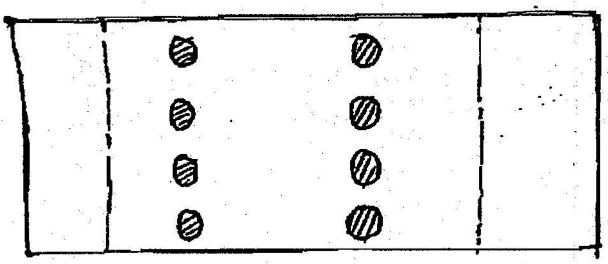
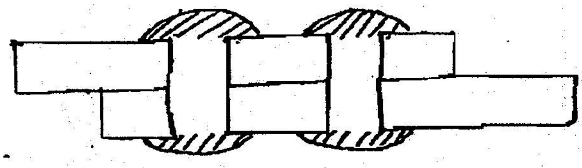
RIVETED JOINT

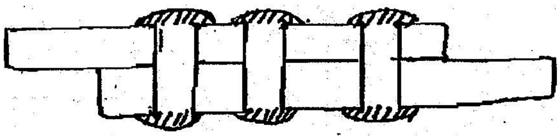
- Joint
  - Temparory
    - Keyed Joint
    - Cotter Joint
    - bolted Joint
    - Screwed Joint
  - Permanent
    - Welded Joint
    - Riveted Joint

- Riveted Joint
  - Lap Joint
    - Single Row Lap Joint
    - Double Row L·J
    - T·R·L·J
    - Quternary Raw L·J
  - Butt Joint
    - Single Strap Butt Joint
      - SR·S·SBJ
      - DRSSBJ
      - TRSSBJ
      - QRSSBJ
    - Double Strap Butt Joint
      - SRDSBJ
      - DRDSBJ
      - TRDSBJ
      - QRDSBJ

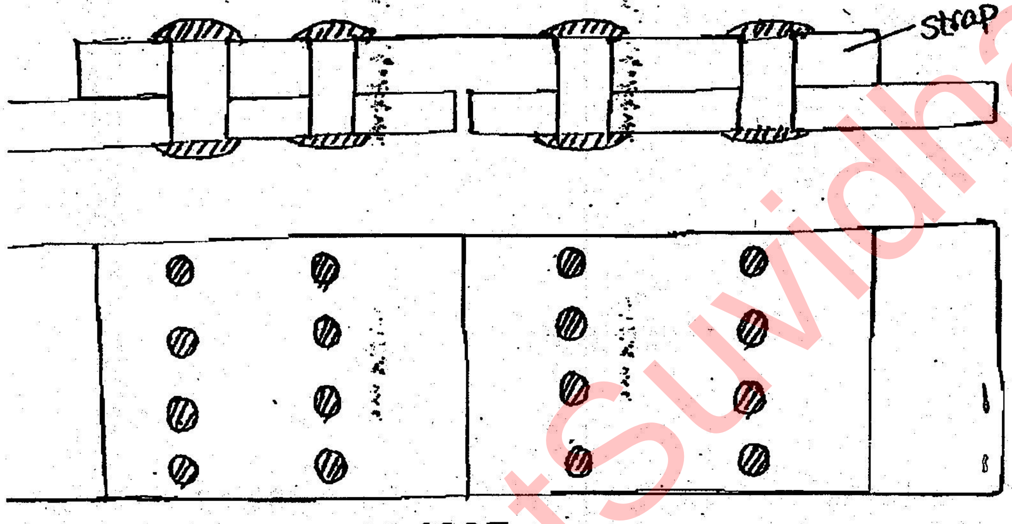




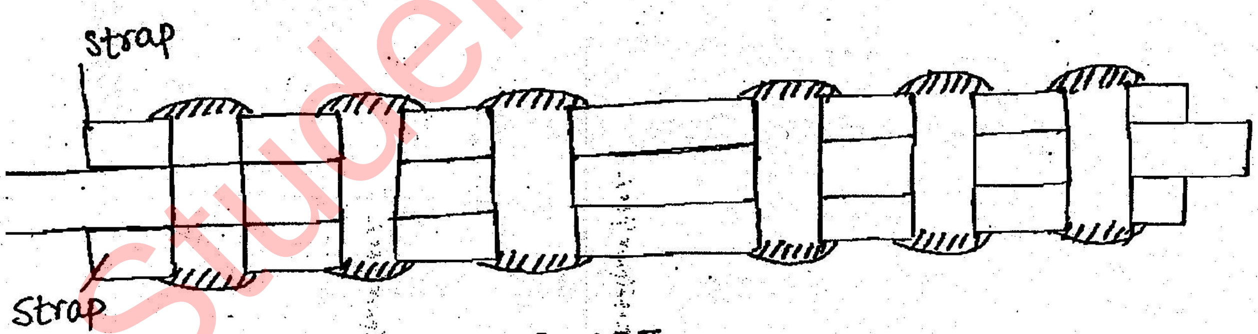
D·R·L·J



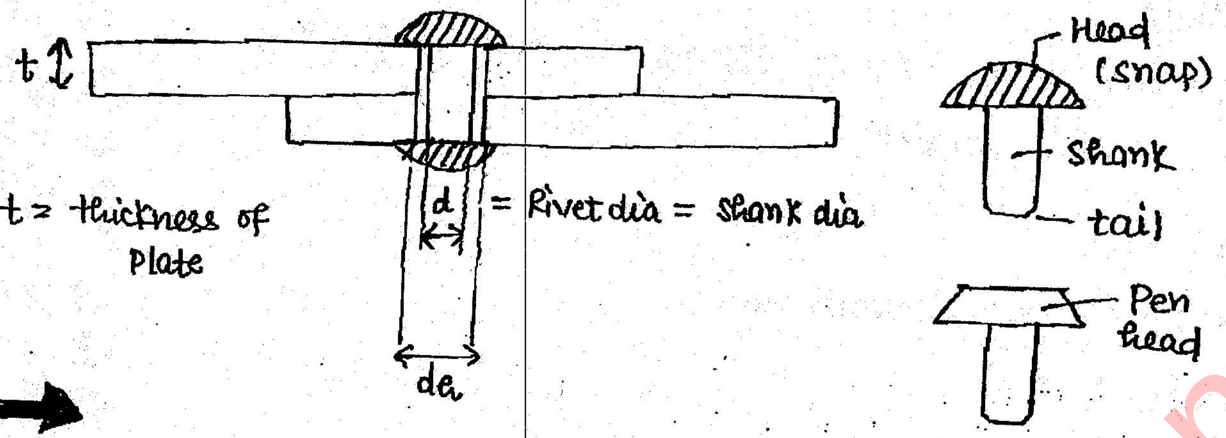
T·R·L·J



DRSSBJ



TRDSBJ



t = thickness of Plate

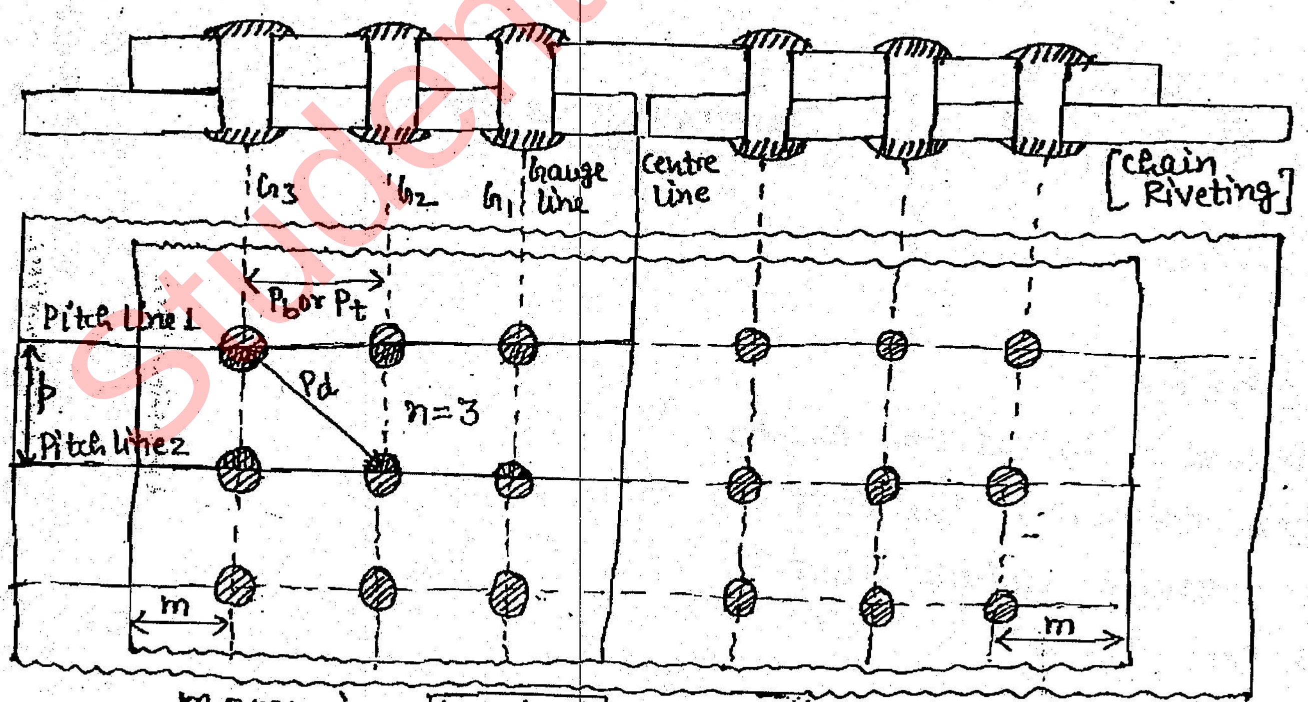
* for the safe design of Rivet shank dia. (d) will be taken into consideration.

* for the safe design of Plate hole dia (d_h) will be taken into consideration.

By Unwin's formula :-

$$d = 6\sqrt{t}$$

Terminology used for Riveted Joint :-



m = margin $m = 1.5d$

Chain Riveting :-

If Rivets are placed exactly opposite in two gauge line is known as chain Riveting.

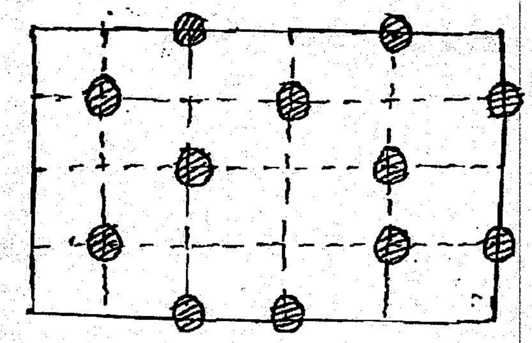
p = pitch

P_b or P_t → Back pitch | transverse pitch

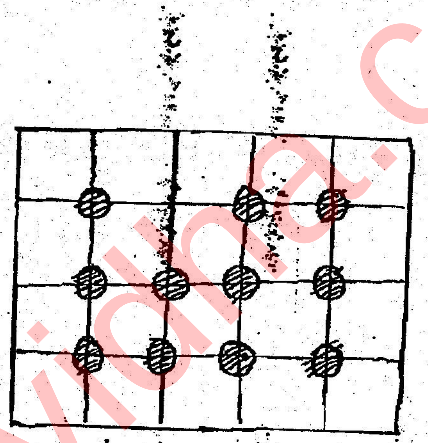
P_d → Diagonal pitch

m → margin.

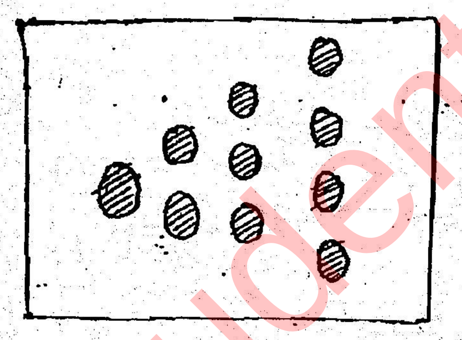
$m = 1.5d$



Zig-zag Riveting



Unsymmetrical Riveting



Diamond / Loganze Riveting

Diamond Riveting :-

1) It is used in bridges and trusses.
2) Uniform strength of the Rivet.
3) Plate thickness required is less.
4) Less cost.

NOTE :- when Riveting is infinite all calculations will be done for per pitch length.

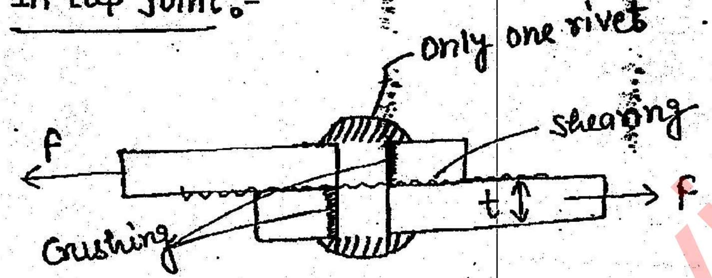
P → Load per pitch length

n → no. of Rivets per pitch length

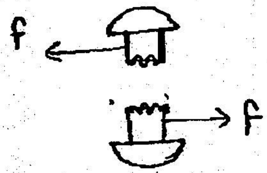
$$\text{Load on each Rivet} = \frac{P}{n}$$

Type of failure :-

In Lap Joint :-



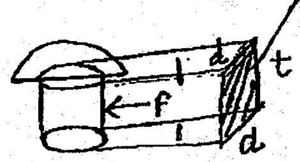
Single shear failure



$$\text{Sheared area} = \frac{\pi}{4}d^2$$

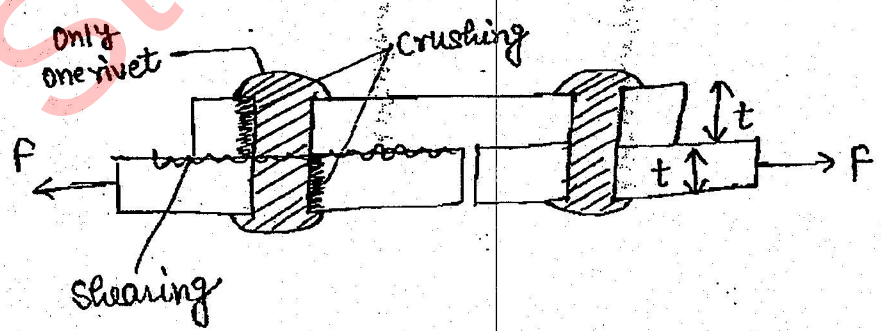
$$\tau_{ind} = \frac{F}{\frac{\pi}{4}d^2}$$

Due to crushing



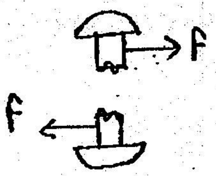
$$(\sigma_{ind})_{crushing} = \frac{F}{dt}$$

In Butt Joint :- (Single strap Butt Joint)



Single Shear Failure

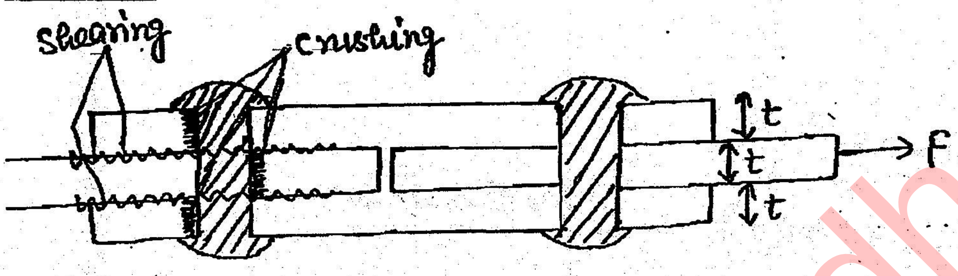
$$\tau_{ind} = \frac{F}{\frac{\pi}{4}d^2}$$



and

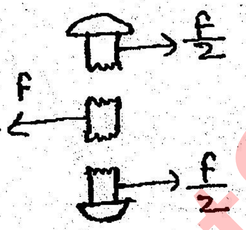
$$(\sigma_{ind})_{crushing} = \frac{F}{dt}$$

Butt Joint :- (Double strap Butt Joint)



Double shear failure

$$\tau_{ind} = \frac{F}{2\cdot\frac{\pi}{4}d^2}$$



$$(\sigma_{ind})_{crushing\ max^m} = \frac{F}{dt}$$

All Riveted Joint :-

$$\tau_{ind} = \frac{F}{k\cdot\frac{\pi}{4}d^2}$$

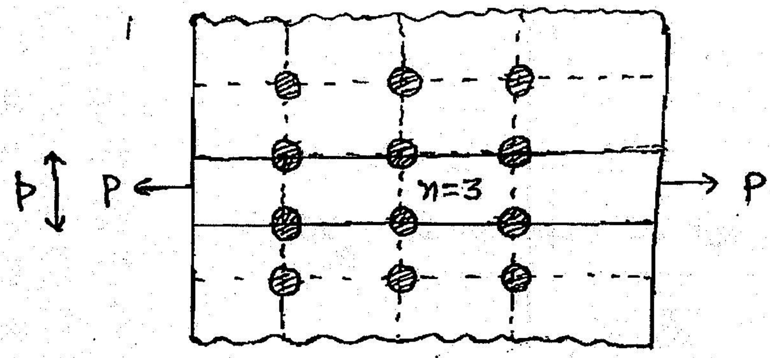
$k=1 \rightarrow$ Single strap

$k=2 \rightarrow$ Double strap

$$(\sigma_{ind})_{crushing} = \frac{F}{dt}$$

LECTURE-6
14/06/2017

CASE-1 : Infinite Riveting :-



P = load per pitch length
n = no. of Rivets per pitch length.

Shear strength of Rivet per pitch length :-

$$F = \frac{P}{n}$$

Force on each Rivet

$$\tau_{ind} = \frac{P}{k n \frac{\pi}{4} d^2}$$

Safe condition

$$\tau_{ind} \leq \tau_{per}$$

$$\frac{P}{k n \frac{\pi}{4} d^2} \leq \tau_{per}$$

$$\boxed{P_{max} = k n \frac{\pi}{4} d^2 \tau_{per}}$$

shear strength of Rivet/Riveted Joint per pitch length

Crushing strength of the Riveted Joint/Rivet per pitch length :-

$$(\sigma_{ind})_{crush} = \frac{F}{dt} = \frac{P}{ndt}$$

Safe condition

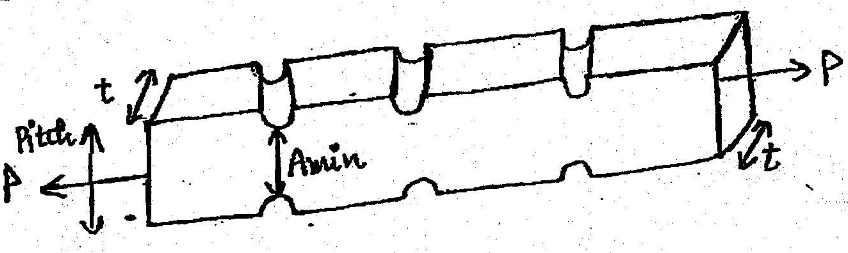
$$(\sigma_{ind})_{crush} \leq \sigma_{per}$$

$$\frac{P}{ndt} \leq \sigma_{per}$$

$$\boxed{P_{max} = ndt\,\sigma_{per}}$$

rushing strength of rivet/ Riveted Joint per Pitch length

Tearing strength of the plate / Riveted Joint per pitch length :-



$$(\sigma_{ind})_{max} = \frac{P}{A_{min}}$$

$$(\sigma_{ind})_{max} = \frac{P}{(p-d_h)t}$$

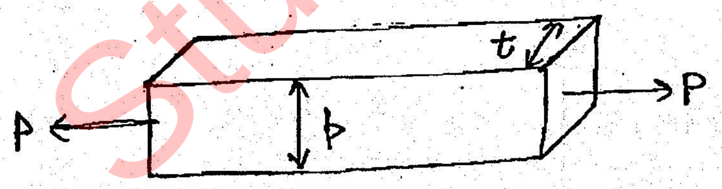
Safe condition

$$(\sigma_{ind})_{max} \leq \sigma_{per}$$

$$\frac{P}{(p-d_h)t} \leq \sigma_{per}$$

$$\boxed{P_{max} = (p-d_h)t\,\sigma_{per}}$$

Strength of the solid plate per pitch length :-



$$\sigma_{ind} = \frac{P}{pt}$$

$$\boxed{P_{max} = pt\,\sigma_{per}}$$

Eg: Actual strength of the Riveted Joint per pitch length =

$$\min \text{ of } \left[(P_{max})_{shearing}, (P_{max})_{crushing}, (P_{max})_{Tearing} \right]$$

Actual strength of the Rivet per pitch length =

$$\min \text{ of } \left[(P_{max})_{shearing}, (P_{max})_{crushing} \right]$$

$(P_{max})_{shear} = 20\,KN$

$(P_{max})_{crush} = 30\,KN$

$(P_{max})_{Tear} = 40\,KN$

$\Rightarrow$

$$\eta_{shearing} = \frac{(P_{max})_{shear}}{(P_{max})_{solid}} = \frac{K \cdot n \frac{\pi}{4} d^2 \tau_{per}}{p \cdot t\, \sigma_{per}}$$

$\Rightarrow$

$$\eta_{crushing} = \frac{(P_{max})_{crush}}{(P_{max})_{solid}} = \frac{n \cdot d \cdot t\, [\sigma_{per}]_{Rivet}}{p \cdot t\, [\sigma_{per}]_{plate}} = \frac{n\, d\, [\sigma_{per}]_{Rivet}}{p\, [\sigma_{per}]_{plate}}$$

$\Rightarrow$

$$\eta_{Tearing} = \frac{(P_{max})_{Tearing}}{(P_{max})_{solid}} = \frac{(p - d_h)\, t\, [\sigma_{per}]_{plate}}{p \cdot t\, [\sigma_{per}]_{plate}} = \left(1 - \frac{d_h}{p}\right)$$

$\Rightarrow$

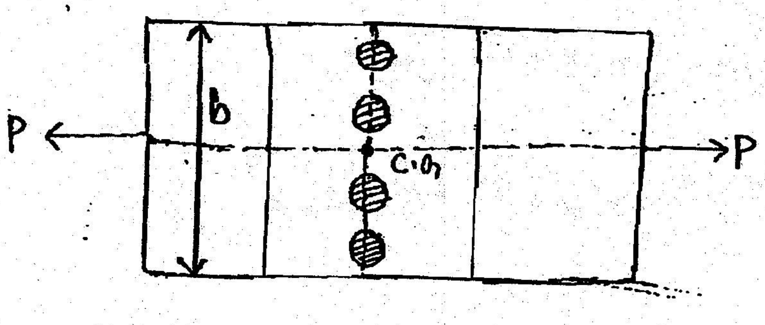
$$\eta_{actual} = \frac{(P_{max})_{actual}}{(P_{max})_{solid}} = \frac{\min \text{ of } \left[(P_{max})_{shear}, (P_{max})_{crush}, (P_{max})_{tear} \right]}{(P_{max})_{solid}}$$

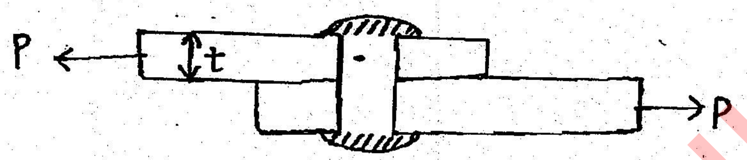
$\Rightarrow$

$$\eta_{actual} = \min \text{ of } \left[\eta_{shearing}, \eta_{crushing}, \eta_{shearing} \right]$$

Case 2 :- Finite Riveting :-

when load is passing through the centre of the gravity of the group of Rivet :-





$k = 1$

$f = \frac{P}{4}$

Shear strength of Rivet / Riveted Joint

$$\tau_{ind} = \frac{P}{4\frac{\pi}{4}d^2}$$

Safe condition

$\tau_{ind} \le \tau_{per}$

$$\frac{P}{4 \cdot \frac{\pi}{4}d^2} \le \tau_{per}$$

$$\boxed{(P_{max})_{shear} = 4 \cdot \frac{\pi}{4}d^2 \, \tau_{per}}$$

Shear strength of the Rivet | R.J

Crushing strength of Rivet / R.J

$$\sigma_{ind} = \frac{P}{4dt}$$

Safe condition

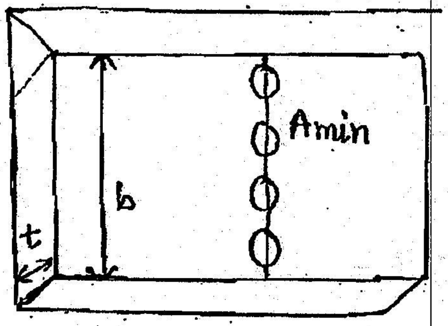
$\sigma_{ind} \le [\sigma_{per}]_{Rivet}$

$$\frac{P}{4dt} \le \sigma_{per}$$

$$\boxed{P_{max} = 4dt \, \sigma_{per}}$$

Crushing strength of Rivet | R.J

Tearing strength of Riveted Joint/plate



$$A_{min} = (b - 4d_a)$$

$$(\sigma_{ind})_{max} = \frac{P}{(b-4d_a)t}$$

Safe condition

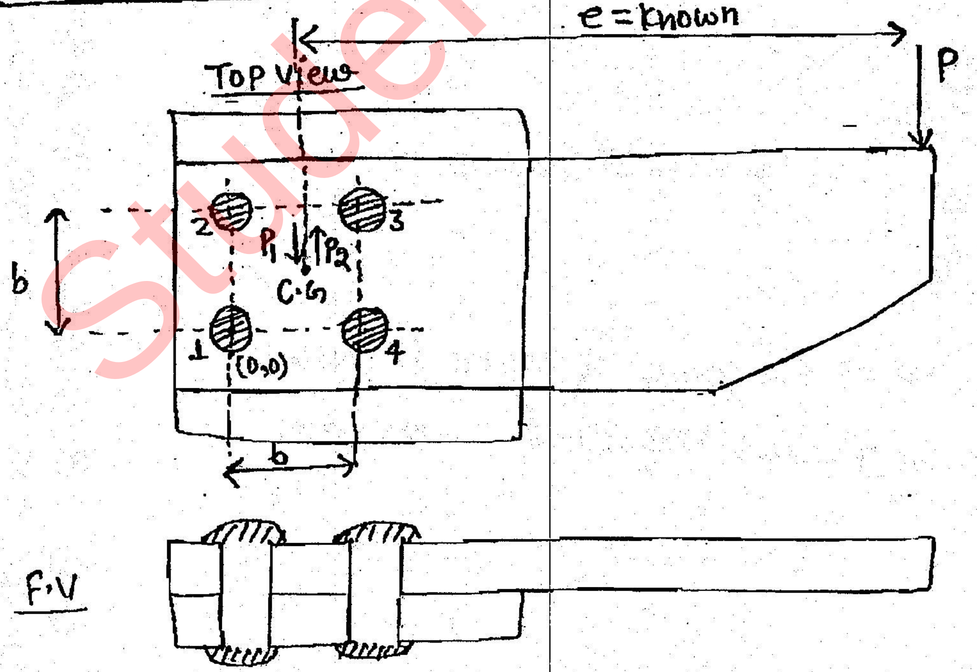
$$(\sigma_{ind})_{max} \le \sigma_{per}$$

$$\frac{P}{(b-4d_a)t} \le (\sigma_{per})_{plate}$$

$$\boxed{P_{max} = (b-4d_a)t \cdot \sigma_{per}}$$

Tearing strength of Riveted Joint/plate

Design of Riveted Joint under Ecentric loading :-



τ_{per} = given

Find out the safe diameter of Rivet :-

Step 1 :- find out the C.G of the group of Rivet →

$$\bar{X} = \frac{x_1 + x_2 + x_3 + x_4 + \cdots}{n} = \frac{0 + 0 + b + b}{4} = \frac{b}{2}$$

$$\bar{Y} = \frac{Y_1 + Y_2 + Y_3 + Y_4 + \cdots}{n} = \frac{0 + b + b + b}{4} = \frac{b}{2}$$

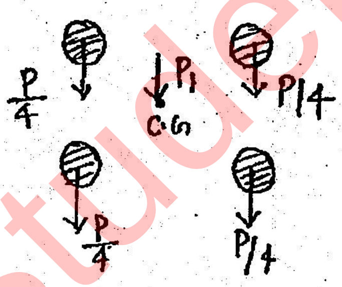
$$\bar{X} = \frac{0 + 0 + b + b}{4} = \frac{b}{2}$$

Step 2 :- Find out eccentricity :-

Eccentricity is the distance b/w C.G of the group of Rivet to the line of action of load.

Step 3 :- Apply to equal and opposite forces P_1 and P_2 passing through C.G of the group of Rivet parallel to the load such that $P_1 = P_2 = P$.

Step 4 :- Effect of P_1.



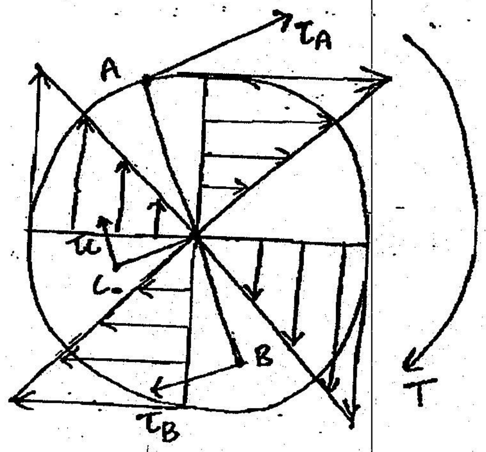
$\frac{P}{4} = P_p$ (Primary force)

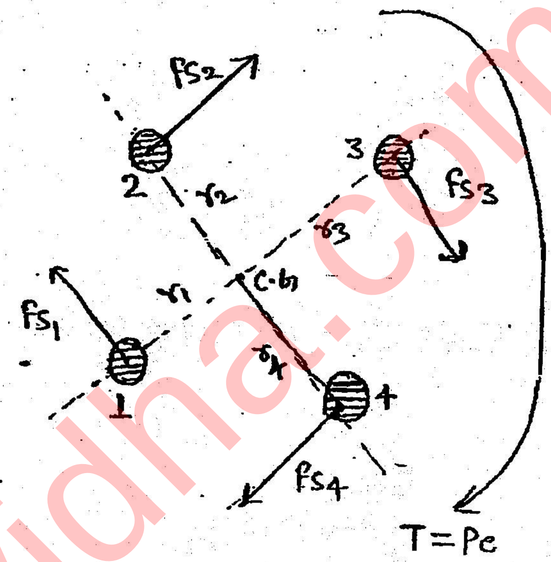
As P_1 passing through C.G of the group of rivet it result primary shear force induced of equal magnitude in each rivet.

Effect of P_2 :-

P_2 and P causes a constant twisting couple of magnitude P.e in clockwise direction about the c.g of the group of Rivet which result torsional shear stress induced in the rivet.

Twisting :- $\tau_{Torsional} \propto r$





$\tau_{Torsional} \propto r$

⇓

Secondary shear force

$F_s \propto r$

$\therefore \quad F_{s_1} r_1 + F_{s_2} r_2 + F_{s_3} r_3 + F_{s_4} r_4 = Pe$

$\because \quad F_s \propto r$

$$\frac{F_{s_1}}{r_1} = \frac{F_{s_2}}{r_2} = \frac{F_{s_3}}{r_3} = \frac{F_{s_4}}{r_4}$$

$$\boxed{\frac{F_{s_1}}{r_1}\left[r_1^2 + r_2^2 + r_3^2 + r_4^2\right] = Pe}$$

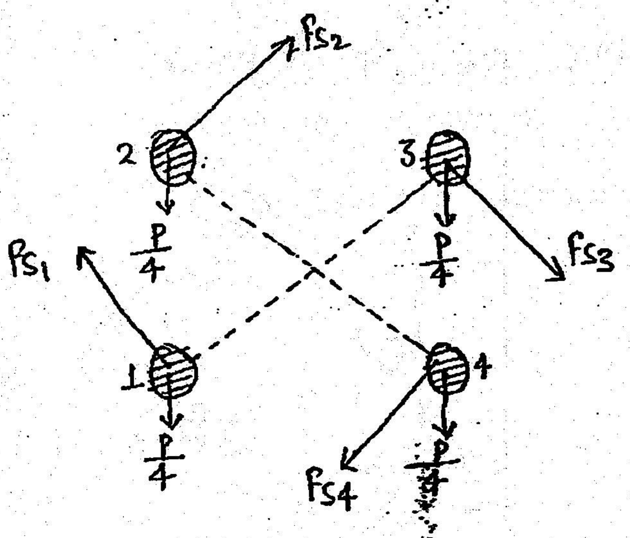
Here $r_1 = r_2 = r_3 = r_4$

$$F_{s_1} = F_{s_2} = F_{s_3} = F_{s_4} = \frac{Pe}{4r}$$

These shear stresses are represented by a secondary shear force and this secondary shear force directly proportional to r.

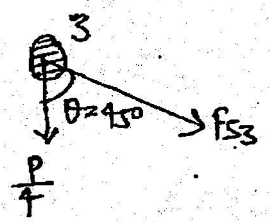
r → distance from centre of the rivet to the c.g of group of rivet.

Step 5: Combined effect of P_1, P_2 and P:-



$$R^2 = P^2 + Q^2 + 2PQ\cos\theta$$

critical Rivet or worst loaded Rivet = 3, 4



$$R = \sqrt{\left(\frac{P}{4}\right)^2 + F_{s3}^2 + 2\left(\frac{P}{4}\right)(F_{s3})\cos\theta}$$

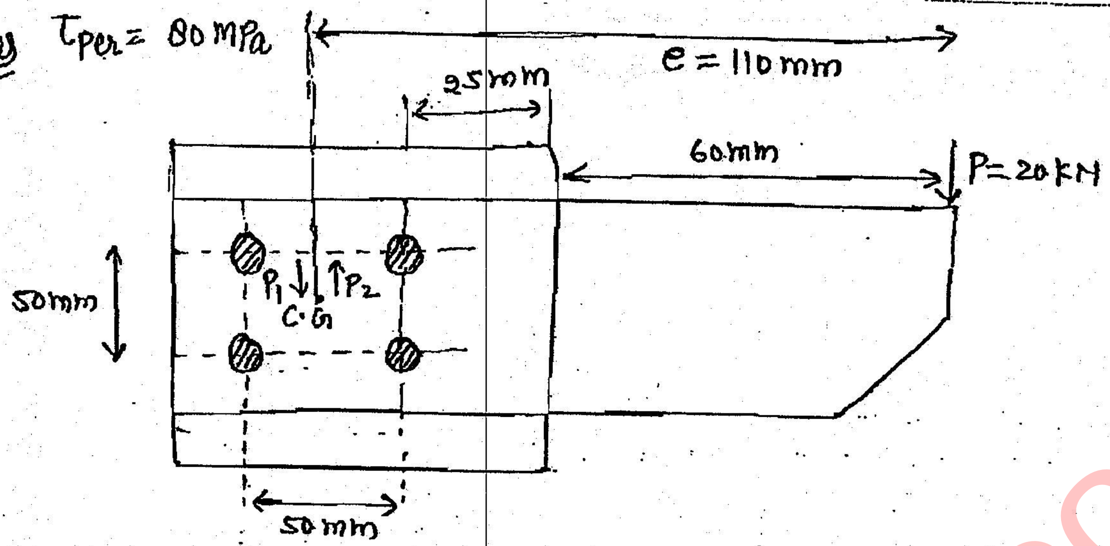
$$(\tau_{ind})_{max} = \frac{R}{\frac{\pi}{4}d^2}$$

Safe condition

$$\frac{R}{\frac{\pi}{4}d^2} \leq \tau_{per}$$

$$d = \text{known}$$

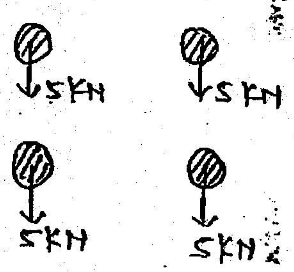
Ques $\tau_{per} = 80$ MPa



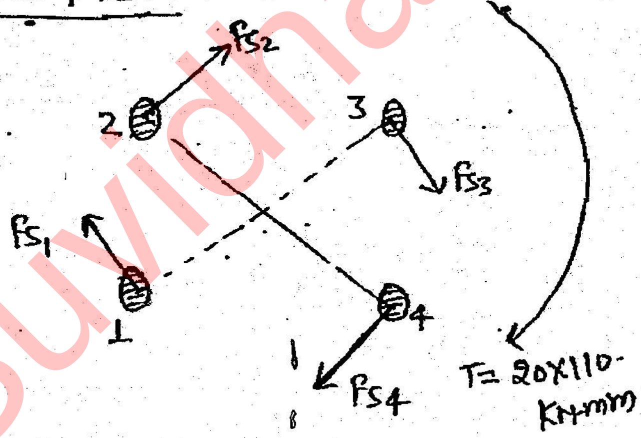
Soln

$P_1 = P_2 = 20$ KN

Effect of P_1 :-



Effect of P_2 & P



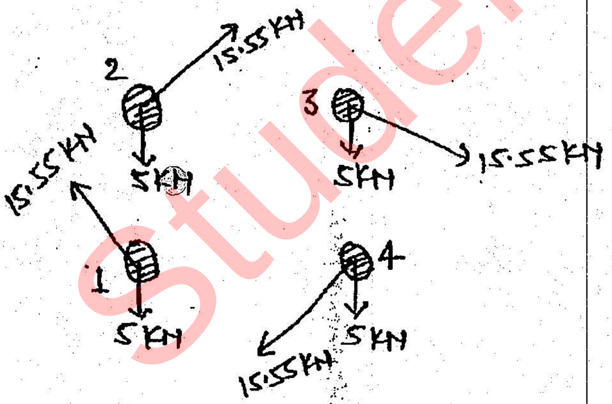
$F_s \propto r$.

$r_1 = r_2 = r_3 = r_4 = 25\sqrt{2}$

$$F_{s_1} = F_{s_2} = F_{s_3} = F_{s_4} = \frac{Pe}{4r}$$

$$= \frac{20 \times 110}{4 \times 25\sqrt{2}} = 15.55 \text{ KN}$$

Combined effect :-



Critical Rivet = 3, 4

$$R = \sqrt{5^2 + (15.15)^2 + 2(5)(15.15)\cos 45^\circ}$$

$R = 19.41\ KN$

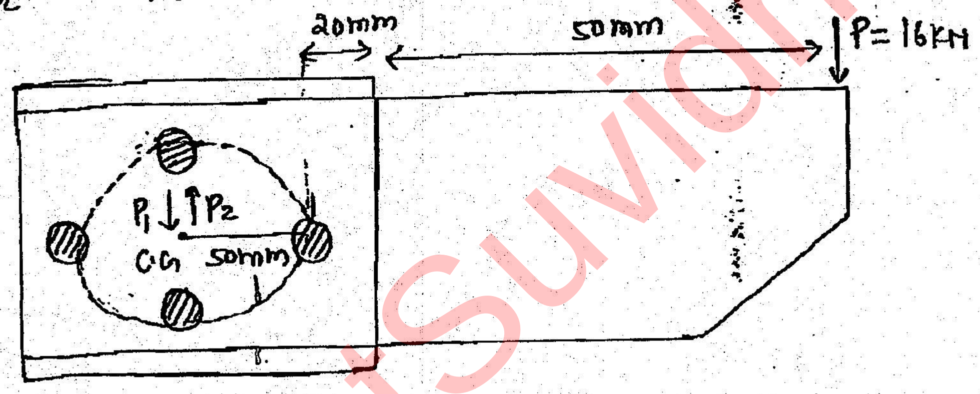
Safe condition.

$$\frac{19.41}{\frac{\pi}{4}d^2} \le 80 \times 10^{-3}$$

$d = 17.57$

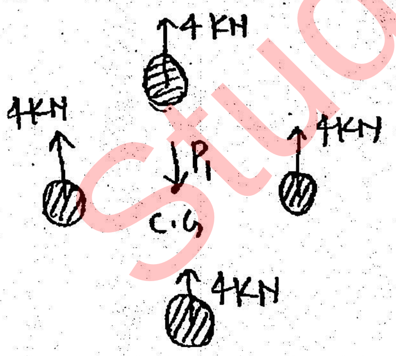
$d = 18\ mm$

Hus. $\tau_{per} = 70\ MPa$

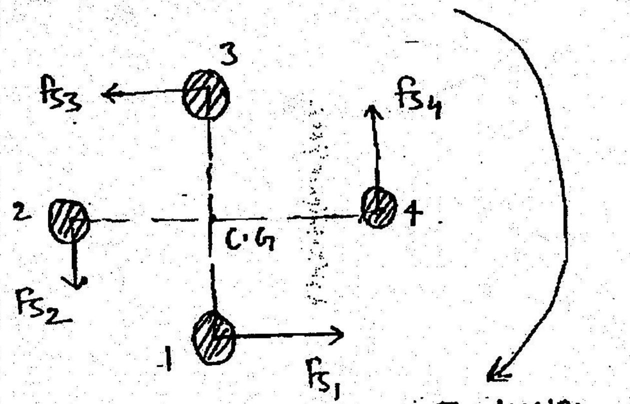


$e = 120\ mm$

Effect of P_1



Effect of P_2



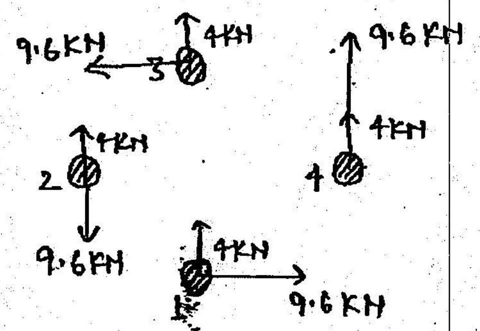
$T = 16 \times 120$ N-mm

$r_1 = r_2 = r_3 = r_4 = 50mm$

$Fs_1 = Fs_2 = Fs_3 = Fs_4 = \frac{Pe}{4r} = \frac{16 \times 120}{4 \times 50}$

$= 9.6 \, KN$

Combined effect :-



Critical rivet = '4'

$R = 13.6 \, KN$

$\tau_{max} = \frac{13.6}{\frac{\pi}{4} d^2}$

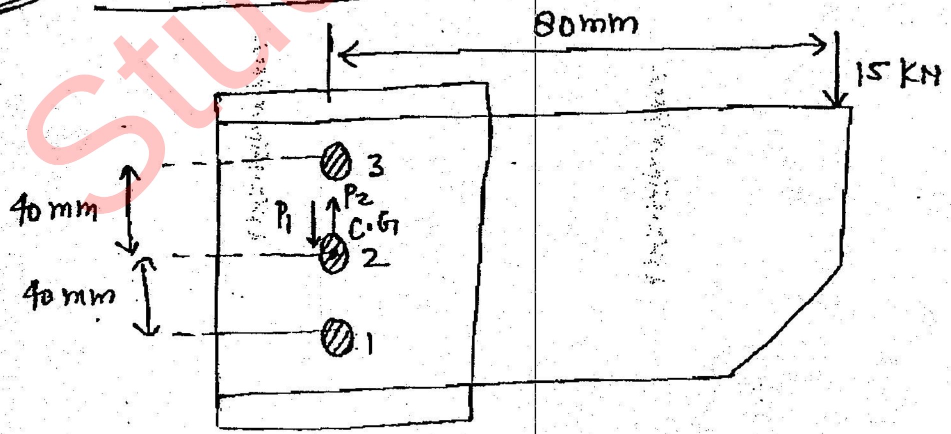
Safe condition

$\frac{13.6}{\frac{\pi}{4} d^2} \leq 70 \times 10^{-3}$

$d = 15.72$

$d = 16 mm$

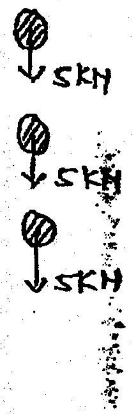
Ans $\tau_{per} = 75 \, MPa$



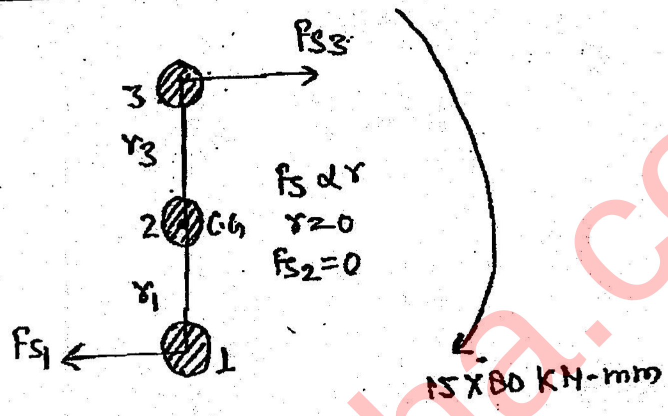
- Find out the worst loaded Rivet.
- Find out the resultant force on each rivet.
- Find out the safe diameter of Rivet.

Sol^n

Effect of P_1



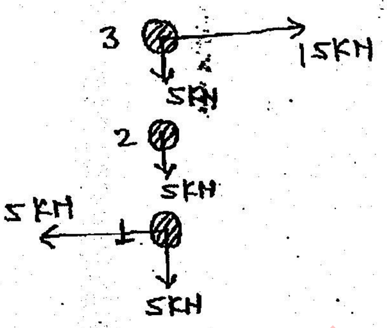
Effect of P_2



$$\frac{F_{s_1}}{40}\left[40^2+0^2+40^2\right]=15\times 80$$

$$F_{s_1}=F_{s_3}=15\ KN$$

Combined effect



Critical Rivet = 1, 3

$$R_1=R_3=\sqrt{5^2+15^2}=15.81\ KN$$

$$R_2=5\ KN$$

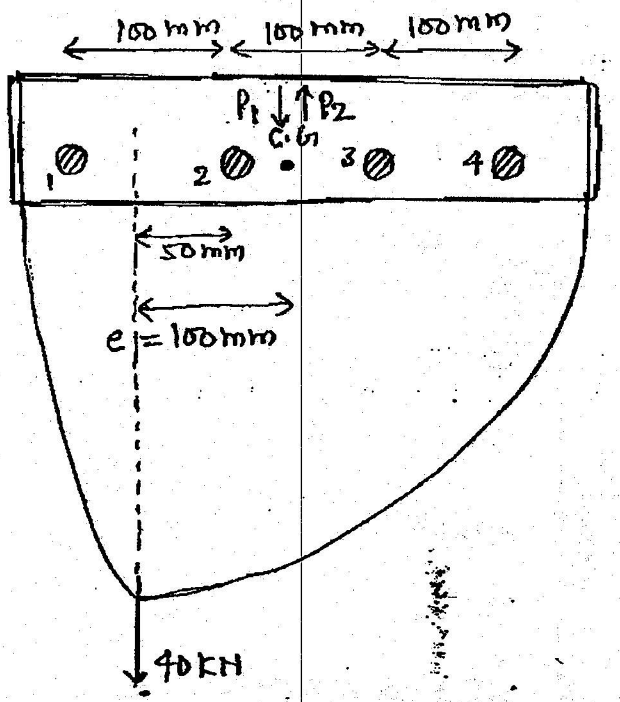
Safe dia.:

$$\frac{15.81}{\frac{\pi}{4}d^2}\le 75\times 10^{-3}$$

$$d=16.38$$

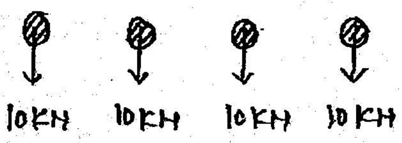
$$\boxed{d=17\,mm}$$

Ques

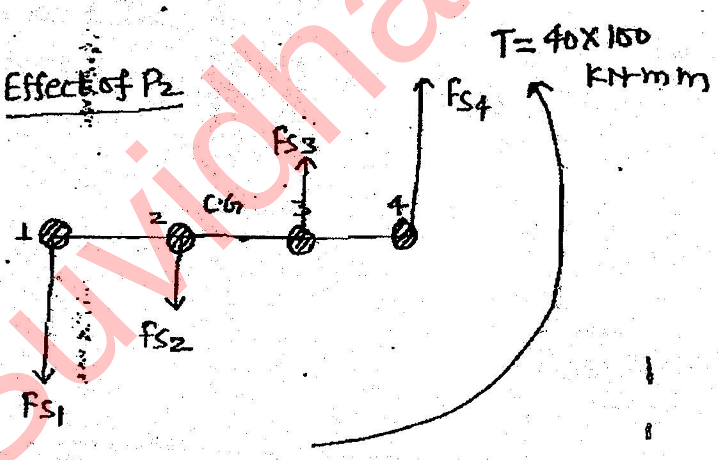


$\tau_{per} = 70 MPa$

Effect of P_1



Effect of P_2

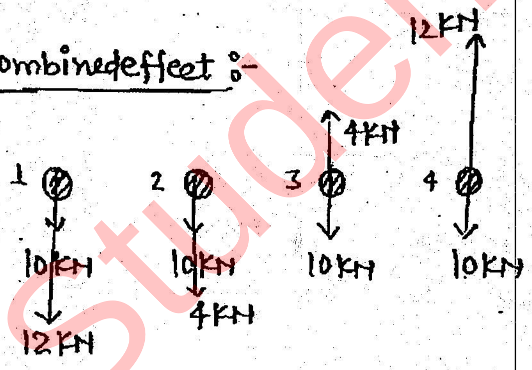


$$\frac{F_{s_1}}{150}\left[150^2 + 50^2 + 50^2 + 150^2\right] = 40 \times 100$$

$F_{s_1} = 12 KN = F_{s_4}$ $[r_1 = r_4]$

$F_{s_2} = F_{s_3} = 4 KN$ $[r_3 = r_4]$

Combined effect :-



$R_1 = 22 KN$

$R_2 = 14 KN$

$R_3 = 6 KN$

$R_4 = 2 KN$

Critical Rivet = 1

$$\frac{22}{\frac{\pi}{4}d^2} \leq 70 \times 10^{-3}$$

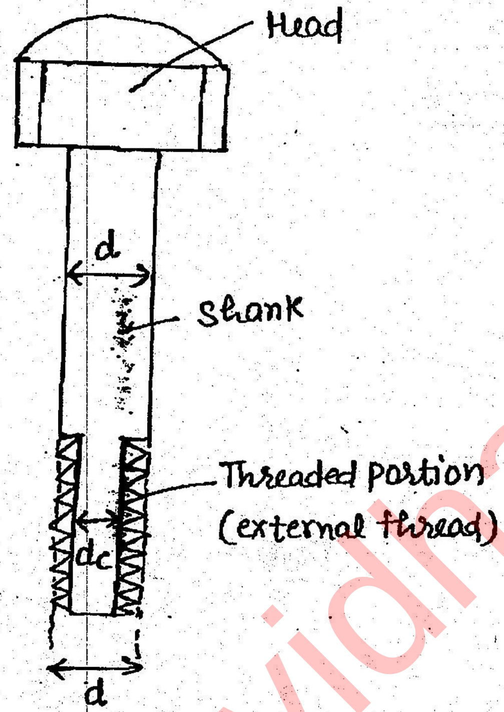
$d = 20.004$

$d = 21 mm$

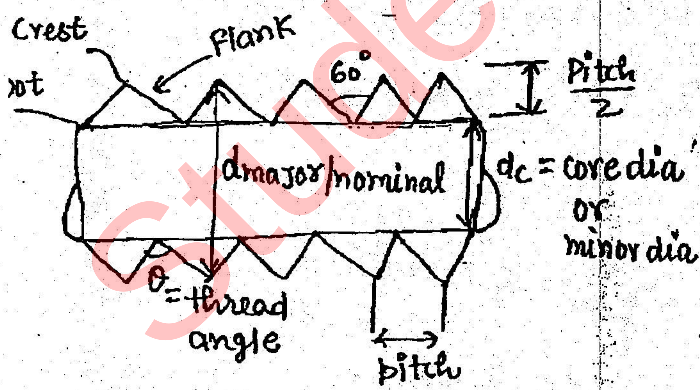
SPECIFICATION OF THE BOLT :-

d = Bolt Dia / Shank Dia
OR
Major dia of Bolt

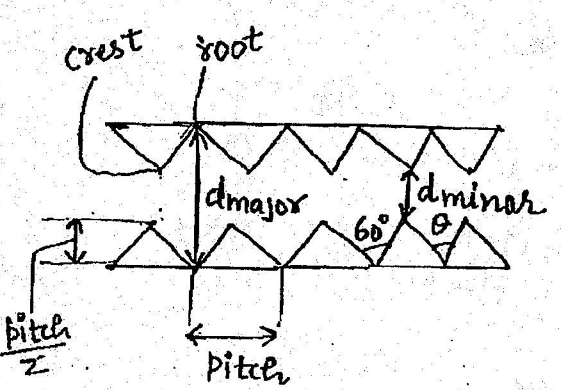
d_c = Core dia / Minor dia of the bolt



Thread
- External thread
- Internal thread

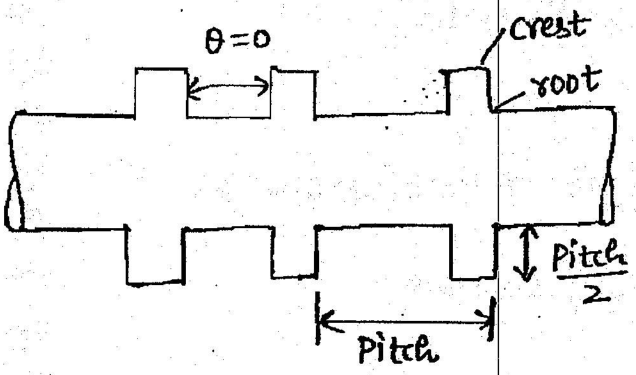


Vee shape Thread



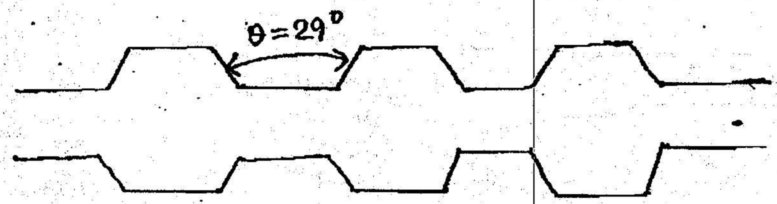
Vee-shape thread

used for fastening purpose.



Square thread

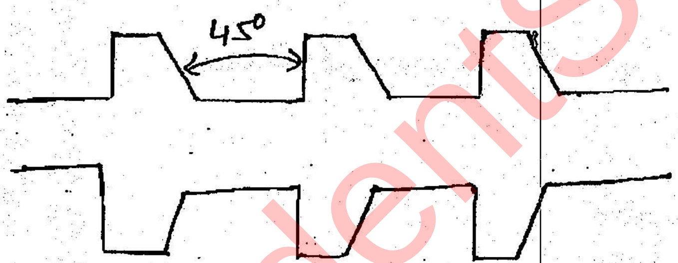
- Used in power screw.



ACME thread

- used in lead screw of lathe.

If θ=30° → Trapezoidal thread.



Butteress thread

- Buttress thread are used in application where power transmission required only in one direction.

➡ $M_{20\times2}$ → 2mm → Pitch (Fine pitch)

→ 20 mm = major dia. of bolt / Dia. of Bolt / Nominal Dia

➡ M_{20} → coarse pitch (invisible) = 10mm

→ 20mm = major dia.

Pitch → / Bolt Dia ↓	2mm	4mm	6mm	8mm	10mm
20mm	✓ (Fine pitch)	✓ (Fine pitch)	✓ (Fine pitch)	✓ (Fine pitch)	✓ (Carse Pitch)
24 mm	✓ (Fine pitch)	X	✓ (Fine pitch)	✓ (Coarse Pitch)	X

* The largest pitch available for any bolt is known as coarse pitch.

➡ $d = \frac{d_c}{0.84}$

$\sigma_{max} = \frac{P}{\frac{\pi}{4} d_c^2} \le \sigma_{per}$

d_c = known

then $d = \frac{d_c}{0.084}$

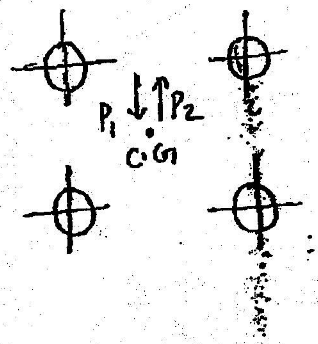
d = known

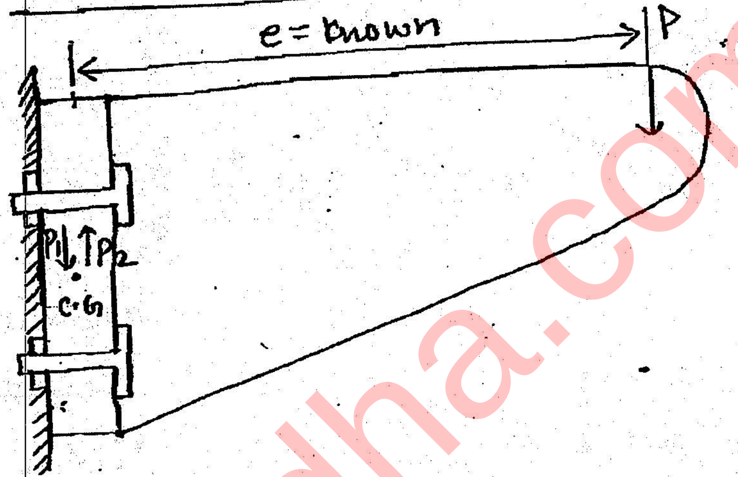
For GATE This formula is not used.

The question of bolt is same as question of Rivet.
question of bolt solved by same as question solved of Rivet previous.

- For the safe design of the bolt core diameter dc will be taken into consideration because core is the weakest portion of the bolt.

DESIGN OF BOLTED JOINT UNDER ECENTRIC LOADING :-





Solution

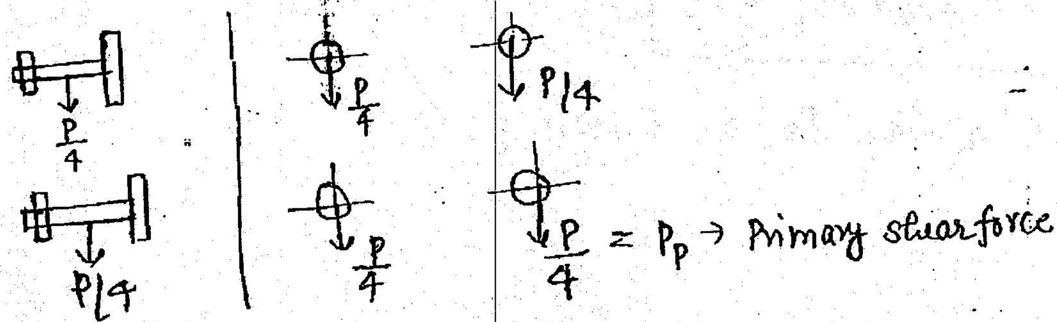
Step 1. Find out C.G :-

$$\bar{X} = \frac{X_1 + X_2 + X_3 + X_4 + \ldots}{n} \qquad \bar{Y} = \frac{Y_1 + Y_2 + Y_3 + Y_4 + \ldots}{n}$$

Step 2 :- Ecentricity :-

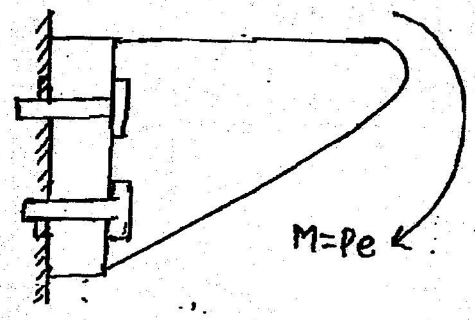
Step 3 :- Apply P_1, P_2 :-

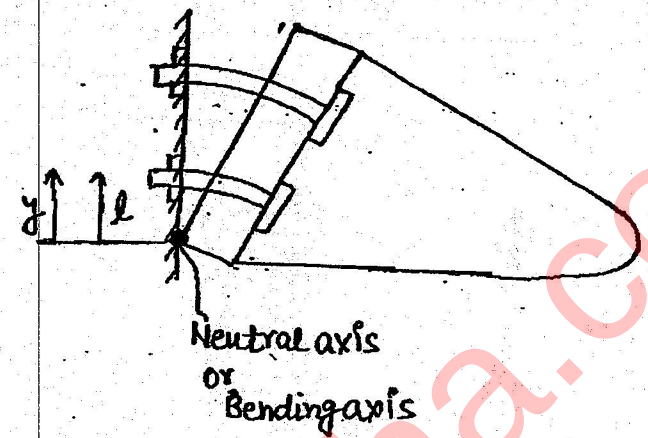
Step 4 :- Effect of P_1 :- As P_1 passing through C.G of the group of bolt it result primary shear force of equal magnitude in each bolt.



Effect of P_2 and P :-

P_2 and P causes a constant bending couple of magnitude $(P \cdot e)$ in clockwise direction about the neutral axis (N·A) which result bending stress induced in the bolt.

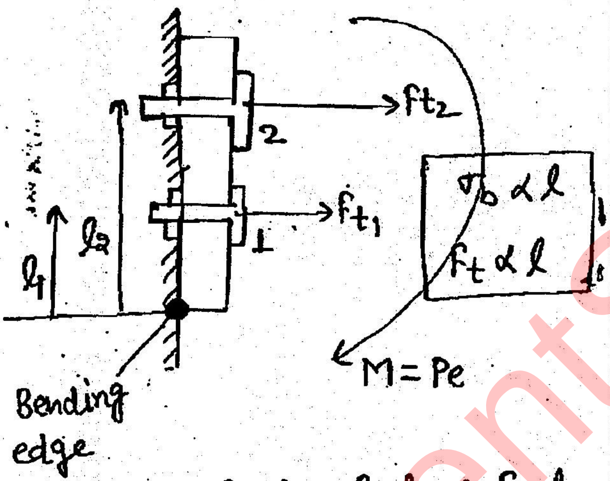




$l_1 = l_4, \; l_2 = l_3$

$\sigma_b \propto y$ इसमे y को l कहते है

$\sigma_b \propto l$



$F_t \rightarrow$ Secondary tensile force.

$$F_{t_1} l_1 + F_{t_2} l_2 + F_{t_3} l_3 + F_{t_4} l_4 = Pe$$

$$F_t \propto l$$

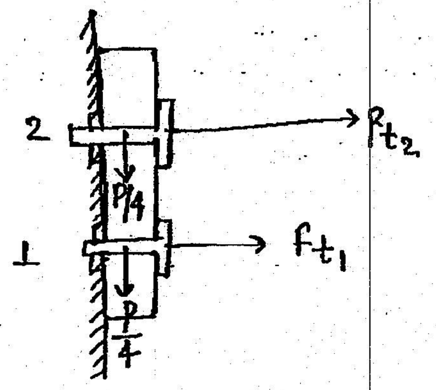
$$\frac{F_{t_1}}{l_1} = \frac{F_{t_2}}{l_2} = \frac{F_{t_3}}{l_3} = \frac{F_{t_4}}{l_4}$$

$$\boxed{\frac{F_{t_1}}{l_1}\left[l_1^2 + l_2^2 + l_3^2 + l_4^2\right] = Pe}$$

$F_{t_1}, F_{t_2}, F_{t_3}, F_{t_4}$ are known.

These bending stresses are represented by a secondary tensile force and this secondary tensile force is directly proportional to l (Distance from the centre of the bolt to the bending edge).

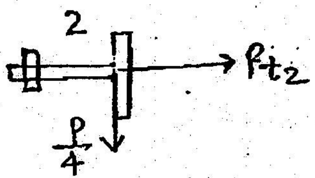
Combined effect of P_1, P_2 and P :-



$\frac{P}{4}$ चारों के equal हैं ∴ F_t decide करेगा की कौन सा Bolt critical है।

F_{t_2} is maximum, ∴ Bolt 2 is critical.

Critical Bolt → 2, 3



$\left(\frac{P}{4}\right)$ → shear stress

F_{t_2} → normal stress

Hence the bolt is in combined stress condition.

Now use MSST THEORY

$$\sqrt{\sigma_x^2 + 4\tau_{xy}^2} \le \frac{S_{yt}}{N}$$

Safe condition :-

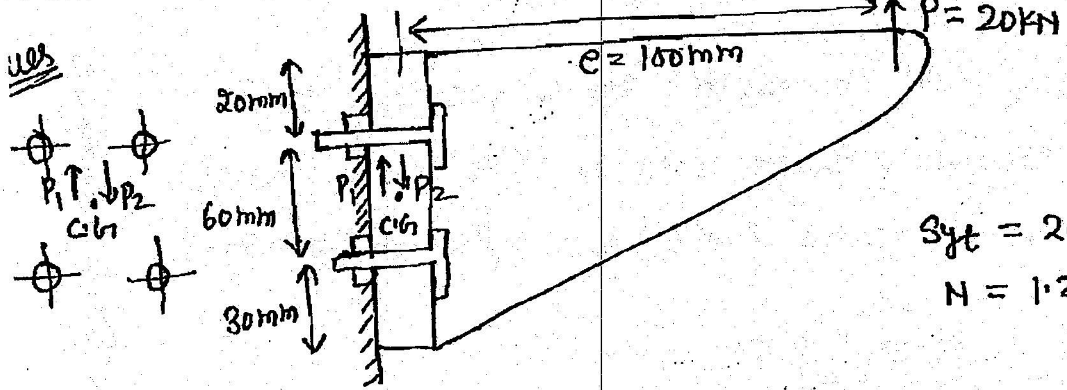
$$\sqrt{\left(\frac{F_{t_2}}{\frac{\pi}{4}d_c^2}\right)^2 + 4\left(\frac{P/4}{\frac{\pi}{4}d_c^2}\right)^2} \le \sigma_{per}$$

In gate use d in place of d_c. The concept d_c is not follow by gate.

d_c = known

$$d = \frac{d_c}{0.84}$$

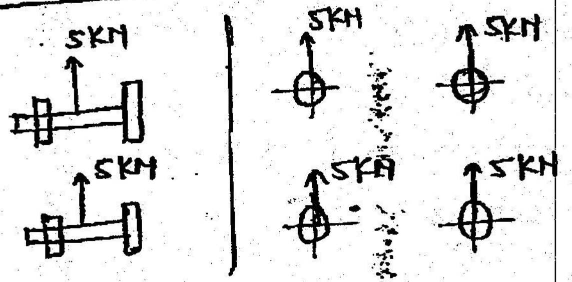
d = known



$S_{yt} = 200\,MPa$

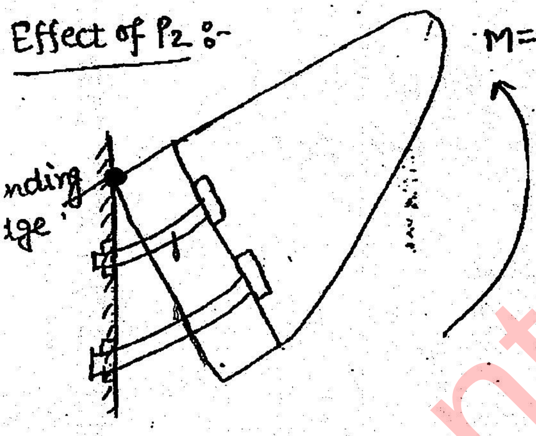
$N = 1.2$

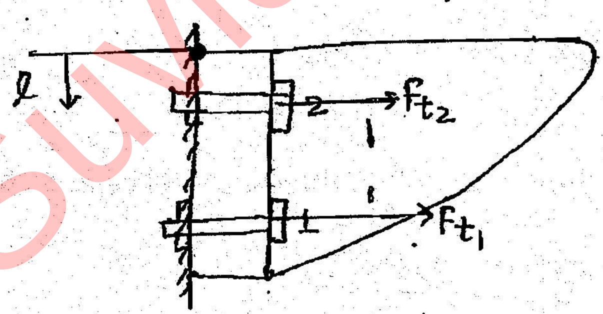
Effect of P_1



Effect of P_2 :-

$M = 20 \times 100\ KN\text{-}mm$



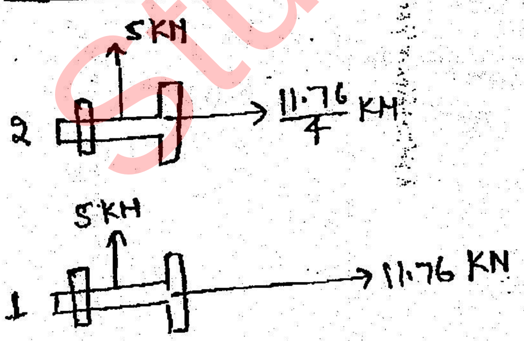


$$\frac{F_{t_1}}{80}\left[80^2 + 20^2 + 20^2 + 80^2\right] = 20 \times 100$$

$F_{t_1} = 11.76\,KN = F_{t_4}$

$F_{t_2} = \frac{11.76}{4}\,KN$

Combined effect :-



$\therefore$ Critical Bolt = 1, 4

MSST :-

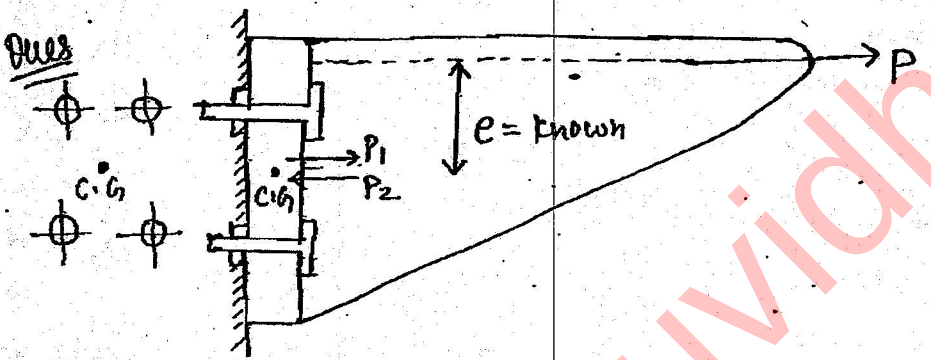
$$\sqrt{\left(\frac{11.76}{\frac{\pi}{4}d_c^2}\right)^2 + 4\left(\frac{5}{\frac{\pi}{4}d_c^2}\right)^2} \leq \frac{260\times10^{-3}}{1.2}$$

$d_c = 10.85$ mm

$d = \frac{d_c}{0.84} = \frac{10.85}{0.84} = 12.9$

$\boxed{d = 13\text{ mm}}$

Ques



Step 1 → C.G

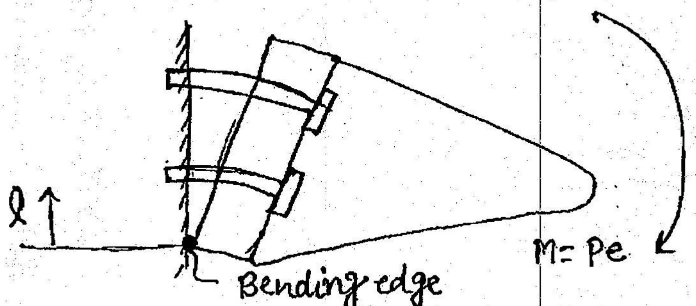
Step 2 – Ecentricity,

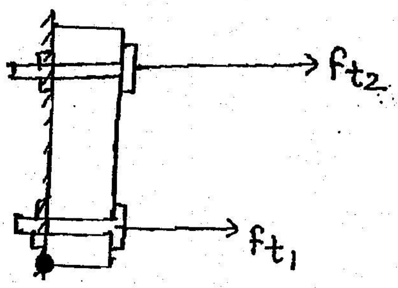
Step 3 – Apply P_1 and P_2

Step 4 – Effect of P_1

As P_1 passes through a grougp of C.G of the bolt parallel to the bolt axis it result primary tensile stress induced in each bolt of equal magnitude.

Effect of P_2 & P :-

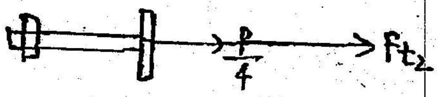


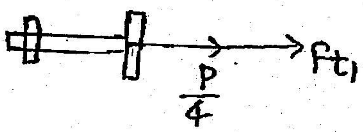


$$\frac{F_{t_1}}{l_1}\left[l_1^2+l_2^2+l_3^2+l_4^2\right] = Pe$$

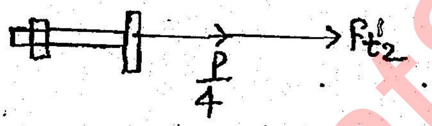
$F_{t_1}, F_{t_2}, F_{t_3}, F_{t_4}$ = known.

Combined effect:-

2 

1 

critical Bolt = 2, 3

2 

$$R = \frac{P}{4} + F_{t_2}$$

$$(\sigma_{ind})_{max} = \frac{R}{\frac{\pi}{4} d_c^2}$$

Safe condition:-

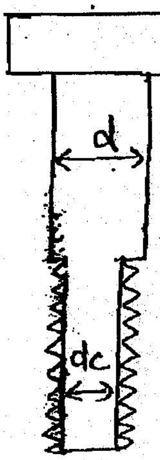
$$\frac{R}{\frac{\pi}{4} d_c^2} \leq \sigma_{per}$$

d_c = known.

$$d = \frac{d_c}{0.84} \Rightarrow \boxed{d = \text{known}}$$

BOLT OF UNIFORM STRENGTH :-

A bolt is said to be a uniform strength when stress induced in shank and threaded portion are equal.

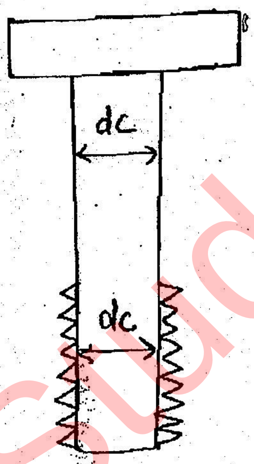


$$\sigma_{shank} = \frac{P}{\frac{\pi}{4}d^2}$$

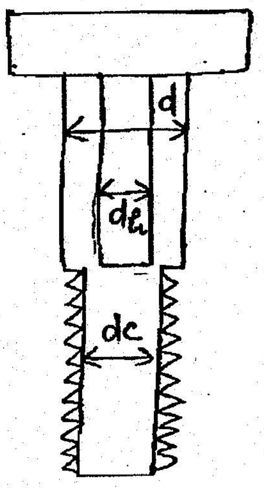
$$\sigma_{thread} = \frac{P}{\frac{\pi}{4}d_c^2}$$

$$\sigma_{shank} \neq \sigma_{thread}$$

Method 1 : (Removal of Material)



Method 2 : (Drilling holes)



$$\frac{\pi}{4}[d^2 - d_h^2] = \frac{\pi}{4}d_c^2$$

$$d^2 - d_h^2 = (0.84)^2$$

$$\boxed{d_h = 0.542d}$$

NOTE:-

⇒ Bolt of uniform strength is used where high impact and fatigue load acting on the member.

⇒ weight of the Bolt decreases and cost also decreases.

Pretensioning :-

- Pretensioning of the bolt is done to wear more impact and jerk.
- Net force on the bolt = $F_{pretension} - F_{actual\ applied\ load}$
- For the safe condition of the bolt actual applied load is less than pre tension force.