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Mechanical properties of materials

Elasticity

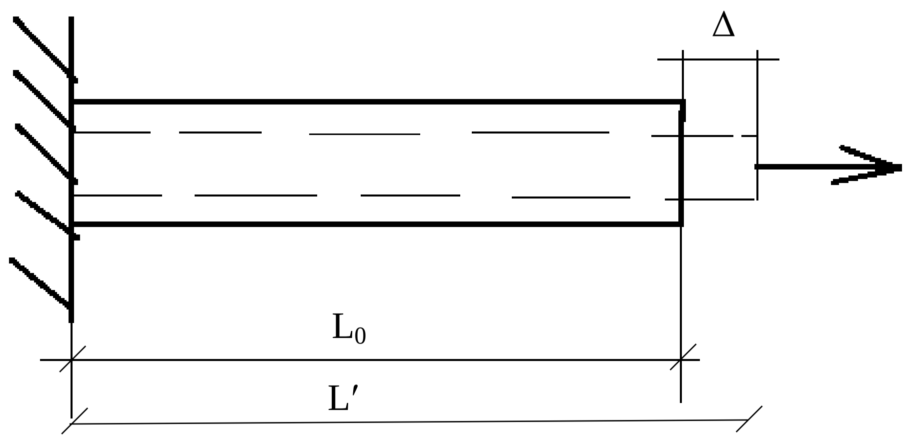
Is the ability of the material to return to its original dimensions when the external applied load is removed.

Plasticity

Is the property which permits materials to undergo permanent change in shape without fracture, i.e the material does not return to its original dimensions.

Ductility

Is the ability of the material to stand large plastic deformation in tension, i.e the property of the material which enables it to be drawn out to a considerable extent before failure.

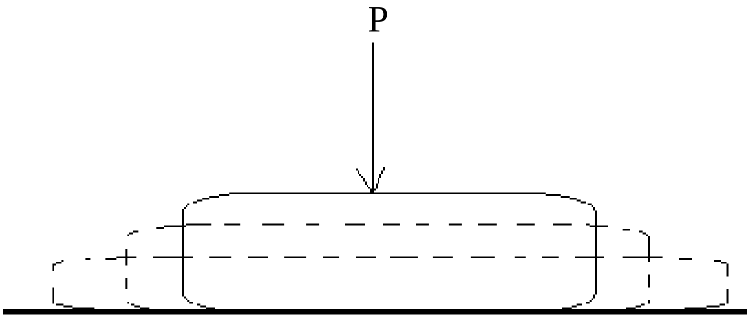


Elongation % = $(L' - L_0)/(L_0) \times 100$

Reduction of area % = $(A_0 - A')/(A_0) \times 100$

Malleability

Is the property which represents the capacity of the material to withstand plastic deformation in compression without failure.



Brittleness

Is the property of the material which makes it fractured before much or no deformation is noticeable.

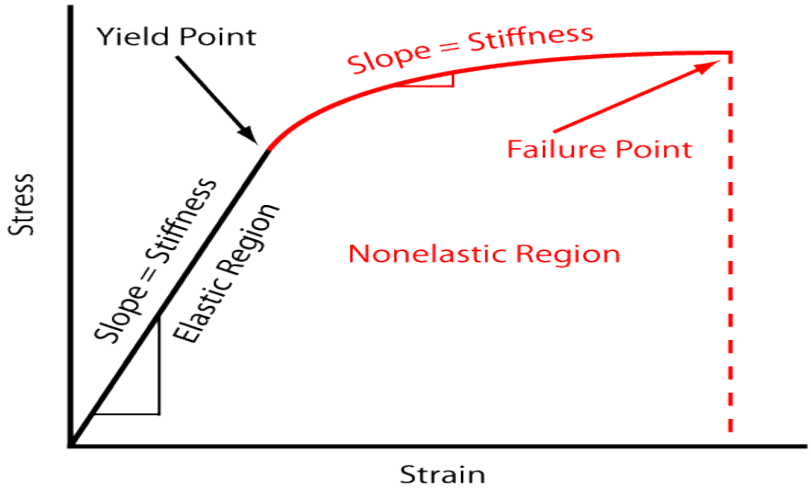
Strength

Is the resistance of the material to any applied forces, and is measured in the known stress units.

This resistance is usually known as the tensile strength if the applied load is tension or compressive strength if the applied force is compression. The ultimate strength is the maximum stress which the material is capable to withstand, developed under a slowly axial applied load.

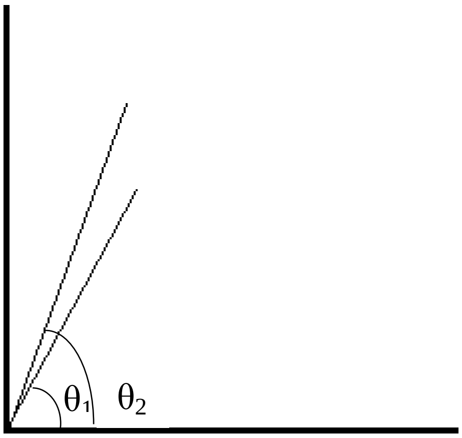
Stiffness

Is the property of the material to resist any sort of deformation. A stiff material is that material which withstand high unit stress with relatively small unit deformation. In uni-axial tension and compression tests, the stiffness is quantitatively measured by the modulus of elasticity within the elastic limit.



$$E = \tan(\theta)$$

$$E = \sigma / \varepsilon$$



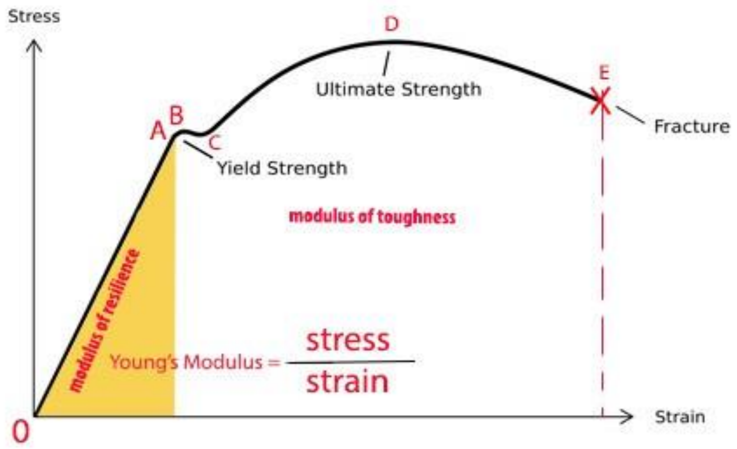
$E_1 = \tan\theta_1$, and $E_2 = \tan\theta_2$

but $\theta_1 > \theta_2$.

then, $E_1 > E_2$, the material no. (1) is stiffer than no. (2)

Toughness

It is the ability of the material to withstand or absorb mechanical energy. Tough material is that material which can withstand great deformation together with high stress. Toughness is measured by means of the modulus of toughness which represents the amount of energy absorbed per unit volume from the time of load application till failure.



Resilience

It is the capacity of the material to store mechanical energy; given in energy units (kg.m, or lb.in i.e. force. distance). Resilience is measured by the Modulus of Resilience, which is the maximum amount of mechanical energy that may be stored in a unit volume and be completely recovered upon the removal of load.

Hardness

Is the ability of the material to resist scratching, abrasion, cutting, or indentation. The hardness of non-metallic materials such as stones, gravel, and rock is usually measured by its resistance to abrasion by friction.

Endurance

Is the ability of the material to withstand repeated application of load. The endurance limit is the highest repeated stress that can be applied infinite number of times causing failure to the material.

Durability

Is the ability of the material to resist the internal or external destructive conditions over long period of time.

Types of loading

Static loading

The load is applied slowly and increases gradually till its maximum value without
developing any impact or vibrations.

a- Short time static loading: the time between the application of load and the load reaches its maximum value (at the specimen failure) is few minutes.

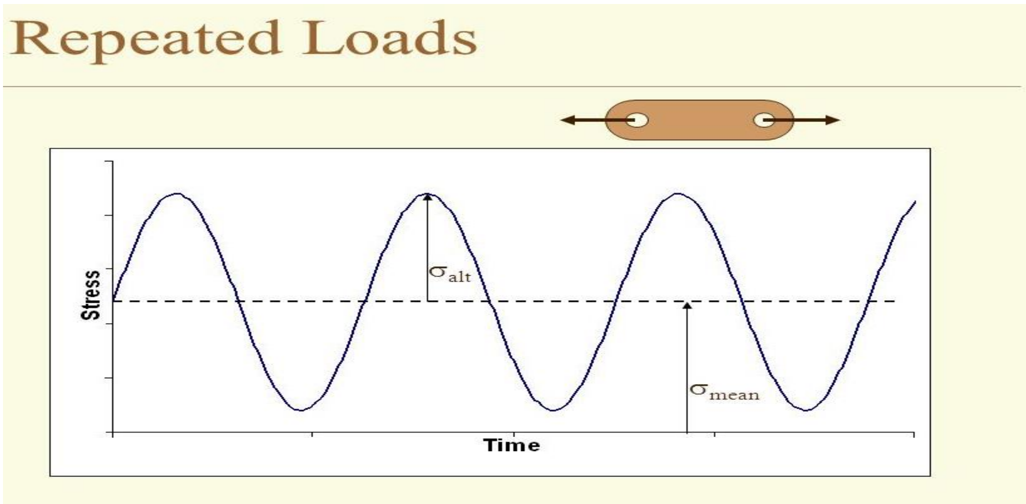
b- Long time static loading: The load is applied gradually till its maximum value, and remains constant for sufficient time to enable its probable final effect to be predicted.

Dynamic loading

The load is applied to the specimen in a form of vibrations or shocks. The dynamic loading may also be caused by impact.

Repeated loading

The load is applied in small quantities for several times.



Types of stress

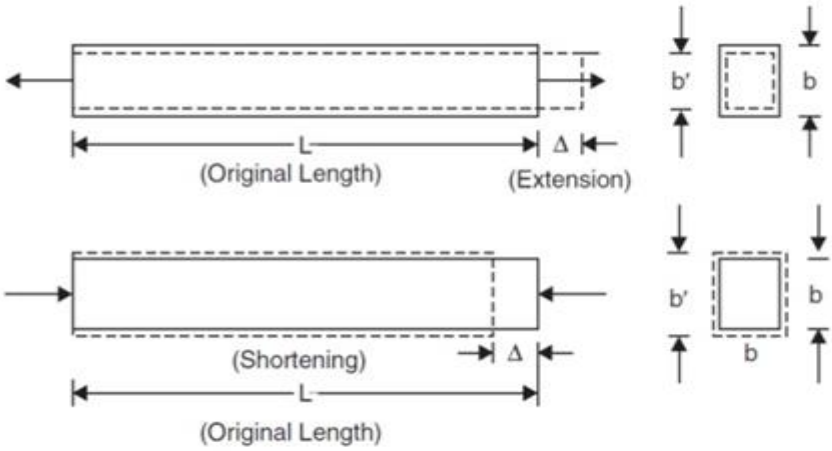
Strain

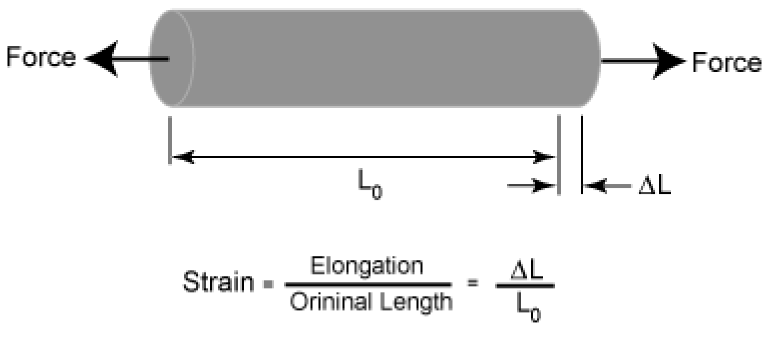
is a dimensionless value, it is the ratio between the change of length to the original length:

$\varepsilon = \Delta L / L_0$

Where:

ΔL = Change in length, L_0 = Original length.





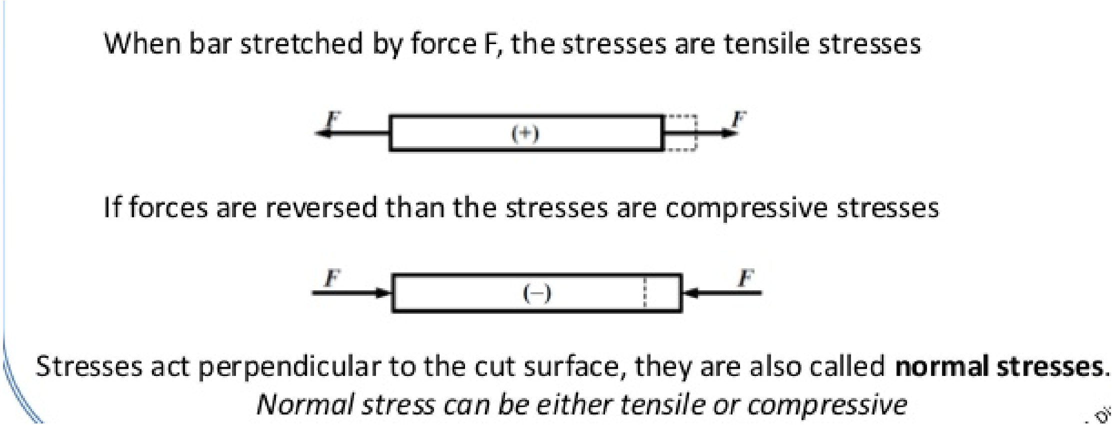
Stress

Is the intensity of internal forces = Force / Area

Stress units = Force unites / Area Units = Kg/cm^2, lb/in^2, T/m^2.

1 Kg. = 2.205 lb. and 1 in. = 2.54 cm

then 1 Kg/cm^2 = 14.223 lb / in^2 , and 1 Kg/cm^2 = 10.0 T/m^2.



Normal Stress

is the stress, normal to the section, and could be tension or compression stress

$\sigma = P/A$

Where: σ =Normal stress, P= Applied load, A =Cross sectional area

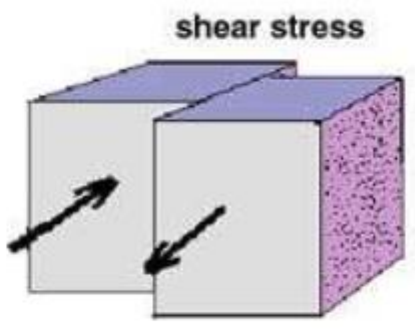
Shear stress

Is the tangential stress.

$\tau = Q/A$

Where:

τ = Shear stress, Q = Shearing (tangential) force, A= Cross-sectional area



Thermal Stress

One of the properties of metals is that it transfers heat. Physical changes that occur with this transfer include that expansion when the temperature increases and shrinkage when the temperature decreases. This happens in all three dimensions.

Thermal stress is stress that occurs as a result of thermal expansion of metallic structural members when the temperature changes. Changes in temperature cause thermal deformation to the structural members. The values of these deformation is given by the following relationship:

$\delta_t = \alpha \times L \times (T - T_0)$

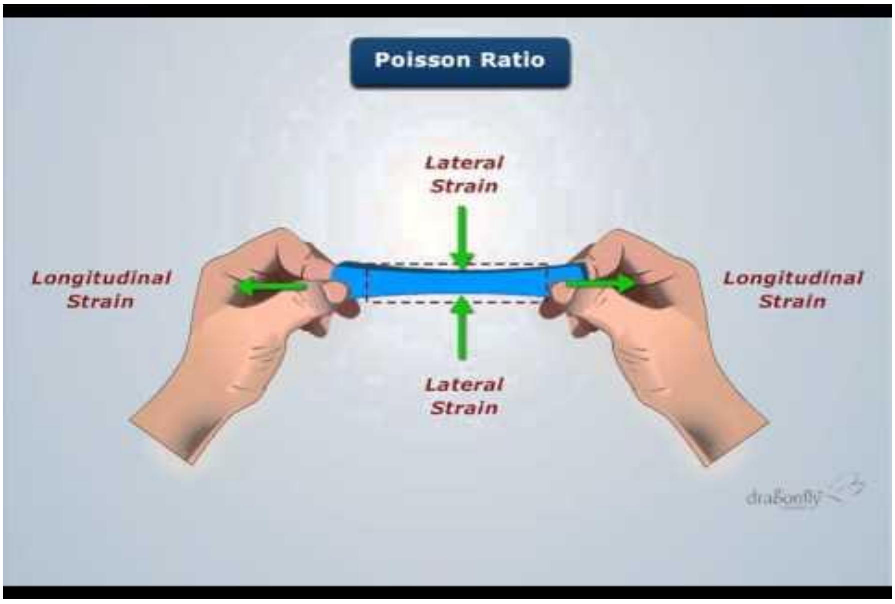
Where:

- δ_t is deformation of the structural member due to a change in temperature
- α is the temperature coefficient of expansion, a material property measured in units of Kelvin (K)
- *L* is original length of the member, measured in feet or meters
- *T* is the final temperature measured in unit of Kelvin or Celsius (^{o} for the international system and F^o for the English system).

Poisson's Ratio

Is the ratio between lateral strain to the longitudinal strain.

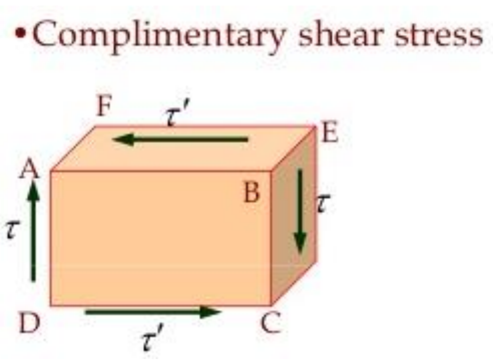
μ = *Lateral Strain/ Longitudinal Strain*



The value of μ for all materials varies over a range of $0.0 \leq \mu \leq 0.50$.

Complementary Shear

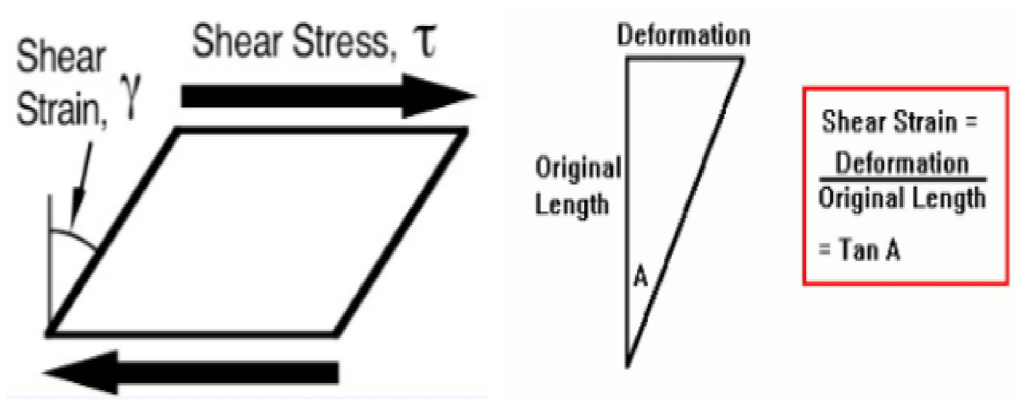
Shear stresses in vertical planes are always accompanied by shear stresses in horizontal planes perpendicular to the applied shearing force. Such stress is called complementary shear.



Shear strain

Is the ratio between the change in length in lateral direction to the original length

Shear Strain , $\gamma = \tan\gamma$, then $\gamma = L/x$



Shear Modulus

The shear modulus is the ratio between shear stress to shear strain

Shear Modulus G = Shear Stress/ Shear Strain , in stress units

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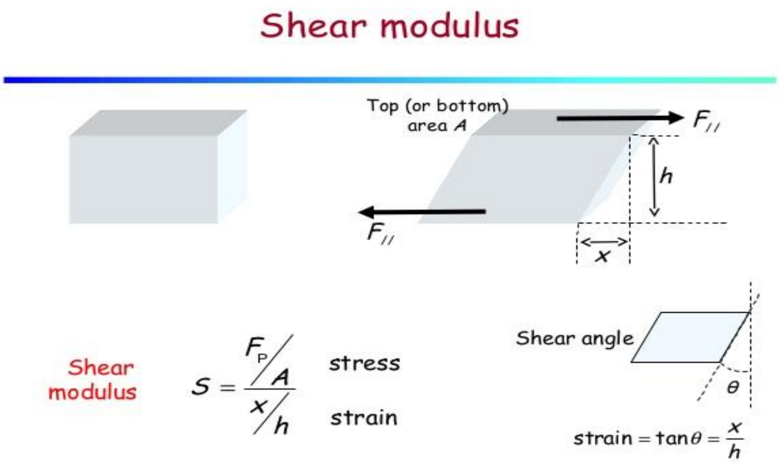

** Relation between E & G:

$G = E/[2(1+ \mu)]$

For steel, E = 2100 T/cm^2 = 2100×10^4 T/m^2

For concrete, E = 210 T/cm^2 = 210×10^4 T/m^2.