1. Design a welded plate of girder of span 24 m laterally restrained throughout. It has to support a uniform span exclusive of self weight. Design the girder width of intermediate transverse stiffeners, steel for the flange & web plate is of grade Fe 410. Design the cross section, and load bearing stiffeners and connection.

Soln.

For Fe 410

f_y = ~~410~~ 250 Mpa, f_u = 410 Mpa

$\mu = 0.3$, $E = 2 \times 10^5$ N/mm^2.

L = 24 m.

1. Design force:

Total superimposed load = 100 kN/m.

Factored load = 1.5 × 100 = 150 kN/m.

Assume,

Self wt. of plate girder $= \frac{WL^2}{400}$

$= \frac{100 \times 24^2}{400}$

= 144 kN.

self wt. of plate 1 m length $= \frac{144}{24} = 6$ kN/m

Factored self wt $= 1.5 \times 6$

$= 9$ kN/m.

Total factored load,

$= 150 + 9$

$w = 159$ kN/m.

Max. Bending moment $= \frac{wl^2}{8}$

$= \frac{159 \times 24^2}{8}$

$$\boxed{M_u. = 11448 \text{ kN m.}}$$

Max. Shear force.

$= \frac{wl}{2} = \frac{159 \times 24}{2}$

$$\boxed{V_u. = 1908 \text{ kN.}}$$

2. Design of web:

$$\boxed{\left.\begin{array}{l}\text{Optimum depth}\\ \text{of plate girder}\end{array}\right\} = d = \left(\frac{M_z K}{f_y}\right)^{0.33.}}$$

Intermediate transverse stiffeners are not provided in the given problem.

From [cl: 8.6.1.1 (b3) IS-800]

$\frac{d}{t_w} \leq 200\ \varepsilon.$

(ie)., 200 serviceability criteria)

from [cl: 8.6.1.2 (64). IS-800]

$$\frac{d}{t_w} \leq 345\, \varepsilon_f^2 .$$

[ie).., 345 - flange buckling criteria]

Let us assume

$$K = \frac{d}{t_w} = 180.$$

$$\therefore \quad d = \left[\frac{11448 \times 10^6 \times 180}{250}\right]^{0.33}$$

$$= 1871.9 \text{ mm}$$

$$\therefore \boxed{d = 1800 \text{ mm}}$$

∴ Optimum thickness of web

$$t_w = \left[\frac{M_z}{f_y K^2}\right]^{0.33}$$

$$= \left[\frac{11448 \times 10^6}{250 \times 180^2}\right]^{0.33}$$

$$t_w = 10.95 \quad \simeq 12.\text{mm} \quad \simeq 16 \text{ mm}$$

$$\therefore \boxed{t_w = 16 \text{ mm.}}$$

∴ Provide size of web plate

$= (1800 \times 16)$ mm.

3. Design of flange:

Let us assume bending moment will be resisted by flanges and shear by web.

∴ Required area of flange

$$\boxed{A_f = \frac{M_z \gamma_{mo}}{f_y d}}$$

$$= \frac{11448 \times 10^6 \times 1.1}{250 \times 1800.}$$

$$\boxed{A_f = 27984 \text{ mm}^2}$$

Assume thickness of flange

$$b_f = 0.3 \times d$$

$$b_f = 0.3 \times 1800$$

$$\boxed{b_f = 560 \text{ mm}}$$

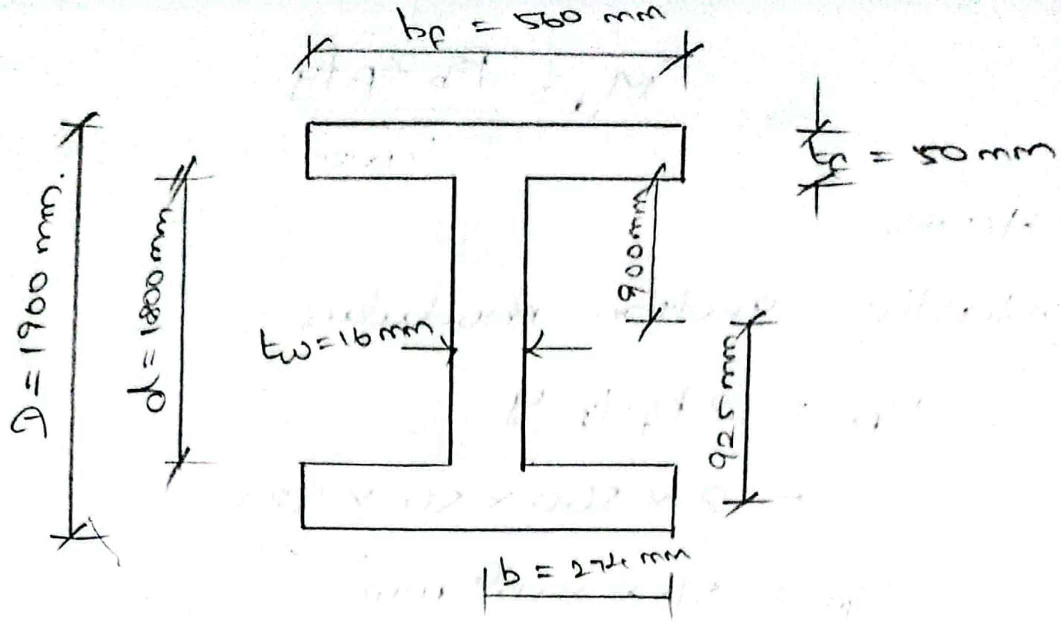
WKT,

$$A_f = b_f \times t_f.$$

$$\therefore t_f = \frac{A_f}{b_f} = \frac{27984}{560} = 49.97$$

$$\therefore \boxed{t_f \simeq 50 \text{ mm}}$$

∴ Size of flange = (560 × 50) mm.



4. Classification of flange

For flanges, take section as plastic

From [Tab-2 IS-800]

$$\frac{b}{t_f} < 8.4\ \varepsilon_f$$

where,

$$b = \frac{b_f - t_f}{2} = \frac{560-50}{2} = 274 \text{ mm.}$$

Therefore,

$$\frac{b}{t_f} = \frac{274}{50} = 5.44 < 8.4\ \varepsilon_f \quad (\because \varepsilon = 1$$

∴ The flange is plastic.

5. Check for Bending strength:

[cl: 8.2.1.2 (53) IS-800]

Now,

[Cl: 8.4.2.2 (59,60) IS-800]

$$V_n = V_{cr}.$$

where,

$$V_{cr} = A_v \tau_b$$

τ_b is shear stress. It depends λ_w.

$$\lambda_w = \sqrt{\frac{f_y}{\sqrt{3}\,\tau_{cr}}}$$

Here, Cl: 8.4.2.2 (60)

$$\tau_{cr} = \frac{K_v \pi^2 E}{12(1-\mu^2)\left(\frac{d}{t_w}\right)^2}$$

$$= \frac{5.35 \times \pi^2 \times 2\times10^5}{12(1-0.3^2)\left(\frac{1800}{16}\right)^2}$$

$\tau_{cr} = 76.41$ N/mm²

Now,

$$\lambda_w = \sqrt{\frac{250}{\sqrt{3}\times 76.41}} = 1.37. > 1.2. \text{ (case-3)}$$

$$\therefore \tau_b = \frac{f_y}{\sqrt{3}\,\lambda_w^2} = \frac{250}{\sqrt{3}\times 1.37^2} = 76.9 \text{ N/mm}^2$$

Now,

$$V_{cr} = A_v \times \tau_b = (16\times1800)\times 76.9$$

$$V_{cr} = 2214.7 \text{ KN} > 1908 \text{ KN}$$

∴ Section is safe.

7. End bearing stiffener:

[Cl: 8.7.4 (67) IS-800]

$V_u < F_w$ (Local capacity of web).

$$F_w = \frac{(b_1 + n_2)\, t_w f_{yw}}{\gamma_{m0}}$$

where,

$b_1 = 125$ to 150 (assume)

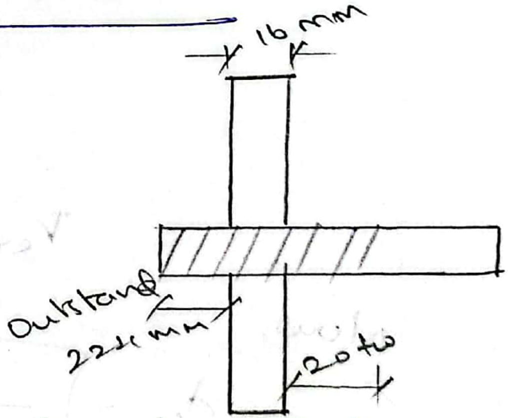
$n_2 = t_f \times 2.5 = 50 \times 2.5$

$= 125$

Now

$$F_w = \frac{(125 + 125) \times 16 \times 250}{1.1}$$

$F_w = 909.09$ kN



Here, $F_w < V_u$

∴ End stiffener must be provided.

[Cl: 8.7.1.2 (65) IS-800]

Max. Permissible outstand

$$= 20 \overset{\rightarrow \text{tks of stiffenner}}{t_q} \varepsilon_1 = 20 \times 16 \times 1$$

$= 320$ mm.

Max. Effective outstand,

$$= 14 t_q \varepsilon = 14 \times 16 \times 1$$

$$= 224 \text{ mm}.$$

∴ (16 mm stiffener provided in both sides)

∴ Take outstand = 224 mm.

∴ Provide (224×16) mm as outstand.

8. Check for buckling of stiffener:

Buckling resistance F_{qd} based on design compressive stress

$$F_{qd} = A_e \times f_{cd}$$

A_e = eff. area of stiffener

$$= [(2 \times 224 \times 16) + (2 \times 20 t_w \times 16)]$$

$$A_e = 17408 \text{ mm}^2$$

$$\lambda = \frac{l_e}{r_{min}} \qquad \because l_e = 0.7 d = 0.7 \times 1800 = 14.41$$

$$r_{min} = \sqrt{\frac{I_{min}}{A}}$$

$$I_{min} = 2\left[\frac{bd^3}{12} + A\bar{y}^2\right]$$

$$= 2\left[\frac{16 \times 224^3}{12} + (16 \times 224) \times (120)^2\right]$$

$$I_{min} = 13319.1 \times 10^4 \text{ mm}^4$$

$$r_{min} = \sqrt{\frac{13319.1 \times 10^4}{17408}} = 87.47 \text{ mm}$$

$$\lambda = \frac{14.41}{87.47} = 14.41$$

Tab - 9(c) (42) IS - 800

$$f_{cd} = 225.67 \text{ N/mm}^2.$$

Buckling resistance

$$P_d = A_c \times f_{cd}$$
$$= 17408 \times 225.67$$
$$= 3928.46 \times 10^3 \text{ N.} > 1908 \text{ kN.}$$

∴ stiffener is safe in compression

11. Connection:

Provide 5 mm fillet weld to end bearing stiffener with web plate.