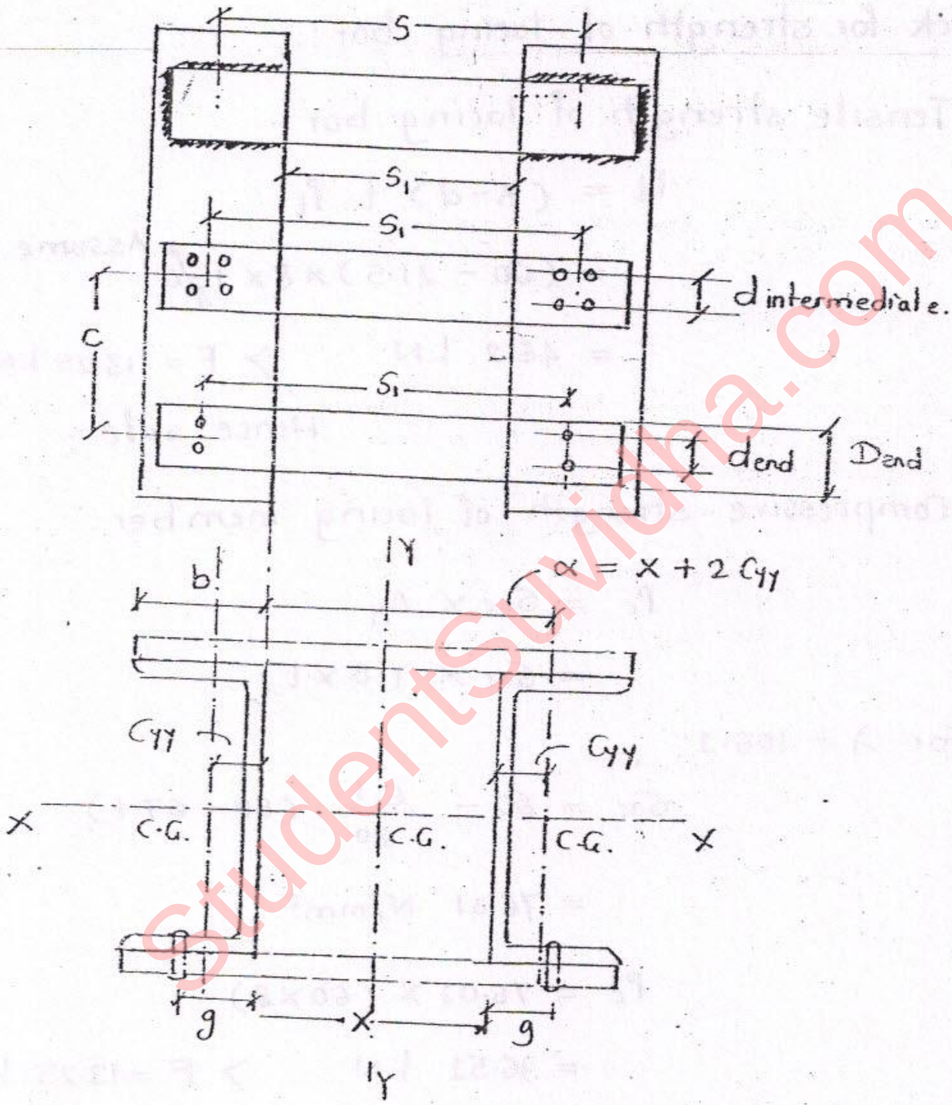
Designing of Battening :

(i) Battening is also method of connecting elements of a built up column.

(ii) Battens are designed as framed elements. i.e. these members are subjected to B.M. also.



where

x - clear distance between column components.

C_{YY} - centroidal distance of component from back of channel.

b - width of column component.

g - gouge distance (where rivets are provided assume 'g' if not given) α- centroidal distance between column components $(X + 2C_{YY})$

S_1 - distance between innermost connecting lines of rivets or welds.

S - distance between C.G. of rivet group in transverse directions

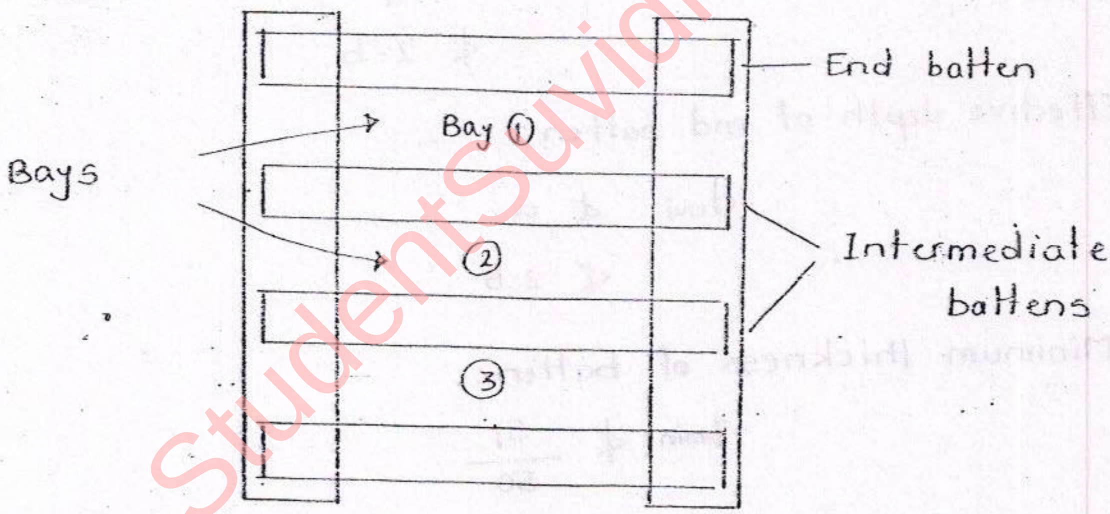
C - spacing of battens in longitudinal direction.

Note:

If there is only one row of rivets

$S = S_1$ as shown in fig.

(iii)



The minimum no. of battens is 4 so that column is divided into minimum of 3 bays.

(iv) If battens are used, then the effective length of a column is increased by 10%. (To take care of shear deformation effects in the column)

By increasing the effective length of the column by 10% we are reducing the load carrying capacity of a column. The additional load developed due to longitudinal shear can be accomodated effectively by reducing L.C.C.

(v) Provide the battens on opposite sides of column such that they are mirror image of each other.

Because if the battens are provided at same level, then analysis will become simple i.e the transverse shear force 'V' is shared by all the battens equally.

(vi) To prevent buckling of individual components between the battens following condition is satisfied:

$$\left(\frac{c}{r_{min}}\right)_{component} \ngtr 50$$

$$\ngtr 0.7\ (\lambda_{column})$$

(vii) Effective depth of intermediate batten

$$d_{intermediate} \nless \frac{3}{4} a$$

$$\nless 2 \cdot b.$$

(viii) Effective depth of end batten:

$$d_{end} \nless a$$

$$\nless 2 \cdot b$$

(ix) Minimum thickness of batten:

$$t_{min} \nless \frac{S_1}{50}$$

(x) Overall depth of end batten:

$$D_{end} = d_{end} + 2\,(\text{edge distance})$$

If welding is done

$$D_{end} = d_{end}.$$

(xi) Forces in battens.

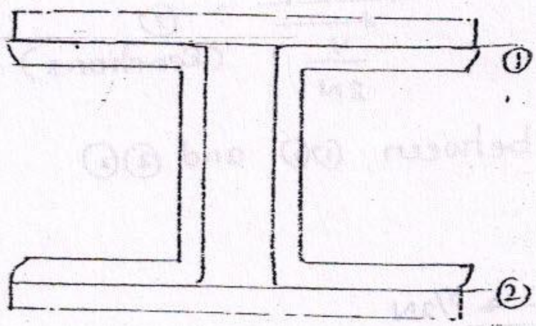
ⓐ Batten is designed as a framed member i.e. moments are also developed in battens but in lacing members moments are zero i.e. they were designed as truss members.

(b) Battens are designed to resist the transverse shear force of

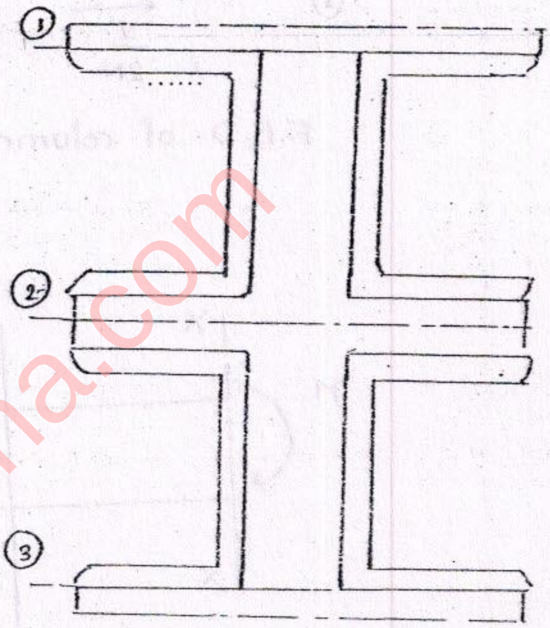
$$V = 2.5\ \%\ \text{column load}.$$

(c) Transverse shear force, V is shared by the parallel planes of battens equally

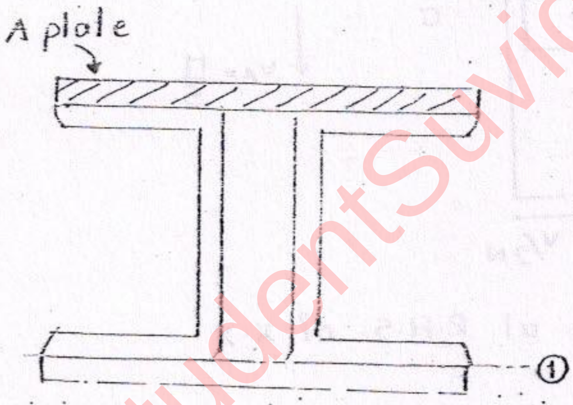
e.g.



No. of parallel planes - 2



No. of parallel planes - 3

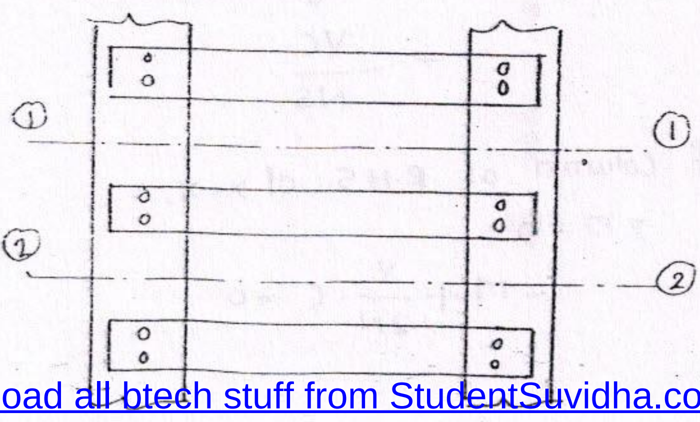


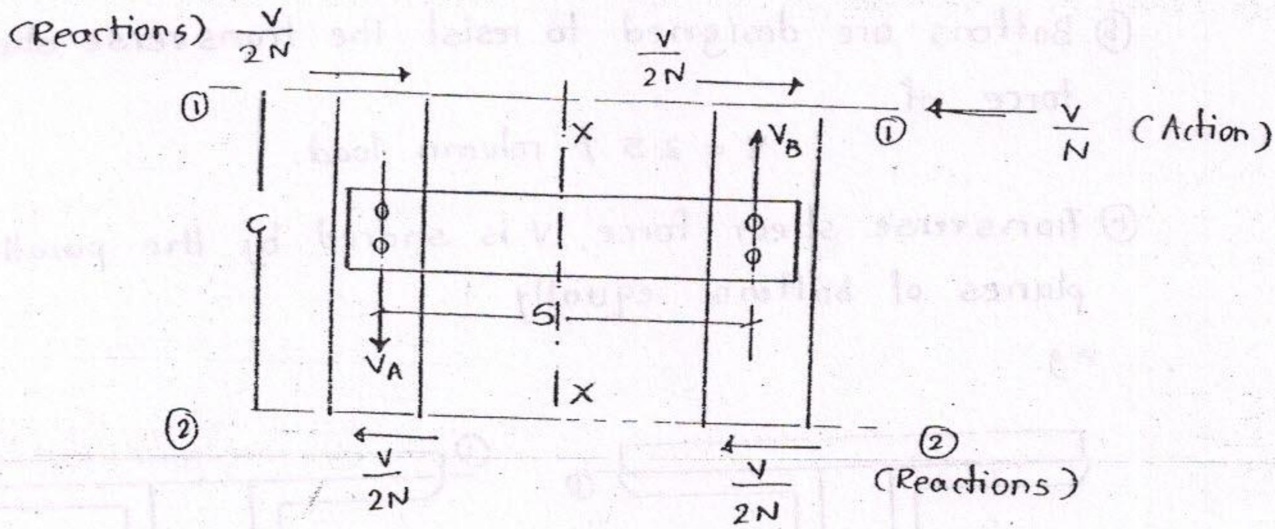
No. of parallel plane - 1

∴ Transverse shear force on each batten $= \frac{V}{N}$.

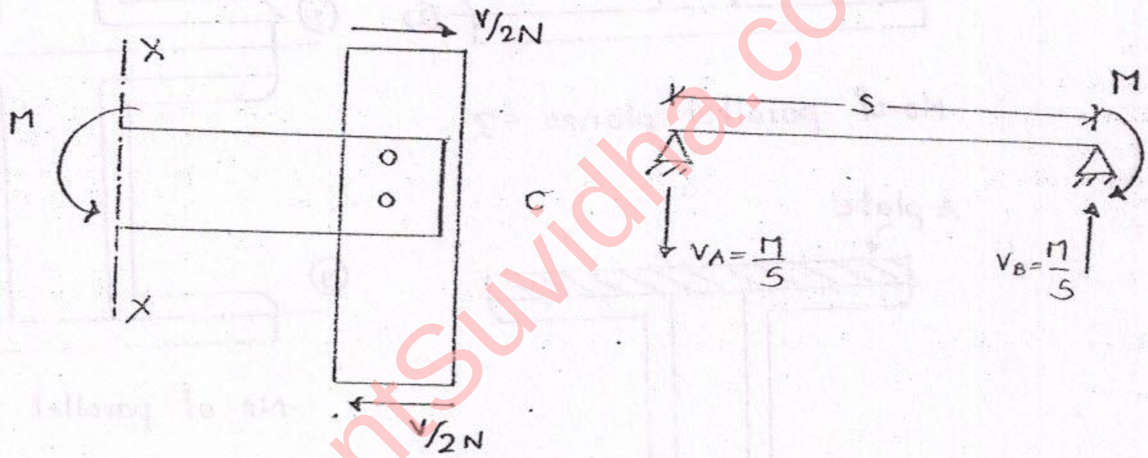
where, N - no. of parallel planes.

(d) F.B.D. of battens.





F.B.D. of column between ①① and ②②



From F.B.D. of colum at R.H.S. of X-X

From F.B.D. of column between ①① & ②②

clockwise moment = Anticlockwise moment

$$\left(\frac{V}{2N} \times C + \frac{V}{2N} \times C\right) = V_A \times S = V_B \times S$$

$$V_A = V_B = \text{longitudinal S.F.}$$

$$= \frac{VC}{NS}$$

- From F.B.D. of column at R.H.S. of X-X,

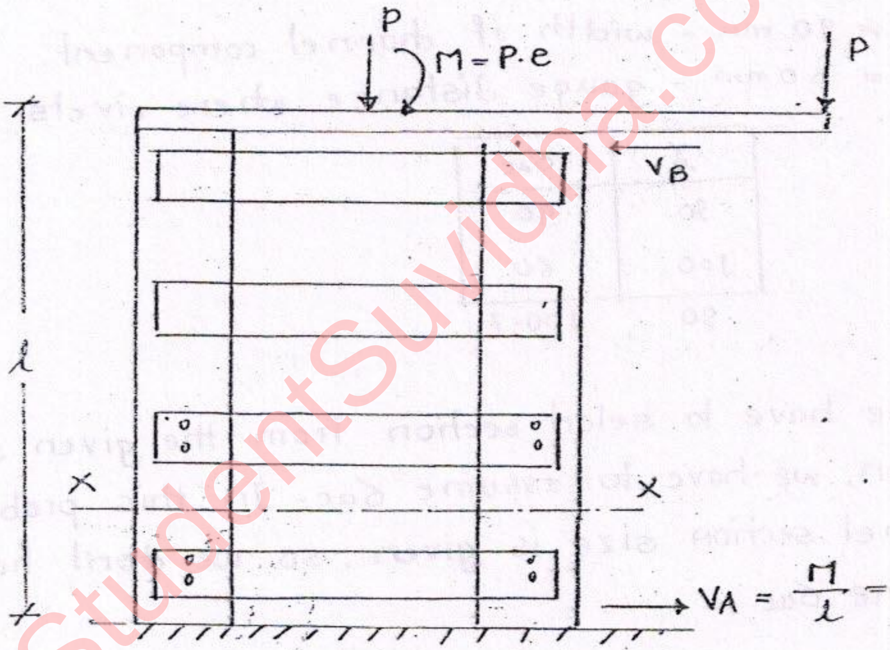
$$\Sigma M = 0$$

$$-M + \frac{V}{2N} \cdot C = 0$$

$$M = \frac{VC}{2N}$$

From the above free body diagrams we find that due to transverse S.F V, battens are subjected to longitudinal S.F. of $\left(\frac{VC}{NS}\right)$ and B.M. of $\left(\frac{VS}{2N}\right)$

As far as possible columns should not be subjected to eccentric loading in the plane of batten because the battens will be subjected to additional transverse S.F. due to B.M. developed due to eccentric load.



S.F. at XX' due to B.M. $= V_A = \frac{P.e}{l}$

Note:

Monday
28^{th} October 2013

Q. Design a built up column of effective length 10 m to carry an axial load of 750 kN. Use 2-channels placed back to back Design a suitable battening system also.

Given ISMC 300 :

$A_g = 4564 \ mm^2$

$I_{xx} = 6362.4 \times 10^4 \ mm^4$

$I_{YY} = 310.8 \times 10^4 \ mm^4$

$r_{xx} = 118.1 \ mm$

$r_{YY} = 26.18 \ mm$

$C_{YY} = 23.6 \ mm$

b = 90 mm - width of channel component.
g = 50 mm - gauge distance where rivets are provided.

λ	σ_{ac}
90	90
100	80
80	100.7

Note:

If we have to select section from the given set of section, we have to assume σ_{ac}. In this problem, the channel section size is given, so we don't have to assume σ_{ac}.

Design:

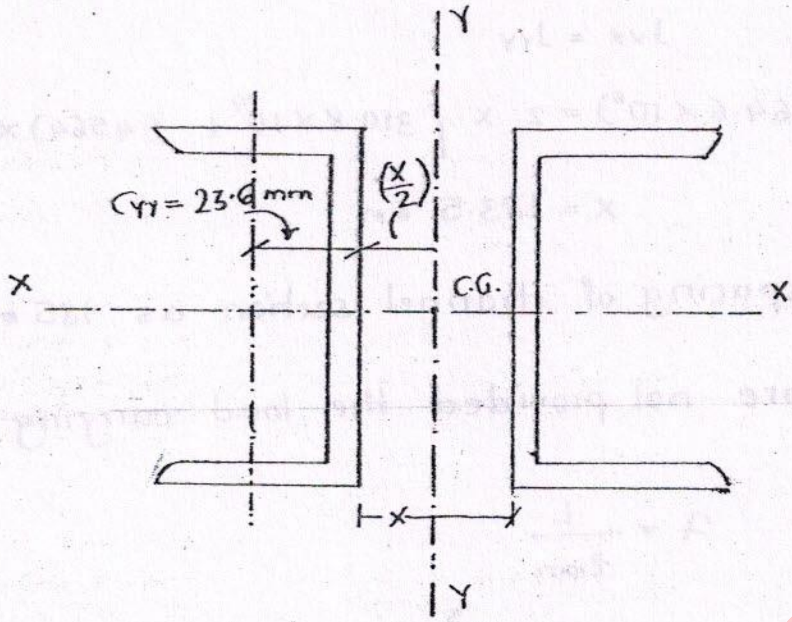
Since battens are used, effective length of column is increased by 10% (to take care of shear deformation effects in column i.e. to take care of longitudinal S.F. developed due to battens)

Effective length of column $= 1.1 \times L$

$= 1.1 \times 10$

$= 11 \ m$

Provide spacing of channels 'X' such that $I_{xx} \simeq I_{YY}$



$r_{YY} = 118.1$ mm (By providing spacing X, r_{YY} is increased from 26.18 mm to 118.1 mm)

$r_{xx} = r_{YY} = 118.1$ mm (for built up column)

$$\lambda = \frac{L}{r_{min}}$$

$$= \frac{11,000}{118.1} = 93.14$$

For $\lambda = 93.14$

$$\sigma_{ac} = 90 - \frac{3.14 \times (10)}{10}$$

$$= 86.86 \text{ N/mm}^2$$

Safe load carrying capacity of column,

$$P_{safe} = \sigma_{ac} \times A_g$$

$$= 86.86 \times (2 \times 4564)$$

$$= 792 \text{ kN} > (750 \text{ kN})$$

Hence, design is safe.

Spacing of channels (X)

$$I_{xx} = I_{yy}$$

$$2 \times (6364.6 \times 10^5) = 2 \times \left[310.8 \times 10^4 + (4564) \times \left(23.6 + \frac{X}{2}\right)^2 \right]$$

$$X = 183.5 \text{ mm}$$

So, provide spacing of channel section as 185 mm

If battens are not provided the load carrying capacity of column is

$$\lambda = \frac{L}{r_{min}}$$

$$= \frac{10 \times 10^3}{118.1} = 84.67$$

For 84.67.

$$\sigma_{ac} = 100 - \frac{4.67}{10} \times 10$$

$$= 95.33 \text{ N/mm}^2$$

$\therefore$

$$P_{safe} = \sigma_{ac} \times A_g$$

$$= 95.33 \times (2 \times 4564)$$

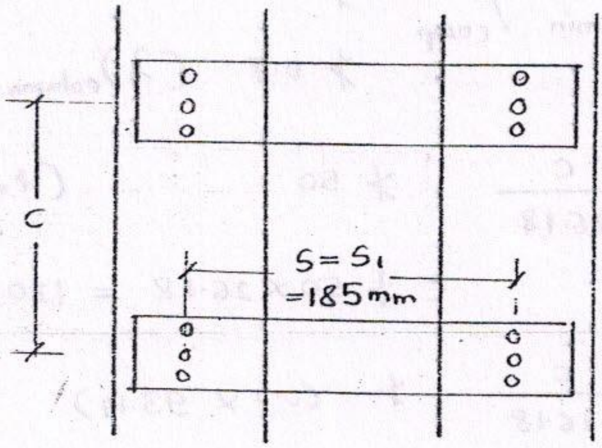
$$= 870.1 \text{ kN}$$

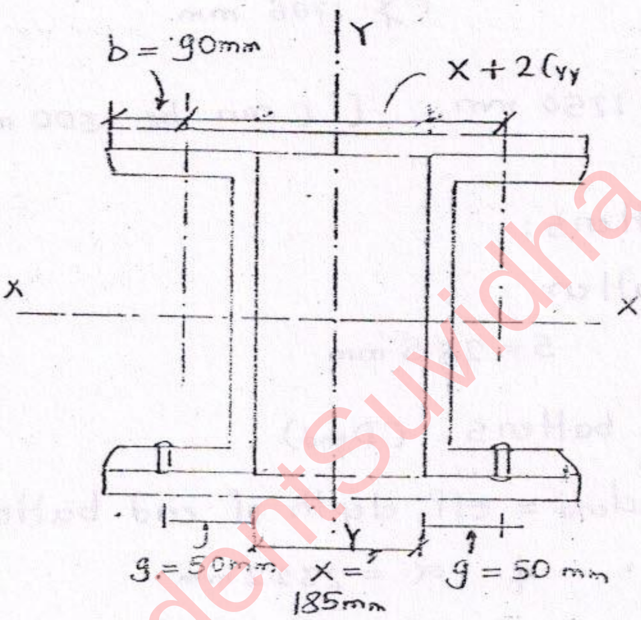
So by providing battens we reduced the load carrying capacity of the column from 870.1 kN to 792 kN only. The additional load comes to the column in the form of longitudinal shear force due to battens.

Design of battens:

(Finding spacing of battens
Finding dimensions of battens - length, width and thickness.
Finding forces in battens)

① Spacing of battens:





α - distance between C.G.'s of column component

$$\alpha = X + 2\,C_{yy}$$
$$= 185 + 2 \times 23.6$$
$$= 232.2 \text{ mm}$$

$S = S_1$ - distance between innermost connecting line of rivi

$$S = S_1 = X + 2g$$
$$= 185 + 2 \times (50)$$
$$= 285 \text{ mm}$$

Spacing of battens is fixed from buckling of column component criteria.

To prevent column component to buckle between battens.

$$\left(\frac{c}{r_{min}}\right)_{comp} \not> 50$$

$$\not> 0.7 \ (\lambda)_{column}$$

$$\frac{c}{26.18} \not> 50 \qquad (r_{min})_{comp} = 26.18$$

$$c \not> 50 \times 26.18 = 1309 \text{ mm}$$

$$\frac{c}{26.18} \not> (0.7 \times 93.14)$$

$$c \not> 1706 \text{ mm}$$

So provide $c = 1250$ mm (c can be 1300 mm also)

② Dimension of battens:

ⓐ Length of batten

$S = 285$ mm

ⓑ Depth of end battens (D_{end})

d_{end} = eff. depth of end batten

$$\not< \alpha = 232.2 \text{ mm}$$

$$\not< 2b = (2 \times 90) = 180 \text{ mm}$$

Take $d_{end} = 232.2$ mm

$D_{end} = d_{end} + 2 \cdot$ edge distance.
↘ $(1.5\ d)$

$$= 232.2 + 2(1.5 \times 21.5) \qquad \because \phi = 20 \text{ mm}$$

$$= 296.5 \text{ mm} \qquad d = 21.5 \text{ mm}$$

So provide $D_{end} = 300$ mm

ⓒ Depth of intermediate battens.

$$d_{int} \not< \frac{3}{4}\alpha = \frac{3}{4} \times (232.2) = 174 \text{ mm}$$

$$\not< 2b = (2 \times 90) = 180 \text{ mm}$$

Take $d_{int} = 180$ mm

$$D_{inl} = d_{inl} + 2\,(\text{edge distance})$$

$$= 180 + 2\,(1.5 \times 21.5)$$

$$= 238.65 \text{ mm}$$

So provide D_{inl} = 250 mm.

(d) Thickness of battens :

$$t_{min} = \frac{S_1}{50} = \frac{285}{50}$$

$$= 5.7 \text{ mm}$$

Provide thickness (t) = 8 mm

So use 250 ISF 8 as intermediate batten and 300 ISF 8 as end batten.

(3) Forces in battens :

(a) Transverse shear force :

V = 2.5 % of column load.

$$= \frac{2.5}{100} \times 750 = 18.75 \text{ kN}$$

(b) Longitudinal shear force :

$$= \frac{VC}{NS}$$

$$= \frac{18.75 \times 1250}{2 \times 285} = 41.12 \text{ kN}$$

where N - no. of parallel planes = 2.

(since longitudinal shear force is more to take care of this effect, the effective length of column is increased by 10 %)

But if lacing is done, longitudinal S.F. is

$$= 2F\cos\theta = 18.75 \text{ kN}$$ (in earlier problem)

(less than battens)

So as per IS 800 : 1984, no increase in effective length was recommended. But as per IS 800 : 2007. effective length of laced column is increased by 5 %.

Ⓒ B.M. in battens:

$$M = \frac{VC}{2N}$$

$$= \frac{18.75 \times 1250}{2 \times 2}$$

$$= 5.85 \text{ kNm}$$

Ⓓ check for B.M. for intermediate battens

Calculated bending compressive stress.

$$\sigma_{bc,cal} = \frac{M}{I_{xx}} \times y$$

$$= \frac{M}{Z} \quad (\leq \sigma_{bc} \text{ - permissible bending stress - } 0.66 f_y)$$

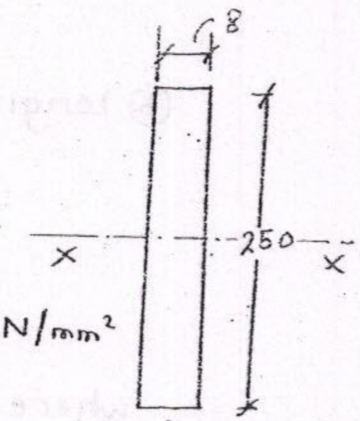
$$Z_{xx} = \frac{tD^2}{6} \quad (\text{since batten bends about X-X axis})$$

$$\sigma_{bc,cal} = \frac{5.85 \times 10^6}{\left(\frac{8 \times 250^2}{6}\right)}$$

$$= 70.2 \text{ N/mm}^2$$

$$\sigma_{bc} = 0.66 f_y = 0.66 \times 250 = 165 \text{ N/mm}^2$$

$\sigma_{bc,cal} < \sigma_{bc}$. hence safe.



c/s of batten

Ⓔ Check for shear,

$\tau_{va,cal}$ - calculated shear stress in batten.

$$= \frac{\text{longitudinal S.F.}}{t \cdot D}$$

$$\leq (\tau_{va} \text{ - permissible shear stress } = 0.4 f_y)$$

$$\tau_{va,cal} = \frac{41.12 \times 10^3}{8 \times 250}$$

$$= 20.55 \ N/mm^2$$

$$\tau_{va} = 0.4 \ f_y = 0.4 \times 250 = 100 \ MPa.$$

$\tau_{va,cal} < \tau_{va}$, safe.

Note:

If intermediate battens are safe in bending and shear, then end battens will be automatically safe in bending and shear, because they have greater c/s area. (i.e. 300 ISF 8)

④ Design of connection.

Note:

Due to transverse S.F. V, longitudinal S.F and B.M. are developed. So calculate the number of rivets required to resist longitudinal S.F. and B.M. seperately and add them to get total no. of rivets.

Rivets are in single shear.

$$P_s = \frac{\pi}{4} \times d^2 \times f_s$$

$$= \frac{\pi}{4} \times (21.5)^2 \times 100$$

$$= 36.3 \ kN$$

$$P_b = d \times t \times f_b$$

$$= 21.5 \times 8 \times 300 \quad (t = \text{lesser of } 8mm \ \& \ 13.6 \ mm)$$

$$= 57.6 \ kN$$

$\therefore R_V = P_s = 36.3$ kN.

No. of rivets to resist longitudinal shear force $= \frac{F}{R_V} = \frac{41.12}{36.3}$

$$n_1 = 1.12$$

No. of rivets required to resist B.M.

$$n_2 = \sqrt{\frac{6M}{R_v \cdot p \cdot m}} \quad \text{(empirical formula)}$$

p - minimum pitch $= 2.5\,\phi$

$= 2.5 \times 20 = 50\ mm$

m - no. of rivet lines = 1

$$n_2 = \sqrt{\frac{6 \times 5.85 \times 10^6\ Nmm}{(36.3 \times 10^3) \times 50 \times 1}}$$

$= 4.39$ rivets. (in each row)

Total no. of rivets required $(n) = n_1 + n_2$

$= 1.12 + 4.39$

$= 5.51 \simeq 6$ rivets.

Note:

The number of rivets n_2 obtained from the above formula is highly conservative value. So we can reduce the number of rivets and check the resultant shear force is less than rivet value.

$$F_R = \sqrt{F_1^2 + F_2^2 + 2F_1 \cdot F_2 \cdot \cos\theta} \leq R_v$$