Methodology

3. METHODOLOGY

The methodology pertaining to the title **"Development of nonwoven fabrics using *Sansevieria roxburghiana* and *Agave vera-cruz Mill* fibres for selected automobile acoustic applications"** was carried out under the following headings which was shown in (Flow chart - 1).

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3.13.2. Evaluation of Fabric Properties

3.13.2.1. Visual Inspection

3.13.2.2. Mechanical properties

3.13.2.2.1. Breaking Strength and Elongation

3.13.2.3. Physical properties

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3.13.2.3.2. Thickness

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3.13.3.2.1. Tensile Properties

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3.15. Nomenclature

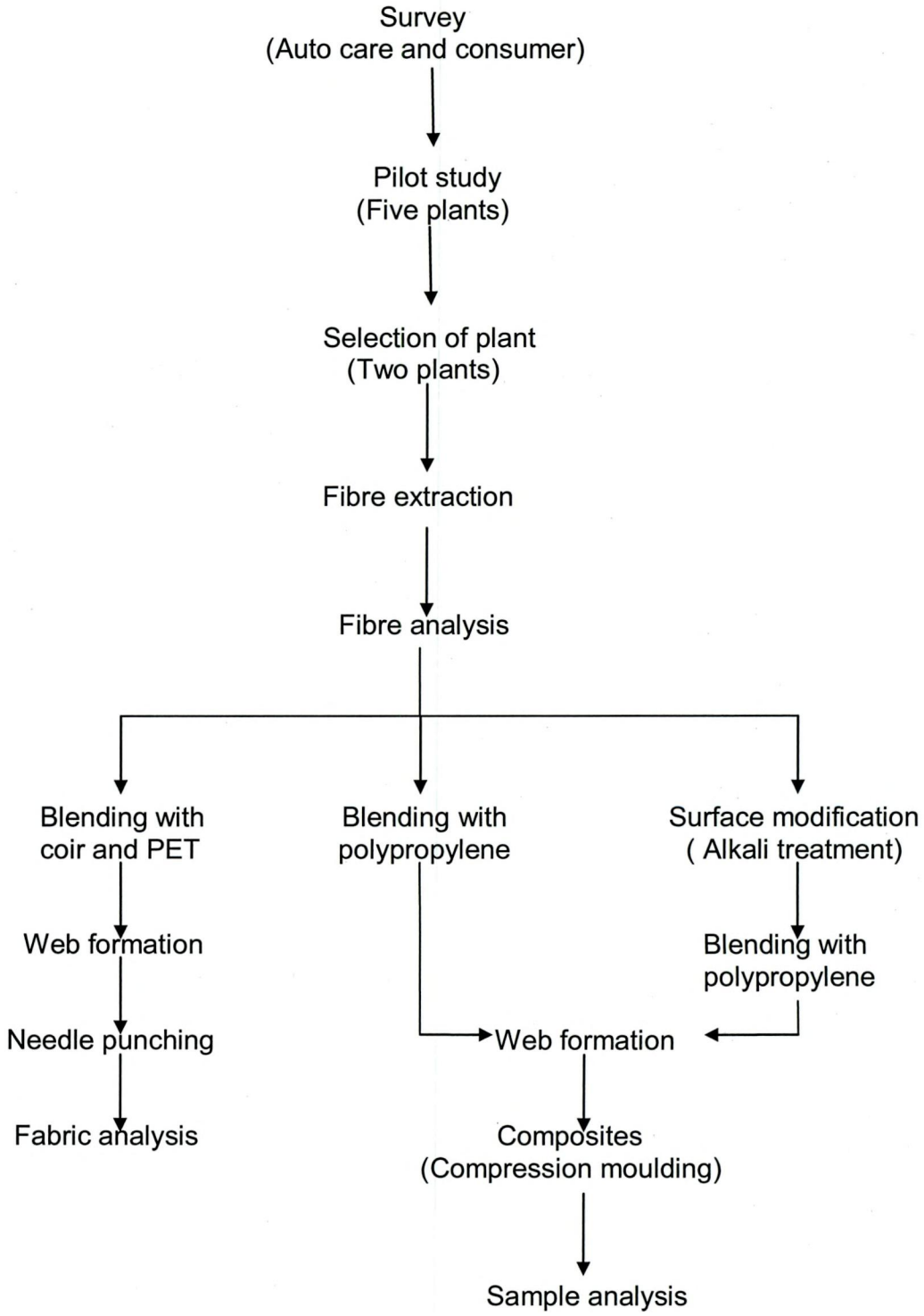
3.1. Survey

The survey is a method of collection of quantified data from a population for the purpose of description or to identify covariation between variables that may point to casual relationships or predictive patterns of influence regards Sapsford (2007). A survey involves a questionnaire of some type that is completed by either an informant, an interviewer, an observer or other agent acting on behalf of the survey organization suggests Biemer (2011). In this study

market and consumer survey was conducted to elicit the required information for the selection of fibre and type of fabric formation.

Flow Chart – 1

Experimental Procedure



3.1.1. Selection of Area

Area for the study was selected keeping the convenience sampling method. Various places in Coimbatore district belonging to Tamilnadu, India were covered to elicit the data regarding the need of textiles in the automotive sector. The areas which were covered in the market survey include Nanjappa Road, Nehru Stadium and Central RTO Office. The areas covered for consumer survey were Velandipalayam, Bharathi Park Road and K.K. Pudur.

3.1.2. Selection of Sample

The sample was used to make inferences about a population say Anderson etal. (2012). Sampling saves on cost and time regard Parasuraman etal. (2009). Random sampling was used for this study in which each sample has the equal chance to be selected. Finally 25 auto care shops who are taking care of the following like upholstery, interior, accessories, seat cover, etc and 25 customers who use the car regularly were selected to obtain the needed information about the existing textile materials, its inconvenience, any modification and requirements needed to enhance the comforts during travelling.

3.1.3. Selection of the Tool

The questionnaire is designed to collect information regarding the study which can be used subsequently as data for analysis. The information was gathered by asking people directly about the points concerned with the research remark Denscombe (2007). The questionnaire for this study consists of three types of questions namely multiple choice, dichotomous and open-ended as pointed by Weiers (2008).

3.1.3.1. Schedule - I Market Survey

The market survey (Appendix - 1) in automobile care shops was planned to know about the type of textile materials used and to find out the demand for innovative eco friendly products. The questionnaire was structured with various questions to facilitate data collection. The first part of the interview schedule contains questions such as the type of fibre, weave of textile materials used in automobiles and its durability. The second part contains questions regarding the performance of the textile material, cost factor, weight of the material and its degradable nature. The last part focusses on the need in auto care shops for light

weight textiles, acceptance for new fabrics, advice for recyclable and biodegradable products and their feedback regarding the existing textile product.

3.1.3.2. Schedule – II Consumer Survey

The customer survey (Appendix - 2) was conducted to know about their problems faced due to the existing textile product in automobiles which was focused in this study. The schedule was framed to gain information about the customer's comfort during travel, care, cost of the available textile products and their satisfaction. It includes questions regarding noise produced in their vehicles and their awareness of sound absorptive material in automobiles. Finally their feedback regarding the present textile products was also collected.

3.1.4. Pretesting of Interview Schedule

Pretests are small-scale rehearsals of the data collection conducted before the main survey. The purpose of a pretest is to evaluate the survey instrument as well as the data collection and respondent selection procedures point out Groves etal. (2009). A pretest is an effective way of fine tuning the questions for use in the actual survey process by assessing such critical factors as the clarity, comprehensiveness and acceptability of the questionnaire discuss Baker etal. (2011). Hence both the prepared schedules were pretested before they were finalized to achieve respondent's interest and to reduce the possibility of bias and error.

3.1.5. Conduct of Interview

The purpose of interviewing is to find out what is in and on someone else's mind views Klein (2009). It helps us to find out from them those things we cannot directly observe says Prada (2007). An interview is called personal when the interviewer asks the questions face to face with the interviewee point out Takona (2002). For the above reasons the investigator selected face to face interview method to collect information from the selected shops and consumers for this study.

3.1.6. Consolidation and Analysis of Data

The collected data from the shops and customers was systematically consolidated, tabulated and analyzed. From the analysis it was found that the auto care shops and consumers prefer textile products which are ecofriendly,

cost effective, have low weight, good sound absorption and need easy maintenance. After referring to the primary data the investigator found that natural fibres have the properties such as low density, bio degradability, low cost and require minimum maintenance and thus satisfy the demand of auto care shops and consumers. Hence the investigator planned to extract fibre from plants and to convert it into nonwoven structures for application in automobiles.

3.2. Pilot Study

A pilot study was conducted with five different plants namely *Sansevieria roxburghiana, Agave vera-cruz Mill, Hibiscus rosa - sinensis, Curcuma longa and Saccharum officinarum* based on the literature to find out the best varieties of plant for fibre extraction. The leaves of *Sansevieria roxburghiana* and *Agave vera-cruz Mill* plants and stem of the *Hibiscus rosa - sinensis, Curcuma longa and Saccharum officinarum* plants were selected for the pilot study. The fibres were extracted by retting method and it was noticed that last three plants are not having the required quantity and fibre properties namely strength and length to prepare the nonwovens. Hence for this study leaves of two plants namely *Sansevieria roxburghiana* and *Agave vera-cruz Mill* which were having good fibre strength and high length to thickness ratio were selected for fibre extraction.

3.3. Selected Plant for the Study

Sansevieria roxburghiana (Plate - 1) grows on the Coromandel Coast of India says Agarwal (2003). It is an erect, xerophytic herb with creeping rhizomes, leaves ranging in length from 44cm long and 1.5cm width, basal, flat, fleshy, lanceolate, acuminate, entire, base subterete and sessile remark Rao and Kumari (2008), Pallithanam (2001). *Agave vera-cruz Mill* (Plate - 2) is naturalized throughout India. It is a stout perennial herb with erect leaves about 45–75 cm long. The leaves are spinescently dentate having flowers in terminal panicles Pullaiah (2006). The leaves of Agave plants have been reported to be rich in textile fibres that belong to the class of hard fibres.

3.3.1. Plant Identification

The selected plants were confirmed for its botanical name by comparing the collected samples with those of known identity in the Herbarium of Botanical Survey of India, Tamilnadu Agriculture University, Coimbatore, India. They

confirmed its name as *Sansevieria roxburghiana* and *Agave vera-cruz Mill* after the examination in their lab. The certificate issued by them was presented in (Appendix - 3).

3.3.2. Collection of Leaves

The growing conditions, age of plant influence fibre characteristics such as strength, length, diameter, fineness, chemistry and homogeneity say Baltiņa etal. (2011); Mediavilla etal. (2001). Moreover the matured leaves contain more crude fibres when compared to young leaves suggest Goel and Rao (2004). Hence the matured leaves are taken leaving the immature ones since the fibre content will be low. *Sansevieria roxburghiana* leaves were collected from the farms in and around the Salem district and *Agave vera-cruz Mill* leaves was collected from Burgur forest, Krishnagiri district, Tamilnadu. Nearly 350kg of *Sansevieria roxburghiana* leaves (Plate - 3) and 200kg of *Agave vera-cruz Mill* leaves were cut from the bottom of the plant so that the length of the fibres will be more. Before extracting the fibres the *Agave vera-cruz Mill* leaves were cleaned to remove the spines using knife manually (Plate- 4).

3.3.3. Fibre Extraction Methods

The fibre extraction is thought to have some influence on the fibre properties as it alters the morphology and chemical composition of the fibres remark Yu (2009); Keller etal. (2001). So various fibre extraction methods namely decortication, retting such as stagnant water retting and running water retting were used in this study to find out the best method of fibre extraction. They are as follows:

3.3.3.1. Decortication

Decorticator is used for the extraction of fibres from some hard leaves such as sisal and murva. There are three types of decorticator available in the market i.e. diesel based, petrol based and electrical decorticator says Kholiya etal. (2011). In this study diesel based mechanical decorticator was used. According to Mukhopadhyay etal. (2008) the fibre extracting machine, also known as a mechanical decorticator (Plate - 5), consists of a pair of feed rollers and a beater. One end of the *Sansevieria roxburghiana* and *Agave vera-cruz Mill* leaves

Plate - 1 *Sansevieria roxburghiana* Plant

Plate – 2 *Agave vera-cruz Mill* Plant

Plate – 3 Collected *Sansevieria roxburghiana* Leaves

Plate – 4 *Agave vera-cruz Mill* Leaves Without Spines

were fed to the beater between the squeezing roller and the scrapper roller by holding the other end and vice versa. Thus the pulp gets separated and fibres were extracted. The fibres thus extracted were dried to remove the juice of the pulp for about 8hours in direct sunlight (Plate - 6). Thus by decortication the fibre damage due to retting was excluded suggests Leupin (2006).

3.3.3.2. Retting

Retting is a process in which fibres in the bark are loosened and separated from the woody stalk due to the removal of various cementing tissue components presumably of pectins, gums, etc regard Singh etal. (2003). In this study only stagnant and running water retting was used and chemical retting was not done since it is very expensive and polluting to the environment points Mittal (2012). The colour of the raw fibre varies depending upon the retting method and conditions.

3.3.3.2.1. Running Water Retting

The collected *Sansevieria roxburghiana* and *Agave vera-cruz Mill* leaves were beaten with wooden hammer to make the compact leaves loose and soft say Borah and Kalita (2004). The crushed leaves (Plate - 7) were tied into small bundles and were placed in the flowing water. A weight was placed on the bundles in order to ensure complete immersion of leaves into the water and to prevent the flow of leaves along the water direction which was shown in (Plate - 8). They were left as such so that the aerobic and anaerobic bacteria and fungi break down the pectins thus the fibre bundles are released from the epidermis and cortex say Goswami etal. (2004). Then fibres were removed by gently squashing the leaves with rocks and washing away the soft tissue with running water (Plate - 9). They were then air and sun dried by hanging them along the wire in open spaces as mentioned by Thamae and Baillie (2007).

3.3.3.2.2. Stagnant Water Retting

Both the *Sansevieria roxburghiana* and *Agave vera-cruz Mill* leaves were crushed and tied into bundles and soaked in tank for degradation of the gum present in the leaves as suggested by Vastrad etal. (2010). Weight was placed over the leaves to keep it submerged in the water (Plate - 10). The leaves were left as such until complete microbial degradation of fleshy pulp of the leaves

Plate – 5 Mechanical Decortication

Plate – 6 Drying of Fibres

Plate – 7 Crushed Leaves

Plate – 8 Running Water Retting

Plate – 9 Washing of the Fibres

Plate – 10 Stagnant Water Retting

occurs. Water was altered every week to reduce the bad odour coming due to microbial degradation. The loosened fibres were washed thoroughly with plain water and dried in sunlight for about 2 days.

Both *Sansevieria roxburghiana* and *Agave vera-cruz Mill* fibres were extracted by using the above discussed extraction methods. The extraction methods were analyzed using the fibres obtained for duration of fibre extraction, quantity and quality by visual inspection. Based on the analysis decortication method was found as the best method of fibre extraction in terms of all the parameters analyzed. Hence eco friendly decortication method was used for this study.

3.4. Combing

Combing of fibres is an essential step for quality fibre, as it removes almost all foreign matter and arranges fibres in a parallel order suggests Arooka (2003). Hence the extracted fibres were combed using hackles (Plate - 11). The hackles were wooden blocks with nails spaced in different progressions which extend outward opines Wade (2011); Rousso (2010).

3.5. Selection of Fibres for Blending

Oxygen – free polymers, like polypropylene and polyethylene, withstand complete biological degradation. The aromatic polyester (PET), although containing oxygen, withstands biodegradation, probably due to its rigid chain, Yadav (2011). Coir fibre has good mechanical and sound insulation property remark Ismail etal. (2010). Hence in this work PET (polyethylene terephthalate) staple fibre of 64mm cut length with 3denier weighing 10kg, polypropylene staple fibres of 40mm cut length with 2.5denier weighing 5kg and brown coir fibre of 60mm cut length with 20micron diameter was used. PET fibres were procured from Nowatex Fabs, Coimbatore, polypropylene from Zenith Fibres, Baroda and coir fibres from coir market in Suramangalam, Salem.

3.6. Cutting of Fibres

The process of blending of different fibres into a single fabric is made to improve quality of the fabric and to give it the desired properties. But long fibres cannot be used in this process (www.textilesindepth.com). So the *Sansevieria roxburghiana* and *Agave vera-cruz Mill* fibres were cut into small pieces with the

help of knife manually and only after that they were blended into fabric. The cut lengths of the fibres were 100 - 150 mm approximately (Plate - 12).

3.7. Blending of Fibres

Generally natural fibres are often blended with synthetic fibres to improve their qualities remarks Udale (2008). So the cut staple fibres such as *Sansevieria roxburghiana* and *Agave vera-cruz Mill* were blended (Plate - 13) with coir and PET fibres for needle punching process in 12 different ratio's as follows:

C / PET	= 50:50
S / C / PET	= 25: 25: 50
A / C / PET	= 25:25:50
C / PET	= 70:30
S / C / PET	= 35: 35: 30
A / C / PET	= 35:35:30
S / PET	= 50: 50
S / PET	= 70: 30
S / A / PET	= 25: 25: 50
S / A / PET	= 35: 35: 30
A / PET	= 50:50
A / PET	= 70:30

Abbrevation:

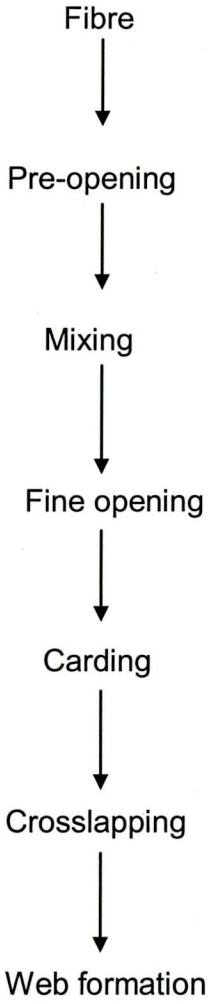
Sansevieria roxburghiana fibre – S; *Agave vera-cruz Mill* fibre – A; Coir fibre – C; Polyethylene terephthalate fibre – PET.

3.8. Steps Involved In Web Formation

The first stage in making a nonwoven fabric is to make a sheet or web of fibres point out Clarkson etal. (2002). It consists of the following steps as shown in (Flow chart – 2).

Flow Chart – 2

Steps In Web Formation



3.8.1. Pre-opening

The formation of web starts with the opening of the fibre supply. The opening process mechanically separates the fibres and thus ensures thorough blending and opening suggests Ichhaporia (2008). The fibres namely *Sansevieria roxburghiana*, *Agave vera-cruz Mill,* Coir and Polyethylene terephthalate were mixed manually according to their desired combinations as mentioned above and were fed to the pre-opening machine (Plate - 14). In the pre-opening machine the fibre opening were intensified and leveled by two pairs of working rollers mounted at the cylinder opine Albrecht etal. (2006). Care should be taken while feeding the fibre into the pre-opener. Rieter MBO type of machine was used for pre-opening the fibres which produce smaller tuft of fibres, thus creating a large surface area

for easy and efficient removal of trash particles during the fine opening process (www.cottonyarnmarket.net).

3.8.2. Mixing

The fibres after pre opening were intermixed (Plate - 15) before they enter into the card. The fibre passes into series of mixing zones by suction method that consist of a pair of bale openers feeding to a cross lattice opines Balasubramaniam (2009). Thus mixing ensures proper opening and blending of the fibres. The mixed fibres were then passed to the fine opener.

3.8.3. Fine Opening

The fine opening rounds of the fibre preparation and provide the fibres for the feeding system for further processing (www.fibre2fashion.com). Good fibre opening is essential to improve the intimacy of the blend and to achieve good web qualities in the down-stream processes say Parikh etal. (2002). So the mixed fibres were passed through a Erko fine opener (Plate - 16) since it suits best for opening and cleaning of natural fibres.

3.8.4. Carding

Opened fibres were pneumatically fed to card feeders. The nonwoven carding machine has a series of revolving drums covered with fine metallic wires (www.technicaltextile.net). The carding operation (Plate - 17) was done in order to remove any impurities and to separate the fibres, then align and deliver the fibres as a web. The carding technique suits the production of high quality staple nonwovens. It is simple and cost effective says Singh (2010). The point per square inch (PPS) was more about this nonwoven carding machine which has 200 hooks to open the fibre. In this study the strength ratio of machine direction : cross direction is 1 : 1 hence the web formed is condensed web suggest Joseph (2005). The condensed web will have even strength in all the directions.

3.8.5. Crosslapping or Layering

A single layer of carded web was too light and diffuses to make into a fabric, so a number of layers must be laid on top of one another to get the necessary weight. So crosslapping was done after the carding process to control the thickness of the web. Card web coming out of the card was passed through a cross lapper (Plate - 18). In this process the prepared webs are laid back and

Plate – 11 Fibre Combing Using Hackles

Plate – 12 Cut Fibre

Plate – 13 Fibre Blending

Plate – 14 Pre-opening

Plate – 15 Mixing

Plate – 16 Fine Opening

forth onto a conveyor moving at a right angle to the cross-layering motion opines Hutten (2007).

3.9. Steps Involved In Needle Punching Technique

The cross laid web was then provided integrity and strength by bonding it using mechanical interlocking method known as needle punching process report Kumar etal. (2011). This process has two steps such as pre-needling and main needling as follows.

3.9.1. Pre-needling

The bulky cross-laid web was fed to a pair of compression rollers thus bonded by pre-needler which squeezes the fibre so that it will pass through the narrow gap between the bed and stripper plates of the needle loom reveal Batra and Pourdeyhimi (2012). In the pre needling process (Plate - 19) downward punching of the web takes place using Fehrer pre-needle punching loom. The cross-laid batt was loosely bonded by some fibre entanglement thereby decreasing batt thickness prior to full consolidation (main needling) regard Albrecht etal. (2006). Thus pre-needling imparts sufficient integrity to withstand the process-tensions during subsequent needle punching. It also squeezes the web, allowing easier movement through the needle loom bed plate and stripper plate gap. This machine has 1500 needles per 1m working width with 40mm stroke height. The width of the needle was 2.2m-9.0m with 500strokes/min. The delivery speed was 0.6m/min.

3.9.2. Main Needling

The pre-needled web was taken to the main loom for final punching. In the main needle punching process the pre-needled batt was made to pass through a number of needles with barbs, mounted on a board which reciprocates at high speed. This machine has needle board, stripper plate and stitching plate. For the needle punching process German based Dilo machine (Plate - 20) was used. The specification of this machine was 2000 needles per 1m working width arranged in 24 rows in a needle board. The stroke height was 50mm, the stroke speed was 400strokes/min with the speed of 500rpm and a punch density of 0.02. The fabric delivery speed was 0.7m/min. The needle used in this process was triangular in cross-section with barbs at the three edges. As the needle penetrates through the

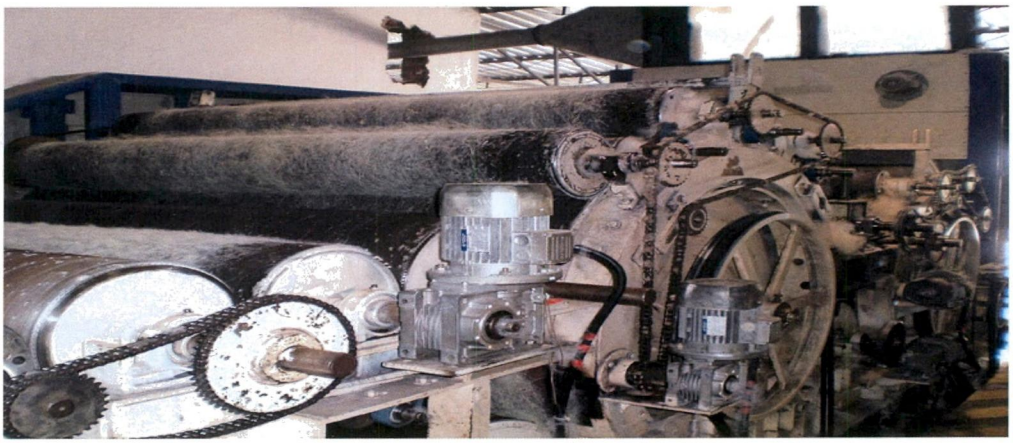


Plate – 17 Carding

Plate – 18 Crosslapping

Plate – 19 Pre-needling

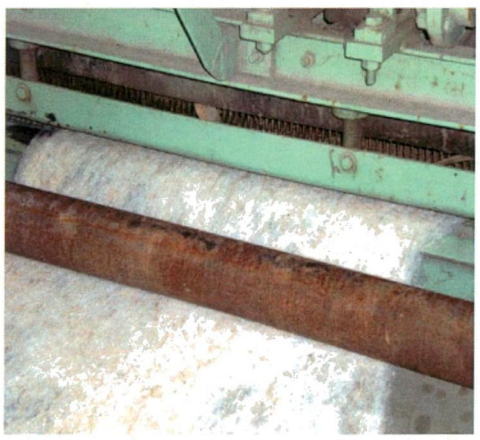


Plate – 20 Main Needling

batt, the barbs carry fibres with them thereby causing mechanical entanglement of fibres suggests Balasubramanian (2011).

3.10. Surface Modification of Fibres

Surface modification of natural fibres contributes to significant increase in both tensile and flexural strength of composites say Raju etal. (2012). Sodium hydroxide (NaOH) treatment causes dissolution of lignin thus binding the fibres of cellulose regard Nandan etal. (2008). Hence the fibres were given alkali treatment with NaOH at three different percentages such as 2, 4 and 6 (Plate – 21). The fibres were treated with these combinations at a temperature of 80°C in water bath. The treatment was continued for 1hour with constant stirring. Then the fibres were removed from the NaOH bath and rinsed thoroughly. After analyzing various characteristics of the treated fibre it was identified that 6 per cent NaOH treated fibre has good surface modification. Hence it was selected for the final study.

3.11. Blending of Fibres For Composites

Fibres were blended to improve the processing and properties of the fabric. The blended ratio of untreated and treated cut *Sansevieria roxburghiana* and *Agave vera-cruz Mill* fibres with polypropylene for composite preparation were listed below.

US / P = 50: 50
US / P = 60: 40
US / P = 70: 30
TS / P = 50: 50
TS / P = 60: 40
TS / P = 70: 30
UA / P = 50: 50
UA / P = 60: 40
UA / P = 70: 30
TA / P = 50: 50
TA / P = 60: 40
TA / P = 70: 30

Abbrevation:

Untreated *Sansevieria roxburghiana* fibre – US; Treated *Sansevieria roxburghiana* fibre – TS; Untreated *Agave vera-cruz Mill* fibre – UA; Treated *Agave vera-cruz Mill* fibre – TA; Polypropylene fibre – P.

3.12. Steps Involved In Composite Preparation

In this study the composites were prepared using nonwoven web which was discussed below.

3.12.1. Web Formation for composites

Composites made up of nonwoven web gains popularity in many applications due to high strength, flexibility and light weight structures remark Kamath etal. (2005). The sample size for composites was small hence to minimize the fibre waste the web was prepared using the mini carding machine. The role of matrix in a fibre reinforced composite was to transfer stress between the fibres, to provide a barrier against an adverse environment and to protect the surface of the fibres from mechanical abrasion and they play a major role in the tensile load carrying capacity of composite structure. Mainly polymer based matrix was commonly used in industries and this matrix plays an important role in composites reveal Gnanavel and Ananthakrishnan (2011). Hence Polypropylene fibre was used as a matrix. Two natural fibres namely *Sansevieria roxburghiana* and *Agave vera-cruz Mill* were used as a reinforcement fibre. In the initial process the web was formed using 100% polypropylene (Plate - 22) and then the web was laid over a flat table. The natural fibre was then spread evenly over the lap and it has been covered using the other end of the polypropylene lap (Plate - 23). Then pressure was applied to that by rolling a cylinder over it. This was done in order to minimize the wastage of natural fibres during carding process. Finally the prepared web was inserted into the carding machine (Plate - 24). The fibres are opened by a series of rollers and finally a web of both polypropylene and natural fibres are formed. Thus the specimen to be compression moulded has been kept ready.

3.12.2. Preparation of Mould

For this study a flat iron plate of 20cm x 20cm was used as a mould. The web was taken and laid over the flat table. Then the web was cut according to the

Plate – 21 Alkali Treatment of Fibres With NaOH

Plate – 22 Polypropylene Web

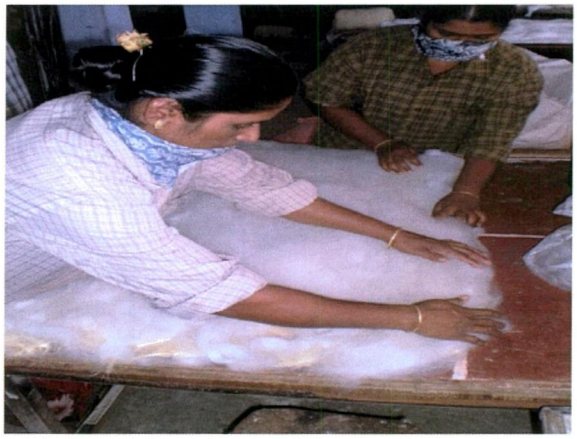


Plate – 23 Hand Laid Web

Plate – 24 Inserting the Hand Laid Web into Carding Machine

mould size. In order to increase the thickness of the composite sample several layers of web were combined together to form a bed. Then the prepared sample was placed on the mould and it was covered by another mould plate (Plate - 25).

3.12.2. Preparation of the Machine

Compression moulding machine has two iron plates among which one was fixed and another one can be moved up and down. It was a high temperature, high pressure process. During this operation the mould was closed and heated. The heat from the mould cures the resin matrix thus solid parts are produced remark Saravanan etal. (2011). The machine requires initial preparation before sample placement. The temperature optimized for this process was 190°C and it was set in the computerized panel board (Plate - 26). The machine was kept empty till it reached the optimized temperature.

3.12.3. Composite Preparation

When the set temperature was reached in the computerized panel board the prepared mould was placed in the compression moulding machine over the fixed iron plate (jaw). The jaws of the machine were tightened to transfer the temperature between plates and to exert pressure over the samples which was noted in the pressure gauge as 20bar (Plate - 27). The temperature in the computerized panel board starts coming down to 5°C–10°C since the samples were in cold condition. Finally the machine will reach the optimized temperature with ±1°C variations. Now the time was noted by using a stop watch. After 10 minutes the pressure was reduced slightly by turning the knob so that the iron plates were loosened. Then the sample was removed from the compression moulding machine. They were allowed to cool for 10 minutes as curing temperature during which the heat from the mould cures the resin matrix. Then the samples were removed from the mould and it has been labeled and stored for evaluation and the same process was followed for all the other samples.

3.13. Testing

Textile testing is the application of scientific principles to measure fibre, yarn and fabric properties, using specialized equipment under standard testing conditions and procedures Textiles Committee (2011). Because of the important changes that occur in textile properties as the moisture content changes, it is

necessary to specify the atmospheric conditions in which any testing is carried out (www.scribd.com). Hence the textile material was conditioned at a temperature of 27± 2°C and 65± 2% relative humidity prior to and during testing as suggested by Mehta (2004).

3.13.1 Evaluation of Fibre Properties

According to Kadolph (2009) understanding fibres and their performance are essential because fibres are the basic unit of most fabrics. Fibres influence product aesthetics, durability, comfort, appearance retention, care, environmental impact and cost. Hence the extracted fibres were tested for its various properties namely visual inspection, chemical composition, mechanical properties, physical properties and characterization studies.

3.13.1.1. Visual Inspection

Visual inspection is the most common nondestructive testing technique. It involves examination and evaluation of the samples by use of the human sensory system. The inspection process was done using looking and feeling. It concluded a cognitive component wherein observations are correlated with knowledge suggests Matzkanin (2011). Fibres extracted using different methods were evaluated by a panel of juries containing 25 members who are having textile knowledge. The judges evaluated the samples using the prepared rating scale for this visual inspection as given in (Appendix – 4) which included the details regarding general appearance, colour, lustre and texture of the samples.

3.13.1.2. Chemical Composition

The chemical composition of natural fibres depends on the type of fibre as well as the age, origin, and mode of extraction. The most natural fibres consist of the major components of cellulose and lignin. Other minor components are wax and pectin that function as protective barriers in plants opines Yu (2009). Hence the chemical composition of *Sansevieria roxburghiana* and *Agave vera-cruz Mill* fibres were tested in the chemistry laboratory at South Indian Textile Research Association using standard procedures.

3.13.1.2.1. Cellulose Content

Cellulose is the common name used for the glucan which constitutes about 42 per cent of wood's dry weight. Cellulose is the primary component of the

walls of cells making up fibres and is the main structural material of plants. In the plants the degree of polymerization of cellulose is approximately 14,000 suggest Riegel and Kent (2003).

The estimation of cellulose content was done according to the procedure given by Sadasivam and Manickam (2005). About 0.5g of the fibre sample was cut and taken in a test tube with 3ml acetic/nitric reagent and heated in a water bath at 100°C for 1 hour. Then the contents were centrifuged for 15-20min and treated with 10ml of 67 per cent sulphuric acid and allowed to stand for 1hour. 1ml of this solution was diluted with 10ml anthrone reagent and mixed well. Then the tube was heated in boiling water for 10min, cooled and measured for its color at 630nm. Thus the cellulose content was estimated spectrophotometrically. The same procedure was repeated 10times and the mean value was calculated.

3.13.1.2.2. Lignin Content

Lignin helps in the bonding of cells of the plant fibres and thus acts as a cementing material. Lignin content of plant fibres influences its structure, properties and morphology regards Joseph etal. (1999). The determination of the lignin content was carried out according to the Klason method. About 2-3g of accurately weighed fibres were cut into small pieces and placed in a 100ml conical flash to which 40ml of 72 per cent ice cold concentrated sulphuric acid, was added. It was then kept in deep frozen condition for 8hours. The sample was then removed, diluted with distilled water up to 800ml and digested for eight hours to precipitate the lignin. The solution was filtered, washed with hot water and subsequently with cold water and then dried in an oven. Residual lignin content was estimated based on original sample weight. The procedure was repeated for 10times and the mean was calculated.

3.13.1.2.3. Wax Content

An accurately weighed portion (about 2-3g) of the samples was extracted with benzene in a Soxhlet apparatus for about 6hours. The extraction was then filtered through a sintered glass crucible into a tared beaker. The beaker was then heated in an oven maintained at a temperature of 90°C for some time and later at 100°C till all the solvent was evaporated as well as the weight of the

beaker with its content reaches a constant value. The same method was followed 10times and the mean value of the wax content was reported.

3.13.1.2.4. Ash Content

A test specimen of about 4g was compressed into pellet form after cutting into 2mm bits. The compressed specimen was placed in a tared silica crucible and weighed accurately. The specimen in the crucible was then ignited over a Bunsen flame until it was carbonized. The crucible was then transferred to a muffle furnace and the ashing was continued at 750^{o}C, until a constant weight was attained. The oven dry weight of the material taken for ashing was found by measuring the moisture content in the sample. From the weight so measured the percentage of ash content was determined on the original dry weight basis. The procedure was repeated 10times for accurate results.

Calculation :

Ash content percentage = A/B x100

A - Mass in g of the residue (ash)

B - Oven dry mass in g of the test specimen.

3.13.1.3. Mechanical Properties

Mechanical properties, like the breaking force and elongation at break, friction force and friction coefficient are very important in influenzing fabric properties state Adomaitiene and Kumpikaite (2011). Hence in this study breaking force and elongation at break of the samples were studied.

3.13.1.3.1. Breaking Strength and Elongation

The Instron tensile tester is a versatile instrument used for measuring various mechanical properties. The tensile load elongation curves of a wide range of samples from single fibres of rupture strength less than 10g to thick fabric strips of strength upto 500kg were measured regard Sundaram etal. (2002). Tensile testing or breaking force of individual fibres was carried out using an INSTRON 5500R which works on the principle of constant rate of extension with a gauge length of 200mm and crosshead speed of 60mm/min. The *Sansevieria roxburghiana* fibre sample was fixed between two mechanical grips pneumatically. Among the two grips holding the specimen, the upper grip is suspended from the load cell and the lower grip is fixed on the crosshead. The

grips are tightened securely to prevent slipping and breaking of the specimen according to the standard ASTM D638. The load sensing was done by a 'load cell' which converts the mechanical force into an electrical signal. The load was fixed on the movable platform known as 'cross-head'. The crosshead was made to move in such a way that specimen starts getting extended. Thus the load exerted on the specimen was measured and the load elongation curve was plotted by the electronic panel attached to the instrument. The same procedure was followed for *Agave vera-cruz Mill* fibre. The test was repeated 50 times and the mean was calculated.

3.13.1.4. Physical Properties

The extracted fibres were tested for physical properties namely length, diameter, moisture properties, fineness and density.

3.13.1.4.1. Length

Length to breadth ratio is considered as one of the essential properties of the textile fibre to convert into a fabric states Nielson (2007). The fibre should be at least 100 times longer than its diameter or breadth with a ratio of 100 : 1. The fibre length measurement using AFIS (Advanced Fibre Information System) and HVI (High Volume Instrument) was not possible due to the brittle nature of fibre which results in fibre breaking say Subramanian etal. (2005). Thus the fibre length of *Sansevieria roxburghiana* and *Agave vera-cruz Mill* fibres were measured by straightening the fibres one by one over a calibrated metal scale directly. Care should be taken that the fibre should not be elongated. Readings were taken of 10 different samples and the mean was calculated.

3.13.1.4.2. Diameter

SEM photograph of the individual *Sansevieria roxburghiana* and *Agave vera-cruz Mill* fibres were used to identify the fibre diameter. To get accurate results scanning electron micrographs were taken at 10 different areas and the average value was taken.

3.13.1.4.3. Moisture Properties

The amount of moisture in a material may be expressed in terms of moisture regain or moisture content. Moisture absorption characteristics of a textile fibre play an important feature for comfort and warmth retention behavior

of clothing. Moisture absorption causes swelling of the fibres which eventually changes size, shape, bending stiffness, strength, elasticity, and permeability of yarns and fabrics opine Goswami etal. (2004). The amount of moisture in a fibre strongly affects many of their most important physical properties such as dimensional, mechanical and electrical properties remarks Saville (2004). Moisture regain is defined as the weight of a material expressed as a percentage of the oven dry weight. Moisture content is the weight of water in a material expressed as a percentage of the total weight says Jewel (2005). Moisture regain and content of *Sansevieria roxburghiana* and *Agave vera-cruz Mill* fibres were determined as per ASTM D 629-1999 and BIS - 2000 method. The cut fibres of 1g were taken in a clean and dry tarred weighing bottle. It was placed in hot air oven for 1.5hours at a temperature of 105°C to 110°C until the mass is constant to within 0.001g and the oven dry mass of the specimen was determined. Moisture regain and content was determined using the following calculation. For accuracy of the results the same procedure was repeated 10 times and the mean was taken.

Calculation :

Moisture regain = A - B /B ×100

Moisture content = A - B /A ×100

A – Original mass in g of the test specimen

B – Oven dry mass in g of test specimen

3.13.1.4.4. Fineness

Fineness or linear density of cut staple fibre was determined by following the procedure recommended by Committee D-13, A.S.T.M., as follows:

A small tuft of 500 to 1,000 *Sansevieria roxburghiana* fibres were selected, made parallel and free of short fibres by hand combing. This group of fibres was then held under tension to remove crimp and cut to a length preferably longer than 22.5mm. Groups of 0.5mg fibres were weighed simultaneously to the nearest 0.002mg. Linear density was calculated using the formula given below.

D = 9000M/(L X N) Denier

Tex = D/9 tex

Where D - Linear density, Denier; M - Fibre mass measured on the balance, mg; L - Fibre length measured with a ruler, mm; N – Number of fibres weighed. The same procedure was followed for *Agave vera-cruz Mill* fibre to find its fineness and the mean value was calculated.

3.13.1.4.5. Density

The density measurement of the *Sansevieria roxburghiana* and *Agave vera-cruz Mill* fibres was carried out at South Indian Textile Research Association using standard procedure. About 1g of the cut fibre sample was taken in a dried standardized measuring glass and weighed in a Metler Toledo weighing balance. The same procedure was repeated for 50ml of water and its weight was noted. Then weighed fibre and water was mixed together without any air bubbles and its weight was taken. Finally the fibre density was calculated using the formula

$$D = (m_2 - m_1) / (m_3 - m_1) (m_4 - m_2) \times \rho_t$$

Where D is the density of the fibre in g/cc, m_1 – mass of the empty standard measuring glass in g, m_2 - mass of standard measuring glass with cut fibres in g, m_3 – mass of 50ml water in standard measuring glass in g, m_4 – mass of standard measuring glass filled with cut fibres and water in g, ρ_t – density of the water in g/cc.

3.13.1.5. Fibre Characterization

Characterization of the microstructure of fibres can provide insights into the fundamental structures present and into the relationship between structure and properties important for applications. Morphological characterization provides information to understand the effects of process history on mechanical and physical properties. Microscopy techniques are used to observe features such as fibre shape, diameter, structure (crystal size, voids, etc), molecular orientation, size and distribution of additives, failure mechanisms, etc. It was noticed that any study of fibres will be incomplete if only microscopy techniques are applied. X-ray scattering, thermal analysis (differential scanning calorimetry (DSC), thermal gravimetric analysis (TGA)) and spectroscopy (IR, Raman and photoelectron spectroscopy (XPS)) are among the many techniques that complement microscopy investigations opine Sawyer etal. (2008). Hence in this study SEM, FTIR, DSC and XRD analysis were done to the fibre samples.

3.13.1.5.1. Scanning Electron Microscopy

According to Schatten and Pawley (2007) Scanning Electron Microscope (SEM) became a significant instrument in the scientific community forty years back. In 1965, the Cambridge instrument company in the United Kingdom marketed their stereoscan 1 SEM, which was followed about six months later by JEOL of Japan with the JSM – 1. There are two different types of electron microscope used for analysis namely Scanning Electron Microscope (SEM) and Tramission Electron Microscope (TEM) opines Federal Register (2011). The SEM provides analysis intermediate between those of the Longitudinal Microscope (LM) and the TEM regard Kulkarani etal. (2011). SEM is used to study the intact fibre surface and their properties says Ansari etal. (2001); Marzoug etal. (2010). SEM analysis was performed for both treated, untreated *Sansevieria roxburghiana* and *Agave vera-cruz Mill* fibres by using a JEOL – MODEL 6390 electron microscope (Plate - 28) at an accelerating potential of 20Kv. SEM scanning is done on the fibre surface in the reflection mode, hence the surface has to be natural without any markings of the knife or microtome blade. The fibre was suitably cut into a small piece without disturbing (or touching) the main fracture surface. The cut fibre surface was coated with gold before examination using the Edward Sputter Coater apparatus in order to avoid the accumulation of electrons or the generation of static charge owing to the poor conductivity of the fibres. This small piece was mounted on the sample holder of the SEM. Thus the SEM photographs were taken in various resolutions in both longitudinal and crosswise direction of the fibre samples.

3.13.1.5.2. Spectroscopic Study

The concept of Fourier transform infrared (FTIR) spectroscopy has been known for more than a century. It began with the invention of the interferometer by Michelson in the 1880s. The first commercial FTIR spectrometers were available in the late 1960s remarks Sun (2009). FTIR is a very useful tool for analyzing organic or inorganic materials and distribution to their interactions. It allows to determine fibre constitution and also gives high specificity since it contains numerous sharp vibrational marker bands opine Zemaityte etal. (2006); Mukhopadhyay (2003); Edwards and Chalmers (2005). The treated, untreated

Sansevieria roxburghiana and *Agave vera-cruz Mill* fibres were investigated by the infrared technique with a SHIMADZU 4200 type FTIR spectrophotometer (Plate - 29) with a resolution of $2cm^{-1}$ in the range of 400 - $4000cm^{-1}$. Fibre was made into fine powder by grinding using mtor mechanically. Pellets were prepared mixing 2mg of ground fibre sample with KBr powder of about 1mm thickness for identification.

3.13.1.5.3. X-ray Diffraction

X – ray diffraction is a technique that provides detailed information about the atomic structure of crystalline substances reveal Ulery and Drees (2008) and Bera etal. (2002). The degree of orientation and the degree of crystallinity are important quantities that strongly influence the physical properties of fibre. XRD is a non – destructive method that requires little or no sample preparation, thus allowing samples to be analyzed simply and quickly in their natural form remarks Pan (2006). X – ray diffractogram of treated, untreated *Sansevieria roxburghiana* and *Agave vera-cruz Mill* fibre samples were analyzed using SHIMADZU Model XRD-6000 (Plate - 30) with nickel filtered Cu Kα (λ - 1.5418Å) from an x-ray tube run at 40KV and 30Ma. The fibre samples was cut into small minute pieces using scissors and were scanned between the angles 0° - 90° to obtain the equatorial reflection. The per cent crystallinity was expressed in the following manner:

$$\text{Degree of crystallinity } \% = (I_t - I_a) / I_t \times 100$$

Where I_t and I_a are integral scattering intensities corresponding to the amount of total and amorphous parts respectively say Oudiani etal. (2009).

According to Mukhopadhyay (2001) crystal size can be determined from the line broadening effect obtained from XRD analysis using the Scherrer equation given below

$$T = k\lambda / B\cos\theta$$

Where T is the crystal thickness in the direction perpendicular to the lattice planes corresponding the diffraction line, B is the half width of the diffraction line of that portion of the reflection due to pure diffraction broadening, θ the Bragg's angle and λ is the wavelength of the x-rays and the K is a constant.

Plate – 25 Preparation of the Mould

Plate – 26 Uni Polymer Composite Machine

Plate – 27 Tightening of the Jaws

Plate – 28 Scanning Electron Microscopy

Plate – 29 FT-IR Spectrophotometer

3.13.1.5.4. Differential Scanning Calorimetry

Antoine Lavoisier, in eighteenth century first invented calorimeter which played a central role in chemistry. Improvements in calorimetric apparatus have led to a blossoming of biology-related studies within the last two decades. According to Serdyuk etal. (2007) the first DSC instrument with sufficient sensitivity was developed independently by P.L. Privalov, S.J. Gill and J.M. Sturtevant. It provides a rapid method for the determination of the thermal properties of polymeric material including thermal history, oxidation induction time (OIT) testing and dynamic and isothermal kinetic studies opine Pielichowski and Njuguna (2005). The *Sansevieria roxburghiana* and *Agave vera-cruz Mill* fibre samples were analyzed using the Mettler Toledo DSC 822e (Plate - 31) to assess the presence of transition temperature in the fibre. The fibre sample preparation for DSC experiment becomes important because of the lengthiness of the fibre and its tendency to shrink upon heating. The fibre sample of known weight was taken, cut into short fibres then packed to achieve a high heat conductivity and placed in a sealed aluminium pan for measuring as suggested by Cheng (2002). The sample was heated from 36°C to 400°C under a nitrogen atmosphere at the heating rate of 10°C/min.

3.13.2. Evaluation of Fabric Properties

The needle punched fabrics were evaluated both visually and objectively as follows.

3.13.2.1. Visual Inspection

The needle punched samples were evaluated visually by the panel members. The panel members were 25 juries who are specializing in the field of Textiles and Clothing. General appearance, colour, texture, lustre and evenness were the main aspects taken into consideration for visual examination (Appendix - 5).

3.13.2.2. Mechanical Properties

The needle punched fabrics were studied for mechanical properties like breaking strength and elongation.

3.13.2.2.1. Breaking Strength and Elongation

The tensile or breaking strength of the fabric is a measure of its resistance to a tensile load or stress defines Singh (2004). Elongation is the increase in length of a specimen during tension test. The needle punched fabric samples were tested for its breaking force in both wet and dry conditions using Eureka tensile strength tester (Plate - 32) which works on the principle of constant rate of extension (C.R.E.). The cut strip test was followed to test the nonwoven fabrics. 12inch X 2inch specimen from each sample was cut both in machine and cross direction of the fabric 2inches apart from the selvedge. The prepared specimen was gripped in a fixed top jaw J_1 and in a bottom jaw J_2 which can be moved downwards at a constant velocity by means of screw mechanism. The dial reading was set to zero by adjusting the pendulum over the quadrant scale. The elongation pointer was checked for its position in zero. Before starting the machine the pendulum lock was released and the machine was switched to run. A force F, initially zero but increasing at a constant rate, was applied to the specimen in a downward direction. The effect of applying this force was to extend the specimen until it eventually breaks. At the point when fabric starts to break the machine was switched off and the dial reading in kg was noted. Elongation reading was noted from the elongation scale. The specimen was removed and the machine positioned back to original and 10 specimens of both machine and cross directions from each sample were tested and readings were noted. For wet strength the samples were immersed in distilled water at room temperature for 1hour, for thorough wetting. The wet sample test was completed within 2minutes after its removal from the water following the same procedure mentioned above.

3.13.2.3. Physical Properties

The needle punched fabrics were tested for its physical properties namely stiffness, thickness, Areal density, air permeability, wicking, sinking, moisture regain, moisture content and thermal conductivity.

3.13.2.3.1. Stiffness

Stiffness is one of the most widely used parameters to judge the bending rigidity and fabric handling Yuksekkaya etal. (2008). This property can influence the aesthetic appearance as well as the comfort of a fabric. The Shirley stiffness

tester was used to test the stiffness of the fabric (Plate - 33). The needle punched fabric sample was cut to the size of 15cm X 2.5cm using the template. The sample was placed on the platform with the template at the top of it, so that the leading edges coincide. Both were slowly pushed forward until the leading edges of the sample and the template projected beyond the edge of the platform. The sliding of the sample was stopped when it cuts both the index lines. Then the stiffness of the sample were read from the scale opposite a datum line engraved on the side of the platform. Four readings were taken from a sample on all sides. The same procedure was repeated for 10 different samples. Mean values of the stiffness in both machine and cross direction were calculated separately.

3.13.2.3.2. Thickness

The thickness of needle punched fabrics was measured using a thickness gauge (Plate - 34). Thickness gauge measures the distance between the upper and lower surfaces of the material, under a specified pressure. It was usually determined as the distance between an anvil, or base, and a presser foot which was used to apply the specified pressure. The specimen should be carefully handled to avoid altering the natural state of the material. Place the specimen on the anvil of the test apparatus and the pressure foot was brought in contact with the opposite side of the material as mentioned in ASTM D 5729 - 97. Thickness was measured at a pressure of $2gf/cm^2$ or 196Pa. Fabric thickness of this pressure can be used to monitor the consistency of fabric opines Kothari (1999). Readings were taken at 10 different places of the sample and the mean was calculated.

3.13.2.3.3. Aerial Density

The aerial density of needle punched fabrics was determined using ASTM D 6242–98. The apparatus namely weighing balance with accuracy of ± 0.0001g and steel ruler of at least 30cm in length with subdivisions of 0.5mm was used. The needle punched specimen was preconditioned to moisture equilibrium for testing in the standard atmosphere as directed in ASTM D 1776. The sample size was cut into 10 x 10cm size. It was then weighed in electronic balance and the value was multiplied by 100. Thus the aerial density (g/m^2) of the needle punched fabrics was calculated as reported by Ramachandran etal. (2010).

3.13.2.3.4. Air Permeability

Air permeability is the property which permits the passage of air and it indicates substances porosity of the fabric reveals Fan (2008). The air permeability of the needle punched samples was tested according to ASTM D737-75 using Shirley electronic air permeability tester (Plate - 35). Air at 125Pa pressure was drawn through the test specimen of area 38cm^2 by means of a suction pump, the rate of flow being controlled by means of the bypass valve and a series valve. The rate of flow was adjusted until the required pressure drop across the fabric which was indicated on a draught gauge, graduated from 0 to 25mm. There was a reservoir which smooths out any disturbance due to the varying velocities of the streams of air drawn through the various paths by the pump. The test area of the specimen was 5.07cm^2, since a 1inch diameter circle was exposed when the specimen was clamped in the holder. The results are displayed digitally which can be directly sent to a computer for data analysis as reported by Basu (2001).

3.13.2.3.5. Wicking

The wicking was applied to evaluate the water uptake of fabrics opines Ferrero (2003). Ten pieces of needle punched samples were cut measuring 15cm length and 2.5cm width parallel to the machine direction as suggested by Hossain (2008). One end of the sample strip was fixed with a glass rod which was placed on the heavy wooden block and at the other end, 2g weight was attached to keep the sample straight. At the weighted end 2cm of the sample was allowed to immerse in a tray of distilled water. The rise of the water level in the strip was observed visually by keeping time as constant (1min). The same procedure was repeated for all the samples and the mean value was calculated and recorded.

3.13.2.3.6. Sinking

Absorbency may be assessed in various ways, the most popular being the sinking time test (AATCC Test Method 17-1994) says Choudhury (2006). In the sinking time test (Plate - 36) method conditioned needle punched fabric was cut into a number of equal sized squares of 25mm X 25mm and dropped onto a 1000ml beaker which was filled with distilled water loosely without putting any

Plate – 30 X - ray Diffraction

Plate – 31 Differential Scanning Calorimetry

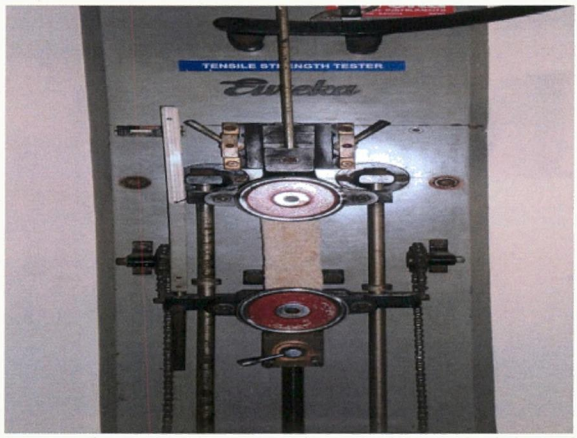


Plate – 32 Eureka Tensile Strength Tester

Plate – 33 Eureka Stiffness Tester

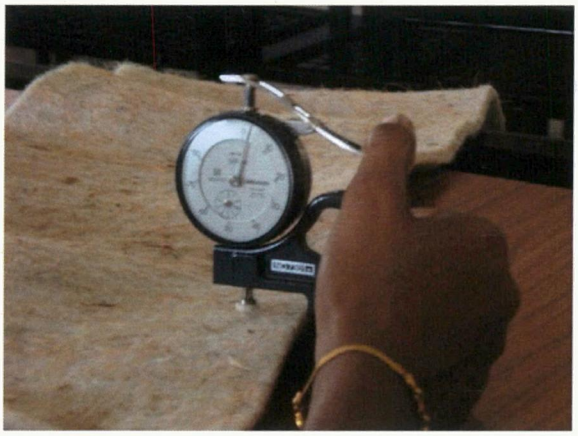


Plate – 34 Thickness Gauge

Plate – 35 Shirley Electronic Air Permeability Tester

thrust. The stop watch was started when the fabric struck the surface of water and stopped when the last corner of the fabric sank below the water surface. The time required by the fabric to go in the water from floating state is known as sinking time regards Saville (2004).

3.13.2.3.7. Moisture Properties

The moisture properties of the needle punched fabrics were a critical element of a study say Nelson and Henry (2000). The sample size for moisture properties estimation was 2inch x 2inch which was placed in Hot Air Oven (Plate - 37). The moisture content and regain of the fabric was estimated following the same procedure discussed in a fibre moisture properties analysis.

3.13.2.3.8. Thermal Conductivity

Thermal conductivity is among the most important features of textile regard Frydrych etal. (2002). The thermal properties of a clothing system are determined by its resistance to heat and moisture transfer. The flow of heat through a textile material is a complex process, as in addition to pure conduction, there will be heat transferred by convection and radiation through open spaces in the fabric. Further, there will be transmission of heat due to evaporation and condensation of moisture. The thermal properties usually studied are (i) thermal insulation value (ii) thermal conductivity and (iii) warm / cool feel of the fabric. Among the three thermal properties thermal conductivity gives the rate of flow of heat by conduction through unit area of the material of unit thickness when a temperature difference of 1°C exists between the two faces of the material say Sundaram etal. (2002).

The thermal conductivity of the needle punched fabric samples was determined by Lee's Disc method (Plate - 38). The material whose thermal conductivity is to be determined was taken in the form of thin discs of 11inch diameter so that the amount of heat passing was considerable. The thickness of the samples was measured at different places using screw gauge and diameter was measured using a mm scale and the mean was calculated. The sample was placed on a brass disc of the same diameter. Above the sample a steam chest made of a hollow brass cylinder with a thick brass base (B) of the same diameter as the sample was placed opines Roy (2001). Thermometers were inserted in

both steam chest and metallic disc. The steam onset was connected to a boiler, steam from the boiler was then passed through the steam chest. When the steady state temperature was attained, the readings θ_1 and θ_2 of both the thermometers T_1 and T_2 respectively are noticed regards Yong (2006). Gently remove the specimen between the disc and the chamber. Place the chamber directly in contact with the disc. The disc gets heated more rapidly. When its temperature rises about 7 or 8°C above the steady state temperature θ_2 carefully remove the steam chamber. Allow the disc to cool and when its temperature falls exactly to 5°C above θ_2, start a stop clock. Note the temperature at every 30sec till it falls to 5°C below θ_2. The thermal conductivity of the samples was calculated using the following equation

$$K = \frac{MS(r+2d)\left(\frac{d\theta}{dt}\right)\theta 2}{\pi r2(\theta 1-\theta 2)(2r+2d)dx}$$

Where K – Thermal conductivity in $Wm^{-1}k^{-}1$; M – Mass of the metal disc; S – Specific heat capacity of the metal disc; D – Thickness of the bad conductor; r – Radius of the metallic disc; d – Thickness of the disc; θ_1 – Steady temperature of the steam chamber; θ_2 - Steady temperature of the metallic disc; ($d\theta/dt$) – Rate of cooling at θ_2.

3.13.3. Testing Methods for Composites

All the mechanical testing methods for composites were carried out based on American Standard Testing Methods (ASTM). For morphological studies, Scanning Electron Microscope (SEM) was used.

3.13.3.1. Visual Inspection

The composite samples were evaluated visually by following the same procedure as discussed in visual inspection of needle punched fabrics using the same rating scale (Appendix - 6).

3.13.3.2. Mechanical Properties

Mechanical properties namely Tensile Test (ASTM D3039), Flexural Test (ASTM D4812-99) and Impact Test (ASTM D790) were studied for the composite samples. They are discussed as follows.

3.13.3.2.1. Tensile Properties

Tensile properties are one of the most widely tested properties of natural fibre reinforced composites. Tensile strength or ultimate strength is the maximum amount of stress that a material can withstand while being stretched or pulled (www.sciencedaily.com). Tensile strength is measured as force per unit area (http://en.wikipedia.org). The ultimate tensile strength of nonwoven composites was determined by the fibre content which was measured according to ASTM D 3039 using a universal INSTRON tester Model 3345 (Plate - 39) provided with a 1000KN load cell. This works on the principle of constant rate of extension. The INSTRON software of Series IX Automated Materials Testing System with an interface type 4200 was used for recording of data. The testing machine has both a stationary head and a movable head. The testing machine drive mechanism is capable of imparting to the movable head a controlled velocity with respect to the stationary head. The velocity of the movable head shall be capable of being regulated as needed. The testing machine contains load-sensing device which is capable of indicating the total load being carried by the test specimen. Specimen preparation was extremely important for this test. The specimen cut for tensile testing should be free from notches, undercuts, rough or uneven surfaces or delamination which results in inappropriate machining methods. Since the samples were hard to cut they were cut using axe with the help of carpenter. The dimension of the sample was fixed after calculating their thickness. The length of the sample was kept as 150mm with width as 25mm.

The Pressley clamps were mounted in specially built grips for the tensile test with the grip distance of 130mm. Before testing, the samples had been conditioned at 27± 2°C and 65± 2% relative humidity for 24hours. Care should be taken to align the long axis of the gripped specimen with the test direction. The grips were tightened and the pressure used on pressure controllable (hydraulic) grips was recorded. The crosshead speed was set at 2mm/min with maximum load. The samples were mounted between the Pressley clamps and pulled apart until breaking. The tensile properties recorded include displacement at maximum load, extension at maximum load, tensile stress, tensile elongation, tensile strain

and time. Ten samples were analyzed for each type of composites and the results were determined.

3.13.3.2.2. Impact Test

Chitale and Gupta (2007) say impact strength is an important factor in choosing composite materials. ASTM D4812-99 test methods cover the determination of the resistance of composites to breakage by flexural shock by the energy extracted from the standardized pendulum type hammers with one pendulum swing. For this study Frank model impact tester (Plate - 40) was used. It consist of a massive base on which was mounted a vise for holding the specimen and to which was connected a rigid frame and antifriction bearings, one pendulum type hammers having an initial energy suitable for use with the particular specimen to be tested, plus a pendulum holding and releasing mechanism and a pointer and dial mechanism for indicating the excess energy remaining in the pendulum after breaking the specimen. A jig for positioning the specimen in the vise and graphs or tables to aid in the calculation of the correction for friction and windage were included. The hammer velocity of this model was 3.46m/s and the pendulum used was 25joules.

The specimens were cut from the sheet with width of 3.17mm and a length of 63.50mm respectively. The test specimen was free of twist, deformation nicks, scratches, pits and sink marks. The test specimens were tested in accordance with procedure D 618. Before fixing the specimen the breaking energy for the specimen was estimated and the pendulum was selected accordingly. The specimen was positioned precisely and rigidly but not tightly clamped in the vise since some are sensitive to clamping pressure. The end of the specimen was matched against the groove of the position jig when the jig was held vertically on the top surface of the specimen. After clamping the specimen in the vise remove the jig. The pendulum was released and the excess energy remaining in the pendulum after breaking the specimen was recorded. The result of this test method was reported as energy absorbed per unit of specimen width. Ten samples were tested for each type of composites and the mean value was calculated.

3.13.3.2.3. Flexural Test

The flexural strength or bending strength is an important mechanical property suggests Siegesmund and Snethlage (2011). Flexural loads are really a combination of tensile, compression and shear loads. When loaded the upper face was put into compression, the lower face into tension and the central portion of the laminate experiences shear suggest Senthilkumar etal. (2007). The flexural properties of both rigid and semi rigid materials can be determined using ASTM D 790-00. Since the designed materials undergo large deflections during testing the flexural strength can only be analyzed. Kalpak universal testing machine (Plate - 41) of 2ton capacity was used for analyzing flexural properties of the samples. It works on the principle of three point loading system.

The specimen was cut from molded sheets of dimension 80mm length and 10mm width. Ten specimens for each sample were tested. The test was conducted in the standard laboratory atmosphere of 23 ± 2°C (73.4 ±3.6°F) and 50 ± 5% relative humidity. The width and depth of the specimen were measured to the nearest 0.03mm at the center of the support span. According to the sample width and depth the type of support used was determined. The distance between the two support span (L) was kept as 50mm with the cross – head motion of 2mm/min. The rate of straining of the outer surface of the test specimen shall be 0.10mm/mm/min. Maximum flexural stress or flexural strength sustained by the test specimen during a bending test was obtained automatically. The same procedure was followed for 10 samples of each type of composites and the mean was noted.

3.13.3.3. Morphological Study

For morphological study, Scanning Electron Microscope (SEM) was used to reveal the fibre orientation in reinforced thermoplastics together with some information concerning the nature of the bond between the fibres and matrix. It is an instrument for obtaining micro structural images using a scanning electron beam. The composite samples of 1cm x 1cm size was cut and coated with gold using Edward Sputter Coater apparatus (Plate - 42). SEM analysis was performed by using a JEOL – MODEL 6390 electron microscope at an accelerating potential of 20Kv as discussed earlier in the fibre SEM analysis.

Plate – 36 Sinking Test

Plate – 37 Hot Air Oven

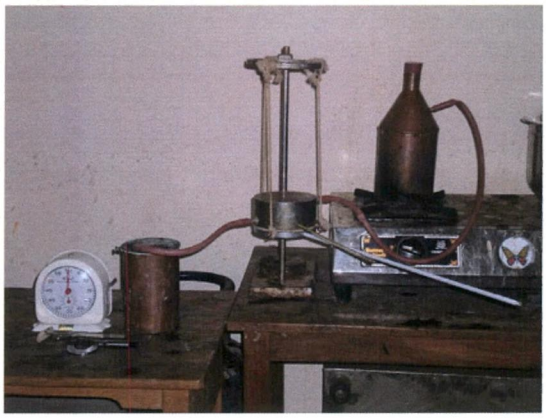


Plate – 38 Lee's Disc Apparatus

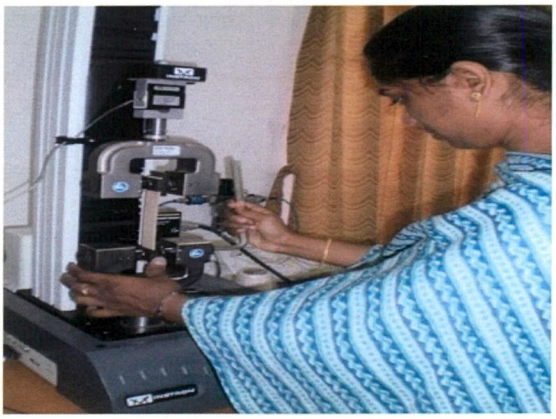


Plate – 39 INSTRON Tester

Plate – 40 Frank Model Impact Tester

Plate – 41 Kalpak Universal Testing Machine

3.13.3.4. Thermal Conductivity

The thermal conductivity of the composite samples was determined following the same procedure given in thermal conductivity of needle punched samples.

3.13.3.5. Sound Absorption Test

3.13.3.5.1. Standing Wave Apparatus

According to India Council of Scientific and Industrial Research (2006), the sound absorption coefficient was measured using the standing wave method. Standing wave apparatus (Plate - 43) covers the use of an impedance tube for the measurement of impedance ratios and the normal incidence sound absorption coefficients of acoustical materials as reported by the American Society for Testing and Materials (2007). Both the needle punched and composite samples were evaluated for its sound absorption coefficient using this method. According to Russell, D.A., the Standing Wave Apparatus Type 4002, one of Bruel & Kjaer first products (almost 50 years ago), was developed primarily to measure the sound absorbing properties of materials, and is still widely used today. The standing wave tube (also called an impedance tube) method allows one to make quick and easy, yet perfectly reproducible, measurements of absorption coefficients. The impedance tube also allows for accurate measurement of the normally incident acoustic impedance, and requires only small samples of the absorbing material. A loudspeaker produces an acoustic wave which travels down the pipe and reflects from the test sample. The phase interference between the waves in the pipe which are incident upon and reflected from the test sample will result in the formation of a standing wave pattern in the pipe. If 100 per cent of the incident wave is reflected, then the incident and reflected waves have the same amplitude; the nodes in the pipe have zero pressure and the antinodes have double the pressure. If some of the incident sound energy is absorbed by the sample, then the incident and reflected waves have different amplitudes; the nodes in the pipe no longer have zero pressure. The pressure amplitudes at the nodes and antinodes are measured with a microphone probe attached to a car which slides along a graduated ruler. The ratio of the pressure maximum (antinode) to the pressure minimum (node) is

called the standing wave ratio SWR. This ratio, which always has a value greater than or equal to unity, is used to determine the sample's reflection coefficient amplitude R, its absorption coefficient α, and its impedance Z.

3.14 Analysis of Test Results

The findings of fibre properties were analyzed using mean, standard deviation and coefficient of variation. The results of both needle punched and composite samples were analyzed statistically with Multivariate tests. The one – way MANOVA was used to determine whether there are any differences between independent groups (various samples) on more than one continuous dependent variable (fabric properties).

3.15 Nomenclature

Nomenclature of Fibres

The nomenclature of the fibre samples were shown in Table 1 and the samples were fixed in (Appendix – 7).

Table 1

Nomenclature of Fibres

Fibres	Nomenclature
Sansevieria roxburghiana fibre	S
Decorticated *Sansevieria roxburghiana* fibre	SA
Running water retted *Sansevieria roxburghiana* fibre	SB
Stagnant water retted *Sansevieria roxburghiana* fibre	SC
Treated *Sansevieria roxburghiana* fibre	ST
Agave vera-cruz Mill fibre	A
Decorticated *Agave vera-cruz Mill* fibre	AA
Running water retted *Agave vera-cruz Mill* fibre	AB
Stagnant water retted *Agave vera-cruz Mill* fibre	AC
Treated *Agave vera-cruz Mill* fibre	AT
Polyethylene terephthalate fibre	PET
Polypropylene fibre	P

Plate – 42 Edward Sputter Coater Apparatus

Plate – 43 Standing Wave Apparatus

Nomenclature of Needle Punched Fabrics

The nomenclature of twelve types of needle punched fabrics produced with different ratios of *Sansevieria roxburghiana* (S), *Agave vera-cruz Mill* (A), Coir (C) and Polyethylene terephthalate (PET) fibres were indicated in Table 2. The needle punched fabrics were given in (Appendix – 8).

Table 2

Nomenclature of Needle Punched Fabrics

Fibre Ratio In Fabric	Nomenclature
C / PET = 50:50	S1
S / C / PET = 25:25:50	S2
A / C / PET = 25:25:50	S3
C / PET = 70:30	S4
S / C / PET = 35:35:30	S5
A / C / PET = 35:35:30	S6
S / PET = 50:50	S7
S / PET = 70:30	S8
S / A / PET = 25:25:50	S9
S / A / PET = 35:35:30	S10
A / PET = 50:50	S11
A / PET = 70:30	S12

Nomenclature of Composites

The twelve types of composites produced with different ratios of fibres namely untreated *Sansevieria roxburghiana* (US), treated *Sansevieria roxburghiana* (TS), untreated *Agave vera cruz Mill* (UA), treated *Agave vera cruz Mill* (TA) and Polypropylene (P) are named as given in Table 3. The composite boards were given in (Appendix – 9).

Table 3

Nomenclature of Composites

Fibre Ratio In Fabric	Nomenclature
US / P = 50 : 50	SC1
US / P = 60 : 40	SC2
US / P = 70 : 30	SC3
TS / P = 50 : 50	SC4
TS / P = 60 : 40	SC5
TS / P = 70 : 30	SC6
UA / P = 50 : 50	AC1
UA / P = 60 : 40	AC2
UA / P = 70 : 30	AC3
TA / P = 50 : 50	AC4
TA / P = 60 : 40	AC5
TA / P = 70 : 30	AC6