

The second part of Solved Problem 10-1

From - ALAN Williams

Steel Structures
Design

We will solve the Bearing part

- a) Use Calculations
- b) Use Manual Table 7-4
7-5

Check requirements in the next slide

Find LRFD value for the Connection

Requirements to solve for Bearing & Tear out

- (a) J3-3 Table to check Hole diameter For bolts
Page 16.1-131 or J3-3M For metric data
- (b) J3-4 Table to check minimum edge distance For bolts
Page 16.1-132 or J3-4M
- (c) Minimum spacing $S \geq 2 \frac{2}{3} d_b$, Clear distance shall or $< d$.
item 3 - Page 16.1-130-132
item 4 \rightarrow Minimum edge distance
item 5 \rightarrow Maximum spacing and Edge distance
- (d) Item (10) Bearing & Tear out Equations Page 13's & Φ_b & R_b
J3-6a, b, c, d

Example 10.1. Bolts in Shear and Bearing with Deformation a Design Consideration

The connection shown in Fig. 10.7 consists of four, grade A490, $\frac{3}{4}$ -in-diameter bolts. The bolts are snug-tight and threads are excluded from the shear planes. Deformation around the bolt holes is a design consideration and the bolt spacing is as indicated. The angles and gusset plate are fabricated from A36 steel. Assuming that the angles and gusset plate are satisfactory, determine the shear force that may be applied to the bolts in the connection.

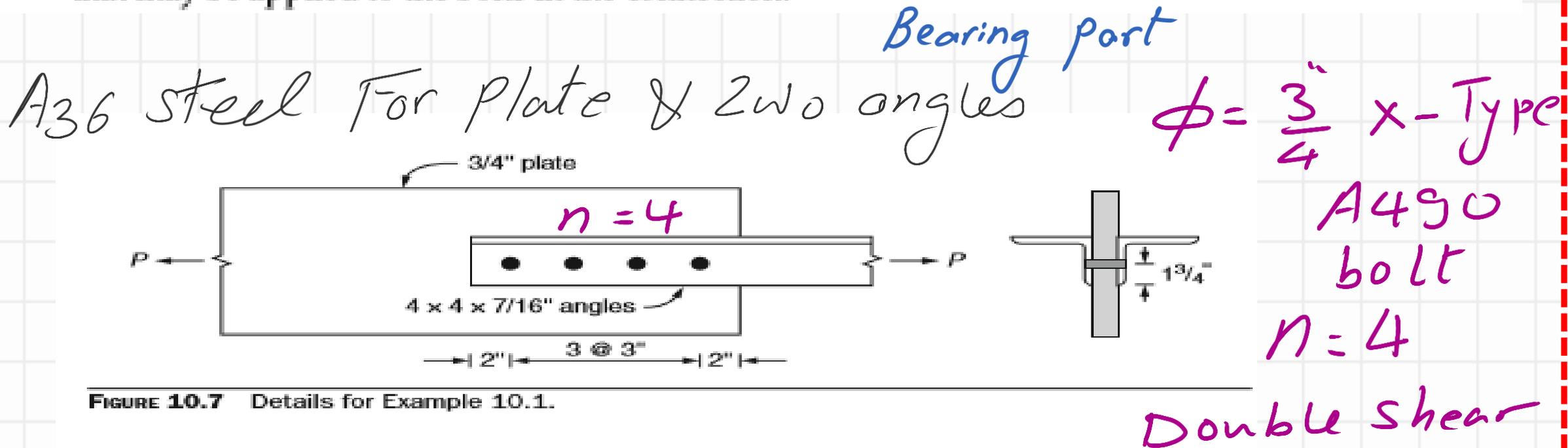


FIGURE 10.7 Details for Example 10.1.

Item ④

Page 16.1-135

AISC-360-16
CM#15

10. Bearing and Tearout Strength at Bolt Holes

The available strength, ϕR_n and R_n/Ω , at bolt holes shall be determined for the limit states of bearing and tearout, as follows:

$$\phi = 0.75 \text{ (LRFD)} \quad \Omega = 2.00 \text{ (ASD)}$$

The nominal strength of the connected material, R_n , is determined as follows:

- (a) For a bolt in a connection with standard, oversized and short-slotted holes, independent of the direction of loading, or a long-slotted hole with the slot parallel to the direction of the bearing force

Prepared by Eng. Maged Kamel.

Deformations Bearing & Tear-out For deformation = 0.25"

(1) Bearing

- (i) When deformation at the bolt hole at service load is a design consideration

Design Criteria

$$R_n = 2.4dtF_u$$

(J3-6a)

Deformation = 0.25"

- (ii) When deformation at the bolt hole at service load is not a design consideration

Not design Criteria

$$R_n = 3.0dtF_u$$

(J3-6b)

(2) Tearout

- (i) When deformation at the bolt hole at service load is a design consideration

D. Criteria

$$R_n = 1.2l_c t F_u$$

(J3-6c)

→ 0.25"

- (ii) When deformation at the bolt hole at service load is not a design consideration

Not D. Criteria

$$R_n = 1.5l_c t F_u$$

(J3-6d)

item (d) requirements

Page ⇒ 16.1-136

For Long Slotted bolts

(b) For a bolt in a connection with long-slotted holes with the slot perpendicular to the direction of force

(1) Bearing

$$R_n = 2.0dtF_u \quad (J3-6e)$$

(2) Tearout

$$R_n = 1.0l_c tF_u \quad (J3-6f)$$

(c) For connections made using bolts that pass completely through an unstiffened box member or HSS, see [Section J7](#) and [Equation J7-1](#);

(c) For connections made using bolts that pass completely through an unstiffened box member or HSS, see [Section J7](#) and [Equation J7-1](#);

where

F_u = specified minimum tensile strength of the connected material, ksi (MPa)

d = nominal fastener diameter, in. (mm)

l_c = clear distance, in the direction of the force, between the edge of the hole and the edge of the adjacent hole or edge of the material, in. (mm)

t = thickness of connected material, in. (mm)

Bearing strength and tearout strength shall be checked for both bearing-type and slip-critical connections. The use of oversized holes and short- and long-slotted holes parallel to the line of force is restricted to slip-critical connections per [Section J3.2](#).

Prepared by Eng.Maged Kamel.

Nominal Hole diameter

requirement (a)

TABLE J3.3
Nominal Hole Dimensions, in.

| Bolt Diameter, in. | Hole Dimensions | | | |
|--------------------|-----------------|-----------------|-----------------------------|----------------------------|
| | Standard (Dia.) | Oversize (Dia.) | Short-Slot (Width x Length) | Long-Slot (Width x Length) |
| 1/2 | 9/16 | 5/8 | 9/16 x 11/16 | 9/16 x 1 1/4 |
| 5/8 | 11/16 | 13/16 | 11/16 x 7/8 | 11/16 x 1 9/16 |
| 3/4 | 13/16 | 15/16 | 13/16 x 1 | 13/16 x 1 7/8 |
| 7/8 | 15/16 | 1 1/16 | 15/16 x 1 1/8 | 15/16 x 2 3/16 |
| 1 | 1 1/8 | 1 1/4 | 1 1/8 x 1 5/16 | 1 1/8 x 2 1/2 |
| ≥ 1 1/8 | d + 1/8 | d + 5/16 | (d + 1/8) x (d + 3/8) | (d + 1/8) x 2.5d |

For bolt
add $\frac{1}{16}$ " only

$$\frac{3}{4}'' \rightarrow \frac{3}{4}'' + \frac{1}{16}'' = \frac{13}{16}''$$

our example

Page 16.1-131

RCSC (Research Council on Structural Connections)
 Specification for Structural Joints Using High-Strength Bolts

AISC-16.2-23

Table 3.1. Nominal Bolt Hole Dimensions

| Nominal Bolt Diameter, d_b , in. | Nominal Bolt Hole Dimensions ^{a,b} , in. | | | |
|------------------------------------|---|------------------------|---|--|
| | Standard (diameter) | Oversized (diameter) | Short-slotted (width × length) | Long-slotted (width × length) |
| $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{9}{16} \times \frac{1}{8}$ | $\frac{9}{16} \times 1\frac{1}{4}$ |
| $\frac{5}{8}$ | $1\frac{1}{16}$ | $\frac{13}{16}$ | $1\frac{1}{16} \times \frac{3}{8}$ | $1\frac{1}{16} \times 1\frac{9}{16}$ |
| $\frac{3}{4}$ | $1\frac{3}{16}$ | $\frac{15}{16}$ | $1\frac{3}{16} \times 1$ | $1\frac{3}{16} \times 1\frac{7}{8}$ |
| $\frac{7}{8}$ | $1\frac{5}{16}$ | $1\frac{1}{8}$ | $1\frac{5}{16} \times 1\frac{1}{8}$ | $1\frac{5}{16} \times 2\frac{3}{16}$ |
| 1 | $1\frac{1}{4}$ | 1 $\frac{1}{4}$ | $1\frac{1}{4} \times 1\frac{5}{8}$ | $1\frac{1}{4} \times 2\frac{1}{2}$ |
| $\geq 1\frac{1}{8}$ | $d_b + \frac{1}{16}$ | $d_b + \frac{5}{16}$ | $(d_b + \frac{1}{16}) \times (d_b + \frac{3}{8})$ | $(d_b + \frac{1}{16}) \times (2.5d_b)$ |

^a The upper tolerance on the tabulated nominal dimensions shall not exceed $\frac{1}{32}$ in. Exception: In the width of slotted holes, gouges not more than $\frac{1}{8}$ in. deep are permitted.

^b The slightly conical hole that naturally results from punching operations with properly matched punches and dies is acceptable.

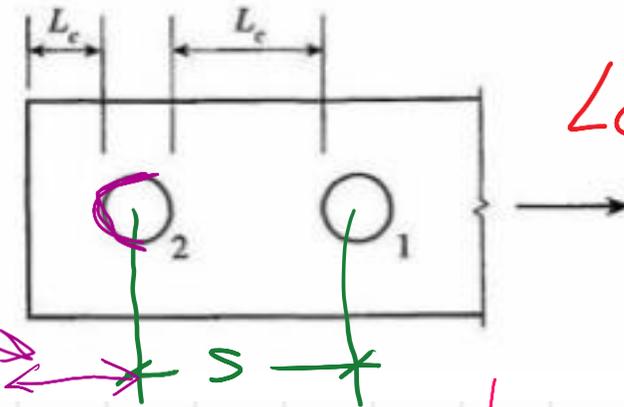
Prepared by Eng.Maged Kamel.

J3.4

$$L_c = L - \frac{d_n}{2} \leftarrow S$$

$$S = 2 \frac{2}{3} d_b \rightarrow 3d$$

$$L_c \neq d$$



min value

$$d_n = d_b + \frac{1}{16}$$

TABLE J3.4
Minimum Edge Distance^[a] from
Center of Standard Hole^[b] to Edge of
Connected Part, in.

| Bolt Diameter, in. | Minimum Edge Distance |
|--------------------|-----------------------|
| 1/2 | 3/4 |
| 5/8 | 7/8 |
| 3/4 | 1 |
| 7/8 | 1 1/8 |
| 1 | 1 1/4 |
| 1 1/8 | 1 1/2 |
| 1 1/4 | 1 5/8 |
| Over 1 1/4 | 1 1/4 d |

3. Minimum Spacing

The distance between centers of standard, oversized or slotted holes shall not be less than $2\frac{2}{3}$ times the nominal diameter, d , of the fastener. However, the clear distance between bolt holes or slots shall not be less than d .

User Note: A distance between centers of standard, oversize or slotted holes of $3d$ is preferred.

$\rightarrow 1\frac{1}{4}$

For 3/4

$$L_{ci} = S - d_n$$

For inner bolts

^[a] If necessary, lesser edge distances are permitted provided the applicable provisions from Sections J3.10 and J4 are satisfied, but edge distances less than one bolt diameter are not permitted without approval from the engineer of record.

^[b] For oversized or slotted holes, see Table J3.5.

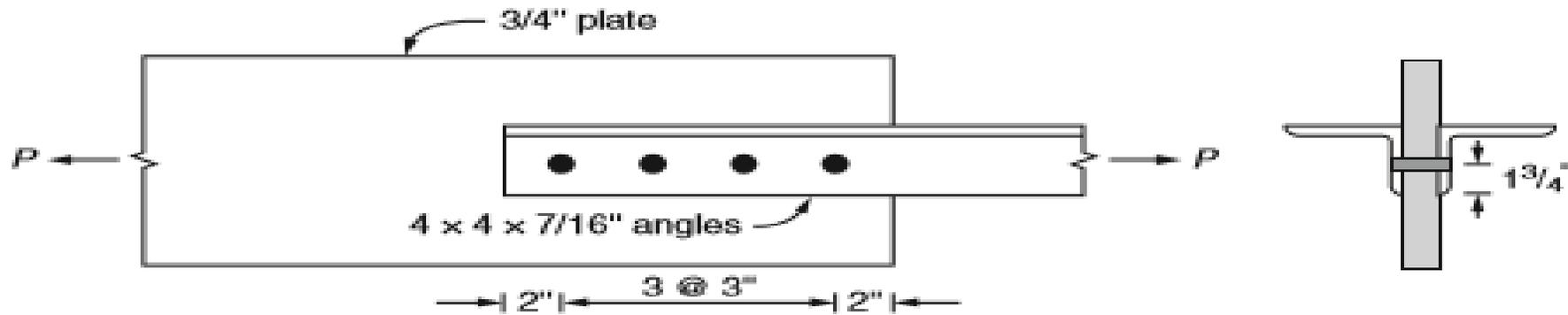


FIGURE 10.7 Details for Example 10.1.

① Edge distance = 2" → requirement $1 \frac{1}{4}"$ J-3-4 OK

$$d_b = \frac{3}{4} \quad l_{c0} = 2" - \frac{d_h}{2} = 2" - \frac{1}{2} \left(\frac{13}{16} \right) = \frac{64-13}{32} = \frac{51}{32}$$

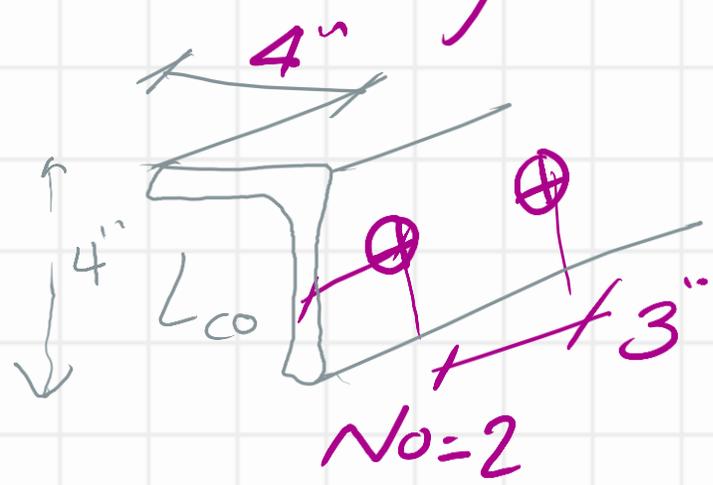
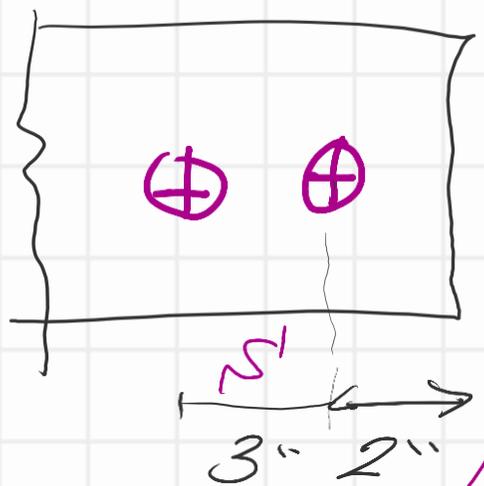
$$d_h = d_b + \frac{1}{16} = \frac{3}{4} + \frac{1}{16} = \frac{13}{16}" \rightarrow \text{Same as Table}$$

Find

② Check S' → requirement $2 \frac{2}{3} d_b = \frac{8}{3} \left(\frac{3}{4} \right) = 2"$
 Given $S = 3" > S_{req}$ OK

Which thickness will govern the design?

G. plate or sum of tw angles?



Two angles

$L_{c0} = 2''$
 $S^l = 3''$

G. plate

$$\sum t_L = 2 \left(\frac{7}{16} \right) = \frac{14}{16} = \frac{7}{8}''$$

$t = \frac{3}{4}''$

is less $< \frac{7}{8}''$
 G. plate will
 thicker

$p^S = S_{2LS}$
 Control the design
 $L_{c0} = L_{c0} 2LS$

check $L_{c0} = \frac{51}{32} = 1.59''$

check $2d_b = 2\left(\frac{3}{4}\right) = 1.50''$

$L_{c0} > 2d$
upper-limit

G.P.L A36 $\rightarrow F_u = 58 \text{ ksi}$

(1) Bearing

(i) When deformation at the bolt hole at service load is a design consideration

$$R_n = 2.4dtF_u$$

(J3-6a)

$t_{pl} = \frac{3}{4}$

Use J3-6a

(2) Tearout

(i) When deformation at the bolt hole at service load is a design consideration

$$R_n = 1.2l_{ct}F_u$$

(J3-6c)

give Lower value

$$R_n = (2.4)d_b t F_u = 2.4\left(\frac{3}{4}\right)\left(\frac{3}{4}\right)(58) = 78.3 \text{ kips}$$

Less than

$$\Rightarrow 1.2l_{ct}F_u = 1.2(1.59)\left(\frac{3}{4}\right)(58) = 83 \text{ kips}$$

For inner Connection

$$S = 3''$$

$$L_{ci} = 3'' - d_h = 3 - \frac{13}{16} = \frac{48-13}{16} = \frac{35}{16} = 2.1875''$$

$$d_h = \frac{13}{16}, \quad d_b = \frac{3}{4}$$

Check whether $L_{ci} \leq 2d_b$

$$2d_b = 2\left(\frac{3}{4}\right) = 1.50''$$

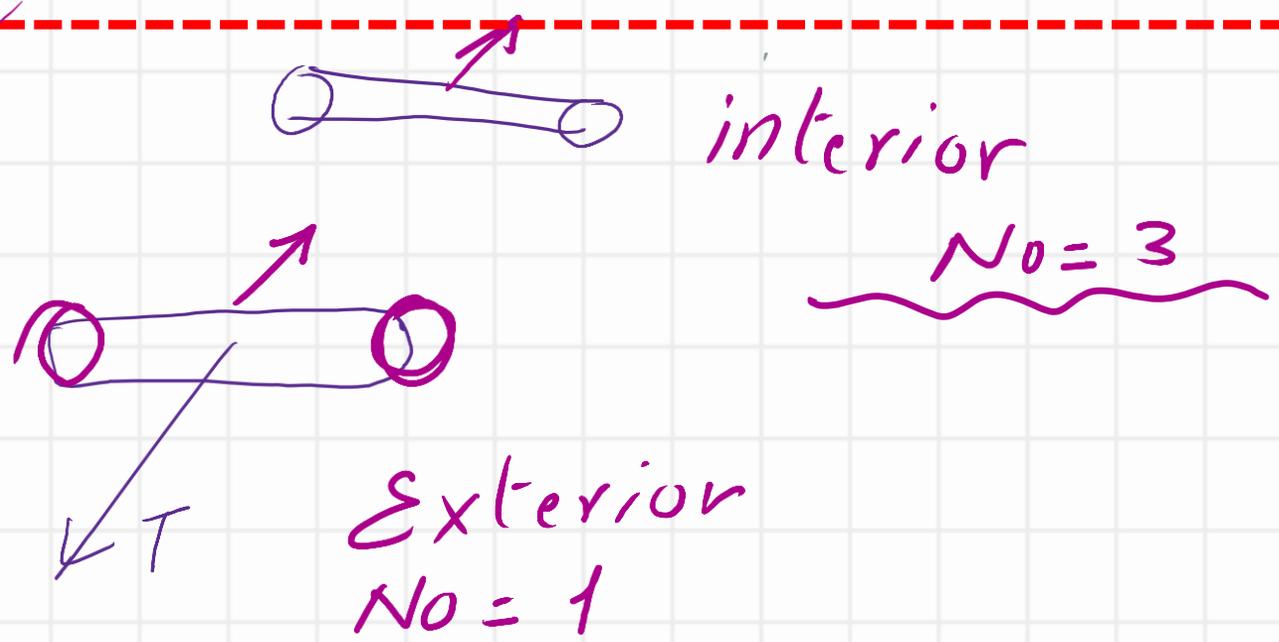
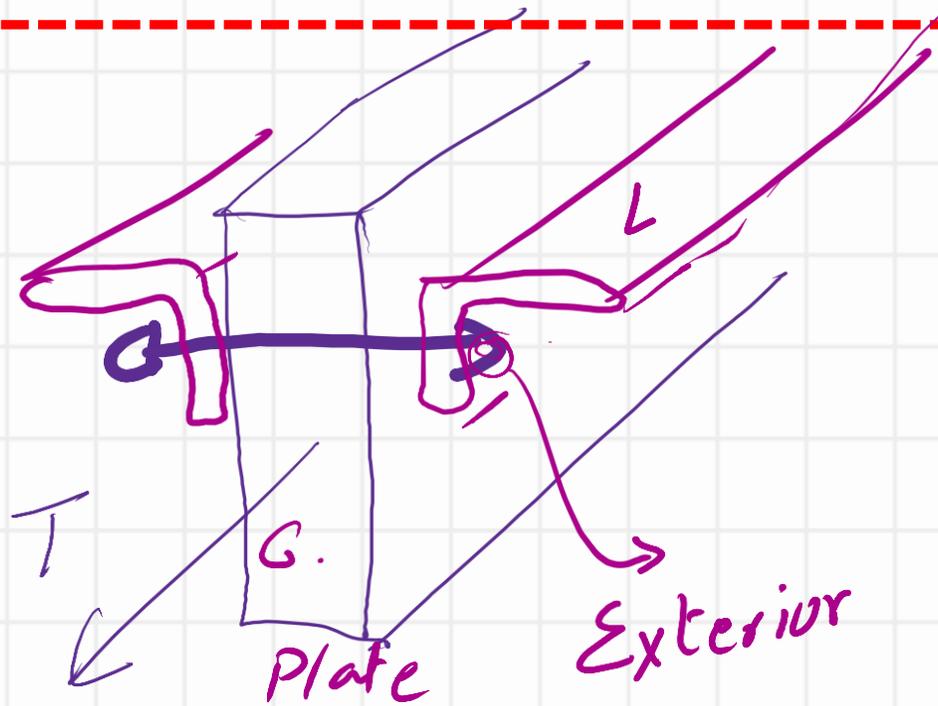
$$L_{ci} < 2d_b \Rightarrow 2.1875'' < 1.50''$$

Use Upper Limit Equation: $2.4(d_b)(t_p)(F_u)$

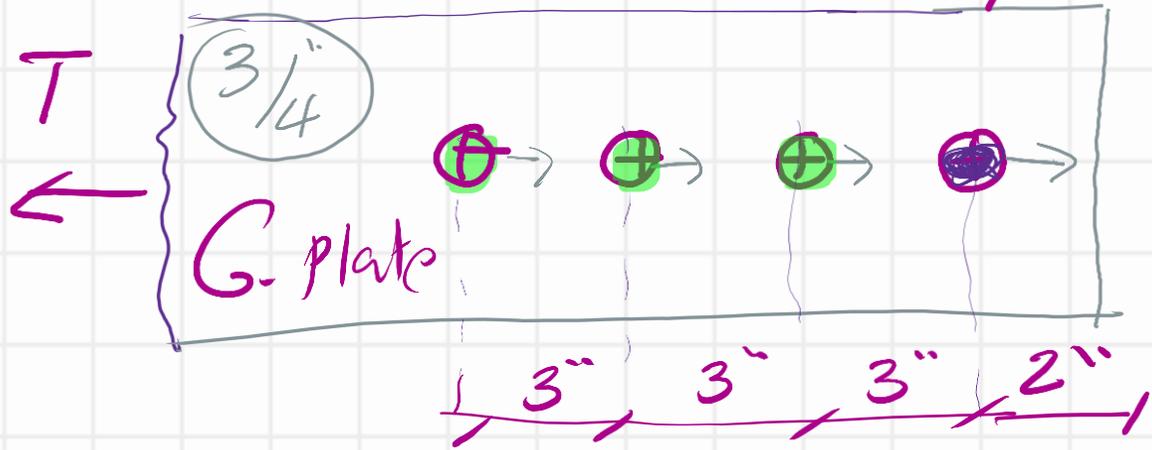
$$R_{ni} = 78.30 \text{ kips}$$

$$R_{ni} = 2.4\left(\frac{3}{4}\right)\left(\frac{3}{4}\right)(58)$$

Do not use $1.2 L_{ci} t_p F_u$



Bolt bearing in Gusset plate



$1 (78.3)$ Exterior
 $3 (78.3)$ inner
 $T = 78.3 (4) = 313.2 \text{ kips}$
 $\approx 313 \text{ kips}$

LRFD

$$\phi_b = 0.75$$

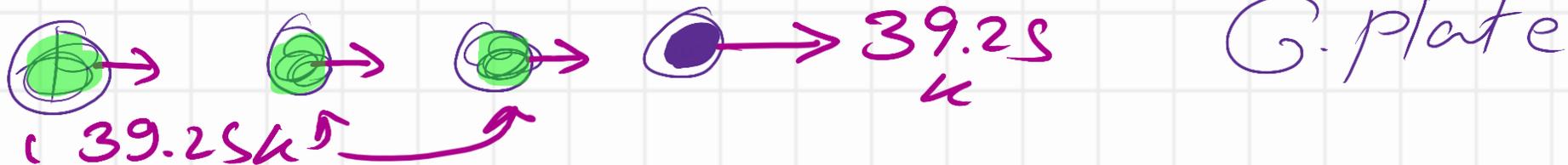
$$\phi R_n = 0.75(313) = 234.75 \text{ kips} \\ \approx 235 \text{ kips}$$



ASD

$$\lambda_b = 2.00$$

$$\frac{1}{\lambda_b} R_n = \frac{1}{2}(313) = 156.50 \text{ kips} \\ \approx 157 \text{ kips}$$



A36 G. plate

Inner bolts

$$d_b = \frac{3}{4}''$$

$$t_p = 3/4''$$



$F_u = 58 \text{ ksi}$
A36 steel

Table 7-4
Available Bearing and Tearout Strength at Bolt Holes Based on Bolt Spacing
kip/in. thickness

| Hole Type | Bolt Spacing, s , in. | F_u , ksi | Nominal Bolt Diameter, d , in. | | | | | | | |
|-------------|-------------------------|-------------|----------------------------------|------------|--------------|------------|--------------|------------|--------------|------------|
| | | | $5/8$ | | $3/4$ | | $7/8$ | | 1 | |
| | | | r_n/Ω | ϕr_n | r_n/Ω | ϕr_n | r_n/Ω | ϕr_n | r_n/Ω | ϕr_n |
| STD SSLT | $2^{2/3} d_b$ | 58 | 34.1 | 51.1 | 41.3 | 62.0 | 48.6 | 72.9 | 53.7 | 80.5 |
| | | 65 | 38.2 | 57.3 | 46.3 | 69.5 | 54.4 | 81.7 | 60.1 | 90.2 |
| | 3 in. | 58 | 43.5 | 65.3 | 52.2 | 78.3 | 60.9 | 91.4 | 65.3 | 97.9 |
| | | 65 | 48.8 | 73.1 | 58.5 | 87.8 | 68.3 | 102 | 73.1 | 110 |

as given $s = 3''$ $\phi r_n = 78.30 \frac{\text{kip}}{\text{inch}} \left(\frac{3}{4} t_p \right) = 58.73 \text{ kips}$
Matches with calculation

Continuation of Table 7-4 $\frac{3}{4}$ " inner bolts

| | | | | |
|--|------------------|---|-----------------|------------------|
| Minimum Spacing ^a = $2\frac{2}{3}d$, in. | $1\frac{11}{16}$ | 2 | $2\frac{5}{16}$ | $2\frac{11}{16}$ |
|--|------------------|---|-----------------|------------------|

STD = standard hole → Standard Hole
 SSLT = short-slotted hole oriented with length transverse to the line of force
 SSLP = short-slotted hole oriented with length parallel to the line of force
 OVS = oversized hole
 LSLP = long-slotted hole oriented with length parallel to the line of force
 LSLT = long-slotted hole oriented with length transverse to the line of force

$(2\frac{2}{3})(\frac{3}{4}) = 2"$

| | | |
|-----------------|---------------|--|
| ASD | LRFD | Note: Spacing indicated is from the center of the hole or slot to the center of the adjacent hole or slot in the line of force. Hole deformation is considered. When hole deformation is not considered, see AISC Specification Section J3.10. ^a Decimal value has been rounded to the nearest sixteenth of an inch. |
| $\Omega = 2.00$ | $\phi = 0.75$ | |

→ $\phi = 0.75$

Exterior bolt

$F_u = 58 \text{ ksi}$ A36 steel

Table 7-5
Available Bearing and Tearout Strength at Bolt Holes Based on Edge Distance
kip/in. thickness

| Hole Type | Edge Distance, l_e , in. | F_{ub} ksi | Nominal Bolt Diameter, d , in. | | | | | | | |
|-------------|----------------------------|--------------|----------------------------------|------------|--------------|------------|--------------|------------|--------------|------------|
| | | | $5/8$ | | $3/4$ | | $7/8$ | | 1 | |
| | | | r_n/Ω | ϕr_n | r_n/Ω | ϕr_n | r_n/Ω | ϕr_n | r_n/Ω | ϕr_n |
| STD SSLT | 1 1/4 | 58 | 31.5 | 47.3 | 29.4 | 44.0 | 27.2 | 40.8 | 23.9 | 35.9 |
| | | 65 | 35.3 | 53.0 | 32.9 | 49.4 | 30.5 | 45.7 | 26.8 | 40.2 |
| STD SSLT | 2 → | 58 | 43.5 | 65.3 | 52.2 | 78.3 | 53.3 | 79.9 | 50.0 | 75.0 |
| | | 65 | 48.8 | 73.1 | 58.5 | 87.8 | 59.7 | 89.6 | 56.1 | 84.1 |

$$d_b = \frac{3}{4}''$$

$l_e = 2''$ as given

Matches with Calculation

$$\phi r_n = 78.3 \frac{\text{kip}}{\text{inch}}$$

$$\phi r_n = 78.3 \left(\frac{3}{4} \right) = 58.73 \text{ kips}$$

For one bolt

Continuation of Table 7-5

| Edge distance for full bearing and tearout strength $l_e \geq l_{e \text{ full}}^a$, in. | STD, SSLT, LSLT | $1\frac{5}{8}$ | $1\frac{15}{16}$ | $2\frac{1}{4}$ | $2\frac{9}{16}$ |
|--|-----------------------|--|------------------|-----------------|------------------|
| | OVS | $1\frac{11}{16}$ | 2 | $2\frac{5}{16}$ | $2\frac{5}{8}$ |
| | SSLP | $1\frac{11}{16}$ | 2 | $2\frac{5}{16}$ | $2\frac{11}{16}$ |
| | LSLP | $2\frac{1}{16}$ | $2\frac{7}{16}$ | $2\frac{7}{8}$ | $3\frac{1}{4}$ |
| <p>STD = standard hole SSLT = short-slotted hole oriented with length transverse to the line of force SSLP = short-slotted hole oriented with length parallel to the line of force OVS = oversized hole LSLP = long-slotted hole oriented with length parallel to the line of force LSLT = long-slotted hole oriented with length transverse to the line of force</p> | | | | | |
| ASD | LRFD | <p>– Indicates edge distance less than minimum required per AISC <i>Specification</i> Section J3.4. Note: Edge distance indicated is from the center of the hole or slot to the edge of the element in the line of force. Hole deformation is considered. When hole deformation is not considered, see AISC <i>Specification</i> Section J3.10. ^a Decimal value has been rounded to the nearest sixteenth of an inch.</p> | | | |
| $\Omega = 2.00$ | $\phi = 0.75$ | | | | |

$$\phi = 0.75$$