Lec. 4

Design of Combined Steel Columns with Lacing and Batten Plates

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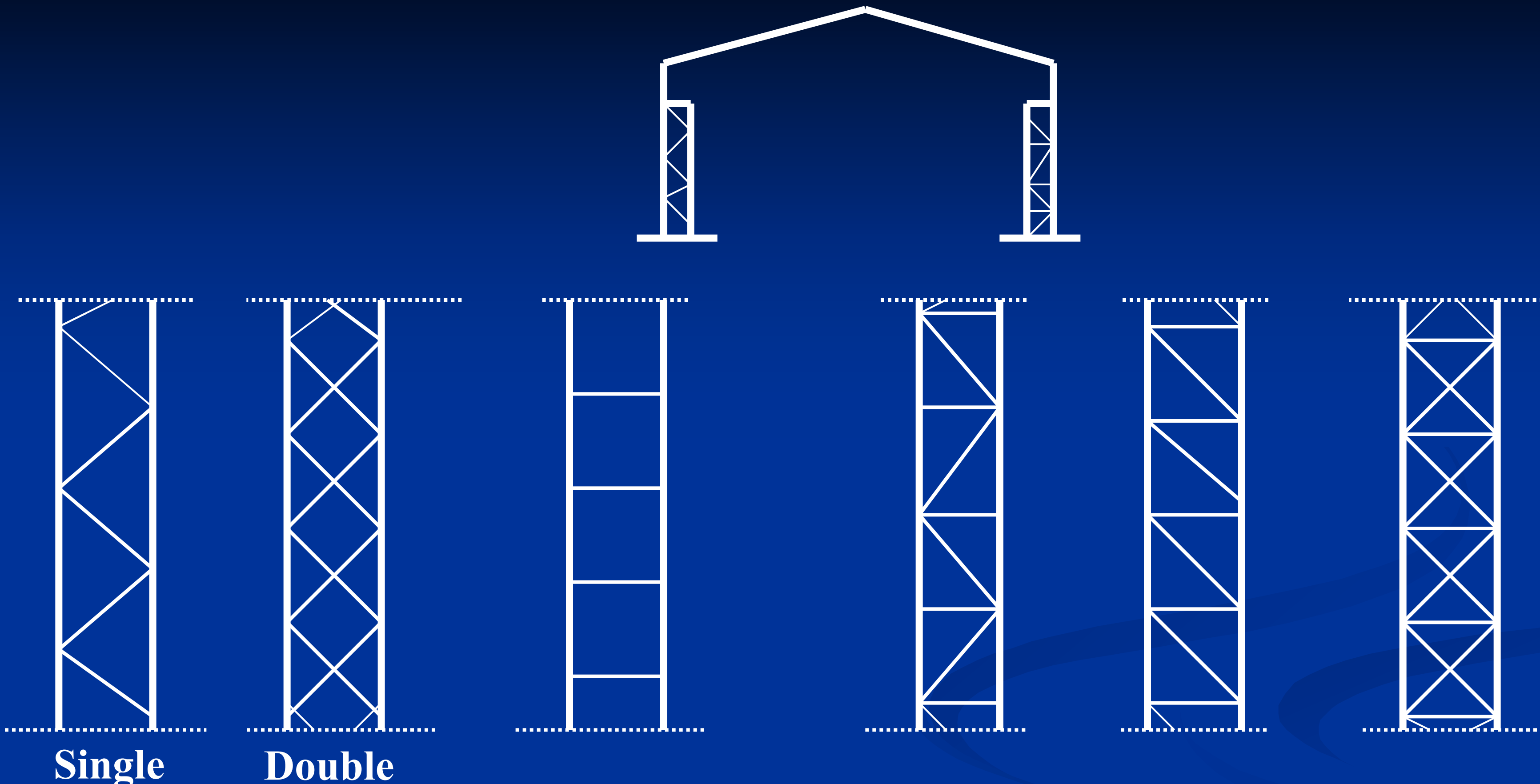


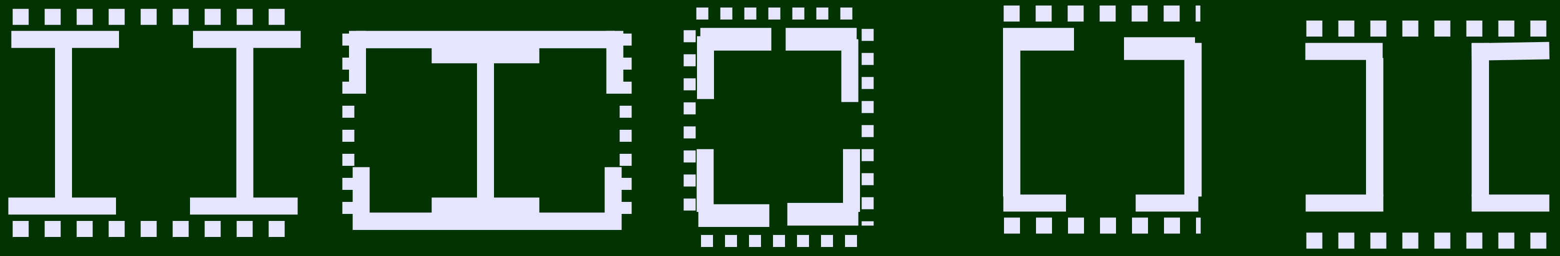
1- Lacing Systems

2- Batten System

3- Combination of Laced and Battened Systems

Systems of Laced and Battened Columns

- Generally, Columns with Combined Section are suitable in case of Large Straining actions or when rolled I-Sections are not readily available.
- The Combined Sections of the Steel Columns are usually chosen to be 2-channels, 2-IPE or 4-angles connected together by Lacing Bars or Batten Plates .



Cross Sections of Built-Up Columns

(II) Combined Columns Subjected to Axial force and Bending Moment (N & M)

Design Procedure of Combined Column subjected to (M &N) :

(1) Data given: {M_D, N_D at Critical Section Along the Column, Side Sway Prevented or permitted and $L_{b\text{-in plan}}$ and $L_{b\text{-out of Plan}}$.

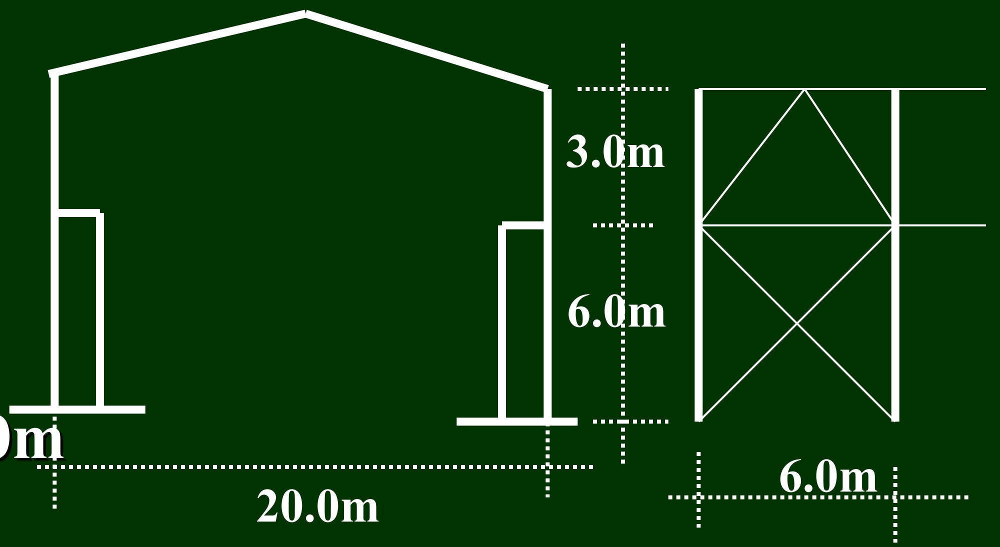
(2) Estimation of the cross section

(3) Check for Local Buckling (Code pp. 9 to 12)

(4) Check of Stresses (Interaction Equation Code pp.25).

- Example :For the pitched Roof Frame shown in Figure is required to design the "AB" as 2-channels spaced 50 cm using lacing bars, if the maximum B.M. at A=30.0t.m, the corresponding normal force, N= 30t and the maximum Shearing Force at A , Q = 4.0 t, Side sway is permitted.

- *(1) __Data Given__:*



- MD = 30 t.m
- ND = 30 t
- Q = 4.0t
- $Lb_{in\text{-}plan}$=1.5h =9.0m
- $Lb_{out\text{-}of\ plan}$ = 6.0m
- Side Sway is permitted

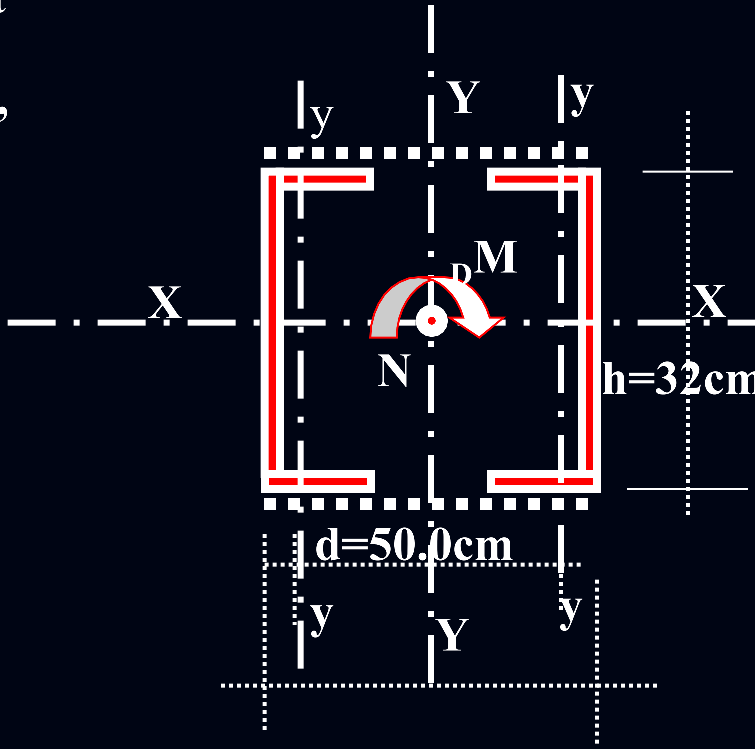
(2) *Estimation of the Cross Section:*

- d = Spacing between two Section Component
  = (h/10-15) = (600/10-15) =60-45cm
- Calculating the max. Compressive Force "C"
  C = -(M/d + N/2)=-(3000/50 +30/2)= -75 t
  on one Channel
- $A_{required}$ =$(C/F_{C\ Assumed})$ =(75/1.0)=75cm^2

Choice 2-Channels 320

d/h= (50/32) =1.56 lies between 1.5 to 2

Then Choose 2-channels 320



A2C = 2*75.8 = 151.6cm2

Iy-y-2C = (2(597 +75.8*25^2)=95944cm^4

$r_{X\text{-}X\text{-}2C}$ =r_{x1C} =12.1cm , $r_{y\text{-}y\text{-}2C}$ =√(95944/151.6) =25.15cm

$rz = r_{y\text{-}1C}$ = 2.81

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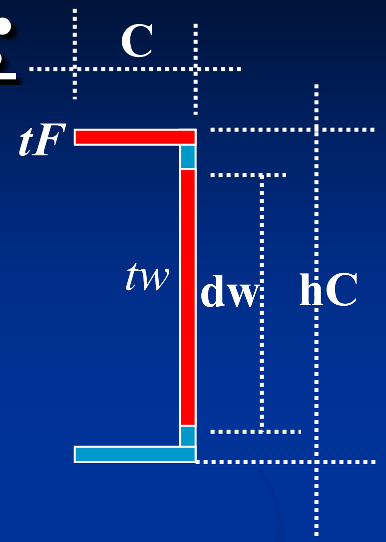
(3) Check for Local Buckling:



Web Element (table2-1a Code pp. 9):

$dw = hC - 4tF = 32 - 4*1.75 = 25cm$

$dw/tw)_{act} = (25/1.4) = 17.86$

$dw/tw)_{Code} = 58/\sqrt{2.4} = 37.44,$

then, $(dw/tw)_{act} < (dw/tw)_{Code}$ O.K. Compact

Flange Element (table2-1c Code pp.11):

C = bf (Code pp.11 table2.1c) =10cm

$C/tf)_{act} = (10/1.75) = 5.7$, $(C/tf)_{Code} = (16.9/\sqrt{2.4}) = 10.9$

$C/tf)_{act} < C/tf)_{Code}$ O.K. Compact.

(4) Check of Stresses (Interaction Equation):

Lb-in =1.5(6) =9.0m , Lb-out = 6.0m , Lz = 90cm ,

k = 1.0 (lacing bars) & K = 1.25 (Batten plate)

$$\lambda_{y-in} = \sqrt{\left(\frac{L_{b-in}}{r_{y-2C}}\right)^2 + \left(k\,\frac{L_z}{r_z}\right)^2} = 48.01 \text{ p } 180$$

(Equivalent Slenderness ratio of Battened or Latticed Steel Columns) Code Eqs.9-1& 9-2 pp.138)

$\lambda_{x\text{-out}}$ =(Lb-out /rx) =(600/12.1) = 49.6

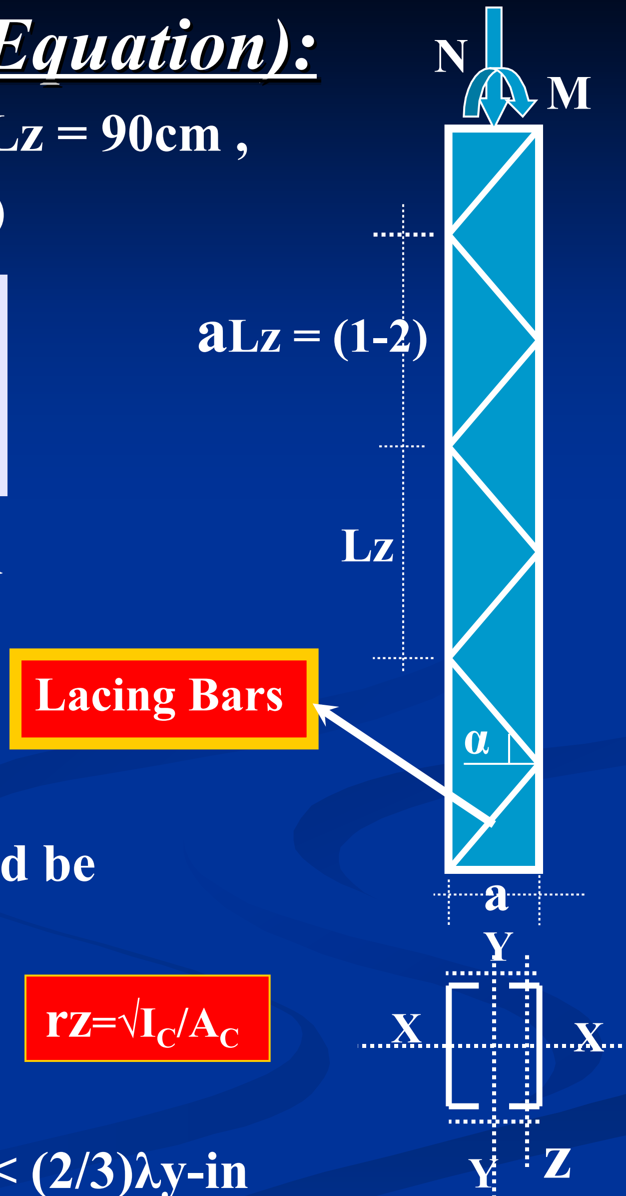
Where :

λz is the Local Slenderness ratio (Lz / rz) should be Satisfied the following Conditions:

λz = (Lz /rz) < 60 and, (Code pp.136)

and < (2/3) λy-in (Code pp.136)

Then, λz = (Lz /rz) = (90/2.81) = 32.0 < 60 and < (2/3)λy-in



$r_z = \sqrt{I_C / A_C}$

- F_C = 1.4 – 0.000065(49.6)^2 = 1.24 t/cm2
- *fca* = *N/A* = *(30/151.8)* = *0.197*

Then, $Fca/F_C = (0.197/1.24) = 0.159 > 0.15$

- *A2* = $(Cmy/(1-(fca/F_{CY})))$ *(Code pp.25)*
- *Where : Cmy = 0.85 (Frame permitted side sway) (Code pp.26)*

$F_{EY} = 7500/\lambda y^2 = 7500/(48.01)^2 = 3.254 t/cm^2$

Then, $A2 = Cmy/(1-(fca/F_{EY})) = 0.96 < 1.0$ *take =1.0*

- *fby* = $(M/I_{y\ -2C})(d/2 + e_C)$

$= (30*100/95944*(50/2 + 2.6) = 0.86 t/cm^2$

- *Fbc* = *0.58Fy* = $1.4\ t/cm^2$

(Interaction Equation):

$$\frac{fca}{Fc} + \frac{fby}{Fbcy} A_2 \leq 1.0$$

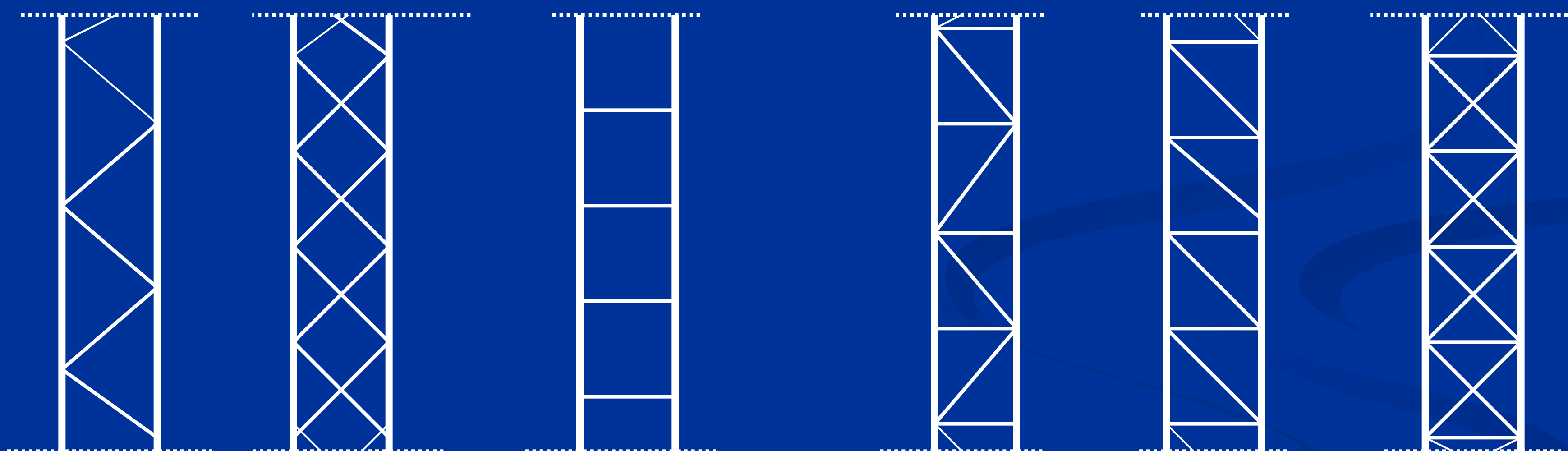
$$\frac{0.179}{1.10} + \frac{0.86}{1.4} * 1.00 = 0.794 \;\; p \;\; 1.0$$

O.K. Safe and Economic

Design of Lacing Bars

Introduction:

Systems of Laced and Battened Columns



1- Lacing Systems

2- Batten System

3- Combination of Laced and Battened Systems

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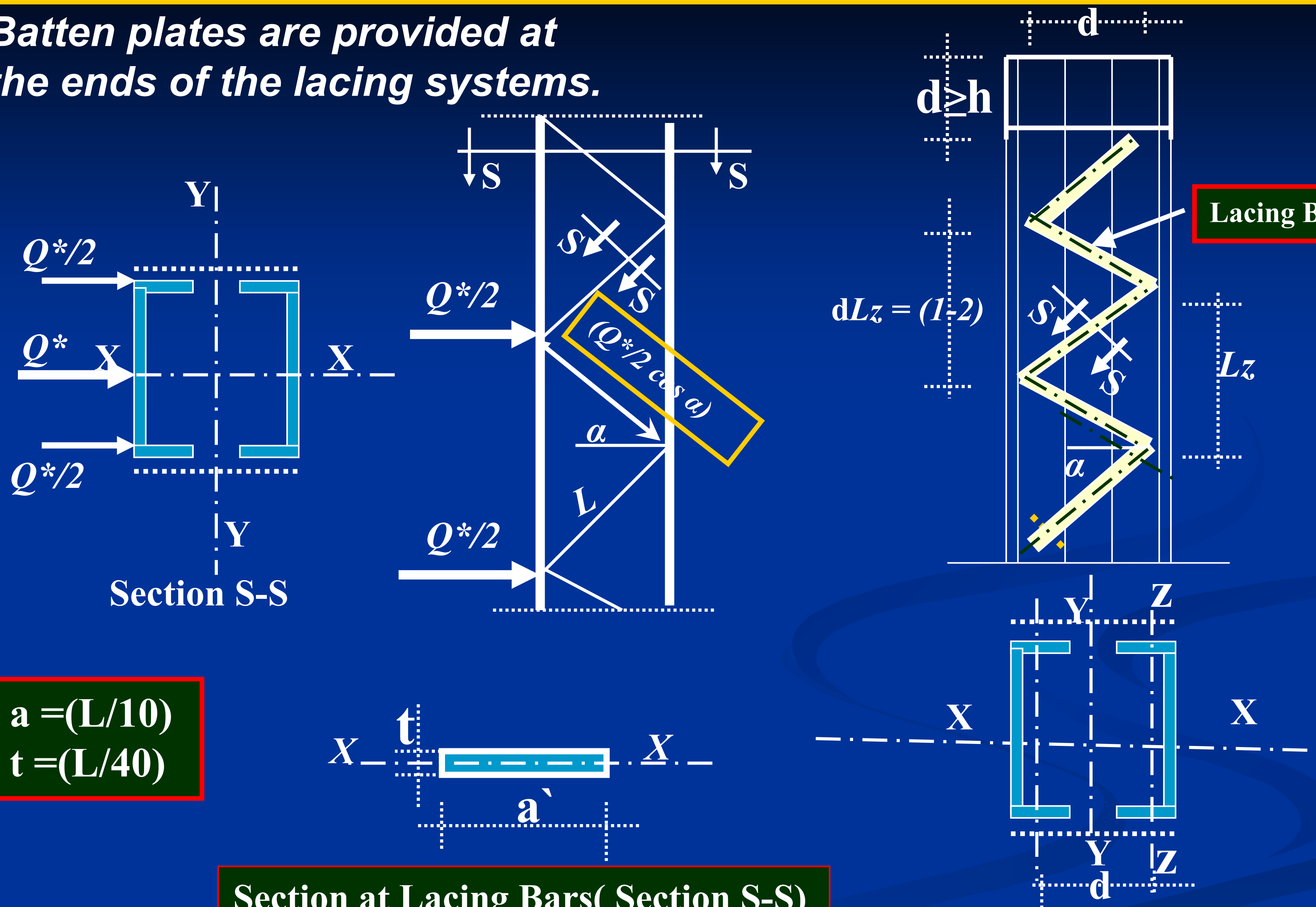
Laced and Battened Columns

Batten plates are provided at the ends of the lacing systems.



a =(L/10)
t =(L/40)

Section at Lacing Bars(Section S-S)

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Notations on Lacing Bars and Batten Plates

(1) Lacing Bars shall be inclined at an angle of $\alpha = 50^o$ to 70^o to the axis of the member where a single interaction System is used and at an angle $\alpha = 40^o$ to 50^o where a double interaction system is used.

(2) Maximum Length between Lacing Bars ($L_z = kL$ = [(1 - 2)d] in a Single Interaction Lacing and L_z = [(0.5-1.0)d] for Double Interaction Lacing) where d is the distance between the Centroids of the main component thickness.

(3) The ratio $(L_z/r_z) \leq 140$

(4) The thickness of the plates ≤ (1/50) of the distance between the inner lines of bolts

(5) Lacing Bares are designed to resist this Force = $Q^* = (Q + 0.02\,N)$. where Q and N are the shearing and the axial forces of the column. The lacing bars are treated as diagonal members of a truss.

- Example : For the frame carrying crane shown in Figure, the crane column subjected to N=20t and M=20t.m and Q = 6.0t ,it is required to : (i) Design the welded lacing bars if the column consists of 2C 320 spaced 50cm. (ii) Design the connection of the lacing bar to the column as Revited connection.

(1) Data Given:

$Q^* = Q + 0.02N = 6.4t$

Force in Lacing Members (F_{Lacing}):

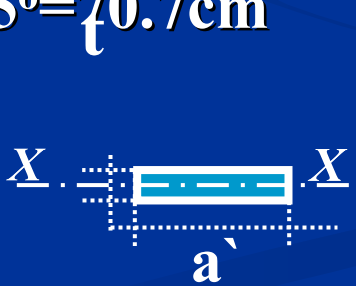
. $F_{Lacing} = Q^*/2\cos\alpha = 6.4/2\cos 45^o = \pm 4.525t$

Length of Lacing =L =50/cos45º=70.7cm

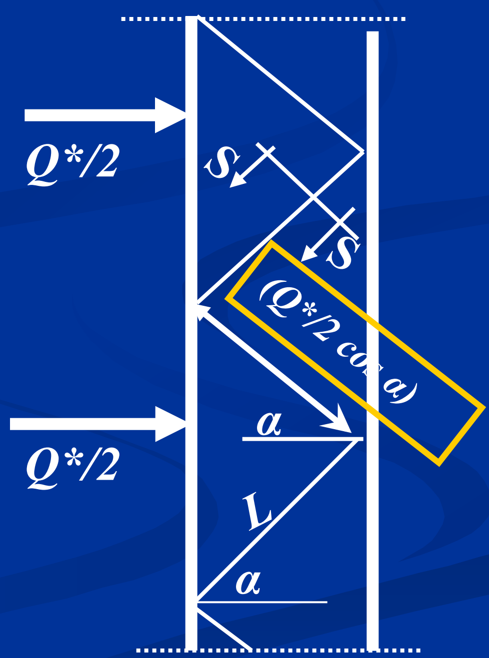
Assume a = L/10 = 7cm

Assume t = L/50 = 14m

Lbx = L = 70cm



Section S-S



(2) Design of the Lacing bar as a Compression Member:

- rx = (√Ix-x/Area) = √(at³/12)/a*t = t/√12 = 1.4/√(12 =0.404
- $\lambda x = L_{bx}$/ rx = 70/0.404 = 173.2 > 140 Unsafe
- Use t = 2.0 cm
- rx = (t/√12) =2.0/√12 = 0.577
- λx = Lbx/rx = 70/0.577 = 121.317 >140
- F_C = $(7500/(121.317)^2$ =0.51t/cm2
- *f*act = F_{Lacing}/Area=(4.525/(7*2)=0.323t/cm^2<F_C O.K. Safe

(3) Design of Lacing bar as a Tension Member:

- f_{act} =(F_{Lacing} /Area)=(4.525/(7*2) =0.323t/cm^2 <1.4 t/cm^2
- (L/a) = (70/7) = 10 ≤ 60 O.K. Safe

(4) *Design of the Connection between the batten plate and column as a Welded Connection:*

Assume Weld Size =s =8mm

- **Force = Area of Weld *Allowable stresses in Weld**

  5.525 = (L*2s)(0.2Fu) = (L*2*0.8)(0.2*3.6)

  get L = 4.8cm

- **$L_{weld\ eff.}$ = 2s +L = (2*0.8+4.8)=6.5cm min L = 5.0cm**

(5) Design of the Connection between the batten plate and column as a Bolted Connection:

Force = 5.525 t ≤ R_{Least} Assume Diameter of Bolts Φ_{16}

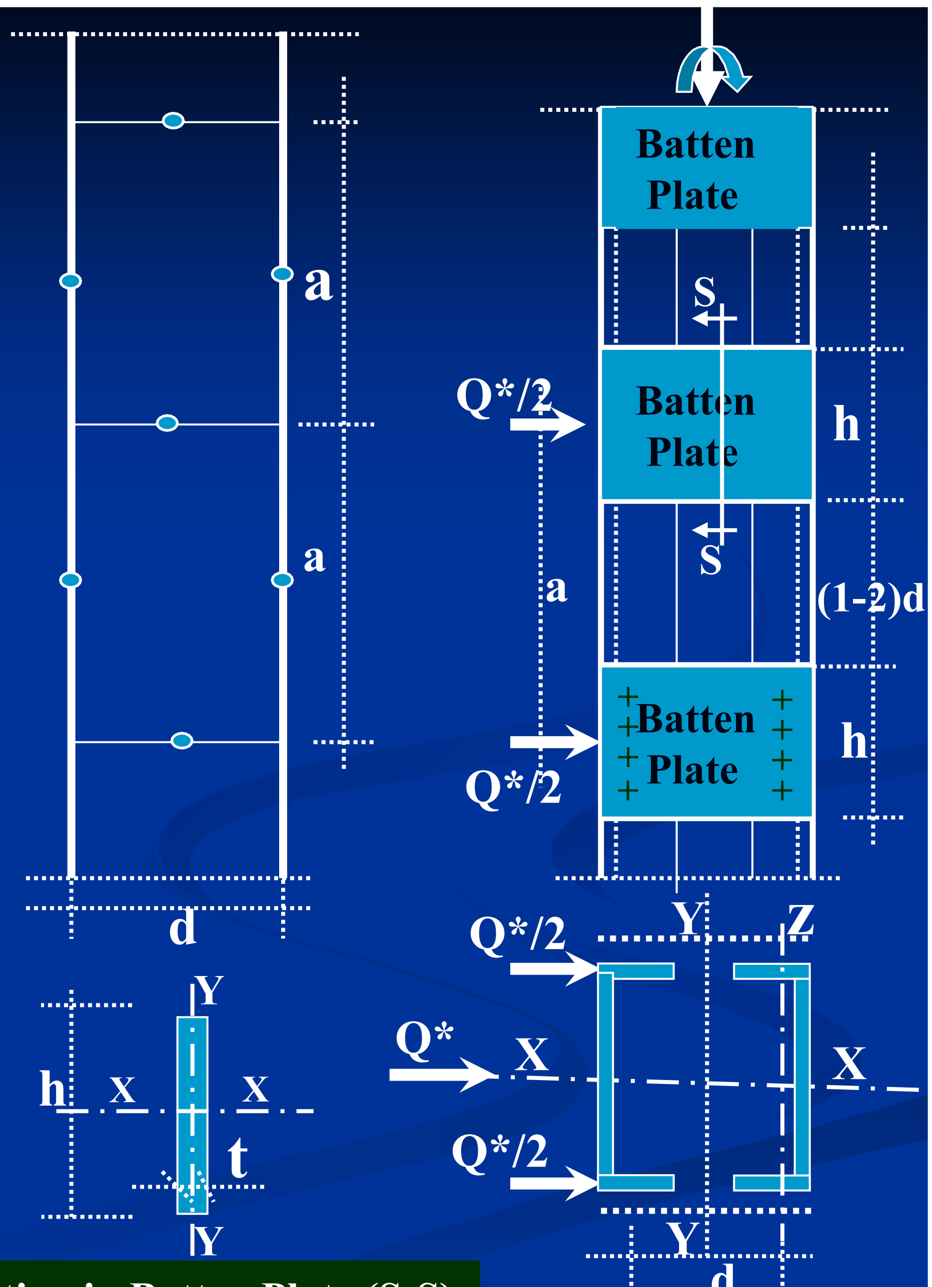
- **R_{Least} is the Least of $R_{S.S.}$ and $R_{bearing}$.**

Design of Batten Plate

- ***Battens shall be plates or Channels and shall be bolted or welded to the main elements.***
- ***The system may be assumed as a virandeel girder or intermediate hinges may be assumed at mid distance to change the system into a statically determinate system.***

h=(0.75 -1.25)d ≈ d

a=h +(1 - 2)d



Section in Batten Plate (S-S)

Design Steps of Batten Plate :

(1) Data Given:

h = (0.75-1.25)d ≈ d

Thickness = t = (h/50)

Q* = Q +0.02N

$I_{x-x} = (t*h^3/12)$ weld Batten

$I_{x-x} = ((t*h^3/12) - I\Phi)$

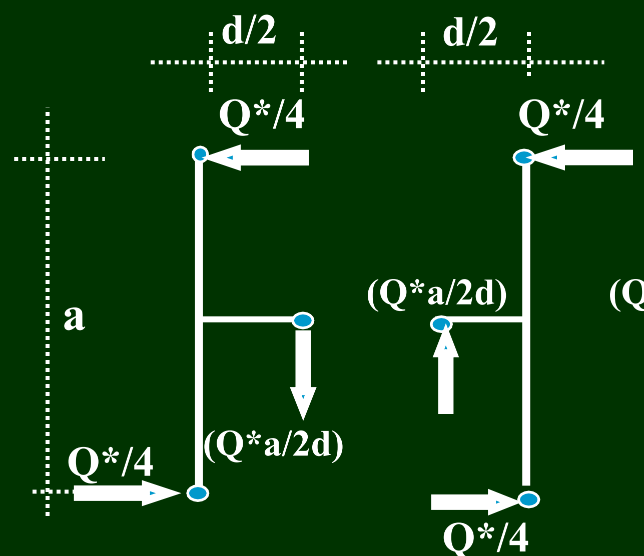
(Bolted batten)

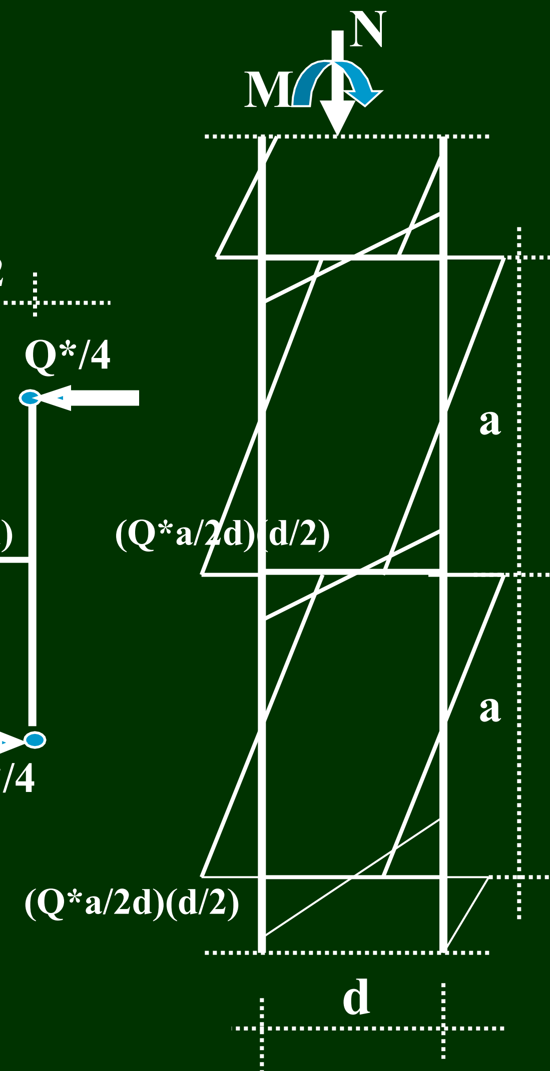
The acting straining actions on the Batten Plate are :

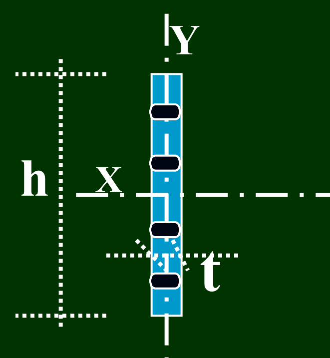
S.F. = (Q*.d/2a)

B.M. = S.F.*(d/2)

= (Q.a/2d)(d/2)







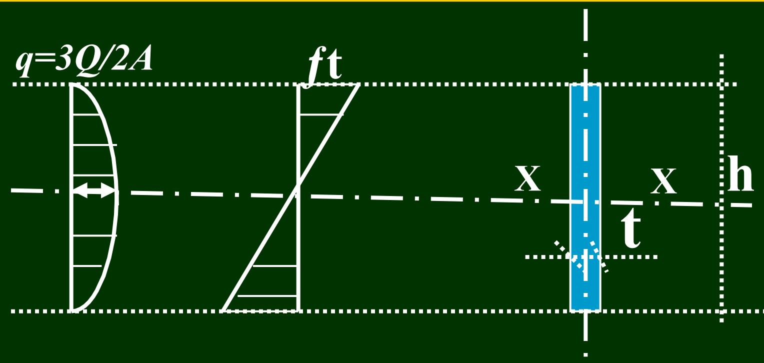
Section in Batten Plate (Bolted Conn.)

(2) Check of Flexure Stresses:

$f_b = (M_x/I_x)(h/2) = \ldots\ldots \leq 0.72F_y$

(3) Check of Shear Stresses:

$Q\ act = 1.5Q/h*t) = \ldots \leq 0.35F_y$



(4) Design of the Connection between the batten plate and column as a Bolted Connection:

$Q = Q^*.a/2d$

$Mt = (Q^*.a/2d)\ (d/2)$

The used Bolts put either in one column or in two column (4-rows)

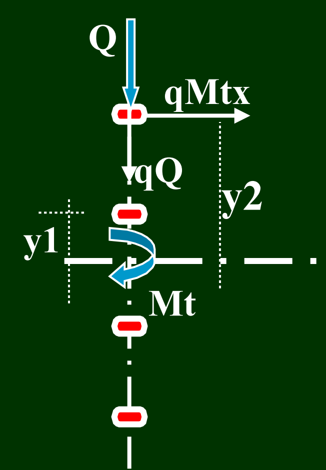
Case1 : to use one row of 4-bolts :

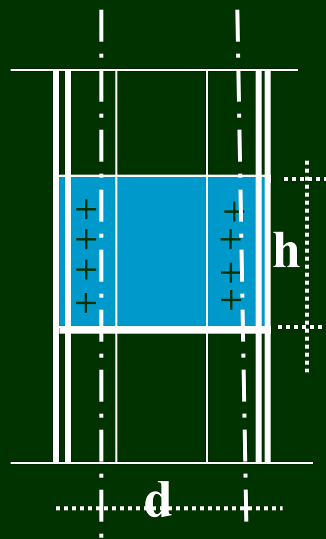
Check of Stresses:

$q_Q \downarrow = (Q^*/n) = \ldots..t$

$q_{Mtx} \rightarrow = (Mt\ .\ y2)\ /\ 2(y1^2 + y2^2) = \ldots.t$

$Qtotal = \sqrt{(qQ)^2 + qMtx^2} = \ldots.t$





Section in Bolts

Rs.s.h. $= \pi\, \Phi^2 /4\ (0.25F_{U\ bolt})$ =….t

Qtotal ≤ Rs.s.h O.K. Safe

Case2 : to use two rows of 4 – bolts (n=8Φ):

Check of Stresses:

qQ ↓ $= (Q^*/n) =$ …..t

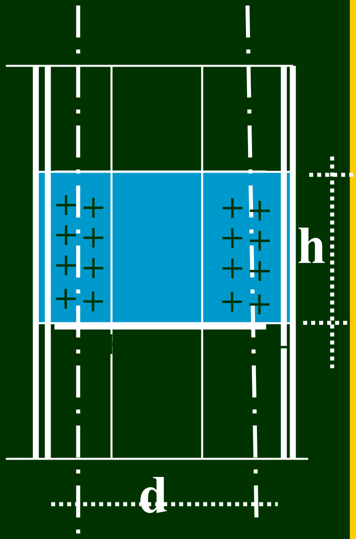
qMtx ⟶ $= (Mt \,.\, Y) / n(r1^2 + r2^2) =$ ….t

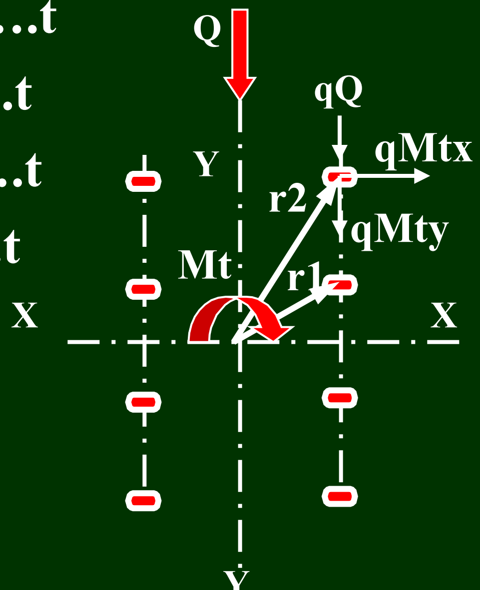
qMty ↓ $= (Mt \,.\, X) / n(r1^2 + r2^2) =$….t

Qtotal $= \sqrt{(qQ+qMt)^2 + qMt^2} =$ ….t

Rs.s.h. $= (\pi\, \Phi 2 /4)\ (0.25F_{U\ bolt}) =$….t

Qtotal ≤ Rs.s.h O.K. Safe





Section in Bolts

(5) Design of the Connection between the batten plate and column as a Welded Connection:

Assume weld size = “s”

Each side is calculated to resist

A shear force = Q = (Q*.a /2d) and

torsional Moment (Q*.a/2d) (d/2)

X` = (2.b.s)(b+s/2)/(2bs +(h+2s)s)

Ix-x = ……..

Iy-y =……….

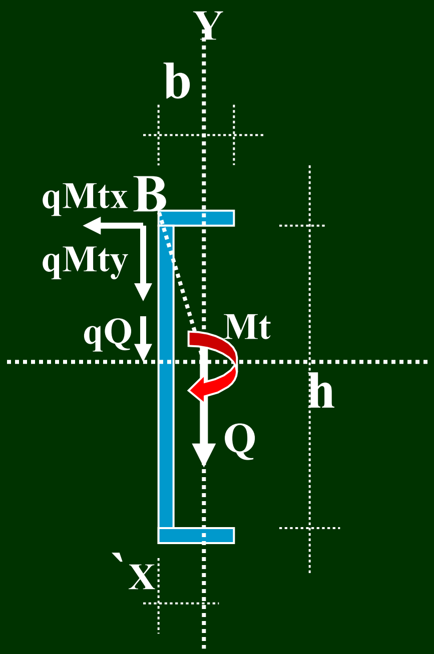
Ip = Ix-x + Iy-y

qQ B ↓ = Q/(h+2s)s =

qMty B ↓ = Mt *X`/Ip =

qMtx B → = Mt*(h/2)/Ip =

qB total = $\sqrt{(qQB\downarrow + qMty\downarrow)^2 + qMtxB^2_{\rightarrow}}$ =……≤ 0.2Fu



Section of Weld