EXPERIMENTAL INVESTIGATION ON BUBBLE DECK SLAB CONFINING HIGH DENSITY POLYETHYLENE(HDPE) SPHERES

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Abstract - *Reinforced concrete is one of the common materials used for construction. With the advent of new techniques concrete could be modified to suit any need such as early setting, high strength and such. But the inherent property which comes with every material that exists is its self-weight. Reinforced concrete even though versatile has its drawbacks owning to its self-weight. Reducing self-weight helps the structure to have better seismic efficiency when constructed as multi-storey among other advantages. The main objective of this project is to obtain a slab element with reduced self-weight by means of confining High Density Polyethylene spheres (HDPE). The Bubble deck slab casted is then studied and compared with that of a conventional slab. To find the most efficient sphere arrangement, two types of Bubble deck slab was casted with zig-zag and uniform arrangement along with a conventional slab. All the 3 slab specimens were tested for load carrying capacity and the results were compared. The amount of weight reduced is also observed. Bubble Deck slab when opted for mass construction not only reduces the weight of structure and cost of construction but is also eco-friendly.*

Key Words: **Bubble Deck, HDPE Sphere, Self-weight, Voided slab, Green technology.**

1. INTRODUCTION

Bubble Deck Slabs are slabs in which the voids are introduced by means of confining High Density Polyethylene Spheres (HDPE). The confining of spheres are based on the structure and need. The spheres are introduced at the neutral axis of the slab and removes the concrete that's not performing any crucial structural function.1kilogram of the polyethylene sphere added removes up to 100 kilos of concrete in the element. The slabs are designed as biaxial flat slabs. The spheres are not placed at the edges of the slab where the shear forces acting are more. About one third of the thickness is reduced when spheres are introduced and thus provides more head room and thus helps in construction of many stories. The structure constructed thus has overall less self-weight and thus the seismic performance of the structure is also increased. The spheres also act in better acoustic performance of the structure.

2. OBJECTIVE

i. The objective of this project is to cast a panel of Bubble Deck Slab and study the structural behavior.

ii. To test and compare Bubble Deck slab of different arrangement of spheres with conventional slab.

iii. To obtain a structural element with relatively Eco-Friendly characters without compromising the Structural integrity.

3. SCOPE OF THE STUDY

The project holds good scope in the future, as the advent of skyscrapers demands much efficient structural elements. Conventional concrete being the most desirable construction material is being rendered undesirable with the advent of increased skyscrapers and structures with long span elements. Thus, there arises a need to not only reduce the dead load of the concrete but also make it more cost effective. These requirements are met by opting Bubble Deck slab in place of conventional slabs

4. MATERIAL PROPERTIES:

a. MATERIAL SELECTION

The Raw materials used for casting of Bubble deck and conventional slab are cement, water, Fine and coarse aggregate. In addition to those materials High Density Polyethylene spheres were used in the Bubble Deck Slab.

b. Cement:

Cement is the binding material that gives concrete its strength and also binds all the ingredients in the mix together. There are various types of cement available such as Early setting time, High strength. Portland cement also varies at grades namely as OPC 33, OPC 43, and OPC 53. Since Bubble Deck slabs are adopted for mass construction, OPC 53 grade is adopted to suit the strength requirement and construction pace.

c. Fine and Coarse Aggregate:

Fine and Coarse aggregate gives the concrete its cohesiveness, strength and toughness. The fine aggregate used for concreting is River sand. Coarse aggregate chosen is of size less than 20mm.The size of coarse aggregate

d. Water:

The water opted for concreting must be free from any impurities and chemicals. Potable water is best suited for concreting. Even though the spheres themselves are resistant to chemical attacks and are of high density, presence of harmful chemicals might reduce the efficiency of the spheres.

e. Steel Reinforcement:

High grade steel of Fe 500 is generally used. The same grade of steel is used in both in top and bottom steel reinforcement. Here 12mm diameter steel bar is used for main reinforcement and distributor reinforcement.

f. High Density Polyethylene Spheres (HDPE):

The spheres used for the formation of voids in the Bubble deck slab must be of High Density so that it is able to withstand not only the weight of the concrete but also the loads acting thereafter. Spheres with density in the range of 10kN/m^3 is generally adopted. The spheres must also possess high thermal resistance so that any accidental fire will not damage the element. The spheres adopted thus should have a fire resistance of at least 450 Degree Celsius. They should also be inert to chemical reactions so that they won't be compromised in case they are exposed to any chemicals. The spheres must also be made from recycled plastic to not only reduce cost of manufacturing but also to produce more eco-friendly product.

Table-1: HDPE Ball Properties

PROPERTY	RANGE
Diameter	60mm
Density	10kN/ m^3
Melting point	127-137°C
Ignition temperature	>355°C

5. TEST ON MATERIALS

Test are conducted with reference with **IS 12269:2013**

Table-2: Test on Cement

CEMENT (OPC 53 GRADE)			
Test Conducted	**Attained Value**	**Allowable Value**	**Purpose**
Specific gravity	3.14	3.1-3.2	Used to find whether the material able to float or sink.
Initial setting time	28 minutes	30 minutes	To understand the time, cement takes for initial setting between mixing, transporting and placing of concrete.
Consistency	31%	26% - 33%	To find out the water content required to produce Cement Paste
Fineness	3%	3% - 6%	It is responsible for quick development of Strength and Greater Cohesiveness

Table-3: Test on Coarse Aggregate

Test are conducted with reference with **IS 2386:1963**

COARSE AGGREGATE(<20mm)			
Test performed	**Attained Value**	**Allow able Value**	**Purpose**
Specific Gravity	2.7	2.6 - 3	Used to find whether the material able to float or sink.
Water Absorption	1.5%	Up to 3%	Used to determine the water holding capacity .
Crushing strength	6.8%	Not greater than 30%	To measure the resistance of an aggregate under gradually applied compressive load

Table-4: Test on Fine Aggregate

Test are conducted with reference with **IS 2386:1963**

FINE AGGREGATE(<20MM)			
Test Performed	**Attained Value**	**IS Limit**	**Purpose**
Specific Gravity	2.6	2.3 – 2.7	Used to find whether the material able to float or sink.
Sieve Analysis	Zone I	---	To assess the particle size distribution.

6. EXPERIMENTAL INVESTIGATION

6.1 General outline of experimental investigation

The investigation is done to study and compare the self - weight, load carrying capacity and strain variation of Bubble Deck slab with that of conventional Slab. Also to arrive cost effective arrangement of spheres in slab

6.2 Mix design

Mix design was done for M40 grade concrete using IS 10262: 2009 for true slump and water cement ratio 0.40. Quantity of materials as per M40 mix design is given in table 5.

Table-5: Quantity of materials per m³

Material	Quantity
Cement	551.2 Kg
Fine Aggregate	597.29 Kg
Coarse Aggregate	974.52 Kg
Weight of Water	220.48 Kg
Water Cement Ratio	0.4
Cement : FA : CA	1: 1.1 : 1.18

6.3 Test on Fresh Concrete

Test on fresh concrete are conducted to check the workability. Workability of concrete is the property of freshly mixed concrete which determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished without segregation and bleeding.

Slump Cone Test:

Purpose - Used to measure the Consistency of concrete

Table-6: Result of Slump cone test

S.NO	W/C ratio	Slump Pattern
1	0.40	True Slump
2	0.45	True Slump

COMPACTION FACTOR TEST:

Purpose - Used to measure the workability of concrete.

Table-7: Result of Compaction factor test

S.NO.	W/C ratio	W_1 (kg)	W_2 (kg)	Compaction factor (W_1/W_2)
1	0.4	14.864	17.895	0.83

Where W_1 – Weight of partially compacted concrete.

W_2 – Weight of fully compacted concrete.

Table-8: Slab Specification

S.no	specimen	Length	Width (mm)	Thickness (mm)	Bubble diameter(mm)	Arrangement	Grade
1	C.S	1000	1000	130	-	-	M40
2	BD-Z	1000	1000	130	60	Zig-Zag	
3	BD-U	1000	1000	130	60	Uniform	

Where C.S - Conventional Slab

BD-Z - Bubble Deck Zig Zag Arrangement

BD-U - Bubble Deck Uniform Arrangement

7. CASTING OF SPECIMEN

7.1 Design of Reinforcement

1) Detailing of Conventional Slab: Reinforcement was designed based on IS:456(2000) as 12mm diameter bars with a spacing of 100mm c/c in both x and y direction.

Cover of 35mm was given on each side. The main bars were placed in the form of a mesh as shown in figure 1.

Fig - 1: Reinforcement details of Conventional Slab

2) Detailing of Bubble Deck Slab- Zig-Zag: Reinforcement was designed as 12mm diameter bars with a spacing of 80mm c/c in x direction and 60 mm c/c in y direction. Cover of 35mm was given on each side. The HDPE balls were arranged in **Zig – Zag** manner which was shown in figure 2.

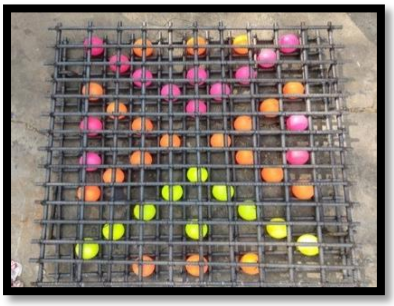

Fig - 2: Reinforcement details of Bubble Deck Slab

3) Detailing of Bubble Deck Slab- Uniform: Reinforcement was designed as12mm diameter bars with a spacing of 80mm c/c in x direction and 60 mm c/c in y direction. Cover of 35mm was given on each side. The HDPE balls were arranged in **Uniform** manner which was in figure 3.

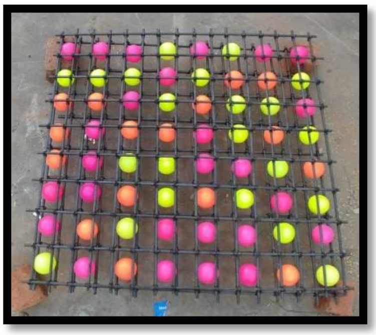

Fig - 3: Reinforcement details of Bubble Deck Slab

7.2 Concreting and Curing of Specimens

The slab specimens were casted with a concrete grade of M40. Weigh batching was adopted and hand mixing was adopted for concreting. The casted specimens were cured using jute bags for a period of 28days.

Fig - 4: Concreating

Fig - 5: Demoulding

Fig - 6: Curing of Specimens

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8. TESTING OF SPECIMENS

The casted specimens were cured for a period of 28 days and then testing was done. The testing was carried out by applying load. Deflection gauge was also used to find the deflection produced on the specimen.

Fig - 7: Test Setup- CS

Fig - 8: Test Setup- BD-Z

Fig - 9: Test Setup- BD-U

From the test, the load at initial crack, ultimate load capacity and the corresponding deflection was found out for each slab. The crack pattern was also observed under the ultimate load capacity of each slab.

9. TEST RESULTS:

Table-9: Test results

S.no	Slab	Load at Initial Crack(kN)	Ultimate load(kN)	Deflection (mm)
1.	C.S	180	192	3.78
2.	BD-Z	156	164	3.88
3.	BD-U	128	140	5.50

10. CRACK PATTERN:

Figures 10, 11 and 12 illustrates the specimen's crack patterns and failure mode under ultimate load. All specimens showed flexural failure mode with diagonal flexural cracks. Some small longitudinal cracks appeared in uniform arrangement and Zig-Zag arrangement specimens. This may be due to relatively thin bottom cover thickness between bottoms of slab to bottom of void. As the thin part of the bottom cover concrete under the void was detached from the plastic sphere, small longitudinal crack occurred.

Fig - 10: Crack pattern on conventional slab

Fig - 11: Crack pattern on uniform arrangement

Fig - 12: Crack pattern on zig-zag arrangement

11. GRAPH INTERPRETATION

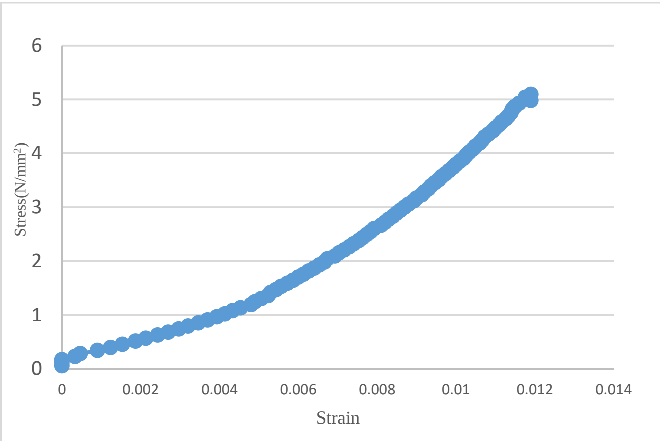

Chart – 1: Stress vs Strain

The above stress strain graph is plotted for the hardened concrete of grade M40, and it could be observed that the graph pattern obtained is almost linear. It is produced by plotting concrete compression strain at various intervals of compression loading (stress). The stress and strain of concrete is obtained by testing concrete cylinder specimen at age of 28 days, using UTM (Universal Testing Machine).

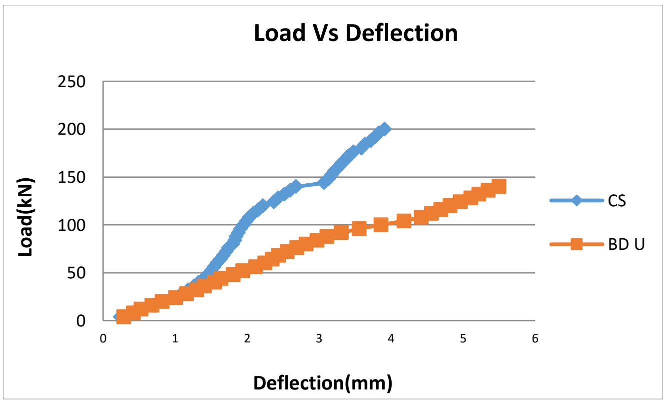

Chart – 2: Load vs deflection (CS vs BD U)

The deflection of the uniform arrangement is much higher at 5.50mm and the load capacity is also comparatively less. The moment deflection curve is also shown.

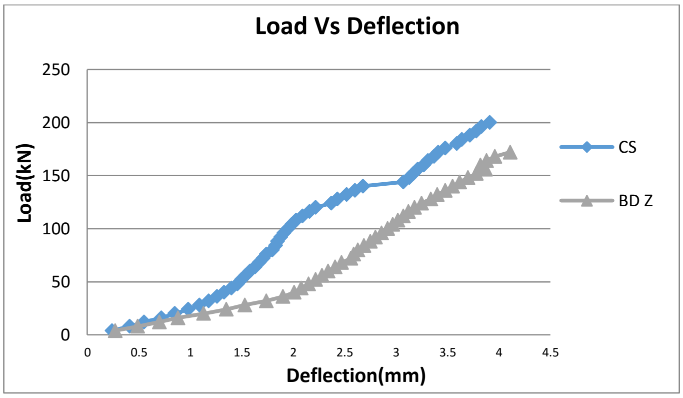

Chart – 3: Load vs deflection (CS vs BD Z)

The deflection of zig-zag arrangement is 3.88mm which is much lesser and the load capacity is also much higher. The moment deflection curve is also shown. From the graphs plotted it could be inferred that both uniform and zig-zag arrangement of sphere has more deflection in comparison with the conventional slab. Also the ultimate load capacity is reached far earlier for uniform arrangement of sphere than zig-zag arrangement.

12. STIFFNESS MODIFICATION FACTOR. (Dr. K. B. Parikh (2014).

The second moment of inertia is a key variable when performing structural analysis of slab. The un-racked moment of inertia is dependent on the thickness and width of the flat plate slab and the contribution made by steel can be ignored since steel is not taking part prior to cracking. In addition, the values in Cobiax Technology Handbook are taken by calculating second moment of inertia in State-1 (uncracked) and in State-2 (cracked). The results have revealed that the stiffness reduction factor in state-1 is the determining factor. The stiffness reduction factor can be derived from the calculation of second moment of inertia of voided slab and solid slab. With the help of this reduction factor and taking into account the reduced self-weight of voided slab deflection of voided slab can be calculated

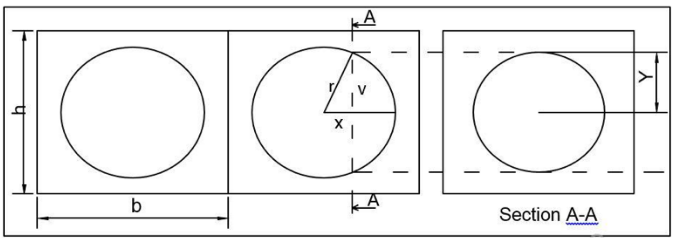

Fig - 13: Voided slab stiffness calculation method

To find out stiffness reduction factor first find out second moment of inertia of conventional slab without void former. And this can be calculated with:

$Ic = bh^3/12$

Where, b = Width of conventional section surrounding a single sphere. h = Total thickness of the slab Second moment of inertia of circle can find out with following equation by considering average void area with radius r.

$Iv = \pi r^4/4$ stiffness reduction factor is given by (Is – Iv)/Is

The stiffness reduction factor for the Bubble Deck Slab with Zig-Zag arrangement is calculated and was found as 0.98 which is within the permissible limits and hence the slab type could be adopted for construction.

13. CONCLUSIONS

The Key conclusions inferred are as follows:

- From the test results obtained, it is found that both the zig-zag arrangement and uniform arrangement of spheres reduce considerable amount of self-weight of the structure. The former reduces the self-weight by about 4.2%, while the latter reduces the self-weight by about 6.5% in comparison with that of a conventional slab.
- The Load capacity of the slab with zig-zag arrangement is about 85% of that of a conventional slab while the Uniform arrangement of spheres yields a load capacity of about 73% of the conventional slab.
- The deflection characteristic which were observed with a deflection gauge was that, it was higher for uniform arrangement of spheres when compared with both zig-zag arrangement of spheres and conventional slab.
- Even though both zig-zag and uniform arrangement of sphere yields a considerably reduction in self weight and cost, the load capacity of the uniform arrangement is much lesser than desirable value. The deflection produced is also more owning to the more number of spheres and the amount of concrete removed. Thus considering these, it becomes a difficulty to adopt this type of arrangement for structure of large scale.
- Thus it could be concluded that, slab with zig-zag arrangement of spheres could be adopted to obtain the desirable advantages without compromising the structural integrity. The slab type adopted is also eco-friendly.

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