EXPERIMENTAL STUDY ON FLEXURAL BEHAVIOUR OF REINFORCED CONCRETE HOLLOW CORE SANDWICH BEAMS

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ABSTRACT

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. In this article, we focus on structural material optimization by introducing hollow core using Expanded Polystyrene Foam in tension zone of RC beams. By material optimization, we can reduce the dead loads which contribute to seismic effect in high rise structures. In addition, the hollow core will act as vibration dampers during earthquake and heat insulator. This paper presents details of the studies carried out on flexural behavior of Hollow Core Sandwich RC Beams with different core shapes. The experimental program consists of casting and testing of RC beams of size 1500mmx150mmx200mm with and without hollow core in tension zone. To study the flexural behavior, all beams are tested after 28 days curing by applying loads at 1/3rd points. The performance of Hollow Core Sandwich Beams under flexure shows better when compared with conventional solid beams.

Keywords: Ductility Factor, Flexural Behaviour, Hollow Core, Optimization, Strain Behaviour

I. INTRODUCTION

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. Massive exploration of the natural for producing concrete affect to the environment condition and global warning. We have responsibility to reduce the effect of the application of concrete materials to environmental impact. The concrete should be used as efficient as possible. Nowadays researches efforts are continuously looking for new, better and efficient construction method. Various theories related to the analysis of structural elements reduced the self-weight of element for a given load- carrying capacity. By structural material optimization can reduce the dead load which contribution of seismic effect in high rise structures and also very good at the vibration dampers and heat isolation. According to its natural behavior of the concrete, strong in compression and weak in tension. Our assumption to design the R.C beams the contribution of tensile stress of the concrete is neglected. The flexural capacity (MR) of the beam is influenced only by compression stresses of the concrete and the tensile stress of the steel reinforcement [11].

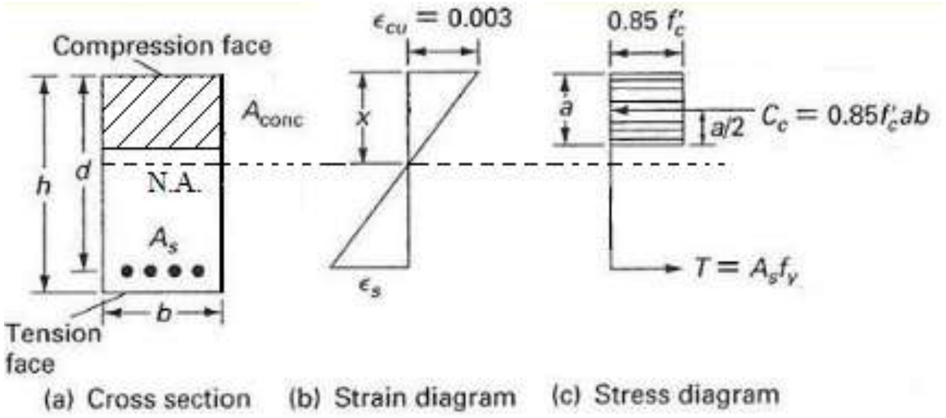

Fig. 1: Flexural Action of Reinforced Concrete beam

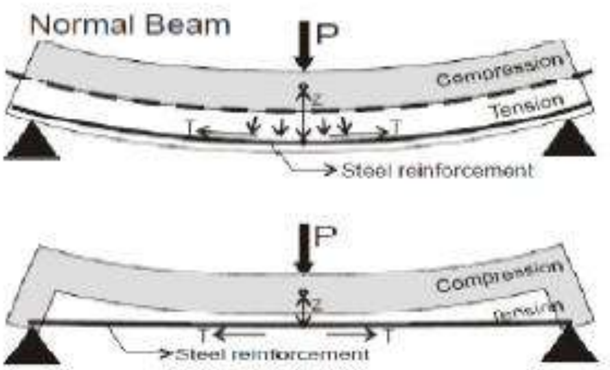

Fig. 2 Effect of without Concrete in Tension Zone

In order to efficiently use the concrete materials, then the compressive strength of the concrete on the tensile stressed zone may be reduced, or the concrete on the tensile stressed zone may be removed. Yasser, Rudy Djamaluddin and Herman Parung [10] presents an experimental study on fully removed concrete in tensile zone, it will affect to the flexural mechanical action between the tension stress and the compression stress of the concrete beam section. As the results, the flexural capacity of the beam decreases. If necessary to keep the lever arm (z) constant between compression force and tensile force of the beam as shown in Figure 2. Kocher Watson and Birman [1] presents a theoretical approach to study several issues related to the design of sandwich structures with a polymer frame reinforced with hollow core using a simple analytical models that describes the contribution to the stability of the structure in hollow at the core. Ezzar H. Fahmy and YousryB.I.Shaheen [2] studied a applying the Ferro cement concept in construction of concrete beams incorporating reinforced mortar permanent forms.

This paper investigates the flexure behaviour of hollow core beam with 25% removal of concrete in tensile zone by expanded polystyrene foam as shown in Figure 4. A series of the experimental specimens were prepared to clarify the effect of the hollow core in the in tension zone of the concrete beam. Besides the control specimens of normal beam (CC-CB), there were two types of beams were prepared. They were the beam with circular shape hollow core portion (CC-HSB-C) and the beam with square shape hollow core portion (CC-HSB-S). The area of hollow core portion is same for all types of beam as shown in Figure 3.

II. MATERIALS AND EXPERIMENTAL PROGRAM

2.1 Experimental Program

The test program consists of casting and testing six beams in given size 150 x 200 x 1500mm out of which two are cement concrete control beams[CC-CB], next two are circular shape hollow core sandwich beams [CC-HSB-C] and other two are square hollow core sandwich beams [CC-HSB-S] the beams designed as under reinforced section according to IS 456-2000.It is reinforced with 2-12Dia at bottom, 2-10 Dia at top using 6mm Dia stirrups @ 125mm c/c casting process is performed according to the basic standards and concrete treatment process is performed for 28 day. Casting specimen concrete was done by placing the reinforcement in the opposite position [tensile reinforcement at upper] in the form work to easily create the hollow on the half height of the concrete beams on the specimens CC-HSB-C and CC-HSB-S. Both beam and with length of 150mm were casted fully for the support during testing. All the beam specimens were submitted to a four point bending test. Three main aspects were examined; flexural strength, center span deformation and strain behaviour of beam.

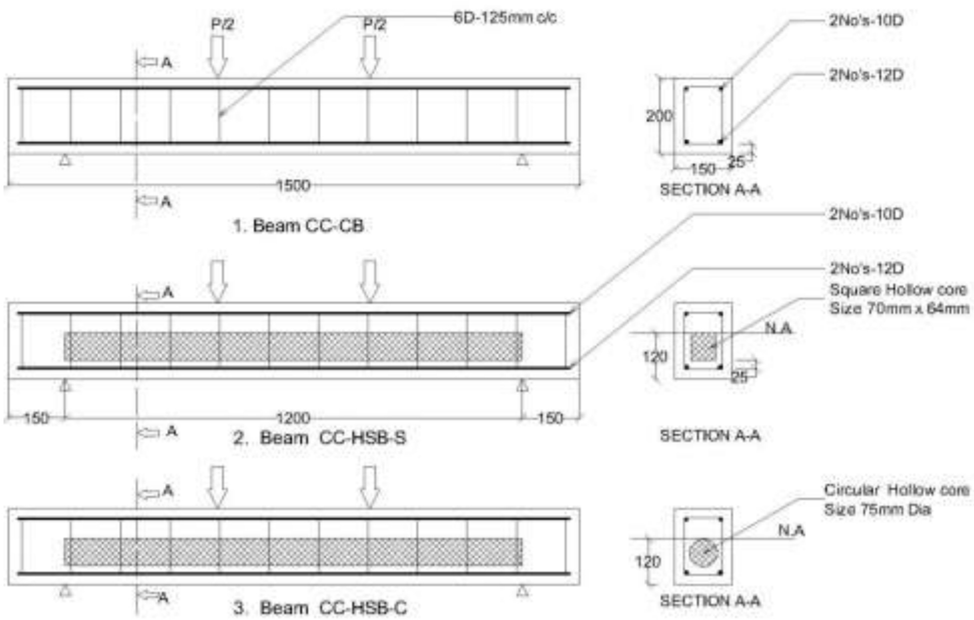

Fig. 3: Detail of Beam Specimens

2.1.1 Control Specimens

To check the concrete properties of concrete mixtures, 150mm x 300mm cylinders, 150mm x150mm cubes and 100mm x 100mm x 500mm prism were cast Cubes were used to determine the compressive strength; cylinders were used to determine the split tensile strength and modulus of elasticity and prism were used to determine the flexural capacity of concrete. The tests were carried out according to the corresponding Indian codes.

2.2 Materials

2.2.1. Concrete

Concrete used for the beam specimens was normal concrete (M25) using Portland pozzolanic cement, fine aggregates, coarse aggregates and potable water. Portland pozzolana cement conforming to IS 1489 (part

1):1991 was used obtained from Ramco Cement. Locally available river sand was used as fine aggregate. They were tested as per IS 2386.crushed aggregate with maximum grain size 12mm and down was used as coarse aggregate and characterization tests were carried out as per IS 2386. Fresh potable water, which is free from acid and organic substance, was used for mixing concrete. To increase the workability of concrete adding super plasticizer (Conplast SP 430 (FOSROC, Mumbai). The detail the properties of concrete are presented in Table 1.

Table 1: Characteristics of Concrete

Concrete Strength Parametric	Value (N/mm^2)
Compressive strength	27.5
Split Tensile strength	3.45
Flexural strength of concrete	3.98
Modulus of Elasticity	24150

2.2.2. Reinforcing Steel

The longitudinal steel reinforcement was provided using Fe415 steel rods and shear stirrups were provided using Fe 250 grade steel rods. The proof stresses of the reinforcement are 0.2 %. Steel reinforcement tensile strength was determine according to IS code. Three tensile tests were made for each bar diameter longitudinal tensile reinforcement (12mm), longitudinal compression reinforcement (10mm) and stirrups bars (6mm).

2.3 Mix Proportions and Mix Details

Concrete mix design was designed as per IS 10262:2009 [7] for M-25 grade concrete.

Table 2: Mix Design Proportions

Volume of Concrete	Cement	Water	Fine Aggregate	Coarse Aggregate	Super Plasticizer
By weight (kg/m^3)	391.05	187.70	708.58	1085.8	3.91
By volume	1	0.48	1.81	2.77	0.5% of Cement

2.4 Test Setup and Instrumentation

A set of 6 “demec” points was placed on the side of the specimen to allow measuring the strain versus load during the test. Demec points were centered on the centerline of the specimens as shown in Fig (5). The testing is setup as shown in Fig (6). The specimen is mounted on beam testing frame of 50 ton capacity. The beams are simply supported over a span 1200mm, and subjected to two concentrate loads placed symmetrically on the span. A Linear Variable Data Transformers (LVDT) was placed under the specimen at the center to measure the deflection versus load. Load was applied by a Hydraulic Power pack system attached with jacks. The strains are recorded demec point by using demec gauge. An Automatic Data Acquisition system with PC Interface is used to collect the data from load cell and LVDT during test. At the time of testing, the specimen was painted with white cement to facilitate the visual crack detection during testing process. Cracks were traced throughout the sides of the specimen and then marked with color markers. The first cracking load of each specimen was recorded. The load was increases until complete failure of the specimen was reached.

Fig. 4: Beam with Circular Expanded Polystyrene Foam in Tension Zone

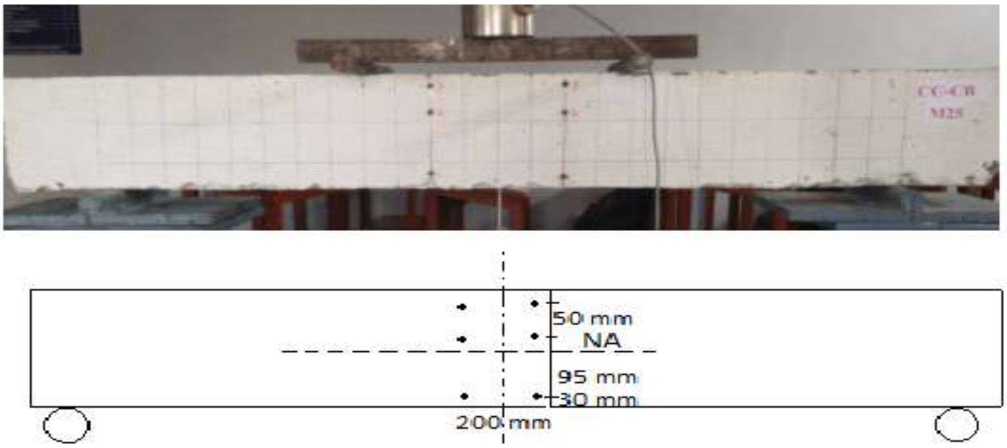

Fig. 5: Location of the Demec Points

Fig. 6: Beam Loading Method

III. RESULT AND DISCUSSION

3.1 Loads- Deflection Response

The load-deflection curves for three beams are shown in Figure-7. All the beams followed the same pattern of load-deflection response. In general the load-deflection curve will consist of three regions; the first region up to concrete was crack, the second region till the steel reinforcement yields and the third region after yielding of steel reinforcement where there is an enormous rate of increase in deflection for subsequent loads.

Table-3 Load and Deflection at Salient Stages

S.NO	Specimen Designation	First Crack Load (kN)	Ultimate Load (kN)	Deflection at First Crack (mm)	Ultimate Deflection (mm)	Companion Specimens Compressive Strength (N/mm^2)	
						Rebound Hammer test	UPV Test
1	CC-CB	20.5	57.5	1.8	19.7	29	30
2	CC-HSB-S	19.0	53.5	1.9	14.2	27	30
3	CC-HSB-C	20.5	56.0	1.7	18.5	29	29

The summary of salient load-deflection results is presented in Table-3. The first crack loads and ultimate load showed almost equal to all beams.

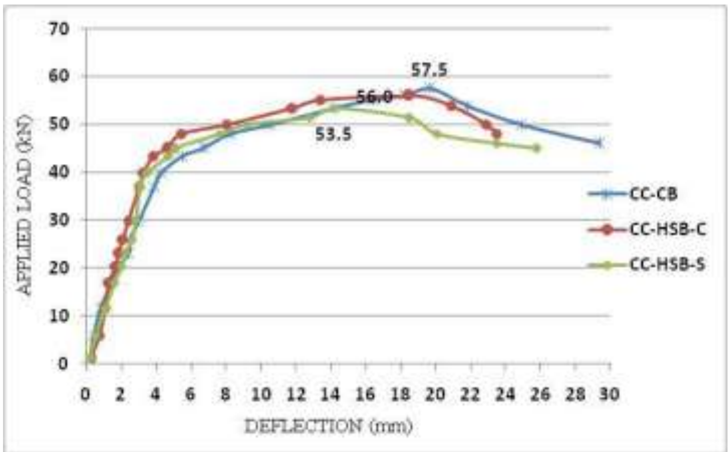

Fig. 7: Load-Deflection responses of beams

Fig. 8: Specimen under Loading

3.2 Ductility Factors and Stiffness Factor

An attempt was made in the investigation to obtain the stiffness and ductility factor for all the beams. The value of the stiffness factor and ductility factor for all beams is presented in Table 4. It was observed the ductility behavior of circular hollow core beam is equal to control beam but stiffness behavior shown increase in CC-HSB-C beam with compare to CC-CB. The Load Vs Ductility response and Stiffness response for all the tested beams are shown in Figure 9, 10.

Table 4: Stiffness and Ductility values

S.NO	Specimen Designation	Stiffness Factor	Ductility Factor	Stiffness Factor Ratio	Ductility Factor Ratio
1	CC-CB	2.92	10.9	1.00	1.00
2	CC-HSB-S	2.94	9.60	1.01	0.88
3	CC-HSB-C	3.03	10.9	1.03	1.00

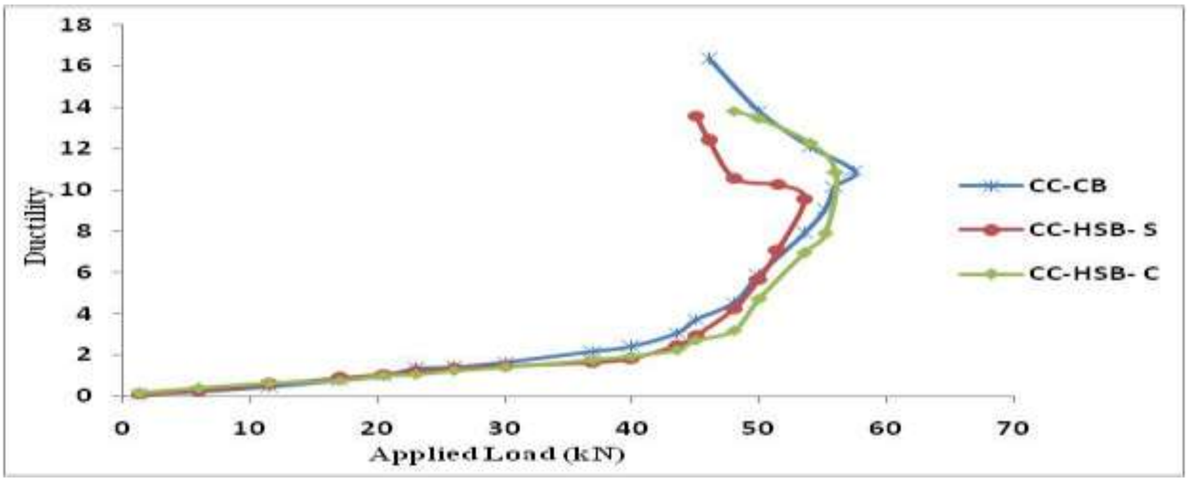

Fig. 9: Load Vs. Ductility Response of the beam

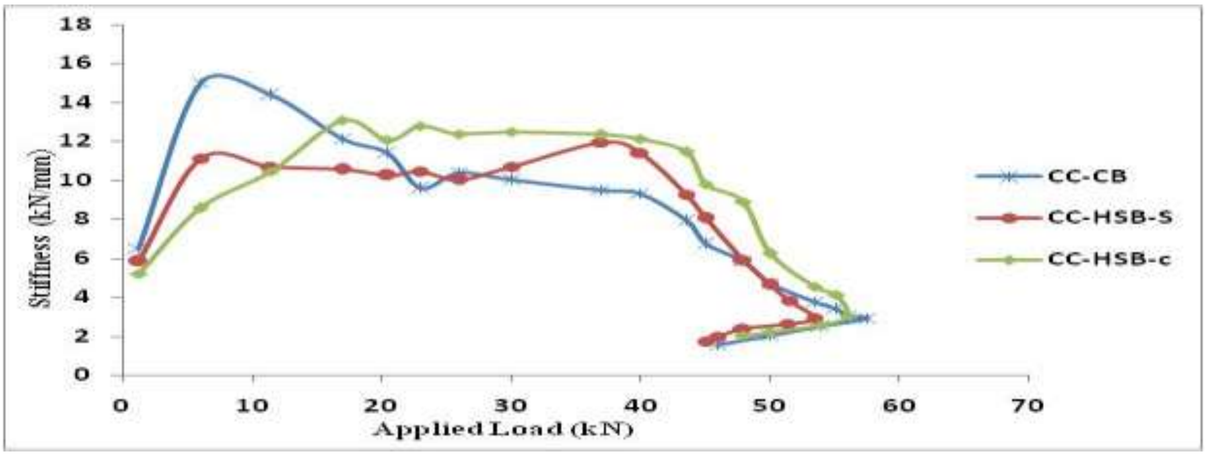

Fig. 10: Load Vs. Stiffness Response of the beam

3.3 Strain Behavior

Strain value of the beams in shown in Fig 11, 12, and 13. The strain distribution over the cross section is plotted for the first crack load and ultimate load. This indicates the N.A is shifted from compression zone to tension zone at failure stage. All the beams showed the strain distribution almost equal.

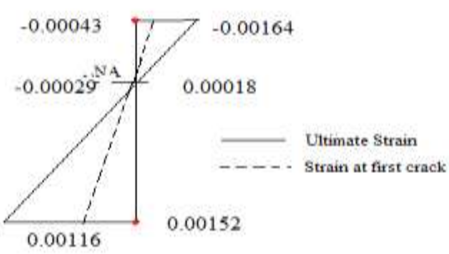

Fig. 11: Strain Distribution for the CC-CB

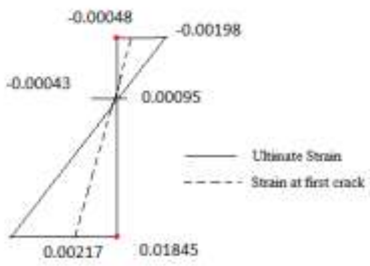

Fig.12: Strain D istribution for the CC-HSB-S

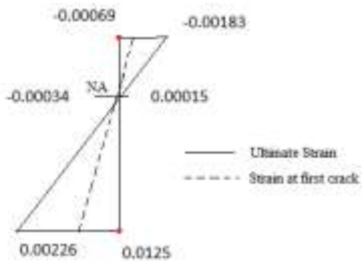

Fig. 13: Strain Distribution for the CC-HSB-C

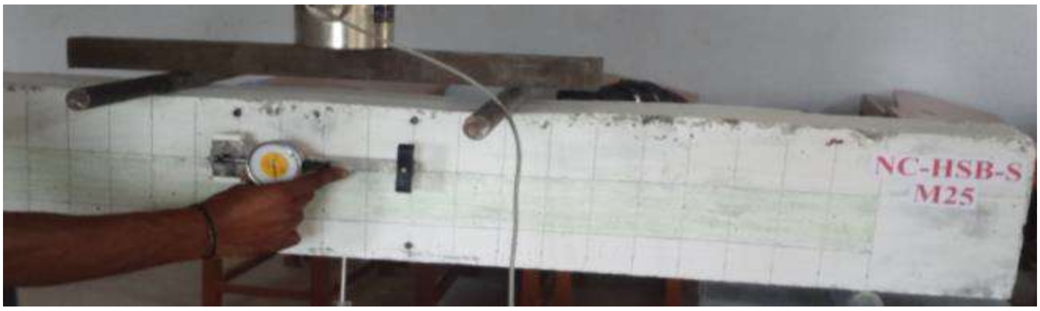

Fig.14: Strain Measurement under Loading

3.4 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. At about 60 to 70% of the ultimate load, shear crack appeared near the supports and processed towards the compression zone. At the stage of ultimate failure, the shear cracks extended till the loading point and the crushing of concrete at that point of loading. All the beams showed the same pattern of failure and the failure modes are shown in Figures 15.

Fig. 15: Crack patterns and failure mode of beam specimens

IV. CONCLUSIONS

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

1. The flexural strength, deflection at yield and at ultimate stage of RC beams with circular hollow core (CC-HSB-C) is same when compared with RC solid beams (CC-CB).
2. The flexural strength and yield deformation of RC beam with square hollow (CC-HSB S) is less compared with RC solid and RC circular hollow beams.
3. By introducing hollow core in tensile zone up to 25% on the beams, the behavior of beam is not affected with respect to flexural strength, deflection and strain measurement.
4. The propagation of crack in hollow core sandwich beams was relatively slower than RC solid beams. Also the number of cracks is less when compared with cracks in RC solid beams. This may be caused due to the fact in bending effect in tensile zone is restricted by introducing core using polystyrene foam sandwich.
5. The strain values are same at all stages in RC hollow core sandwich beams at all salient point when compare with RC solid beams.

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BIOGRAPHICAL NOTES

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