Experimental and numerical studies of axial compressive behaviour of slender I-section column

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Abstract - *This paper represents the behaviour of slender I-Section as a column under axial loading. Experimental work has been done to derive load Vs displacement, stress and strain behaviour of the column. Abaqus Finite Element software is used to validate the post behaviour and plastic properties of the I-Section. The section is designed as per Indian standard code and tested for its load carrying capacity. The experimental values are validated using the numerical analysis. Both linear and non-linear analysis of the Finite Element model is performed. The experimental results provides good representation of the axial deformation at the peak load, post behaviour and failure mode are observed in this test. The finite element model is also able to predict the experimental results.*

Key Words: I-section, axial compression, numerical analysis, Abaqus

1. INTRODUCTION

The contribution of steel in the building is very important one. The favorable properties of steel are its high tensile strength and ductility. Nowadays, I-Sections are widely used in composite constructions. In addition to, the several advantages of composite column, it also offers simplified beam column joint as well as reduced or no shuttering. Thus, resulting in more cost-effective construction. There are different types of composite columns such as encased column and in-filled column. Fully and partially encase composite column are the different types of encased column. In this method, special type of shear connectors, studs and stirrups are used to increase the bond and anchorage between the I-Section and concrete. In this paper, I-Section was fully studied with the different types of analysis such as buckling behavior, strength characteristics and Numerical studies. Normally, composite construction is used in tall buildings, heave load carrying structures, power plant structures etc.

The structural elements of these types of structures require adequate structural capacity and transmission of load. These members may fail due to over loading or stress and inadequate section. In the member columns may fail easily due to its slender nature. In order to avoid buckling, large size columns are used. But it is uneconomical and not aesthetic in nature. To solve this problem, composite columns is one of the solutions. The concrete and steel are combined in such a fashion that the advantages of both the materials are utilized effectively in composite column. In composite column both steel and column can resist the external loading by mutual interaction between them by bond and anchorage. There is no requirement to provide additional reinforcing steel for composite concrete filled tubular sections. Use of high strength concrete in columns can significantly reduce the size of the column and consequently reduce the dead load on the foundation system. To enhance the property of concrete used fibers are been impregnated. Numerous researches have been undergone around the world to investigate the behavior and strength of composite column. In composite construction, the bare steel sections support the initial construction loads, including the weight of structure during construction.

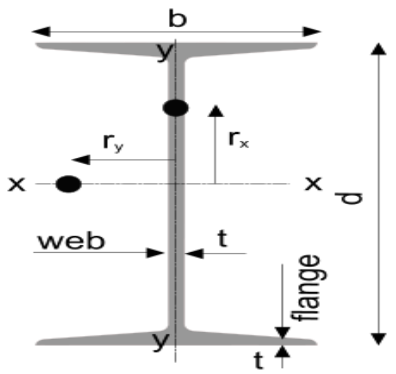

Figure-1 I-section column (ISMB 125 X 75)

2. OBJECTIVE AND SCOPES

The main objective of this thesis is to study the buckling behavior and strength characteristics of slender I-Section as a column. The characteristic of steel I-Section is experimentally studied. The Finite Element model created can be further used for numerical analysis of similar I-Section. Linear elastic material behavior is assumed for steel.

3. STEEL -I – SECTION BACKGROUND

ISMB 125 X 75 mm size slender I –section was used for this study.t_f =7.6 mm, t_w =4.4mm,the grade of steel f_y =250 mpa. In accordance with IS-800, 2007.The basic strength of I-section is 380 kN to 420 kN (Nominal yield stress).The Length of the column is 800 mm(average of three). r_{xx} =5.20 cm ,r_{yy} =1.62cm.

$r_{yy} < r_{xx}$, so the column will buckle about y-y axis.

$h/b_f = 1.67>1.2$

t_f =7.6 mm <40 mm

buckling curve for x-x axis is " a " ; buckling curve for y-y axis is " b "

Table-1: Dimension and area of I-section

Specimen label	Dimension Of The Specimen (mm)	Area of steel (mm^2)
I – section	125 X 75 X 7.6	1660

To obtain the basic properties of the steel section, the test was conducted in the UTM. Geometrical properties of the steel section are given by

Table-2 : Geometric properties of the I-section

Yield stress	Ultimate stress (fu) mpa	h/b_f	Fu/fy
250	480	1.67 > 1.2	2.08

The theoretical calculation is made to select the size of the specimen. Indian standard code IS -800 and steel tables are used for the calculation and design the Section.

$$f_{cd} = f_y /y_{mo} /\varphi+(\varphi^2 +\lambda^2)^2 \quad \leq fy/ y_{mo}$$

This formula was taken from I.S – 800, Page No.34 cl.7.1.2.1

$$\Phi= 0.5\ (1+ \alpha(\lambda-0.2)+\lambda^2)$$

$$\lambda=\sqrt{(fy(k_l /r)^2 /\prod 2E)} \quad ; \quad P_d = A_e Fcd$$

This formula was consider for both X-X and Y-Y axis. The main purpose of design the section is to know about the buckling behavior and load carrying capacity of the section , then only it will adopt or not for the testing capacity (UTM -1000 kN). Design compressive stress in Y-Y axis =390 KN; design compressive stress in X-X axis =442 KN.

4. EXPERIMENTAL PROGRAMME

In order to study the behavior of I-section column under axial compression, three specimens with various length 700 mm, 800mm, 900mm were fabricated from flame cut ISMB 125X75 steel section. The test were performed with a 1000 KN universal testing which provided essentially fixed end condition to the bottom and the top was free end. Specimens end plates provide a uniform load distribution over the column cross section. Prior to testing the alignment of the column was checked up to 20% of the predicted ultimate load, using the monitor values. The Stub column was generally loaded at the rate of 120 kN/min. Near and after failure, the load was manually controlled to allow visual observation and capture post peak behavior, the experimental load (Pu_{exp}) for the steel column are presented in Table -1.The specimen was applied to the section up to failure mode. The different stage of failure has noted in the graph.

Figure-3 Testing of axial compression of I-section column

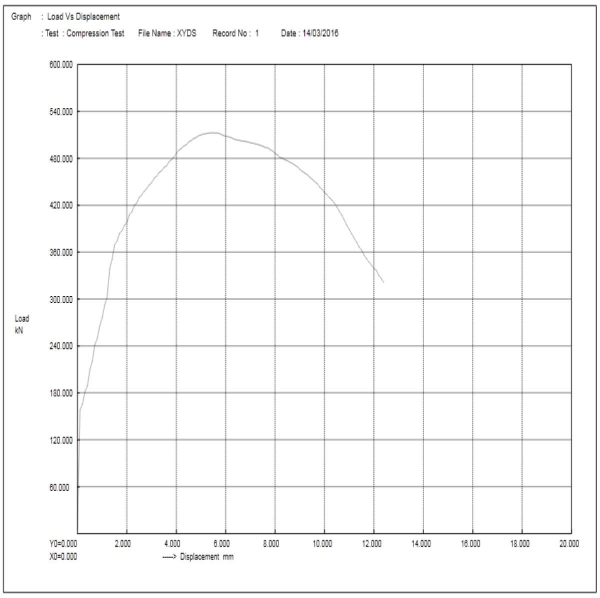

Figure-4 Experimental results of load Vs displacement

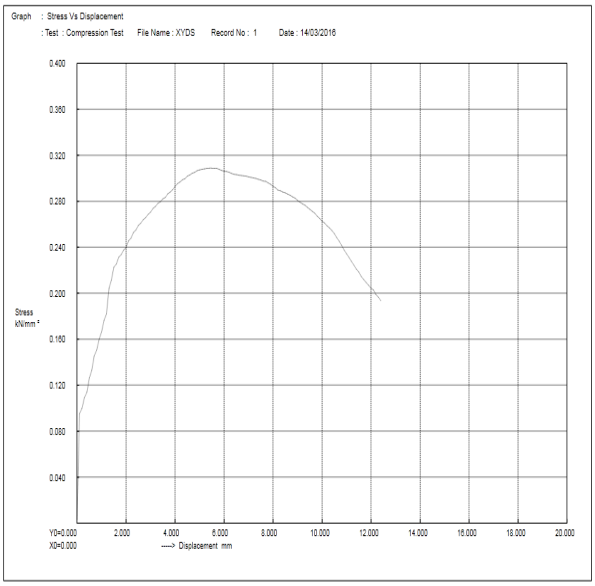

Figure-5 Experimental results of stress Vs strain

Table-3 : Experimental results of axial compressive test on I-section

Load (kN)	Displacement (mm)	Stress kN/mm^2	Strain	Reference
60	0.023	0.04	4.55 E-05	
120	0.07	0.08	9.09 E-05	
168	0.09	0.1	1.35 E-04	Elastic limit
180	0.27	0.11	5.50 E-04	
240	0.675	0.145	9.16 E-04	
300	1.17	0.18	1.36 E-03	
360	1.44	0.22	2.01 E-03	
376	1.53	0.235	2.28 E-03	
420	2.25	0.253	3.14 E-03	
480	3.87	0.3	6.02 E-03	
522.67	5.4	0.33	6.82 E-03	ultimate load
480	8.28	0.289	9.62 E-03	
420	10.35	0.253	1.25 E-02	
360	11.43	0.22	1.51 E-02	
326.65	12.24	0.196	1.54 E-02	failure load

The experimental values are validated with theoretical calculation and finite element software (Abaqus). In theoretical calculation stress and strain values are found by the following formulae
Stress = P/A in kN/mm^2
Strain = stress / E
E- young's modulus

The strain values from theoretical are uniformly varying and linear up to failure load. But in case of experimental results strain are varying ununiformly and nonlinear in near and after the ultimate load. In experimental results the strain values are linearly increasing up to the failure load but in theoretical calculation strain values are decreasing about failure load.

Table 4 : Results from theoretical calculation

Load (kN)	stress	strain	Reference
60	0.04	2.00E-04	
120	0.08	4.00E-04	
168	0.1	5.00E-04	Elastic limit
180	0.11	5.50E-04	
240	0.145	7.25E-04	
300	0.18	9.00E-04	
360	0.22	1.10E-04	
376	0.235	1.15E-03	
420	0.253	1.27E-03	
480	0.3	1.50E-03	
522.67	0.33	1.60E-03	ultimate load
480	0.289	1.45E-03	
420	0.253	1.27E-03	
360	0.22	1.10E-03	
326.65	0.196	9.80E-03	failure load

Figure-6 Deformed shape of I-Section

5. NUMERICAL APPLICATION

ABAQUS Finite element software was used to validate the experimental results and the post behavior and plastic properties of the I-Section. Both linear and non-linear analysis of the Finite Element model is performed. The steel used in this study was modeled with "Standard & Explicit model". Base Feature is solid (shape), Extrusion (type).The given type of element is Deformable and Modeling Space is 3D .The material is assumed as linear Elastic up to yield and solid, homogeneous. The concentrated load was applied and time period 1.the load increment is Automatic. The maximum number of increment is 100.The equation solver is direct method, the salvation technique is full – Newton. the fixed support was given in the bottom encasted ($u_1 = u_2 = u_3 = u_{r1} = u_{r2} = u_{r3}$).The both Elastic and Plastic model in ABAQUS was used to simulate the steel materiel in the composite beam. Elements which have all capabilities and properties needed to accurately predict the behavior of all grades of steel (Fe 250, 415, 500). The experimental results provides good representation of the axial deformation at the peak load, post behavior and failure mode are observed in this test. The finite element model is also able to predict the experimental results. Finite-element model that can be applied for a variety of geometries of PEC columns subjected to various loading conditions and provide accurate simulations of behavior without numerical difficulties well into the post peak regime. The model therefore is to be capable of simulating numerically the full behavioral history including the peak and residual post peak capacities and the failure mode caused by local buckling of the steel plates.

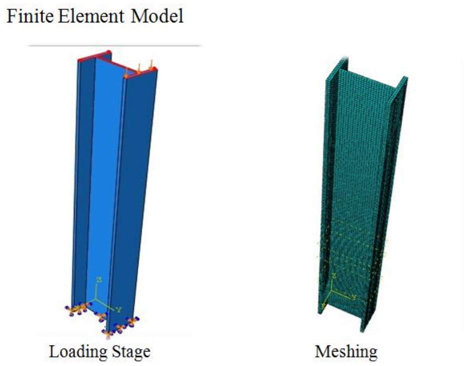

Figure-7 Finite element model of the I-section

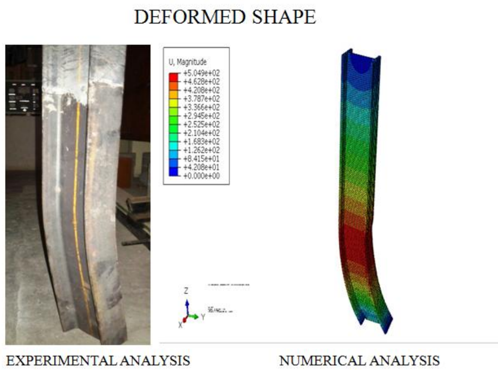

Figure-8 Deformed shape of the I-section after experimental and numerical analysis

VALIDATION

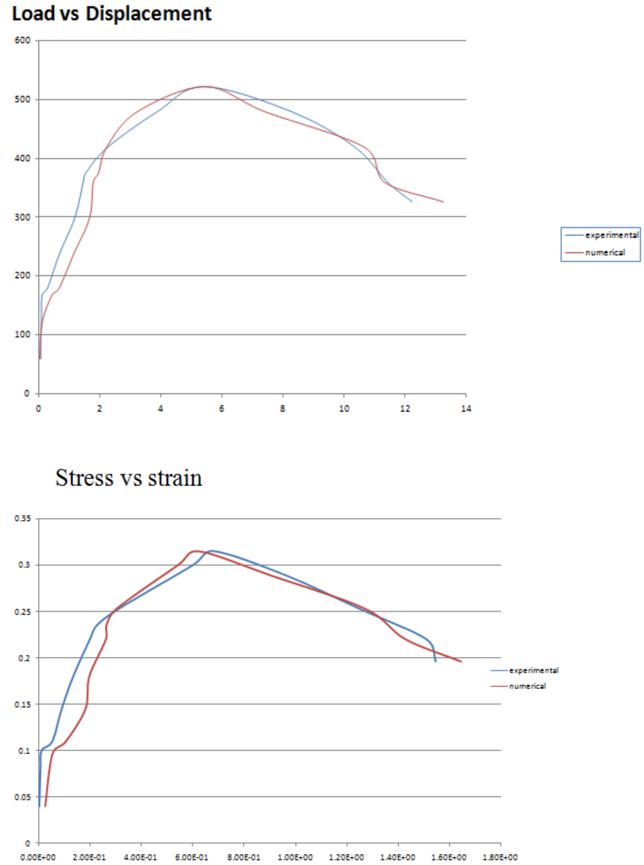

Figure-9 Validation of experimental results with numerical analysis

The above figure shows the numerically and experimentally obtained loads plotted against displacement and stress against strain. The numerical analysis results of the steel model are found to be in good agreement with the experimental results in the pre-peak zone. However near and after the ultimate load, the strains and displacement from this model are found to be higher than those obtained experimentally .Near the peak load some fluctuations are observed in the numerical and experimental response. This is mainly due to the local buckling .The failure of the specimen observed in the numerical analysis is due to initiation of the local instability of flange and local buckling similar behavior is observed in the experimental results.

6. CONCLUSIONS

[1] Elastic and Plastic buckling Behaviour of Steel I-Section column was studied both experimentally and numerically through finite element modeling.
[2] The comparison values between the experimental test and the Abaqus were in good agreement. It can be concluded that the compressive behavior of proposed steel I-section can be predicted from the FEM technique.
[3] Finite Element model that can be applied for a variety of Geometries of I-Section column of varies loading condition and it provides accurate simulation of behavior without numerical difficulties well into the post peak regime.
[4] The failure of the column is due to buckling causing a progressive reduction of the column strength (523.3 KN).the column has fixed at bottom and free at top. But in numerical analysis it was studied in different end condition.
[5] From the study of separate steel I-Section ,we can ensure the how mush composite action when I-Section used as composite column and failure pattern.
[6] The buckling behavior of steel column I-Section is not only depends upon the length (or) Slenderness ratio also geometry of the section and the direction of loading.

7. REFERENCES

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