CHAPTER I

INTRODUCTION

Materials are probably more deep seated in our culture than most of us realize. Transportation, housing, clothing, communication, recreation and food production - virtually every segment of our daily life is influenced to one degree or another by materials. Historically the development and advancement of societies had depended on the member’s ability to produce and manipulate materials to fill their needs. In fact early civilizations were recognized by the level of their materials development. The earliest humans had access to only a very limited number of materials, those that occur naturally: stone, wood, clay, skins and so on. With time they discovered techniques for producing materials that had properties superior to those of the natural ones; these new materials included ceramics and various metals. Furthermore, it was discovered that the properties of a material could be altered by heat treatments and by the addition of other substance.

At this point materials utilization was totally a selection process that involved deciding from a given, rather limited set of materials, the one best suited for an application by virtue of its characteristics. This knowledge acquired over approximately the past 100 years has empowered them to fashion, to a large degree, the characteristics of materials. Thus tens of thousands of different materials have evolved with rather specialized
characteristics that meet the needs of our modern and complex society; these include metals, ceramics, polymers, and composites.

Metals are composed of one or more metallic elements such as iron, aluminum, copper, titanium, gold, nickel and often also non metallic elements (for example, carbon, nitrogen, and oxygen) in relatively small amounts. With regard to mechanical characteristics, these materials are relatively stiff, and strong, yet are ductile, and are resistant to fracture, which accounts for their widespread use in structural application.

Ceramics are compounds between metallic and non metallic elements; they are most frequently oxides, nitrides, and carbides. For example some of the common ceramic materials include aluminum oxide, silicon dioxide, silicon carbide, silicon nitrate etc. With regard to mechanical behavior, ceramic materials are relatively stiff and strong – stiffnesses and strengths are comparable to those of the metals. Ceramics are typically very hard. On the other hand, they are extremely brittle, and are highly susceptible to fracture. Ceramics are more resistant to high temperature and harsh environments than metals and polymers.

Polymers include the familiar plastic and rubber materials. Many of them are organic compounds that are chemically based on carbon, hydrogen, and other nonmetallic elements. Some of the common and familiar polymers are polyethylene, nylon, polyvinyl chloride, silicone rubber, etc. These materials typically have low densities, whereas their mechanical characteristics are generally dissimilar to the metallic and ceramic materials – they are not as stiff or strong as these other materials.
Many of the polymers are extremely ductile and plastic, which means they are easily formed into complex shapes. In general they are relatively inert chemically and un-reactive in a large number of environments. One major drawback to the polymers is their tendency to soften and decompose at modest temperatures, which in some instances, limits their use. There is abating thirst for new materials with improved desired properties. All the desired properties are difficult to find in a single material. But experts did lot of research and found that suitable material with all the desired properties could be developed as composites.

1.1 NATURAL FIBERS

The use of natural fiber for the reinforcement of the composites has received increasing attention both by the academic sector and the industry. Natural fibers have many significant advantages over synthetic fibers. Currently, many types of natural fibers have been investigated for use in plastics including flax, hemp, jute straw, wood, rice husk, wheat, barley, oats, cane (sugar and bamboo), grass, reeds, kenaf, oil palm empty fruit bunch, sisal, coconut fiber, kapok, paper mulberry, raphia, banana fiber, pineapple leaf fibre etc. All these fibers are grown as agricultural plants in various parts of the world and are commonly used for making ropes, carpet backing, bags, and so on. The components of natural fibers are cellulose microfibrils dispersed in an amorphous matrix of lignin and hemicellulose. Depending on the type of the natural fiber, the cellulose content is in the range of 60–80 wt% and the lignin content is in the range of 5–20 wt%. In addition, the moisture content in natural fibers can be up to 20 wt%. The properties of some of the natural fibers in use are given in Table 1.1.
Table 1.1 Properties of Selected Natural Fibers

<table>
<thead>
<tr>
<th>Property</th>
<th>Hemp</th>
<th>Flax</th>
<th>Sisal</th>
<th>Jute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (g/cm³)</td>
<td>1.48</td>
<td>1.4</td>
<td>1.33</td>
<td>1.46</td>
</tr>
<tr>
<td>Modulus (Gpa)</td>
<td>70</td>
<td>60 – 80</td>
<td>38</td>
<td>10 – 30</td>
</tr>
<tr>
<td>Tensile strength (Mpa)</td>
<td>550 – 900</td>
<td>800 – 1500</td>
<td>600 – 700</td>
<td>400 – 800</td>
</tr>
<tr>
<td>Elongation to failure</td>
<td>1.6</td>
<td>1.2 – 1.6</td>
<td>2 – 3</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Recently, natural fiber–reinforced polymers have created interest in the automotive industry for the following reasons. The applications in which natural fiber composites are now used include door inner panel, seat back, roof inner panel, and so on.

1. They are environment–friendly, meaning that they are biodegradable, and unlike glass and carbon fibers, the energy consumption to produce them is very small.

2. The density of natural fibers is in the range of 1.25 – 1.5 g/cm³ compared with 2.54 g/cm³ for E-glass fibers and 1.8 – 2.1 g/cm³ for carbon fibers.

3. The modulus to weight ratio of some natural fibers is greater than that of E-glass fibers, which means that they can be very competitive with E-glass fibers in stiffness-critical designs.

4. Natural fiber composites provide higher acoustic damping than glass or carbon fiber composites, and therefore are more suitable for noise reduction, an increasingly important requirement in interior automotive applications.

5. Natural fibers are much less expensive than glass and carbon fibers.
However, there are several limitations for natural fibers. The tensile strength of natural fibers is relatively low. Among the other limitations are low melting point and moisture absorption. At temperatures higher than 200°C, natural fibers start to degrade, first by the degradation of hemicellulose and then by the degradation of lignin. The degradation leads to odor, discoloration, release of volatiles, and deterioration of mechanical properties. Natural fibers include those made from plant, animal and mineral sources. Natural fibers can be classified according to their origin. The detailed classification is shown in Figure 1.1.

![Figure 1.1 Classification of Natural Fibers](image)

**Figure 1.1 Classification of Natural Fibers**

(1) **Animal Fiber**

Animal fiber generally comprises of proteins; examples mohair, wool, silk, alpaca, angora, etc., Animal hair (wool or hair) are the fibers taken from animals or hairy mammals, examples sheep’s wool, goat hair (cashmere, mohair), alpaca hair, goat hair, and sheep’s wool which are shown in
Figure 1.2. Silk fibers are the fibers collected from dried saliva of bugs or insects during the preparation of cocoons, examples include silk from silk worms. Avian fibers are the fibers from birds, examples feathers and feather fiber.

![Figure 1.2 (a), (b) and (c) Examples of Animal Fibers](image)

(a) Alpaca fiber    (b) Goat hair   (c) Sheep’s wool

(2) Mineral Fiber

Mineral fibers are naturally occurring fibers or slightly modified fibers procured from minerals. These can be grouped into the following categories: Asbestos is the only naturally occurring mineral fibre. Variations are serpentine amphiboles and anthophyllite. Ceramic fibers include glass fibers (Glass wood and Quartz), aluminium oxide, silicon carbide, and boron carbide. Metal fiber includes aluminium fibers.

(3) Plant Fiber / Vegetable Fiber

Plant fibers are generally comprised mainly of cellulose, examples include cotton, jute, flax, ramie, sisal and hemp. Cellulose fibers serve in the manufacture of paper and cloth. This fiber can be further categorized into following; seed fiber are the fibers collected from the seed and seed case, example cotton and kapok. Leaf fibers are the fibers collected from the leaves,
example sisal and agave. Skin fibers are the fiber collected from the skin or bast surrounding the stem of the respective plant. These fibers have higher tensile strength than other fibers. Therefore, these fibers are used for durable yarn, fabric, packaging, and paper. Some examples are flax, jute, banana, hemp, and soybean.

Fruit fibers are the fibers collected from the fruit of the plant, example coconut (coir) fiber and palm fiber. Stalk fibers are the fibers that are actually the stalks of the plant. example straws of wheat, rice, barley, and other crops including bamboo and grass. Tree wood also is such a fiber. Natural fiber composites are by no means new to mankind. Already the ancient Egyptians used clay that was reinforced by straw to build walls. In the beginning of the 20th century. Wood or cotton fiber reinforced phenol or melamine formaldehyde resins were fabricated and used in electrical applications for their non-conductive and heat-resistant properties. Present day natural fiber composites are mainly found in automotive and building industry and then mostly in applications where load bearing capacity and dimensional stability under moist and high thermal conditions are of second order importance.

For example, flax fiber reinforced polyolefins are extensively used today in the automotive industry, but the fiber acts mainly as filler material in non-structural interior panels. Natural fiber composites used for structural purposes do exist, but then usually with synthetic thermoset matrices which of course limit the environmental benefits. Natural fibers are generally lignocellulosic in nature, consisting of helically wound cellulose micro fibrils in a matrix of lignin and hemicelluloses. According to a Food and Agricultural Organization survey, Tanzania and Brazil produce the largest amount of sisal. Henequen is grown in Mexico. Abaca and hemp are grown in
the Philippines. India and Sri Lanka produce the largest amount of coconut. The largest producers of jute are India, China, and Bangladesh. Presently, the annual production of natural fibers in India is about 6 million tons as compared to worldwide production of about 25 million tons. The details of fibers and the countries of origin are given in Table 1.2.

### Table 1.2 Fibers and Countries of Origin

<table>
<thead>
<tr>
<th>Fiber</th>
<th>Countries of Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flax</td>
<td>Borneo</td>
</tr>
<tr>
<td>Hemp</td>
<td>Yugoslavia, China</td>
</tr>
<tr>
<td>Sun Hemp</td>
<td>Nigeria, Guyana, Siera Leone, <strong>India</strong></td>
</tr>
<tr>
<td>Ramie</td>
<td>Honduras, Maurititus</td>
</tr>
<tr>
<td>Jute</td>
<td><strong>India</strong>, Egypt, Guyana, Jamaica, Ghana, Malawi, Sudan, Tanzania</td>
</tr>
<tr>
<td>Kenaf</td>
<td>Iraq, Tanzania, Jamaica, South Africa, Cuba, Togo</td>
</tr>
<tr>
<td>Roselle</td>
<td>Borneo, Guyana, Malaysia, Sri Lanka, Togo, Indonesia, Tanzania</td>
</tr>
<tr>
<td>Sisal</td>
<td>East Africa, Bahamas, Antiqua, Kenya, Tanzania, <strong>India</strong></td>
</tr>
<tr>
<td>Abaca</td>
<td>Malaysia, Uganda, Philippines, Bolivia</td>
</tr>
<tr>
<td>Coir</td>
<td><strong>India</strong>, Sri Lanka, Philippines, Malaysia</td>
</tr>
</tbody>
</table>

Natural fibers such as jute, sisal, pineapple, abaca and coir have been studied as a reinforcement and filler in composites. Growing attention is being paid now-a-days to coconut fiber due to its abundant availability. The coconut husk is available in large quantities as residue from coconut production in many areas, which is yielding the coarse coir fiber. Coir is a lingo-cellulosic natural fiber. It is a seed - hair fiber obtained from the outer shell, or husk, of the coconut. It is resistant to abrasion and can be dyed. Total
world coir fiber production is 2,50,000 tones. The coir fiber industry is particularly important in some areas of the developing world.

Over 50% of the coir fiber produced annually throughout the world is consumed in the countries of origin, mainly in India. Because of its hard-wearing quality, durability and other advantages like light weight, high quality, environmental friendly, odorless, pleasant to handle and also its use for making a wide variety of floor furnishing materials, yarn, rope etc., it remains the most useful natural fiber. However, these traditional coir products consume only a small percentage of the potential total world production of coconut husk.

1.2 USES OF COIR FIBER

1.2.1 Use of Coir in Agricultural Textiles

Coir having the strong characteristics of retention of moisture is preferred for the agricultural applications. It is naturally resistant to rot, moulds and moisture. To suit the specific applications the coir fiber can be used as it is or by making a suitable product, which adapts the specific needs. Coir can be converted to coir yarn (Figure 1.3) and then to woven mesh matting (Figure 1.4), which is used mainly to control soil erosion and conditioning the soil. One more use of non-woven coir is for controlling soil erosion and conditioning the soil by more ground cover and soil retention. Non woven coir is also used in the manufacture of basket liners, mulching mats, grow sticks, cultivation mats for plants, roof green applications, portable lawn or instant lawn and many more applications. The coir fiber is also used for coco logs and coco beds for shore protection and stream banks.
1.2.2 Erosion Control Blankets for Controlling Slope Erosions

The natural coir material is having a very good application in erosion control blankets (Figure 1.5) for landscaping. The mesh of woven coir matting acts as miniature dams and prevent the seeds or seedlings from being washed away by rain and wind and facilitate the growth. The netting breaks up run off from heavy rains and dissipates the energy of flowing water. Once the growth of vegetation occurred the function of the coir is over and the vegetation will take over the protection of soil further. Coir also promotes the growth of new vegetations by absorbing water and preventing the topsoil from drying out.
Figure 1.5 Erosion control blanket

Non-woven erosion blanket protects the soil from effective erosion and creating microclimates and mulching action. The blankets will be much suited for dry lands and low fertile soil. The applications are road embankments; rail embankments, river embankments and hill slide slope.

1.2.3 Mulch Blankets

Coir due to its property can retain moisture for longer period. The coir non-woven or closely woven matting acts as a filter allowing the water to flow across its plane as well as separator. The mulch mats will suppress the weeds and retain moisture in the soil, which will protect the roots from winter frost and summer scorching sun.

1.2.4 Basket Liners

Coir basket liners are used for hanging baskets. These coir pads facilitate better aeration of the growing media. As air can flow on more easily through the pores of coir pad, it will help the roots to grow faster and more vigorously. Coir non-woven felt cut in different shapes depending upon the size of the wire basket are used as basket liners. Coir non-woven felt due to its permeability will increase the growth and retain moisture for longer period and separate the pot soil by filtering the excess water.
1.2.5 Bio-Rolls

Coir non-woven felt mats made in the form of rolls filling it with peat moss/coir pith composite are used for bio-rolls. Rapid root growth is observed using these bio-rolls. The natural product combination will support the development of plant.

1.2.6 Roof Greening Mats

Roof greening mats are manufactured with coir non-woven felt spread with seeds or seeds in laid with stitch bonded coir pads. These roof greening mats will spread on the roof surface and the seeds on the coir pads will sprout out and grow evenly on the surface (Figure 1.6). Roof greening mats are available in standard sizes or according to customer requirements.

![Figure 1.6 Roof greening mat](image)

1.2.7 Grow Sticks

Grow sticks are used as natural supports for plants and creepers. They consist of wooden pole wrapped with the layer of coir-fibre or non-woven felt. The roots of the plant can easily penetrate on the pores of coir pad. Grow stick are available in standard sizes or according to customer requirements. Figure 1.7 shows the use of coir grow sticks
1.2.8 Coco Logs

Coco logs are used along stream, river, and lake banks to protect against scour. It consists of coir fiber or coir non-woven pads in the form of rolls and covered with coir nets. Coco logs are kept at the edge of the bank secured by wooden pegs may be used on alternate sides of logs. Coco logs work as a brake on waves and reduces the impact of erosion the natural product combination will support the development of plant by roots binding which take over the protection.

1.3 APPLICATION OF COIR FIBER COMPOSITES

1.3.1 House Construction

Luisito et al. (2005) have invented coconut fibre boards (CFB) for different applications as shown in Figure 1.8. According to them, CFB can replace construction materials such as tiles, bricks, plywood, and asbestos and cement hollow blocks. It is used for internal and exterior walls, partitions and ceiling. It can also be used as a component in the fabrication of furniture, cabinets, boxes and vases, among others.
1.3.2 Motorcycle Helmet

Yuhasri and Dan (2007) utilized coconut fibers in the manufacturing of motorcycle helmet. They used epoxy resins from thermo set polymer as the matrix material and coconut fibers as the reinforcement. After the development of helmet shells fabrication method, mechanical testing (dynamic penetration) was performed on this composite material to determine its performance. The result showed that coconut fibers performed well as a suitable reinforcement to the epoxy resin matrix.

![Image of coconut fiber boards in house construction and other utilities]

Figure 1.8 Applications of coconut fibre boards in house construction and other utilities
1.3.3 Bullet Proof Vest

Yuhazri and Dan (2008) developed a unique bullet proof vest made of coconut fibre, which provides all the protection that can be found in a regular vest. It is not only economical but also lighter. A normal bullet-proof vest costs about Rs. 16,000/- and weighs 9 kg, but this vest is only 3 kg and cost Rs. 2,000/-. The test proved that the vest was capable of stopping 9mm caliber bullets at a 5m range. They also tested high impact hybrid composite material with coconut fibers as reinforcement for ballistic armor, and satisfactory results were reported.

1.3.4 Car Parts

A team of Baylor University researchers is trying to develop technology to use coconut fiber as a replacement for synthetic polyester fibers in compression molded composites. Their aim is to use the coconut fibers to make trunk liners, floorboards and interior door covers on car.

1.3.5 General Use

Apart from applications in engineering, coconut fibers are also used in yarn, ropes, mats, mattresses, brushes, sacking, caulking boats, rugs, geo-textiles, insulation panels and packaging.