4.4 Polymers, ceramics and composites

Name: _____ Class: _____ Date: _____ **Total: 14 marks**

KEY WORDS rule of mixtures • glass transition • Weibull modulus

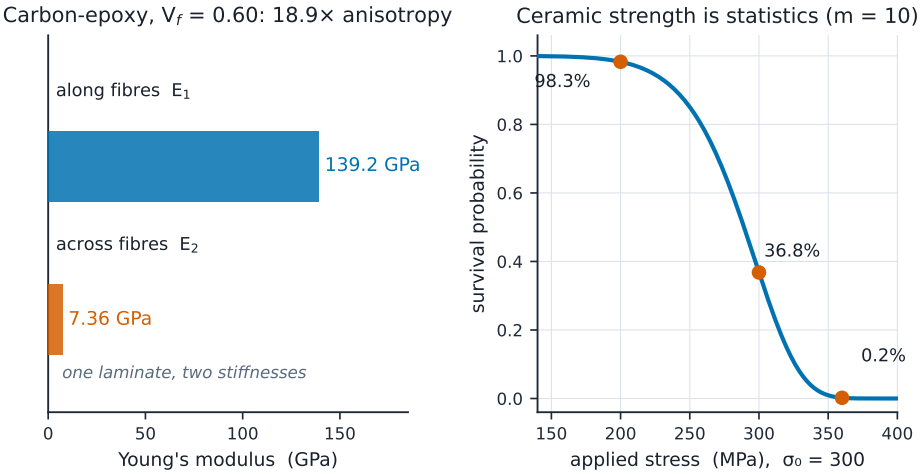
Objective

Apply the rule of mixtures along and across fibres, the glass transition as a service limit, and Weibull survival arithmetic.

1 Key knowledge and worked examples

■ **Non-metal tools**

$E_1 = V_f E_f + V_m E_m$; $E_2 = E_f E_m/(V_m E_f + V_f E_m)$. Survival $\exp[-(\sigma/\sigma_0)^m]$. Nylon $T_g = 55°\text{C}$.



*One laminate, two stiffnesses; ceramics are statistics

■ **Worked example. The laminate**

$V_f = 0.60$: $E_1 = 139.2$ GPa, $E_2 = 7.36$ GPa - 18.9× ✓. With $m = 10$, $\sigma_0 = 300$: survival 0.983 / 0.368 / 0.002 at 200 / 300 / 360 MPa ✓.

2 Practice

A glass-fibre laminate has $V_f = 0.55$, $E_f = 230$ GPa, $E_m = 2.5$ GPa.

2.1 The modulus along the fibres (one decimal, GPa). [3]

2.2 The modulus across the fibres (two decimals, GPa) and the anisotropy ratio (two decimals). [4]

2.3 A ceramic has Weibull modulus $m = 8$ and characteristic strength 250 MPa: the survival probability at 200 MPa (three decimals). [4]

2.4 One sentence each: why does a mount of nylon 6 need thermal certification, and why does a laminate datasheet quote moduli per direction? [3]

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Solutions

2.1

- $E_1 = 0.55 \times 230 + 0.45 \times 2.5 = 127.6$ GPa.

2.2

- $E_2 = 230 \times 2.5 / (0.55 \times 2.5 + 0.45 \times 230) = 575 / 104.9 = 5.48$ GPa.
- Ratio $127.6 / 5.48 = 23.3$.

2.3

- $P_s = \exp[-(200/250)^8] = \exp[-0.8^8] = \exp[-0.168] = 0.846$.

2.4

- Nylon's T_g (55°C) sits near service temperature: stiffness and creep change across the transition, so the spring rate must be re-read hot.
- E_1 and E_2 differ by more than an order of magnitude - one number would mislead in the other direction.

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