Toughness and fracture toughness of interfaces in composite materials

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Definitions of terms in mechanics of materials

Strength: The maximum single-component of stress that can be sustained at a **material point** (tensile strength, compressive strength, shear strength)

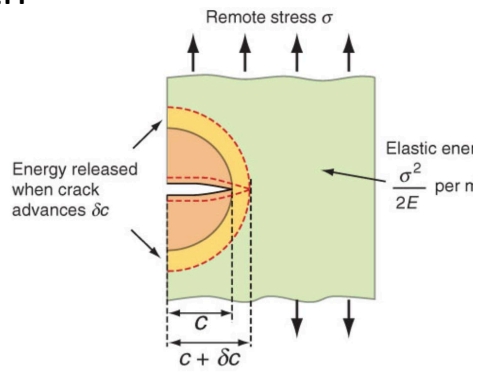
Toughness: The energy uptake *per unit volume* until failure at a **material point.** Units: J/m^3

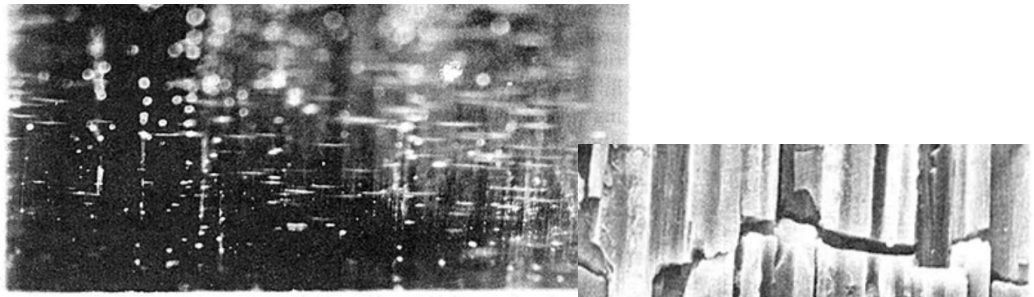
Fracture toughness (at a single crack front): Energy released for incrementally advancing a crack front *per unit crack surface area*. Units: J/m^2

Work of fracture (in a volume):

a) Total energy uptake in *distributed fracture* **per unit volume**. Units: J/m^3

b) Total energy uptake in *localized fracture* **per unit plane area**. Units: J/m^2

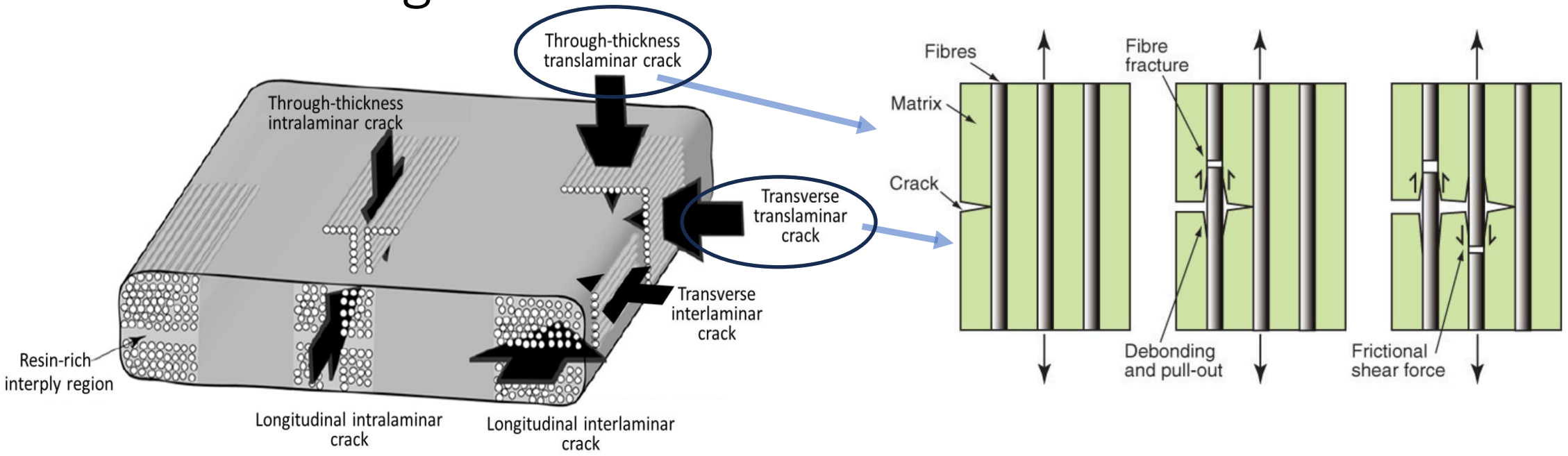




a)

b)

Crack growth involving fiber fracture and fiber-matrix debonding

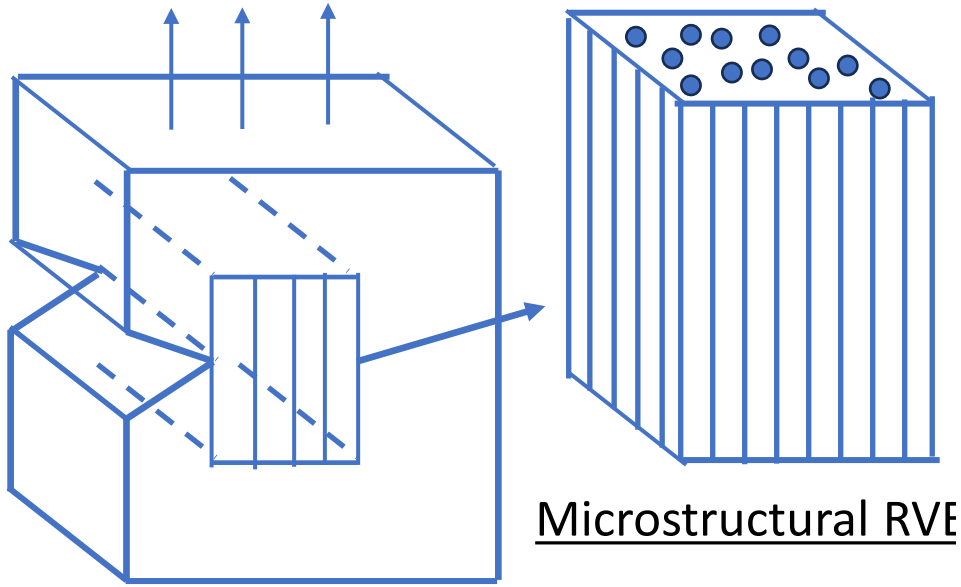


Questions:

1. Can fracture toughness be defined at the mesoscale, while fracture mechanisms occur at the microscale?
2. How do we characterize energy uptake in failure at fiber-matrix interfaces, and in providing resistance to advancement of a translaminar crack?

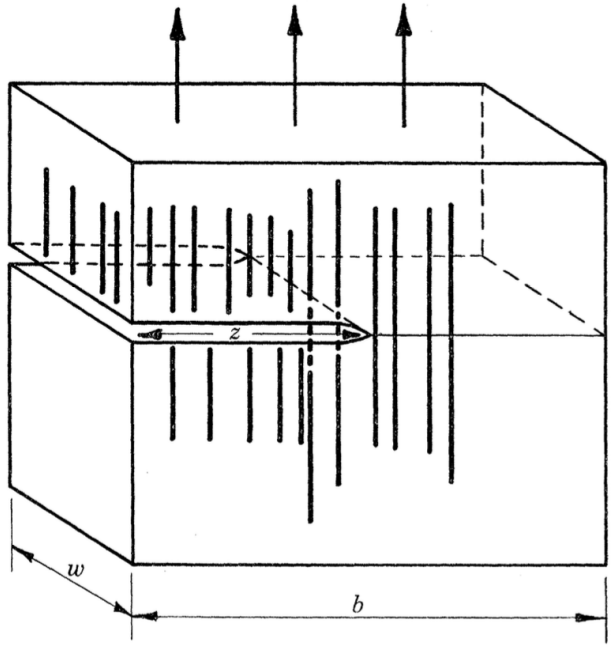
Fracture toughness when a crack has a potential to advance by breaking and debonding fibers

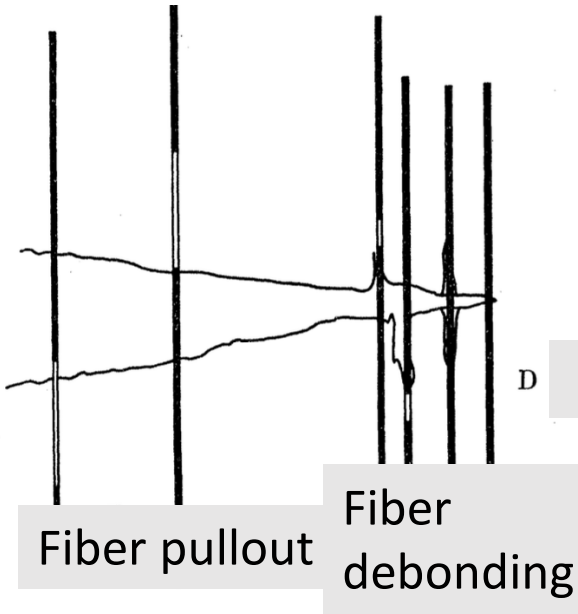
Case 1: **Small crack**
(crack length less than microstructural length scale)



Case 1: RVE can be smeared into a volume that uptakes energy in distributed fracture.
Work of fracture: J/m^3

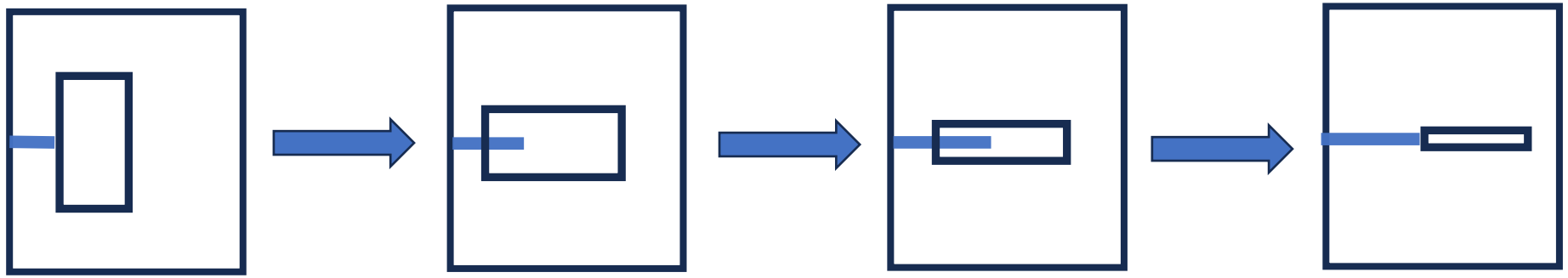
Case 2: **Large crack**
(crack length greater than microstructural length scale)





Case 2: Uptake of energy in localized volume.
Work of fracture per (projected) crack plane.
Work of fracture: J/m^2

Material properties vs model parameters



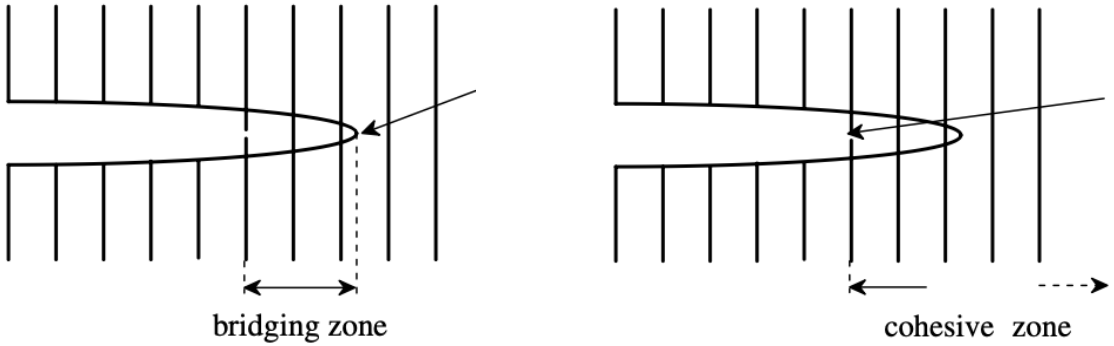
Distributed fracture.
Work of fracture: J/m^3

Transition.
Undefined RVE

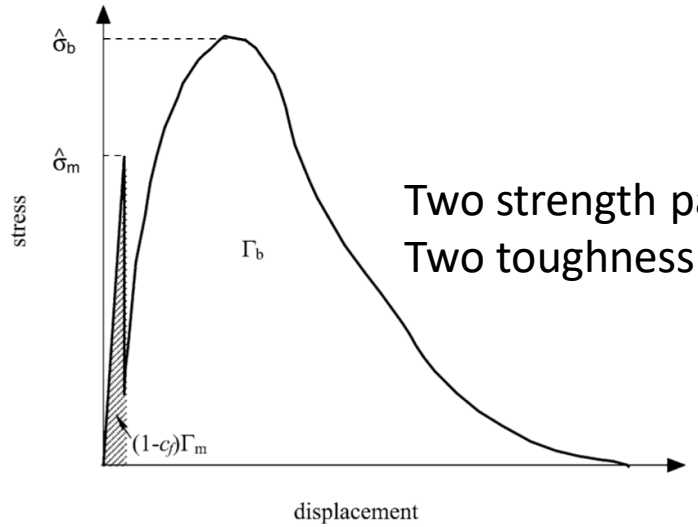
Localized fracture.
Work of fracture: J/m^2

Self-similar crack growth.
Fracture toughness: J/m^2

Bridging and cohesive zone models



Arrow points to crack tip



Two strength parameters
Two toughness parameters

Li et al, CST, 2005