International Journal of Scientific & Engineering Research Volume 10, Issue 5, May-2019
ISSN 2229-5518

ExperimentalInvestigations on Flexural Behaviour of Hybrid Concrete Beams

Renjith P.C, V. Jayadevan

Abstract—A beam is a one dimensional (horizontal) flexural member which provides support to the slab and walls. In a beam having support at both ends, concrete above neutral axis (NA) take compressive stress, steel below NA take tensile stress and concrete below NA only act as strain transferring medium. These fundamentals lead to the idea of hybrid concrete beam (HC).This study is concerned with a new type of composite configuration of concrete beam where the different type of concrete are used as per required capacity to improve in terms of constructability and material optimization. This study is focused on fabrication of HC beam. In this study high strength concrete (HSC) beam and HC beam of rectangular and T in shape were fabricated and tested. Rectangular HC beam fabricated using high strength concrete above neutral axis and high volume fly ash concrete (HVFAC) below neutral axis. In HC T-beam the web is of high volume fly ash concrete and flange is of high strength concrete.

Index Terms— Hybrid concrete, High strength concrete, High volume fly ash concrete, Neutral axis, Self compacting, Sacrificial concrete.

1 Introduction

According to the "Theory of Flexure" for initially straight beams, plane sections originally perpendicular to longitudinal axis of the beam remain plane and perpendicular to the longitudinal axis even after bending and in the deformed section, the planes of this cross-section have a common intersection i.e. any time originally parallel to the longitudinal axis of the beam becomes an arc of circle. We know that when a beam is under bending, the fibres at the bottom will be lengthened (Tension) while at the top will be shortened (Compression). In between these, there are some fibres which remain unchanged in length that is they are not strained, that is they do not carry any stress. The plane containing such fibres is called neutral surface. The line of intersection between the neutral surface and the transverse exploratory section is called the neutral axis (N A).

As concrete is weak in tension, to take this tension steel reinforcement is provided at the bottom side of the beam section. As compressive stresses are induced in the zone above the neutral axis, compressive strength of the concrete lying above neutral axis is very important parameter. This induces compressive force in the top zone at a distance of 0.42 X_u (X_u, the neutral axis distance from top of section). The tension force acts at centroid of steel reinforcement provided at bottom of section. The distance between the point of action of compressive force and tension force is called lever arm and it is directly proportional to moment of resistance. So logically no concrete is required in tension side. But this concrete needs to be provided on tension side to act as strain transferring media to steel and may be called as 'sacrificial concrete'.

- *Renjith P.C, PG Scholar, Department of Civil Engineering, VAST, Thalakkottukara Email: renjithchithambaran111@gmail.com*
- *V. Jyadevan., Professor, Department of Civil Engineering, VAST, Thalakkottukara,Email: jayadevan@vidyaacademy.ac.in*

There are a lot of researches conducted to reduce the thickness of wall, and to reduce the size of the beam and column and also removal of sacrificial concrete by providing holes. But no research or study has been made until now on replacement of sacrificial concrete in case of deep beams. This is also a research area in structural design. Generally being an engineer one should concentrate towards the structural as well as functional design of the structure. Butwhile designing, the economy of the project is also a major factor. The concept of "Hybrid Concrete (HC) Beam" keeps both these aspects economy and safety in mind.

A hybrid concrete beam is a normal beam cast with two grades concrete, one above and other below the neutral axis. HC beam is a striking application of engineering in building construction works to achieve economy as well as reduction in the environmental impact due to construction works.

Since the fabrication of HC beam consist of two different grades, Compaction of concrete is not possible. Hence it is necessary to use "Self Compacting Concrete (SCC)" in the fabrication of HC beams. Self-compacting concrete is a flowing concrete mixture that is able to consolidate under its own weight. The highly fluid nature of SCC makes it suitable for placing in difficult conditions and in sections with congested reinforcement. Use of SCC can also help to minimize noise pollution at worksites induced due to vibration of concrete. Another advantage of SCC is that the time required to place large sections is considerably reduced. Mixture proportions for SCC differ from those of ordinary concrete, in that the former has more powder content and less coarse aggregate. Moreover, SCC incorporates high range water reducers (HRWR, super-plasticizers) in larger amounts and frequently a viscosity modifying agent (VMA) in small doses.

2.Methodologies

The experimental program mainly consists of two parts, viz., preparation of the required types of specimens and testing the same. The experimentation is aimed at studying flexural strength of hybrid concrete beam and studying the crack formation. The quality as well as the characteristics of the concrete depends on the properties of its ingredients. Hence the preliminary tests were conducted on cement, coarse aggregate and fine aggregates, before the commencement of the experimental programme. Due to presence of different type of concrete, compaction of concrete with the help of external vibrating techniques are not desirable. Hence the concrete mixes are designed as self-compacting concrete (SCC). To get a covetable strength for the mixes, the mix design was prepared for a fixed water-cement ratio. The designed mix proportions of high strength concrete for a w/c ratio 0.4 and High volume fly ash concrete(60% and 70% weight of cement) for w/c ratio 0.45 are shown in Tables 1, 2 and Table 3.

Water	**Cement**	**Fly ash**	**FA**	**CA**	**Plasticizer**	
240	390	210	667	699	10.5	By mass
0.4	1		1.11	1.16	0.0175	Absolute volume

Table 1: Mix design for HSC of w/c = 0.4

Water	**Cement**	**Fly ash**	**FA**	**CA**	**Plasticizer**	
240	231	347	632	662	10.11	By mass
0.45	1		1.09	1.15	0.0175	Absolute volume

Table 2: Mix design for HVFAC (60%) of w/c = 0.45

Water	**Cement**	**Fly ash**	**FA**	**CA**	**Plasticizer**	
260	173	404	623	652	10.11	By mass
0.45	1		1.08	1.13	0.0175	Absolute volume

Table 3: Mix design for HVFAC (70%) of w/c = 0.45

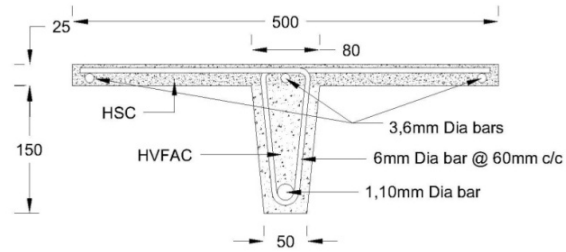
Theoretically the rectangular beams are designed to take a live load of 1.23 tonne and similarly for T-beams maximum live load is 0.83 tonne. Designed section of specimens is shown in the figures 1 and figure 2.

fig1. The T- beam section used

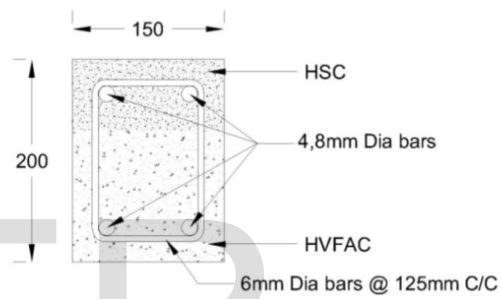
fig2. The Rectangular beam section used

3. Experimental Programs

For control specimen, mix design was carried out for a



fixed water-cement ratio of 0.4 (1:1.11:1.16 with w/c 0.40) and cube test was carryout for this design mix to determine the



strength of concrete under compression. Results of cube tests are shown in Table 4.

Table 4. Test results for Mix of 0.4 w/c ratio

Day	Load (kN)	Compressive strength(Mpa)	Avg. Compressive strength(Mpa)	Chara. Compressive strength(Mpa)
7	657	29.2	28.75	
7	618	27.45		
7	666	29.6		
28	981	43.6	43.78	35.53
28	967	42.98		
28	1007	44.75		

The formworks are prepared and ingredients are weighed accurately with weight balance. Ingredients are mixed with the help of concrete mixer. Concrete was placed in the formwork in layers of approximately 10 cm and end faces were properly finished to get smooth surface. After completion of about 10 hours, wet gunny bags were placed on the newly cast beam.

For hybrid concrete beams separate mix designs were done for high volume fly ash concrete at a fixed water cement ration of 0.45 (Fly ash- 60% - 1:1.1.09:1.15), (Fly ash 70% - 1:1.08:1.13). Also cube tests are conducted for this mixes. Cube test results are given in Table 5 and 6.

Table 5: Test results for Mix of 0.45 w/c ratio, 60%Fly ash

Day	Load (kN)	Compressive strength (Mpa)	Avg. Compressive strength(Mpa)	Chara. Compressive strength(Mpa)
7	371	16.48	18.64	10.39
7	437	19.42		
7	450	20		
28	624	27.33	27.95	19.7
28	653	29.02		
28	610	27.11		
56	733	32.57	31.71	23.46
56	712	31.64		
56	696	30.93		

Neutral axis is marked in the rectangular beam with the help of a string stretched between two legs of shearreinforcement. Concrete in the tension zone was placed in the formwork in layers HVFAC. The layers were successively placed one above the other. After the level of string was reached, the concreting operation was stopped with high volume fly ash concrete above the other. After the level of string was reached, the concreting operation was stopped with high volume fly ash concrete. Above the high strength concrete was filled and top of the layer was properly finished to get smooth surface. Similarly in T-beam, first the web was filled with high volume fly ash concrete then the flange is filled with high strength concrete and finished to get smooth surface.

Table 6: Test results for Mix of 0.45 w/c ratio, 70%Fly ash

Day	Load (kN)	Compressive strength(Mpa)	Avg. Compressive strength(Mpa)	Chara. Compressive strength(Mpa)
7	214	9.51	9.82	
7	246	10.93		
7	203	9.02		
28	382	16.97	17.31	10.71
28	411	18.26		
28	376	16.71		
56	481	21.37	21.25	14.65
56	452	20.08		
56	502	22.31		

After completion of 28 days of curing, the specimens were tested. First, the control specimens were tested. The beams were placed on the loading frame as shown in fig. to apply two-point loading. Simple support with a bearing of about 10 cm is provided beneath the beam as shown in fig.3 and fig 4. LVDT was attached to the beam at the mid span to the left and right to note down the deflection after the application of the two point load. Load was then applied gradually and uniformly. Simultaneously deflection was noted down carefully. For each deflection corresponding load was observed and noted down. Similarly, the test was repeated for hybrid beams.

Fig 3. Test setup for rectangular beam

Fig 4. Test setup for T-beam

4 Result and Discussion

4.1 Crack formation

Cracks were initiated in HSC beam earlier than in the HC beam. At the stage of crack initiation, the crack formed in the HSC beams were smaller but in HC beam initial cracks developed towards the neutral axis more quickly. On further loading, new cracks were formed in the HC beam for each increase in load. But the crack width in HC beam was smaller than that of HSC beam. Also in HC beams vertical cracks were visible in the shear zone. Figure 5, 6, 7 and 8 shows the crack pattern in HSC, HC rectangular beams and T-beams.

Fig 5: Crack pattern in HSC rectangular beam

Fig 6: Crack pattern in HC rectangular beam

Fig 7: Crack pattern in HC T-beam

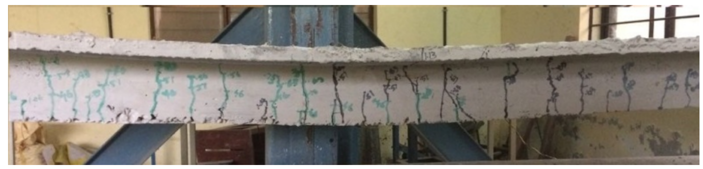


Fig 8: Crack pattern in HSC T-beam

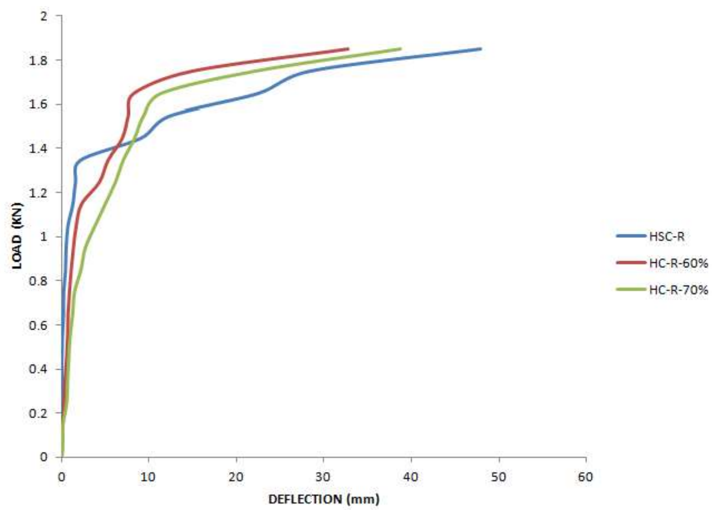
4.2Mode of failure

According to the loading scheme, all beams started to show flexural cracks at the middle part of the span and with further loading, flexural cracks began to get distributed around the middle part and increased in their lengths and widths. In the sequel, vertical cracks were developed in the shear zone of HC beams. Subsequently, all beams were failed in flexure.

4.3Ultimate load and Load-Deformation curve

It is observed that HC beam failed in the same way as the HSC beam but the load taken at crack propagation and bending failure are different as shown in fig. 5, 6, 7, 8 and Table 7. For HSC rectangular beam load at first crack is 0.91 tonne and at failure it is 1.87 tonne. For HC rectangular beam with 60% fly ash in sacrificial concrete load at first crack is 0.85 tonne and at failure 1.85 tonne. For HC rectangular beam with 70% fly ash in sacrificial concrete load at first crack is 0.67 tonne and at failure 1.81 tonne.

Similarly, for HSC T-beam load at first crack is 0.4 tonne and at failure it is 1.11 tonne. For HC T-beam with 60% fly ash in sacrificial concrete (web) load at first crack is 0.44 tonne and at failure 1.12 tonne. For HC T-beam with 70% fly ash in sacrificial concrete (web) load at first crack is 0.41 tonne and at failure 1.03 tonne.



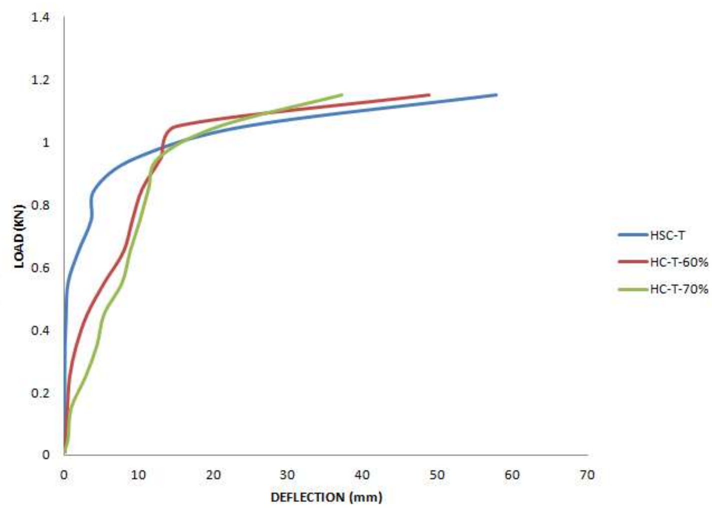


Fig 9: Load v/s Deformation curve for Rect- beamFig 10: Load v/s Deformation curve for T-beam

Table 7: Crack formation and failure load

Sl.No:	Beam	Property	Load at crack formation (Tonne)	Load at failure (Tonne)
1	1-I	HSC-Recatgular-M35	0.91	1.87
2	1-II	HSC-Rectangular-M35	0.94	1.9
3	2-I	HSC-T-M35	0.4	1.11
4	2-II	HSC-T-M35	0.41	1.18
5	3-I	HC-Rectangular-M35+M20-60% fly ash	0.85	1.85
6	3-II	HC-Rectangular-M35+M20-60% fly ash	0.88	1.87
7	4-I	HC-T-M35+M20-60% fly ash	0.44	1.12
8	4-II	HC-T-M35+M20-60% fly ash	0.5	1.15
9	5-I	HC-Rectangular-M35+M20-70% fly ash	0.67	1.81
10	5-II	HC-Rectangular-M35+M20-70% fly ash	0.72	1.82
11	6-I	HC-T-M35+M20-70% fly ash	0.41	1.03
12	6-II	HC-T-M35+M20-70% fly ash	0.40	1.1

6 CONCLUSION

- Even when there is quite a lot of difference in the mechanical characteristics of the used concretes, the mechanical behaviour of the HSC beam and the HC beam were quite similar.
- The ultimate load carrying capacity of High strength concrete beams and hybrid concrete beams are almost same.
- The HC beam deflections are slightly smaller than that of the homogeneous HSC beam.
- HC beam produced a large no of flexural cracks than the HSC beam
- Crack width of HC beams were smaller than that of the HSC beam for a given load
- All the type of beams shows flexural failure, none exhibited major shear cracks.

ACKNOWLEDGMENT

I owe a great debt of gratitude to teaching staffs and Department of Civil Engineering, Vidya Academy of Science and Technology, for great support throughout this project. I am deeply indebted to Leela K.V, Justin Jose and V. Jayadevanfor their valuable suggestions and encouragement.

REFERENCES

[1] Edward G. Moffatt, Michael D.A. Thomas, Andrew Fahim" Performance of high-volume fly ash concrete in marine environment", *Jourrnal of Science Direct,*Volume: 102, pp 127-135, 2017-12

[2] Ade Lisantono, HaryantoYosoWigroho, Roy ArnolPurba"Shear behavior of high volume fly ash concrete as replacement of Portland cement in RC beam" *IJSERT,*Volume: 3pp80-87, 2017

[3] ArunMurugesan, Ph.D.1 and Arunachalam Narayanan, Ph.D.2 "Influence of a Longitudinal Circular Hole on Flexural Strength of Reinforced Concrete Beams", *DOI: 10.1061/(ASCE) SC.1943 5576.0000307. © 2016 American Society of Civil Engineers.*

[4] F.I. Olmedoa , J. Valivonisb , A. Coboa"Experimental study of multilayer beams of lightweight concrete and normal concrete", *6, 28040 © 2016 American Society of Civil Engineers.*

[5] AnilBanchhor and S. KrishnanEvaluating the effectiveness of fly ash incorporation as PPC vis-à-vis separated addition to the site-mixed OPC Concrete",*TheIndianconcreteJournal,*,April2006,pp.17-26.

[6] DevadasMenon and UnnikrishnaPillai S,"Reinforced concrete design",*Mc Grow Hill, 2, 2009.*

[7] Shetty M.S.,"Concrete Technology-Theory and Practice", *S Chand Publication, 6, 2013.*

[8] IS 456. IS 456-2000 Plain and Reinforced Concrete.