International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Buckling Behaviour and Lateral Load Performance of Web Tapered Sectional Steel Columns

Anjana B. Raj[1], Dr. D. Ramesh Kumar[2]
[1]PG Student, Department of Civil Engineering, Ilahia College of Engineering & Technology, Mulavoor, Kerala, India-686673
[2]Associate Professor, Department of Civil Engineering, Ilahia College of Engineering & Technology, Mulavoor, Kerala, India-686673
Email address: anjanadazz95@gmail.com, rameshkumar@icet.ac.in

Abstract- *This paper deals with the axial and lateral load performance of web tapered sectional steel columns. Different type of tapered steel column sections studied are I section, C section and Box section. For each column section, taper is provided in two shapes (i.e. L shape and V shape). The column is axially loaded and the weight of the column for every section is kept constant. The study were proposed to compare and fix the tapered column with best taper ratio. Double tapered column is modeled and analysed using column with best taper ratio. Web tapered and double tapered steel column frame is analysed to determine the lateral load performance. The axial and lateral load behavior of tapered column sections is analysed and developed a finite element model using the software ANSYS 16.1. The result is analysed to determine the buckling behavior and lateral load performance of tapered column section.*

Keywords- *Tapered column, axial loading, lateral load, double tapered column, tapered column frame*

I. INTRODUCTION

Tapered steel columns are non prismatic members that have better cross-section utilization, which makes them aesthetically better and more economical alternative. In architecture and structural engineering, a column or pillar is a structural element that transmits the whole weight of the above structure to the below structural elements. Steel columns have good compressive strength, but have a tendency to bend or buckle under extreme loading. Buckling is an instability that leads to structure failure. This occurs mainly due to the column length, cross-sectional area and the support conditions provided. Many practical applications of steel columns do not make use of the capacity of their cross section along the length. The most suitable application of column for this is tapered column which is more aesthetically pleasing. They are used in structures mainly due to their structural efficiency, provides more rigidity and stability to the buildings. Tapered columns are commonly seen in telephone towers, post towers, steel frames such as industrial halls, warehouses, exhibition centers etc. Now a days it is used in buildings as diagonal members.

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 popular in building construction. Tapered members are type of reduced sections. They 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 stability of tapered steel column section depends on the shape of tapering provided. The work can be extended to study the load bearing capacity of web tapered C section and Box section. The main objectives of the study are as follows.

- To find the best tapering ratio of different shapes for a sectional column.
- To analyse the double tapered sectional steel column with best taper ratio chosen.
- To determine the buckling behaviour and lateral load resistance of web tapered sectional column.
- To evaluate the performance of double tapered column in a framed structure.

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

A. Geometry

Three dimensional models were developed to demonstrate the behavior properly. All the three sections are 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 reference to *Trayana Tankova et al*. 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 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 tapered column

Yh	hmax (mm)	hmin (mm)	btop,bot (mm)	tw (mm)	tf,top&tf,bot (mm)
2	320	160	100	10	16
3	360	120	100	10	16
4	385	96.3	100	10	16

Anjana B. Raj and Dr. D. Ramesh Kumar, "Buckling Behaviour and Lateral Load Performance of Web Tapered Sectional Steel Columns," *International Research Journal of Advanced Engineering and Science*, Volume 4, Issue 2, pp. 363-367, 2019.

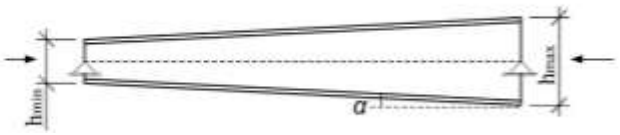


Fig. 2. Typical Geometry of L Shaped Tapered Column Section

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 section

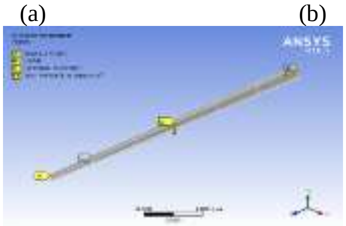
MATERIAL PROPERTY	VALUE
Density	7860 kg/m^3
Young's Modulus	2x10^{5}MPa
Poisson's Ratio	0.3
Bulk Modulus	1.67x10^{5}MPa
Shear Modulus	7.69x10^4 MPa
Yield Strength	355 MPa

C. Modelling and Analysis

Web tapered sectional steel column with different taper ratios are modeled using ANSYS Workbench 16.1. 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, C section and Box section columns are modeled with same material properties, loading and support conditions. For each column section, six models are created. Three models are L shaped tapered column with taper ratios 2,3 and 4 and the other three models are V shaped tapered column with taper ratios 2,3 and 4. The bilinear isotropic hardening rule was used for the finite element analysis. The isometric view, finite element modeling and boundary conditions provided for the tapered column section are shown in Fig.3.

(a)

(b)



(c)

Fig. 3. (a) Isometric view (b) Finite element modeling (c) Boundary conditions of tapered column sections

D. Results and Discussion

After analyzing the models, the results are obtained and are summarized as follows. Fig.4. shows the total deformation of the tapered column section. The load deformation curve of different column sections (i.e. I section, C section and Box section) are shown in Fig.5.

- By comparing the models of all the three sections, tapered column with taper ratio 2 has the maximum load carrying capacity.
- For web tapered Box section steel column, the deflection is more as that compared to I and C section steel column. Hence ductility is more in Box section steel columns.
- Web tapered C section columns are thin column sections, thus buckling may occur sideways because of low stiffness.
- Considering the shapes of sectional column for I section, L shaped columns are best and for C and Box section, V shaped columns are best.
- If there is an option to choose column with higher taper ratio, it is better to prefer Box section.

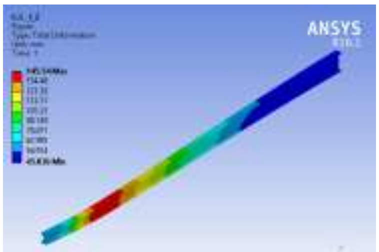
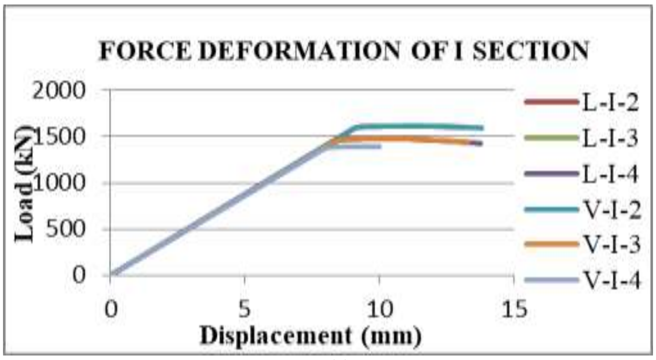
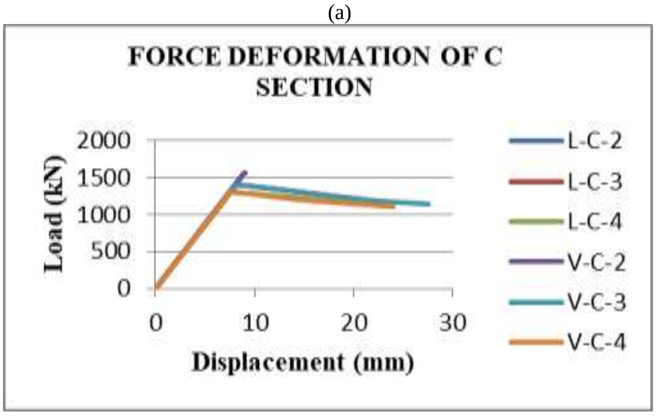


Fig. 4. Total Deformation of Tapered Column

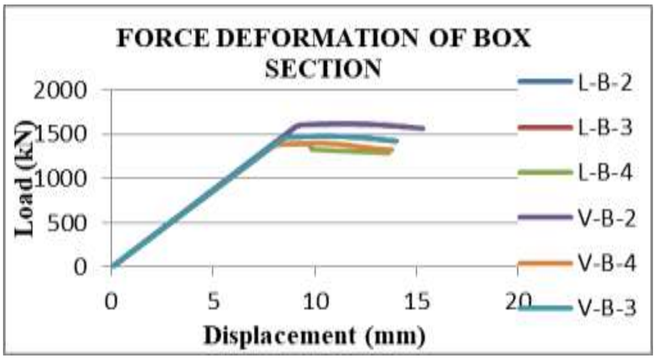


(a)



(b)

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024



(c)

Fig. 5. Load –Deformation Curve of Different Tapered Column Sections

L-I-2 represents L shaped I section steel column with taper ratio 2 and V-I-2 represents V shaped I section steel column with taper ratio 2, similar for all other sections.

IV. Finite Element Modelling of Double Tapered Steel Column

From the analysis of 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 taper ratio chosen, double tapered column is modeled and analysed for I section, C section and Box section. The column is modeled for both L shape and V shape.

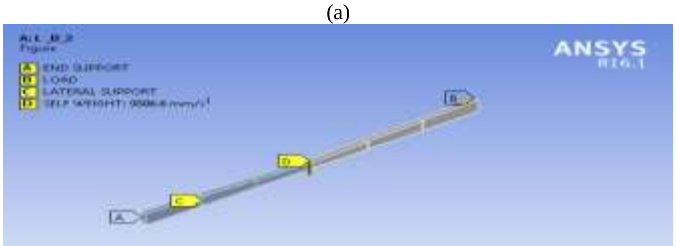
A. Geometry and Material Properties

Double tapered column is modeled with taper ratio 2 for I section, C section and Box section. Dimensions and the material properties are same as the web tapered column section. The column is simply supported with pinned connection at its ends and the column is loaded axialy at one end. The length of the column is 6m.

B. Modelling and Analysis

The column sections are modeled using ANSYS workbench 16.1. The material properties are assigned and the support and the loading conditions are provided. The bilinear isotropic hardening rule was used for the finite element analysis. Lateral restraints are provided along the length of the column in order to prevent it from sideways buckling. Isometric view and boundary conditions are shown in Fig.6.

(a)



(b)

Fig. 6. Isometric view and Boundary Condition of Double tapered steel column

C. Results and Discussion

Double tapered steel column is modeled and analysed and the results are obtained as follows. Total deformation of the double tapered steel column is shown in Fig.7. Fig.8. shows the load – deformation curve of double tapered steel column sections.

- Double tapered column is modeled for taper ratio 2, V shaped double tapered column has the maximum load carrying capacity as compared to L shaped column.
- Deflection is more in L shaped tapered column as compared to V shaped tapered column.
- By comparing the three sections of column with taper ratio 2, Box section has the maximum load bearing capacity.

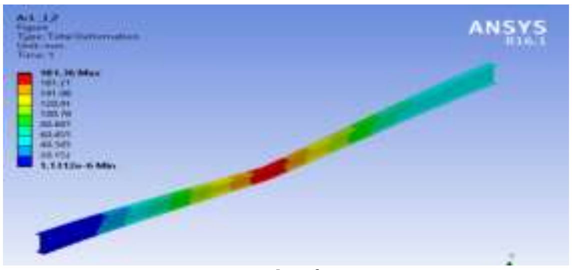


Fig. 7. Total Deformation

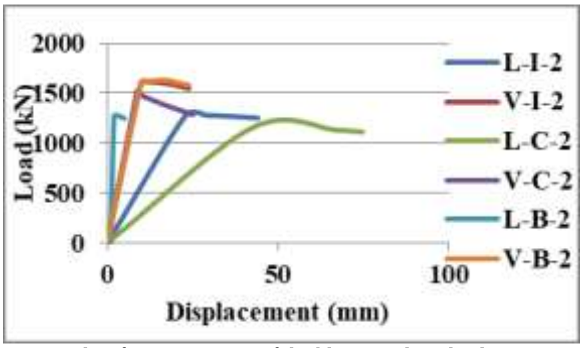


Fig. 8. Load Deformation curve of double tapered steel column sections

V. Lateral Load Performance of Web Tapered Column Frame

Non uniform steel frame with tapered members have provided practical and economical design solutions for ware-houses and factory buildings. Because of the non uniform distribution of bending moments, materials can be saved by using members with variable depth. From the analysis of web tapered steel column and double tapered steel column, box section with taper ratio 2 has the maximum load carrying capacity. Thus the frame is modeled with Box section steel column with taper ratio 2.

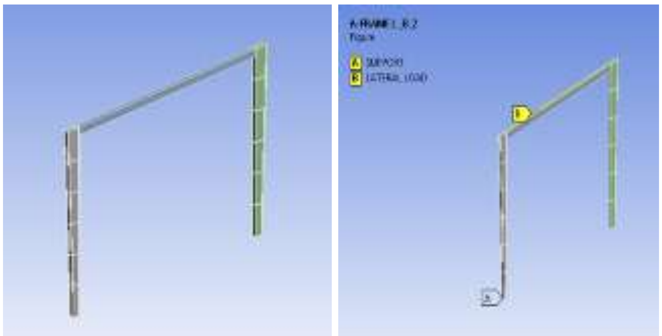
A. Geometry and Material Properties

Web tapered frame is modeled with Box section steel column with taper ratio 2.L shaped and V shaped columns are modeled for both web tapered frame and double tapered frame. Material properties of tapered frame section are same as that tapered column. One end of both the columns are simply supported with pinned connection.

Anjana B. Raj and Dr. D. Ramesh Kumar, "Buckling Behaviour and Lateral Load Performance of Web Tapered Sectional Steel Columns," *International Research Journal of Advanced Engineering and Science*, Volume 4, Issue 2, pp. 363-367, 2019.

B. Modelling and Analysis

The tapered frame sections are modeled using the software ANSYS Workbench 16.1. Properties are assigned to the frame section and the support conditions are provided. For tapered frame section lateral restraints are not provided along its length. Lateral load is provided on the top portion of the frame. Fig.9. shows the geometry and loading condition of tapered frame section.



(a) (b)

Fig. 9. Geometry and Boundary Conditions of tapered frame section

C. Result and Discussions

Tapered column frame sections are analysed and the results are summarized as follows. Fig.10. shows the total deformation of tapered frame section. Comparison of lateral load performance of tapered frame section is shown in Fig.11. V shaped double tapered column frame of Box section column have good lateral load performance as compared to other frame.

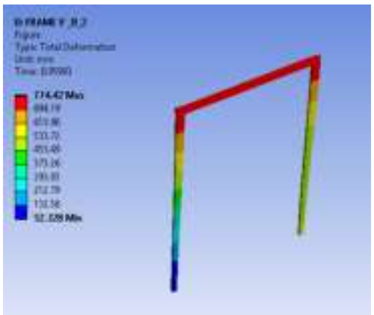


Fig. 10. Total deformation of tapered frame section

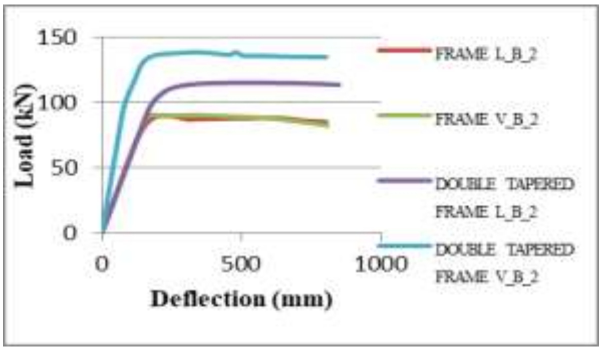


Fig. 11. Comparison of Lateral Load Performance of Tapered Frame Section

VI. BUCKLING BEHAVIOUR OF TAPERED COLUMN

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

VII. CONCLUSIONS

- For web tapered I,C and Box section columns, taper ratio 2 is best for both L shaped and V shaped column.
- For C sectional columns, sideways buckling occurs due to low stiffness.
- Considering the shapes of sectional column, L shaped columns are best for I section and for C and Box section, V shaped columns are best.
- V shaped double tapered frame with taper ratio 2 shows maximum load value with minimum deflection.
- For I and Box section steel columns, in plane buckling is mostly seen because of its stiffness.
- In case of C section columns, as it is a thin member, out of plane buckling commonly occurs.
- For double tapered steel columns, box section is found to have good load carrying capacity and thus local buckling is seen in this type of columns.

ACKNOWLEDGEMENT

I wish to thank the Management, Principal and Head of Civil Engineering department of Ilahia College of Engineering and Technology, affiliated by Kerala Technological University for their support. This paper is based on the work carried out by me (Anjana B. Raj), as a part of my PG course, under the guidance of Dr. D. Ramesh Kumar (Associate Professor, Ilahia College of Engineering and Technology, Muvattupuzha, Kerala). I express my gratitude towards him for his valuable guidance.

REFERENCES

[1] S.W.Liu, R. Bai, S.L.Chan, Y.P.Liu,Second order direct analysis of domelike structures consisting of tapered members with I-sections, J. Struct. Eng. 142(5) (2016)
[2] L. Marques, L. Simoes da Silva, R. Greiner, c. Rebelo, A. Taras, Development of a consistent design procedure for lateral torsional buckling of tapered beams, J. Constr. Steel res. 89 (2013)
[3] L. Marques, R. Greiner, Development of a consistant design procedure for tapered columns, J.Constr. Steel Res. 72 (2012) 61-74
[4] Y.D. Kim, Behaviour and design of metal building frames using general prismatic and web tapered steel i section members PhD thesis, Georgia Institute of Technology, (2010).
[5] Chen, Y.Z. et al. Buckling Loads of Columns with Varying Cross Sections. Journal of Engineering Mechanics, (1989) Vol. 115, No. 3, pp. 662-667
[6] Kim, M.C. et al. Elastic and Inelastic Buckling Analysis of Thin-Walled Tapered Members. Journal of Engineering Mechanics. (1997) Vol. 123, No. 7, pp. 727-737

[7] Lind, N.C. Discussion of Critical Buckling Loads for Tapered Columns (Gere and Carter, 1962). ASCE, Journal of the Structural Division. (1962) Vol. ?, No. 4, p. 235

[8] Williams, F. W. and G. Aston. Exact or Lower Bound Tapered Column Buckling Loads. Journal of Structural Engineering. (1989) Vol. 115, No. 5, pp. 1088-1100