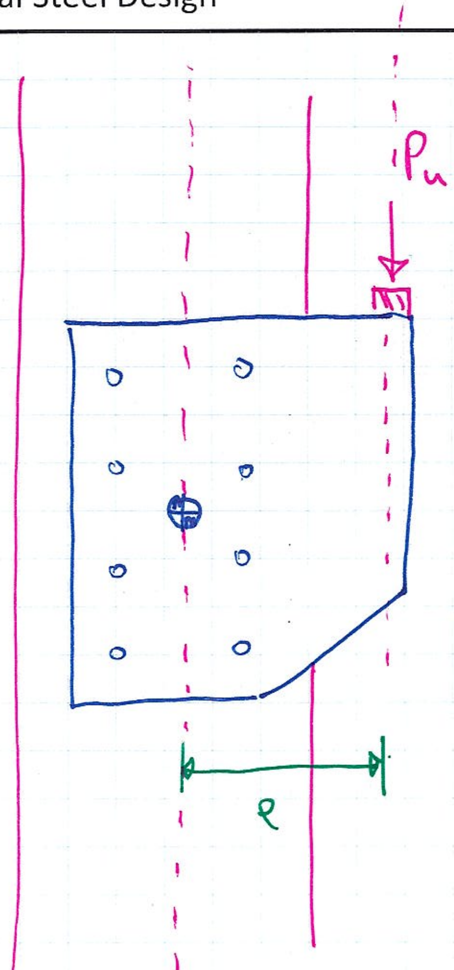

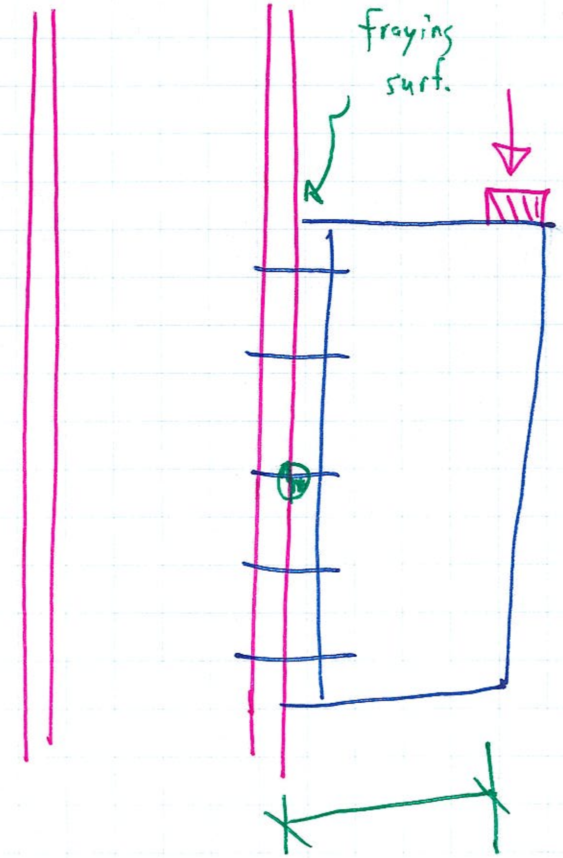

1) Load in-plane of fraying surface (Shear Only)

2) Load not in-plane of fraying surf. (bolts in shear & tension)

ECCENTRIC LOAD - SHEAR ONLY

1) Elastic Method / Analysis - Simplified Method, but inaccurately conservative

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SUMMARY

Force due to direct shear

$$P_{cx} = \frac{P_x}{n} \quad ; \quad P_{cy} = \frac{P_y}{n}$$

Force due to moment

$$P_m x_i = \frac{M y_i}{\sum_1 (x_i^2 + y_i^2)} \quad ; \quad P_m y_i = \frac{M x_i}{\sum_1 (x_i^2 + y_i^2)}$$

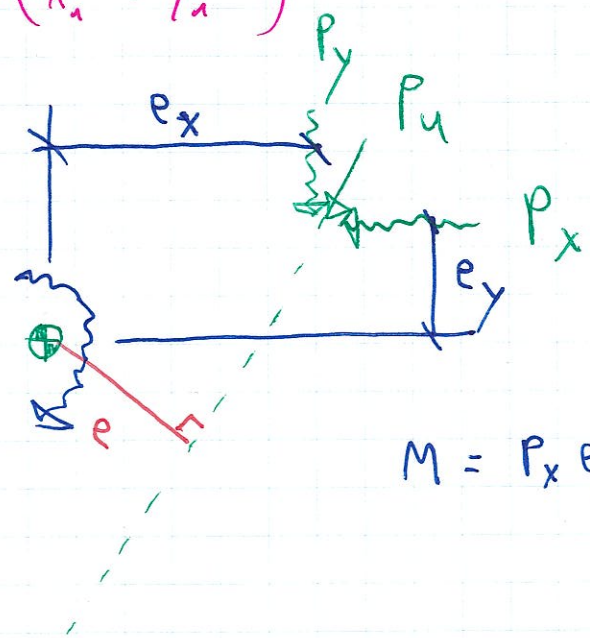
where: $M = \pm P_x e_y \pm P_y e_x$

P_x = applied Force in x

P_y = " " " y

x_i = horz. dist. from CG to bolt i

y_i = Vert. " " " " " i



$M = P_x e_y - P_y e_x = P_u e$

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Resultant Force

$$P_i = \sqrt{\left(P_{cx} \pm P_m X_i\right)^2 + \left(P_{cy} \pm P_m Y_i\right)^2}$$

2) Method of Instantaneous Centers / Ult. Strength Analysis

- More accurate, but iterative & complex
- AISC part 7 uses this method - Provide a coef. "C" which is the ratio of design strength of bolt group to the design strength of a single bolt

$$C = \frac{P_u}{\phi r_n} = f(\text{bolt spacing, eccentricity, \# of bolts, arrangement of bolts, \& angle of load, etc.})$$

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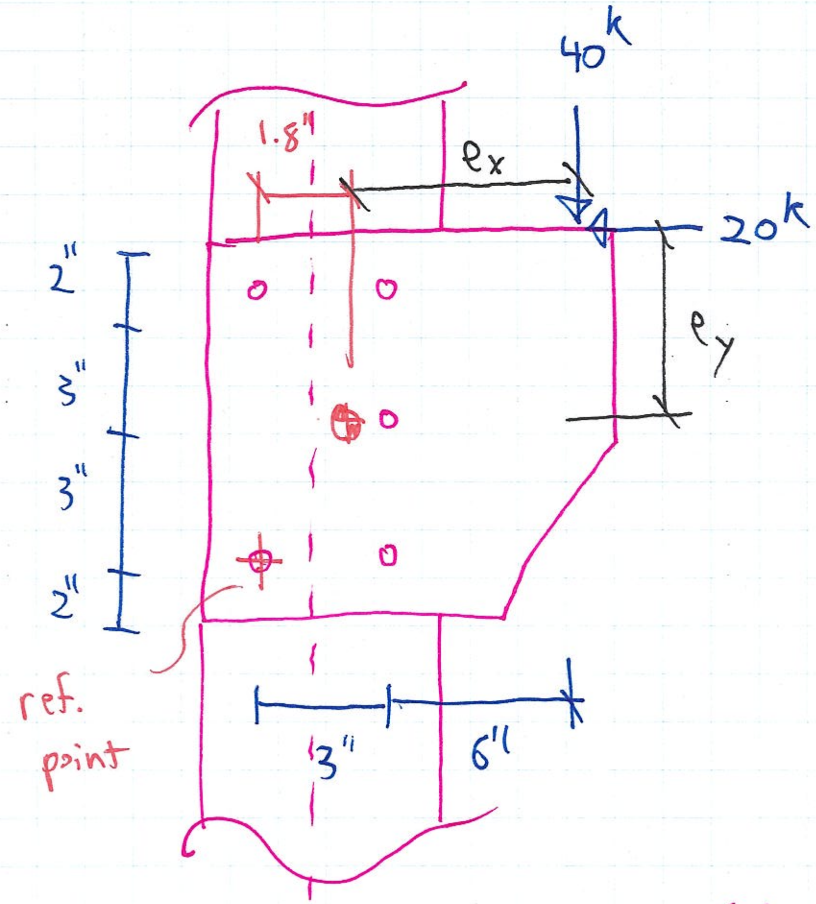
EXAMPLE

GIVEN: A ℘ bolted to a colm. flange. ∴



Determine CG of bolts

$$\bar{y} = \frac{(1\text{ bolt})(3") + (2\text{ bolts})(6")}{(5\text{ bolts})} = 3.0"$$

$$\bar{x} = \frac{(3\text{ bolts})(3")}{(5\text{ bolts})} = 1.8"$$

REQ'D: a) Max bolt shear force (elastic method)
b) What size A325 bolts are required?

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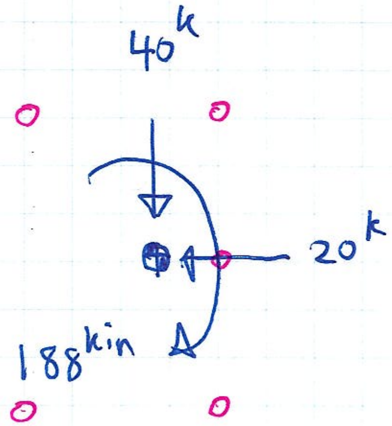
SOLN: a)

$$e_x = 9'' - 1.8'' = 7.2''$$

$$e_y = 3'' + 2'' = 5''$$

MOMENT: $\overset{+}{M} = \pm P_x e_y \pm P_y e_x$

$$= +40^k(7.2'') - 20^k(5'') = 188^{k\text{-}in}$$



DIRECT SHEAR:

$$P_{cx} = \frac{20^k}{5\text{ bolts}} = 4^k/\text{bolt} \quad \leftarrow$$

$$P_{cy} = \frac{40^k}{5\text{ bolts}} = 8^k/\text{bolt} \quad \downarrow$$

SHEAR DUE TO MOMENT:

$$\sum_i (x_i^2 + y_i^2) = \overbrace{(2\text{ bolts})(1.8'')^2 + (3\text{ bolts})(1.2'')^2}^{X} + \underbrace{(2\text{ bolts})(3'')^2 + (2\text{ bolts})(3'')^2}_{Y}$$

$$= 46.8\text{ in}^2$$

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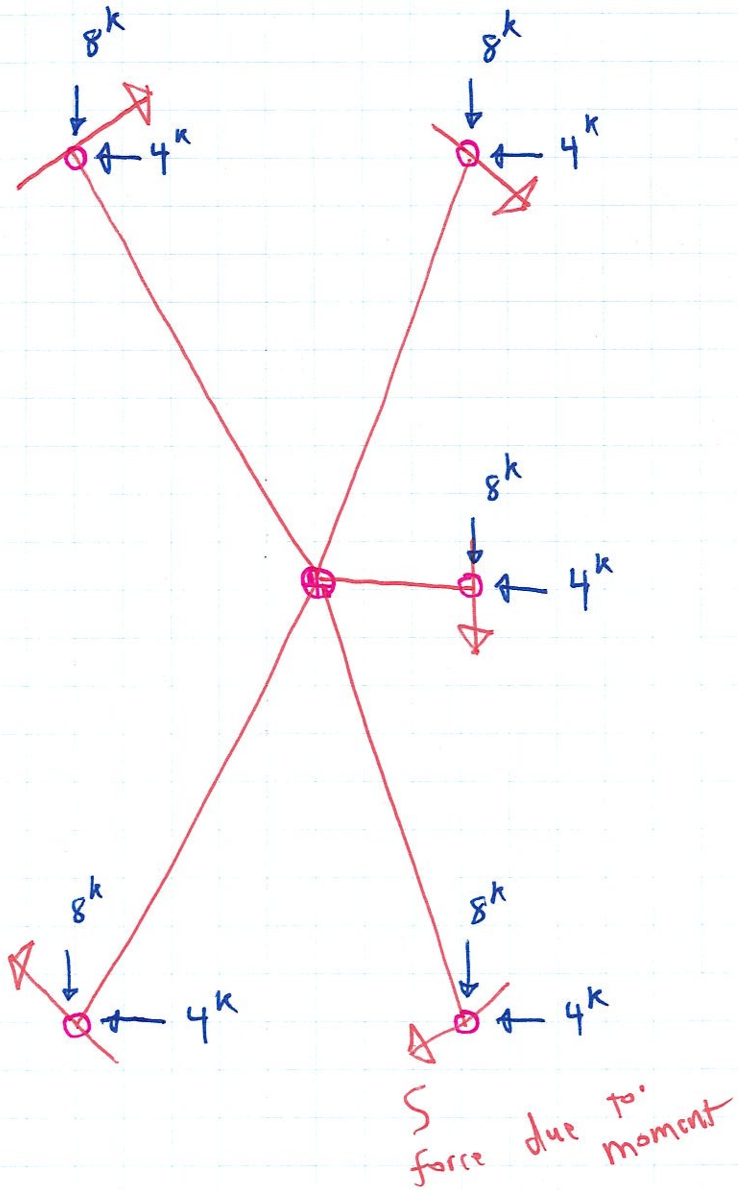

Btm. Rt. bolt is critical b/c direct shear & moment comp. are additive

$P_{cy} = 8^k$ $\quad P_{my}$

$P_{cx} = 4^k$ $\quad + \quad$ P_{mx}

Direct shear $\qquad$ Moment

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$$P_{mx} = \frac{My}{\sum(x_i^2 + y_i^2)} = \frac{188^{kin}(3'')}{46.8\ in^2} = 12.05^k \leftarrow$$

$$P_{my} = \frac{Mx}{\sum(x_i^2 + y_i^2)} = \frac{188^{kin}(1.2'')}{46.8\ in^2} = 4.82^k \downarrow$$

Total Shear

$$\overset{+\leftarrow}{\sum P_x} = P_{cx} + P_{mx} = 16.05^k \leftarrow$$

$$\overset{+\downarrow}{\sum P_y} = P_{cy} + P_{my} = 12.82^k \downarrow$$

$$P = \sqrt{16.05^2 + 12.82^2} = \underline{\underline{20.5}}^k$$

b) AISC Table 7-1, p7-22 $\frac{7}{8}''\phi$, A325N, S, STD: $\phi r_n = 24.3\ ^k/_{bolt} > P = 20.5\ ^k/_{bolt}$ ✓

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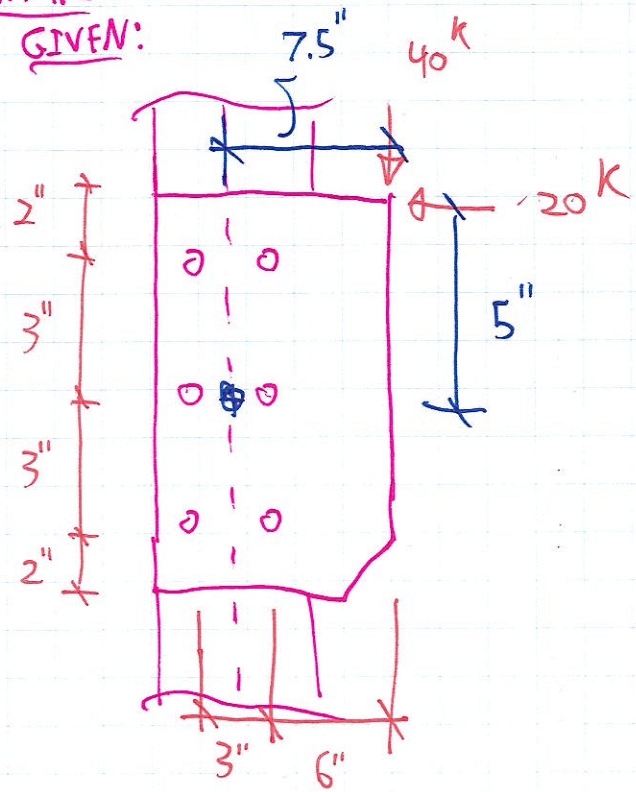
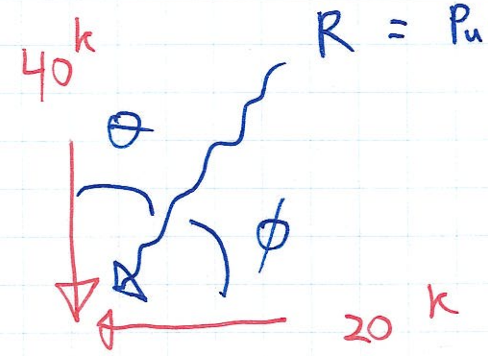
EXAMPLE

GIVEN:





$$R = P_u = \sqrt{20^2 + 40^2} = 44.7^k$$

$$\phi = \tan^{-1}\left(\frac{40}{20}\right) = 63.43^\circ$$

$$\theta = 90 - \phi = 26.6^\circ$$

REQ'D: Determine the size of A325 bolts req'd for the bearing type connection:

a) threads included

b) threads excluded

c) slip-critical

Use Ult. Strength Analysis

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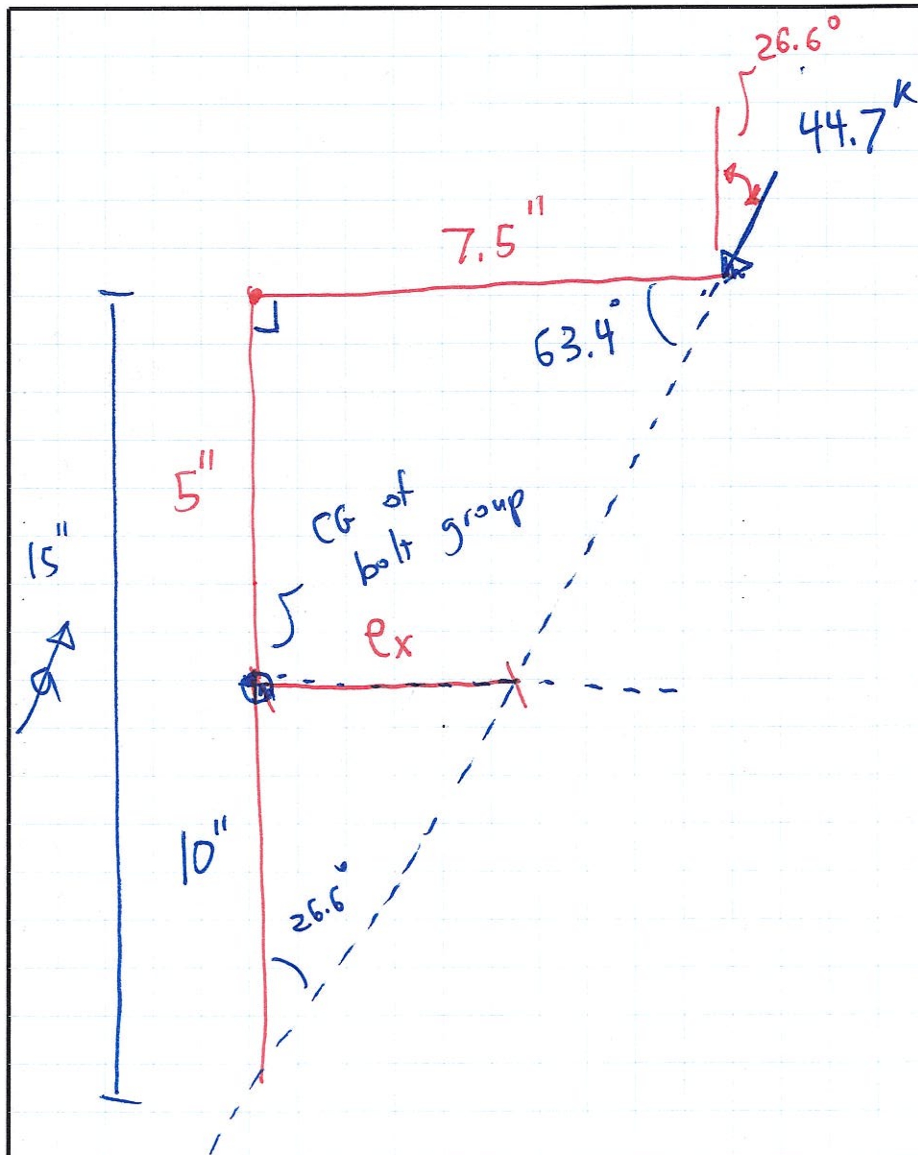

$$\frac{7.5''}{\sin(26.6^\circ)} = \frac{a}{\sin(63.4^\circ)} \Rightarrow a = 15''$$

(law of sines)

$$\frac{e_x}{10''} = \frac{7.5''}{15''} \Rightarrow e_x = 5''$$

(similar triangles)

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$S = 3''$; $e_x = 5''$; $n = 3$ $\rightarrow$ $C = 2.66$ @ $15°$; $C = 2.85$ @ $30°$ } Table 7-7, p7-38 & 39

$$C = 2.66 + \frac{(2.85 - 2.66)}{(30 - 15)}(26.6 - 15) = 2.81$$

$$C = \frac{P_u}{\phi r_n} \Rightarrow (\phi r_n)_{req'd} = \frac{P_u}{C} = \frac{44.7^k}{2.81} = 15.93\ ^k/_{bolt}$$

a) $\frac{3}{4}''\phi$, A325N, S, STD $\quad \phi r_n = 17.9\ ^k/_{bolt} > 15.9\ ^k/_{bolt}$ ✓

b) $\frac{3}{4}''\phi$, A325X, S, STD $\quad \phi r_n = 17.9\ ^k/_{bolt}$ ✓

} Table 7-1, p7-22

c) $1''\phi$, A325SC, S, STD $\quad \phi r_n = 17.3\ ^k/_{bolt} > 15.9\ ^k/_{bolt}$ ✓ Table 7-3, p7-24

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