# Unacademy

## Civil Engineering

## Toppers Handwritten Notes

## Strength Of Material

**By-Jaspal Sir**

# STRENGTH OF MATERIAL

★ Strength of material / Solid mechanics / Mechanics of solid / Mechanics of deformable bodies.

## Properties of Material

- It is the branch of science which deals with study of the behaviour of material when it is subjected to external loading. (Here load can be in form of force/moment).

- Each member of structure [eg:- beam, column, foundation, dams, pavement] are made up of different material, which could be rigid material or deformable material.

### ★ Rigid material

- It is the type of material which doesn't undergo any change in its geometry (shape/size) upon application of load.

  (or)

- A body/material is termed as rigid body/material if the distance between any two points

### ★ Deformable material

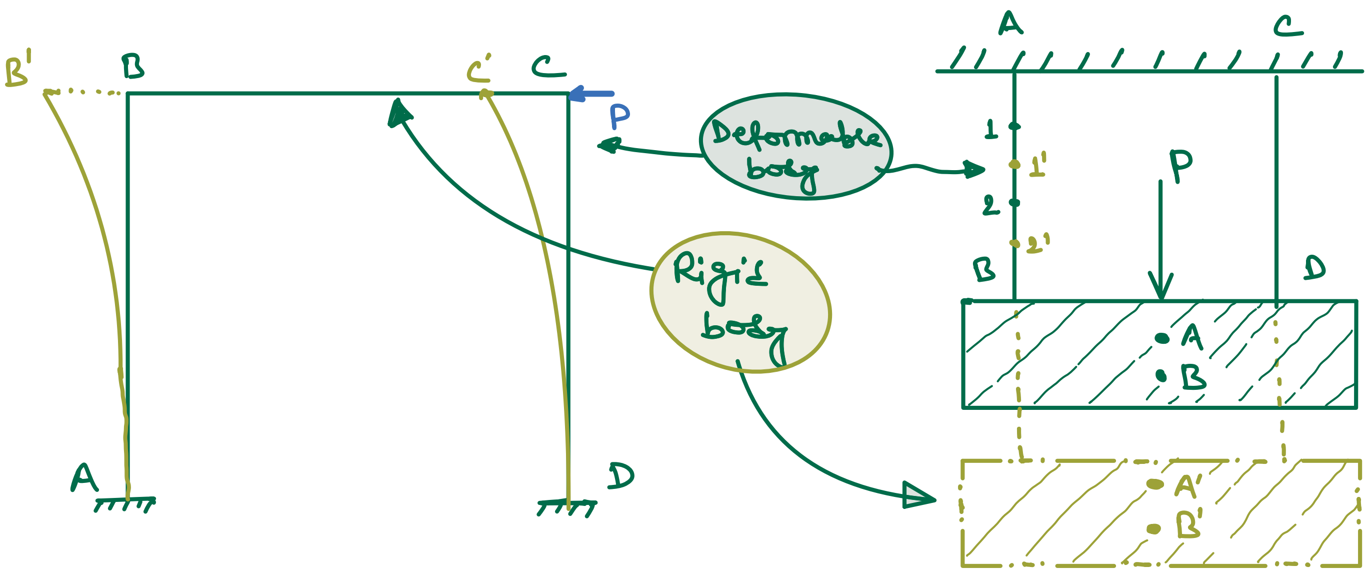
- It is the type of material which undergoes change in geometry (shape/size) upon application.

- This geometrical change in the body is termed as deformation/Strain.

  (or)

- A body is termed as deformable when distance between any two point changes upon application of load.

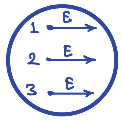
**Note:-**
The concept of ideal rigid body is hypothetical and this hypothesis is made to simplify the calculation.



# ★ Assumptions in strength of material

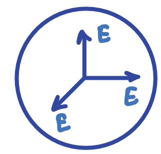
## i.) Material is considered to be homogeneous

- material is termed to be homogeneous if it exhibit same elastic properties at any point in given direction.
- Hence properties of homogeneous material is independent of point.
- Eg:- Steel.




## ii.) Material is considered to be isotropic.

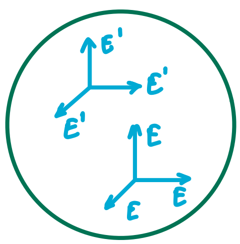
- material is termed to be isotropic if it same elastic properties in all directions at at a given point
- Hence, properties of isotropic material is independent of direction.
- Eg:- Glass



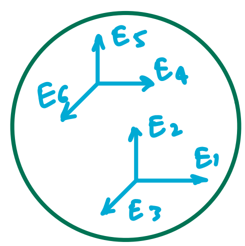

**Note :-**

- A homogeneous material need not be isotropic & an isotropic material need not be homogeneous.
- on macro level almost all materials are homogeneous & isotropic but on micro level all materials are Non-Homogeneous & Non-isotropic
  Atomic level.
  (here material is used for metals)

→ practically all combinations of these two properties are possible as follows:-



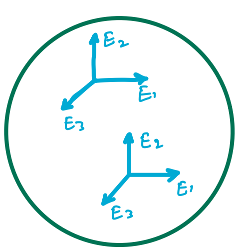

Non-Homogeneous + isotropic



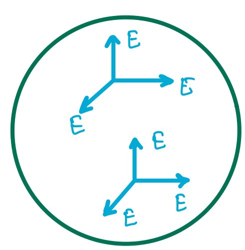

Non-Homogeneous + Non-isotropic

In actual every material is like this.

this is assumed for simple calculation




Homogeneous + Non-isotropic




Homogeneous + isotropic

# Load

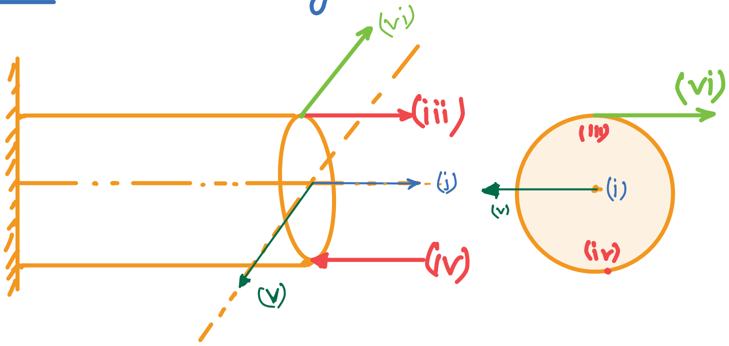
- It is an External force or moment experienced by the body.

classification

a.) **Based on direction of loading**

1.) Axial / longitudinal load :- Load being applied parallel to the axis of member
- May be tensile / compressive (i, iii) (ii) (iv) Eg:- [(i), (ii), (iii) (iv)]
- may be Eccentric / concentric (i) (ii) (iii) (iv)

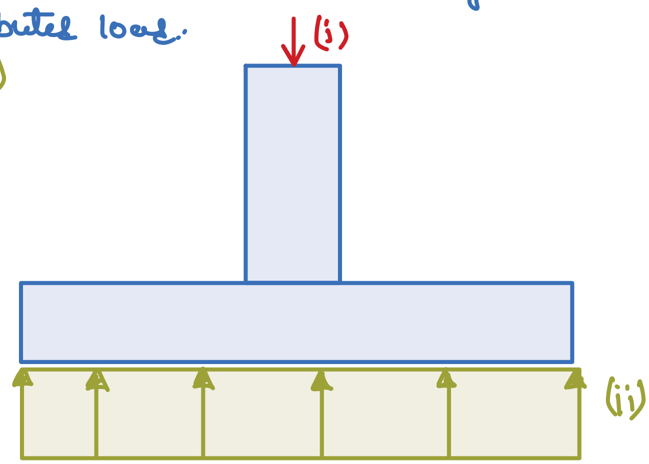
ii.) Transverse load. : Load being applied perpendicular to axis of member [(v), (vi)]




b.) **Based on Extent of loading**

i.) point load :- If the load acts comparatively on smaller area it is termed as point load. eg (i)

(ii) Disbuted Load :- If load is distributed over a larger area it is termed as Distributed load.
Eg:- (ii)




c.) **Based on dimension**

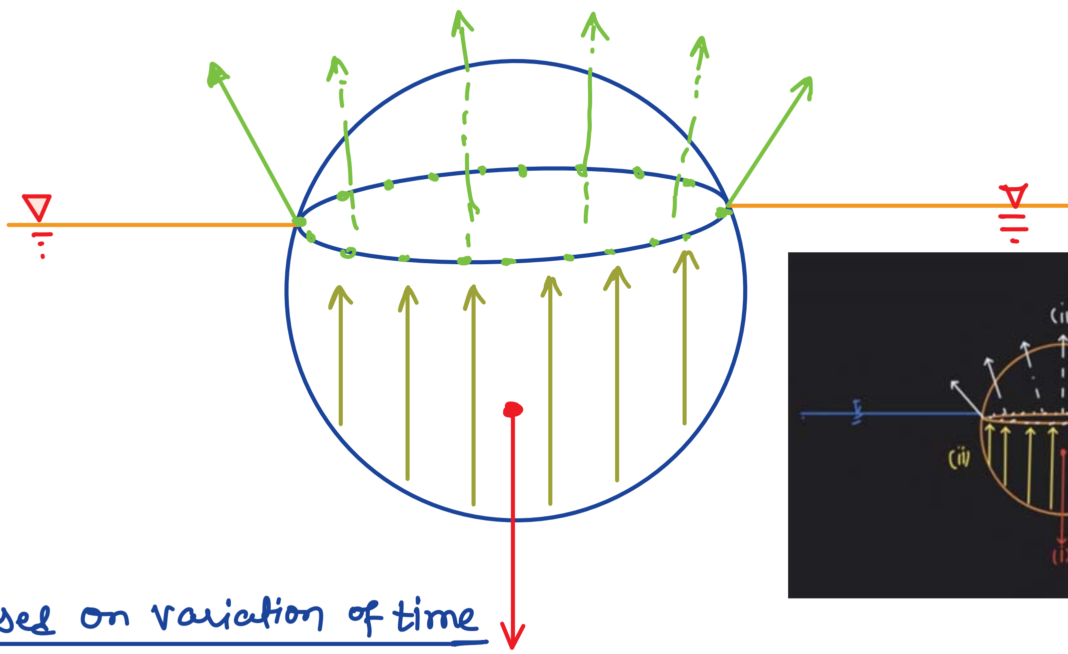
i.) Body / volume load : It is the load which acts over the volume or Body.
Eg:- Self weight, Buoyant weight centrifugal force.

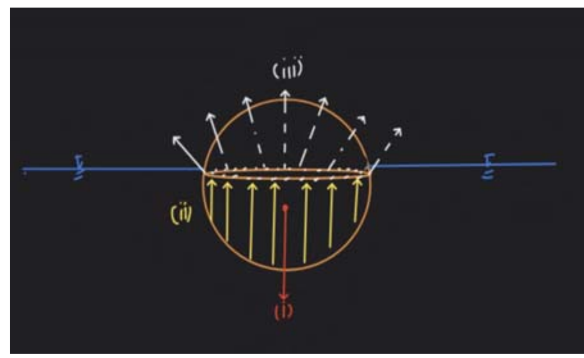
ii.) **Surface load** : load which acts over the surface.

Eg:- Drag force, Shear force.

iii.) **Line load** : Load which acts over the length (one dimension).

eg:- Rail Road, Surface Tension





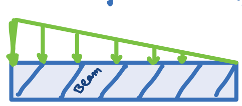

## e.) Based on variation of time

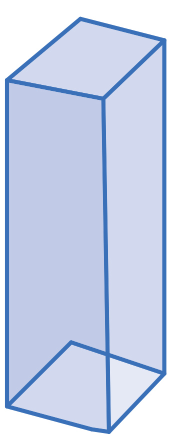
i.) **Static load** : A load is said to be static if its magnitude, direction & point of application do not changes wrt time.

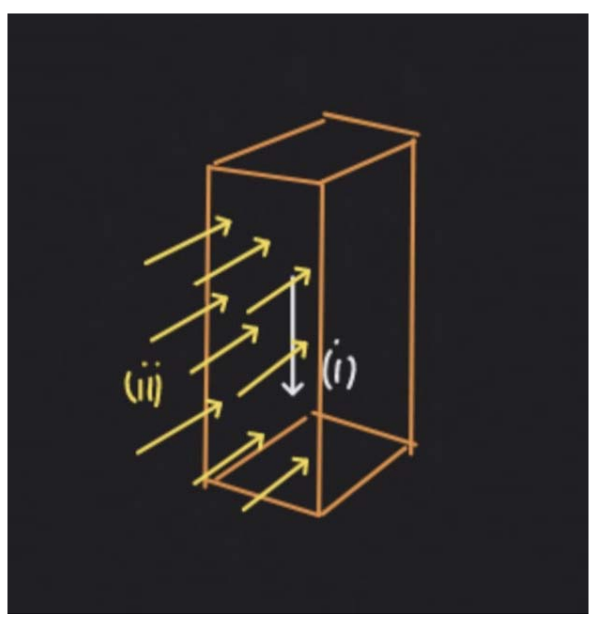
Eg:- Self weight. (i)

ii.) **Dynamic load** : A load is said to be dynamic any of its magnitude direction & point of application varies with respect to time.

(ii)

Eg:-  wind load, Seismic load, wave load.



## f.) Based on load Application time

i.) Gradually applied load / Quasi load. : It is type of load which reaches its maximum value in infinite time.

ii.) Suddenly Applied load : Type of load which reaches its maximum value instantly.

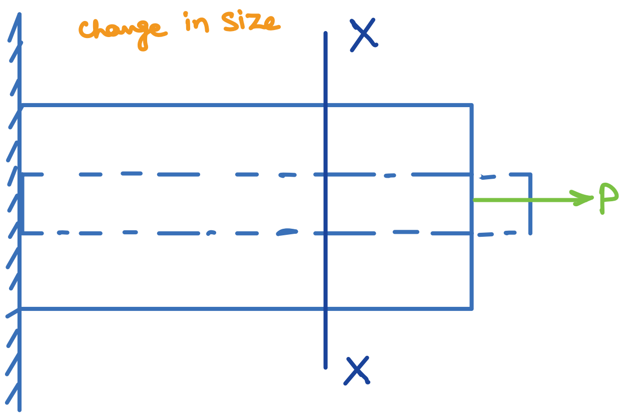
iii.) Impact Loading : In this type of loading, the time gap of application of load is more and relative velocity exist between loading and loading member.

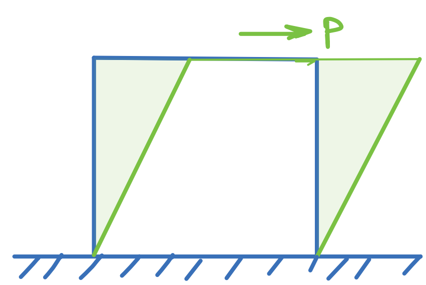
iv.) Shock loading : It is the type of load for which rate of application is very & time of application is very less.

## ☆ Stress and Strain

**Stress** : The internal resistance offered by material at a point against deformation caused by external load is termed as stress.

- It is always developed when body is restricted/constrained against deformation.

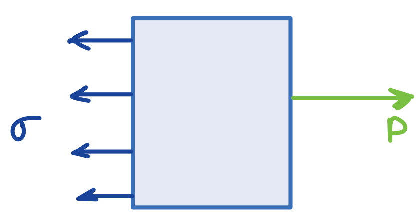



change in shape

$\sigma_{Longitudinal} \neq 0$

$\sigma_{Lateral} = 0$




Note:-

- Hence, "Strain is the Cause of Stress"
- "The maximum value of Stress which a body can resist without failure is termed as Strength."

→ Strength is the inherent property of material & does not depend upon its shape size, area or load being applied on it.

→ whereas Stress is not the property of material & is dependent upon load & area on which it is applied.

**Note:-**

- Stress may appear to be similar to pressure but is totally different from it as follows :-

a.) Stress is internal force per unit area whereas pressure is external force per unit area.

b.) Stress may not be normal to area, but pressure is always normal to area.

c.) Stress does not lead to pressure, but pressure lead to stress.

d.) Stress cannot be measured

e.) Pressure is a scalar quantity but stress is tensor quantity of 2nd degree or order.

# Stress can be classified as follows :-

i.) Normal Stress. ii.) Shear Stress

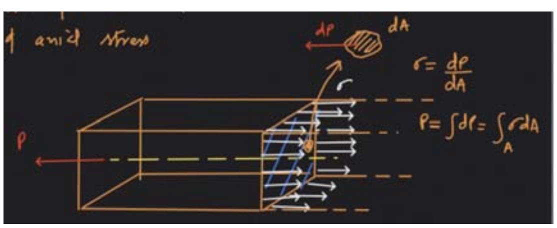
1.) Normal Stress :-

- It can be tensile or compressive.

★ These are further classified as:-

a.) Axial Stress :-

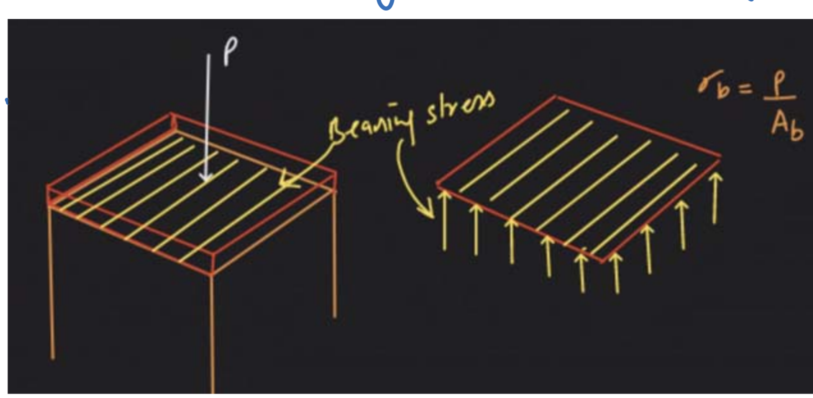
- If the load is directed along the axis of member it would lead to the development of axial stress.





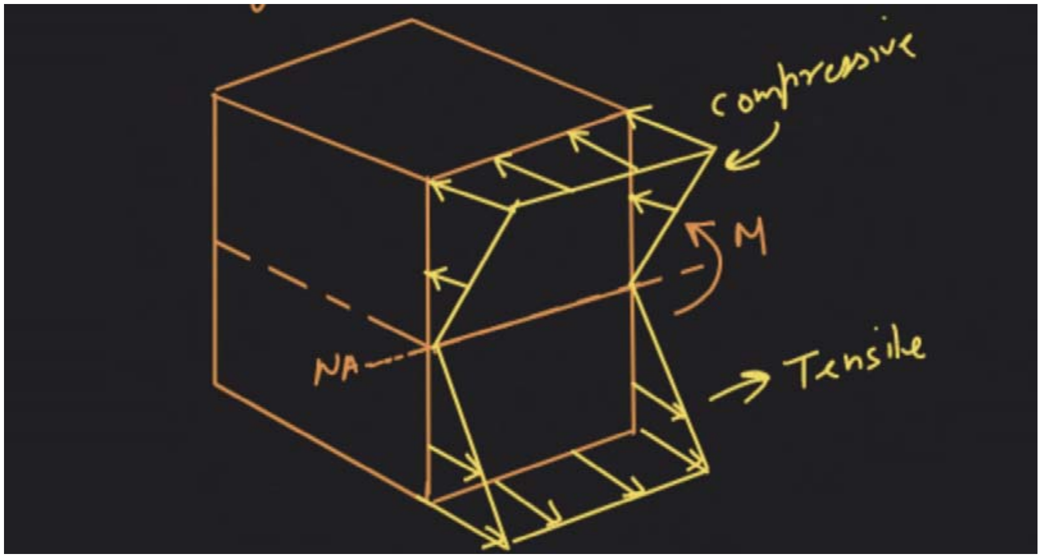
b.) Bearing Stress :-

- It is a stress which develops when body is supported by another body.
- It is compressive in Nature.



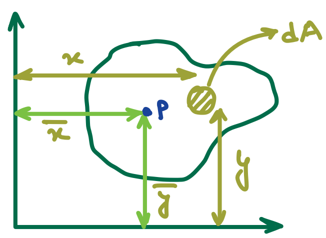
c:) **Bending Stress** :– Stresses developed due to bending of the members.

– It may be tensile or compressive in Nature.




**Note** :-

Line of action of axial force for uniform stress passes through C.G of Section.




Moment about x-Axis due to uniform Stress $= \int \sigma \, dA \, y$ — (i)

Moment about y-Axis due to Uniform Stress $= \int \sigma \, dA \, x$ — (ii)

moment about x-axis $= P\bar{y}$ – (iii)

Moment about y-axis $= P\bar{x}$ - (iv)

from (i) & (iii)

$$\int \sigma \, dA \, y = P\bar{y}$$

$$\int \frac{P}{A} dA \, y = P\bar{y}$$

$$\boxed{\bar{y} = \int y \frac{dA}{A}} \quad \text{- - - (A)}$$

from (ii) & (iv)

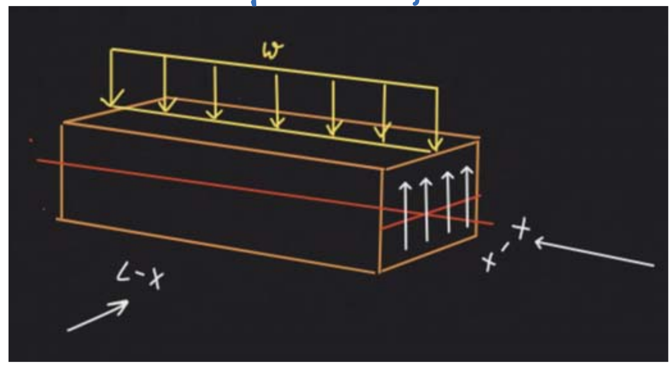
$$\int \sigma \, dA \, x = P\bar{x}$$

$$\int \frac{P}{A} dA \, x = P\bar{x}$$

$$\boxed{\bar{x} = \int x \frac{dA}{A}} \quad \text{- - - (B)}$$

## iii.) Shearing Stress

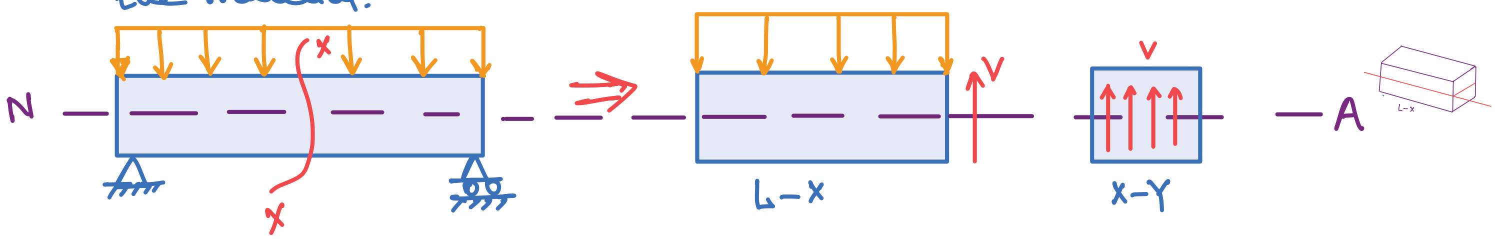
- It is the type of stress which acts in the plane of section.




- It is further classified as :-

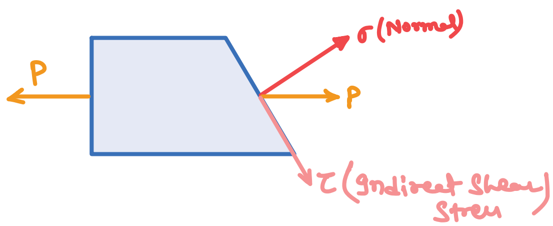
### i.) Direct Shear Stress

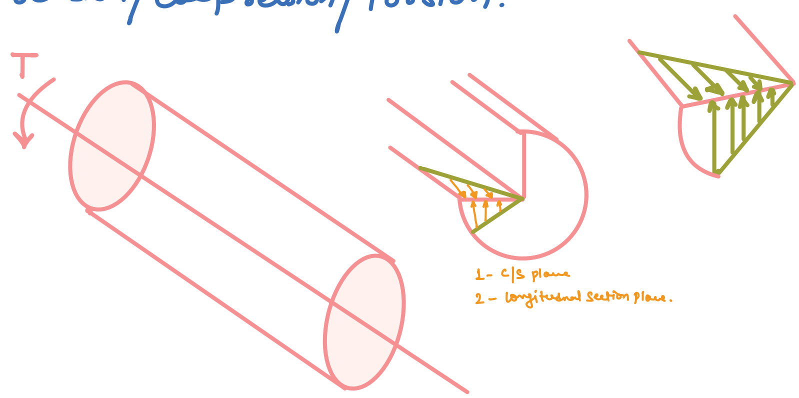
- The Shear stress which is developed due to direct action of force trying to cut through the material.




### ii.) Indirect Shear Stress

- It is developed due to either tension/Compression/Torsion.

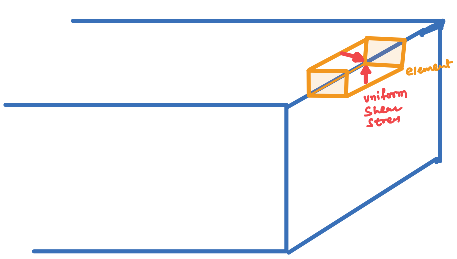


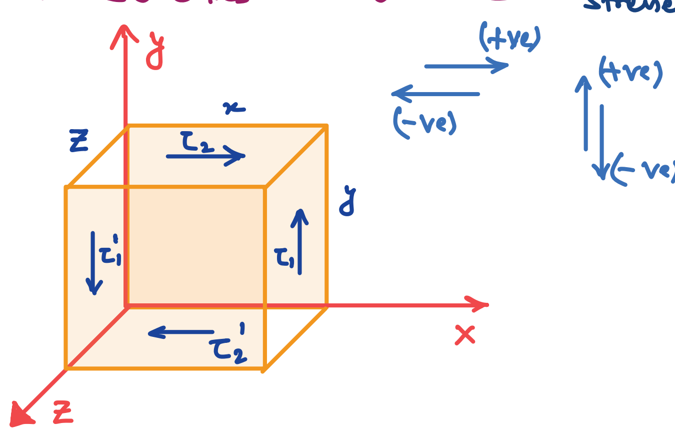




**Note:-**

i.) Shear stress acting on opposite faces of the element are equal in magnitude but opposite in direction.

ii.) Shear stress acting on adjacent and perpendicular faces of the element are equal in magnitude. Such that both the stresses point towards each other or both point away from line of intersection of the faces. (These stresses are termed as Conjugate Stresses)



## from force equilibrium :-

i.) $\Sigma F_y = 0$

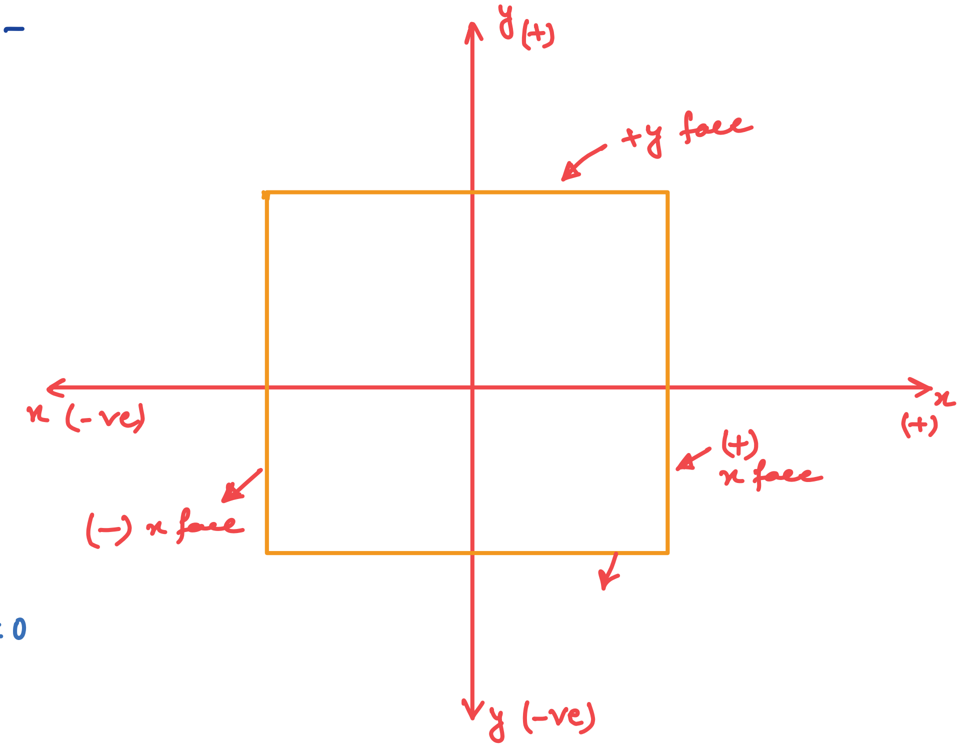
$$\tau_1 (yz) - \tau_1' (zy) = 0$$

$$\tau_1 = \tau_1'$$

ii.) $\Sigma F_x = 0$

$$\tau_2 (xz) - \tau_2' (xz) = 0$$

$$\tau_2 = \tau_2'$$




## from moment equilibrium:-

iii.) $\Sigma M_z = 0$

$$\tau_1 (yz) x - \tau_2 (xz) y = 0$$

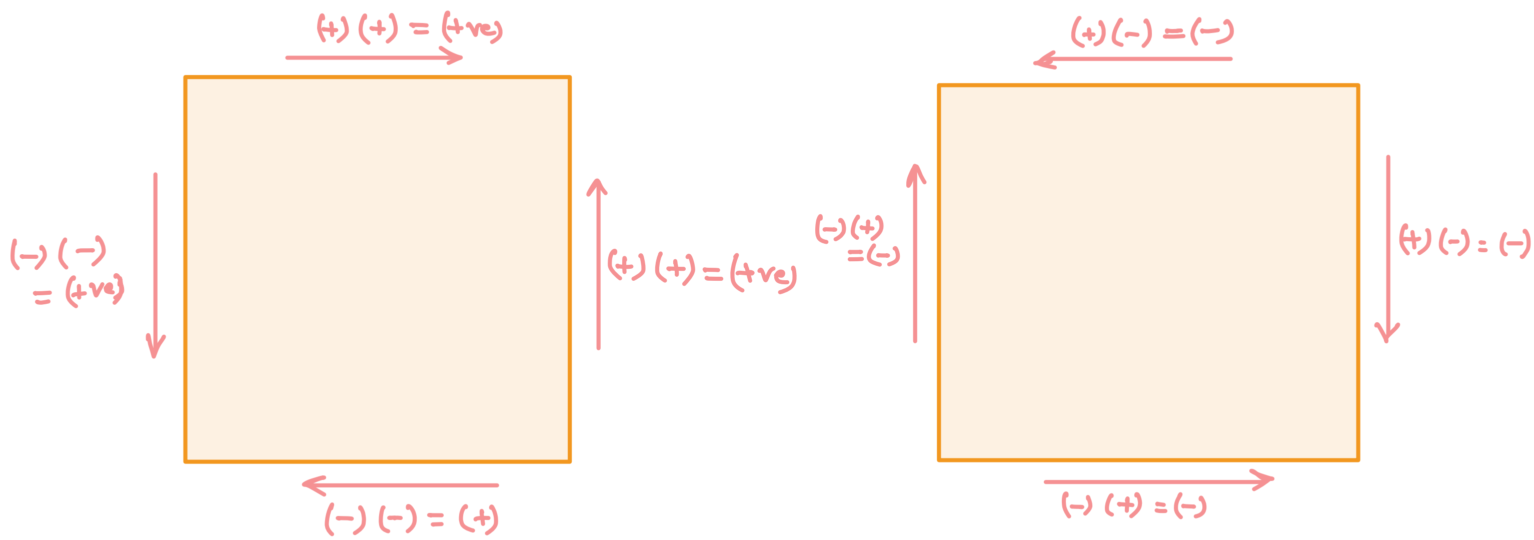
$$\tau_1 = \tau_2$$

## Note:-

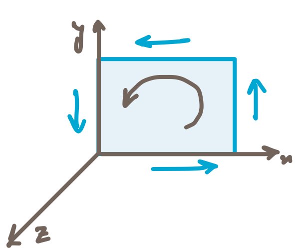
Sign convention for Shear Stress :-

a.) A Shear stress acting on positive face is (+ve) when if it acts in positive co-ordinate direction.
& (−ve) if it acts in (−ve) coordinate direction

b.) A Shear stress acting on Negative face is positive, if it acts in negative (−ve) coordinate direction. & Negative, if it acts in (+ve) positive coordinate direction.

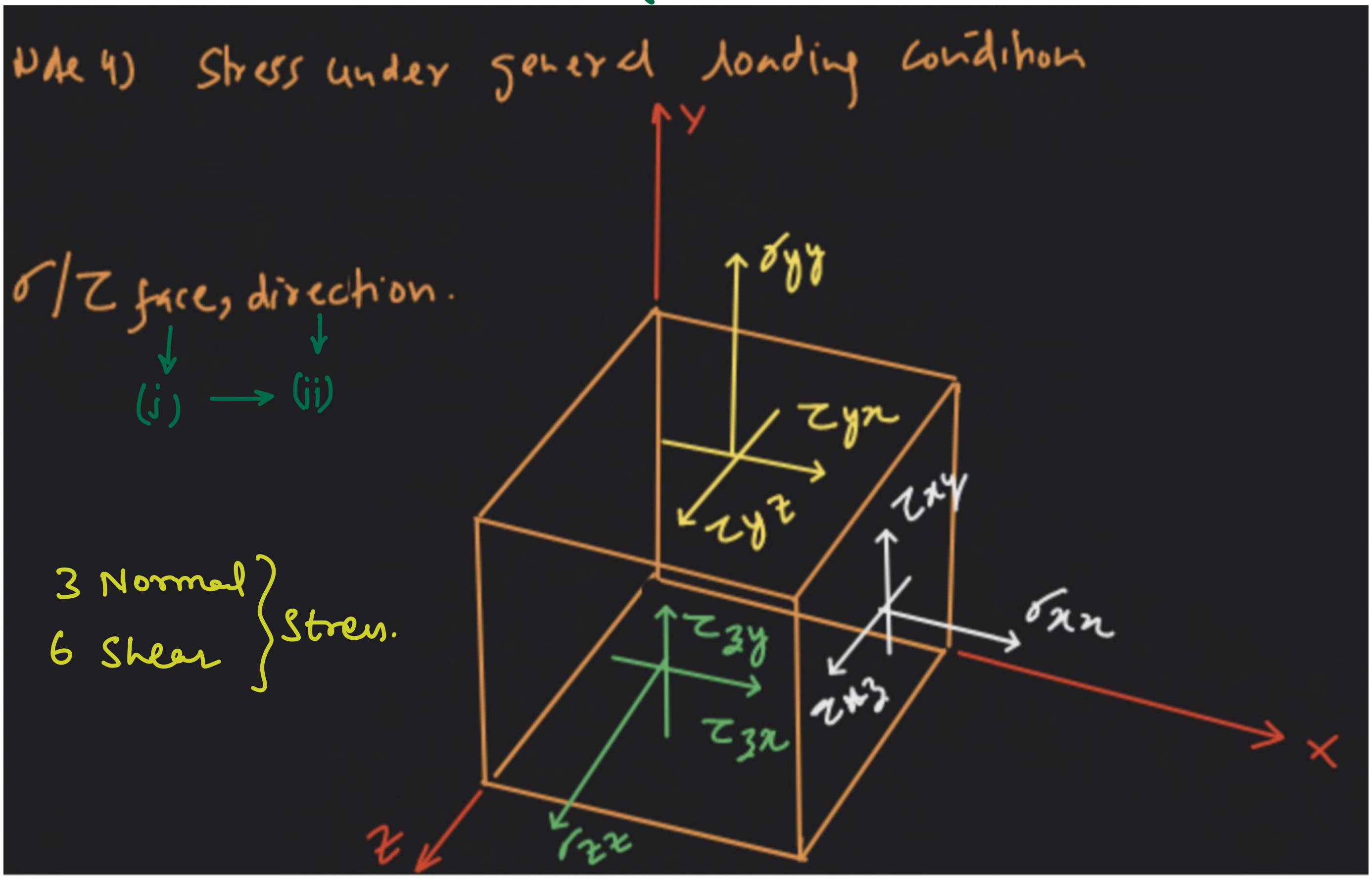



## problem:-




⇒ Not in equilibrium
— this case isn't possible.

**Note :-** Stress under general loading condition :-




— Stress tensor is as follows :-

$$
\sigma\left(\begin{matrix}\text{stress}\\ \text{tensor}\end{matrix}\right) = \begin{array}{c c} & \begin{matrix} x & \quad y & \quad z \end{matrix} \\ \begin{matrix} x \\ y \\ z \end{matrix} & \begin{bmatrix} \sigma_{xx} & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & \sigma_{yy} & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & \sigma_{zz} \end{bmatrix} \end{array}
$$

face

direction

→ Hence, at any point Stress has 9 dimensions/components in which
- 3 are Normal Stresses ($\sigma_{xx}, \sigma_{yy}, \sigma_{zz}$)
- 6 are Shear Stresses ($\tau_{xy}, \tau_{yx}, \tau_{xz}, \tau_{zx}, \tau_{yz}, \tau_{zy}$)
- But Complementry Stress are equal in magnitude.
- Hence only 6 dimensions/component are required to define the Stress at any given point.

→ 2D → $\sigma = \begin{bmatrix} \sigma_{xx} & \tau_{xy} \\ \tau_{yx} & \sigma_{yy} \end{bmatrix}$ ⇒ only 3 are required to define in 2D.