IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

"Study of Characteristics of Sisal and Coir Blended Nonwoven Fabrics"

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Abstract

This paper reports an experimental study on the fabrication and parametric evaluation of non-woven textile material prepared from uni-fiber natural material. The test parameters on which these fabrics are evaluated are Thickness, Grams per Square meter (GSM), Air permeability, Mechanical properties, Pore size distribution, and Moisture Absorbency. These parameters have been studied and discussed for three types of non-woven fabrics, namely Sisal (100%), a blend of Sisal (70%) and Coir (30%), and a blend of Coir (70%) and Sisal (30%).

Sisal (70%) and Coir (30%), blend has greater Air permeability and Bursting strength were specific treatment should be given for the material for future application such as noise control, sound proof lamination board, air conditioning, RCC curing material. The use of inexpensive and abundantly available raw materials to prepare a value-added product has been the aim of this study. The physical and chemical properties of fiber study and tangle of fiber by using web method process sisal 30%and coir 70% intrinsic lower air permeability and good in busting strength. Developed nonwoven fabrics using needle punching method can be converted as house hold wipes, geo textiles, mattress, and in agriculture. Specific treatment should be given for the material for future application such as noise control, false roofing material, printing, embossing wall hangings.

Keywords- Blending, Natural fiber, Needle punch technique, Nonwoven fabric properties and Testing

1. INTRODUCTION

Natural fibers are known to be eco-friendly, and therefore there is an increased interest in the industry for blends of natural fibers to create nonwoven fabrics. In the recent years, a lot of research is being carried out in the field of natural fibres especially in the ones that are reinforced using plastics[1]. In fact, natural fibres represent a traditional class of renewable materials that nowadays are experiencing a great revival. These natural fibres can be classified according to their origin and grouped into *leaf:* abaca, cantala, curaua, date palm, henequen, pineapple, sisal, banana; *seed*: cotton; *bast*: flax, hemp, jute, ramie; fruit: coir, kapok and oil palm. Among them flax, bamboo, sisal, hemp, ramie, jute, and wood fibers are of particular interest in research[2].

The utility of the Non-woven fabric is determined by the physical and chemical properties of the individual fibers. Though the natural fiber composites are lower in strength as compared to the synthetic fiber reinforced composites[3], they have lower density and are less expensive which make them competitive in terms of pricing and various other characteristics[4].

The "GREEN MOVEMENT" has gained popularity in both consumer and business sectors. Due to public awareness, demands of biodegradable or environmentally friendly textiles increases, especially disposable nonwoven products such as diapers, incontinence products, surgical gowns have attracted special attention in an effort to solve the solid waste crisis[5]

The nonwoven wipes for household application using the hydro entanglement bonding technique with the blends of polyester, viscose and flax were compared in terms of tensile strength and elongation properties. It was concluded that flax fibers can be successfully utilized for developing household or individual wipes, having higher tensile strength in wet state compared to polyester fiber blended fabrics[6]

Air permeability of nonwoven filter fabrics; the study showed that with the increase of pressure drop, the air permeability increased. Fabrics of higher weight per sq. meter show lower air permeability with the increase of depth of needle penetrations the air permeability decreases[7]

In this work, an attempt has been made to produce different types of needle punch based non-woven natural fibers. Although, needle punching is the oldest form of non-woven processes, recently there have been some developments in this method in producing lightweight fabrics. Therefore, this paper presents a study on the use of different types of blended non-woven material made from natural fibers using needle-punching technique.

In view of the increasing success and demand of non-woven materials in a wide variety of applications, their characterization and testing are of paramount importance before assessing their suitability. In this paper sisal and coir were procured, processed and blended at different ratios to study their physical and mechanical proprieties.

2. MATERIALS AND METHODS

Three different types of nonwoven fabrics are developed by means of needle punching method. The physical and chemical properties of the fibres used in study are presented in table 2.1 and 2.2 respectively.

Table 2.1: Physical Properties of fibers

Properties	Sisal	Coir
Mean breaking strength GSM	731.01	412.32
CV% Strength	31.96	35.96
Mean Elongation %	7.63	9.78
CV% elongation	21.64	30.75

Table 2.2: Chemical Properties of fibers

Properties	Sisal	Coir
Wax content %	0.23	-
Moisture content %	10.119	11.25
Density room temperature g/cc	1.036	1.4
Ash content %	5.62	2.22
Cellulose content%	78.39	35.6
Lignin content %	4.9	32.7

2.1 Preparation and processing of fiber Material

The Sisal fiber is produced from, Tumkur district, Karnataka. The coir fibers are collected from Central Institute of Coir Technology, Coir Board Bangalore.

2.1.1 Sisal

The processing of the raw sisal was carried out very meticulously. After cutting the Sisal leaves from the plant the thorns were removed and the leaves were made to pass through a set of crushing rollers. The leaves were held firmly at their center and the pulp was scraped off from the edges by the roller blades as shown in Figure 1. The exposed sisal fibers were then separated washed and dried. The fiber strands were graded based on the maturity and then sorted based on length and color. Long Fiber strands were cut into a staple length of 6″ inches. Staple fibers were straightened and parallelized by the mechanical process of carding. Carding also helps in removing foreign particles such as dust, sand and leaf bits.

Figure 1 Typical sisal fiber-scraping machine used in cottage industry

2.1.2 Needle punching

The carded fabric is processed next using felting looms. These needle looms may have one to four needle boards and needles from the top or from bottom or from top and bottom. The primary function of this type of loom is to perform interlocking of fibers resulting in a flat, one-dimensional fabric. This was carried out on the machine Ferher NL-6-24. To create uniform parallelized sisal and coir fabric, the fibers were put into the bale and then needle punching of fiber is performed. This is essentially a mechanical intertwining of fiber by a number of needles which passes in and out of the carded fiber. A thin tangled web is created by this process. The types of products made with this process and needle loom are diverse and multifaceted.

As mentioned in the introduction, three different proportions of the fibers were created using this method, namely;

- Sample 1: Sisal 100%
- Sample 2: Sisal/Coir 70:30%
- Sample 3: Sisal/Coir 30:70%.

2.1.3 Preparation of Sisal Fabric

The Sisal Fibers were first cut into 5-inch-long pieces as shown in Figure 2. Then the 5-inch fibers were then fed into the Needle Punching machine (Felting Loom). Using this method, a nonwoven fabric of 52 inches width and 2 ½ meters length was produced as shown in Figure 3.

Figure 2 Sisal fiber

Figure 3 Need Punched Sisal fabric

2.1.4 Preparation of Sisal/Coir Blended Fabric

The 5-inch-long sisal and coir fibers were cut and weighed. 7 kg of Sisal fiber as shown in Figure 2 and 3 kg of Coir fiber which is exhibited in figure 4 were mixed manually, and then fed into the needle punching machine to produce nonwoven fabric which was 52 inch wide and 2 ½ meter long. The same procedure was repeated for 3kg of sisal and 7 kg of coir and the blending was done. The photographs of the resultant fabric can be viewed from figures 5 and 6.

Figure 4 Coir Fibers.

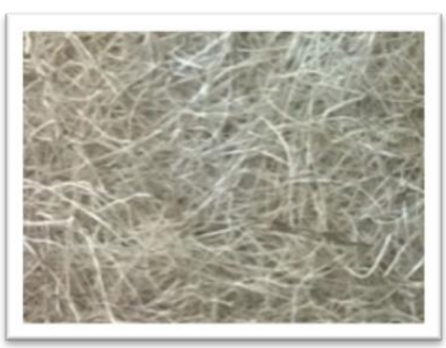

Figure 5 Blended Fabric of Sisal and Coir (70%-30% (sample 2))

Figure 6 Blended Fabric of Sisal and Coir (30%-70% (sample 2))

2.2 Testing

This section lists the tests that were carried out for analyzing the different parameters of the nonwoven fabric such as thickness, GSM, Air permeability, Pore Size (Mean Flow Pore Diameter), Absorbency (seconds) Water drops, and Bursting Strength (kg/cm^2). All the fabric samples were tested at a relative Humidity of 65±2% and at a temperature of 25%ºC.The details are shown in Table 3.1

2.2.1. Fabric density (GSM)

The standard test procedure ASTM–D3776 was followed for determining the fabric density expressed in Grams/Square Meter (GSM). Three samples of 150 mm radius was cut from the fabric and weighed. The weight of fabric in grams divided by its area in square meter gives its GSM value.

2.2.2 Fabric thickness

The test procedure EN ISO 5084 was used to measure the fabric thickness. A digital thickness gauge is used to measure this parameter at three different pressures namely 0.5 kPa, 1.0 kPa and 2.0 kPa for each of the Nonwoven fabrics. The dimensions of the material used were 0.5 m^2 with diameters greater than 56.5 mm and less than 106 mm. The experiment was performed for 3 samples of the fabric.

2.2.3 Fabric Porosity

The standard test procedure ASTM D-4716 was followed to determine the distance gap. Porosity can be obtained from the ratio of the fabric density and the fibre density. Existing definitions of pore geometry and the size of pore in nonwoven are based on various physical models of fabric for specific applications. In general, cylindrical, spherical or convex shaped pore are assumed with distribution of pore diameters. Bubble point refers to the pressure at which the first flow of air though a liquid saturated fabric sample occurs and it is a measure of the largest pore throat in a sample.

2.2.4. Air permeability

The standard test procedure ASTM D737-04 was followed to determine the air permeability. In permeability testing the fluids used are either air or water and the volumetric rate of fluid flow per unit cross-sectional area are measured and recorded against specific differential pressure to obtain the air permeability or water permeability. In air permeability test, the volumetric airflow through a nonwoven fabric of unit cross sectional area at unit differential pressure under laminar flow conditions is defined as the fabric permeability.

2.2.5 Water absorbency

The standard test procedure AATCC –22 was followed to determine the water absorbency parameter of non-woven fabrics. The test method used is burette to find the surface water absorption of fabrics. These determine the ability of the non-woven fabric. In many process techniques and end use characteristics, water absorbency of textile material is the key factor in dyeing and finishing processes. The absorption property may affect the characteristics of fabric.

2.2.6 Bursting strength

The standard test procedure ASTM - D3676 is generally used for woven fabrics. Non -woven fabrics however have distinct directions in which their strength is higher. Bursting strength is an alternative method of measuring strength in which the material is stressed in all directions at the same time and is therefore more suitable for such materials.

3. Results and Discussion

Table 3.1 Properties of Non-woven Fabric

Parameters/ Samples Code	Fabric weight (gsm)	Thickness (mm)	Air permeability (cm^3/ cm^2)	Bubble point(microns)	Pore size, mean flow (microns)	Water Absorbency (%)	Busting strength (kg/cm^2)
Sisal 100%	449.6	9.93	272	719.53	427.86	15.2	22.6
Sisal& coir 70%+30%	554	11.02	375	693.83	398.92	11	18.5
Sisal +coir 30%+70%	636.7	11.54	442	693.83	511.31	26.8	19.1

3.1 GSM Test

Non-woven fabrics can be manufactured with different weights by changing the number of web arrangement. GSM has a direct impact on fabric and manufacturing cost. For this research work single web method is adopted. The GSM value for Pure Sisal was 449.6; and for Sample 2 it was 636.7. According to the samples tested, Sample 2 is greater than Sample 1 and Sample 3 has a significant difference among all the samples. The weight of a unit length of fabric will obviously be affected by its width, other factors such as Fiber thickness, Fiber maturity, Fiber density, Needle density, Needle sharpness; Pressure applied on needle plate also affects GSM of non-woven fabric. Density of Sisal 1.036, Coir 1.4 has influenced majorly on GSM. The fiber density also influences on thickness of the fabric.

3.2 Thickness Test

The fabric thickness was acquired by a random sample selection based on ENISO -5084 test. The results showed the pure sisal fabric to have a thickness of 9.93 mm, and the Sample 2 had a thickness of 11.02 mm, which exceeds the previous thickness by 9.8 %. The Sample 3 had an average thickness of 11.54 mm, which is 13.95 % more than pure sisal, and 4.5 % more than blend one. Individual Fiber thickness and density also contributed increase of fabric thickness. Coir has higher fiber thickness and density compared to Sisal. Individual Fiber thickness and density also contributed increase of fabric thickness. Coir has higher fiber thickness and density compared to Sisal.

3.3 Pore size

In all absorbing material pore of the fabric has an important influence on resistance of air and moisture. Interlocking of fiber and porosity helps to decrease the amplitude of sound/air waves as it passes through fibrous material. Air permeability affects sound absorption, filtration and thermal properties. The air permeability of the pure sample 1 is close to 272 cm^3/cm^2. It was noted that the sample 1 permeability has increased by 27.4%, and the sample 3 has the highest value of 442 cm^3/cm^2, which is higher than that of the sample 1 by 15.15%. Bubble point based on sample test result sample 2 and sample 3 have same reading 693.83 micron comparatively sample 1 719.53 micron have larger pore throat.

3.4 Absorbency

Water absorbency is a measure of the total amount of water that a fabric will absorb. The sisal fabric absorbs 15.2% of water, the sample 2 absorbs 11 % of water and the sample 3 absorbs 26.8 % of water. Therefore, blend one exhibit the least water absorbency and the sample 3 exhibits the most absorbency.

3.5 Bursting Strength

Nonwoven fabrics are web structures made by interlocking fibres using a mechanical method. The failures of nonwoven fabrics can be due to the fact that bursting strength in the random webs was lower than that in the parallel webs. The fibre arrangement in the random webs is anisotropic, so there are more interlacing spots and voids in these webs. The failure extends from these voids to the perimeter under breaking conditions. The bursting strength in the Pure sisal webs is better, being 22.6 kg/cm^{2}followed by Sisal-Coir (30-70%),and Sisal-Coir (70-30%) being last with 18.5kg/cm^2

3.6 Correlation between fabric properties.

3.6.1. Relationship between Air Permeablity and Thickness

Fig.3.1 represents the relationship between air permerablity and thickness of the non woven fabric. The experimental result shows that a higher air permiablity is observed in case of sample of lower thickness. A postive correlation has been noticed in all the fabrics studied. Fabric sample 1 has the lowest density among the three materials tested.

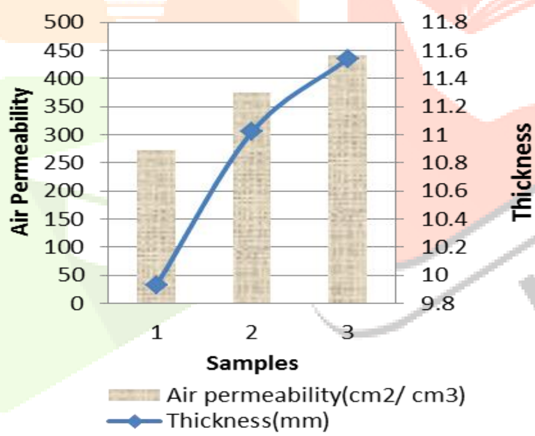

Fig. 3.1: Relationship between Air Permerablity and Thickness

3.6.2 Relationship between Bursting Strength and Thickness

Fig.3.2 represents the relationship between bursting and thickness of the non woven fabric. The experimental result shows that a higher concentration of interlocking spots and voids in the web is observed when the thickness is lower. Therefore negative correlation has been noticed in all fabrics. Fabric sample 1 have the lowest density among the sample 2 and sample 3.

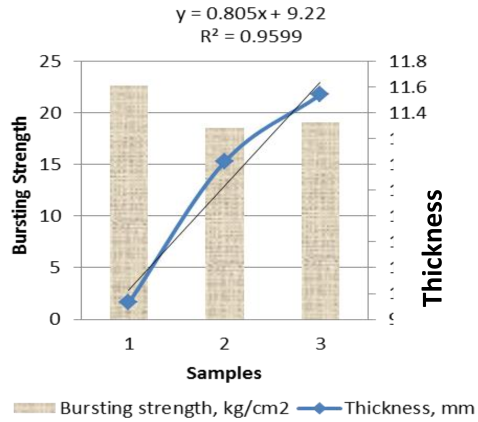

Fig. 3.2: Relationship between Bursting Strength and Thickness

3.6.3 Relationship between Water Absorbency and Thickness

Fig 3.3 displays the relationship between water Aborbency and thickness of the non woven fabric. In the experimental result it has been shown that the coir fibre has high hydrophilic property, hence the sample 3, which contains more coir has shown much larger water absorbency. As thickness increseas absobency requied more time to travel from face side to back side of fabric. It also depends upon entanglement of fibers.

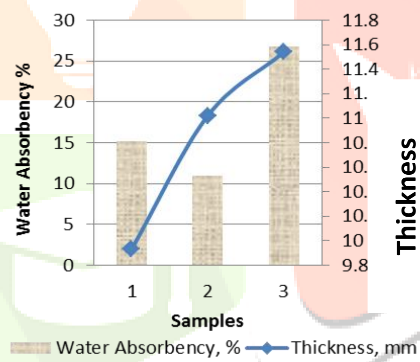

Fig. 3.3: Relationship between Water Absorbency and Thickness

3.6.4 Relationship between Pore Size and Thickness

Fig. 3.4 represent the relationship between pore size and thickness of the non woven fabric.The higher thickness fibers exhibit lower pore sizes. The needle length, size, pentration time, and desity, pressure, of needle which effect entangled the fiber cause pore size. As pore size increases the thickness of the fabric deceases. Individual fiber thickness also contibute towards the pore size and thickness of the fabric. As sample 3 has shown the coir is more density fiber which cause lower fabric pore because of the indiviual fiber charsterstics.

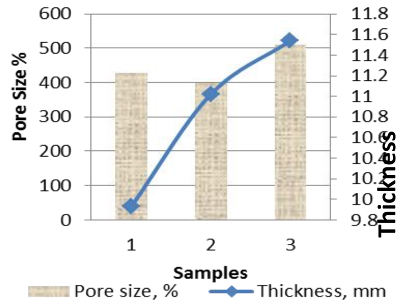

Fig. 3.4: Relationship between Pore Size and Thickness

3.7 Single (one way) ANOVA analysis

A single ANOVA helps to find out how each group is significantly different from one another. From the results it is observed that there is significant difference between the samples at 95% confidence level result as shown in Table 3.2. The degree of freedom is 2, 12 and the $F_{critical}$ is 3.89. The value of $F_{critical} < F_{actual,}$ proves that the nonwoven fabric resulting high significant on the above fabric properties. The fibre blend modification in the nonwoven fabric results in major blow on the fabric properties. Table 3.2 values confirm that the air permeability and absorbency reflect very high influence when compared to bursting strength on fibre blend ratios. In bursting strength F_{actual} is 4.87 which is close to $F_{critical}$ and the P-value is 0.02827, showing the less impact on the blended nonwoven fabrics. The minute changes in nonwoven fabric thickness (9.93 – 11.54) and weight reflects major impact in fabric permeability and absorbency properties.

Statistical analysis of test result pertaining to air permeability, thickness and bursting are carried out and details are given in Table 3.2

Table 3.2 Single ANOVA analysis

Air permeability						
Source of Variation	***SS***	***Df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	73196.4	2	36598.2	53.8737	1.01E-06	3.885294
Within Groups	8152	12	679.3333			
Total	81348.4	14				
Bursting strength						
Source of Variation	**SS**	**Df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	49.03333	2	24.51667	4.870861	0.02827	3.885294
Within Groups	60.4	12	5.033333			
Total	109.4333	14				
Thickness test						
Source of Variation	**SS**	**Df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	6.016053	2	3.008027	25.57049	4.71E-05	3.885294
Within Groups	1.41164	12	0.117637			
Total	7.427693	14				
Absorbency						
Source of Variation	**SS**	**Df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	669.7333	2	334.8667	84.42017	8.54E-08	3.885294
Within Groups	47.6	12	3.966667			

Total	717.3333	14				
GSM						
Source of Variation	**SS**	**Df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	87908.43	2	43954.22	130557.1	9.42E-27	3.885294
Within Groups	4.04	12	0.336667			
Total	87912.47	14				

4. Conclusion

Nonwoven natural fibers such as sisal and sisal-coir blends were processed and fabrics were developed using needle punch technique resulting in a thickness of 0.8mm and width, 52 inches for possible home textile applications. The physical properties of Sisal fiber has a greater Mean breaking strength 43.6% compared to Coir, the diameter of the Sisal is almost uniform & distribute load equally. CV% Strength of Sisal is lesser than Coir fiber by 12.51 CV%. Mean Elongation% of Coir fiber is greater than Sisal by 28.17%, this is due to the presence of natural convolution or crimp on Coir fiber. Moisture content of Coir is more than Sisal by 11.7%. Sisal exhibits lesser density (1.036) at room temperature, lignin content. Sisal contains more Cellulose (78.39%) & Coir has less.

Three different non-woven fabrics have been studied for their material characteristics the following results obtained for key parameters air permeability of Sample 1 is lesser than Sample 2 by 37.86%, & Sample 3 has higher Air Permeability by 17.86%. Air Permeability is affected by the Density, Thickness of Fiber & Fabric, Blend % of Fiber, Density of Fibers in Unit Area. Thickness of Sample 2 is increased by 10.97% than Sample 1; Sample 3 has increased by 4.71%. The fiber thickness & Blend % has majorly affected the thickness of the fabric. Sample 3 contains 70% of Coir which contributed more thickness. Fabric Weight (GSM) of Sample 2 has higher weight than Sample 1 by 23.22%, Sample 3 has higher thickness than Sample 2 by 15%, due to the more percentage of Coir. Bursting strength of Sample 1 is higher than Sample 2 by 18.14% & Sample 3 has 3.24% higher Bursting Strength. Air Permeability of Sample 2 is 37.86% higher than Sample 1, & Sample 3 has 17.86% higher than Sample 2, which is due to density of fiber & entanglement of Fibers. Sample 3 exhibits higher Air Permeability due to presence of crimps on Coir & blend percentage is 70% also contributes for higher percentage of Air Permeability.

The developed fabrics have wide range of applications in home textiles, agriculture, and geotextiles. Specific treatment should be given for the material for future application such as noise control, false roofing material, printing, embossing, sound proof lamination board, air conditioning, RCC curing material. This research work will go a long way in the design of home textiles.

Acknowledgement

The authors are thankful to Dr. BS Rajanikanth, IISc, Bangalore, Dr. T. Ananta Krishnan, professor & HOD, SKSJTI, Bangalore and Mr. Babu Rajendra Prasad R, Principal, The BSE Institute of Management Studies, Bangalore, for their valuable suggestions and discussion at various stages of this research work. Thanks are also due to Ms. Anusuya Bhattacharyya (PhD scholar, IISc) and Mr. Sudhindra Sridharan for assisting in the preparation of this manuscript.

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