Experimental Investigation on Bubble Deck Concrete Using Plastic Waste

A. Dinesh, R. Prasanth Kumar and S. R. Abijith

Abstract Reinforced concrete and steel are the commonly used building materials in which reinforced concrete plays a vital role in the construction of buildings. In the structural components like slab and beam, the concrete below the neutral axis is assumed that it will not take any tensile stresses and will act only as a filler material. Hence, those ineffective concrete can be replaced with other material which in turn reduces the self-weight of the structure. Plastic waste which is nondegradable becomes a great concern to the environment. Such plastic waste must be recycled to create an eco-friendly atmosphere. Hence, plastic waste are recycled in the form of balls and can be used in the slab, such type of slab is called Bubble deck slab. Bubble deck slab replaces ineffective concrete by plastic balls, thereby dramatically reducing the structural self-weight which in turn reduces the magnitude of seismic forces which will be highly useful in seismically active areas. Hence in this paper, spherical balls made of recycled plastic were introduced to replace the ineffective concrete near the neutral axis of the concrete slab. Two slabs are casted with dimensions 0.75 m × 1 m, one with bubbles (Bubble deck slab) and one without bubbles (Conventional slab). It is found that, though ultimate load of Conventional slab is more than the Bubble deck slab, the cracking load of Bubble deck slab is comparatively higher than the Conventional slab due to its flexibility. And also the Bubble deck slab undergoes maximum deflection before failure while compared to the Conventional slab which will give sufficient warning to the users before failure of the structure.

Keywords Bubble deck slab · Cracking load · Deflection · Plastic waste · Ultimate load

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1 Introduction

Concrete is the most commonly used construction material due to its sustainability, durability, versatility etc. It is highly used in the construction of buildings, bridges, and pavements. The various constituents of concrete are cement, fine aggregate, coarse aggregate, and water in which 5% of the world's CO_2 is produced during the manufacture of the cement. In addition, the concrete is heavy, thus in order to reduce the self-weight of the structure, some portion of the concrete needs to be removed. Hence, to achieve this, a new type of concrete is introduced called Bubble deck concrete. Bubble deck concrete is a type of concrete in which some amount of the concrete is replaced by the plastic hollow bubbles, which are made by the waste plastic material that reduces the self-weight of the structure and reduces the CO_2 emission. The main advantage of using Bubble deck slab is that it can be highly used for large-span structures, large overhang areas, and it can be used where only fewer supporting points (like columns and walls) are available for the slab [1–7].

In this project, Bubble deck slab is cast by using hollow balls made by recycled plastic. It is an innovatory method of virtually eliminating the concrete part below the neutral axis of Conventional slab, which does not contribute to the tensile strength of the member. By introducing this recycled plastic in the concrete, there is nearly one-third reduction in the weight of Bubble deck concrete compared to Conventional concrete. This reduction in slab weight reduces the load acting on the beams, walls, and columns, which in turn reduces the size of the beam, column, and other structural components of the building.

In this project, slab of size 0.75 m × 1 m is used, since most of the slab used in the construction of the buildings are rectangular. The depth of the slab is taken as 230 mm, to have sufficient depth below the neutral axis to place the plastic balls. The recycled plastic is made of high-density polyethylene hollow plastic spheres.

The casting of the slab with recycle plastic in the zone below neutral axis is shown in Fig. 1.

Fig. 1 Bubble deck slab

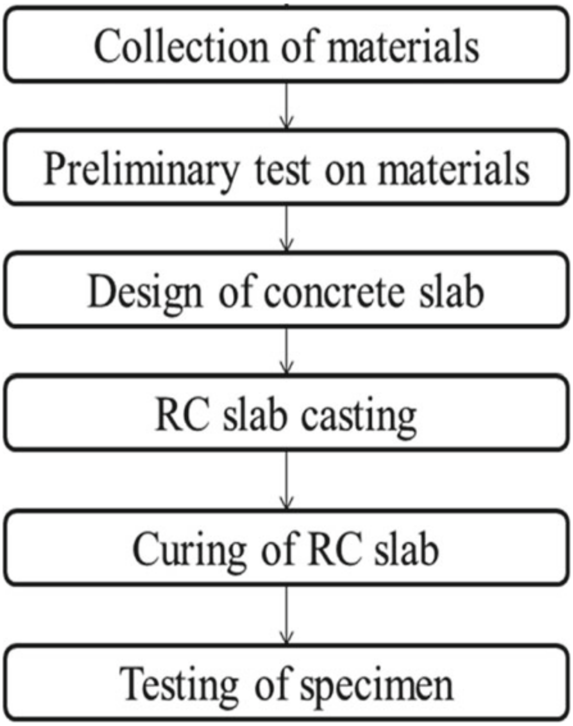
2 Objectives

The main objective of this study is

- To use HDPE—High-density polyethylene balls in the reinforced concrete slab in order to avoid the dumping of plastic, make use of the recycled plastic in concrete and reduce the self-weight of the slab,
- To study the behavior of Conventional slab and Bubble deck slab,
- To present a procedure for comparison of all parameters between solid Conventional slab and Bubble deck slab, and
- To study the deflection and load carrying characteristics of Conventional slab and Bubble deck slab.

3 Methodology

The methodology defines the strategy that shows the way in which this research is carried out. The methodology of the project is as follows.



4 Materials Used

The various materials used for the casting of Bubble deck concrete are

- Cement,
- Aggregates,
- Reinforcement bars,
- Waste Plastic bubbles, and
- Formwork.

5 Preliminary Design of Slab

The preliminary design of the concrete slab is as follows.

5.1 Slab Details

Slab size: 0.75 m × 1 m

(since most of the slabs are rectangular, this size is chosen)

Grade	:	M20
Steel	:	Fe 415
Rod diameter	:	8 mm
Spacing	:	150 mm c/c
Cover	:	15 mm
Depth	:	150 mm
Clear span	:	1 m
Live load	:	3000 N/m^2
Concrete	:	M20
Steel	:	Fe 415.

5.2 Design of Slab

Depth required = (SPAN/2 X MF)
= 50 mm

Assuming the overall depth of the slab as 150 mm

Dead load of slab = 25 × 150
= 3750 N/m^2
Live load = 3000 N/m^2

Total = 6750 N/m^2
Factored load = 1.5 × 6750
= 10,125 N/m^2
α_X = 0.056
α_Y = 0.056
r = 1
Maximum span BM per meter length, Mu = 0.056 × 10,125 × 1^2
= 567 Nm
Maximum span BM per meter length, Mu = 0.056 × 10125 × 1^2
= 567 Nm

Equating Mu, limit to Mu

$0.138Fckbd^2$ = 567
d = 45 mm
Percentage of steel = 0.4%
Spacing of 8 mm dia bars, required = 300 mm

Provided 8 mm dia bars at 150 mm c/c.

6 Quantity of Materials Used

The mix design of concrete is done as per IS 10262:2009 and by using IS 456:2000. The mix design is done using the following stipulations for proportioning which is commonly adopted in Coimbatore zone and it is tabulated in Table 1.

The final quantity of materials arrived through mix design is shown in Table 2.

The quantity of the materials per cubic meter is calculated as per IS 10262:2009 and IS 456:2000. This value is ascertained for the volume of 1 m × 0.75 m × 0.23 m for Conventional slab and they are tabulated in Table 3 and the values are again ascertained for the volume of 1 m × 0.75 m × 0.146 m (84 mm is deducted since plastic balls are used) for Bubble deck slab and they are tabulated in Table 4. It is seen that the quantity of materials in Bubble deck slab is reduced compared to Conventional slab because of the usage of recycled plastic.

Table 1 Stipulations for proportioning

1.	Grade designation	M20
2.	Type of cement	OPC 53 grade conforming to IS12269-1987
3.	Maximum nominal aggregate size	20 mm
4.	Coarse aggregate	165 kg
5.	Exposure condition	Normal
6.	Degree of supervision	Good

Table 2 Quantity of materials for M20 grade concrete

Materials	Cement	Fine aggregate	Coarse aggregate	Water
Quantity	319 kg/m^3	478.26 kg/m^3	956 kg/m^3	174 l
Mix ratio	1	1.5	2	0.5

Table 3 Quantity of materials for Conventional slab

Grade of Concrete—M20		
S. No.	Materials	Quantity
1.	Cement	55 kg
2.	Fine aggregate	82.5 kg
3.	Coarse aggregate	165 kg
4.	Water	30 l

Table 4 Quantity of materials for Bubble deck slab

Grade of concrete—M20		
S. No.	Materials	Quantity
1.	Cement	35 kg
2.	Fine aggregate	52.5 kg
3.	Coarse aggregate	105 kg
4.	Water	17.5 l

7 Experimental Investigations

A formwork for Conventional Slab and Bubble deck slab is prepared for the inner dimension of 1 m × 0.75 m × 0.23 m. The slab is provided with a clear cover of 15 mm. A wire mesh is placed over the concrete in both the slabs above the concrete cover. In Conventional concrete slab, concrete is placed over the wire mesh until the depth of the slab becomes 230 mm. In case of Bubble deck slab, a layer of concrete is poured over the wire mesh and plastic balls are placed till it reaches the neutral axis of the slab and again concrete is placed over the balls till the depth of the slab becomes 230 mm. The casting of Conventional slab is shown in Fig. 2.

The completed Conventional slab and Bubble deck slab is shown in Fig. 3. The Conventional slab and Bubble deck slab is kept under curing for 28 days using gunny bags. At the end of 28 days, curing experimental investigations are made. In addition to this, nine cubes are cast to validate the mix design done.

Fig. 2 Casting of Conventional slab

Fig. 3 Casted Conventional and Bubble deck slab

7.1 Rebound Hammer Test

The rebound hammer test, which is one of the nondestructive testings, is conducted to determine the compressive strength of the concrete. The mean values obtained by testing in three different horizontal positions are tabulated in Table 5 for and the mean values obtained by testing in three different vertical positions are tabulated in Table 6.

Table 5 Rebound hammer values for horizontal position

S. No.	Type of slab	Rebound value	Compressive strength (N/mm^2)
1.	Conventional slab	30	20
2.	Bubble deck slab	24	18

Table 6 Rebound hammer values for vertical position

S. No.	Type of slab	Rebound value	Compressive strength (N/mm^2)
1.	Conventional slab	34	22
2.	Bubble deck slab	24	18

Table 7 Characteristic strength of concrete at the age of 7, 14, and 28 days

S. No.	Type of concrete mix	7 days (MPa)	14 days (MPa)	28 days (MPa)
1.	Conventional	17.64	20.27	22.66

7.2 Compression Test

The cubes are cast in order to validate the mix design done as per IS 10262:2009 and IS 456:2000. The cubes are kept in curing for 7 days (=3 cubes), 14 days (=3 cubes), and 28 days (=3 cubes) and its compressive strength is determined by placing it in the compression-testing machine. The mean value of compressive strength is tabulated in Table 7.

8 Results and Discussions

After 28 days, curing the slab is placed in loading frame of 200T. The load is applied through the load cell to the I-girder, which is placed directly on the top surface of the Conventional slab. A dial gauge is placed beneath the slab to indicate the deflection of the slab when the load is applied. The experimental setup for the slab is shown in Fig. 4. The load is applied to the slab and the corresponding deflection values are measured. This process is repeated until a particular point where the load values get reversed. The load corresponding to this point is called yield load and the deflection corresponding to the yield load is noted. Now the dial gauge is removed and the load is continuously applied till the slab breaks and the load corresponding to this point is called as ultimate load. The yield load, corresponding deflection, and ultimate load values are computed for both the Conventional and Bubble deck slabs.

Fig. 4 Experimental setup of the slab

Table 8 Test results of Conventional concrete slab

S. No.	Yield load (kN)	Deflection (mm)	Ultimate load (kN)
1.	340	12	380

8.1 Conventional Concrete Slab

The Conventional concrete slab has been cast and tested for the load carrying capacity and its corresponding deflection. The test results of Conventional concrete slab obtained are shown in Table 8.

8.2 Bubble Deck Concrete

The Bubble deck slab has been cast and tested for the load carrying capacity and its corresponding deflection. The test results of Bubble deck concrete slab obtained are shown in Table 9.

Table 9 Test results of Bubble deck concrete

S. No.	Yield load (kN)	Deflection (mm)	Ultimate load (kN)
1.	280	16	320

9 Conclusions

- The yield load of Conventional slab is 340 kN and for Bubble deck slab is 280 kN, thus the yield load of Bubble deck slab is reduced by 17.64%.
- The deflection of Conventional slab is 12 mm and for Bubble deck slab, it is 16 mm; thus the deflection of Bubble deck slab is increased by 4 mm contributing more ductility to the Bubble deck slab.
- The ultimate load carrying capacity of the Conventional slab is 380 kN and for Bubble deck slab, it is 320 kN; though the load carrying capacity is decreased, the Bubble deck slab exhibits more ductility behavior compared to Conventional slab.
- The flexural capacity of Bubble deck concrete slab is improved (since deflection is higher compared to conventional) compared to Conventional concrete slab even with the usage of the same quantity of reinforcement and the same grade of concrete.
- Since the quantity of concrete materials are reduced in the Bubble deck slab (due to the usage of recycled plastic) compared to Conventional concrete slab, the economy of the structure is reduced.
- By using the hollow elliptical balls, though the load bearing capacity for the Bubble deck slab was reduced, the self-weight of the structure was also reduced which in turn will reduce the size of the other structural components and reduce the overall economy of the structure.

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