BMM4893: Mechanics of Composite Materials

Chapter 1: Introduction to Composite Materials

by

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Synopsis

This chapter introduces the concept of composite materials, the characteristics and types of fibers and matrices, and applications of composites. The student will discussing some terminologies used for mechanics of composite.

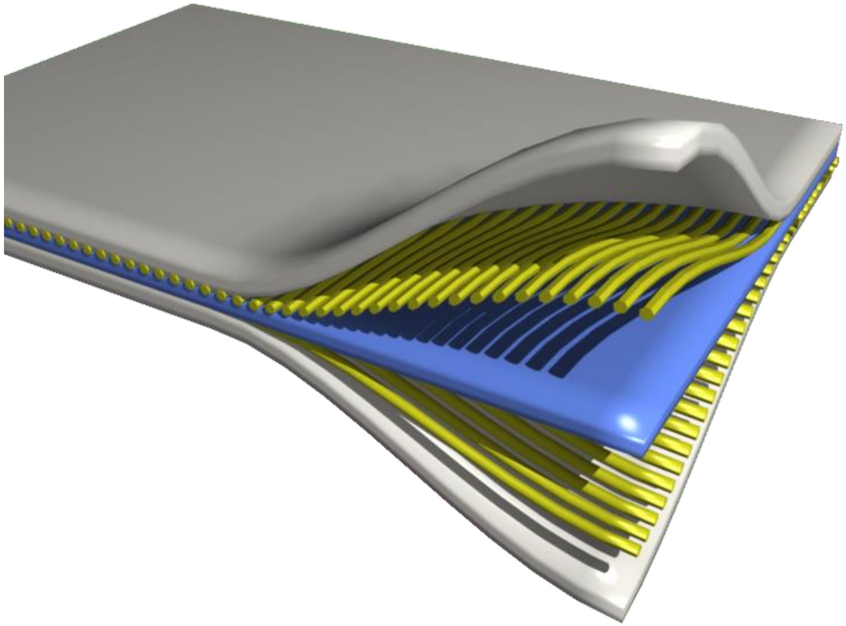
Learning Outcome

By the end of this topic, student should be able to:

- Explain the concept of composite
- Explain the characteristics , types of fibers and matrices, and applications of composites
- Discuss terminology used for mechanics of composite

Definition

"An advanced material technology that combine two or more materials of different properties and characteristics to produce a superior material properties of those materials on their own"



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Composites

Composites consist of:

1. Combination of two or more materials ; Composite = matrix + fiber (filler):
   - Matrix:
     - material component that surrounds the fiber.
     - Usually **a ductile, or tough, material with low density**
     - **Strength usually = 1/10 (or less) than that of fiber**
     - Examples include: thermoplastic or thermoset
       - Thermoset most common (epoxy, pheneolic)
     - Serves to hold the fiber (filler) in a favorable orientation.
   - Fiber a.k.a reinforcing material a.k.a Filler:
     - **Materials that are strong with low densities**
     - Examples include glass, carbon or particles.
2. Designed to display a combination of the best characteristics of each material i.e. fiberglass acquires strength from glass and flexibility from the polymer.
3. Matrix and filler bonded together (adhesive) or mechanically locked together!

Fiber (Reinforcement)

GLASS FIBER

Low cost reinforcement for general application. Widely used in corrosion resistance.

ARAMID FIBER

High end impact absorption application such as ballistic protection

CARBON FIBER

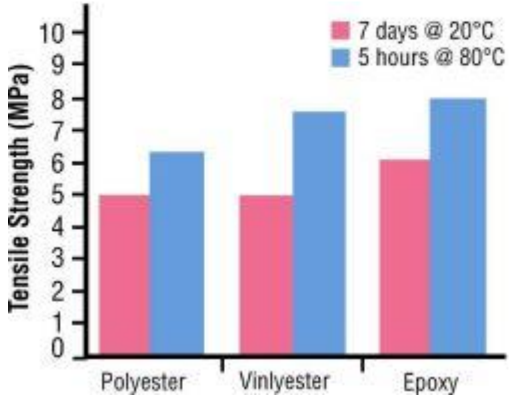
High end low weight high strength application such as structural reinforcement and aerospace parts

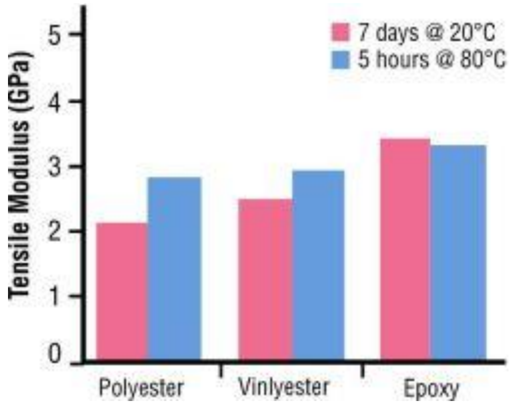
Property	Glass	Carbon	Aramid
Strength	Worst	In – between	Best
Stiffness	Worst	Best	In – between
Cost	Best	Worst	In – between
Weight	Worst	Best	In – between

Resin (Binding Matrix)

“Resins is a polymer based material that bind the reinforcement i.e. fibers, particulate.”

RESINS	APPLICATION
POLYESTER	General corrosion resistant application.
VINYLESTER	Heavily corrosive environment
EPOXY	High strength and fire rating performance

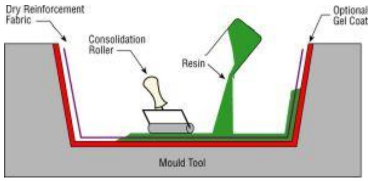


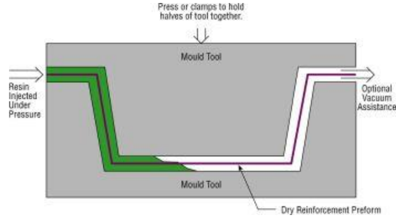


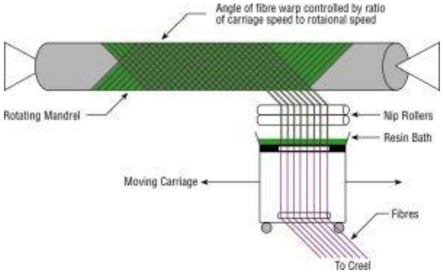
Processing the Product

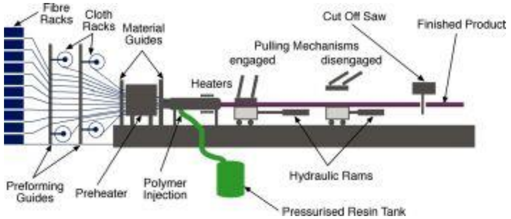
“Various processing method to suit end product design and properties requirements”

PROCESS	APPLICATION
OPEN MOLD	Economic processing method for non-structural or tolerance critical application
CLOSE MOLD	Complex 3-dimensional requirements with close tolerance
FILAMENT WINDING	Tubular high pressure rating application such as pipe.
PULTRUSION	Profile based end product









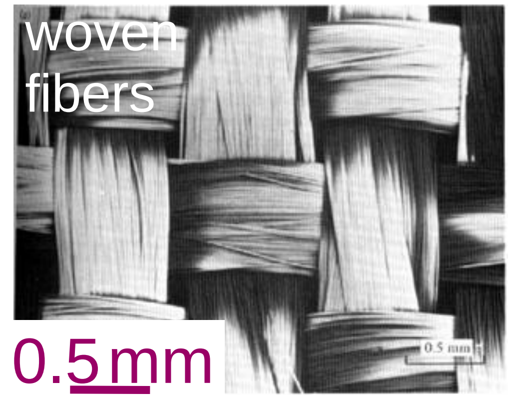
Typical Cured Laminated to compare with Metal Properties

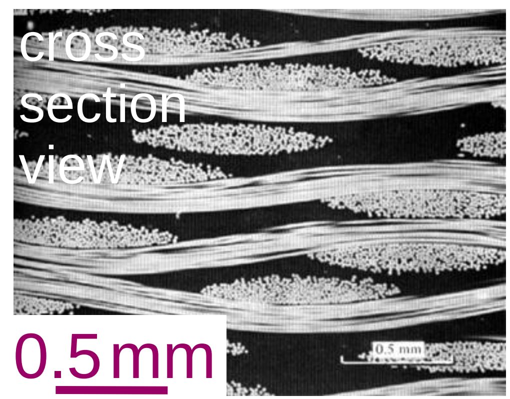
Material	Density (kg/m^3)	UTS (MPa)	Tensile Modulus (GPa)	Specific Strength (MPa/kgm^{-3})/	Specific Strength (GPa/kgm^{-3})/
Kevlar-49	**1380**	**1448**	**75.8**	**1.05**	**0.055**
S-Glass	**1990**	**1931**	**51.7**	**0.97**	**0.026**
E-Glass	**2080)**	**1103**	**44.8**	**0.53**	**0.022**
Type HMS Graphite	**1630**	**1172**	**206.8**	**0.72**	**0.127**
Type AS Carbon	**1550**	**1724**	**137.9**	**1.11**	**0.089**
Aluminum (7075-T6)	**2770**	**572**	**68.9**	**0.21**	**0.025**
Titanium (6A-4V)	**4430**	**1103**	**113.8**	**0.25**	**0.026**
Steel (4130)	**8000**	**1379**	**200.0**	**0.17**	**0.025**

Terminology/Classification

- Composites:
  -- Multiphase material with significant proportions of each phase.
- Matrix:
  -- The continuous phase
  -- Purpose is to:
    - transfer stress to other phases
    - protect phases from environment
  -- Classification: MMC, CMC, PMC

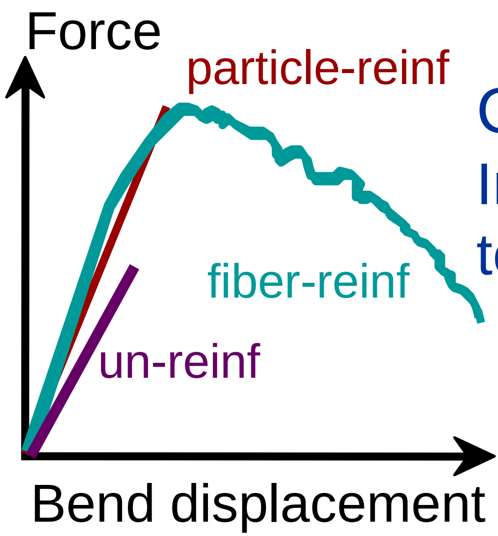
  metal ceramic polymer
- Dispersed phase:
  -- Purpose: enhance matrix properties.
  MMC: increase σ_y, TS, creep resist.
  CMC: increase K_c
  PMC: increase E, σ_y, TS, creep resist.
  -- Classification: Particle, fiber, structural



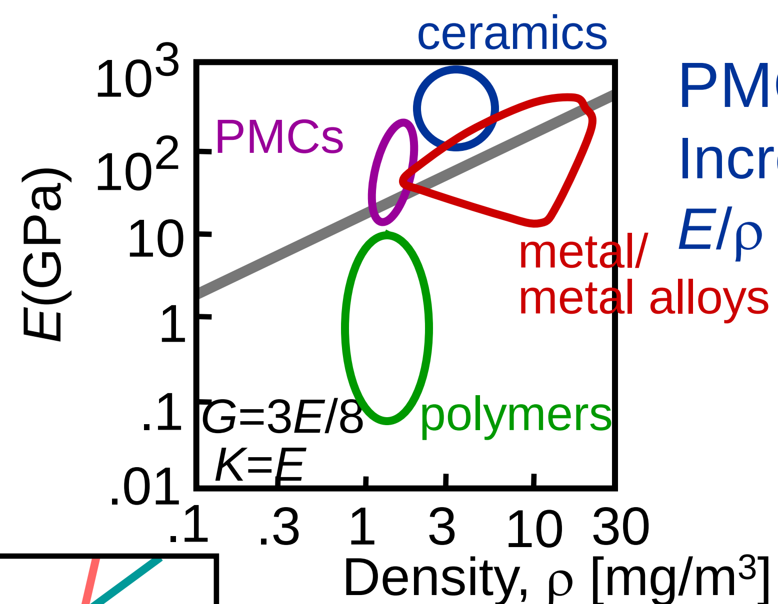


D. Hull and T.W. Clyne, *An Introduction to Composite Materials*, 2nd ed., Cambridge University Press, New York, 1996, Fig. 3.6, p. 47.

Benefits: MMC vs PMC vs CMC

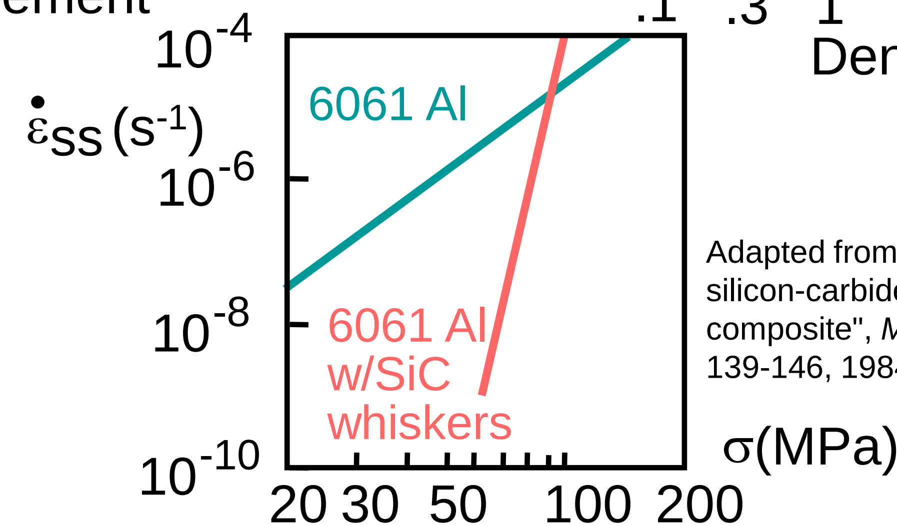


CMCs:
Increased
toughness



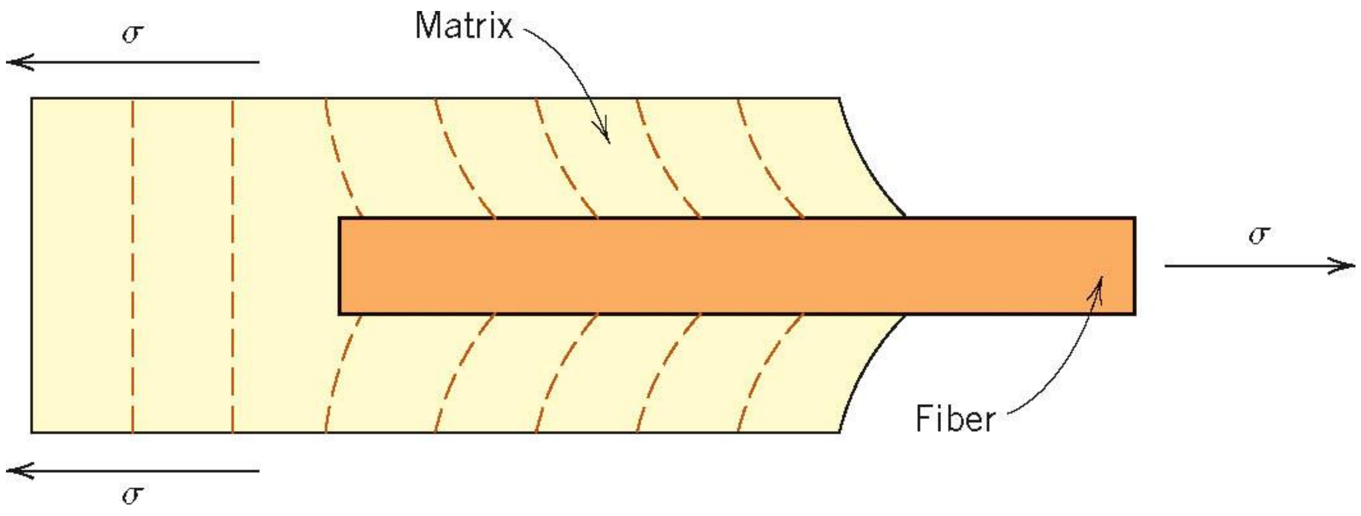
PMCs:
Increased
E/ρ

MMCs:
Increased
creep
resistance

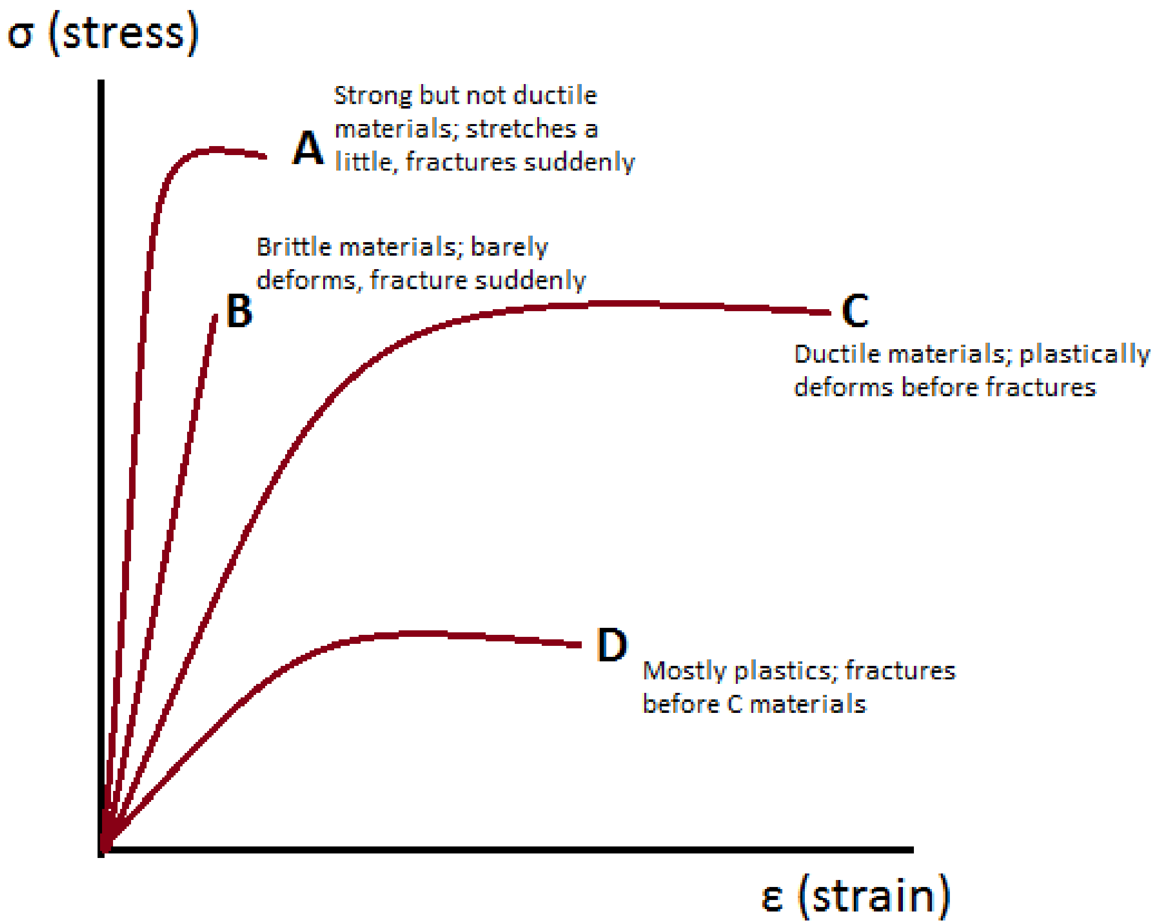


Adapted from T.G. Nieh, "Creep rupture of a silicon-carbide reinforced aluminum composite", *Metall. Trans. A* Vol. 15(1), pp. 139-146, 1984. Used with permission.

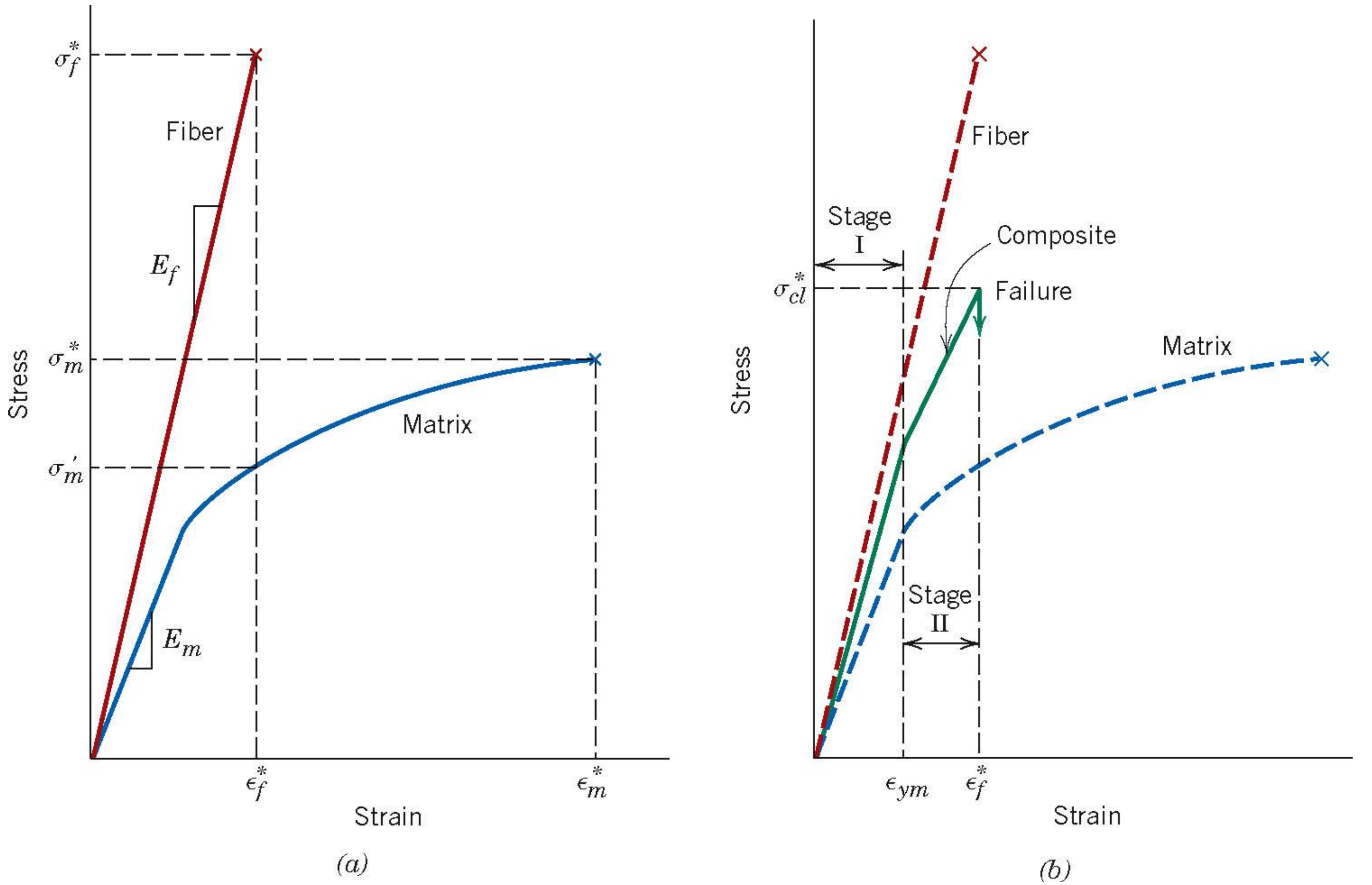
Fiber Loading Effect under Stress



Stress-strain behaviour



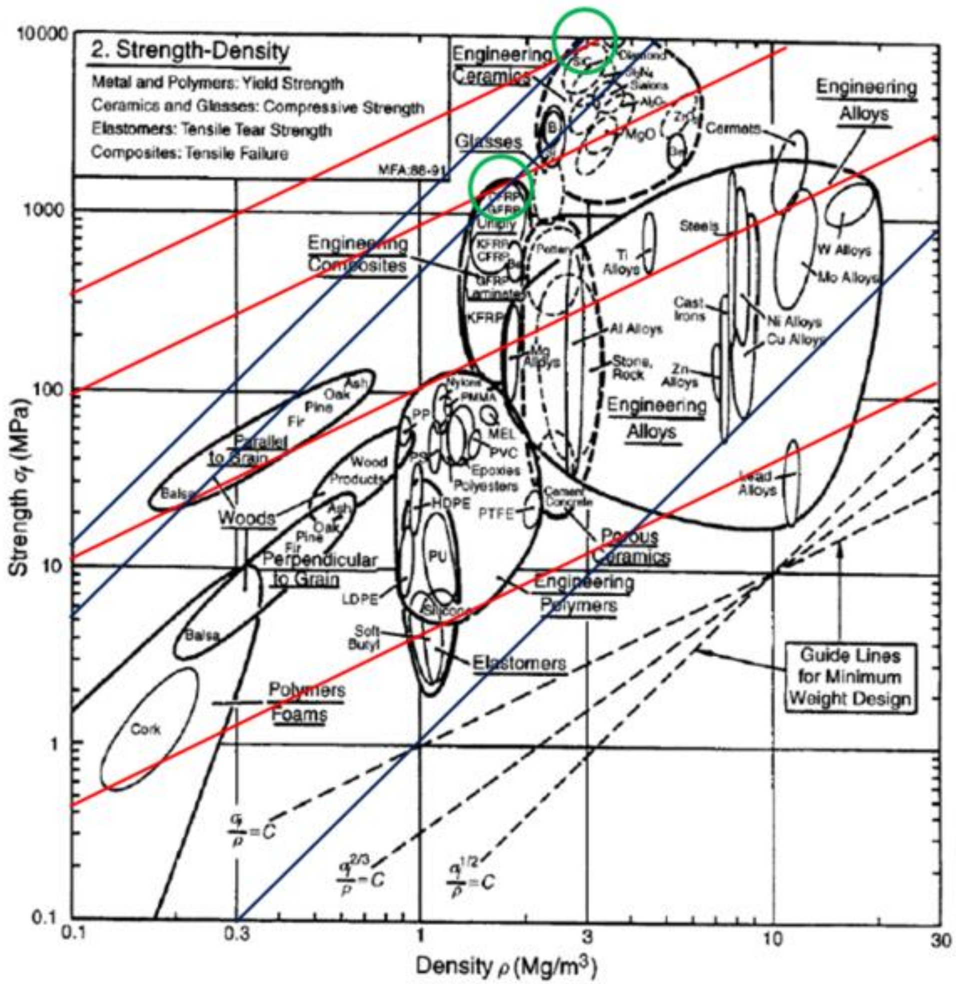
Behavior under load for Fibers & Matrix



Benefits

1. CORROSION RESISTANT *Unaffected by a wide range of corrosive chemicals and environments. Minimal maintenance costs.*
2. HIGH STRENGHT, LIGHT WEIGHT *Density of composite is 20% of steel and 60% of aluminum. Higher performance at less weight costs.*
3. MAINTENANCE FREE *Non corrosive. No repainting cost.*
4. DIMENSIONAL STABILITY *Stretch-, warp-, and swell-resistant over a wide range of temperatures and physical stresses. Close tolerances*
5. THERMAL INSULATION *Low thermal conductivity rating of 1/250 of aluminum; 1/60 of steel. No condensation problems*
6. HIGH DIELECTRIC STRENGHT *Excellent electrical insulating properties. Non conductive.*
7. DESIGN FLEXIBILITY *Many individual components can be combined into one large profile. Reduced assembly costs.*
8. THEFT FREE *ZERO recycle value. Help reduce theft for public facility and infrastructure i.e. signage*

Strength-Density



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MARKET AREAS

> "As a material driven industry, application of composites are not only limited to certain sectors, but limited to designers imagination and capability"

1. AUTOMOTIVE *Front end, fender, doors, rocker cover, tail gate, etc.*
2. MARITIME *Boat, jetty, sheet pile, etc.*
3. INFRASTRUCTURE *Bridges, railing, grating, pipe, façade & facia facelift, lighting poles, signage, shed, mosque dome, etc.*
4. AEROSPACE *Body parts component.*
5. MILITARY *Ballistic protection, missile launcher, etc.*
6. CORROSION RESISTANT *Water treatment infrastructure, Jetty infrastructure, offshore platform, etc..*
7. ELECTRICAL *Feeder pillar cabinets, insulation, doors, cable management system, etc.*
8. OTHERS

VEHICLE BRIDGE

“ KOLDING bridge is all composite apart from the nuts and bolts holding it together ”

Source of image from Creative Common

MARINE PILE & SHEET PILE

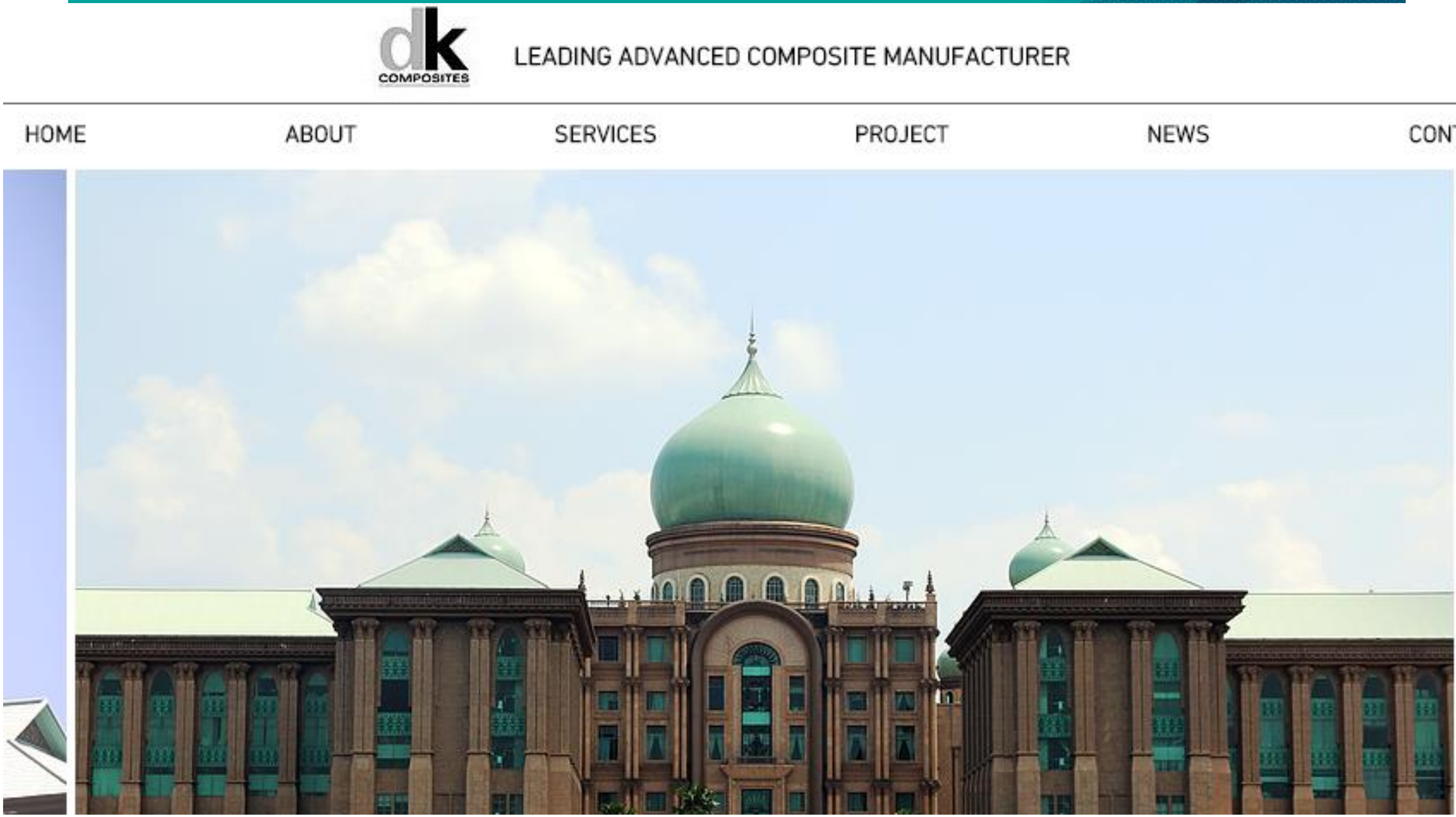
Complete composite sheetpile installation, including SuperLoc™ sheetpile and composite top cap. (Picture courtesy of Creative Pultrusions.)

Navy pier structure made using pultrusion. (Picture courtesy of Owens Corning: www.owenscorning.com.)

Composite piling being used for a dock installation in Rotterdam. (Picture courtesy of Seaward International/PC Jansen Marine Agencies.)

“Excellent corrosion resistant properties put composites as the most preferred material ”

OTHER APPLICATIONS



OTHER APPLICATIONS

Besting Big Ben

A MARVEL IN MAKKAH

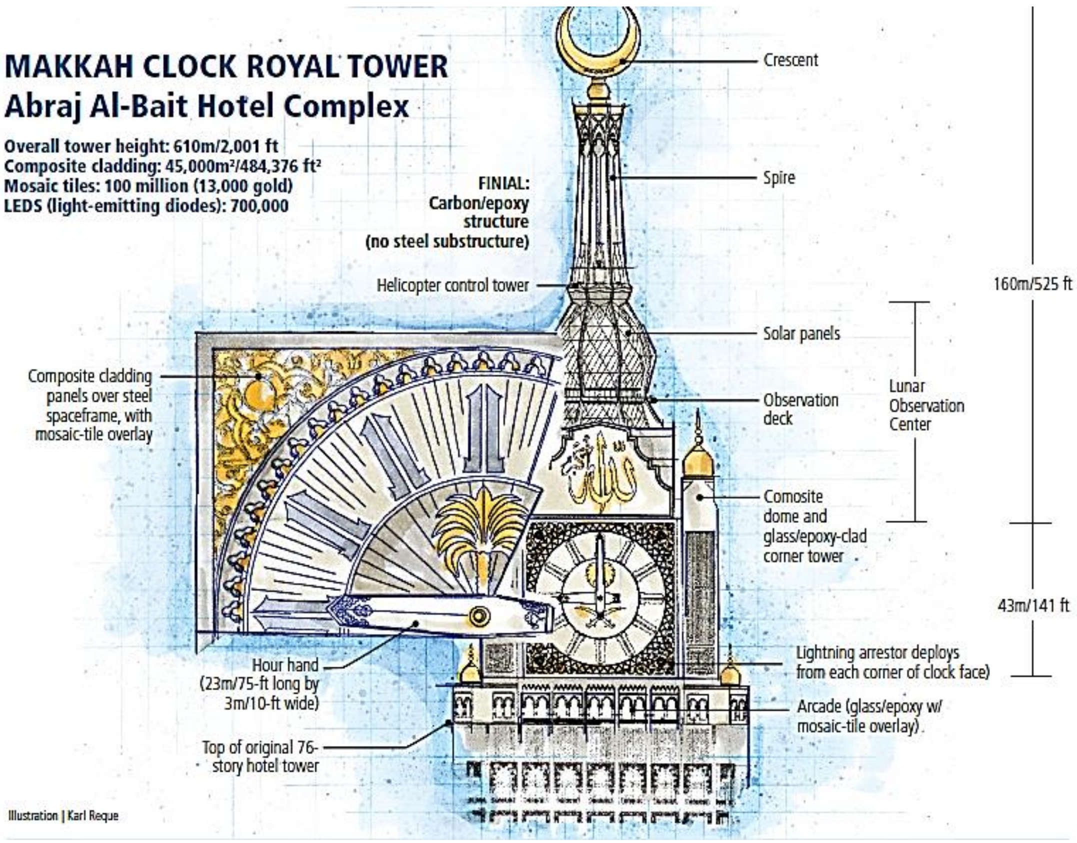
Composite design makes possible the world's largest clock and tallest clock tower.

ENGINEERING CHALLENGE:

Add a 200m/656-ft tall clock and finial to a hotel tower originally designed to accommodate neither, using materials that minimize added weight yet can reproduce the complex, sculpted architectural style of the Middle Eastern locale.

DESIGN SOLUTION:

Use steel-spaceframe-supported carbon- and glass-fiber-reinforced, sandwich-construction cladding panels for the clock and clock hands, and the corners, and top the structure with a self-supporting, all-carbon composite structure for the finial.



SPECIAL APPLICATION:AEROSPACE

Transport Aircraft

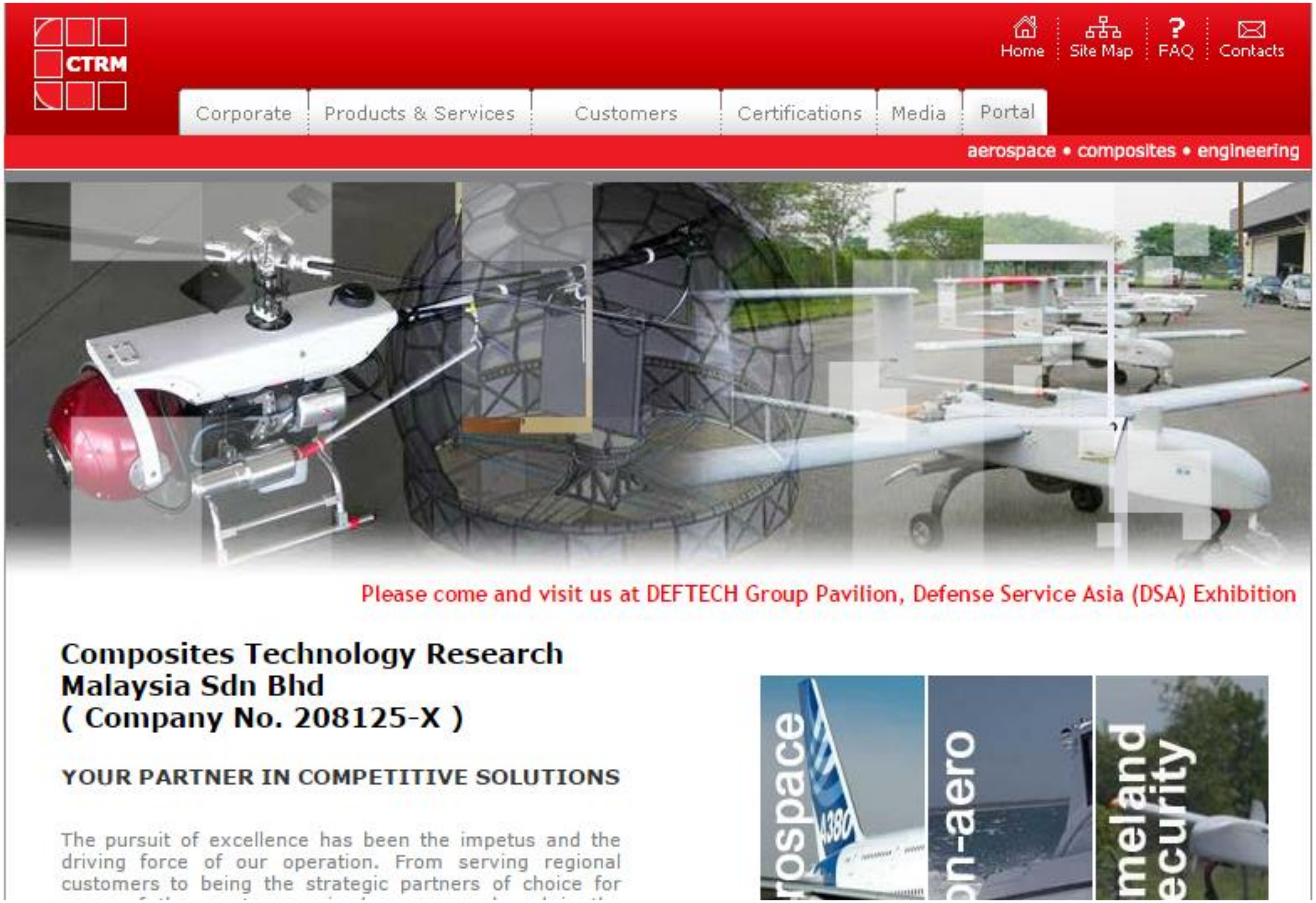
- Manufacturing cost
- Non-recurring development costs
- Maintenance technology
- Limited resources with sufficient training (engineers & technicians)
- Lack of standardization

Small Airplanes and Rotorcraft

- Manufacturing cost
- Need to reach high production rates
- Maintenance technology
- Limited resources with sufficient training (engineers & technicians)
- Lack of stable material supplier base
- Lack of standardization

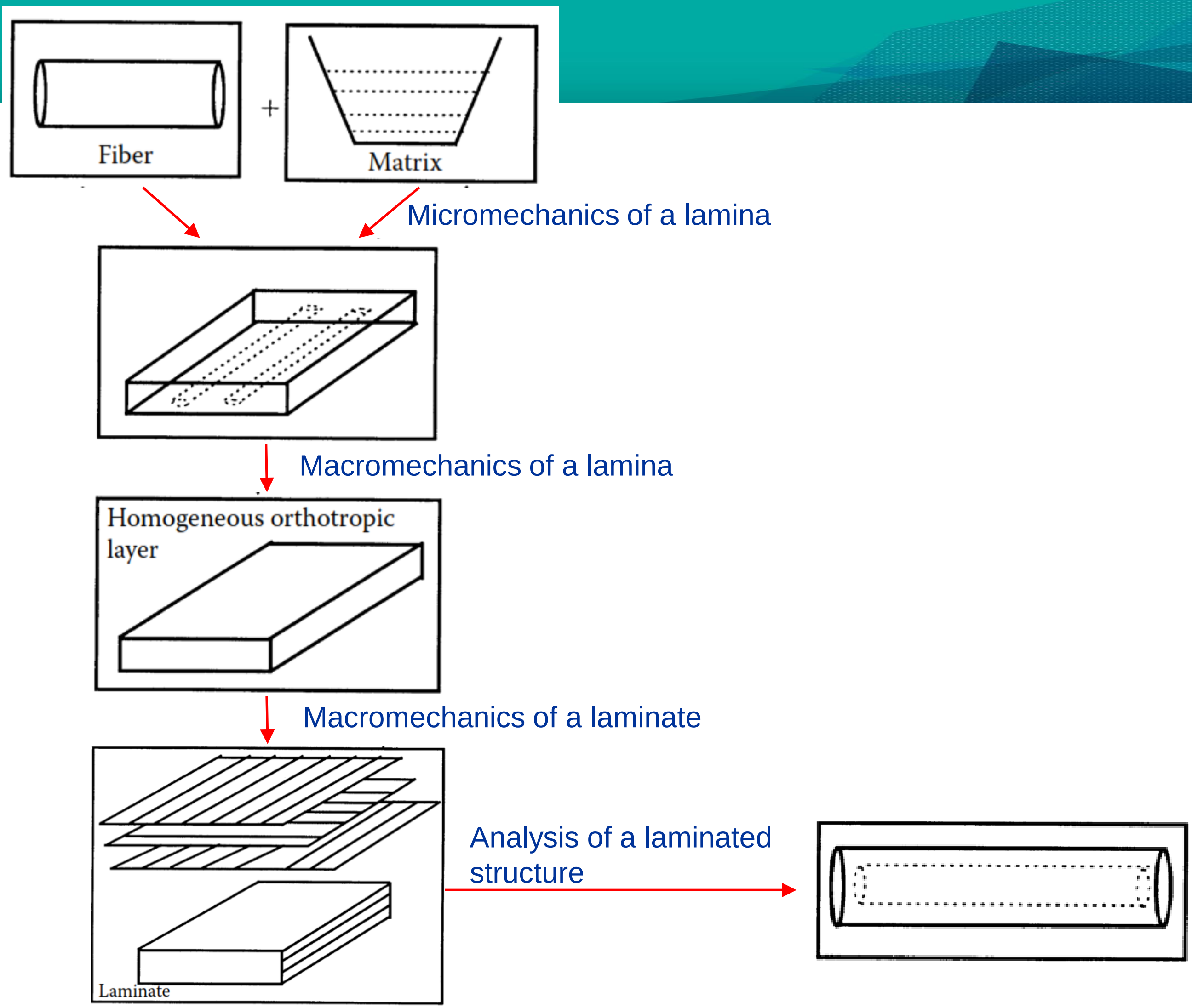
Presented by L. Ilcewicz at 11/10/09 Montana State Univ. Seminar

Composites @ Malaysia



Composites @ Malaysia

Mechanics of the Composites



Thank you

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