An Experimental Study of Fabric Construction using Minor Fibers for Sound Resistant Materials

Synopsis of Proposed Ph.D. Thesis

by

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INTRODUCTION AND REVIEW OF LITERATURE:

Efficient work output needs effective communication at work. One out of the various barriers to communication is Physical Distractions caused by many reasons, amongst which 'poor acoustics' is also critical. Also, the prolonged hours spend within a premise where the presence of mind alongwith physical activities are important, needs suitable environment to concentrate for achieving appropriate outcome. As important is the need for effective communication and concentration at work, so also is the need for physiological and psychological health of human beings. Such health issues occur mostly due to unwanted sound known as noise. Hence, the need for effective acoustics is very critical.

There are many ways to improve the acoustics of any room, e.g. removing hard surfaces and things that vibrate from the room, absorb and diffuse sounds with furniture and décor, furnish walls with equally sized foam panels, use rolls and slabs of insulation as absorbers, etc.

This study pertains to the process of development of such textile fabrics incorporating natural minor fibers, fabric structures and finishes which will absorb, resist or scatter the sound too an extent and thereby improve the acoustics of any room, theatre, etc.

While it is important to have effective acoustics to reduce sound pollution, it is equally important to ensure the quality of the resources used for increased sound resistance, which should not be unsafe for the human beings, our environment and economy. Due to the certain advantages like availability, easy handling and manufacturing process, some of the manmade fibers namely, glass wool, polyurethane or polyester etc. are frequently used as sound absorbing materials. As the demand of these fibers has increased, the processing cost and use of petrochemicals has increased. Additionally, pollution has also increased as chemicals are used for processing of these fibers and are non-renewable. This, thus, acts as one of the major factor for global warming.

This establishes the need to look at alternative fibres for the said purpose, "Natural Minor Fibres" sounding most promising. Inspite of having abundant natural minor fibers, they are less utilized for many reasons like: lack of knowledge about these less explored resources, complex product manufacturing process, need of additional finishes and tedious care and handling methods, etc. These fibers have porous cell structure, low density, they are nonabrasive, cheaper and renewable, and hence can be utmost useful and effective for creating a healthy and aesthetic working environment. With the alarming need to retard global warming by all means, people must and are moving towards extensive experimentation with natural minor fibers for their effective utilization.

The absorption of sound results from the dissipation of sound energy to heat. Fridolin et al. described the mechanism of sound dissipation as: when sound enters porous materials, owing to sound pressure, air molecules oscillate in the interstices of the porous material with the frequency of the exciting sound wave. This oscillation results in frictional losses. A change in the flow direction of sound waves, together with expansion and contraction phenomenon of flow through irregular pores, results in a loss of momentum. Owing to exciting of sound, air molecules in the pores undergo periodic compression and relaxation. This results in change of temperature. Because of long time, large surface to volume ratios and high heat conductivity of fibers, heat exchange takes place isothermally at low frequencies. At the same time in the high frequency region compression takes place adiabatically. In the frequency region between these isothermal and adiabatic compression, the heat exchange results in loss of sound energy. This loss is high in fibrous materials if the sound propagates parallel to the plane of fibers and may account up to 40% sound attenuation. [K. A. Jayaraman, Acoustical Absorptive Properties of Nonwovens, Fiber Innovation Technology, Inc. - Saved in laptop e drive]

Porous materials used for noise control are generally categorized as fibrous medium or porous foam. The porous nature of absorptive materials renders them susceptible to contamination, moisture retention and deterioration due to physical abuse. To avoid these problems, facings may be attached to at least one side of the absorber. The addition of a facing to acoustical foam has the effect of increasing the lower frequency absorption at the expense of the higher frequencies.

The healthy environment with the use of natural minor fibers for sound resistant materials will reduce the pollution as well as increase the utilization of such unexplored resources. It will also provide the fresh working environment while also enhancing the economic and otherwise well being of the farmers.

Health issues associated with noise

Auditory damage, physiological and behavioral changes are the effects caused by unwanted sound and are majorly observed in the employee's working in the office or industry. This unwanted sound known as noise pollution causes annoyance and aggression, hypertension, high stress levels, tinnitus, hearing loss, sleep disturbances, and other harmful effects. Furthermore, stress and hypertension are the leading causes to health problems, whereas tinnitus can lead to forgetfulness, severe depression and at times panic attacks. High noise levels can contribute to cardiovascular effects and exposure to moderately high levels during a single eight hour period causes a statistical rise in blood pressure of five to ten points and an increase in stress.

Changes in the immune system and birth defects have been attributed to noise exposure, but evidence is limited. Beyond these effects, elevated noise levels can create stress, increase workplace accident rates, and stimulate aggression and other anti-social behaviors. The most significant causes are vehicle and aircraft noise, prolonged exposure to loud conversations or music, and industrial noise. (STATUS OF AMBIENT NOISE LEVEL IN INDIA)

Natural fibers for sound absorbing materials

According to a study by Parikh, Chen and Sun had experimented for floor covering system of automobiles. Natural fibers which are itself noise absorbing materials, are renewable and biodegradable were converted into nonwovens using needle punch technique. Also, blended with polypropylene and polyester and underpad coverings were made out of re-bonded polyurethane foam or soft cotton. All the natural fiber based floor coverings individually and with combination of underpad were evaluated by ASTM E-1050 in the frequency range of 100 to 3200Hz. As a result all the natural fiber based nonwovens gave good reduction coefficients and the most reduction was observed with kenaf and polyurethane pad at 3.2 KHz were – 1.0, compare to soft cotton underpad i.e 0.81. The floor covering system thickness ranged between 8 to 10 mm including the cotton underpad, but due to less density (998g/m2) little difference was observed in comparison to polyurethane underpad. Hence, floor covering system with natural fiber nonwovens and rebounded polyurethane provided better noise absorption as well as reduced overall sound level and can be utilized for quiet passenger compartments. (REDUCING AUTOMOTIVE INTERIOR NOISE WITH NATURAL FIBER NONWOVEN FLOOR COVERING SYSTEMS)

Nonwoven fabric using different bread of sheep wool and PET fibers were manufactured under the study conducted by Rey R., Uris A. et al with an aim to make efficient use of natural fibers having most of physical properties similar to PET fibers. Seven sheep wool samples having different compositions and densities were considered for the study. The blended fabrics having 80 per cent sheep wool and 20 per cent PET fiber were analysed for airflow resistance and sound absorption coefficient using different measurements – Impedance tube, reverberation chamber and empirical model. From the results it was demonstrated that sheep wool absorbed sound well at medium and high frequencies and showed good performances compare to mineral wool and recycled polyurethane foams. (Characterization of Sheep Wool as a Sustainable Material for Acoustic Applications, Romina del Rey, Antonia Uris, Jesus Alba and Pilar Candelas, www.mdpi.com/jounal/materials, doi: 10.3390,2017)

Jayamani E., and Hamdan S., studied Sound Absorption coefficients Natural Fibre Reinforced Composites. Two different set of sample preparation using different techniques of composite manufacturing was experimented. Each set consists of two different kenaf fiber lengths. The results showed unclear effect of fiber length on to the sound absorption, while the thermoplastic (Polypropylene) showed high sound absorption coefficient compared to the thermoset plastic (Urea-formaldehyde). By introducing the composite materials from natural fiber reinforced polymeric materials, the resulting materials shows good potential to be an environmentally friendly product. These composites are cheaper, light weight and environmentally superior compare to glass fiber and mineral based synthetic fiber. (Jayamani E., and Hamdan S., Sound absorption coefficients natural fiber reinforced composites, Advanced Materials Research Vol.701, 2013, pp 53-58)

Effect of different fabric construction/surface ornamentation on sound absorbing materials

Teli, Adivarekar and Pal, study Application of Textile and Polymeric Surfaces for Acoustic Properties. Five different materials Polyester, Viscose, Cotton, Thermocol and commercial samples were considered for the experiment and various surface textures were also created. The highest sound absorption observed in case of thermocol samples which was partially melted to create crest compare to plain weave. The absorption test was conducted at various distance ranging from 50 to 300 cm and at frequency from 250 – 8000Hz. Finally the commercial samples and theromocol sheet layers were created and reduction at 8000Hz was observed. Thus, nature of the fiber, thickness, numbers of layers, surface modification, and changes in morphology enhances the effect of sound absorption. (APPLICATION OF TEXTILE AND POLYMERIC SURFACES FOR ACOUSTIC PROPERTIES)

Three different paintings on canvas and cotton tapestry art work done by the students was analyzed by Martellotta F. and Castiglione M. for sound absorption coefficient. Cotton canvas of two different GSM was finished by oil painting and embroidery with silkscreen paintings as covering of polyester fiber panel of 5cm and 10cm thickness. As well as jute canvas was painting with special fabric colours were used as the cover of polyester fiber panel of 10cm thickness. All the three painted samples were investigated for sound absorption coefficient at various frequencies from 125Hz to 4k Hz. The large cotton tapestry of 9m2 was hung straight to a movable frame and tested in reverberation room varying in distance from 5cm to 100cm, to know the effect of distance on sound absorption. While, the pores of the canvas were blocked by the paintings and embroidery, but sound could pass through the embroidered sample thus able to absorb sound at low frequencies. The lightweight tapestry gave better absorption simply by changing the distance from the wall. Thus, a proper solution can create an effective sound absorption in the buildings. (Martellotta F. and Castiglione M., On the use of paintings and tapestries as sound absorbing materials, Forum Acusticum 2011 – Aalborg, Denmark, 27th June – 1st July 2011.)

Wood and polyester fiber blended composite fabrics were created and investigated by Peng L. et. al. owing to the fact that polyester fibers are widely used as it posses good sound absorbing characteristics. The chemical process in producing polyester fibers has high impact on environment and also they are costly. Thus, wood fiber as a partial substitute of polyester fiber for sound absorbing composite materials was experimented. The microstructure of the material was analyzed to know the mechanism of the sound absorption using scanning electronic microscopy, further tested with impedance tube method. Sound absorption coefficient increased with the decrease in the airflow. When there were cavities behind the composite material, the sound absorbing peak value moved to lower frequencies. Thus, as the thickness of the cavities increased, sound absorption coefficient increased at low frequency. (Mechanic and Acoustic Properties of the Sound Absorbing Material made from Natural Fiber and Polyester, Peng L., Song B., Wang J and Wang D., Advances in Materials Science and Engineering, Vol.25)

Soltani, P. and Mohammad, Z. conducted the research on Acoustic Performance of Woven Fabrics in Relation to Structural Parameters and Air Permeability. The sound absorption coefficient of plain weave fabric using polyester yarn was analyzed using Texsonicmeter maintaining airspace of 4cms at the back of the sample. Also air permeability at 100Pa was performed to evaluate the porous structure of the fabric. The results for lower sound absorption of the woven fabrics were compared with the nonwoven samples; it was observed that woven fabrics were less appropriate in terms of both technical and economically for certain applications. With additional airspace provided at the back of woven fabrics were more effective for sound absorption. Thus, six layered samples were analyzed for sound absorption including other parameters like pick density, fabric thickness and yarn twist. Hence it was observed that all the mentioned parameters for woven fabrics plays important role in absorption, low twist yarns and higher pick density absorbs sound well and it was confirmed with the lower air permeability of the woven fabrics. (Acoustic performance of the woven fabrics in relation to structural parameters and air permeability, Parham Soltani & Mohammad Zarrebini, Journal of The Textile Institute, Vol. 104, No.9, pp 1011-1016)

Mankodi H. and Mistry P. conducted a research on Woven Fabrics Combination for Acoustics of Building Interior had selected various fabrics like velvet, denim, jacquard, etc based on the characteristics and method of manufacturing the fabrics from the market. The GSM and thickness of woven and polyester needle punched nonwoven fabrics were analyzed. Also an experimental setup was created based on Steady State Method as per ASTM E336-71to evaluate the sound reduction of the fabrics. It was concluded that amongst the parameters like nature of the fabric, air permeability, thickness, GSM, distance and level of sound. Air permeability had a negative impact on the sound absorbing capacity. In case of cover fabric i.e woven fabrics the sound absorption properties and air permeability depends on the compactness and design of the fabric as well as surface finishes applied on it. The variation of distance was 5cm to 20cms from which 20cm distance gave the best results and one sided laminated fabric in combination with backing material showed sound reduction between 10 to 15dB. (Mankodi H. and Mistry P., Woven Fabrics Combination for Acoustics of Building Interior, International Journal of Industrial Engineering & Technology, Vol. 4, issue 2, April 2014, pp 19-26)

Acoustic textile A new era of noise control by Pal S., Pal S. and Jajpura L, covered various details such as noise control, method of noise control, sound absorptive materials, mechanism of sound absorption in fibrous materials, factors influencing sound absorption by nonwoven, woven and knitted fabrics and placement and application of sound absorptive materials. Majorly all materials were created using synthetic fibers and future needs were analysed by the researcher. Apart from the testing parameters and various applications of the products, a need for various fabrics manufacturing technique such as woven and knitted fabrics using different fibre type, size, shape and structure was felt. Also acoustic quality attention was felt for aesthetic look. Hence, an intensive research need was felt for economical fabric having aesthetics. (Acoustic textile A new era of noise control by Pal S.,Pal S. and Jajpura L., Asian Textile Journal, November 2015, pp 65-70.)

Instruments and parameters for sound absorbing materials

Cotton and synthetic blended needle punched fibrous materials were examined by Seddeq H. to know the factors influencing acoustic performance of sound absorptive materials. The sound absorption was measured according to the ASTM E1050 - two microphone impedance tube method wherein the sample was static and the results were compared with influence of specific air flow resistance, thickness, film and air gap. Higher airflow resistance always gives better sound absorption values but for airflow resistance higher than 1000 reduction in values was seen because of difficulty in the movements of sound waves through the materials. Tortuosity mainly affects the location of the quarter-wavelength peaks, while porosity and air flow height and the width of the peaks. Smaller diameter fiber and denser structure gave better absorption above the 2000Hz frequencies. Also the created air gap and layer of film on the fabric increased the sound absorption coefficient values at mid and higher frequencies. (Seddeq H., factors influencing acoustic performance of sound absorptive materials, Australian Journal of Basic and Applied Sciences, 2009)

Jayaram. K in his study Acoustical Absorptive Properties of Nonwovens explained about the absorptive materials, synthetic acoustic materials and its drawbacks and need to divert towards the natural fibrous materials. Also the effects of physical and secondary properties on the sound absorptive materials were discussed. The results emphasized upon the increase in Normal Absorption Coefficient (NAC) with the increase in the number of layers and thickness, Aluminum and PVC coating increases the absorption but at low and mid frequencies, as the fiber surface area increases and fiber size decreases the absorption increases, flame retardant finish and by creating airgap between the layers shows effect on the absorption values. Hence, further recommendation included experimentation with measurement of tortuosity and porosity, creating 100% natural fiber materials, creating multiple layer composite structures and utilization of same fiber size with different cross section to product such material using various manufacturing technology. (ACOUSTICAL ABSORPTIVE PROPERTIES OF NONWOVENS)

PURPOSE OF THE STUDY:

A good sound or a good composition of it has a pleasure giving effect and was well appreciated by the living beings in past. Earlier the life was quiet and simple so humans enjoyed the natural sounds then may it be birds voice, sound of waterfall, sound of a cart passed through the street. Even there were instruments made from the waste which created melodious sound. Sports or adventures activities were also possible by utilizing the natural resources. Other activities were also possible to fulfill easily and without harming the nature. While, the most important point is the needs were limited and people had an art of creating utility products from the objects offered by the nature, also were non-hazardous.

In present scenario, the case is reverse the sound which was giving pleasure has been converted into noise pollution especially in urban areas. In rural life sounds rarely becomes noise partly because they provide a sense of participation in the social life of the community and partly because they hardly ever reach intolerable levels. Urbanization brings about rapid increase of noise sources (industry, traffic, aircraft, radio, etc.), but also a change in social attitudes: in a village one knows everyone else, every sound from a known source conveys some meaningful information; but a town is full of strangers and unidentified noises, for which we have little tolerance. The low density of rural areas ensures a greater distance between noise source and listener, thus reducing the disturbance, while in high density towns there are more potential noise sources in each area – also the distances between sources and listeners are much less. (MANUAL OF TROPICALHOUSING AND BUILDING)

The adverse effects of noise causes various annoyance and aggression, hypertension, high stress levels, tinnitus, hearing loss, sleep disturbances, severe depression and at times panic attacks. High noise levels can contribute to cardiovascular effects and blood pressure. Immune system issues and birth defects have been also attributed, increase workplace accident rates, and stimulate other anti-social behaviors.

Noise pollution is a rising phenomenon. Studies indicate that, the overall loudness of environmental noise doubles after every 10 years in pace with our social, industrial and economic development. Some other studies have also reported a jump of 30 decibels in the past thirty years in our cities, which amount to a rise of one decibel per year. Apparently, no major or long term study has been conducted either to verify or refute this estimate. As of now the way things stand, it seems rather obvious that the perpetrators of this nuisance are least threatened or concerned to contain noise pollution, or even worst fail to recognize this as a serious threat to human community. This geometric progression-wise growth of noise could be mindboggling in view of the ever increasing pace of technological growth. (Noise Pollution: Legislative Aspects and Concerns).

The noise is captivated a bit by the air, somewhat by audience and yet textile materials could be used in form of furniture, furnishings, ceilings, floors, panels, etc. through which the absorption will be possible. Moreover, it will also be possible by using or creating porous materials, resonant panels, cavity resonates and composites. These products can be utilized as alongwith building materials or metals or as textile materials only and these products could be termed as eco-friendly products (BUILDING CONSTRUCTIONS).

Hence with increase in the awareness of environmental pollution, noise pollution has started getting attention. The proper surrounding for working becomes a legitimate right of the workers. Therefore, noise pollution could be controlled – by quieting the source of noise, by blocking the passage of noise from one place to another and by absorbing noise energy. Sound resistant or absorbing textile materials could be used at various places for this purpose. (NATURAL FIBERS NONWOVEN FOR AUTOMOTIVE ACOUSTICS).

The utilization of textile for sound resistant or absorption materials is majorly based on major on low production costs and durability. They are commonly used to soften the acoustic environment of a closed volume by reducing the amplitude of the reflected waves. These materials are resistive in nature, either fibrous or porous and also mostly used in conjunction with barriers of some type since their porous construction permits noise to pass through. Materials when used with backing acts as barrier which reduces the energy in a sound wave by converting the mechanical motion of the air particles into low grade heat. This action prevents a buildup of sound in enclosed spaces and reduces the strength of reflected noise. (Acoustic Textiles)

These products are manufactured using natural and synthetic resources and mostly non woven are majorly used for industrial or architectural purposes depending upon the end use and other factors like cost effectiveness, easy manufacturing process, maintenances, etc. With the growing awareness related to the terms like bio-degradable, recycled and eco-friendly needs, increase in the consumption of such products wherein the raw materials as well as manufacturing process both are non hazardous will boost.

Now a day's synthetic fiber such as mineral wool, glass fiber are commonly used for thermal and sound insulation, because of their good performance and low cost. These widely used raw materials can be harmful to human health if inhaled, since they can lay down in the lung alveoli, and can cause skin irritation. Moreover, they can be pulverized and are not resistant to water, oil and chemical agents and can make it non suitable for absorbing noise. (Natural fibrous materials for sound absorption applications)

An escalating alarm of eco-friendly surroundings is drawing attention towards the utilization of natural fibers replacing the synthetic fibers which will provide high acoustic and thermal performance, has low toxicity and its production process would also bring revolution in our environment. Each of these fibers has unique properties like stiffness, less cohesive, sticky, low density, thermal insulation, filament length, strength, low weight, etc. Moreover they are highly disposable, renewable, recyclable, biodegradable and cheaper than synthetic fibers. Amongst these fibers very few are used as it is for clothing and majorly they are blended with synthetic fibers for wider applications.

These fibers are cultivated in huge amount in our country and apart from country's economic growth; it plays a major role in the life of farmers. Amongst these fiber procuring plants, a huge proportion goes waste as they can be used for few products only. Ministry of textile is constantly making some kind of policy and formulating projects to give a new direction for such less utilized fibers.

Increasing the utilization of natural resources and skills of handloom sector will increase the national economy. Owing to the benefits of the minor fibers, a wider exploration is needed; also it will show growth our economy by providing the huge employment not only to skilled workers but also to the rural people and homemakers. Even an opportunity for the handloom sector can be created through a new direction i.e. towards sound resistant materials category of technical textiles.

The research aimed to explore minor fibers owing to those factors which would assist in absorbing the sound. Two different cellulosic minor fibers were considered and examined further for its physical properties, also application softening treatment to increase its spinnability and manufacture woven fabrics with various weave structure was carried out. The idea was to extract all the inherent properties of the selected fibers and make use of it as much as possible for sound resistant.

OBJECTIVES OF THE STUDY:

1. To study the chemical and physical properties of the ramie and sisal fibers.
2. To optimize the process of treating the fibers with enzymes for softening.
3. To prepare spun yarns of the untreated and treated fibers.
4. To develop hand woven fabrics with various weave structures and their effect on sound absorption.
5. To evaluate the effect of sound absorption properties of various unfinished and finished fabrics.
6. To assess the performance properties of the fabrics as per the end use requirements.

DELIMITATION OF THE STUDY:

1. The study was limited to utilize two cellulosic minor fibers i.e. Sisal and Ramie.
2. The study was limited for woven fabric structures as front layer using different weaves i.e. Plain weave, Twill weave, Double cloth.
3. The study was also limited for the resin finish using natural resin.
4. The study is yet limited to the utilization of the sound resistant fabrics for office interiors.

SCOPE OF THE STUDY:

Providing materials which can resist or absorb the sound, also fulfills the aesthetic needs and having wider range of application. The main motto is to provide eco friendly products, also to increase the utilization of cellulosic minor fibers and giving a new direction to the handloom sector.

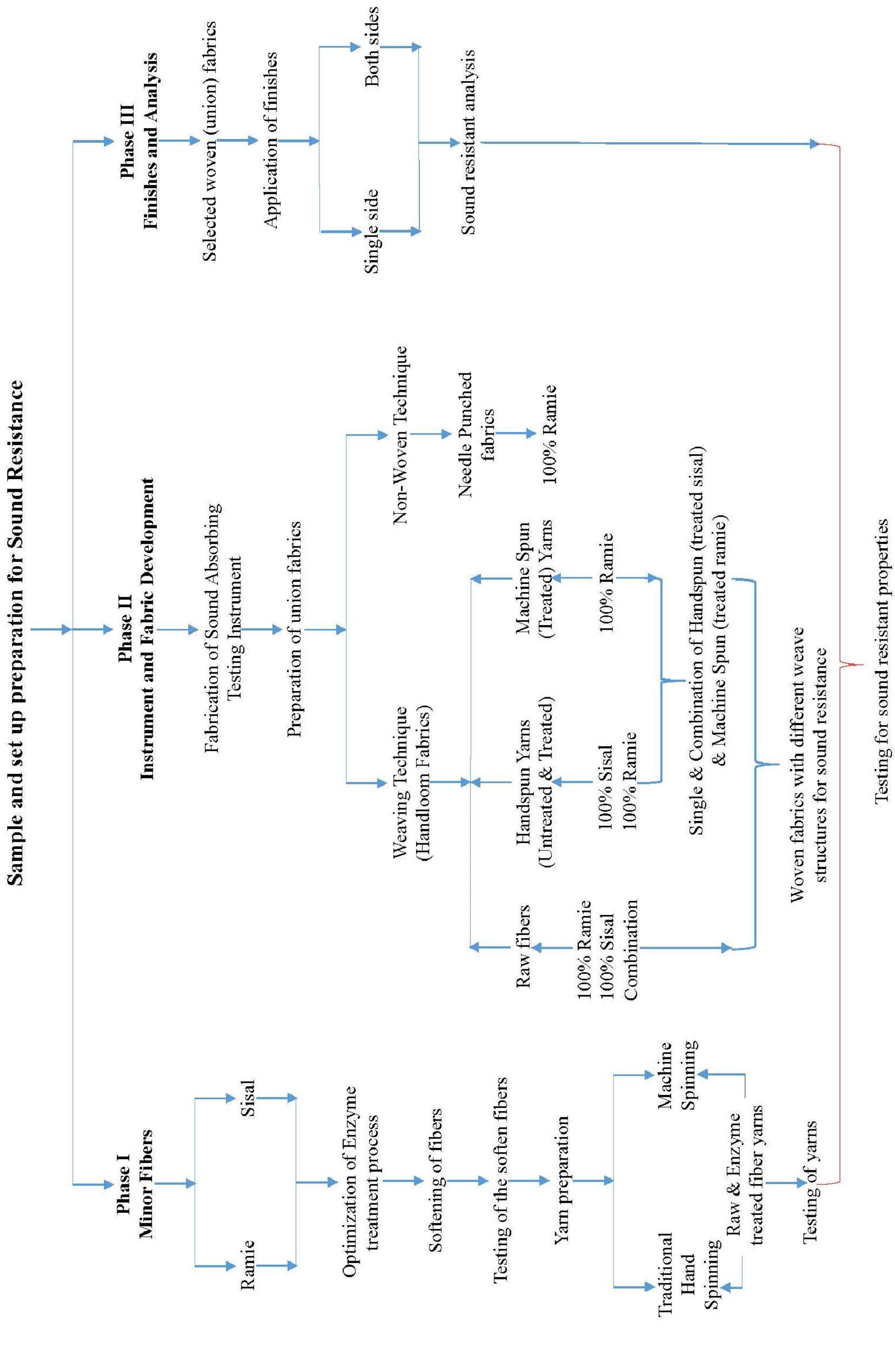
Less utilized cellulosic fibers like Ramie, Sisal, Pineapple, Coir, etc are cultivated, procured and goes waste too. These fibers are either less explored or are non-suitable for clothing purposes. With modifications in the fiber structure, making it softer and pliable, these fibers can be utilized individually or as blends. They are bio degradable, eco friendly, less hazardous and renewable hence utilization of these fibers will bring change in our environment, moreover by increase in the utilization increase in cultivation will bring environmental change as well as farmers living standard will also grow.

With constant exploration and experimentation of minor fibers for various end application will provide employment in different sectors. Right from cultivation to selling of minor fiber products needs experts. Gradually these fibers will be replaced by synthetic fibers in major products. Thereby, reduction in the consumption of petro chemicals for the preparation of synthetic fibers and positive impact on ecology will be observed.

Establishment of an entire handloom sector catering technical textiles using minor fibers could be planned. Most of the minor fibers are extracted manually, hand spinning technique is used for yarn preparation and handlooms are the best possible way to create fabrics with various weave structure. According to the fiber content and end application small tools or machines can also be fabricated in house for the ease and speedy progress. Also, set up of small cottage industries in the areas where such fibers are procured will motivate people around those areas and bring overall change in the standard of living of our country.

RESEARCH DESIGN AND METHODOLOGY:

Research design:



An experimental study is based on the utilization of the cellulosic minor fibers and woven fabrics for sound resistant materials.

The study was conducted to construct woven fabrics which can either resist or absorb the sound. Also to examine the raw and enzyme treated cellulosic minor fiber properties, its correlation with different weave structures and resin finished fabrics role as individual and in combinations to create an eco friendly sound resistant materials for various applications.

Experimental Procedure

The fabrics constructed in the study were created by cellulosic minor fibers and could be used as single or topmost layer, also in natural form or with application of natural resin finish to have eco friendly and aesthetic indoor products.

Methods and procedure followed in order to elicit the necessary data for objectives:

- **Experimentation of softening process for minor fibers**
  Optimization of enzyme treatment process for softening of selected cellulosic minor fibers was worked out for commercial viability and to increase the cohesiveness of the fibers hence to increase its spinnability.
- **Preliminary data of the materials used**
  Fiber cross section, fiber size, moisture, bundle strength, SEM, XRD, EDS, FTIR and Chemical Composition were analyzed to identify the fiber properties and to observe the effect of enzymes on it. As well as the results will be correlated with the analysis of the sound resistant materials to know it effectiveness.

- **Fabrication of tools for the softening treatment process and testing of sound resistant materials**
  Three different tools – Fiber combing tool and beating machine, also sound resistant material testing instrument based on ASTM E1050 were fabricated wherein recommendations of previous research articles for modifications were taken into consideration to have easy and in-house equipment for the research.
- **Development of yarn and woven fabrics**

➢ Preparation of the yarns

  According to the properties of the fibers, conversion process of fibers to yarn was identified and applied. Two different yarn conversion process i.e. Charkha spinning and machine spinning was carried out to prepare handspun and machine spun yarns.

- Testing of the selected yarns

  Yarn Count, yarn strength and TPI (Twist per Inch) of both the charkha and machine spun yarns were analyzed to know the yarn properties.
- Preparation of various fabrics

  Woven fabrics of various weave structures for the front or topmost layer using bundle of fibers as filament yarn for end to end weaving, handspun, machine spun and combination of both the yarns for continuous weaving was created by the artisan on the loom and by the research on table loom.

  Non woven fabrics of various GSM were created at NIRJAFT, for backing materials. Combination woven and non woven fabrics and number of layers would depend on the absorption or resistance of sound as well as on end application.
- Testing of all the woven and nonwoven fabrics

  GSM, EPI (Ends per Inch) & PPI (Picks per Inch), Thickness, Air permeability, and Parameters related to Sound Resistant (dB) of both fabrics individually and in combination were analyzed to propose its end use. Finally the selected combination will undergo resin finish and sound resistant analysis will also be done.

RESULTS AND INTERPRETATIONS:

The research was aimed to explore various weave structures using minor fibers for sound resistant materials. The two different cellulosic minor fibers i.e. Ramie (R) – bark fiber and Sisal (S) – leaf fiber were purposively selected for the study.

Phase I covers the following points:

Preliminary data of the fibers

Fiber length, diameter, shape and count of both the fibers were determined. Fiber shape and diameter were analyzed through SEM test where the diameter of ramie and sisal was 78.81µm and 178.7µm, and been liked shape with swelling on the walls were observed. The length of both the fibers would be 48 ms and 70cms and count 70's and 21's respectively. Hence from all the fiber analysis, the difference inner structure of the fiber was observed after the enzyme treatment, which will play an important role in the sound absorbing.

Optimization of enzyme treatment process

A pilot work was executed using previous recipes and combination of recipes on both the fibers, also method of treating these fibers with given recipes were explored too reduce the stiffness and increase the cohesiveness of the fibers. The fibers were individually scoured and enzyme treated with various permutation and combination i.e change in percent concentrations of each enzymes, temperature and treatment duration. Also combinations of enzymes onto the fibers were conducted. Finally the samples were analyzed to identify the effect of treatment onto the fibers in terms of spinnability and strength. Hence, two samples i.e. Sisal high concentrated combing beating combing (Shcbc) and Sisal high concentrated combing beating combing having 4hours treatment process ($Shcbc_4$) was taken further for both the fibers based on feel and bundle strength test.

Yet, another pilot work for commercializing the enzyme treatment process was experimented with finalized recipe on both the fibers using Infra Colour Machine, Colourtex, Surat. The yarn dyeing machine having 12 beakers of 500ml each was used for the experiment wherein the speed and temperature was maintained. Also a trial on Launder-O-Meter in the Department of Clothing and Textiles, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda, Vadodara was carried out wherein again speed and temperature was controlled. The main advantage was treating good quantity of fibers at a time controlling temperature and testing duration. Also the rotation speed was such that the force generated in the bath were able to keep the fibers wet thus penetration was good. Finally, Launder-O-Meter process was continued for bulk treatment as continuous rotation of the fibers and proper penetration of the solution was giving good results.

Application of beating machine and combining tool

In between and after the treatment fabricated beating machine was used for removal of pithy substances. It was also useful in breaking/slacken off the lignin substances present in the fibers. Thereby, it was easy to reduce the lignin content from the fibers after the softening process, which was essential to increase the cohesiveness which is needed for spinning. Combing tool was used after the scouring and enzyme treatment for the removal of pithy material and small length fibers were also removed due to entanglements. Straightening of the fibers for appropriate penetration of the enzymes and easy picking of fibers for spinning process were the additional benefits. And the analysis was observed based on amount of wastage including pithy substances, SEM and spinnability test.

Evaluation of softening treatment process on the fibers

Any treatment applied onto the fiber will affect the structure and strength of the fiber. Thus, the bundle strength of untreated and treated ramie fibers was 242 gms/tex and 153.2 gms/tex similarly, in untreated and treated sisal fibers 109.8 gms/tex and 102 gms/tex was observed due to the chemical and structural modification in the fibers. Further the results were supported by the XRD and FTIR observations.

The samples were further analyzed through EDS and SEM, wherein its clearly observed by EDS results that the high concentrated followed by combing beating combing process shows crystalline structure which will let the sound pass through. This fact was supported by the SEM results also.

Analysis of the yarns

A pilot work was conducted to check suitable spinning technique for ramie and sisal, as they both have different properties i.e. the former one being rough and sticky while the other one is stiff and less cohesive. Hence techniques like traditional spinning, charkha spinning, hand spinning and mechanical spinning were explored. Ramie showed good results in traditional and mechanical spinning (after treatment), while sisal showed good result with traditional and hand spinning (after treatment) technique.

Strength analysis was carried out using Bundle strength tester for all the yarns. Ramie Treated Rove spinning (RTR) showed 9.24gm/denier which is less compare to the untreated fiber but for the sound absorption purpose its structure will be effective hence was selected. While 26.14 gm/denier of Sisal Treated Hand spinning (STH) showed good results then the untreated fiber yarn, which could be due to the structure modification of fiber and number of fiber strands used for yarn making. Both the fibers will be used as weft yarns only.

Phase II covers the following points:

Assessment of fabricated Sound absorbing testing instrument

In the fabricated instrument, the source was kept constant and the sample was adjustable. Resistant at various distance as well as different frequency were studied. Also the sample holder was fabricated such that it could be adjustable in terms of thickness of the sample or number of layers. Hence with all these variables the testing was carried out to know an appropriate distance and frequency for the single and multiple layered samples. Finally three different samples were tested in another laboratory for the accuracy of the fabricated instrument.

Evaluation of woven fabrics

The first/upper most layer of sound resistant fabrics were created by using two different natural minor fibers – ramie and sisal. Twelve different handloom samples using individual minor fibers i.e. ramie and sisal and combination of both were produced based on five different categories – untreated/treatment, type of weft insertion and weave. Basic weaves were incorporated to understand and analyze the sound resistant properties of the samples. All the samples were initially tested using 1200Hz frequency and at the interval of 20cms distance from 0cm (next to source) till 80cms, to optimize the standard distance. Further, all these samples were again analyzed with different frequencies – 1000Hz, 1400Hz, 1800Hz and 2200Hz. Based on the findings of the above to test variables, finally 40cms distance and 1400Hz frequency were optimized for the further evaluation.

Evaluation of Non woven fabrics

Natural minor fibers have certain properties according to which the utilization was to be decided. So, needle punch nonwoven technique was decided based on characteristics of the fibers and with a motto of manufacturing eco friendly products. Both the fibers were analyzed for the needle punch nonwoven process. Ramie being more cohesive and softer compare to sisal was selected for nonwovens. Nonwovens were created as a backing material in order to provide support to the front layer and additionally it will also absorb the rest of the sound passed through the front layer. Based on which certain amount of thickness was needed, hence nonwovens of 620, 814 and 919 GSM was prepared. A trial was conducted to create nonwoven of 1000 GSM, but breaking of needles and uneven surface was the result. All the three samples were also tested for Sound resistant properties and finally nonwoven of 919 GSM was finalized.

Comparison of woven fabrics for sound resistant materials

The comparison was based on the sound resistant properties – thickness, air permeability and sound resistant coefficient of the woven samples. All these properties were correlated and also the characteristics of the fiber and yarn were considered during analysis. The combination fabric samples showed less resistant compare to the single fiber fabric sample. Further it was observed that ramie fiber fabric samples had higher per cent coefficient. Hence the ramie was able to resist sound more compare to sisal, which could be because of the fiber, yarn and weave structure. The sample manufactured using ramie gave smooth and even structure and aesthetical appearance.

Analyses of layers of fabrics for sound resistant materials

Three different set of layered sound resistant materials with different combinations were prepared. The first set consists of single layer woven sample and nonwoven sample having an airgap in between. Second set was prepared with a single layer of woven sample followed by an airgap, three layers of nonwoven samples and a ply. Third set of combination was single layer of woven sample, three layers of nonwoven sample having airgaps in between all the samples and ply as the last layer. The first set showed 0.29 to 0.68 per cent noise resistant coefficient, but with the increase of nonwoven layers, airgaps and having a ply the noise resistant coefficient observed were between 0.97 to 0.99 which near to coefficient 1.0 i.e. 100 per cent resistance. Hence based on the application and frequency, the combinations can be prepared to achieve the required resistance. To have more effective results the textile and architecture designer should work together which will provide assistance to meet other parameters.

CONCLUSION:

Minor fibers, majorly utilized by the artisans residing nearby the cultivating areas for cord making and in handicraft products are constantly seeking trajectory towards the commercial process and application. With the ease, accurate and constant bulk production rate at comparative low cost manmade fibers have achieved a position in the textile market. Nowadays, with the need and awareness the eco friendly products at each level is in demand to control the pollution at every stage – manufacturing to application as well as increase the country's overall standard of living.

The study was emphasized on the properties of the ramie and sisal fibers, softening treatment process of the fibers to increase its spinnability and a move towards commercializing the process, creating woven fabrics with various weave structure for sound resistant application and evaluating the properties of these fabrics for sound resistance with and without the application of finishes.

Consequence of the study indicates that both the fibers having particular properties which were analyzed for sound resistance. Fiber size or diameter is one of the main parameter which was evaluated through SEM - the longitudinal and cross section observation clearly shows that each fiber had multiple sub-fibers. The pithy material, lumen and walls clearly seen in the untreated fibers were removed and modified after the treatment creating more porous structure in the fiber. While through FTIR and XRD, less changes in the bonds and crystalline structure was observed in the fibers after the treatment which might be assisting the absorption properties of the materials. Bundle strength test results also shows that diameter has reduced which will increase the fiber content and thereby high specific surface area in the material will be seen, the strength has reduced in sisal which will affect other properties – hairiness, handling of the fiber while spinning, softness and its spinnability.

Pliability and cohesiveness was increased with the softening treatment given to both the fibers. Traditional hand spinning technique was initially carried out for the untreated fibers and after the treatment for sisal hand spinning was only possible owing to its stiffness thickness compare to ramie, while machine spinning technique was used for ramie. Both the yarns were having S twist, but the ramie rove yarn structure was loose thus sound was able to penetrate more compare to sisal yarn. Variation in the yarn count was observed in the untreated and treated yarns which might be because of the morphological changes and number of fibers used for spinning. The treatment has not only increased the feel and spinnability of the fiber but also increased the consumption during the fiber to yarn process with reduction in the wastage.

Twelve woven fabrics using various weave structure – Plain weave, Broken Twill weave and Double cloth weave was evaluated for GSM, thickness and air permeability as the main parameters of sound resistant materials. Fabric using fiber as weft insertion and using treated yarns were further divided into three different set of fabrics i.e. using only ramie, only sisal and combination of both were created to understand the effect of weave on sound resistance. High GSM and thickness with low air permeability was observed in the ramie fabrics compare to sisal and combination fabrics. While comparing between the fiber and yarn as weft insertion, fabric with rove yarn showed better results followed by fiber combination fabrics and handspun sisal fabrics. Ramie treated plain weave and broken twill weave fabrics showed the best sound resistance performance owing to the results of air permeability and thickness, also the rove yarn structure as well as the hairiness on the surface of the fabric might have assisted in absorbing and scattering of the sound.

Further the woven samples were tested for sound reduction coefficient after optimizing the standard distance and frequency, also creating the air gap in between the woven and nonwoven samples and having three layered nonwoven samples as backing materials. Thus with all the variables and testing parameters reduction coefficient near to 1 was achieved in most of the multi layered samples. The natural minor fiber woven fabric seems to be functionally and aesthetically more appealing compare to nonwovens.

The eco friendly and renewable raw material used, weaves creating structural effect, change in combination based on application and sound source, complete handicraft product creating livelihood for the weavers and farmers with the increases of its utilization, thereby minor fibers entering into woven technical textiles will have impact not only on our environment but also on our economy.

The outcome of the study has visualized a future possibility of channelizing a commercial minor fiber to fabric set up for rural areas, especially those which are nearby the minor fiber research centers with the assistance in fabricating small equipments for the process. This will increase the utilization of minor fiber, also employment generation in rural areas, further more exploration and application of such products altogether will have a great impact on our environment and economy.

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Endorsement from the Supervisor:

Ms. Arpita Desai has researched on "**An Experimental Study of fabric construction using Minor Fibers for Sound Resistant Materials**" vide Registration No. FoFCSC/2/152, (Dated: September 20th, 2013). She conducted extensive work which have been substantiated its originality. She has presented her progress of work in seminars well attended by teachers and students of the department. She has personally presented two papers at International level, one was on "*Innovation in minor fibers towards technical textiles for women empowerment*" in 2nd International conference organized by Birla Vishvakarma Mahavidyalaya (Engineering College)(An Autonomous Institution), Managed by Charutar Vidya Mandal, Vallabh Vidyanagar, Anand, Gujarat, India from 28th to 30th June, 2018 and second on *"Conjoining Minor Fibres with Khadi and Handloom for Technical Textiles"* in International Conference on Empowering Khadi And Handlooms Through Design Intervention, organized by Consortium of Green Fashion (Fourth Edition) held from 30th September &1st October 2016. Also presented a poster at International level on "" in International Conference on Technical Textiles and Nonwovens (ICTN), organized by IIT Delhi, held from 6th to 8th November 2014. She has also presented a paper at National level, on "*Traditional Process for Technical Textile"* in National seminar on Make in India - A Paradigm Roadmap for Growth of India, jointly organized by M. K. Amin Arts & Science College and College of Commerce, Padra held on 4th March 2017. An abstract has been published in the proceedings of 14th Asian Textile Conference on "Disruptive Innovations for Textiles and the Supply Chain" held in Hong Kong from 27th – 30th June 2017 and a paper has also been sent for publication in the National Journal & two more papers are prepared for publications in due course of time.

Synopsis is approved by

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