MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages: 5396-5398

INVESTIGATION ON RELATION OF MATERIAL THICKNESS AND DENSITY AGAINST SOUND ABSORPTION BEHAVIOURS IN (SISAL/PALM) E-POXY HYBRID COMPOSITE

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ABSTRACT:

This study investigates the physical, mechanical, thermal, and acoustic properties of sisal/palm fiber reinforced epoxy hybrid composites fabricated with different weight ratios (Samples A, B, and C). The influence of thickness and density on sound absorption capacity (SAC) is analyzed, along with the relationship between thermal conductivity and acoustic performance. Results show that an increase in thickness and density significantly enhances sound absorption, with Sample C exhibiting the highest SAC due to improved fiber–matrix interaction and porous structure. Thermal conductivity decreases with increasing sound absorption, indicating better insulation performance, particularly in Samples B and C. Mechanical properties such as tensile, flexural, and impact strength are also found to be superior in Sample C, supported by strong interfacial bonding observed in SEM analysis. Additionally, Sample C demonstrates lower moisture absorption and better structural integrity. Overall, the study confirms that sisal/palm hybrid composites, especially Sample C, are highly suitable for applications requiring combined thermal insulation and sound absorption performance.

1. INTRODUCTION:

The increasing demand for multifunctional and sustainable materials has led to the development of natural fiber reinforced polymer composites for engineering applications. Natural fibers such as sisal and palm are gaining significant attention due to their biodegradability, low cost, light weight, and acceptable mechanical, thermal, and acoustic properties. These fibers, when reinforced with polymer matrices like epoxy resin, form hybrid composites that can effectively replace conventional synthetic materials in various applications including automotive interiors, building insulation, and acoustic panels.Sisal fiber is well known for its high strength, stiffness, and durability, making it a suitable reinforcement material for improving the mechanical properties of composites. In contrast, palm fiber possesses a highly porous structure and low density, which enhances thermal insulation and sound absorption characteristics. The hybridization of sisal and palm fibers in a single matrix allows the combination of their individual advantages, resulting in improved overall performance. The epoxy matrix plays a crucial role in binding the fibers, transferring load, and improving the structural integrity of the composite.The performance of such hybrid composites is influenced by several parameters such as fiber content, thickness, density, and interfacial bonding between fiber and matrix. Among these, thickness and density play a significant role in determining the sound absorption capacity (SAC) of fibrous materials. It is observed that thicker materials tend to absorb more sound energy, especially at low frequencies, due to increased path length and internal friction. Similarly, an increase in density enhances the sound absorption performance by increasing fiber packing and surface interaction, which leads to higher energy dissipation.In addition to acoustic properties, thermal conductivity is an important parameter that determines the insulation capability of composite materials. Natural fiber composites generally exhibit low thermal conductivity due to the presence of air voids and porous structures within the fibers. It has been observed that materials with higher sound absorption capacity often show lower thermal conductivity, indicating better thermal insulation performance. This relationship highlights the potential of hybrid composites in applications requiring both acoustic and thermal insulation.

Furthermore, mechanical properties such as tensile, flexural, and impact strength are critical for structural applications. These properties are significantly influenced by fiber composition, surface treatment, and fiber–matrix adhesion. Improved interfacial bonding enhances load transfer efficiency and overall composite performance. Moisture absorption is another important factor that affects durability, and it is generally reduced with better fiber treatment and matrix compatibility.

Therefore, this study focuses on the fabrication and characterization of sisal/palm hybrid epoxy composites with different weight ratios. The objective is to evaluate the influence of thickness, density, and fiber composition on mechanical, thermal, and acoustic properties. By understanding these relationships, the study aims to identify an optimal composite configuration suitable for applications requiring lightweight structure, sound absorption, and thermal insulation.

2. LITERATURE SURVEY:

1. Nowadays, the world needs materials that are renewable, biodegradable, less costly, environmentally friendly, and lightweight. To achieve those needs, developing natural fiber composite material is one alternative. In Ethiopia, there are untapped resources of natural fibers but their applications are limited. For instance, sheep wool is a natural fiber. They have a high production capacity of sheep wool fiber at a low cost and it was applied to the textile and non-textile industries. Those composites are prepared from natural and man-made fibers. Natural fibers can be produced from natural sources and they can be classified according to their origin. Those are made from plant, animal, or mineral sources. Natural fibre-based composites are less harmful to the environment and are utilized in transportation (automobiles, railway coaches, aerospace), military, construction, and building applications.

2.Researchers in numerous industries, including civil construction, automotive, and biomedicine, have paid close attention to natural fibers and natural fiber composites in recent decades, mostly due to three factors: cost- cutting, weight-loss, and long-term viability.

3.Natural fibre composites for interior and exterior applications have been pioneered by Mercedes- Benz, BMW, Audi, and Volkswagen, all German automakers. The inner door panel of the 1999 Mercedes-Benz S- Class, which is made of 35 percent Bay percentage of semi- rigid (PUR) elastomer from Bayer and 65 percent flax, hemp, and sisal, was the first commercial example.

4.Ethiopia is the most populous country in Africa and one of the top ten livestock- producing countries in the world. The country's cattle population is 55.03 million, sheep is 27.35 million, and goats are 28.16 million.

5.Sheep are a ruminant, quadrat pedal mammal that is commonly used as livestock. Sheep are raised for their f leece, meat, and milk, among other things. Sheep wool is a popular animal fiber that is usually obtained by shearing.

6.Wool fiber is made up of a fibrous protein called keratin, according to the results of the survey. A high-modulus fiber is combined with a viscoelastic matrix with a lower modulus. The matrix acts as a medium for transferring the applied load to the fiber, preventing crack propagation due to local flaws or rupture points.

7.Agave sisalana, sometimes known as sisal or sisal hemp, is an agave species. An Agavaceae (Agave) plant that produces a durable fiber is used to make rope. Sisal is a fiber plant that grows well in poor soil, doesn't require fertilizer, and is drought resistant. The fiber is made from Sisalana, a perennial shrub endemic to Mexico. Also, it is found throughout South and Central America, as well as Eastern Africa.

3. THE RELATION OF MATERIAL THICKNESS WITH SOUND ABSORPTION

The thickness of the material is one among the important factor that have an effect on the sound absorption capacity of fibrous material. Various investigations that dealt sound retention in porous materials have concluded that low frequency sound assimilation has direct relationship with material thickness. When the thickness of material is around one-tenth of the wavelength of the occurrence sound, the effective sound absorption of the porous sound absorber follows the rule of thumb. At a resonant frequency of one-quarter wave length of the incident sound, the peak absorption occurs. It can be noticed from Figure 4.15 that the average values of the hybrid composite samples A, B and C with thickness of 0.337 cm, 0.3306 cm and 0.341 cm are 0.0414, 0.0771 and 0.145 respectively. Sample C with a thickness of 0.341 mm results in an average SAC of 0.145, which is higher than that of samples A and B. The results show that increase in material thickness of the hybrid composite sample, the sound absorption capability of the composite material increases.

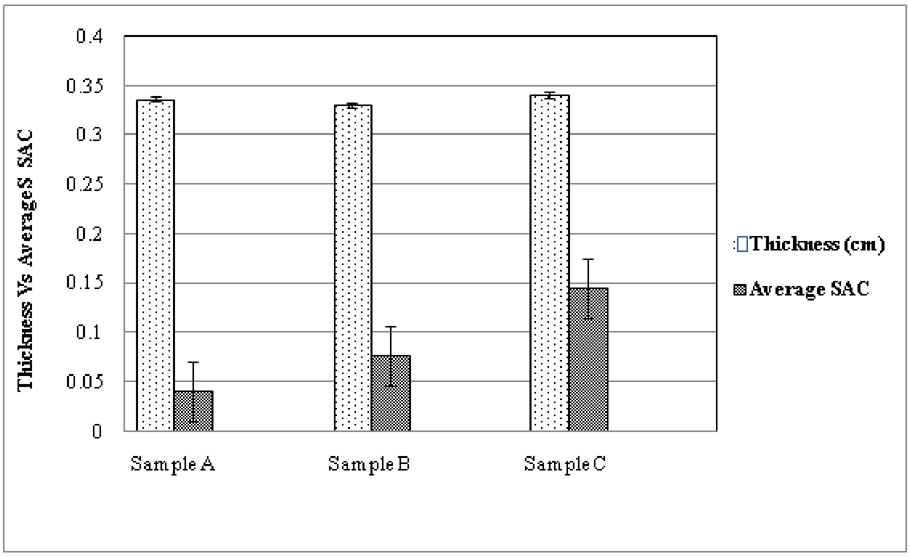

Figure 3 Thickness effect on Sound absorption

The earlier study (Martin Vašina et al.2019) states that thickness of material is directly related to sound absorption. It is obvious that compared with lowest thickness, the highest thickness of the hybrid composite material engrosses more amount of sound energy.

3.2 The Impact of Material Density on Sound Absorption

The significant aspect that influences the sound absorption capability of composite material be the material density. It can be seen in Figure 4.16, the influence of density on sound absorption of sisal/palm hybrid composite samples A, B and C. This shows that the average SAC increase, the material density increases. The density difference between samples A and B is 0.0234g/cm^3 , the average SAC increases by 46%, the difference between samples B and C is 0.0533 g/cm^3,an average increase SAC of 46.83%.

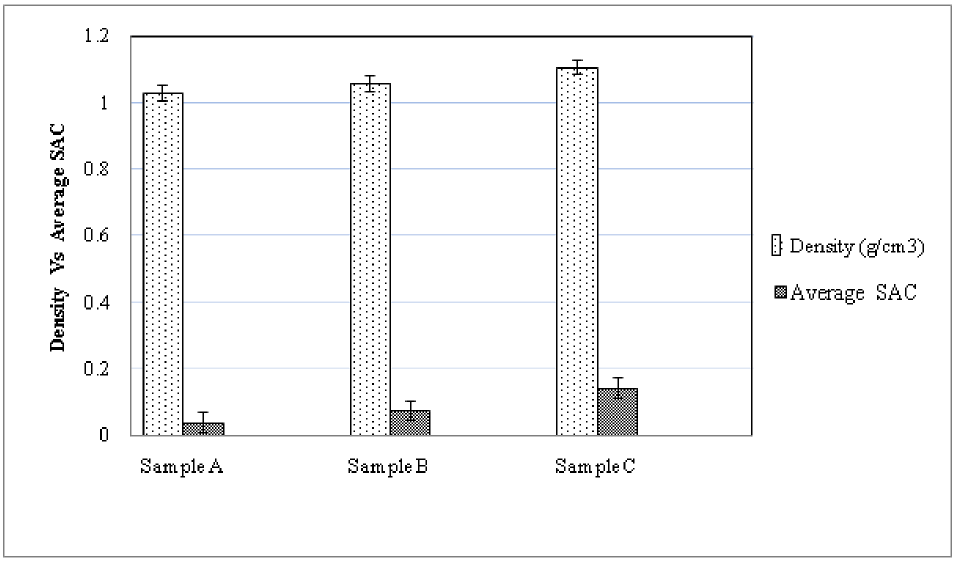

Figure 3.2 Influence of density on Sound absorption

In addition, the consequence of density of sound absorption capacity hybrid materials, open structure less dense material absorbs low sound frequency (500Hz) and denser structure absorbs sound frequencies above 2000 Hz. The high sound frequency is effectively absorbed in the fiber alone and also composite's pores are used for absorbing low sound frequency. The same results are in line with Koizumi et al (2002).

3.2.1 The Effect of Sound Absorption Capacity of materials on Thermal properties

The influence of sound absorption on thermal conductivity of hybrid composite is depicted in Figure 4.17. For the various weight ratios of sisal/palm hybrid composite samples, the thermal conductivity values are different. It can be seen from the results that the average sound absorption value of the hybrid composite increases, while the thermal conductivity of the composite decreases. The samples B and C of the hybrid composite materials are evaluated a thermal insulation performance. The sample A has the thermal conductivity of 3.29W/m-K and the average SAC is 0.0414, which is superior to that of the sample B and C. The thermal conductivity value of the sample A is 3.29W/m-K, which has an average SAC of 0.0414, is superior to that of the sample B and C. The material with lesser thermal conductivity i.e., 2.42 W/m-K,(sample C) is used as insulating material .The same occurrence is noticed by Rahul Vallabh(2008).

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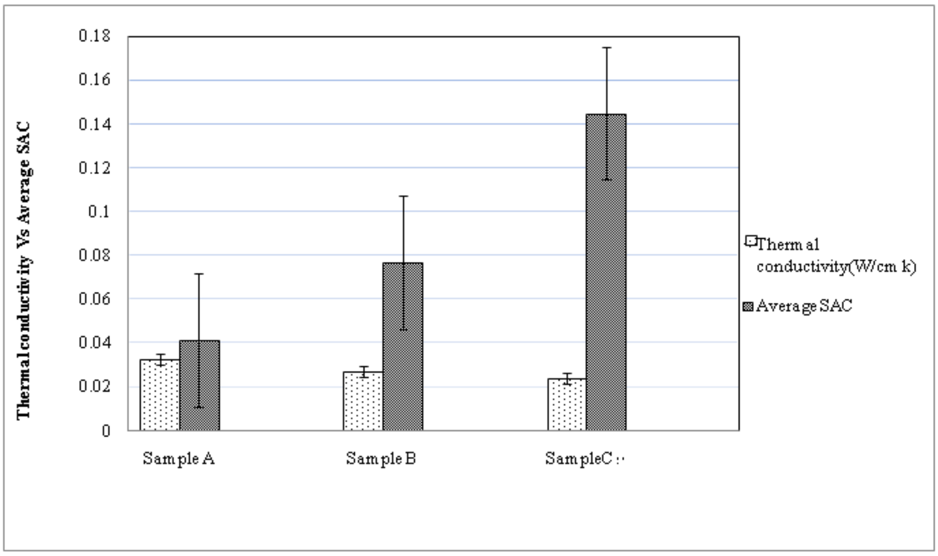

Figure 3.2.1 Influence of Sound Absorption on Thermal Conductivity

CONCLUSION

The study confirms that material thickness and density significantly influence the sound absorption behavior of sisal/palm hybrid epoxy composites. An increase in thickness leads to higher sound absorption capacity due to improved energy dissipation. Similarly, higher density enhances sound absorption by increasing fiber interaction and internal friction. Thermal conductivity decreases with increasing sound absorption, indicating better insulation performance. Among all samples, Sample C exhibits superior acoustic and thermal properties, making it suitable for insulation applications.

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