The distance between two consecutive rivets measured parallel to the force direction is called pitch of rivets (p)

(ii) Gouge distance (q)

It is distance between two consequtive rivets which is measured perpendicular to the direction of force

(iii) End distance:

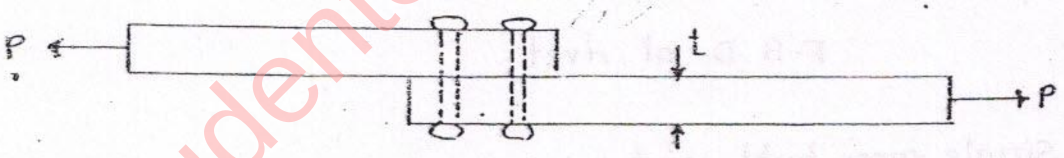
It is distance between centre of rivet and edge of the plate element, measured parallel to direction of force.

(iv) Edge distance:

It is distance between centre of rivet and edge of the plate element, measured perpendicular to direction of force.

Types of joints:

(1) Lap joints:



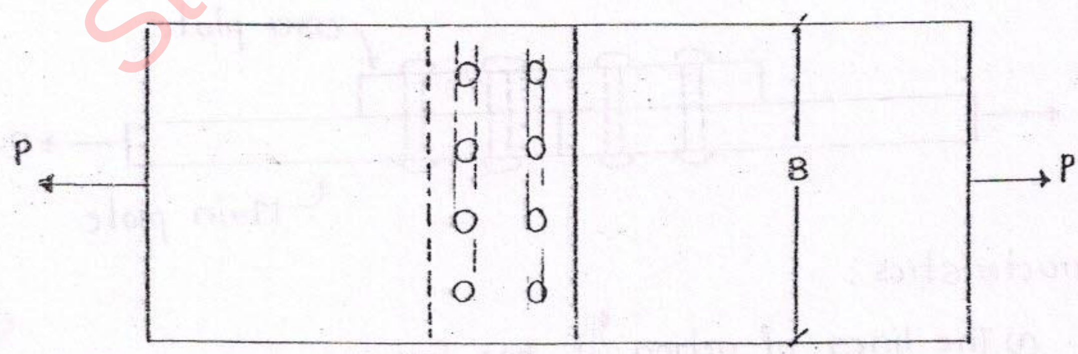
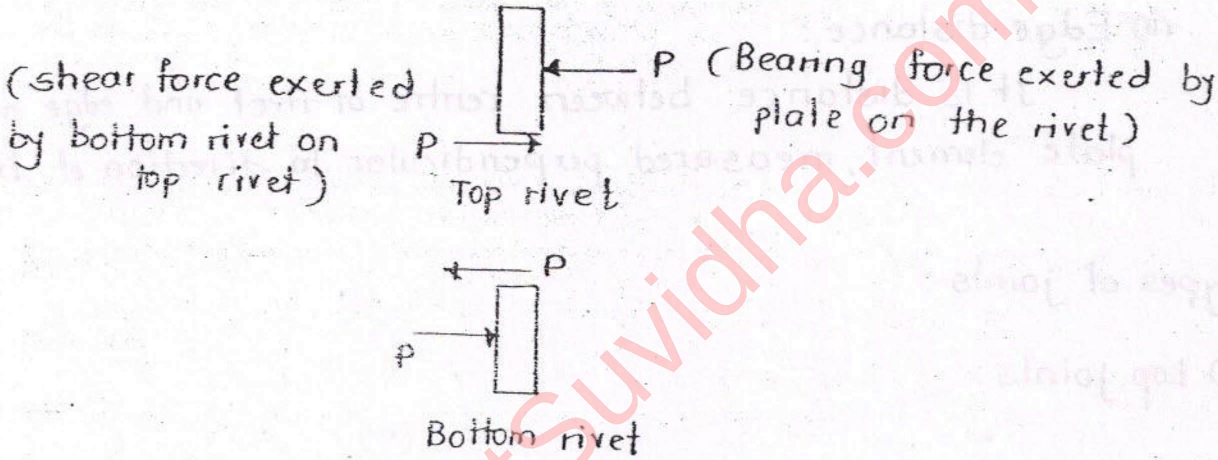


Fig. Lap joint

Characteristics :

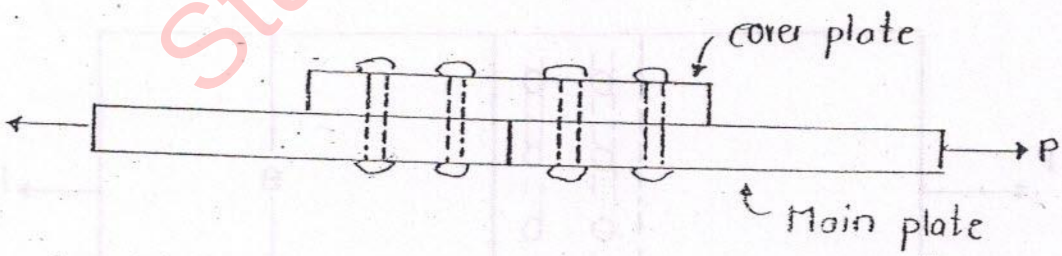
(i) It is least efficient joint. (Because the lines of actions of two forces are not same. These two forces form a couple and additional bending stresses are developed in rivets)

(ii) In lap joint the rivets are subjected to single shear and bearing. (without bearing stress. shearing stress cannot exist)



F.B.D. of rivet.

(2) Single cover butt joint :

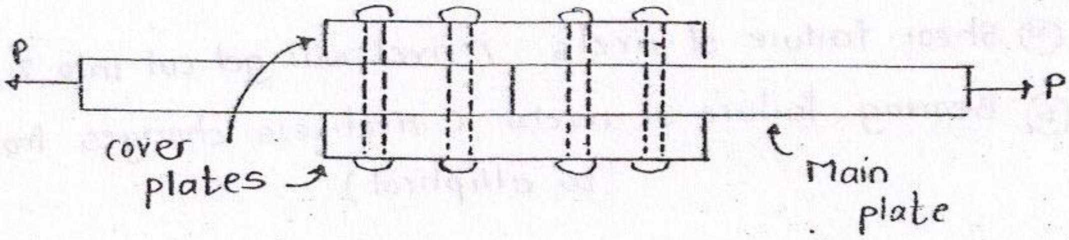


Characteristics :

(i) The lines of action of two forces is same but the connection is not symmetrical. So it is slightly more efficient than Lap joint.

(ii) The rivets are subjected to single shear and bearing.

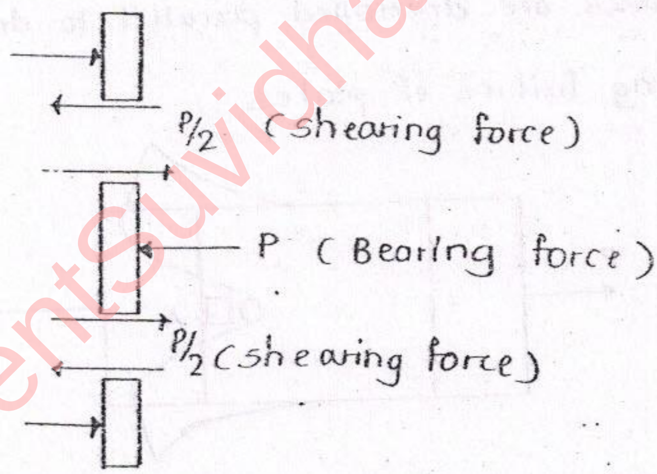
(5) Double cover butt joint :



Characteristic :

(i) It is the most efficient joint. (Because the lines of action of two forces is same and connection is symmetrical w.r.t applied load)

(ii) The rivets are subjected to double shear and bearing



FBD of rivet.

Failure of riveted joints: Wednesday 9th October 2015

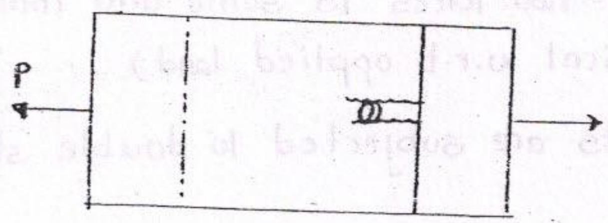
(1) Failure of rivets:

ⓐ Shear failure of rivets (rivet will get cut into 2 pieces)

ⓑ Bearing failure of rivets (rivet c/s changes from circular to elliptical)

(2) Failure of plates

ⓐ Shear failure of plates .....



(cracks are developed parallel to direction of applied load)

ⓑ Splitting failure of plates:

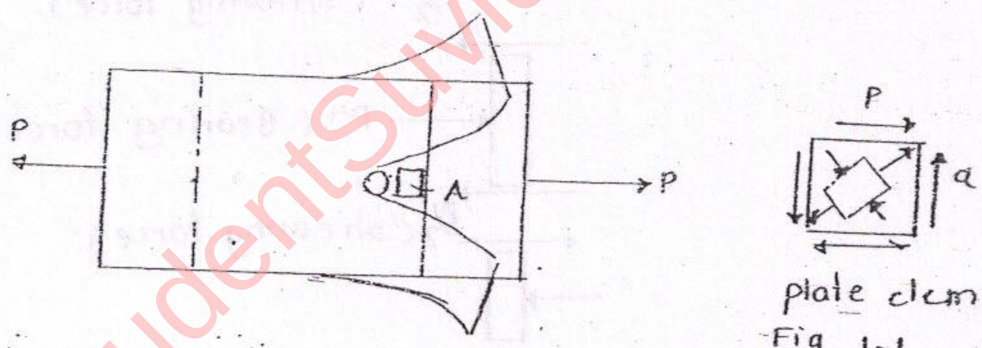
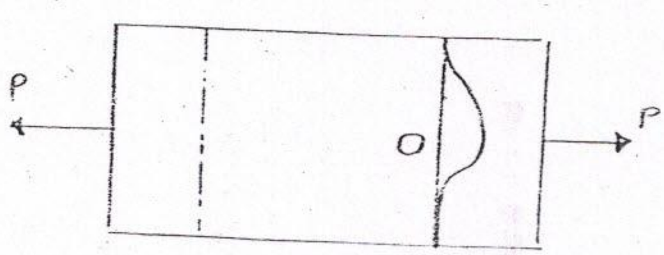


Fig. 1-1

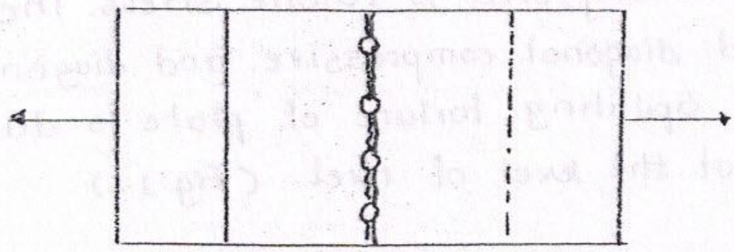
(Occurs due to diagonal tension in plate at rivet level.

ⓒ Bearing failure of plates



(plate is pushed forward by rivet)

(d) Tearing (tension) failure of plates:

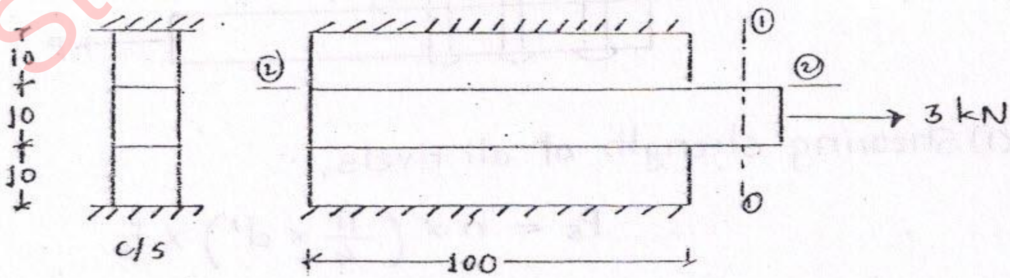


(racks are developed ⊥ar to the direction of applied force)

shear failure of plates, splitting failure and bearing failure are due to insufficient end distance. By providing the proper end distance, these three failures can be prevented. so, in the design of a riveted joint we should consider the remaining three failures only i.e. shearing and bearing failur of rivets and tearing failure of plates.

In the design of a riveted joints we have to ensure that, shear strength and bearing strength of rivets is more than the tearing strength of plate because rivel failure is more dangerous than component failure. (plate).

Consider an example.



$$\text{Tensile stress at ①-① } = f_1 = \frac{3\times10^3 \text{ N}}{10\times10} = 30 \text{ N/mm}^2$$

$$\text{Shear stress at ②-② } = f_2 = \frac{3\times10^3 \text{ N}}{2(10\times100)} = 1.5 \text{ N/mm}^2$$

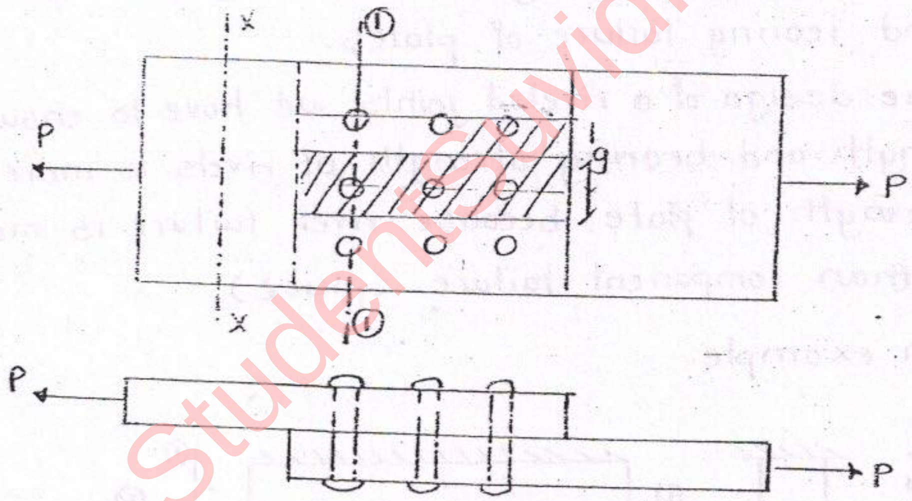
If an element is subjected to pure shear then one diagonal is subjected to compressive stress and other diagonal is subjected to tensile stress. These stresses are called diagonal compressive and diagonal tensile stresses. Spilliting failure of plate is due to diagonal tension at the level of rivet. (Fig 1.1)

Strength of riveted joint :

...... It is taken as minimum of shear strength of all rivets (P_s), Bearing strength of all rivets at the joint (P_b) and tearing strength of plate (P_t).

(A) For lap joint :

Case I: For entire plate:



(i) Shearing strength of all rivets,

$$P_s = n \times \left(\frac{\pi}{4} \times d^2 \right) \times f_s$$

where.

n - total no. of rivets at the joint (9 here)

f_s - permissible shear stress in rivet

$$f_s = 100 \text{ MPa} \quad (\text{in W.S.M})$$

$$= \frac{f_u}{\sqrt{3} \times 1.25} \quad (\text{in L.S.M.})$$

f_u - ultimate shear stress in rivet material.

γ_m - partial factor of safety $= 1.25$

Note:

From distortion energy theory or shear strain energy theory to prevent failure of ductile material the max. shear stress is $\frac{f_u}{\sqrt{3}}$.

Partial safety factor 1.25 is applied to this value to get permissible shear stress.

d - gross diameter of rivet or nominal diameter of the bolts.

(ii) Bearing strength of all rivets.

$$P_b = n \times (d \times t) \times f_b$$

where,

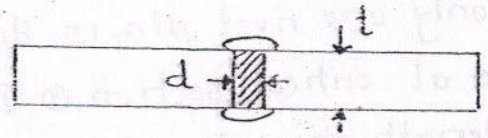
n - total no. of rivets

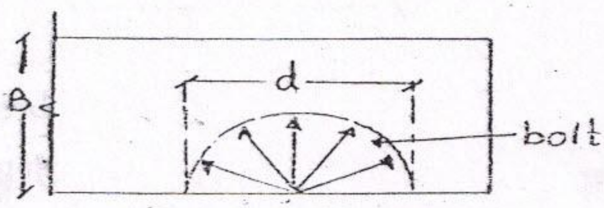
t - thickness of thinner main plate.

f_b - permissible bearing stress

$$f_b = 300 \text{ MPa} \quad (= 1.2 f_y)$$

and $(d \times t)$ = projected area of rivet against plate.





Pressure exerted by bolt on plate

(iii) Tearing strength of main plate:

At critical section ① - ①

$$P_t = (B - n_1 \cdot d) \cdot t \times f_t$$

where.

n_1 - no of bolts at critical section ① - ① (5)

t - thickness of thinner main plate.

f_t - permissible tensile stress in plate

$$f_t = 0.6 f_y$$

Case II: For gauge length:

(i) Shear strength of all rivets (in shaded gauge length)

$$P_{s_1} = m_1 \times \left(\frac{\pi}{4} \times d^2\right) \times f_s$$

where.

n_1 - total no. of rivets in shaded gauge length.

(ii) Bearing strength of all rivets (in shaded gauge length)

$$P_{b_1} = n_1 \times (d \times t) \times f_b.$$

(iii) Tensile strength of plate in gauge length.

$$P_{t_1} = (g - d) \cdot t \times f_t$$

only one rivet dia. is deducted because at critical section ①-①, in the gauge length there is only one rivet.

t - thickness of thinner main plate.

Least value of P_{s_1}, P_{b_1} and P_{t_1} is strength of joint.

In. L.S.M.

P_{t_1} - tensile strength of plate at x-x

$$= A_g \times \left(\frac{f_y}{1.1}\right)$$ — where yielding govern strength of plate.

or

P_{t_2} - tensile strength of plate at ②②

$$= A_{net}\left(\frac{0.9\, f_u}{1.25}\right)$$ — where rupture or cracking governs streng

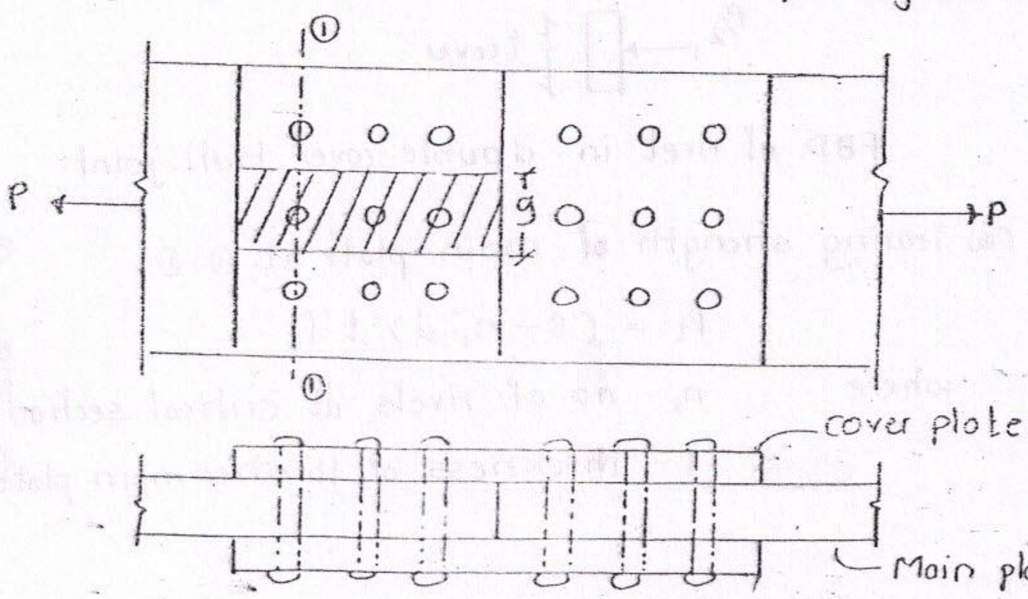
Note:

(i) Yielding of plate takes place at gross area level. so when f_y is considered, gross area is taken while calculating tensile strength of plate in L.S.M.

(ii) Cracking of plate take place at net area level when the ultimate stress point is crossed in stress-strain curve. so net area is considered when f_u is taken while calculating tensile strength of plate.

∴ least of the above two values is tensile strength of plate in L.S.M.

(B) Strength of rivet joint for double cover plate joint:



Case I: For entire plate:

(i) Shear strength of all the rivets in joint

$$P_s = n \times \underbrace{\left(2 \times \frac{\pi}{4} \times d^2\right)}_{\text{double shear}} \times f_s$$

where

n - total no. of rivets at the joint (9 here)
(not 18)

(ii) Bearing strength of all rivets

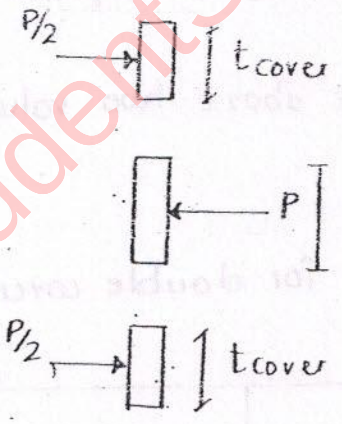
$$P_b = n \times (d \times t) \times f_b$$

where

n - total no. of rivets at joint (9 here)

t - sum of cover plates thickness or thickness of thinnest main plate } Min.

(Sum of cover plate thickness is taken because force on cover plate will act in same direction



P- bearing force

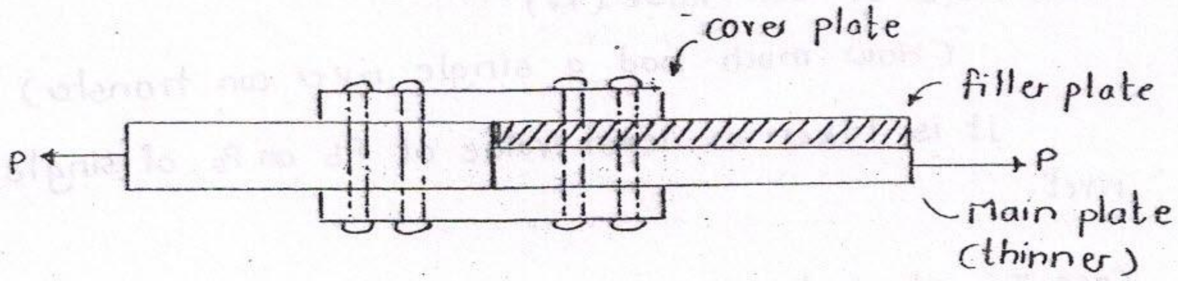
FBD of rivet in double cover butt joint.

(iii) Tearing strength of main plate at ①-①

$$P_t = (B - n_1 \cdot d) \cdot t \, f_t$$

where n₁ - no. of rivets at critical section ①-① (3)

t - thickness of thinner main plate.



Note:

(i) Sum of cover plates ≥ main plate thickness
(so that cover plates will not be broken)

(ii) Filler plates are used only to fill gap between the cover plate and thiner main plate to avoid entry of unwanted things. It does not serve any structural purpose.

Case II : for gouge length :

(i) Shear strength of all rivet joints in gouge length

$$P_{S_1} = n_1 \times \left(2 \times \frac{\pi}{4} \times d^2\right) \times f_s$$

double shear.

where

n_1 - total no. of rivets in shaded gauge length (3 in given fig not 6)

(ii) Bearing strength of rivets

$$P_{b_1} = n_1 \times (d \times t \times f_b)$$

where,

n_1 - total no. of rivets in gouge length (3)

t - sum of cover plate thickness
or
Main plate thickness

(iii) Tearing strength of plate

$$P_{t_1} = (g-d) \cdot t \cdot f_t$$

t - thickness of thiner main plate.

Rivet value or Bolt value (R_v)

(How much load a single river can transfer)

It is taken as least value of P_b or P_s of single rivet.

Case I: If rivet is in single shear:

$$\left.\begin{aligned} P_s &= \frac{\pi}{4} \times d^2 \times f_s \\ P_b &= d \times t \times f_b \end{aligned}\right\} \text{whichever is less} \;\ldots\ldots\; \text{is } R_v$$

where t - sum of cover plates or main plate (whichever is less)

Case II: If rivet is in double shear

$$\left.\begin{aligned} P_s &= 2 \times \frac{\pi}{4} \times d^2 \times f_s \\ P_b &= d \times t \times f_b \end{aligned}\right\} \text{whichever is less is } R_v$$

Note:

If rivet is subjected to triple shear, we have to take double shear only.

Number of rivets required at a joint

$$n = \frac{\text{Total force at the joint}}{\text{Rivet value}}$$

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

Efficiency of a joint

(i) For entire plate:

$$\eta = \frac{\text{Least value of } P_s, P_b \text{ and } P_t}{\text{strength of solid plate}}$$

(we have to ensure that P_t is less value)

$$\eta = \frac{(B - n_1 d) \cdot t \cdot f_t}{B \cdot t \cdot f_t}$$

$$= \frac{(B - n_1 d)}{B}$$

(ii) For gauge length:

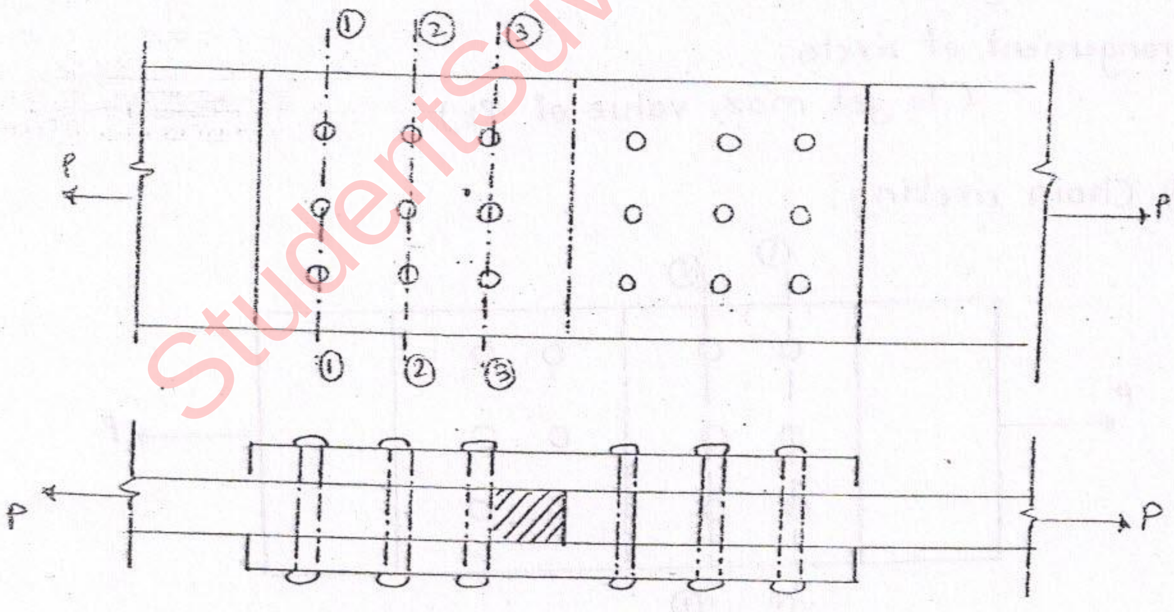
$$\eta = \frac{\text{least value of } P_s, P_b, P_t}{\text{strength of solid plate in gauge length}}$$

$$= \frac{(g-d) \cdot t \cdot f_t}{g \cdot t \cdot f_t}$$

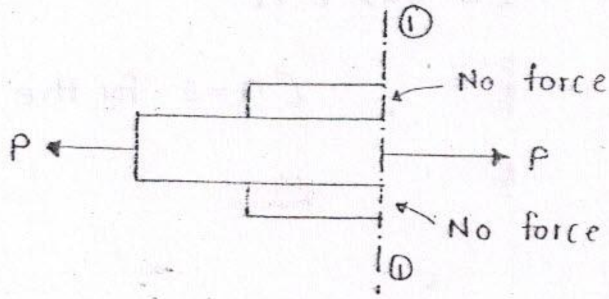
$$\eta = \frac{(g-d)}{g}$$

Note:

(i) For a given joint both efficiencies can be same or different.



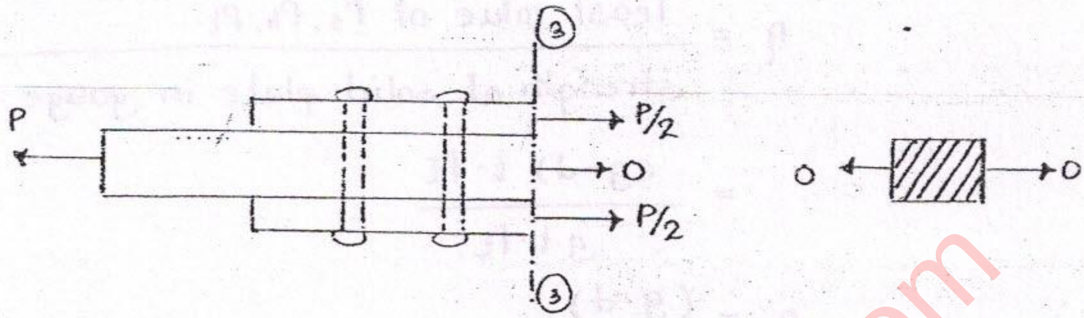
(ii) Cut the joint at ① - ① and consider F.B.D of L.H.S. of it.



F.B.D.

From above F.B.D. we find that entire load P is taken by main plate at section ①-①. So critical section for main plate is at ①-①

(iii) Cut the joint at R.H.S. of ③-③ and consider F.B.D. of left portion.



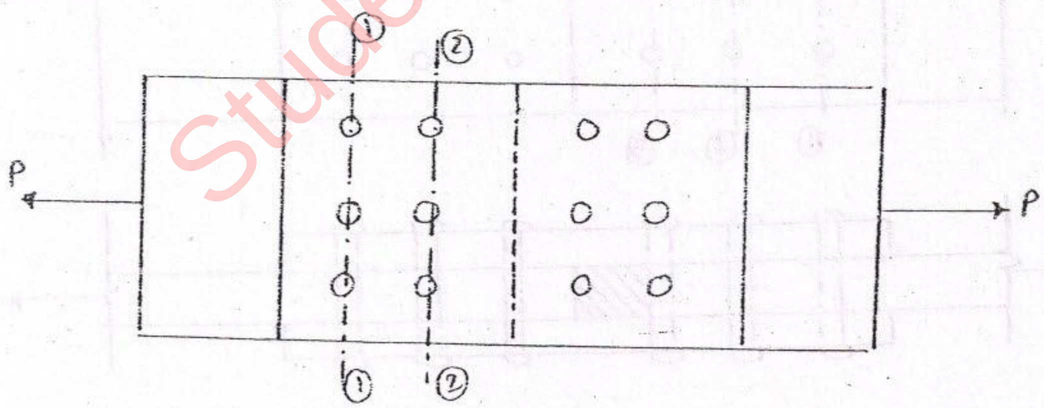
From the above FBD. we find that the entire load P is taken by cover plates at section ③-③. So critical section for cover plates is at ③-③.

(iv) Arrangement of

Arrangement of rivets:

(To get max. value of P_t)

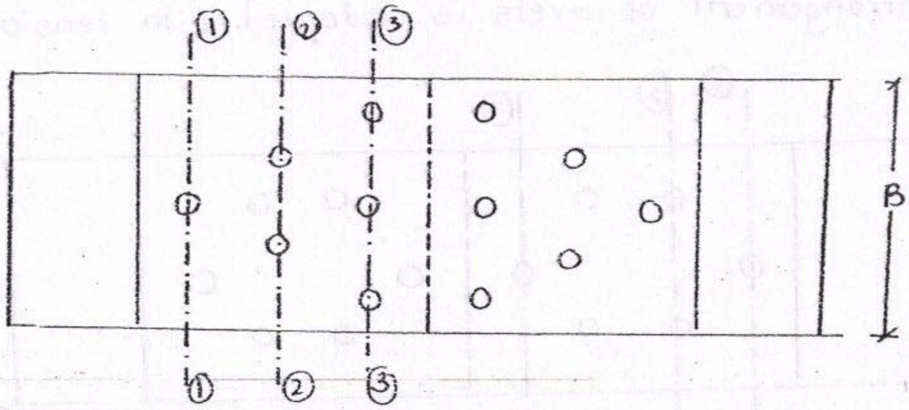
ⓐ Chain riveting:



$$P_t = (B-3d) \cdot t \cdot f_t$$

($n = 3$ for the above fig.)

(b) Diamond riveting.



$$P_t = (B-d) \cdot t \cdot f_t$$

Note:

(i) Diamond riveting is more efficient than chain riveting because only one rivet diameter is deducted from the width in diamond riveting.

(ii) Tensile strength of main plate

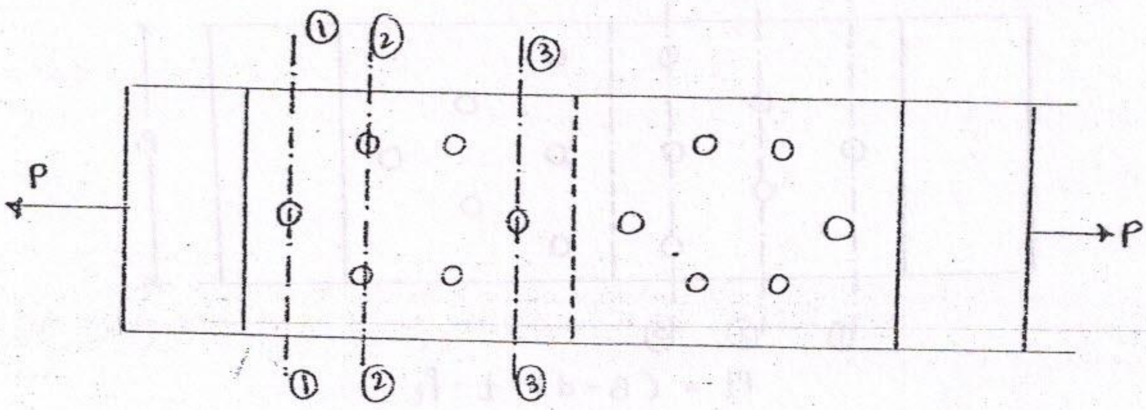
	at ①-①	at ②-②
(a) Chain riveting	$(B-3d) \cdot t \cdot f_t$	$(B-3d) \cdot t \cdot f_t + 3 \cdot R_v$ to crack plate, to shea 3 rivets
(b) Diamond riveting	$(B-d) \cdot t \cdot f_t$	$(B-2d) \cdot t \cdot f_t + R_v$

From the above table we find that, in chain riveting it is impossible, for tearing failure to happen at ②-② because it requires more load to fail at ②-②.

In diamond riveting, failure can happen at ②-②, if $d t \cdot f_t > R_v$.

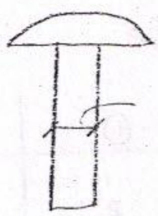
(iii) Critical section for cover plates is at ③-③. To make cover plates strong, the variation of diamond riveting as shown in fig. is best arrangement.

(iv) Both cover and main plates are strong for the following arrangement of rivets is adopted. (in tension)



Specifications for pitch of rivets :

(i) Minimum pitch of rivets = 2.5 × nominal dia. of rivet or bolt.



(ii) Minimum end and edge distance

(To prevent shear, splitting and bearing failure of plates)

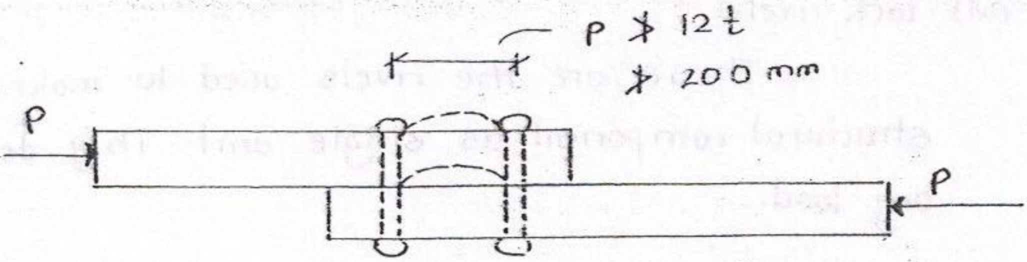
= 1.5 × gross dia. of rivet (for machine cut element)

= 1.7 × gross dia. of rivet (for hand cut element)

(iii) Maximum pitch of rivets or welds in compression zone

$$\left.\begin{array}{l} = 12 \cdot t \\ = 200\ mm \end{array}\right\}$$ whichever is less.

t - thickness of thinner plate

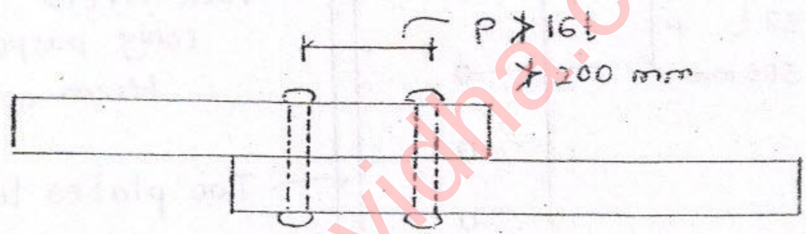


(To prevent buckling between the connections)

(iv) Maximum pitch of rivets or welds in tension zone

$= 16t$ } whichever is less
$= 200$ mm

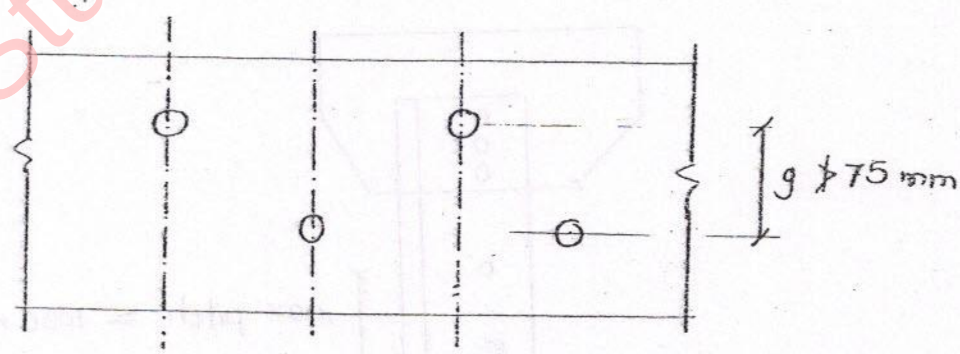
t - thickness of thinner plate.



(To prevent seperation of plates between connection)

(v) If the rivets are staggered (not in one line) and if $g \ngtr 75$ mm, the above values can be increased by 50%.

i.e.



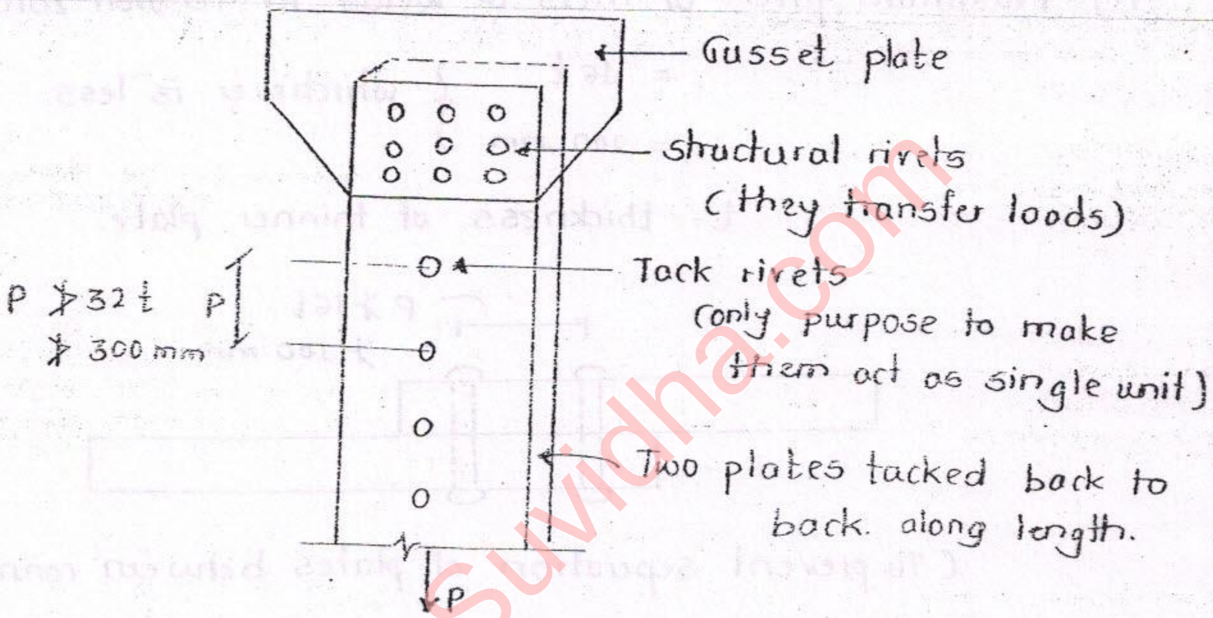
Max. pitch of rivets in compression zone $= 18t$ } whichever is less
$= 300$ mm

Max. pitch of rivets in tension zone $= 24t$
$= 300$ mm

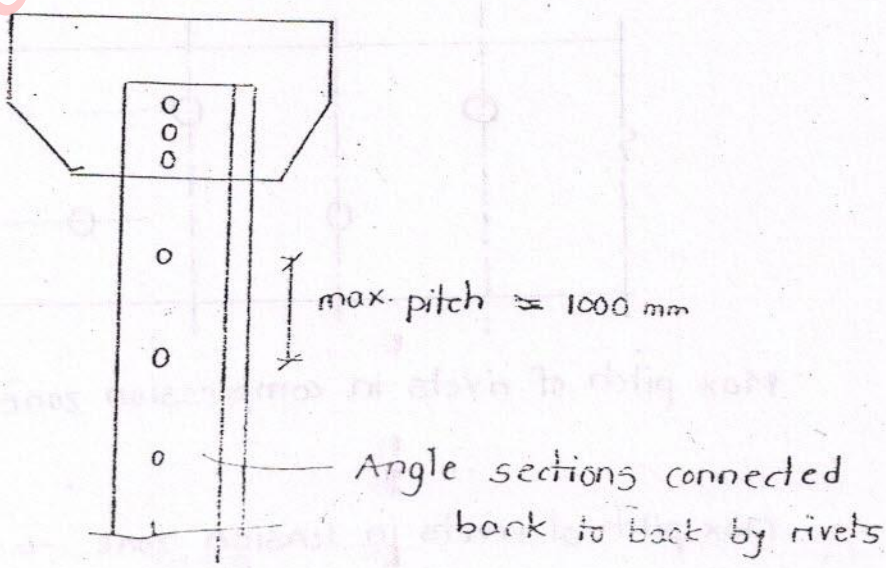
(vi) Tack rivets.

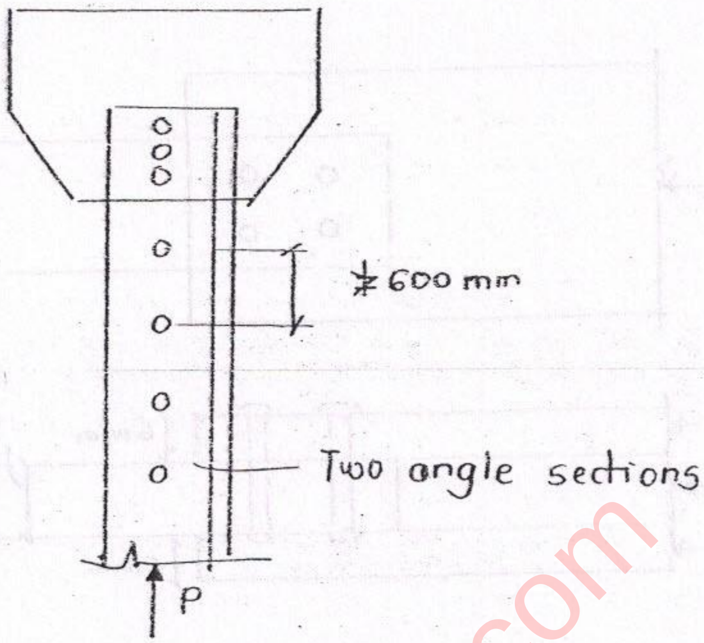
These are the rivets used to make the structural component as single unit. They do not cary any load.

Max. pitch of tack rivets = 32t } whichever is minimum.
= 300 mm



(vii) Max. pitch of tack rivets when angles, T-sections, channel sections are used as tension members is 1000 mm.





(viii) Max. pitch of angles tack rivets when angles, T-sections, channels are used as compression members is 600 mm

(ix) Gross diameter of rivet or diameter of rivet hole is

$$= \text{nominal dia} + 1.5 \text{ mm} \quad (\text{if } \phi \leq 25 \text{ mm})$$
$$= \text{nominal dia.} + 2 \text{ mm} \quad (\text{if } \phi > 25 \text{ mm})$$

(1.5 mm is added to take care of buldging of rivet while driving into plate)

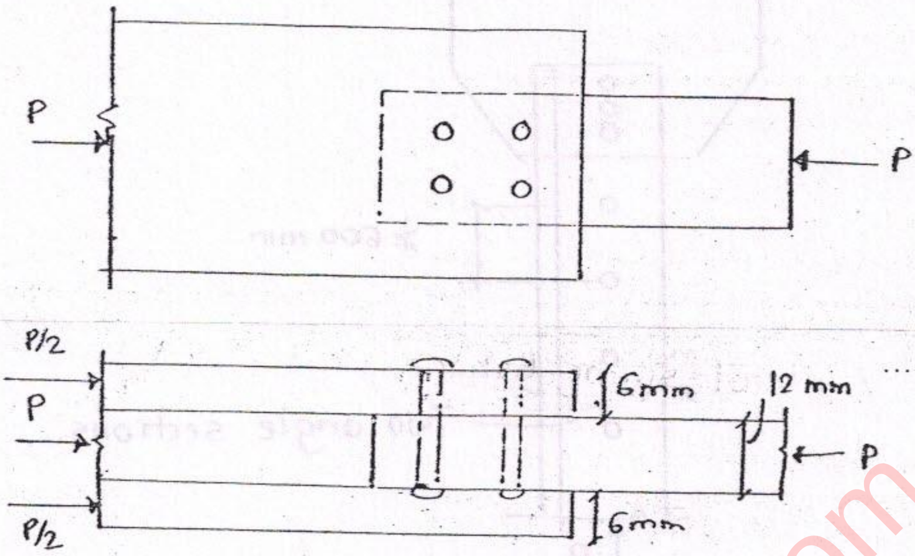
(x) Nominal diameter of rivet is from Unwine's formula

$$\phi = 6.04 \sqrt{t} \qquad (\text{empirical formula})$$

where,

t - thickness of thinner plate in mm

Q. Consider riveted joint as shown in fig. the max. permissible pitch p is.



Since the plate are under compression.

$$\text{Max pitch} = 12t = 12 \times 6$$

$$= 72 \text{ mm}$$
$$= 200 \text{ mm}$$
} whichever is less

$\therefore$ $P = 72$ mm

Q. In above problem if the plates are subjected to tension, the max. pitch is —

$$\text{Max pitch} = 16t = 16 \times 6$$

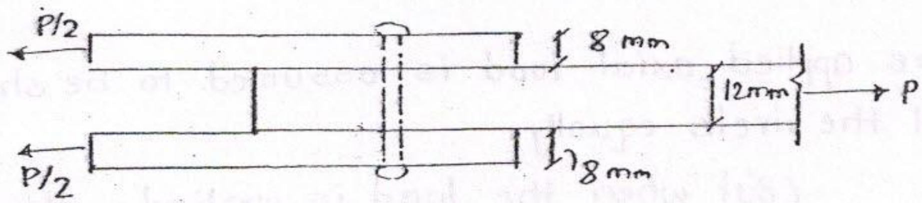
$$= 96$$
$$= 200 \text{ mm}$$
} Minimum

$P = 96$ mm.

Q. A 12mm thick plate is connected to two 8mm plates on either sides through 16 mm dia rivets. as shown in fig.

If $f_s = 90$ MPa. $f_b = 270$ MPa.

What is the rivet value



Gross dia. of boll.

$$d = \phi + 1.5\,mm$$

$$d = 16 + 1.5$$

$$= 17.5\ mm$$

$$\therefore\ P_s = 2 \times \frac{\pi}{4} \times d^2 \times f_s$$

$$= 2 \times \frac{\pi}{4} \times (17.5)^2 \times 90$$

$$= 43.2\ kN$$

$$P_b = d \times t \times f_b$$

$$= 17.5 \times t \times 270$$

Here (because direction forces is same)

t = sum of top and bottom plates $(8 + 8 = 16\,mm)$

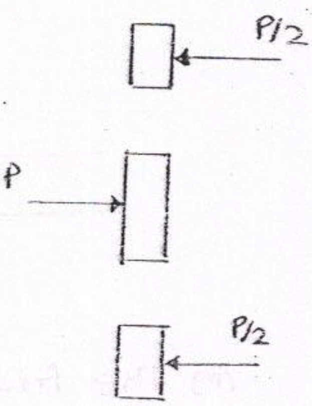
or

= central plate thickness $(12\,mm)$

$\therefore$ $t = 12$ mm (minimum of above)

$$P_b = 17.5 \times 12 \times 270$$

$$= 56.7\ kN$$



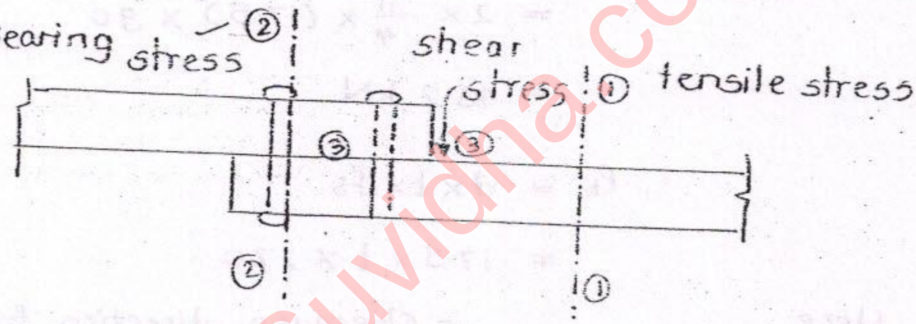
$\therefore$ Rivet value $= P_s = 43.2$ kN

Assumptions in the design of Riveted joints:

(i) The applied axial load is assumed to be shared by all the rivets equally.

(But when the load is applied within the proportionality limit, outer rivets take more load than inner rivets.) The above assumption is valid only at collapse loads. At collapse load condition, all the rivets yield and share the applied load equally.

(ii) The tensile stress, shear stress and bearing stress at their respective c/s are assumed to be uniform.



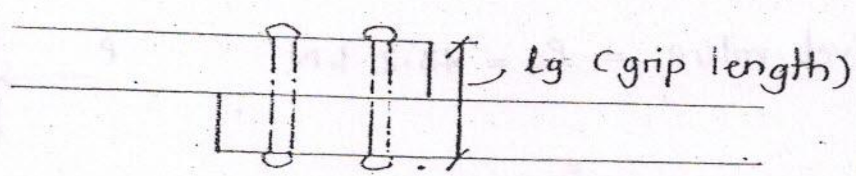
(iii) The effect of bending stress in neglected.

To ensure that effect of bending stress is less, the IS code specifies the 'grip length (l_g) $\ngtr$ 5 times dia. of rivet. (nominal)

i.e.

$l_g \ngtr 5(\phi)$ (As per IS 800-2007)

$\ngtr 8\phi$ (As per IS 800-1984)

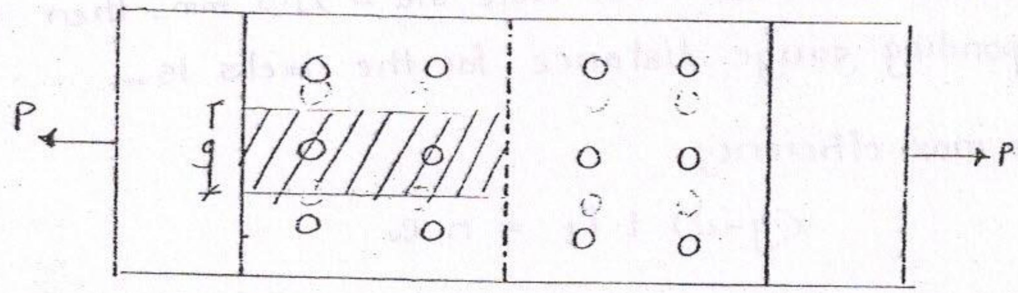


(iv) The frictional force between the plates is neglected.

(v) Most important consideration in the design of rivetted joint is

$$(g-d)\cdot t\cdot f_t \leq n\cdot R_v$$

10th October 2013
Thursday



n- no.of rivets in shaded gauge length. (2)

$(g-d) \cdot t \cdot f_t \leq 2 \cdot (P_s)$

or

$(g-d) \cdot t \cdot f_t \leq 2 \cdot (P_b)$

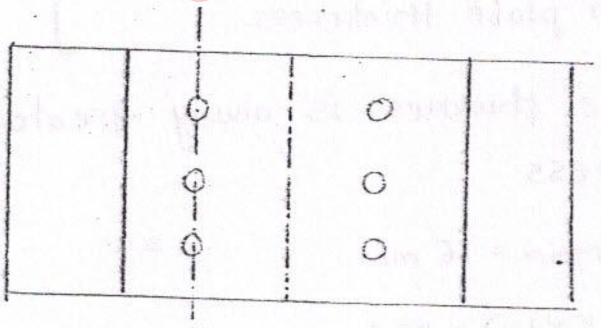
If above condition is followed, plate will fail but not the rivets.

The above condition is also used to find the value of gauge distance (g) to find maximum efficieny of rivets.

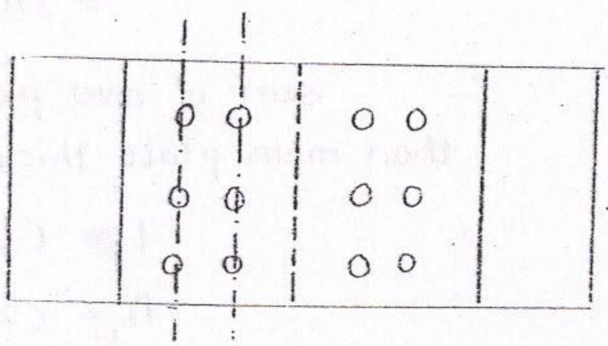
Note:

(i) Single riveted joint means one line of rivets (in that line there can be many rivets)

(ii) Double riveted joint means two lines of rivets (there will many rivets in each line.)



Single rivetted joint



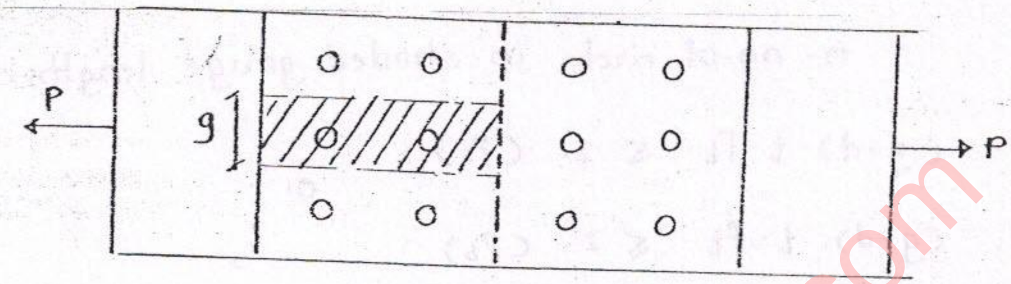
Double riveted joint

63

Q. A double rivetted double cover butt joint connecting 16 mm thick plates is to be designed for max. efficiency. If $f_t = 150$ MPa. $f_s = 90$ MPa. $f_b = 230$ MPa. hole dia = 21.5 mm, then the corresponding gauge distance for the rivets is—

For max. efficiency

$$(g-d)\cdot t\cdot f_t = n\cdot R_v$$



Double rivetted joint.

Rivets are in double shear, in double cover butt joint.

$$P_s = \underbrace{2}_{\text{double shear}} \times \frac{\pi}{4} \times d^2 \times f_s$$

$$= 2 \times \frac{\pi}{4} \times 21.5^2 \times 90$$

$$= 65.35 \text{ kN}$$

$$P_b = (d \times t) \times f_b$$

where

t = sum of cover plates thickness } Minimum
= Main plate thickness

∴ sum of cover plate thickness is alway greater than main plate thickness

∴ $t = (t)_{Main} = 16$ mm

$$P_b = (21.5 \times 16) \times 230$$

$$= 79.12 \text{ kN}$$

$$R_v = P_s = 65.35 \text{ kN}$$

$\therefore \quad (g-21.5) \cdot 16 \times 150 = 2 \times 65.35$

No. of rivets in shaded gauge area.

$\therefore \quad g = 75.9 \text{ mm}$

Design of rivetted joint :-

Procedure:

(i) ⓐ Diameter of rivet $(\phi) = 6.04\sqrt{t}$, mm

ⓑ Rivet value (R_v) - Minimum of P_s and P_b

ⓒ No. of rivets required $(n) = \frac{F}{R_v}$

(ii) Arrangement of rivets to get maximum efficiency i.e. to get max. value of P_t.

(iii) Width and thickness of main plate (B_{main}, t_{main})

(iv) Width and thickness of cover plate (B_{cover}, t_{cover})

15 Marks

Q. A tie member has to transmit a pull of 400 kN. Design a butt joint to connect 2- 12 mm thick plates. Also find the efficiency of the joint. Take $f_t = 150$ MPa. (in plate) $f_s = 100$ MPa (in rivets). $f_b = 300$ MPa (in rivets).

If a butt joint is to be designed, always use double cover butt joint, because it is the most efficient joint.

(i) Design of rivets:

ⓐ Dia. of rivet:

$$\phi = 6.04\sqrt{t}$$
$$= 6.04\sqrt{12}$$
$$= 20.95 \text{ mm}$$

So use $\phi = 20 \text{ mm}$

(b) Rivet value (R_r):

Rivets are in double shear in double cover butt joint.

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

$$= 2 \times \frac{\pi}{4} \times 21.5^2 \times 100 \qquad (\because d = \phi + 1.5 = 20 + 1.5 = 21.5 \text{ mm})$$

$$= 72.6 \text{ kN.}$$

$$P_b = (d \times t) \times f_b \qquad \because t = \text{sum of cover plates} = \text{main plate thickness (12mm)}$$

$$= (21.5 \times 12) \times 300$$

$$= 77.5 \text{ kN}$$

$$\therefore R_v = P_s = 72.6 \text{ kN}$$

(c) No. of rivets required.

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

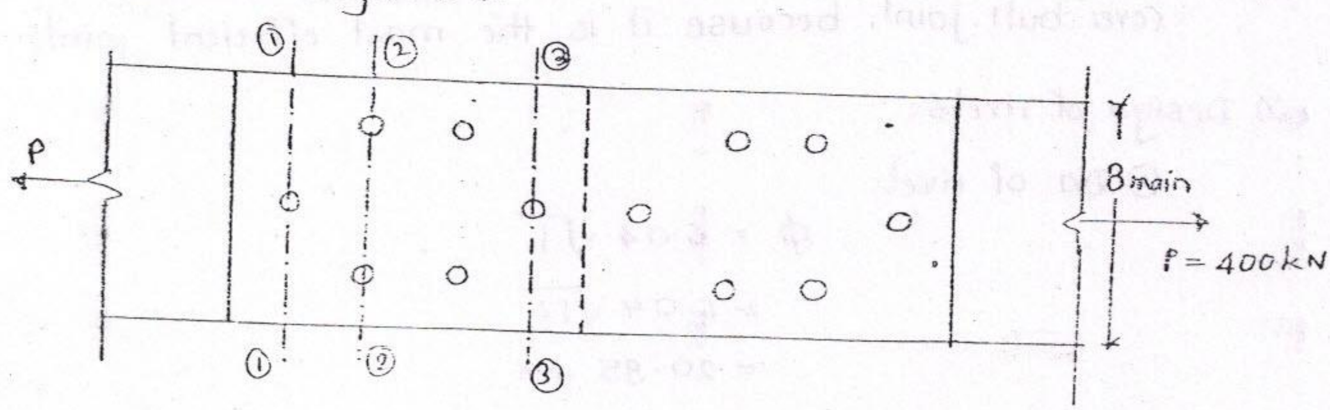
$$= \frac{400}{72.6}$$

$$= 5.5 \simeq 6 \text{ rivets.}$$

(ii) Arrangement of rivets:

(To get max value of $(P_t)_{cover}$ and $(P_t)_{main}$)

To get max. value of P_t for main plates and cover plates a variation of diamond rivetting as shown in fig. is best arrangement.



(iii) Width and thickness of plates (B_{main} . t_{main})

$$t_{main} = 12 \text{ mm (given)}$$

Critical section for main plate is at ① - ①

$$Pt @ ①-① = (B_{main} - d) \cdot t_{main} \cdot f_t = 400 \times 10^3$$

$$\therefore \quad 400 \times 10^3 = (B_{main} - 21.5) \times 12 \times 150$$

$$B_{main} = 243.7 \text{ mm}$$

$\therefore$ Provide Width of main plate $(B_{main}) = 250$ mm.

Since it is a variation of diamond rivetting. there is a possibility of failure of ② - ② also.

$$(Pt)_{2-2} = (B_{main} - 2d) \cdot t_{main} \cdot f_t + R_v$$

$$= (250 - 2 \times 21.5) \times 12 \times 150 + (72.6 \times 10^3)$$

$$= 445.3 \text{ kN} > 400 \text{ kN}$$

Hence, the rivet joint is safe at ② - ②.

(iv) Width and thickness of cover plates (B_{cover}, t_{cover})

Assume

$$B_{main} = B_{cover} = 250 \text{ mm.}$$

Critical section for cover plates is at ③ - ③

$$\therefore \quad (P_t)_{3-3} = (B_{cover} - d) \cdot t \cdot f_t = 400 \times 10^3$$

$$400 \times 10^3 = (250 - 21.5) \times t \times 150$$

$$t = 11.67 \text{ mm}$$

$\therefore$ sum of thickness of two cover plates $= t = 11.67$ mm

$\therefore$ Thickness of each cover plate $= \frac{t}{2}$

$$= \frac{11.67}{2}$$

$$= 5.88 \simeq 6 \text{mm}$$

(v) Efficiency of joint :

$$\eta = \frac{\text{least value of } P_s, P_b, P_t}{\text{strength of solid plate}} \times 100$$

Shear strength of all rivets,

$$(P_s) = n \times \frac{\pi}{4} \times d^2 \times f_s \times 2$$

$$= 6 \times \frac{\pi}{4} \times 21.5^2 \times 100 \times 2 \text{ — double shear}$$

$$= 435.6 \text{ kN}$$

Bearing strength of all rivets.

$$(P_b) = n \times (d \times t) \times f_b$$

$$= 6 \times 77.4$$

$$= 464.4 \text{ kN}$$

Tearing strength of main plate

$$(P_{t_1}) = (B-d) \cdot t_{main} \cdot f_t$$

$$= (250 - 21.5) \times 12 \times 150$$

$$= 411.3 \text{ kN}$$

Tearing strength of cover plate.

$$(P_{t_2}) = (B-d) \cdot t_{cover} \cdot f_t$$

$$= (250 - 21.5) \times 12 \times 150$$

$$= 411.3 \text{ kN}$$

Strength of solid plate.

$$B \cdot t \cdot f_t = 250 \times 12 \times 150$$

$$= 450 \text{ kN}$$

$\therefore$ Efficiency of joint, $\eta = \frac{411.3}{450} \times 100$

$$= 91.4\ \%$$

Note :

In a rivetted joint 100% efficiency cannot be achieved because of rivet plate holes.

(vi) Sketch of joint :

Minimum pitch and Minimum gauge

$= 2.5\ \phi$

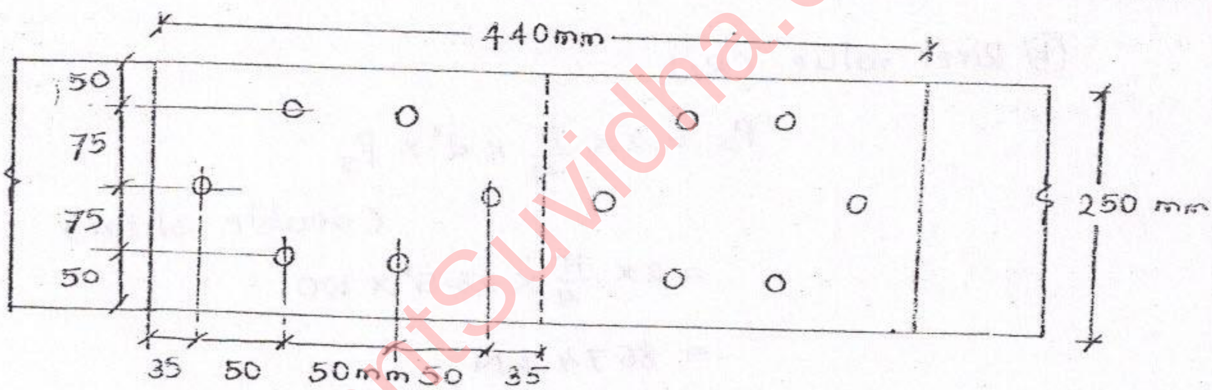
$= 2.5 \times 20$

$= 50\ mm$

Minimum end and edge distance $= 1.5\ d$

$= 1.5 \times 21.5$

$= 32.5 \simeq 35\ mm$



Maximum pitch $= 16t$ or $200\ mm$ } less

$= 16 \times 6 = 96\ mm$

Length of cover plate $= (6 \times 50) + (4 \times 35)$

$= 440\ mm$

Q. Design a riveted splice (joint) for a tie member of a steel bridge, 200 mm wide and 20 mm thick, carrying an axial tensile force of 500 kN. Use 12 mm cover plates and 22 mm dia. rivets. Take $f_t = 150$ MPa. $f_s = 100$ MPa. $f_b = 300$ MPa. Give neat sketch of arrangement of rivets.

Use double cover butt joint as it is most efficient use.

(1) Design of rivets.

(a) Dia. of rivets.

$$\phi = 22 \text{ mm}$$

$$\therefore \quad d = \phi + 1.5 \text{ mm}$$

$$= 22 + 1.5 = 23.5 \text{ mm}$$

(b) Rivet value (R_v)

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

(double shear)

$$= 2 \times \frac{\pi}{4} \times 23.5^2 \times 100$$

$$= 86.74 \text{ kN}$$

$$P_b = d \times t \times f_b$$

t = sum of cover plate thickness or main plate thickness } Minimum

$= 12 + 12 = 24$ or

$= 20$ mm

$$\therefore \quad P_b = (23.5 \times 20 \times 300)$$

$$= 141 \text{ kN}$$

$$\therefore \quad R_v = P_s = 86.74 \text{ kN}$$

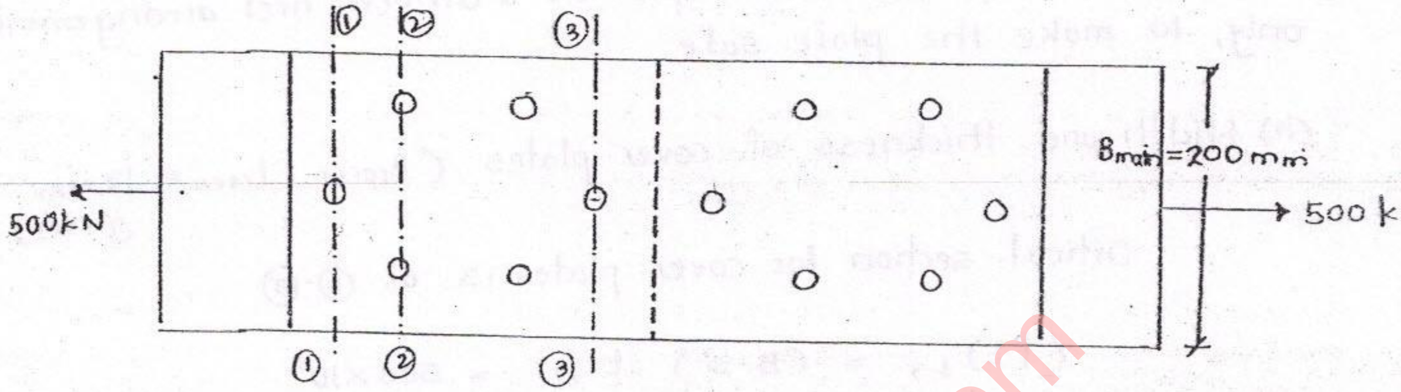
(c) Number of rivets.

$$n = \frac{F}{R_v} = \frac{500}{86.74} = 5.76$$

$\simeq 6$ rivets.

(ii) Arrangement of rivets:

To make cover plates and main plates strong the variation of diamond riveting is provided as shown in fig.



(iii) Width and thickness of main plate ($t_{main} = 20$mm, $B_{main} = 20$

critical section for main plate is at ①-①

$$(P_t)_{1-1} = (B-d) \cdot t \cdot f_t = 500 \times 10^3$$

$$500 \times 10^3 = (200 - 23.5) \times 20 \times 150$$

$$= 529.5 \text{ kN} > 500 \times 10^3 \text{ N} \quad \text{safe.}$$

Since it is variation of diamond riveting, it may fail at section ②-②

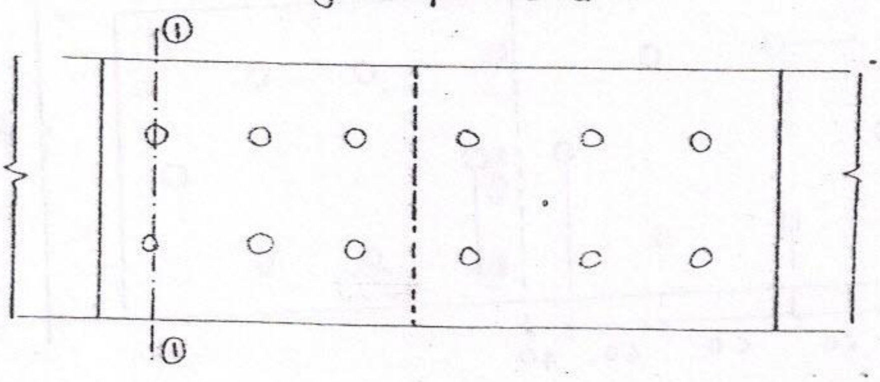
$$(P_t)_{2-2} = (B-2d) \cdot t \cdot f_t + R_v$$

$$= (200 - 2 \times 23.5) \times 20 \times 150 + 86.75 \times$$

$$= 545.75 \text{ kN} > 500 \text{ kN} \quad \text{safe.}$$

Note:

If chain riveting is provided.



$$(P_t)_{1-1} = (B-2d)\, t \cdot f_t$$
$$= (200 - 2\times 23.5)\times 20 \times 150$$
$$= 459.09 \text{ kN} < 500 \text{ kN} \quad \text{not safe.}$$

It means, we have to provide diamond rivet arrangement only, to make the plate safe.

(iv) Width and thickness of cover plates (B_{cover}, $t_{cover} = 12$ mm given)

Critical section for cover plates is at ③-③

$$(P_t)_{3-3} = (B-d)\cdot t \cdot f_t = 500\times 10^3$$
$$500\times 10^3 = (B - 23.5)\times 12 \times 150$$
$$B_{cover} = 162.3 \text{ mm} \simeq 170 \text{ mm}$$

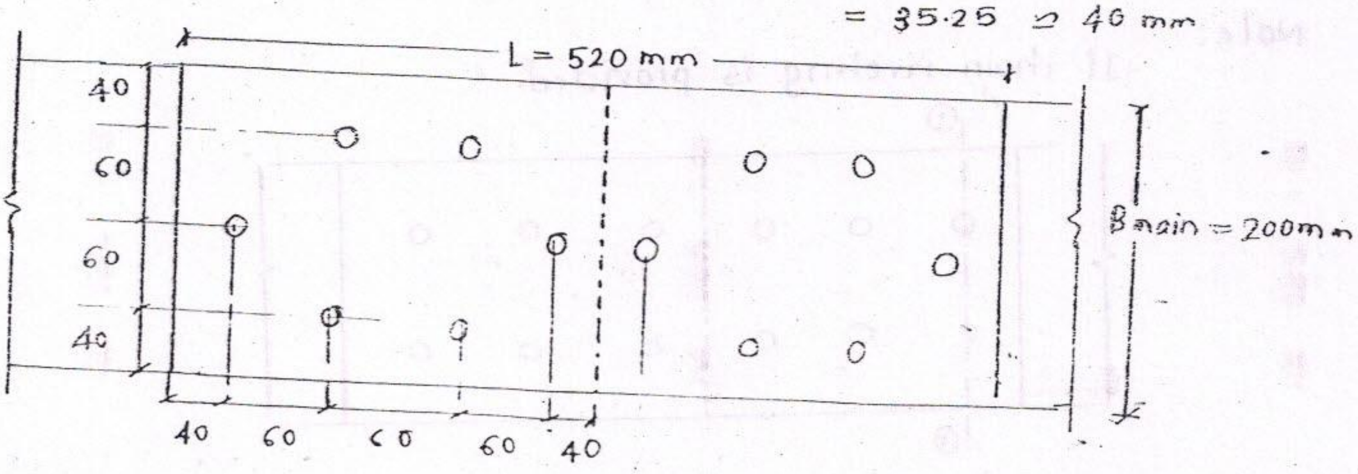
To accomodate minimum gauge distance and edge distance provide

$$B_{cover} = B_{main} = 200 \text{ mm}$$

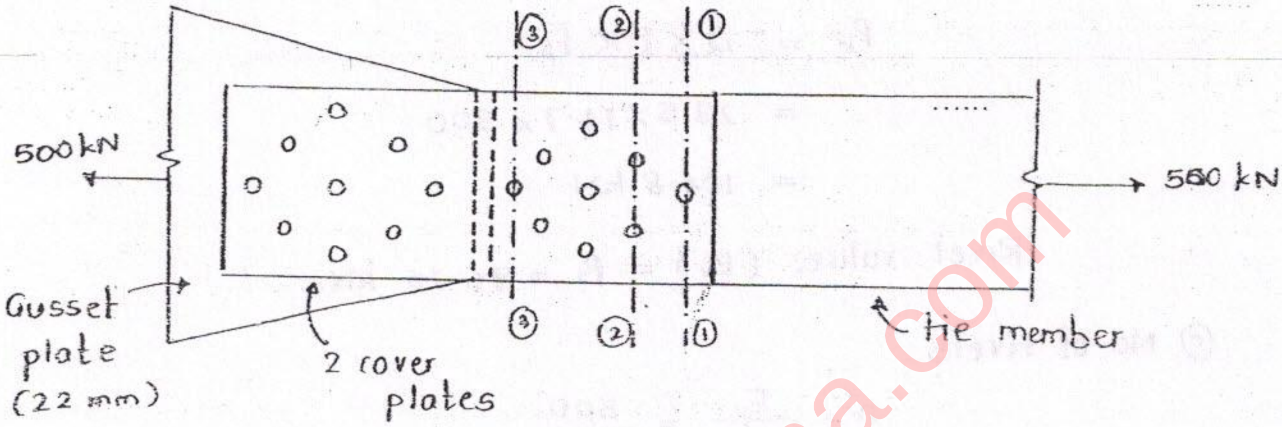
(v) Sketch of the joint :

Min. pitch & Min. gauge distance $= 2.5\cdot\phi$
$= 2.5 \times 22 =$
$= 55 \simeq 60$ mm

Min. end and edge distance $= 1.5 \cdot d$
$= 1.5 \times 23.5$
$= 35.25 \simeq 40$ mm



Q. A bridge truss diagonal carries an axial pull of 500 kN. It is connected to a gusset plate of 22 mm thick by a doble cover butt joint with 22 mm ϕ rivets. Find the thickness of tie bar. assuming its width as 250 mm. Design the joint and find the efficiency. $f_s = 100$ MPa. $f_b = 300$ MPa. $f_t = 150$ MPa.



(i) Design of rivets:

ⓐ Dia. of rivets:

$$\phi = 22 \text{ mm} \quad (\text{given})$$

$$\therefore d = \phi + 1.5 \text{m}$$

$$= 23.5 \text{ mm}$$

ⓑ Rivet value: (R_v)

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

$$= 2 \times \frac{\pi}{4} \times 23.5^2 \times 100$$

$$= 86.75 \text{ kN}$$

$$P_b = d \times t \times f_b$$

where t - sum of cover plate thicknesses or main plate thickness } Minim

So, find t_{main}:

Critical section for main plate is at ①-①

$$(P_t)_{1-1} = (B_{main} - d) \cdot t_{main} \cdot f_t = 500\times10^3$$

$$500\times10^3 = (250 - 23.5) \cdot t_{main} \times 150$$

$$t_{main} = 14.7 \text{ mm} \qquad \text{provide } 16 \text{ mm}$$

$\therefore$

$$P_b = d \times t \times f_b$$

$$= 23.5 \times 14.7 \times 300$$

$$= 104.8 \text{ kN}$$

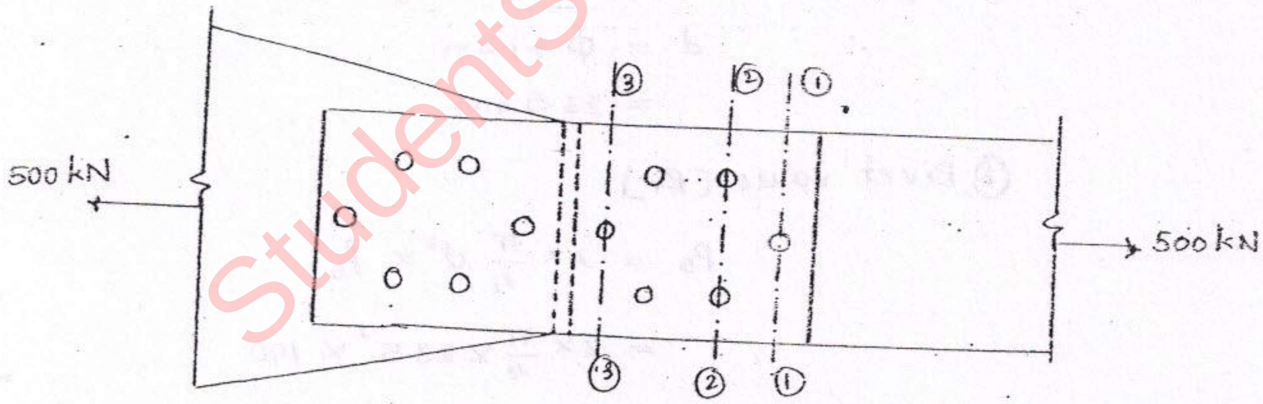
$\therefore$ Rivet value $(R_v) = P_s = 86.75$ kN

ⓒ No. of rivets:

$$n = \frac{F}{R_v} = \frac{500}{86.75}$$

$$= 5.76 \simeq 6$$

(ii) Arrangement of rivets:



(iii) Thickness and width of main plate (t_{main} & B_{main})

Since it is variation in diamond section rivetting section may fail at ②-②

$$(P_t)_{2-2} = (B - 2d) \cdot t \cdot f_t + R_v$$

$$= (250 - 2\times23.5)\times16\times250 + 86.75$$

$$= 573.9 \text{ kN} > 500 \text{ kN} \quad \text{safe.}$$

(iv) Thickness and width of cover plate:

Assume

$$B_{cover} = B_{main} = 250 \text{ mm}.$$

critical section for cover plate is at ③-③

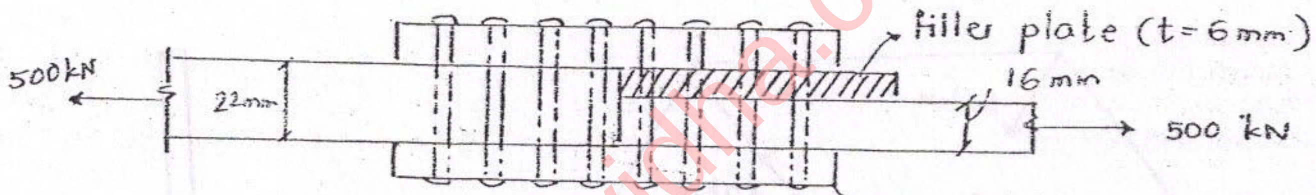
$$(P_t)_{3-3} = (B_{cover} - d) \cdot t \cdot f_t = 500 \times 10^3$$

$$500 \times 10^3 = (250 - 23.5) \times t_{cover} \times 150$$

t - sum of cover plate thicknesses

$$t = 14.72 \text{ mm}$$

∴ thickness of each cover plate is $= \frac{14.72}{2} = 7.8 \simeq 8$ m



(v) Efficiency of joint:

$$\eta = \frac{\text{least value of } P_s, P_b \text{ and } P_t}{\text{strength of solid plate.}}$$

shearing strength of all rivets, $P_s = 6 \times 86.75$
$= 520.5$ kN

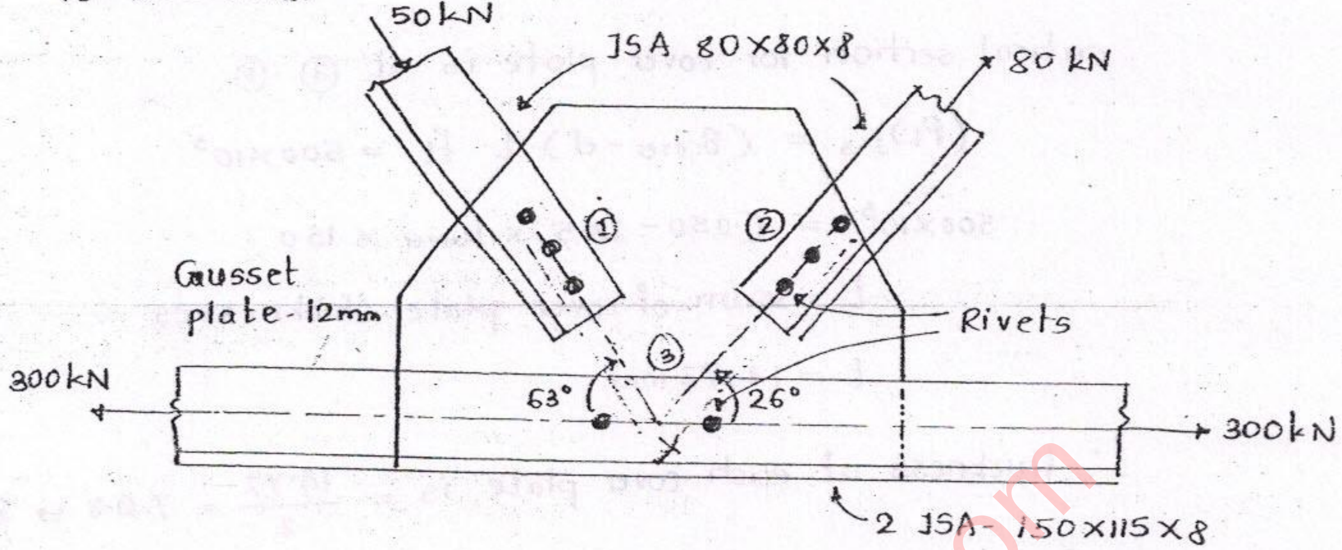
Bearing strength of all rivets. $P_b = 6 \times 112.8$
$= 676.8$ kN

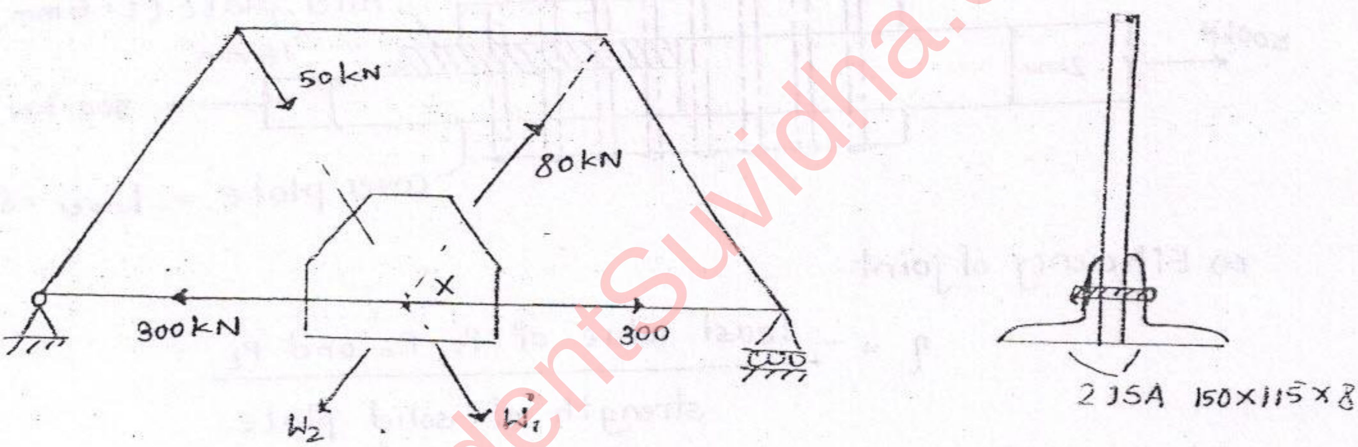
Tensile strength of the plate $P_t = (B-d) \cdot t \cdot f_t$
$= (250 - 23.5) \times 16 \times 150$
$= 542.3$ kN

Strength of solid plate. $= B \cdot t \, f_t$
$= 250 \times 16 \times 150$
$= 600$ kN

$$\eta = \frac{520.5}{600} = 86.65 \%$$

Q. Determine the number of 20 mm ϕ power driven shop rivets for the truss connection shown in fig. Take $f_s = 102.5$ MPa. $f_b = 236$ MPa.





(i) In a truss joint lines of action of all forces must meet at one point otherwise joint will not be in equilibrium. In the above case all forces are at x

(ii) Since the joint is in equilibrium under the action of external and internal forces, we should not keep the joint in equilibrium with internal forces alone.

(i) No. of rivets required at 1 and 2

$\phi = 20$ mm $\quad \therefore \quad d = 21.5$ mm

(Rivets are in single shear at 1 and 2)

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

$$= \frac{\pi}{4} \times 21.5^2 \times 102.5$$

$$= 37.2 \text{ kN}$$

$$P_b = d \times t \times f_b$$

t - lesser of 12mm (gusset) & 8mm (angle

$$P_b = 21.5 \times 8 \times 236$$

$$= 40.6 \text{ kN}$$

$\therefore$ Rivet value $= R_v = P_s = 37.2$ kN

$\therefore$ No. of rivets at 1

$$n_1 = \frac{F_1}{R_v} = \frac{50}{37.2} = 1.34 \simeq 2$$

$$n_1 = 2 \text{ rivets}$$

No. of rivets at 2

$$n_2 = \frac{F_2}{R_v} = \frac{80}{37.2} = 2.15 \simeq 3$$

$$n_2 = 3 \text{ rivets.}$$

(ii) No. of rivets required at 3

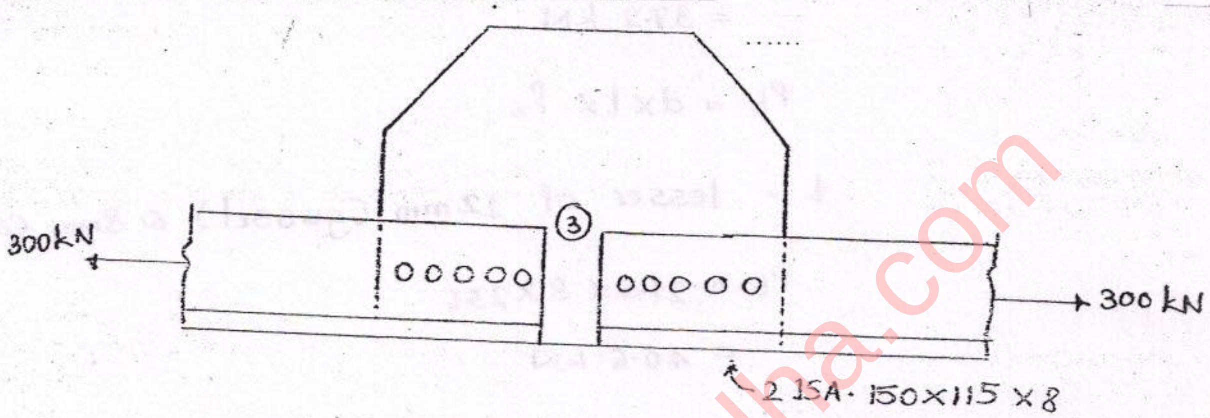
Since horizontal member is continuous member the rivets are provided for the difference of horizontal forces.

In this case the difference of horizontal forces is zero (300 - 300 = 0). So we don't have to provide rivet at 3, but to prevent seperation of angle from gusset plate, Tack rivets are provided.

Provide 2 tacks on both sides of intersection as shown in fig.

Note:

If at all, the horizontal members are discontinuous members, rivets are provided for each member for a force of 300 kN.



Rivets are in double shear at 3

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

$$= 2 \times \frac{\pi}{4} \times 21.5^2 \times 102.5$$

$$= 74.39 \text{ kN}$$

$$P_b = d \times t \times f_b = 21.5 \times 12 \times 2360 = 60.89 \text{ kN}$$

t – sum of angle thicknesses $= 8 + 8 = 16$ mm

sum because bearing forces are acting in same direction on two angles

– Gusset thickness $= 12$ mm

$$R_v = P_b = 60.89 \text{ kN}$$

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

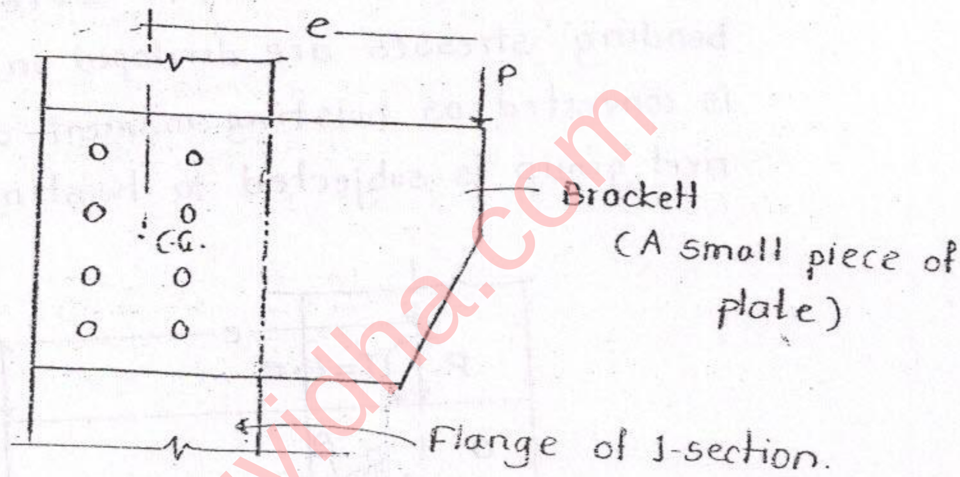
$$= \frac{300}{60.89} = 4.9 \simeq 5 \text{ rivets.}$$

Eccentric riveted connections:-

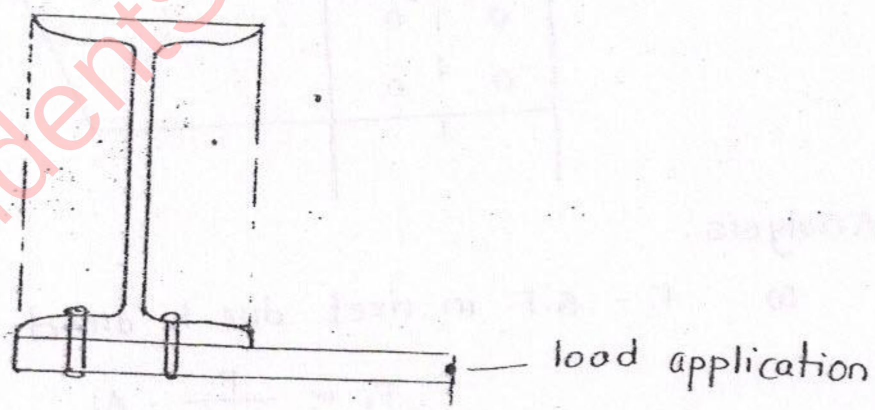
(i) When the C.G. of rivet group does not lie on line of action of load, then connection is called eccentric connection.

(ii) Plane eccentric connection:

i.e. rivet group and load lie in a same plane.

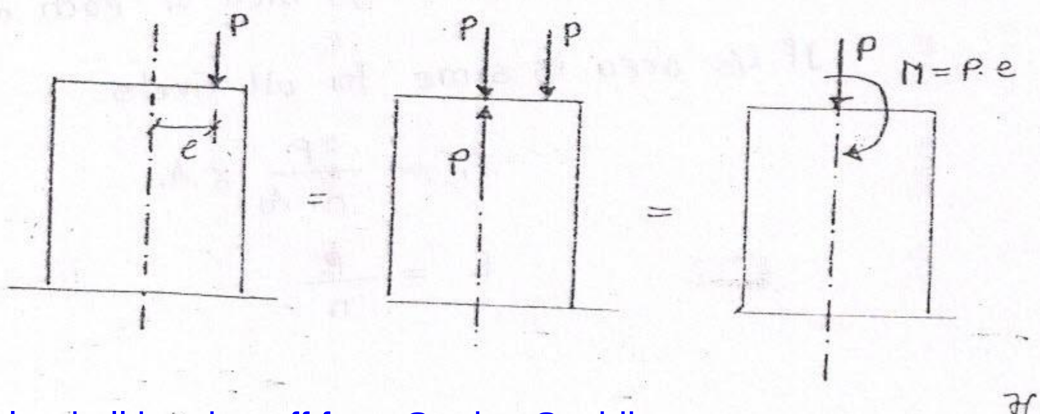


Front view.



Top view.

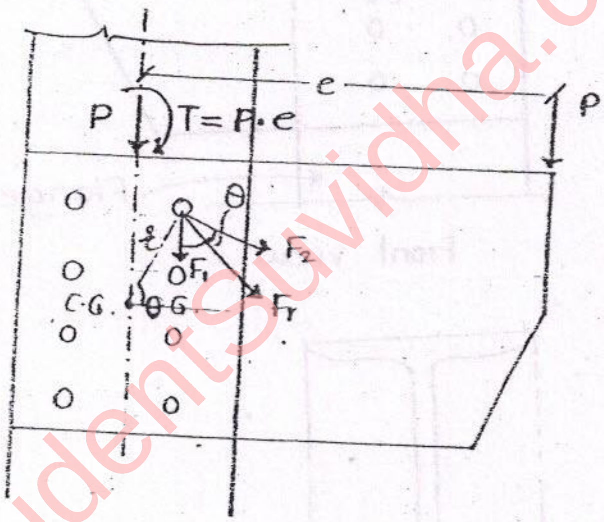
Note:



(i) The effect of eccentric load at the C.G. of rivet group will be direct load of P and twisting moment of $T = P \cdot e$.

(ii) Due to direct load P, direct shear stress is developed in rivets while due to Torsional moment, torsional shear stress is developed in rivets.

(iii) Due to the eccentric load, P. brackett will bend. so bending stresses are developed in brackett. This B.M. is converted as twisting moment at rivet connection. So. rivet group is subjected to twisting moment.



Analysis:

(i) F_1 - S.F. in rivet due to direct load P

$$F_1 = \frac{P}{\Sigma A_i} \cdot A_i$$

where

A_i - c/s area of each rivet.

If c/s area is same for all rivets.

$$F_1 = \frac{P}{n \cdot A_i} \times A_i$$

$$F_1 = \frac{P}{n} \qquad \text{------ (i)}$$

(ii) F_2 - S.F. in the rivet due to twisting moment T.

$$F_2 = \frac{P \cdot e}{\Sigma r_i^2} \cdot r_i$$

where,

r_i - radial distance of each rivet from C.G. of rivet group.

Proof :

From torsion formula (applicable to circular qs)

$$\frac{T}{J} = \frac{f_s}{r} = \frac{C \cdot \theta}{l}$$

$$f_s = \frac{T}{J} \times r$$

f_s - torsional shear stress.

J - polar moment of inertia.

$= I_{zz} = A \cdot r^2 = \Sigma A_i r_i^2$

$T = P \cdot e$.

substituting,

$$f_s = \frac{P \cdot e}{\Sigma A_i \cdot r_i^2} \times r_i$$

S.F. in the rivet,

$$F_2 = f_s \times A_i$$

$$= \frac{P \cdot e}{\Sigma A_i \cdot r_i^2} \times A_i \cdot r_i$$

$$\therefore \quad F_2 = \frac{P \cdot e}{\Sigma r_i^2} \cdot r_i$$

(iii) Resultant shear force in the rivet (F_R)

$$F_R = \sqrt{F_1^2 + F_2^2 + 2 F_1 \cdot F_2 \cdot \cos\theta}$$

(iv) For rivet to be safe,

$$F_R \not> R_v.$$

Note:

(i) The direction of F_2 is perpendicular to the line joining C.G. of rivet group and centre of rivet under consideration.

Whatever moment P. produces about the C.G. of rivet group, F_2 also must produce same moment about C.G. of rivet group.

(ii) Components of force:

ⓐ Rectangular components - angle between the components is 90°.

ⓑ Oblique components - angle between the components is not 90°.

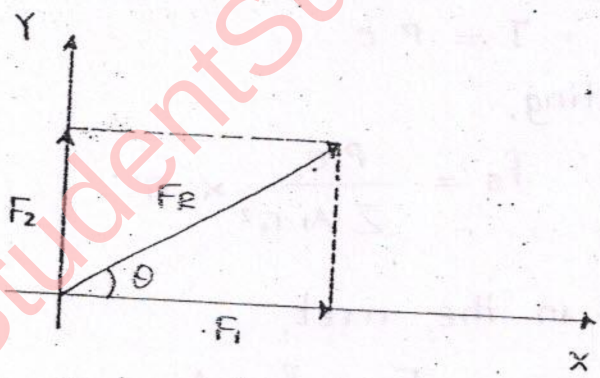
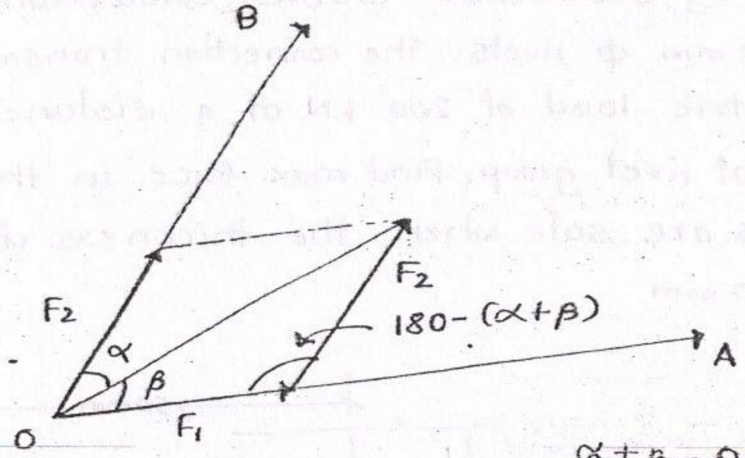


Fig. Rectangular components.

$$F_R = \sqrt{F_1^2 + F_2^2}$$

$$F_1 = F_X = F_R \cdot \cos\theta$$

$$F_2 = F_Y = F_R \cdot \sin\theta$$



$\alpha + \beta = \theta$

Using cos rule.

$$F_R^2 = F_1^2 + F_2^2 - 2 F_1 \cdot F_2 \cdot \cos(180-\theta)$$

$$F_R = \sqrt{F_1^2 + F_2^2 + 2 F_1 \cdot F_2 \cos\theta}$$

(iii) $\because \quad F_1 = \frac{P}{n}$

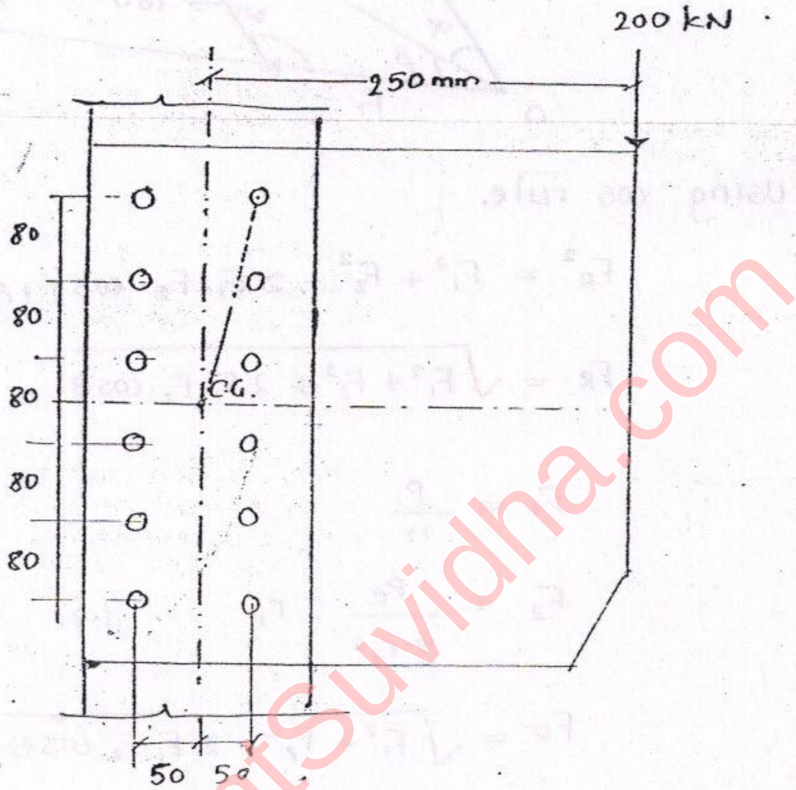
$\because \quad F_2 = \frac{Pe}{\Sigma r_i^2} \cdot r_i$ i.e. $F_2 \propto r_i$

$$F_R = \sqrt{F_1^2 + F_2^2 + 2 F_1 \cdot F_2 \cos\theta}$$

If the rivets are of same diameter then most critically stressed rivet is the one which for which r is max and θ is minimum. (between F_1 & F_2)

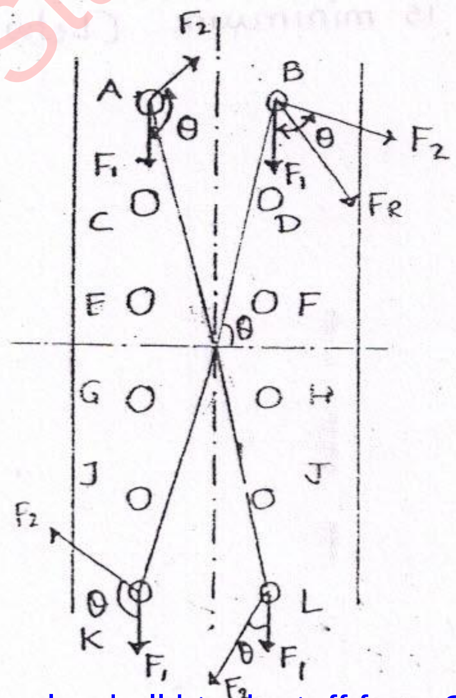
Friday
11^{th} October 2013

Q. The fig shows steel brackett connection using 12-22 mm ϕ rivets. The connection transmits an eccentric load of 200 kN at a distance of 250 mm from C.G. of rivet group. Find max. force in the rivet Check whether rivets are safe when the thickness of plate connecting rivets is 20 mm



Note:

The most critically stressed rivet is the one for which r is max. and θ is min.



In the above problem the most critically stressed rivets are B and L. (Because for these two rivets 'r' is max. and θ is min.) The rivets A and K are also at max. distance but θ is not min. for the rivets A and K. So the rivets A and K are not stressed more.

(i) S.F. in rivet B due to direct load 'P'

$$F_1 = \frac{P}{n} = \frac{200\times10^3}{12} = 16.66\ kN$$

(ii) S.F. in rivet B due to twisting moment $(T = P.e)$

$$F_2 = \frac{P.e}{\Sigma r_i^2} \cdot r_B$$

where, r_B - radial distance of B from C.G. of rivet group.

$$= \sqrt{(80+80+40)^2 + 50^2}$$

$$r_K = r_A = r_L = r_B = 206.15\ mm$$

$$\therefore r_C = r_D = r_I = r_J = \sqrt{(80+40)^2 + 50^2}$$

$$= 130\ mm$$

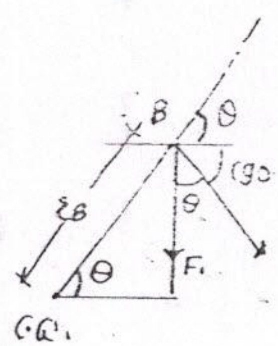
$$r_E = r_F = r_G = r_H = \sqrt{40^2 + 50^2}$$

$$= 64.03\ mm$$

$$\therefore F_2 = \frac{200\times10^3\times250}{4r_B^2 + 4r_C^2 + 4r_E^2} \times 206.15$$

$$= 47.45\ kN$$

(iii) Resultant force,



$$F_R = \sqrt{F_1^2 + F_2^2 + 2F_1 F_2 \cdot \cos\theta}$$

$$\tan\theta = \frac{200}{50}$$

$$\theta = 75.96^\circ$$

$\therefore \quad F_R = \sqrt{(16.67)^2 + (40.58)^2 + 2 \times 16.67 \times 40.58 \times \cos 75.96^\circ}$

$= 47.45$ kN

(iv) For rivet B to be safe. $F_R \ngtr R_v$

R_v :

Rivets are subjected to single shear.

$\phi = 22$ mm $\quad \therefore d = 23.5$ mm

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

$= \frac{\pi}{4} \times 23.5^2 \times 100$ ← Assume

$= 43.37$ kN

$\therefore \quad P_b = (d \times t) \times f_b$

$= (23.5 \times 20) \times 300$ ← Assume

$= 141$ kN

$\therefore \quad R_v = P_s = 43.37$ kN

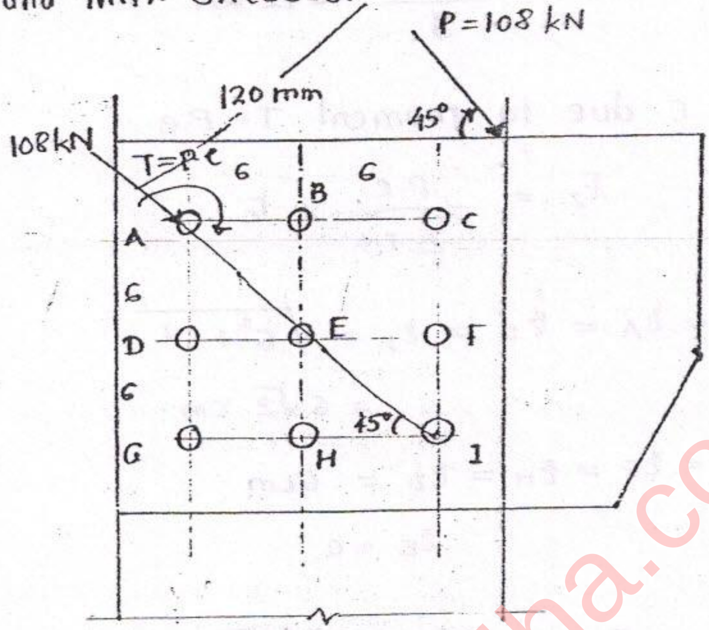
$\because \quad F_R > R_v \quad$ Rivets B and L are unsafe.

Note:

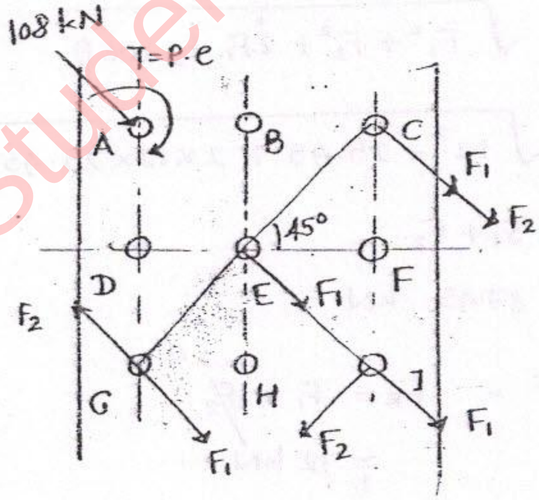
To make the rivets safe increase the diameter of rivet so that P_s of rivet will increase.

Q. A group of 9 - 24 mm ϕ rivets shown in fig. is subjected to load of 108 kN acting in a direction parallel to AK at a distance of 12 cm from AK. Find which rivets are subjected to max. and min. stresses.

20 Marks



The effect of inclined eccentric load at C.G. of rivet group will be an inclined load P and twisting moment T as shown in fig.



From the diagram we find that the most critically stressed rivet is C and minimum stressed rivet is E or G depending on relative magnitudes of F_1 and F_2

(i) S.F. in rivet C due to direct load. P

$$F_1 = \frac{P}{n}$$

$$= \frac{108}{9} = 12 \text{ kN}$$

(ii) S.F. in rivet C due to moment $T = P \cdot e$

$$F_2 = \frac{P \cdot e}{\Sigma r_i^2} \times r_c$$

$$r_c = r_A = r_G = r_J = \sqrt{6^2 + 6^2}$$

$$= 6\sqrt{2} \text{ cm}$$

$$r_B = r_F = r_H = r_D = 6\text{cm}$$

$$r_E = 0$$

$$\therefore \quad F_2 = \frac{108 \times 12 \times 6\sqrt{2}}{(4 r_c^2 + 4 r_B^2 + r_E^2)}$$

$$= 25.45 \text{ kN}$$

(iii) Resultant shear force. (F_R)

$$F_R = \sqrt{F_1^2 + F_2^2 + 2F_1 \cdot F_2 \cdot \cos\theta}$$

$$= \sqrt{12^2 + 25.45^2 + 2 \times 12 \times 25.45 \times \cos 0^\circ} \qquad \theta = 0^\circ$$

$$= F_1 + F_2$$

$$= 37.45 \text{ kN}$$

Resultant force in E = $F_R = F_1 + \cancel{F_2}^{\,0}$

$$= 12 \text{ kN}$$

Resultant force in G = $F_R = F_1 - F_2$

$$= 12 - 25.45$$

$$= 13.45 \text{ kN}$$

So minimum force is in rivet E = 12 kN

Max. stress in rivet C $= \frac{P}{A}$

$$= \frac{37.45 \times 10^3}{\frac{\pi}{4} \times (25.5)^2}$$

$= 73.37$ N/mm²

Max. stress in rivet E $= \frac{P}{A}$

$\because d = \phi + 1.5$
$= 24 + 1.5$
$= 25.5$ mm

$$= \frac{12 \times 10^3}{\frac{\pi}{4} \times (25.5)^2}$$

$= 23.5$ N/mm²

Q. A double cover butt joint is provided with the following details.

Size of plates to be spliced = 320 × 14 mm

Size of cover plates = 320 × 8 mm

30 Marks

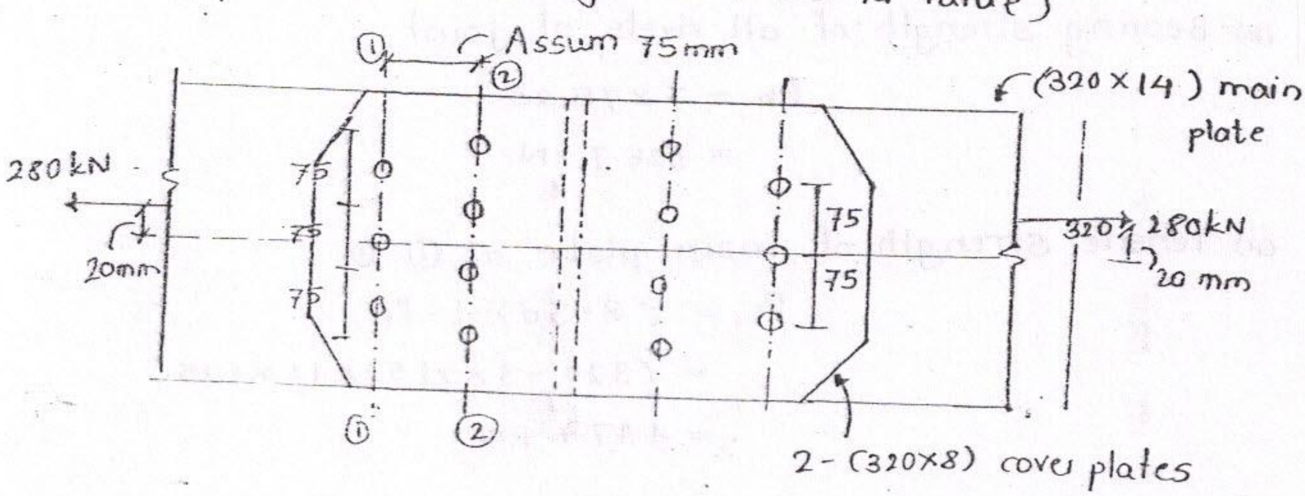
No. of 20mm ϕ rivets = 7

$f_t = 125$ MPa $\quad f_s = 80$ MPa $\quad f_b = 250$ MPa.

(i) Determine the strength of connection.

(ii) Find the force in the extreme rivet, when the connectic is subjected to a pull of 280 kN with $e = 20$ mm.

(iii) Find the limiting value of 'e' if the force in any rivet is not to exceed its strength (i.e. its R_v value)



(1) Strength of connection:

(Assuming applied load is axial)

It is taken as minimum value of P_s, P_b and P_t of main plate and cover plates.

(i) Rivet value (R_v)

The rivets are in double shear in double cover butt joint.

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

$$= 2 \times \frac{\pi}{4} \times 21.5^2 \times 80$$

$$= 58.08 \text{ kN.}$$

$$P_b = d \times t \times f_b.$$

$$= 21.5 \times 14 \times 250 \qquad t = 8+8 = 16\text{ mm}$$

$$= 75.25 \text{ kN} \qquad = 14 \text{ mm} \text{ } \Big\} \text{Min.}$$

∴ Rivet value (R_v) = P_s = 58.08 kN. i.e. strength of single rivet.

(ii) Shear strength of all rivets at joint

$$P_s = n \times \frac{\pi}{4} \times d^2 \times f_s$$

$$= 7 \times \frac{\pi}{4} \times 21.5^2 \times 80$$

$$= 406.56 \text{ kN}$$

(iii) Bearing strength of all rivets at joint

$$P_b = 7 \times 75.25$$

$$= 526.7 \text{ kN}$$

(iv) Tensile strength of main plate at ①-①

$$P_{t_1} = (B - 3d) \cdot t \cdot f_t$$

$$= (320 - 3 \times 21.5) \times 14 \times 125$$

$$= 447.1 \text{ kN}$$

(v) Tensile strength of cover plate at ② - ②.

$$F_{t_2} = (B - 4d) \cdot t \cdot f_t$$

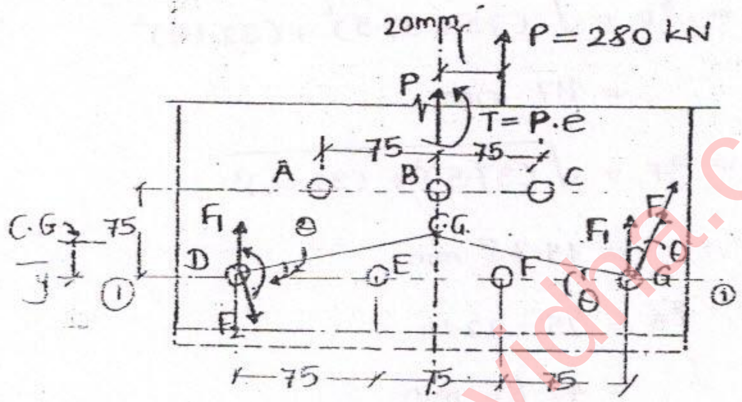
$$= (320 - 4 \times 21.5) \times (8+8) \times 125$$

$$= 468 \text{ kN}.$$

∴ Strength of the connection is = 406.56 kN.

(II) Force in extreme rivet:

P = 280 kN. e = 20 mm



Note:

(i) If the rivet group is symmetrical about both X & Y axe then C.G. lies on point of intersection of axes.

(ii) If the rivet group is symmetrical about only one axis then C.G. lies on that axis. (In this case, rivet group is symmetrical about Y-axis. Thus C.G. lies on Y-axis.)

(iii) To locate C.G. To take axis of reference ①-① as shown in fig.

(iv) From varignon's theorem

Moment of total area = Moment summation of components areas.

$$\bar{y} = \frac{\Sigma ay}{\Sigma a} \qquad \text{a-area of each rivet.}$$

$$= \frac{4a \times 0 + (3a) \times 75}{7a} = 32.14 \text{ mm}$$

(from ①-①)

The most critically stressed rivet is G (because r is max. and θ is minimum)

(i) S.F. in rivet G due to direct load.

$$F_1 = \frac{P}{n} = \frac{280}{7} = 40\ kN$$

(ii) S.F. in rivet G due to moment (T = P.e)

$$F_2 = \frac{P.e}{\Sigma r_i^2} \cdot r_G$$

$$r_D = r_D = \sqrt{(75+37.5)^2 + (32.14)^2}$$

$$= 117\ mm$$

$$r_E = r_F = \sqrt{(37.5)^2 + (32.14)^2}$$

$$= 49.38\ mm$$

$$r_B = 75 - 32.14$$

$$= 42.86\ mm$$

$$r_A = r_C = \sqrt{(75)^2 + (42.86)^2}$$

$$= 86.8\ mm$$

$$\therefore F_2 = \frac{280 \times 20 \times 117}{(2 \times 117^2) + 2 \times 49.38 + 42.86^2 \times 2\,(86.8)^2}$$

$$= 49014 \cdot 13.36\ kN$$

(iii) Resultant S.F.

$$F_R = \sqrt{F_1^2 + F_2^2 + 2F_1 \cdot F_2 \cdot \cos\theta}$$

$$\tan\theta = \frac{32.14}{(75+37.5)}$$

$$\theta = 15.94^\circ$$

$$\therefore F_R = \sqrt{40^2 + 13.36^2 + 2 \times 40 \times 13.36 \times \cos 15.94^\circ}$$

$$= 52.97\ kN$$

Force in extreme rivet is 52.97 kN

III) Limiting value of 'e' so that $F_R = R_v$.

$\therefore \quad R_v = 58.08 \text{ kN}$

$\therefore \quad F_1 = \frac{P}{n} = 40 \text{ kN}$

$$F_2 = \frac{P \cdot e_{max}}{\Sigma r_i^2} \times r_6$$

$$= \frac{280 \times e_{max}}{49014.76} \times 117$$

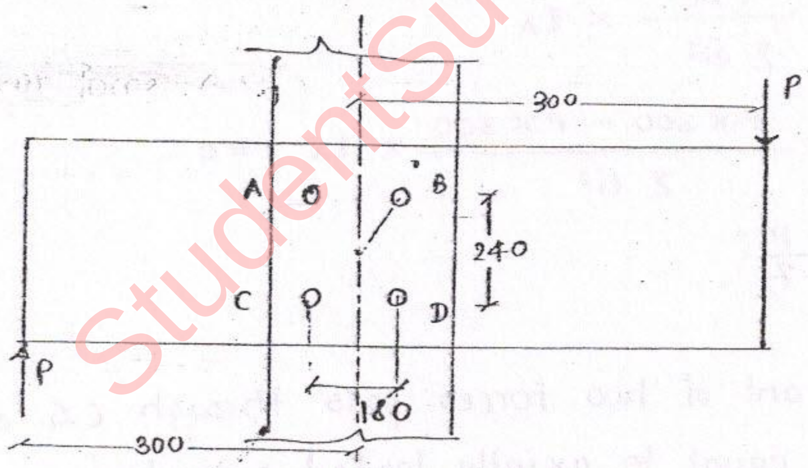
$$= 0.66 \, e_{max}$$

$\therefore \quad F_R = \sqrt{40^2 + (0.66 \, e_{max})^2 + 2 \times 40 \times 0.66 \, e_{max} \times \cos 15}$

$F_R = R_v = 58.08 \text{ kN}$

$\therefore \quad e_{max} = 27.78 \text{ mm}$

Q. Find force in extreme rivet.



$\therefore$ (i) $F_1 = \frac{P}{n} = \frac{P-P}{4} = 0$

(ii) $F_2 = \frac{P.e}{\Sigma r_i^2} \times r_A$ (all rivets are equally stressed) when $F_1 = 0$

$r_A = r_B = r_C = r_D = \sqrt{120^2 + 90^2} = 150 \text{ mm}$

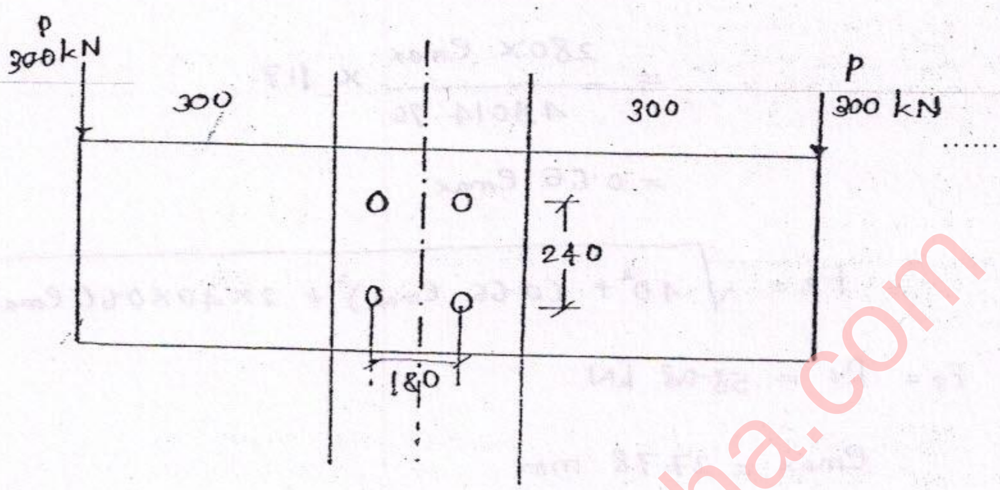
$$F_2 = \frac{2 \times (P \times 300)}{4 (150)^2} \times 150 = P$$

$$F_R = \sqrt{F_1^2 + F_2^2 + 2F_1 \cdot F_2 \cdot \cos\theta}$$

$$= F_2$$

$$= P.$$

Q. Find force in extreme fibre : rivet :



$$F_1 = \frac{\text{net force}}{n} = \frac{P+P}{4} = \frac{P}{2}$$

$$F_2 = \frac{P * e}{\Sigma r_i^2} \times r_A$$

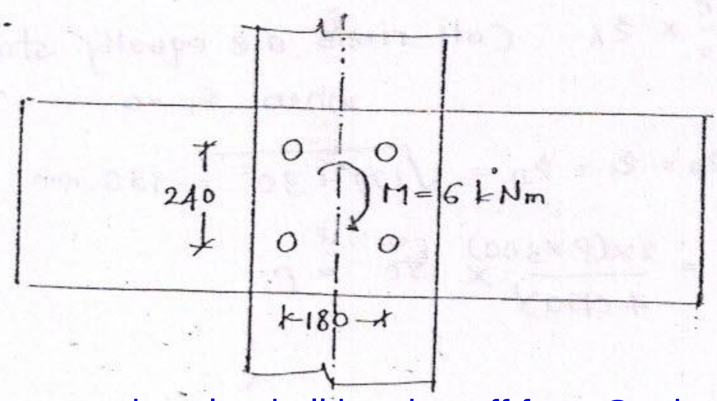
$$= \frac{P \times 300 - P \times 300}{\Sigma r_i^2} \times r_A = 0$$

$$\therefore F_R = \frac{P}{2}$$

Note:

Since resultant of two forces pass through C.G. of rivet group, it is equal to axially loaded connection.

Q. Find force in extreme rivet :



$$F_1 = 0$$

$$F_2 = \frac{P \cdot e}{\Sigma r_i^2} \times r_A$$

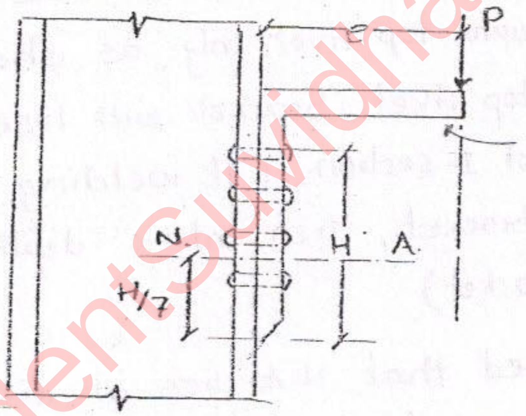
$$= \frac{6 \times 10^6 \times 150}{4 \times (150)^2}$$

$$= 10 \text{ kN}$$

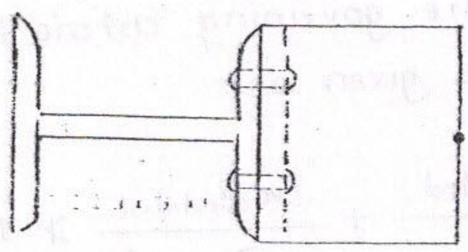
$$\therefore \quad F_R = 10 \text{ kN}$$

Out of plane eccentric riveted connections :

(i) Rivet group and load are not in a same plane.



Front view



Top view

(i) Due to eccentric load P. bracket will bend and the bending stresses are developed in the bracket.

(iii) The effect eccentric load, at C.G. of rivet group will be a direct load P and bending moment M (= P.e)

(iv) Due to direct load P, all the rivets are subjected to shearing and bearing. Due to B.M., the rivets above N.A. are subjected to tension but rivets below N.A. are useless in resisting compression.

Compressive stresses are resisted by two plates by pressing against each other. So it means that the rivets above N.A. are subjected to tension, shearing, bearing. Rivets below N.A. are subjected to shearing & bearing only.

(v) The depth of the brackett is measured from bottom of brackett upto top rivet only as shown in fig. Because above the top rivet, bracket will lose its contact, with the flange of I-section. (If welding is done at the top of the bracket, then entire depth is taken as the depth of bracket)

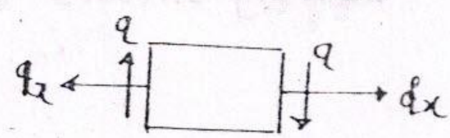
(vi) It is assumed that N.A. lies at distance of H/7 from bottom of bracket.

(vii) Since the rivets above N.A. are subjected to tension and shearing, the governing criteria to prevent the failure of rivet is given as.

$$\frac{\sigma_{at\ calculated}}{\sigma_{at}} + \frac{\tau_{va\ calculated}}{\tau_{va}} \ngtr 1.4 \qquad \text{(IS 800:1984)}$$

– (from complex stress concept)

$$\sigma_1 = \frac{f_x}{2} + \sqrt{\left(\frac{f_x}{2}\right)^2 + q^2}$$



or

$$\left(\frac{P_{T\,calculated}}{P_T}\right)^2 + \left(\frac{P_{S\,calculated}}{P_S}\right)^2 \leq 1.0$$

(in L.S.

where,

$\sigma_{at,\,calculated}$ = calculated axial tensile stress in rivet

σ_{at} = permissible tensile stress in rivet

$\tau_{va,\,calculated}$ = calculated shear stress in rivet.

τ_{va} = permissible shear stress in rivet

P_t calculated = calculated factored tensile force in rivet

P_T = tension carrying capacity of rivet.

P_S calculated = calculated factored shear force.

P_S = shear capacity of rivet.

Interaction equation between P_S and P_T:

(i) Working stress method:

$$\frac{\sigma_{at}\ calculated}{\sigma_{at}} + \frac{\tau_{va}\ calculated}{\tau_{va}} \ngtr 1.4$$

cancelling the areas, we get.

$$\frac{P_{T.}\ calculated}{P_T} + \frac{P_{S\,calculated}}{P_S} \ngtr 1.4.$$

$$\frac{P_{T\,calculated}}{P_T} \ngtr 1 \quad \& \quad \frac{P_{S}\ calculated}{P_S} \ngtr 1$$

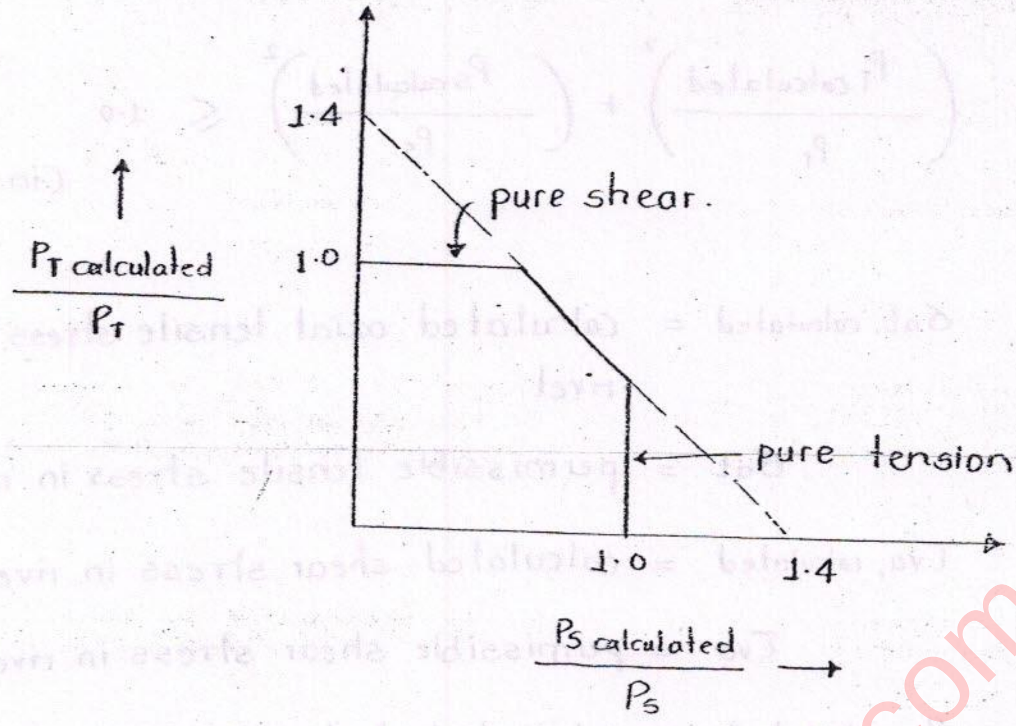
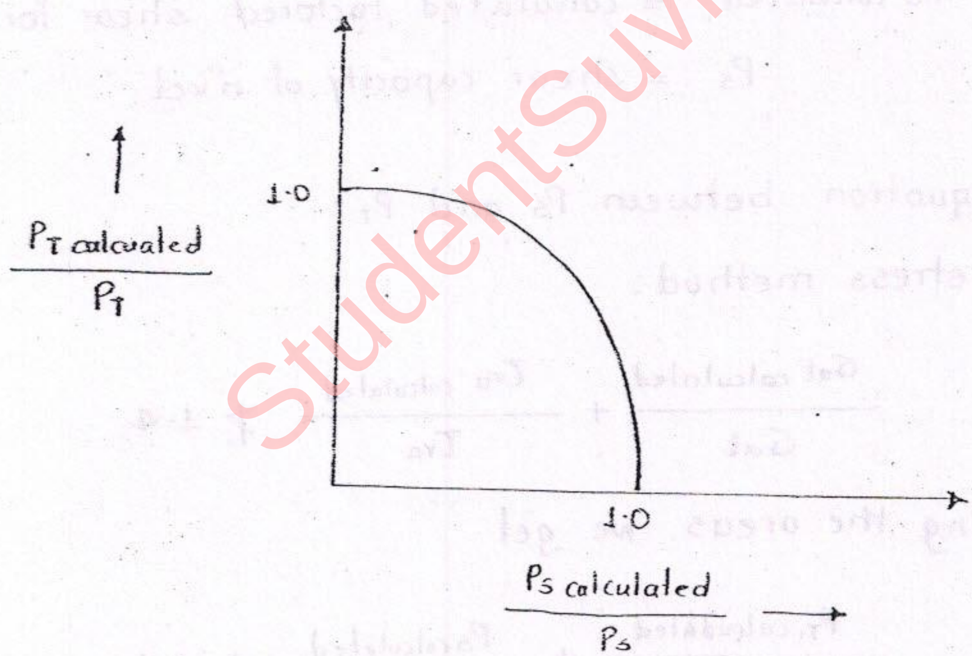


Fig. Interaction curve in WSM.

(ii) In Limit state method:

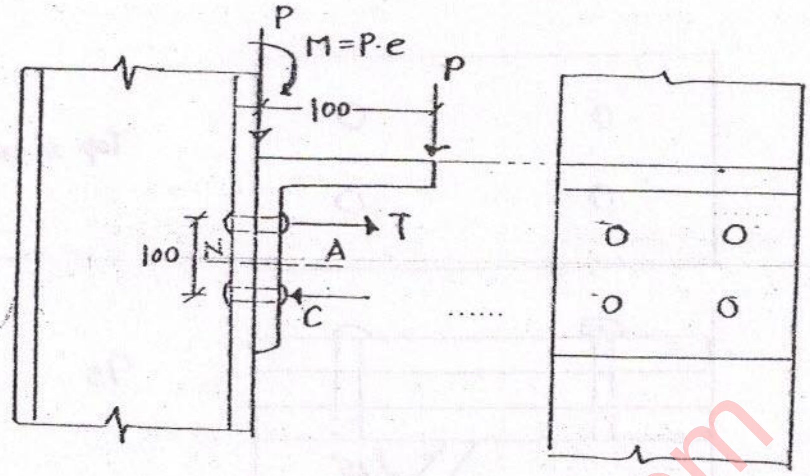


$$\left(\frac{P_S \text{ calculated}}{P_S}\right)^2 + \left(\frac{P_T \text{ calculated}}{P_T}\right)^2 \leq 1.0$$

— (In L.S.M.)

Q. Each bolt shown in fig. is capable of resisting a S.F. of 20 kN and tension of 15 kN. The interaction equation between two forces is —

1 Marks



Interaction equation is,

$$\frac{P_{T\,cal}}{P_T} + \frac{P_{s\,cal}}{P_s} \not> 1.4$$

$P_{s\,cal}$ - calculated S.F. in top rivet $= \frac{P}{4}$ ← No. of rivets.

$P_s = 20$ kN

$P_T = 15$ kN

$P_{T\,cal}$ - Calculated tensile force in rivet

$\therefore \quad P \times 100 = T \times 100 = C \times 100$

$T = P$

The tensile force T is shared by top 2 rivets

$\therefore$ tensile force in each top rivet $= P_{T\,calculated}$

$= \frac{T}{2} = \frac{P}{2}$

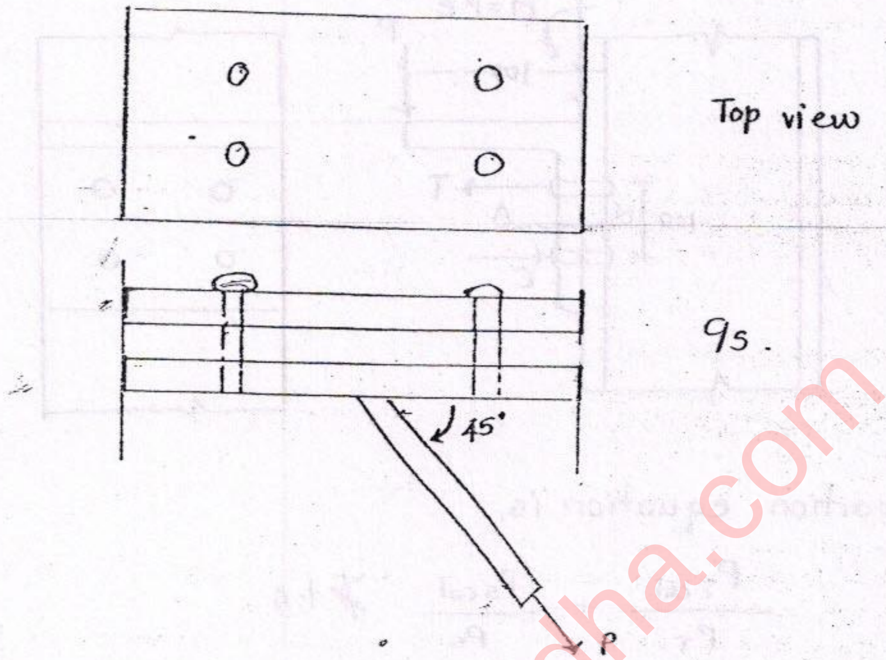
$$\therefore \quad \frac{P/2}{15} + \frac{P/4}{20} \not> 1.4.$$

$$\therefore \quad \frac{P}{30} + \frac{P}{80} \not> 1.4.$$

Note:

It is assumed that the compressive stress is resisted by the bracket and the resultant compressive force is acting at bottom line of rivet.

Q. Four bolts share load P, as shown in fig. The shear strength of bolt is 30 kN and tensile strength of bolt is 40kN. What is the value of P_



$$P_S \text{ calculated} = \frac{P\cos 45}{n} = \frac{P/\sqrt{2}}{4} = \frac{P}{4\sqrt{2}}$$

$$P_T \text{ calculated} = \frac{P\cdot\sin 45}{n} = \frac{P}{4\sqrt{2}}$$

$$P_S = 30\ kN \qquad P_T = 40\ kN$$

$$\frac{P/4\sqrt{2}}{30} + \frac{P/4\sqrt{2}}{40} = 1.4$$

$$P = 135.76\ kN.$$

Note:

Due to X and Y components of the force P. The bolts are subjected to shearing and tension. So interaction equation is used to find the value of P.