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SEC B

STEEL STRUCTURE

SUMMER 2020

Prob #01

Lightest W-shape Column
A-36 Steel
Dead load = D.L = 60k
Live load = L.L = 110 k
Pin supported at top & bottom
$K_xL_x = 36ft$, $K_yL_y = 18ft$

AISC/LRFD Method.

Sol:-

Required Capacity = $(1.2\times60)+(1.6\times110)$
$= 248\ k$.

Enter design strenght Table of manual with $KL = 18ft$ & $P = 248k$.

Some possible Sections are:-

$W_{14}\times61$	$P = 364$	$r_x/r_y = 2.44$
$W_{12}\times53$	$P = 320$	$r_x/r_y = 2.11$
$W_{10}\times49$	$P = 301$	$r_x/r_y = 1.71$
$W_8\times58$	$P = 300$	$r_x/r_y = 1.74$

Now

$$\frac{K_xl_x}{K_yl_y} = \frac{36}{18} = 2$$

Try W12x53 $\quad r_x/r_y = 2.11$

$r_x/r_y > K_x l_x / K_y l_y$

$r_x = 5.23$, $r_y = 2.48$ $\quad A = 15.6 \text{ in}^2$

$$K_x l_x / r_x = \frac{36 \times 12}{5.23} = 82.6$$

$$K_y l_y / r_y = \frac{18 \times 12}{2.48} = 87.09$$

$$\frac{KL}{r} = 87.09$$

$$\lambda_c = \frac{KL}{r\pi}\sqrt{\frac{F_y}{E}}$$

$$= \frac{87.09}{\pi}\sqrt{\frac{36}{29{,}000}}$$

$$= 0.97 < 1.5$$

$$F_{cr} = 0.658^{\lambda_c^2} \times F_y$$

$$= 0.658^{(0.97)^2} \times 36$$

$$F_{cr} = 24.58$$

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$P_n = A_g F_{cr}$

$= 15.6 \times 24.28$

$P_n = 378.78K$

$\phi P_n = 0.85 \times 378.78$

$= 321.96 > 248K$

OK

So use $W_{12} \times 53$.

Prob # 02

→ Lightest W - section
→ D.L = 1.5k , L.L = 4.5k
(at each quater point)
→ Total length = 52'
→ live load deflection = $\frac{1}{360}$ of span
→ F_y = 36ksi
AISC /ASD Method

Sol:-

Design load = 4.5+1.5 = 6 k

$$\Delta = \frac{5}{48}\frac{ML^2}{EI} \quad \text{—— (i)}$$

Δ by this equation is multiplied by the factor from table 5.4

$$M = \left(\frac{3}{2}\times 6\times 26\right) - \left(6\times 13\right) = 156 \text{ k.ft}$$

eq (i) ⇒ $I = \frac{5}{48}\times\frac{ML^2}{E\Delta}\times 0.95$

$$I = \frac{5}{48}\times\frac{(156\times 12)(52\times 12)^2}{29000 \times\left(\frac{52}{360}\times 12\right)}$$

$I = 1510.51 \text{ in}^4 \times 0.95$ $\boxed{I = 1434.98 \text{ in}^4}$

Try $W_{24}\times 62$, $I_x = 1550 \text{ in}^4$
$b_f = 7.04$ in, $d/A_f = 5.72$

$$L_c = \frac{76 b_f}{\sqrt{F_y}} \Rightarrow \frac{76 \times (7.04)}{\sqrt{36}} = 89'' = 7.41'$$

$$L_c = \frac{20000}{F_y \, d/A_f} \Rightarrow \frac{20000}{36 \times 5.72} = 97.12'' = 8.09'$$

$L > L_c$ from table 5.2

$C_b = 1.13$

$$\sqrt{\frac{102{,}000\, C_b}{F_y}} = \sqrt{\frac{102{,}000 \times 1.13}{36}} = 57$$

$$\sqrt{\frac{510{,}000\, C_b}{F_y}} = \sqrt{\frac{510{,}000 \times 1.13}{36}} = 127$$

$$\frac{L}{r_T} = \frac{13 \times 12}{1.71} = 91.22$$

Condition

$$\sqrt{\frac{102{,}000\, C_b}{F_y}} \le \frac{L}{r_T} \le \sqrt{\frac{510{,}000\, C_b}{F_y}}$$

So,

$$F_b = \left[\frac{2}{3} - \frac{F_y (L/r_T)^2}{1530 \times 10^3 \times C_b}\right] F_y$$

$$= \left[\frac{2}{3} - \frac{36 (91.22)^2}{1530 \times 10^3 \times 1.13}\right] 36$$

$F_b = 17.76$ ksi allowable.

The beam self weight = 62 lb/ft

= 0.062 k/ft

$$M = \frac{WL^2}{8} = \frac{1}{8}(0.062)(52)^2$$

$M = 20.95$ kft

Total $M = 156 + 20.95$

$M = 176.95$

$S_x = 131$

$$f_b = \frac{M}{S_x} \Rightarrow \frac{176.95 \times 12}{131} = 16.2 \text{ ksi}$$

$f_b < F_b$

OK.

Use $W_{24} \times 62$.

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Prob # 03

Given:-

Dead load = D.L = 50k

Live load = L.L = 150k

Bolts dia = 3/4"

length = 18ft

Connection type = Bearing

Design A36 steel double angle tension member = ?

AISC/ASD Method

Sol:-

Total Load = D.L + L.L

= 50 + 150

= 200k or 100 k/Angle

-> For yielding at the gross area allowable stresses are

$0.6 f_y = 0.6 \times 36$

$= 22$ ksi

-> For fracture at the net area allowable stresses are

$0.5 F_u = 0.5 \times 58$

$= 29$ ksi

-> Since the connection is bolted so

$A_g \neq A_n$

Now $A_e = 0.85 A_n$

For yielding

$$Ag \times 22 = 100$$

$$Ag = \frac{100}{22}$$

$$Ag = 4.54 in^2$$

For fracture:-

$$29 \times Ae = 100$$

$$Ae = 3.44 in^2$$

$$An = Ae/0.85 \Rightarrow 3.44/0.85 \Rightarrow \boxed{An = 4.04 in^2}$$

→ Assume 15% deduction in gross area for holes.

So,

$$Ag = An/0.85 \Rightarrow Ag = 4.04/0.85$$

$$\boxed{Ag = 4.76 in^2}$$

For $L4 \times 4 \times 5/8$ $Ag = 4.61 \cong 4.74$ ok

$r_x = 1.20$, $r_y = 1.20$ with 3/8 in Gusset Plate

$$\frac{l}{r_{min}} = \frac{18 \times 12}{1.20} = 180 \leq 300 \text{ k}$$

ok.

Bolt Design.

Using A325 bolts with threads included in shear plane. as dia = 3/4"

$$Area = \frac{\pi}{4}(d)^2 = \frac{\pi}{4}(0.75)^2$$

$$\boxed{A = 0.441\, in^2}$$

Allowable bolts shear = 21 ksi

Since bolts are in double shear so
Allowable shear per bolt = $2 \times 21 \times 0.44 = 18.5k$
Allowable bolt bearing stress = $1.2 f_u = 1.2 \times 58$
$= 69.6\, ksi$
Allowable bearing on two 5" thick angle
long legs = $69.6 \times 2 \times \frac{5}{8} \times 0.75 = 65.25 > 18.5$

So shear governs.

Number of bolts = $\frac{200}{18.5} = 10.81$

Use 10 bolts.

Design of Gusset plate:-

Bearing stress = $1.2 f_u$
$= 1.2 \times 58 = 69.6\, ksi$
So, Allowable bearing = $69.6 \times 10 \times 0.75 \times t = 200$
$t = 0.38$ in

Use 3/4" G.P.

Checking various limit states

yielding $= 0.6\, F_y\, A_g$

$= (0.6)(36)(8 \times 0.75)$

$= \cancel{129} \; 129.6\,k < 200k$

$\Rightarrow$ Not ok

Try $L\, 7 \times 4 \times 1/2 \Rightarrow A_g = 5.25$

$r_x = 2.25 \quad r_y = 1.11$ with $\frac{3}{8}''$ G.P

$\frac{L}{r_{min}} = \frac{18 \times 12}{1.11} = 194.59 < 300\,k$

OK.

Allowable bearing on two $1/2''$ thick angle long legs $= 69.6 \times 2 \times \frac{1}{2} \times 0.75$

$= 52.2 > 18.5$

So shear governs.

Checking various limit states

yielding $= 0.6\, A_g\, F_y$

$= 0.6 \times 36 \times (14 \times 0.75)$

$= 226.8 > 200k$ ok

Fracture $= 0.5 \times F_u \times A_e$

$= 0.5 \times 58 \times 0.85 \left[14 - \left(\frac{3}{4}\right) \times 2\right] \times \frac{3}{4}$

$= 231k > 200\,k$ ok

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Check for tearing failure

$$L_e = \frac{2P}{F_u t}$$

$$1.25 = \frac{2P}{58 \times 0.5}$$

$$(1.25)(58 \times 0.5) = 2P$$

$$P = 18.125\ k.$$

$$L = \frac{2P}{F_u t} + \frac{d_b}{2}$$

$$2 = \frac{2P}{58 \times 0.5} + \frac{\frac{3}{4}}{2}$$

$$2 \times (58 \times 0.5) = 2P + 0.375$$

$$116.1 - 0.375 = 2P$$

$$115.72 = 2P$$

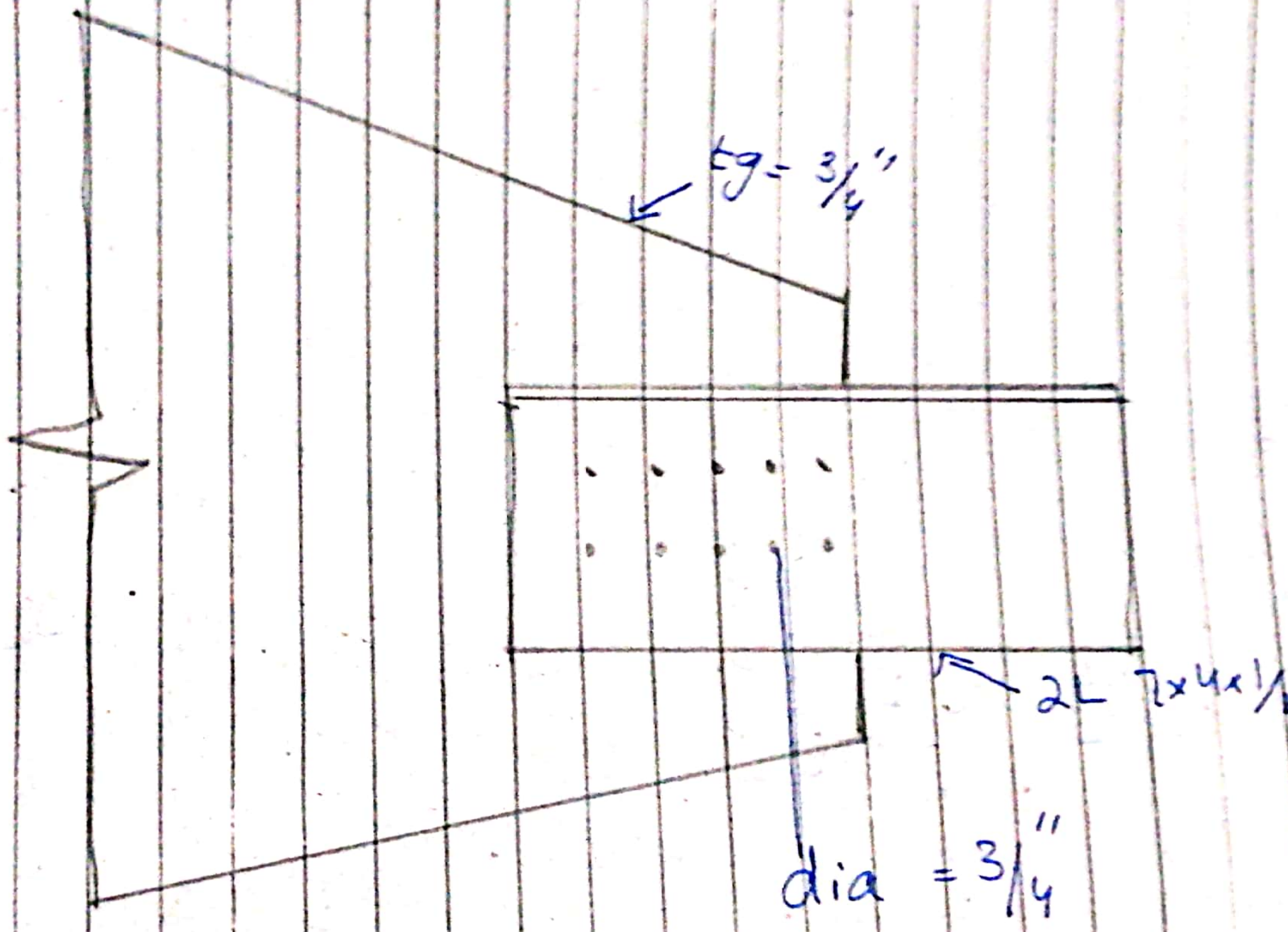
$$P = 57.86k$$

Capacity Since 10 bolts & five bolts per row

$$2 \times 18.125 + 8 \times 57.86$$

$$499.13k > 200k$$

OK


tg = 3/4"
2L 7x4x1/2
dia = 3/4"