

STUDY ON FINITE ELEMENT ANALYSIS OF REINFORCED CONCRETE BEAMS WITH GGBS USING ANSYS

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Abstract — To build an efficient and safe structure during loading it is necessary to understand the response of structures. Finite Element analysis of Reinforced concrete beams were carried out using ANSYS to study the flexural behavior. Six beams were modelled in Finite Element software using ANSYS. Out of six beams, two beams were control beams without GGBS and other four beams with GGBS. The beams were of size 2500mm x 250mm x 150mm. The modelled beam resembled the real beam considered for experimental investigation. Displacement boundary conditions were assigned similar to the experimental set up. From the analyses, the load-deflection plots were obtained and compared with the experimental results. The load-deflection plots obtained from numerical studies shows good agreement with the experimental plots.

Keywords — Flexure, load, deflection, failure, ANSYS

I. INTRODUCTION

In general, design of reinforced concrete structures will be based on experimental data. Although traditional empirical methods can be used for ordinary design of reinforced concrete members, much more complex systems can be easily analysed using finite element method. This paper presents the flexural behavior of reinforced concrete beams with and without Ground Granulated Blast furnace Slag (GGBS) using ANSYS.

The application of the finite element method for the analysis of RC structures was presented by **Ngo and Scordelis** [2]. In their study, simple beams were analyzed with a model in which concrete and reinforcing steel were represented by constant strain triangular elements, A linear elastic analysis was performed on beams with predefined crack patterns to determine principal stresses in concrete, stresses in steel reinforcement and bond stresses. The load-deflection response of ordinary reinforced concrete beams and post-tensioned concrete T beams were investigated by **Fanning** [1]. The suitability of numerical modelling for predicting the ultimate response of RC beams by FE software ANSYS was analysed. The correlation of test and numerical data was found to depend on the values of linear and nonlinear material properties assigned to the materials. A finite element study on RC beams was

carried out by **Revathi and Devdas Menon [3]**. Reinforced concrete beams were modelled using ANSYS and concluded that predicted results from ANSYS showed good agreement with the physical experiments. **Tanarat [4]** developed Finite Element (FE) modelling techniques to isolate the different contributions of corrosion damage to structural response of experimental reinforced concrete beams with shear-dominated behavior. The FE results matched experimental results well and quantitatively estimated capacity reduction of the experimental specimens. The flexural response of Reinforced Geopolymer Concrete (RGPC) beams was studied in detail by **Uma et al [5]**. They compared the results from both ANSYS modelling and experimental data and concluded that there was 20% difference between experimental and analytical investigation.

II FINITE ELEMENT ANALYSIS

Finite Element Analysis (FEA) is a method used for the evaluation of structures, to evaluate the structural components response subjected to various structural loads. It is a numerical analysis method which divides the structural element into finer parts and then simulates the loading conditions to evaluate the response of concrete. The response of each element is expressed in terms of a finite number of degrees of freedom. In reality most of the problems are non linear in nature. In the present study an attempt is made to perform nonlinear finite element analysis to analyze the flexural behaviour of reinforced concrete beams with and without GGBS at 28 and 56 days from casting.

III MODELLING OF RC BEAMS

The analysis of beams using the software begins with providing data such as the units system, active code, materials, element types, section and model geometry definition. Modelling of all beams were carried out using the design modeler. For this analysis, six beams were modelled out of which, two beams were control beams without GGBS and other four beams with GGBS. The beams were of size 2500mm x 250mm x 150mm. The RC beam specimens were modelled in ANSYS workbench. The modelled beam resembled the real beam considered for experimental investigation. Geometry of the beam specimen and reinforcement details for the experimental analysis and ANSYS modeling are shown in Figure 1.

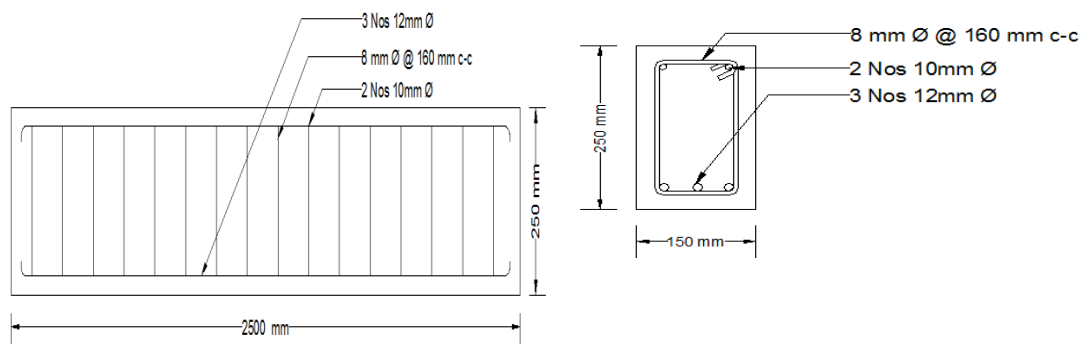


Figure 1 Geometry and Reinforcement Details of Beam Specimen

IV MATERIAL PROPERTIES

The software has a library of materials data. The engineering data for new materials for the project were input and edited in this. M30 grade of concrete and Fe 415 grade of steel was chosen for all the beam specimens. ANSYS automatically defines the material properties as per the selected grade of concrete and steel. In the longitudinal direction, 3 numbers of 12mm diameter rods were used in the tension side and 2 numbers of 10mm diameter rods were used in the compression side. 8mm stirrups at 160mm c/c were used in the transverse direction. The steel for the finite element models has been assumed to be an elastic-perfectly plastic material and identical in tension and compression. The ANSYS model of the beam specimens with reinforcement is shown in Figure 2.

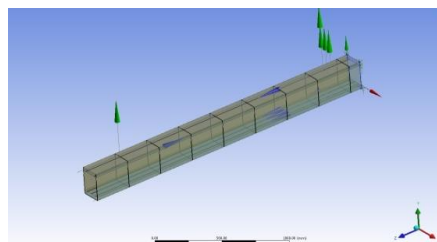


Figure 2 ANSYS Model of Beam Specimen with Reinforcement

Compressive Uniaxial stress strain relationship

The stress-strain behavior of concrete with and without GGBS was obtained by testing cylinders of standard size, 150mm diameter and 300mm long in axial compression under strain control mode. A total of eighteen specimens were tested in axial compression to get the stress-strain behavior of concrete mixes of various replacement ratios of GGBS such as 0%, 40% and 50%. Three

specimens were cast in each series. From the stress-strain values of control and GGBS mixes stress-strain plots were drawn. The software allows us to define stress-strain diagrams and to select the activation time of the material. Very fine meshing was selected to get accurate results. The numbering control command is used to merge all the items to make it as a single entity. The meshed model of the beam specimen is shown in Figure 3.

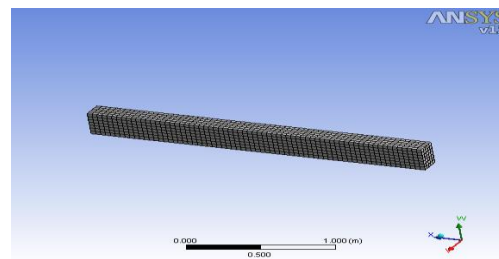
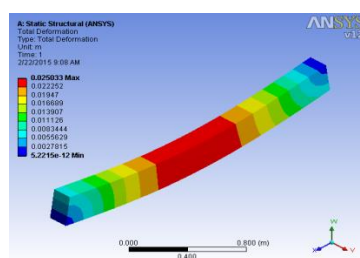


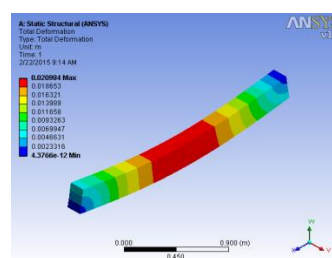
Figure 3 Meshed Model of the Beam Specimen

V ANALYSIS OF RC SPECIMENS USING ANSYS

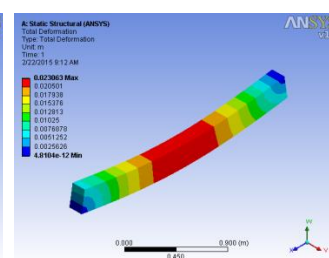
A four lettered designation is given to the specimens. First letter represents the beam, 2nd letter represent percentage of GGBS added and 3rd one identity of specimen in a particular series as two specimens were tested in each series and the last one indicates on which day the specimen was tested. The RC beam specimens modelled were analogous to the beam specimens B 0% 1-28, B 0% 1-56, B 40% 1-28, B 40% 1-56, B 50% 1-28 & B 50% 1-56 tested in the laboratory. Displacement boundary conditions were assigned similar to the experimental set up so as to constrain the model to get a unique solution. One end of the beam had hinged support and the other end had a roller support. The analysis type chosen was static. The beam specimens were analysed at various load increments until failure load. The deflected shapes are shown in figure 4. analysis are shown in figure 5(a) to (f).



(a) B 0% 1-28



(b) B 40% 1-28



(c) B 50% 1-28

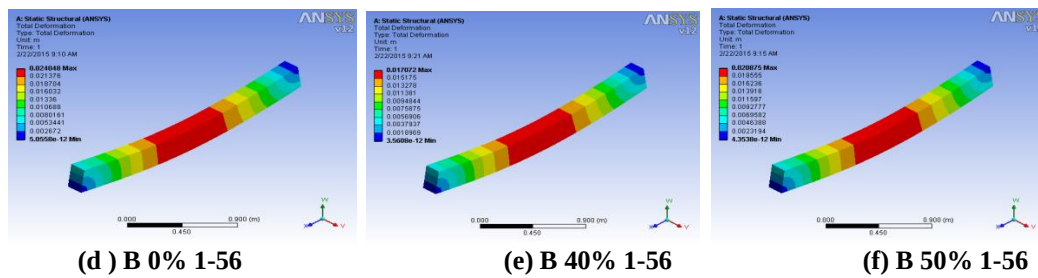


Figure 4. Deflected Shapes of the Beam Specimens at 28th and 56th Day

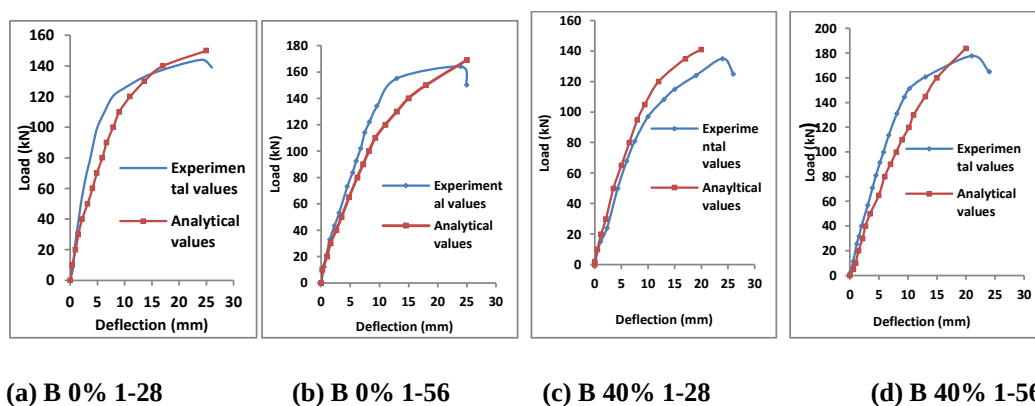
VI VALIDATION OF RESULTS

The experimental results obtained from the beam specimens tested in loading frame of 400kN capacity were compared with the results obtained from finite element analysis.

Table 1 Comparison between Experimental Ultimate Load and ANSYS Final Load

Specimen Type	Ultimate Load from the Experiment (kN)	Final Load from ANSYS (kN)	% Difference
B 0% 1-28	144	150	4.0
B 40% 1-28	135	141	4.25
B 50% 1-28	132	138	4.35
B 0% 1-56	164	169	3.0
B 40% 1-56	178	184	3.26
B 50% 1-56	166	172	3.5

From experimental and analytical results it was observed that specimens with 50% GGBS has the maximum deflection when compared with other specimens. The load-deflection relationships until failure were obtained and compared with the experimental results as shown in figure 6(a) to (f). The load-deflection plots obtained from numerical studies shows good agreement with the experimental plots. The experimental results when compared to analysis using ANSYS found to vary between 3% to 5%. This difference might be because of the toughening mechanisms at the crack faces which may also slightly extend the failures of the experimental beams before complete collapse. The finite element models do not have such mechanisms. Table 1 shows the comparison of the ultimate loads obtained from the experimental and analytical results.



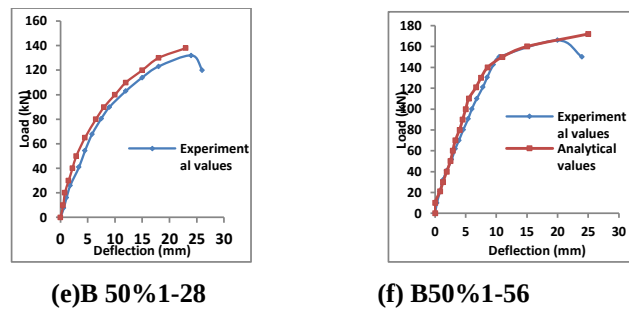


Figure 5. Comparison of results

From the Figures 5 (a) to (f) it is observed that the analytical results are in good agreement with the experimental values.

VIII CONCLUSIONS

- The study contributes to the development of new eco-friendly binder in concrete. Use of industrial waste products saves the environment and conserves natural resources. Reuse of the slag helps to protect the environment from pollution.
- It is observed that up to 50% replacement of Ordinary Portland Cement with GGBS gives optimum performance based on the above said parameters and economy.
- The experimental results were compared with analytical results obtained by ANSYS analysis and it was found that the analytical results were in good agreement with the experimental values.

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