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Acoustic and Mechanical Properties of Sisal and Kenaf Fibers Reinforced Composites

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Abstract: Natural fibers have recently attracted the attention of researchers in the academic and industrial fields due to their porous structure and unique composition. This study aimed to examine the sound absorption coefficient (SAC) values of front and back surfaces of composite materials reinforced with natural fibers. Additionally, the effect of the weight fraction of natural fibers relative to the polyester resin weight on acoustic and mechanical properties was studied. Sisal and Kenaf fibers were used in different proportions (5%, 10% and15%) relative to the resin weight of polyester polymer. The composite material was fabricated using the hand lay-up technique. The acoustic and mechanical properties, specifically hardness and compression stress were measured. Results revealed that the back surface of all samples exhibited 0.01 SAC that means these panels are suitable for building facades. In the case of the front surface, sisal fibers are considered absorbing materials of sound waves compared to kenaf fibers, especially at 10% and 15% of sisal fibers recorded (0.206 and 0.325) SAC respectively. Additionally, hardness and compression decreased as the weight ratio of fibers increased; kenaf fibers showed a greater impact on reducing mechanical fibers properties compared to sisal fibers.

Keywords: Acoustic, mechanical, hardness, compression, natural fibers, composites, kenaf, sisal

1. Introduction

Researchers have shown considerable interest in utilizing natural fibers as a support material for polymers in composite material applications due to their numerous positive attributes. These fibers are lightweight, widely available, environmentally friendly, non-toxic to humans, biodegradable, and possess good mechanical properties. Additionally, they are an excellent raw material for producing sound-absorbing panels because of their high porosity. Natural fibers can be chemically treated and exploited to effectively regulate noise [1- 5]. Noise is an unwanted sound and a prevalent physical pollutant. The effect of noise depends on several factors such as loudness, duration, time of occurrence, and changes in noise level with time. Its impact can range from temporary effects to catastrophic consequences with negative outcomes accumulating over prolonged exposure, business that needs focus. Noise causes discomfort, pain, hearing loss, and even chronic cardiovascular diseases [6, 7]. Flax and kenaf fibers were used as reinforced composite materials, and the effect of Fiber volume fraction (FVF) regarding the weight of the fibers was investigated. The following mechanical properties were determined; tensile, flexural, and inter-laminar shear performance of flax/epoxy composite. The results showed that an improvement of the mechanical properties by an increment of kenaf FVF and the highest tensile strength was (59.8 MPa) [8]. Pure Hemp epoxy composite achieved the superior mechanical characteristics, tensile strength, flexural strength and impact strength, compared to kenaf/hemp hybrid composites and exhibited the highest sound transmission loss level at the lowest and the highest frequency regions of sound waves [9]. The effect of Sisal treatment by using NaHCO3 treatment followed by PLA coating was studied. Tensile, hardness and flexural characteristics of treated sisal were found to be greater than untreated whereas impact strength decreased [10]. Various factors affect mechanical and acoustic properties of natural fibers reinforced composites. Kaliappan, S., and Natrayan, L. [11] examined the effect of the fiber type and the thickness of the composite material on mechanical and acoustic properties. By comparing between Kenaf, jute, sisal and calotropis gigantea fibers as polymer reinforcement, mechanical results showed that mechanical characteristics improved with sisal fibers (42.35 MPa tensile strength) and calotropis gigantean (73.26 shore value of Hardness). Acoustic characteristics enhanced by increasing the thickness of the composite material. Elfaleh, I. [12] reviewed the performance of different types of natural fibers, polymer resins, volume fraction, fiber orientation and chemical treatment of the mechanical and the thermal properties of natural fibers reinforced composite materials. In addition, the influencing factors of mechanical and acoustic characteristics of composite materials based on natural fibers were studied. These parameters were such as fiber properties, hybridization effect, sample thickness, filler material and binder amount [13 - 18]. Moreover, frequency of sound waves, the depth of the back cavity, location of sound absorbers, perforation, and porosity and tortuosity of composite materials were studied especially for acoustic characteristics [19]. According to the researchers' knowledge, authors discovered a deficiency in the surface properties of both sides of the sample, as well as a deficiency in the hardness and compression tests. Moreover, there is a lack of use of kenaf fibers in terms of sound absorption and mechanical properties such as hardness and compressibility.

2. Experimental Work

2.1 Materials

Natural fibers (kenaf and sisal fibers) were used as reinforcement for polyester resin. Table (1 and 2) show the properties of reinforcement materials and the polyester resin used as a matrix.

Table 1. Properties of Kenaf and Sisal fibers

Fiber type	Fiber length	Fiber diameter	Tensile strength	Elongation%
Kenaf Fiber	34,2 μm To 43,2 μm	4,2 m	283 – 800 MPA	17,3 %
Sisal Fiber	8,75 cm to 30 mm	0,10 – 0,13 mm	371+28 MPA To 365+5,2 MPA	3,9 %

Table 2. Physical and mechanical properties polyester resin

Resin	Density cm^3/gm	Tensile strength MPa	Young modulus MPa	Elongation at failure %
Polyester	1.2	50-65	3	2-3

2.2 Fabrication steps of Composites

Sisal fibers and Kenaf fibers were used in different proportions (5%, 10%, and 15%) relative to the resin weight of polyester resin. The composite material was fabricated using the hand lay-up technique and hardener was mixed with the resin at a ratio of 2% by weight, with adjustments made based on prevailing weather conditions. The fibers were cut to the specified length and quantity required for the tests, Vaseline was applied as a release agent between the mold and the sample to facilitate easy removal. The mold was prepared in accordance with the standards specified for each test. Moreover, the mixture of fibers, polyester resin, and hardener was poured into the mold and then the samples were left to dry for a period ranging from 12 to 24 hours.

2.3 Testing of Composites Materials

The mechanical properties, specifically hardness and compression stress, and acoustic properties were measured. The acoustic test was performed using an impedance tube device at a temperature of 28°C. The test was performed according to ASTM E1050, using circular samples for high and low frequencies, respectively, with diameters of 10 cm and 3 cm. The test was performed on the samples, and values were obtained, and the average was taken. The compression test was conducted using a compression testing machine with a maximum load capacity of 1500 kN and a loading rate of 15 mm/min. The test was carried out according to ASTM D3410 standard, cut samples to desired dimension (140mm x 12mm x 12mm). The hardness test was conducted using the durometer technique according to ASTM D2240, as it is shown in figure (1).

3. Results & Discussion

This section presents the results of acoustic measurements, hardness ratio, and compressive stress. The sound absorption coefficient (SAC) was measured for both the front and back surfaces of the samples, with the back surface of all samples exhibiting 0.01 SAC. This indicates that the resin accumulated at the bottom of the samples, creating a smooth surface that enhances sound wave reflection, making the back surface is suitable for building facades. The following results of acoustic characteristics are related to the front surface of samples during SAC measuring.

3.1. Effect of weight ratio of fibers:

Figure 2 illustrates that increasing the weight ratio of sisal fibers relative to the amount of resin leads to a significant rise in SAC values. The resonance frequency of sisal fibers is consistently at 1650 Hz across all samples. However, the SAC values are 0.01, 0.13, 0.18, and 0.35 for weight ratios of 0%, 5%, 10%, and 15% sisal fibers, respectively. This indicates that the optimal SAC result is achieved with 15% sisal fibers in the low frequency range.

On the other hand, in the case of kenaf fibers, Figure 3 shows that increasing the weight ratio of fibers shifted the resonance frequency from 1650 Hz in the blank sample to 1000 Hz in all kenaf samples. For example, increasing the weight ratio of kenaf fibers from 5% to 15% resulted in a change in SAC from 0.13 to 0.25 at the resonance frequency.

(A) (B) (C)

Figure 1. Sampling of natural fiber composites according to ASTM Standards, (A) Acoustic test {ISO-10534-2} , (B) hardness test { ASTM D2240 }, (c) Compression test { ASTM D3410 }

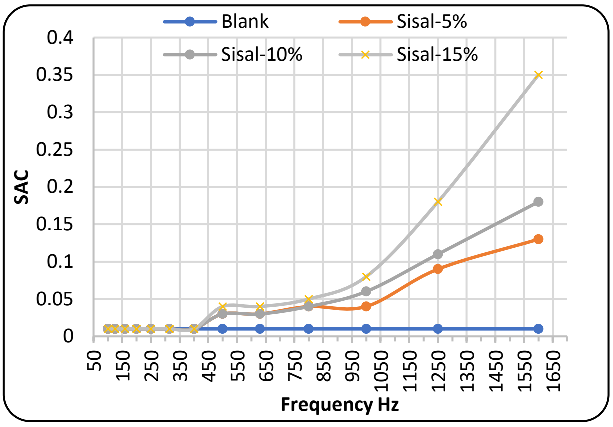

Figure 2. Sisal fibers' SAC

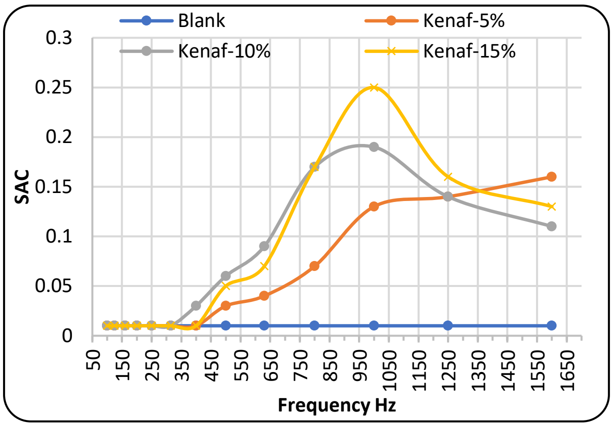

Figure 3. Kenaf fibers' SAC

Regarding high frequencies of sound waves, Figure 4 shows that increasing the weight ratio of sisal fibers improves sound absorption. For example, SAC values increased from 0.04 in the blank sample to 0.8 in the 15% sisal fiber sample at a resonance frequency of 6300 Hz. Conversely, Figure 5 illustrates that SAC values with kenaf fibers fluctuated between 0.04 and 0.23. This indicates that sisal fibers provide better SAC results at high frequencies compared to kenaf fibers.

3.2. Effect of fiber type:

Average SAC is calculated at low frequencies and high frequencies separately as it is shown in figures (6 and 7) to highlight the effect of increasing the amount of fibers relative to the resin weight at different frequencies of sound waves. In the case of sisal fibers, increasing the amount of sisal fibers leads to an improvement in sound absorption compared to the blank sample at low and high frequencies. In the case of kenaf fibers, although increasing the amount of fibers leads to an increase in SAC values at low frequencies, there is a decrease in SAC values compared to the blank sample in the case of 5% and 10% amount of fibers at high frequencies. According to [20], 10% and 15% of sisal fibers recorded (0.206 and 0.325) SAC respectively therefore they are considered absorbing materials of sound waves.

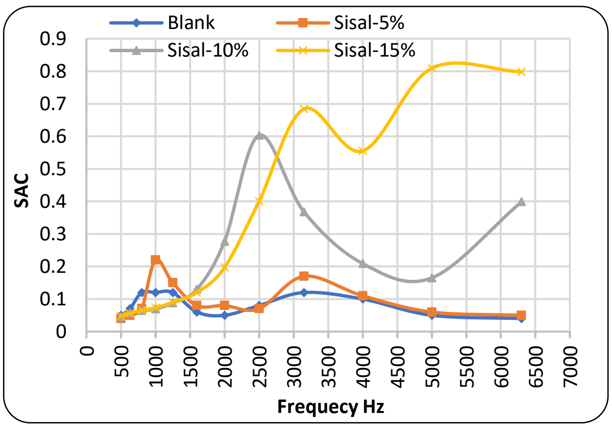

Figure 4. Sisal fibers' SAC

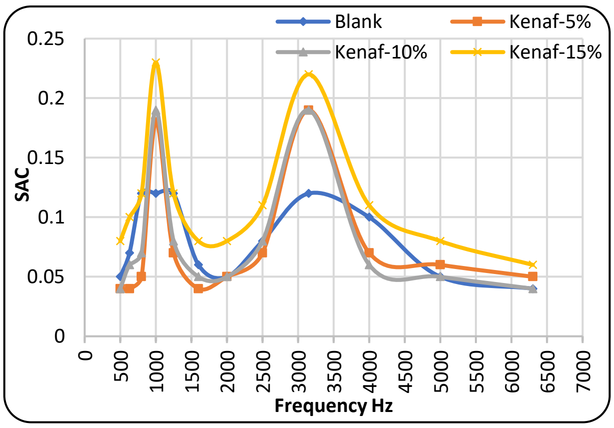

Figure 5. Kenaf fibers' SAC

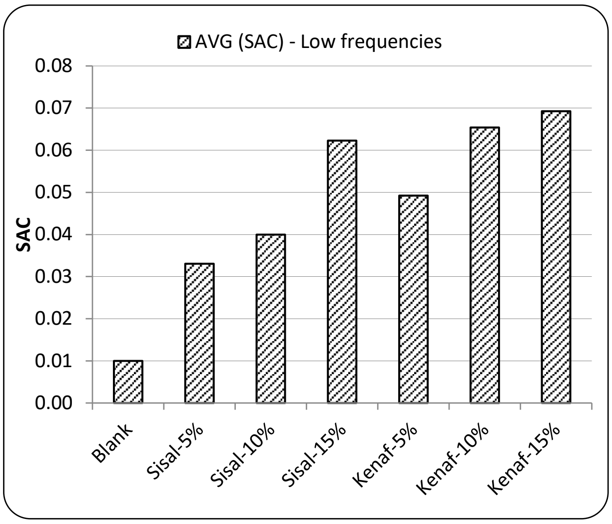

Figure 6. SAC with low frequencies

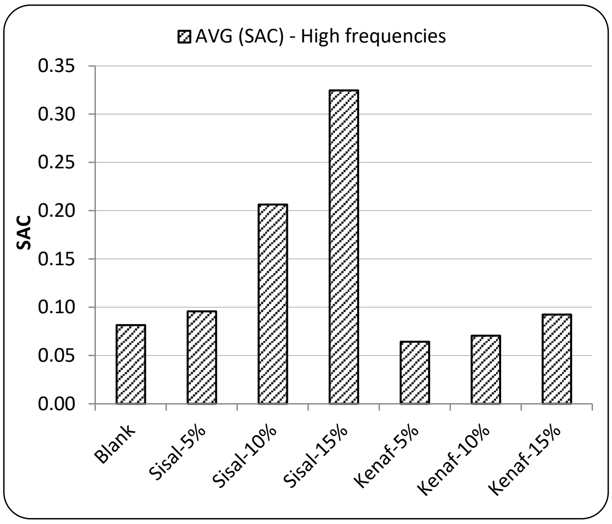

Figure 7. SAC with high frequencies

By calculating the SAC and NRC, Figure 8 compares the values for sisal and kenaf fibers according to standard methods [20]. A weight ratio of 15% sisal fibers is optimal for noise reduction, while the highest sound absorption performance is achieved with 15% kenaf fibers. Overall, the SAC and NRC values indicate that these panels are suitable as sound insulators in building walls to reduce noise transmission.

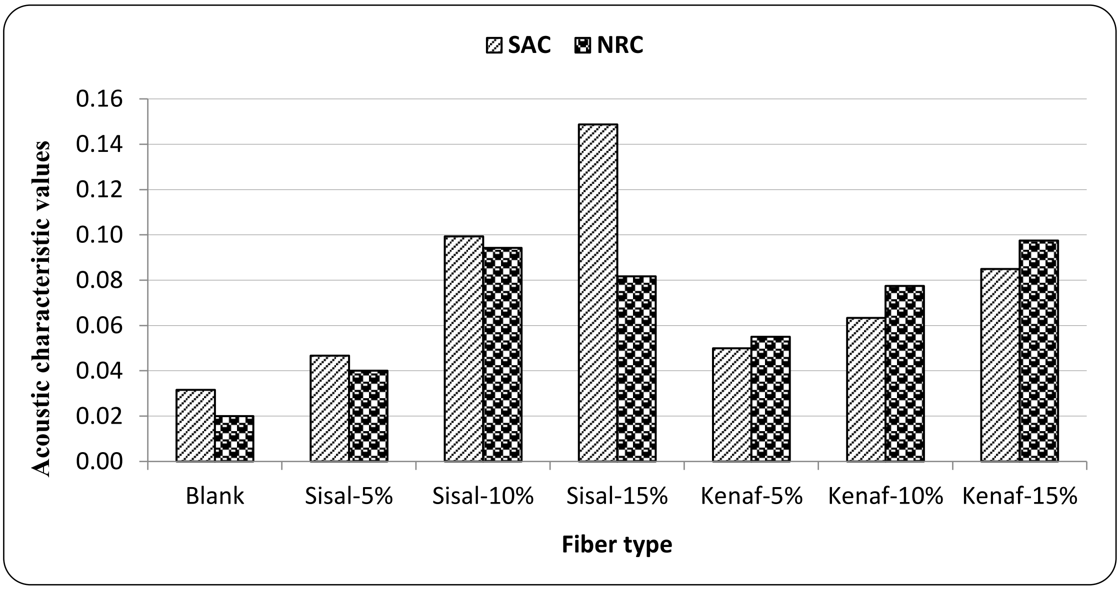

Figure 8. Acoustic characteristic values

3.3. Mechanical properties:

As shown in Figures 9 and 10, increasing the weight ratio of sisal and kenaf fibers leads to a decrease in hardness and compressive stress values. The fibers weaken the bonds between resin molecules, making the composite material's structure more ductile to be affected by various types of loads [21].

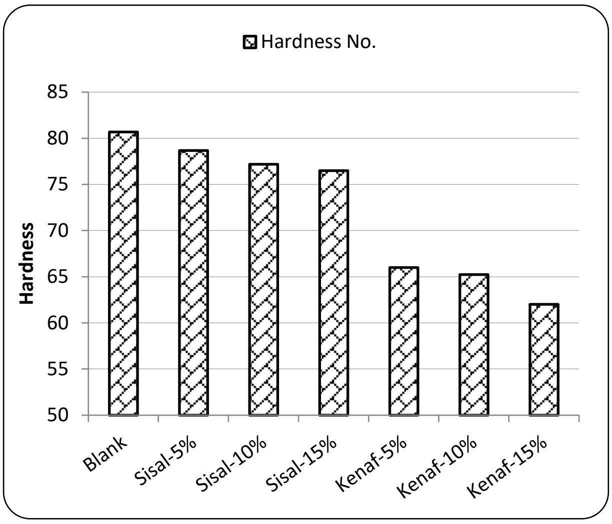

Figure 9. Hardness No. of Sisal and Kenaf

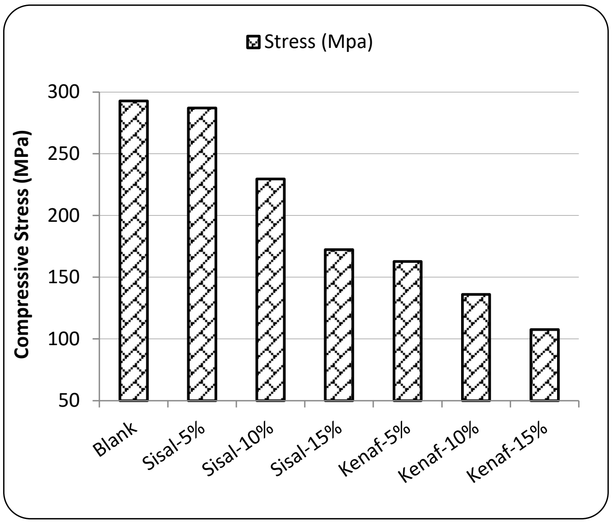

Figure 10. Stress (Mpa) of Sisal and Kenaf

5. Conclusions

Polyester resin was used as a reinforcement polymer for sisal and kenaf fibers with different proportions of weight. The effect of three different proportions (5%, 10% and 15%) of fibers' weight relative to resin weight on acoustical and mechanical properties was studied. SAC of front and back surfaces of composite materials was measured. The results were summarized in:

- There is an improvement in sound absorption by increasing the frequencies of sound waves and increasing the volume fraction (Vf) of fibers.
- SAC was 0.01 of the back side of all samples. The smooth surface and free of porosity led to lower SAC value and more reflection of sound waves. In other words, this case is ideal for building facades.
- In the case of the front surface of samples, values of SAC were (0.206 and 0.325) with 10% and 15% respectively which make them sound absorbing materials.
- Increasing the percentage of fiber weight in relative to the amount of resin reduces the hardness No. of the material. In addition, kenaf fibers have a greater effect in reducing surface hardness compared to sisal fibers at the same proportions. The fibers weakened the bonds between the resin molecules, making the structure of the composite material more ductile to be affected by various types of loads.
- It was found that in the compression test, increasing the weight percentage of sisal fibers and kenaf fibers led to a decrease in compressive stress values.

Recommendations:

It was noted that increasing the weight fraction of natural fibers relative to the resin weight improved sound absorption. Therefore, in the future work it is recommended that:

- Improving the compression technique to get rid of the excess resin during fabricating the composite materials.
- Studying the weight fraction of fibers relative to resin weight to be more than 15%.
- Using a resin with multifunctional properties such as fire-retardant properties.
- Testing more properties of composite materials as flexural and tensile strength.

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