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Structural Investigation on Buckling Behaviour of Double Web Tapered Steel Columns

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***Abstract*— This paper deals with the Buckling Behavior of double web tapered steel columns. Two shapes are provided (ie, L shape and V shape) in I section. All the column sections are of constant weight. The column is axially loaded. This paper is done in order to find the column of best taper ratio with maximum load carrying capacity. Hollow flange double web tapered steel column is analysed using best taper ratio.The buckling behavior is studied by developing finite element model using the ANSYS 16.1**

Keywords—Tapered column; double web tapered column; hollow flange; axial loading; non prismatic column

I. INTRODUCTION

Non-prismatic columns are structural members which are important in many engineering applications. Main reasons in the increase for their use compared to that of prismatic columns are less use of materials, increased load capacity functional requirements, and increased aesthetic appearance etc. Buckling is the form of deformation as a result of axial compression forces. This results in bending due to the instability of column. This failure mode is quick and hence dangerous. So it is very important to perform buckling analysis in this type of columns in order to determine critical buckling load. Buckling occur due to the column length, support conditions and cross-sectional area. Main advantages of this type of columns are due to their structural efficiency, provides more stability and rigidity to the buildings. Tapered columns are used in post towers, telephone towers, steel frames such as warehouses, exhibition halls, etc. Nowadays it is used as diagonal members in buildings.

Tapered columns are non-uniform sections with more width at one end and tapered at the other end. The tapering is provided in two shapes, L shape and V shape. The shape of tapering provided has the effect in the stability of tapered steel column section. Many practical applications of steel members do not exploit the capacity of their cross-section along the length. In fact, in almost of all applications, the design internal forces are not constant and assuming constant properties along the length (i.e. constant cross-section) is often not the optimal structural arrangement, especially for structures with large spans. An efficient solution is to change the dimensions of member along its length by adjusting them to the requirement for cross-section resistance. The most efficient application are columns with stepped section, more aesthetical applications are tapered members, either with varying depth and/or flange widths.

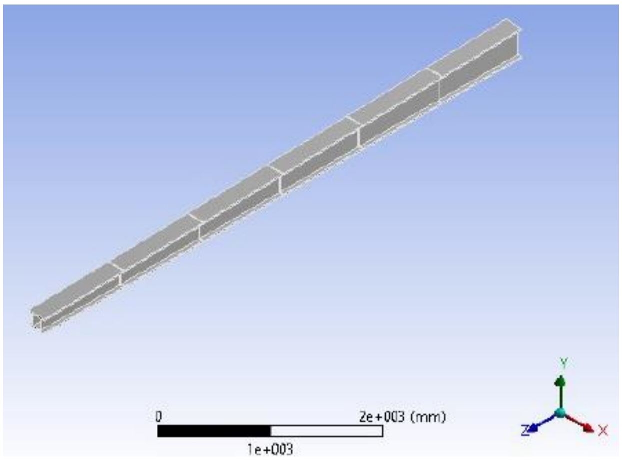

Fig. 1. Isometric view of L shaped I section steel column

II. SCOPE AND OBJECTIVES OF THE STUDY

Web tapered I section steel columns have become very common in building construction. Tapered members are a type of reduced sections. Tapered columns are most commonly used in telephone towers, post towers, steel frames such as warehouses, exhibition halls, industrial buildings etc. Now a days it is used in buildings as diagonal members. The load considered in all the journals were axial loads, no eccentric load was considered. The effect of double web tapered columns are considered in this study. The study on the effect of hollow flange effect in beams, girders etc. were already done, but hollow flange effect in column is not considered yet. The main objectives of the study are:-

- To investigate the effect of different taper ratios in double web non-prismatic column.
- To investigate non-prismatic column with Hollow Flange effect with best taper ratio.
- To investigate the hollow flange effect of non-prismatic column with different d/t ratios.

III. FINITE ELEMENT MODELLING OF DOUBLE WEB TAPERED STEEL COLUMN SECTIONS WITH DIFFERENT TAPER RATIOS

A. Geometry

Three dimensional models were developed to demonstrate the behavior properly. The three sections are double web tapered with different taper ratios in two different shapes were used. For L shaped column, different inclination of flange with respect to the centroidal axis and for V shaped column, equal inclination of flange is provided with respect to the centroidal axis. The different taper ratios chosen are ratios 2, 3 and 4. Taper ratio 2 and the material properties are fixed with

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reference to Trayana Tankova. The other ratios are fixed by adjusting the h_{max} and h_{min} of the column by keeping the weight constant for all the tapered column sections. The length of the column is taken as 6m. Lateral supports are provided along the length of the column with 1m spacing. Lateral supports are provided to prevent sideways buckling. The loading and support conditions provided are same for all the column sections.

Table 1: Cross sectional details of double web tapered column

Taper ratio	MaximumHeight h_{max}	Minimum Height h_{min}	Width $b_{top,bot}$	Thickness of web t_w	Thickness of flange $t_{f,top}$ & $t_{f,bot}$
	(mm)	(mm)	(mm)	(mm)	(mm)
2	320	160	100	10	16
3	360	120	100	10	16
4	384	96	100	10	16

B. *Material Properties*

The material properties used for the steel section of all the models are given in Table 2.

Table 2: Material property of steel column section

MATERIAL PROPERTY	VALUE
Density	7860 kg/m^3
Young's Modulus	$2x10^5$MPa
Poisson's Ratio	0.3
Yield Strength	355 MPa

Using ANSYS Workbench 16.1 double web tapered sectional steel column with different taper ratios are modelled. The material properties are assigned and the loading and support conditions are provided. All the columns are simply supported with pinned connections. Lateral restraints are provided along the length of the column with 1m spacing. The type of loading provided is axial loading. I section columns are modelled with same material properties, loading and support conditions. For column section, six models are created. Three models are L shaped double web tapered column with taper ratios 2, 3 and 4 and the other three models are V shaped double web tapered column with taper ratios 2, 3 and 4. The isometric view, finite element modelling and boundary conditions provided for the tapered column section are shown in Fig.2.

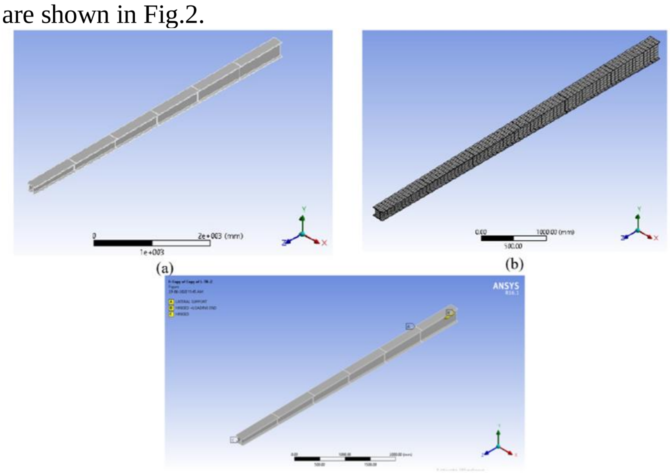


Fig 2: (a) Isometric view (b) Finite element modelling (c) Boundary conditions of tapered column sections

C. *Results and Discussion*

After analyzing all the models, the results are obtained and are summarized as follows. Fig.3. shows the total deformation of the double web tapered column section. The load deformation curve of different column sections are shown in Fig.4.

- By comparing the models of all the sections with different ratio, maximum load carrying capacity is obtained by tapered column with taper ratio 2.
- The deflection of V shaped column is more than that in L shaped column; (ie, the stiffness in L section is more).

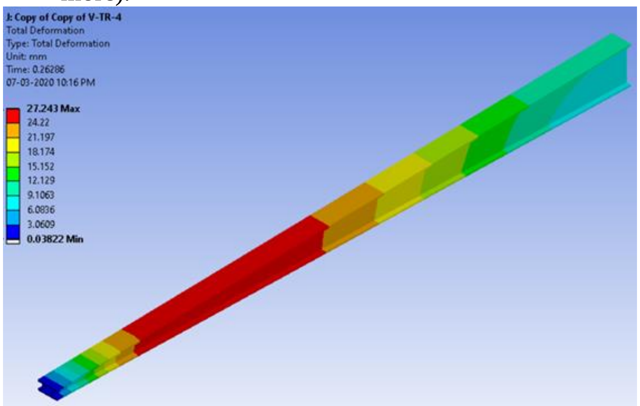


Fig 3: Total Deformation

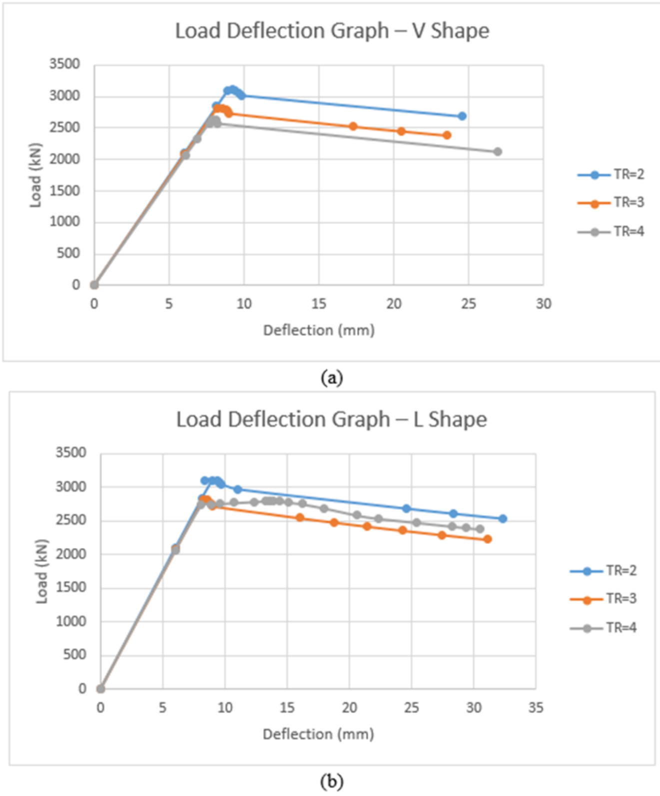


Fig 4: Load –Deformation Curve of Different Tapered Column Sections

IV. FINITE ELEMENT MODELLING OF DOUBLE WEB TAPERED STEEL WITH HOLLOW FLANGE COLUMN SECTIONS

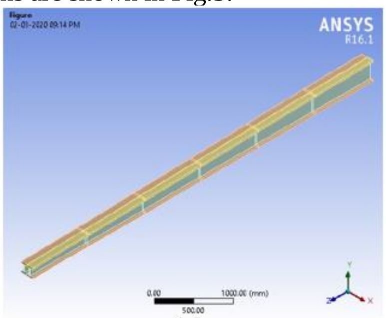
From the above analysis of double web tapered steel column section, column having maximum load carrying capacity is chosen as the best column and the corresponding taper ratio is noted. With the best two taper ratio chosen, double web tapered column with hollow flange is modelled and analyzed for I section. The column is modelled for both L shape and V shape.

A. Geometry and Material Properties

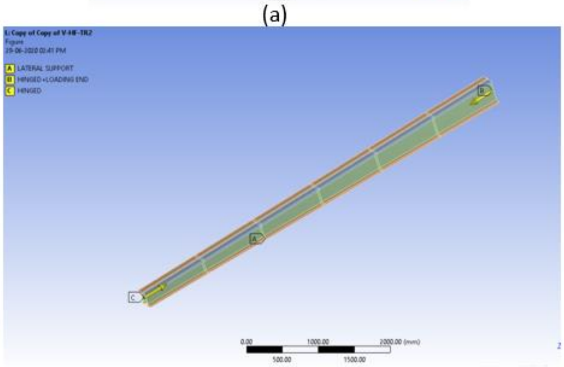
Double web tapered column with hollow flange is modelled with taper ratio 2 & 3 for I section. Dimensions and the material properties are same as the above double web tapered steel column section. The column is loaded axially at one end and is simply supported with pinned connection at its ends. The length of the column is taken as 6m.

B. Modelling and Analysis

Using ANSYS workbench 16.1 the column sections are modelled. The material properties are assigned and the support and the loading conditions are provided. For the finite element analysis bilinear isotropic hardening rule was used. Lateral restraints are provided along the column length in order to prevent it from sideways buckling. Isometric view and boundary conditions are shown in Fig.5.



(a)



(b)

Fig 5: Isometric view and Boundary Condition of Double tapered steel with hollow flange

C. Results and Discussion

Double web tapered steel column with hollow flange is modelled and analysed and the results are obtained as follows. Total deformation of the double web tapered steel column is shown in Fig.6.The load – deformation curve of double tapered steel column sections in Fig 7.

- Double web tapered column with hollow flange is modelled for taper ratio 2 and 3, V shaped and L shaped column has almost same maximum load carrying capacity.
- Introduction of hollow flange improved stiffness of the section.

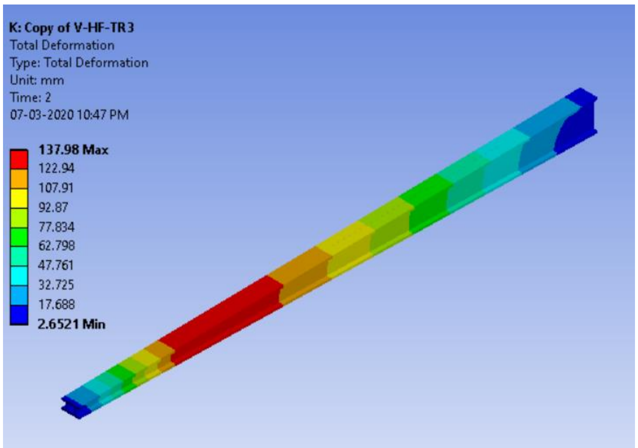
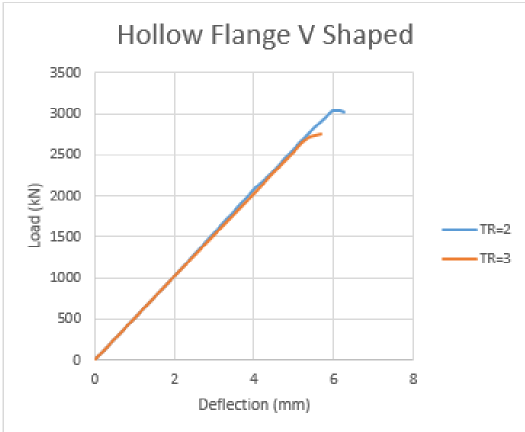


Fig 6: Total Deformation



(a)

(b)

Fig 7: Load –Deformation Curve of Different Tapered Column Sections with hollow flange

V. FINITE ELEMENT MODELLING OF DOUBLE WEB TAPERED STEEL WITH HOLLOW FLANGE COLUMN WITH DIFFERENT D/T RATIO

From the above analysis of double web tapered steel column section, column having maximum load carrying capacity is chosen as the best column and the corresponding taper ratio is noted. With the taper ratio chosen, double web tapered column with hollow flange with different D/T ratio is

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modelled and analyzed for I section. The column is modelled for both L shape and V shape.

A. Geometry and Material Properties

Double web tapered column with hollow flange with different D/T ratio is modelled with taper ratio 2 for I section. Dimensions and the material properties are same as the above double web tapered steel column section. The column is loaded axially at one end and is simply supported with pinned connection at its ends. The length of the column is taken as 6m.

B. Modelling and Analysis

Using ANSYS workbench 16.1 the column sections are modelled. The material properties are assigned and the support and the loading conditions are provided. For the finite element analysis bilinear isotropic hardening rule was used. Lateral restraints are provided along the column length in order to prevent it from sideways buckling. Isometric view and boundary conditions are shown in Fig.8.

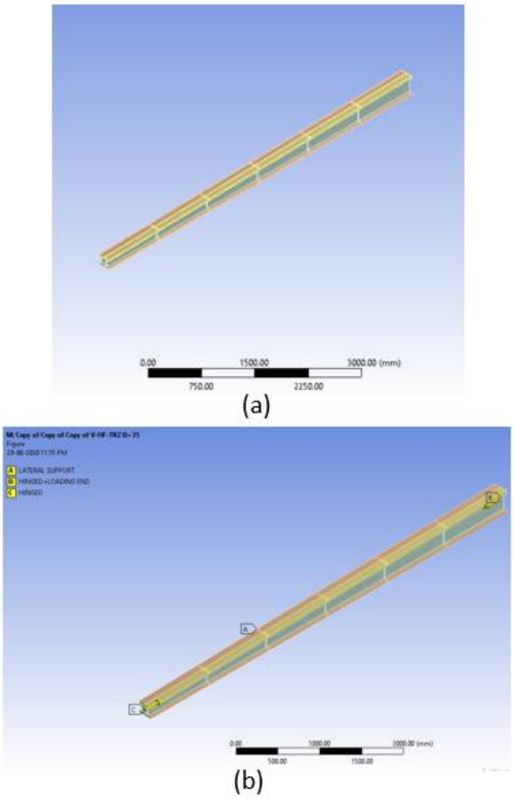

Fig 8: Isometric view and Boundary Condition of Double tapered steel with hollow flange with different D/T ratio

C. Results and Discussion

Double web tapered steel column with hollow flange is modelled with different d/t ratios and analysed and the results are obtained as follows. Total deformation of the double web tapered steel column is shown in Fig.9.The load – deformation curve of double tapered steel column sections in Fig 10.

- From these studies it was observed that upto d = 35 mm the strength is improved and the stiffness is increased.

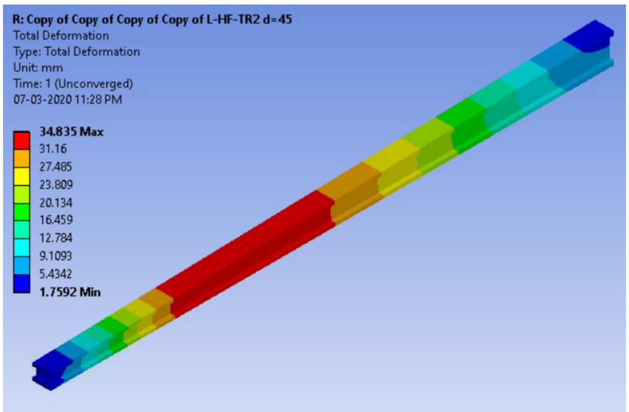

Fig 9: Total Deformation

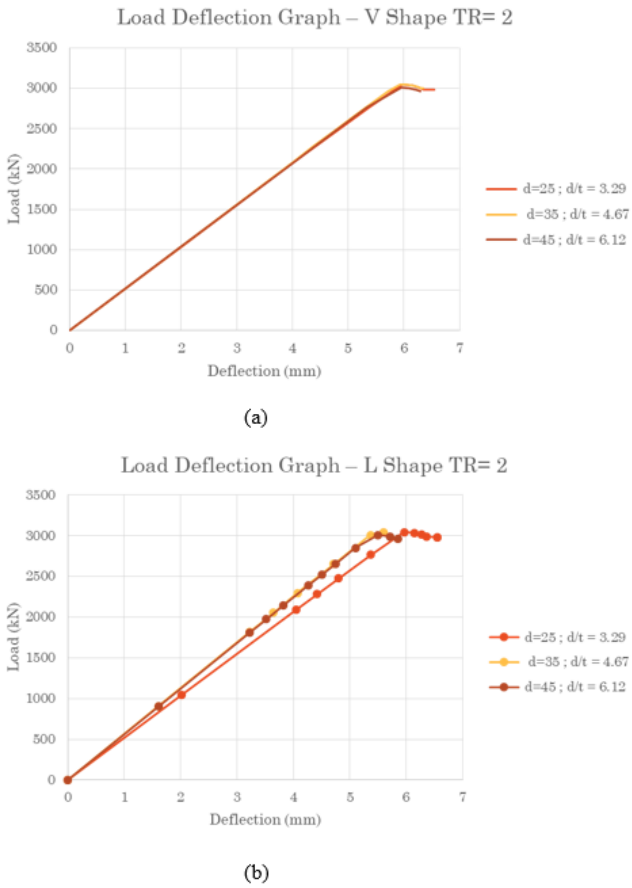

Fig 10: Load –Deformation Curve of Different Tapered Column Sections with hollow flange with different D/T ratios

VI. BUCKLING BEHAVIOUR OF TAPERED COLUMN

Steel members have tendency to bend or buckle when extreme loading condition is applied. In thin steel members, buckling occurs sideway. In order to prevent this, at particular intervals buckling lateral supports are provided. Buckling is mainly classified into three types, a) In plane buckling b) Out of plane buckling c) Local buckling. The plane buckle in its own plane in plane buckling, so the plane will be much stiffer. It will form a bend out or curve of its original plane in out of plane buckling. Local buckling occur before yielding of the whole cross-section thus preventing the structure reaching its full axial capacity.

VII. CONCLUSIONS

- By comparing the models of all the sections with different taper ratio, maximum load carrying capacity is obtained by double web tapered column with taper ratio 2.
- The deflection of V shaped column is more than that in L shaped column; (ie, the stiffness in L section is more).
- Double web tapered column with hollow flange is modelled for taper ratio 2 and 3, V shaped and L shaped column has almost same maximum load carrying capacity.
- Introduction of hollow flange improved stiffness of the section.
- From these studies it was observed that upto d = 35 mm the strength is improved and the stiffness is increased.

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