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Summary and Conclusion

Nature has abundance of natural fibres that are also renewable. Natural fibres are very essential to meet the environmental challenges that are growing every day in the field of technical textiles. Due to growing environmental awareness, public interest, new environmental rules, and unsustainable petroleum consumption, eco-friendly materials are now being taken into account. Synthetic fibers destroy the environment due to their non-biodegradable and polluting nature, which leads to the utilization of natural fibre-based materials. In the last few years, natural resources have been considered as alternatives to synthetic fibres in several engineering applications. Natural fibres are being utilized as reinforcements along with the polymer matrix for composite manufacturing because of their distinctive advantages over synthetic materials with essential properties. A biocomposite is a material made of resin as the matrix and reinforcement from natural fibres. Currently, composites have entered nearly all major industrial, commercial, and domestic sectors. Acoustic materials assist in preventing undesirable sounds from affecting the human ear, and these have major potential in build tech, mobile tech, and home tech applications. Nonwoven structures have good acoustic and thermal properties, and when converted into composite structures, these can be easily utilized for applications in buildings. With stronger stiffness and torsion properties than conventional materials like steel and aluminum, composite materials have tensile strengths that are four to six times greater. Nowadays, Biopolymer hybrid composites are employed in a variety of applications. Considering these facts, the study entitled **"Modification and Fabrication of Selected Natural Fibres into Thermal Bonded Structures for Hybrid Polymer Composites"** has been undertaken as an attempt to make materials that would be suitable for application as building components in the future. This research work focused on the manufacture of biomaterial reinforced composite structures after fiber surface modification and blending to prepare hybrid materials. The objectives of the study are expressed below;

- To understand the prevailing problems and the need for natural fibre made building materials over the existing ones

- To select natural fibres based on local availability
- To choose appropriate surface modification technique to enhance natural fibre functionality for the creation of compatible composite materials
- To select appropriate treatment method for fibre surface modification
- To fabricate and evaluate nonwoven structures utilizing surface modified natural fibre blends
- To develop natural fibre reinforced hybrid composite materials utilizing the prepared nonwoven structures
- To characterize the composite structures
- To select the nonwoven material reinforced polymer composite structures
- To evaluate the selected composite material for performing specific functional properties
- To obtain the feedback for the composite slabs to be utilized for build tech

The study was carried out in five phases, which are clearly explained as follows;

In **Phase I** the survey was conducted to obtain information regarding the existing use and potentiality of natural fibres in civil applications. Using purposeful sampling technique and with questionnaire as the tool, the survey was conducted among the civil engineers, architects, builders, and building contractors. The questionnaire comprised of questions based on demographic aspects, employment details, materials preferred for construction, type of materials used, factors considered for material selection, usage of natural fibres in the construction field, awareness about the use of natural fibres, existing applications of natural fibres, fabricated structures used and suitability, local availability of construction materials, other fibres used in construction field, ecofriendly products, reusable materials, satisfaction about existing materials challenges faced in the civil field, and understanding the potentiality of natural fibres in various civil applications. During Phase I, considering the facts from the literature survey and for the reasons of easy local availability, the three plant sources, namely *Abutilon indicum, Agave americana* and *Areca Catechu* were selected with the idea of combining their positive attributes as these are different parts of the stalk, leaf, and fruit from the sources.

In **Phase II**, the plants selected for the study were authenticated before procurement. The fibres extracted by different means, namely retting, decortication, and mechanical processing, were procured from Sudha Industries, Salem District, Tamil Nadu. The procured fibres were cleaned and treated with chemicals (9 samples) by various processes, namely acetylation, alkalization, and benzoylation, and enzymes (9 samples), namely cellulase and pectinase. The untreated (3 samples) and treated fibres (9+9 samples) were evaluated for various properties by analyzing them subjectively and objectively. Visual evaluation was done for subjective assessment, and for objective assessment, the tests namely Spectrophotometric Analysis, Assessment of Chemical Constituents, Moisture Content, Regain, Water Absorption and Density, Tensile Strength and Elongation, Thermogravimetric Analysis (TGA), Scanning Electron Microscope (SEM) and Fourier Transform Infrared Spectroscopy (FTIR) were carried out. The results obtained were compared and analyzed for selecting the best fibre treatment and from Phase II, the treatments that gave satisfactory results on fibres (9 samples) were selected for further study.

In Phase III, nonwoven fabrication of the selected fibres was carried out by mechanical and thermal bonding techniques. These natural fibres were blended in stipulated proportions along with the low melt Polyethylene Terephthalate (PET) fibres. The needle punching technique was the method used for converting the selected fibres directly into nonwoven fabric which were then thermally bonded using Teflon sheets. Thus, thermal bonded fabric samples (Samples 12), namely UNAS, CHAS, ENAS, UNAAB, CHAAB, ENAAB, UNABS, CHABS, ENABS, UNAABS, CHAABS, and ENAABS were produced for the study. All the nonwoven samples were evaluated for essential properties according to standards after preconditioning as per ASTMD 1776. These were analysed for Thickness, Weight, Tensile Strength, Elongation, Abrasion Resistance, Moisture Regain, Air Permeability, Water Absorption properties by Sinking, Wicking and Spray Tests, Thermal Conductivity, Thermogravimetric Analysis, Scanning Electron Microscopic appearance (SEM), and Acoustic Test Sound Absorption Coefficient (SAC). Also, to analyze the impact of the thickness of the nonwoven structure on acoustic properties, corelation was done. All other tests were statistically analyzed and compared to select the best fabric (Sample 4) for further study.

During **Phase IV** of the research, the fabrication of composites was done using the selected nonwoven fabrics as reinforcement and Epoxy resin as matrix. The moulding technique was used for fabrication. Also, an unreinforced, neat epoxy specimen was prepared for comparison (5 samples) All the specimens were machined as per standards for characterization. The tests carried out for composites for mechanical characterization were tensile strength, elongation, flexural strength, compressive strength, hardness, and Impact strength as per standard test methods. The spectrophotometric analysis was carried out to assess the brightness of the composite, which would aid in its aesthetic application. The thermal behavior of the composite was analyzed by the Thermogravimetric Analysis (TGA), and the density of composites and volume fraction of voids were analyzed to understand the presence of voids in the specimen. The liquid absorbency test was carried out in different liquid environments, Scanning Electron Microscopic Appearance was observed at different magnifications to analyze the morphology of the composite. Fourier Transform Infrared Spectroscopic Analysis was done to know the presence of chemical functional groups in the composite specimens. The biodegradation study was carried out by soil burial tests for an established time period, after which weight loss, degradability, and visual evaluation were done. These samples were compared and analyzed statistically and with a radar diagram for mechanical properties. In phase IV, the composites that gave satisfactory results (2 samples reinforced and 1 unreinforced) were subjected to further functional analyses.

In **Phase V**, the evaluation was carried out for the selected composite structures (2 samples reinforced and 1 unreinforced). The special tests carried out were the acoustic tests for assessing the Sound Transmission Loss (STL) and Sound Absorption coefficient (SAC). As for the acoustic property, both the Composite Specimen and the respective reinforcements (nonwoven fabric) were compared for the purpose of analyzing the betterment of the composite specimen. Further, the Noise Reduction Coefficient was also calculated to assess the absorbency of the prepared composites. Roughness, drill test, and flammability tests were conducted for the selected composites, which were compared with a neat epoxy sample. The cost of the prepared composite material was also estimated. The feedback was obtained for the prepared composites to obtain information regarding various aspects, namely general appearance, idea about utilization of underutilized fibres, suitability for building material, future application, cost effectiveness, market potentiality in the future, environment friendliness, reason for preference of eco-friendly materials, and willingness to recommend the prepared slabs to builders. The results obtained are diagrammatically represented with appropriate statistical analysis.

Findings of the Study

Phase I Survey and Fibre Selection

Out of the 50 respondents surveyed, 84 per cent of them were male and 16 per cent of them were female, of whom some were working in private companies and others were running their own firms. From the survey, it was understood that all types of building work were undertaken by them. The material very often used for roofing, wall covering, and water proofing were wood and stones, white cement, wood, respectively. The predominant factors considered by them while selecting building materials were anti pest attacks, appearance, and durability. Acrylic fibres were maximum utilized, and the fabricated structures used for buildings were nonwovens, composite materials for interior decoration. They were aware of the use of natural fibres and also expressed the lack of availability of these in the construction field. Their preference for eco-friendly products and reusable materials for building was also high. Thus, from the survey, it was understood that green building concepts could be initiated as there was a problem of waste disposal. Hence, there may be high potential for eco-friendly building materials.

Phase II Selection of Treated Fibres

- **As for the visual evaluation,** a gain in brightness was observed in samples AC2 and AE3 on chemical and enzyme treatments, respectively, which was higher in the enzyme treated fibre sample. The *Agave americana* and *Areca catechu* fibres also showed the highest brightness on combined enzymatic treatments with pectinase and cellulase. The general appearance of Agave americana fibres on chemical and enzyme treatments was good. The luster showed improvement in the chemical treated sample AC1 and in the enzyme treated samples, namely AE3 and BE3. Texture improved to soft in chemical treated samples, namely AC1 and BC1 and enzyme treated samples namely AE3 and BE3. The general appearance improved in chemical treated samples, namely AC1 and BC2, and in enzyme treated samples namely AE2 and BE1.

- In the **spectrophotometric analysis,** sample AC1 exhibited the maximum yellowness index and minimum brightness index. Among the chemical and enzyme treated *Abutilon indicum* fibre samples, the brightness was the highest in samples AC2 and AE3 respectively. The fibre treated with a combination of the enzymes' pectinase and cellulase exhibited the highest brightness among all the treated fibre samples. The chemical treated samples increased in yellowness index, whereas the brightness index was higher on enzyme treatments than chemical treatments, with the highest brightness in sample BE3 in *Agave americana.* The *Abutilon indicum* for brightness index was the highest in the sample.
- The brightness index was the highest in samples CC2 and CE1 in chemical and enzyme treated samples, respectively, when compared with the original fibre samples of *Areca catechu.*
- The **chemical constituents,** namely cellulose, lignin, wax, and ash, in all three selected fibres underwent modification by both chemical and enzyme treatments. In *Abutilon indicum* fibres, the cellulose content decreased in the sample AC2 to the maximum, the lignin content increased in samples AC1 and AC3, the wax content increased in samples AC3 and AC1 and the ash content increased in samples AC2 and AC3. A slight increase in the chemical constituents was also observed in the samples AC2 for lignin, wax in sample AC2 and ash in sample AC1 (41.36). On enzyme treatment of the fibers, there was a decrease in cellulose content in samples AE1 (9.86 per cent) and AE3, lignin in sample AE2, ash in sample AE1, AE2 and AE3. A slight increase in lignin content was exhibited in samples AE1 and AE3 and in wax content (AE1, AE2 and AE3).
- In *A. americana,* the **cellulose content** decreased on chemical treatments (BC2 and BC3) but increased on enzyme treatments in all the three samples (BE1, BE2 and BE3). This increase may assist in improving the strength and stiffness of the composites by reinforcing such fibres. This factor was considered in fibre selection for further study.
- In the *Areca catechu* fibre treated with chemical and enzyme treatments, cellulose content decreased in samples CC1 and CE2, lignin content decreased to the maximum in samples CC2 and CE2, and wax content was reduced in both the treated samples CC3 and CE1. A drastic reduction of ash content was seen in both

treatments in samples CC2 and CE2. All the chemically treated samples showed an increase in moisture regain, which was the highest in sample BC2 (3.73 per cent) and among the enzyme treated samples, a decrease in moisture regain was observed in sample BE1 (0.40 per cent). Water absorption was noted to be 234.22 per cent in the sample CUN. Water absorption reduced in all the chemically treated samples of which it was the maximum in the sample CC3 (143.64 per cent) and in sample CE3 (222.59 per cent) on enzyme treatment.

- **Density, Moisture Content, Moisture Regain** The chemical and enzymatic treatments have altered the moisture absorption properties of the fibres, which would serve the purpose of composite preparation. The density reduced in the fibre samples due to the removal of chemical constituents.
- **The Tensile Strength and Elongation** of the *Abutilon indicum Fibres* improved in the samples AC1 and AE2 alkali and pectinase treatments, which would help in composite making. The *Agave americana* fibres improved in breaking strength with benzoylation. The **tensile strength** of the fibres, showed an improvement in *Abutilon indicum Fibres* in samples AC1 and AE2, which were chemical treated and enzymes treated samples respectively. The improved strength in *Abutilon indicum* fibers due to alkali and pectinase treatments would help in composite making. The strength of *Agave americana* (BC3) fibres improved in breaking strength and elongation on benzoylation.
- The **Thermogravimetric analysis** (**TGA)** of chemical treated fibre samples AC1 and BC1 showed the maximum thermal stability at 450^{o}C and 380^{o}C with least weight loss among the other samples. The fibre sample BE1 showed the highest thermal stability with a minimum weight loss of 86.5 per cent even at a very high temperature of 580^{o}. The treatments have improved the thermal stability of the *Agave americana* fibres. The weight loss was minimum at high temperatures in sample CC1 depicting the thermal stability of the alkali treated *Areca catechu fibres* was good would assist in composite making when used as reinforcement**.**
- The **fibre morphology** observed in the Scanning Electron Microscopic **(SEM)** appearance showed that the fibre surface turned rougher with the presence of ridges and breaks, especially in the sample *Abutilon indicum* fibres treated with pectinase (AE2) and alkali (AC1). The chemical treatment showed a high degree of roughness

in *Agave americana* fibre which underwent benzoylation which would help in resin uptake during composite preparation. The treated samples of *Areca catechu fibres* (CC1) and (CE2) turned rougher than the untreated samples. This induced surface roughness would assist in matrix absorption of the fibres leading to better compatibility enhancing the mechanical properties.

- The Fourier Transform Infrared Spectroscopy **(FTIR)** also expressed the modification in the functional groups present in the treated fibre samples over the untreated fibre samples.

Phase III Nonwoven Fabrication, Evaluation, and Selection

- **The thickness** of the treated nonwoven fabric samples ENAS, ENAAB, CHABS, and CHAABS showed the highest thickness with their respective comparisons, and among all these samples, the sample ENAS (**8.09 mm)** exhibited the maximum thickness. The statistical analysis also showed a significant difference at the 1% level.
- Among the nonwoven structures prepared, the highest **weight** was expressed in the samples ENAS, ENAAB, CHABS and CHAABS when compared within their respective sets. The statistical analysis also showed a significant difference at the 1% level. Among these samples, the highest weight was exhibited by the sample ENAS (**922 GSM)**
- The highest **bulk density** was observed in the sample ENAAB (854 **g/cc**) followed by the samples UNABS, UNAS and CHAABS. The weight and thickness of the samples ENAAB and CHAABS were the highest with their respective sets of comparisons, which was also reflected in the bulk density.
- In machine direction, the highest **tensile strength** was exhibited in the samples CHAS, CHAAB, ENABS and CHAABS. In cross direction, the samples CHAS, ENAAB, ENABS and UNAABS showed the best tensile strength results with their respective sets of comparison. Among all these samples, CHAS and ENABS exhibited the highest strength in chemical and enzyme treated samples. The statistical analysis also showed a significant difference at 1% level. The elongation at break was the highest in samples CHAS, ENAAB, CHABS, and UNAABS in machine direction and in samples CHAS, CHAAB, CHABS, and CHAABS in cross direction. The time taken for a break in machine direction was the highest in sample

CHAS and in sample cross direction. The time taken for the break of the sample also implies the strength of the sample as exhibited in ENAABS. The high strength of the nonwoven structures would result in better mechanical properties when utilized for composite making. This was one of the aspects considered in the selection of the samples for further study.

- As for the **abrasion resistance** of the samples the samples ENAS, ENAAB, CHABS and ENAABS showed the best results for abrasion resistance when compared with their respective sets of samples.
- **Moisture Regain** in the samples ENAS, ENAAB, UNABS and CHABS and UNAABS showed the least regain among their respective sets of samples, and among all these samples, it was the least in both the samples UNABS and CHABS. This may be due to the fibre present in the nonwoven material and the compactness of the interlocked fibres also which would also aid in composite fabrication.
- **The air permeability** was the lowest in the sample UNAABS followed by the samples CHABS and the highest in two samples CHAAB and ENABS. It was noted to have a significant difference at the 1 % level in statistical analysis as well.
- Among the **absorbency tests** carried out for the nonwoven samples in water absorption test, least was exhibited in the sample CHAABS followed by the ENABS; As for the sinking of the nonwoven samples, the chemically treated samples CHAS, CHAAB, CHABS and CHAABS took the minimum sinking time, of which the least was shown by the sample CHAAB, which depicted the highest absorbency. The highest time taken was by sample ENAABS depicting poor absorbency; As far as Wicking is concerned, the chemically treated fibre utilised nonwoven samples showed the highest capillary movement of water in the samples depicting more absorbency. It was noted to be the highest in the samples CHAS, CHAAB, CHABS and CHAABS with their respective comparisons. The least height of wicking was exhibited by sample UNAS. The tendency of good absorbency of the nonwoven fabric samples might assist in the uptake of resin while preparing composites. The **spray test** showed the highest absorbency on spraying, with only fifty ratings in few samples among all the nonwoven fabric samples. The absorbency results that have been observed were noted to be poor in all the nonwoven structures.

- In the analysis made for the **thermal behavior** of the fibre samples, the **thermal conductivity** of the nonwoven samples ENAS, UNAAB, CHABS, and UNAABS had the lowest thermal conductivity among each set of comparisons. The thermogravimetric analysis **(TGA)** exhibited the minimum weight loss at high temperature in samples CHAS, CHAAB, CHABS, and CHAABS among the respective sets of comparison. The sample CHAABS showed the least weight loss among all the samples which may help in maintaining the thermal stability even after resin coating.
- The **Scanning Electron Microscopic Appearance (SEM)** exhibited good interlocking of the fibres which may be due to the softening of the fibre by chemical and enzyme treatments that has aided in the fabric formation during needle punching and thermal bonding processes.
- As for the **acoustics properties,** the sample ENAS showed the highest SAC values at nine different frequency points and the sample CHAS showed the highest average SAC value in Set I. Among the set II samples, the sample CHAAB showed the best performance at six frequency points, whereas the average SAC value of the sample ENAAB was the highest with 0.3348α and could be called as sound absorption material.
- In the III Set, among the treated fibre blended nonwoven structures, the denser sample CHABS performed better in SAC at six frequency points and the thickest sample ENABS showed the highest SAC values at nine different frequency points. The average SAC values were the highest in the sample CHABS (0.3091). Among the III Set, the highest average SAC values were noted in sample UNAABS (0.27976), followed by sample CHAABS (0.26667). The density of these three samples is noted to be in the order CHAABS > UNAABS> ENAABS, and so the densest nonwoven sample, ENAABS, exhibited the least average SAC value among all the samples. The sample CHAABS showed better SAC values than the sample ENAABS and hence considered for further study. From the statistical analysis by **correlation coefficient**, it was understood that there is an influence of thickness on the acoustic properties in the nonwoven structures at frequencies of 1200, 1800, 3000, 3200, and 3400 Hz.

- All the nonwoven materials exhibit the **average α** values above 0.20 and hence all the prepared structures could serve as soft acoustic material in absorbing sound. In the samples CHAS, ENAAB and CHABS absorption is greater than 0.30 which may be more suitable as a sound absorbing material.

Phase IV Composite Preparation, Evaluation, and Selection

- The **Tensile Strength and Elongation of** reinforced samples exhibited better strength than the neat epoxy sample, and among the reinforced structures, the sample CABSE showed the best result, for the tensile strength. It is notable that the elongation of all the reinforced samples decreased compared to the neat epoxy sample.
- **As for the Flexural strength,** all the fabric reinforced samples increased, which was the highest in sample CASE. It is notable that better results have been achieved than in earlier study. In sample CASE (86.61 MPa) which is the combination of *Areca catechu* and *Agave americana* fibres blended into a nonwoven structure, which may be due to the hybridization. All the fabric reinforced samples exhibited greater **Compressive Strength** than the non-reinforced sample, of which it was the highest in sample CAABE.
- **As far as the Shore D Hardness is concerned,** there was a gain in hardness in all the fabric reinforced samples, of which the highest was in sample EAABSE over the neat epoxy sample.
- The sample EAABSE showed the best result in **impact strength**, among all the fabric reinforced samples, and all the reinforced samples gained impact strength over the sample EP.
- The sample CABSE exhibited the highest whiteness and brightness indices, whereas the sample CAABE showed the least brightness index in the **Spectro Photometric Analysis**
- As for the **Thermogravimetric Analysis,** all the nonwoven fabric reinforced composite structures exhibited higher degradation than the neat epoxy sample EP and among the fabric reinforced structures, the least degradation was observed in sample CABSE indicating higher thermal stability in the sample.

- The **density** increased with fabric reinforcement and was the highest in the sample CASE among all the samples.
- All the composites exhibited the **volume fraction of voids,** which was found to be reasonably small < 1.5 per cent in par with earlier studies.
- **In the liquid absorbency test, a**mong all the four samples, the sample CASE showed quick saturation in weight gain in the liquids, namely dionized water (after four days of immersion), ionized water (after three days of immersion) and kerosene (after three days of immersion) depicting the minimum absorbency rate on exposure to various liquid environments. The samples attained saturation quickly, and absorption of liquid was also minimum which may be due to the minimum presence of voids.
- **FESEM** of the composites shows (CASE) that the reinforced material has been well coated by the epoxy resin. Perfect compatibility between the matrix and reinforcement is observed. Cracks and gaps were also observed (EAABSE).
- **FTIR** showed the presence of carboxylic acid, alcoholic, and fluoride functional groups in the fabric reinforced composite samples, which were not present in the neat epoxy sample.
- In the **Soil Burial Test** all the fabric reinforced samples exhibited **weight loss,** and it was the highest in sample CAABE which may be due to the attack of microbes on the sample. The **degradation** was the highest in the CAABE sample due to the fact that *Areca catechu* fibre is more favorable to microbes. The **visual evaluation** showed that the longer duration of soil burial had made the samples duller and it was the highest after longest period of burial. All the fabric reinforced samples gradually turned rough with an increase in the period of soil burial and of these, the sample CAABE turned very rough. The general appearance reduced in all the samples after soil burial and the effect was maximum in the sample CAABE after a longer period of soil burial.
- **Radar** All the mechanical properties of the sample reinforced with the nonwoven had improved when compared with the non-reinforced samples, and average results in the properties were noted in the samples CASE and CABSE. Hence, these two-hybrid samples (CASE and CABSE) along with a neat epoxy sample were considered for further analysis.

Phase V Further Study of Selected Composites

- **The roughness of** both the fabric reinforced samples showed better results than the unreinforced neat epoxy sample, whose roughness was greater in sample CABSE. This roughness property may aid in good acoustic properties.
- **The drill behavior of selected composites showed** that the time taken was the highest in the sample CASE using a 4mm drill bit, and least in the sample CASE with a 2mm drill bit. **Regarding the damage and cut fibres** in the case of a 4 mm drill bit, the sample CABSE showed a low level of cut fibers, and the sample CASE exhibited a high level of cut fibres. This may be due to the insertion of a drill bit with a larger diameter. In all three cases though the damage was minimum on the exit side of the drill bit in the slab, it showed protruding effects, which were also absent in the sample CABSE. The perfect drilling without delamination was noted in the sample CABSE even while using a 4 mm drill bit. This enables an easy riveting process and may be useful for application as panels.
- **The flammability of the selected composites exhibited a** delayed ignition in the sample CABSE though flame was noticed for the longest duration. There was no dripping noted in the reinforced composite samples.
- **As for the acoustic tests,** the sample CABSE showed the best results even at highest frequencies. The average SAC (α) value was the highest in sample CABSE which was due to the increased roughness exhibited by the sample and the reinforcement that has been done.
- In the **comparison** made between the **nonwoven material and respective composites,** the natural fibre reinforced composites, namely CASE and CABSE, exhibited the highest sound absorption coefficient values of 0.810151 and 0.82667, respectively, at lower frequencies of 800 Hz and 600 Hz. At the maximum frequency (4000 Hz), the sample CABSE showed the best result (0.838832 dB). The average SAC value was the highest in the sample CABSE. The fabric reinforced hybrid composite structures may serve as good acoustic panels even at higher frequencies.
- The **Noise Reduction Coefficient (NRC) o**f the sample nonwoven fabric reinforced composite specimen CABSE showed the greatest noise reduction coefficient, representing 49 per cent of the sound absorbency rate. The material with a noise

reduction coefficient value greater than 0.20 is an absorption material. The nonwoven fabric samples namely CHAS and CHABS, showed NRC values of 0.219655 and 0.24197 respectively, which were improved by the conversion into composites to 0.247512 and 0.496911 in samples CASE and CABSE.

- **The cost estimation made for the** hybrid composite slab for one square foot made using natural fibres was assessed at Rs. 370/- When produced in large scale, it would definitely be cost effective.
- **The feedback for selected composite materials obtained from the study indicated** that this ecofriendly composite slab with novelty and functionality would find its application as panel boards, decorative products, and furniture in the future, as this would find its market potential due to its ecofriendly nature.

Conclusion

From the survey conducted to elicit information regarding the use and potentiality of natural fibres for building materials, it was understood that there was awareness about the use of natural fibres and the preference for eco-friendly products and reusable materials for building was also high. Therefore, green building concepts could be initiated to prevent waste disposal and contribute to the welfare of the environment. The fibres obtained from plant sources, namely *Agave americana, Abutilon indicum*, and *Areca catechu,* can be effectively modified physically, chemically, and morphologically by chemical and enzymatic treatments. The chemical treatments, namely alkalization and benzoylation, gave better results for fibres and among the enzymatic treatments, pectinase treatment resulted in better fibre modifications. The induced roughness observed in the morphological analysis of the fibre surface assists in improving the compatibility of the matrix with reinforcements. These fibres can be blended and converted into thermally bonded nonwoven fabrics with improved properties. The nonwoven material as such exhibited average sound absorption coefficient (α) values above 0.20, and this could serve as a soft acoustic material at this stage itself. The composites made by reinforcing these nonwoven materials by compression molding have given satisfactory results in various mechanical, thermal, morphological, absorbency, and acoustic properties with minimum voids. The reinforcement done using the nonwoven blends, namely *Abutilon indicum*/*Agave Americana* and *Areca catechu/ Agave americana*, gave satisfactory results. It is noticeable that the fibres utilized for these blends were *Abutilon indicum* and *Areca catechu* fibres which underwent chemical treatments, namely alkalization and benzoylation, respectively. The special functional evaluation for roughness has given reasonable results for acoustic properties. An improvement in acoustic property is significant in the composite structures over the respective nonwoven materials. The acoustic properties with respect to sound absorbency coefficient and noise reduction coefficient have given satisfactory results, indicating that these composite slabs can be utilized as panels or other building components to fulfill acoustic requirements. The best results were exhibited by the *Abutilon indicum* and *Agave Americana* blended nonwoven material-reinforced polymer composites. Thus the hybrid polymer composite slab with novelty could serve as an acoustic material, which may be utilized for build tech in future. The outcome of this study is that the abundantly available nonconventional fibres could be well modified and converted into blended nonwovens. The polymer composite materials could be well prepared with minimum voids by reinforcing the nonwoven blends. These materials have proved to have acoustic properties with viable cost which could be further improved.

Recommendation of the Study

- Fiber may be treated with other chemicals also
- Blending of the fibres may be tried with other proportions of natural
- Large-scale production of these hybrid polymer composites may aid in bringing down costs
- The nonwoven structure may be reinforced with other ecofriendly polymers for producing biomaterials.