• Elastic materials are known to experience elongation when put into tension.

• The transverse (lateral) dimension will change as a result of axial strain.

• The ratio of lateral strain to axial strain is called Poisson’s Ratio.

• This is a material constant and commonly used values of Poisson’s Ratio are given in Appendix G.

\[ \text{Poisson’s Ratio} = \mu = \frac{\varepsilon_{\text{Transverse}}}{\varepsilon_{\text{Axial}}} \]
A 10 foot long rectangular A572 Grade 50 steel plate 1" by 12" is used as a hanger and subjected to a tensile load of 240 kips, the proportional limit (yield strength) is the steel is 45 ksi.

Compute:

a) Axial stress
b) Axial strain
c) Transverse strain
d) Axial elongation
e) Transverse deformation of the 12 inch side
Example: Poisson’s Ratio loading in two directions

A 12 inch long 1” x 3” A36 steel bar is loaded as shown. The proportional limit of the steel is 34 ksi.

Compute:

a) Strain in x and y direction
b) Dimensional changes in x and y directions
Shear Modulus

• Similar to Modulus of Elasticity \( E = \frac{s_{\text{axial}}}{e_{\text{axial}}} \)

• Elastic materials also have a Shear Modulus “G”:
  \[ G = \frac{s_{\text{shear}}}{e_{\text{shear}}} \]

Where shear strain \( e_s = \frac{\delta}{L_0} \)

AND shear stress is: \( s_s = \frac{P}{A} \)

• There is a relationship between \( E \) & \( G \)
  \[ G = \frac{E}{2(1+\mu)} \]
A two inch diameter metal specimen is subjected to an axial load of 40 kips. Transverse and longitudinal changes are measured and strains are measured to be .0012 longitudinally and .0004 transversely.

Compute:

A) Poisson’s Ratio  
B) Modulus of Elasticity E  
C) Shear Modulus G
Materials used in engineering will experience changes in shape due to temperature changes.

Most materials expand as they heat and contract as they cool.

The coefficient of thermal expansion “α gamma” is a known constant for most materials and can be found in App. G.

**The change in length due to thermal effects:** \( \delta = \alpha L (\Delta T) \)

If an element is restrained against thermal effects, it will experience internal **stress which can be calculated as**:

From our previous work: \( \delta = \frac{PL}{A} = s(L) \), since P/A equal stress “s”

\[ \frac{AE}{E} \]

Equating the two values: \( \delta = s(L) = \alpha L (\Delta T) \)

\[ \frac{E}{E} \]

So, stress due to thermal effects: \( s = \alpha E \Delta T \)
Compute the stress in the A36 steel rod shown if the supports yield and total displacement is .02 inches as the temperature drops from 70°F to 0°F. Cross sectional area of the rod is 2 in².
Steel crane rails are laid with their adjacent ends 3.2 mm apart when the temperature is 15°C. The length of each rail is 18 m.

a. Calculate the temperature at which the rails touch end-to-end.

b. Calculate the gap between adjacent ends when the temperature drops to -10°C.

c. Calculate the compressive stress when the temperature reaches 45°C.
Members Composed of Two or More Components

- We must also be able to evaluate thermal effects when we have members that are composed of different materials.
  - I.e., deformation will be and/or stress will be cumulative.

- Calculate the stress in each component of the member shown when the temperature rises 20°F.
• Sometimes you will see differing materials sandwiched or layered to create a member.

• In this case, the deformations of the components is equal but the stresses are different due to the difference in E between the materials.

• Given the same deformation, the stress in the material with the higher E value will be greater than the stress in the material with the lower E value.

• For instance, assuming the materials are the same length initially and deform equally (see sketch)

\[ \delta_a = \delta_b \quad \text{AND} \quad e_a = e_b \quad \text{SO} \quad \frac{S_a}{S_b} = \frac{E_a}{E_b} \]

So, we can find the stress in material A by solving for

\[ S_a = \frac{E_a S_b}{E_b} \]

We can replace \( \frac{E_a}{E_b} \) with modular ratio \( n \)

So, then

\[ S_a = n \ S_b \]
Composite Members inParallel (Sandwiched)

This parallel concept can be taken further: \[ P_{\text{total}} = P_a + P_b \]

Substitute the stress formula rearranged: \[ P_{\text{total}} = A_a S_a + A_b S_b \]

We can now substitute: \( S_a = n S_b \) into the above equation to get:

\[ P_{\text{total}} = A_a (n S_b) + A_b S_b \]

Which can be rewritten as:

\[ P_{\text{total}} = S_b (n A_a + A_b) \]

“\( n A_a \)“ is sometimes thought of as the equivalent area, whereby it could hypothetically replace \( A_a \) and the new cross-section would be of one homogeneous material.
A short post consisting of a 6 inch diameter standard weight steel pipe is filled with concrete that has a compressive strength of 3000 psi. The pipe is made of ASTM A501 steel. The post is subjected to an axial compressive load of 100,000 lbs. Both materials deform equally under the load. Compute the stress developed in the steel and the concrete.
Stress Concentrations: Tensile stress distributions.

- When holes or slots are bored thru tension members, a localized stress concentration occurs, as shown.
- The maximum stress value must be considered.
- $k$ is an experimentally determined value commonly used in engineering design and depends on the geometry and size of the member and the hole.

\[
S_{t\text{ (max)}} = k \frac{P}{A_{\text{net}}}
\]

\[
S_{t\text{ (aver)}} = \frac{P}{A_{\text{net}}}
\]

\[
S_{t\text{ (gross)}} = \frac{P}{A_{\text{gross}}}
\]
A ¾” diameter hole is drilled on the centerline of a flat steel bar as shown. The bar is subjected to a tensile load of 4,000 lbs. Calculate the average stress in the plane of the reduced cross section and the maximum tensile stress immediately adjacent to the hole.