CVL3211 : Civil Engineering Materials

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Material Classification & Selection

Outlined factors are used to distinguish materials.

- Mechanical properties
- Non-mechanical properties
- Economic factors
- Production/Construction considerations
- Aesthetic properties

Mechanical Properties

Major Engineering properties of materials are highlighted below:

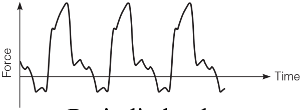
- Loading Conditions
- Stress-Strain Relations
    1. Elastic Behavior
    2. Elastoplastic Behavior
    3. Viscoelastic Behavior
- Work and Energy: Other factors related to stress-strain trend
- Failure and Safety
- Temperature and Time Effects

Loading Conditions

Loading of materials can be :

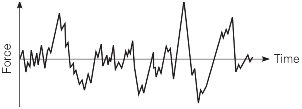
1. Static - Stationary load or dead load
2. Dynamic - Moving load or live load

Different kind of dynamic loading conditions as shown below, affect materials differently:



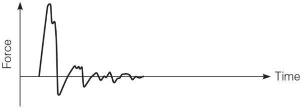
Periodic load

Machine load



Random load

Earthquake load, wind load



Transient load

Truck load

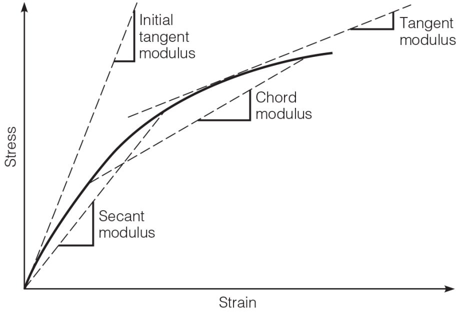
Stress-Strain Relations

A material shows deformation if load is applied. This give rise to basic Stress-strain response of material.

According to Hooke's law, Stress $\propto$ Strain

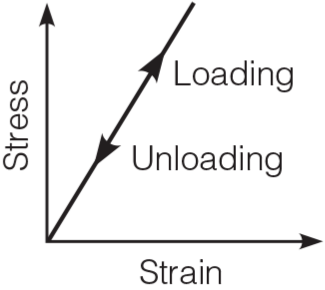
$\equiv \sigma \ \ \propto \epsilon \equiv \sigma \ \ = E\epsilon$

Where E = Young's modulus, It is defined by various methods from stress-strain response as shown below.

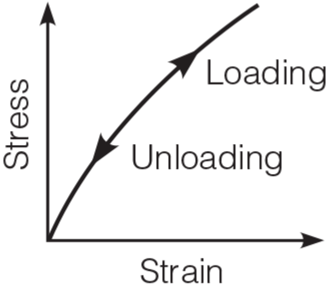


Elastic Behavior

Material regains its shape after removal of load. Stress-strain path can be linear or non-linear.



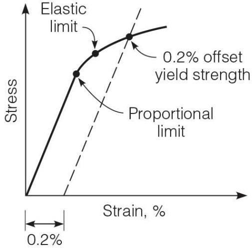
Linear Elastic



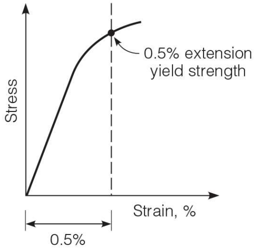
Non-linear Elastic

Elastoplastic Behavior

- This kind of materials behave in both ways: elastic and plastic.
- At elastic limit, elastic to plastic transition occurs.
- Elastic limit is not well defined as the transition from elastic to plastic is generally gradual not abrupt.
- That's why Yield stress/strength is defined. Two methods given below show how to locate Yield strength.



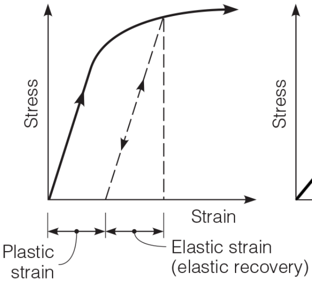
Offset method

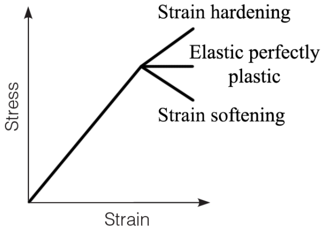


Extension method

Elastoplastic Behavior

- If stress is applied beyond elastic limit, after unloading, material retains a residual (plastic) deformation.
- After elastic point/Yield strength, material can follow any of the three paths:
  1. Strain hardening. e.g. Steel (ductile)
  2. Perfectly plastic. e.g.
  3. Strain softening. e.g. Concrete (brittle)

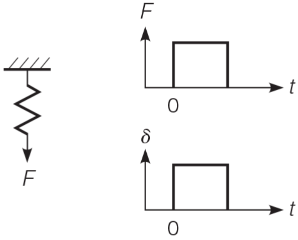




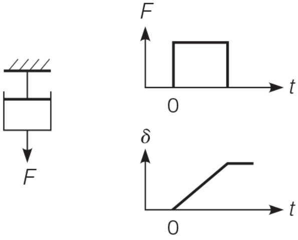
Viscoelastic Behavior

This type of material shows:

1. Elastic behavior - Hooke's law is followed.
2. Viscous behavior - Newton's law is followed.



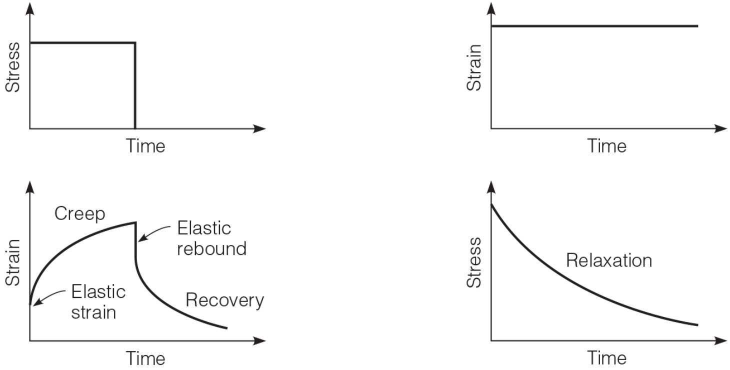
Hooke's model



Newton's model

It can be seen that stress and strain both are time dependent.

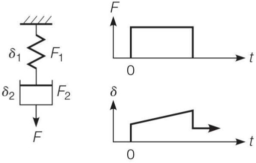
Viscoelastic materials like Asphalt show creep and relaxation behavior.



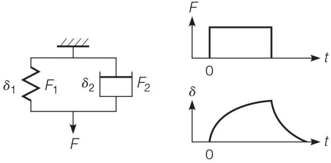
A constant load is applied on material for long time. After unloading, some residual strain remains.

A constant strain is applied for a long time. Stress dissipates as the material relaxes.

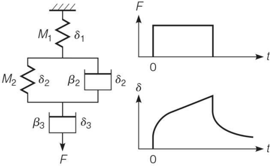
1. Several rheological model have been hypothesized as a combination of Hooke (Spring) and Newton (Dashpot) model.
2. Best fit model is Burger's model as shown below. It can be only fitted for uniaxial behavior of material.
3. Triaxial behavior of viscoelastic material is still a debatable topic.



Maxwell's model

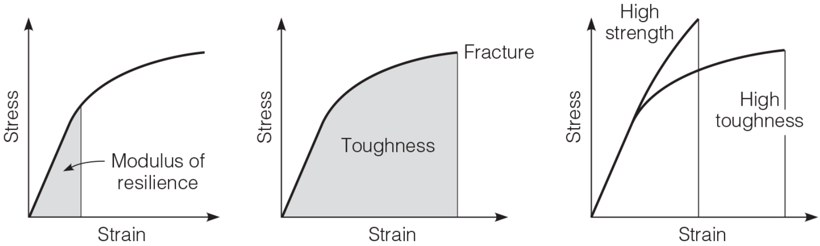


Kelvin's model



Burger's model

Resilience and Toughness



Two points can be generalized from above figures:

1. Higher the Modulus of Resilience, longer will be elastic range or vice versa
2. More toughness means higher fracture limit or vice versa.

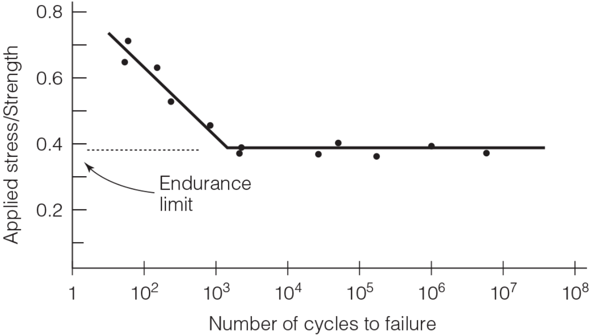
Modes of failure and Safety

A material may undergo any of the few outlined modes of failure:

- Fracture
  Brittle materials undergo sudden fracture and fail.
- Fatigue
  Repeated loading lesser then Yield strength cause fatigue
- General yielding
  Reaching the Yield strength of a material.
- Buckling
  Slander members may undergo twisting or buckling.
- Excessive deformation
  Ductile materials may undergo excessive deformation and fail for serviceability.

Fatigue

Repetitive loading cause fatigue.
Figure below shows how a material can be withheld a repetitive load for given number of cycles.
Below Endurance limit, a material is safe for fatigue (loading till infinite number of cycles).



Non-mechanical Properties

- Density and Unit Weight
  unit weight $=$ density $\times$ acceleration due to gravity i.e. $\gamma = \rho g$
- Thermal Expansion
  Linear expansion: $\alpha_l \delta T = \delta L$
  Volume expansion: $\alpha_v \delta T = \delta V$
  For isotropic materials: $\alpha_v = 3 \times \alpha_l$
- Surface Characteristics
  - Corrosion and Degradation
  - Abrasion and Wear resistance
  - Surface texture