Toppersnotes

Unleash the topper in you

IES/GATE

CIVIL ENGINEERING

VOLUME – XI

S.O.M.

SIERRA INNOVATIONS

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SOM

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SOM

Chapter 1 - Introduction

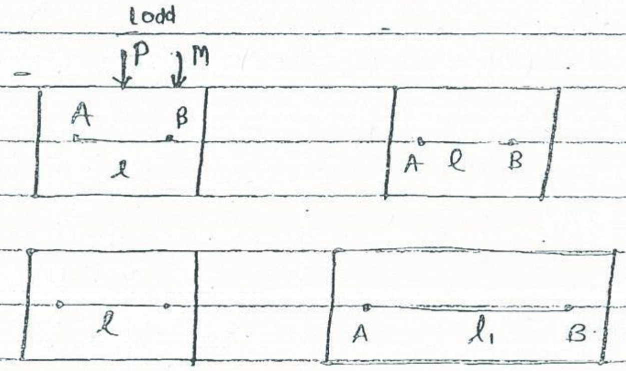
Engg science

- Solid Mechanics
  - Engg Mechanics (study of Rigid Body)
    - statics
    - Dynamic
      - Kinematic
      - Kinetics
  - SOM / MOS / SOHDB (study of Deformed Body)
- Fluid Mechanics
- Heat and Mass transfer
- properties of Material.

Kinematic: F = m(a) ✓ → (v) ✓

Kinetics: ✓(F) = m(a) → (v) ✓

Note:



Rigid Body (Engg. Mech)

$l_1 \neq l$

Deformed Body (SOM).

Engineering Mechanics

A physical science which deals with effect of forces of the object. In this we study of Rigid Bodies.

Rigid Body

A Body is considered a rigid when by Applying load (forces and Moment) changes in distance Betn the two points is Negligibale.

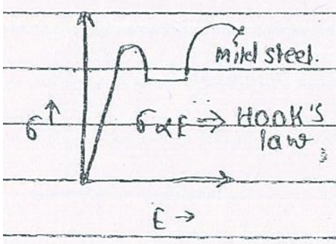
Deformable Body

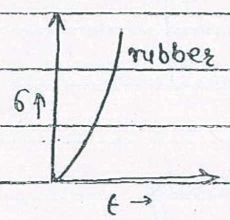
By Applying load if changes in distance betn two points is considerable called deformable body.

In Strength of Material we study deformable bodies

SOM

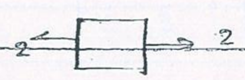
- Plastic Body
  - ✓ Linear elastic Body
  - Non-linear Elastic Body
- Viscoplastic Body





$\tau = \mu \frac{dv}{dy}$

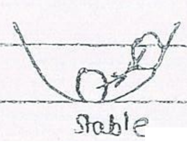
$v = u + at$

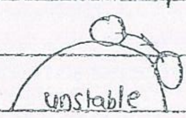


2 min → 0.01

2 hr → ≠ 0.01

*
- ✓ Stable eqm
- unstable eqm





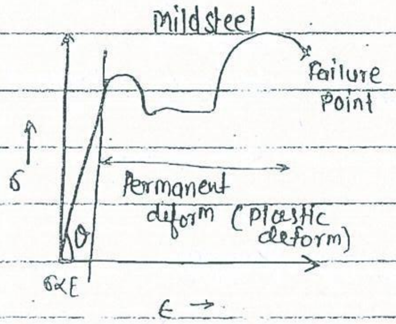
*
- ✓ equilibrium condn (F.B.D.)
- Non-eqm condition

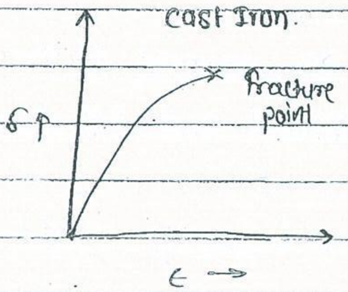
* Solid Mechanics are developed a Relationship betⁿ The load Applied two Non Rigid Body, Internal forces and The deformation Induced in the Body.

* Viscoplastic solid explain The Time dependant inelastic Behaviour of The solid (Viscoplastic and Viscoelastic Solid) have high plastic deformation zone.

* Failure

Failure
- plastic deformation
- fracture.





- Design engg. prefer Ductile Material Compare to Brittle Material

- In Ductile Material when plastic deformation starts (perm. deformⁿ or yielding) failure occures.

- In Brittle Material There is no plastic deformation and failure occures at The fractured point

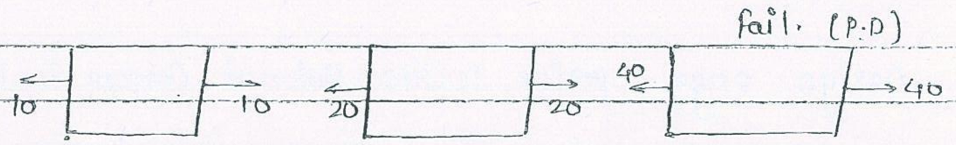
- In Ductile Material Before fracture Some indication to The designer, in The form of plastic deformation That Mean Component will fail after Some time But in Brittle Material There is No ~~indication in the form of yielding Before Fracture~~

That's why designer preffered ductile Material for designing purPose.

Strength

- It is defined as max^m value of stress that a Material can with stand without any failure.
- Strength is The Mechanical property of Material which does not depend on shape and size of The Component.
- It has a constant value (It is a True characteristic of Material).
- Stress Can be varried in The Material which ~~does not~~ depend on The load Applied and C/s Area used.
- Mild steel is frequently used for The designing purpose

Why



$\sigma = \frac{P_{in}}{A} = \frac{10}{2}$ $\quad$ $\sigma = \frac{20}{2}$ $\quad$ $\sigma = \frac{40}{2}$

$= 5\ mpa$ $\quad$ $= 10\ mpa$ $\quad$ $= 20\ Mpa$

$\sigma = 20 \rightarrow$ Strength of Material

* Stress only due to Internal force.

* Why Mild steel is preffered for the Design purpose ?

- It is ductile Material so it provide Indication to the designer in the form of yielding Before fracture. (Brittle Material does not show yielding Behaviour).

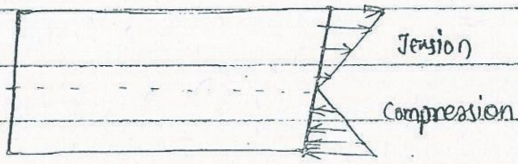
- Coefficient of Thermal expansion of Mild steel is Almost equal to the coefficient of Thermal expansion of Concrete.

- Young's Modulus of elasticity is same if Both Tension and compression

$$E_{Tension} = E_{compression}$$

$E_T = \frac{\text{Stress}}{\text{strain}}$

$E_C = \frac{\text{comp. stress}}{\text{strain}}$

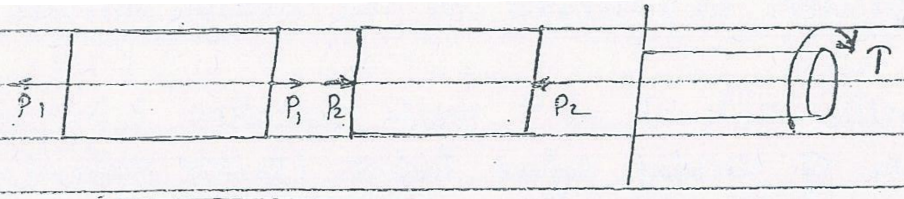


Bending stress

- Steel can be easily welded and joined
- It is easily Available and have less cost Compare to other Material.
- It is easily Recyclable
- Scrap value is ~~less~~ good.

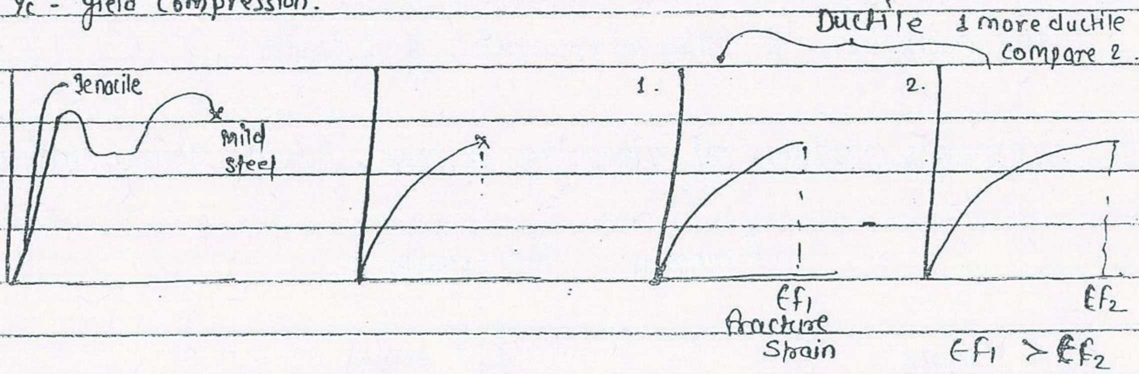
* Ductility

- Ductility Mean Can be drawn easily Into Thin wires.
- Ductile Material is strong in Tension, Moderate in Compression and weak in shear.
  (Any Material which have high tensile strength called as Tenacile Material)
- when The fracture strain is large it is called ductile ~~Material.~~



$\sigma_{yt} > \sigma_{yc} > \tau_y$

yt - yield Tension
yc - yield compression.

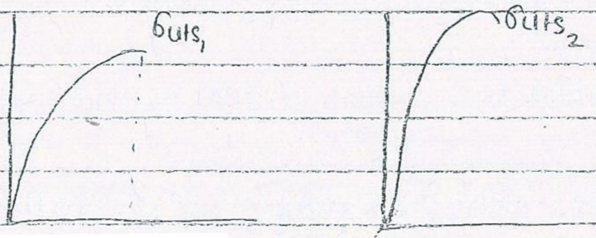


Mild steel : Aluminium, copper, Gold, silver, Lead.

* Brittleness

- Lack of ductility is called Brittleness
- Brittle Material strong in compression. Moderate in shear and weak in Tension.
- Tungston Brittle at Room Temprature and ductile at elevated Temp
- Brittle Material have less Fracture strain value compare to ductile Material

$\sigma_{yc} > \tau_y > \sigma_{yt}$



$\sigma_{uts_2} > \sigma_{uts_1}$

more Brittle

* Assumption used in SOM

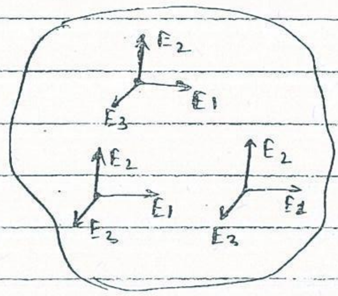
- Material is continous and deformable that means No voids and cracks in The Material.

- All The Materials are Homogenous and Isotropic

Homogenous :-

A Material is called homogenous when it have same elastic property E, G, K, ν at any point in given direction.

ex. Wood, Iron, Aluminium, steel.

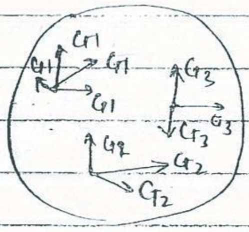


Homogenous

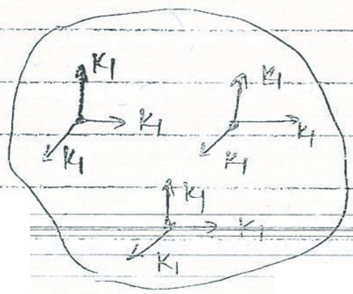
Isotropic :-

A Material is called Isotropic when it has same elastic property in Any Direction at a given point.

ex. glass, Brass, Aluminium, Copper, steel, Iron



Isotropic

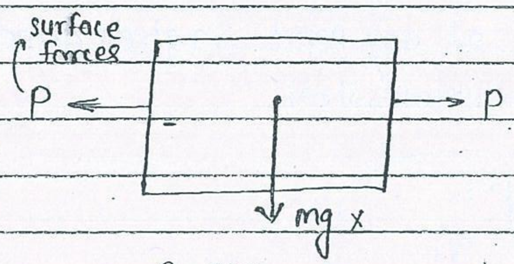


Homogenous + Isotropic.

Note :- If Test is Conducted on Average value Metal shows homogenous and Isotropic property.

But if Test is Conducted on Molecular level (Atomic level) Material are Non Homogenous and not show Isotropic properties.

- All Member are weightless that mean effect of body forces are Neglected and Analysis is carried out by the surface forces only.

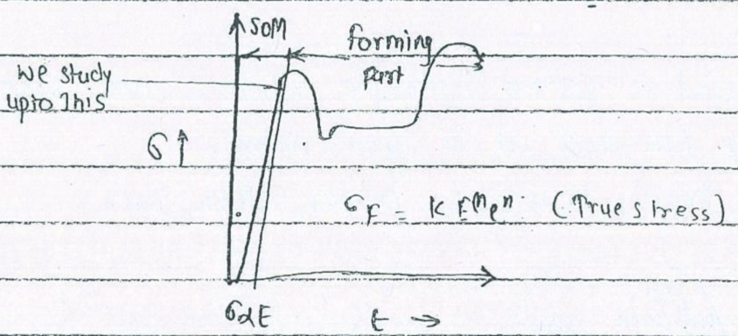


$\sigma = \frac{P}{A}$

$\sigma = \frac{mg}{A}$ x

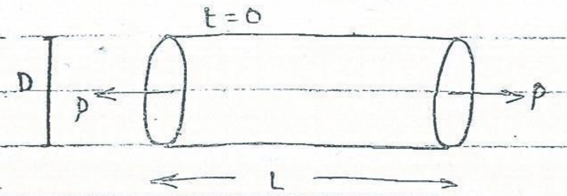
- Material follow hook's law that Means (Stress ∝ strain)

$E = \frac{\text{Stress}}{\text{Strain}}$

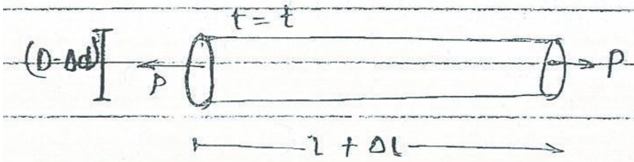


$\sigma_T = K \epsilon^{m} \epsilon^{n}$ (True stress).

- Superposition principal is valid (Algebric Sum) is used for The Calculation purpose Because hook's law is Valid.

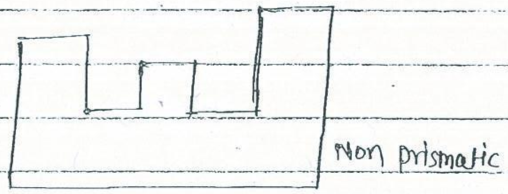


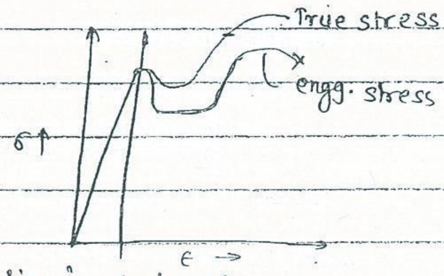
engg stress $= \frac{P}{A_{initial}} = \frac{P}{\frac{\pi}{4} D^2}$



True stress $= \frac{P}{A_{instanteniow}} = \frac{P}{\frac{\pi}{4}(D^2-\Delta d)^2}$

– Effect of True stress and True strain is Neglected





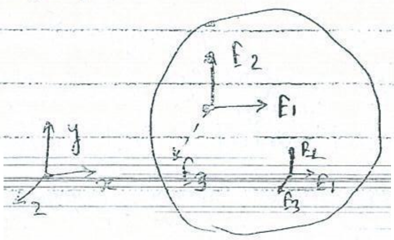
– All The Material should be prismatic in Nature
(prismatic - uniform Cross section Throughout The length)

– effect of residual stresses (Initial stresses) are Neglected that Mean Material used in The Analysis are stressed free.

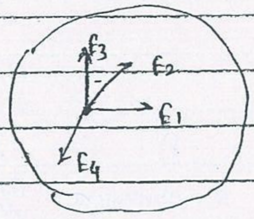
– Material follow Saint Vanant's principal

Orthotropic

A Material is said to be orthotropic if it has different elastic properties at any point in a given ⊥r Direction (orthogonal dirn)
ex wood graphite (All Material with layers)



* Anisotropic



It has different elastic property in different direction at a given point

ex. Material with Cracks, Voids, will Behave as Anisotropic Material.

* Factor of Safety

Ductile Material

$$FOS = \frac{\text{Yield stress}}{\text{Design stress / Working stress}}$$

Brittle Material

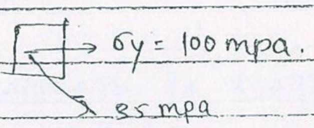
$$FOS = \frac{\text{Ultimate Tensile strength}}{\text{Design stress / working stress}}$$

$$FOS > 1$$

$$\boxed{FOS = 1.6 \text{ to } 4}$$

A — FOS = 2

B — FOS = 4



$\sigma_{Des} = \frac{100}{2} = \boxed{50 \text{ mpa}}$

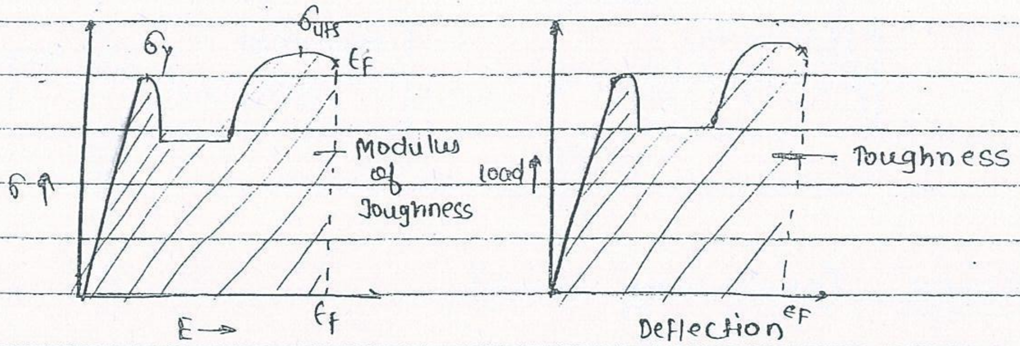
$\sigma_{Des} = \frac{100}{4} = \boxed{25 \text{ mpa}}$

- Since Assumption is used in SOM not possible practically so Factor of safety is used for the design Calculation.
- Higher the value of FOS lower will be the design efficiency That mean Total cost for designing is Increased.
- If used High FOS then for fullfilling the Reqm either High strength Material is used (condition) or c/s Area of the same Material is Increased. So both the Material cost will Increase

~~(for increasing the c/s Area some extra material deposit~~ which Increase the cost)

Toppersnotes
Unleash the topper in you

* Toughness

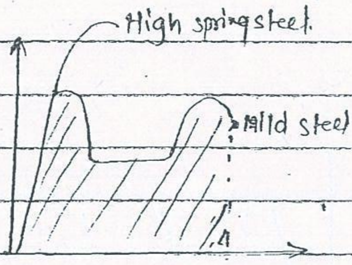


$$\frac{\text{Toughness}}{\text{Vol. of component}} = M.O.T \qquad MOT = \frac{\sigma_u + \sigma_y}{2} \cdot \epsilon_F$$

(σ_u → σ_{uts})

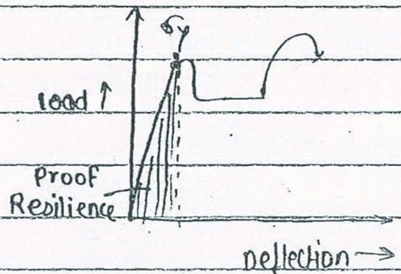
$$MOT = 0.75\, \sigma_{uts}\, \epsilon_F$$ ← Brittle

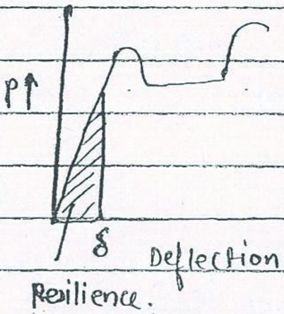
- It is for Impact loading
- It is Resistant Against fracture
- It is The Amount of energy i.e stored in The Material Before The fracture occures.
- To Determine The Toughness Tensile test is Conducted on The specimen and stress strain dig. is obtained (By load - Deflection curve)
- The Total Area under stress strain curve will Represent the energy Req. per unit volume to fracture The Material
- Irom is much Tougher Than glass because when we applied Impact load glass will break immediately while Iron piece absorbed substantial energy before fracture.
- for Designing of gears, Clouches, Crane, chains, very High strength Material used That Time designer used toughness property that so designed beyond the yield strain.
- since Ductile Material fracture strength is Higher than Brittle Material so generally toughness is more fo ductile material compare to Brittle Material.

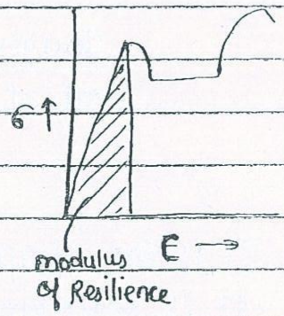


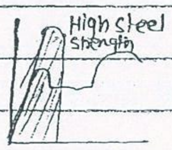
Toughness (Mild steel) > Toughness (H.S.S)

* Resilience (Strain energy Density)



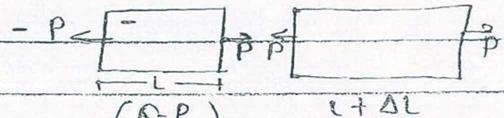






$(H.S.S)_{Resilience} > (Mild\ steel)_{Resilience}$

$$\text{Resilience} = \frac{1}{2} \times P \times \delta$$



$$= \frac{1}{2} \times (\sigma \cdot A)\ (\epsilon \cdot L) \qquad \left(\sigma = \frac{P}{A}\right)$$

$$= \frac{1}{2} \times \sigma \cdot \epsilon\ (A \cdot L) \qquad E = \frac{\sigma}{\epsilon}$$

$$= \frac{1}{2} \times \sigma \cdot \frac{\sigma}{E}\ V \qquad \epsilon = \frac{\sigma}{E}$$

$\text{Strain} = \frac{\Delta L}{L} = \frac{\delta}{L}$

$\Delta L = \delta$

* $\text{Resilience} = \frac{\sigma^2}{2E} \times \text{Volume}$

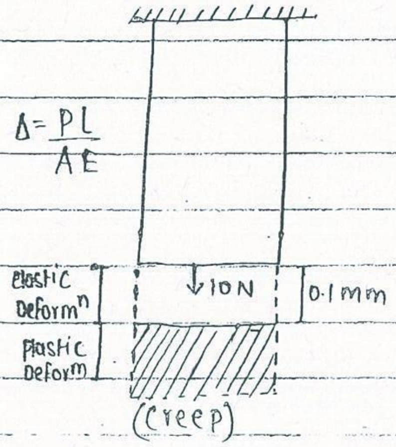
* $\text{proof Resilience} = \frac{\sigma_y^2}{2E} \times \text{volume} \qquad (\sigma_y = \sigma_{max})$

$M.O.R = \frac{\sigma_y^2}{2E}$

- The ability of Material to absorb energy when deformed elastically and to Retumed it when unloaded is called Resilience.
- This property is used for shock and vibration load.
  eg. used in spring.

- Since Modulus of Resilience does not depend on the dimension so it is True charachteristic of the Material (It has constant value)

* Creep



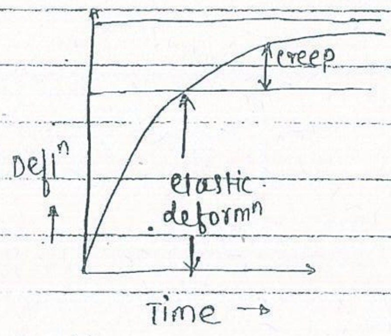
1] Temprature
2] Time
3] Magnitude of Load
4] Type of load.

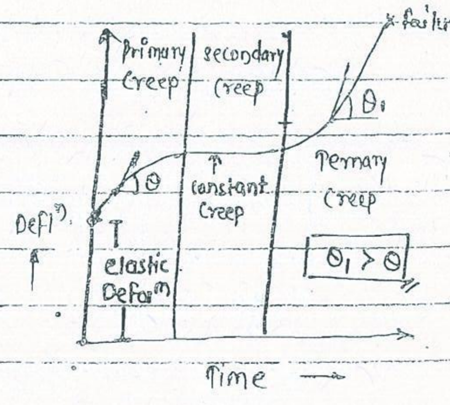
Fe → 1539°C

$\left(\frac{MP}{2}\right) = \frac{1539}{2}$

⇓

Homologus Temp^r





- It is a Material property due to This Material gets deformed progressively at a slow rate with Time at constant stress (due to dead load)
- Most Metal show Creep at elevated Temp, when Temp. Reaches half of The Melting point Temp of Metal creep becomes untolerable. Such Temp. is called Homologus Temp.

- Air craft, pressure vessel at High Temp, steam Turbine, gas Turbine are subjected to constant stress for a long period under such condition Material experience slow deformation which is called creep.

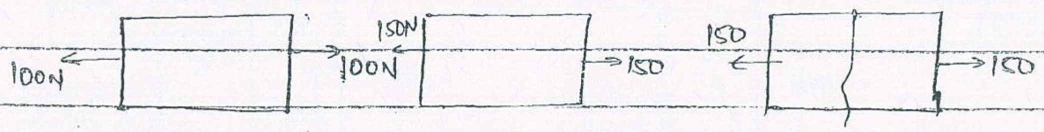
- In primary creep Rate of creep deformation decreases with Time

- In Secondary creep Rate of creep deformation is constant and called steady state.

- In Ternary creep Rate of creep deformation increases with Time until fracture occures (called progressive stage).

* Fatigue

yield strength = σ_y = 100 mpa



$\sigma = \frac{100}{2} = 50$ mpa. $\sigma = \frac{150}{2} = 75$ mpa

static

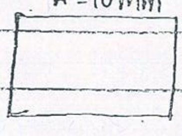
Force — vector quantity — Direction / Magnitude

σ_y = 250 mpa - mild steel

σ_e = 181 mpa - endurance limit (fatigue limit)

eg.

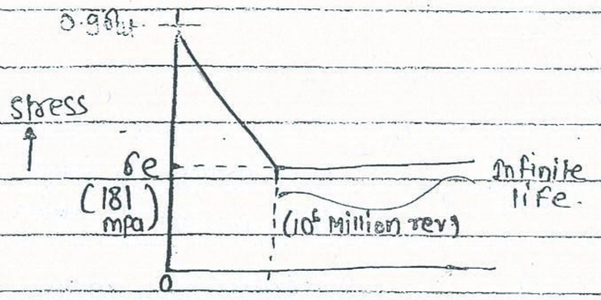
A = 10mm^2



Static load: $f = 250 \times 10 = 2500$ N

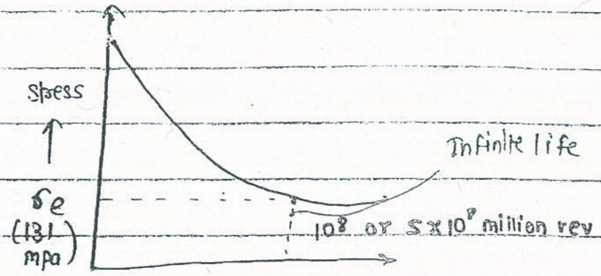
variable load: $f = 181 \times 10 = 1810$ N.

S-N Diagram (fatigue).



No of Revolution Before failure

(Mild steel)



No of Revolution Before failure

(Aluminium)

- when The loading is cyclic (variable) and No of Repetations are large a Metal Specimen may fail at a stress level below The yield stress such a failure is called fatigue failure.

- fatigue failure is to be Avoided when stress developed in The Component does not cross a particular limit called endurance limit or fatigue limit.

- fatigue failure always show Brittle fracture in The ductile Material (If variable load is Applied in The ductile Material it will not give any Indication in The form of yielding (plastic deformation) Before fracture.
  - eg Aircraft wings, Bridges, Multistorey Building, steam and gas Turbine Bear This Type of variable load

- endurance limit is quite below The yield strength of Material