International Journal of Research and Review
www.ijrrjournal.com E-ISSN: 2349-9788; P-ISSN: 2454-2237

Short Communication

A Structural Study on Bubble Deck Slab and Its Properties

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ABSTRACT

Housing all over the world majorly comprises of concrete structures. They provide isolation and thermal comfort to the occupants. Majority of the concrete structures have flooring/roofing of thick concrete to bear the design loads. Due to his, the complete volume (eliminating the negligible volume of the reinforcement) of the roof slab comprises of concrete. Due to this, production of concrete has increased. Concrete production is not environment friendly. It is the primary producer of Carbon dioxide. In addition to this, the problem of concrete waste is at rise. Concrete waste can be reduced by two ways: recycling and using efficient volumes. Recycling is using the concrete waste in concrete generation which is of course of lower quality. Efficient volume is the way of using concrete in the most efficient way possible by substituting materials. In this paper, polyethylene balls are used in the slab to reduce concrete volume while maintaining the structural properties of the concrete. A comparison of strength of slab with the polyethylene balls and without them has been done to show the effectiveness of the new method. Various other strength tests were carried out and have been tabulated. At the end, cost effectiveness of the proposed slab has also been given.

Index terms: Bubble deck slab, Polyethylene balls, recycling concrete, concrete slabs systems.

1. INTRODUCTION

Concrete is strong in compression and weak when under tension. While considering a reinforced concrete slab, all the concrete above the neutral axis is subject to compressive forces and all the concrete below the neutral axis is subject to tensile forces. This supports the fact that concrete is the tension zone is of little use and contributes to making the slab heavier and reducing its overall efficiency. Upon having more slabs, it shall contribute to increased dead load of the structure. This dead load which is additional in nature and does not serve any positive purpose can be removed. This is done by introducing voids in the slab. Since voids cannot be made to form on their own, hollow balls or low weight balls are placed in the concrete to reduce the overall weight of the concrete. This concept bubble deck slab has hollow spheres made from recycled plastic placed between two layers or meshes of reinforcement. In this paper, we are going to study two-way slabs and design two ways slabs (both conventional and bubble deck and its types).

If weight of slab is reduced, then dimensions of other supporting structural members (such as beams and columns) shall also decrease. Since there is decrease in both the slab and supporting member volumes, reduction in total load of the structure and the volume of concrete used is evident.

A bubble deck slab reduces volume of concrete up to 33% in the slab itself and up to 18% reduction in the supporting structural members. This reduction is done by removing the volume of concrete in the center portion where there is no need of concrete structurally. Such a practice of removal of concrete from regions where there is little or no structural requirement is a very old practice, but in this case the approach is different due to use of recyclable plastic (polyethylene) balls. It also provides greater insulation due to air trapped inside since air is a bad conductor of heat. The structure shall retain the heat inside for a long period of time. This causes efficiency in energy utilization to heat up the room or cool down the room depending on the region of construction.

Time is also saved in laying a bubble deck slab as the amount of concrete needed to be handled is far less than a conventional slab. The number of manual labors involved in the task can also be reduced for the same area of the slab. It was observed that a bubble deck slab is developed 20% fast that a conventional slab of same area. All the previous statements show the savings done in terms of concrete volume, time, manual effort and transport timings.

2. Objectives

- To use hollow polyethylene balls in a slab.
- To show the procedure of the experiment and a comparison of all parameters between a bubble deck slab and a conventional slab.
- To estimate concrete volume saved
- To study and compare the self-weights of the slabs
- from the Universal Testing Machine.
- To study failure or cracking patterns on both the slab types
- To analyze the results of M20 and M25 grades of concrete on the slabs

3. Properties of materials used

3.1 Polyethylene bubbles

Bubbles are made of high-density polyethylene. It is a non-porous material which does not react chemically with concrete or the reinforcement. The bubbles usually have high stiffness and strength to support the concrete in conjunction with the reinforcement provided safely during both placing the concrete and after.

Diameter of bubbles ranges from 90mm to 120mm. Due to this, the depth of slab varies from 140mm to 170mm.

Bubble spacing should be more than $1/9^{th}$ of bubble diameter.

3.1.1 Chemical properties:

Table 1: Chemical properties

Property	Description
Marketing name of product	HDPE (High Density Poly-Ethene)
Chemical name	Polyethylene
Chemical designation	$(-CH_2-CH_2-)_n$
Genus	Polyolefin
Hazardous substance	NO
Color	desired color can be obtained
Odor	feebly of paraffin
Relative Density	950 kg/m^3
Melting point	135˚C
Softening point	123˚C
Solubility	Insoluble in water

3.2 Concrete

Concrete used for filling the slab should be more than M30. It is an added advantage if a self-compacting concrete variant is used. This way, there will be proper compaction ensured in every unreachable region inside the slab. Aggregate used in this concrete should be less than 15mm.

For the experiment,

Table 2: Properties of concrete

Material	Description
Concrete	M30 Concrete mix design as pe IS 10262: 2009 Slump Value: 74mm
Cement	Ordinary Portland Cement (OPC) 53 Grade Testing done as per IS 456: 2000 Fineness: 9.2% Specific gravity: 3.14 Consistency: 31.06%
Coarse aggregate	10mm Conforming to IS 383 Specific Gravity: 2.8
Fine aggregate	River sand 4.75mm to 150 microns Conforming to IS 383 Specific Gravity: 2.59 Sieve Analysis: C_c = 0.863, C_u = 9.702, D_{10} = 0.17
Water	Potable water used for curing and mixing Conforming to IS 456: 2000

3.3 Reinforcing bars:

This is an integral part of the whole assembly. The top and bottom slab of concrete have one mesh each, which can be either tied or welded. Transverse ribs are used to keep these meshes intact after the bubbles are placed in the allocated positions between the meshes. Height difference between the bars is related to the bubble diameter. If the bubble diameter is greater, the height difference is greater and vice versa.

For the experiment,

F_y = 500 N/mm^2 were used.

Diameter of the bars used is as per the design.

4. Advantages

Following are the advantages of bubble deck slabs that have been justly outlined.

1) Structure
   a) Less weight than a conventional slab
   b) Depth of foundation is less
   c) More strength for same volume of slab
   d) Use of beams can be nullified if the span allows
   e) Columns used are of less thickness
   f) Has similar stiffness and bending strength of that of a conventional slab
2) Fabrication
   a) Light weight
   b) Less equipment or cheap lifting equipment
   c) Less work for manual labors
3) Engineering properties
   a) Less time required to cure the slab due to less volume of concrete
   b) Lower creep due to less concrete in the center and less heat generation
   c) High explosion resistance due to bi-axial design of the slab
   d) High earth-quake resistance due to less weight and rigid design
4) Environment
   a) Less CO_2 emissions
   b) Less concrete used
   c) Recycling of plastic possible
   d) Less efforts for transporting
5) Safety
   a) Fire proofing design
   b) Moisture or condensation proof design
   c) Earthquake resistance to an extent due to reduced weight
6) Cost
   a) Savings in concrete costs
   b) Savings in manual labor costs
   c) Decrease in construction and/or fabrication time
   d) Savings in transportation costs due to low weight handling
   e)

5. Experiment

5.1 Design of concrete specimen

Design of concrete mix was carried out as per the IS 10262: 2009. Size of the specimen is taken as 0.5m×0.5×0.1m for calculation purposes. Material required for the said dimensions is given below in table

Table 3: Experiment material specification

Material	Weight in kg and volume in liter
Cement	438 kg
Fine aggregate (Sand)	583 kg
Coarse aggregate	920 kg
Water (from water: cement ratio taken as 0.45)	198 liters

5.2 Design of the reinforcement specimen

Dimension of the specimen is 0.5m×0.5m×0.1m

Cover for the specimen is 20mm in both directions

5 bars of 8mm diameter have been used

Figure 1: Cover and specimen Reinforcement

5.3 Compressive strength of Conventional Concrete Slab:

Testing was done on the UTM after curing for 28 days. Dimensions of the block for testing was 0.5m×0.5m×0.1m. Its weight when measured was 22.76Kg.Maximum load on the slab was observed as 640 KN.

Equation 1: Calculation of compressive strength

$$\text{Compressive strength of the block} = \frac{\text{Ultimate Load}}{\text{Area of Slab}}$$

From the above equation, the compressive strength of the concrete slab is 25.6 N/mm^2.

5.4 Compressive strength of Bubble Deck Slab:

Testing was done on the UTM after curing for 28 days. Dimensions of the block for testing was 0.5m×0.5m×0.1m. Its weight when measured was 20.43 Kg. It can be noted that the weight of the bubble deck slab is lighter in weight than the conventional slab. Maximum load on the slab was observed as 655 KN.

Equation 2: Calculation of compressive strength of the bubble deck

$$\text{Compressive strength of the block} = \frac{\text{Ultimate Load}}{\text{Area of Slab}}$$

From the above equation, the compressive strength of the concrete slab is 26.2 N/mm^2.

6. Testing procedure

1. This testing is done at 28-day age as described. The test slabs are simply supported and load at a single point.
2. To ensure uniformity, the cover distances from the either sides of the loading frame are checked and ensured that the load is acting at the center.
3. These specimens were placed on the Universal Testing Machine and load was made to act at the centerline.
4. All gauges were kept in appropriate locations and initial readings were noted.
5. After every load increment made, the values on gauges were recorded for both middle span deflection and cracks developed along with their propagation.
6. All deflections were measured at their middle-span. When the loading was advanced, the increment of load was made smaller till failure was reached.
7. At failure, the load indicator stopped working and deflection increased very fast without any increase in the load application.
8. All the values of load and deflection were noted for every 5KN interval.

Cracking patterns on the slab can be seen in the figure below.

Figure 2: Crack patterns while testing the slabs

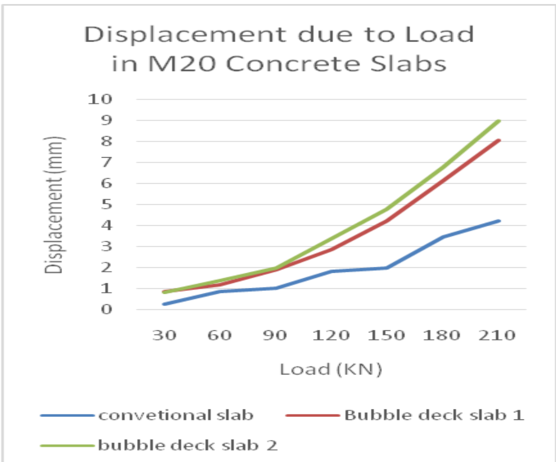
7. Observation

The first observation is that the behavior of the bubble deck slab is very much dependent on the ratio of bubble diameter to the thickness of the slab.

For M20 concrete

Table 4: M20 concrete slab load and deflections

Load in KN	Conventional Slab	Bubble Deck Slab 1	Bubble Deck Slab 2
30	0.29	0.89	0.84
60	0.89	1.23	1.42
90	1.07	1.91	1.99
120	1.85	2.89	3.42
150	2.01	4.23	4.82
180	3.49	6.19	6.79
210	4.25	8.09	9.01

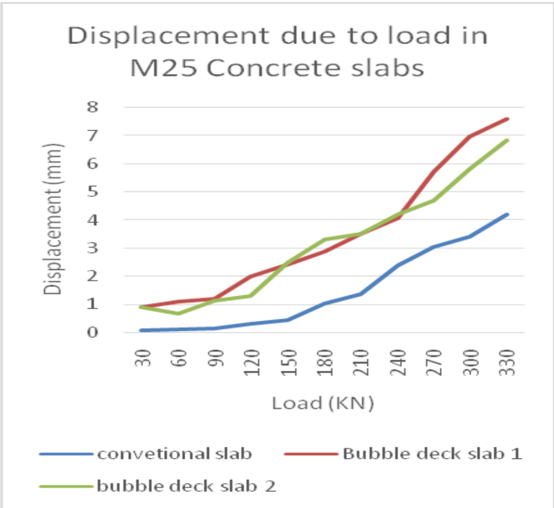


Graph 1: Displacement due to load in M20 Concrete slabs

For M25 Concrete used in the slab

Table 5: M25 concrete load and deflections

Load in KN	Conventional Slab	Bubble Deck Slab 1	Bubble Deck Slab 2
30	0.069	0.91	0.91
60	0.091	1.11	0.67
90	0.121	1.21	1.12
120	0.29	2.01	1.31
150	0.44	2.41	2.49
180	1.03	2.9	3.31
210	1.35	3.5	3.52
240	2.39	4.07	4.21
270	3.02	5.7	4.71
300	3.39	6.98	5.81
330	4.19	7.59	6.84



Graph 2: Displacement due to load in M25 concrete slabs

8. DISCUSSION

From this experiment, we can say that the bubble deck slab has a reduced volume of concrete which ultimately decreases the dead load on the slab. Parallelly, the load bearing capacity also increases with respect to a conventional concrete slab.

Type of arrangement of bubbles also plays a major role on the load carrying capacity of the slab. In alternative arrangement of the bubbles, there is an increase in the load bearing capacity than the convention slab but less than that of a continuous bubble deck slab. There is also a considerable change in the deflections shown by the bubble deck slabs which are nearer in deflection the conventional slabs.

Bubbles in the bubble deck slab improved the elasticity of the slab. A conventional slab deflects less than a bubble deck slab before failure. Based on the deflection, the failure can be estimated, and other preventive measures can be taken. Quantity of bubbles in the slab affects the elasticity property.

For a given volume, the compressive strength of a bubble deck slab is higher than the compressive strength of the conventional slab.

Comparison between the two slabs:

In a conventional slab, with dimensions 500mm×500mm×180mm, the maximum shear load taken by the slab was 160 KN. Crack propagation occurred at 75 KN.

In a bubble deck slab, with dimensions 500mm×500mm×180mm, the maximum shear load taken by the slab was 156 KN. Crack propagation occurred at 59 KN.

9. CONCLUSION

Bubble deck slabs give greater flexural strength, stiffness and shear force capacity. It was observed that when same quantity of concrete and reinforcement were used, the said structural properties of the slab increased by at least 60% than that of a conventional slab. The economy of construction increased by 40% when compared to a conventional slab.

For various experimental cases, the bubble deck slab had had deflections equal to that of conventional slabs under same loading conditions. Similarly, moments were 7-10% reduced to that of a conventional slab. The base shear of the structure also reduced (12-14%) due to decrease in loads by the concrete.

Economy in the corresponding structural members (such as beams and columns) was also obtained. It is due to the decrease in dead load and achievability of longer spans without increasing any dimension of the beams or columns.

There is an increased load bearing capacity in the bubble deck slab when compared to a conventional slab of same volume.

Usage of concrete is drastically decreased since 1kg of plastic replaced 100kg of concrete. This makes the bubble deck a green initiative due to decrease in cement production and its CO_2 production.

Foundation sizes decrease for buildings as overall concrete weight decreases (in slabs, beams and columns).

Since concrete weight is decreased, the concrete handling time is also greatly reduced making the time to lay a slab lesser than that of a conventional slab. Time saving practice leads to money saving as the project will require less time and less labor to be completed.

If spacing between the balls increase the flexural strength also increases without any relation to the thickness of the slab.

Voids present in the slab due to the balls give it great thermal insulation compared to a conventional slab.

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How to cite this article: Ali MS, Babu SA. A structural study on bubble deck slab and its properties. International Journal of Research and Review. 2019; 6(10):352-357.

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