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(1.) Composites ~~are~~ have two or more phases.

For Any Composite, we can calculate the density as :

$$\rho = V_f \rho_f + (1-V_f)\rho_f$$

$V_f \rightarrow$ Volume fraction.

For a given V_f, we can have several diff^r kinds of arrangements of structures and how the forces are applied on them

Considering a uni-directional composite, we can have ~~either~~ diff^r comb^n of stress & strain in b/w the material.

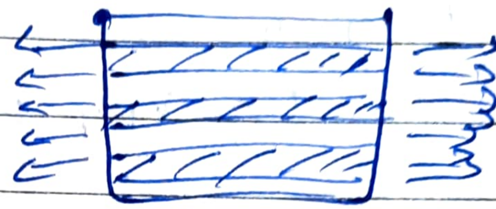
Considering stress as Const, we get the Modulus lower Bound (Reuss Bound)

or

If strain is Const, we get Modulus Upper Bound (Voigt Bound)

Modulus = $\dfrac{\text{stress}}{\text{strain}}$

Consider the case where we get all the stress parallel to the fibers



$$\frac{\sigma_f}{E_f} = \epsilon_f = \epsilon_m = \frac{\sigma_m}{E_m}$$

$$\therefore \sigma_{Tot} = f\sigma_f + (1-f)\sigma_m$$

$f \rightarrow$ volume fr of matrix

Considering Hooke's law,

$$E_{comp} \times \epsilon_{comp} = f E_f \epsilon_f + (1-f) E_m \epsilon_m$$

$$\rightarrow \epsilon_{comp} = \epsilon_f = \epsilon_m$$

$$E_{comp} = f E_f + (1-f) E_m$$

(Voigt Bound)

Similarly, if we keep the stress $\perp$ to fibers

$$\sigma_{Tot} = \sigma_f = \sigma_m$$

$$E_{comp} = \frac{\sigma_{Tot}}{\epsilon_{comp}} = \frac{\sigma_f}{f\epsilon_f + (1-f)\epsilon_m}$$

$$\therefore \boxed{\frac{1}{E_{comp}} = \frac{f}{E_f} + \frac{1-f}{E_m}}$$

Reuss Bound