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Design Aids of Parallel Flange Section Subjected To Axial Compression, As Per I.S.800: 2007

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Abstract

Compression members are one of the basic structural elements which are primarily designed to carry axial compression. The mission of structural designer is to design a structure that can withstand such demands throughout its expected life. The design of compression members in IS 800:2007 is fairly straight forward, but required lot of computations.

In this paper, attempts are made to prepare a practical guide to the design of compressive steel elements subjected to axial compression, as per I.S.800:2007 and its essential applications on Parallel flange sections. The design tables include section and its capacity calculated according to I.S.800:2007.

Keywords : Compressive Strength, Parallel Flange Sections, Design Tables, Effective Length .

Introduction

The aim of structural design is to produce a safe and economical structure fulfilling its required purpose. The mission of structural designer is to design a structure that can withstand such demands throughout its expected life. The design of compression members in IS 800:2007 is fairly straight forward, but required lot of computations.

The design of a steel column is necessarily a trial- and-error procedure. In this paper, attempts are made to prepare a practical guide to the design of compressive steel elements subjected to axial compression, as per I.S.800:2007 and its essential applications on Parallel flange sections. The design tables include section and its capacity calculated according to I.S.800:2007.

The use of Parallel flange sections as structural elements are becoming very popular in the present days and is widely used in building materials. It is established that Parallel flange sections are far superior to those conventional tapered sections, in terms of strength, sectional efficiency, load bearing capacity, workability and pricing. It is also offer higher axial compression load bearing capacity. Some advantages of parallel sections over tapered sections are it has greater choice of profile, facilitated bolted or welded construction, reduced steel consumption, time saving construction, efficiency in construction etc.

Design Procedure - Limit State Design

To cater for the inherent variability of loading and structural response, engineers apply factors to ensure the structure will carry the loads safely. By limit state approach the applied loads are multiplied by factors, capacities and resistances are determined using the design strength of the material. Limit states are the states beyond which the structure becomes unfit for its intended use. It ensures proper structural safety and serviceability and covers all forms of failure. Limit states are classified as :

1. Limit state of strength; and
2. Limit state of serviceability.

The limit states of strength are those associated with failures, under the action of probable and most unfavorable combination of loads on the structure using the appropriate partial safety factors, which may endanger the safety of life and property.

The limit state of serviceability includes deformation and deflections, vibrations in the structure, repairable damage, corrosion, durability, fire.

I.S. 800:2007 is follow Limit State design standard. The minimum

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material design strength P_y is specified as being 1.0 f_s (minimum yield strength). The value of yield strength and thus design strength decreases with thickness. For rolled sections, the design strength for the whole section is based on the thickest elements usually the flange. The design capacities of members are based on the material design strength without the application of any prior factor.

Plate elements of a cross-section may buckle locally due to compressive stresses. In turn, this may limit the axial load carrying capacity to a value below the squash load (cross-sectional area times yield strength) and the bending resistance to a value below the fully plastic moment of resistance. This phenomenon is independent of the length of the member and hence is termed by local buckling. It is dependent upon :

1. Width to thickness ratio of the element.
2. Support condition.
3. Yield strength of the material.
4. Stress distribution across the width of the plate element.
5. Residual stresses in rolled or welded section.

The local buckling can be avoided before the limit state is achieved by limiting the width to thickness ratio of each elements of a cross-section subjected to compression due to axial force, moment or shear. Different elements of a cross-section can be in different classes. In such cases the section is classified based on the least favorable classification.

Design Compressive Strength

The design of a column is necessarily a trial-and-error procedure since the design stress depend upon the value of slenderness ratio and radius of gyration is dependent upon the distribution of the cross sectional area.

$P_d = A_e . f_{cd}$

The effective sectional area, A_e, is equal to the gross sectional area for all sections that are classified as 'non slender'. Elements which are below semi-compact limits are to be taken as of non slender cross-section. Slender cross-sections contain elements that are so slender that local buckling is likely to occur before the attainment of the material design strength on the extreme fibers. Special procedures are needed to evaluate the capacity of the section. For 'slender' sections, the effective sectional area is obtained by deducting the area of the compression plate element in excess of the 'non slender' section limit from the gross sectional area. Holes not filled with rivets, bolts or pins shall be deducted from gross area in either case. If the section is slender then A_e the effective area is not equal to gross sectional area. Then effective area of the section is $\mathbf{A_e = A - (d - 42.\varepsilon.t_w)\, t_w}$

The value of design compressive stress (fcd) depends upon **yield stress, effective slenderness ratio and buckling class.**

Where, the value of yield stress $\mathbf{f_y}$ is depends on the thickness of the flange of the particular section. Yield Stress for most commonly available **Fe410** grade steel is **250 N/mm2** for thickness of elements less than **20mm**. When the thickness of elements is equal to or greater than 20mm, the yield stress is reduced to **240 N/mm2** and this value is further reduced to **230 N/mm2** for thickness more than **40mm**.

Section classification

$t_f < 20$mm. $f_y = 250$ N/mm^2
$20 < t_f < 40$mm $f_y = 240$ N/mm^2
$t_f > 40$mm $f_y = 230$ N/mm^2
$\varepsilon = (250/f_y)^{0.5}$
if $(b/2)/t_f < 15.7\,\varepsilon$ then flange is not slender
if $d/t_w < 42\,\varepsilon$ then web is not slender.

For non-slender member $A = A_e$

The end restrained conditions of a compressive member will affect the buckle shape of the compressive member and also the buckling resistances. So it is very important step in design to identify the effective length of the member. The effective length KL is calculated from the actual length L of the member, and K is the effective length factor, considering the rotational and relative translational boundary conditions at the ends of the column section in the plane of the buckling deformation. The actual length shall be taken as the length from centre to centre of its intersections with the supporting members in the plane of the buckling deformation, or in the supported end.

The buckling tendency of a column varies with the ratio of the length to least lateral dimension, this ratio is known as slenderness ratio. So it is the ratio of effective length (KL) to appropriate radius of gyration(r). Slenderness ratio about the major axis KL/r_x, and about the minor axis KL/r_y of the sections. Here both are considered up to 180.

For buckling about major (Z-Z) axis, radius of gyration r_z is to be used and for buckling about minor (y-y) axis, radius of gyration r_y is to be used. For hot rolled parallel and tapered flange steel sections, r_z is always much more than r_y. In cases where effective lengths are different for both the axes, both possibilities should be checked, unless the governing axis is very obvious.

There is no strength property of the material appears in the Euler's formula, yet it determines the carrying capacity of a column.

Euler buckling stress $f_{cc} = \pi^2 E/(KL/r)^2$

Buckling class is introduced to solve the problem of residual stresses, lack of straightness etc, which effects on stresses of the members. Now define buckling class :-

$d/b > 1.2$,& $t_f \leq 40$mm
major class – a minor class - b
$d/b \leq 1.2$, & $t_f \leq 100$mm
major class- b minor class - c

imperfection factor :- a – 0.21 , b – 0.34 , c - 0.49 , d – 0.76

Non dimensional effective slenderness ratio $\lambda = (f_y/f_{cc})^{0.5}$

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

Stress reduction factor for different buckling class, slenderness ratio and yield stress

$$\boldsymbol{\chi = 1/[\Phi + (\varphi^2 - \lambda^2)^{0.5}]}$$

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If stress reduction factor is less than 1 then considering the stress reduction factor, or considers 1.

i.e., $\chi < 1$, then χ, nor 1

Stress reduction factor $X = 1/(\varphi + (\varphi^2 - \lambda^2))^{0.5}$

If $X < 1$, then X. nor 1

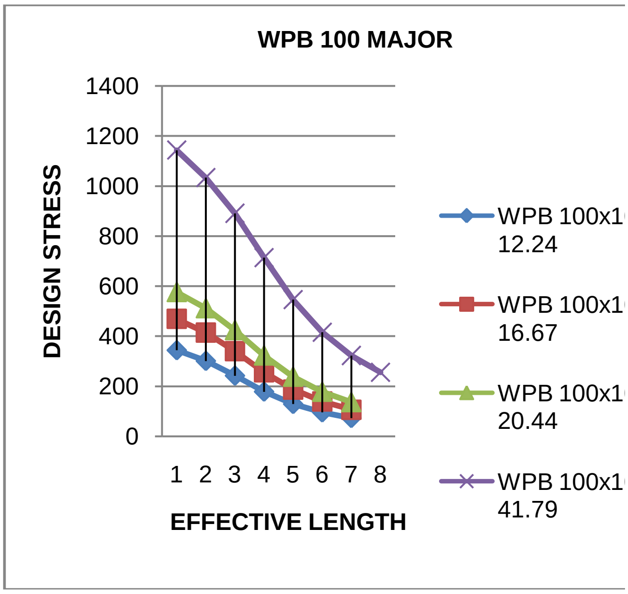
Compressive stress $f_{cd} = X(f_y/\lambda_{mo})$

Results

The compressive strength of Indian Standard Wide parallel flange sections with respect to the effective length of the column section shows different properties on different sections.

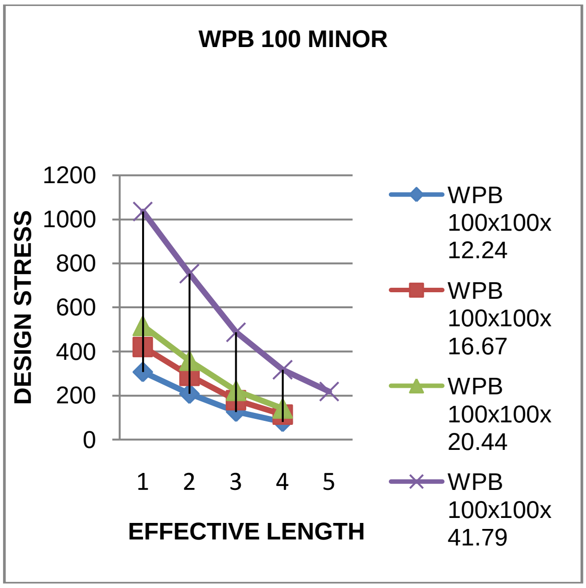
In WPB 100X100 sections compressive strength on the major axis of the sections vary from 73KN to 1143KN. As the mass increases on these sections compressive strength also increases. With increase of effective length compressive strength is reduced. Between two consecutive effective lengths it reduced linearly, but the effective length between 3m to 4m is reduced rapidly and which represents by a curve.

WPB 100x100 x 12.24	343	301	242	178	129	95	73	
WPB 100x100 x 16.67	469	414	340	255	187	139	107	
WPB 100x100 x 20.44	576	512	424	323	238	178	136	
WPB 100x100 x 41.79	1143	1034	890	714	546	416	322	256



On the other hand on minor axis of these sections compressive strength are considered up to 5m due to slenderness ratio exceeding the value of 180.

Designation/ KL	1	2	3	4	5
WPB 100x100 x 12.24	306	207	125	79	
WPB 100x100 x 16.67	420	290	179	114	
WPB 100x100 x 20.44	516	358	221	141	
WPB 100x100 x 41.79	1035	753	486	316	218



These graphs help new designer to select the appropriate section. As there are known axial load and known effective length, any body can choose most economical section from graph without any previous knowledge about design of steel section.

Now by Using table of Design Aids

1. Calculate the effective length (KL) of column.
2. Select a trial section from table according to a value of axial load applied on the member.
3. Read the design compressive strength (P_{cd}) from tables.
4. Then choose the most economical section for design.

Conclusion

1. According to I.S.800: 2007 using limit state approach, tables are prepared for design compressive strength of a given rolled column section parallel flange section with respect to the effective length.
2. The Designer can select the appropriate steel section using these tables which ensures that the section is capable of resisting the anticipated loading with an adequate margin of safety and is economical..

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3. It removes the tedious trial and error method of design.
4. Many developed country have prepared tables for design aids as per their standard code.
5. In India there are no such types of tables according to the new IS :800 code which is based on Limit State method design.
6. Some comparison studies are prepared according to IS: 800 code and design aids table.

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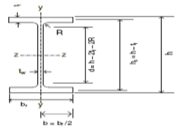
Indian Standard Narrow Parallel Flange (NPB) Sections



I.S.CODE800:2007 **compression**

NPB Section- designation	Axis	Compressive strength Pcd$_{zz}$ / Pcd$_{yy}$ for effective lengths, L$_e$ (KN) 1	2	3	4	5	6	7	8	9
NPB 200X165X48	P_{cz}	1389	1374	1333	1285	1225	1147	1048	932	812
	P_{cy}	1357	1209	1011	778	577	433	333	310	212
NPB 200X165X42.47	P_{cz}	1230	1205	1146	1080	1003	914	815	714	619
	P_{cy}	1183	1003	798	599	444	335	260		
NPB 200X165X35.68	P_{cz}	1034	1012	962	906	840	763	678	593	513
	P_{cy}	994	840	664	496	367	276	214		
NPB 200X150X30.45	P_{cz}	882	868	839	803	757	695	618	535	456
	P_{cy}	847	728	565	402	285	209			
NPB 200X130X31.55	P_{cz}	914	903	875	842	801	746	677	598	518
	P_{cy}	862	710	507	340	235				
NPB 200X130X27.37	P_{cz}	793	783	759	729	692	643	582	511	442
	P_{cy}	746	610	430	286	197				
NPB 200X100X25.09	P_{cz}	727	716	692	663	625	574	511	443	378
	P_{cy}	647	444	258	158					
NPB 200X100X22.36	P_{cz}	648	637	616	589	555	509	452	391	333
	P_{cy}	572	385	220	135					
NPB 200X100X18.42	P_{cz}	534	525	507	486	457	419	372	321	273
	P_{cy}	471	316	180	110					

1. All sections are non-slender under axial compression.
2. Indian standard parallel flange sections are from relevant code/steel table of I.S.800:2007.

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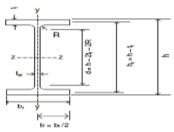
Indian Standard Wide Parallel Flange (WPB) Sections



I.S.CODE 800:2007 **compression**

WPB Section-designation	Axis	Compression resistance Pcd_{zz} / Pcd_{yy} for effective lengths, L_e (KN) 1	2	3	4	5	6	7	8	9
WPB 550x300x 278.19	P_{cz}	7732	7732	7732	7732	7668	7584	7498	7406	7309
	P_{cy}	7732	7437	6974	6425	5765	5021	4272	3596	3026
WPB 550x300x 199.44	P_{cz}	5544	5544	5544	5544	5492	5431	5367	5300	5228
	P_{cy}	5544	5317	4973	4563	4069	3518	2973	2490	2088
WPB 550x300x 166.23	P_{cz}	4621	4621	4621	4621	4575	4524	4470	4413	4352
	P_{cy}	4621	4430	4142	3799	3386	2924	2470	2067	1733
WPB 550x300x 119.98	P_{cz}	3473	3473	3473	3468	3428	3387	3344	3298	3248
	P_{cy}	3473	3299	3059	2767	2416	2040	1691	1396	1160
WPB 500x300x 270.27	P_{cz}	7512	7512	7512	7500	7413	7323	7229	7128	7018
	P_{cy}	7512	7238	6796	6276	5652	4944	4223	3566	3007
WPB 500x300x 187.33	P_{cz}	5206	5206	5206	5192	5130	5066	4998	4926	4847
	P_{cy}	5206	5001	4684	4307	3855	3347	2839	2384	2003
WPB 500x300x 155.07	P_{cz}	4309	4309	4309	4295	4244	4190	4133	4072	4006
	P_{cy}	4309	4137	3874	3560	3183	2760	2338	1962	1648
WPB 500x300x 129.77	P_{cz}	3757	3757	3757	3740	3694	3645	3594	3538	3477
	P_{cy}	3757	3593	3352	3064	2716	2332	1959	1633	1366
WPB 500x300x 107.45	P_{cz}	3111	3111	3111	3094	3055	3013	2969	2922	2869
	P_{cy}	3111	2964	2755	2503	2199	1869	1557	1291	1075

1. All sections are non-slender under axial compression.
2. Indian standard parallel flange sections are from relevant code/steel table of I.S.800:2007.