Study on the Structural Behavior of Concrete Encased Steel Composite Column

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Abstract – *This paper reports the findings of study that was undertaken to investigate the structural performance of the concrete encased steel composite columns. These composite members provide an economical solution to structure requiring high strength and ductility and results in more sustainable construction as it reduces the usage of resources. The main parameters considered in in this study are concrete compressive strength and the members with encased steel section. Theoretical and analytical studies were carried out and compared with the experimental results. The results indicated that concrete encased steel composite columns provide a significant enhancement in the load carrying capacity, decrease in axial shortening when compared to reinforced concrete column.*

Key Words: concrete encased steel composite column, FEM, axial shortening, deflection…

1. INTRODUCTION

Composite structures using steel and concrete are widely used in construction industry for the past few decades.Generally concrete is stronger in compression and could withstand more compressive force and steel is stronger in tension. In composite construction the steel and concrete combined in such a fashion that the advantages of the both the materials are used effectively. In the concrete encased steel composite members, steel beam (hot rolled steel section) is encased with concrete which provides fire protection to the steel member and also increases the overall stiffness of the section which in turn increases the load carrying capacity of encased steel members when compared with reinforced concrete section and leads to reduction in size of the section. Longitudinal and transverse reinforcement in the concrete encasement prevents excessive spalling of concrete under loading conditions.

Several works has been carried out in the past to study the behavior of concrete encased steel composite members. Tomoya motsui [1] investigated the structural performance of concrete encased steel columns with H-shaped steel and concluded the deformation capacity of CES columns can be improved by increasing fibre contents ratio and the increase of the flange width produce an increase of the confined concrete area, which leads to improve the deformation capacity of CES columns. On the other hand, the increase of flange width produces smaller cover concrete area, therefore when the fibre contents ratio is increased the effect of increasing the deformation capacity is not so significant. The flexural behavior of steel reinforced concrete columns with T-Shaped steel by yasushi NISHIMURA [2] He studied the effects of the applied axial load and the loading angle to the principle axis of the reinforced concrete column section were investigated. Hysteretic response of SRC columns with T-shaped steel showed large energy dissipating capacity up to storey drift angle of 2% regardless of the applied axial load and loading angle. The ultimate flexural strength in the positive and negative loading is affected by the loading angle. the ultimate flexural strength could we predicted by the numerical analysis and the superposed strength method. Skelton curves could we predicted by the numerical analysis.

Cristina campian [3] tested the behavior of fully encased steel-concrete composite columns subjected to monotonic and cyclic loading. In composite columns with HSC case, even if elastic displacement v_y decreases, the value of the lateral force H_y corresponding to the v_y displacement and the maximum lateral loading H_{max} indicates a significant increase. Failure modes were different, characterized by sudden and violent concessions due to cracking developments through aggregate in columns with HSC , while columns with NSC shows a “slow” failure mode characterized by gradual decline of bearing capacity with the growth of the displacements. It is well known that the high strength concrete is more susceptible to fragile failure than the normal concrete, so it is, in a way, the presumed result.

Cheng-Chih Chen [4] investigated the Experimental behaviour and strength of concrete-encased composite beam-columns with T-shaped steel section under cyclic loading. The crushing and spalling of the concrete and buckling of the longitudinal bars in the compression zone with less structural steel are the cause of pinching of the hysteresis curve. The ultimate flexural strength, ductility and energy absorption capacity can be enhanced by providing the cross ties and decreased spacing of the hoops. This is attributed primarily to the increased confinement provided by the transverse reinforcement. K.Z.Soliman [5] studied the Review of design codes of concrete encased steel short columns under axial compression. The tube-shaped steel section led to better confinement than the SIB section which resulted in a noticeable increase in both ductility and ultimate axial capacity of the columns. Finally, the concrete contribution is mainly dependent on the number of ties and shear transfer between the concrete and steel sections.

2. THEORETICAL STUDY

The theoretical study was carried out using euro code 4 to find the load carrying capacity of the proposed concrete encased steel composite column. The details of the specimens are given in table 1.

Table -1 : Sample column specimen details

S.No	Specimen Details	Legend	Steel Beam Angle
1.	Reinforced concrete column	C1	0
2.	Concrete encased steel column	C2	90
3.	Concrete encased steel column	C3	45

2.1 Specimen Description

The specimen encloses structural steel section, longitudinal reinforcement and transverse reinforcement. The I shaped structural steel section is made into two halves by cutting at the centre at longitudinal direction, then the both t shaped flanges are welded together and its used in the specimen is hot rolled section. The longitudinal bars are placed at each corners of the column, the stirrups spacing is 200mm c/c and the adopted concrete cover is 40mm as per EC4 recommendations. Fig.1 and fig.2, shows the cross section of the columns.

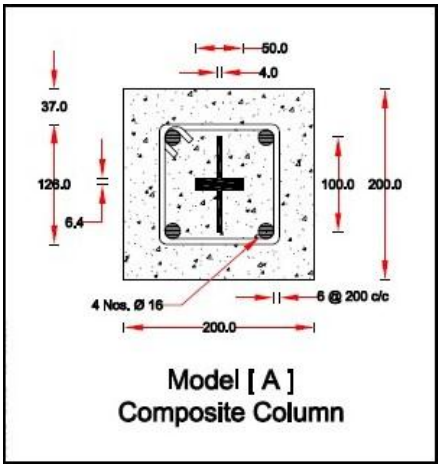

Figure -1 : Model composite column-C2

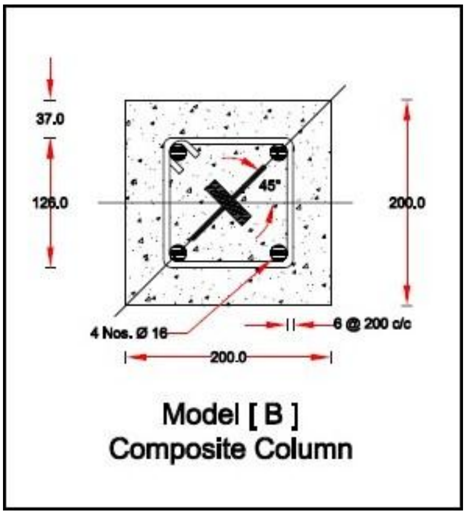

Figure -2 : Model composite column-C3

2.2 Material Properties

The 'I' section provided in the specimens is ISLB 100 @8kg/m, which comply with the standards in IS 808:1989. The properties of concrete and reinforcement steel were given in the table 2.

Table -2 : Material Properties

S.No	Materials	Properties
1.	I steel beam	ISLB 100@8kg/m
2.	Reinforcements [Fe415]	4Nos.@ 16mm and 6mm @200mm c/c
3.	concrete	M25

2.3 Method of Design

At present, there is no Indian standard covering composite columns. The method of design suggested in this chapter largely follows EC4, which incorporates the latest research on composite construction. Isolated symmetric columns having uniform cross sections in braced or non-sway frames may be designed by the simplified design method describes in the next sections. This method also adopts the European buckling curves for steel columns as the basis of column design. it is formulated in such a way that only in hand calculations required practical design. This method cannot be applied to sway columns. When a sufficiently stiff frame is subjected to in-plane horizontal forces, the additional internal forces and moments due to the consequent horizontal displacement of its nodes can be neglected, and the frames is classed as non-sway frames.

2.4 Plastic Resistance Of The Column Section

The plastic load for the concrete encased columns calculated using provisions given in euro code4.

$$P_p=(A_a f_y/\gamma_a)+(\alpha_c A_c f_{ck} C_y/\Upsilon_c)+(A_s f_{sk}/\Upsilon_s)$$

Where,

A_a-area of steel section

f_y- yield strength of steel section

α_c-0.85

A_c-area of concrete

f_{ckcy}-compressive strength of cylinder

A_s-area of reinforcing steel

f_{sk}-yield strength of reinforcing steel

Υ_a,Υ_c and Υ_s are partial safety factors

Figure -3 : Modification of I-Steel Section

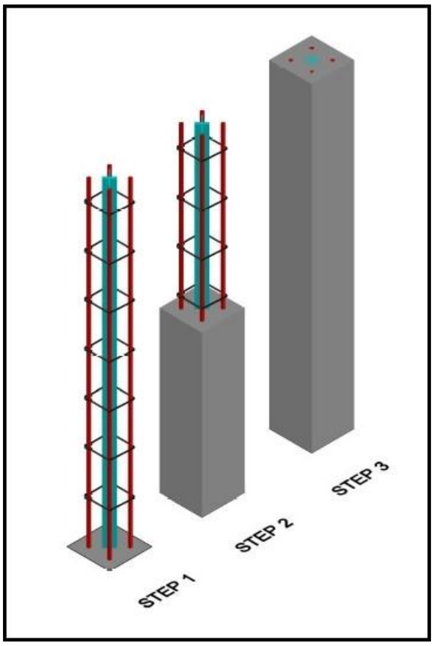

Figure -4 : Construction steps of C2 column

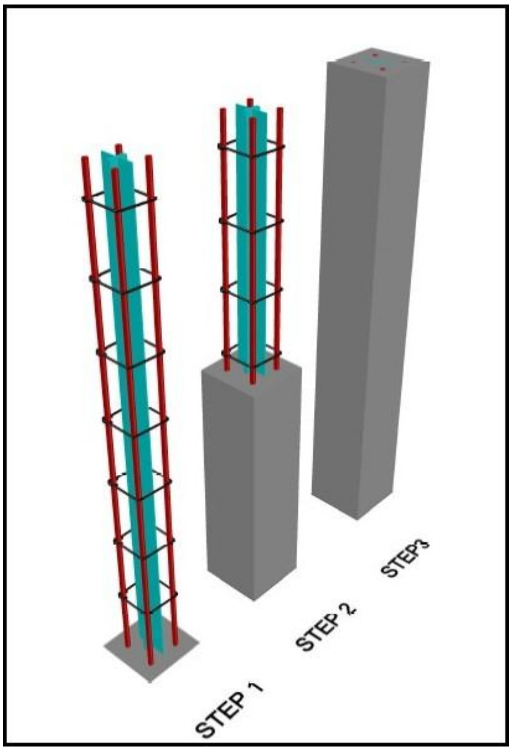

Figure -5 : Construction steps of C3 column

3. ANALYTICAL STUDY

3.1 Finite Element Analysis

Finite element software is used to analyze the concrete encased steel section. Beams and columns were modeled in ANSYS workbench based on the cross sectional details provided in the specimen description and the details given in table 1.

Out of various analysis systems in the ANSYS workbench, static structural is used to model the section, meshing of the sections in to finite elements, solving and reviewing results. Material properties are given in the material table available in the ANSYS workbench and it is assigned to concrete encased steel members. The same material properties given in the table 2 were adopted.

3.2 Modeling of Composite Column In Finite Element Software

The modeled composite column is given in fig.4 and fig.5 respectively. The columns is axial load is given fig.8 and their corresponding deformations, equivalent stress and strain were observed. The column members were discretized and analysis was performed till the failure of the members.

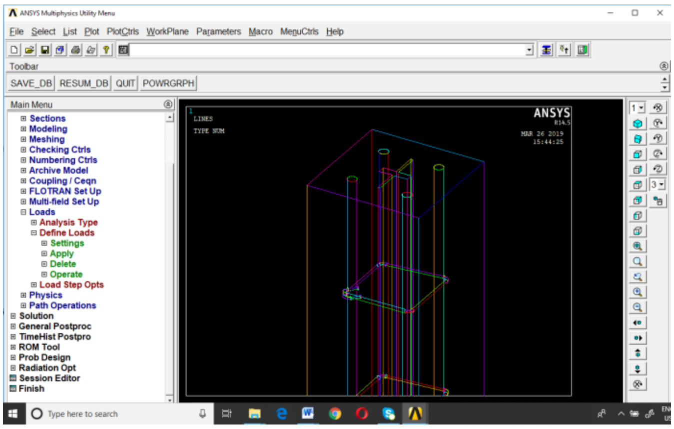

Figure -6 : Ansys workbench analysis 1

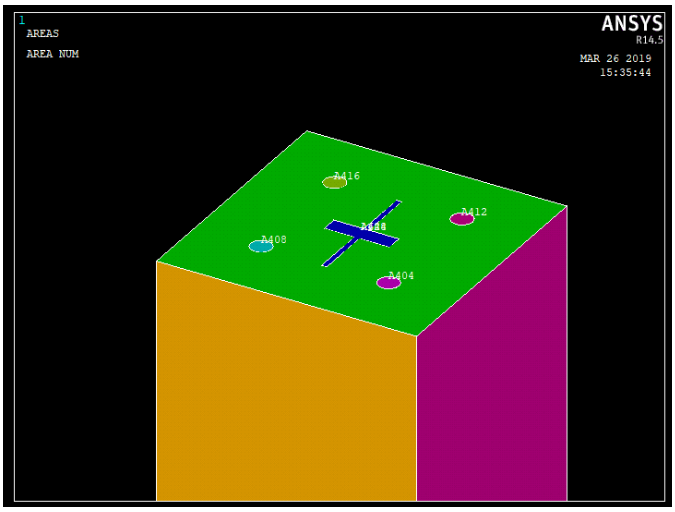

Figure -7 : Ansys workbench analysis 2

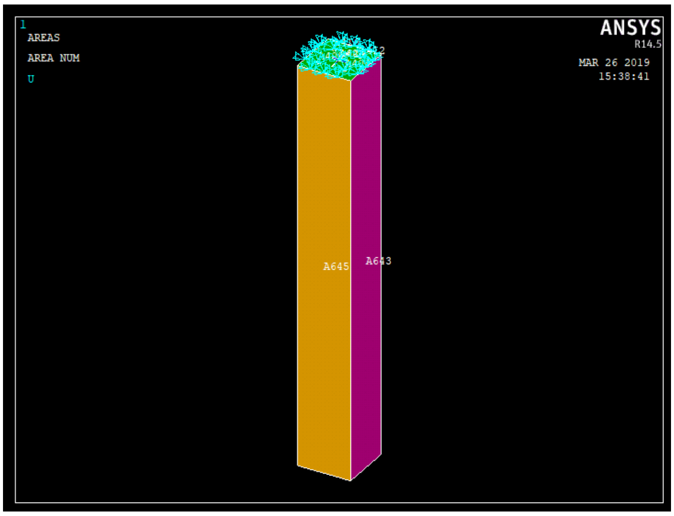

Figure -8 : Ansys workbench analysis 3

4. EXPERIMENTAL INVESTIGATION

4.1 Details of Experimental Program

The specimens were cast according to the categories provided in the table 1.Three specimens are cast in each category in order to obtain accurate results.

4.2 Test Setup and Instrumentation

The loading setup for testing the specimen is shown in figure 6 and 7 the axial load is applied to the column using 100t universal testing machine. Load cell and transducer where connected to the computer via data logger which records the data's during the application of load and the data was recorded for every second during the loading period.

Figure -9 : Test Setup

4.3 Test Procedure

The specimens are progressively loaded till the failure. The crack pattern exhibited by the specimen upon the loading is observed and crack load is identified. The displacement transducer connected to the data logger measures the axial shortening of the column corresponding to its load.

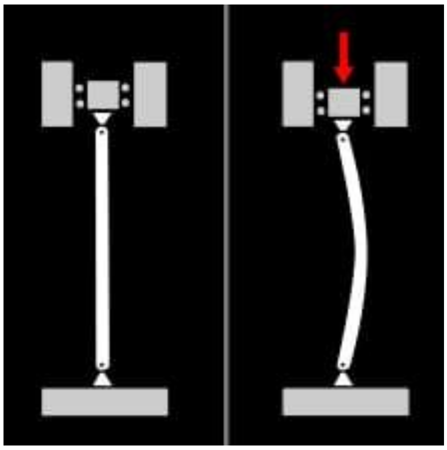

Figure -10 : Load Transfer in column

5. RESULTS AND DISCUSSIONS

5.1 Failure Modes

At low loading level all the specimen exhibited similar cracking behaviour. The column specimens showed the crushing of the concrete, when the load is increased progressively. Initially cracks appeared at the top face of the column upon further increase of load the encased concrete began to crush at the top face and spalled off. The crack load of C1 is easily obtained minimum load. The C2 and C3 column cracks are obtained maximum load condition. The C2 column specimen crack is started to give maximum load condition compared with the C1 and C3 column specimens. The first crack load of C1,C2 and C3 specimens are 252KN,462KN and 450KN respectively and the specimen fails at the load of 480KN,920KN and 883KN respectively figure 11 shows the cracks in C1,C2 and C3.

Table -3 : Failure Modes

S.No	Specimen	Initial Crack Load (kN)	Failure Load Crack (kN)
1.	C1	252	480
2.	C2	462	920
3.	C3	450	883

In analytical study, the analysis performed till the failure of the specimens. Typical failure modes of the columns specimens from the analytical results are shown in figure 13 respectively.Which shows same behaviour that was exhibited in the experimental study.

Figure – 11 : Cracks in Specimen

5.2 Load – Axial Shortening Behaviour

From figure 12, it is observed that the load carrying capacity of the C2 is 61.2% high when compared with C1 due to the composite action between the concrete and the steel section. The effect of change in steel section orientation the load carrying capacity of concrete encased steel column c2 by 8% then c3 and the axial shortening is reduced by 12%, which is depicted from the figure 13.

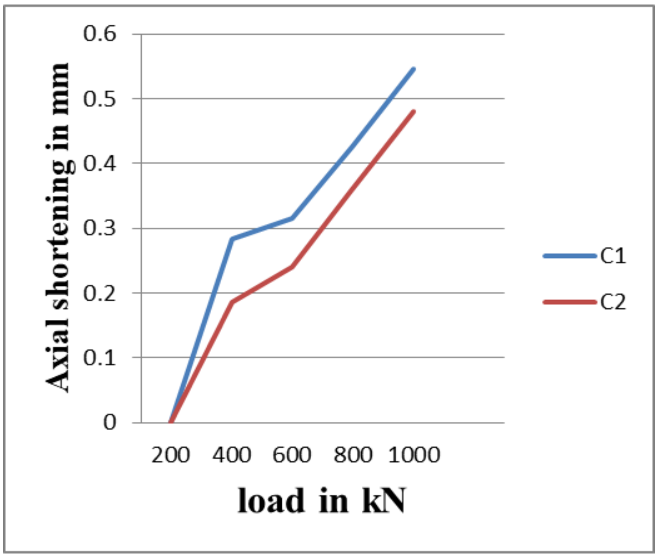

Figure -12 : Comparison between C1 and C2 Columns

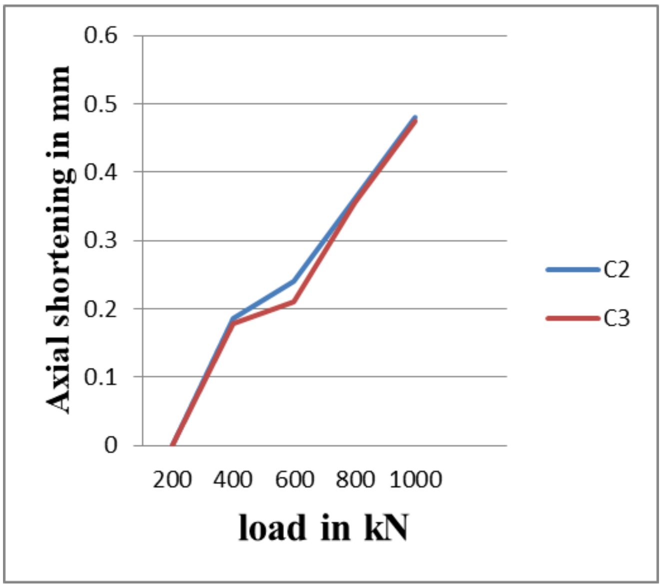

Figure -13 : Comparison between C2 and C3 Column

6. CONCLUSION

The study on the concrete encased steel composite column gives better understanding of the structural behaviour of composite column. From this study the following conclusions were made,

1) Theoretical work and analytical work is carried out in addition to the experimental work to correlate the results. Analytical work is done using the finite element software.

2) The load taken by the concrete encased steel section C2 is found to be 61.2% higher when compared with C1.

3) Specimen C2 is exhibits 8% increased load carrying capacity than C3.

4) The steel section orientation to be changed in the column specimen and gave better result from the structural behaviour analysis.

5) Due to higher load carrying capacity and stiffness, the concrete encased steel composite members can be suitable for extreme loading condition.

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