A STUDY ON REINFORCED CONCRETE BEAMS INFILLED WITH LIGHT-WEIGHT MATERIALS BELOW NEUTRAL AXIS

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Abstract-*In recent days the problem faced by the construction industry is acute shortage of raw materials. In case of normally simply supported reinforced concrete beam, the region below the neutral axis is in tension and the region above the neutral axis is in compression. The concrete below the neutral axis acts as a stress transfer medium between the compression and tension zone. As concrete is weak in tension, steel reinforcement is provided in this region. Partial replacement of concrete below the neutral axis using light weight aggregate is an idea to reduce the weight of the concrete structure. By doing so, we can save the material and hence cost. This project deals with the experimental investigation on the behavior of reinforced concrete beam after partially replacing the concrete below the neutral axis with light weight materials like brick and crumb rubber.*

Key Words: Neutral axis, Reinforced concrete beam, light-weight material, Stress transfer.

1.INTRODUCTION

In recent days one of the main problem faced by the construction industry is the acute shortage of raw materials. Lots of researches were carried out for the investigation of alternative materials that can be used in concrete. Some locally available materials like fly ash, copper slag, rice husk etc. are experimentally evaluated.

Reinforced concrete has established itself as a widely used composite material for structural elements such as slabs, beams, column, wall, footing etc., 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 [3].

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 acts as the medium for transferring stress from compression zone to the tension zone. The concrete provided below the neutral axis is known as sacrificial concrete. This sacrificial concrete can be replaced by light weight material inorder to reduce the weight of structure and to achieve economy. The compressive force is acting in the top zone at a distance of 0.42 X_U. X_U is the neutral axis distance from top of section [1,4,6].

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 cause 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, brick and crumb rubber will not greatly affect the strength and stress characteristics of the beam. Also it will not affect the geometry and shape [7,2].

This project deals with the experimental investigation on the behaviour of reinforced concrete beam after partially replacing the concrete below the neutral axis with light weight materials like brick and crumb rubber.

2. EXPERIMENTAL PROGRAM

2.1 MATERIALS

Table 2 gives the details of material testing

Table-1 : Material Tests

Tests	Materials	Equipment used	Value obtained
Specific gravity	Cement(PPC)	Le chatelier flask	3.1
Consistency limit	Cement(PPC)	Vicat apparatus	33.5%
Fineness	Cement(PPC)	Sieve shaker	10%
Initial setting time	Cement(PPC)	Vicat apparatus	45 min
Specific gravity	Course aggregate	Wire basket	2.8
Specific gravity	Fine aggregate	Pycnometer	2.7

2.2 MIX PROPORTION

Mix design for M25 concrete have been worked out as per IS 10262:2009. The same mix proportions were used for all the specimens. In table 2 gives the details of mix proportion.

Table-2 : Mix proportion for M25 grade,Kg/m³

Cement	Fine aggregate	Course aggregate	Water
441Kg/m³	703.93Kg/m³	1220.61Kg/m³	441Kg/m³

2.3 MIXING AND CASTING OF BEAM

A total of eight concrete beam specimens were casted. Out of the 8 beams, one beam was designed as control beam, 4 beams were composite beams with 10%, 15%, 20% and 30% of coarse aggregate replaced by bricks, 3 beams were composite beams with 10%, 15% and 20% of coarse aggregate replaced by crumb rubber. The entire specimen dimensions were 1000mm x 120mm x 140mm with an effective span of 750mm. The beams are designed as singly reinforced beam with 2 nos. of 8mm diameter bars at the tension region. Table 3 gives the specimen details.

Table-3: Specimen details.

Sl.No	Specimens	Details
1	RCCB	Reinforced concrete control beam
2	RCBB10	Reinforced concrete beam replaced with 10% of Coarse Aggregate (C.A) below neutral axis with brick.
3	RCBB15	Reinforced concrete beam replaced with 15% of C.A below neutral axis with brick.
4	RCBB20	Reinforced concrete beam replaced with 20% of C.A below neutral axis with brick.
5	RCBB30	Reinforced concrete beam replaced with 30% of C.A below neutral axis with brick.
6	RCBR10	Reinforced concrete beam replaced with 10% of C.A below neutral axis with crumb rubber.
7	RCBB15	Reinforced concrete beam replaced with 15% of C.A below neutral axis with crumb rubber.
8	RCBB30	Reinforced concrete beam replaced with 20% of C.A below neutral axis with crumb rubber.

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. For balanced or under-reinforced sections, the steel also reaches yields at the time of concrete failure. 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 =fstAst -------------------(1)
Total compression, C =0.36fckb(Xu)----------(2)
Where fst= actual tension in steel corresponding to the strain in steel.
Equating the two expression, we obtain fstAst =0.36fck b(xu)
i.e. Xu = fst Ast/ 0.36 fckb----(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

Xu /d = 0.87fstAst/ 0.36fckbd--------(4)

Xu=0.87*500*157.07/0.36*25*120

= 63.26mm

= 64mm

The zone below the neutral axis is made of light weight concrete by replacing the coarse aggregate with 10%,15%,20% and 30% of low quality brick in four specimens and 10%,15% and 20%crumb rubber in three specimens.

Fig-1: Reinforcement cage for beam specimen

Fig-2: Casting of replaced beam

Fig-3: Casted beam specimen

2.4 TEST SETUP AND INSTRUMENTATION

The ultimate load carrying capacity of specimens were tested in UTM with 1000KN loading frame. The tests were carried out under three point loading condition as shown in Fig 4.

Fig-4: Test setup

Table-4 summary of test results

Specimen	Ultimate Load	% increment/decrement
RCCB	35	—
RCBB10	35	0
RCBB15	37	5.17%
RCBB20	34	-2.85%
RCBB30	32	-8.57%
RCBR10	37	5.71%
RCBR15	43	22.85%
RCBR20	42	17.41%

3. RESULT AND DISCUSSIONS

A.LOAD CARRING CAPACITY

It is found that there is no much difference in the load carrying capacity of control specimen and that of beams with replacement below the neutral axis. The load deflection curve of tested specimens were shown in Fig.5 and Fig.6 Fig.7 shows the ultimate load carrying capacity of tested specimens in the form of bar chart. Table.4 shows the summary of test results.

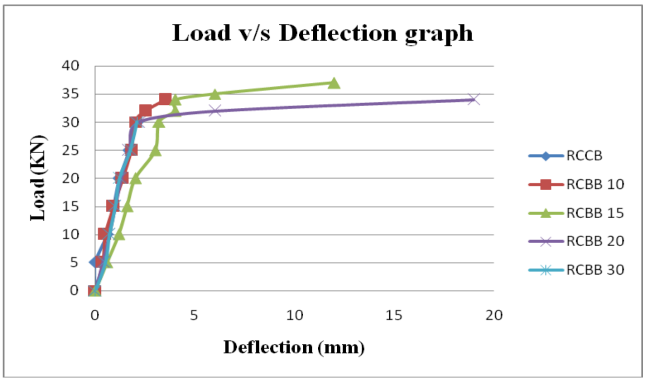

Fig-5: Load v/s deflection curve of RCB, RCBB10, RCBB15, RCBB20 and RCBB30

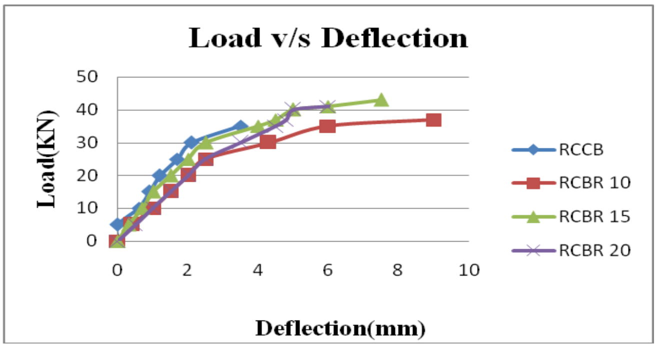

Fig-6: Load v/s deflection of RCCB, RCBR10, RCBR15 and RCBR20

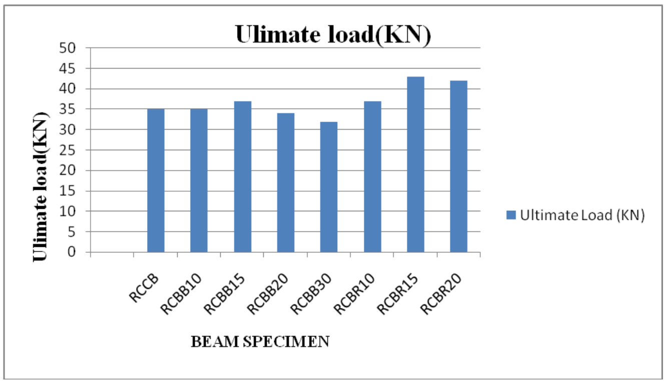

Fig -7: Ultimate load of tested beam specimens

The ultimate load of specimens RCBR10, RCBR15 RCBR20 were increased when compared to the control beam RCCB, higher increment being observed for specimen RCBR15 with 15% replacement of CA by crumb rubber.

Beam specimens with 15% brick replacement (RCBB15) shows slight increment in ultimate load carrying capacity compared to control beam. But when it increased to 20% and 30%, ultimate load carrying capacity is found to decrease with respect to control beam. This may be due to the reduced bonding between cement mortar and brick.

Beam specimen with 20% crumb rubber replacement (RCBR20) shows increment in ultimate load carrying capacity but a reduction in strength was observed with respect to 15% replacement (RCBR15). This may be because of reduced bonding force between crumb rubber and cement due to the smooth surface of crumb rubber.

4. CONCLUSIONS

1. The ultimate load carrying capacity of control beam and that of composite beam specimen and the replaced specimens were found to be almost similar.
2. Beam specimens with 15% replacement of CA in tension zone with brick and crumb rubber showed higher increment in load carrying capacity with respect to control beam. Therefore 15% is found as the optimum percentage

for replacement of concrete in tension zone with light weight materials.

3. It has been observed that the replacement of concrete in the tension zone by light weight materials does not require any extra labour or time. 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. Light weight composite 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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