Composite Members in Parallel (Sandwiched)

• 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)

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

\[ E_a \quad E_b \]

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

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

We can replace $E_a$ with modular ratio $n$

\[ \frac{E_a}{E_b} \]

So, then

\[ S_a = n S_b \]
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.
Stress Concentration Factors for Flat Bars

(a) 2r Circular hole
(b) Semicircular grooves
(c) Fillets

Graph showing stress concentration factors ($k$) as a function of $r/d$ for different shapes:
- I: Circular hole
- II: Semicircular grooves
- III: Fillets

Legend:
- $D$: Diameter of circular hole
- $d$: Diameter of fillet or width of groove
- $r$: Radius of curvature
- $1/2 d$: Half the diameter of the circular hole
A $\frac{3}{4}$" 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.