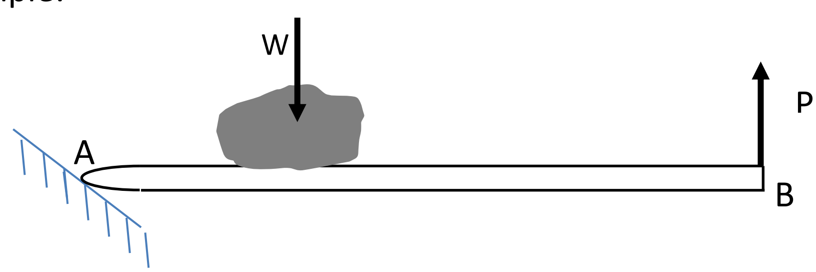
Strength Of Materials

Chapter One **Simple stresses**

Strength of materials extends the study of forces that was begun in Engineering Mechanics, but there is a sharp distinction between the two subjects. Fundamentally, the field of mechanics covers the relation between forces acting on rigid bodies; in statics, the bodies are in equilibrium , whereas in dynamics , they are accelerated but can be but in equilibrium by applying correctly inertia forces .

In contrast to mechanics, strength of materials deals with the relation between externally applied loads and their internal effects on bodies. Moreover, the bodies are no longer assumed to be ideally rigid; the deformations, however small, are of major interest. The properties of the material of which a structure or machine is made affects both its choice and dimensions that will satisfy the requirements of strength and rigidity.

The difference between mechanics and strength of materials can be further emphasized by the following example:-



$\sum MA = 0$ (in statics)

We can find the load P

Member AB assumed to be rigid enough and strong enough to permit the desired action .

In strength of materials we must investigate the bar itself to be sure that it will neither break nor be so flexible that it bends without lifting the load.

<u>SI Units (System International Units)</u>

A. Selected SI Units

Quantity	Name	SI Symbol
Energy	Joule	J (1J=1 N.m)
Force	Newtons	N (1N = 1Kg.m/s)
Length	meter	m
Mass	Kilogram	Kg
Moment (torque)	Newton meter	N.m
Plane angle	Radian dgree	Rad °
Rotational frequency	Revolution per second	r/s
Stress (pressure)	pascal	Pa (1 Pa =1 N/m^2)
Temperature	Degree celsius	˚C
Time	second	s
Power	watt	W (1 W = 1 J/s)

B.Commonly used SI Prefixes

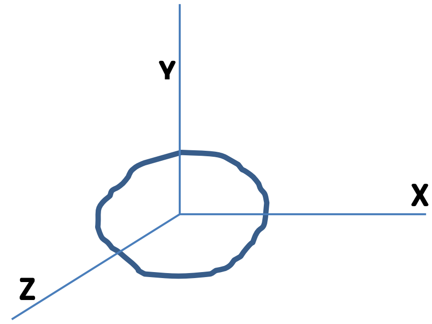
Multiple Factor	Prefix	SI Symbol
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	K
10^{-3}	milli	m
10^{-6}	micro	µ
	nano	n

Units

	British	Metric	S.I.(System International)
Force (1 N = 4.448 lb)	lb(lebra),kip,Ton 1 kip = 1000 lb 1 ton = 2240 lb	g (gram), kg 1 kg = 1000 g 1 Ton = 1000 kg	N(Newton),kN 1 KN =1000 N 1 kg = 10 N
Length (1 in = 2.54 cm)	In (inch), ft 1 ft = 12 in	mm, cm,m 1 cm = 10 mm 1 m =100 cm 1 m = 1000 mm	Mm,cm,m 1 cm =10 mm 1m =100 cm 1 m = 1000 mm
Stress (force/area) kPa = 6.894)	psi (ib/in^2) ksi (kip/in ^2)	Pa[pascal](N/m^2), kPa,Mpa,GPa MPa[Mega Pascal] =10^6 Pa (N/mm^2) GPa[Giga Pascal] = 10 ^9 Pa (kN/mm^2)	

Determinate and Indeterminate Problems

- The equation of static equilibrium for the three dimensional problems are :-

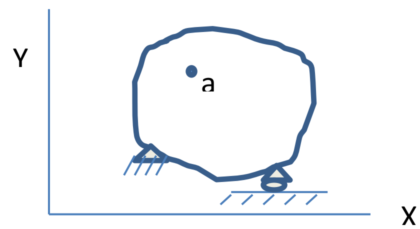


$$\sum Fx = 0 \quad , \sum Mx = 0$$
$$\sum Fy = 0 \quad , \sum My = 0$$
$$\sum Fz = 0 \quad , \sum Mz = 0$$

If the number of the unknowns is greater than 6 the problem is of indeterminate type .

- In the planar problems the equations of static equilibrium,

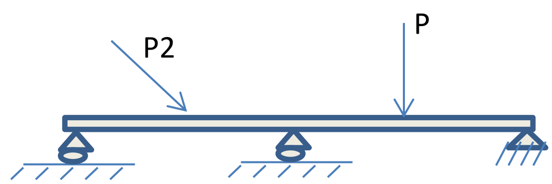
$$\sum Fx = 0$$
$$\sum Fy = 0$$
$$\sum Ma = 0$$



Where (a) is any point on the xy plane at which a normal axis to this plane passes . If the number of unknown reactions is greater than three the problem is of indeterminate type .

Examples

Statically determinate to the 1st degree



No. of unknowns =5

No. of static equilibrium equations=3

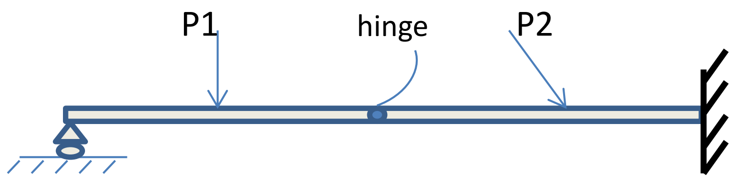
Indeterminate to the 2nd degree .

No.of unknowns =7

No.of equations =3

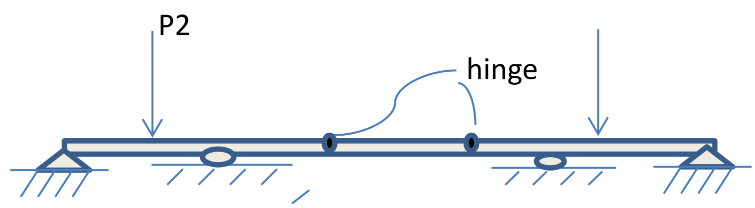
Indeterminate to the 4^{th} degree.

Indeterminate to the 2^{nd} degree .



The hinge will now add another equation (equation of condition) and the beam is now determinate.

No. of unkowns =6



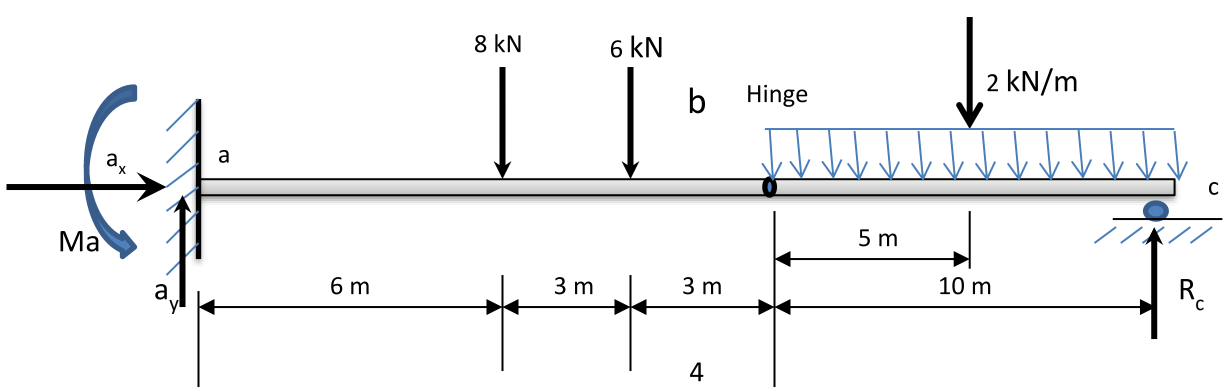
No.of equations =3+2

3 static equilibrium equations

2 equations of condition (2-hinges)

So the beam is indeterminate to the 1^{st} degree.

Example :- Find the reactions .

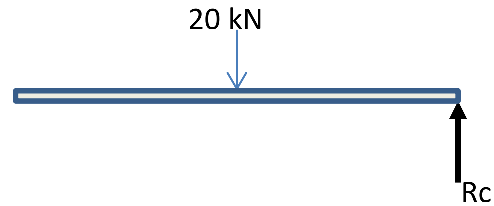


member bc as F.B.D

$\sum Mb = 0$ Type equation here.

20*5 =10 Rc

Rc = 10 KN



The whole frame as F.B.D

$\sum Fx = 0$, $\sum Fy = 0$ Type equation here.

ax =0

ay -8-6-20+10 =0

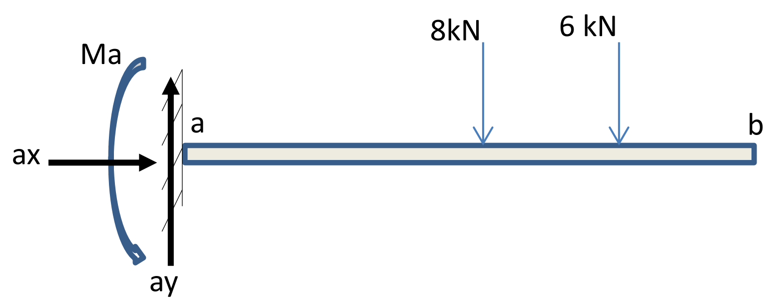
ay = 24 kN

Member ab as F.B.D

$\sum Mb = 0$

Ma +8*6 +6*3 -24*12 = 0

Ma = 222 kN.m



Example :- For the frame shown , find the reactions .

Member cd as F.B.D

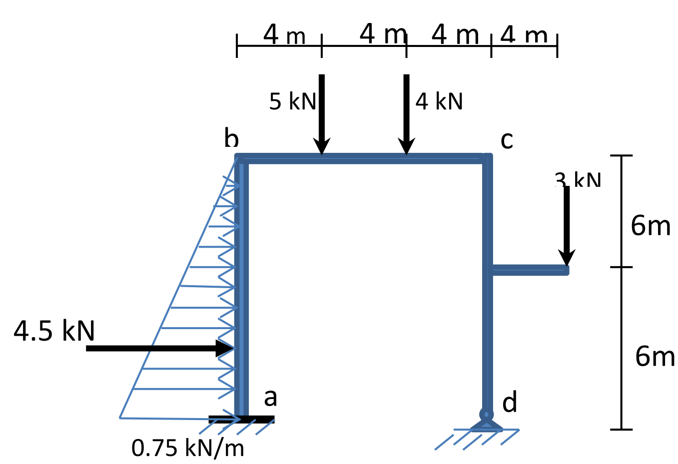
$\sum Mc = 0$ Type equation here.

3*4 = 12 dx

dx = 1 kN

member bc as F.B.D

$\sum Mb = 0$



4*5 +4*8 -12 cy = 0

cy = 4.33 KN

for member cd

$$\sum Fy = 0$$

dy = 7.33 KN

whole frame as F.B.D

$$\sum Ma = 0$$

4.5*4 +5*4 +4*8 +3*6 -7.3*12 –Ma =0

Ma = 30.4 KN.m

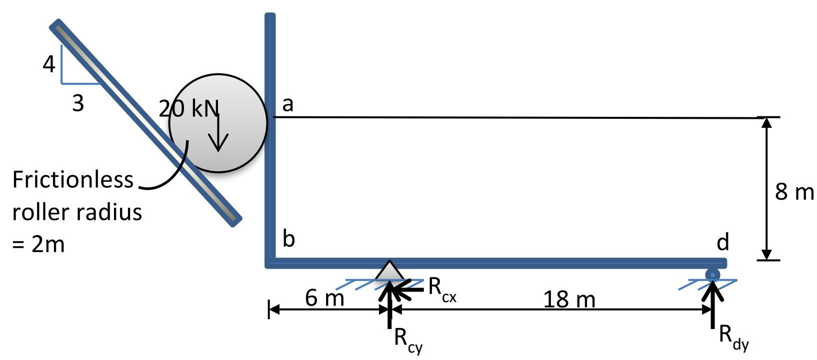
$$\sum Fy = 0$$

ay = 4.6 kN

$$\sum Fx = 0$$

WLax +4.5 +1 =0 , ax = 5.5 kN

Example



The roller as F.B.D

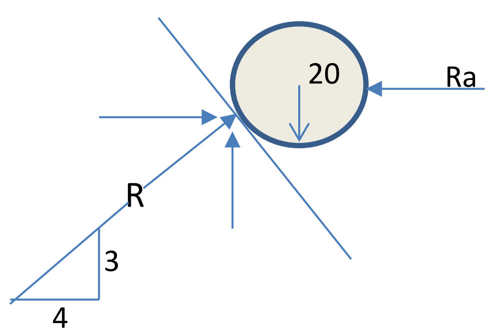
$\sum Fy = 0$

$\frac{3}{5}$ R = 20 ,R = 33.33 kN

$\sum Fx = 0$

$Ra = 33.33 * \frac{4}{5}$, $Ra = 26.67\ kN$

6



The whole frame as F.B.D

$\sum Mc = 0$

8 *Ra = 18 * Rdy

Rdy = 11.85 KN

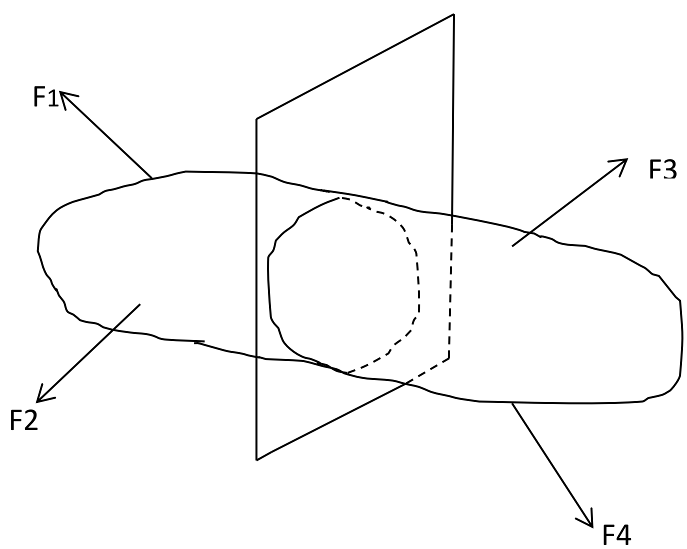
$$\sum Fx = 0$$

Rx = 26 .67 KN

$$\sum Fy = 0$$

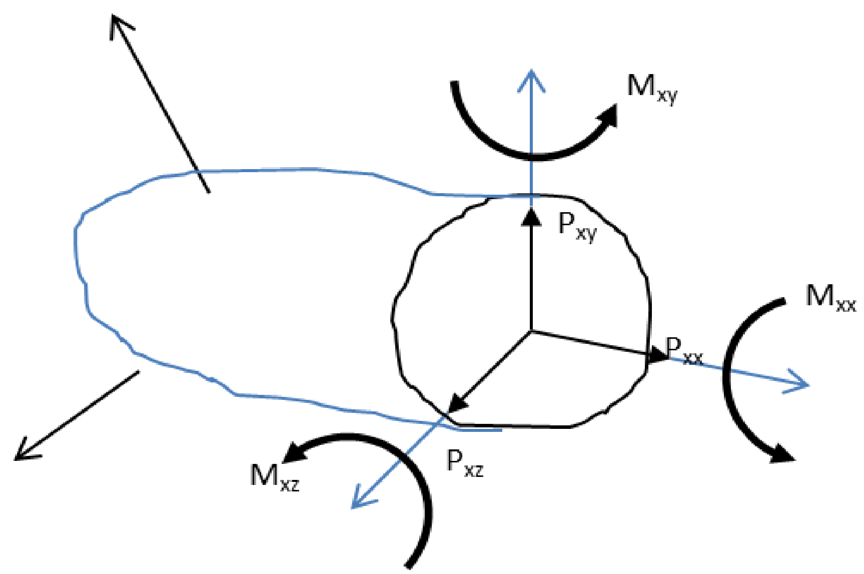
Rcy = 11.85 KN

Analysis of Internal Forces



- In engineering mechanics we would start by determining the resultant of the applied forces to determine weather or not the body remains at rest .

- In strength of materials , we would make additional investigation of the internal forces.
- The internal forces reduce to a force and couple which resolved into component normal and tangent to the section .
- The plane a-a is normal to x-axis so it’s known as x-surface or x face.

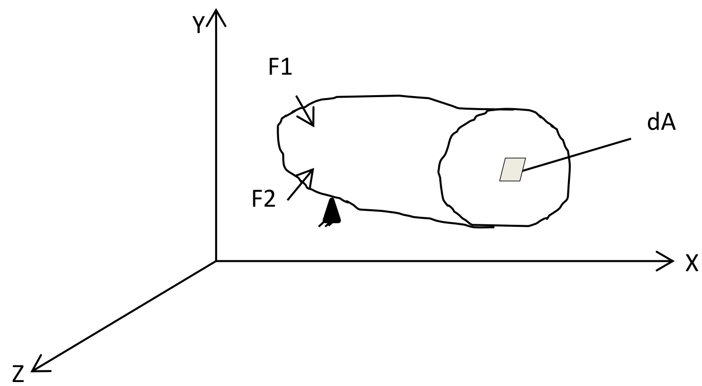


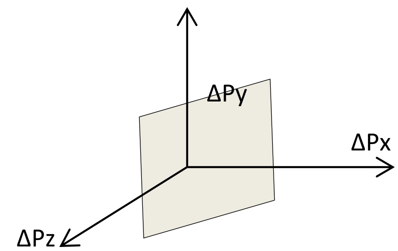
Pxx Axial Force : This component measure the pulling (or pushing) action over the section . It is often denoted by **P**.

Pxy , Pxz Shear forcec : These components of the total resistance to sliding the portion to one side of the explorary section past the other . it often denoted by **V**.

Mxx Torque : This component measure the resistance to twisting the member and is commonly given the symbol **T** .

Mxy ,Mxz Bending Moments : These components measure the resistance to bending member about the **Y** or **Z** axes and are often denoted by **My** , **Mz** .





$(segma) normal\ stress$

$\tau (tau) shearing\ stress$

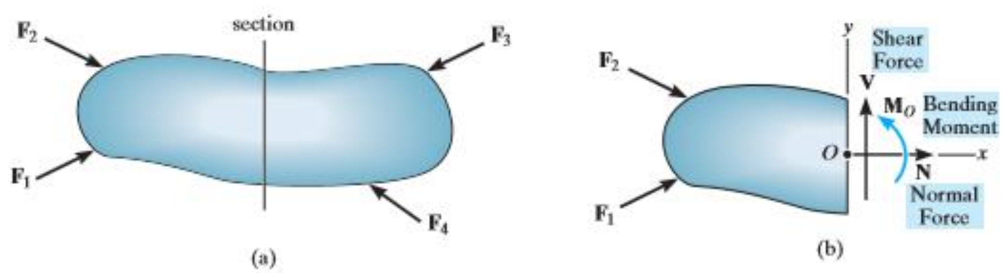
$\sigma x = \lim_{\Delta A \to 0} \Delta Px / \Delta A$ ……………………………………………normal stress

$\tau xy = \lim_{\Delta A \to 0} \Delta Py / \Delta A$ …………………………………………… shearing stress

$\tau xz = \lim_{\Delta A \to 0} \Delta Pz / \Delta A$ ……………………………………………shearing stress

Positive if in positive directions of x ,y , z .

<u>If the loads act in one plane ,</u>



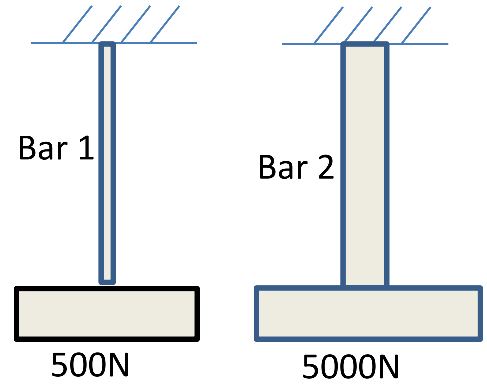
The resistance per unit area to deformation, is known as stress. Mathematically stress may be defined as the force per unit area.

$\sigma = P/A \qquad , \tau = V/A$

$P , V = load\ of\ the\ force\ acting\ on\ the\ body$.

$A = cross - sectional\ area\ of\ the\ body$.

Units of stress



Pascal (Pa) = N/mm²

MPa = MN/m² or equal to **N/mm²**

GPa = GN/m² or equal to **kN/m²**

Example : Which one of these two bars is stronger?

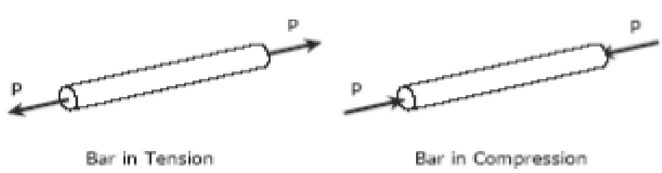
$$\sigma 1 = \frac{500\ N}{10\times10^{-6}} = 50\times10^{6}\ \ N/m^{2}$$

$$\sigma 2 = \frac{5000\ N}{1000\ \times10^{-6}\times m\hat{}2} = 5\times10^{6}\ N/m^{2}$$ Type equation here.

The material of the bar 1 is ten times as stronger as material 2.

Normal Stress

The resisting area is perpendicular to the applied force, thus normal. There are two types of normal stresses; tensile stress and compressive stress. Tensile stress applied to bar tends the bar to elongate while compressive stress tend to shorten the bar. Where P is the applied normal load in Newton and A is the area in mm2. The maximum stress in tension or compression occurs over a section normal to the load

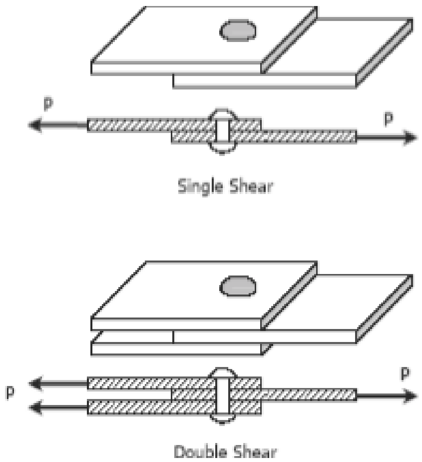


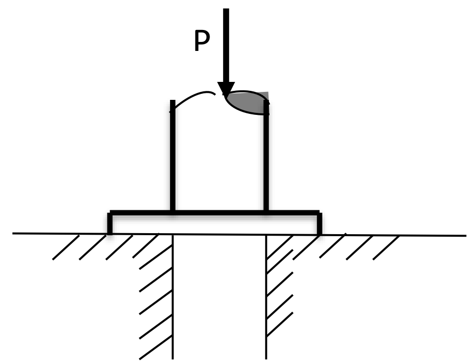
Shearing Stress

Forces parallel to the area resisting the force cause shearing stress. It differs to tensile and compressive stresses, which are caused by forces perpendicular to the area on which they act. Shearing stress is also known as tangential stress.

$$\tau = V/A$$

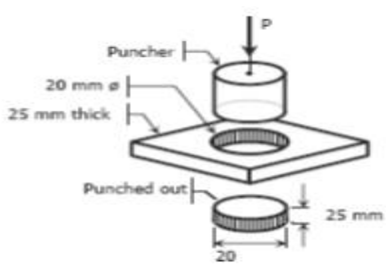
Where V is the resultant shearing force which passes through the centroid of the area A being sheared. Type equation here.





Example

What force is required to punch a 20-mm-diameter hole in a plate that is 25 mm thick? The shear strength is 350 MN/m2.



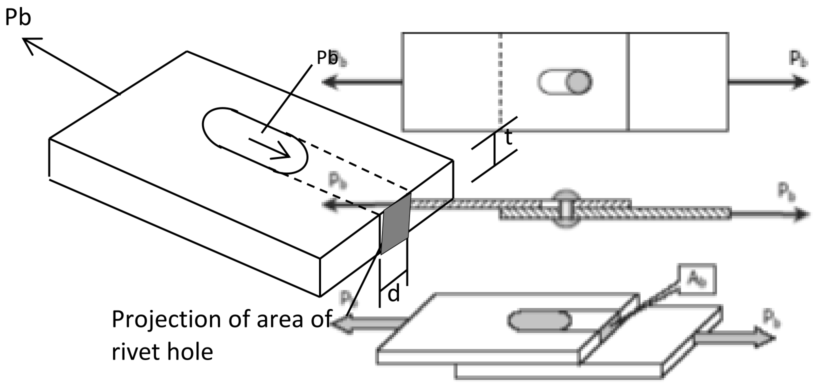
The resisting area is the shaded area along the perimeter and the shear force V is equal to the punching force P.

$$V = \tau A$$

$$P = 350[\pi(20)(25)]$$
$$= 549\,778.7 \text{ N}$$
$$= 549.8 \text{ kN}$$

Bearing Stress

Bearing stress is a <u>compressive stress</u> but it is differs from the normal compressive stress in that the latter is an internal stress caused by internal compressive force whereas the former is a <u>contact pressure</u> between two separate bodies. Some examples of bearing stress are soil pressure beneath the pier and the forces on bearing plates. We now consider the contact pressure between a rivet or bolt and the contact surface of the plate against which it pushes.



$$\sigma_b = \frac{P_b}{A_b}$$

$\sigma b = \frac{Pb}{Ab}$; $Ab = td$

$Pb = Ab\,\sigma b = (td)\sigma b$

123(Singer) : In figure above , assume that a(20 mm) diameter rivet joins the plates which are each (100mm)wide. (a)If the allowable stresses are (140 MN/m^2) for bearing in the plate material and (80 MN/m^2) for shearing of the rivet , determine the minimum thickness of each plate. (b) Under the conditions specified in part (a), what is the largest average tensile stress in the plate ?

Solution: (a)

$\tau = \frac{V}{A}$ $, \sigma b = \frac{Pb}{td}$

$80 = \frac{V}{\frac{\pi}{4}(20)^2}$ $, V = 25132.74\ N$

$140 = \frac{25132.74}{20\ t}$ $,\ \ t = 8.98\ mm$

(b) $\sigma = \frac{P}{A}$

$A = Bt - td$

$\quad = 100{\times}8.98 - 8.98{\times}20$ $;\ A = 718.4\ mm^2$

$$\sigma = \frac{25132.74}{718.4} = 35.0\ MPa$$

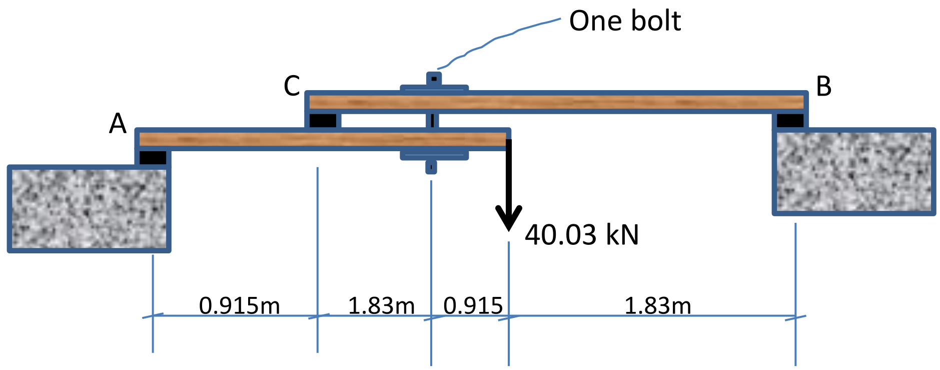
<u>Example(popov)</u>: For the structure shown in the figure, calculate the size of the bolt and the area of the bearing plates required if the allowable stresses are (124 MPa) in tension and 3.44 MPa in bearing. Neglect the weight of the beams.

<u>Solution:</u>

Whole structure as F.B.D

$$\sum MA = 0$$

$$RB = 26.69\ kN\ \uparrow$$



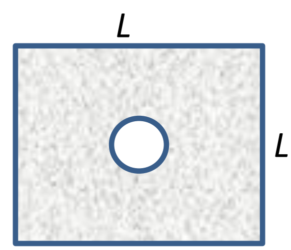
Member cb as F.B.D , gives the tensile force in the bolt

$$T = 66.73\ kN$$

$$Abolt = \frac{66.73\times10^3}{124\times10^6} = 5.38\times10^{-4}\ m^2$$

$$A = \frac{\pi}{4}\ d^2 \quad , 5.38\times10^{-4} = \frac{\pi}{4}\ d^2$$

$d = 26\ mm$ (Diameter of the bolt)



$$A\ of\ plate = \frac{66.73}{3440} = 0.019\ m^2$$

$$0.019 = l^2 - 5.38\times10^{-4}$$

$$l = 0.014\ m \quad ; l = 140\ mm$$

A 12-inches square steel bearing plate lies between an 8-inches diameter wooden post and a concrete footing as shown in Fig. P-110. Determine the maximum value of the load P if the stress in wood is limited to 1800 psi and that in concrete to 650 psi.

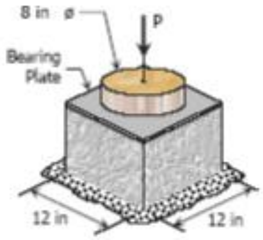


Figure P-110

Solution 110

For wood:

$P_w = \sigma_w A_w$

$= 1800[\frac{1}{4}\pi(8^2)]$

$= 90\ 477.9$ lb

FBD of Wood

From FBD of Wood:

$P = P_w = 90\ 477.9$ lb

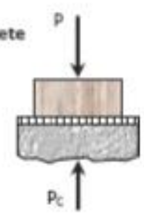
For concrete:

$P_c = \sigma_c A_c$

$= 650(12^2)$

$= 93\ 600$ lb

FBD of Concrete



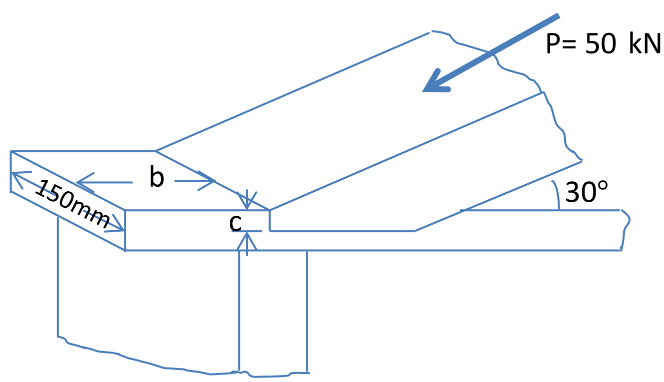
From FBD of Concrete:

$P = P_c = 93\ 600$ lb

Safe load $P = 90\ 478$ lb

115. The end chord of timber truss framed into the bottom chord as shown in the figure. neglect friction (a)compute dimension b if the allowable shearing stress is 900 kPa ; and (b) determine dimension c so that the bearing stress does not exceed 7 MPa.

Solution :



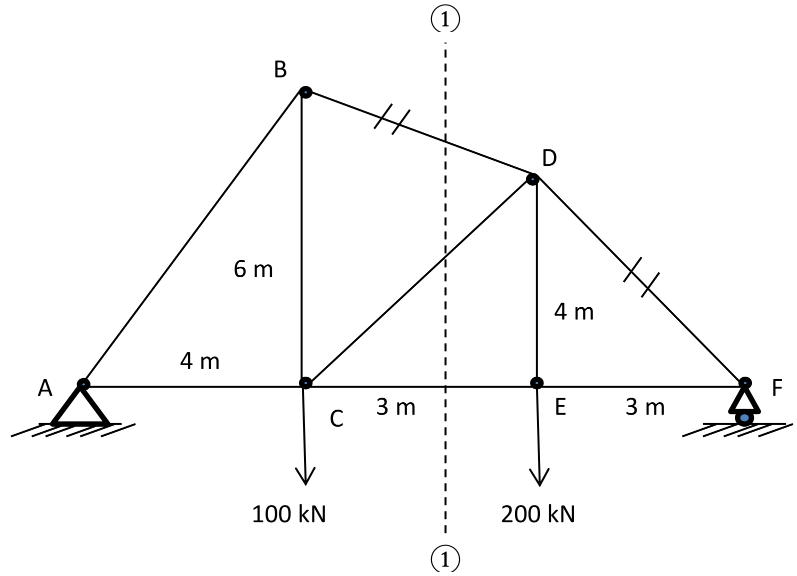
$\tau = V/A$; $\quad 900\times10^3 = \dfrac{50\ cos30\ \times10^3}{0.15\times b}$

$b = 0.321\ m$ $\quad$; $b = 321\ mm$

$\sigma b = \dfrac{Pb}{Ab}$

$7\times10^6 = \dfrac{50\times10^3\times cos30}{0.15\times c}$ $\quad$; $c = 0.0412\ m$; $c = 41.2\ mm$

104. For the truss shown in the figure , calculate the stresses in member DF,CE . and BD.The cross-sectional area of each member is 1200 mm^2 .Indicate tension (T) and compression (c).



Solution :

The whole truss as F.B.D

$\sum MA = 0$

$100 \times 4 + 200 \times 7 - 10\, Rfy = 0$

$Rfy = 180\ kN$

Joint F as F.B.D

$\sum Fy = 0$

$Fdf \times \frac{4}{5} = Rfy \qquad ;\ Fdf = 225\ kN$

$\sum Fx = 0$

$Fdf \times \frac{3}{5} = Fef \qquad ; Fef = 135\ kN\ T$

Joint E as F.B.D

$\sum Fx = 0 \qquad ; Fce = 135\ kN$

Section 1-1 as F.B.D

$\sum Mc = 0$

$$200 \times 3 + \frac{2}{\sqrt{13}} Fbd \times 3 + \frac{3}{\sqrt{13}}\ Fbd \times 4 - 1800 \times 6 = 0$$

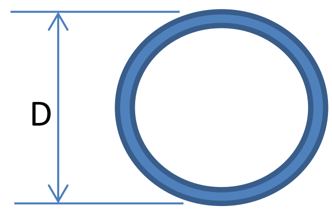
$Fbd = 96.15\ kN$

$\sigma = P/A$

$\sigma df\ = 188\ MPa$ C ; $\sigma ce = 113\ MPa$ T ; $\sigma bd = 80.1\ MPa$

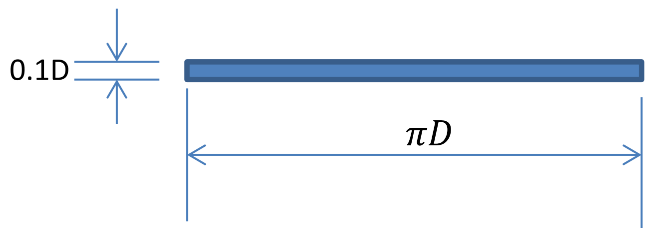
108. Determine the outside diameter of hollow steel tube that will carry a tensile load of 500 kN stress of 140 MN/m^2 .Assume that wall thickness to be one tenth of the outside diameter.

Solution: Assume the outside diameter=D



$\sigma = \frac{P}{A}$

$t = 0.1D$



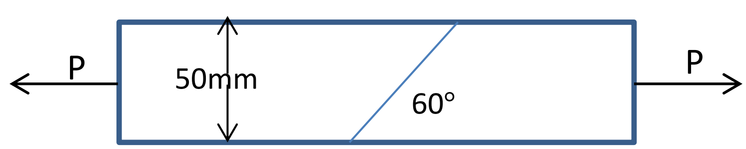
$A = \frac{500\times10^{-3}}{140\times10^{-6}}$; $A = 3.57\times10^{-3}\ m^2$

$0.1D\times\pi D\ = 3.57\times10^{-3}$

$D\ = 0.107\ m$; $D\ = 107\ \ mm$

120. Two blocks of wood, 50 mm wide and 20 mm thick, are glued together as shown in figure. (a) Using the free body diagram concept illustrated before, determine the shear load and from it the shearing stress on the glued joint if P=6000 N. (b)Generalize the procedure of part (a) to show that the shearing stress on a plane inclined at any angle θ to a transverse section of area A is $\tau = Psin\theta/2A$.

Solution: (a)



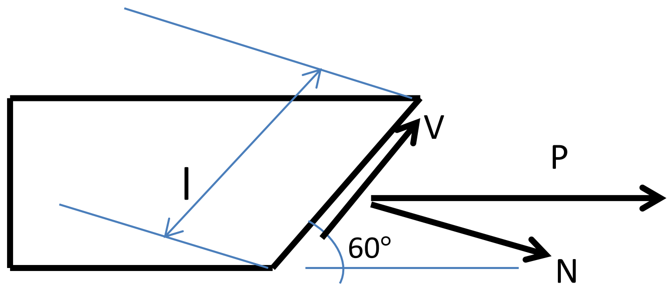
$\frac{50}{l} = sin60$; $l = 57.735\ \ mm$

$A\ = 20\times57.735 = 1154.7\ mm^2$

$\tau = \frac{V}{A}$; $V\ = Pcos60$

$V\ = 3000\ N$

$$\tau = \frac{3000}{1154.7} = 2.6\ MPa$$

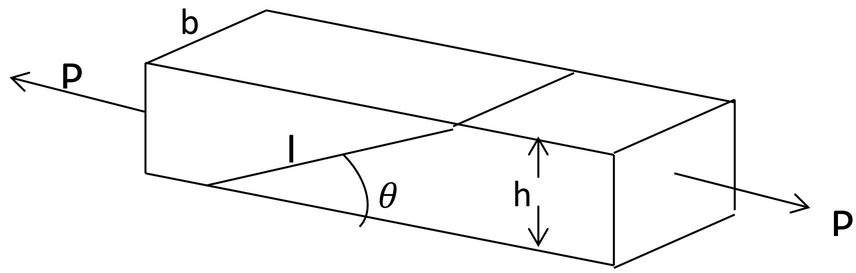


(b) $\frac{h}{l} = sin\theta \ \ ; \ l = h/sin\theta$

$$A' = b\times l \qquad ; A' = b\times h/sin\theta$$

$$V = Pcos\theta \quad ; \ sin\theta = 2sin\theta cos\theta$$

$$\tau = \frac{V}{A'} = \frac{Pcos\theta}{bh/sin\theta} = \frac{Psin2\theta}{2A}$$



109. Part of landing gear for a light plane is shown in figure. Determine the compressive stress in the strut AB caused by a landing reaction R=20 kN . Strut AB is inclined at 53.1° with BC .Neglect weight of the members.

Solution:

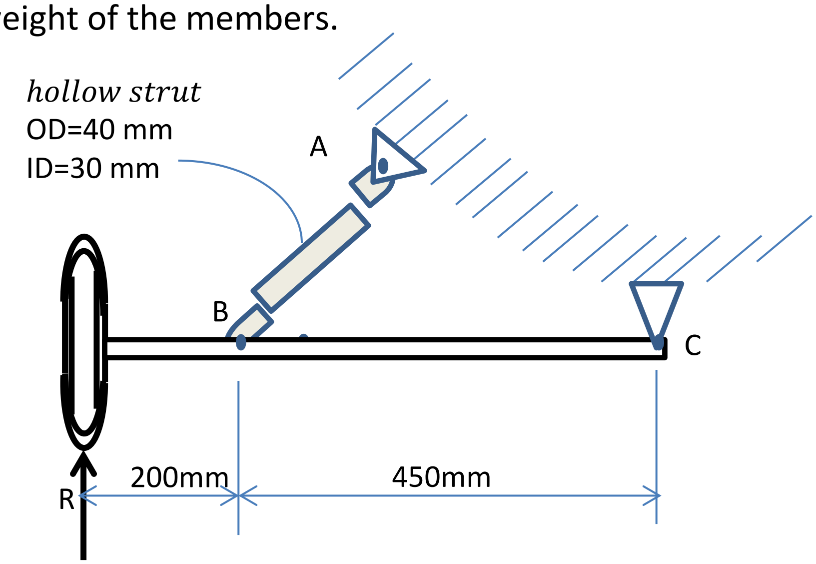
$$\sum Mc = 0$$

$$20\times 650 - Fab\times sin53.1\ \times 450 = 0$$

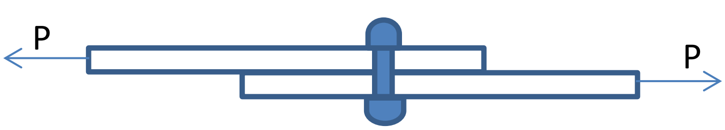
$$Fab = 36.125\ kN$$

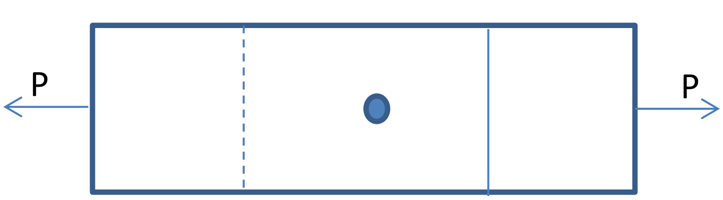
$$\sigma = P/A$$

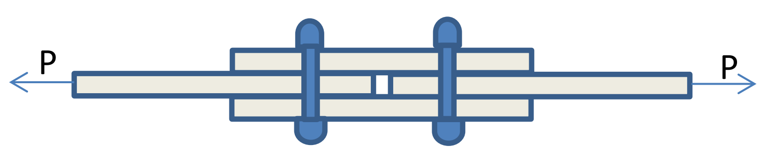
$$\sigma = \frac{36.125\ \times 10^3}{\frac{\pi}{4}(40^2 - 30^2)} \qquad ; \sigma = 65.7\ MPa$$

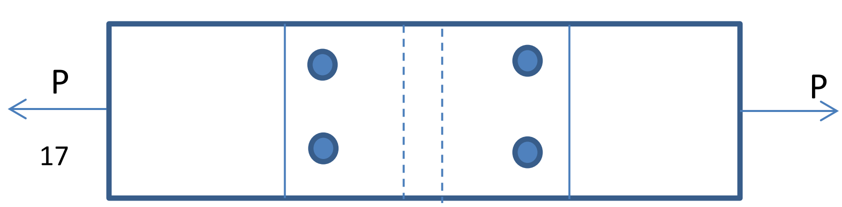


Bolted and Riveted Connections







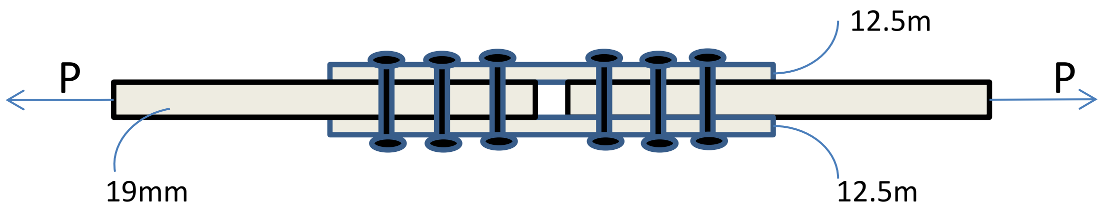


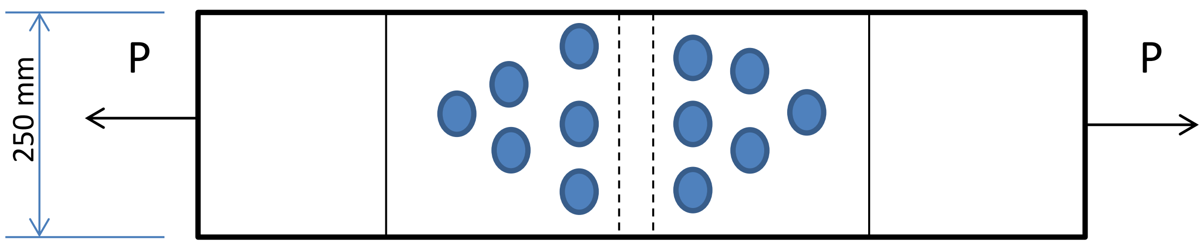
*The total force acting concentrically on a joint is assumed to be equally distributed between connectors (bolts or rivets) of equal size.

Example: Determine the safe load of the butt joint shown in the figure, given that:

$\tau = 103.4\ MPa \quad , \sigma = 372.3\ MPa \quad ,\rho(tension) = 165.5\ MPa$

Use 19mm rivets.





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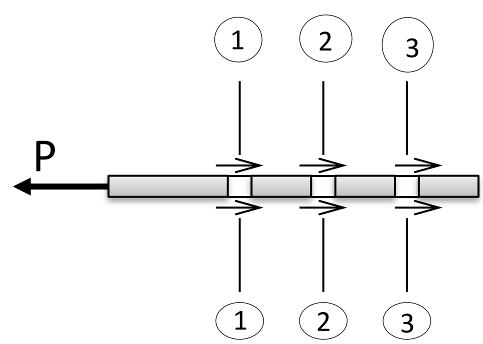
1. Shearing stresss

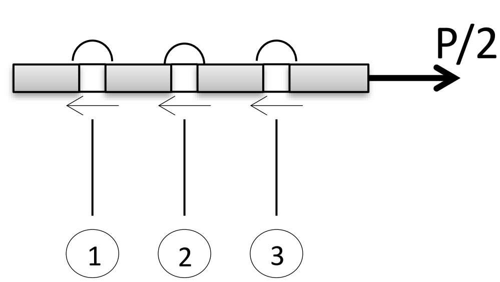


For the middle plate ,

$$P = 6\left[2\times\frac{\pi}{4}\times(0.019)^2\times103.4\times10^6\right]$$

$$P = 351.8\ kN$$

For the cover plate



$$\frac{P}{2} = 6\left[\frac{\pi}{4}\times(0.019)^2\times103.4\times10^6\right]$$

$$P = 351.8\ kN$$

2. Bearing Stress

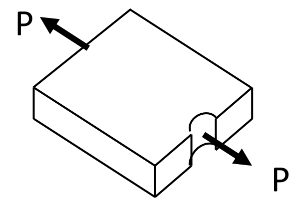
   For middle plate

$P = 6[0.019 \times 0.019 \times 372.9 \times 10^6]$
$P = 807.7\ kN$
For each of the outer plates
$\frac{P}{2} = 6[0.019 \times 0.0125 \times 372.9 \times 10^6]$
$P = 1062.765\ kN$

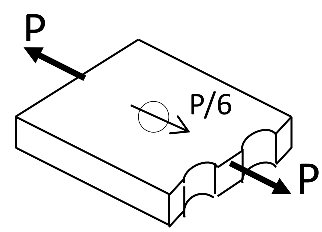
3. Tensile Stresses

- In this case you should check the critical section (1-1),(2-2) and (3-3).

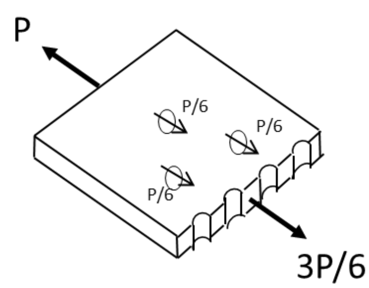
Middle Plate ,



Sec(1-1)
$P = (0.25 - 0.019) \times 0.019 \times 165.5 \times 10^6$
$P = 726.38\ kN$

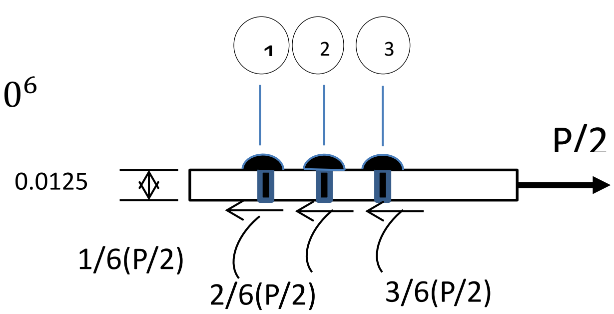


Sec (2-2)
$\frac{5}{6}P = [0.25 - 2 \times 0.019] \times 0.019 \times 165.5 \times 10^6$
$P = 800\ kN$
Sec (3-3)
$\frac{3}{6}P = (0.25 - 3 \times 0.019) \times 0.019 \times 165.5 \times 10^6$
$P = 1213.7\ kN$



Cover plate

Sec (3-3)
$\frac{P}{2} = (0.25 - 3 \times 0.019) \times 0.0125 \times 165.5 \times 10^6$
$P = 798.5\ kN$



Sec (2-2)

$$\frac{P}{2} - 3\times\frac{P}{12} = \frac{P}{4}$$

$$\frac{P}{4} = (0.25 - 2\times0.019)\times0.0125\times165.5\times10^6$$

$$P = 1754.3\ kN$$

Sec (3-3)

$$\frac{P}{2} - \frac{5P}{12} = \frac{P}{12}$$

$$\frac{P}{12} = (0.25 - 1\times0.019)\times0.0125\times165.5\times10^6$$

$$P = 4493\ kN$$

$\therefore P = 351.8\ kN$ Is the safe load for this joint.

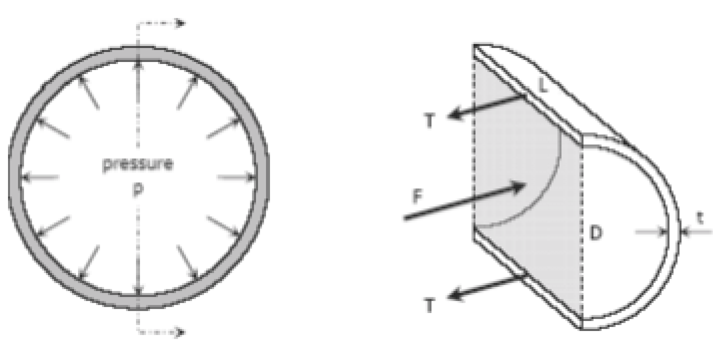
Thin-Walled Pressure Vessels

A tank or pipe carrying a fluid or gas under a pressure is subjected to tensile forces, which resist bursting, developed across longitudinal and transverse sections.

TANGENTIAL STRESS σt

(Circumferential Stress)

Consider the tank shown being subjected to an internal pressure p. The length of the tank is L and the wall thickness is t. Isolating the right half of the tank:



$$F = PA = PDL$$

$$T = \sigma t \ Awall = \sigma t \ L \ t$$

$$\sum Fx = 0$$

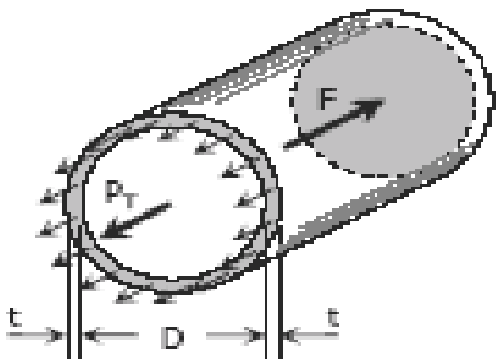
$$PDL = 2T$$

$$PDL = 2(\rho t \ L \ t)$$

$$\boldsymbol{\sigma t = \frac{PD}{2t}}$$

LONGITUDINAL STRESS, $\boldsymbol{\sigma l}$

Consider the free body diagram in the transverse section of the tank:



The total force acting at the rear of the tank F must equal to the total longitudinal stress on the wall PT = σl Awall. Since t is so small compared to D, the area of the wall is close to πDt

$$F = PA = P\frac{\pi}{4}D^2$$

$$PT = \sigma l \ \pi \ D \ t$$

$$\sum Fx = 0$$

$$PT = F$$

$$\sigma l \ \pi \ D \ t = p \ \frac{\pi}{4} \ D^2$$

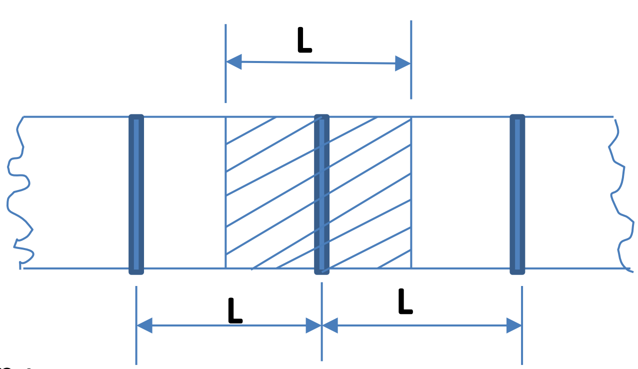
$$\boldsymbol{\sigma l = \frac{PD}{4t}}$$

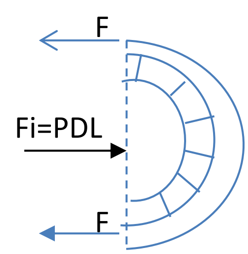
It can be observed that the tangential stress is twice that of the longitudinal stress.

$$\boldsymbol{\sigma t = 2\,\sigma l}$$

- If the pressure in a cylinder is raised to the bursting point , failure will occur along the longitudinal section.
- When a cylindrical tank composed of two sheets riveted together , the strength of the longitudinal joint should be twise the strength of the girth joint.
- The equation (σt , σl) $are\ not\ to\ be\ memorized.$
- If the ends are dished or rounded the bursting force may be computed as the product of the internal pressure multiplied by the projection area of the transverse section.

<u>130 :</u> A large pipe , called penstock in hydraulic work , is 1.5 m in diameter. Here it is composed of wooden staves bound together by steel hoops , each 300 mm ^{2} in cross sectional area , and is used to conduct water from reservoir to a power house . If the maximum tensile stress permitted in the hoops is 130 MPa ,what is the maximum spacing between under a head of water of 30 m.





<u>Solution :</u>

$$P = \gamma\omega\ h$$

$$= \rho g h$$

$$P = 1000\frac{kg}{m^3}\times 9.81\times 30m$$

$$= 294\times 10^3 \ \frac{N}{m^2}$$

$$= 294 \ kPa$$

Assume the spacing between hoops =L

$$F = \sigma A$$

$$PDL = 2F$$

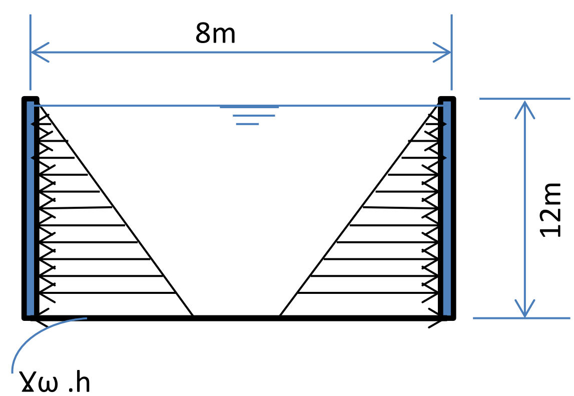
$$294\times 10^3\times 1.5\times L = 2\times(300\times 10^{-6})(130\times 10^6)$$

$$L = 0.177 \, m$$

$$l = 177 \, mm$$

<u>134.</u> A water tank is 8 m in diameter and 12m high. If the tank is to be completely filled , determine the minimum thickness of the tank plating if the stress is limited to 40 MPa.

Solution :



$$Pmax = \ \gamma\omega \, . h$$

$$= 1000\times 9.81\times 12$$

$$= 117720 \quad N/m^2$$

$$\rho t = \frac{PD}{2t}$$

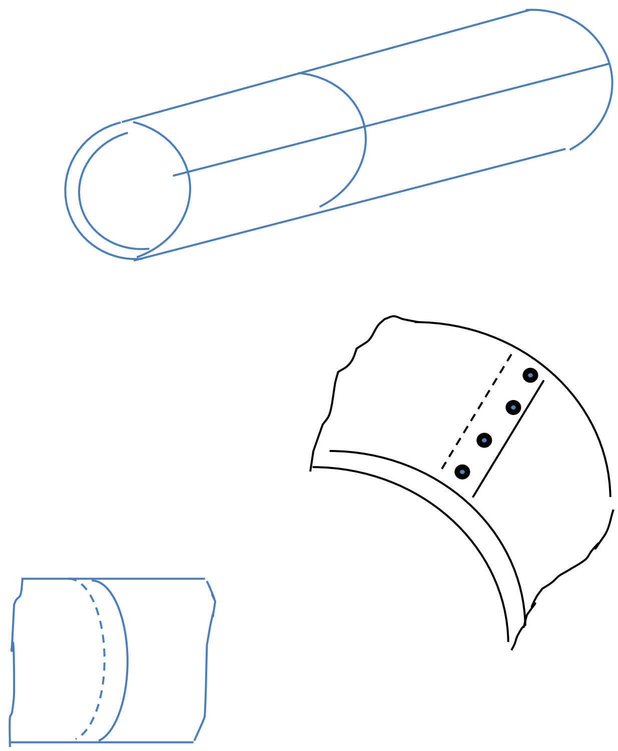
$$40\times 10^6 = \frac{117720\times 8}{2t}$$

$$= 0.118 \ m$$

$$= 118 \ \ mm$$

<u>135.(Singer):</u> The strength per meter of the longitudinal joint in the figure shown ,is 480 kN , whereas for the girth joint is 200 kN .Determine the maximum diameter of the cylindrical tank if the internal pressure is 1.5 MN/m^2 .

Solution :



$\sigma t = \frac{480}{1\times t}$

$\sigma t = \frac{PD}{2t}$

$$\frac{480}{1\times t} = \frac{1.5\times10^6\times D}{2\times t}$$

$D = 0.64 \ \ m$

$$\sigma l = \frac{PD}{4t}$$

$\sigma l = \frac{200}{1\times t}$

$$\frac{200\times10^3}{1\times t} = \frac{1.5\times10^6\times D}{4\times t}$$

$D = 0.53 \ \ m$

$= 530 \ \ mm$ (governs)

<u>139 (singer)</u> : The tank shown in the figure is fabricated from 10mm steel plate . Determine the maximum longitudinal and circumferential stress caused by an internal pressure of 1.2 MPa .

Solution :

To find σt

$Fi = P\times L\times(0.4 + 0.6)$

$= 1.2\times1\times l$

$F = \sigma t \times t\times L$

$Fi = 2F$

$(1m)\times 1.2\times 10^6\times L = 0.01\times L\times \sigma t\times 2$

$\sigma t = 60\ MPa$

To find σl

$Al = 0.6\times 0.4\times \frac{\pi}{4}\times (0.4)^2$

$= 0.36566\ m^2$

$Fi = P\times Al$

$= 12\times 0.36566$

$= 0.43879\quad MN$

$F(resisted\ by\ the\ tank\ material) = (circumference\ of\ the\ tank)\times t\times \sigma l$

$F = [(0.6\times 2 + \pi\times 0.4)\times 0.01]\ \sigma l$

$Fi = F$

$0.43879 = 0.02457\ \sigma l$

$\sigma l = 17.9\quad MPa$

131.(singer) : Show that the stress in thin - walled spherical shell of diameter D and wall thickness t subjected to internal pressure P is given by $\sigma = \frac{PD}{4t}$.

Solution

$\sigma t = \sigma l = \sigma$

$F(resisted\ by\ shell\ material) = \pi D t \sigma$

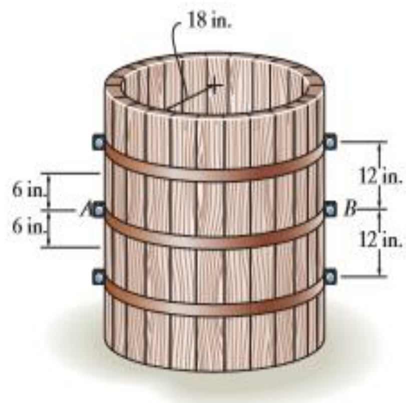
$Fi = P\times \frac{\pi}{4}\ D^2$

$$Fi = F$$

$$P \times \frac{\pi}{4} D^2 = \pi D t \sigma$$

$$\sigma = \frac{PD}{4t}$$

8–11(Hibbler): The staves or vertical members of the wooden tank are held together using semicircular hoops having a thickness of 0.5 in. and a width of 2 in. Determine the normal stress in hoop AB if the tank is subjected to an internal gauge pressure of 2 psi and this loading is transmitted directly to the hoops.Al so, if 0.25-in.-diameter bolts are used to connect each hoop together,determine the tensile stress in each bolt at A and B.Assume hoop AB supports the pressure loading within a 12-in. length of the tank as shown.



Solution :

$$\sum Fx = 0$$

$$Fi = 2F$$

$$P \times 12 \times 36 = 2 \times F$$

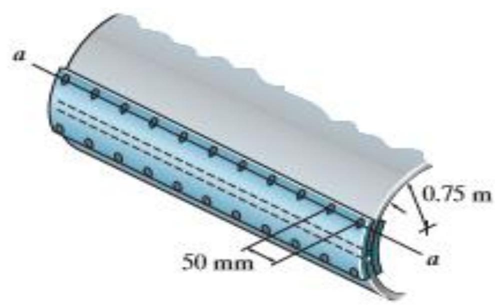
$$2 \times 12 \times 36 = 2 \times F$$

$$F = 432\ lb$$

$$\sigma(hoop) = \frac{432}{0.5 \times 2} = 432\ psi$$

$$\sigma(bolt) = \frac{432}{(0.25)^2 \times \frac{\pi}{4}} = 8801 \quad psi$$

H.W : A boiler is constructed of 8-mm thick steel plates that are fastened together at their ends using a butt joint consisting of two 8-mm cover plates and rivets having a diameter of 10 mm and spaced 50 mm apart as shown .If the steam pressure in the boiler is 1.35 MPa, determine (a) the circumferential stress in the boiler's plate apart from the seam, (b) the circumferential stress in the outer cover plate along the rivet line a–a, and (c)the shear stress in the rivets.



132 (singer): A cylindrical pressure vessel is fabricated from steel plate which have thickness of 20 mm. The diameter of pressure vessel is 500mm and its length is 3 m . Determine the maximum internal pressure which cancan be applied if the stress in the steel is limited to 140 MPa . If the internal pressure were increased until the vessel burst , sketch the type of fracture which would occure .

Solution :

$$\sigma t = \frac{PD}{2t}$$

$$140 = \frac{P \times 0.5}{2 \times 0.02}$$

$$p = 11.2 \; MPa$$

$$\sigma l = \frac{PD}{4t}$$

$$140 = \frac{P\times 0.5}{2\times 0.02}$$

$$P = 22.4\ MPa$$

$$\therefore P = 11.2\ \ MPa$$