Scientific Journal of Impact Factor (SJIF): 5.71

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Technophilia-2018.

Volume 5, Special Issue 04, Feb.-2018 (UGC Approved)

Experimental investigation on buckling analysis of hexagonal castellated column

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Abstract-*Perforated-web steel sections have been used as structural members since the Second World War in an attempt to enhance the flexural behavior without increasing the cost of the material. Hexagonal castellated column is the modified column in which width of column is increases by castellation process without increasing the self weight of the section. The buckling of column can be found out by many methods in which mathematical analysis, finite elemental analysis, experimental analysis and software analysis. In this paper the buckling analysis of column is found out by experiment and this is compare with the Ansys software. This project contain castellated column and this column is analyses for four end condition like both end fixed, both end pinned, one end fixed one end pinned and one end fixed one end free. Due to the castellation the radius of gyration of column get increases and slenderness ratio get decreases so that load carrying capacity of column increases. The main benefit of using a castellated column is to increase its buckling resistance about the major axis. However, because of the openings in the web, castellated columns have complicated sectional properties, which make it extremely difficult to predict their buckling resistance analytically.*

Keywords- *Castellation, Radius of Gyration, Slenderness ratio*

I. INTRODUCTION

Castellated column is defined as the column in which increasing width of column without increasing the self-weight of column. Now a day castellated column is a new technique. A castellated column is fabricated from a standard steel I-shape by cutting the web on a half hexagonal line down the center of the column. The two halves are moved across by one spacing and then rejoined by welding. This process increases the width of the column and hence the major axis bending strength and stiffness without adding additional materials. Due to the opening in the web, castellated column are more susceptible to lateral-torsional buckling. The main benefit of using a castellated column is to increase its buckling resistance about the major axis. However, because of the openings in the web, castellated columns have complicated sectional properties, which make it extremely difficult to predict their buckling resistance analytically.

A. Hexagonal castellated column

In the hexagonal castellated column the opening is provided 45’ or 60’ angle. Hexagonal castellated column give greater resistance to buckling.

Fig. 1 Hexagonal castellated column

II. OBJECTIVE

- Comparison between between buckling of regular section and castellated section at various end condition
- Analysis and design of castellated column.
- To find out failure points in castellated column.
- To find out buckling load and deflection of section.

III. LITERATURE REVIEW

DelphineSonck[et al] (2016) In this paper Cellular and castellated members are usually produced by performing cutting and rewelding operations on a hot rolled I-section member. As illustrated in previous work, these operations will influence the residual stresses present in the members in a manner which is detrimental for the flexural buckling resistance.

G. Panduranga[etal] (2015) In this paper the buckling analysis of 4140 alloy steel with different cross sections like I-section, C-section and T-section is done in a fixed free conditions. Columns are the basic parts of a many engineering structures, they may be aero structures or civil structure or any other mechanical load carrying structures.

Jian-kang Chen [etal] (2013) This paper presents an analytical solution for the linear elastic buckling analysis of simply supported battened columns subjected to axial compressed loading. The critical buckling load is derived by using the classical energy method. Unlike most of existing work, the present approach considers not only the shear effect but also the discrete effect of battens on the global buckling behaviour of the columns.

IV.METHODOLOGY

A. Assembly for various end condition

There are four end condition given below

- Column with both the ends fixed
- Column with both the ends pin
- Column with one end is fixed and other end is pin
- Column with one end is fixed and other end is free

Assembly for testing of column is prepared from steel material. This is a plate and nut combination assembly which can achieve four end condition of testing.

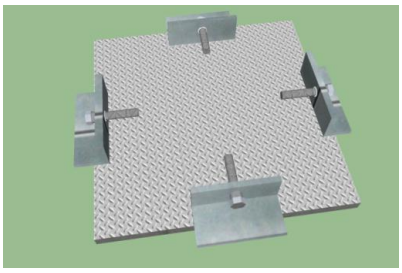


Fig. 2 Assembly for testing

B. Geometry of a typical castellated column

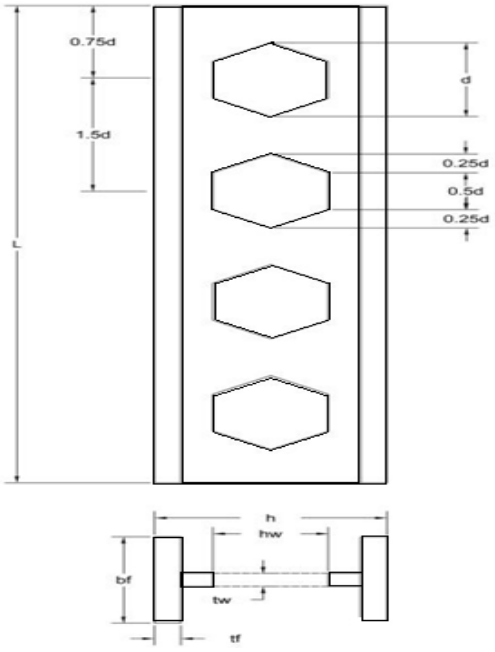


Fig. 3 Geometry of a typical castellated column

Typical geometry of modelled castellated columns is presented in Fig. 6. According to this illustration, the typical spacing between castellation is 1.5d, centre-to-centre, where d represents the diameter of the circle enclosing the hexagonal perforation. The gain in the depth of the expanded section, relative to the original depth, is estimated as 0.433h.

- Section properties

ISMB100
$A = 1470mm^2$
h = 100mm
b = 70mm
b_f = 7.5mm
t_w = 4.5 mm
$I_{xx} = 2.52 \times 10^6 mm^4$
$I_{yy} = 0.35 \times 10^6 mm^4$
r_{xx} = 41.4mm
r_{yy} = 15.5mm

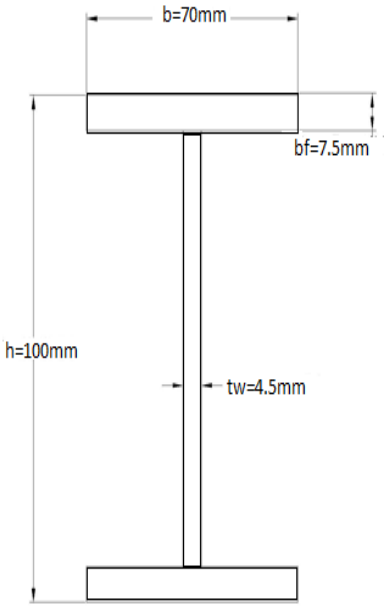


Fig. 4 Dimension of first original section

According to above geometry modified section is given below

The diameter of the circle enclosing the hexagonal perforation

$d = 0.443h$
$= 0.443 \times 100$
$= 44.3mm$

Centre-to-centre spacing between castellation

$s = 1.5d$
$= 1.5 \times 44.3$
$= 66.45mm$

End distance of the hexagonal opening = 0.75d

$= 0.75 \times 44.3$
$= 33.25mm$

Inclined side height of hexagonal opening = 0.25d

$= 0.25 \times 44.3$
$= 11.07mm$

Vertical side height= 0.50d

$= 0.50 \times 44.3$
$= 22.15mm$

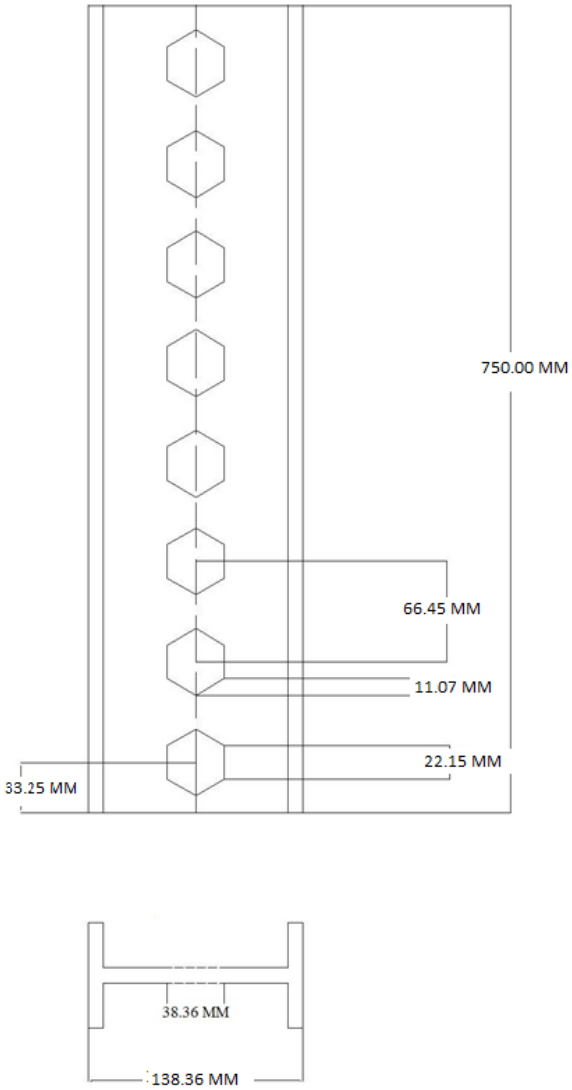


Fig.5Dimension of first Modified section

V. CASTING ANDTESTING OF SPECIMEN

I. A.FABRICATION OF SECTION

The end condition assembly is prepared from the mild steel plate, angle section with bolt. This assebly is used fot the testing of castellated column at various end condition. The castellated section is manufacture from the mild steel I section. Firstly the hexagonal pattern is drawn on the column and by using gas cutter this section is cut into two part. After this two parts are welded each other with the help of gas welding.

Photo 1 Pattern marking on the section

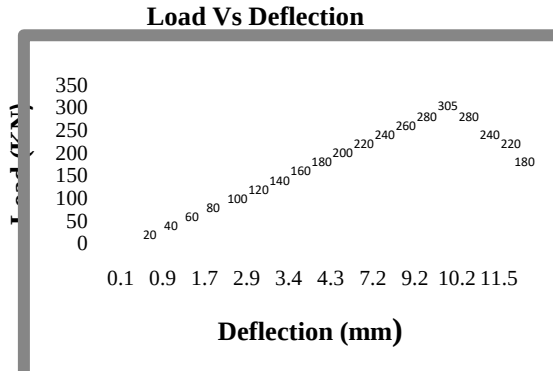
Photo 2 Fabricated section with end condition aseembly

B.Testing of section

Buckling test on regular section (both end fixed)

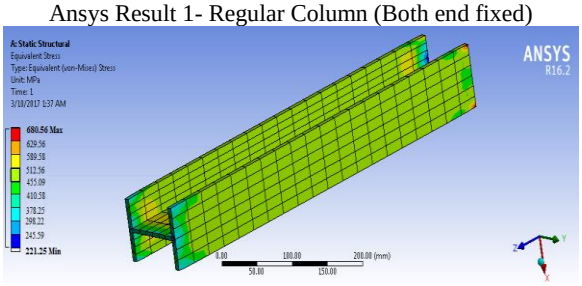
The buckling test on regular section is conducted on Universal testing machine. The test arrangement for test is shown in below photo. The end condition for this testing is both end fixed.

Graph 1 Load vs Deflection for regular I section (both end fixed)



From graph the maximum load taken by section is 305 KN at deflection 9.2 mm.

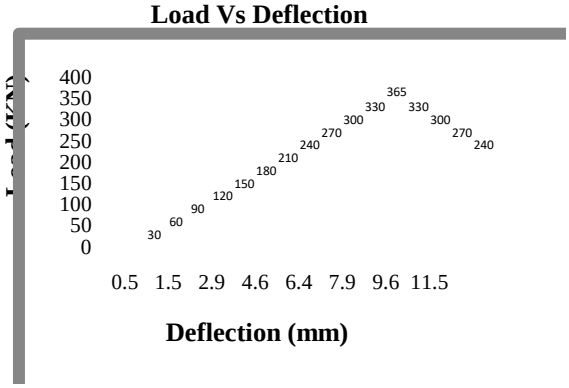
Ansys Result 1- Regular Column (Both end fixed)



From Ansys result the maximum stress is 680.56 MPa and minimum stress is 221.25 MPa.

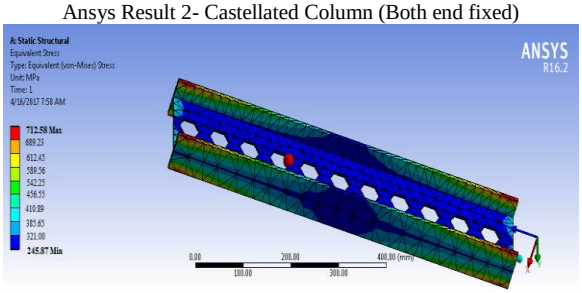
Buckling test on castellated section (both end fixed)

Graph 2 Load vs Deflection for Castellated I section (both end fixed)



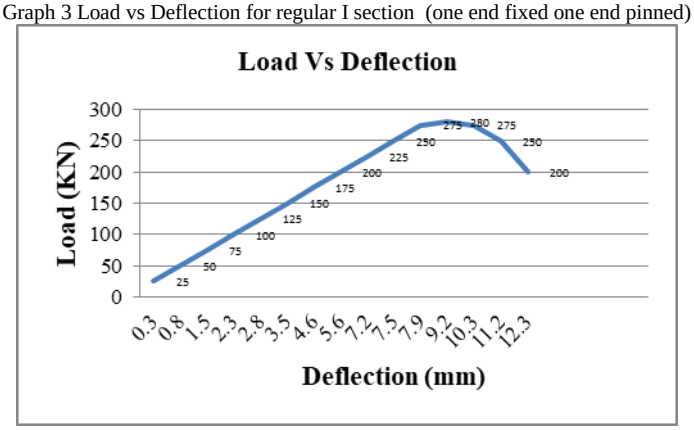
From graph the maximum load taken by section is 365 KN at deflection 8.2mm.

Ansys Result 2- Castellated Column (Both end fixed)



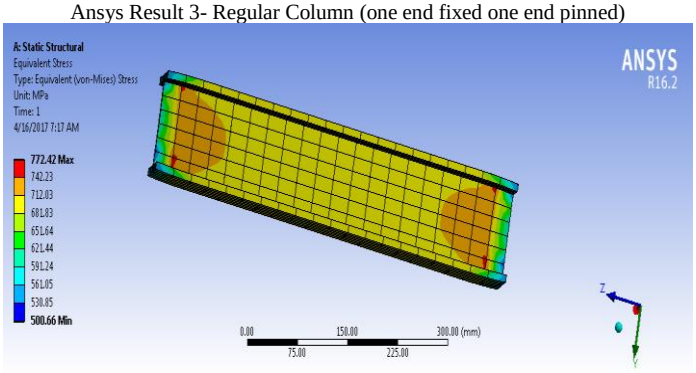
From Ansys result the maximum stress is 712.58 MPa and minimum stress is 245.87 MPa.

Buckling test on regular section (one end fixed one end pinned)
The next section is tested for one end fixed and other end pinned
Graph 3 Load vs Deflection for regular I section (one end fixed one end pinned)



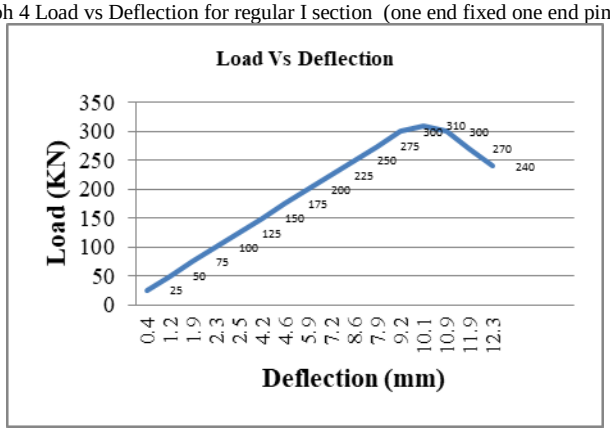
From graph the maximum load taken by section is 280 KN at deflection 9.2mm

Ansys Result 3- Regular Column (one end fixed one end pinned)



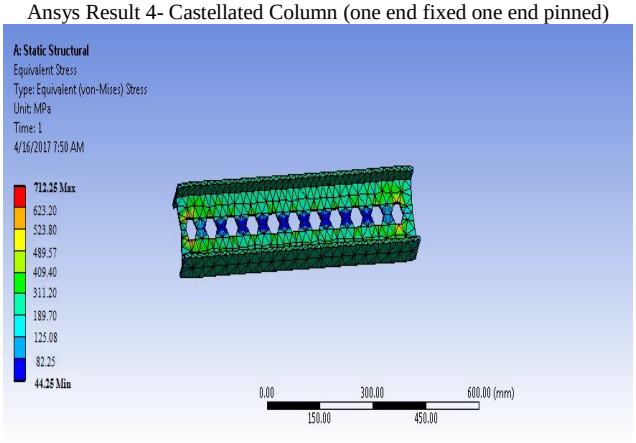
From Ansys result the maximum stress is 772.42 MPa and minimum stress is 500.66 MPa.

Buckling test on castellated section (one end fixed one end pinned)
Graph 4 Load vs Deflection for regular I section (one end fixed one end pinned)



From graph the maximum load taken by section is 310 KN at deflection 10.1 mm.

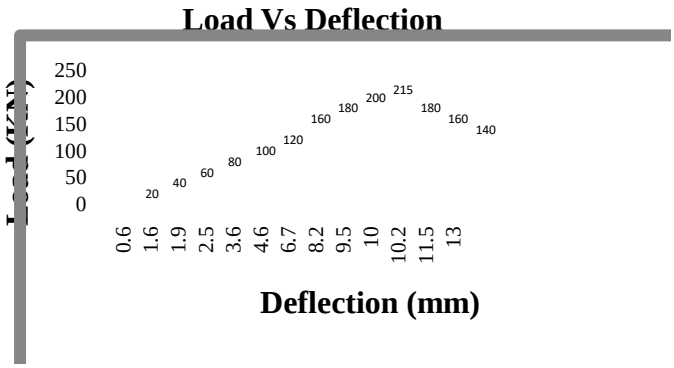
Ansys Result 4- Castellated Column (one end fixed one end pinned)



From Ansys result the maximum stress is 712.25 MPa and minimum stress is 44.25 MPa.

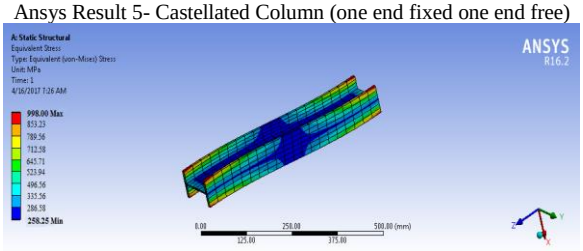
Buckling test on regular section (one end fixed one end free)

Graph 5 Load vs Deflection for regular I section (one end fixed one end free)



From graph the maximum load taken by section is 115.00 KN at deflection 10mm.

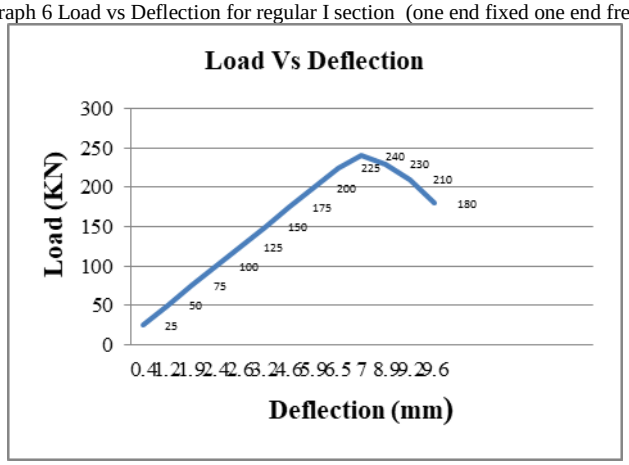
Ansys Result 5- Castellated Column (one end fixed one end free)



From Ansys result the maximum stress is 998 MPa and minimum stress is 245.25MPa.

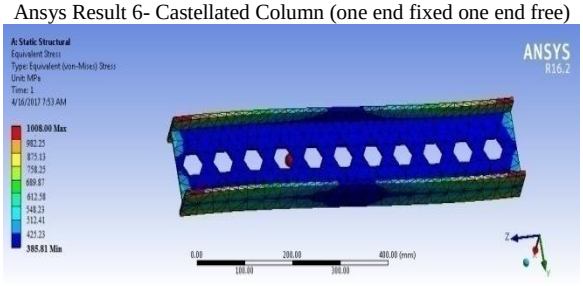
Buckling test on castellated section (one end fixed one end free)

Graph 6 Load vs Deflection for regular I section (one end fixed one end free)



From graph the maximum load taken by section is 240.00 KN at deflection 7 mm.

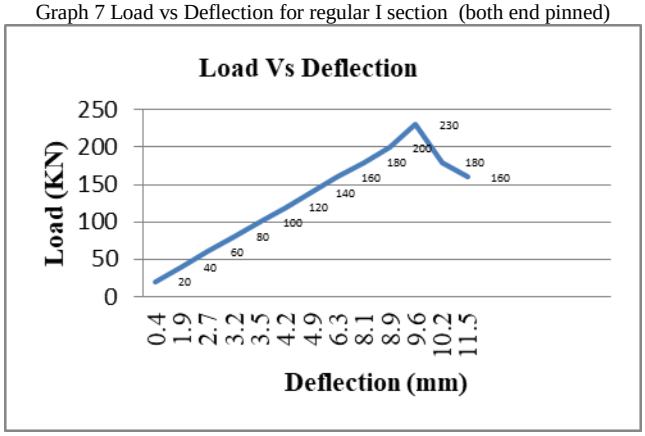
Ansys Result 6- Castellated Column (one end fixed one end free)



From Ansys result the maximum stress is 1008 MPa and minimum stress is 385.81MPa.

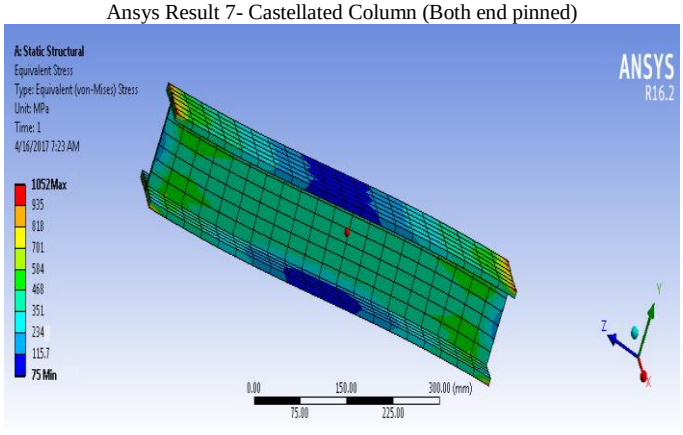
Buckling test on regular section (both end pinned)

Graph 7 Load vs Deflection for regular I section (both end pinned)



From graph the maximum load taken by section is 230 KN at deflection 9.6mm.

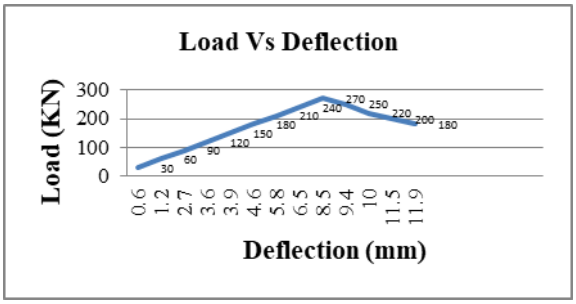
Ansys Result 7- Castellated Column (Both end pinned)



From Ansys result the maximum stress is 1052 MPa and minimum stress is 75 MPa.

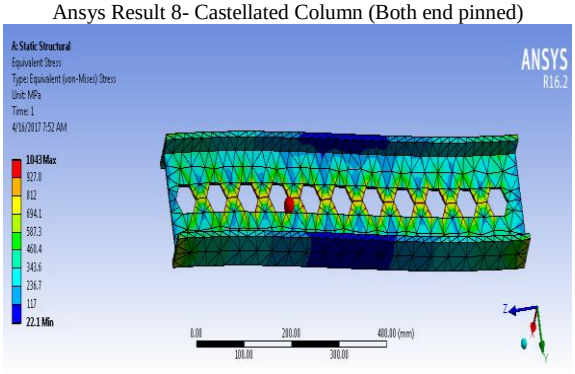
Buckling test on castellated section (both end pinned)

Graph 8 Load vs Deflection for castellated I section (both end pinned)



From graph the maximum load taken by section is 270 KN at deflection 8.5mm.

Ansys Result 8- Castellated Column (Both end pinned)



From Ansys result the maximum stress is 1043 MPa and minimum stress is 22.1 MPa.

VI. CONCLUSION

The maximum stresses developed in the castellated section are at corner. Both end fixed column carry more load as compare to other end condition.
The load taken by the regular column is 305 KN and castellated column is 365 KN for the both end fixed. The castellated column carries 17% more load as regular column.
Stresses developed in castellated column are less as compared to regular column. Load carrying capacity of castellated section is more as compare to normal section. Stress developed in castellated section is nearer same to regular section.

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