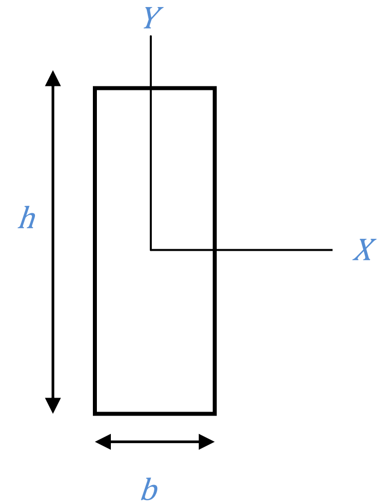
Major axis X-X

Minor axis Y-Y



$$I_x > I_y \Rightarrow r_x > r_y$$

Example:-

If b= 200 mm and h=500mm. Calculate the moment of inertia and

Radius of gyration?

$$I_x = \frac{b * h^3}{12} = \frac{200 * 500^3}{12} = 2.083 * 10^9 mm^4$$

$$I_y = \frac{h * b^3}{12} = \frac{500 * 200^3}{12} = 0.333 * 10^9 mm^4$$

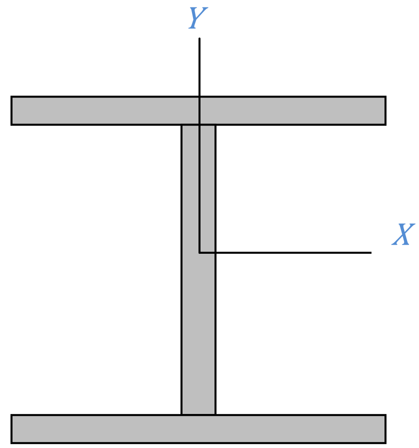
$$A = 200 * 500 = 100 * 10^3 mm^2$$

$$r_x = \sqrt{\frac{I_x}{A}} = \sqrt{\frac{2.083 * 10^9}{100 * 10^3}} = 144.34\, mm$$

$$r_y = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{0.333 * 10^9}{100 * 10^3}} = 57.74\, mm$$

Major axis X-X

Minor axis Y-Y



Euler formula:-

$$P_E = \frac{\pi^2 EI}{L^2}$$

Buckling stresses:-

$$F_{cr} = \frac{\pi^2 E}{(KL/r)^2}$$

Column formulas:-

$$\emptyset P_n = 0.85 * A_g * F_{cr}$$

If $\lambda_c > 1.5 \Rightarrow$ (Elastic buckling, long column)

$$F_{cr} = \frac{0.877}{{\lambda_c}^2} * F_y$$

If $\lambda_c \leq 1.5 \Rightarrow$ (Inelastic buckling, short and intermediate column)

$$F_{cr} = (0.658^{{\lambda_c}^2}) * F_y$$

Where

$$\lambda_c = \frac{KL/r}{\pi} * \sqrt{\frac{F_y}{E}}$$

<u>Using LRFD table to find factor tensile strength:-</u>

1. Use (KL_y) to enter the table and find $\emptyset P_n$.
2. Since (KL_y) < (KL_x) check the buckling strength about major axis.
3. $(KL)_{eq} = \frac{KL_x}{\frac{r_x}{r_y}}$
4. If $(KL)_{eq} < KL_y$ $\therefore$ Major buckling is not problem.
5. If $(KL)_{eq} > KL_y$ $\therefore$ Reenter the table and find $\emptyset P_n$ at $(KL)_{eq}$.

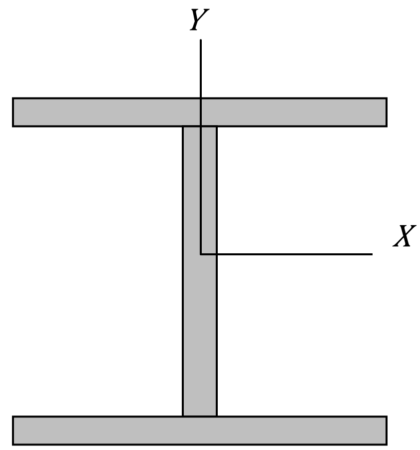
Example 1)

Determine the factor tensile strength of W 310X60. Knowing that (KL_x) =6m, (KL_y)=6m.
Given:

$A_g = 7590 mm^2$ $r_x = 130\ mm$, $r_y = 49.1\ mm$,

Neglect the effect of local buckling

Solution:-



$$(KL_x/r_x) = \frac{6000}{130} = 46.15\ mm$$

$$(KL_y/r_y) = \frac{6000}{49.1} = 122.2\ mm$$

Buckling @ Y-Y axis is critical:

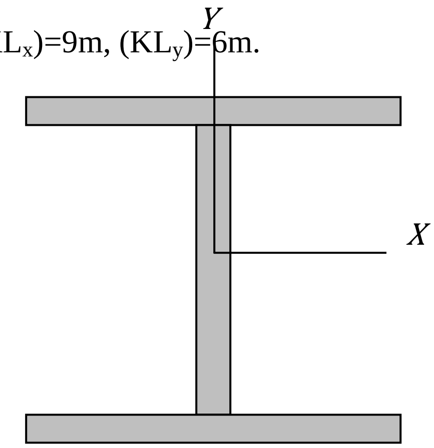
$$\lambda_c = \frac{KL_y/r_y}{\pi} * \sqrt{\frac{F_y}{E}} = \frac{69.23}{\pi} * \sqrt{\frac{250}{200000}} = 1.38 < 1.5$$

$$F_{cr} = \left(0.658^{\lambda_c{}^2}\right) * F_y = \left(0.658^{0.78^2}\right) * 250 = 113.19\ Mpa$$

$$\emptyset P_n = 0.85 * A_g * F_{cr} = 0.85 * 7590 * 113.19 * 10^{-3} = 730.25\ Kn$$

Example 2)

Determine the factor tensile strength of W 310X60. Knowing that (KL_x)=9m, (KL_y)=6m.



Given:

$A_g = 7590 mm^2$, $r_x = 130\ mm$, $r_y = 49.1\ mm$,

Neglect the effect of local buckling

Solution:-

$$(KL_x/r_x) = \frac{9000}{130} = 69.23\ mm$$

$$(KL_y/r_y) = \frac{6000}{49.1} = 122.2\ mm$$

Buckling @ Y-Y axis is critical:

$$\lambda_c = \frac{KL_y/r_y}{\pi} * \sqrt{\frac{F_y}{E}} = \frac{69.23}{\pi} * \sqrt{\frac{250}{200000}} = 1.38 < 1.5$$

$$F_{cr} = \left(0.658^{\lambda_c{}^2}\right) * F_y = \left(0.658^{0.78^2}\right) * 250 = 113.19\ Mpa$$

$$\emptyset P_n = 0.85 * A_g * F_{cr} = 0.85 * 7590 * 113.19 * 10^{-3} = 730.25\ Kn$$

<u>By using LRFD table:-</u>

At (KL_y) = 6 m⇒ $\emptyset P_n = 731\ Kn$

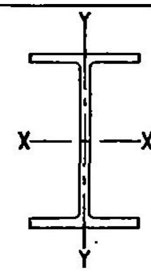
Since (KL_y) < (KL_x) check the buckling strength about major axis.

$$(KL)_{eq} = \frac{9}{2.65} = 3.4\ m$$

If $(KL)_{eq} < KL_y$ ∴ Major buckling is not problem.

$F_y = 250$ MPa
$F_y = 345$ MPa

COLUMNS
W shapes
Design axial strength in kilonewtons ($\phi = 0.85$)



Designation		W310									
kg/m		86		79		74		67		60	
F_y		250	345	250	345	250	345	250	345	250	345
Effective length KL (m) with respect to least radius of gyration r_y	0	2340	3230	2150	[redacted]	2020	2780	1810	2500	1610	2230
	2.25	2190	2940	2010	[redacted]	1810	2400	1620	2140	1440	1910
	2.50	2150	2880	1970	[redacted]	1760	2310	1580	2070	1410	1840
	2.75	2120	2810	1940	[redacted]	1710	2220	1530	1990	1370	1770
	3.00	2080	2740	1900	[redacted]	1660	2130	1490	1900	1320	1690
	3.25	2040	2670	1860	[redacted]	1610	2040	1440	1820	1280	1620
	3.50	1990	2590	1820	[redacted]	1550	1940	1380	1730	1230	1530
	3.75	1950	2500	1780	[redacted]	1490	1830	1330	1630	1180	1450
	4.00	1900	2420	1730	[redacted]	1430	1730	1280	1540	1130	1370
	4.25	1850	2330	1680	[redacted]	1370	1630	1220	1450	1080	1290
	4.50	1790	2240	1640	[redacted]	1310	1530	1160	1360	1030	1200
	4.75	1740	2150	1590	[redacted]	1240	1430	1110	1270	982	1120
	5.00	1690	2060	1540	[redacted]	1180	1330	1050	1180	931	1040
	5.50	1570	1870	1430	[redacted]	1050	1140	935	1000	829	889
	6.00	1460	1690	1320	[redacted]	981	958	825	845	731	748
	6.50	1350	1510	1220	[redacted]	814	816	720	720	637	637
	7.00	1230	1330	1110	[redacted]	704	704	621	621	549	549
	7.50	1120	1170	1010	[redacted]	613	613	541	541	479	479
	8.00	1010	1030	910	[redacted]	539	539	476	476	421	421
	8.50	909	909	814	[redacted]	477	477	421	421	373	373
	9.00	811	811	726	[redacted]	426	426	376	376	332	332
	10.00	657	657	588	[redacted]						
	11.00	543	543	486	[redacted]						
	12.00	456	456	408	[redacted]						
Properties											
u		2.41	2.22	2.39	2.16	2.85	2.51	2.79	2.37	2.69	2.22
P_{wo} (kN)		398	549	363	501	411	568	351	484	291	401
P_{wi} (kN/mm)		2.28	3.14	2.20	3.04	2.35	3.24	2.13	2.93	1.88	2.59
P_{wb} (kN)		467	548	422	496	513	603	381	447	261	307
P_{fb} (kN)		374	516	300	414	374	516	300	414	241	333
L_p (m)		3.17	2.70	3.13	2.67	2.47	2.11	2.45	2.09	2.44	2.08
L_r (m)		11.6	8.23	10.8	7.78	9.32	6.60	8.62	6.20	8.03	5.87
A (mm^2)		11000		[redacted]		9490		8510		7590	
$I_x/10^6$ (mm^4)		199		[redacted]		165		145		129	
$I_y/10^6$ (mm^4)		44.6		[redacted]		23.4		20.7		18.3	
r_y (mm)		63.7		[redacted]		49.7		49.3		40.1	
Ratio r_x/r_y		2.12		[redacted]		2.66		2.66		2.65	
$P_{ex}(KL)^2/10^3$		396		[redacted]		326		288		253	

Example 3)

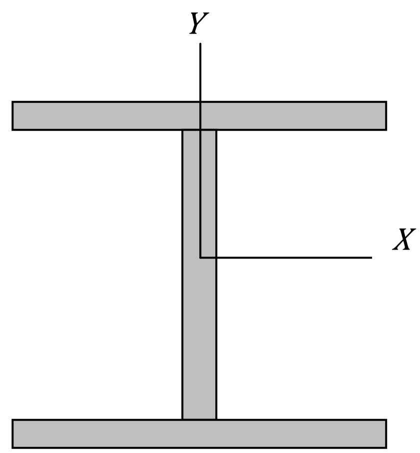
Determine the factor tensile strength of W 360X216. Knowing that (KL_x) =12m, (KL_y) =6m.

Given:

$A_g = 27600 mm^2, r_x = 161\ mm \quad , r_y = 101\ mm$,

Neglect the effect of local buckling

Solution:-



$$(KL_x/r_x) = \frac{12000}{161} = 74.53\ mm$$

$$(KL_y/r_y) = \frac{6000}{101} = 59.41\ mm$$

Buckling @ X-X axis is critical:

$$\lambda_c = \frac{KL_x/r_x}{\pi} * \sqrt{\frac{F_y}{E}} = \frac{74.53}{\pi} * \sqrt{\frac{250}{200000}} = 0.839 < 1.5$$

$$F_{cr} = \left(0.658^{\lambda_c{}^2}\right) * F_y = \left(0.658^{0.839^2}\right) * 250 = 186.202\ Mpa$$

$$\emptyset P_n = 0.85 * A_g * F_{cr} = 0.85 * 27600 * 186.202 * 10^{-3} = 4368.309\ Kn$$

By using LRFD table:-

At (KL_y) = 6 m$\Rightarrow \emptyset P_n = 4860\ Kn$

Since (KL_y) < (KL_x) check the buckling strength about major axis .

$$(KL)_{eq} = \frac{12}{1.59} = 7.54\ m$$

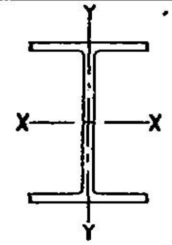
If $(KL)_{eq} > KL_y$ $\therefore$ Reenter the table and find $\emptyset P_n$ at $(KL)_{eq}$.

At $(KL)_{eq} = 7.54m \Rightarrow \emptyset P_n = 4366\ Kn$

F_y = 250 MPa

F_y = 345 MPa

COLUMNS
W shapes
Design axial strength in kilonewtons ($\phi = 0.85$)



Designation	W360									
kg/m	314		287		262		237		216	
F_y	250	345	250	345	250	345	250	345	250	345
Effective length KL (m) with respect to least radius of gyration r_y										
0	8480	11700	7780	10700	7120	9820	6400	8830	5870	8090
2.25	8270	11300	7580	10400	6940	9480	6230	8510	5710	7810
2.50	8220	11200	7540	10300	6900	9400	6190	8440	5680	7740
2.75	8160	11100	7490	10200	6850	9320	6150	8360	5640	7670
3.00	8110	11000	7440	10100	6800	9220	6100	8280	5600	7590
3.25	8040	10900	7380	9980	6750	9120	6050	8180	5550	7500
3.50	7980	10800	7320	9860	6690	9010	6000	8080	5500	7410
3.75	7900	10600	7250	9740	6630	8900	5950	7980	5450	7320
4.00	7830	10500	7180	9610	6560	8780	5890	7870	5400	7220
4.25	7750	10300	7110	9480	6490	8650	5820	7750	5340	7110
4.50	7660	10200	7030	9330	6420	8520	5760	7630	5280	7000
4.75	7570	10000	6950	9190	6350	8380	5690	7510	5220	6880
5.00	7480	9850	6860	9030	6270	8240	5620	7380	5150	6770
5.50	7290	9500	6690	8710	6100	7940	5470	7110	5010	6520
6.00	7080	9180	6500	8370	5930	7630	5360	6820	4860	6250
6.50	6870	8740	6300	8020	5740	7300	5140	6520	4710	5980
7.00	6640	8350	6090	7660	5550	6960	4960	6210	4550	5700
7.50	6400	7940	5870	7280	5340	6610	4780	5900	4380	[illegible]
8.00	6160	7530	5650	6900	5140	6260	4590	5580	4210	[illegible]
8.50	5910	7110	5420	6520	4930	5910	4390	5260	4030	4820
9.00	5660	6690	5190	6140	4710	5560	4200	4940	3850	4530
10.00	5140	5870	4720	5390	4280	4860	3800	4310	3490	3950
11.00	4630	5080	4250	4660	3840	4200	3410	3710	3130	3400
12.00	4130	4330	3790	3970	3420	3560	3030	3140	2780	2880
13.00	3640	3690	3340	3380	3010	3030	2660	2670	2440	2450
14.00	3180	3180	2920	2920	2620	2620	2310	2310	2110	2110
Properties										
u	1.95	1.93	1.96	1.93	1.94	1.92	1.94	1.92	1.93	1.90
P_{wo} (kN)	1770	2450	1530	2100	1340	1860	1110	1530	973	1340
P_{wi} (kN/mm)	6.23	8.59	5.65	7.80	5.28	7.28	4.73	6.52	4.33	5.97
P_{wb} (kN)	8160	9590	6090	7160	4960	5830	3570	4190	2740	3220
P_{fb} (kN)	2210	3040	1880	2600	1560	2150	1280	1770	1080	1490
L_p (m)	5.13	4.36	5.13	4.36	5.08	4.32	5.03	4.28	5.03	4.28
L_r (m)	34.9	23.1	32.3	21.4	29.4	19.6	26.6	17.8	24.7	16.7
A (mm²)	39900		36600		33500		30100		27600	
$I_x/10^6$ (mm⁴)	1100		997		894		788		712	
$I_y/10^6$ (mm⁴)	426		388		350		310		283	
r_y (mm)	103		103		102		101		101	
Ratio r_x/r_y	1.61		1.60		1.60		1.60		1.59	
$P_{ex}(KL)^2/10^3$ (kN-m²)	2170		1970		1760		1560		1410	
$P_{ey}(KL)^2/10^3$ (kN-m²)	836		766		688		606		556	

7.54 → 4266