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Article

Investigated the Sound Absorption Performance of Wood-Based Sandwich Panels with Reinforced BFRP, GFRP, and Jute Fabric

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Abstract

The sound absorption efficiency of the wood based sandwich panels with reinforced basalt fiber reinforced (BFRP), glass fiber reinforced (GFRP), and jute fabric composite materials and evaluate their potential as acoustic panels were investigated. Four experimental groups were created. Wood based sandwich panels were reinforced with BFRP (Group A), jute fabric (Group B), GFRP (Group C), and unreinforced (Group D). The sound absorption coefficients of the unreinforced and experimental groups were tested *via* the impedance tube method, according to ASTM standard E1050 (2006). Attention was paid to the acoustic behavior at 200 Hz to 2400 Hz). The sound absorption coefficient was highest in sapwood at 200 Hz frequency level with 0.67, while the highest in heartwood was 0.05 at 2400 Hz frequency level. It can be suggested that the experimental groups be used as sound absorbing acoustic panels.

Keywords: sound absorption coefficient; acoustic properties; industrial design

1. Introduction

Wood-based sandwich panels (WBSPs) have experienced significant technological and scientific advancements over the past several decades. Initially developed in the mid-20th century as lightweight and thermally efficient structural materials, WBSPs were designed to provide sustainable alternatives to traditional construction components. Early investigations primarily focused on understanding their basic mechanical performance and potential as energy-efficient building elements. Fundamental studies in the late 20th century [1] clarified the structural behavior of sandwich panels under different stress states, including bending, compression, and shear, thereby establishing the theoretical foundation for modern applications. With the progress of material science, polymer chemistry, and adhesive technologies, the functionality of these composites has been remarkably enhanced. More recently, sustainability-driven innovations have introduced new adhesives and core materials derived from recycled or renewable resources, aligning WBSP development with circular economy principles.

The layered structure of WBSPs provides distinct mechanical and thermal advantages. Typically consisting of two stiff outer face sheets bonded to a lightweight core via an adhesive, the design enables the efficient transfer of loads while maintaining low mass. The outer faces primarily bear bending and tensile stresses and protect the core from external damage, while the core acts as a shear-resistant element that distributes stresses between the facings [2]. As a result, WBSPs demonstrate a unique combination of high mechanical strength, good thermal insulation, and low density, offering significant benefits such as reduced transportation costs and simplified installation. Moreover, the use of wood a renewable and carbon-sequestering resource directly supports global sustainability targets, contributing to reduced greenhouse gas emissions and resource-efficient construction [3,4].

Usually, the core of a wood-based sandwich panel comprises lightweight materials like foam, balsa wood, or other fibrous materials arranged in the structure of a given type [5–7]. The core sets the thickness of the panel; it may have lower stiffness and strength [1]. It is responsible for controlling the panel's weight and limiting the relative movement of faces [8]. The face materials are usually made from engineered wood products like plywood, oriented strand board (OSB), or laminated veneer lumber (LVL), providing the structural strength and rigidity required for construction applications. In the case of sandwich-structured composite plywood panels, the variations in the veneer thickness ratio in plywood significantly change the stress distribution in each layer of the sandwich panel. Also, it influences the stiffness of a sandwich panel. Stiffness can be increased by increasing the thickness ratio of the parallel-oriented veneer sheets [9]. Moreover, the low density suggests a hollow structure, which contributes to the reduced weight and provides excellent thermal and sound insulation properties. This property is important in various applications, especially in the construction and aerospace industries, where lightweight yet strong materials are highly desirable. Therefore, a comprehensive understanding and optimization of this strength-to-density ratio is critical for maximizing the structural performance of sandwich panels and ensuring their cost-effectiveness across various applications. Further research into core designs has shown that innovative approaches can significantly enhance the mechanical performance of wood-based sandwich panels [10].

Recent research has expanded the range of core materials used in WBSPs, including low-density wood fiber [11,12], plywood [13–15], wood strips [16], cork [17], wooden dowel lattices [18], corrugated cardboard [19,20], and 3D-shaped wood strands [21]. Other works have incorporated polymeric or hybrid cores such as balsa wood, polypropylene honeycomb, and polystyrene foam [22], as well as advanced combinations like balsa/glass-epoxy [23], jute/epoxy-cork [24], aluminum honeycomb-balsa hybrids [25], paulownia or southern pine wood cores with glass fiber-reinforced polymer (GFRP) skins [26–28], and thermoplastic GF/PP composite layers bonded to plywood [27].

Among the various reinforcing strategies, fiber-reinforced polymers (FRPs) have gained significant attention due to their high strength-to-weight ratio, corrosion resistance, and versatile bonding compatibility with wood substrates. FRPs are composite materials consisting of high-strength fibers embedded in a polymer matrix. Common fibers include glass (GFRP), basalt (BFRP), carbon (CFRP), and aramid (AFRP) [29]. The reinforcement of WBSPs with FRPs effectively enhances stiffness, load-bearing capacity, and flexural strength while maintaining lightweight characteristics. For instance, Keller et al. [30] successfully developed and validated a GFRP-balsa sandwich bridge deck that met serviceability criteria for load-bearing applications. Shi et al. [31] reported pseudo-ductile flexural behavior in wood-core sandwich beams reinforced with GFRP skins and lattice webs, while Nadir et al. [32] demonstrated that FRP sheets significantly improve the mechanical performance of laminated wood beams. Likewise, studies by Qi et al. [28], Almutairi et al. [33], and Szwajka et al. [34] confirmed that GFRP and CFRP reinforcements can substantially enhance flexural rigidity, bending strength, and energy absorption. Li et al. [35] also examined fiberglass-faced foam-core panels, highlighting the mechanical failure mechanisms and the role of polymer-wood interfacial bonding.

While most studies have focused on the mechanical and structural performance of FRP-reinforced WBSPs, there is growing recognition that the acoustic properties of such composites are equally important, particularly in modern architectural applications. Increasing urbanization has intensified the demand for sound-absorbing, noise-reducing, and vibration-damping materials [36]. Owing to its natural porosity and anisotropic structure, wood inherently exhibits favorable acoustic properties, including the ability to absorb and diffuse sound waves [37,38]. The directionality of fibers plays a crucial role in sound conductivity—longitudinally oriented fibers transmit sound more effectively, whereas transverse orientations enhance absorption [39]. Acoustic parameters such as sound absorption, sound insulation, and noise reduction coefficients are therefore critical for evaluating the suitability of wood composites in interior environments [40].

Studies have shown that porous and fibrous materials can improve sound clarity, reduce reverberation time, and increase speech intelligibility in enclosed spaces such as theatres, concert halls, and conference rooms [41–43]. The sound absorption coefficient of wood-based materials generally increases with higher internal porosity, rougher surface texture, and lower density [44,45]. Research on related composites has revealed that carbon fiber materials tend to reflect or transmit low-frequency (bass) sound waves rather than absorb them [46]. Conversely, bark-based insulation panels [47], plywood–carbon fiber composites [48], and rice stick–wood splinter boards [49] demonstrated enhanced sound absorption across mid and high frequencies. The acoustic efficiency of wooden materials also depends on species type, fiber structure, and surface geometry; for instance, perforated panels of Scots pine have shown superior absorption between 400 and 1000 Hz compared to flat panels or denser hardwood species [50,51].

The objective of this study was to examine the acoustic absorption behavior of wood-based sandwich panels reinforced with BFRP, GFRP, and jute fabric across low (bass), medium, and high (treble) frequency ranges. To the best of our knowledge, no comprehensive studies have previously addressed the sound absorption mechanisms of wood-based sandwich panels incorporating these specific fiber-reinforced polymer (FRP) systems. Therefore, the present work provides a novel contribution to the understanding of polymer-reinforced wood composites with tailored acoustic functionalities.

2. Materials and Methods

2.1. Materials

The face and bottom layers of the composite panels consisted of 4 mm thick poplar plywood (PPWD) manufactured from three types of veneer commonly utilized in the furniture sector (Figure 1a). The core material was composed of 9 mm thickness oriented strand board (OSB-2 class) (Figure 1a). All materials were procured randomly from suppliers located within the Uşak 1 September Industrial Site Market.

A single-component polyurethane adhesive (Apel Kimya Industrial Industry and Trade Co., Istanbul, Turkey) was employed as the bonding agent (Figure 1b). The BFRP and GFRP fabrics with a nominal areal weight of 200 g/m² (Dost Kimya Industrial Raw Materials Industry and Trading Co., Istanbul, Turkey), together with a jute fabric of 265 g/m² (Polatoğlu Garden Agriculture Hardware Co., Turkey), were used as the reinforcing media (Figure 1c). The densities of all constituent materials used in the fabrication of the wood-based sandwich panels are listed in Table 1.

Table 1. Density of wood-based sandwich panels and FRP materials used in the study.

No	Material Name	Density (gr/cm ³)	Where used in the panel
1	OSB-2 Class	0.630	core layer
2	PPWD	0.500	face layer and bottom layer
3	BFRP	2.800	face layer between core layer, and bottom layer between layer
4	GFRP	2.500	face layer between core layer, and bottom layer between layer
5	Jute Fabric	1.300	face layer between core layer, and bottom layer between layer

The mechanical properties of the reinforcement materials were as follows: for BFRP, the Young's modulus, tensile strength, and fracture elongation were 89 GPa, 2800 MPa, and 3.15%, respectively [52]. For GFRP and jute fabric, these parameters were 70 GPa and 26.5 GPa, 2000–3500 MPa and 393–

773 MPa, and 0.9% and 1.8%, respectively [53]. At 20 °C, the adhesive had a density of 1.11 ± 0.02 g/cm³ and a viscosity of $14,000 \pm 3,000$ mPas at 25 °C. Under laboratory conditions (20 ± 2 °C and $65 \pm 3\%$ relative humidity), the adhesive achieved surface hardening within approximately 30 minutes.



Figure 1. Materials used in experiments.

2.2. Preparation of Test Samples

The OSB and PPWD panels were cut using a CNC router into 31 identical specimens per panel, each with dimensions of $162 \times 1700 \pm 1$ mm (Figure 2a). In the multilayer configurations, two sheets of reinforcing fabrics BFRP, GFRP, or jute were interposed between the OSB and plywood layers to provide additional structural reinforcement. Polyurethane adhesive was uniformly applied to the bonding surfaces at a rate of about 200 g/m² (Figure 2b). The assembled panels were subsequently cold-pressed using a hydraulic press (Hydraulic Veneer SSP-80; ASMETAL Wood Working Machinery Industry Inc., İkitelli, Istanbul, Turkey) at a pressure of 1.5 N/mm² and ambient temperature (25 °C) for 3 hours (Figure 2c). After pressing, the panels were conditioned under standard environmental conditions (20 ± 2 °C, $65 \pm 5\%$ RH). The pressing and specimen preparation procedures are illustrated in Figure 2d. Specimens were labeled according to their constituent layers: poplar plywood (PPWD) as “PP,” oriented strand board (OSB-2) as “O,” and reinforcing materials basalt, glass, and jute as “B,” “G,” and “J,” respectively. The structural configurations are presented in Figure 3. In total, 12 distinct combinations of wood-based sandwich panels were manufactured, as summarized in Table 2.

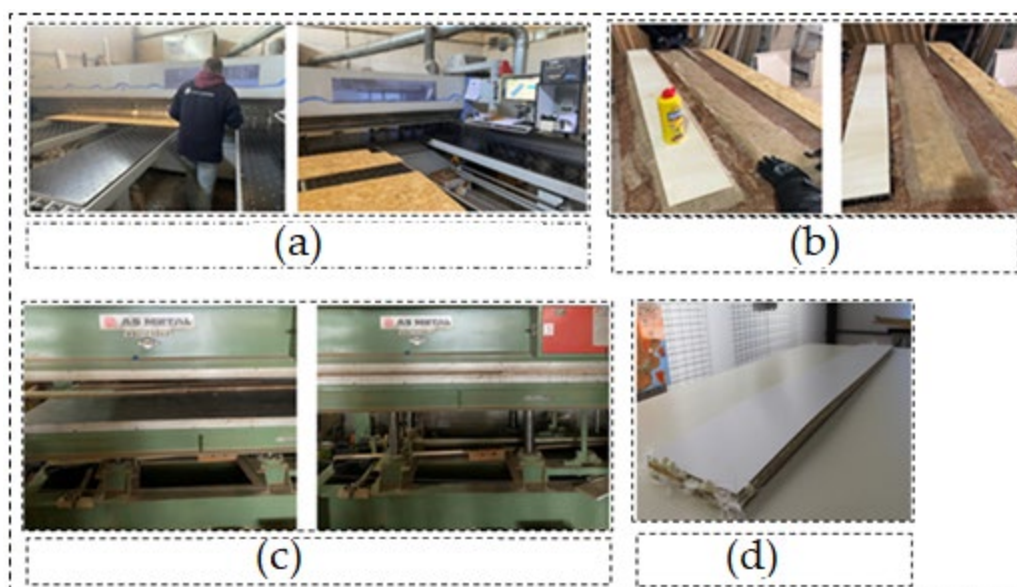


Figure 2. The production process of test samples: (a) using a CNC machine; (b) polyurethane adhesive was used for surface; (c) Hydraulic Veneer SSP-80; ASMETAL; (d) the pressing of samples.

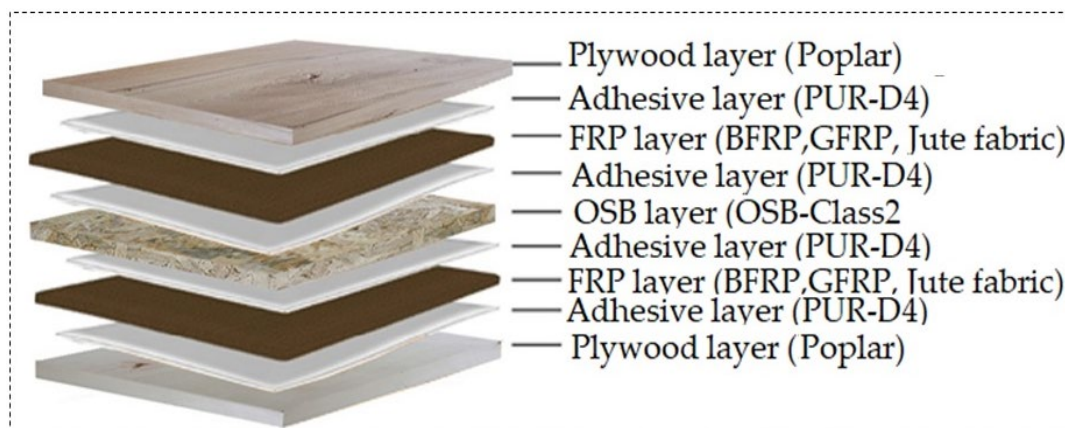


Figure 3. Exploded view of a multi-layered wood-based sandwich panels structure.

Table 2. Combinations of wood-based sandwich panels were manufactured.

Group	Code	Face Layer	FRP Types	Core Layer	Bottom Layer
A	PP-B-O-B-PP	PP (PPWD)	B (BFRP)	O (OSB-2 class)	PP (PPWD)
B	PP-J-O-J-PP	PP (PPWD)	J (Jute Fabric)	O (OSB-2 class)	PP (PPWD)
C	PP-G-O-G-PP	PP (PPWD)	G (GFRP)	O (OSB-2 class)	PP (PPWD)
D	PP-O-PP	PP (PPWD)	-	O (OSB-2 class)	PP (PPWD)

All sample groups (A–D) were conditioned at 20 ± 3 °C and 65% relative humidity before testing.

2.3. Test Method

The air-dried density (δ_{12}) of the test specimens was determined following the TS EN 323/1 [54] standard. For each panel type, 10 replicate samples were prepared. The air-dried density was calculated using Eq. (1):

$$\delta_{12} = \frac{M_{12}}{V_{12}} \quad (1)$$

where δ_{12} is the air-dried density (g/cm^3), M_{12} is the air-dried weight (g), and V_{12} is the air-dried volume (cm^3).

The sound absorption coefficients (SAC) of the fabricated sandwich composites were measured according to ASTM E1050–19 (2019). The samples were precisely machined to the specified geometry using a CNC system to ensure dimensional uniformity (Figure 4a). The SAC values were evaluated using an impedance tube (BSWA TECH SW422) based on the two-microphone transfer-function method. Circular specimens with a diameter of 30 mm were tested over a frequency range of 0–2400 Hz (Figure 4b,c).

The impedance tube, with an internal diameter of 29.95 mm, facilitated measurements within the low-frequency region (0–2400 Hz). The acoustic responses of the wood-based composites were analyzed frequencies. During testing, incident acoustic waves were directed toward the specimen surface, and reflected/transmitted pressures were recorded to compute SAC values. Each configuration was tested at least three times, with ten independent samples per type, to ensure reproducibility and minimize uncertainty. The consistent results confirmed the reliability of the acoustic characterization.

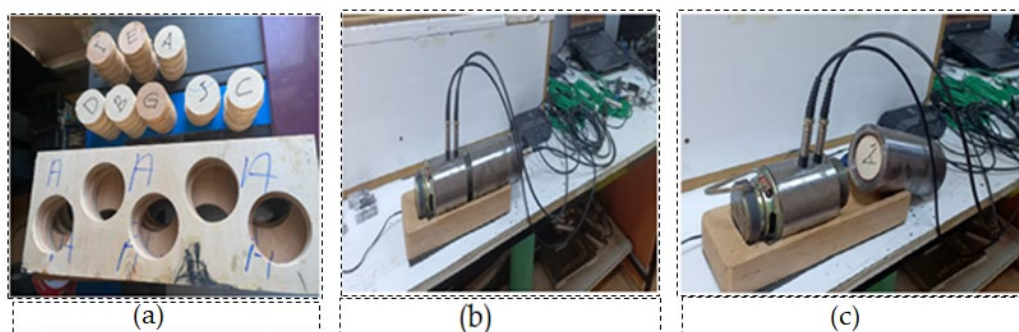


Figure 4. The sound absorptions process of test samples: (a) Test samples; (b) Impedance tube equipment; (c) Impedance tube equipment with test samples attached.

2.4. Data Analyses

Statistical analyses were performed using SPSS software (version 22, IBM Corp., Armonk, NY, USA). A analysis of variance (ANOVA) was applied to assess the effects of the independent factors wood-based panel type and fiber-reinforced polymer type on the SAC results. Significant differences among the groups were further examined using Tukey's post hoc test at a 95% confidence level.

3. Results and Discussion

Firstly densities of wood based sandwich panels with reinforced BFRP, GFRP, and Jute fabric were determined. The average, maximum, minimum and standard deviations of air-dry densities of the test specimens are given in Table 3.

Table 3. Air-dry densities of experimental samples (gr/cm^3).

Values	Groups			
	A	B	C	D
X	0.566	0.529	0.552	0.512
S	0.006	0.003	0.004	0.003
X min	0.558	0.522	0.558	0.508
X max	0.578	0.534	0.545	0.517
N	10	10	10	10

Note: X: average value; S: the standard deviation; X min: minimum value; and X max: maximum value.

According to the results, there are differences between the air-dry density values of the experimental samples (Groups: A, B, C, and D). The density was found as $0.566 \text{ g}/\text{cm}^3$ for A group samples, $0.529 \text{ g}/\text{cm}^3$ for B group samples, $0.552 \text{ g}/\text{cm}^3$ for C group samples, and $0.512 \text{ g}/\text{cm}^3$ for D group samples.

The statistical data related to the sound absorption coefficients of the wood-based sandwich panels produced in different combinations were given in Table 4.

Table 4. Statistical results regarding sound absorption coefficients values (α).

Groups	Frekans (Hz)	Xmin	Xmax	Xmean	Std. Dev.	V (%)
A	200	0.67	0.68	0.67	0.00	0.00
	400	0.53	0.54	0.54	0.00	0.00
	600	0.20	0.20	0.20	0.00	0.00

	800	0.52	0.53	0.52	0.00	0.00
	1000	0.43	0.44	0.43	0.00	0.00
	1200	0.09	0.09	0.09	0.00	0.00
	1400	0.12	0.13	0.12	0.00	0.00
	1600	0.16	0.17	0.16	0.00	0.00
	1800	0.20	0.20	0.20	0.00	0.00
	2000	0.11	0.11	0.11	0.00	0.00
	2200	0.07	0.08	0.07	0.00	0.00
	2400	0.05	0.05	0.05	0.00	0.00
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	200	0.41	0.52	0.48	0.06	0.00
	400	0.36	0.45	0.42	0.05	0.00
	600	0.24	0.30	0.28	0.04	0.00
	800	0.08	0.22	0.13	0.07	0.01
	1000	0.14	0.17	0.16	0.02	0.00
B	1200	0.73	0.93	0.85	0.11	0.01
	1400	0.53	0.67	0.62	0.08	0.01
	1600	0.31	0.40	0.37	0.05	0.00
	1800	0.08	0.10	0.10	0.01	0.00
	2000	0.23	0.30	0.27	0.04	0.00
	2200	0.32	0.40	0.37	0.05	0.00
	2400	0.06	0.08	0.07	0.01	0.00
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	200	0.43	0.62	0.55	0.11	0.01
	400	0.41	0.49	0.44	0.04	0.00
	600	0.25	0.46	0.38	0.12	0.01
	800	0.32	0.34	0.33	0.01	0.00
	1000	0.14	0.18	0.16	0.02	0.00
	1200	0.18	0.19	0.18	0.00	0.00
C	1400	0.48	0.55	0.51	0.03	0.00
	1600	0.07	0.08	0.07	0.01	0.00
	1800	0.09	0.14	0.12	0.03	0.00
	2000	0.08	0.24	0.13	0.10	0.01
	2200	0.31	0.33	0.32	0.01	0.00
	2400	0.07	0.09	0.08	0.02	0.00
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	200	0.51	0.54	0.53	0.02	0.00
	400	0.41	0.43	0.42	0.01	0.00
	600	0.15	0.16	0.16	0.00	0.00
	800	0.40	0.42	0.41	0.01	0.00
D	1000	0.33	0.35	0.34	0.01	0.00
	1200	0.07	0.08	0.08	0.00	0.00
	1400	0.10	0.10	0.10	0.00	0.00
	1600	0.13	0.14	0.13	0.00	0.00
	1800	0.15	0.16	0.16	0.00	0.00

2000	0.09	0.09	0.09	0.00	0.00
2200	0.06	0.06	0.06	0.00	0.00
2400	0.04	0.05	0.05	0.00	0.00

According to Table 4, it can be seen that the sound absorption coefficients of the wood-based sandwich panels were different from each other based on the fiber reinforced polymers types and frequency level.

For the wood-based sandwich panels reinforced with BFRP (Group A), the highest SAC values was recorded at 200 Hz (0.67), whereas the lowest SAC value was observed at 2400 Hz (0.05). In the samples reinforced with jute fabric (Group B), the highest SAC occurred at 1200 Hz (0.85), while the lowest was again measured at 2400 Hz (0.06). For the GFRP-reinforced samples (Group C), the SAC reached its peak at 200 Hz (0.55) and its minimum at 1600 Hz (0.07). In the unreinforced samples (Group D), the highest SAC value was identified at 200 Hz (0.53), and the lowest at 2400 Hz (0.05). These results are summarized in Table 4.

ANOVA analysis was performed to determine whether this difference was significant or not. The results of ANOVA analysis of variance are given in Table 5.

Table 5. Summary of the ANOVA results for the sound absorption coefficients values.

Source	Sum of Squares	DF	Mean Square	F Value	P < 0.05)
Corrected Model	5.485 ^a	47	0.117	72.046	0.000
Intercept	10.718	1	10.718	6616.182	0.000
Fiber reinforced Polymers Types (A)	0.319	3	0.106	65.680	0.000
Frequency (B)	2.559	11	0.233	143.598	0.000
AXB	2.607	33	0.079	48.774	0.000
Error	0.156	96	0.002		
Corrected Total	5.641	143			
Total	16.359	144			

a. R Squared = .972 (Adjusted R Squared = .959)

According to the analysis of variance as presented in Table 5, the effects of the main factors including fiber reinforced polymers types (A), frequency (B), and two-way interactions of fiber reinforced polymers types × frequency (A×B) were statistically significant at the level of 0.05. Tukey test was carried out in order to determine these differences. The SAC mean according to independent effects of test variables were given in Table 6,7

The sound absorption coefficients values according to the fiber reinforced polymers types and the homogeneous groups and the results based on these values are given in Table 6.

Table 6. The results from the Tukey's test for fiber reinforced polymers types.

Source of variance	Mean Values (α)	HG
Fabric Jute (Group B)	0.34	A
GFRP (Group C)	0.27	B
BFRP (Group B)	0.26	B
Unreinforced (Group D)	0.21	C

When the comparative results of the fiber-reinforced polymer types were evaluated, the jute-fabric-reinforced samples (Group B) exhibited the highest SAC value. In contrast, the lowest SAC

value among all FRP types was recorded in the unreinforced samples (Group D). A detailed evaluation revealed that the unreinforced (Group D) exhibited lower the SAC values compared with Groups A, B, and C. Among the experimental groups, the wood based sandwich composite materials reinforced with jute fabric (Group B) the highest sound absorption performance (Table 6).

Plywood, as a natural fiber-based material, possesses an intrinsically porous microstructure that facilitates the dissipation of acoustic energy. This internal void network enables incoming sound waves particularly within the mid-frequency range to penetrate the material and interact with its pores, where frictional mechanisms convert sound energy into heat. When plywood is integrated with fiber-reinforced polymers (FRPs), characterized by their high stiffness to weight ratio and superior tensile performance, the resulting hybrid laminates exhibit markedly improved damping capacity. The addition of FRP layers mitigates resonant behavior and reduces structural vibrations, thereby decreasing sound transmission while increasing absorption relative to unreinforced plywood. Moreover, the mismatch in acoustic impedance between the FRP and plywood layers induces multiple internal reflections and scattering events. These additional interfacial boundaries disrupt wave propagation pathways, further augmenting energy dissipation and enhancing the composite's overall acoustic response.

Previous studies reported that carbon-fiber-reinforced configurations generally show limited absorption at low frequencies but demonstrate significant improvements at mid-frequencies (315–1600 Hz), where absorption rates may reach approximately 40% of incident sound [38,48,56]. Investigations of laminated wood composites reinforced with poplar veneers and elastomeric materials such as rubber, sponge, and felt have likewise confirmed that introducing reinforcement materials can significantly enhance acoustic absorption [56,57]. The findings of the present study are consistent with this literature, offering additional evidence for strategies aimed at developing acoustically optimized wood-based composites. In this context, the hybrid plywood-FRP-OSB configuration provides superior multifunctional performance when compared with conventional wood panels, combining enhanced mechanical characteristics with improved acoustic behavior. Furthermore, Çavuş and Kara [58], who evaluated sound transmission across 16 wood species in the 100–1000 Hz range, reported no strong relationship between wood density and mean sound transmission loss; however, they observed that lower-density woods tended to display greater transmission loss at higher frequencies.

The sound absorption coefficients values according to the frequency (Hz) and the homogeneous groups and the results based on these values are given in Table 7.

Table 7. The results from the Tukey's test for frequency (Hz).

Source of variance	Mean Values (α)	HG
200	0.56	A
400	0.45	B
600	0.25	E
800	0.35	C
1000	0.28	DE
1200	0.30	D
1400	0.34	C
1600	0.18	FG
1800	0.15	GH
2000	0.14	H
2200	0.21	F
2400	0.06	I

The SAC values of wood based sandwich panels with reinforced FRP are given Figure 5.

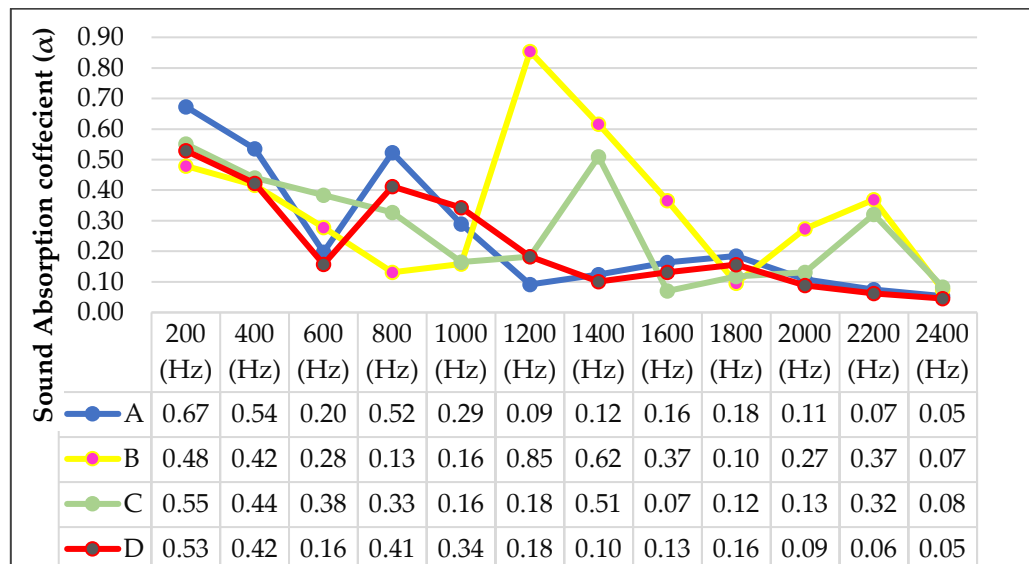


Figure 5. The SAC values of wood based sandwich panels with reinforced FRP.

According to Table 7, when the frequency was compared; the highest SAC values was recorded at 200 Hz ($\alpha=0.58$), while the lowest SAC value was observed at 2400 Hz ($\alpha=0.06$).

A considerable body of research has explored the acoustic behavior of different wood-based panel configurations. Altunok and Ayan [44] analyzed laminated structures composed of Scots pine (*Pinus sylvestris* L.) and iroko (*Chlorophora excelsa*) as surface layers combined with a Uludağ fir (*Abies bornmülleriana* Mattf.) core. Their findings demonstrated that panels manufactured with the lower-density Scots pine exhibited superior sound absorption relative to iroko. For instance, non-perforated Scots pine panels produced absorption coefficients near 0.25 within the 160–200 Hz band, whereas iroko panels recorded values closer to 0.20. Under perforated conditions, Scots pine attained a peak coefficient of approximately 0.60 at 500 Hz, while perforated iroko panels reached roughly 0.50 at 400 Hz. In another study, Karlinasari et al. [59] showed that low-density particleboards displayed diminished absorption below 250 Hz, with coefficients spanning 0.20–0.65 between 250 and 800 Hz and reaching up to 0.90 at 2000 Hz. Medium-density particleboards, by comparison, demonstrated coefficients of 0.20–0.70 in the 1000–1250 Hz range. Similarly, Smardzewski et al. [60] reported a maximum value of 0.65 at 1000 Hz for particleboard panels, noting that only those incorporating Dendrolight cores consistently maintained coefficients between 0.55 and 0.65 at 2000–4000 Hz. This behavior was attributed to the synergistic effect of low-density outer layers and high porosity, which enhances internal friction and energy dissipation. Ivanova et al. [62] found peak absorption within 600–2000 Hz, with a maximum of 0.25 at 1600 Hz. At higher frequencies, Özyurt and Özdemir [56] observed that panels manufactured with elastomeric sponge cores yielded a maximum coefficient of 0.92 at 6300 Hz, whereas unmodified reference panels showed the minimum value of 0.28. Additionally, Muslu (2025) evaluated the influence of cutting orientation and water-based varnish on Scots pine (*Pinus sylvestris* L.) and Eastern beech (*Fagus orientalis* L.), concluding that absorption characteristics in the 500–1000 Hz region were comparable, with the highest coefficient occurring at 5000 Hz ($\alpha = 0.169$). Collectively, these studies affirm that factors such as wood species, panel density, core composition, perforation patterns, and finishing processes play decisive roles in determining the frequency-dependent acoustic performance of wood-based panels.

4. Conclusions

This study systematically investigated the sound absorption performance of wood-based sandwich panels reinforced with BFRP, GFRP, and jute fabrics across low, medium, and high frequency bands. Among all configurations, jute-reinforced panels demonstrated the most pronounced overall absorption capacity. Frequency-dependent variations were observed in the

acoustic behavior of all FRP-reinforced systems. Group B exhibited maximum absorption near 1200 Hz, while the lowest absorption for Groups A and D occurred around 2400 Hz.

Hybrid plywood–FRP–OSB composites exhibited limited low-frequency response due to their stiffness but showed significant improvement at higher frequencies. The best-performing reinforced sample reached its highest absorption near 200 Hz, indicating frequency-dependent damping mechanisms within the multilayered system. Overall, the inclusion of BFRP, GFRP, and jute reinforcements substantially improved the acoustic impedance and damping efficiency of the panels, demonstrating their suitability for noise-control and sound-insulating applications.

These findings confirm that FRP-reinforced wood-based sandwich structures have considerable potential for use in furniture and architectural systems requiring effective acoustic insulation. The results provide a scientific basis for the future design and optimization of next-generation wood–polymer hybrid composites with tailored acoustic characteristics for sustainable engineering and construction applications.

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