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An Experimental Analysis of Reinforced Composite Beam Using Various Concrete Grades in Different Sections

Prof. Anandrao Jadhav¹, Kaneez Fatima²

Assistant Professor, Department of Civil Engineering, MIT SOE, Loni Kalbhour Pune, Maharashtra, India¹

P.G. Student, Department of Civil Engineering, MIT SOE, Loni Kalbhour Pune, Maharashtra, India²

ABSTRACT: Reinforced concrete firstly emerged as an innovative and versatile composite, gaining ever-growing popularity in civil engineering constructions, such as high-rise buildings, sports stadiums and long span bridges, primarily due to their superior performance. The successful use of these materials in structural elements attributed to the bond between steel and concrete. The reinforcing steel imparts ductility to a material that is otherwise brittle. In spite of these important contributions, it should be noted, however, that most of the past studies have been conducted on use of polymer matrix composites for designing structural members. Very few works have been conducted on concrete as a composite. In flexural members, concrete is weak in tension, steel is introduced in the tension zone to take the tensile force, but as strength of concrete is ignored in the tension zone with respect to the compression zone. The shear force comes at one-third portion of the length of the beam along support and maximum tension force is at the mid part of the beam. Shearing forces are unaligned forces pushing one part of a body in one direction, and another part of the body in the opposite direction, so we have provided a high grade of concrete where shear strength is maximum and providing comparatively low grade of concrete where tension strength is maximum. A total of 2 beams of 150mm X 150mm X 1000mm are casted, out of which 1 specimen is casted as conventional beam, and remaining specimen is casted as composite beam of M20 & M30 grade of concrete, wherein the higher grade is placed at the ends up to a distance of $L/3$ from supports (as shear is maximum here) and the lower grade of concrete is placed in the middle portion where tensile strength is maximum.

KEYWORDS: Reinforced Composite Concrete

I. INTRODUCTION

Reinforced concrete has established itself as a widely used composite material for structural elements such as slabs, beams, column, wall, footing etc. And is one of the important materials in the construction industry. Now days the use of concrete is increasing very much. However, there is acute shortage of raw materials for its preparation. Lot of researches was carried out for the investigation of alternative methods that can be used in concrete which can reduce the consumption of cement in concrete. Reinforced concrete is a composite material comprising concrete and steel reinforcements. The successful use of these materials in structural elements attributed to the bond between steel and concrete which ensure the strain compatibility so that the load on structural elements is shared by steel and concrete without distribution of the composite material. The reinforcing steel imparts ductility to a material that is otherwise brittle. In flexural members, concrete being weak in tension, steel is introduced in the tension zone to take the tensile force, but as strength of concrete is ignored in tension zone with respect to compression zone. So logically no concrete is required in tension side. But this concrete which is provided on tension side acts as strain transferring media to steel and may be called as sacrificially concrete. This concrete has no tension more than strain transfer hence there is no necessity to use same grade of concrete throughout beam. The shear force comes at one third portion of the length of beam along support and maximum tension force is at mid part of beam and the concrete have high compressive strength and weak tension strength. Shear force is an internal force in any material which is usually caused by any external force acting perpendicular to the material, or a force which has a component acting tangent to the material. Shearing forces are unaligned forces pushing one part of a body in one direction, and another part of the body in the opposite direction, so we will provide high grade of concrete where shear strength is maximum and providing comparatively low grade of concrete where tension strength is maximum.

II. RELATED WORK

BalaMoorthi et al. [1] investigated of the lower grade of concrete placed below the neutral axis has been done to create reduction in cost saving in material. Hence, they compared a reinforced composite concrete beam with a reinforced concrete solid beam in terms of flexural strength. The beam was investigated in terms of crack load and deflection curves. A reinforced concrete beam is a normal beam but they were used lower grade of concrete placed below the neutral axis and normal concrete was placed above the neutral axis.

Vincy et al. [2] observed reinforced concrete beams after dividing it into 3 layers: bottom layer, middle layer and top layer. In the initial phase a high strength concrete beam of grade M70 throughout the cross section was casted and tested. Thereafter by replacing the M70 concrete in the middle layer by M20 grade concrete, a number of beams were casted with different thickness (100, 90, 80, 60, 40 mm). The variation in thickness of middle layer was based on the stress block diagram given in Indian standard code, from which the optimum thickness of the middle layer of lower grade concrete (M20) is found out.

Lightweight concrete placed below the neutral axis and normal concrete was placed above the neutral axis. Moreover, Self-compacting concrete was used to increase the fresh properties of the concrete. Kumar et al. [3] experimented to reduce greenhouse gasses emissions study by reducing weight of the beam and saving quantity of concrete by saving cement. So, it was environmentally friendly. As compressive stress induced in the above the neutral axis, compressive strength of the concrete lying above neutral axis is very important parameter. This induced compressive force in the top zone at a distance of 0.416 XU. (XU –Neutral axis distance from top of section).

B.S Karthik et al. [8] studied the behaviour of concrete grade variation in tension and compression zones of RCC beams. A beam is a one dimensional (normally horizontal) flexural member which provides support to the slab and vertical walls. In a normal beam (simply supported) two zones generally arise, viz. compression zone at top and tension zone at bottom. The concept of Partial beam was taken into consideration and concrete grade reduction in tension zone for RCC beams was carried out in order to reduce construction cost. A partial beam is a normal beam cast with two grades concrete, one above and other below the neutral axis. Partial beam is a beautiful result of the application of engineering in building construction works to achieve economy as well as reduction in the environmental impact due to construction work.

Mita Ann Zachariah, Sunitha A Daniel [9] observed on partial replacement of concrete below the neutral axis by light weight concrete using different percentage of pieces of bricks as a replacement of coarse aggregates so as to save materials and gain economy. The behaviour of reinforced concrete beams with region below the neutral axis with light weight composite section created using replacement of coarse aggregate by low quality bricks was similar to that of conventional reinforced concrete beams. The presence of light weight composite section instead of concrete in the low stressed zone has not caused significant reduction in strength of reinforced concrete beams. The replacement of concrete by light weight composite section in reinforced concrete beams did not require any extra labour or time.

III. METHODOLOGY

Detailed study on materials used for the research and their properties were carried out. The cement, fine aggregate, coarse aggregate, water tested for its basic properties, which facilitates in arriving the mix proportion of concrete to be used. Basic design of RCC structures and design of singly reinforced beams. A beam of 150mm X 150mm X 1000mm was casted with 3-10mm bars in tension zone and 2-10mm bars in compression zone with 8mm diameter stirrups at a spacing of 100mm. Specimens were casted for 7 days, 14 days and 28 days curing period and were ready for testing after having reached their final strength, the flexure test were carried out on a loading frame having capacity 150 kN. Two-point loading test was performed to obtain the flexural strength and load carrying capacity of Reinforced Concrete Beam and Reinforced Concrete Composite Beam and behavioural aspects of beams under loading and failure patterns were observed.

IV. EXPERIMENTAL RESULTS

1. Problem Statement

Casting of Reinforced Concrete Beam and Reinforced Concrete Composite Beam and testing under two-pointloading to obtain the flexural strength and load carrying capacity of the two beams. Compare the results in the form of tabular and



graphical representations to achieve the objectives by size 150mm X 150mm X 1000mm with a nominal cover of 25mm is designed under self-weight and super imposed live load using M20 and M30 grade of concrete.

2. Mix Design Results.

Mix design calculated by referring IS456:2000 for M20 and M30 grade of concrete and calculated material quantity which is given in table 1 and table 2 respectively.

Table 1. Mix Design Ingredient Quantity for M20 grade

Grade of concrete	Material	Quantity (kg/m ³)
M20 (1:2.10:3.42) (w/c ratio =0.45)	Cement	348.88 Kg
	Coarse aggregate	1194.46 Kg
	Fine aggregate	734.85 Kg
	Admixture	5.23 Kg
	Water	157.73Litres

Table 2. Mix Design Ingredient Quantity for M30 grade

Grade of concrete	Material	Quantity (Kg / M ³)
M30 (1:1.7: 3.08) (w/c ratio = 0.36)	Cement	425Kg
	Coarse aggregate	1311 Kg
	Fine aggregate	721 Kg
	Admixture	3.4 Kg
	Water	153Litres

3. Test preparation and set-up for beams

The material used for the formwork was timber or wood. The joints of the formwork were sealed to avoid leakage of cement slurry. Black oil was then applied to the inner faces of the formwork. Beam specimen sizes were decided from the calculation of aspect ratio. Specimens were casted and tested after 7, 14 and 28 days of curing. RCB beam was designed using M20 grade of concrete and RCCB was designed using M30 grade at end one-third portion of length of beam and M20 grade in middle one third portion of beam. Flexure loading was applied to the beams and peak load for RCB and RCCB was recorded. Figure 1a shows the demoulded M20 grade concrete specimen ready to be tested after 28 days of the curing period.

Table 4.7: Details of specimen

Beam Notation	Specimen Details	Dimensions
RC-SB	RCC Beam	0.15 X 0.15X 1 M
RC-CB	RCC Beams with composite Concrete	0.15 X 0.15X 1 M

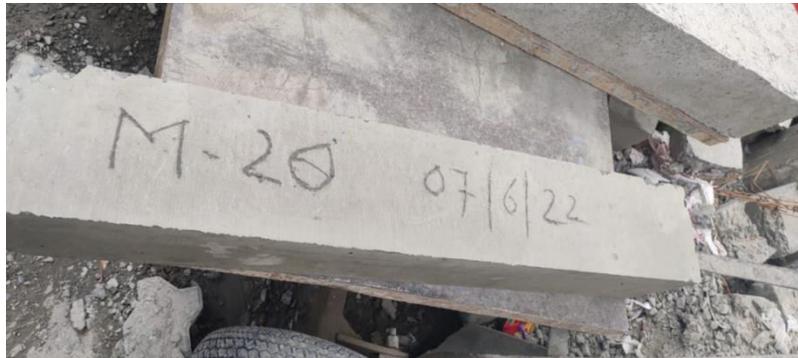


Figure 1a RCB specimen after 28 days curing period



Figure 1b Testing of Specimen

IV. RESULTS AND DISCUSSIONS

Obtained results by experimental study are discussed here.

4.1 Flexural strength for Reinforced Concrete Beams of M20 grade

The comparison between load carrying capacity and flexure strength of Reinforced Concrete Beam and Reinforced Concrete Composite Beam in experimental investigation is done. Table 2, table 3 and Fig. 2 exhibits the overall combined results and graph comparison of Flexural strength for both beams at different curing periods respectively.



Table 2 Comparison of results for RCB

Sr.no.	Size	Curing days	Peak load (KN)	Length of shear (mm)	Flexural strength (N/mm ²)
1	150mm x150 mm x1000 mm	7 days	50.6	a >20	14.99
2	150mm x150 mm x1000 mm	14 days	47.8	a >20	17.30
3	150mm x150 mm x1000 mm	28 days	55.5	a >20	17.45

Table 3 Comparison of results for RCB

Sr.no.	Size	Curing days	Peak load (KN)	Length of shear (mm)	Flexural strength (N/mm ²)
1	150mm x150 mm x1000 mm	7 days	45.5	a >20	13.68
2.	150mmx150mm x1000mm	14 days	66.4	a >20	19.67
3.	150mmx150mm x1000mm	28 days	71.5	a >20	23.31

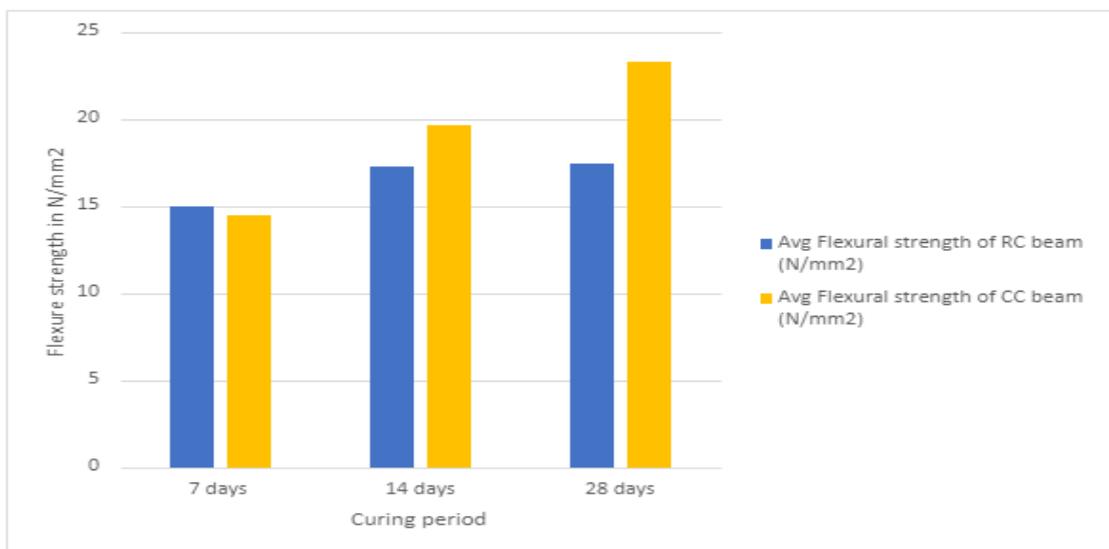


Figure 2 Comparison of RCB and RCCB

Flexure on 7 days curing observation: It has been observed that on 7 days curing period test a composite concrete beam fails at the end part of beam, but at the same time conventional grade concrete fails at central part of beam because of no development of good bond between different grades, with flexural strength of RC beam more than 0.6 % as compared to RCC beam.

Flexure on 14 days curing observation: It has been observed that on 14 days curing period test composite grade concrete beam gives same deflection i.e. (central deflection) as it is conventional grade concrete beam but the flexural strength of composite grade concrete beam is more than 13 % as compared to conventional grade concrete beam.

Flexure on 28 days curing observation: on 28 days test it has been observed that flexural strength of composite concrete beam is greater than 27 % than the conventional grade concrete beam, and crack pattern are approximately same as a conventional grade concrete beam.

4.2 Cracking pattern and mode of failure at 7 days of curing period

It identified that the concrete beam of composite nature has obtained cracks thick and deep at the junction due to irregular strength gain of two different grades of concrete when the specimen was tested on 7 days. Further, during 28 days, the two different grades form good integrity and regular cracks started appearing on the sides similar to that of conventional concrete. It forms in between tension zone and compression zone. The developed crack pattern is illustrated in figure 3b. The crack patterns for RCB on 7 days of curing were shear cracks developed at the end one third portion of the length of the beam with uneven cracks at the centre portion of the beam. On the other hand, RCCB developed cracks in the region where bonding between the two different grades was present. The cracks were deep enough and developed at the point of application of load and extended up to the ends. Following figure 3a and 3b shows the failure pattern for Reinforced Concrete Beam and Reinforced Concrete Composite beam at 7 days of curing period.



Figure 3a Failure pattern of Reinforced Concrete Beam



Figure 3b Failure pattern of Reinforced Concrete Composite Beam-1

V. CONCLUSION

1. Reinforced Concrete Composite Beam gives lower flexural strength in 7 days as compared to Reinforced Concrete Beam by 4%. Flexural strength of Reinforced Concrete Composite Beam-2 was 12.8 % more as compared to Reinforced Concrete Beam on 14 days of curing period. At the age of 28 days, flexural strength of Reinforced Concrete Composite Beam was greater than Reinforced Concrete Beam by more than 28%. A relatively good bond and structural integrity was observed in Reinforced Concrete Composite Beam after 28 days of curing period. In Reinforced Concrete Composite Beam, the crack pattern was developed on the end one third section of beam at the age of 7 days due to insufficient bond between the two different grades and flexural tension and compression cracks were observed. A uniformly distributed crack pattern was observed on 28 days of curing period and development of shear cracks were observed.

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