Design of laterally unsupported beam:
(Working stress method)

(i) If the compression flange of the beam is not restrained laterally then it is called laterally unsupported beam, since there is possibility of buckling of compression flange.

$$\sigma_{bc} = 0.66\, f_y$$
$$= \frac{0.66\, f_{cb}\, f_b}{\left[(f_{cb})^n + (f_y)^n\right]^{1/n}}$$
} whichever is less.

n - imperfection factor = 1.4.

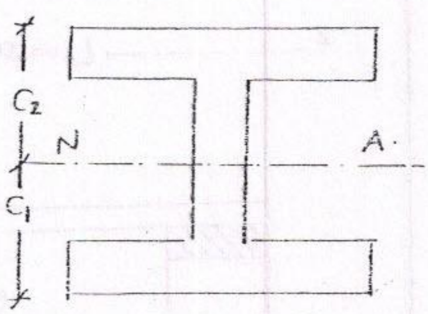
f_{cb} - Euler's elastic critical state in bending

$$f_{cb} = k_1 (X + k_2 Y) \frac{c_2}{c_1}$$

X and Y values are dependant on $\left(\frac{D}{T}\right)$ and $\left(\frac{l}{r_y}\right)$

where, D - overall depth of beam
T - mean thickness of compression flange
l - eff. length of compression flange of bea
r_y - radius of gyration about Y-axis.
c_1, c_2 - distances from N.A. to extreme fibres

for symmetric c/s $\frac{c_2}{c_1} = 1$

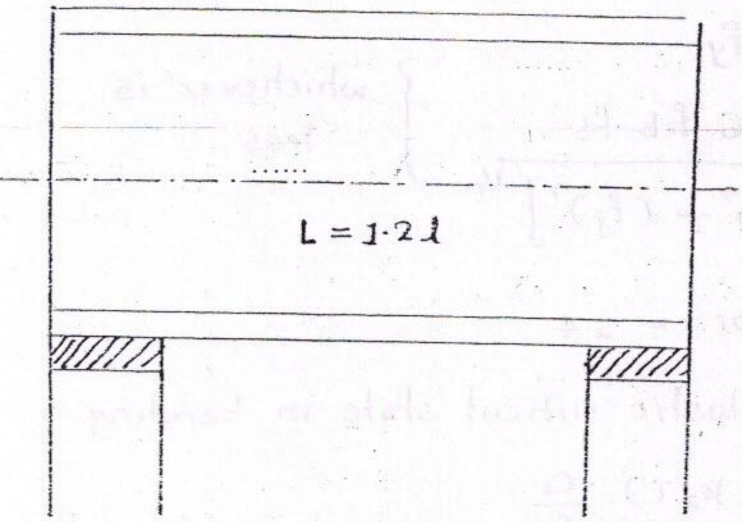


(ii) Effective length of compression flange of beam.

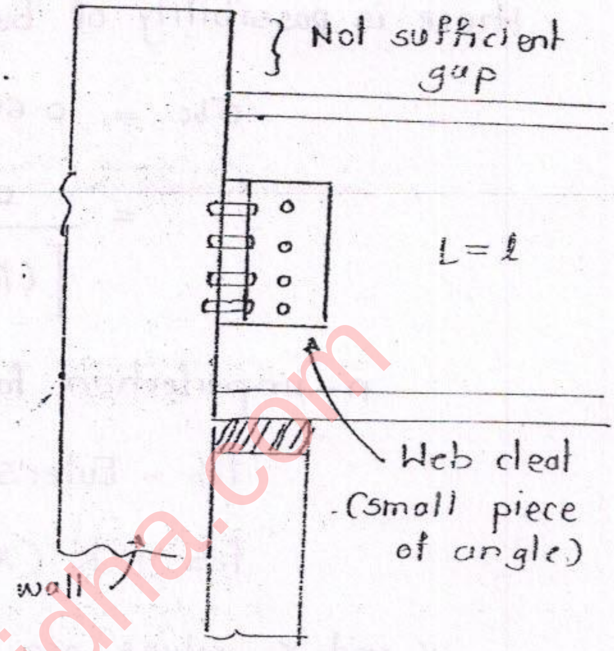
(a) Effective length of compression flange depends on warping restraint and torsional restraint provided at the ends of the beam.

(b) Warping restraint prevents rotation of flange in its plane.

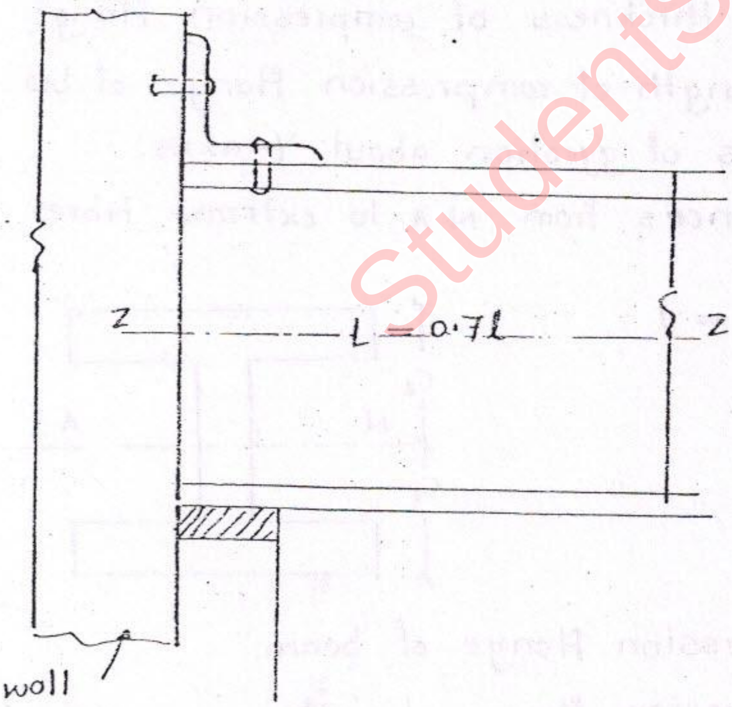
(c) Torsional restraint prevents rotation of beam about its longitudinal axis.



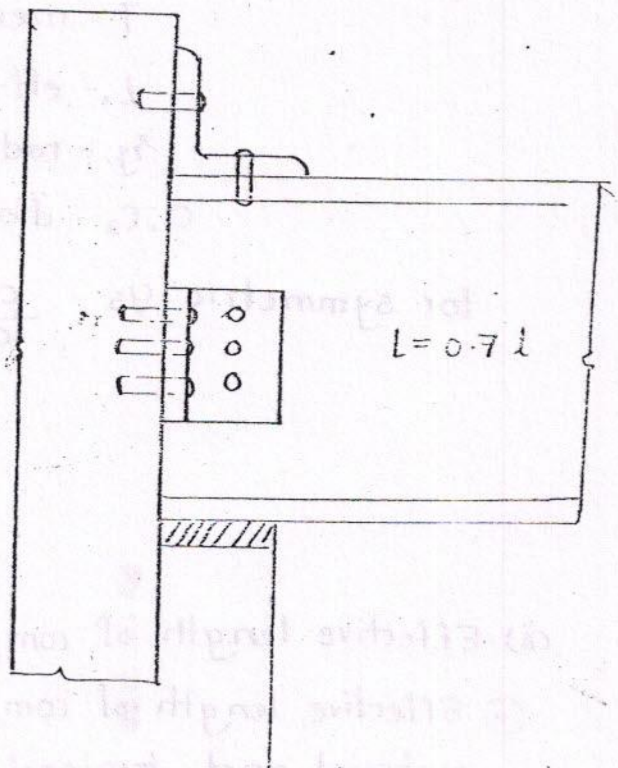
No warping restraint and no torsional restraint.



Torsional restraint provided but not warping restraint.



Warping and torsional restraint provided



Warping and torsional restraint provided.

Note:

- (i) If flange cleat alone is provided, it will act as torsional restraint and warping restraint.
- (ii) Torsion restraint can also be provided by bearing stiffners or extending beam into supports or walls.
- (iii) If torsional restraint is provided and warping restraint is not provided then effective length of compression flange ($L = l$)
- (iv) If warping and torsional restraint are provided... then the effective length of compression flange, $L = 0.7\,l$.
- (v) If warping and torsional restraint are not provided then effective length is increased by 20%. i.e $L = 1.2\,l$.

Q. An ISMB 600 @ 1.23 kN/m is supported over an effective span of 9m. Two floor joists (light beams) transmits floor loads at a distance of 1.5m on either side of span mid. Determine the safe load which the two floor joists can transmit on the beam if the beam is restrained laterally by floor joisk effectively.

Given: ISMB 600:

$D = 600$ mm

$b_f = 210$ mm

d_1 = clear depth of web = 558.4 mm

(depth of beam between toes of fillet

$t_f = 20.8$ mm

$t_w = 12$ mm

$r_{yy} = 41.2$ mm

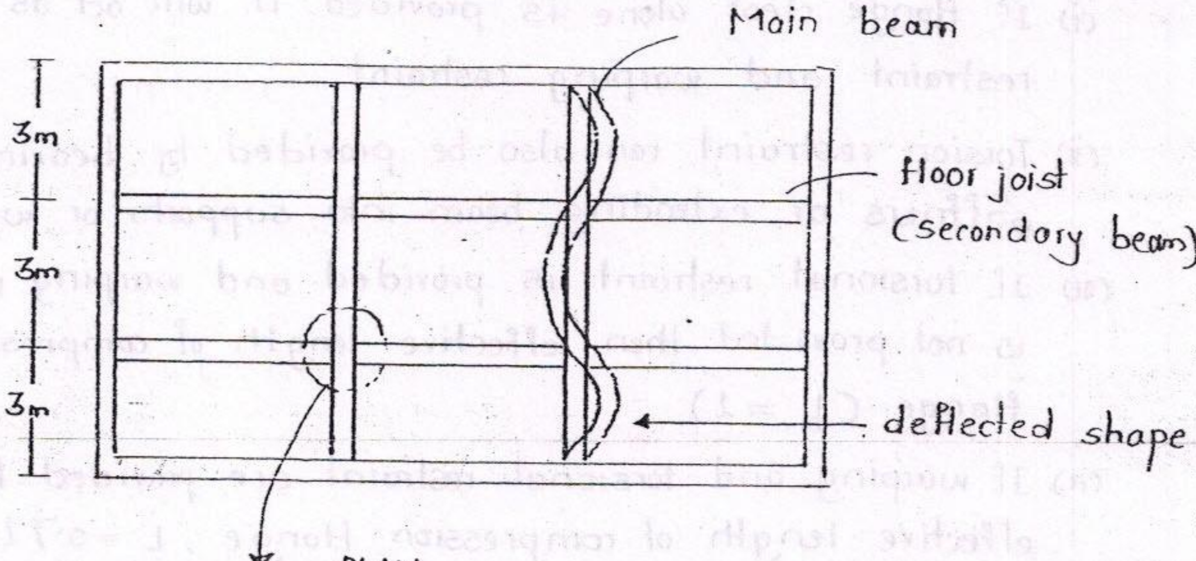
$Z_{xx} = 3060 \times 10^3$ mm^3

$Z_{YY} = 252 \times 10^3$ mm^3

σ_{bc} for $\frac{t_f}{t_w} < 2$, $\frac{d_1}{t_w} < 85$ are given as

$\frac{l}{r_y}$ \ D/t_f	20	25	30	35
65	148	147	146	146
70	146	144	143	142
75	143	141	140	139

(7)



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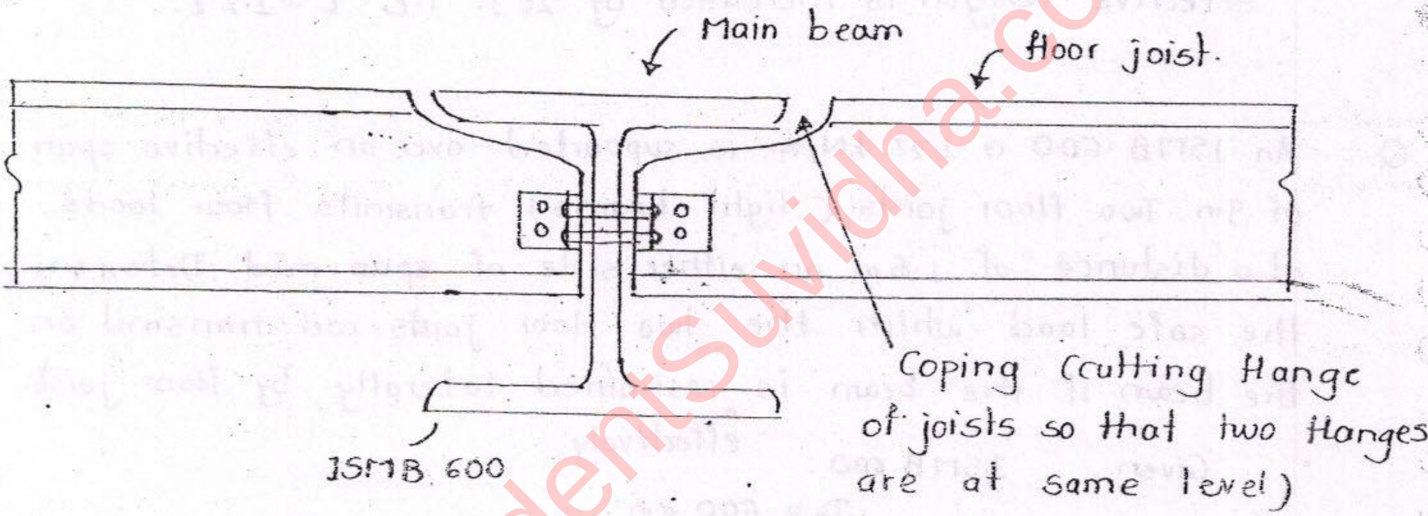


Framed connection

Analysis:

(i) M.R. of beam section

$$M.R. = \sigma_{bc} \times Z$$

$$Z = Z_{xx} = 3060 \times 10^3 \ mm^3$$

σ_{bc} depends on $\frac{l}{r_y}$ and $\frac{D}{t_f}$

$$\frac{t_f}{t_w} = \frac{20.8 \ mm}{12} = 1.73 \quad (< 2)$$

$$\frac{d_1}{t_w} = \frac{558.4}{12} = 46.5 \quad (< 85)$$

So we can use given table to find σ_{bc}

Effective length of compression flange = L = 3m

(Because floor joists provide torsional restraint but not warping restraint. So L = l = 3m - distance between joists)

$$\frac{l}{r_y} = \frac{3000}{41.2} = 72.81$$

$$\frac{D}{t_f} = \frac{600}{20.8} = 28.85$$

For $\frac{D}{t_f} = 25$. $\quad \sigma_{bc} = 144 - \frac{2.81}{5}(144-141)$

$= 142.314$ MPa.

For $\frac{D}{t_f} = 30$. $\quad \sigma_{bc} = 143 - \frac{2.81}{5}(143-140)$

$= 141.314$ MPa

For $\frac{D}{t_f} = 28.85$, $\quad \sigma_{bc} = 142.314 - \frac{3.85}{5}(142.314 - 141.314)$

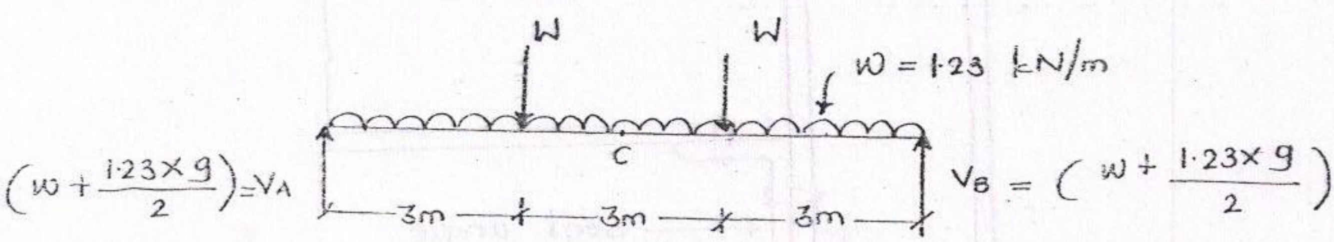
$= 141.55$ MPa.

$\therefore$ M.R. $= \sigma_{bc} \times Z$

$= 141.55 \times 3060 \times 10^3$

$= 433.14$ kNm.

(ii) Max. B.M. in the beam :



(Since structure and loading are symmetrical, reactions are equal and max. B.M. is at centre)

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Max. B.M. @ centre $= V_B \times 4.5 - w \times 1.5 - (1.23 \times 4.5) \times \frac{4.5}{2}$

$= (3W + 12.43)$ kNm

↑ forces, + B.M

↓ forces, − B.M

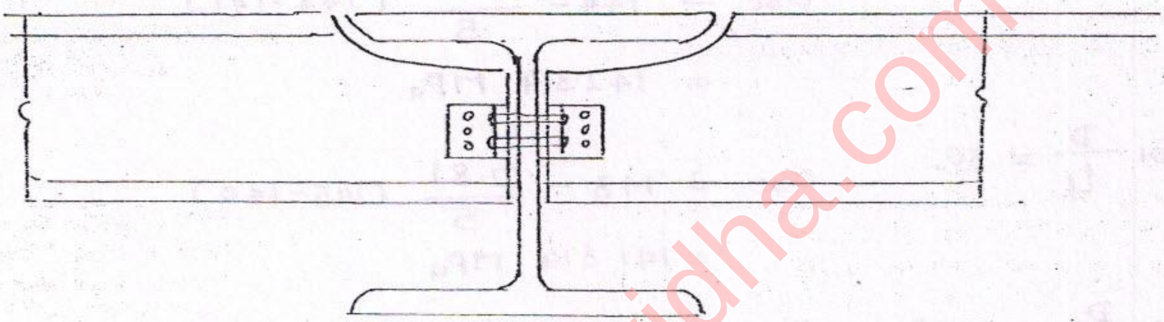
$$3W + 12.43 = 433.14$$

$$W = 140.48 \text{ kN}$$

Types of connections :

(i) Framed connections :

If connection is made on the both sides of web, it is called Framed connection.



(ii) Seated connection :

If angles are used at top and bottom, it is called seated connection.