Module 1

M1.General Introduction to Composite Materilas

Learning Units of Module 1

M1.1 Introduction to Composites

M1.2 Basic Definitions and Classification of Composites

M1.3 Advantages, Disadvantages of Composite Materials; Comparison of Composite materials with Metals

Learning Unit 1: M1.1 Introduction to Composites

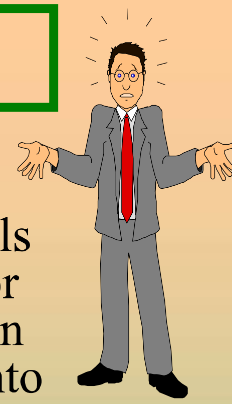
- Definition of Composites: What are Composites?
- What is Concept of Composites?
- History of composites.

Composite Material

A combination of two or more materials to form a new material system with enhanced material properties

Reinforcement + Matrix = Composite

What are Composites?



- **Composites:** A combination of two or more materials (reinforcement, resin, filler, etc.), differing in form or composition on a macroscale. The constituents retain their identities, i.e.., they do not dissolve or merge into each other, although they act in concert. Normally, the components can be physically identified and exhibit an interface between each other.
- **Composites:** Artificially produced multiphase materials.
- **Composites:** Design materials with properties better than those of conventional materials (metals, ceramics, or polymers).

Continued……

- **Composites:** materials, usually man-made, that are a three-dimensional combination of at least two chemically distinct materials, with a distinct interface separating the components, created to obtain properties that cannot be achieved by any of the components acting alone.
- **Composites:** are combinations of two materials in which one of the materials, called the **reinforcing phase**, is in the form of fibers, sheets, or particles, and is embedded in the other materials called the **matrix phase**. The reinforcing material and the matrix material can be metal, ceramic, or polymer.

Continued……

- In their broadest form, **composites are materials consist of two or more constituents. The constituents are combined in such a way that they keep their individual physical phases and are not soluble in each other or not to form a new chemical compound.**
- One constituent is called **reinforcing phase** and the one in which the reinforcing phase is embedded is called **matrix**.
- Historical or natural examples of composites are abundant: brick made of clay reinforced with straw, mud wall with bamboo shoots, concrete, concrete reinforced with steel rebar, granite consisting of quartz, mica and feldspar, wood (cellulose fibers in lignin matrix), etc.

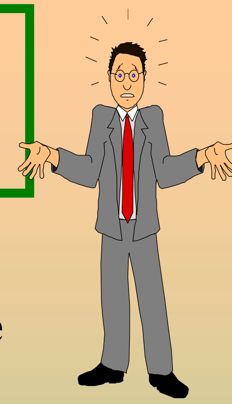
Continued……

- **Composites:** A *judicious* combination of two or more materials that produces a *synergistic* effect. A material system composed of two or more physically distinct phases whose combination produces aggregate properties that are different from those of its constituents.

Some Definitions

- Repair: To replace or correct deteriorated, damaged or faulty materials, components, or elements of a structure.
- Rehabilitation: Process of repairing or modifying structure to the desired or useful condition
- Restoration: Process of reestablishing the materials, form and appearance of a structure to those of a particular era of the structure
- Preservation: Process of maintaining a structure its present condition and arresting its further deterioration
- Strengthening: Process of increasing the load resistant capacity of a structure or a portion of it

What are Advanced Composites?

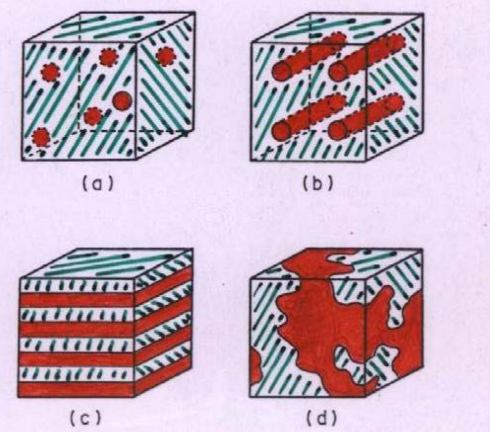


- **Advanced Composites:** Advanced composite materials are refereed to those composite materials developed and used in the aerospace industries. They usually consist of high performance fibers as reinforcing phases and polymers or metals as matrices.

Advanced Composite Materials

Definition: An advanced composite material comprises at least two chemically different materials (heterogeneity): a *reinforcement*, and a *matrix* that binds the reinforcement and is separated from it by a sharp interface.

Dispersed phase within continuous phase



Composite geometries: (a) random dispersion of spheres in a continuous matrix; (b) regular array of aligned filaments; (c) continuous laminae; and (d) irregular geometry

Phases of Composites

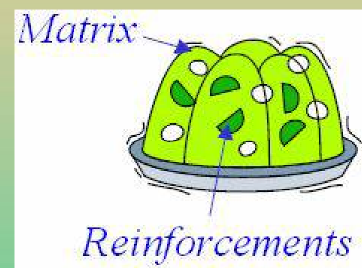
- **Matrix Phase:** Polymers, Metals, Ceramics

  Also, continuous phase, surrounds other phase (e.g.: metal, ceramic, or polymer)

- **Reinforcement Phase:** Fibers, Particles, or Flakes

  Also, dispersed phase, discontinuous phase (e.g.: metal, ceramic, or polymer)

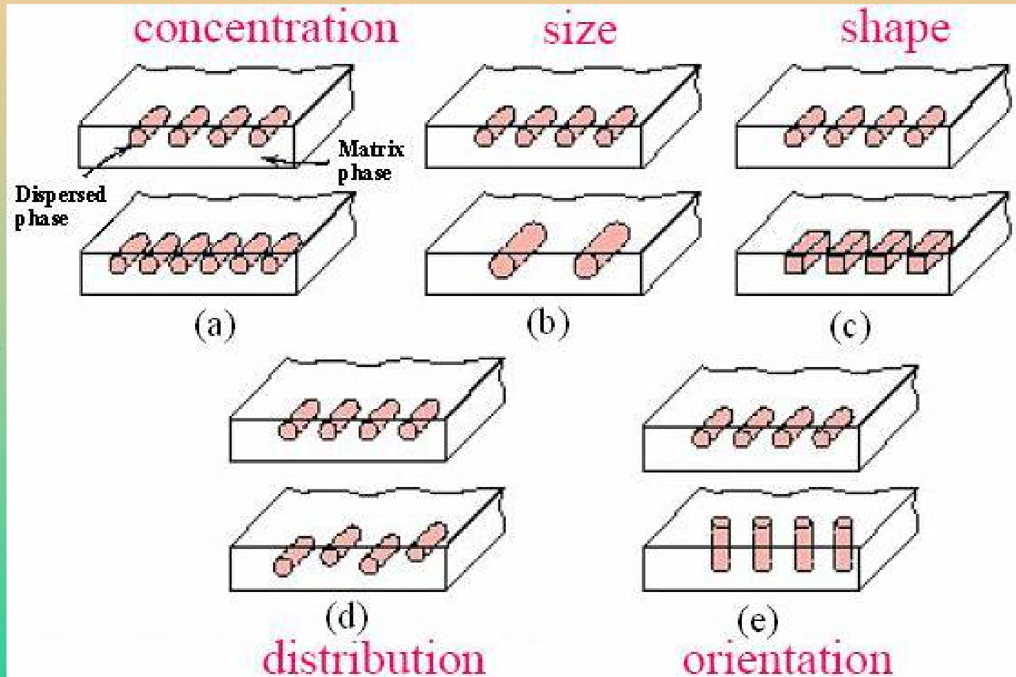
- → Interface between matrix and reinforcement



  - **Examples:**
    - Jello and cole slaw/mixed fruit
    - Peanut brittle
    - Straw in mud
    - Wood (cellulose fibers in hemicellulose and lignin)
    - Bones (soft protein collagen and hard apatite minerals)
    - Pearlite (ferrite and cementite)

Factors in Creating Composites

- **Factors** in creating composites:
  - Matrix material
  - Reinforcement material



- → control or design properties

Basic Definitions

Ceramics

- **Ceramics:** Ceramic materials are inorganic, nonmetallic materials. Most ceramics are compounds between metallic and nonmetallic elements for which the interatomic bonds are either totally ionic or predominantly ionic but having some covalent character.
- The term **ceramic** comes from the Greek word **keramikos**, which means **burnt stuff**, indicating that desirable properties of these materials are normally achieved through a high-temperature heat treatment process called **firing**.

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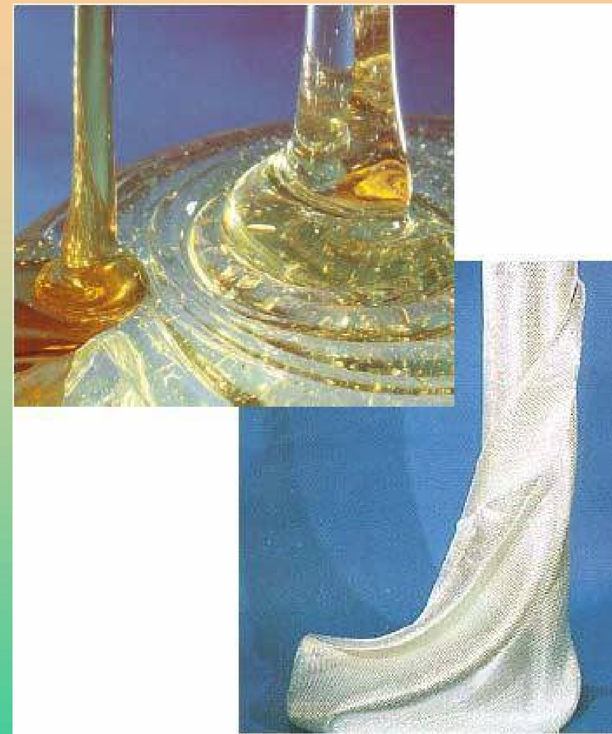
- **Composites** are a combination of two or more distinct materials
- Fiber reinforced polymers (FRP)
  - Fibers (carbon or glass)
  - Resins (epoxy matrix)



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- Reinforced concrete (Particle Reinforced Composites):
  - – Concrete (matrix)
  - – Steel (reinforcement)
  - **Dispersion-strengthened** (large particles):
  - – Fine particles of hard and inert materials (e.g., Al_2O_3, ThO_2)
  - – Matrix transfers some load to particles

Continued……

- **Examples:**
  1. **Concrete**= **cement** matrix + **sand/gravel** particles
  2. **Cermets -** ceramic particles in metallic matrix

     WC + Co (cutting tools)

M1.1.2 General Principles and Basic Concepts of Composites

- A **“Principle of combined action” -** better properties by the combination of two or more distinct materials
- In Antiquity: mechanical properties = decisive factor in materials selection – Still true today!
- But: new concepts, new families of materials
- Reinforcement of ‘matrix’ by a second dispersed phase = <u>optimum answer</u> to stringent requirements: performance, price, lightweight.
- This concept is old and simple.

Observations

- Four fundamental concepts form the basis of the composite principle:

Heterogeneity

Anisotropy

Symmetry

Hierarchy

- Many natural forms of dispersed phase possess a nanometric dimension, whereas most current man-made composites include micron-scale fibers

The Main Characteristics Of Composite Materials

(I) Heterogeneity: Non-uniformity of the chemical/physical structure

(II) Anisotropy: Direction dependence of the physical properties

(III) Symmetry: Tensorial nature of material properties

(IV) Hierarchy: Stacking of individual structural units

Moreover:

Interfacial properties - the interface may be regarded as a third phase

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Also in early Central and South America

Also in Nature: same concept (bones, finger nails, rhinoceros horn, wood, etc)

Examples for composites

- **Fibre reinforced plastics:**
  - Classified by type of fiber:
    - Wood (cellulose fibers in a lignin and hemicellulose matrix)
    - Carbon-fibre reinforced plastic (CRP)
    - Glass-fibre reinforced plastic (GRP) (informally, "fiberglass")
  - Classified by matrix:
    - Thermoplastic Composites
      - short fiber thermoplastics
      - long fiber thermoplastics or long fiber reinforced thermoplastics
      - glass mat thermoplastics
      - continuous fiber reinforced thermoplastics
    - Thermoset Composites

Continued……

- Reinforced carbon-carbon (carbon fibre in a graphite matrix)
- Metal matrix composites (MMCs):
  - White cast iron
  - Hardmetal (carbide in metal matrix)
  - Metal-intermetallic laminate
- Ceramic matrix composites:
  - Bone (hydroxyapatite reinforced with collagen fibers)
  - Cermet (ceramic and metal)
  - Concrete
- Organic matrix/ceramic aggregate composites
  - Asphalt concrete
  - Dental composite
  - Syntactic foam
  - Mother of Pearl

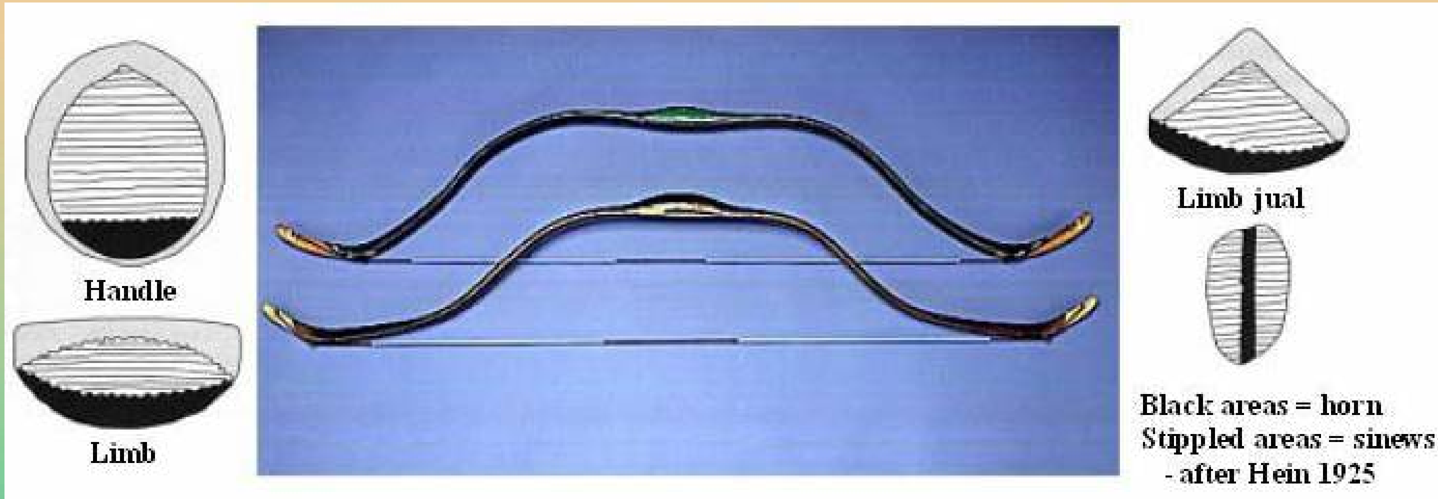
Continued……

- Chobham armour (see composite armour)
- Engineered wood
  - Plywood
  - Oriented strand board
  - Wood plastic composite (recycled wood fiber in polyethylene matrix)
  - Pykrete (sawdust in ice matrix)
- Plastic-impregnated or laminated paper or textiles
  - Arborite
  - Formica (plastic)

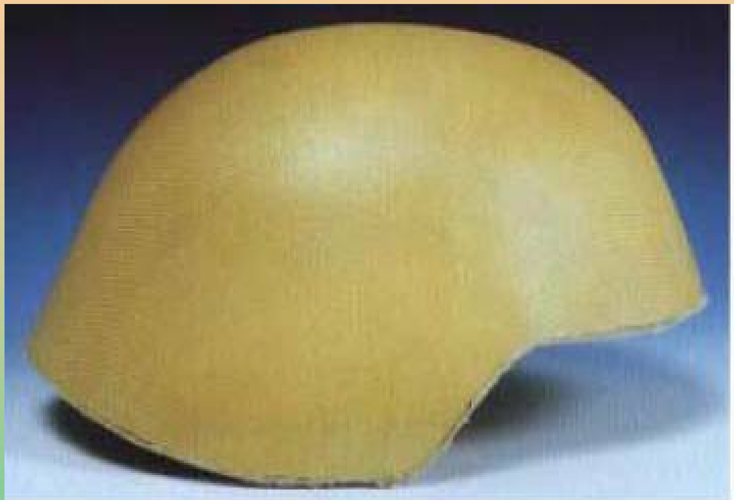
History of Composites

- Nature
  - Uses composites in structural components of both animals and plants
- Man
  - Ancient civilizations made bricks of mud and straw
  - Mongols made bows of cattle tendons, wood and silk
  - Japanese samurai swords and Damascus gun barrels, were both made of layers of Iron and Steel.

Past


Handle
Limb
Limb jual
Black areas = horn
Stippled areas = sinews
- after Hein 1925

Present



Light weight composite
military helmet

Interior part of the Mercedes A – 200
(Generation of A - classes)

Future

- In future, composites will be manufactured even more according to an integrated design process resulting in the optimum construction according to parameters such as shape, mass, strength, stiffness, durability, costs, etc. Newly developed design tools must be able to instantaneously show customers the influence of a design change on each one of these parameters.

Classification of Composites

- Classification of Composites
- Basic Definitions/ Terminology

M1.2.1 Classification of Composites

Composite materials are commonly classified at following two distinct levels:

1. **The first level of classification:** is usually made with respect to the matrix constituent. The major composite classes include Organic Matrix Composites (OMCs), Metal Matrix Composites (MMCs) and Ceramic Matrix Composites (CMCs). The term organic matrix composite is generally assumed to include two classes of composites, namely Polymer Matrix Composites (PMCs) and carbon matrix composites commonly referred to as carbon-carbon composites.
2. **The second level of classification:** refers to the reinforcement form **- fibre reinforced composites**, **laminar composites** and **particulate composites**. Fibre reinforced composites can be further divided into those containing discontinuous or continuous fibres.

M1.2.2 Organic Matrix Composites

- **M1.2.2.1 Polymer Matrix Composites (PMC)/Carbon Matrix Composites or Carbon-Carbon Composites**
- **M1.2.2.2 Metal Matrix Composites (MMC)**
- **M1.2.2.3 Ceramic Matrix Materials (CMM)**

M1.2.3 Classification Based on Reinforcements

- **M1.2.3.1 Fiber Reinforced Composites/Fibre Reinforced Polymer (FRP) Composites**
- **M1.2.3.2 Laminar Composites**
- **M1.2.3.3 Particulate Reinforced Composites (PRC)**

M1.2.5 Common Categories of Composite Materials based on fibre length

1. **Fibers as the reinforcement (Fibrous Composites):**
    a. **Random fiber (short fiber) reinforced composites**
    b. **Continuous fiber (long fiber) reinforced composites**

2. **Particles as the reinforcement (Particulate composites):**

3. **Flat flakes as the reinforcement (Flake composites):**

4. **Fillers as the reinforcement (Filler composites):**

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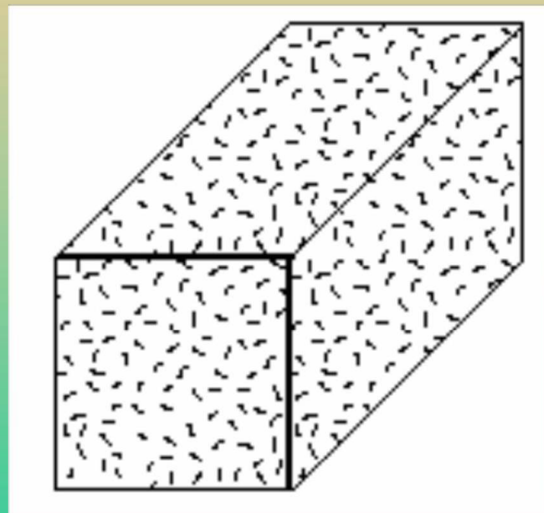
1. **Fibers as the reinforcement (Fibrous Composites):**
   a. **Random fiber (short fiber) reinforced composites**



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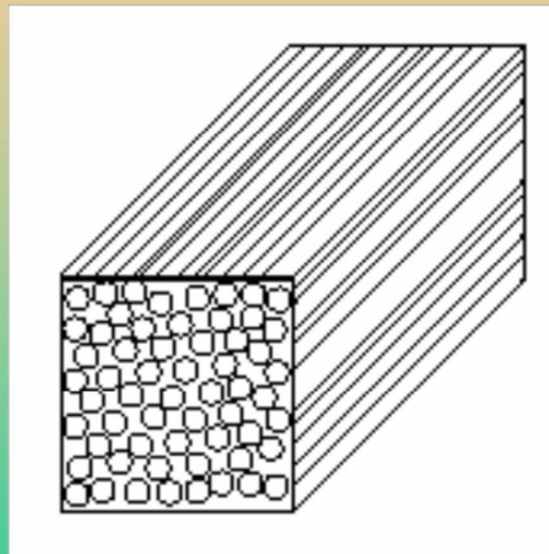
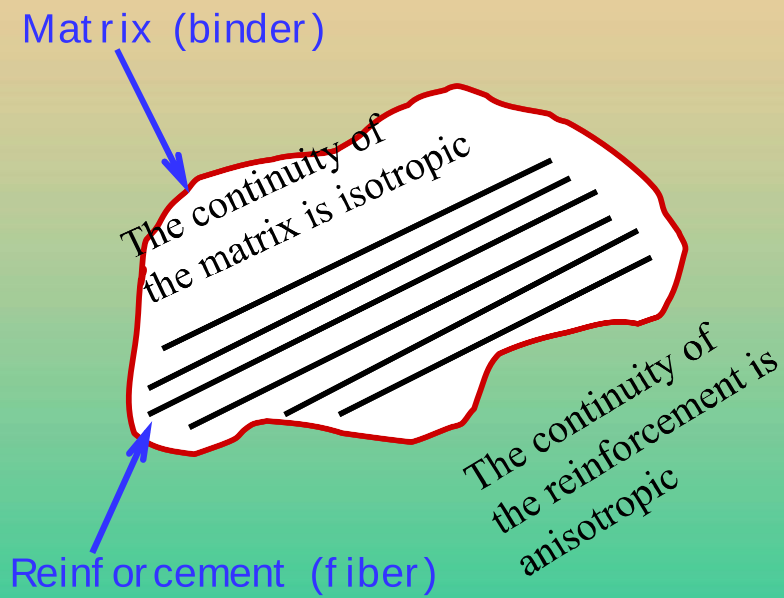
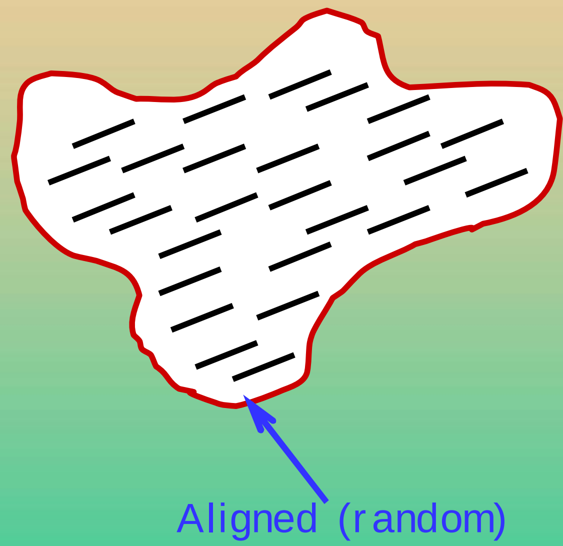
1. **Fibers as the reinforcement (Fibrous Composites):**
   b. Continuous fiber (long fiber) reinforced composites



Continuous Composite



Discontinuous Composite



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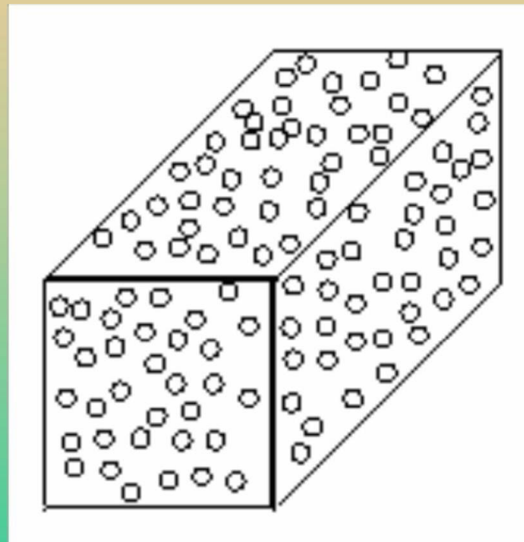
2. Particles as the reinforcement (Particulate composites):



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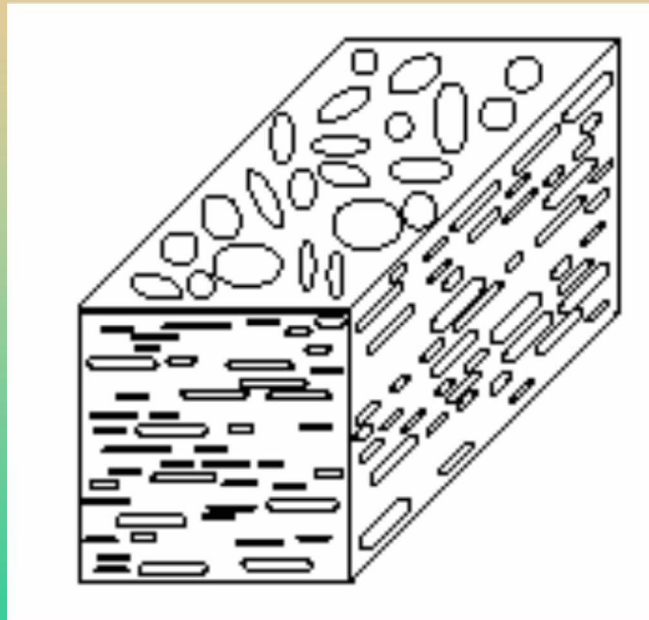
3. Flat flakes as the reinforcement (Flake composites):



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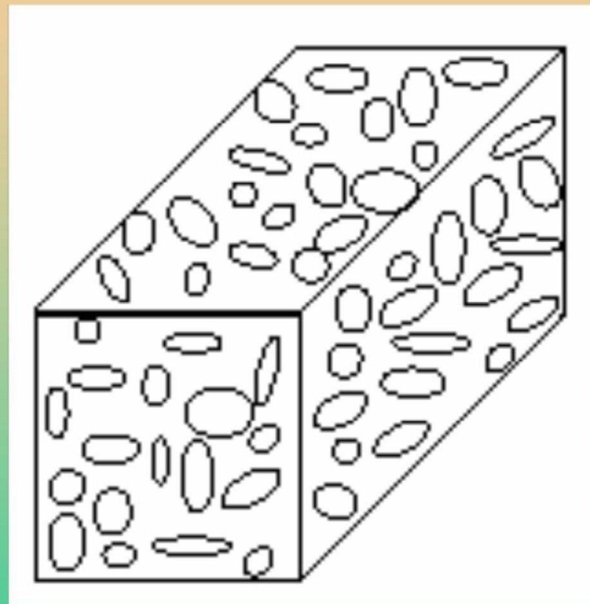
4. Fillers as the reinforcement (Filler composites):



Examples of particulate composites

- Concrete - hard particles (gravel) + cement (ceramic/ceramic composite). Properties determined by particle size distribution, quantity and matrix formulation
- Additives and fillers in polymers:
  - carbon black (conductivity, wear/heat resistance)
  - aluminium trihydride (fire retardancy)
  - glass or polymer microspheres (density reduction)
  - chalk (cost reduction)
- Cutting tool materials and abrasives (alumina, SiC, BN bonded by glass or polymer matrix; diamond/metal matrix)
- Electrical contacts (silver/tungsten for conductivity and wear resistance)
- Cast aluminium with SiC particles

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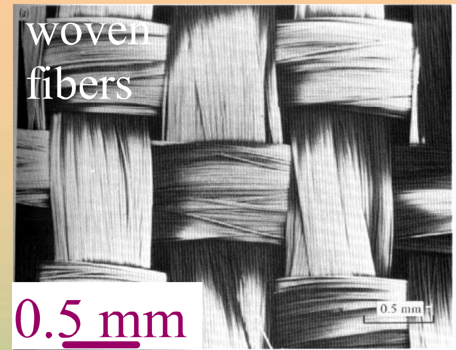

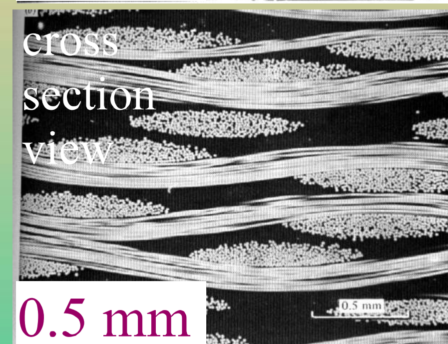

- Matrix:
  - •Classification: MMC, CMC, PMC

    Metal Ceramic Polymer
- Classification: Particle, Fiber, Structural

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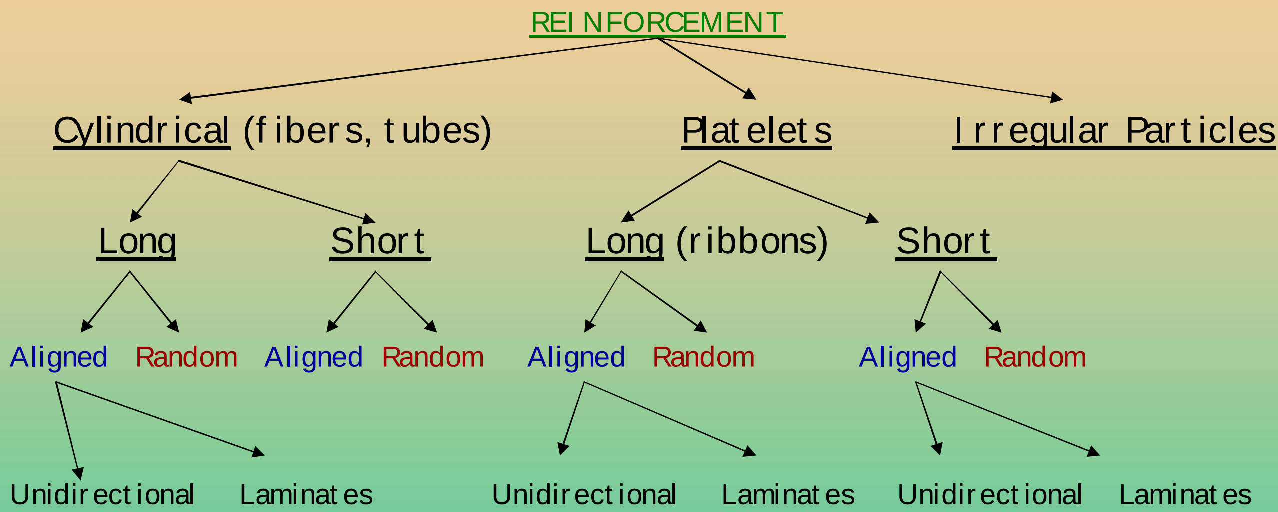
D. Hull and T.W. Clyne, An Introduction to Composite Materials, 2nd ed., Cambridge University Press, New York, 1996, Fig. 3.6, p. 47.

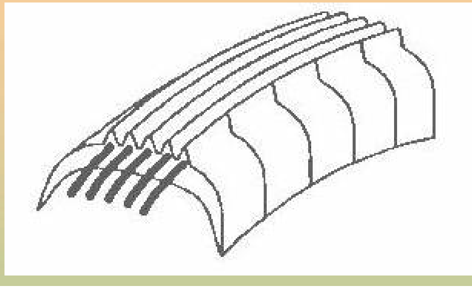
Classification Of Composites

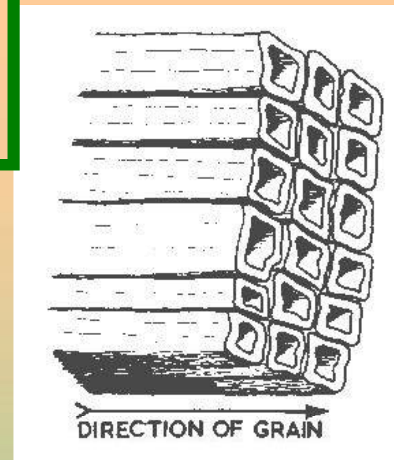


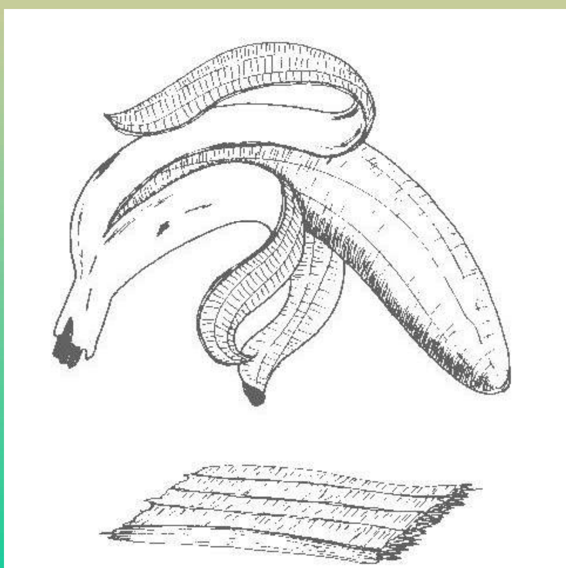
Types of Natural Fibre

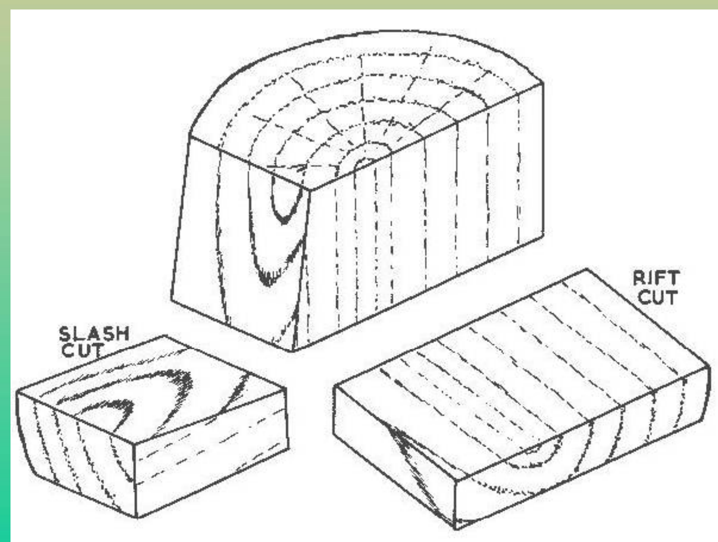
- Bast fibres (flax, hemp, jute, kenaf…)
  - wood core surrounded by stem containing cellulose filaments
- Leaf fibres (sisal, banana, palm)
- Seed fibres (cotton, coconut (coir), kapok)

Examples of Natural Composites

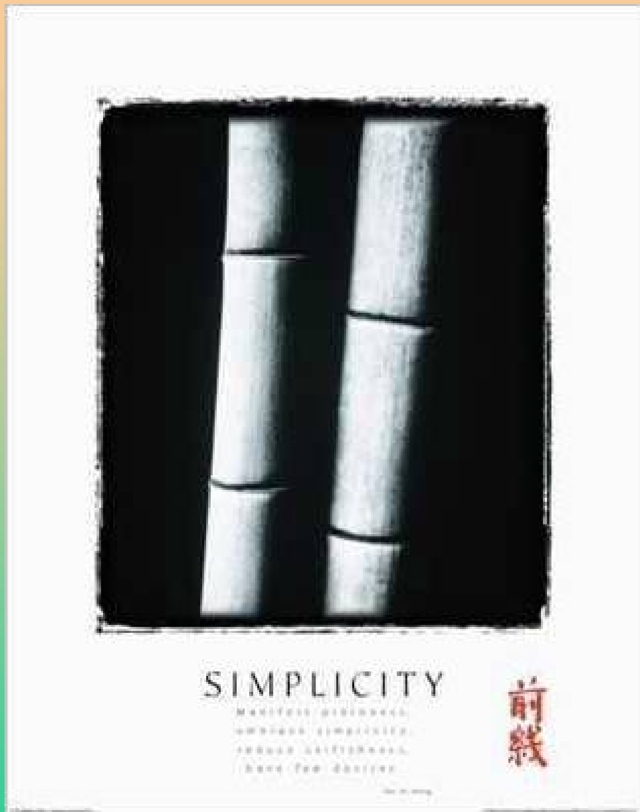








Natural composites



Terminology

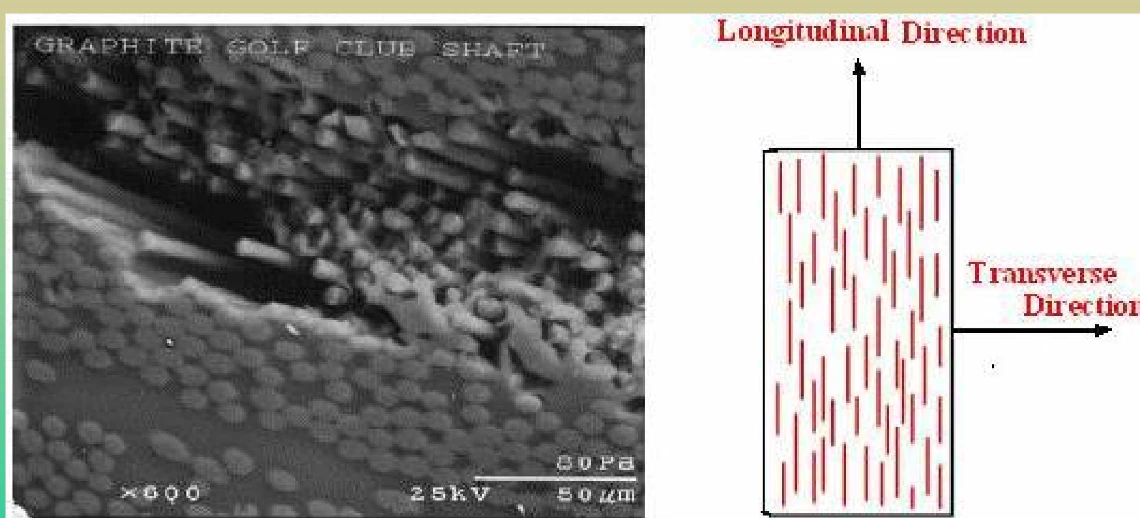
- **Fibre Reinforced Composites** are composed of fibres embedded in matrix material. Such a composite is considered to be a discontinuous fibre or short fibre composite if its properties vary with fibre length. On the other hand, when the length of the fibre is such that any further increase in length does not further increase, the elastic modulus of the composite, the composite is considered to be continuous fibre reinforced. Fibres are small in diameter and when pushed axially, they bend easily although they have very good tensile properties. These fibres must be supported to keep individual fibres from bending and buckling.
- **Fiber Reinforced Polymer (FRP) Composites:** "A matrix of polymeric material that is reinforced by fibers or other reinforcing material”

Continued……

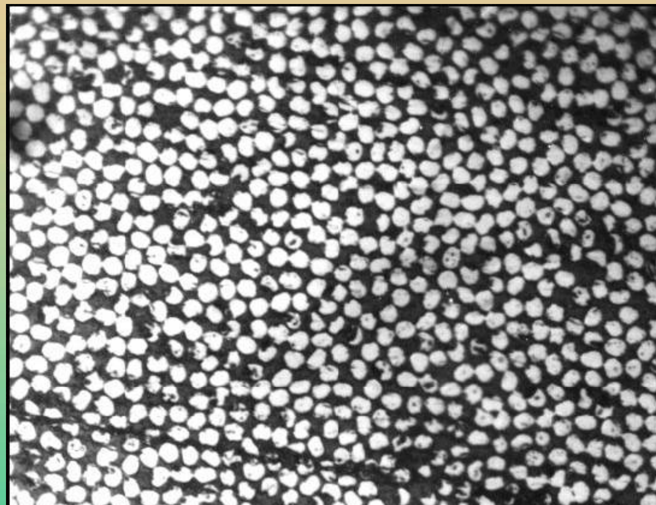
- **Laminar Composites:** are composed of layers of materials held together by matrix. Sandwich structures fall under this category.
- **Particulate Composites:** are composed of particles distributed or embedded in a matrix body. The particles may be flakes or in powder form. Concrete and wood particle boards are examples of this category.
- **Metal Matrix Composites (MMCs):** A metal matrix composite (MMC) is a type of composite material with at least two constituent parts, one being a metal. The other material may be a different metal or another material, such as a ceramic or organic compound. When at least three materials are present, it is called a hybrid composite. An MMC is complementary to a cermet.

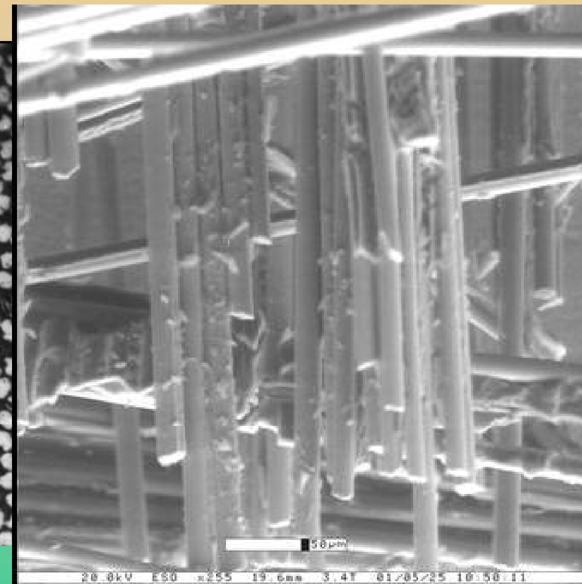
Fiber Reinforced Composites

- Long continuous fibers whiskers, wires stronger than bulk provides high specific strength or stiffness
- Orientation of fibers *(anisotropic)* in direction of loading fibers carry load



Fiber-Reinforced Composites





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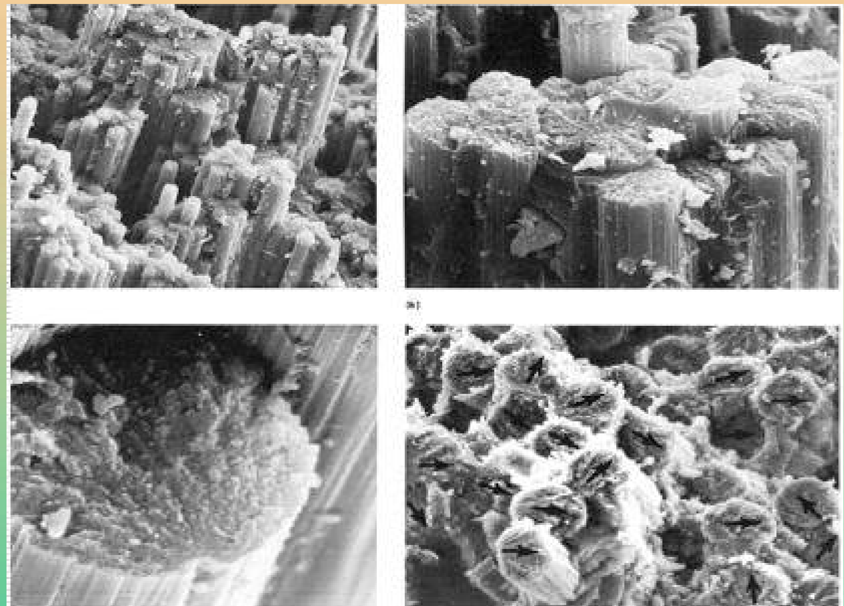

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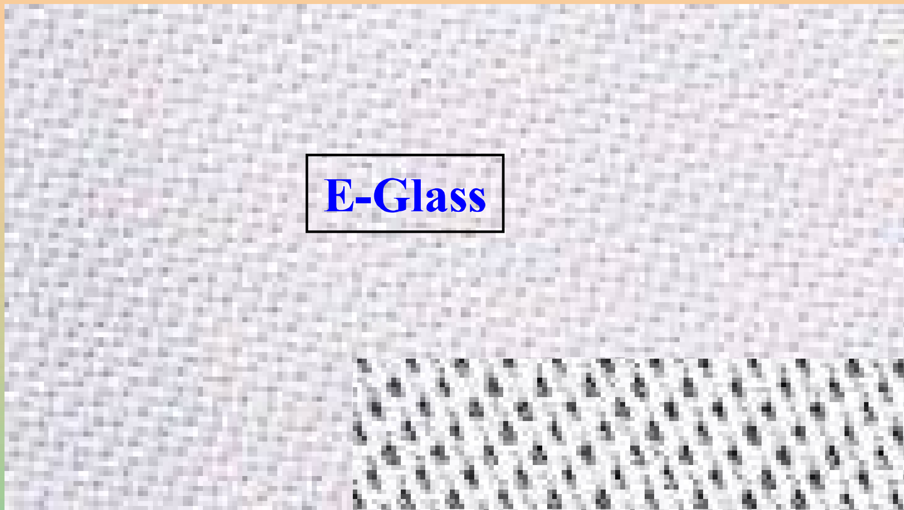

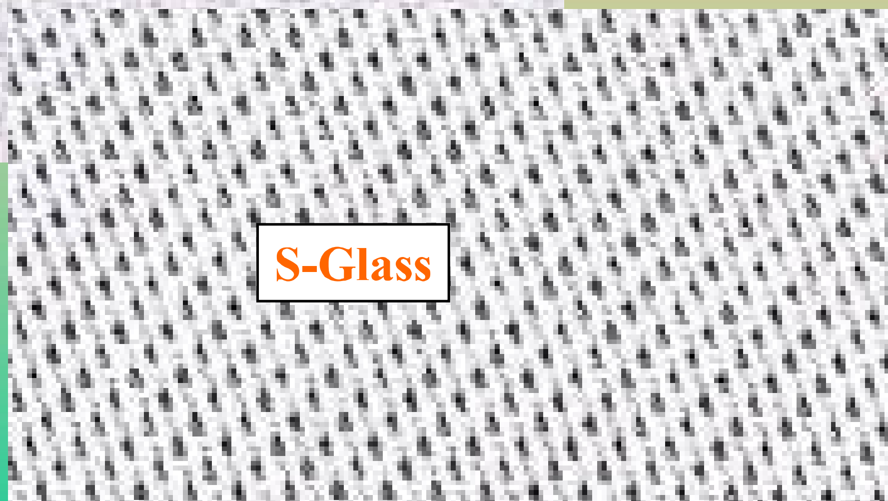

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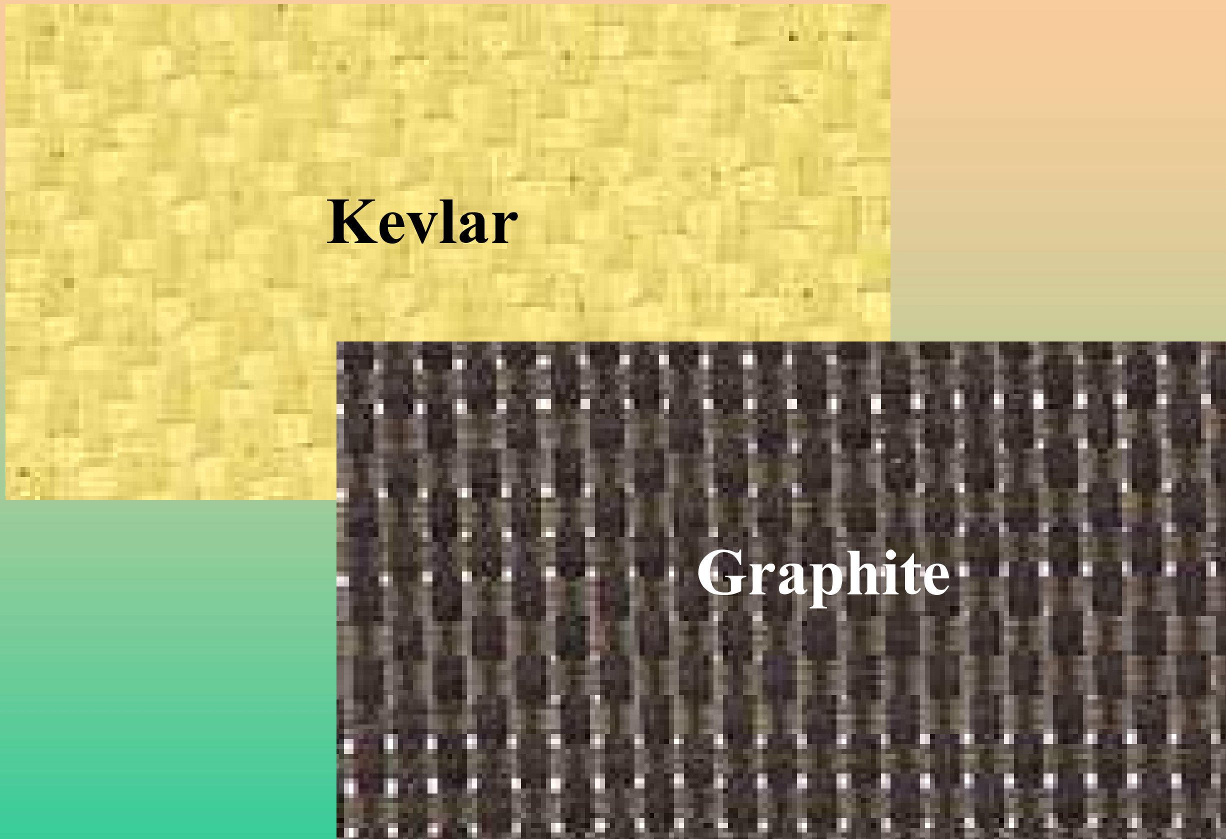
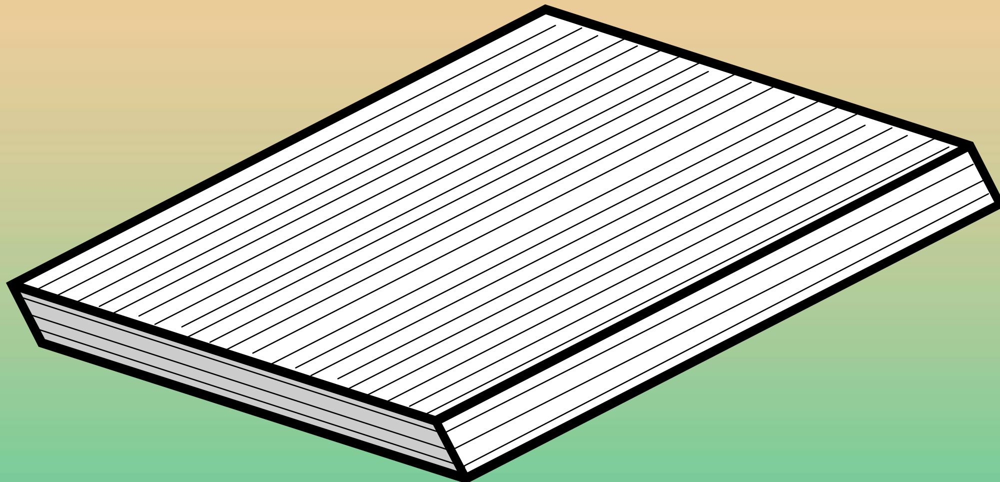


Continuous Fiber Composite



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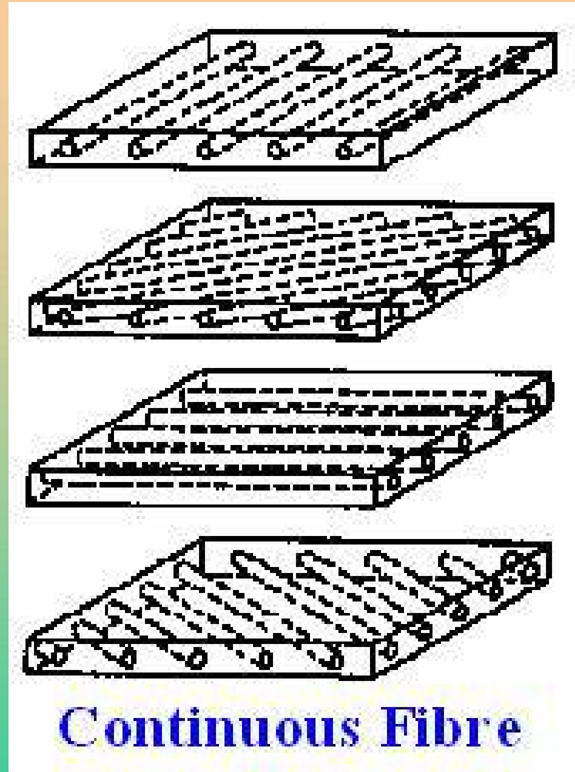
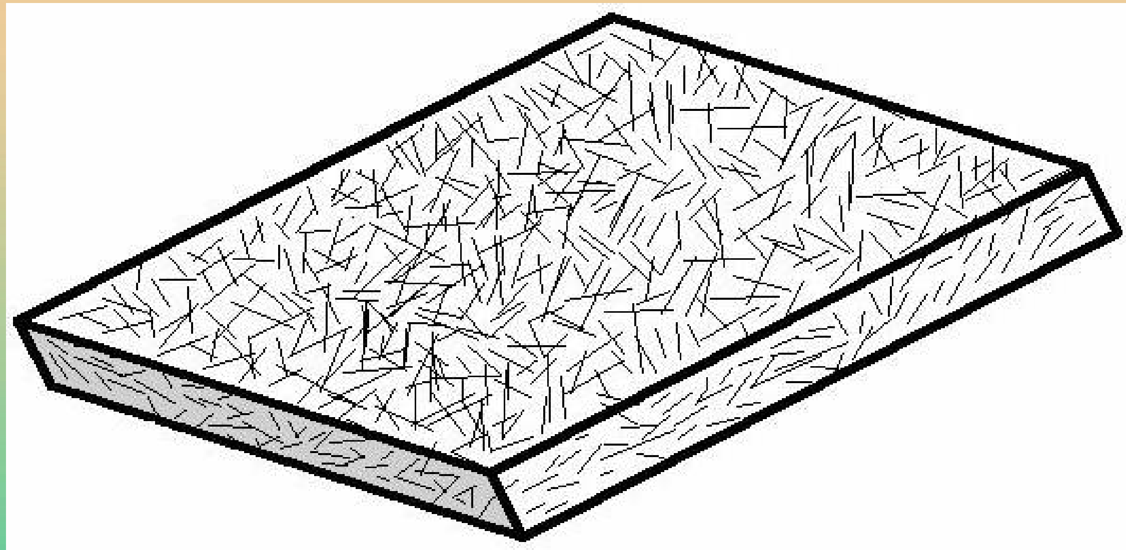
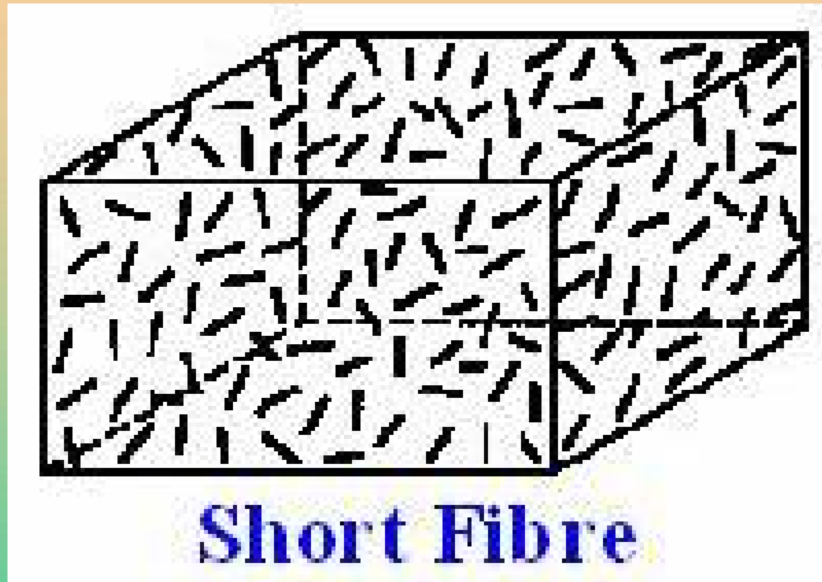


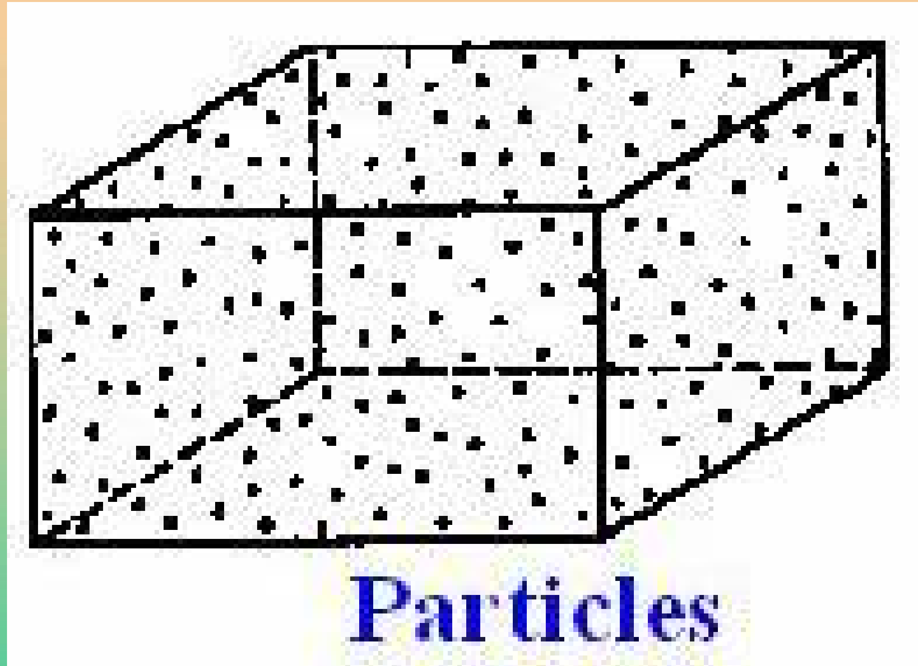
Chopped Fiber Composite



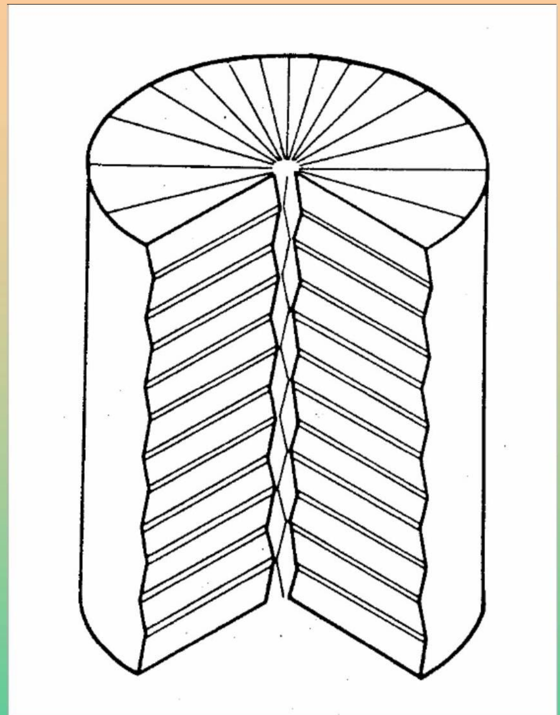
Short Fibre



Particles



Kevlar fibers



Schematic diagram of Kevlar® 49 fiber
showing the radially arranged
pleated sheets

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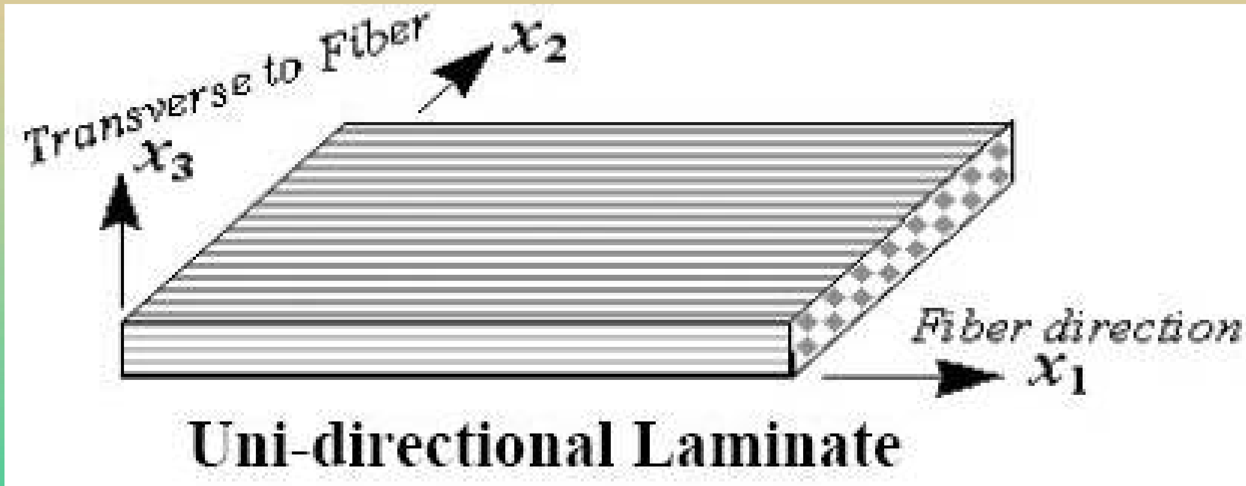
- **Lamina (or Ply):** It is a single layer (plane or curved) of unidirectional or woven fabric in a matrix.



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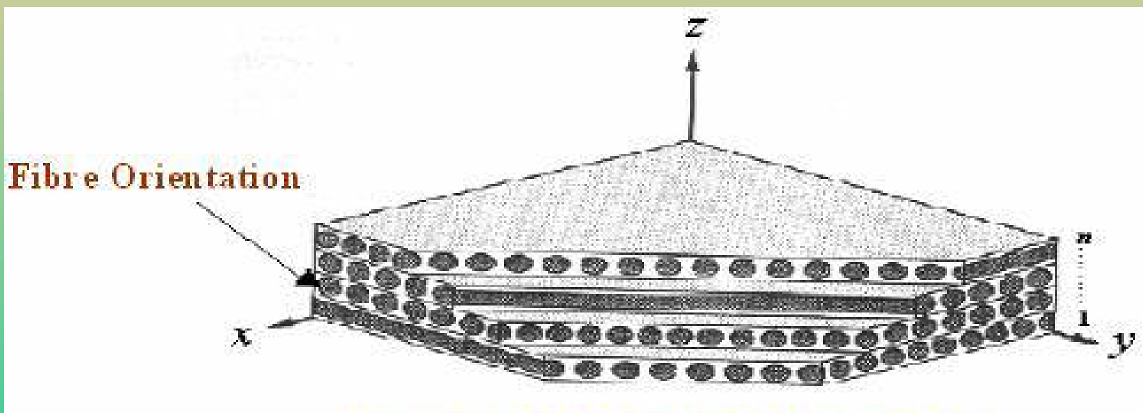
- **Laminate:** Two or more unidirectional laminae or a ply stacked together at various orientations is called Laminate.

  The laminae (plies) can be of various thicknesses and consists of different or same materials. Ex: (0/90/0), (0/0/0/0) = (04)



Laminate Stacking Sequence

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- **Fibre:** A slender, elongated, threadlike object or structure.
- **Fibre:** Fiber (American English) or Fibre (Commonwealth English, French) is a class of materials that are in discrete elongated pieces, similar to pieces of thread. Fibers are often used in the manufacture of other materials. They can be spun into thread or rope. They can be used as a component of composite materials. They can also be matted into sheets to make products such as paper or felt.

Continued……

- **Fibre:** A unit of matter, either natural or man-made, which forms the basic element of fabrics. The term refers to units which can be spun into a yarn or felting and can be processed by weaving, tufting, knitting or fusion bonding.
- **Fibre:**
  - Any of the filaments constituting the extracellular matrix of connective tissue.
  - Any of various elongated cells or threadlike structures, especially a muscle fiber or a nerve fiber.

Role and Selection of fibers

- The points to be noted in selecting the reinforcements include compatibility with matrix material, thermal stability, density, melting temperature etc.
- The efficiency of discontinuously reinforced composites is dependent on tensile strength and density of reinforcing phases. The compatibility, density, chemical and thermal stability of the reinforcement with matrix material is important for material fabrication as well as end application.
- Also, the role of the reinforcement depends upon its type in structural Composites. In particulate and whisker reinforced Composites, the matrix are the major load bearing constituent. The role of the reinforcement is to strengthen and stiffen the composite through prevention of matrix deformation by **mechanical restraint**.

Continued……

- In continuous fiber reinforced Composites, the reinforcement is the principal load-bearing constituent.
- The metallic matrix serves to hold the reinforcing fibers together and transfer as well as distribute the load.
- Discontinuous fiber reinforced Composites display characteristics between those of continuous fiber and particulate reinforced composites.
- Typically, the addition of reinforcement increases the strength, stiffness and temperature ca-pability while reducing the thermal expansion coefficient of the resulting MMC. When combined with a metallic matrix of higher density, the reinforcement also serves to reduce the density of the composite, thus enhancing properties such as specific strength.

Matrix Materials

- Although it is undoubtedly true that the high strength of composites is largely due to the fibre reinforcement, the importance of matrix material cannot be underestimated as it provides support for the fibres and assists the fibres in carrying the loads. It also provides stability to the composite material.

Factors considered for Matrix Selection

In selecting matrix material, following factors may be taken into consideration:

- The matrix must have a mechanical strength commensurate with that of the reinforcement i.e. both should be compatible. Thus, if a high strength fibre is used as the reinforcement, there is no point using a low strength matrix, which will not transmit stresses efficiently to the reinforcement.
- The resultant composite should be cost effective.

Continued……

- The matrix must stand up to the service conditions, viz., temperature, humidity, exposure to ultra-violet environment, exposure to chemical atmosphere, abrasion by dust particles, etc.
- The matrix must be easy to use in the selected fabrication process.
- Smoke requirements.
- Life expectancy.

Matrix Selection

- Thermodynamically stable dispersoids are essential for the use of metal matrix composites for high temperature applications.
- Aluminium and magnesium alloys are regarded as widely used matrices due to low density and high thermal conductivity.
- Composites with low matrix alloying additions result in attractive.
- Reducing the tensile ductility of the composite.

1.Role of Matrix

Role of Matrices in Composites

- Transfer stresses between the fibers.
- Provide a barrier against an adverse environment.
- Protect the surface of the fibers from mechanical abrasion.
- Determine inter-laminar shear strength.
- Determine damage tolerance of composites.
- Determine in-plane shear strength.
- Determine the processibility of composites.
- Determine heat resistance of composites.

2.Role of Matrix

- The primary roles of the matrix alloy then are to provide efficient transfer of load to the fibers and to blunt cracks in the event that fiber failure occurs and so the matrix alloy for continuously reinforced composites may be chosen more for toughness than for strength.
  - On this basis, lower strength, more ductile, and tougher matrix alloys may be utilized in continuously reinforced composites.
  - For discontinuously reinforced composites, the matrix may govern composite strength.
    - Then, the choice of matrix will be influenced by consideration of the required composite strength and higher strength matrix alloys may be required.

Continued……

- Additional considerations in the choice of the matrix include potential reinforcement/matrix reactions, either during processing or in service, which might result in degraded composite performance; thermal stresses due to thermal expansion mismatch between the reinforcements and the matrix; and the influence of matrix fatigue behavior on the cyclic response of the composite.

Continued……

- In composites intended for use at elevated temperatures, an additional consideration is the difference in melting temperatures between the matrix and the reinforcements. A large melting temperature difference may result in matrix creep while the reinforcements remain elastic, even at temperatures approaching the matrix melting point. However, creep in both the matrix and reinforcement must be considered when there is a small melting point difference in the composite.

Functions of Matrix

In a composite material, the matrix material serves the following functions:

- Holds the fibres together.
- Protects the fibres from environment.
- Distributes the loads evenly between fibres so that all fibres are subjected to the same amount of strain.
- Enhances transverse properties of a laminate.
- Improves impact and fracture resistance of a component.
- Helps to avoid propagation of crack growth through the fibres by providing alternate failure path along the interface between the fibres and the matrix.
- Carry interlaminar shear.

Desired Properties of a Matrix

The needs or desired properties of the matrix which are important for a composite structure are as follows:

- Reduced moisture absorption.
- Low shrinkage.
- Low coefficient of thermal expansion.
- Good flow characteristics so that it penetrates the fibre bundles completely and eliminates voids during the compacting/curing process.
- Must be elastic to transfer load to fibres.

Continued……

- Reasonable strength, modulus and elongation (elongation should be greater than fibre).
- Strength at elevated temperature (depending on application).
- Low temperature capability (depending on application).
- Excellent chemical resistance (depending on application).
- Should be easily processable into the final composite shape.
- Dimensional stability (maintains its shape).

Continued……

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- Excellent chemical resistance (depending on application).
- Should be easily processable into the final composite shape.
- Dimensional stability (maintains its shape).

Composites as Unique Materials

Advantages:

- Specific tensile strength is 4 to 6 times greater than steel or aluminum
- Specific modulus is 3 to 5 times that of steel or aluminum
- Specific thermal conductivity 40 times that of copper
- Greater fatigue resistance than steel or aluminum
- Greater design flexibility than homogeneous materials
- Potential for corrosion is significantly reduced
- Minimize part count and simplified fastening methods

Disadvantages:

- Raw material cost
- Lack of clear-cut design rules
- Lack of high productivity manufacturing methods

Advantages of Composites

Summary of the advantages exhibited by composite materials, which are of significant use in aerospace industry are as follows:

- High resistance to fatigue and corrosion **degradation**.
- High 'strength or stiffness to weight' ratio. As enumerated above, weight savings are significant ranging from 25-45% of the weight of conventional metallic designs.
- Due to greater **reliability**, there are fewer inspections and structural repairs.
- Directional **tailoring capabilities** to meet the design requirements. The fibre pattern can be laid in a manner that will tailor the structure to efficiently sustain the applied loads.
- Fibre to fibre redundant load path.

Continued……

- Improved dent resistance is normally achieved. Composite panels do not sustain damage as easily as thin gage sheet metals.
- It is easier to achieve smooth **aerodynamic profiles** for drag reduction. Complex double-curvature parts with a smooth surface finish can be made in one manufacturing operation.
- Composites offer improved **torsional stiffness**. This implies high whirling speeds, reduced number of intermediate bearings and supporting structural elements. The overall part count and manufacturing & assembly costs are thus reduced.
- High resistance to impact damage.
- Like metals, thermoplastics have indefinite shelf life.

Continued……

- Thermoplastics have rapid process cycles, making them attractive for high volume commercial applications that traditionally have been the domain of sheet metals. Moreover, thermoplastics can also be reformed.
- Composites are **dimensionally stable** i.e. they have low thermal conductivity and low coefficient of thermal expansion. Composite materials can be tailored to comply with a broad range of thermal expansion design requirements and to minimize thermal stresses.
- Manufacture and assembly are simplified because of part integration (joint/fastener reduction) thereby reducing cost.
- The improved **weatherability** of composites in a marine environment as well as their corrosion resistance and durability reduce the down time for maintenance.

Continued……

Some of the physical properties of the matrix which influence the behaviour of composites are:

- **Shrinkage** during cure
- Modulus of elasticity
- Ultimate elongation
- Strength (tensile, compressive and shear)
- **Fracture toughness**.

Some more Advantages of Composites

1. Low weight, high specific properties (many natural, and biological materials are composites)
2. Use of extremely high property (strength and modulus) constituents
3. Design flexibility: the “rule-of-mixtures” - an additional design degree of freedom
4. Synergistic effects: role of the interface, of heterogeneity/anisotropy/hierarchy
5. Anisotropy: property directionality
   Heterogeneity: chemical variability

Composite Effect

Ideally, the composite has properties that are radically different !
=Synergism (the “composite effect”)

- **Example 1:** Rule of mixture (RoM) for a physical property P:
- $P_{RoM} = P1f1 + P2f2$ (f1 + f2 = 1)
- *Useful but not interesting…*
- Synergism: $P_{Observed} >>> P_{RoM}$
- Toughness (energy to fracture): $G_{glass} \approx$ **5** J/m2, $G_{Polyster} \approx$ **100-1000** J/m2
- $G_{RoM} \approx$ 5 – 1000 J/m2 but….. $G_{Observed} \approx$ 104 - 105 J/m2 !!

WHY? HOW?

“Composite effect”

- Example 2: Mode of fracture is radically modified

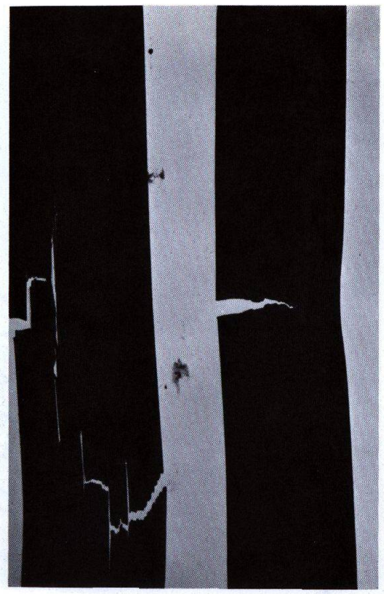

Plate 11
Chapter 5

Effect of weak interfaces in stopping or hindering cracks. Material on the left contains numerous interfaces, that on the right none. This crack-stopping mechanism is important in artificial composite materials such as fibre-glass and in wood and other biological tissues. These photographs of a copper-tungsten model material were taken by G. Cooper of Cambridge University.

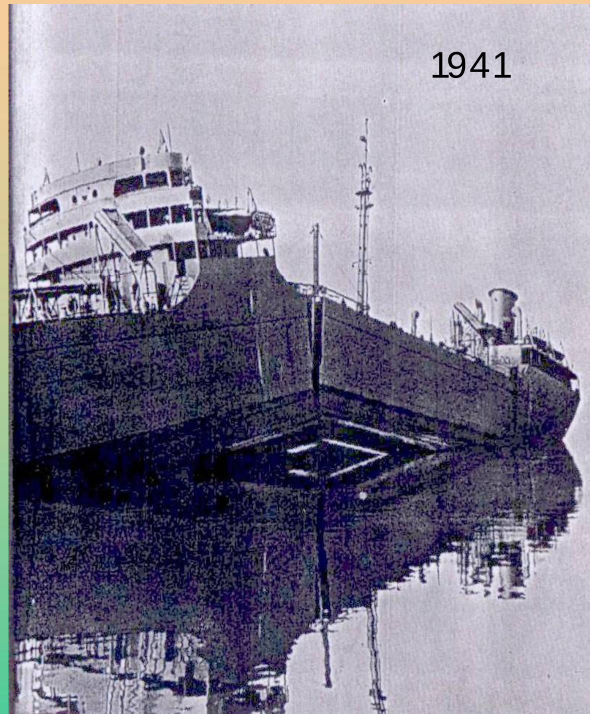

Plate 3
Chapter 1

S.S. Schenectady, designed, more or less, on simple beam theory. A crack has started at the sharp corner of a hatchway on deck and has run down to the keel.

Explanation: Composites advantages

- **High Strength with Low Weight:** Composites exhibit a higher strength to weight ratio than steel or aluminum and can be engineered to provide a wide range of tensile, flexural and impact strength properties.
- **Corrosion Resistant:** Composites are corrosion resistant to most chemicals, do not suffer from electrolysis and incorporate long term benefits Longevity

Limitations of Composites

Some of the associated disadvantages of advanced composites are as follows:

- High cost of raw materials and fabrication.
- Composites are more brittle than wrought metals and thus are more easily damaged.
- Transverse properties may be weak.
- Matrix is weak, therefore, low toughness.
- Reuse and disposal may be difficult.
- Difficult to attach.

Continued……

- Repair introduces new problems, for the following reasons:
  - Materials require refrigerated transport and storage and have limited shelf life.
  - Hot curing is necessary in many cases requiring special tooling.
  - Hot or cold curing takes time.
  - Analysis is difficult.
  - Matrix is subject to **environmental degradation**.

Why Composites?

Steel	Vs	Composites
Low material cost		High material cost
High installed cost		Low installed cost
Corrosive		Non-corrosive
Heavy		Lightweight
Fabrication required		No fabrication required
High maintenance		Low maintenance

Fibres have better stiffness and strength compared to *bulk* materials

- Atomic or molecular alignment
  (Carbon, Aramid)
- Removal of flaws and cracks (Glass)
- Strain hardening (Metals)

Continued……

- Specific tensile strength is 4 to 6 times greater than steel or aluminum
- Specific modulus is 3 to 5 times that of steel or aluminum
- Specific thermal conductivity 40 times that of copper
- Greater fatigue resistance than steel or aluminum

Comparison with Metals

- **Fatigue endurance limit** of composites may approach 60% of their **ultimate tensile strength**. For steel and aluminium, this value is considerably lower.
- Fibre composites are more versatile than metals, and can be tailored to meet performance needs and complex design requirements such as **aero-elastic loading** on the wings and the vertical & the horizontal stabilizers of aircraft.
- Composites offer significant weight saving over existing metals. Composites can provide structures that are 25-45% lighter than the conventional aluminium structures designed to meet the same functional requirements. This is due to the lower density of the composites.

Continued……

- Unidirectional fibre composites have specific tensile strength (ratio of material strength to density) about 4 to 6 times greater than that of Steel and Aluminium.
- Unidirectional composites have specific -modulus (ratio of the material stiffness to density) about 3 to 5 times greater than that of Steel and Aluminium.
- Fibre reinforced composites can be designed with excellent structural **damping features**. As such, they are less noisy and provide lower vibration transmission than metals.
- High corrosion resistance of fibre composites contributes to reduce life- cycle cost.

Continued……

- Composites offer lower manufacturing cost principally by reducing significantly the number of detailed parts and expensive technical joints required to form large metal structural components. In other words, composite parts can eliminate joints/fasteners thereby providing parts simplification and integrated design.
- Long term service experience of composite material environment and **durability behaviour** is limited in comparison with metals.

Why are Fibers of a Thin Diameter?

The diameters of fibers are generally very small (from few to hundred microns). Using thinner fibers in composites has the following advantages:

1. Thinner fiber has higher ultimate strength because less chance for inherent flaws. Similar phenomenon in metals and alloys (Strength of a thin wire can be higher than its bulk material).
2. For the same volume of fibers, thinner fibers has larger surface area thus has stronger bond with matrix. (The total surface area of fibers is inversely proportional to the diameter of fibers)
3. Thinner fiber has larger flexibility (1/(EI)) and therefore is able to be bent without breaking (Woven fabric performs can be made before impregnated with polymer matrix).

Thank You!