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FLEXURAL BEHAVIOR OF REINFORCED CONCRETE BEAM WITH HOLLOW CORE IN SHEAR SECTION

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Abstract - *Concrete materials are still a dominant material for construction due to its advantages such as workability, low cost and fire resistance as well as its low maintenance cost. It is formed from a hardened mixture of cement, fine aggregate, coarse aggregate, water and some admixture. Nowadays research efforts are continuously looking for new, better and efficient construction material and method. We have responsibility to reduce the effect of the application of concrete materials to environmental impact. The concrete should be used as efficiently as much as possible. This research focuses on structural material optimization by introducing hollow core using PVC pipe in RC beams. By material optimization, we can reduce the dead loads which contribute to seismic effect in high rise structures. The Beam is casted with steel reinforcement and another beam is casted with steel reinforcement and hollow pvc pipe along with closure cap/plug. So, that the use of hollow pvc pipe the volume of concrete and weight of concrete is reduced . An experimental investigation is carried out on a beam. The Material was produced, tested and compared with conventional concrete in terms of workability and strength. These tests were carried out on beam of 1200*150*200 mm for 28 days to determine the mechanical properties of concrete.*

Key Words*: *Neutral axis, sacrificial concrete, stress transferring, center point loading, hollow beam

1. INTRODUCTION

Reinforced cement concrete is one of the important component in the construction industry. Now a days the use of concrete increased very much. There is acute shortage of raw materials for its preparation. Lot of researches were carried out for the investigation of alternate materials that can be used in concrete. Some locally available materials like fly ash, copper slag, rice husk etc. are experimentally evaluated.

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, ie, 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.. . X.. is the neutral axis distance from top of section.

2. SIGNIFICANCE OF WORK

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 causes 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 pvc pipes 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 pvc pipes are discussed.

2.1 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 infilled 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 pvc pipes of diameter 1 nos 50mm,2 nos 25m and 3 nos 16mm.

2.2 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 pvc pipes without affecting the geometry of the section. The pvc pipes are prepared from recycled plastic waste, hence it adds to the sustainable development.

3. Methodology

The methodology of the work consist of

1. Selection of proper grade; M30
2. Mix design of M30 grade concrete.
3. Casting beam specimens of normal RC beams and 1 nos 50mm and 2 nos 25mm and 3 nos 16mm dia pipes replaced beam specimens.
4. Conducting two point loading test using UTM machine.
5. Study the effect and documentation.

4. 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	2.66
Specific Gravity	Coarse Aggregates	Pycnometer	2.87
workability	M30 concrete	Slump cone apparatus	100mm

5. Mix Design

Table 2: M30 Mix Proportioning

Cement (Kg/m³)	358.6
Fine aggregate (Kg/m³)	536.27
Coarse aggregate (Kg/m³)	1305.5
Water (li/m³)	165
Water cement ratio	0.46
Mix ratio	1:1.5:3.63

6. Experimental Investigation

6.1 Experimental Procedure

A total of eight specimens are casted and tested; Two of these specimens are reference beams and the others are replaced with voids created by using pvc pipe of diameter 50mm,2 nos of 25mm and 3 nos of 12mm

All the specimens is of dimension 150mm x 200mm x 1200mm with an effective span of 900mm. The beams are designed as doubly reinforced beam with 2 nos. of 12mm diameter bars and 2nos of 12mm diameter bar at the tension region . 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 1000kn UTM.

The depth of neutral axis is calculated by considering M30 grade concrete and Fe415 steel with an effective cover of 25mm. 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, $C = 0.36f_{ck}\, b(x_u)$ --(2)

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

Equating the two expression, we obtain $f_{st}A_{st} = 0.36f_{ck}\, b(x_u)$

i.e. $X_u = \frac{f_{st}A_{st}}{0.36 f_{ck}\, b}$ ---------------- (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

$\frac{X_u}{d} = \frac{0.87 f_y A_{st}}{0.36 f_{ck}\, b}$ = 71mm ---------- (4)

The zone below the neutral axis is divided into three zones and the two zones adjacent to the neutral axis is replaced with voids created by using pvc pipe of diameter 50mm,2 nos of 25mm and 3 nos12mm.

Figure 1: Reinforcement Cage for Beam Specimens

Figure 2: Casting of Control Beam

Figure 3: Casting of Replaced Beam

6.2 Test Procedure

The specimens were tested using a 1000 kN Universal Testing Machine; a dial gauge having a travel of 25 mm was used to record the vertical deflection at the bottom of the mid-span of the beam. The behaviour of the beams was keenly observed from beginning to failure. The appearance of the first crack, the development and the propagation of cracks due to the increase of load were also recorded. The loading was continued after the initial cracking load and was stopped when the beam was just on the verge of collapse.

The universal testing machine consists of a set up for testing the three point bending set up facilities. For performing four point flexural test to achieve pure bending an additional fixture was made using an iron block of loading span 266mm and load is applied manually using hydraulic cylinder. 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.

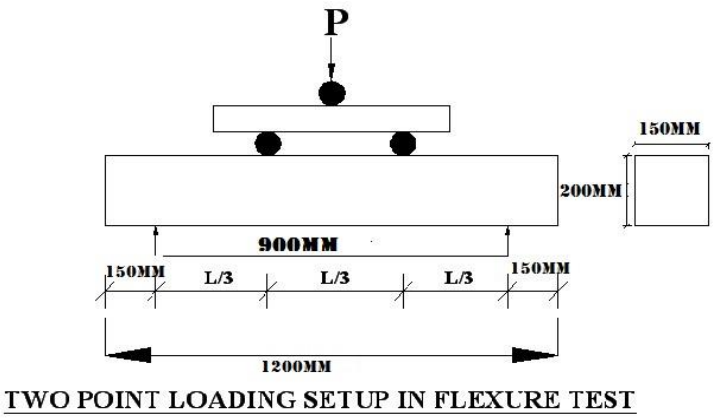

Figure 4: Schematic Test Setup

Figure 5: UTM test setup for 4-point flexure

7. EXPERIMENTAL RESULTS

Ultimate strength of beams under four point flexural test was confirmed through recording the maximum load indicated by load dial, 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 hollow neutral axis. However the hollow section decrease in load capacity and increase in corresponding deflection for the same properties when compared with solid control beams. The comparison of the results between the solid control beam and beam with hollow neutral axis .

The solid control beam are designated as CB1, CB2. Beam section with hollow neutral axis with 50mm pipe is designated as HW1, HW4 and that with 25mm pipe is HW2, HW5 and with 12mm pipe is HW3,HW6

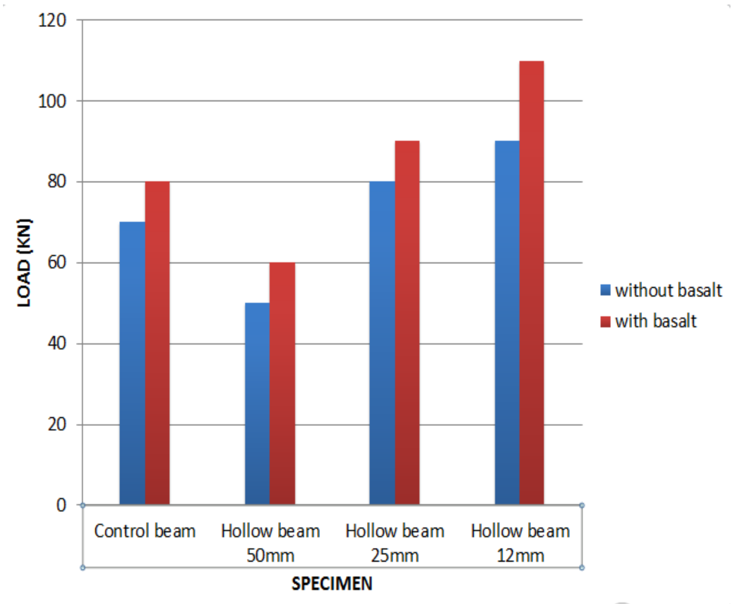

Figure 6: First Crack Load of beam Specimens

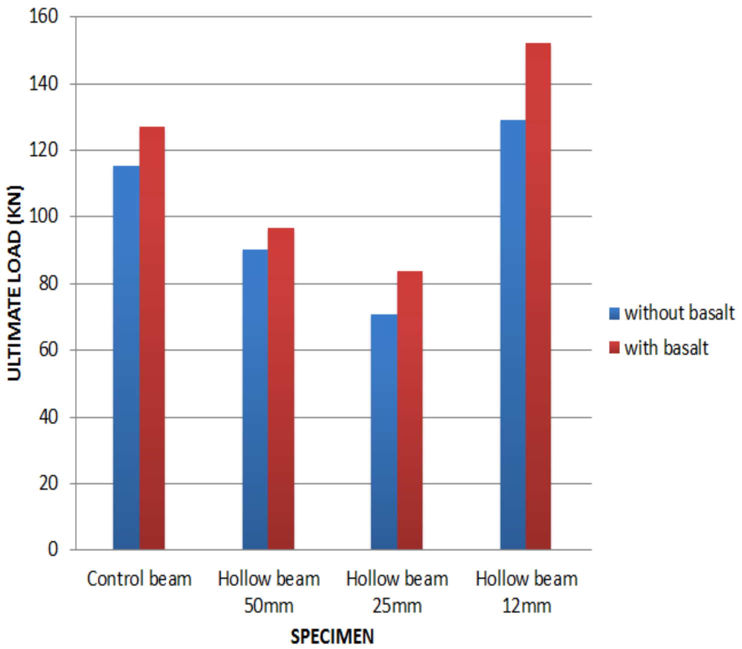

Figure 7: Ultimate crack load of beam

7.1 Load Vs Deflection Graph

Due to increase in the load, deflection of the beams starts, up to certain level the load vs. deflection graph will be linear that is load will be directly proportional to deflection.

Due to further increase in the load 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 hollow neutral axis is given in table

Table 3: Flexural Test Results Beam With 0.25 % 0f Basalt Fibre

LOAD (KN)	DEFLECTION (mm)			
	HW1	HW2	HW3	CB 1
0	0	0	0	0
10	0.04	0.14	0	0.13
20	0.25	0.52	0.07	0.26
30	0.51	1.23	0.26	0.63
40	0.82	1.37	0.47	1.24
50	1.19	1.88	0.73	1.64
60	1.87	2.65	1.03	2.06
70	3.02	3.78	1.43	2.60
80	4.24	4.94	1.86	3.47
90	5.41	6.04	2.35	4.46
100	6.85	-	2.84	5.55
110	-	-	3.42	6.42
120	-	-	4.47	7.22
130	-	-	5.55	7.63
140	-	-	6.74	-
150	-	-	8.03	-

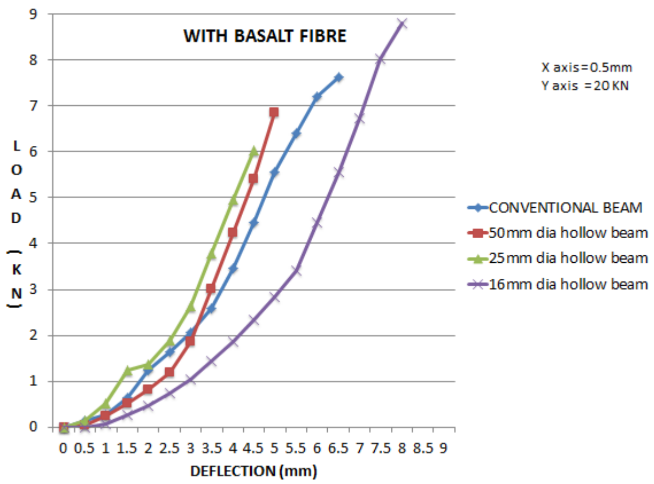

FIGURE 8 : Load Vs Deflection

TABLE 4 : Flexural Test Results Beam Without Basalt Fibre

LOAD (KN)	DEFLECTION (mm)			
	HW4	HW5	HW6	CB2
0	0	0	0	0
10	0.06	0.19	0.07	0
20	0.28	0.48	0.36	0.027
30	0.43	0.80	0.73	0.22
40	0.75	1.38	1.19	0.50
50	1.06	1.77	1.81	0.82
60	1.50	2.37	2.19	1.07
70	2.26	2.91	3.51	1.81
80	3.21	3.50	4.74	2.56
90	4.74	-	5.77	3.96
100	-	-	7.02	5.35
110	-	-	7.77	6.81
120	-	-	8.88	7.5
130	-	-	9.47	-

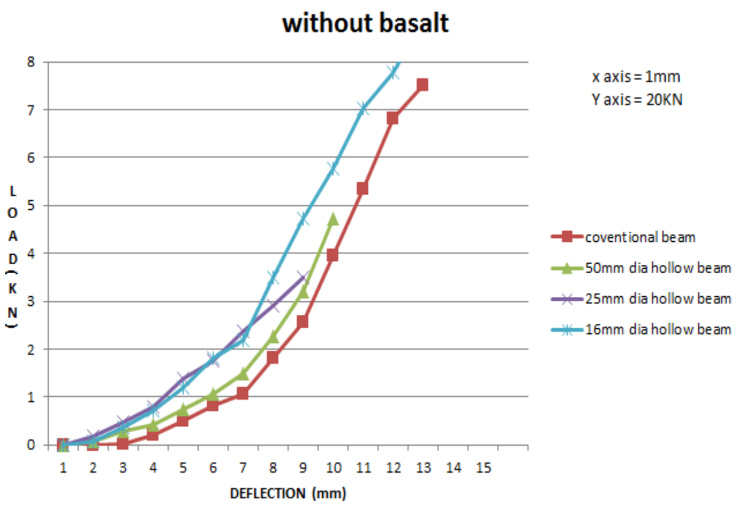

FIGURE 9 : Load Vs Deflection

7.2 Ultimate Load Vs. Depth of Hollow core

As the depth of hollow core increases the ultimate load decreases. Also by the increase of core depth deflection increases. It can be observed from Figure 7. So the optimum depth for providing hollow core is just below the neutral axis.

7.3 Crack Pattern

At Initial stages of loading, all beams were un-cracked beam. When the applied load reached to the rupture strength of the concrete on specimens, the concrete started to crack. The failure pattern in the all the tested beams was observed as a flexure-shear failure. The beams showed initial cracking in the constant bending moment region and then the cracks patterns in the vertical direction as the load was increased. At about 60 to 70% of the ultimate load, crack started to appear. All the beams showed the same pattern of failure and the failure modes are shown figure.

7.4 Concrete Saving and self-weight reduction

Concrete is one of the most versatile building material. In construction industries huge wastage in concrete occurs. 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.

If we consider the beam in this study, the dimensions are of length = 120cm, breadth = 15cm and depth = 20cm with PVC pipe having 2.5cm radius and length 90cm. By calculating the volume, we can know the percentage reduction in concrete volume.

Volume of the beam,

$V1 = lbh = 120 x 15 x 20 = 36000$ cu.cm

Volume of the pipe,

$V2 = \pi r2l = 3.14x(2.5)2x\ 90 = 1766.25$ cu.cm

% reduction in concrete=[(V2)/(V1)]x100

= [1766.25/36000]x100 = **4.9%**

Dead load shall include weight of all structural and architectural components which are permanent in nature. It includes self-weight of the structure. The unit weight of concrete is 25kN/m3. If we can reduce the volume of concrete then the self-weight of the beam also get reduced.

Weight of 1m3 concrete= 2500kg

Considering beam of dimensions: length= 120cm=1.2m Breadth= 15cm= 0.15m ; depth= 20cm= 0.2m

Volume of beam, V1= lbh= 1.2x0.15x0.2= 0.036m3

Weight of beam, W1= 2500x0.036= 90kg

Considering PVC pipe of dimensions,

radius= 2.5cm=0.025m;

length= 90cm= 0.9m

Volume of pipe,

$V2= \pi r2l= 3.14x(0.025)2x\ 0.9 = 0.0018m3$.

Weight of concrete saved, W2= 0.0018x 2500 = 4.5kg Weight of hollow beam=W1-W2= 90-4.5= 85.5kg

Since we have assumed a small beam, the self-weight reduction is also small. When we assume this for a larger section, the weight reduction will be larger.

7.4 Labour Reduction

Labours are one of the major resources in construction industries. Construction labour is most disorganised in India. 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.

7.5 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 study we have come to a conclusion that by using reinforced beam with hollow neutral axis, we can save significant amount of concrete without bearing any strength loss. This saving in material cost is more effectively utilised when considering large depth and length of beam or in similar other works, where abnormal lose 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.

7.6 Applications

From the evaluation of the results, it was observed that the areas of application of the experimental reinforced beamwith hollow neutral axis include various fields of construction where abnormal losses in concrete occurs. The wastage of concrete can be minimised by adopting this technique of hollow neutral axis of low stress zone without any strength loss. The fields of application are:

- Plinth beams
- Raft foundations
- Piers
- Similar other works

8. Conclusion

Based on the experimental study conducted on hollow core RC beams and test result obtained, the following conclusions were drown:

1. Flexural behaviour of reinforced concrete beams with hollow core is similar to that of conventional reinforced concrete beams.

2. Presence of hollow PVC pipe instead of concrete in the low stressed zone has caused an increase of 21percentage in strength of reinforced concrete beams.
3. The optimum depth of hollow core is 71 mm from top, iejust below the neutral axis.
4. It has been observed that the replacement of concrete by hollow pipe in reinforced concrete beams does not require any extra labour or time.
5. 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.
6. Hollow 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.

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