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Analysis of Axial Compressive Behaviour of Steel Fibre Reinforced Concrete Filled Square and Rectangular Glass Fibre Reinforced Polymer Tubes

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Abstract: **This research study focuses on performance of SFRC filled GFRP tubes under axial compression and their composite behaviour. The main objective is to study the behaviour that various with parameters including grade of concrete, corner radius, thickness of the tube and cross section. The SFRC filled GFRP tubes were simulated choosing square and rectangular cross section areas of 133*133mm and 150*118mm having tube thickness 3 and 4mm with corner radius 10, 15 and 20mm. In order to obtain the good composite action the concrete with the compressive strength of 30N/mm^2, 40N/mm^2 and 50N/mm^2 would be used. The height of the sections is chosen as 266 and 300 mm. The aspect ratio (H/D) was confined to two. The volumetric fraction of steel fibre used is 0.5%. The pultruded GFRP tubes would be used and the fibre orientation would be $\pm$ 90°.3D model of the specimens is created and simulated using finite element software ANSYS. A new confinement model of 36 specimens are analysed in ANSYS and the results are tabulated. The ultimate loading capacity of the concrete filled rectangular GFRP tubes was arrived using the codal provisions available in ACI Code (ACI committee 440, 2R-08).**

Keywords: **SFRC, GFRP, FEA, compression, concrete.**

1. INTRODUCTION

SFRC filled GFRP tube has many significant advantages over other CFFT's. FRP tube gives better confinement to the concrete and steel fibre increases the strength of the concrete. It is now well understood that the compressive behaviour of FRP confined concrete is significantly influenced by the distribution of the confining pressure around the perimeter of the concrete section and that this distribution is affected greatly by the shape of the cross-section and corner radius. Steel fibre is a composite material whose components includes traditional constituents of port-land cement, fine aggregate, coarse aggregate admixtures ad dispersion of randomly oriented short discrete steel fibre. The use of SFRC increased due to its improved material and structural behaviour relative to plain concrete and even to conventionally reinforced concrete with the same volume fraction. One of the most beneficial aspect for using fibres in concrete structures is non-brittle behaviour after cracking of concrete can be achieved with fibres.

A finite element analysis (FEA) software package ANSYS 15.0 is used to analyze the stress-strain and contact behaviour of the 3D model of the specimens.

2. THEORETICAL PREDICTIONS

1. ACI 440.2R-08 GUIDE FOR DESIGN:

From chapter 12 of ACI 440.2R – 08 design the maximum confined concrete compressive strength f'cc and the maximum confinement pressure fl are calculated using Equation and respectively (Lam and Teng 2003a,b) with the inclusion of an additional reduction factor $\psi f = 0.95$.

3. ANALYTICAL PREDICTIONS

1. FINITE ELEMENT ANALYSIS:

Finite element analysis is a computerized method for predicting how a product reacts to real–world forces, vibrations, heat, fluid flow and other physical effects. Finite element analysis shows whether a product will break, wear out, or work the way it was designed.

2. 3D MODELING:

Steel fibre reinforced concrete filled square and rectangular GFRP tubes was modeled and simulated using ANSYS. Concrete is modeled using SOLID 65. GFRP tube is modeled using SHELL 281. The interaction between the concrete and tube is given using CONTACT 174.

4. PREPROCESSOR

In preprocessor choosing element type, element real constant, material properties defining, defining geometry are done.

4.1 CONCRETE:

The concrete used in this study was modeled using SOLID65 element which had all the capabilities and properties needed to accurately predict the behavior of all grades of concrete are given as input. The eight node - solid element SOLID65 has three degrees of freedom at each node i.e., translation in x, y and z directions was used to model concrete. This 3d element has the capacity to undergo deformation, cracking, crushing.

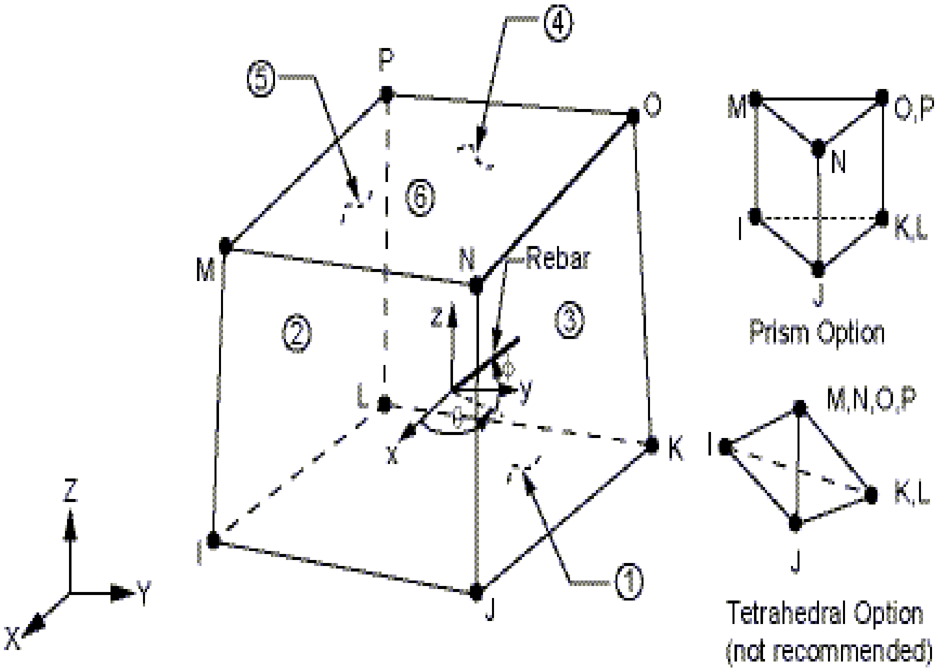


Fig 1 SOLID 65

The unconfined concrete strength was adopted as 30, 40 and 50 MPa . The nonlinearity of the concrete was modeled as per IS 456: 2000 and the elastic modulus was defined as and the Poisson's ratio was taken to be 0.20.

The Open Shear Transfer Coefficient and Closed Shear Transfer Coefficient were taken to be 0.3 and 1 respectively and the tensile strength of the concrete element was given as. The concrete element SOLID 65 was adopted from the FEA software ANSYS 15.0. This study was confined to FEA modeling only and hence the short stocky column having GFRP tube confinement was assumed to be having unreinforced.

4.2 GFRP TUBE:

The GFRP tube was simulated using element type SHELL- 8 NODED 281. Three layers of shell each 1mm for 3mm thickness GFRP tube and also for four layers of each 1mm for 4mm thickness tube is created in shell section as layers with fibre orientation 90^0.

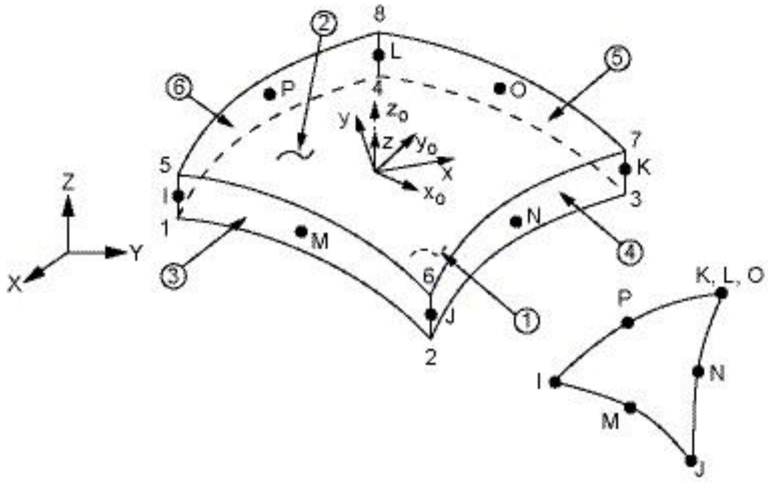
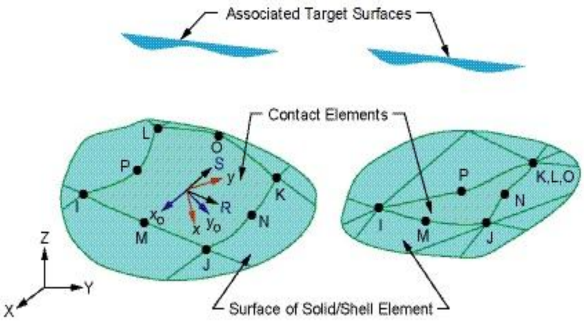


Fig 2 SHELL 281

4.3 CONTACT BETWEEN TUBE AND CONCRETE:

Contact pair is created between concrete and GFRP tube. Surface to surface contact is created. Penalty stiffness is given as 1 and coefficient of friction is given as 0.2



R = Element x-axis for isotropic friction

x_0 = Element axis for orthotropic friction if ESYS is not supplied (parallel to global X-axis)

x = Element axis for orthotropic friction if ESYS is supplied

Fig 3 CONTACT 174

5. SIMULATION OF MODELS USING FEA SOFTWARE

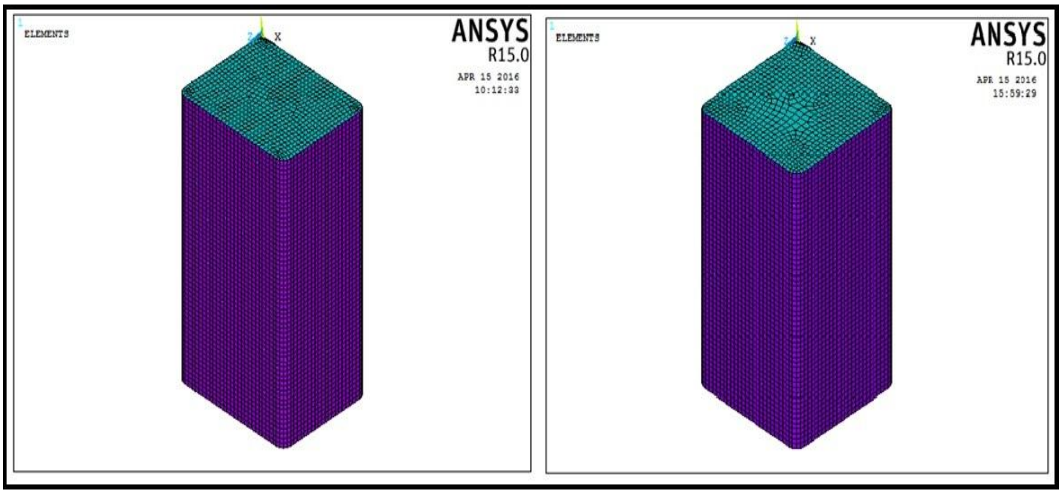


Fig 4 Rectangular and square model

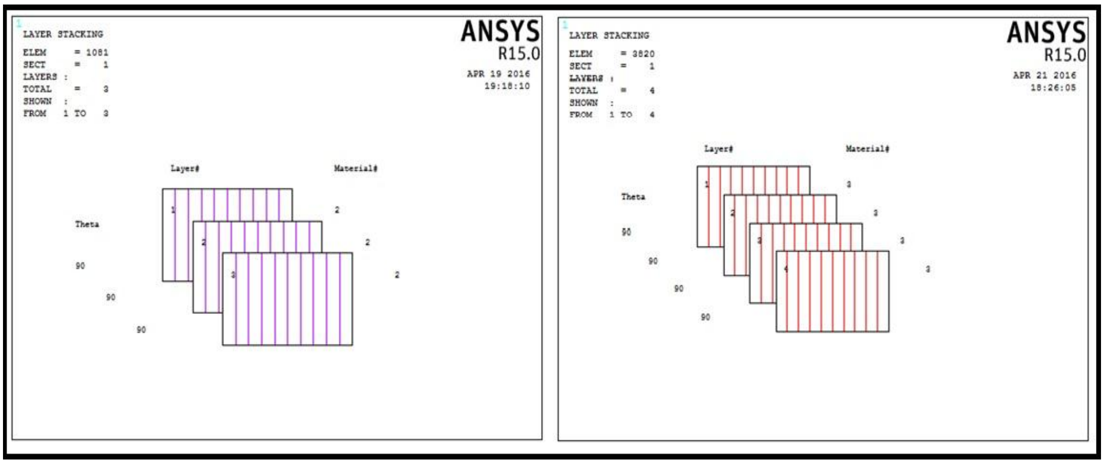


Fig 5 Layer element with 3mm and 4mm thickness

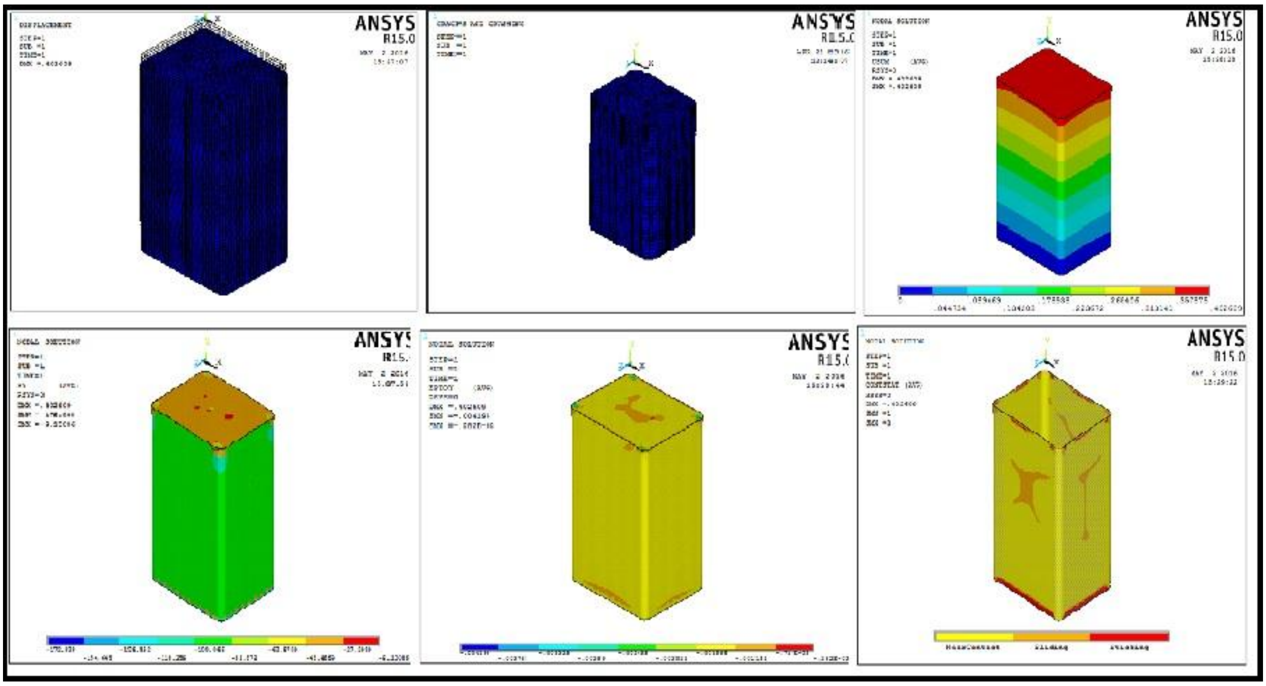


Fig 6 Deformation, stress, strain and contact status

6. ANALYTICAL VALUES

Table 1

Specimens	Thickness (mm)	f'cc(Mpa)	Displacement(mm)	$\varepsilon_{cu\%}$
R150CR10M30	3	172.828	0.40261	0.42
R150CR15M30	3	215.238	0.51701	0.46
R150CR20M30	3	244.868	0.64018	0.7
R150CR10M30	4	195.882	0.453618	0.4527
R150CR15M30	4	262.759	0.653049	0.5774
R150CR20M30	4	283.152	0.77064	0.9007
R150CR10M40	3	172.022	0.393219	0.3541
R150CR15M40	3	207.158	0.494392	0.403
R150CR20M40	3	236.454	0.60759	0.6662
R150CR10M40	4	191.067	0.435282	0.4176
R150CR15M40	4	247.894	0.600879	0.5212
R150CR20M40	4	286.465	0.698302	0.8014

R150CR10M50	3	167.526	0.38259	0.3373
R150CR15M50	3	202.547	0.481254	0.3838
R150CR20M50	3	251.298	0.58983	0.6349
R150CR10M50	4	156.492	0.423705	0.3955
R150CR15M50	4	238.553	0.57484	0.4861
R150CR20M50	4	295.106	0.654216	0.7405
S133CR10M30	3	147.136	0.3247685	0.3001
S133CR15M30	3	140.076	0.3512	0.4000
S133CR20M30	3	198.278	0.487	0.5000
S133CR10M30	4	175.738	0.367107	0.3862
S133CR15M30	4	200.777	0.472677	0.5432
S133CR20M30	4	287.375	0.671085	0.7028
S133CR10M40	3	153.814	0.317113	0.2988
S133CR15M40	3	166.632	0.37659	0.4337
S133CR20M40	3	208.299	0.502906	0.525
S133CR10M40	4	172.035	0.357013	0.3602
S133CR15M40	4	193.055	0.443621	0.5097
S133CR20M40	4	235.791	0.578828	0.6083
S133CR10M50	3	144.965	0.317231	0.2927
S133CR15M50	3	163.678	0.366786	0.4207
S133CR20M50	3	205.188	0.490465	0.5108
S133CR10M50	4	161.698	0.350055	0.3437
S133CR15M50	4	189.657	0.418719	0.4813
S133CR20M50	4	230.068	0.547797	0.5741

7. CONCLUSION

1. From the table values infer that confinement effectiveness of GFRP tubes increases with increase in corner radius of the tube.

2. GFRP tube thickness has a significant influence on the ultimate strain and ultimate strain increases with increase in thickness results in increase strength of SFRCFFT's.

3. The well rounded corner radius of SFRCFFT's develops higher ultimate strain when compared to smaller corner radius.

4. The square tube offers better confinement when compared with the rectangular GFRP tube thus showing an increase in the stress of the SFRCFFT confined GFRP tubes.

5. Fig 5.87 shows that Theoretical and analytical load capacity of specimens is more or less equal. Maximum error is 2 – 3% only.

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