FLEXURAL STRENGTH OF REINFORCED CONCRETE BEAM WITH HOLLOW CORE AT VARIOUS DEPTH

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Abstract - *Concrete is a composite material composed mainly of water, aggregate and cement. Partial replacement of concrete below neutral axis is an idea that can create reduction in weight and savings in material. However, in RC beams strength of concrete lying in near the neutral axis is not fully utilized. So, this unutilized concrete can be removed by replacing with any light-weight material. This project focused on material optimization by introducing hollow core using PVC pipe in RC beam. For this, four beams of size 150x150x1000 mm is planning to be casted with one control beam and 3 beams with hollow core using PVC pipe of diameter 25mm at various depth below neutral axis. M20 grade concrete with Fe415 grade steel is to be used. The beam samples will be finally tested after 28 days for flexural strength, under gradually increasing single point loading. By using cheap and light material sustainability can be achieved. This saving in material cost is more effectively utilized when considering large depth and length of beam or in similar other works, where abnormal loss of concrete occurs.*

Key Words: Reinforced concrete beam, Hollow reinforced concrete beam, PVC pipe, Flexural behaviour etc

1.0 INTRODUCTION

Concrete is still a dominant material for construction purposes. For the rapid increase in the use of concrete results the shortage of raw materials. In recent days many researches are going on to find new better and efficient construction material but concrete materials are still preferred because of its beneficial properties such as workability, low cost and fire resistance as well as low maintenance cost. So there is need to reduce the use of concrete or make a optimum use of concrete. To overcome this situation we have to reduce the effect of application of concrete by replacing the concrete effectively by some other material.

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.

So this un-utilized concrete is removed by placing a PVC pipe instead, hence making the beam hollow at the neutral axis. As the top most and bottom portion in the beam experience maximum stress and zero at neutral axis, so a cheap and light material such as PVC pipe could be used near the neutral axis. Thus cement can be saved by saving concrete and there by reduces the self -weight.

1.1 OBJECTIVE OF THE PROJECT

- To cast hollow concrete beam with PVC pipe at various depth.
- To find the load carrying capacity of hollow concrete beam.
- To study the flexural strength characteristics of hollow concrete RC beam.
- To compare strength characteristics of hollow concrete RC beam and conventional RC beam.
- To study the reduction in amount of concrete and self-weight of hollow concrete RC beam.

2.0 Materials

3.1 Cement

In this work, 43 grade ordinary Portland cement was used. The properties are tabulated in table.

Table -1: Physical Properties of Cement

Tests	Material	Result
Specific gravity	Cement 43 grade	3.15
Standard consistency	Cement 43 grade	30 %
Initial setting time	Cement 43 grade	30 min
Fineness of cement	Cement 43 grade	4.9 %

3.2 Fine Aggregate

Table -2: Physical Properties of M Sand

Tests	Material	Result
Fineness modulus	Fine aggregate	3.12
Specific gravity	Fine aggregate	2.68

3.3 Coarse Aggregate

Aggregate of size of 20 mm confirming to IS 383 – 1970 and collected from local sources was used.

Table -3: Physical properties of coarse aggregate

Tests	Material	Result
Fineness modulus	Coarse aggregate	2.33
Specific gravity	coarse aggregate	2.33

3.4 PVC pipe

PVC is the third-most widely used plastic. PVC used in construction purpose because of its abrasion resistance, light weight, good mechanical strength and toughness. It is essential to have better bond between PVC pipe and concrete layers at the interface of pipe and concrete and it is ensured that no slip occurs between two layers. Here we are using 25mm diameter PVC pipe.

3.5 Steel

Reinforcement steel is a steel bar used as a tension device in reinforced concrete to strengthen and aid the concrete under tension. Here we are providing Fe415 grade steel. Reinforcement provided for the beams are 2 bars 8mm diameter at the tension and the compression zone. And 6mm diameter stirrups at 150mm spacing are provided for both solid and hollow beams.

3.6 Water

Water is an important ingredient of concrete, because hydration takes place only in the presence of water. The water, which is used for making concrete, should be clean and free from harmful impurities such as oil, alkali, acid etc. In general the potable water is considered satisfactory

3.7 Plywood mould

A rectangular mould of size 150 x 150 x 1000 mm is used.

4.0 MIX DESIGN

Cement (kg/m^3)	397
Fine aggregate (kg/m^3)	595
Coarse aggregate (kg/m^3)	1190
Water (l/m^3)	218
Water cement ratio	0.55
Mix ratio	1 :1.5 : 3 : 0.55

5.0 METHODOLOGY

The methodology of the work consists of
1. Selection of grade of concrete; M20
2. Mix design of M20 grade concrete.
3. Casting beam with and without hollow core.
4. Conducting single point load testing using UTM.
5.Analyse the result by comparing normal and hollow RC beam

6.0 RESULTS AND DISCUSSIONS

A. Discussion on Load Carrying Capacity

Ultimate strength of beams under three point tests was confirmed through recording the maximum load indicated of solid control beam section. The comparison of the results between the solid control beam and beam with hollow core below neutral axis is shown in Fig.1. The beam with hollow core at 79 mm shows high load carrying capacity.

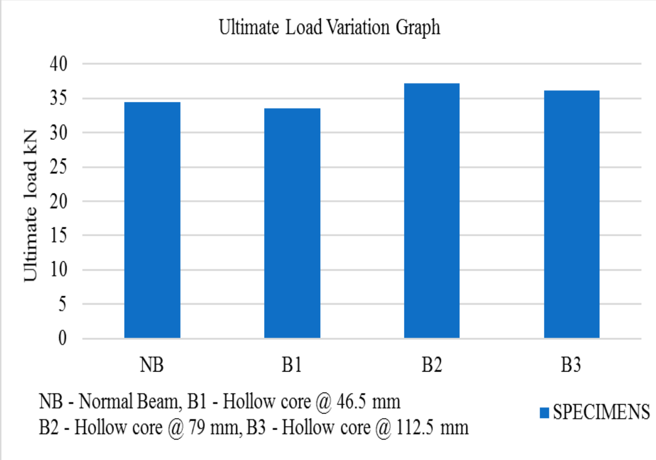

Fig 1: Ultimate load variation graph

B. Discussion on Loads 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 up to a safe load of 30 kN as per the test results shown in table 4 and the load deflection curve shown in chart 1

Table -4: Load deflection test results

Load kN	Deflection (mm)			
	Normal Beam	Hollow core @ 46.5 mm	Hollow core @ 79 mm	Hollow core @ 112.5mm
2	0.06	0.04	0.06	0.07
4	0.07	0.08	0.09	0.12
6	0.10	0.11	0.14	0.16
8	0.15	0.16	0.18	0.23
10	0.21	0.26	0.25	0.30
12	0.30	0.36	0.40	0.44
14	0.42	0.50	0.58	0.57
16	0.57	0.65	0.80	0.72

18	0.84	0.85	0.95	0.90
20	1.06	1.08	1.10	1.27
22	1.22	1.22	1.25	1.54
24	1.40	1.45	1.45	1.78
26	1.47	1.74	1.80	2.22
28	2.24	2.50	1.95	2.72
30	3.42	3.44	2.32	2.83

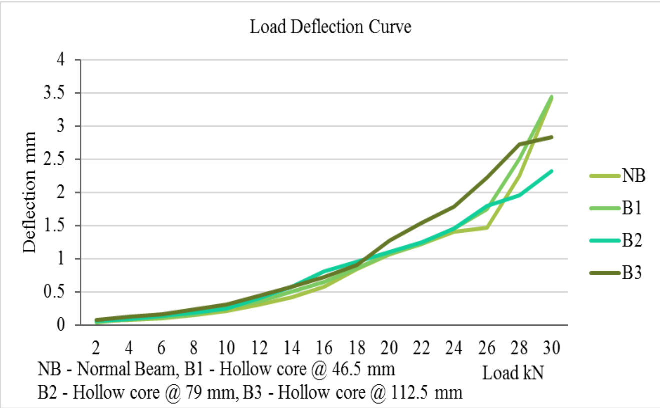

Chart -1: Load deflection curve

C. Discussion on Ultimate Load vs. Depth of Hollow core

As the depth of hollow core increases the ultimate load decreases after attaining optimum depth which is shown in the table 5. So the optimum depth for providing hollow core is below the neutral axis (here it is 79mm).

Table -5: Ultimate load vs. depth of hollow core

Specimen	Depth of hollow core placed (mm)	Ultimate load (kN)
Normal beam (NB)	0	34.4
Hollow beam (B1)	46.5	33.6
Hollow beam (B2)	79	37.2
Hollow beam (B3)	112.5	36.2

D. Discussion on Crack Pattern

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. All the beams showed the same pattern of failure which is shown in fig 2.

(a)

(b)

(c)

(d)

Fig.2: crack pattern of (a) normal beam (b) hollow core @46.5 mm (c) hollow core @ 79 mm (d) hollow core @ 112.5 mm

E. Discussion on Flexural Strength Results

The flexural strength of beam with and without hollow core was tested after 28 days curing period. The flexural strength of beam with and without hollow core are recorded. In all cases, the load at failure of the beam was noted. The results based on the flexural strength test are given in table 6 and variation in the flexural strength are shown in chart 2. Hollow core @ 79 mm show more flexural strength compared to other beam.

Table -6: Flexural strength test results

Specimen	Depth of hollow core placed (mm)	Ultimate load (kN)	Flexural strength *(N/mm²)*
Normal beam (NB)	0	34.4	13.76
Hollow beam (B1)	46.5	33.6	13.44
Hollow beam (B2)	79	37.2	14.88
Hollow beam (B3)	112.5	36.2	14.48

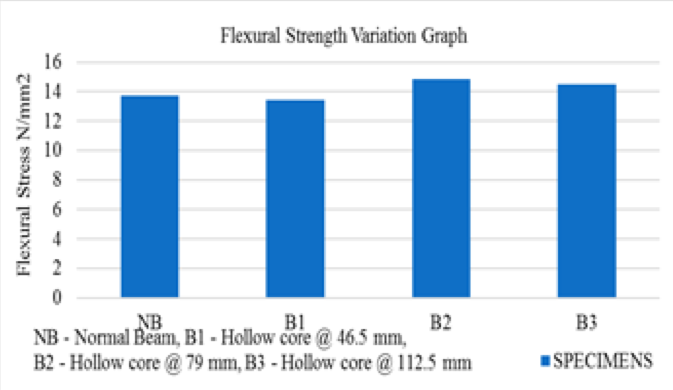

Chart -2: Flexural strength variation graph

F. 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 utilized 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 = 100cm, breadth = 15cm and depth = 15cm with PVC pipe having 2.5cm radius and length 100cm. By calculating the volume, we can know the percentage reduction in concrete volume.

Volume of the beam,

V1 = l×b×h= 100x15x15= 22500cu.cm

Volume of the pipe,

V2 = $\pi r^2 l$ = 3.14 x $(2.5)^2$x100 = 1962.5cu.cm

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

= [1962.5/22500]x100 = 8.7%

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

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 = 2500 kg

Considering beam of dimensions: length= 1m; breadth= 0.15m; depth= 0.15m

Volume of beam, V1 = l×b×h

= 1x0.15x0.15= 0.0225 m3

Weight of beam, W1 = 2500x0.0225= 56.25 kg

Considering PVC pipe of dimensions,

Radius = 2.5cm=0.025m;

Length = 100cm= 1m

Volume of pipe,

V2 = $\pi r^2 l$ = 3.14x$(0.025)^2$x 1 = 0.0019625m3.

Weight of concrete saved, W2 = 0.0019625x 2500 = 4.9kg

Weight of hollow beam, W3 = W1-W2 = 56.25-4.9= 51.35kg

Self-weight reduction = [(W1-W3)/W1]×100

=[(56.2551.35)/56.25]×100

= 8.7 %

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.

7.0 CONCLUSIONS

Reinforced cement concrete is one of the important component in the construction industry. Nowadays the use of concrete increased very much. There is acute shortage of raw materials for its preparation. For overcoming such situation, we can provide locally available material below the neutral axis by creating air voids. Results from testing three RC beam with hollow core at various depth and one beam without hollow core are compared.

- It is found that the behaviour of reinforced concrete beams with region below the neutral axis with voids created using PVC pipe 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 is found that the ultimate load carrying capacity of the beam is high in tensile zone of hollow core at 79 mm when compared to other zones of hollow core.
- The maximum load for normal beam is 34,4 kN and the maximum load for hollow beam at 79mm depth is 37.2 kN.
- The ultimate load carrying capacity of hollow beam at 46.5 mm depth shows 33.6 kN and 112.5 mm depth shows 36.2 kN.
- The flexural strength of normal beam is 13.76 N/mm^2 and for hollow beam at 79 mm depth shows 14.88 N/mm^2

- The flexural strength of hollow beam at 46.5 mm depth shows 13.44 N/mm² and 112.5 mm depth shows 14.48 N/mm².
- The value of flexural strength of hollow beam at 46.5 mm is decreases due to the reason that the hollow core is placed near to the compression zone.
- As the depth of the hollow core increases the ultimate load decreases after attaining optimum depth. The value of hollow beam with 46.5 mm shows 33.6 kN, 79 mm depth shows 37.2 kN and 112.5 mm shows 36.2 kN.
- The selection of circular hollow section proves to be advantageous because curved sections bear more load than any other sections as it avoids sharp corners.
- The crack pattern of all the beams shows same mode of failure i.e. flexural-shear failure.
- Concrete saving and reduction of weight in beams depends on the percentage replacement of concrete.
- By using 25 mm size hollow beam we can reduce 8.7 % concrete and 4.9 kg weight.
- The concrete saving will be more effective as the length and depth of the beam increases.
- By using hollow core beam it reduces the self-weight and ultimate load of the beam. Thus the dimensions of column and foundation can be reduced. So less amount of concrete is needed for the construction work.
- 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.

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