Lecture 4

RIVETED AND WELDED CONNECTIONS

Shearing Stress (S_s)

- Shearing Stress (S_s):

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

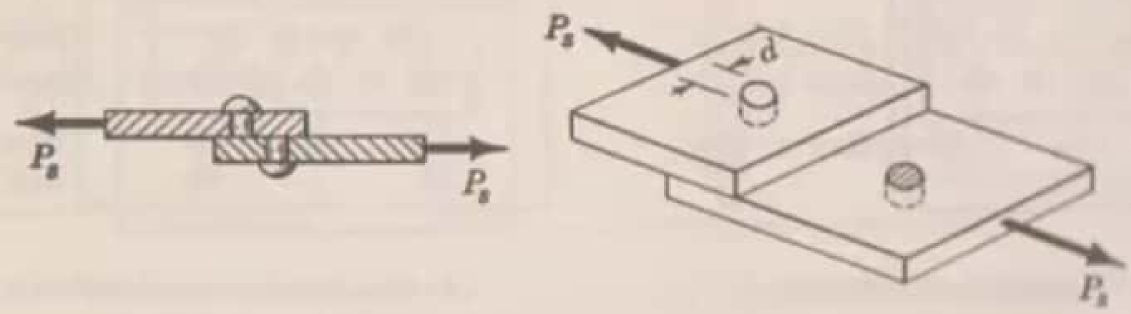
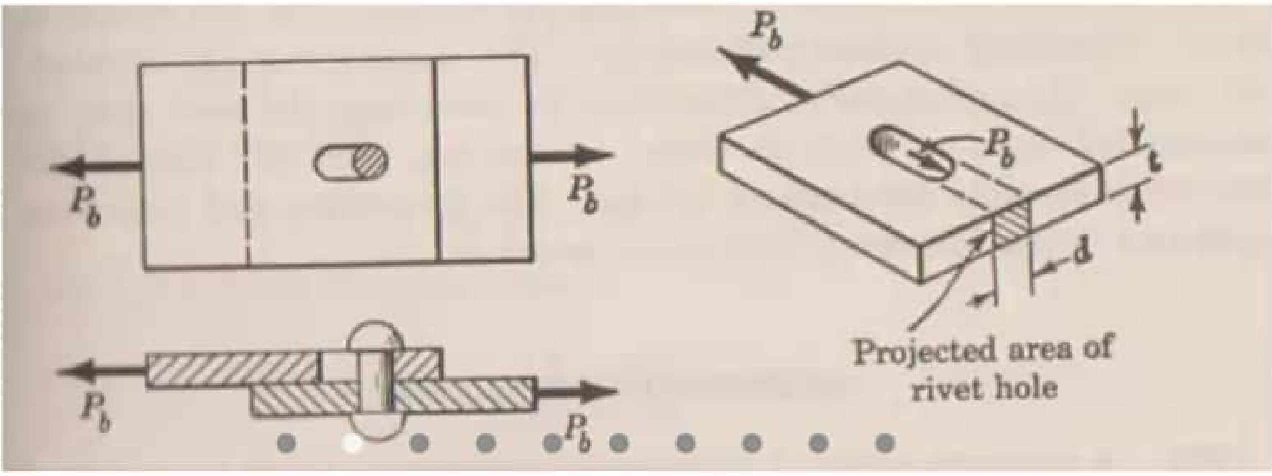


Fig. 12-3. — Shear failure.

Bearing Stress (S_b)

- Bearing Stress (S_b):

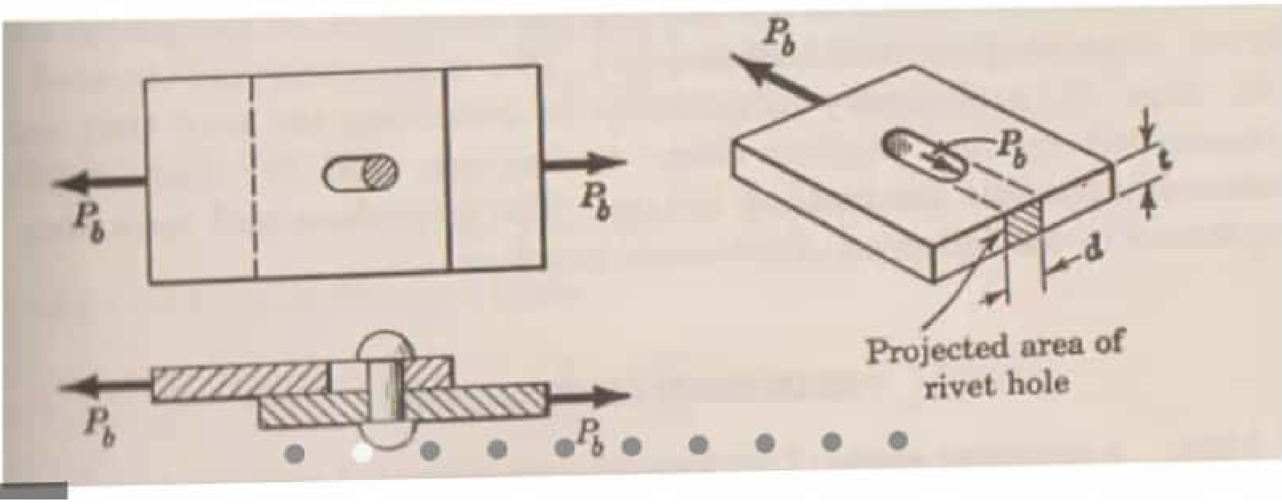
$$P_b = A_b \times S_b = (t \times d) \times S_b$$



Bearing Stress (S_b)

- Bearing Stress (S_b):

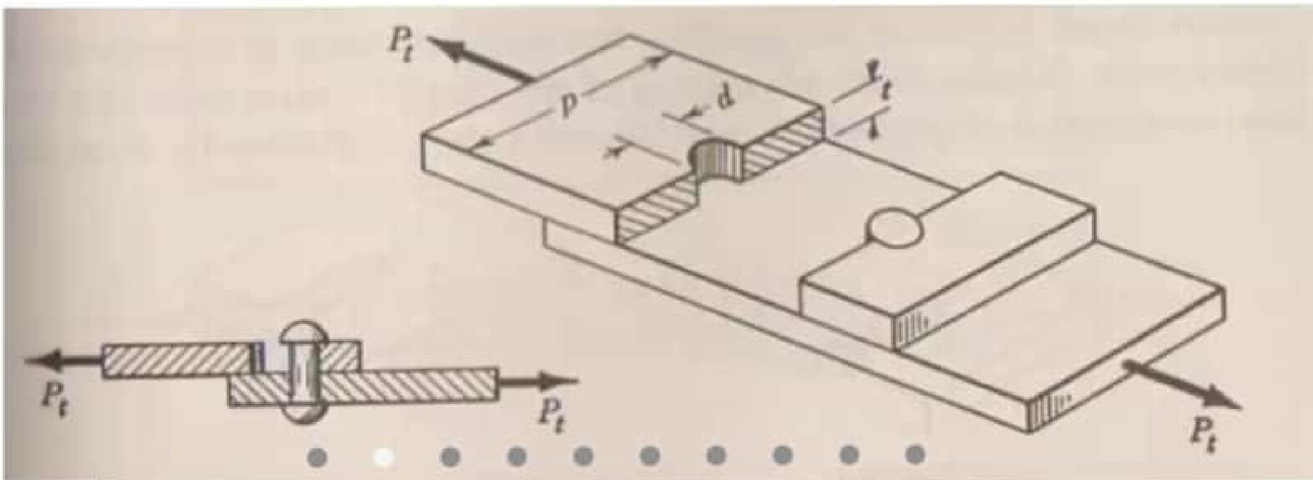
$$P_b = A_b \times S_b = (t \times d) \times S_b$$



Tearing Stress (S_t)

- Tearing Stress (S_t):

$$P_t = A_t \times S_t = (p-d) \times t \times S_t$$



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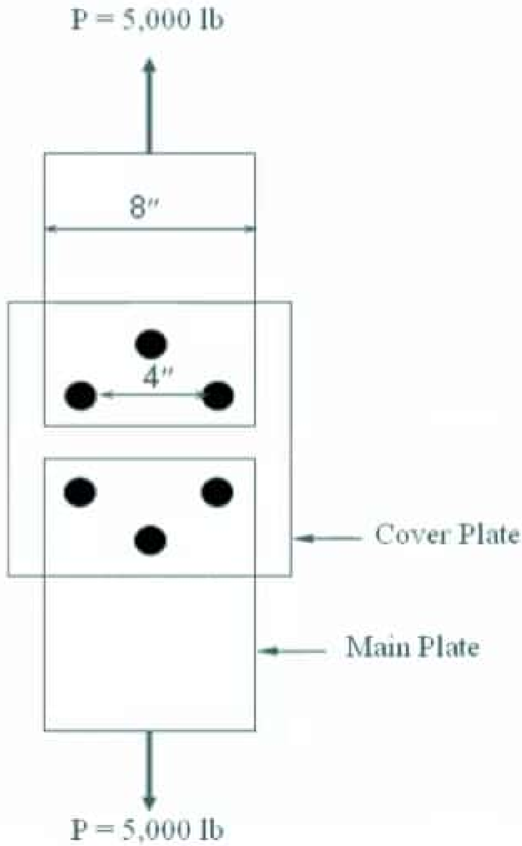
Problem 1

- Calculate the Shearing, Bearing and Tearing Stress of the connection.
- Given that *(i)* diameter of rivet = ⅛″ and *(ii)* thickness of main plate & cover plate = ⅛″.
- Pitch = 8″ for both Main Plate & Cover Plate.



Solution 1

1. $P_s = A_s \times S_s = \frac{\pi}{4} d^2 S_s \quad \Rightarrow \quad S_s = \frac{P_s}{A_s} = \frac{5000}{(\pi/4)\times(1/8)^2\times 3} = 135.81 \ \ ksi$

2. $P_b = A_b \times S_b \quad \Rightarrow \quad S_b = \frac{P_b}{A_b} = \frac{5000}{(1/8)\times(1/8)\times 3} = 106.66 \ \ ksi$

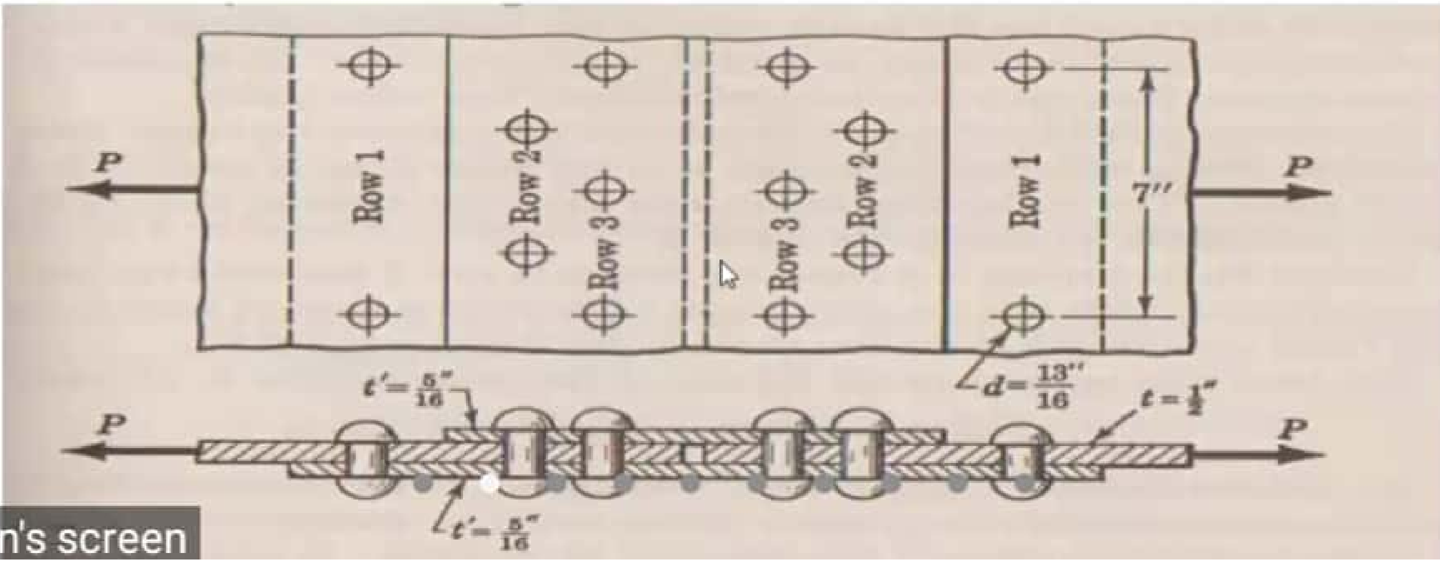
3. $P_t = A_t \times S_t \quad \Rightarrow \quad S_t = \frac{P_t}{A_t} = \frac{5000}{(8-\frac{1}{8})\times\frac{1}{8}} = 5.08 \ \ ksi \ (Main\ Plate)$

4. $P_t = A_t \times S_t \quad \Rightarrow \quad S_t = \frac{P_t}{A_t} = \frac{5000}{(8-2\times\frac{1}{8})\times\frac{1}{8}} = 5.16 \ \ ksi \ (Cover\ Plate)$

(Ans.)

Problem 2

- Find the Allowable Load, P. Given that *(i)* Ultimate S_s=44,000 psi *(ii)* Ultimate S_b = 95,000 psi *(iii)* Ultimate S_t = 55,000 psi & Factor of Safety = 5.



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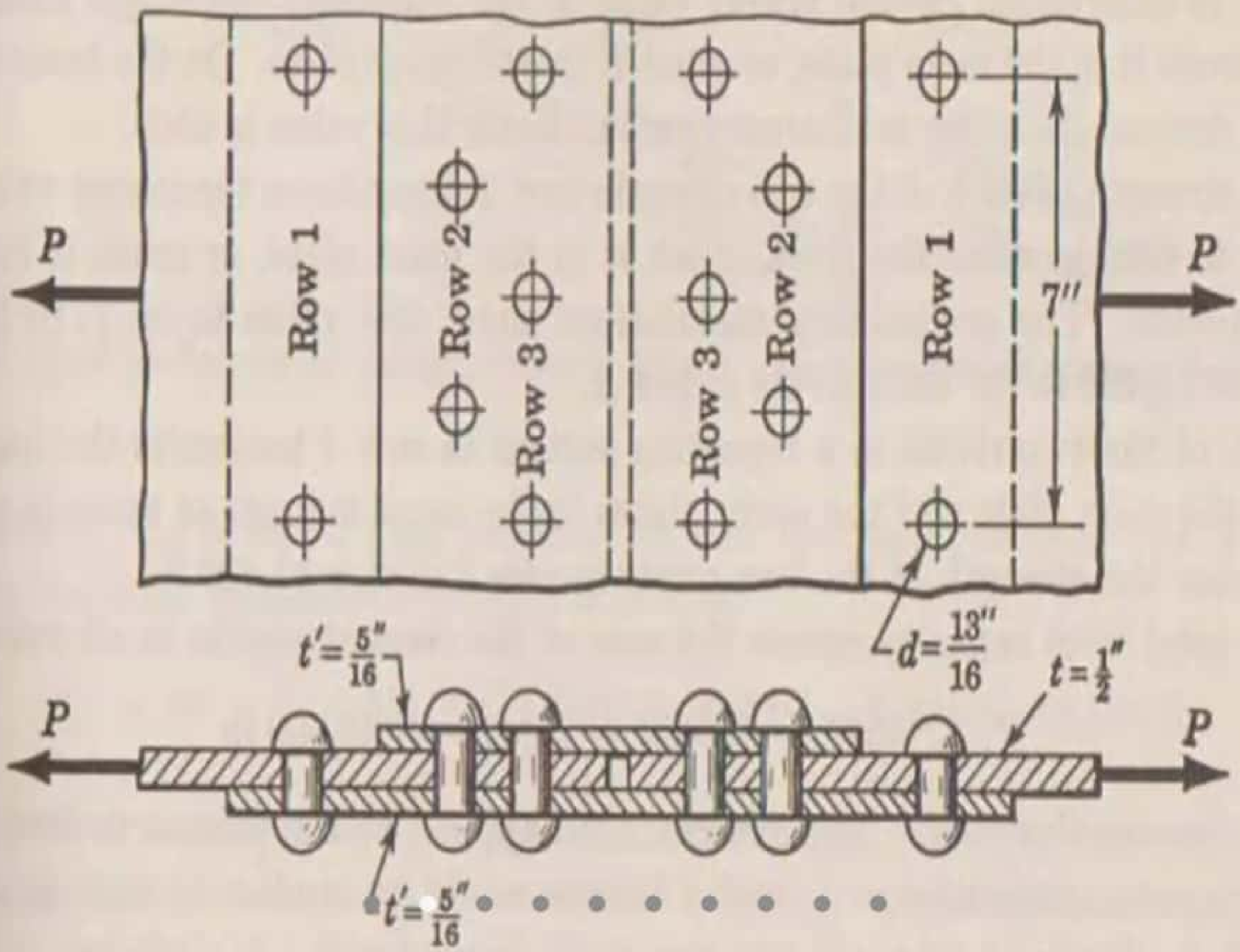

P
Row 1
Row 2
Row 3
Row 3
Row 2
Row 1
7″
P
d = 13″/16
t′ = 5″/16
t = 1/2″
P
P
t′ = 5″/16

Working Stress

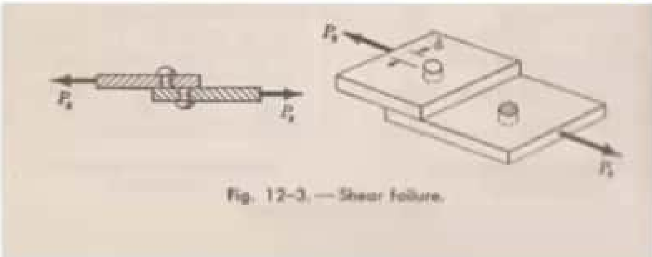
- Considering Factor of Safety = 5
  - *(i)* Working S_s=44,000 / 5 = 8,800 psi
  - *(ii)* Working S_b = 95,000 / 5 = 19,000 psi
  - *(iii)* Working S_t = 55,000 / 5 = 11,000 psi

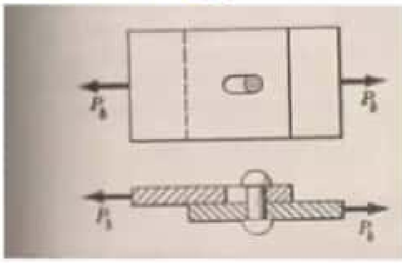
Solution 2

- Allowable Load due to Single Shear in One Rivet –
  - $P_s = (\pi/4)d^2S_s = (\pi/4) \times (13/16)^2 \times 8800 = 4,562.67$ lb
- Allowable Load due to Double Shear in One Rivet –
  - $P_s = (\pi/4)d^2S_s = (\pi/4) \times (13/16)^2 \times 8800 \times 2 = 9,125.34$ lb
- Allowable Load due to Bearing in Main Plate in One Rivet –
  - $P_b = (t \times d)\ S_b = (1/2) \times (13/16) \times 19000 = 7,718.75$ lb
- Allowable Load due to Bearing in 1 Cover Plate in One Rivet –
  - $P'_b = (t' \times d)\ S_b = (5/16) \times (13/16) \times 19000 = 4,828.22$ lb

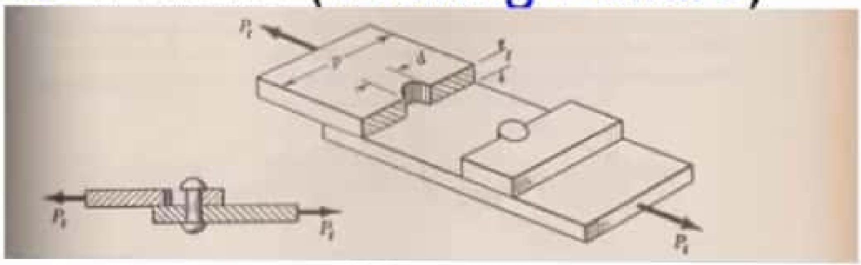
Solution 2

- Possible Modes of Failure:
  - 1. Rivet Failure (Shearing & Bearing)





  - 2. Plate Failure (Tearing Failure)



1. Rivet Failure

- Row 1
  - Shear = 4,562.67 lb ....(Lowest)
  - Bear = 7,718.75 lb (Main Plate)
  - Bear = 4,828.22 lb (Cover Plate)
- Row 2
  - Shear = 9,125.34 x 2 = 18,250.68 lb
  - Bear = 7,718.75 x 2 = 15,437.5 lb (Main Plate) ....(Lowest)
  - Bear = 4,828.22 x 2 x 2 = 19,296.88 lb (Cover Plate)
- Row 3
  - Shear = 9,125.34 x 2 = 18,250.68 lb
  - Bear = 7,718.75 x 2 = 15,437.5 lb (Main Plate) ....(Lowest)
  - Bear = 4,828.22 x 2 x 2 = 19,296.88 lb (Cover Plate)

- Total Rivet Capacity Equals the Sum of the Rivet Strength in All Rows: P = 4,562.67 + 15,437.5 + 15,437.5 = 35,437.67 lb.

2. Plate Failure (Main Plate)

- Row 1:
  - $P_1 = (p - d) \times t \times S_t$

    $= \{7-(13/16)\} \times ½ \times 11{,}000 =$ **34,031.25 lb**
- Row 2:
  - $P_2 = (p - 2d) \times t \times S_t$ + Rivet Strength in Row 1

    $= \{7-2x(13/16)\} \times ½ \times 11{,}000 + 4{,}562.67 = 34{,}125.17$ lb
- Row 3:
  - $P_3 = (p - 2d) \times t \times S_t$ + Rivet Strength in Row 1 + Row 2

  $= \{7-2x(13/16)\}x½x11{,}000 + 4{,}562.67 + 15{,}437.5$

  $= 49{,}562.67$ lb

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2. Plate Failure (Cover Plate)

- Row 3:
  - $P_3 = (p - 2d) \times t' \times S_t$

  $= \{7 – 2 \times (13/16)\} \times (5/16) \times 11{,}000 \times 2$

  $= 36{,}953.125$ lb

Safe Load

- Minimum Load for Plate Failure Considering Both Main and Cover Plate is = 34,031.25 lb.
- Minimum Load for Rivet Failure Considering Both Shearing and Bearing is = 35,437.67 lb.

- Hence the Safe Load for the Connection is 34,031.25 lb. (Ans.)
- And the Failure will Occur by Tearing at the Main Plate at Row 1. (Ans.)

Problem 3

- Find the Safe Load, P on the Butt Connection. Given that *(i)* S_s=15,000 psi *(ii)* S_b = 40,000 psi *(iii)* S_t = 20,000 psi.
- Given that *(i)* diameter of rivet = ¾″ and *(ii)* thickness of main plate = ½″ & each cover plate = ⅜″ .

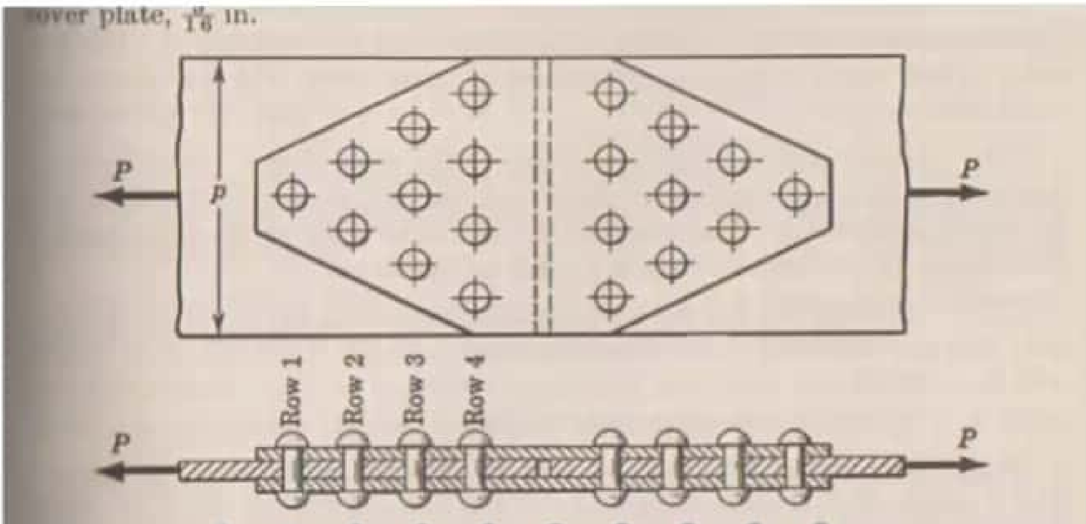

Fig. 12-11.

Rivet Capacity (Shearing & Bearing)

- Row - 1:
  - Shear: $P_s = (\pi/4)d^2S_s = (\pi/4) \times (¾)^2 \times 2 \times 15000 =$ 13,254 lb
  - Bear: $P_b = (t \times d)S_b = (½) \times (¾) \times 40000 =$ 15,000 lb (Main Plate)
- Row - 2:
  - Shear: P_s = 13,254 x 2 = 26,508 lb
  - Bear: P_b = 15,000 x 2 = 30,000 lb (Main Plate)
- Row - 3:
  - Shear: P_s = 13,254 x 3 = 39,762 lb
  - Bear: P_b = 15,000 x 3 = 45,000 lb (Main Plate)
- Row - 4:
  - Shear: P_s = 13,254 x 4 = 53,016 lb
  - Bear: P_b = 15,000 x 4 = 60,000 lb (Main Plate)

- Hence; Rivet Capacity = 13,254 x (1 + 2 + 3 + 4) = 132,540 lb.

Plate Capacity (Main Plate)

- Row 1:
  - $P_1 = (p - d) \times t \times S_t$
  - $= (11 - 0.75) \times ½ \times 20{,}000 = 102{,}500$ lb...........(Lowest)
- Row 2:

  $= (11 - 2 \times 0.75) \times ½ \times 20{,}000 + 13{,}254 = 108{,}254$ lb
- Row 3:

  $= (11 - 3 \times 0.75) \times ½ \times 20{,}000 + 13{,}254 + 26{,}508 = 127{,}262$ lb
- Row 4:

  $= (11 - 4 \times 0.75) \times ½ \times 20{,}000 + 13{,}254 + 26{,}508 + 39{,}762$

  $= 159{,}524$ lb

Hence, Lowest Load in Main Plate = 102,500 lb.

Plate Failure (Cover Plate)

- Tearing Load in Cover Plate at Row 4:
  - $P_1 = (p - d) \times t' \times S_t$
  - $= (11 - 4 \times 0.75) \times ⅜ \times 20{,}000 \times 2 = 120{,}000$ lb
- Minimum Load for Plate Failure Considering Both Main and Cover Plate is = **102,500** lb.
- Minimum Load for Rivet Failure Considering Both Shearing and Bearing is = 132,540 lb.
- Hence, Safe Load for the Connection is **102,500** lb.

(Ans.)

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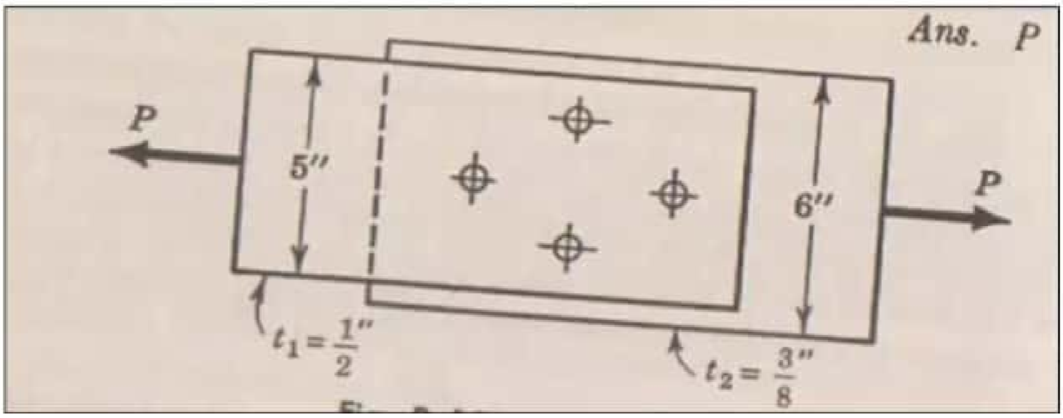
Problem 4

- Find the Allowable Load, P.
- Given that *(i)* S_s=10,000 psi *(ii)* S_b = 20,000 psi *(iii)* S_t = 15,000 psi & Rivet dia, φ = 1 in.



Rivet Capacity (Shearing & Bearing)

- Row – 1 & Row – 3:

  Shear: $= (\pi/4)d^2S_s = (\pi/4) \times (1)^2 \times 10000 = 7{,}854$ lb

  Bear: $= (t \times d)S_b = (½) \times 1 \times 20000 = 10{,}000$ lb (Main Plate, ½″)

  Bear: $= (t \times d)S_b = (⅜) \times 1 \times 20000 =$ 7,500 lb (Main Plate, ⅜″)

- Row - 2:

  Shear: = 7854 x 2 = 15,708 lb

  Bear: = 10,000 x 2 = 20,000 lb (Main Plate, ½″)

  Bear: = 7,500 x 2 = 15,000 lb (Main Plate, ⅜″)

- Hence; Rivet Capacity = 7,500 x (1 + 2 + 1) = 30,000 lb.

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Rivet Capacity (Shearing & Bearing)

- Row – 1 & Row – 3:

  Shear: = $(\pi/4)d^2S_s = (\pi/4) \times (1)^2 \times 10000 = 7{,}854$ lb

  Bear: = $(t \times d)S_b = (\frac{1}{2}) \times 1 \times 20000 = 10{,}000$ lb (Main Plate, ½″)

  Bear: = $(t \times d)S_b = (\frac{3}{8}) \times 1 \times 20000 = 7{,}500$ lb (Main Plate, ⅜″)

- Row - 2:

  Shear: = 7854 x 2 = 15,708 lb

  Bear: = 10,000 x 2 = 20,000 lb (Main Plate, ½″)

  Bear: = 7,500 x 2 = 15,000 lb (Main Plate, ⅜″)

- Hence; Rivet Capacity = 7,500 x (1 + 2 + 1) = 30,000 lb.

Plate Capacity (Main Plate)

- Row 1:
  - $P_t = (p - d) \times t \times S_t$
    - $= (5 - 1) \times \frac{1}{2} \times 15,000 = 30,000$ lb
  - $P'_t = (p' - d) \times t \times S_t$
    - $= (6 - 1) \times \frac{3}{8} \times 15,000 = 28,125$ lb………..(Lowest)
- Row 2:
  - $P_t = (p - d) \times t \times S_t$ + Rivet Strength in Row 1
    - $= (5 - 2) \times \frac{1}{2} \times 15,000 + 7500 = 30,000$ lb
  - $P'_t = (p' - d) \times t \times S_t$ + Rivet Strength in Row 1
    - $= (6 - 2) \times \frac{3}{8} \times 15,000 + 7500 = 30,000$ lb………..(Lowest)

Rivet Capacity = 30,000 lb & Plate Capacity = 28,125 lb.
Hence, Lowest Load or Safe Load = 28,125 lb. *(Ans.)*

Problem 6

- Determine the Resultant Load on the Most Heavily Loaded Rivet.

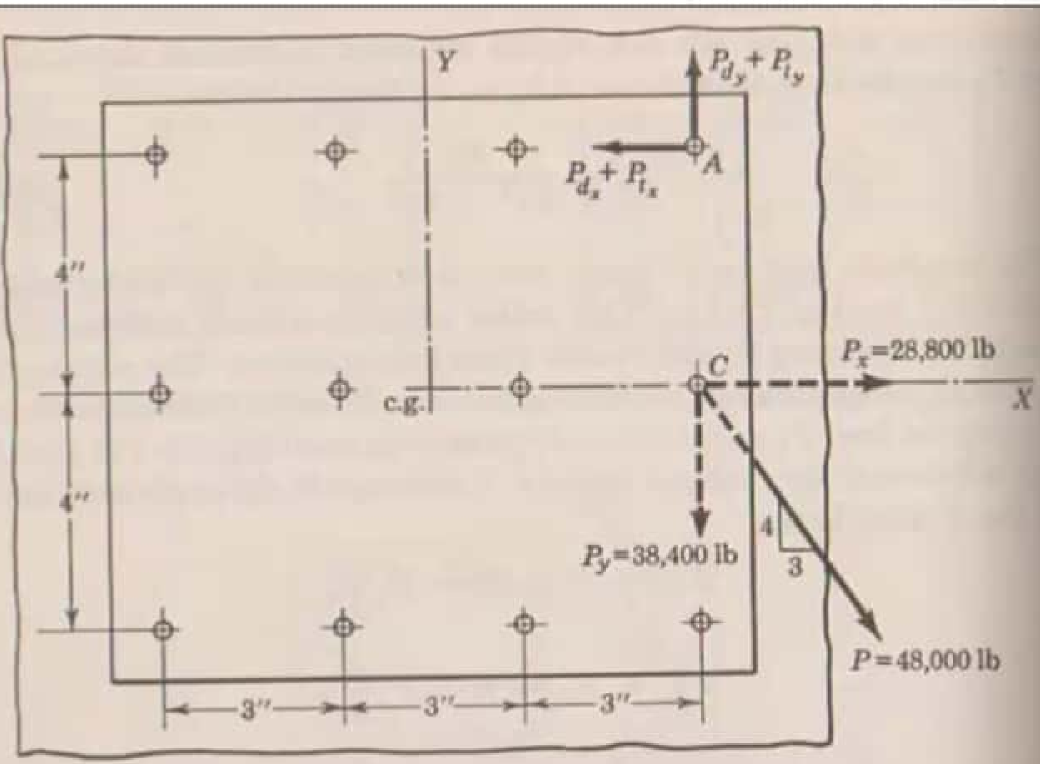
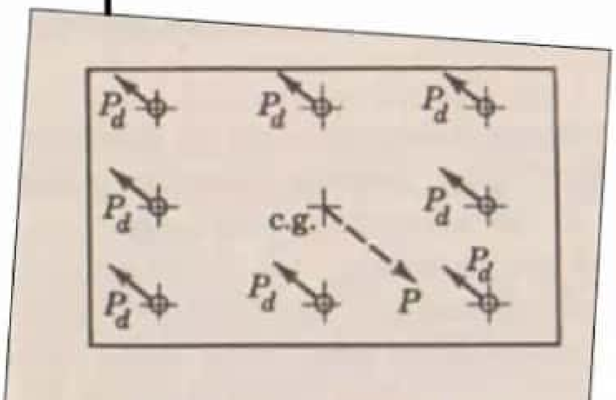


Fig. 12–15.

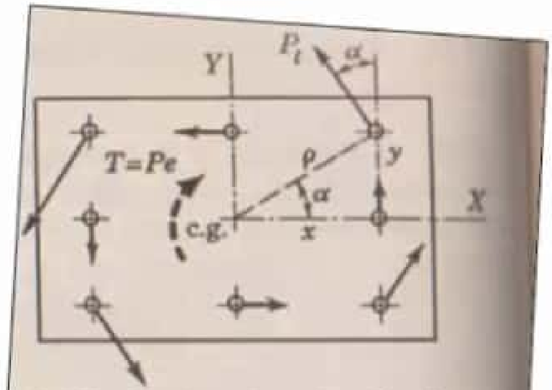
Resultant Load

- The Effect of the Applied Load is Equivalent to an -
  - Equal Central Load Acting Through the Centroid of the Rivet Group plus a
  - Torsional Couple Equal to the Moment of P About the Centroid of the Rivet Group.

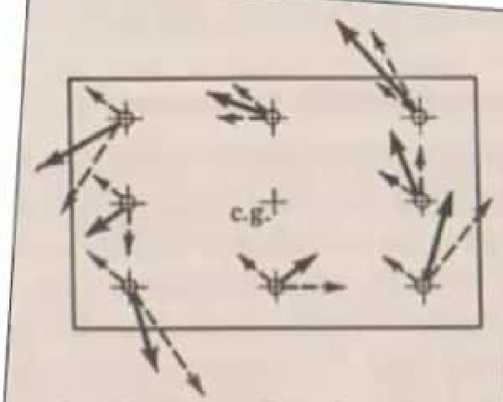
Resultant Load



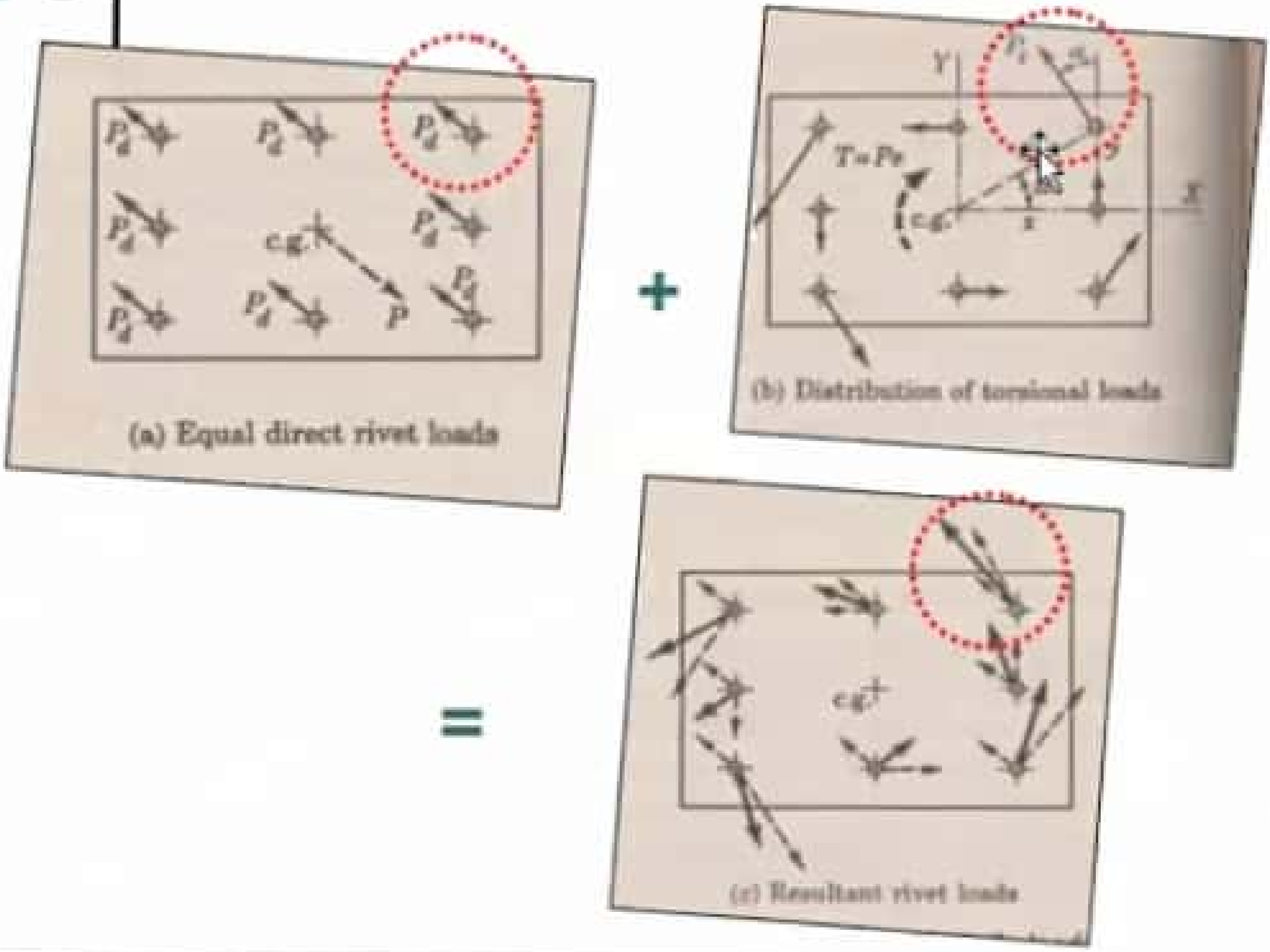
(a) Equal direct rivet loads



(b) Distribution of torsional loads



(c) Resultant rivet loads



(a) Equal direct rivet loads

(b) Distribution of torsional loads

(c) Resultant rivet loads

Resultant Load

- Replacing 'P' by its Components –
  - Px = (3/5) x 48000 = 28800 lb
  - Py = (4/5) x 48000 = 38400 lb

- **Torsional Couple (Moment) is –**
- **T = 38400 x 4.5 = 172800 lb-in.**
  - **Therefore; $\Sigma x^2 + \Sigma y^2$ =**
  - **{6 x 1.5^2 + 6 x 4.5^2} + 8 x 4^2**
  - **= 263 in^2.**

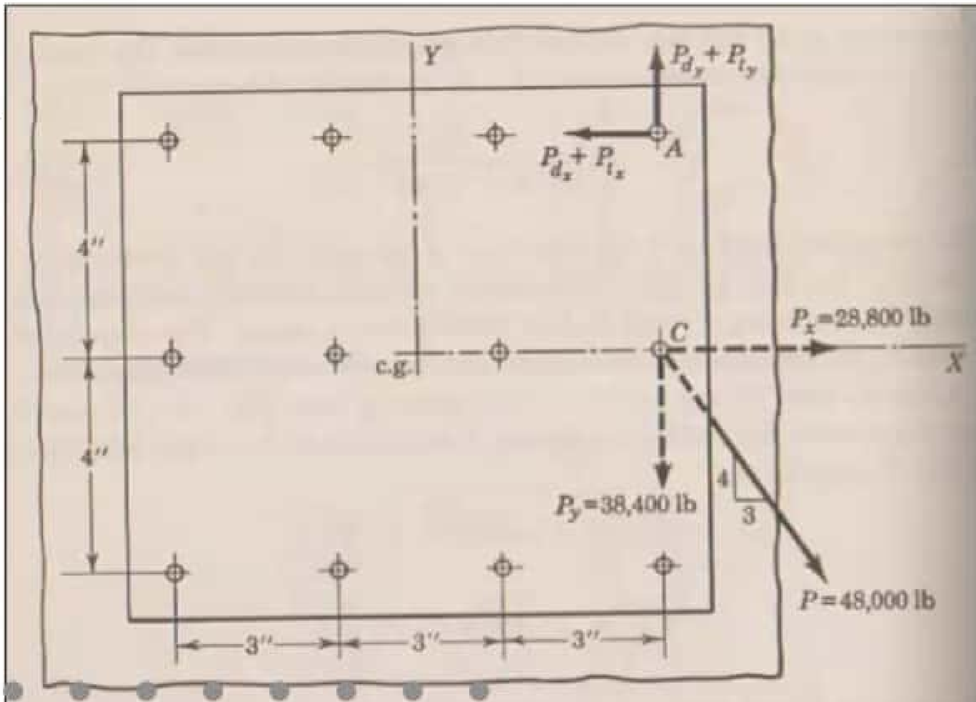


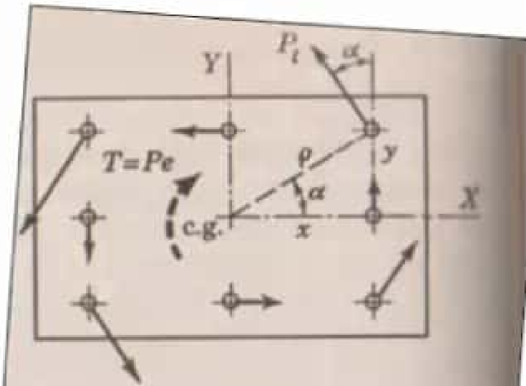
Fig. 12–15.

Torsional Component

- Distributed Torsional Component –

$$P_{tx} = \frac{T}{\sum x^2 + \sum y^2} \times y = \frac{172800}{263} \times 4 = 2{,}628\, lb$$

$$P_{ty} = \frac{T}{\sum x^2 + \sum y^2} \times x = \frac{172800}{263} \times 4.5 = 2{,}953.65\, lb$$



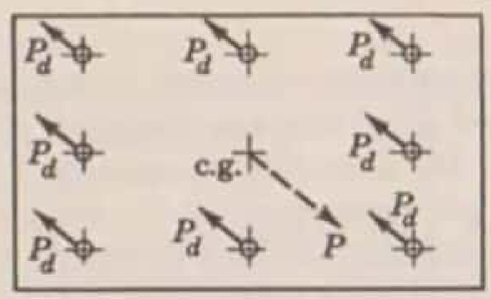
(b) Distribution of torsional loads

Direct Component

- Equal Direct Component –

$$P_{tx} = \frac{28800}{12} = 2{,}400\,lb$$

$$P_{ty} = \frac{38400}{12} = 3{,}200\,lb$$



(a) Equal direct rivet loads

man's screen

Most Heavily Loaded Rivet

- The Most Heavily Loaded Rivet is at 'A', Where the Maximum Components of the Direct and Tortional Loads are Additive. Hence –

$$P_R = \sqrt{\left[(P_{dx} + P_{tx})^2 + (P_{dy} + P_{ty})^2\right]}$$

$$= \sqrt{\left[(2400 + 2628)^2 + (3200 + 2956.65)^2\right]}$$

$$= 7{,}949\,lb \qquad (Ans.)$$