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# Numerical Investigation of Fully Encased Composite Columns

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**ABSTRACT:** Composite columns encased with core steel sections can be utilized as a structural member to enhance the strength performance of a structure effectively. A steel- concrete composite column encased with conventionally rolled steel section has been researched to convey that the composite columns exhibit larger amount of strength as compared to the reinforced concrete columns. Parallel flange steel sections, which are widely preferred over conventional taper flange sections in India, are used to replace the Indian standard medium beam section in composite columns within this study. A comparison is made between the columns by performing the finite element analysis of the short column sections in Abaqus simulia. It was found that the composite columns that are reinforced with structural parallel flange steel section have exhibited a larger strength when compared against the composite column encased with standard medium beam section. As the column cross section and the percentage of steel sectional encasement is increased, a growth in the load carrying capacity of column is observed.

**KEYWORDS:** Finite element analysis, composite, parallel flange, conventional, Abaqus.

## I. INTRODUCTION

Hot rolled sections have a very important place and wide application in the sphere of structural engineering. With time, structural engineering has undergone a tremendous development around the world and leading international industrial organizations have adapted to the latest technologies in their effort to provide ever increasing efficiency and optimization in construction. In recent times, these trends have also been started to be practiced in India. Indian standard beams that are traditionally manufactured have a reduced flange thickness at the edges. This symmetry differs from the symmetry of steel sections that are produced internationally, which have parallel flanges, commonly known as H beams. The parallel flange beam sections have much better sectional properties which perform better and have better applications. These parallel flange sections are widely preferred by today's structural engineers, architects, and construction companies. Parallel flange sections are hot rolled steel sections with parallel or nearly parallel flange with square toes and curves at the root of flange and web. These PF sections are divided in 3 categories as per IS: 12778-2004. They are Narrow parallel Flange sections (NPB), Wide Parallel Flange Sections (WPB) and Bearing Pile Sections. Some advantages offered by parallel flange sections are; possibility of broad range of properties having the same depth of beams that permits selection of the most optimum flange width and thickness as well as web depth and thickness. Higher Flexibility in availability of sections, PF sections are available in a wide range of categories like NPB's, WPB's, UC and UB sections. PF sections are also available in various weights, i.e. light weight, standard weight and heavy weight. So the structural designer has a wider range of sections available to perform an efficient and economical design of columns. Also wider range in parallel flange sections reduces the use of built-up sections thereby reducing the fabrication work and increase the speed of construction.

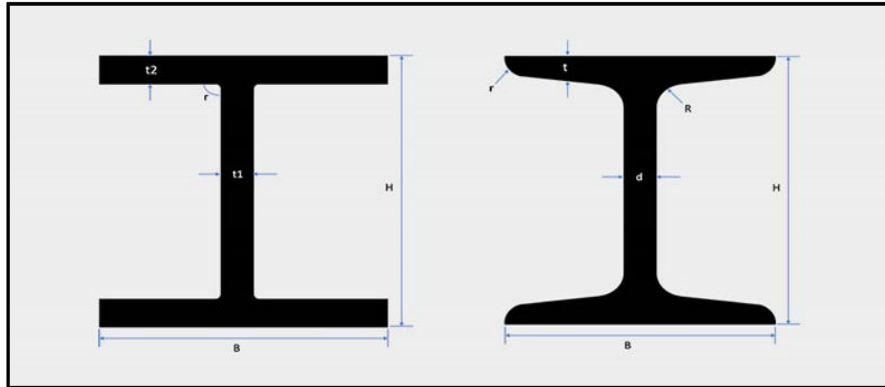


Figure 1: Parallel Flange Beam and Conventional I Beam

A steel- concrete composite section is one that includes a structural steel element casted or connected along with concrete. Usually steel-concrete composite sections are achieved by means of connections or partially or fully encasing the steel sections in concrete. The major advantage of composite member is that the properties of each material can be combined to form a single unit that performs better than that if used independently. In buildings, composite construction is achieved by incorporating composite beams, composite columns and composite slabs. Composite columns have high strength even with a relatively smaller cross-sectional area which means that more floor space area can be achieved with consideration of size and aesthetical appearance of columns. The basic concept of composite structures lies in the fact that the concrete is stronger in compression than steel and steel is stronger in tension. By application of this composite action, the advantages of both materials can be utilized to the fullest.

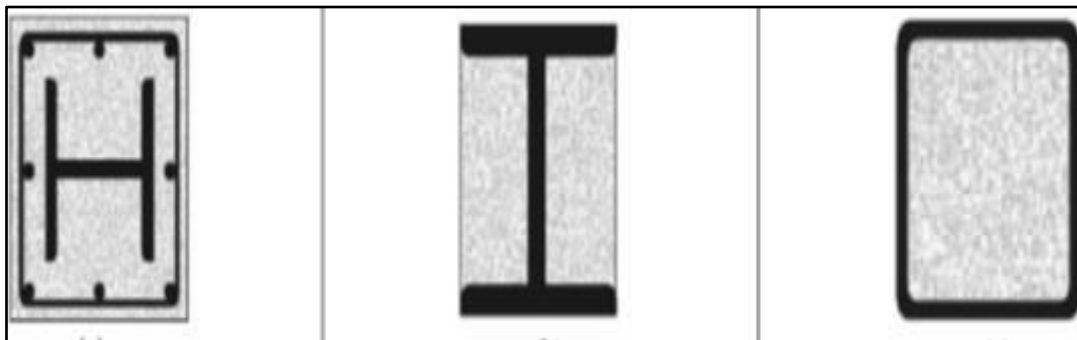


Figure 2: Composite Column Sections

**Aim of the study:** Finite element analysis of fully encased composite columns in Abaqus software to determine the ultimate load and deformation of columns encased with parallel flange steel sections.

**Objectives:** 1. To perform finite element analysis of composite columns.

2. To compare load vs. deformation of composite column encased with parallel flange section and medium beam section.

## II. LITERATURE SURVEY

A review of the on-going trends for steel- concrete composite constructions in India was conducted by **D. Datta**[1]. The use of Steel-Concrete composite construction methodologies will help the engineers and developers to make more profit and the users could also get more carpet area and durable structure at their affordable price. A steel intensive construction is fully recyclable and is beneficial in environmental aspect and such construction also offers a sustainable development with minimum consumption of energy, minimising of the waste and utilization of the renewable resources etc. which is achievable through steel concrete composite construction.

**N.E. Shanmugam & B. Lakshmi** [2] reviewed the work done on composite columns. A review of previously published investigations regarding various parameters of both encased and in-filled columns is presented. All the experimental



data has been collected and compiled in a comprehensive format, listing the parameters involved in the study. A summary of considerable progress made in the research work related to steel- concrete composite columns is published. An exercise is carried out by **Kulkarni Swati Ajay &VesmawalaGaurang R [3]** to study suitability of PF steel (Indian Profile- NPB and WPB) for use in seismic steel moment resisting frames. Higher numbers of beam sections are available; however limited number of column- WPB sections is available for SMF. Slenderness checks applied to these sections show that slenderness limits are satisfied for use as column members.

Experimental and numerical investigations of the behaviour of concrete encased steel composite columns subjected to short-term axial load are reported by **Md. SoeburRahman et.al. [4]**. The FE model was validated against the experimental results obtained from the tests conducted and also the results published by previous researchers. It was observed that the ABAQUS model was able to predict the experimental behaviour of FEC columns under concentric gravity loads with good accuracy in relation with the experimental results.

Finite element models of the beam are established in the Ansys software by **PalaniveluSangeetha et.al. [5]** To simulate the flexural behaviour of the beams under two point loads. The results obtained through the study show that the beams connected with channel type of shear connectors perform better than the beams with stud connectors. The beam that is connected with two numbers of connectors results in additional deflection due to slippage in the connectors as compared to the beams with four numbers of connectors. The analytical model turns out to be stiffer than experimental model due to the rigid connectors between studs and concrete, hence exhibit better results.

Behaviour of composite columns and reinforced concrete columns is determined by the Finite Element Analysis in the Abaqus software **ThungaKarthik& T. Venkat Das [6]**. FEC columns of cross section 230x230 mm and length 1000 mm are modelled and analysed. Abaqus results were almost in correspondence with practical test results. The composite column also exhibits lesser axial deformation under loading.

### III. METHODOLOGY

The Abaqus/CAE workspace consists of the major subsections: the viewport- the main screen where pre and post processing data is visualised, the model tree view- where all the modelling steps and sub steps are presented, the toolbar section- where each node of modal tree has a corresponding toolbar and finally, the prompt region- upon selecting to perform a certain function, tips and or command buttons appear on prompt region. Simulation of one of each FEC column from the specimens group is performed in the software to analyse the behaviour of column under concentrated axial load and to relate the numerical model with experimental model. Abaqus modelling procedure is executed through a group of commands gathered each in a number of modules; each module contains commands and tools that serve specific tasks in the modelling process. Three short FEC columns with specifications from each group described in table 1 (CWPF-Composite Wide Parallel Flange, CMB-Composite Medium Beam and CNPF-Composite Narrow Parallel Flange) are modelled and finite element simulation is performed.

Table1: Details of Column Models

Sr. No.	Column	Core Steel Section size (bxdxt <sub>f</sub> xt <sub>w</sub> )	Core Steel area (mm <sup>2</sup> )	Column Size (mm) (B x D x H)
1	CMB	50x100x7x4.7	1140	140x180x1000
2	CNPF	60x120x6x4	1150	140x180x1000
3	CWPF	100x100x6x4	1552	180x 180x1000

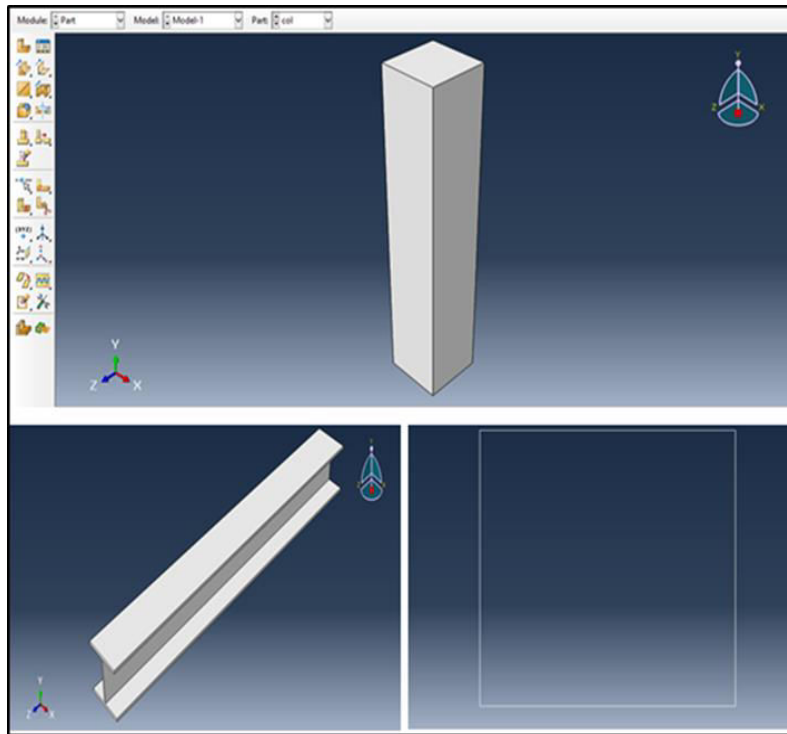


Figure 3: Part Module in Abaqus

Minimum requirement for the reinforcement is fulfilled by providing 4 numbers of 8 millimetre diameter of bars (area of steel provided is 201 millimetre square). For the shear strength requirement stirrups are provided in the form of 6 millimetre diameter links at a minimum spacing of 120 millimetres. Finite element simulation in Abaqus involves workflow divided in various modules. Sketches of elements are drawn in part module, properties of the materials are assigned in property module, all the elements are assembled in assembly module, analysis steps are defined in step module, interaction between steel and concrete is generated in interaction module, boundary condition and loading is defined in load module, elements are meshed in mesh module and results of the job are simulated in job module.

#### IV. RESULTS AND DISCUSSIONS

Numerical simulation is performed on the columns as detailed in table 1. The reinforcement properties are as assigned in below table 2. Concrete damage plasticity is generated to simulate a non- linear behaviour of the load versus deformation graph to be obtained. Results obtained for three of the columns are as mentioned in the table 3, based on the Abaqus load versus deformation output as shown in figure 4.

Table2: Properties of Materials

Properties of Concrete		Properties of Reinforcements		Properties of Steel Section	
Compressive Strength (Mpa)	Elastic Modulus (5000√fck) (Mpa)	Yield Strength (Mpa)	Elastic modulus (Mpa)	Yield Strength (Mpa)	Elastic modulus (Mpa)
34.51	29368	510	200000	250	200000

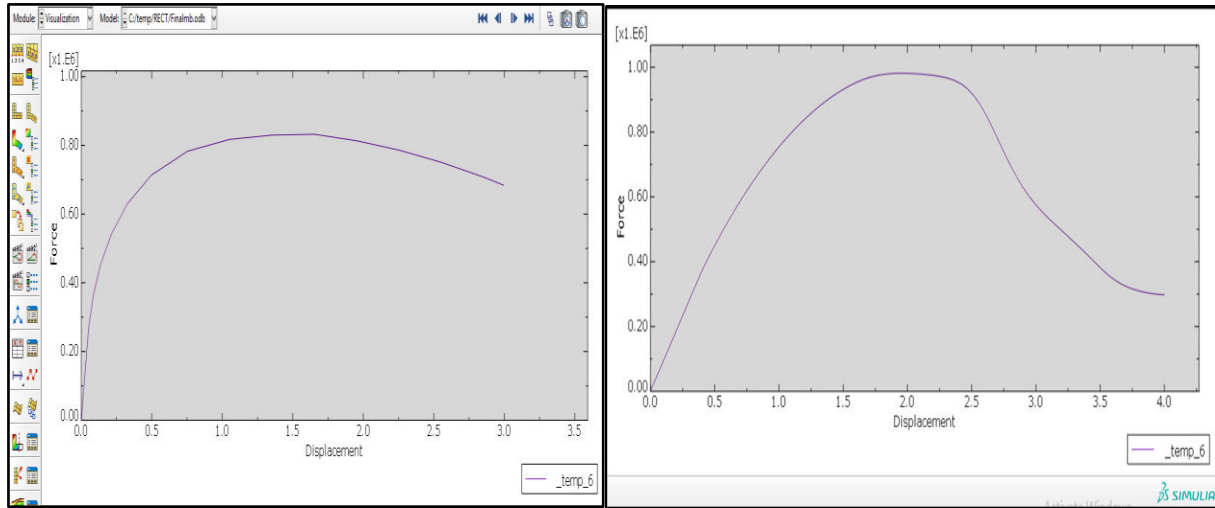


Figure 4: Load versus Deformation of Columns

Finite element analysis of CNPF and CMB columns is performed to determine ultimate load carrying capacity of the column and respective deformation for both columns. The deformation and failure behaviour of both columns is almost similar to each other. The numerical peak load of CNPF is obtained as 821.1 KN with a deformation of 1.59 millimetres whereas the CMB model carried a peak load of 817.14 kilo newton and deformation of 1.7 millimetres. Therefore, a percentage difference of 0.5% and 6% is observed in ultimate load and deformation values respectively.

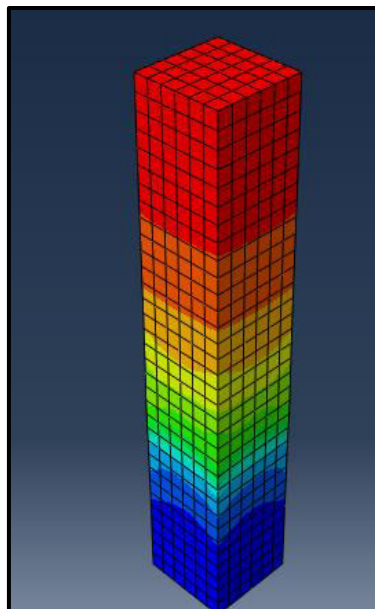


Figure 5: Result Visualization

Similarly, CWPF column is analysed. The values of loads and the relative displacement are plotted on a smooth graph for clear understanding. The maximum load required to cause failure of the column specimen is estimated as 981.5 kilo newton. Axial deformation of 1.98 millimetres for ultimate load value is obtained through analysis. Percentage increase of 19.5% in peak load of CWPF (Column cross section- 32400 mm<sup>2</sup>) as compared to CNPF (Column cross section- 25200 mm<sup>2</sup>) and 19.7% less deformation in CNPF column as compared to CWPF column is observed.

Table 3: Load and Deformation Results

Column Designation	Ultimate Load (KN)	Axial Deformation (mm)
CMB	817.14	1.7
CNPF	821.1	1.59
CWPF	981.5	1.98

## V. CONCLUSION

Composite columns encased with parallel flange steel sections exhibit better strength properties as compared with conventional medium beam steel sections. Failure behaviour of both columns encased with narrow parallel flange and conventional medium beam is similar in nature. Yet, a percentage increment of 0.5% in peak load and 6% less deformation in composite narrow parallel flange column (CNPF) as compared to composite medium beam column (CMB). A percentage increment of 19.5% and 19.7% in peak load and axial deformation respectively, of composite wide parallel flange column (CWPF) columns with 28% higher cross sectional area as compared to composite narrow parallel flange column (CNPF) is observed.

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