37.81
3.6	52.30	3.6	39.30	3.6	43.38	3.6	38.04
3.8	52.43	3.8	40.74	3.8	43.74	3.8	39.21
4.0	52.67	4.0	42.08	4.0	44.10	4.0	39.37
4.2	52.73	4.2	43.20	4.2	44.36	4.2	41.34
4.4	52.99	4.4	44.38	4.4	44.62	4.4	42.44
4.6	53.23	4.6	45.22	4.6	44.78	4.6	42.26
4.8	53.43	4.8	45.76	4.8	44.90	-	-
5.0	53.62	5.0	46.00	-	-	-	-
5.2	53.93	5.2	46.06	-	-	-	-
5.4	54.07	5.3	45.88	-	-	-	-
5.6	54.01	-	-	-	-	-	-
5.7	53.93	-	-	-	-	-	-
Slab failure occurs at 53.93 kN load, 5.7 mm displacement		Slab failure occurs at 46.06 kN load, 5.2 mm displacement		Slab failure occurs at 44.92 kN load, 4.9 mm displacement		Slab failure occurs at 42.26 kN load, 4.6 mm displacement	

The nature and outcome of the displacement Vs load of individual bubble slab with reference to the solid slab are represented through the pictorial views in Fig 4.7, 4.8, 4.9 and the combination of all bubble slabs in Fig 4.10.

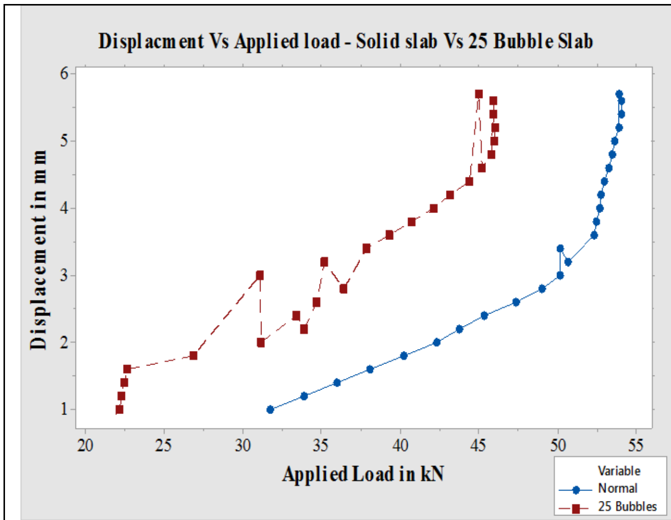

Fig 4.7 Solid slab Vs 25 Bubble Slab

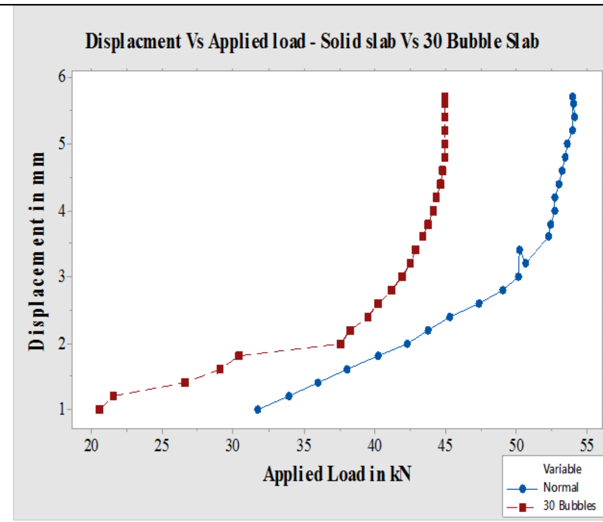

Fig. 4.8 Solid slab Vs 30 Bubble Slab

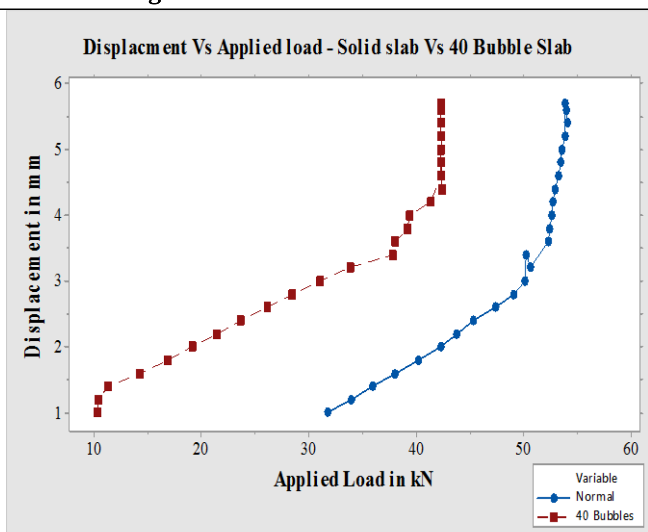

Fig. 4.9 Solid slab Vs 30 Bubble Slab

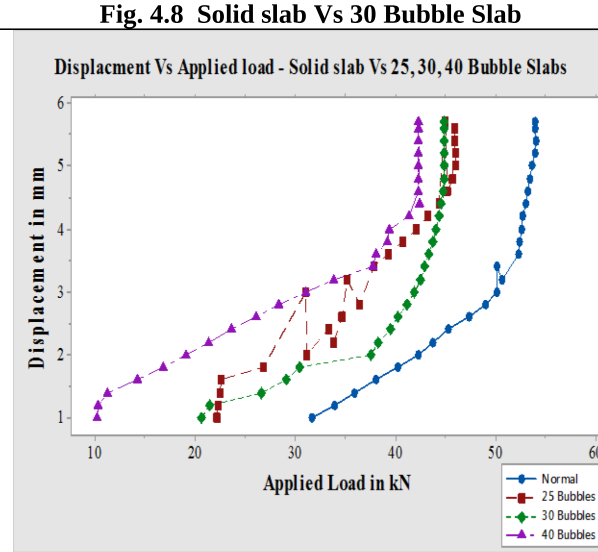

Fig. 4.10 Solid slab Vs 30 Bubble Slab

5 RESULTS AND CONCLUSION

5.1 Results

From the results the ultimate load carrying capacity of all three bubble slabs are determined.

1) The solid slab carries an ultimate load of 53.93 kN with corresponding displacement 5.7 mm.
2) The bubble slab with 25 balls could withstand an ultimate load of 45.88 kN with corresponding displacement of 5.3 mm.
3) The bubble slab with plastic 30 balls could withstand an ultimate load of 44.92 kN with corresponding displacement of 4.9 mm.

4) Bubble slab with plastic 40 balls could withstand an ultimate load of 42.26 kN with corresponding displacement of 4.6 mm.
5) The ultimate load carrying capacity of bubble slab of 25 balls is 14.92 % lesser than conventional slab on the saving of 5.27 % concrete.
6) The ultimate load carrying capacity of bubble slab of 30 balls is 16.71 % lesser than conventional slab on the saving of 5.66 % concrete.
7) The ultimate load carrying capacity of bubble slab of 40 balls is 21.64 % lesser than conventional slab on the saving of 6.46 % concrete.
8) The deflection on applying load begins after 31.0 kN of conventional solid slab, 22.0 kN for 25 Bubble slab, 20 kN for 30 Bubble slab and 10 kN for 40 Bubble slab which reveals that the 25 Bubble slab withstands the load of 22 kN without any deflection (ie) 70.96 % of the conventional solid slab, 30 Bubble slab able to withstand the load of 20 kN (ie) 64.52 % of the conventional solid slab without any deflection and 40 Bubble slab withstands the load of 10 kN (ie) 32.26 % of the conventional solid slab without any deflection.
9) Comparison of slabs in terms of failure recorded on load carrying capacity, 25 bubble slabs shows that 91.23 % of positively of solid slab, while the 30 bubble, 40 bubble slabs reserved the 85.97 % and 73.68 % respectively.

5.2 Conclusions

1) The main objective of this study which to practically using hollow spherical plastic balls in reinforced concrete slabs which is called as bubble deck slab is carried out with different volume.The load bearing capacities as well as the point of failure are compared between conventional slab and bubble deck slab.
2) Towards the Compressive strength and Flexural capacities, Bubble deck slab is conceptualized to exclude a significant volume of concrete as compared to a solid slab in the central core where the slab is principally un-stressed in flexure.
3) In terms of Durability, the staying power of bubble deck slab is not approximately different from ordinary solid slabs. The concrete is standard grade and combined with suitable bar cover provides most control of durability equal with normal standards for solid slabs. Bubble deck slab elbow have a chamfer on the inside to assure that concrete surrounds each bubble does not grant a direct route to air from the surface. This is mainly a fusion of the fire resistance but is also relevant to durability.
4) The fire resistance of the slab is a compound matter but is especially dependent on the ability of the steel to maintain sufficient strength during a fire when it will be heated and lose powerful strength as the temperature increases. While Bubble deck slabs are not designed to provide thermal insulation due to enclose of the air bubbles in the middle of the concrete slab. Bubble deck slabs can therefore make a useful improvement towards he thermal insulation obtained by the overall construction.
5) A relation was made between Bubble Deck and one-way prefabricated hollow deck of similar height. The noise reduction with Bubble Deck was 1db higher than the one-way prefabricated hollow deck slab. Bubble deck behaves acoustically in a better way than any other hollow or solid floor surfaces. Because of the three-dimensional structure

and the graduated force flow, the hollow spheres have a positive influence on sound insulation. This indicates the bubbles have a positive influence on sound insulation.

6) Structural advantages - Less in weight, increased strength, free choice of shape and less foundation depth.
7) Constructional advantages - weightless equipment is required, easy incorporation of ducts and pipes into slab and less work on construction site.
8) Environmental advantages – Less in material and energy consumption, reduced CO_2 emission, and every component is recyclable.
9) Economical advantages - savings in construction materials, transportation costs reduced, faster construction time and the buildings could be more flexible and easy in installations.
10) Out of the three Bubble slabs casted and tested 25 bubble slab takes the first position in terms of load carrying capacity where as the 30 bubble, 40 bubble slabs reserved the second and third position respectively.
11) As the factor of safety on construction with reinforced concrete structures are calculated as 1.5 as per standard, up to 66.67 % load carrying capacity is safer. Hence all three volume bubble slabs could be used for the construction in houses with the advantages like Environmental, economical status in mind.

5.3 Recommendations

- Further study may be conducted through introducing instead of plastic spherical balls elliptical balls, long pvc pipes, rubber balls may be used for insertion of bubbles.
- Bubbles could be arranged in zig- zag position and experiments may be continued.
- Bubble space may be created more than a single plane and study may be conducted.
- Results may be optimised through various optimisation algorithms to fix the concrete guidelines for various applications.

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