BEHAVIOR OF H-SECTION WITH SLENDER WEB BUILT-UP SECTION IN PRE-ENGINEERED BUILDINGDS

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Abstract - *Steel members with built-up cross-sections are extensively used in Pre-engineered buildings. Besides overall instability due to Euler's buckling, lateral torsional buckling etc. thin plates are susceptible to local buckling. In general, local buckling reduces the load carrying capacity of steel member. In the report provided herein, local buckling behavior of slender web is examined. Analysis is done to determine the effects of local buckling on the behavior of doubly symmetric H-section. For the purpose of analysis, a finite element model of simply supported beam is prepared on ANSYS. Length of beam and width over thickness (b/t) ratio of flange is kept constant whereas, depth of web is varied from 720 mm to 1200 mm. In order to observe buckling behavior of web, flange is kept semi compact and is restrained with the help of spring. Results such as, buckling load, deformation in x-direction and total deformation is obtained. The buckling load obtained in ANSYS is compared with the critical buckling load Pcr of the thin plate. Furthermore, difference in the provisions on local buckling of web outlined by AISC and IS 800:2007 is highlighted.*

KEYWORDS: built-up sections, local buckling, ANSYS, buckling load, slender web

1. Introduction

Plate assembled beams undergo various failures such as torsional buckling, lateral-torsional buckling, flange local buckling, web local buckling. In this study, local buckling behavior of slender web is analyzed. Local buckling plays an important role in design of Pre-Engineered buildings (PEBs). It describes structural behavior up to final collapse state. Since strength of steel comprises of strength before buckling and strength after buckling therefore, buckling of elements does not mean the end of load carrying capacity and the locally buckled member can undergo further deformation [1][7][8] [11]. The research presented in this paper deals with the behavior of H/I section with slender web.

The local buckling phenomena arising from compressive force acting in the transverse direction is less understood. This compressive force cause degradation of beam due to yielding and leading to various failures such as web buckling, web crippling etc. [4][5][9] In the view of foregoing background, theoretical studies were presented aimed at predicting critical buckling load for web [14] That is, the load at which web starts buckling.

Up to now many analytical studies on H-sections have been reported [1][6] These studies aimed at examining width-thickness ratio or depth-thickness ratio and relating them to the load carrying capacity of H-section thereby, restricting them in order to prevent local buckling. [3][2][7][8] [12] [13] However, different codes have specified different limiting ratios. [7][8] Therefore it is important for structural engineer to know which ratio to use in order to get optimal solution.

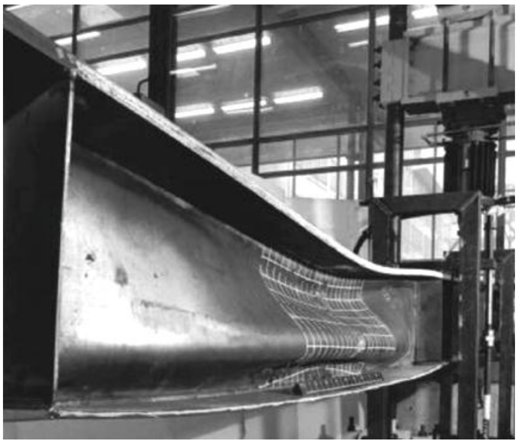

Fig 1: Vertical web buckling

This paper presents analytical study on H-section beam with slender web with varying depth-thickness ratios in a large of deformations. For analysis, a finite element model is prepared using ANSYS. The purpose is reveal buckling behavior of web and the load at which it stars buckling

2. Consideration on plate buckling

The aim of this section is to provide the reader with a brief examination of methodological experiments as well as theoretical history of localized buckling analysis of thin web plates. Webs of steel member can be idealized as simply supported along the edges subjected to compressive forces. Critical elastic buckling load computed by simple analytical formula. [10] [14]

$$Pcr = \frac{k\pi^2 Et^3}{12(1-\mu^2) * h} \text{.........eq}^n. 1$$

Where,

Pcr= critical load,

k= buckling coefficient,

E=Young's modulus,

t=thickness of web

μ=Poisson's ratio,

h= web depth

where value of k depends on support and loading conditions. For simply supported beam value of k is taken as 4 as per IS 800:2007 [7] [12] [13]

3. Methodology

3.1 H/I Section Beam

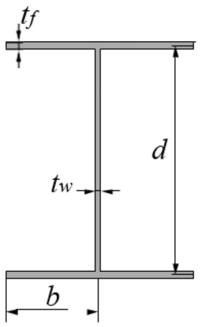

Fig 2: I-section beam

Table 1: Notations

Marks	Meaning
l	Length of beam
d	Web depth
t_w	Web thickness
b	Flange width
t_f	Flange thickness
d/t_w	Depth-thickness ratio of web

3.2 ANSYS modelling

During the present study, 17 models of I-section beams were developed in ANSYS software. The beam was assigned length of 7500 mm which is kept constant. Flange width-thickness ratio is kept same and is non-compact. Web depth is varied from 720 mm -1200 mm with constant web thickness (6 mm).

Fig.3 shows 3-D view of I-section beam.

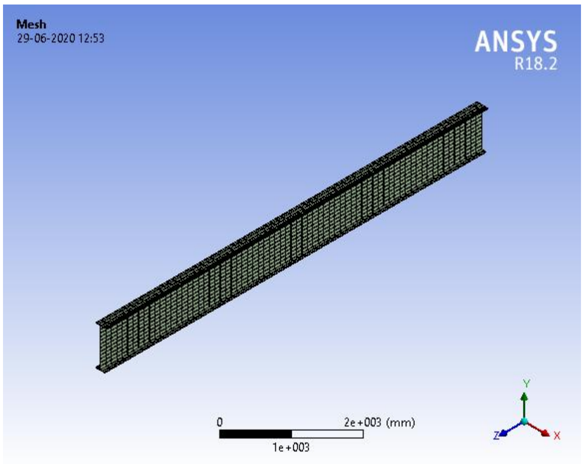

Fig 3: 3-D model of I-section

For trail purpose pressure of 1 Mpa is applied on compression flange as shown in Fig. 4.

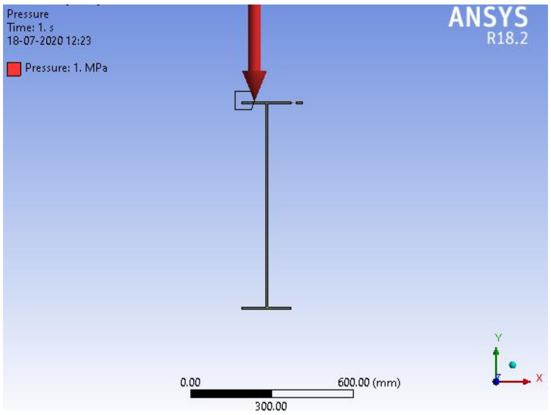

Fig 4: Application of pressure

In order to observe behavior of web compression flange is restrained with the help of spring.

Material property and physical properties of beam are given in table 2 and 3 respectively.

Table no. 2-EngineeringData Material Property

Property	Value
Density	7850 Kg/m³
Young's modulus	2E+11 Pa
Poisson's ratio	0.3
Bulk modulus	1.6667E+11 Pa
Shear modulus	7.6923E+11 Pa
Tensile yield strength	3.45E+08 Pa

Table no. 3- Physical Properties of Beam

Property	Value
Length	7500 mm
Flange Width (B)	180 mm
Flange thickness (t_f)	8 mm
Web thickness (t_w)	6 mm
Web depth (d)	720-1200 mm

4. Results

4.1 ANSYS results

After processing the model through Eigenvalue bucking ANSYS gives load factor. In order get buckling load this load factor must be multiplied with the applied load. The results obtained from ANSYS are shown in table 4 and table 5.

Table no.4- Variation in Buckling load with depth

Depth (d) mm	d/t_w	Buckling Load (KN)
720	120	189.135
750	125	183.6135
780	130	173.3265
810	135	165.4965
840	140	158.274
870	145	151.5915
900	150	144.4905
930	155	138.7665
960	160	133.4367
990	165	128.46465
1020	170	123.5115
1050	175	119.1591
1080	180	115.07265
1110	185	110.8053
1140	190	107.19135
1170	195	103.7853
1200	200	100.5642

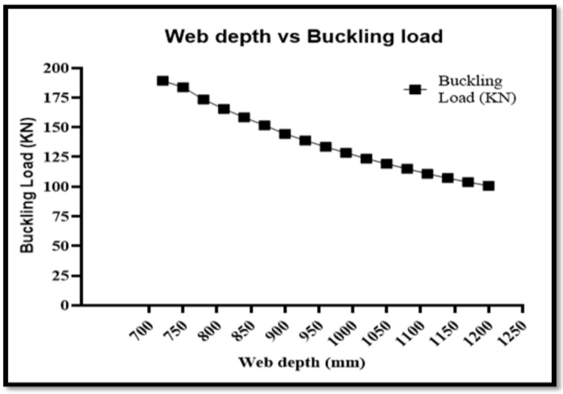

Fig 5:Web depth vs Buckling load (ANSYS)

It can be seen from fig.5, with the increase in web depth buckling load decreases.

Table no.5- Variation in total deformation and with slenderness ratio

d/tw	Total deformation (mm)	Directional deformation in x-direction (mm)
120	69.875	0.016839
125	66.395	0.016013
130	69.191	0.016456

135	56.557	0.015101
140	52.447	0.013703
145	48.761	0.012365
150	45.511	0.012365
155	42.566	0.011026
160	39.911	0.0097041
165	37.502	0.0083468
170	35.354	0.0077953
175	33.369	0.0076123
180	31.574	0.0074395
185	29.963	0.0072483
190	28.463	0.007093
195	27.075	0.0069449
200	25.811	0.0068044

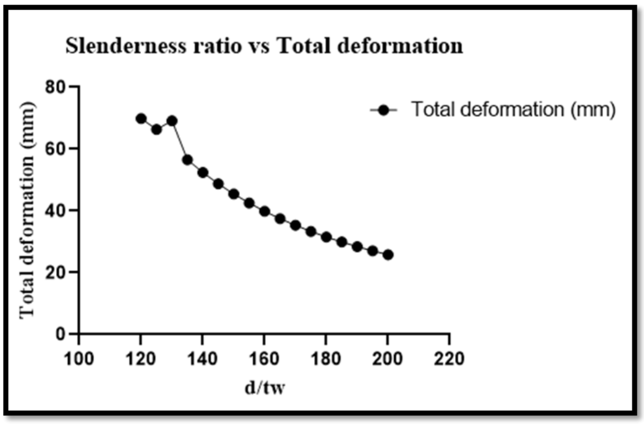

Fig 6: Variation in total deformation with slenderness ratio

Fig.6 represents variation of total deformation with slenderness ratio. It can be seen from the fig. that with the increase in slenderness ratio total deformation of beam decreases.

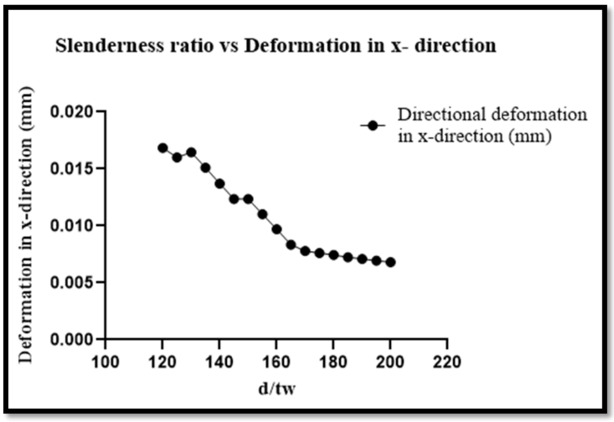

Fig 7: Variation in directional deformation with slenderness ratio

Fig. 7 represents variation in total deformation with increase in slenderness ratio. It can be from above fig. directional deformation decreases with increase in slenderness ratio. This represents directional behavior of slender web.

4.2 Theoretical results

Theoretical results are obtained by putting the values in eq$^{n.}$ 1. Results is tabled 6

Table no.6- Buckling load (Theoretical)

Depth (d) mm	Web thickness (mm)	Elastic critical buckling load (KN)
720	6	216.9143825
750	6	208.2378072
780	6	200.2286607
810	6	192.8127844
840	6	185.9266135
870	6	179.515351
900	6	173.531506
930	6	167.9337154
960	6	162.6857868

990	6	157.7559145
1020	6	153.1160347
1050	6	148.7412908
1080	6	144.6095883
1110	6	140.701221
1140	6	136.9985573
1170	6	133.4857738
1200	6	130.1486295

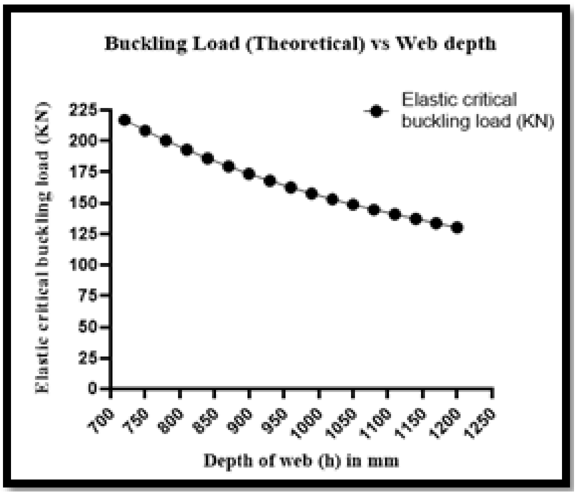

Fig 8: Variation in buckling load vs web depth

It can be seen from fig.8, with the increase in web depth buckling load decreases. This variation satisfies theoretical equation as critical buckling load *Pcr* is inversely proportional to web depth h.

Table no. 7 below shows difference in results obatined through ANSYS and elastic critical load in terms of buckling load.

Table No. 7- Comparaison Between ANSYS and critical buckling load

Depth (d) mm	d/t_w	ANSYS Buckling Load (KN)	Elastic critical buckling load (KN)
720	120	189.135	216.914
750	125	183.6135	208.237
780	130	173.3265	200.228
810	135	165.4965	192.812
840	140	158.274	185.926
870	145	151.5915	179.515
900	150	144.4905	173.531
930	155	138.7665	167.933
960	160	133.4367	162.685
990	165	128.46465	157.755
1020	170	123.5115	153.116
1050	175	119.1591	148.741
1080	180	115.07265	144.609
1110	185	110.8053	140.701
1140	190	107.19135	136.998
1170	195	103.7853	133.485
1200	200	100.5642	130.148

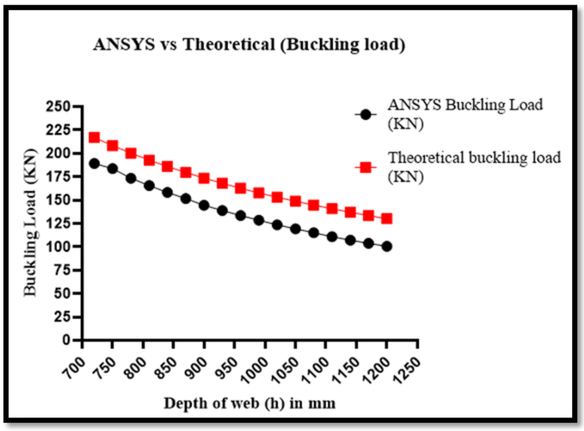

Fig 9: ANSYS buckling load vs Theoretical buckling load

5. Conclusion

This analytical study is an attempt to understand the behavior of slender web. From the results it can be concluded that,

1. With the increase in depth over thickness ratio web tends to buckle at lower loads which is true as slenderer the element gets lower will be its load carrying capacity. Also, according to critical buckling formula

$$Pcr = \frac{k\pi^2 E t^3}{12(1-\mu^2)*h}$$

Pcr is inversely proportional to depth ***h***.

2. With the increase in slenderness ratio total deformation decreases. Also deformation minimum deformation in x-direction decreases.

3. Buckling load obtained from ANSYS is less than theoretical load as the flange is restrained.

4. For steel having yield stress of 345 Mpa IS 800:2007 classifies a section as slender when slenderness ratio exceeds 107 and AISC classifies it as slender when slenderness ratio exceeds 137. This means if a structure is designed as per IS 800 designers would have to introduce stiffener as soon as ratio exceeds beyond 107. This will increase the cost of fabrication and the structure will not be economical. Therefore, AISC gives more economical result as it allows slenderness ratio to extend up to 137 before the introduction of stiffeners.

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