An Experimental Study on Flexural Behaviour of Reinforced Concrete Sandwich Beam By Varying the Aggregate In Tension Zone

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***Abstract*— A beam is a horizontal flexural member which provides support to the slab and vertical walls. A normal beam (simply supported) consist of two zones generally arise, compression zone at top and tension zone at bottom. Our aim is to reduce the self-weight of the structure and reduction in cost without losing its strength and serviceability in the structural design. In this paper, an experimental investigation of the lightweight aggregate concrete placed below the neutral axis has been done to create reduction in weight and savings in materials. Hence we are comparing a reinforced LECA concrete sandwich beam with a reinforced concrete solid beam in terms of flexural strength. The beam is investigated in terms of crack load and deflection curves.**

***Keywords*— LECA* (Light weight Expanded Clay Aggregate), flexural strength, deflection, beam, compression zone, tension zone**

I. Introduction

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. 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 needs to be provided on tension side act as strain transferring media to steel and may be called as 'sacrificial concrete'. This concrete has no tensions more than strain transfer. Hence there is no necessity to use the same grade of concrete which is used upper zone. Why to use lightweight concrete in tension zone? The basic question which led to the idea of light weight concrete reductioning tension zone for RC beams to reduce construction cost, materials and weight. 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 0.416 XU. (XU –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. Generally being a structural engineer we should concentrate towards the structural as well as functional design of the structure. But while designing, economy of the project is also a major factor. Keeping economy and safety of the structure in mind, we came with the concept of "Sandwich Beam". **A Reinforced concrete sandwich beam** is a normal beam but we are using lightweight concrete placed below the neutral axis and normal concrete is placed above the neutral axis. Moreover, SCC is used to increase the fresh properties of the concrete. In this study by reducing weight of the beam and saving quantity of concrete by saving cement reduced the greenhouse gasses emissions. So it is environmental friendly.

II. Scope Of The Project

The main scope of this investigation are

- To reduce the weight of beam
- To reduce the amount of material and cost
- To increase the height of the building

III. Objective Of The Project

The main objective of this investigation are

- The objective of the present investigation is to reduce the self-weight of the beam and comparative study on conventional concrete beam with lightweight LECA concrete sandwich beam.
- To study the load versus deflection characteristics
- To study the ultimate load carrying capacity of the beams.

IV. Methodology

The methodology of works includes:

1. Material collection
2. Parameter study on materials
3. Arrival of mix design
4. Preparation of beam specimens
5. Testing of beam specimens under two point loading on loading frame
6. Result and discussion

V. Material Investigation

The test results of cement, fine aggregate, coarse aggregate & Leca are given in table 1

Table 1 Test result on constituent materials

Material	Test	Result
OPC 53 grade	Specific gravity	3.16
	Fineness modulus	0.4%
	Consistency	34%
	Initial setting time	40 min
	Final setting time	10 hrs
Fine aggregate passing 4.75mm	Specific gravity	2.62
	Fineness modulus	2.80
Coarse aggregate	Specific gravity	2.64
	Fineness modulus	4.46
LECA	Specific gravity	0.65
	Water absorption	20%

A. *Mix proportions*

The mix design has been made for M25 grade conventional concrete and light weight concrete use of code IS 10262- 2000, IS 456-2000 recommended. The water cement ratio (W/C) was kept constant at approximately 0.48 for all mixes, The lightweight aggregate concrete placed below the neutral axis of beam. The mix de

Table 2 Quantity of material

Grade of Concrete	Material	Quantity (Kg/M^3)
M25 (1: 1.20 : 2.61) (w/c ratio = 0.48)	Cement	446
	Fine aggregate	535.90
	Course aggregate	1168.34
	water	191.6
M25 SCC (1: 1.76 : 1.60) 1: 1.76 : 1.60 (w/c ratio = 0.40)	Cement	503.97
	Fine aggregate	888.10
	Course aggregate	809.36
	water	201.588

VI. Experimental Investigation

A. *Specimen details*

Normal and sandwich RCC beams of size 0.15m x 0.20 x 1.5m were casted. Specimen details are given in table 3

Table 3 Details of specimens

Beam Notation	Specimen Details	Dimensions
RC-SB	Solid RCC beam	0.15 m x 0.20 m x 1.5 m
RC-LB	RCC beams with Leca placed below the neutral axis	0.15 m x 0.20 m x 1.5 m

B. *Reinforcement details*

The beam was designed as singly reinforced beam. The support conditions were simply supported at both ends. Reinforcement details are given in fig 1. The loading type was two point loading. Reinforcement details were designed as per IS 456:2000 specification are given in below in brief

Ast = 3 Nos of 12 mm Ø
6 mm Ø stirrups @ 150 mm C/C
Hanger bar of 2 Nos of 8 mm Ø
20 mm cover

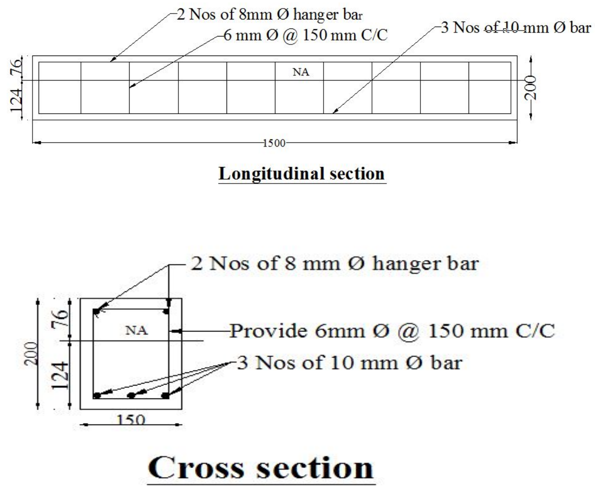

Fig 1: Reinforcement Details of beam

Neutral axis calculated as $X_u = \frac{0.87 \times f_y \times A_{st}}{0.36 \times f_{ck} \times b}$

$= 76$mm

C. Mould preparation

Steel moulds of size 0.15 m x 0.2 m x 1.5 m were used for casting of beam specimens. The moulds were greased properly. Reinforcement cage placed inside the moulds by providing proper cover blocks.

D. Casting of beam specimens

The beam specimens were casted with M25 mix concrete of mix ratio 1: 1.20: 2.61 and water cement ratio of 0.48 for used conventional or solid beam & the sandwich beam casted with M25 SCC mix ratio 1: 1.76 : 1.60 and water cement ratio of 0.40. SCC was only used above the neutral axis & below the neutral axis used lightweight concrete but same mix of M25. The quantity of materials (cement, water, fine aggregate, coarse aggregate and water) required for casting beams of size 0.15 m x 0.20 m x 1.5 m were taken and mixed well. The concrete mix first was poured into the moulds at the level of neutral axis and compacted well. Compaction was given with the help of damping rod then above the neutral axis used SCC it eliminating the mixing of two layer. The surface of beams were finished to get a level surface after concreting. The specimens were demoulded after 24 hours. The specimens were then subjected to curing for 28 days.

Fig 2: Fixing of reinforcement with cover inside the mould

Fig 3: Placing of lightweight aggregate concrete below the Neutral axis

E. Testing of beam specimen

Each of the beam specimens were tested under two point loading on the loading frame of capacity 50 ton. The flexural strength of beams were tested. The beams were simply supported at the two ends. The supports were provided at a distance of 0.15m from both the ends of the beam specimens. Effective length of beam was 1.2m. The effective span of beam is divided into three equal spans. The two points of loading were fixed at the ends of central span. LVDT gauges readings were taken at Centre of each span. Dial gauges of 10mm capacity were attached at the two points of loading and at the Centre of beam. The beam specimens were given two point loading at an interval of 0.5 ton. The behaviour of beams under loading was observed. The beam specimens were loaded till failure. The dial gauge readings were noted for each load applied. The development of first crack and propagation of cracks were observed.

Fig 4: Beam subjected to two point loading on loading frame

VII. Results & Discussions

A. Load vs Deflection characterstics

The load versus deflection characteristics of the beams were studied. The deflection is plotted along the X – axis corresponding to the loads in the Y – axis. The load is taken in kN and deflection in mm. The load - deflection characteristics of both beams specimens show similar curves. The load – deflection characteristics of both beams are linear, i.e., the deflection of all the beams is directly proportional to load. The load – deflection characteristics of beams are compared in figure 5

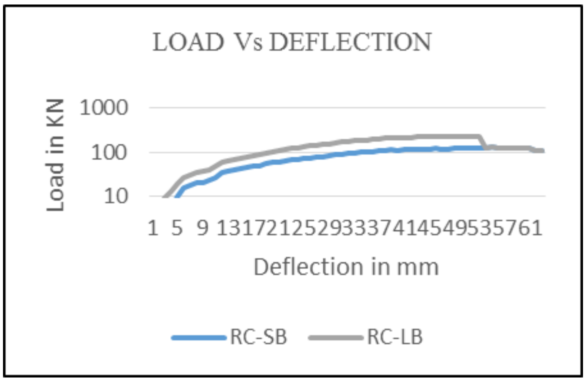

Fig 5: comparison of Load Vs Deflection curves

B. Ultimate load carrying capacity of the beam

The ultimate load taken by each of the beams was observed. Beyond this load the beam takes no load and failure occur. The load at which first crack is developed was also noted for each beam. Table 4 shows ultimate load carrying capacity and initial crack load of each beam. Figure 6 and 7 shows the comparison of ultimate load carrying capacity and first crack load of beams. The reinforced sandwich beam has 7.6% reduction in ultimate load carrying capacity when comparing conventional beam.

Table 4: Ultimate load & Initial crack load of beams

Analyzing Parameters	RC-SB	RC-LB
Initial Crack load (kN)	79	82
Maximum load(kN)	112.2	106.6

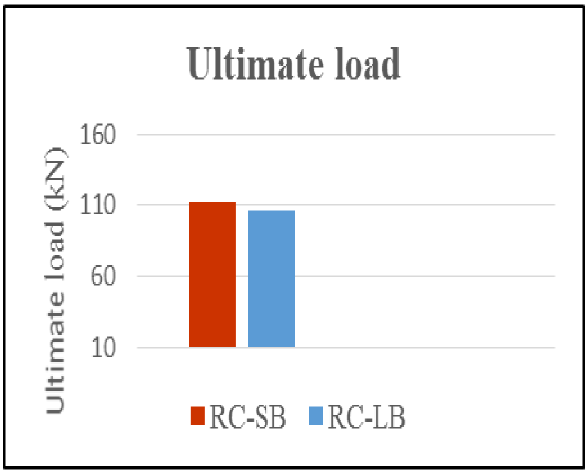

Fig 6: Ultimate load carrying cpacity of beams

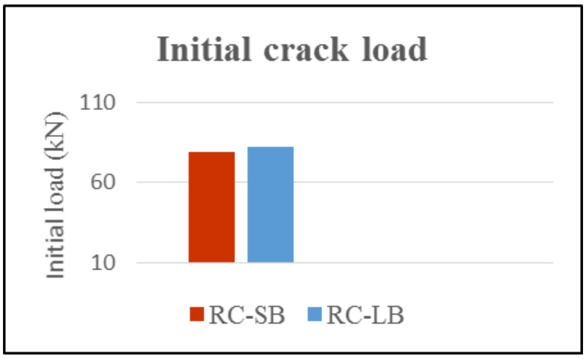

Fig 7: Initial crack load of beams

C. Ductility ratio

Table 5: Ductility ratio

Beam specimens	Yield deflection	Ultimate deflection	Ductility ratio
RC-SB	3.6	7.5	2.08
RC-LB	6.2	12.4	2

Load carrying capacity until total failure. In reinforced concrete beam the deformation most suited for measurement of ductility is the curvature of the beam. Alternatively here the deflection is used to measure the ductility. Ductility ratio, $\mu = \Delta u/\Delta y$ Where, Δu- Maximum deflection occurred at failure stage. Δy- deflection occurred at member yields. Ductility behaviour of the test specimens are shown in Table 23. From the ductility ratio calculation, it is found Ductility is the ability of the member to sustain deformation beyond the elastic limit while maintaining the reasonable that the ductility of Sandwich Beams and grade variation beam are similar to the conventional beams, according to code it is permissible and can be considered for structural member subjected to large displacements, due to sudden force caused by earthquake.

D. Crack patten

Mainly shear cracks were developed from the supporting points and widened up as the load increased. At failure, the concrete in the compression region crushed. The cracks continued to widen as the load increased, and failure occurred soon after depicting a typical sudden type of shear failure. The crack pattern of sandwich beam is similar to that of control specimen.

Fig 9: crack pattern of RC-SB & RC-LB

E. Weight reduction

The weight comparison of RCC sandwich beam and Normal RCC beam is given in table 5. When comparing self-weight of reinforce sandwich beam (RC-LB) of 27.66% which is lower than normal beam RC-SB.

Table 6: weight comparison

Beam Notation	Weight of concrete in (kg)	Difference in weight of concrete (kg)	Weight of concrete reduction by %
M25 RC-SB	126.5 kg		
M25 (RC-LB)	91.51 kg	34.99	27.66%

VIII. CONCLUSION

The flexural behaviour of beams by varying the aggregate used in below the neutral axis was studied. Based on the investigation the following conclusion were made.

- The flexural behaviour was similar for both beams.
- Self-weight of beams can be reduced by use of lightweight aggregate in below the neutral axis of beam.
- By providing Reinforced concrete sandwich beam give much better result than RC-SB due to increase in initial crack and decrease in ultimate load and deflection.
- Hence reinforced sandwich beam can be adoptable to the field because of its increase flexural strength.

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