XI: Composites

1:Introduction

1.1 What is composites

- A multiple phase material that possesses properties of constituent phases.
- Components require low densities,strong,stiff,abrasion,impact and corrosion resistant.
- Natural composites
  - Wood
  - Bone

1.2 Composites materials

- Often consist of two phases;
  - Matrix phase: continuous phase
  - Dispersed phase:
  - Factors that need to be considered :
    - a:Concentration
    - b:Size
    - c:Shape
    - d:Distribution
    - e:Orientation

2:Particle and Fibre-Reinforced Composites

2.1 Particle-reinforced composites

- The matrix distributes some of the applied stress to the particles.

- The degree of the reinforcement depends on strong bonding at the matrix-particle interface.
- For small particles, the dispersed particles can impede the dislocation motions and thus the plastic deformation is restricted and improved yield, strength and hardness.
- For example: concrete use ceramics for both matrix and dispersed particles.

2.2 Rule of mixture

- It is used to predicted the upper and lower bound od modulus of elasticity.
- For a two-phase composites:
  - The upper bound:$E_{c,u} = E_m V_m + E_p V_p$
  - The lower bound :

$$E_{c,l} = \frac{E_m E_p}{V_m E_p + V_p E_m}$$

  - E and V denotes the modulus of elasticity and volume fraction.
  - c,m and p represent composites,matrix and particulate phases

2.3 Fibre-reinforced composites

- It is designed to produce a materials with high strength and/or stiffness on a weight basis.
- This depends on the fibre length,orientation and concentration.
- The properties are highly anisotropic.(Different properties in different directions).
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- Stage I, elastic deformation for both fibre and matrix.
- Matrix will yield and undergo plastic deformation at ε_{ym} while the fibre continues to be elastic. (Stage II).
- In Stage II, it is nearly linear, but the slope is less steep than Stage I.
- In Stage II, the proportion of the applied load borne by the fibres increases.
- The composites begins to fail when the strain reaches ε_f^*.
- But the failure is not catastrophic due to:
  - Variation of fibre strength.

- The matrix is still intact as $\varepsilon_m^* > \varepsilon_f^*$
- The fractured fibres is still embedded in the matrix ad can still sustain load as the matrix continues to deform plastically.

3:Elastic behaviour - longitudinal adn transverse loading

3.1 Longitudinal loading

- $F_c = F_m + F_f$
- $\sigma_c A_c = \sigma_m A_m + \sigma_f A_f$
- $\sigma_c = \sigma_m \frac{A_m}{A_c} + \sigma_f \frac{A_f}{A_c}$
- F,σ and A are load, stress, cross-section area.
- c,m and f are composites, matrix and fibres.
- If the composites, matrix and fibre phase lengths ae equal, $\frac{A_m}{A_c}$ is equal to volume fraction of the matrix(V_f), $\sigma_c = \sigma_m V_m + \sigma_f V_f$
- With excellent bonding between the interface, deformation of both matrix adn fibres are the same Isolation state:$\varepsilon_c = \varepsilon_m = \varepsilon_f$.
- $\frac{\sigma_c}{\varepsilon_c} = \frac{\sigma_m}{\varepsilon_m} V_m + \frac{\sigma_f}{\varepsilon_f} V_f$
- $E_{cl} = E_m V_m + E_f V_f$
- $V_m + V_f = 1$, so $E_{cl} = E_m(1 - V_f) + E_f V_f$
- $\frac{F_f}{F_m} = \frac{E_f V_f}{E_m V_m}$

3.2 Transverse Loading

- Isostress State:

$$\sigma_c = \sigma_m = \sigma_f = \sigma$$

$$\varepsilon_c = \varepsilon_m V_m + \varepsilon_f V_f$$

$$\frac{\sigma}{E_c} = \frac{\sigma}{E_m} V_m + \frac{\sigma}{E_f} V_f$$

$$\frac{1}{E_c} + \frac{V_m}{E_m} + \frac{V_f}{E_f}$$

$$E_{ct} = \frac{E_m E_f}{V_m E_f + V_f E_m} = \frac{E_m E_f}{(1 - V_f) E_f + V_f E_m}$$

3.3 Tensile Strength

- Max longitudinal tensile strength of a composites, σ_{cl}^*, $\sigma_{cl}^* = \sigma_m^{'}(1 - V_f) + \sigma_f^* V_f$
- $\sigma_m^{'}$: stress in the matrix at fibre failure
- σ_f^* : fibre max strength
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4:Types of Composites and Processing

4.1 Types of composites

- Polymer matrix composites
    - Glass fibre-reinforced polymer(GFRP)
    - Carbon f-r-p(CFRP)
    - Aramid f-r-p(AFRP)
- Metal matrix composites
    - Higher operating temperatures, greater resistance to degradation by organic fluid and non-flammability.
    - The cost is much higher.
    - Examples: carbon,boron,silicon carbide in Al-alloy matrix.
- Ceramic matrix composites
    - Transformation toughening:
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4.2 Processing of fibre-reinforced composites

- Pultrusion:
- Prepreg: