Tension Members

A member of the structure subjected to axial pull is called tension member. And the tension member as in inclined position in a frame is called Tie. ⇒ They are used in Trusses, bracing for buildings and bridges cables etc.

Important Section for tension member –

i) Eye-bar
ii) Flat
iii) Angle Section
iv) Channel section
v) T-Section
vi) Built up Section.

Designing the tension member is simplex as compared to the compression members. be cause ~~Types of Tension members~~ buckling does not occur in tension members.

Types of Tension members :

The types of structure and method of end connections determine the types of tension members. Tension members used may be broadly grouped into four groups/types..

① Wires and Cables
② Rods and bars ~~shapes~~.
③ Single structural shapes and plates.
④ Built up members

Wires and Cables :– The wire types are used for hoisting purposes, derricks, guy wires and hangers etc and cables are used for suspension bridges.

Rods And Bars :- The square and round bars are shown in fig and often used for small tension members. The round bars with threaded ends are used with pin connections at the ends, instead of threads. The eye bar are also used with the pin connections

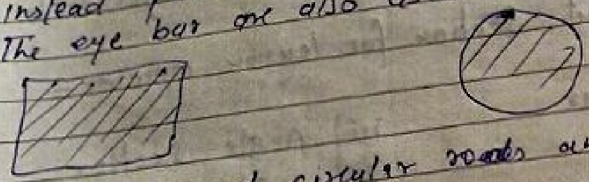


fig- Square and circular rods and bars.

Single structural shapes and plates :-
The single structural shapes i.e. angle sections or tee section as shown in fig are quite often used as tension members. The angle sections are considerably more rigid than the wire ropes, bars and rods. When the length of the tension member is too long, then the single angle section also becomes flexible.

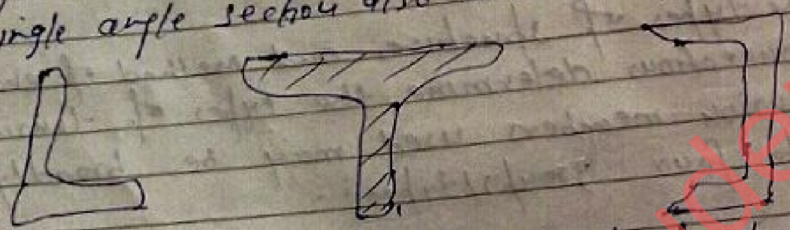


fig- Single structural shape for tension members

Built up Sections :-
Two or more than two members form built up sections. When the single rolled steel sections can not furnish the required area then the built up sections are used.

Net Sectional Area :-

Strength of a tension member is depend upon Net area available.

Strength of a tension member is equal to

Net area × force in tension or compression

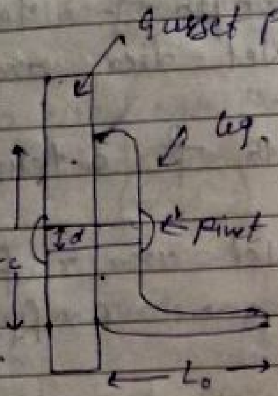
$= A \times f_t$

$[f_t = 150\ N/mm^2$, if not given$]$

A tension member is designed for its net sectional area at the joint. When the tension member is joined or spliced to a gusset plate by rivets or bolts, the gross sectional area is reduced by rivet holes.

Case-I

To determine Net area for a single angle section with longer length connected to the gusset plate -



where

L_c = Length of connected leg.
L_o = length of outstanding leg.
A_1 = Area of connected leg
A_2 = Area of outstanding leg.
d = dia of rivet hole.
t = thickness of angle plate.

$$A_1 = (L_c - t/2 - d) \times t \quad mm^2$$

$$A_2 = (L_o - t/2) \times t \quad mm^2$$

$$k = \frac{3A_1}{3A_1 + A_2}$$

Net area = $A_1 + A_2 \cdot k$

So, strength of tension member = Net area × tensile stress.

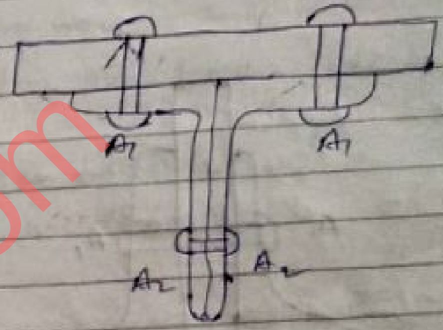
Note:- For Fillet weld

$$A_1 = (L_c - t/2) \times t$$

$$A_2 = (L_o - t/2) \times t$$

Case-II

To determine the Net area for a double angle section with longer legs connected to the same side of the gusset plate.



where -

$$A_1 = 2(L_c - t/2 - d) \times t$$

$$A_2 = 2(L_o - t/2) \times t$$

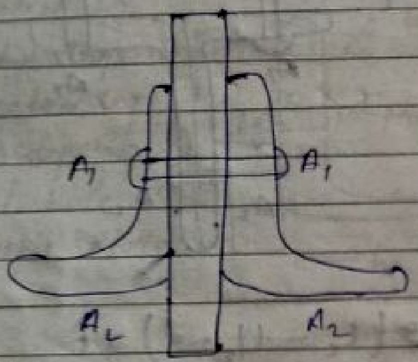
$$k = \frac{5A_1}{5A_1 + A_2}$$

Net area = $A_1 + A_2 \cdot k$.
Strength (P) = Net area × f_t.

In which outstand are joined by tacking rivets at 1 m (1m) interval so that it act likes a double angle section. If no tacking is provided these angle behaves as two single angles.

Case - III

Double angle section with longer leg connected to the both sides of the gusset plate.



Net area = 2 (Gross area - dt)

where

d = dia of rivet hole.

t = thickness of section.

And Gross area is taken by steel table.

Numerical

Determine the strength of a double angle ISA 125 x 75 x 8. Use 20 diameter of rivet for cases -

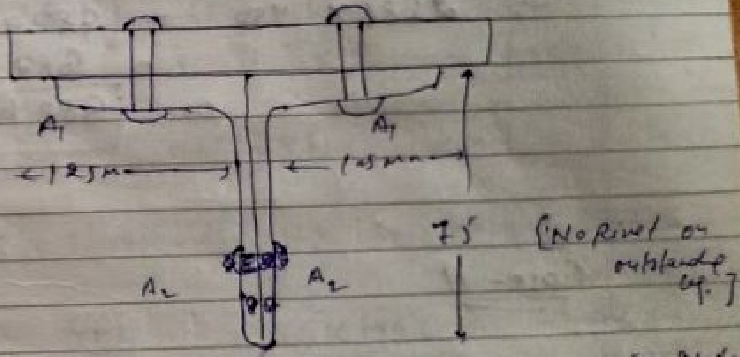
1) Longer length (legs) on same side of a gusset plate

II) Longer legs on both side of a gusset plate

III) Angles are welded.

Soln

Case - I



Nom. dia = 20mm, Gross dia = 20 + 1.5 = 21.5mm

$A_1 = 2(l_c - t/_2 - d) \times t$

$= 2[125 - 8/_2 - 21.5] \times 8$

$= 1592\ mm^2$

$A_2 = 2[l_o - t/_2] \times t = 2(75 - 4) \times 8$

$= 2[75 - 8/_2] \times 8$

$= 1136\ mm^2$

$K = \frac{5A_1}{5A_1 + A_2} = \frac{5 \times 1592}{5 \times 1592 + 1136}$

$= 0.875$

Net area $= A_1 + A_2 \cdot K$

$= 1592 + 1136 \times 0.875$

$= 2586\ mm^2$

Strength of the tension member =

Net area x tensile stress.

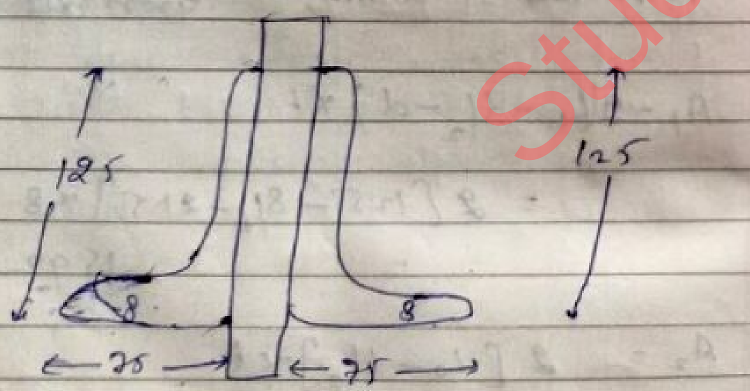
Net area x σ_t

$= 2586 \times 150 = 387900\ N$

$= 387.900\ kN$

or **388 kN**

Case - II



From steel table –

Area $(A_1 + A_2) = 1538\ mm^2$

Net area $= 2\,[\text{Area} - \text{Area of rivet}]$

$= 2\,[1538 - dt]$

$= 2\,[1538 - 21.5 \times 8]$

$= 2732\ mm^2$

Strength $= 2732 \times 150$

$=$ **410 kN**

Case - III (For Welding i.e. No Riveting).

$A_1 = 2\,[l_c - t/_2] \times t$

$= 2\,[125 - 8/_2] \times 8 = 1936\ mm^2$

$A_2 = 2\,[l_o - t/_2] \times t$

$= 2\,[75 - 8/_2] \times 8 = 1136\ mm^2$

$K = \frac{5A_1}{5A_1 + A_2} = \frac{5 \times 1936}{5 \times 1936 + 1136} = \frac{9680}{10816}$

$= 0.89497$

$= 0.894$

~~Net area~~

Net area $= A_1 + A_2 \cdot K$

$=$

Strength = Net area x σ_t

Steps for design Tension member

Step-I

Assume max. permissible tensile strength i.e. 150 N/mm²

Here

$$\text{Net area} = \frac{\text{Given load}}{150} \; mm^2$$

Step-II

Calculate the gross area of the section as follows –

A) Gross Area = 1.3 × Net area.

⇒ This is for single angle section or double angle section on the same side of the gusset plate

B) Gross Area = 1.2 × Net area.

⇒ This is for when angles are provided on both side of gusset plate

c) Gross Area = 1.1 × Net area

⇒ This is for welded joint.

Step - III

Corresponding to gross area select a section from steel table and find its Net area.

Step - IV

Strength of the selected section is equal to

Net area of the selected section × tensile stress

⇒ This shall more than given load. Otherwise try another section. [i.e. section is unsafe]

Step - V

No. of Rivets is equal to

$$\frac{\text{Given load}}{\text{Rivet value}}$$

Spacing of Rivet = 3× dia of rivet
Gauge distance = 2× dia of rivet
Edge distance = 1.5× dia of rivet.

Numerical

Design a tension subject to a pull of 140 kN. Use dia = 20mm.

Sol^n :-

Step - I

$$\text{Net area} = \frac{\text{Given load}}{\text{stress}}$$

$$= \frac{140 \times 10^3}{150} = 933 \text{ mm}^2$$

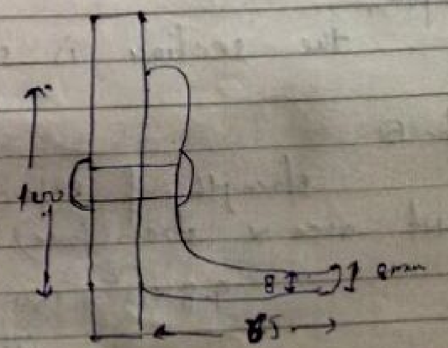
$$= 9.33 \text{ cm}^2$$

Step - II

Gross Area = 1.3 × Net area
= 1.3 × 9.33
= 12.13 cm²

Step III

From steel table, try ISA 100×65×8 having net area 12.52 cm²



for single angle section.

$A_1 = [L_c - t/_2 - d] \times t$
$= (125 - 8/_2 - 21.5) \times 8$

$= 596 \ mm^2$

$A_2 = [L_0 - t/_2] \times t$

$= [65 - 8/_2] \times 8$

$= 488 \ mm^2$

$k = \frac{3A_1}{3A_1 + A_2} = \frac{596}{596+488} = 0.78$

Net Area = $A_1 + A_2 \cdot k$ =
$596 + 488 \times 0.78$

$= 980 \ mm^2$
$= 9.8 \ cm^2$

which is greater than 9.33
Therefore,
the section is safe.

Step- 5

Strength of selected section =
Net area × stress (force)
$= 9.8 \times 10^2 \times 150 \times 10^{-3}$

147 kN

which is greater than 140 kN.
Hence,
Section is safe.

Step- 6

Strength of rivet in shearing
$\frac{\pi}{4} d^2 \times \sigma_s$

$= \frac{\pi}{4} \times (21.5)^2 \times 100 = 36305 N$

Strength of rivet in bearing
$d t \times \sigma_b$
$= 21.5 \times 8 \times 300 = 51600 N$

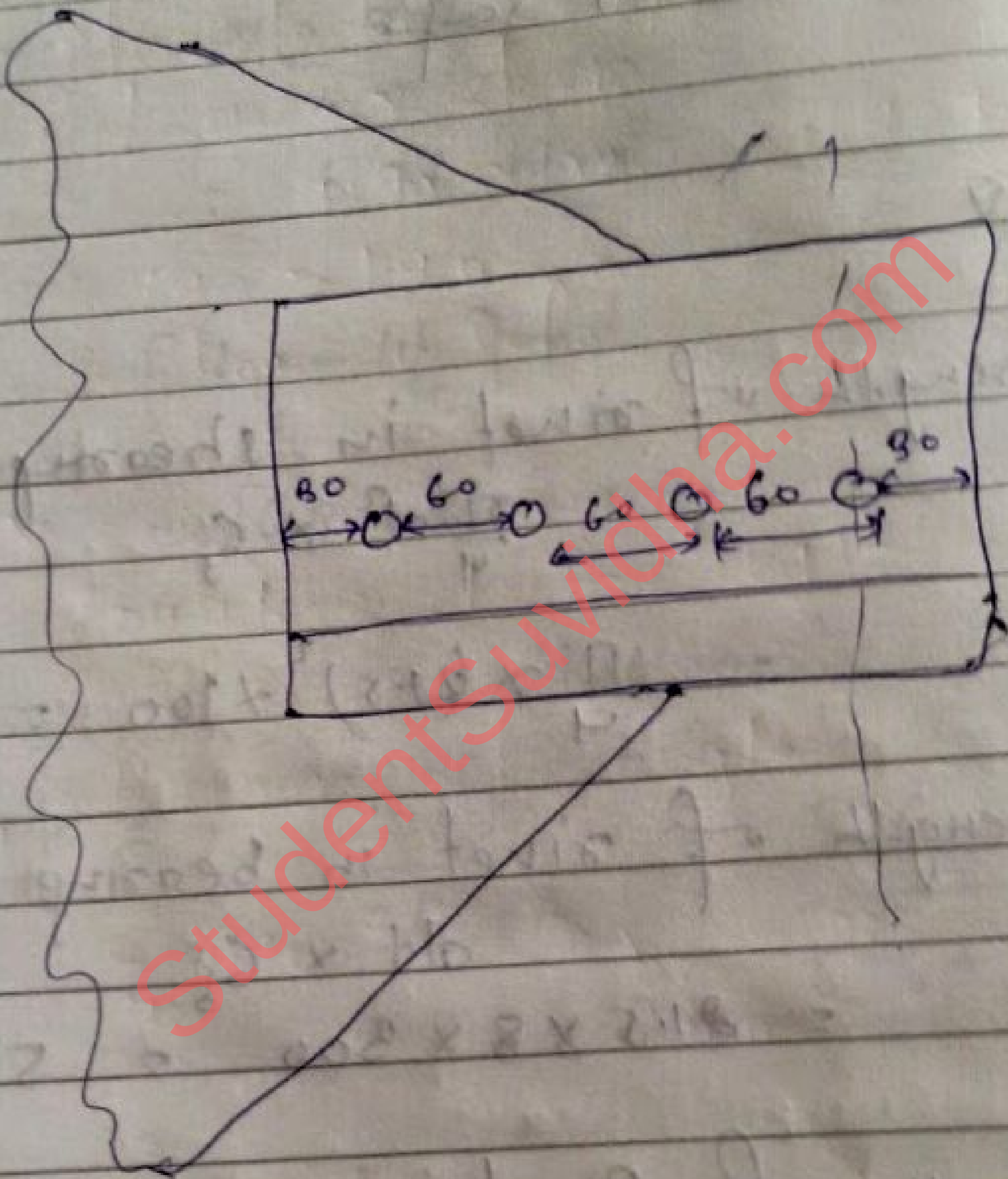
∴ Strength of Rivet or Rivet value =
36305 N.

No. of Rivets = Rivet
$\frac{\text{Given load}}{\text{Rivet value}} = \frac{140 \times 10^3}{36305}$

$= 3.85 = 4$ rivets

Pitch of Rivet =
3 × Dia of rivet ⇒ 3 × 20 = 60 mm

Edge distance
= 1.5 × dia of rivet
1.5 × 20 = 30 mm


80
60
60
60
80

Numerical :-

Design a welded Section having a load of 140 kN.

Sol^n :-

Step - I

Net area = $\frac{\text{load}}{\text{stress}} = \frac{140 \times 10^3}{150} = 9.33 cm^2$

Step - II

Gross Area for welding

$1.1 \times 9.33 = 10.27 cm^2$

Step - III

[Corresponding to Gross Area]

from steel table

Try ISA 70×45×10 having area 10.52

$A_1 = (70 - \frac{10}{2}) \times 10$

$= 650 mm^2$

$A_2 = (45 - \frac{10}{2}) \times 10$

$= 400 mm^2$

$k = 3A_1 / 3A_1 + A_2$

0.81

Net area $= A_1 + A_2 \cdot k$

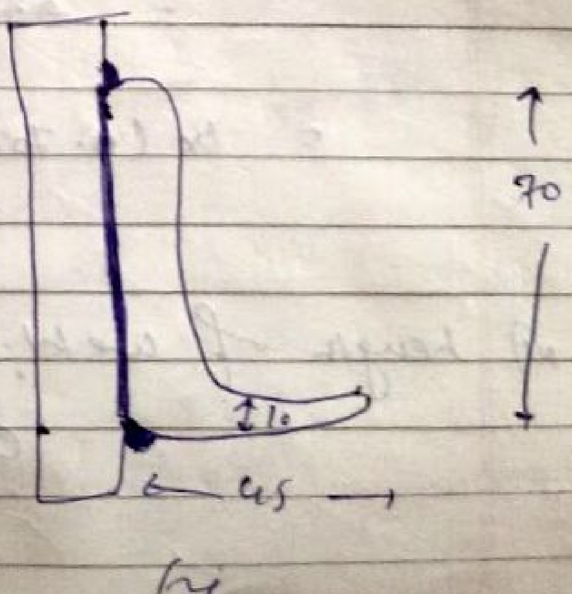
$= 650 + 400 \times 0.81$

$= 974 mm^2$

$= 9.7 cm^2$

$9.7 > 9.33$

So, section is safe.



fig

Step-IV

Strength of selected section :
Net area x stress
= 9.80 x 150 = 147 kN

147 > 140 .
Section is safe

Step - V
Consider 1mm length of weld

$\frac{3}{4}$ x thickness of angle

= $\frac{3}{4}$ x 10 = 7.5 or
size of the weld = 8 mm (approx)

i) Shear strength of weld per mm.

Lw x throat thickness (0.707 x 8) x fs
= ~~0.707~~

= 1 x (0.707 x 8) x 110
= 622 N

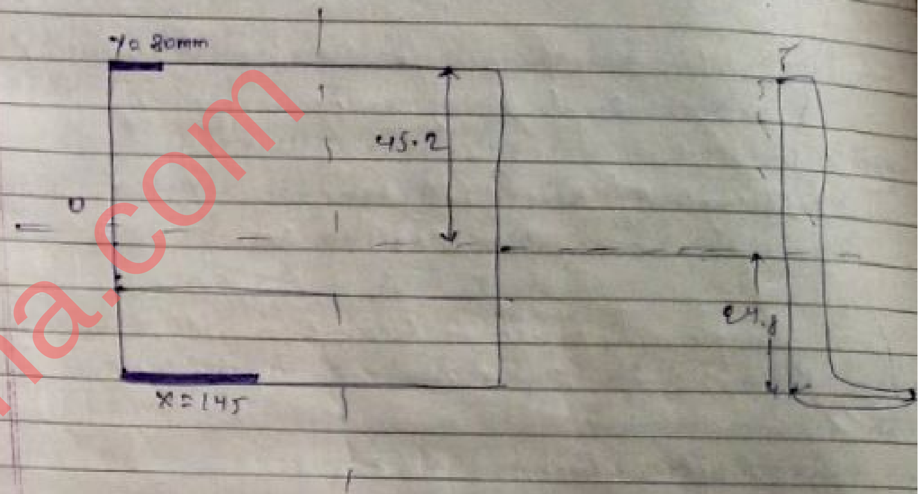
ii) Length of weld (Lw) :

$\frac{\text{Given load}}{\text{strength}} = \frac{140 \times 10^3}{622}$

= 225 mm

iv) For two side connected ~~base~~ case -

Lw = x + y = 225 — ①



Taking moment about 0

y x 45.2 = x x 24.8
x = $\frac{y \times 45.2}{24.8}$ = 1.882 y

Put in eqn (1).

Lw = 1.882 y + y = 225
= 2.882 y = 225

y =

x =

LUG ANGLE

[Main angle connected to a gusset plate if there are large no. of sivets]*

When a tension member is connected to a gusset plate and its ends a large no. of sivets are required especially when the tension member is large. ~~and~~ it increase the length of the gusset plate. The size of the gusset plate can be decreased by the use of a lug angle.
Thus,
A lug angle is a short length of an angle section which is attached to a main tension member at the connecting end to provide extra gauge lines for accomodating the required no. of sivets

⇒ Lug angles are short angles used to connect the gusset and outstanding leg of the main memb as shown in fig.
The lug angles help to increase the efficiency of the outstanding leg of the angles or channels..
They are normally provided when the tension member carries a very large load. Higher load results in a larger end connection which can be reduced by providing lug angles.
It is ideal to place the lug angle at the beginning of the connection than at any other portio

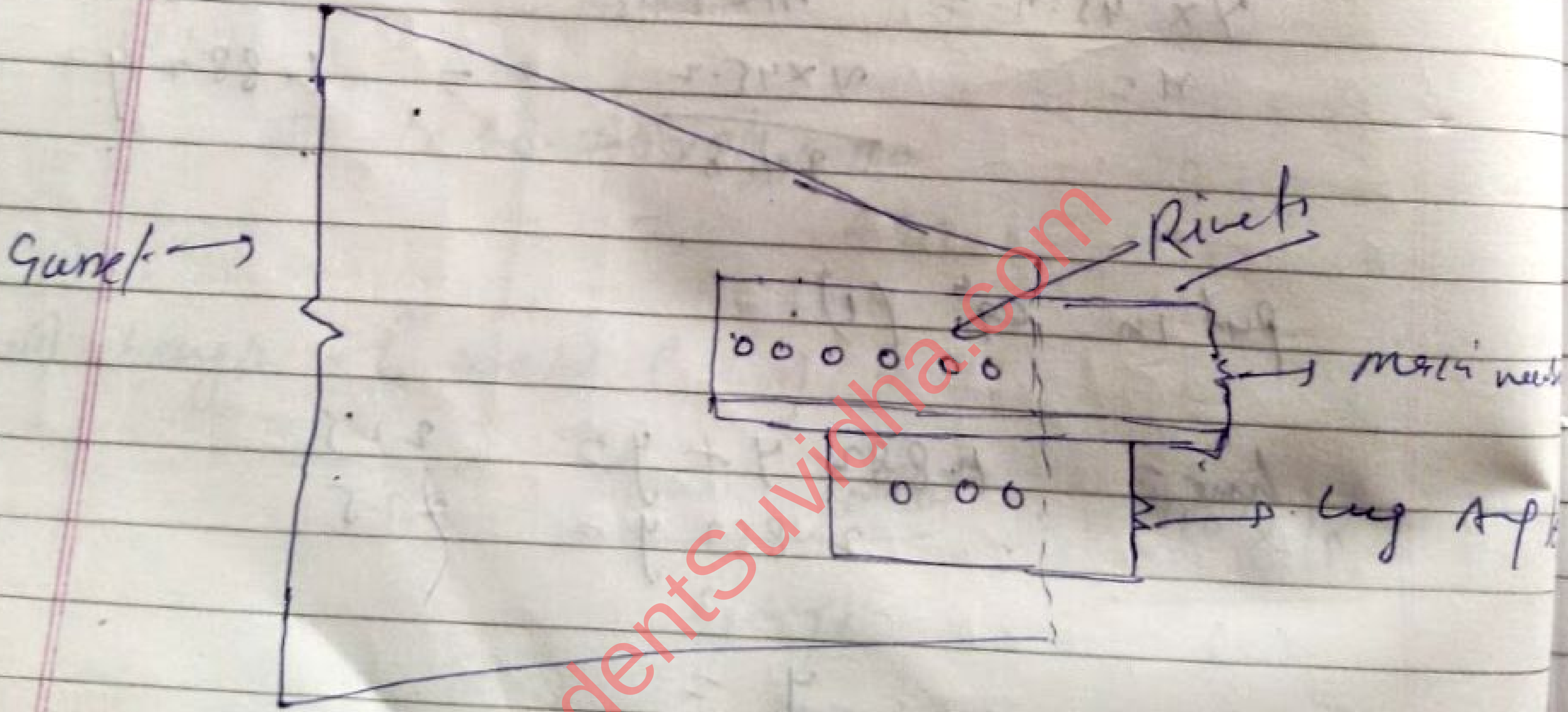


Fig Lug Angle

Numerical:

A tension member is subjected to a load of 200 kN. Size of the angle is 125×75×10. Design lap angle using 20 mm dia of rivet.

Solⁿ :-

Step-I

Find Rivet value.

Strength of Rivet in shear = $\pi/4 \times d^2 \times \sigma_s$

$= \pi/4 \times (21.5)^2 \times 100 = 36305$ N

Strength of Rivet in Bearing = $dt \times \sigma_b$

$= 21.5 \times 10 \times 300 = 64500$

∴ Rivet value = 36305

Step-II

No. of Rivet = Load / Rivet value.

$\frac{200 \times 10^3}{36305} = 5.5$ i.e. 6

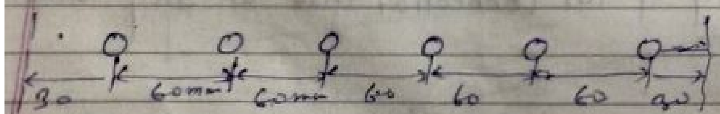
Pitch of Rivet -

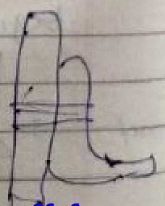
3× dia of rivet = 3×20 = 60 mm.

Edge distance = 1.5 × 20 = 30 mm

Length of gusset plate = 60+60+60+60+60+30+30

= 360mm.





(if load or strength not given, then calculate by shear i.e. 150 N/mm² × Net area

150 × Net area N)

Step-III

$A_1 = (L_c - t/2) \times t$

$= (125 - \frac{10}{2}) \times 10 = 1200$ mm²

$A_2 = (L_o - t/2) \times t = (75 - \frac{10}{2}) \times 10 = 700$ mm²

Total area = 1200 + 700 = 1900 mm²

Step-IV

Load taken by longer length (strength of connected leg

= $\frac{\text{Area of leg} \times \text{Given load}}{\text{Total Area}}$

$= \frac{1200 \times 200 \times 10^3}{1900} = 126.3$ kN

Strength of outstanding leg -

200 - 126.3 = 73.7 kN.

Step-V

Connection to gusset plate.

No. of rivets required -

$\frac{126.3}{36.305}$

$= \frac{126.3 \times 10^3}{36305} = 3.48$ or say 4 rivets.

strength of member = Net area × stress.

⇒ Net area = $\frac{\text{strength of member}}{\text{stress}}$

Step – VI Design of lug Angle –

strength of lug angle =

strength of outstanding leg of main angle + 20% of strength of outstanding leg of main angle

i-e –

1.2 × strength of outstanding leg of main angle.

$= 1.2 \times 73.7$

$= 88.44$ kN.

Net area Required (A_{net}) $= \frac{88.44 \times 10^3}{150}$

$= 590\ mm^2$

Gross Area $= 1.3 \times 590 = 767\ mm^2$

∴ Adopt a lug angle ISA 125×75×6 from steel table

Area $= 11.66\ cm^2$ or $1166\ mm^2$

Net area $= A - dt$ (dt = area of rivet)

$= 1166 - dt$

$= 1166 - 21.5 \times 6$

$= 1038\ mm^2$

Net area is greater than area of lug angle

1038 > 590

So, the section is safe.

Number of Rivets Required to Connect –

lug angle with main angle

$= \frac{1.4 \times 73.7 \times 10^3}{36305} = 2.84$ or 3 rivets

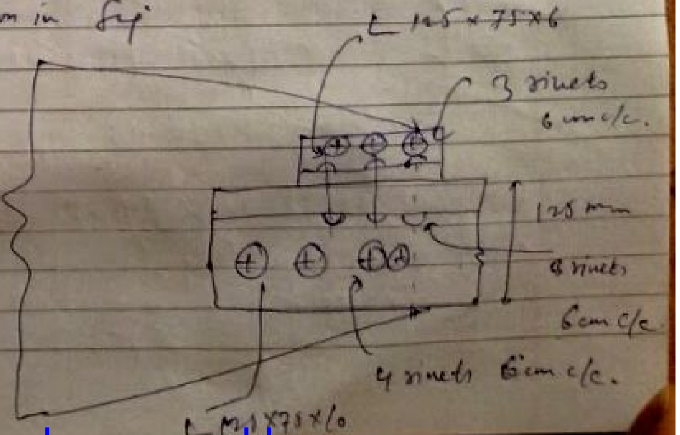
lug angle with gusset plate –

$\frac{1.2 \times 73.7 \times 10^3}{36305} = 2.43$ say 3 rivets

All rivets will be spaced at a pitch

$21.5 \times 3 = 64.5$ (say 6 cm c/c)

as shown in fig



Tension & Splices I

When the required length of the tension member is less than the available length (or two lengths of tension member have different cross sectional area), tension splices are provided to join the two length of the member.

i.e. Tension splices are the cover plates used on both sides of the butt jointed members.

The area of the splices should be slightly more than that the member joined.

Numerical

Design a tension splice to connect two plates of size 300 x 18 mm and 250 x 10 mm. if the design load is 810 kN. Assume $f_y = 250\ N/mm^2$.

Sol^n:

Step-I

Thickness of the packing required

$= 18 - 10 = 8\ mm$

Step-II

Assuming thickness of splice plates on both sides of joints = 10 mm (least thickness)

Using 22 mm dia of rivet

Gross dia $= 22 + 1.5 = 23.5$ mm.

Step-III

strength of rivet in bearing

Area x stress

$= dt \times \sigma_b$

$= 23.5 \times 10 \times 270$ (either 270 or 300)

$= 63.45$ kN.

Step - IV

Strength of rivet in double shear

$2 \times \frac{\pi}{4} d^2 \times \sigma_s$

$= 2 \times \frac{\pi}{4} (23.5)^2 \times 90$

$= 78$ kN

Step - V

Rivet value — 63.45 kN

No. of rivets = $\frac{\text{Given load}}{\text{Rivet value}}$

$= \frac{310}{63.5} = 4.8$ or say 5 rivets

Step - Thickness of packaging required

$= 18 - 10 = 8$ mm.

thickness of packaging is greater than 6 hence additional rivets are required for each 2 mm thickness of pack

$= 2.5\%$ for each 2mm thickness of packaging

$= 2.5 \times \frac{8}{2} = 10\%$

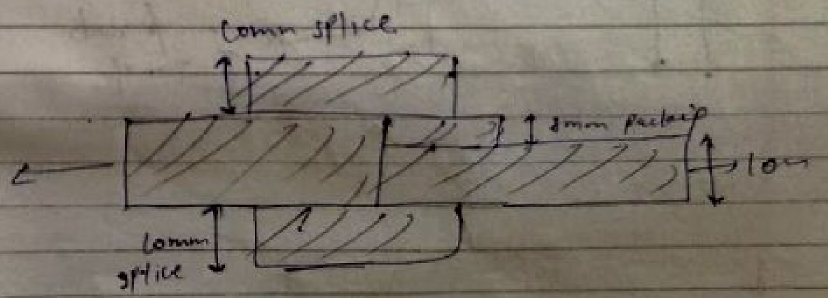
Additional rivets $= \frac{10 \times 5}{100}$

$5 \times \frac{10}{100} = 0.5$ or say 1 rivet

Total no. of rivets $= 5 + 1 = 6$

Five rivets will be provided on the splice plate and one in the extension of the packaging packing.

fig shows the arrangement of rivets at spacing of $3 \times 23.5 = 7$ cm c/c



strength of splice plate at critical section x-x

$2 \times (b - 2d) \times t \times \sigma_t$

$= 2 \times (250 - 3 \times 23.5) \times 10 \times 150 \times 10^{-3}$

$= 538.5 > 310$ kN

which is safe