Experimental Study on Partial Replacement of Concrete Below Neutral Axis of Beam

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Abstract— **Concrete is the primary structural component, that exist in buildings and bridges. In recent days the problem faced by the construction industry is acute shortage of raw materials. In case of simply supported reinforced concrete beam, the region below neutral axis is in tension and above neutral axis is in compression. As concrete is weak in taking tension, steel reinforcements are provided in this zone. We have to consider concrete below the neutral axis act as a stress transfer medium between the compression and tension zone. Partial replacement of the concrete below the neutral axis is an idea that can create reduction in weight and savings in materials. In this paper, an experimental investigation on partial replacement of concrete below the neutral axis by creating air voids using polythene balls is discussed.**

Keywords— Neutral axis, sacrificial concrete, stress transferring, center point loading.

I. INTRODUCTION

In case of normal simply supported reinforced concrete beam, the neutral axis divides the tension zone and compression zone. The region below the neutral axis is in tension and the region above neutral axis is in compression. Since concrete is weak in taking up tension, steel reinforcements are provided at the tension zone of the beam. The concrete below the neutral axis act as the medium for transferring stress from compression zone to the tension zone, i.e., steel reinforcement provided at the bottom. So the concrete provided below the neutral axis is known as sacrificial concrete. (The compressive force is acting in the top zone at a distance of $0.42X_u$. X_u is the neutral axis distance from top of section).

There are methods for increasing the effectiveness of concrete below neutral axis such as prestressing and converting the beam into other shapes such as Tee beams. But these methods cause change in the geometry of the structure and increases the construction cost. An alternate method of replacing the zone below the neutral axis with inert weightless substances like polythene balls or plastic balls will not greatly affect the strength and stress characteristics of the beam. Also it will not affect the geometry and shape.

In this paper, studies on partial replacement of concrete below the neutral axis by creating air voids using different percentage of polyethylene balls are discussed.

II. SIGNIFICANCE OF WORK

A. *Scope of the Work*

From the referred literature reviews, it is understood that in RC beams less stressed concrete in and near the neutral axis can be replaced by some light weight material. Different types of unfilled materials like brick, hollow pipes, grade variation of concrete, terracotta hollow blocks and expanded polystyrene sheets etc. gives good result in reducing the self-weight. But the ultimate load carrying capacity and first breaking load is very small when compared to control beam. To overcome these drawbacks air voids are created alternatively below the neutral axis by using plastic balls of diameter 3.5cm.

B. *Objective of the Work*

The objectives is to conduct a pilot study on introducing a new method by replacing some amount of the concrete below neutral axis by creating air voids using polyethylene balls without affecting the geometry of the section. The polythene balls are prepared from recycled plastic waste, hence it adds to the sustainable development.

C. *Methodology*

The methodology of the work consist of

i. Selection of proper grade; M30.
ii. Mix design of M30 grade concrete.
iii. Casting beam specimens of normal RC beams and 4% and 8% replaced beam specimens.
iv. Conducting centre point load test using 100T loading frame.
v. Study the effect and documentation.

III. MATERIAL TEST

TABLE.1 MATERIAL TESTING RESULTS

TEST	MATERIAL	EQUIPMENT USED	VALUES OBTAINED
Specific Gravity	Chettinad cement (PPC)	Le Chatelier flask	3.15
Specific Gravity	Fine Aggregates	pycnometer	2.61
Specific Gravity	Coarse Aggregates	Wire basket	2.641
Water absorption	Fine Aggregates	Vessel	1.42%
Water absorption	Coarse Aggregates	vessel	0.23%
workability	M30 concrete	Slump cone apparatus	75mm

IV. MIX DESIGN

TABLE.2 M30 MIX PROPORTIONING

Cement (Kg/m^3)	477
Fine aggregate (Kg/m^3)	489.5
Coarse aggregate (Kg/m^3)	1181.2
Water (li/m^3)	186
Water cement ratio	0.39
Mix ratio	1:1.026:2.47

V. EXPERIMENTAL INVESTIGATION

A. Experimental Procedure

A total of nine specimens are casted and tested; three of these specimens are reference beams and the others are replaced beam with 4% and 8% of air voids created using polythene balls of 3.5cm diameter respectively.

All the specimens is of dimension 200mm x 300mm x 1000mm with an effective span of 800mm. The beams are designed as singly reinforced beam with 2 nos. of 20mm diameter bars and 1 no of 12mm diameter bar at the tension region and 2 nos. of 12mm diameter bars as hanger bars. 8mm diameter bars at a spacing of 150mm is used as the shear reinforcement. The designation of control beam specimens are appended as (CB) while with those of replaced beam as (RB). The specimens are tested using center point loading using 100t loading frame.

The depth of neutral axis is calculated by considering M30 grade concrete and Fe415 steel with an effective cover of 20mm. Beams are assumed to fail when the concrete reaches failure compression strain. But in all cases of design, the steel need not have reached its yield point at the same time, unless it is so designed. If the section is designed as a balanced or under-reinforced one, the steel also reaches yield as concrete fails. But in over-reinforced beams, the steel stress at failure will be below its yield strength. As equilibrium of forces in bending requires that at all times tension be equal to compression, we have

Total tension, $T = f_{st}A_{st}$ ------------------------(1)

Total compression, $C = 0.36 f_{ck}\, b(x_u)$----------(2)

Where fst= actual tension in steel corresponding to the strain in steel.

Equating the two expression, we obtain

$f_{st}A_{st} = 0.36 f_{ck}\, b(x_u)$

i.e. $X_u = \frac{fstAst}{0.36fck\ b}$--------------(3)

For under-reinforced beams, steel first reaches yield stress of 0.87fy. Substituting its value and dividing both sides by the effective depth d (IS 456 Annexure G), we get

$$\frac{X_u}{d} = \frac{0.87 fy Ast}{0.36 fck\, b}$$ ----------(4)

$X_u = \frac{0.87x415x1232}{0.36x30x200x280}$=73.5mm

The zone below the neutral axis is divided into three zones and the two zones adjacent to the neutral axis is replaced with 4% and 8% voids created by using polythene balls of diameter 3.5mm.

Fig.1. Reinforcement Cage for Beam Specimens

Fig.2. Casting of Control Beam

Fig.3. Casting of Replaced Beam

Fig.4. Cast Beam Specimens

B. Test Procedure

The flexural strength of the specimens were tested using a 100t loading frame; LVDT was used to determine the deflection at the center of the beam.

The effective span of the test specimen is taken as 800mm which achieved by using cast iron support. The flexural strength of the beam is done as center point loading using the jack attached to the loading frame. The behavior of beam is keenly observed from beginning to the failure. The loading was stopped when the beam was just on the verge of collapse. The first crack propagation and its development and propagation are observed keenly. The values of load applied and deflection are noted directly and further the plot of load vs. deflection is performed which is taken as the output. The load in KN is applied with uniformly increasing the value of the load and the deflection under the different applied loads is noted down. The applied load increased up to the breaking point or till the failure of the material

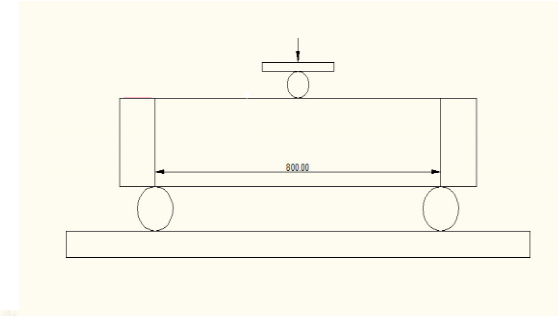

Fig.5. Schematic Test Setup

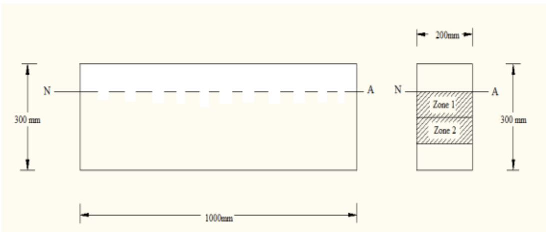

Fig.6. Replacement Zones of Beam

Fig.7. Experimental Setup of Beam Specimens

VI. EXPERIMENTAL RESULTS

A. Load Carrying Capacity

Ultimate strength of beams under centre point test was confirmed through recording the maximum load indicated by LVDT, but the cracking load was specified with developing the first crack on the concrete. It was found that there is not much difference in the load carrying capacity of solid control beam section and that of beam section with replacement below the neutral axis. The comparison of the results between the solid control beam and beam with replacement below the neutral axis is shown in Fig.8. The solid control beams are designated as CB1, CB2, and CB3. Beam section with 4% replacement below neutral axis is designated as RB1, RB2, RB3 and that with 8% is RB4, RB5, and RB6.

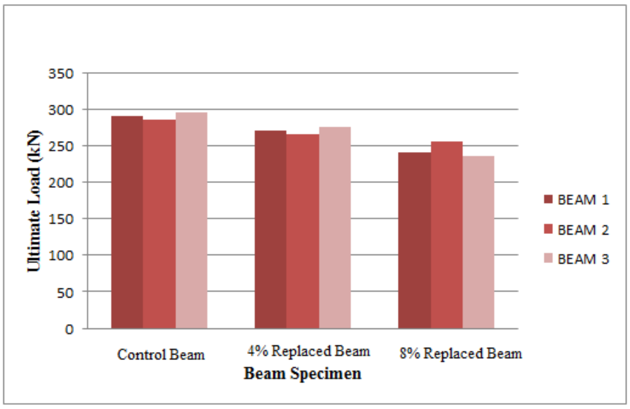

Fig.8. Ultimate Load of Beam

B. Load Vs Deflection Graph

As the load increases the deflection of the beam begins. Initially load will be directly proportional to deflection. Due to further increase in the load, value will not be proportional to deflection, since the deflection values goes on increasing as the strength of the material goes on increasing material loses elasticity and undergoes plastic deformation. Hence by this graph we can predict the strength of the material by knowing the deflection at the respective load values. The load values and corresponding deflection of solid control beam and beam with replacement at the neutral axis upto a safe load of 220kN is given in table 2.

TABLE 2: LOAD AND DEFLECTION VALUES OF BEAM SPECIMENS

Load (kN)	**Deflection (mm)**		
	CB	*RB 4%*	*RB 8%*
50	22.79	26.51	28.31
60	22.79	26.89	28.62
70	22.79	27.28	29.28
80	22.85	27.66	29.58
90	23.33	27.75	29.96
100	23.5	28.33	30.01
110	23.79	28.51	31.25
120	24.78	29.15	32.56
130	25.17	30.25	32.86
140	25.75	31.43	33.24
150	26.22	32.58	33.46
160	27.17	33.89	34.21
170	27.65	34.12	34.75
180	28.79	34.33	35.11
190	29.15	34.51	35.42
200	29.55	34.79	36.14
210	30.02	34.95	37.52
220	30.73	35.16	37.85

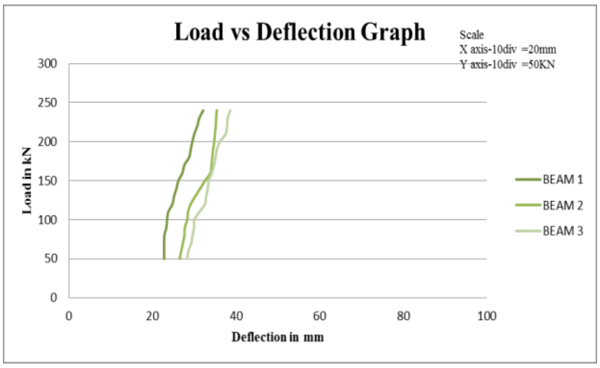

Fig.9. Load vs. Deflection Graph up to 220kN

VII. EVALUATION AND DISCUSSION

A. Load deflection relationship

From Fig. 8 the load deflection relationship of control beam and that of replaced beams are found to be similar.

B. Concrete saving

Concrete is one of the important construction materials. In construction industries large wastage of concrete is taken place. Material cost is a main component in the total cost of the product varying from 25 to 70%. Therefore, in order to control the cost, it is necessary to pay maximum attention for controlling material cost especially through abnormal losses. It should be made sure that the right quantities of materials are consumed with less wastage. This issue can be minimized by avoiding concrete in the neutral axis without bearing significant strength. Saving of concrete can be efficiently achieved with increase in length and depth of the beam. Therefore it can be effectively utilised during the construction of plinth beams, raft foundation, piers and similar other works.

Total volume of the beam =60000cu.cm

Volume of concrete below neutral axis in zone 1 and zone 2 = 20000cu.cm

In case of 4% replaced beam, 50nos. of 3.5cm diameter polythene balls are used.

Volume of 50 polythene balls=1122.46cu.cm

We can see that reduction in volume below neutral axis in zone and zone 2 =18877.5 cu.cm.

We can see that percentage reduction of volume in zone 1 and zone 2= 5.613%.

It is more advantageous for large construction where wastage is more.

C. Ultimate load carrying capacity

The ultimate load carrying capacity of control beam is comparable to that of replaced beam with 4% and 8% voids.

D. Labour reduction

Labours are one of the major resources in construction industries. Direct labour cost is also a part of the prime cost. It is clearly evident from the study that the total volume saving in concrete is directly proportional to the percentage reduction in labour. Concreting works in construction industry is labour intensive. When the volume of concreting works reduces, the need for labour also get decreased simultaneously, which in turn minimise the production cost.

E. Cost reduction

In current days of competition, it is necessary that a business concern should have utmost efficiency and minimum possible wastages and losses to reduce the cost of production. If the cost of inputs increases, then naturally, the cost of the production will go up. The inputs in construction fields include material, machines, labour and other overhead expenses. From the above conducted pilot study it can be concluded that by using partial replacement of reinforced beam below neutral axis will bring significant reduction in the amount of concrete without bearing the strength upto a certain limit. This saving in material cost is more effectively utilised when considering large depth and length of beam or in similar other works, where abnormal loss of concrete occurs. This can be compared to a chain reaction because as the volume of concrete decreases, the material cost reduces which decreases the labour cost, which in turn minimise the construction cost.

F. Application

From the evaluation of the results, it is observed that the areas of application of the experimental reinforced beam with region below the neutral axis is replaced with voids include in various fields of construction where abnormal losses in concrete occurs. The wastage of concrete can be minimized by adopting this technique of hollow neutral axis of low stress zone without suffering much strength. The fields of application are:

- RC beam.
- Raft foundation.
- Slabs.

VIII. CONCLUSION

Behaviour of reinforced concrete beams with region below the neutral axis with voids created using polythene balls is similar to that of conventional reinforced concrete beams. Presence of voids instead of concrete in the low stressed zone has not caused significant reduction in strength of reinforced concrete beams. It has been observed that the replacement of concrete by voids in reinforced concrete beams does not require any extra labour or time. Economy and reduction of weight in beams depends on the percentage replacement of concrete. The concrete saving will be more effective as the length and depth of the beam increases. Replaced reinforced concrete beams can be used for sustainable and environment friendly construction work as it saves concrete which reduces the emission of carbon dioxide during the production of cement. This work can be further elevated by doing experiment with various percentage of replacement and by introducing other weightless inert materials which can take up stress.

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