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Question-1 :

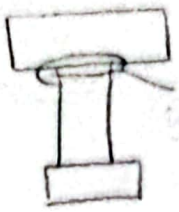
1- Areas and Centroid ($\bar{y}$)

$A_f = b_f \cdot t_f = 300 \cdot 20 = 6000 mm^2$

$A_{web} = t_w \cdot h_w = 10 \cdot 760 = 7600 mm^2$

$A_{bottom} = 100 \cdot 20 = 2000 mm^2$

$A = 6000 + 7600 + 2000 = 15600 mm^2$

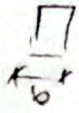


$$\bar{y} = \frac{6000 \cdot 10 + 7600 \cdot 400 + 790 \cdot 2000}{15600} = 300 mm$$

1.2 - Moment of Inertia :

Elastic Section Modulus : $We = \frac{I}{c}$

$I = I_0 + Ad^2$



$\frac{bh^3}{12} = I$

$I_{x,ft} = \frac{300 \cdot 20^2}{12} = 2105$ [mm^4]

$I_{x,ow} = \frac{10 \cdot 760^2}{12} = 3,658 \cdot 10^8$

$I_{x,ob} = \frac{100 \cdot 20^3}{12} = 6,67 \cdot 10^4 mm^4$

$Ad^2 = 6000 \cdot 290^2 = 50416 \cdot 10^6$

$Ad^2 = 7600 \cdot 100^2 = 76 \cdot 10^6$

$Ad^2 = 2000 \cdot 480^2 = 480,2 \cdot 10^6$

$$I_x = 1,4268 \cdot 10^9$$

1.3 Elastic Section Module and elastic moment capacities :

$$We,top = \frac{I_x}{300} = 4756\ 10^6\ mm^3$$

$$We,bottom = \frac{I_x}{500} = 2,854 \cdot 10^6\ mm^3$$

$$M_{e,x} = \sigma_y \cdot We_{bottom} = 355 \cdot 2854\ 10^6 = 1,1013 \cdot 10^9\ N/mm = 1013\ kN/m$$

1.4 Plastik Neutral Axis (PNA) and Plastic Section modulus $W_{p,x}$

PNA is located so that compression area = tension area = $A/2 = 7800 mm^2$

Accumulating area from the top :

Top flange gives 6000

Need = 7800 - 6000 = 1800 more = $10 \cdot t \Rightarrow t = 180$ mm of web

Hence PNA is 200 mm below the top (70+180)

Compression above PNA

- Top flange $A = 6000$, centroid $200 - 10 = 190 \rightarrow 6000 \cdot 190$.
- Top web part $A = 10 \cdot 180 = 1800$ centroid distance $= 90. \rightarrow 1800 \cdot 90$

$Q_c = 1.302.000\ mm^3$

Tension (Below PNA)

- Bottom web part; $A = 10 \cdot 580 = 5800$, centroid d. $= 290 \rightarrow 5800 \cdot 290$
- Bottom flange $A = 2000$ centroid dis. $= 590 \rightarrow 590 \cdot 2000$

$Q_t = 2.862.000\ mm^3$

Plastic modulus (x-axis):

$$W_{p,x} = Q_c + Q_t = 4.164 \cdot 10^6\ mm^3$$

Plastic moment:

$$M_{p,x} = f_y \cdot W_{p,x} = 355 \cdot 4{,}164 \cdot 10^6 = 1{,}478 \cdot 10^9 = 1478\ kNm$$

Shape factor (k):

$$\frac{W_{px}}{W_{e,bot}} = \frac{4.164}{2854} = 1.459 > 1 \ \checkmark$$

Weak-axis (y) properties

2.1) $I_{y,top} = 20\,300^3/12 = 45.10^6$

$I_{y\,web} = 760\,10^3/12 = 631333$

$I_{y\,bot} = 20 \cdot 100^3/12 = 1{,}67 \cdot 10^7$

$\Big\} \; I_y = 4{,}673 \cdot 10^7\ mm^4$

2.2) Elastic and plastic modulus about y

$$W_{e,y} = I_y / c_y = \frac{4{,}673 \cdot 10^7}{150} = 3{,}115 \cdot 10^5\ mm^3$$

Plastic moduls about y (rectangle short axis) $\left[Z_y = \frac{tb^2}{4}\right]$

$$Z_y = \frac{20\,300^2 + 20 \cdot 100^2 + 760\,10^2}{4} \quad 5119 \cdot 10^5\ mm^3$$

$$M_{ey} = f_y \cdot W_{ey} = 355 \cdot 31115 \cdot 10^5 = 1{,}106 \cdot 10^8 = 110.6\ kNm$$

$$M_{py} = f_y \cdot W_{py} = 355\ 5{,}19 \cdot 10^5 = 1.842 \cdot 10^8 = 184.2\ kNm$$

$$k = \frac{W_{py}}{W_{ey}} = \frac{5{,}19}{3{,}115} = 1{,}67$$

Question - 2

TUBO 323 12:

$D_o = 323\,mm \rightarrow R_o = 161,5\,mm$

$t = 12\,mm \rightarrow R_i = 149,5\,mm$

$I_{tubo} = \frac{\pi}{3}(R_o^4 - R_i^4) = 1,0186 \cdot 10^8\,mm^4$

$W_{p\,tubo} = \frac{4}{3}(R_o^3 - R_i^3) = 1161\,10^6\,mm^3$

UPE 300

$A = 5660\,mm^2$

$I_x = 3,24 \cdot 10^7\,mm^4$

$I_y = 1,52 \cdot 10^6\,mm^4$

$W_{ex} = 2,16 \cdot 10^5\,mm^3$

Horizontal CG ofset

$$x_c = R_o + 28,9 + 27,5 = 217,9\,mm$$

Moments of inertia :

$$I_x = I_{tube} + 2I_{upe} = 1,0196 \cdot 10^8 + 2 \cdot (3,24 \cdot 10^7) = 2,0676 \cdot 10^8$$

$$I_y = I_{y\,tube} + 2(I_{yupe} + A x_c^2) =$$

$$1,0196 \cdot 10^8 + 2(1,52 \cdot 10^6 + 5660\,(718,9^2)) = 6,874\,10^8\,mm^4$$

Elastic Section Module $W_e = I/c$

Extreme fibers

$c_x = 161,5\,mm \qquad c_y = (217,9 + 50) = 267,9\,mm$

$$W_{e,x} = \frac{2,0676 \cdot 10^8}{161,5} = 1,2803 \cdot 10^6\,mm^3$$

$$W_{e,y} = \frac{6,8748 \cdot 10^8}{267,9} = 2,5675 \cdot 10^6\,mm^3$$

Plastic section Modul W_p

X-axis : use tube W_p + 2 (UPE strong axis W_{px})

$$W_{px} = 1,161 \cdot 10^6 + 2 \cdot (2,419 \cdot 10^5) = 1,6448 \cdot 10^6\,mm^3$$

approximate value

Y-axis

$$W_{py} = 1,161 \cdot 10^6 \cdot 10^6 + 2 \cdot (5660 \quad 217,9) = 3,6276 \cdot 10^6\,mm^3$$

Capacities

$M_e = f_y W_e \qquad M_p = f_y \cdot W_p \qquad k = \frac{W_p}{W_e}$

	W_e (mm^3)	W_p (mm^3)	M_e (kNm)	M_p (kNm)	k
X	$1,2893 \cdot 10^6$	$1,6548 \cdot 10^6$	454,51	583,19	1,285
Y	$2,5435 \cdot 10^6$	$3,6276 \cdot 10^6$	924,37	1287,81	1,424

Question 3

Geometry and Positions

TUBE : $D_o = 323 \rightarrow R_o = 161,5$ $t = 12mm$ $R_i = 149,5$ $I_{tube} = 1,4186 \cdot 10^8$

UPE : $A = 5660\ mm^2$

$I_x = 3,24 \cdot 10^8\ mm^2$

$I_y = 1,52 \cdot 10^6\ mm^2$

Vertical centroid spacing :

$y_c = 161,5 + 28,9 = 190,4mm$

Centroid of the build up section is at the tube center (0,0)

Moment of Inertias :

$I_x = I_{tube} + 2(I_{xupe} + A y_c^2)$

$1,4186 \cdot 10^8 + 2 \cdot (3.24 \cdot 10^7 + 2.052 \cdot 10^8) = 6,17 \cdot 10^8\ mm^4$

$I_y = I_{tube} + 2I_{upe} = 1,4186\ 10^8 + 2(152 \cdot 10^6) = 1,45 \cdot 10^8\ mm^4$

Elastic Section Modules; $W_e = I/c$

x-axis extreme fiber is the top of the UPE

$c_x = y_c + \frac{h}{2} = 190,4 + 150 = 340,4mm$

$W_{ex} = \frac{6.17 \cdot 10^8}{340,4} = 1,81 \cdot 10^6\ mm^3$

Y-axis extreme half-width governed by the tube radius

$c_y = 161,5 \qquad W_{ey} = \frac{1,45 \cdot 10^8}{161,5} = 8,97 \cdot 10^5\ mm^3$

Plastic Section Moduls Wp

x-axis .. $A_{yc} = 5660 \quad 190.4 \cong 1.078 \cdot 10^6 \quad W_{px} = W_{plube} + 2A_{yc}$

$$W_{px} = 1.161 \cdot 10^6 + 2 \cdot (1.078 \cdot 10^6) = 3.32 \cdot 10^6 \text{ mm}^3$$

Y-axis:

$$W_{py\,upe} = 2 \cdot \left(\frac{t_f \cdot b^2}{4} \right) + \frac{h_i \cdot t_w^2}{4} = 75.000 + 6.092 = 81.092 \text{ mm}^3$$

$$W_{py} = W_{plube} + 2W_{py\,upe} = 1.161 \cdot 10^6 + 2 \cdot (81.092) = 1.32 \cdot 10^6 \text{ mm}^3$$

Capacities and Shape factors

$M_e = f_y \cdot W_e$, $M_p = f_y \cdot W_p$ $\qquad \phi = \frac{W_p}{W_e}$

	W_e (mm^3)	W_p (mm^3)	M_e (kNm)	M_p (kNm)	k
X	$1.81 \cdot 10^6$	$3132 \cdot 10^6$	643	1178	1.83
Y	$8.97 \cdot 10^5$	$1.32 \cdot 10^6$	318	469	1.47