SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSIONS

The growth and development are essential for the economic progress of the country. Every change has pros and cons i.e. economic progress will bring change in the standard of living, with that lifestyle changes and thus has an impact on health as well as environment. Some of the risk owing to economic growth is pollution, congestion, diseases of affluence, increases utilization of non-renewable resources, etc. Amongst the pollution after air, nowadays noise pollution has also become dangerous for the living beings. Noise pollution is an unwanted sound that harms human beings psychological and physiological. Any sound above 85dB level and prolonged engagement with that is dangerous. This hazardous situation has been invited by us unknowingly or knowingly though various sources like noise due to traffic, air traffic, construction site, catering and night life, increased use of electronic devices, etc. to fulfil our needs or for leisure.

Population growth and destruction of natural resources like trees and plants for the development of urban areas has an impact on increased rate of noise pollution. It has hazardous impact on health like sleep disturbance, high blood pressure, hypertension, reduction in immune system, cardiovascular diseases, irritation, frustration, hearing loss, reduces the capacity of mind and physical activities, lack of concentration, communication gap, and over a period of time causes death also. Thus, the alarming situation has created awareness of developing sound absorbing materials for different applications.

Since long various sound absorbing materials are developed specially for the offices and factories to avoid machinery sound. These materials are majorly developed using synthetic fibers like glass wool, polypropylene and other blended raw materials. While manufacturing process used are mainly nonwoven and composite preparation and additionally certain chemical process or finishes as per the need are also applied. Thus, such materials are definitely useful for sound reduction but on other hand utilization of synthetic materials thereby reduction in petrochemicals and increased usage of chemicals are polluting our environment.

While on other side, with the increasing demand of eco-friendly products exploration with minor natural fibers is gaining attention. These fibers are mainly lignocellulosic or protein procured from any of the part of plant or from animals. India being agricultural land many different plants are cultivated for different purpose. Some of the plants were majorly grown for purpose of having fence, manufacturing of cords and mats. Owing to certain properties of this category of fiber, they are explored for various technical textile products.

With the above mentioned need and availability of the lignocellulosic fibers need was sensitized to develop sound absorbing materials using natural fibers and woven technique for fulfilling the purpose of utility as well as aesthetic. The enhancement of the interiors is equally important to have a working ambiance.

Hence an experimental study was formulated for developing an eco-friendly sound resisting materials using sisal and ramie lignocellulosic fibers. Owing to environmental issues enzyme treatment for softening process was the suitable process. The entire concept of fiber to fabric development process was formulated in such a way that the future commercial setup can be built as well as the employment can be raised. Finally, that will have an impact on overall health issues, farmer's standard of living with the increased utilization of such fibers as well as on our economy also.

To achieve the intensive exploration process, objectives are framed and are as follows:

5.1. Objectives of the study

5.1.1. To study the chemical and physical properties of the ramie and sisal fibers.

5.1.2. To optimize the process of treating the fibers with enzymes for softening.

5.1.3. To prepare spun yarns of the untreated and treated fibers.

5.1.4. To develop hand woven fabrics with various weave structures and measure their effect on sound absorption.

5.1.5. To develop lab scale facility for the testing and analysis of sound absorption.

5.1.6. To evaluate the sound absorption properties of various unfinished and finished fabrics.

5.1.7. To assess the performance properties of the fabrics as per the end use requirements.

5.2. Experimental Procedure

The two minor lignocellulosic fiber – sisal and ramie were selected for the experimental study based on sustainability, availability and acoustic application. Both the fibers were scoured and soften using enzyme treatment. These treated fibers were separately converted into yarn and testing at both the stages were determined as per standard methods.

The study was divided into three phases:

Phase I incorporates the process of fiber softening and yarn preparation. The fiber surface modification was done using four different enzymes. While, depending upon the fiber characteristics different spinning technique was considered for a particular fiber.

To optimize the enzyme treatment process different variables experimented were – percent concentration, treatment time duration along with different techniques and processing method to achieve softer and pliable fibers. While, M:L 1:40 ratio, 5pH and 55°C temperature were kept constant. For the removal of impurities and having aligned bundled of fibers beating machine and combing tool was fabricated. The three different methods of treating fibers were using lab-based utensils and instruments like Infracolor and Launder-O-Meter. All the treated fiber samples were tested using ASTM standards.

Based on the test analyses raw fibers as a standard sample and two enzyme treatment i.e. sisal/ramie-high percent concentration-combing-beating-combing and sisal/ramie-high percent concentration (4hrs treatment without changing water)-combing-beating-combing using Launder-O-Meter was finalized. The softer fiber, less treatment duration and possibility of treating the fibers in bulk which can further be planned for commercializing was main motto, which was achieved. This treated fibers also showed its impact on sound absorbing properties.

The handspun yarns were developed from both the raw fibers, while after the treatment handspun yarns were only possible with sisal, ramie hand spinning was difficult due to change in fiber properties. Hence for treated ramie rove technique using DREF machine system was finalized to have a coarser and hollow yarn structure. As per the need of the research all the yarns prepared were of coarser quality, to have a thicker fabric. All four yarns – Sisal-Untreated-Traditional (Hand) Spinning Technique (SUT), Sisal-Treated-Hand spinning technique (STH), Ramie-Untreated-Traditional (Hand) Spinning Technique (RUT) and Ramie-Treated-Rove spinning technique (RTR) were analyzed using ASTM standards.

Phase II was focused on preparation of woven fabrics using different weaves as top/front layer and nonwoven fabrics of different GSM for backing material. Total twelve woven fabrics using Plain weave, Broken twill and Double Cloth weave were prepared on handloom. The plain weave fabrics were developed using scoured fibers as well as using 100% sisal and 100% ramie yarns were separately used, while in broken twill weave only the yarns were used and in double cloth woven fabric both the yarns are alternately inserted as weft with ramie stuffing. While three nonwoven ramie fabrics of different GSM were developed using needle punch technique. All the aesthetically appealing fabrics were analyzed for fabric as well as sound absorbing properties.

As the fabrics were developed for sound absorbing purpose another factor i.e. aesthetics was also considered as these fabrics could be used as office/residential interiors. Additionally, owing to fibers inherent properties like anti-microbial and anti-flammable three different fabrics – enzyme treated ramie fabric, enzyme treated sisal fabric and scoured ramie nonwoven fabric were tested. Further all the fabrics with and without resin finish were analyzed for sound absorption and the data was derived in terms of sound reduction (dB) and Noise reduction coefficient (NRC).

Phase III consists of sound absorbing instrument, resin finish and sound absorbing testing. To analyze the absorption an instrument was developed based on ASTM E1050 standard. A little variation i.e. moveable plunger with which sample holder is attached to conduct absorption test at various distance and one microphone (dB) for measuring frequency. All the woven and nonwoven samples were initially tested individually, then combination with number of airgaps and backing material and finally with number of layers with ply was carried out.

Out of twelve fabrics, three i.e. Sisal-Untreated handspun yarn-Plain weave (SUP), Ramie-Treated rove yarn-Broken twill weave (RTBT) and Ramie/Sisal fibers-Untreated-Plain weave (RS FUP) were selected for resin finish. The concept was to overcome the roughness and to create a lamination layer on the fabric surface. The natural resin was applied at 150°C temperature using padding mangle pressure with 65% pick up. Finally, comparisons of these three resin fabrics were done with unfinished fabrics as standard sample using Scanning Electronic Microscopy (SEM), Sound Resistant (dB) and Noise Reduction Coefficient (NRC).

5.3. Result and Discussion

5.3.1 Characterization of fibers

- The sisal and ramie fibers having inherent characteristics and hollow structure was suitable for sound absorbing materials.
- Both the sisal (70cm) and ramie (48cm) fibers were of filament category with the diameter of 179μm and 79 μm respectively. While the denier was 198 and 739 respectively.
- Under the microscope both the fibers were observed, which clearly showed that bundle of fibers was forming a strand having pithy materials on the surface.

5.3.2 Optimization of Softening treatment

- The sisal and ramie fibers were treated with four different enzymes for softening of the fibers. To optimize the recipe percent concentration, sequence of enzymes and treatment method were studied. The optimized stepwise recipe was beating of the fibers after scouring process → combing to remove sticky pitchy material → Pectinase → Laccase → Cellulase → Hemicellulase → Oil emulsion process → Batching → Combing. While the same recipe but with adding of enzymes on after another during the process was also found to be effective. As the treatment time as well as consumption of water was reduced and most importantly it was little more impactful then the former process.
- All the enzyme treated fibers were analyzed by single fiber strength test, feel test and pliability.
- Amongst the 14 different enzyme treated samples two from each fiber category were taken further for the fabric development. The finalized fiber samples were - Sisal-High % concentrated-Combing-Beating-Combing (*Shcbc*), Sisal-High % concentrated-Combing-Beating-Combing (4hrs treatment without changing water) (*Shcbc4*), Ramie-High % concentrated-Combing-Beating-Combing (*Rhcbc*) and Ramie-High % concentrated-Combing-Beating-Combing (4hrs treatment without changing water) (*Rhcbc4*).

- The enzyme treatment using Launder-O-Meter machine was finalized as the penetration of enzyme solution due to constant rotation at a particular speed, constant temperature, less processing hours with less of water consumption and most importantly bulk quantity treatment was possible with required quality of soften fibers.

5.3.3 Analysis of the untreated and treated fiber

The two selected fibers having natural colour were compared with the finalized treated fiber and it was observed that change in whiteness index with negligible change in yellowness which might be due to effect of enzymes onto the fibers.

a. Chemical analysis

To analyze the change in the active molecular functional groups in the fiber constituents Fourier Transform Infrared Spectroscopy (FTIR) was done. The impact of four different enzymes on the components of the fibers – pectin, cellulose, hemicellulose and lignin were identified.

- In sisal, O-H groups i.e. hydrogen bonds between cellulose and hemicellulose were weaken, C-H stretching in lignin and with continuous activated laccase enzyme throughout the process it was observed from the graph 4.1 that the lignin might have affected. Further, with C-H deformation of lignin in the range of 1400-1500 cm^{-1} indicates that lignin structure must have broken and deteriorated.
- In ramie, also similar observations were made from the Graph 4.2, i.e. C=O stretching, C-H deformation and stretching and C-O deformation in lignin.

Hence it can be concluded that the treatment and process had an impact on softening of the fibers. The treatment has majorly affected lignin structure than to cellulose and hemicellulose structure. And so, the change in fiber properties, surface area and crystallinity of the fiber were observed further. With the treatment the fibers were softer and change in cohesion of the fiber was achieved.

b. Structural analysis

To identify the surface characteristics and morphological structure of fibers Scanning Electronic Microscopy (SEM) tests were done. Each fiber consists of bundle of hollow fibers which are bonded due to the components like pectin, cellulose, hemicellulose and lignin. In general, Lignin gives strength but higher the amount makes the fiber stiff and the lignin is surround by hemicellulose and cellulose. Due to which penetration of enzymes becomes difficult and thereby difficult to reduce the stiffness specially in case of sisal fiber.

After the enzyme treatment Shcbc and Rhcbc fibers showed less of pithy material at the surface and the fibers were more aligned. Further in cross section view it was observed that both the fibers were having different shape and diameter of the fiber, which were swollen and thus had an impact on surface characteristics as well as smoothness was improved. While in case of Shcbc the cohesion was increased in little amount compare to the raw fiber and porous structure was seen in Rhchc.

While in enzyme treatment process with less time duration and no change of water had good impact on the fibers. Shcbc4 fibers were more of crystalline porous structure and soft, with increased cohesion. In case of Rhcbc, the fibers were much more porous in structure, more soft and lustrous surface characteristics was achieved.

c. Element analysis

The micro structure/element analyses have been done to see the change in crystallinity in the material using X-Ray Diffraction (XRD). Due to the enzyme treatment, removal of surface impurities of the fibers, modification in crystalline region and disruption of the hydrogen bonds takes place in the natural fibers. With effect of treatment it was observed that percent crystallinity reduced, crystalline size increased and change in orientation angle at 2θ compare to the raw fibers and similar results was can be support with SEM analysis.

Energy-dispersive X-ray spectroscopy (EDS) was mainly done to identify the elemental composition of the material and to understand the addition of elements or deformation of bonds in fiber. Carbon and Oxygen are the main elements of the cellulosic fiber for the formation or deformation of the bonds after any kind of treatment or finishes.

In sisal, negligible change in carbon and oxygen with reduction in calcium element was observed in Shcbc fiber sample which might be affected the formation or structure of cell wall in this particular treatment compare to Sh and Shcbc4. And similar effect was also seen with ramie treated fibers samples.

Presence of sodium, magnesium, iron, and aluminum in all the treated fibers were due to the scouring process and utensils used during the process. All the elements are in permissible limits and thus the softening treatment is harmless to the ecology and environment.

d. Physical properties

The enzyme treatment of the fibers was to remove the impurities as well as to reduce the stiff and thereby having strength to convert into yarn. The change in the bonds and removal of impurities has reduced the strength of both the fibers. While, better elongation was observed in ramie fibers. The fibers stress in gm/denier and stiffness reduced after the treatment. But as the fibers can withstand the twist as well as even yarn structure could be spun. Hence based on strength analysis, stress, percent strain and elongation enzyme treated fibers without changing the water i.e Shcbc4 and Rhcbc4 were selected for yarn preparation.

5.3.4 Analysis of yarn properties

a. Yarn fineness and twist

Coarser yarns were developed based on the concept that quality of yarn will have an impact on fabric thickness. All the yarns were handspun, but due to the surface characteristics of the treated ramie fiber rove technique was selected to have a hollow yarn structure for better absorption. The denier of raw fibers was high due to fiber properties and spinning technique compare to treated fibers. Similarly, the twist per inch was also higher in untreated fiber yarn i.e. SUT and RUT compare to the treated yarns i.e. STH and RTR. While, for better strength and less of protruding fiber ends “S” twist was purposively kept constant in all the yarns.

b. Yarn strength

The fiber after the treatment showed reduction in lignin content that means softness has been achieved but was still stiff for machine spun. While in case of ramie after the treatment the fibers were difficult to handspun due to change in cohesion. Thus, 100% sisal and 100% ramie yarns were developed using hand spinning technique for untreated and treated sisal fibers as well as untreated ramie fibers and machine spinning using rove technique for treated ramie fibers. the denier of all the yarns are high as purposively the coarser yarns were developed for the sound absorption. While the breaking point was almost same in case of sisal, in ramie the difference was more owing the spinning technique used. Both the yarns comparatively had good strength for this particular study where absorption of sound was the main motto. Hence, both the treated yarns with “S” twist having better strength and even structure were considered further for fabric development.

5.3.5 Analysis of the structural properties of the fabrics

The twelve woven fabrics of different weaves – plain, broken twill and double cloth were developed using fiber stands/yarns as weft with mercerized cotton of 7 count and 4ply as front/top layer. The three nonwovens from ramie fiber of different GSM were prepared for backing material. Hence, properties like fabric count, thickness, GSM, air permeability and cover factor were analyzed of all the samples.

Fabrics using fiber strands

The three different plain weave samples were developed using sisal, ramie and combination of both the fiber strands. The physical properties like thickness, GSM and air permeability are main factors which has an impact on the sound absorption property of fabric. It was observed that as the GSM value increases, air permeability decreases and fabric becomes more compact. The fiber density can be increased but the cohesion between fiber is less and also the placement of the fiber are uneven which makes the structure coarser. While comparing the three fabrics - R FUP showed stable fabric structure. The protruding fibers on surface with harsh feel was observed in fabric S FUP. While blend fabric R/SFUP having two different fiber strands showed unbalanced porous structure.

Fabrics from sisal yarns

The two plain weave and a broken twill weave fabric were developed with untreated and treated handspun yarns. Having similar fabric count and cover factor, the thickness and GSM was higher and air permeability is lower in SUP fabric. While, depending upon the weave, number of warp yarns were increased in case of STBT. The visual and feel of the fabric showed that STBT was more porous than SUP and STP. Overall, it can be analyzed that SUP might absorb sound better because of rough texture and protruding fibers.

Fabrics from ramie yarns

The three different ramie fabrics were developed using handspun untreated fibers and rove yarn technique using treated fibers. Owing to yarn quality the structure of fabric differs with similar weave. RTP having more number of weft yarns and little difference in thickness showed might absorb sound more compare to RUP, owing to the air permeability results. While comparing plain weave fabrics with broken twill, it seems that RTP followed by RTBT and RUP might be the sequence for better sound absorption. The major factor is the fiber and yarn structure for having a compact woven fabric.

The air permeability being one of the parameters, amongst the sisal and ramie fabrics RTP and RTBT (both the ramie fabrics) will have good absorption compare to others.

Fabrics from sisal and ramie (R/S) of yarns

The Double cloth weave fabrics were developed using ramie and sisal yarns alternately for both absorption and aesthetic look. The three different fabrics developed were – Double cloth without stuffing (R/STDC), Double cloth with stuffing (R/STDCs) and tubular cloth with stuffing (R/STTC). For stuffing scoured ramie fibers were used.

The air permeability reading was high in all the three samples, which was due to two different thickness of yarn and pores at the intersection points. Hence, the fabrics was only considered for the sound absorbing test purpose. And amongst the samples it can be said that R/S TTCs might absorb sound better compare to other samples.

Nonwoven fabrics

The three ramie nonwoven fabrics of GSM ranging from 620 to 920 were developed to identify the more compact and thicker fabric for backing materials. As the thickness will increases, number of layers will reduce and thereby the final product will have strong base with reduced bulkiness. But, owing to fiber properties the clusters of fibers were observed at certain areas of fabric due to which accurate readings of air permeability or sound absorption was difficult. Hence, R919 having good air permeability and thickness was considered as the final backing material for the study.

5.3.6 Factors affecting the sound properties of different fabrics

The optimization of distance and frequency for sound testing process was done using single layer fabrics. For creating composite product combination of fabrics and number of layers were tested with optimized distance and frequency.

a. Effect of distance between sound source and sample

Single layer fabrics were tested for sound absorption properties at various distance ranging 0 cm to 80 cm with the increment of 20 cm.

Plain weave fabrics using fiber strands

The noise reduction of three untreated fiber strand fabrics were analyzed at 1200 Hz frequency. The results reveal that all the samples showed almost similar readings till 60 cm and with the increment of 20 cm absorption also increased. Amongst the sample's absorption was high in S FUP followed by R FUP and R/S FUP that means the absorption depends on the nature of the fiber and weave.

Plain weave fabrics

The sound absorption can be altered of the fabric structure based of the fiber and yarn structure. The plain weave providing a basic and stable weave structure was developed as the base of the study. The four plain weave fabrics using untreated and treated fiber yarn was compared, amongst which Ramie Treated Plain weave (RTP) fabric showed good absorption compare to others. It could be said that after the treatment fibers were soft, bulky and swelling within the fibers might have impact on absorption. While, between 20 cm and 60 cm the absorption results were better. Hence, the plain weave structure can be considered as best structure for sound absorption.

Different weaves of the fabrics

The weave changes the characteristics of the fabrics, appearance, lustre and strength changes. Thus, three different weaves – plain, broken twill and double cloth weave fabric structures were developed as sound absorption materials. While comparing the five samples Ramie Treated Plain weave (RTP) showed good results, followed by Ramie Treated Broken Twill weave (RTBT) from broken twill category. While, having double cloth with air pockets, the Ramie and Sisal Treated Double Cloth without stuffing (R/S TDC) absorbed approximately 50% only due to the pores at interchanging points from which the sound passed away. Hence, plain weave fabric and 40cm distance were found to be appropriate for sound absorption.

Double Cloth weave fabrics

The number of layers and uneven fabric surface will have impact on sound absorption, so double cloth weave and its variation was analyzed. Double cloth weave with and without showed similar absorption as the pores at interlocking points were same from which the air was passing out. Other reasons could be stuffing material as well as combination of different thickness of sisal and ramie yarns.

Thus, Ramie and Sisal Treated Tubular Double Cloth with stuffing (TTDCs) was analyzed which showed little better absorption compare to the two double cloth samples. But as the absorption was nearby the 50% only these three samples were only considered for the testing purpose. And owing to the fabric structure it was also difficult to optimize the distance.

Different weaves in ramie fabrics

The fibers inherent property and fabric structure are the two major factors for sound absorption. It seems that Ramie Fiber Untreated Plain weave (R FUP) absorbs better than Ramie Untreated Plain weave (RUP). Having more thickness, RUP could not absorb good amount of sound due to coarser yarn structure created pores in the fabric. While Ramie Treated Plain weave (RTP) absorbed better than Ramie Untreated Plain weave (RUP) due to the difference in yarn structure. Having similar yarns but different weave, the visibility of warp yarns makes the difference. With Ramie Treated Broken Twill weave (RTBT) equal amount of warp yarns were visible so, that might be have an impact on sound absorption. Hence, all the ramie fabrics Ramie Treated Pain weave (RTP) shows the best results and all the fabrics showed good absorption at 40cm distance.

Different weaves in sisal fabrics

Sisal a less cohesive and stiff fiber, woven fabrics developed might have different impact on sound absorption. Thus, comparative analysis between sisal woven fabrics showed that Sisal Fiber Untreated Plain (S FUP) weave has better absorption, amongst the weaves Sisal Treated Plain weave (STP) followed by Sisal Treated Broken Twill (STBT). It can be said that sisal untreated fibers creating rough texture and the basic structure with treated yarn having more aligned weft yarns are absorbing more sound. Overall, S FUP and SUP shows good sound absorption results and at 20 and 60 cm distance almost all the fabrics showed similar results.

Nonwoven fabrics

The amount of fiber and density and thickness of the fabric, it will have an impact on sound absorption. Similar trend was observed while comparing ramie nonwoven fabrics of different GSM. A negligible difference which was observed at different distance could be because of clustering of the fibers owing to its cohesive nature and thus uneven distribution of fibers thereby uneven fabric surface. Thus, based on the need of thicker fabric as backing material R919 was selected. While major difference of absorption was observed within 0 cm to 60 cm distance.

Hence, with overall comparison it was found that a fix trend was difficult to identify for optimizing the distance in case of minor fiber fabrics. So, 40 cm distance was optimized for the study as majority of fabrics showed better results.

b. Effect of frequency on different types of fabrics

To optimize the frequency for the sound absorbing testing of the developed samples at 40 cm distance, mid frequency range from 1000 Hz to 2200 Hz were taken and tested using single layer fabrics only.

Plain weave fabrics using fiber strands

The plain weave fabrics using fiber strands having variation in pick density, its impact on sound absorption at various frequency was analyzed. R FUP having lowest cover factor (4X22) and highest thickness (2.7) showed good absorption owing to the fact that rough textured fabric having untreated ramie fibers must have scattered the sound. According to the sound mechanism lesser the pores more with rough surface, more the absorption. Hence, the absorption was better with R FUP followed by S FUP and R/S FUP and at 1400 Hz appropriate readings were achieved, while at 1200 Hz lowest readings were observed.

Plain weave fabrics

The plain weave fabrics using untreated yarn compare to treated yarn alongwith other fabric properties – cover factor and thickness has its impact on sound absorption. Overall, Ramie Treated Plain weave (RTP) fabric owing to fiber property, pick density and yarn structure must have showed good absorption followed by SUP, RUP and STP. While stable reading was observed at 1800 Hz and 1400 Hz. Hence, being a mid-value and showing stable result, 1400 Hz was observed as average reading point.

Different weaves of the fabrics

The yarn denier and its impact on sound absorption was analyzed with different weave fabrics. Amongst the plain weave Ramie Treated Plain weave (RTP) showed better absorption owing to pick density and less of pores compare to Sisal Treated Plain weave fabric. Ramie Treated Broken Twill (RTBT) showed better absorption but when compared with other ramie fabrics the absorption is low due to the fabric structure. While Ramie and Sisal Treated Double Cloth (R/S TDC) fabric had lowest absorption amongst all the fabrics due to pores at interlocking sections. Hence, amongst all the fabrics RTP followed by RTBT showed good absorption majorly at all frequency and it was clearly visible that before and after 1400 Hz frequency the absorption increased/decreased.

Double Cloth weave fabrics

The uneven fabric surface with less of pores will absorb sound better. Thus, amongst the three double cloth fabric Ramie and Sisal Treated Tubular Cloth (R/S TTCs) showed better results at higher frequency only. It can be because of the untreated ramie stuffing in form of bundle of stands. But overall, all the fabrics gave on an average 50% reduction only. Hence, for frequency optimization this category showed better absorption at 1400 Hz and then reduced at 1800 Hz and 2200 Hz.

Different weaves in ramie fabrics

The ramie woven fabrics were compared for sound absorption at various frequency. The Ramie Treated Plain weave (RTP) followed by Ramie Fiber Untreated Plain weave (R FUP) gives overall better results, owing to fiber and yarn characteristics. While other two fabrics having pores at the intersecting points showed less absorption. Almost at all frequency average to high absorption was observed but it was found that before and after 1400Hz it increased or decreased.

Different weaves in sisal fabrics

The untreated sisal fiber fabric (S FUP) showed better absorption than the untreated and treated yarn fabrics. Having thicker untreated fiber, the fabric Sisal Untreated Plain weave showed second highest absorption, followed by Sisal Treated

Plain weave (STP) and Sisal Treated Broken Twill weave (STBT). Hence in this category major factor was raw material followed by weave showing best results at 1800Hz and 1400Hz frequency based on thickness and level of compactness to resist the sound wave of particular frequency.

Nonwoven fabrics

The sound absorption is better with the increasing thickness of the nonwoven fabrics and its uneven fabric structure. It was observed that ramie nonwoven fabric (R919) showed increased trend of absorption till 1400Hz frequency and after it reduced.

Overall, with the testing of all the single layered fabrics at various frequency it was concluded that the minor fiber fabrics owing to its rough texture and fabric structure the average absorption was at 1400Hz mid-frequency.

c. Effect of number of layers

The sound absorption panels are composed of number of layers. The top woven layer will serve as an aesthetic as well as absorption layer. While the nonwovens as will be considered as second layers which are comparatively thicker. Further to have more effective absorption the airgaps in between the fabrics are kept and finally mounted on the ply to create the panel a strong and long-lasting product. The main motto was to have maximum absorption with less layers in order to decrease the bulk of final product. Hence the comparisons of combination of layers were analyzed at optimized 40cm distance with 1400Hz frequency.

Different weaves in ramie fabrics

The ramie fabrics were analyzed with the increase of number of layers. The rough and unbalanced fabric will absorb more sound and the same was observed with Ramie Untreated Plain weave fabric (RUP) followed by Ramie Treated Plain weave (RTP) and Ramie Fiber Untreated Plain weave (R FUP). While, by adding the layers it was found the all the three fabrics absorption increases but the highest was by fabric RTP. Thus, the treated fibers with rove structure showed better absorption with the increasing number of airgaps and nonwoven followed by ply. With Ramie Treated Broken Twill weave fabric it was showed that with addition of layers it absorption sound equivalent to other fabrics. Thus, orientation of each fabrics might be a secondary factor for sound absorption.

Different weaves in sisal fabrics

The sisal fibers become smooth and lustrous after the treatment and makes it pliable. All the sisal fabrics were compared amongst which Sisal Fiber Untreated Plain weave fabric showed better absorption followed by Sisal Treated Plain Weave (STP) and Sisal Untreated Plain weave (SUP) fabrics. It was observed that the untreated fiber giving rough textured and uneven surface scattered the sound better than the smooth yarn surfaced fabric. The Sisal Treated Broken Twill (STBT) showed better reaction only after the having more numbers of airgaps and nonwovens followed by ply. Thus, with the number of layers and orientation of the layers of the fabrics all the fabrics showed higher absorption.

Combination of ramie and sisal

The combination of ramie and sisal fiber strand fabric and three different double cloth weave fabrics were analyzed for sound absorption as single and multiple layers. Amongst the four fabrics Ramie and Sisal Fiber Untreated Plain weave (R/S FUP) fabric gave better results, while all the double cloth fabrics gave poor results as single layer as well as by adding a layer of nonwoven and airgap. Owing to the pore areas and the uneven fabric surface the sound must be passing easily.

As the number of layers increases absorption will be high, with this concept and for aesthetic reasons double cloth fabrics were developed. By adding layers with airgaps and ply it showed more absorption. Hence, it could be said that scattering of sound took place at each layer owing to fiber, yarn and fabric structure. So, based on the kind of demand these fabrics could also be a part of collection.

5.3.7 Analysis of fabric properties of selected fabrics

The resin finish was given to the woven fabrics having more rough and open structure amongst the basic weaves to enhance its aesthetic as well as absorption quality. Thus, to identify its effect on fabric surface as well as sound absorption and comparative analysis were done on the unfinished and resin finished fabrics.

a. Comparative analysis of unfinished and resin finished fabrics

The structural analysis and sound absorbing test were done to identify the effect of resin on the fabric surface and porous areas of the fabric as well as to understand its impact on the sound absorption.

Scanning Electronic Microscopy (SEM)

Natural resin applied on the selected fabrics had penetrated and absorbed by the fiber and fabrics instead of creating a layer on the surface of the fabrics. The finish has improved the surface characteristics of the fabric but reduced the thickness of the fabrics. Hence, sound absorption characteristics were to be identify.

Sound absorbing properties:

The resin finished woven fabrics and unfinished fabrics (standard sample) were analysed for sound absorption characteristics, it was observed unfinished fabrics absorbed more. Which can be correlated with the SEM results that the resin has penetrated into the fabric rather than creating a layer. Hence, for sound absorption the unfinished fabric samples were considered.

b. Performance analysis

The fabrics developed using lignocellulosic fibers – sisal and ramie are having inherent properties. As these fabrics will be serving dual purpose i.e. sound absorption as well as aesthetics it was tested for anti-microbial and flammability. Thus, it will identify their additional properties and its potentiality towards natural atmosphere.

Antimicrobial properties

The test results show that the number of colonies forming units (cfu) as well as bacterial counts are more in Ramie needle punch fabric of 919 GSM (R 919) followed by Ramie Treated Plain weave (RTP) and Sisal Untreated Plain weave (SUP). The growth on fabrics after the treatment might be because of the residues of scouring and enzyme treatment on the fabrics which attracts microorganisms. While another observation was the enzyme treated fabrics had lesser growth rate of microorganisms compare to scoured fabrics.

Flammability test

All the three fabrics were non-flammable even after exposing the fabrics for 15seconds. The natural fibers are more flammable due to the chemical components present like cellulose, hemicellulose and lignin. Amongst this lignin is the major factor. Thus, from the flammability results and its correlation with FTIR analysis it can be said that lignin has reduced and so having good non-flammable materials for sound absorption.

Conclusion

- The sisal and ramie fibers need softening treatment and enzyme treatment is an effective process owing to environmental concerns. It softens the fibers as well as increases its pliability specially in case of sisal.
- The inherent property of the sisal like stiffness give limitation in terms of machine spinning process hence after treatment hand spinning has been done.
- The resiliency increases within the ramie fiber after treatment, which makes the hand twisting difficult and thus, machine spun with rove technique has been done.
- Sound absorption properties improve with change in fiber diameter; it has been observed that ramie fiber with lesser diameter (79 µm) compare to sisal (179 µm) shows better absorbency.
- The enzyme treatment for the minor fiber has been standardized using Launder-O-Meter. This method is more economical, eco-friendly and reduces the water wastage. Hence, this method can be utilized as a commercial setup.
- The Fourier Transform Infrared Spectroscopy (FTIR) analysis shows that deterioration and deformation of lignin structure after the treatment. Hence the fiber become smooth, soft and pliable.
- Due to the fibers having inherent hollow structure, further also with enzyme treatment it swells and space between the fibers in a bundle increases which affects the sound absorption. Hence, it is recommended.
- The X-Ray Diffraction (XRD) and Energy-dispersive X-ray spectroscopy (EDS) analysis of both the fibers showed changes in the bond and making the fibers more crystalline. While minimum changes in the chemical composition which was within permissible limit. Hence, the treatment is non-hazardous.

- The enzyme treatment affects the physical properties of the fiber but the change is not significant in terms of strength and abrasion. Hence overall, the chemical, structural, elemental and physical analysis reveals that, the treated fiber - Shcbc4 and Rhcbc4 provides better feel, texture and strength after treatment and has an impact on sound absorption.
- The developed yarns were smooth, lustrous and formed even yarn structure, that will create balanced fabric structure.
- The fiber strands were inserted as weft and the fabric surface characteristics found good but rough. Also, these fabrics shows good sound absorption (R/S FUP, R FUP and S FUP)
- The rough surface with protruding fibers and after the long run the fibers will start fraying. Hence, further with some kind of finishes these fabrics could be incorporated in the sound absorbing material collection.
- For the experiment work carried out at different distance and the different frequency in fabricated lab model. The 40cm distance (from sound source) and 1400Hz frequency has been optimized.
- Noise reduction coefficient (NRC) of minor fiber fabrics generally ranges between 0.2 to 0.6, but the fabrics developed using ramie and sisal showed NRC values ranging from 0.4 to 0.8. Hence, the fabrics using these two fibers can be used for acoustic purpose.
- During the analysis of all the fabrics amongst which the plain weave fabrics using treated fiber yarns gave better absorption which could be correlated with its compactness and thickness that limits the passage of sound.
- Plain weave fabrics gives a stable fabric structure and better absorption compare to broken twill and double cloth weave. Hence further explorations with other minor fibers could be done for having a range of sound absorbing materials.
- As the layers increases the absorption increases, hence the woven fabrics where kept as top layer and airgaps with nonwoven were attached. But further when ply was added as a solid backup, all the combinations showed NRC value between 0.95 to 0.99.
- Overall, RTP and SUP gives better absorption owing to its structural and surface properties.
- To have better aesthetically appealing fabrics, resin finish was applied but the resin penetrated into the fabric instead of creating a layer onto the fabric as well

as the thickness of fabric reduced due to resin finish method. Hence, it gave low NRC values.

- To check the effect of the moisture on the fabrics prepared using the treated fibers and yarns were tested for anti-microbial and flame retardancy properties. It observed that the microbial growth was more on the untreated fiber fabric compare to the treated ones. Also, the flame retardancy was good of all the fabrics.
- Hence, with the inherent properties these fibers can be utilized for sound absorbing materials having aesthetically appealing features as additional benefit. The interiors created using these fabrics will have minimal attack by microbes and to some extent they are flame resistance. Thus, as eco-friendly product can be utilized for interiors as per the need of sound absorption.
- Production and utilization of such stiffer and rough fibers has affecting the farmer’s standard of living, thus commercial eco-friendly enzymatic treatment and the portable tools for the same will be a great support to them.
- These fibers as well as the cottage or handloom industry will have a new pathway to work and explore with it.
- The increased utilization of natural fibers will have an impact on environment as well as the economy of the country.