Non-Linear Finite Element Analysis of GGBS & CRF based Reinforced Self Compacting Concrete Elements using ANSYS

V. Manjula
Department of Civil Engineering
Dr. M. G. R. Educational & Research Institute
Chennai, India

Dr. T. Felixkala
Department of Civil Engineering
Dr. M. G. R. Educational & Research Institute
Chennai, India

***Abstract*—The ANSYS finite element program (ANSYS 2015) was used in this study to simulate the behavior of the SCC beams and columns in flexure and buckling. To create the finite element model in ANSYS, there are multiple tasks that have to be completed for the model to run properly. Models can be created using command prompt line input or the Graphical User Interface (GUI). For this model, the GUI was utilized to create the model. This section describes the different tasks and entries used to create the finite element model. In this research paper the response of reinforced concrete SCC beam and reinforced concrete SCC column under static loading has been studied. The nonlinear finite element analysis response of the beams and columns was studied, along with initial and progressive cracks up to failure. The experimental and analytical results were compared and presented in this research work to make more scientific conclusions.**

Keywords*—ANSYS, Analytical Analysis, Finite Element method, stress- strain behaviour, Flexural Resistence, Axial Deformation, crack width

I. INTRODUCTION

Self Compacting Concrete (SCC) is one of the innovative techniques to overcome the placement of concrete in narrow and congested reinforced concrete elements with high deformability and excellent stability characteristics. In this experimental research , SCC mixture was developed with GGBS and Crusher Rejected Fines (CRF) replaced to cement and river sand respectively to achieve the lower strength of M20 to M30 concrete grade. The paper focused on the experimental study on the actual behaviour of the structural component member under transverse and axial loading. As well as to provide a valuable supplement to the laboratory test results , using sophisticated numerical tool ANSYS finite element software , Reinforced self compacting concrete beams were modeled and analyzed. The comparison between ANSYS results and experimental test results were made in terms of strength, flexural resistance and deflection of the structural elements. Reinforced SCC beams and columns were designed as per IS 456-2000 and two point loading method is implemented to study on the behaviour of beam element on first cracking , behaviour beyond first cracking and load deformation response at different mix ratios.

II. LITERATURE REVIEW

Saifullah et al. (2011) started with literature reviews and calibrated a beam model using finite element analysis package (ANSYS, SAS 2005). The conclusions based on the calibration model is that the Deflections and stresses at the centre line along with initial and progressive cracking of the finite element model compare well to experimental data obtained from a reinforced concrete beam. The failure mechanism of a reinforced concrete beam is modeled quite well using FEA and the failure load predicted is very close to the failure load measured.

Vijaya Sekhar Reddy et al. (2013) the experimental study focuses on the mechanical properties of M60 HPC with partial replacement of Cement by Ground Granulated Blast Furnace Slag (GGBS) and fine aggregate by robo-sand (crusher dust) with the addition of super plasticizer. It is observed that the maximum compressive strength achieved in M60 grade of concrete is 65.3 Mpa with 40% replacement of cement by Ground Granulated Blast Furnace Slag and 15% replacement of fine aggregate by robo-sand.

Bullo et al (2009). Preformed test on unconfined and confined SCC and Rehoplastic concrete columns subjected to axial and lateral strain, to measure the mean stress and strain. The experimental test was conducted on columns of uniform cross section 22x22 cm in size and 180 cm in height. According to the results, the load displacement curve highlights the different behaviour due to the steel reinforcement distribution and no clear difference due to SCC and PPC. They concluded the axial and lateral behaviour of unconfined concrete are similar in both SCC & RPC and there is better crack control ability and ductibility in confined SCC columns.

Pawar (2016) presented the behaviour of reinforced concrete columns subjected to axial symmetric and eccentric loading and also the failure mechanism by experimental was modeled using finite element analysis (FEA) and the results were compared. In Non linear analysis the total load applied to a finite element model is divided into a series of load increment called load steps. Columns subjected to axial loading shows very less horizontal deflection and vertical deflection is more at the free end, where the load is applied. The results from FEA are very distinct and were very close to expectation.

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III. ELEMENT TYPES

TABLE I. Elements used for Modeling

Material Type	Element (ANSYS)
Concrete	Solid 65
Steel Reinforcement	Link 8

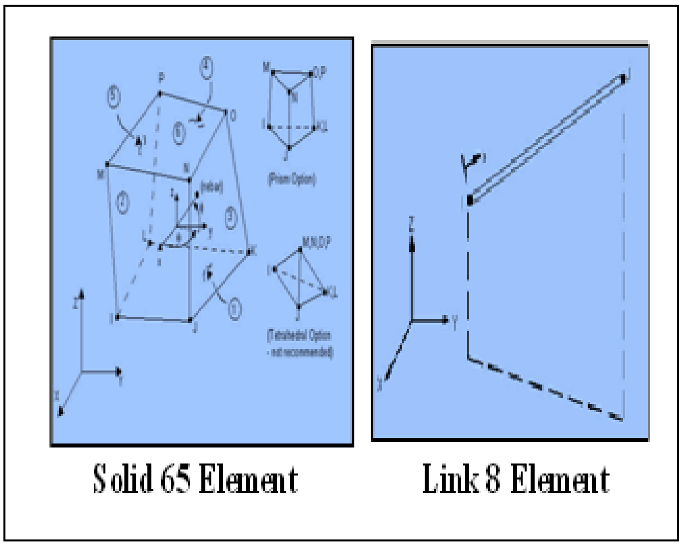

Fig. 1. 3Degrees of Freedom at each node (Translation in x, y, z directions)

IV. ANALYSIS ASSUMPTIONS

1. The bond between each element/material type is assumed perfect. Unless the failure mode of a structure involves a bond failure, the perfect bond assumption used in the structural modeling will not cause a significant error in the predicted load-deflection response specially while considering serviceability study.
2. A constant poisons ratio of 0.2 is assumed for concrete throughout the loading history.
3. The concrete is assumed to be isotropic prior to cracking and orthotropic after cracking. The steel is assumed to be isotropic.
4. The element matrices are reformed every iteration.
5. Time-dependent nonlinearities such as creep, shrinkage, and temperature change are not included in this study.

V. FINITE ELEMENT DISCRETIZATION

The finite element analysis requires meshing of the model. For which, the model is divided into a number of small elements, and after loading, stress and strain are calculated at integration points of these small elements. An important step in finite element modeling is the selection of the mesh density. A convergence of results is obtained when an adequate number of elements are used in a model. This is practically achieved when an increase in the mesh density has a negligible effect on the results.

VI. NON – LINEAR SOLUTION

In nonlinear analysis, the total load applied to a finite element model is divided into a series of load increments called load steps. At the completion of each incremental solution, the stiffness matrix of the model is adjusted to reflect nonlinear changes in structural stiffness before proceeding to the next load increment. The ANSYS program (*ANSYS 2015*) uses Newton - Raphson equilibrium iterations for updating the model stiffness. Newton - Raphson equilibrium iterations provide convergence at the end of each load increment within tolerance limits.

VII. MESHING

To obtain good results from the Solid 65 element, the use of a rectangular mesh is recommended. Therefore, the mesh was set up such that square or rectangular elements were created. The volume sweep command was used to mesh the steel plate and support. This properly sets the width and length of elements in the plates to be consistent with the elements and nodes in the concrete portions of the model.

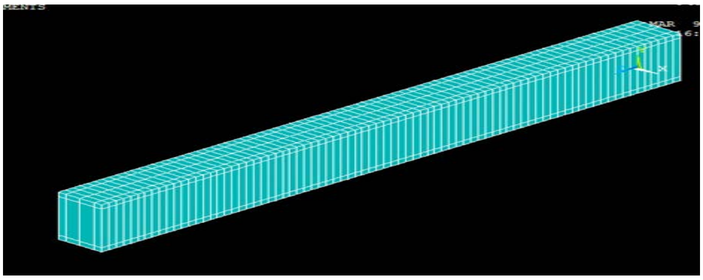

Fig. 2. SCC Beam Modeled

VIII. LOADS AND BOUNDARY CONDITIONS

Displacement boundary conditions are needed to constrain the model to get a unique solution. To ensure that, the model acts the same way as the experimental beam, boundary conditions need to be applied at points of symmetry, and where the supports and loadings exist.

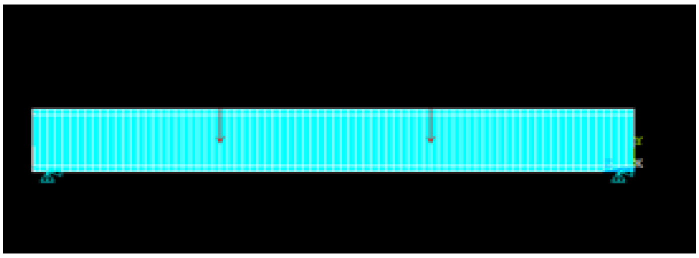

Fig. 3. Loading and Boundary conditions

IX. RESULTS OF FINITE ELEMENT ANALYSIS & DISCUSSION

The SCC beam specimens that were tested under four-point bending were analyzed using the ANSYS finite element code. The results pertaining to the objectives of the study are presented and discussed in this section. The finite element analysis results of the reference specimens and reinforced concrete beams at different load levels are presented in Table II.

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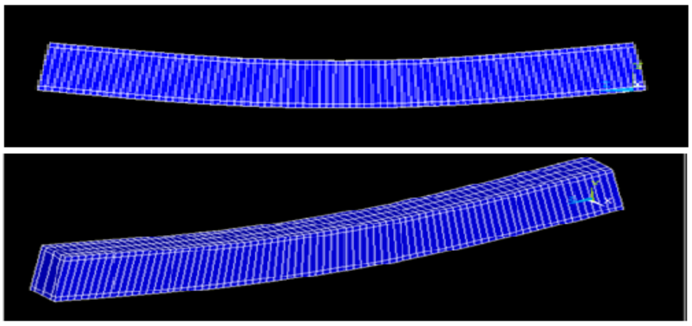

Fig. 4(a). Load-Deflection Response of Reinforced Beam SCC40 and SCC50

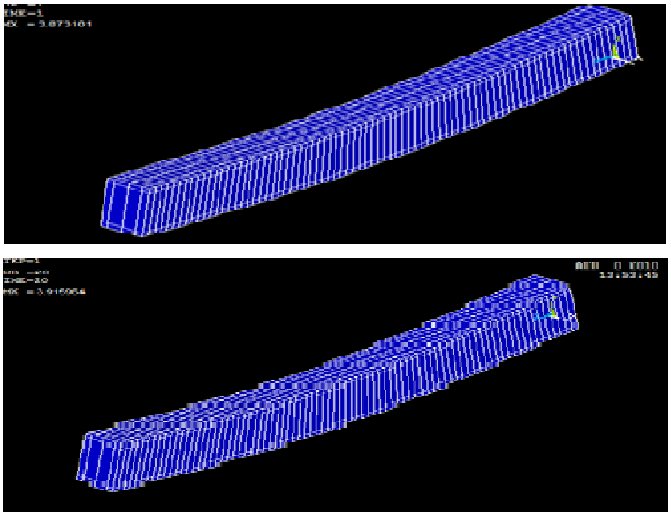

Fig. 4(b). Load-Deflection Response of Reinforced Beam SCC60 and SCC70

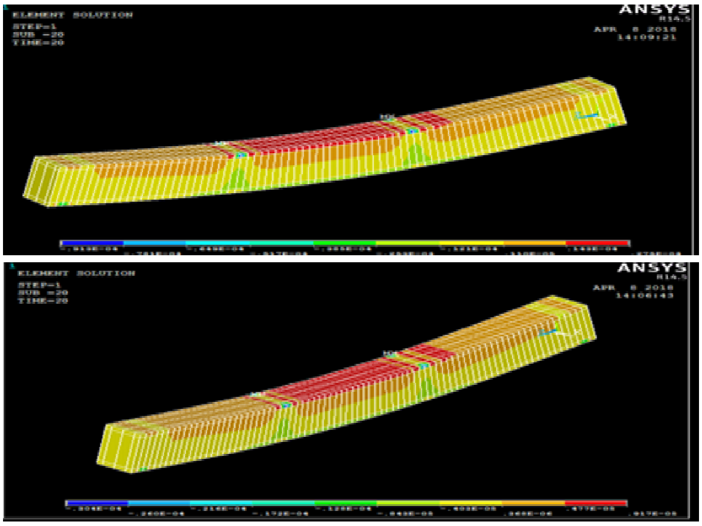

Fig. 5(a). Load – Strain Response of SCC40 and SCC50 Beams

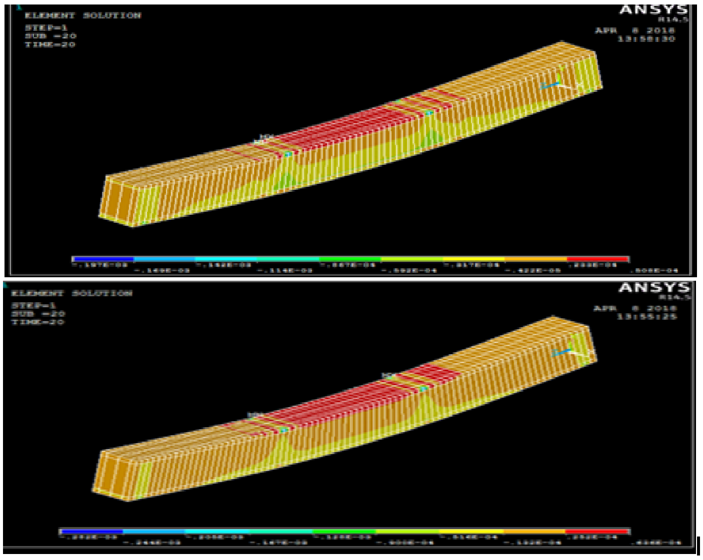

Fig. 5(b). Load – Strain Response of SCC40 and SCC50 Beams

A. *Crack Pattern of SCC Beams*

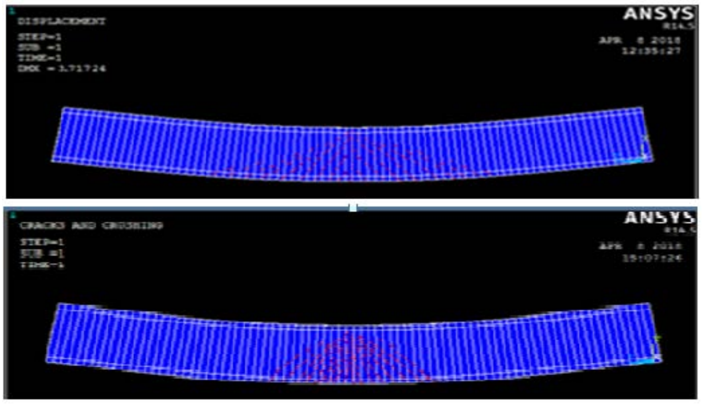

Fig. 6(a). Flexural Crack Pattern of Reinforced Beam SCC40 and SCC50

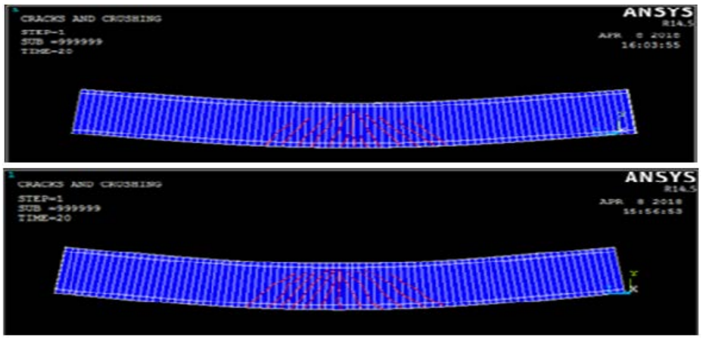

Fig. 6(b). Flexural Crack Pattern of Reinforced Beam SCC60 and SCC70

TABLE II. Strength and Deformation Properties Pertaining to Ultimate Stage

Beam	Experimental Ultimate load (KN)	Analytical Ultimate load (KN)	Experimental Deflection	Analytical Deflection (mm)
Control SCC	105.95	121	2.691	3.717
SCC40	99.70	124	1.675	3.788
SCC50	94.00	123	1.633	3.873
SCC60	90.40	119	1.671	3.915
SCC70	90.35	113	1.674	3.915

B. Column analysis

The column specimens that were tested under axial loading were modeled and analyzed using the ANSYS finite element code. The results pertaining to the objectives of the study are presented and discussed in this section. The finite element analysis results of the reference specimens and reinforced concrete column at different load levels are presented in Table III. The various stages in modeling reinforced concrete column with and without SCC are shown in Fig. 7(a), Fig. 7(b), Fig. 8(a) and Fig. 8(b) below.

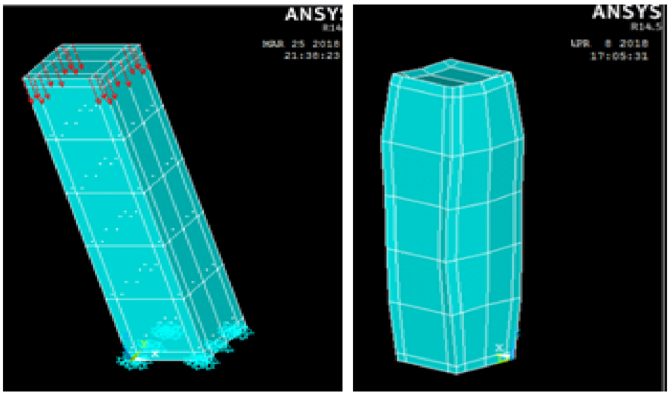

Fig. 7(a). Deflection Response of SCC2 Reinforced Concrete column

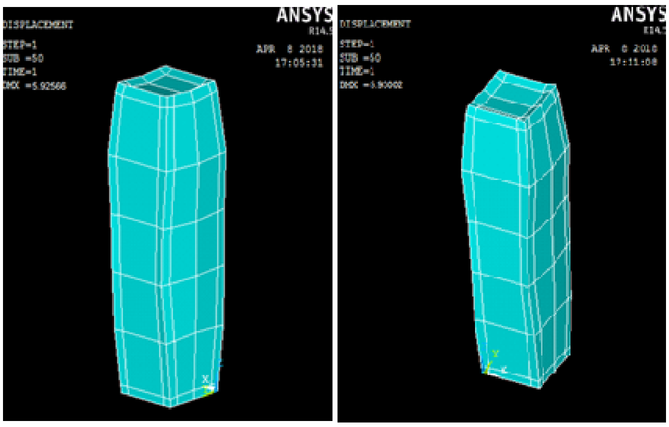

Fig. 7(b). Deflection Response of SCC2 Reinforced Concrete column

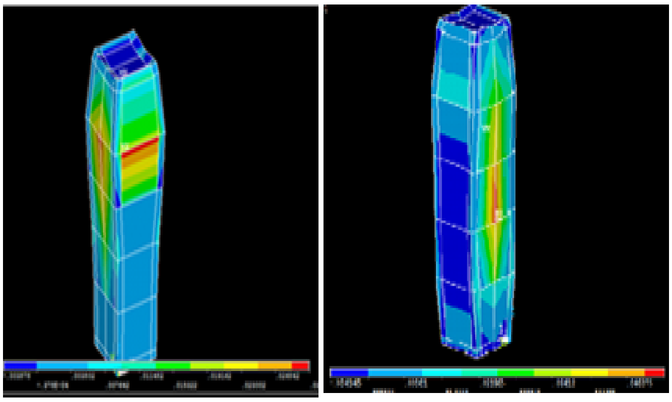

TABLE I. Strain response of SCC40 and SCC50 Column

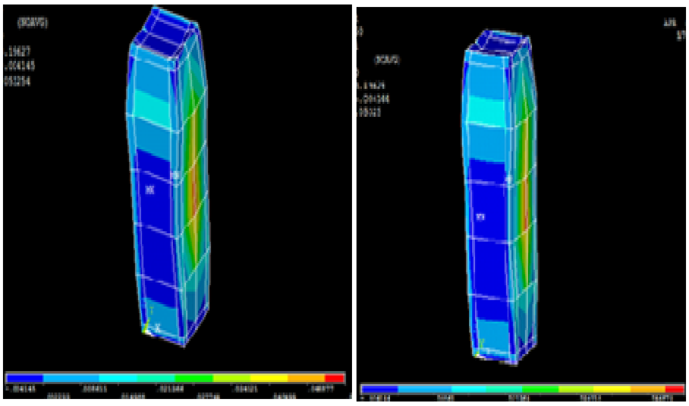

TABLE II. Strain response of SCC60 and SCC70 Column

TABLE III. Experimental Test Results

Column Designation	Ultimate Load (KN)	Ultimate Axial Deflection
Control SCC	857.67	4.57
SCC40	678.21	5.81
SCC50	620.61	5.92
SCC60	587.31	5.93
SCC70	528.73	6.07

TABLE IV. *Analytical Test Results*

Column Designation	Ultimate Load (KN)	Ultimate Axial Stress (Mpa)	Ultimate Axial Deflection	Ultimate Axial Strain
SCC40	850	33.09	5.81	0.03
SCC50	750	41.93	5.92	0.03
SCC60	700	42.48	5.93	0.03
SCC70	650	45.05	6.07	0.03

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X. CONCLUSION

The comparison in deflection at ultimate load level of the reference specimens are presented in Table II.An observation shows that the finite element modeling can estimate the prediction values with reasonable levels of accuracy for ultimate deflection. It has been found that the finite element model can make a reasonable estimate on the prediction values ultimate loads and ultimate deflections. A close agreement has been obtained between the predicted results. The finite element model can make a reasonable estimate on the prediction values of ultimate loads and ultimate deflections

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