Structural Steel Design Project **Calculation Sheet**	Job No:	Sheet ***1 of 6***	Rev
	Job Title: *BEAM COLUMN*		
	Worked Example - 1		
		Made by *SSSR*	Date *3-1-00*
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PROBLEM: 1

A non – sway intermediate column in a building frame with flexible joints is 4.0 m high and it is ISHB 300 @ 588 N/m steel section. Check the adequacy of the section when the column is subjected to following load:

Factored axial load = 500 kN

Factored moments:

	M_z	M_y
Bottom	*+ 7.0 kN –m*	*- 1.0 kN - m*
Top	*+ 15.0 kN – m*	*+ 0.75 kN - m*

$[\ f_y = 250\ N/mm^2\ ;\ E = 2*10^5\ N/mm^2]$

Assume effective length of the column as 3.4 m along both the axes.

CROSS-SECTION PROPERTIES:

Flange thickness = T = 10.6 mm

Clear depth between flanges = d = 300 – (10.6 * 2) = 278.8 mm

Thickness of web = t = 7.6 mm

Flange width = $2b$ = 250 mm

b = 125 mm

Area of cross-section = A_g = 7485 mm^2

C/c distance between flanges = h_f = 289.4 mm

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$R_z = 129.5\ mm$

$r_y = 54.1\ mm$

$I_z = 12545.2*10^4\ mm^4$

$I_y = 2193.6*10^4\ mm^4$

$Z_z = 836.3*10^3\ mm^3$

$Z_y = 175.5*10^3\ mm^3$

$Z_{pz} = 953.4*10^3\ mm^3$

$Z_{py} = 200.1*10^3\ mm^3$

(i) Type of section:

Table 3.1 of IS: 800

$$\frac{b}{T} = \frac{125}{10.6} = 11.8 > 10.5\varepsilon \;\&\; < 15.7\varepsilon$$

$$\frac{d}{t} = \frac{278.8}{7.6} = 36.7 < 42\varepsilon$$

$$where\ ,\varepsilon = \sqrt{\frac{250}{f_y}} = \sqrt{\frac{250}{250}} = 1.0$$

Hence, cross- section is " SEMI-COMPACT" (Class 3)

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(ii) ***Check for resistance of cross-section to the combined effects*** *for yielding:*

$f_{yd} = f_y/\gamma_a = 250/1.15$

$= 217.4\ N/mm^2$

$A_g = 7485\ mm^2$

$Z_z = 836.3*10^3\ mm^3$

$Z_y = 175.5*10^3\ mm^3$

$P = 500\ kN$

$M_z = 15\ kN\text{-}m$

$M_y = 1.0\ kN\text{-}m$

The interaction equation is:

$$\frac{P_c}{A_g f_{yd}} + \frac{M_z}{Z_z f_{yd}} + \frac{M_y}{Z_y f_{yd}} \le 1$$

$$= \frac{500\times 10^3}{7485\times 217.4} + \frac{15\times 10^6}{836.3\times 10^3\times 217.4} + \frac{1\times 10^6}{175.5\times 10^3\times 217.4}$$

$$= 0.307 + 0.083 + 0.026 = 0.416 < 1.0$$

Hence, section is O.K. against combined effects

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(iii) Check for resistance of cross-section to the combined effects for buckling:

(a) Determination of P_{dz}, P_{dy} and P_d (Clause 7.1.2) --------

$KL_y = KL_z = 3.4m$

$$\lambda_z = \frac{KL_z}{r_z} = \frac{3400}{129.5} = 26.03, \ \lambda_y = \frac{KL_y}{r_y} = 54.1 = 62.8$$

$$\lambda_1 = \pi.(E/f_y)^{1/2} = 88.857$$

Therefore, non-dimensional slenderness ratios

$$\lambda_z = \frac{\lambda_z}{\lambda_1} = 0.296 \text{ and } \lambda_y = \frac{\lambda_y}{\lambda_1} = 0.706$$

Calculation of χ :

Imperfection factors: $\alpha_z = 0.21$; $\alpha_y = 0.34$

ϕ - values:

$$\phi = 0.5[1 + \alpha(\bar{\lambda} - 0.2) + \bar{\lambda}^2]$$

$$\phi_z = 0.5[1 + 0.21(0.296 - 0.2) + (0.296)^2] = 0.554$$

$$\phi_y = 0.5[1 + 0.34(0.706 - 0.2) + (0.706)^2] = 0.835$$

χ - values:

$$\chi = \frac{1}{\phi + (\phi^2 - \bar{\lambda}^2)^{\frac{1}{2}}} \le 1.0$$

$$\chi_z = 1/[0.554 + (0.554^2 - 0.296^2)^{1/2}] = 0.978$$

$$\chi_y = 1/[1.006 + (0.835^2 - 0.706^2)^{1/2}] = 0.780$$

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Therefore,

P_{dz} *=7485 x0.978 x250 / 1.10 x 10* $^{-3}$ *=1663.7 kN*

P_{dy} *=7485 x0. 78 x250 / 1.10 x 10* $^{-3}$ *=1327.0 kN*

Therefore $P_d = P_{dy}$ **= 1327.0 kN**

(b) Determination of M_{dz}

Elastic Critical moment is given by

$$M_{cr} = \frac{\pi^2 E I_y h_f}{2 L_{LT}^2}\left[1+\frac{1}{20}\left[\frac{L_{LT}/r_y}{h_f/t_f}\right]^2\right]^{0.5}$$

$$M_{cr} = \frac{\pi^2 x 2E5x2193.6E4x289.4}{2x(3400)^2}\left[1+\frac{1}{20}\left\{\frac{3400/54.1}{289.4/10.6}\right\}^2\right]^{0.5} = 6.319x10^8\,N-m$$

$$\lambda_{LT} = \sqrt{Z_{ez}.f_y/M_{cr}} = \sqrt{836.3E3x250/6.319E8} = 0.5856$$

$$\phi_{LT} = 0.5\left[1+\alpha_{LT}\left(\lambda_{LT}-0.2\right)+\lambda_{LT}^2\right] = 0.5\left[1+0.21x\left(0.586-0.2\right)+0.586^2\right] = 0.71$$

IS: 800 (Clause 9.3.2.2 Clause 8.2.2)

[α_{LT} = 0.21]

$$\chi_{LT} = \left[\frac{1}{\left[\phi_{LT}+\left\{\phi_{LT}^2-\lambda_{LT}^2\right\}^{0.5}\right]}\right] = 0.90 \le 1.0$$

$$f_{bd} = \chi_{LT}.f_y/\gamma_m = 0.90x250/1.1 = 204.55MPa$$

$M_{dz} = Z_{ez}.f_{bd}$ ***= 836.3 x 10*** ^{3} ***x 204.55 x 10*** $^{-6}$ ***= 179.42 kN-M***

(c) Determination of M_{dy} --------

$M_{dy} = Z_{ey}.f_y/\gamma_m$ ***= 175.5 x 10*** ^{3} ***x 250 / 1.1 x10*** $^{-6}$ ***= 39.9 kN-M***

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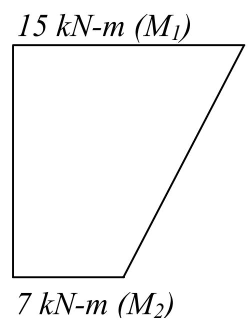
The interaction equations to be satisfied

$$\frac{P}{P_{dy}} + k_y \frac{C_{my} M_y}{M_{dy}} + k_{LT} \frac{M_z}{M_{dz}} \le 1.0$$

$$\frac{P}{P_{dz}} + 0.6 k_y \frac{C_{my} M_y}{M_{dy}} + k_z \frac{C_{mz} M_z}{M_{dz}} \le 1.0$$

(d) Determination of C_{my} -------

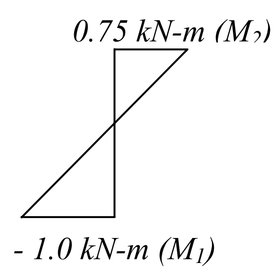


$\psi_z = M_2 / M_1 = 7/15 = 0.467$

$C_{my} = 0.6 + 0.4\,\psi \ge 0.4$

$C_{my} = 0.6 + 0.4 \times 0.467 = 0.7868 \ge 0.4$

(e) Determination of C_{mz} -------



$\psi_y = 0.75/(-1.0) = -0.75$

$C_{mz} = 0.6 + 0.4\,\psi \ge 0.4$

$C_{mz} = 0.6 - 0.4 \times 0.75 = 0.30 \approx 0.4$

(f) Determination of C_{mLT} -------

$\psi_z = M_2 / M_1 = 7/15 = 0.467$

$C_{mLT} = 0.6 + 0.4\,\psi \ge 0.4$

$C_{mLT} = 0.6 + 0.4 \times 0.467 = 0.7868 \ge 0.4$

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(g) Determination of k_z, k_y & k_{LT}------

$k_y = 1+(\lambda_y-0.2)n_y \le 1+0.8\, n_y$

$k_z = 1+(\lambda_z-0.2)n_z \le 1+0.8\, n_z$

$$k_{LT} = 1-\frac{0.1\lambda_{LT} n_y}{(C_{mLT}-0.25)} \ge 1-\frac{0.1 n_y}{(C_{mLT}-0.25)}$$

$n_y = P / P_{dy} = 500 / 1327 = 0.377$

$n_z = P / P_{dy} = 500 / 1663.7 = 0.30$

$$\lambda_z = \frac{\lambda_z}{\lambda_1} = 0.296 \ ; \lambda_y = \frac{\lambda_y}{\lambda_1} = 0.706 \text{ and } \lambda_{LT} = 0.5856$$

Therefore,

$k_y = 1 + (0.706 - 0.2) \times 0.377 = 1.19\ [\le 1.3016 = 1+0.8\, n_y]$

$k_z = 1 + (0.296 - 0.2) \times 0.30 = 1.03\ [\le 1.24 = 1+0.8\, n_y]$

$$k_{LT} = 1-\frac{0.1x0.5856x0.377}{(0.7868-0.25)} = 0.959 \ge [1-\frac{0.1x0.377}{(0.7868-0.25)} = 0.93]$$

(h) Interaction checks------

<u>Check no 1</u>

$$\frac{P}{P_{dy}} + k_y \frac{C_{my} M_y}{M_{dy}} + k_{LT} \frac{M_z}{M_{dz}}$$

$$= \frac{500}{1327} + 1.19x\frac{0.7868x1.0}{39.9} + 0.93x\frac{15}{179.42}$$

= 0.3767 + 0.023 + 0.077 = 0.478 < 1.0

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Check no 2

$$\frac{P}{P_{dz}} + 0.6 k_y \frac{C_{my} M_y}{M_{dy}} + k_z \frac{C_{mz} M_z}{M_{dz}} \leq 1.0$$

$$= \frac{500}{1663.7} + 0.6x1.19x\frac{0.7868x1.0}{39.9} + 1.03x\frac{0.4x15}{179.42}$$

= 0.30 + 0.014 + 0.034 = 0.348 < 1.0