Experimental and Analytical Analysis of Flexural Behaviour of Reinforced Concrete Composite Beams

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Abstract - *Concrete is the primary structural component, that exists in buildings and bridges. In recent days the problem faced by the construction industry is acute shortage of raw materials. In case of simply supported reinforced concrete beam when load acts in the top, the region below neutral axis is in tension and above neutral axis is in compression. Concrete is weak in taking tension, therefore steel reinforcements are provided in this zone. It is to be considered that concrete below the neutral axis act as a stress transfer medium between the compression and tension zone. So partial replacement of the concrete below the neutral axis is an idea to reduce weight and save materials.In this paper, an experimental and analytical investigation on partial replacement of concrete below the neutral axis by light weight concrete is discussed. Experimental models of light weight composite beams were cast and tested in UTM of 600kN. Then modeling light weight concrete tensile layer in reinforced concrete prisms using a continuum-based finite element model test was conducted in ANSYS 16.1 and the experimental and analytical results were analysed and discussed.*

***Key Words*: Flexural Strength, Reinforced Concrete, Composite Beam, Light Weight, Neutral axis**

1.INTRODUCTION

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 the neutral axis is in compression. Since concrete is weak in taking up tension, steel reinforcements are provided at the tension zone of beam. The concrete below the neutral axis act as the medium for transfering stress from the compression zone to tension zone, i.e., steel reinforcement are provided at the bottom. So the concrete provided below the neutral axis is known as sacrificial concrete. The compressive force is acting in the top zone at a distance of 0.42Xu. Xu is the neutral axis distance from the top of the section.[1]

In this paper, studies on partial replacement of concrete below the neutral axis by light weight concrete using different percentage of pieces of bricks are discussed. A total 12 beam specimens are casted and tested for the same. 6 beam specimens were casted without providing stirrups and the other 6 specimens were casted with stirrups. 6 beams without stirrups were first tested before casting the other 6 to understand the response of the beam and to measure the load at which it fails under shear [2]. This test has enabled to understand the load at which the beam fails under shear and also it enabled to design the stirrups for the next 6 beams so that enabled to ensure that the beam will only fail under flexure and not under shear, as this project was done to check the flexural property of the composite beam with light weight concrete under neutral axis.[3]

One of the important aspect of this thesis is that the experimental analysis has been compared with the analytical analysis, which was done using the software ANSYS 16.1. The same experimental model beams were modelled and similar loading conditions were applied in the ANSYS and the results are obtained and they were compared with that of the result obtained in experimental analysis. The compressive strength, Modulus of Elasticity, Density of the M25 Concrete used for experimental analysis were calculated experimentally and the same values were input in the Ansys so as to provide similar concrete properties.[4]

2. EXPERIMENTAL PROGRAM

2.1 Materials

Portland Pozzolana cement (PPC) conforming to IS:1489(part I):1991, M sand with a specific gravity of 2.44 conforming to Grading Zone III of IS 383: 1970, and coarse aggregate having a maximum size of 20mm with a specific gravity of 2.69 were used for investigation.

2.2 Mix proportion

Mix designs for M25 concrete have been worked out as per the code IS 10262:2009. The same mix proportions were used for all the specimens. In Table 1 details of mix proportions are given.

Cement	Fine aggregate	Coarse aggregate	Water
394 kg/m^3	751.22kg/m^3	1146.51kg/m^3	197kg/m^3

Table -1: Mix proportion for M25 grade, kg/m^3

2.3 Mixing and Casting of the Beams

All the materials were mixed manually in the laboratory at room temperature. A total of twelve specimens were cast and tested out of twelve 6 beams were of without stirrups and other 6 beams were with stirrups; out of 6 beams from both type two of the specimens were reference beams and the others were composite beams with 15% and 30% of coarse aggregate replaced by bricks. All the specimens was of dimension 100mm x 100mm x 750mm with an effective span of 700mm. The beams were designed as singly reinforced beam with 2 numbers of 8mm diameter bars at the tension region . Reinforcement detail of beam with stirrups are given in fig 1 and the cast beam specimens are shown in fig 2.

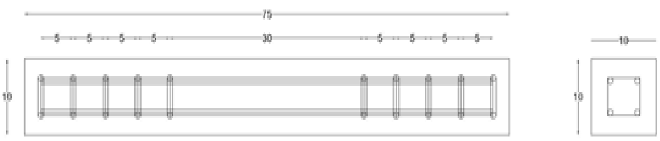

Fig -1 : Reinforcement detail of the beam

Fig -2 : Cast beam specimens

2.4 Test Setup and Instrumentation

The flexural strength of the specimens were tested using a 600kN loading frame; LVDT were used to determine the deflection at the center of the beam. The effective span of the test specimen was taken as 700mm which was achieved by using cast iron support. The flexural strength test of the beam was done with two point loading using a plate attached to the loading frame. Fig 3 shows the test setup.

Fig -3: Test Setup

3 ANALYTICAL PROGRAM

3.1 Finite Element Modelling

Solid 65 element (Fig 4) was used to model the concrete material, since it has capability of both cracking in tension and crushing in compression. Solid 65 element has 8 nodes with three degrees of freedom at each node – translations in the nodal x, y, and z directions. For concrete, ANSYS requires input data for material properties as shown in table 2. The steel for the finite element models was assumed to be an elastic-perfectly plastic material and identical in tension and compression. The LINK8, spar element, was used to represent the reinforcing steel bar. Two nodes are required for this element such that each node has three degrees of freedom, translations in the nodal x, y, and z directions. The element is also capable of plastic deformation.

Material Property	Symbol	values
Modulus of Elasticity	E	26100 N/mm^2
Ultimate uniaxial compressive strength of concrete	f_c	27.04 N/mm^2
Poissons Ratio	v	0.2
Density of concrete	ρ	2400 kg/m^3

Table -2: Input data for material properties

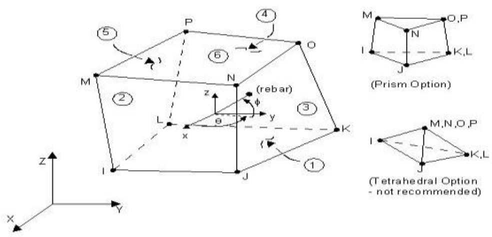

Fig 4-: Solid 65

Figure 5, 6 & 7 shows the model of the beam, loading pattern and deflection of the beam in ANSYS 16.1

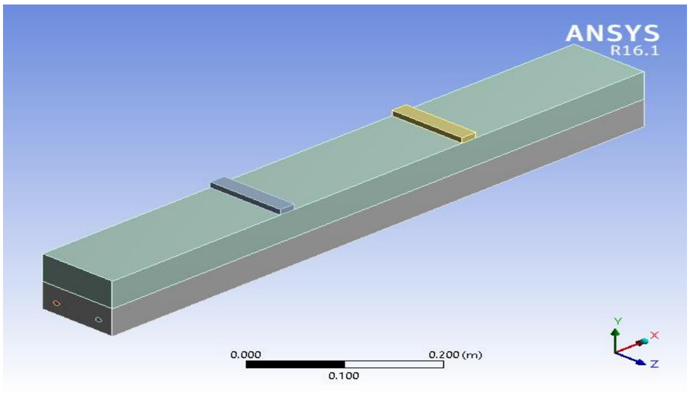

Fig 5 -: Model of the beam

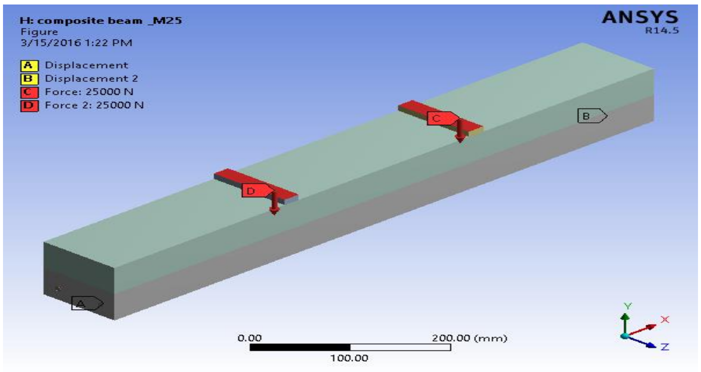

Fig 6-: Loading Pattern

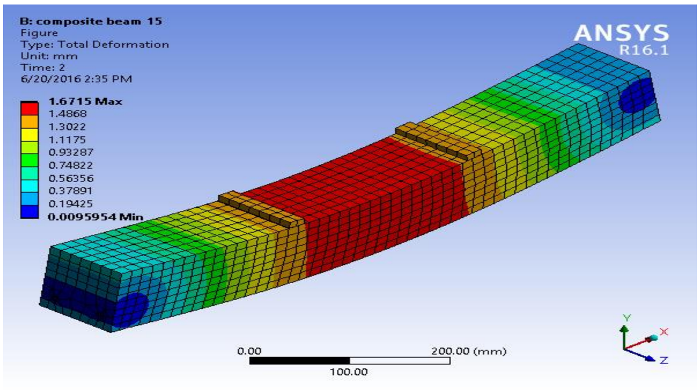

Fig 7-: Deflection of the beam

4 RESULT AND DISCUSSION

4.1 Comparison of Experiment Results and Analytical Results

The experimental tested beam results and the analytical results are compared in this section.

4.1.1Load vs Deflection graph of beams without stirrups

Load vs deflection graph of the beams without stirrups were plotted based on the analytical and experimental results obtained from experimental and analytical analysis of beams and in this section a comparison of the results obtained from both the analysis was done and the results are shown in Fig8, Fig9 & Fig10.

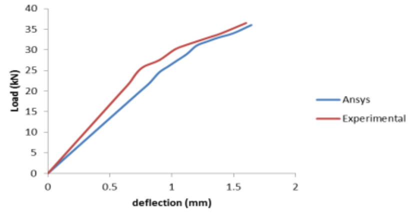

Fig 8 -: Load vs Deflection graph of Control Beam

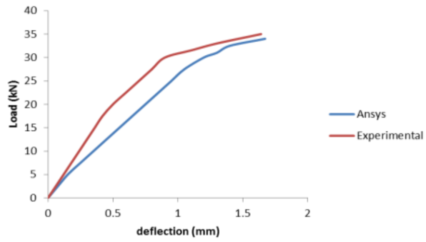

Fig 9 -: Load vs Deflection graph of Composite beam with 15% replacement of coarse aggregate

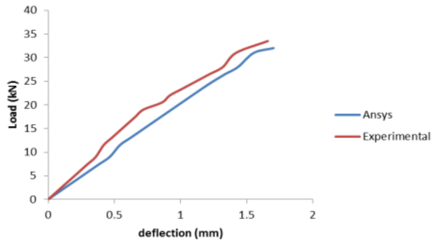

Fig 10 -: Load vs Deflection graph of Composite beam with 30% replacement of coarse aggregate

4.1.2 Load vs Deflection graph of beams with stirrups

Load vs deflection graph of the beams with stirrups were plotted based on the analytical and experimental results obtained from experimental and analytical analysis of beams and in this section a comparison of the results obtained from both the analysis was done and the results are shown in Fig11, Fig12 & Fig13.

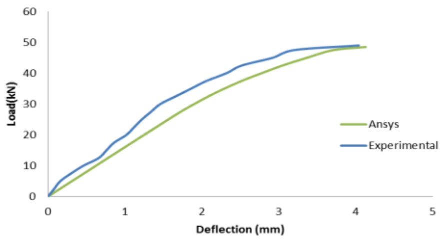

Fig 11 -: Load vs Deflection graph of Control Beam

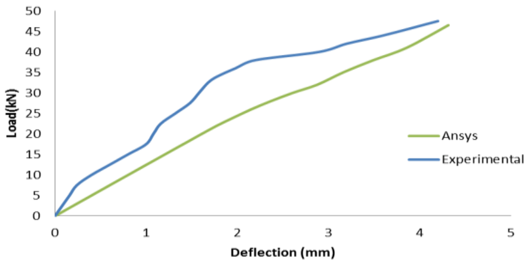

Fig 12-: Load vs Deflection graph of Composite beam with 15% replacement of coarse aggregate

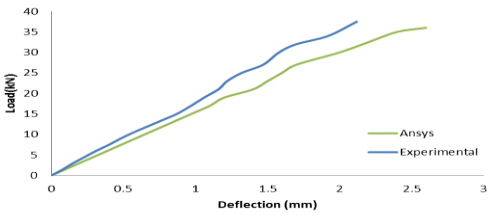

Fig 13-: Load vs Deflection graph of Composite beam with 30% replacement of coarse aggregate

DISCUSSION

From the above comparison it was found that the experimental and analytical results were comparable and only minor differences were seen. Load deflection characteristics and the load carrying capacity of the analytical result were found lower compared to the experimental results.

5. CONCLUSIONS

1.The load deflection relationship of control beam and that of composite beams were found to be similar in both experimental and analytical analysis.

2. The Load carrying capacity of the control beam and composite beams were found to be comparable in both the experimental and analytical analysis.

3. From the evaluation of the results, it was observed that the areas of application of the experimental reinforced beam with region below the neutral axis was replaced with light weight composite section include in various fields of construction where abnormal losses in concrete occurs. The wastage of concrete can be minimized by adopting this technique.

4. By replacing the concrete with light weight composite section under the neutral axis has proved to be very much economic without affecting the strength of the beam section upto 15% replacement.

5.Finite element models were developed using ANSYS 16.1 and deformation studies were carried out.

6. The difference in the value of experimental load-deflection and finite element load-deflection for all the beam sections were due to meshing. These values can be minimised by modifying the size of elements in meshing.

7. The load deflection characteristics of all the beams using ANSYS 16.1 were found to be marginally lower compared to experimental test results.

8. The measured deflection of beams and the predicted deflections using ANSYS 16.1 show fair agreement.

9. The total load is divided into a number of suitable load steps (load increment) by conducting a few trial analysis until a smooth load deflection curves obtained.

10. The accuracy of the results depend upon meshing of finite element model.

11. In order to get more accurate behaviour, the tension reinforcements are to be precisely incorporated using discrete modelling technique.

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. 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. It has been observed that the replacement of concrete by light weight composite section in reinforced concrete beams 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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