CHAPTER 3

PROCEDURES OF CHARACTERIZATION TESTS ON
FIBERS AND COMPOSITES

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CHAPTER 3
PROCEDURES OF CHARACTERIZATION TESTS ON
FIBERS AND COMPOSITES

3.1. TESTS ON FIBERS

The natural fibers performance depends on its composition and structure. The surface defects on the fiber will reduce the strength. The fibers can be examined by the optical microscope. The trinocular microscope will give magnified images and these images can be saved in a computer with the help of the software. The trinocular microscope images are taken in KITS S.

The Scanning Electron Microscope (SEM) images will give idea of the morphology of the fibers surface. The SEM images can also be taken at different magnifications. The fibers can be examined with and without fiber treatment. The SEM images are taken at CCMB Centre for Cellular and Molecular Biology, Hyderabad.

The spectroscopy will also used to find the nature of fibers, its structure. The differential scanning calorimetry gives the thermal properties of the fibers. The spectroscopy and DSC tests are conducted at SAIF, IIT madras.

3.2. EXAMINATION OF NATURAL FIBERS BY SEM IMAGES OF NATURAL FIBERS

The scanning electron microscope images can be used to study the fibers in nano scale also. This SEM image gives the clear picture of the fibers when they are fractured.
The effect of alkali treatment can be seen in these SEM images. The bonding between the fiber and the resin matrix can also be analyzed by the images. The surface defects, surface texture of natural fiber can be seen by SEM.

The image analyzing software has measuring tools. The linear distances can be measured easily. Other parameters like radius of a curve, thickness, etc can be measured.

Table 3.2.1. Images of fibers taken from trinocular microscope at 100x

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of fiber</th>
<th>Location 1</th>
<th>Location 2</th>
<th>Location 3</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Coir</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td></td>
<td>Longitudinal surface</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>2</td>
<td>Coir</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td></td>
<td>Longitudinal cross section</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>3</td>
<td>Coir</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td></td>
<td>Cross section</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td></td>
<td>Perpendicular to length</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
</tbody>
</table>

Table 3.2.2. SEM Images of treated fibers

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Fiber</th>
<th>100 x</th>
<th>200 x</th>
<th>900 x</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Coir</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>S.No.</td>
<td>Fiber</td>
<td>100 x</td>
<td>200 x</td>
<td>900 x</td>
</tr>
<tr>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>1</td>
<td>Coir</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>2</td>
<td>Flax</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>3</td>
<td>Hemp</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>4</td>
<td>Jute</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
</tbody>
</table>

Table: 3.2.3. SEM Images of Untreated
The microscope is a tool for examining, natural fibers, the cellulose (plant) fibers and protein (animal) fibers can be distinguished with the microscopic examination. The color of the fibers indicates the condition of the fiber, for example the dark colored fibers are poor in condition. The Clemex Vision PE image analysis system can distinguish impurities in the fiber bundles. The length, width and count measurements can be done and the statistical analysis with graphs is automatically displayed. The impure fibers data can be compared with the pure fibers. The inspection with manual vision system is costly and time consuming process. Gravimetric mechanical model of removing foreign particles is also costly and less efficient because of more mechanical components. HIS (hue, saturation and intensity) and Y’CbCr (Y lumina component, Cb blue difference and Cr Red difference) are the efficient ways of finding the foreign contaminants in the cotton fiber bundles by using image analysis. The structure of the natural fiber is complex and confusing, the fibers covers a wide range of sizes, shapes, morphology and internal pores. The study of pores on natural fibers by using 3D image analysis gives the efficient conclusion and with this the thermal conductivity of the natural fibers can be calculated accurately. Understanding of the basic mechanical properties of natural fibers is important before they are used in making composites. Electron microscopy image analysis is largely feasible to analyze the geometrical data available in the images, the large number of individual fibers in lesser time. SEM Scanning
Electron Microscope is a modern, fundamental and well suited investigative tool in the characterization of micro- and nano structured materials. 2D visualization of the natural fiber can provide qualitative and quantitative information on any physical parameters like size, morphology, surface texture, roughness. The surface morphology of plant fibers has been recognized as significant factor for composite interfaces. The surface morphology is changed by application of Electron beam irradiation. The chemical and special information can be simultaneously obtained by combining light microscopy with infrared spectrometer.ovel functional materials can also be studied with image analysis. The image analysis allows the micro examination of FRP composites. The resin distribution on the fibers and the free surface area due to hygroscopic behavior is most important in the study of the composite materials. It is possible to determine the geometrical parameters such as shape of fibers, thickness of cell walls, and the orientation can be studied with the help of image analysis. The fiber should be distributed evenly in the composite while fabricating the composite, in the composite material the distribution of the fiber in resin can be studied with the image analysis. The average diameter of fiber is required to know the performance of the fiber, to price it. Optical fiber diameter Analyzer OFDA is introduced to assess the fiber diameter. The OFDA gives the fiber diameter rapidly and accurately. The morphology of the materials used to fabricate the composites can be found with the image analysis. The fracture
analysis can also be done with image analysis of broken resin and fibers. Raman spectroscopy offers a non-destructive technique to identify the plant fiber. The Raman spectroscopy can be used to analyze the fiber and compare the fiber with other fibers. The spectroscopic analysis confirmed that the chemical treatment gives specific properties to the fibers.

3.3. SPECTROSCOPY OF NATURAL FIBERS

The spectroscopy is carried out in this work by FT IR and Raman method. These methods have been variously applied for the study of natural fibers. Spectroscopic approaches have been widely used to distinguish the wide varieties of natural fibers. The spectroscopic study can differentiate the chemically similar fibers. Spectroscopic technique requires a minimal amount of sample preparation and is easy to operate. It allows the sample to examine both at laboratory and on field environments. Spectroscopic technique can also be applied to know the maturity of the natural fiber. The Raman and IR spectroscopes are on vibrational modes, they are regarded as complementary to each other.

3.3.1. FT IR Spectroscopy:

The FT IR means, Fourier Transform Infra – Red. It is a suitable method of Infrared spectroscopy. IR radiation will be allowed to pass through the sample, of which some radiation will be absorbed by the material and remaining will be sent back to the transmitter. The
resulting IR spectrum represents the finger print of the material. The Fourier transform infrared FTIR spectroscopy was carried out to qualitatively identify the constituents of the natural fiber. FTIR allows the measurement of constituents of the natural fiber, FTIR spectra were principally observed in between 400 to 4000 cm$^{-1}$ range.

FT IR spectroscopy is used to know the effect of chemical treatment on a natural fiber.

3.3.2. Raman Spectroscopy:

Raman spectroscopy can examine the samples in glass/ plastic container. Particles with size as small as 1µm can be tested with Raman spectroscopy. Raman measurements are insensitive to water. So Raman spectroscopy became a useful and powerful tool. It can provide molecular structure information to complement infrared analysis. It can be used to characterize both natural and synthetic fiber. Fibers of different structures show different spectra and can be easily analyzed. Slight variation in composition or structure can be differentiated easily with the spectra. Raman spectra will provide a rapid, non destructive and non contact technique [25].

3.3.3. Materials and methods

3.3.3.1. Preparation of natural fibers:

The natural fibers are collected from the market where they are sold by agricultural farmers. These fibers are used to make ropes, brushes for use.
3.3.3.2. **FTIR Spectroscopy instrument:**

The interference pattern obtained from a two beam interferometer and path difference between the two beams is altered. When Fourier transformed, it gives raise to the spectrum. The transformation of the interferogram into spectrum is carried out mathematically with an on line computer.

The Perkin Elmer spectrum FTIR instrument consists of globar and mercury vapour lamp as sources. An interferometer chamber comprising of KBr and Mylar beam splitters followed by a simple chamber and detector. Entire region of 450-4000 cm\(^{-1}\) is covered by this instrument. The spectrometer works under purged conditions. Solid samples are dispersed in KBr or polyethylene pallets depending on the region of interest. This instrument has a typical resolution of 1.0 cm\(^{-1}\). Signal averaging, signal enhancement, base line correction and other spectral manipulations are possible.

3.3.3.3 **RAMAN spectrometer:**

FT-RAMAN spectrometer is a multiRAM, stand alone model. The spectral range is 4000–50 cm\(^{-1}\). The laser source is Nd: YAG 1064 nm. The spectrometer has a large sample compartment to accommodate different sample formats, from powders to liquids in vials.
3.4. **DSC ANALYSIS OF NATURAL FIBRES**

DSC examination of fiber gives thermal properties of the natural fiber. The fibers are dried sufficiently before they are kept in the analyser.

### 3.4.1. Materials and methods:

The natural fibers coir, jute, cotton and hemp are collected from local agricultural market. Thermo gravimetric is a technique in which mass of substance is measured as a function of temperature or time. The DSC Differential Scanning Calorimetry is a technique in which the difference in energy input into substance and reference material measured as a function of temperature or time.

The DSC test was performed at SAIF IIT – Madras India, by using NETZSCH STA 449 F3 Jupiter analyzer. This system can operate in a temperature range from 25 to 1400°C. This instrument is equipped with a dual furnace made up of SiC. The sensor is made up of Pt-Rh wire. The measurement can be carried out at inert, oxidizing and vacuum conditions.

### 3.4.2. Specifications of the instrument :

The instrument is NETZSCH STA 449 F3 Jupiter analyzer.

- Temperature range: 25 – 1400 deg
- Sample required: 10 to 40 mg
- Software: Proteus 6.1.0 version
- Heating rate: 0.001 to 50 K/min
3.5. **CALCULATION OF ECO INDICATOR FACTOR:**

The main reason for choosing a natural fiber reinforced composite is that, there are many potential users and it is assumed that these materials can provide environmental benefits.

The use of natural composite materials are being encouraged for many reasons like environmental benefit, low cost, providing employment to agricultural farmers, good healthy condition for fabrication workers and end users etc. Among this environmental benefit is to be discussed in depth. The health and environmental impact can be found theoretically from Life Cycle Analysis LCA. The numbers used here are taken from literature. The natural materials can also pose health problems to the workers of use of pesticides, dust produced; continuous contamination with natural materials can be caused effect by bacteria or fungus etc. But these health problems by the natural materials are not serious compared to those produced by artificial materials.

**3.5.1. Eco-indicator 95 method**

Eco-indicator 95 method is developed by a consortium of Dutch companies. The Eco-indicator 95 method weighs environmental effects that damage ecosystems or human health on a European scale. This method has taken all possible factors which make the environment polluted. Eco-indicator 95 is expressed in number mPt millipoints as a
dimension. This number is combination assigned by taking all the effects into consideration.

The environment is damaged by some important elements, examples like some will affect ozone layer, some will cause smog in summer and winter, and some others will cause green house effect. All these polluting elements effects and damages the human health. While assigning the Eco indicator number, the extent of human health damages is considered as an important factor.

The following environmental effects are taken into account in assigning the Eco-indicator 95:

- Greenhouse effect (caused by carbon dioxide, CO$_2$).
- Ozone layer depletion (caused by cloro floro carbons).
- Acidification (reference is sulphate, SO$_4$ $^{2-}$).
- Eutrophication
  (Biomass are formed, caused by phosphate, PO$_4$ $^{3-}$).
- Heavy metals (like lead, Pb).
- Carcinogenic (possible damage of health is cancer, caused by polyaromatic hydrocarbons).
- Winter smog (caused by dust and soot particles, due to SO$_2$).
- Pesticides (pollutes the agricultural land).
Table: 3.5.1. Weighing factors used in the Eco-indicator 95 method

[186-189]

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Environmental effect</th>
<th>Weighing factor</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Greenhouse effect</td>
<td>2.5</td>
<td>Damage to ecosystems</td>
</tr>
<tr>
<td>2</td>
<td>Ozone layer depletion</td>
<td>100</td>
<td>Cause to death of people</td>
</tr>
<tr>
<td>3</td>
<td>Acidification</td>
<td>10</td>
<td>ecosystem damage</td>
</tr>
<tr>
<td>4</td>
<td>Eutrophication</td>
<td>5</td>
<td>Aquatic life is in dangerous situation</td>
</tr>
<tr>
<td>5</td>
<td>Summer smog</td>
<td>2.5</td>
<td>Damage to peoples health and damage to agriculture</td>
</tr>
<tr>
<td>6</td>
<td>Winter smog</td>
<td>5</td>
<td>Occurrence of smog periods, health complaints esp. asthma patients and elderly</td>
</tr>
<tr>
<td>7</td>
<td>Pesticides</td>
<td>25</td>
<td>Damage to environment</td>
</tr>
<tr>
<td>8</td>
<td>Heavy metals</td>
<td>5</td>
<td>Lead content in blood of children, death of people due to lead</td>
</tr>
<tr>
<td>9</td>
<td>Heavy metals</td>
<td>5</td>
<td>Cadmium presence in lakes, rivers then cause people death</td>
</tr>
<tr>
<td>10</td>
<td>Carcinogenics</td>
<td>10</td>
<td>Causing death of people</td>
</tr>
</tbody>
</table>
Table: 3.5.2 Eco indicator factor of various fibers and resins [186-189]

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Material category</th>
<th>Materials</th>
<th>Material Eco-indicator [mPt/kg]</th>
<th>Remarks</th>
</tr>
</thead>
</table>
| 1     | Fiber             | Flax      | 0.34                            | Pesticides are not used  
No risk to humans in preparing Flax fibers |
|       |                   | Glass     | 2.31                            | Production glass makes lot of pollution, causing health problems and leading to death of people |
| 2     | Matrix            | Epoxy     | 10.2                            | Epoxy resin systems exposure to epoxy for longer time makes skin allergies, irritation sense; breathing affects lungs, headache and dizziness. |
|       |                   | Urea formaldehyde | 9.451 | Causes health problems, environment problems, problems of workers, deaths of people |
|       |                   | Polypropylene | 2.99  | Pollution while producing and transporting and using |
|       |                   | Polyvinyl chloride | 4.2   | Addition of stabilizers increases the pollution |
|       |                   | Polyester | 8                               | Polyester have high impact on environment pollution |
|       |                   | Natural rubber | 1.5    | Not galvanized |
|       |                   | Natural rubber | 4.3     | Galvanized |
3.6. PROCEDURES OF CHARACTERIZATION  TESTS ON COMPOSITES

The composites have two phases one is reinforcing phase and other is matrix phase. The reinforcing phase can either be fibrous or non-fibrous (particulates) in nature and if the fibers are extracted from plants, bonded to a matrix with a distinct interface between them, the combination results in superior properties not exhibited by the individual materials.

To design a composite material to fulfil a certain desire of a certain user, one may ask about the conditions (mechanical, thermal, chemical, etc) under which the composite will perform.

3.7. TENSILE TEST

The tensile properties of a composite laminate are found first among the mechanical properties. The difficulty of performing an acceptable tensile test typically increases as the orthotropy of the material increases. The unidirectional composite laminate can be tested easily by following the standard procedure.

3.7.1. Computerized Universal Testing Machine:

UTM (TUE-600C) is used for finding the strength and deformation of all kinds of materials, such as steel and other materials in the form of rods, sheets, wires, tubes, chains and so on.

This machine is designed especially for determining tensile, compressive, elongation, fold resisting, bending, adhesive, extension, flaking and appropriate test attachments which are optional.
3.7.2. Specifications Tensile test machine

1. Structure and Base: made of steel plates and hardened through surface treatment to withstand the load and vibrations.

2. Capacity: Available from 5 to 300 Ton(50 to 300KN)

3. Min resolution: 1/10000 in N

4. Accuracy: ±1%.

5. Driving method: Hydraulic system.

6. Ram stroke (mm): ranges from 100 to 250 depending upon machine capacity.

7. Effective Column Interval (mm): 300 to 750 depending upon machine capacity.

8. Cross head speed (mm/min): ranges from 50 to 100 depending upon machine capacity.

9. Testing speed (mm/min): from 50 to 250 depending upon machine capacity.
10. Machine weight: 1500 to 4000kg depending upon machine capacity.

11. Power: 220/440v, 50HZ or as desired by customers.


3.7.3. Tensile test procedure

1. Measure the dimensions of the specimen by means of a vernier calipers and steel rule respectively.

2. Grip the test specimen vertically and firmly between the upper cross head jaws and middle cross head jaws of the UTM by operating the hand wheels provided on the above two cross heads.

3. Adjust the machine to read zero on the elongation scale by opening the left control valve and closing the right control valve.

4. Select the load measuring range according to the capacity of the test piece by operating the load selector knob.

5. Adjust the load indicator pointer and dummy pointer to zero position in the dial of the control panel before conducting the actual test.

6. Now close both the left control valve and the right control valve completely.

7. To apply the loads on the specimen press the pump ON button existing on the control panel.
8. Increase the load on the specimen gradually and by opening the right control valve and then record the corresponding increase in length of the specimen from the elongation scale provided at the load elongation recording system.

9. Continue loading the specimen till the end point is reached. After yield point is reached, continue to apply the load till the fracture of the specimen occurs.

10. Switch off the machine as soon as the sample breaks. Close the right control valve and then open the left control valve slowly to release the load.

11. Now remove the broken specimen from the machine.

12. By joining the two broken halves of the specimen, measure the final length between the gauge points by using a vernier calipers and steel rule respectively.

The applied force should be applied on the composite laminate, for this reason, the ASTM 638 dog bone shaped specimen is used for testing.

Fig: 3.7.3.1. ASTM D 638 Sample specifications
3.8. COMPRESSION TEST

Fig: 3.8.1. Compression test machine

The compression strength is obtained by direct end loading of the specimen. If the sample is thin, lateral supports are to be provided to prevent buckling. This is followed by the standard test ASTM D 695. The standard ASTM D 695 specimen is dog bone shaped. The purpose of the dog bone shape is to ensure the increased load bearing area at the ends which eliminates the end crushing.

Fig: 3.8.2. Compression test ASTM D 695 end loading

3.8.1. Compression test procedure:

The general test procedure is summarized as follows:
1. Each individual specimen is treated for fabrication and material defects and based on this either note the nature or severity of the defect or discard the specimen if deemed necessary.

2. Carefully measure and record the critical dimensions of each specimen (overall length, gauge length, width, thickness) and verified to ascertain if the specified parallelism, perpendicularity and flatness requirements are met. Reject all out of tolerance specimens.

3. Attach electrical resistance strain gauges, if required and verify whether the quality of the gauge installation is acceptable.

4. Mount the fixture in the testing machine.

5. Set and record the load range and specified loading rate of the testing machine.

6. Initiate the test and manually record the data or confirm that the automated data acquisition system is functioning properly.

7. During the test, equip with suitable eye protection and transparent shield surrounding the specimen to protect eyes.
8. Verify if the test results and failure modes are reasonable before proceeding to the next specimen. Suspend testing and identify and correct the suspected problems.

3.9. SHEAR TEST

A shear test is performed on the composite laminate to know its shear modulus or shear strength. The IOSIPESCU shear test method and specimen configuration is made as per ASTM D 3410. Analysis of the specimen under load reveals that a state of uniform shear stress exists in the centre of the notched specimen on the cross section through the notches.

![Shear test sample](image)

Fig: 3.9.1. ASTM D 3410 Shear test sample

3.9.1. Shear test procedure:

1. The specimen should be centered horizontally in the test fixture using the specimen centre pin.

2. Vertical alignment is achieved by the back face of the specimen in contact with the fixture while the wedge adjustment is done with the screws.
3. The upper half of the test fixture is loaded in compression through a suitable adaptor, attaching it to the cross head of the test machine.

4. The applied load and the strain signals are monitored until the specimen fails.

5. Premature damage in the form of longitudinal matrix cracks initiating from the notch roots is a common occurrence in 0° unidirectional specimens.

6. Set the load range and load rate in the machine and apply the load. Proper safety measures are to be taken to protect from the fragments coming out.

**3.10. FLEXURAL TESTS**

Flexural test (three point bending test)

The flexure specimen is simply a strip of test material of constant width and thickness.

The deflection $\delta$ is measured using a calibrated linear variable differential transformer LVDT at the mid span. Test machine cross head maximum strain rate is 0.01 / min.
3.10. Flexural Test set up

Fig: 3.10.1. ASTM D 790 Flexural test sample

3.11. IMPACT TEST

Impact test is conducted as per ASTM D 256, it is carried out on Charpy type of impact test machines FIT 300 EN.

Fig 3.11.1. ASTM D 256 Impact test sample

3.12 BIO DEGRADATION TESTS
The properties of the composites depend on many factors, most importantly the resin and fiber individual properties and their behavior when they are composed to make the composite laminates. The volume fractions of fiber and resin in the composite, the interface strength, the curing period highly influence the properties. By studying the stress strain curve of composites, it is noted that, in all the composites the matrix is failed first followed by the fiber. It is noticed that, the fibers elongated more than the resin. The natural composites have lesser flexural strength than the glass reinforced composite laminates. All the natural materials are hydrophilic in nature. The bonding between the two hydrophilic fibers and the resin is weaker than the bonding between the hydrophobic glasses with the resin. The flexural modulus and flexural strength of these composites is less than their tensile properties. The degradation of the composites shows that the rice starch composite degraded more, the wheat starch degraded moderately.

3.13 WATER ABSORPTION TEST

The water and moisture take up properties for natural composites is considerable. Along with natural fibers the synthetic fiber should also be used to retain the strength with water absorption.

The water absorption tests were conducted at room temperature. The samples were soaked in pure water. After every two hours the weight of sample recorded. The absorption rate became
slow after 24 hours. The moisture absorption helps to increased crack propagation in the matrix region. The water dissolves the resin in some regions; the water penetrates in the fiber, and moves along the fiber. The fiber is bulged forming the cracks in composite. Ultimately the composite becomes weaker.

The water absorption test is conducted by keeping the specimen in oven at 50degree centigrade for 24 hours to evaporate any water particles in the specimen and weight of (conditioned) the specimen is noted. After that, the specimen is immersed in water for 24 hours and the weight of specimen is noted and again the specimens are kept in the oven for 24 hours.

![Fig: 3.13.1. ASTMD570 Water absorption sample](image)

Average percentage of increase in weight = \[
\frac{\sum_{i=1}^{n} X_2 - \sum_{i=1}^{n} X_1}{\sum_{i=1}^{n} X_i} \times 100
\]

\(X_1 = \text{Average (conditioned) weight of specimen before immersion.}\)
\(X_2 = \text{Average (wet) f of specimen after immersion.}\)
Fig: 3.13.2. Conditioning of water absorption specimens

Fig: 3.13.3. Electronic weighing machine for finding weights of water absorption

3.14 HYGROTHERMAL EFFECT

The action of heat and moisture has a combined effect on the composite laminate. In determining this hygro thermal effect, the tensile test is conducted on few samples. Few tensile samples are prepared. On a few of them, tensile test is conducted. This testing is called initial testing. The reaming samples were then stored in the cupboard for six months. During this time the samples are affected by moisture and heat. Then the tensile test is conducted on these
remaining samples. This testing is called final testing. The initial and final test results were analysed

**3.15 ECO INDICATOR ASSIGNMENT**

The Eco-indicator method is based on the LCA (Life Cycle Assessment) methodology. The method expresses environmental impact as mPt Eco-indicator score. There is a large database containing their impact in mPt of often used materials and processes.

Table :3.15.1. Test standards (all dimensions are in mm) m

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Test, test standard dimensions</th>
<th>Figure</th>
<th>No of samples prepared</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tensile Test ASTM D 638 type III</td>
<td>![Figure 1]</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>Compression test ASTM D 695 L = 79.5, w = 19, t = 12.5</td>
<td>![Figure 2]</td>
<td>20</td>
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<tr>
<td>3</td>
<td>Shear test ASTM D 3410</td>
<td>![Figure 3]</td>
<td>20</td>
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<td>4</td>
<td>Flexural testing ASTM D 790</td>
<td>![Figure 4]</td>
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<td></td>
<td>Test Description</td>
<td>Standard</td>
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<td>5</td>
<td>Impact ASTMD 256</td>
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<td>6</td>
<td>Moisture absorption test</td>
<td>ASTM D 570</td>
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<td>7</td>
<td>Biodegradation test</td>
<td>ASTM D 5338</td>
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