CHAPTER 3

FIBER SEPARATION AND PRE TREATMENT

3.1 INTRODUCTION

The plant fiber composites have been used by the human race ever since the onset of civilization as a source of energy, to make shelters, clothes, etc. The best example is the use of straw as reinforcement for clay to build walls in ancient Egypt, 3000 years ago. Glue laminated beams were also introduced using a casein adhesive in 1893 in Basel, Switzerland. Some creative designs were made but limited by the shape and weight of the structural elements. As early as 1908, the first composite materials were attempted for the fabrication of large quantities of sheets, tubes and pipes (paper or cotton to reinforce phenol- or melamine-formaldehyde resins sheets). In recent years, there has been a renewed interest in the natural fibers as substitute for synthetic fibers. Natural fibers as reinforcements in polymer matrix composites provide positive environmental benefits with respect to disposability and raw material utilization.

This chapter deals with the fiber separation process and their properties. One of the major disadvantages of the natural fiber is the presence of moisture in it. Due to the presence of moisture, the mechanical properties of the natural fiber based composite is lesser. In order to study the effect of moisture in banana and kenaf fiber based composite, the moisture absorption tests were carried out.
3.2 FIBER SEPARATION PROCESS

Kenaf (Etymology: Persian), Hibiscus cannabinus, is a plant in the Malvaceae family. Hibiscus cannabinus is in the genus Hibiscus and is probably native to southern Asia, though its exact natural origin is unknown. It was grown in Egypt about 3000 years ago and its leaves were consumed by man and animal, the bast fiber was used for ropes, bags, and the sails for Egyptian boats. Today, principal farming areas are China and India, and it is also grown in many other countries such as the US, Mexico and Senegal. The name also applies to the fiber obtained from this plant. Kenaf is one of the allied fibers of jute and exhibits similar characteristics. Banana and Kenaf fibers find traditional and age old applications in the form of high strength ropes in India. The main uses of kenaf fiber have been rope, twine, coarse cloth (similar to that made from jute), and paper (Aji et al 2009). The kenaf fibers used as low weight and high strength ropes to lift the heavy weight from well etc. The banana fibers used to fix together the coconut leaf and wooden stem while preparing the roof of a house. These fibers have not been really examined from a composite angle at that time. These fibers have been the main source of revenue of the people in this area for more than three decades.

The kenaf plant is a relative of hibiscus and okra. Kenaf grows about 3 to 5 meters in 100-150 days (Higgins and White 1969). The kenaf bast fiber has excellent strength as compared to other bast fibers (Mwaikambo 2006). The main reason for the selection of kenaf fiber for various applications is its tensile strength and the adhesive capabilities of the fiber bundle.
Table 3.1  Mechanical properties of bast and leaf fibers (Mwaikambo 2006)

<table>
<thead>
<tr>
<th>Properties</th>
<th>Tensile strength (MPa)</th>
<th>Specific tensile strength (MPa)</th>
<th>Young’s modulus (GPa)</th>
<th>Specific Young’s modulus (GPa)</th>
<th>Failure strain (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abaca</td>
<td>12</td>
<td>-</td>
<td>41</td>
<td>-</td>
<td>3.4</td>
</tr>
<tr>
<td>Banana</td>
<td>529 – 914</td>
<td>392 – 677</td>
<td>27 – 32</td>
<td>20 – 24</td>
<td>1 - 3</td>
</tr>
<tr>
<td>Pineapple</td>
<td>413 – 1627</td>
<td>287 – 1130</td>
<td>60 – 82</td>
<td>42 – 57</td>
<td>0 – 1.6</td>
</tr>
<tr>
<td>Bamboo</td>
<td>575</td>
<td>383</td>
<td>27</td>
<td>18</td>
<td>-</td>
</tr>
<tr>
<td>Flax</td>
<td>500 – 900</td>
<td>345 – 620</td>
<td>50 -70</td>
<td>34 – 48</td>
<td>1.3 – 3.3</td>
</tr>
<tr>
<td>Hemp</td>
<td>310 – 750</td>
<td>210 – 510</td>
<td>30 -60</td>
<td>20 – 41</td>
<td>2 – 4</td>
</tr>
<tr>
<td>Kenaf</td>
<td>295 – 1191</td>
<td>-</td>
<td>22 – 60</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ramie</td>
<td>915</td>
<td>590</td>
<td>23</td>
<td>15</td>
<td>3.7</td>
</tr>
</tbody>
</table>

Natural fibers give good economic value to the people involved in the kenaf and banana related cultivation and other related work. The fiber from kenaf is extracted manually or mechanically. Manual separation process of kenaf from their plants is shown in Figures 3.1 and 3.4.

3.2.1 Extraction of kenaf fibers

Figure 3.1 shows the extraction method of kenaf fibers. The retted fibers are washed in running water and the bark and core are removed manually and eventually the bast fiber is dried in the sunlight.
Figure 3.1  Extraction of kenaf fibers (a) kenaf plant (b) retting in water for 90 days, (c) removing the top portion of the bast and (d) final form of kenaf fibers
3.2.2 Structure of natural fiber

The lumen (Figure 3.2) or cavity inside mature, dead fiber cells is very small when viewed in cross section. Fibers are one of the components of sclerenchyma tissue, along with shorter, thick-walled sclereids (stone cells) which produce the hard tissue of peach pits and the gritty texture in pears. The typical structure of natural fibers is shown in the Figure 3.2.

Figure 3.2 Plant fiber structure (Mwaikambo et al 2006)

Natural fibers can be considered as composites of hollow cellulose fibrils held together by a lignin and hemicellulose matrix. Each fiber has a complex layered structure consisting of a thin primary wall which is the first layer deposited during cell growth encircling a secondary wall. The secondary wall is made up of three layers and the thick middle layer determines the mechanical properties of the fiber. The middle layer consists of a series of
helically wound cellular microfibrils formed from long chain cellulose molecules. The angle between the fiber axis and the microfibrils is called the microfibrillar angle. The characteristic value of microfibrillar angle varies from one fiber to another. The lumen at the center of the fiber is hollow.

Figure 3.3. Kenaf bast fiber structure (Mwaikambo 2006)

3.3 EXTRATION OF BANANA FIBERS

The fully grown plant is used to extract the fibers. Figure 3.4 shows the extraction procedures of Banana fibers. Banana fiber is extracted from Banana plant. Brown-green skin is thrown away retaining the white portion which will be processed into knotted fibers. The fibers are extracted using fiber extraction machine. The peel is clamped between the wood plank and knife and hand-pulled through, to remove resinous material. Once dried, the fibers are ready for knotting. A bunch of fibers are mounted or clamped on a stick to facilitate segregation. Each fiber is separated according to sizes and grouped accordingly. To knot the fiber, each fiber is separated and knotted to the end of another fiber manually. The separation and knotting is repeated until bunches of unknotted fibers are finished to form a long continuous strand.
Figure 3.4  Extraction of banana fibers (a) cultivated banana plant (b) stalks in the form of bundles (c) retting in water for 3-4 days (d) removing the fibers from the stem, and (e) final form of banana fibers
The abstracting processes for the continuous natural banana fibers consist of two major procedures. First, the banana fiber is abstracted from the fully grown trunk after the fruit has been plucked and the banana trunks are dried under the sunlight for two weeks. After drying, the fibers are soaked in water for two weeks. In order to orientate the fiber in the composite material, dried banana fibers need to be made into monofilament fibers or be twisted before being woven. The method for weaving the natural fiber was first developed by Jones in 1975. During the separation of fibers from the plants, a large quantity of fibrous waste is produced, in which the kenaf fibrous wastes are used as a fertilizer for other plants during cultivation, but the banana fibrous wastes have no value. For the present study the fibers are separated from the kenaf and banana plants by traditional method. The fibers thus obtained have lot of impurities and these impurities are cleaned by the motorized combing device. The fibers and the waste materials are collected separately. The fibers are subjected to different mechanical test and environmental condition to study their mechanical properties and the environmental effect on mechanical properties.

3.4 CHEMICAL COMPOSITION OF BANANA AND KENAF FIBERS

The chemical composition of natural fibers varies depending upon the type of fibers. The chemical composition of kenaf and banana fiber is shown in the Table 3.1. Plant fibers are a composite material designed by nature which contains crystalline cellulose, amorphous hemi-cellulose, lignin and waxes and other water soluble components. The properties of the constituents contribute to the overall properties of the fiber. Hemi cellulose is responsible for the biodegradation, micro absorption and thermal degradation of the fiber as it shows least resistance, whereas lignin is thermally stable but prone to UV degradation. The percentage composition of each of these
components varies for different fibers. Generally, the fiber contains 60 - 80 % cellulose, 5 - 20 % lignin and up to 20 % moisture. The cell wall of the fibers undergoes pyrolysis with increasing processing temperature and contributes to char formation.

Table 3.2 Chemical composition of plant fibers (Bodig and Jayne 1982)

<table>
<thead>
<tr>
<th>Fiber type</th>
<th>Cellulose %</th>
<th>Hemi Cellulose %</th>
<th>Lignin %</th>
<th>Pectin %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana</td>
<td>60-65</td>
<td>6-19</td>
<td>5-10</td>
<td>3-5</td>
</tr>
<tr>
<td>Kenaf</td>
<td>44-57</td>
<td>21</td>
<td>15-19</td>
<td>2</td>
</tr>
</tbody>
</table>

Figure 3.5, which is the cross section of a fractured banana fiber, shows the circular nature of the fiber, along with the presence of some protruding fibrils.

Figure 3.5 SEM Micrographs of cross section of banana fiber
Figure 3.6, which is the cross section of a fractured kenaf fiber, shows the circular nature of the fiber, along with the presence of some protruding fibrils.

![SEM Micrographs of cross section of kenaf fiber](image)

Figure 3.6 SEM Micrographs of cross section of kenaf fiber

3.5 ALKALI AND SODIUM LAURYL SULPHATE TREATMENT OF BANANA AND KENAF FIBERS

The quality of fiber reinforced composite depends considerably on the fiber-matrix interface, because the interface acts as a binder and transfers stress between the matrix and the reinforcing fibers. Strong interfacial bonding can be developed as result of good wetting of the fibers by the matrix and the formation of a chemical bond between the fiber surface and the matrix. In order to develop composites with good mechanical properties and good environmental performance, it is necessary to impart hydrophobicity to the fibers by mechanical treatments, surface treatments and chemical treatments. This results in increase of the strength of the composite specimen.
Many studies were carried out to improve the properties of the composites. Mwaikambo et al 2002 studied the alkalization or acetylation of plant fibers resulting in the changes of the surface topography of the fibers and their crystallographic structure.

The fibers were washed with sodium hydroxide prior to any treatment. The sodium hydroxide opens up the cellulose structure allowing the hydroxyl groups to get ready for the reactions. During washing with sodium hydroxide, the wax, cuticle layer and part of lignin and hemicellulose were removed. The major reaction takes place between the hydroxyl groups of cellulose and the chemical used for the surface treatment. The fiber treatment resulted in the decrease of the properties of the fiber, but increase in the strength of the specimen as a whole.

The alkali treatment process has some critical parameters like:

- Alkali used
- Concentration of the solution
- Treatment duration

Here, any two of the parameters need to be fixed such that the variation in the properties of the composite can be studied carefully. The concentration of solution and treatment duration plays major role. There is a positive effect cited when the concentration increases up to certain limit, beyond that the value drops suddenly. In this case, the banana and kenaf fibers are treated in 5 %, 10 % and 15 % of alkali solution (NaOH) for 2 hr, 4 hr, 6 hr and 8 hr.

Figures of alkali treated banana fibers, SLS treated banana fibers, kenaf fiber bundle and NaOH treated kenaf fiber are given in
Figure 3.8 to 3.11. SEM pictures of NaOH treated banana fiber, SLS treated banana fiber, NaOH treated kenaf fiber, SLS treated kenaf fiber, untreated banana fiber and untreated kenaf fiber are shown in Figure 3.12 to 3.17
Figure 3.11 Scanning Electron Micrographs of treated banana fiber with NaOH

Figure 3.12 Scanning Electron Micrographs of treated banana fiber with SLS

Figure 3.13 Scanning Electron Micrograph of keanf fiber treated with NaOH

Figure 3.14 Scanning Electron Micrograph of keanf fiber treated with SLS
The details of the fiber separation processes of banana and kenaf fibers were presented. The fiber separation process and physical and mechanical properties of various fibers were reviewed. The kenaf and banana fibers are treated with alkali solution and sodium lauryl sulphate for different duration and then used for the fabrication of the composites. The moisture absorption study was carried out to analyze the effect of moisture on the mechanical property of the composites.