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ARTICLE

Investigation the Performance of a Low-Cost Test Box Design Like to the Alpha Cabin for Sound Transmission Loss Tests

Hatice Mehtap Buluklu

Graduate Education Institute, Tarsus University, 33400 Mersin, Turkey

ABSTRACT

Today, noise control is of critical importance. In order to provide sound insulation, parameters such as Sound Transmission Loss (STL) and sound absorption coefficient are measured in environments such as impedance tubes, Alpha Cabin and echo chambers. However, the low number of accredited acoustic test rooms in Turkey and the high-test costs cause these tests to be performed in limited numbers. In this direction, test box similar to the Alpha Cabin designed aims to both reduce costs and perform tests in a healthy way using natural and recyclable materials, and to prevent damage to test devices caused by hard materials. In this study, samples with STL values above 30 dB at 500–8000 Hz. were selected and tested in the designed system. As a result, it was seen that the data were close to each other. The highest value was obtained as 49.13 dB at 4000 Hz. in a 2 cm thick gypsum board, gypsum and concave walnut shell sample (moving surface L_1). This situation provides an important contribution in terms of sound insulation by using natural and recyclable materials and the proposed test box, meeting the experimental criteria at low cost and in the field of noise control.

Keywords: Acoustic; Sound Transmission Loss (STL); Alpha Cabin; Natural Material; Noise

1. Introduction

Today, the sound of the machines used with technological developments brings noise, which is seen as a disadvantage. Noise is known as a factor that can cause negative effects on people's health and work efficiency. In order to reduce noise, products are developed and used in many fields

*CORRESPONDING AUTHOR:
Hatice Mehtap Buluklu, Graduate Education Institute, Tarsus University, 33400 Mersin, Turkey; Email: mehtapbuluklu@gmail.com

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such as engineering, architecture, etc. by taking advantage of the sound absorption properties of various fibers. Some institutions and organizations such as the World Health Organization (WHO) have also conducted studies on this subject. WHO has defined health as a mental and physical state and

publishes scientifically proven guidelines on harmful noise levels for the protection of human health. In 1999, these guidelines, which define noise in various environments, were based on current scientific evidence and aimed to provide guidance for the protection of public health [1].

It is seen that acoustics has an important place in the literature and in many fields in terms of noise reduction. Among these, in a study where it is stated that the type of material used in buildings can be important in sound insulation, research studies on how acoustic performance can be improved using optimization algorithms or control techniques are presented [2]. At this stage, experimental criteria such as Sound Transmission Loss and sound absorption coefficient play a critical role. In the measurement of these criteria, special setups such as impedance tube, Alpha Cabin and reverberation chamber are used. However, high test costs and the damage caused to devices such as impedance tubes by samples with hard characteristics are among the factors that prevent measurements from being made accurately. This situation limits the applicability of acoustic tests. Therefore, overcoming these difficulties has necessitated the development of more economical and ergonomic test methods in the design and testing processes of acoustic materials. As a result, it will be possible to provide noise control and obtain more effective results in sound insulation. In addition, considering that it will be important to analyze multiple test results and make preliminary selections, test box like to Alpha Cabin has been proposed. In addition, the ability to test a large number of samples with different characteristics without damaging the setup is among the advantages that can be considered important.

There are various findings in the literature regarding the tests performed in these setups and the acoustic materials used. One of these is based on the calculation of the results using the Kirchhoff- Helmholtz integral by making measurements in the designed acoustic small-scale anechoic chamber [3]. In another study, a reverberation chamber with a volume of 1.12 m^3 was designed, which allows the testing of 0.3 m^2 samples. In this reverberation chamber, small-sized samples are tested and compared before the production of larger sizes. This approach plays an important role in material selection by providing a small laboratory opportunity in the decision-making process [4]. Such tests and setups make a significant contribution to the evaluation of the effectiveness of sound insulation materials and pave the way for the development of innovative solutions for noise control. A study was conducted to determine the Sound Transmission Loss using four building materials, namely autoclaved aerated concrete (AAC), laminated glass, expanded polystyrene and rock wool in the impedance tube currently in use. When samples with thicknesses of 10 mm and 20 mm were tested in the frequency range of 3000–5500 Hz., they stated that higher Sound Transmission Loss values could be obtained in thicker samples [5]. Different test box designs are also encountered in testing Sound Transmission Loss in the acoustic field. In a study conducted on this subject, the results of samples with different thicknesses tested in accordance with ISO 15186-1 and ISO 717-1 standards were compared with the test results conducted in an anechoic chamber. Since the results were close to each other, it was envisaged that the designed sound reduction box could be developed as an alternative device for acoustic material testing [6]. In a study where a small-sized reverberation chamber was designed to reduce test costs, the acoustic characteristics of prototype noise barriers were determined. The results obtained show that the design provides reliable results for frequencies above 500 Hz. and that its performance is good according to international standards. In addition, the environmental benefits of new materials were emphasized [7]. In a study on the acoustic properties of various materials, multilayered structures were produced using felt, viscoelastic material and four different perforated GYP materials. As a result of testing the sound reduction index in accordance with the standards in the designed test box, it was proven that the sound absorption coefficient in samples obtained from viscoelastic and perforated plates was over 0.5 [8]. There are source and receiver chambers in the test box designed using plywood material for determining the Sound Transmission Loss. When samples prepared from coconut, kenaf and kapok fibers were tested, it was observed that they had lower STL at higher frequencies such as 1 kHz. and 3.15 kHz. compared to lower frequencies such as 125–630 Hz. It was stated that increasing the mass of panels that can be produced from natural fibers is an effective parameter in improving the Sound Transmission Loss [9]. In addition, in a sound insulation box designed as an alternative to an anechoic chamber, 2 cm and 4 cm thick wooden materials were used in tests conducted in accordance with 15186-1 and ISO 717-1 standards. It has been stated that this box offers an alternative method for testing acoustic materials [10]. In a study where the importance of recycled materials was determined, test box was designed and single and multi-layered samples were prepared from different materials. In a designed test box, 50% Polypropylene, 20% Polyethylene Recycled synthetic materials with a blend ratio of Terephthalate (PET) and 30% Hollow PET were preferred and samples with a thickness of 2.45, 3.17 and 3.61 mm and a needle density of 250, 300 and 400 were tested [11]. In a study conducted to determine the sound absorption coefficient, a miniature test box designed as a cube made of compressed multi-layered wooden panels with a volume of 2.8 m^3 was used and the sample was placed in the partition between two rooms [12]. It is understood that such setups provide an effective method to evaluate Sound Transmission Loss at smaller scales. In another study, sound absorption measurements were made in the frequency range of 200–1600 Hz. using felt and silicone-applied felt type materials with thicknesses of 10, 15 and 25 mm. It was observed that different thicknesses were an important parameter affecting sound absorption performance [13]. In another study conducted with natural fibers, test box was designed to measure the sound absorption capacities of samples prepared from wood dust, rice hulls, rice straw and their mixtures [14]. In the study conducted on Sound Transmission Loss, synthetic materials were placed between the gypsum board layers by leaving 75 mm and 100 mm gaps. It has been determined that the highest Sound Transmission Loss value is 50.15 dB at 1000 Hz. when synthetic material is used at 75 mm interval. This experimental box, whose inner surfaces are covered with rock wool, plays an important role in optimizing the sound insulation [15]. In a study conducted in the reverberation chamber and anechoic chamber used in the acoustic field, the sound absorption coefficient and Sound Transmission Loss were tested by creating an ABA (Absorber - Barrier- Absorber) structure with porous materials such as cotton or microfibers. A is defined as sound absorption and B as sound insulation layer, and A is usually porous cotton consisting of superfine fibers or microfibers. In A, when kapok fiber is compared with superfine fibers, it is concluded that kapok fiber, which has a hollow structure, provides better sound absorption and reduces noise to a great extent [16]. These studies emphasize the importance of different material types and structures in terms of the development and application of acoustic materials. In a study where kapok fiber is mixed with fibers such as cotton and wool and combined with rubber waste, which is known to be difficult to decompose in nature, and recycled, sound insulation panels were prepared. As a result of testing these panels in the sound insulation measurement setup they designed, Sound Transmission Loss values of 47 dB, 40 dB and 35 dB were obtained for kapok, wool and cotton, respectively. These values show that kapok fiber is an effective material in sound insulation [17]. In another study, samples prepared using cotton fiber mixtures and microfibers with different porosity and thickness were evaluated in the "Alpha Cabin" test room with a volume of 6.44 m3. In the study conducted in the frequency range of 250 Hz–10 kHz. it was stated that the sound absorption efficiency is related to the thickness of the material and is more effective at high frequencies [18].

In a study where a low-cost Alpha Cabin like test box was designed, products such as carpet, double-layer blanket, 100% natural felt, and cotton material were used for sound insulation. The most efficient sound insulation in insulation was provided with 100% natural felt. In addition, various materials such as acoustic facade panel, recycled polyester felt, acoustic flat sponge, and egg sponge of different thicknesses were used in testing Sound Transmission Loss [19]. With the development of this design, many experiments were conducted in the 500-8000 Hz. frequency range (most commonly used in the architectural field). When the results of synthetic samples obtained from different companies are compared with measurements carried out in laboratories or test rooms, it shows that like values can be obtained. In addition, samples were prepared and tested with new acoustic materials that are sensitive to human health and have low carbon emissions, grown in Turkey, do not harm the quality of interior spaces, and can be used in the industry. In particular, as a result of obtaining Sound Transmission Loss values of 63,27 dB in conifer and egg- shaped samples and 62,41 dB in concave walnut shell and egg-shaped samples, it has been determined that these types of natural materials have high acoustic performances. It has been supported by comparative analyses that these developed natural materials can be alternatives to synthetic materials available on the market [20]. This situation encourages the use of natural materials in the industry by showing their usability and effectiveness, and by providing environmentally sustainable solutions for natural materials produced from renewable resources that can be recycled in the acoustic field. It is concluded that it can also provide significant advantages in terms of health.

Although there are existing test setups and methods in the literature, it has been observed that their use is limited due to the high-test costs. This study aims to overcome the limitations of high-test costs in applications. Therefore, a setup like to the test box such as Alpha Cabin, but in smaller sizes, was designed and its efficiency was examined.

In this study, it is important to choose environmentally friendly and recyclable materials for experimental studies in this system to reduce carbon gas emissions. For this reason, the hypothesis of the study was based on the hypothesis that recyclable natural materials, which can constitute an advantage over synthetic materials, can provide high Sound Transmission Loss. Cones and walnut shells, which are the fruits of pine trees that grow extensively in the Mediterranean region, were selected as materials. The samples created with gypsum and gypsum board were tested in the test box designed similar to the Alpha Cabin and it was aimed to achieve high Sound Transmission Loss. Therefore, it will be possible to conduct multiple tests at low-cost for the pre-selection of samples that can be effective in providing Sound Transmission Loss. And so, pre-studies can be carried out at low-cost to propose products that are sensitive to human health and can provide environmentally friendly Sound Transmission Loss.

In order to present the study systematically and to provide a clear evaluation of the information obtained, each of the five sections in the study has been detailed. Accordingly; in the first section, previous studies and current information in the field of acoustics have been evaluated. In the second section, the issue of sound and noise and the importance of acoustic insulation have been discussed. In the third section, information on the test box designed like to the Alpha Cabin has been given, and the method used in the testing process has also been mentioned. In the fourth section, the results obtained from the study have been focused on and suggestions have been made for future studies. In the fifth section, the findings of the study have been discussed in detail, and the meaning and importance of the obtained data have been emphasized.

In the literature and in the market, it is seen that different methods, natural and synthetic fibers or materials containing chemicals are preferred for the prevention of noise.

In this study, the aim is to develop new acoustic materials from natural materials grown in Turkey that are sensitive to human health, have low carbon emissions, are recyclable, do not harm indoor quality and can be used in the industry. As a result of the comparative analysis of the Sound Transmission Loss values of these materials with synthetic materials on the market, it has been understood that they can be an alternative to synthetic materials.

Also, this study supports the usability of the low-cost Alpha Cabin like test box in acoustic tests and provides a practical approach for the development of new acoustic materials. Such innovative designs can contribute to the development of acoustic insulation solutions in both research and industrial applications.

2. Sound and Noise

There are important studies in the literature on sound and noise. (Crocker, 1998) defined acoustics

as the science of sound and sound as the pressure change transmitted to the receiver through fluids [21]. Noise has a subjective feature and is expressed as unwanted sound [22]. Health problems occur depending on the duration of exposure to noise. According to ILO (International Labour Organization) standards, it is stated that the working time at 85 dB level is 8 hours. If the data obtained from noise measurements exceed 85 dB (A), it is recommended to prepare noise maps in workplaces [23]. Because noise can cause various damages in terms of worker health and work safety.

For example, the damage caused by unwanted disturbing sound in the inner ear is given in **Figure 1** [24].

Figure 1 shows that it may become impossible to hear loud sounds due to complete damage to the inner ear layer and approximately one third of the nerve endings found there. Such information helps to better understand the effects of sound and noise and prepares the ground for taking precautions in this regard. In a study conducted on this subject, it is stated that "The behavior of sound waves when they encounter materials found in nature should be determined and analyses should be conducted in search of new solutions." In this context, it is stated that acoustic waves hit various layers while moving in the air environment from the moment they emerge from the source and the pressure and speed values they create on the surface in these layers are examined [25]. Sound pressure is defined as the change in time and intensity of the air pressure generated by the sound source mixed with the air pressure in the atmosphere. Sound pressure is measured in Pascal (Pa (N/m^2)). The sound pressure, whose unit is decibel (dB, decibel), is expressed with LP and is calculated with the formula in Equation (1). The Po reference pressure for the sound pressure level in air is 20 x 10^{-6} Pa [26].

Figure 1. Damage caused by disturbing sound in the inner ear [24].

$$L_P = 10 \log \frac{P}{P_o} \quad (1)$$

L_P: Sound pressure in dB

P: Measured sound pressure

P_o: Reference sound pressure

The power of sound energy emitted by a sound source is the sound pressure level (sound power or acoustic power) and is expressed in watts. The reference power level Wo = 10–12 watts and the sound power level in dB (LW) is calculated with the formulas in Equation (2) [25] and measured with a sound level meter [27].

$$L_W = 10 \log \frac{W}{W_o} \quad (2)$$

L_W: Sound power in dB

W: Measured sound power

W_o: Reference power level

Frequency plays an important role in the measurement of sound pressure level. Frequency is defined as the number of vibrations occurring in one second and its unit is Hertz [28]. The sounds heard generally consist of many frequencies, but the lowest among these frequencies is the fundamental frequency (fundamental tone) [29]. Depending on the frequency, the amount of sound absorption or Sound Transmission Loss has an important share in the measurement of sound pressure level. Sound Transmission Loss values in building materials vary depending on many variables. The most important of these differences is the frequency of the sound. While the Sound Transmission Loss value of low frequency (bass) sounds is generally low, a tendency for increased Sound Transmission Loss is observed when the frequency increases or the sound becomes higher. **Figure 2** shows the change in the Sound Transmission Loss of a panel with frequency [30].

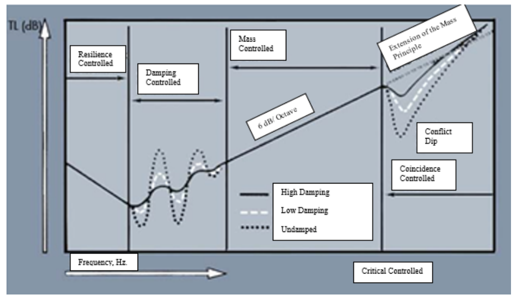


Figure 2. Variation of Sound Transmission Loss of a panel with respect to frequency [30].

In **Figure 2**, it is seen that the Sound Transmission Loss of the structural elements increases as the frequency increases. However, at a frequency called the overlap frequency or critical frequency, the Sound Transmission Loss suddenly drops rapidly and forms the overlap pit. This frequency is the frequency at which the wavelength of the sound wave in the air is equal to the wavelength of the vibration wave in the panel. Since the panel acts as a sound source at the overlap frequency, a decrease in the Sound Transmission Loss is observed. Although there is no analytical expression for determining this frequency, empirical approaches are developed for some materials. The overlap frequency is determined experimentally and the direction of the sound emission is parallel to the surface of the panel. For example, in steel panels, this frequency is inversely proportional to the thickness of the panel. The amount of damping present in the panel is a factor that determines the size of this pit. If the damping ratio of the panel material is high, the decrease in the overlap frequency is less [30]. In this respect, the selection of the type of material is an important factor. In noisy environments, there may be people who have difficulty in understanding speech, while there are also those who have less problems. This situation emphasizes the importance of acoustic design [31]. Experimental determination of the acoustic properties of structures with high noise levels, especially in urban areas and places with heavy traffic, has become increasingly important due to the demand for suitable materials. It makes an important contribution to noise management and ensuring indoor comfort[32].

3. Materials and Methods

In the material section, information is given about the test box designed like to the Alpha Cabin, while the method followed in conducting the tests is mentioned in the method section. Accordingly, the flowchart of this study is given in **Figure 3**.

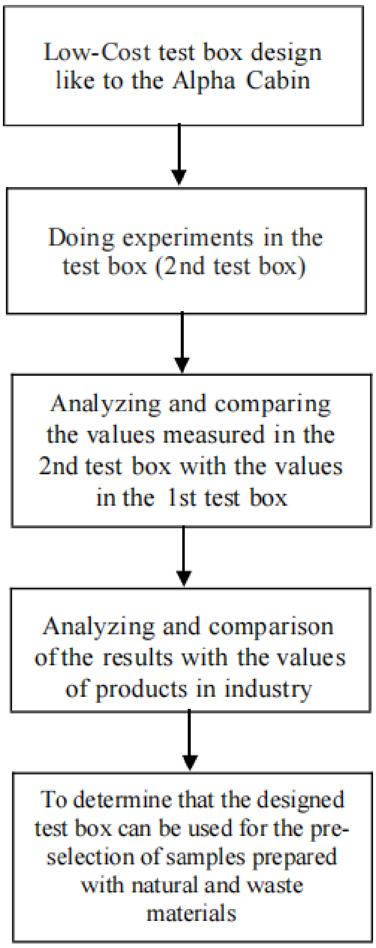
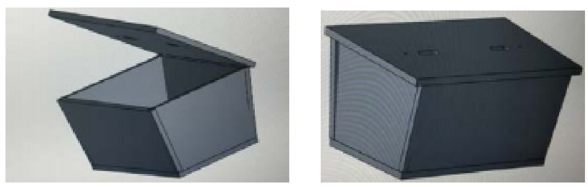


Figure 3. The flowchart of this study.

In this study, firstly, test box like to the Alpha Cabin was designed according to the workflow given in **Figure 3**. The Sound Transmission Loss of samples prepared with recyclable materials from nature was measured and comparative analysis was made.

3.1. Material

In this study, test box like to the Alpha Cabin was designed. In the production of the designed setup, MDF (Medium Density Fiberboard), plywood was used on the inside. In order to provide sound insulation during the production phase of the test box, thickness 10 mm, 100% natural wool felt with a density of 100 kg/m^3 was placed between MDF and plywood. Inner, outer surfaces and the lid were covered with this felt. The most important reason for preferring felt is that in the study conducted by Buluklu et al., efficient results could be obtained both in the isolation study and in the measurements in the box with many different materials such as polar, carpet flex and styrofoam in the experimental box designed and developed[19]. During the experimental studies, care was taken not to have parallelism in order to prevent the formation of nodes (sound nodes). In **Figure 4a,b**, the floor, height dimensions and volume of the test box like to the Alpha Cabin, whose lid is open and closed are approximately 50x100x50 (widthxlengthxheight, in cm) and its volume is 0.226 m^3 respectively.



(a) **(b)**

Figure 4. View of the test box like to the Alpha Cabin; (**a**) with the lid open and (**b**) with the lid closed (Drawing made by Mechanical Engineer Abdulkadir Demez).

The inner and outer surfaces and the cover of the test box, shown with the cover open and closed in **Figure 4a,b**, are covered with felt used between MDF and plywood. The opening of the test box is given in **Figure 5**.

Sound Pressure Levels (SPL, Sound Pressure Level) were tried to be measured between the inside and outside of the test box, the expansion of which is given in **Figure 5**. Measurements are made through the openings on the cover of the test box. The wide openings are used as sound sources (loudspeakers) and the round openings are used as receivers (measuring device or microphone). After the inner, outer and cover sections of the test box were covered with %100 natural felt, the background sound pressure level was measured. In measuring the Sound Pressure Levels (SPL, measurement device), TASI- TA8151 (Digital sound level meter) device was preferred. In the measurement of Sound Pressure Levels, "Sound meter-Decibel and noise meter", in the measurement of frequency, "Frequency Generator" programs were loaded to the devices used as sound source and receiver. In the test box like to the Alpha Cabin, in order to provide sound insulation, a single material was tried to be used in order to reduce the cost and 100% natural felt was preferred. In addition, it was shown that felt was efficient in the samples prepared with natural materials to provide Sound Transmission Loss and in the coating of the designed test box [20]. Therefore, in this study, the test box prepared using felt is given in **Figure 6**.

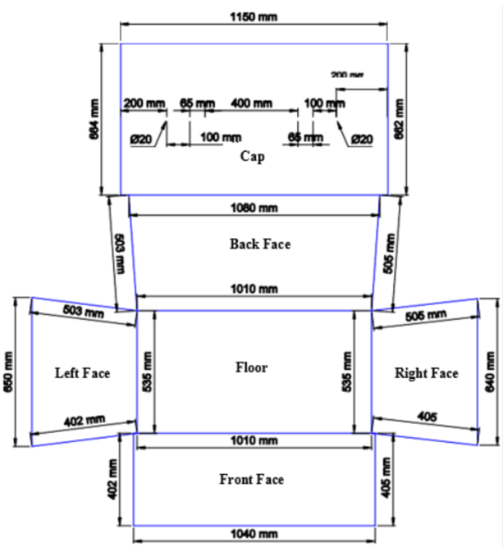


Figure 5. Expansion of the test box like to the Alpha Cabin. (Drawing made by Mechanical Engineer Abdulkadir Demez).

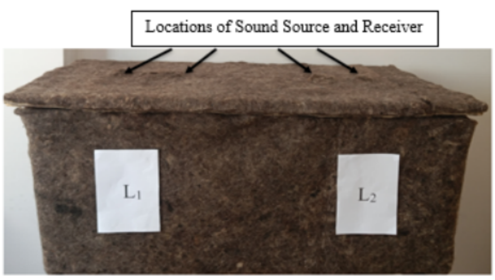


Figure 6. Visual of the test box like to the Alpha Cabin covered with %100 natural felt.

Background noises were measured in the test box and the room where the setup was located, as shown in **Figure 6**. It is known that background noises are common in daily environments such as homes, workplaces, schools, transportation, etc. [31]. In this study, measuring background noises before starting the experimental studies was considered important because background sound levels would affect the experimental process and experimental results. Accordingly, since the sound pressure level in the room where the setup was located was measured as approximately 37 dB, it was predicted that it could be done healthily. In addition to background sound levels, white and pink noise were also measured. Accordingly, the average values of white and pink noise measured before and after covering the test box with felt are given in **Table 1**.

When the average values of white and pink noise (measured before and after felt covering) shown in **Table 1** are compared, it is seen that %100 natural felt can provide sound insulation at the desired level. Background noises were determined to be 37.1–38 in the room before felt covering and 36.7–37.2 dB in the test box, and 36.1–36.9 in the room after felt covering and 35.2–35.6 in the test box.

3.2. Method

In the test box, experiments were carried out in the range of 500–8000 Hz. known as the mid- frequency range of the human voice. The sample location area in the test box, the visual of the L1 and L2 rooms are given in **Figure 7**.

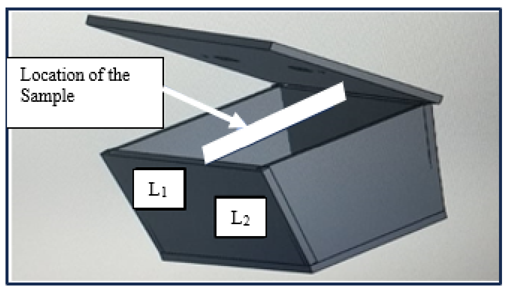


Figure 7. Sample placement area in the test box, visual of rooms L1 and L2.

As seen in **Figure 7**. when the sample is placed, L1 and L2 chambers (source chamber and receiver chamber) are formed. By placing the loudspeaker and measurement device in the openings in the cover corresponding to these chambers, Sound Transmission Loss values can be calculated approximately. Measurements are made by taking into account the measurement system defined in ISO 15186, ISO 140-3 and ISO 140-5 standards. The schematic view of the structure matching the L1 and L2 chambers in the test box according to the standard is given in **Figure 8** [33].

Table 1. Measurement results according to whether the sound source and receiver are inside or outside the designed test box like to the Alpha Cabin.

Serial No	Sound Source (Speaker)	dB Measuring Device	Before Being Covered with Felt		After Being Covered with Felt	
			White Noise Average (dB)	Pink Noise Average (dB)	White Noise Average (dB)	Pinkes Noise Average (dB)
1	Inside the mechanism	Inside the mechanism	95. 1–95.7	92.9–93.4	76.2–76.5	67.5–68.3
2	Inside the mechanism	Outside the system	76–76.6	75.5–76	56.9–57.6	55.9–56.1
3	Outside the system	Inside the mechanism	64. 1–64.8	65.5–66.7	49.5–50.5	51.5–52.3
4	Outside the system	Outside the system	86–86.6	84.7–85.3	78.9–80.2	79.8–81.1

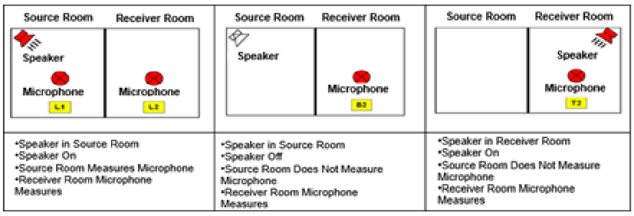


Figure 8. Schematic view of the structure matching the L1 and L2 rooms in the test box according to the standard [33].

The measurement results made with natural materials were analyzed according to the measurement system shown in **Figure 8**. The formula used to calculate the Sound Transmission Loss values in theoretical calculations is given in Equation (3) [34].

$$R = L1 - L2 + 10.\log(S/A) \qquad (3)$$

L1: Average sound pressure level in the source room (dB)

L2: Average sound pressure level in the receiver room (dB)

S: Surface area of the test material (m^2)

A: Equivalent absorption area in the receiver room (m^2)

Sound Transmission Loss values are calculated theoretically from the formula given in Equation (3) and can be compared with experimental results and analyzed.

4. Results

The samples used in the test box and the results of the experiments performed with these samples are given below.

In the test box designed like to Alpha Cabin; 2 cm thick gypsum board, gypsum and conifer (on L1 and L2 of the movable surface), 2 cm thick gypsum board, gypsum and concave walnut shell (on L1 and L2 of the movable surface), 4 cm thick gypsum board, gypsum and egg-shaped conifer (on L1 and L2 of the movable surface), heraclite and %100 natural felt samples with like appearance on both surfaces were tested. In the samples prepared with gypsum board and gypsum, one surface was defined as "*movable surface*" because it was conifer, walnut and egg-shaped, and the other surface was flat. For this reason, the movable surface was placed facing the L1 and L2 rooms and tested in the 500–8000 Hz. frequency range in the 8-band frequency range in the literature. In the test box, the use of a small number of materials in production and insulation was preferred in order to reduce the cost. Sound Transmission Loss values of the tested samples are given in **Table 2**.

Table 2. Sound Transmission Loss values of the tested samples.

Frequency (Hz.)	STL Value (L1 - L2)	STL Value (L2 - L1)
500	6,30	20,97
1000	26,37	17,70
2000	29,13	32,93
4000	32,67	40,07
8000	35,90	28,03

2 cm thick gypsum board, gypsum and conifer sample (movable surface L_1)

Frequency (Hz.)	STL Value (L1 - L2)	STL Value (L2 - L1)
500	7,13	19,27
1000	17,83	17,43
2000	22,80	27,03
4000	31,90	43,07
8000	30,63	30,30

2 cm thick gypsum board, gypsum and conifer sample (movable surface L_2)

Frequency (Hz.)	STL Value (L1 - L2)	STL Value (L2 - L1)
500	8,57	23,53
1000	15,13	18,73
2000	24,73	22,30
4000	49,13	33,80
8000	31,13	26,90

2 cm thick gypsum board, gypsum and concave walnut shell sample (movable surface at L_1)

Frequency (Hz.)	STL Value (L1-L2)	STL Value (L2-L1)
500	3,23	10,97
1000	14,20	15,53
2000	27,87	22,83
4000	37,93	32,40
8000	33,90	31,33

2 cm thick gypsum board, gypsum and concave walnut shell sample (movable surface at L_2)

Frequency (Hz.)	STL Value (L1 - L2)	STL Value (L2 - L1)
500	4,27	8,37
1000	24,13	15,57
2000	25,37	23,27
4000	41,83	38,50
8000	23,57	29,17

4 cm thick gypsum board, gypsum and egg-shaped conifer sample (movable surface L_1)

Frequency (Hz.)	STL Value (L1-L2)	STL Value (L2 -L1)
500	5,47	13,47
1000	17,90	26,50
2000	29,13	23,70
4000	38,53	35,93
8000	40,37	31,33

4 cm thick gypsum board, gypsum and egg-shaped conifer sample (movable at L_2)

Frequency (Hz.)	STL Value (L1- L2)	STL Value (L2- L1)
500	7,13	21,60
1000	9,33	9,43
2000	16,00	24,87
4000	6,33	13,30
8000	18,07	25,63

Heraclite (both surfaces have like appearance)

Frequency (Hz.)	STL Value (L1-L2)	STL Value (L2-L1)
500	11,87	12,37
1000	19,10	26,17
2000	9,53	6,57
4000	34,67	30,50
8000	29,47	26,90

%100 Natural felt (both surfaces have like appearance)

Table 2 shows that in general, values of 30 and above can be obtained at frequencies of 2000 Hz. and above. Among these, it has been observed that in samples with 2 cm thickness of gypsum board, gypsum and conifer (in case the movable surface is at L1 and L2) and 2 cm thickness of gypsum board, gypsum and concave walnut shell (in case the movable surface is at L1) the Sound Transmission Loss values can be approximately 40 dB and above at a frequency of 4000 Hz. in the 4 cm thick gypsum board, gypsum and egg-shaped conifer sample; it has been observed that the highest value of 41.83 dB can be obtained at a frequency of 4000 Hz.

on the movable surface L1 and the highest value of 40.37 dB can be obtained at a frequency of 8000 Hz. on the movable surface L2. Among the samples with the same appearance on both surfaces, it was determined that the highest value was 25.63 dB at 8000 Hz. in heraclite and 34.67 dB at 4000 Hz. in %100 natural felt. It was predicted that increasing the samples thickness may contribute positively to the increase in Sound Transmission Loss. While increasing the thickness of the samples, the sound absorption area was increased in the samples with rough surfaces formed with reduced cones placed on the gypsum board with gypsum and in the samples prepared with concave walnut shells and egg-shaped specimens with cones. It was found that these surfaces created in different shapes can provide better Sound Transmission Loss values at high frequencies. It was also found that higher values can be obtained at higher frequencies depending on the wavelength of the frequency and the area of the chambers in the test box. The graphs of the Sound Transmission Loss values given in **Table 2** are given in **Figure 9**.

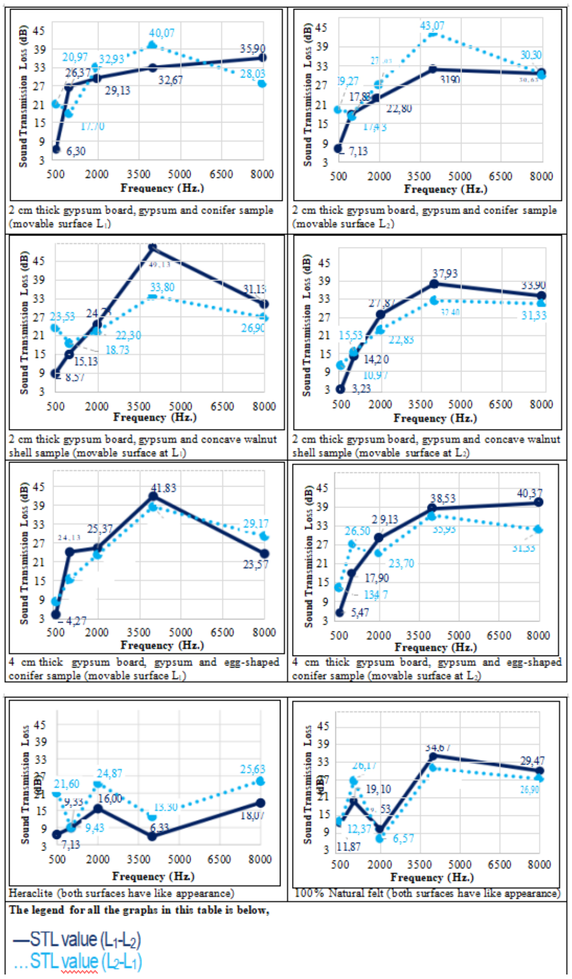


Figure 9. Graphs of Sound Transmission Loss values.

Figure 4, it was determined that the Sound Transmission Loss values could be close to each other if the moving surface was at L1 and L2. It was understood that the difference at 500 Hz. in heraclite, where both surfaces had the same appearance, could be due to the distribution of the gaps on the surface. In 100% natural felt, the Sound Transmission Loss values could be obtained at approximately 20 Hz. and above after 1000 Hz. (**2nd setup)** designed in this study is given in **Table 3**, compared with the Sound Transmission Loss values[20] given in **Figure 9** (**1st setup**).

Table 3. Comparison of Sound Transmission Loss values measured in the 2nd and 1st test boxes.

Frequency (Hz.)	STL Value in 2nd Test Box (L1 – L2)	STL Value in 2nd Test Box (L2 - L1)	STL Value in 1st Test Box (L1 – L2)	STL Value in 1st Test Box (L2 - L1)
500	6,30	20,97	4,54	6,74
1000	26,37	17,70	19,47	15,72
2000	29,13	32,93	29,25	22,68
4000	32,67	40,07	37,96	35,12
8000	35,90	28,03	36,85	41,40

2 cm thick gypsum board, gypsum and conifer sample (movable surface L1)

Frequency (Hz.)	STL Value in 2nd Test Box (L1 – L2)	STL Value in 2nd Test Box (L2 - L1)	STL Value in 1st Test Box (L1 – L2)	STL Value in 1st Test Box (L2 - L1)
500	7,13	19,27	15,85	17,36
1000	17,83	17,43	30,11	18,38
2000	22,80	27,03	17,29	19,89
4000	31,90	43,07	34,57	47,23
8000	30,63	30,30	43,25	42,85

2 cm thick gypsum board, gypsum and conifer sample (movable surface L2)

Frequency (Hz.)	STL Value in 2nd Test Box (L1 – L2)	STL Value in 2nd Test Box (L2 - L1)	STL Value in 1st Test Box (L1 – L2)	STL Value in 1st Test Box (L2 - L1)
500	8,57	23,53	16,9	15,27
1000	15,13	18,73	32,3	23,52
2000	24,73	22,30	29,79	29,31
4000	49,13	33,80	22,36	32,98
8000	31,13	26,90	32,69	44,02

2 cm thick gypsum board, gypsum and concave walnut shell sample (movable surface at L1)

Frequency (Hz.)	STL Value in 2nd Test Box (L1 – L2)	STL Value in 2nd Test Box (L2 - L1)	STL Value in 1st Test Box (L1 – L2)	STL Value in 1st Test Box (L2 - L1)
500	3,23	10,97	15,53	15,44
1000	14,20	15,53	35,52	21,14
2000	27,87	22,83	24,98	29,6
4000	37,93	32,40	39,36	29,86
8000	33,90	31,33	35,52	44,81

2 cm thick gypsum board, gypsum and concave walnut shell sample (movable surface at L2)

Frequency (Hz.)	STL Value in 2nd Test Box (L1 – L2)	STL Value in 2nd Test Box (L2 - L1)	STL Value in 1st Test Box (L1 – L2)	STL Value in 1st Test Box (L2 - L1)
500	4,27	8,37	23,48	22,26
1000	24,13	15,57	18,89	19,7
2000	25,37	23,27	27,12	27,88
4000	41,83	38,50	37,39	33,86
8000	23,57	29,17	41,04	35,13

4 cm thick gypsum board, gypsum and egg-shaped conifer sample (movable surface L1)

Frequency (Hz.)	STL Value in 2nd Test Box (L1 – L2)	STL Value in 2nd Test Box (L2 - L1)	STL Value in 1st Test Box (L1 – L2)	STL Value in 1st Test Box (L2 - L1)
500	5,47	13,47	17,98	16,95
1000	17,90	26,50	40,05	24,15
2000	29,13	23,70	32,98	40,45
4000	38,53	35,93	37,98	33,08
8000	40,37	31,33	41,54	39,85

4 cm thick gypsum board, gypsum and egg-shaped conifer sample (movable surface at L2)

Frequency (Hz.)	STL Value in 2nd Test Box (L1 – L2)	STL Value in 2nd Test Box (L2 - L1)	STL Value in 1st Test Box (L1 – L2)	STL Value in 1st Test Box (L2 - L1)
500	7,13	21,60	11,52	17,74
1000	9,33	9,43	20,06	9,73
2000	16,00	24,87	35,29	15,71
4000	6,33	13,30	17,58	17,31
8000	18,07	25,63	18,74	8,37

Heraclite (both surfaces have like appearance)

Frequency (Hz.)	STL Value in 2nd Test Box (L1 – L2)	STL Value in 2nd Test Box (L2 - L1)	STL Value in 1st Test Box (L1 – L2)	STL Value in 1st Test Box (L2 - L1)
500	11,87	12,37	7,41	7,87
1000	19,10	26,17	13,84	22,57
2000	9,53	6,57	7,87	5,59
4000	34,67	30,50	25,15	23,37
8000	29,47	26,90	25,37	20,77

%100 Natural felt (both surfaces have like appearance)

When the graphs in **Table 3** are examined, it is seen that although the Sound Transmission Loss values at some frequencies are better in the 1st setup, the data is generally better in the 2nd setup. The graphs of the compared data are given in **Figure 10**.

In the graphs in **Figure 10**, it is seen that the measurement results are close, higher than each and mostly values above 40 dB can be obtained.

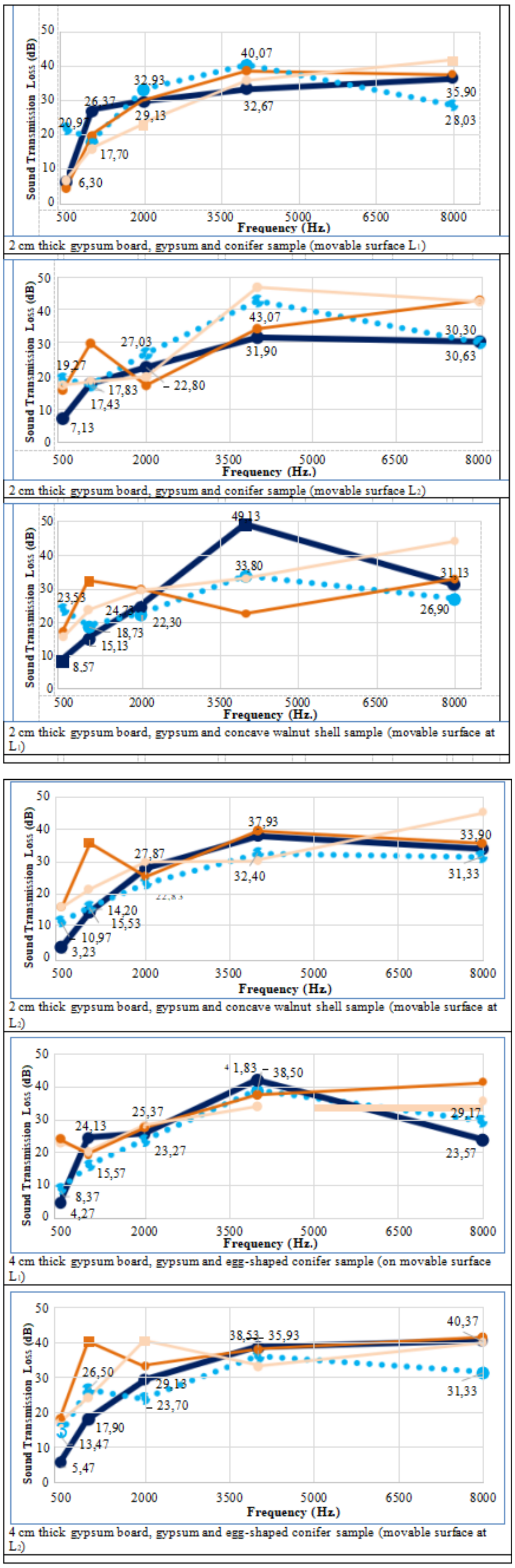


Figure 10. *Cont.*

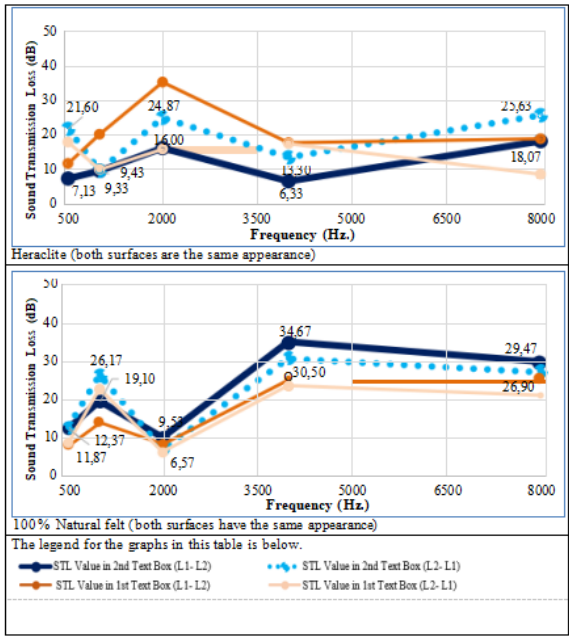


Figure 10. Comparative graphs of Sound Transmission Loss values measured in the 2nd and 1st test boxes.

In 2 cm thick gypsum board, gypsum and conifer sample; (moving surface is at L1) in the 2nd setup, the L2-L1 value is 20.97 dB at 500 Hz. and the highest value is 40.07 dB at 4000 Hz. in the 1st setup, it is over 40 dB at 8000 Hz. and in the 2nd setup, it is over 40 dB at 4000 Hz. in the same sample, when the moving surface is at L2, values over 40 dB at 4000 Hz. can be obtained in both setups,

2 cm thick gypsum board, gypsum and concave walnut shell sample; (moving surface is at L1); in the 2nd setup, the L1-L2 value at 4000 Hz. is 49.13 dB, in the 1st setup, the L2-L1 value at 8000 Hz. is 44.02 dB, when the moving surface is at L2, the values are very close in both setups. In the 1st setup, the L2-L1 value at 8000 Hz. is 44.81 dB, in the 2nd setup, it is close to 40 dB at 4000 Hz. *4 cm thick gypsum board, gypsum and egg-shaped conifer sample;* (on movable surfaces L1 and L2) in both setups, L1-L2 and L2- L1 values are 20 dB and above at frequencies of 1000 Hz. and later. In the 1st setup (on movable surface L2) they are over 40 dB at 1000, 2000 and 8000 Hz. at 4000 Hz. (on movable surfaces L1 and L2), L1 -L2 and L2-L1 values are over 30 dB, and in the 2nd setup (on movable surfaces L2) the L1 -L2 value is 40,37 dB at 8000 Hz.

In the Heraclite sample; the highest values were found as 25.63 dB in L2 -L1 at 8000 Hz. in the 2nd setup, and 35.29 dB in L1 -L2 at 2000 Hz. in the 1st setup. The differences in the 500–8000 Hz. frequency range may be due to the fact that both surfaces of the sample are flat and have a like appearance, but the number of voids on the surfaces and their distribution vary.

In the %100 natural felt sample, both surfaces have the same appearance, in the 500–8000 Hz. range, the results in the 2nd setup were slightly higher than the values in the 1st setup. The highest value in the 1st setup was 25.37 dB, and in the 2nd setup, values over 30 dB could be obtained at 4000 Hz.

Sound Transmission Loss values over 30 dB, 2 cm thick gypsum board, gypsum and conifer, 2 cm thick gypsum board, gypsum and concave walnut shell, 4 cm thick gypsum board, gypsum and egg-shaped, heraclite and 100% natural felt samples were tested. The fact that most of the results obtained in both test boxes were close and some were higher showed that the setup designed in this study could be effective in tests conducted to determine Sound Transmission Loss.

In the 2nd text box within the scope of this study, when the movable surfaces were placed facing rooms L1 or L2, it was observed that the highest values were at frequencies of 4000–8000 Hz. Especially, it was observed that 2 cm thick gypsum board, gypsum and conifer sample (movable surface L2) was 43.07 dB at 4000 Hz. and 2 cm thick gypsum board, gypsum and concave walnut shell sample (movable surface L1) was 49.13 dB at 4000 Hz.

Among the values given in **Table 3**, those with high Sound Transmission Loss values measured in the 2nd experimental box were taken. The comparison of the samples tested within the scope of the study with the Sound Transmission Loss of products in the market (19 cm pumice block wall, 20 cm gas concrete wall, horizontal perforated 19 cm unplastered brick wall, vertical hole 19 cm unplastered brick wall, 10 cm brick, 20 cm clinker block with holes)[35] is given in **Table 4**.

The graph comparing the Sound Transmission Loss values of the samples in the study with the products used in the market compared in **Table 4** is given in **Figure 11**.

In **Figure 11**, it is seen that the following data can be obtained when the approximate test results of the samples prepared in the study are compared with the products with natural ingredients in 10, 19 and 20 cm thicknesses from the products used in the market.

At 2000 Hz. frequency, the 19 cm thick pumice block wall sample is 24,7 dB and the "2 cm thick gypsum board, gypsum and conifer sample (movable surface L2)- (L2-L1)" sample is approximately 27.03 dB.

Table 4. The comparison of the samples tested within the scope of the study with the Sound Transmission Loss of products in the market.

Frequency (Hz.)	19 cm pumice block wall	20 cm gas concrete wall	Horizontal perforated 19 cm unplastered brick wall	Vertical hole 19 cm unplastered brick wall	10 cm brick	20 cm clinker block with holes	2 cm thick gypsum board, gypsum and conifer sample (movable surface L_2)- (L_2-L_1)	2 cm thick gypsum board, gypsum and concave walnut shell sample (movable surface at L_1)- (L_1-L_2)	2 cm thick gypsum board, gypsum and concave walnut shell sample (movable surface at L_2)- (L_1-L_2)	4 cm thick gypsum board, gypsum and egg-shaped conifer sample (movable surface L_1)- (L_1-L_2)	4 cm thick gypsum board, gypsum and egg-shaped conifer sample (movable surface L_1)- (L_2-L_1)	4 cm thick gypsum board, gypsum and egg-shaped conifer sample (movable at L_2)- (L_1-L_2)	%100 Natural felt (L_1-L_2)	%100 Natural felt ((L_2-L_1)
500	11,2	31,6	38,9	37	37	33	19,27	8,57	3,23	4,27	8,37	5,47	11,87	12,37
1000	13,7	29,8	44,8	40,1	37	39	17,43	15,13	14,2	**24,13**	15,57	17,90	19,1	26,17
2000	24,7	35,9	46,3	41,9	37	45	**27,03**	**24,73**	**27,87**	**25,37**	**23,27**	**29,13**	9,53	6,57
4000	28,6	36,1	47,7	42	43	51	**43,07**	**49,13**	**37,93**	**41,83**	**38,5**	**38,53**	**34,67**	**30,5**
8000	Measurements at these frequencies have not been encountered in the literature.						30,3	31,13	33,9	23,57	29,17	**40,37**	29,47	26,9

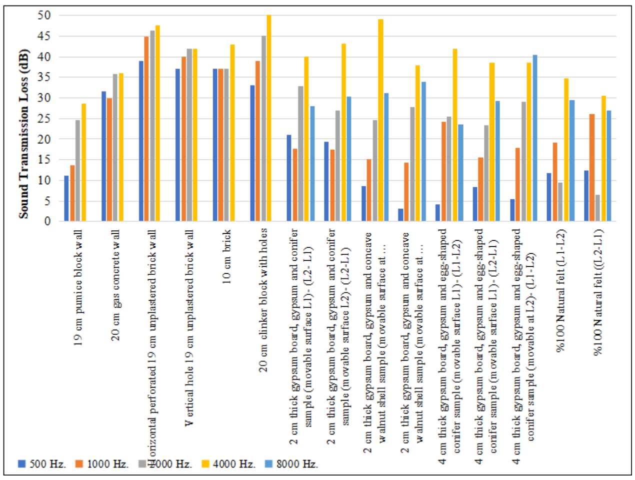


Figure 11. Comparison of Sound Transmission Loss values with the samples in the scope of the study with the products in the market.

At 4000 Hz. frequency, it is approximately 49.13 dB for the "2 cm thick gypsum board, gypsum and concave walnut shell sample (movable surface at L1)- (L1-L2)" sample, which is higher than the Sound Transmission Loss values of the products used in the market.

Although the samples tested in the study were thinner than the products on the market, it was determined that close values, 40 dB value could be reached when measured at 8000 Hz. frequency. When different composite structures are created with the samples tested in this study and Sound Transmission Loss is measured, similar to the study by Buluklu et al.[36], it was understood that values of 55–65 dB can be obtained. Therefore, the test box like to the Alpha Cabin designed within the scope of the study will be able to make preliminary selections of samples that can provide Sound Transmission Loss.

5. Discussion

proportions appropriate to the standard. The purpose of the test box like to the Alpha Cabin designed within the scope of the study is to enable testing of multiple samples to measure Sound Transmission Loss and to be able to offer more material suggestions at low-cost. For the isolation process of the setup box, %100 natural felt (it has a tight surface due to being a non-woven surface), which was seen to contribute to Sound Transmission Loss in the study conducted by Buluklu et al., was used extensively. In the study conducted by Buluklu et al.[36], some of the samples with Sound Transmission Loss values over 30 dB in the experimental box designed and developed like to low- cost Alpha Cabin were tested in this study and the results were compared. In addition, a minimum number of materials were preferred in order to be able to produce and isolate the setup at low-cost. It was predicted that increasing the samples thickness may contribute positively to the increase in Sound Transmission Loss. While increasing the thickness of the samples, the sound absorption area was increased in the samples with rough surfaces formed with reduced cones placed on the gypsum board with gypsum, and in the samples prepared with concave walnut shells and egg-shaped specimens with cones. Depending on the chamber areas of the test box designed in this study, the wavelength of the frequency and the surface structure of the samples, better Sound Transmission Loss values can be obtained at high frequencies.

A comparison with products on the market shows that the specimens in the study can achieve values close to 50 dB. When composite structures with natural content are prepared and tested with these samples, it is predicted that new acoustic materials with higher Sound Transmission Loss values, as in 1st test box can be produced.

These results show that natural materials that are recyclable, sensitive to human health and have low carbon emission can be tested effectively.

As a result, test box like to the Alpha Cabin will provide more research and application opportunities on sound insulation so that testing can be done more practically, in less time and at low-cost.

6. Conclusions

When the measurements made in the frequency range of 500-8000 Hz. were evaluated, it was seen that the values in the 2nd setup could be higher, although they were mostly close to the test results in the 1st setup. It was also determined that the reason why some values were not close could be due to the differences in the size of both setups and the materials used in sound insulation.

The structure and findings of the study were discussed in detail.

I. It is shown that test box like to the Alpha Cabin can be designed and developed. It is emphasized that it offers an alternative method for acoustic tests.
II. It has been understood that the developed system can provide savings in terms of time and cost, with the possibility of making preliminary selections through numerous tests before proceeding to the testing process under laboratory conditions.
III. The samples are being transported to acoustic laboratories can be prevented. This is a factor that increases the reliability of the test results.
IV. It is anticipated that the Sound Transmission Loss values of many recyclable materials from nature can be determined and that this can contribute to human health and literature.

As a result, it is envisaged that samples prepared with recyclable, low carbon emission, sensitive to human health, natural materials can be tested and the results can be analyzed, contributing to the literature and industry on sound insulation.

In this study, the hypothesis of the study could be verified by obtaining values close to 50 dB in the tested samples. It is envisaged that Sound Transmission Loss values can be obtained at higher levels with these specimens and many composite structures to be created by using different materials with natural ingredients. It is very important that materials with hard characteristics can be tested without scratching etc., damage to the test box and the possibility of multiple tests at low cost and can be an advantage over synthetic materials.

Therefore, it is expected that new natural, recyclable, low carbon emission and sensitive to human health materials will contribute to better levels of Sound Transmission Loss.

In the literature, although there are studies on acoustic materials and the tests applied to these materials in devices such as impedance tubes, alpha cabinets and reverberation chambers, it has been observed that the application is more limited. In addition, the lack of widespread laboratories, the high cost of testing due to the import and high cost of professional Alpha Cabin systems and the inability to measure especially hard characteristic materials due to the damage it may cause to the impedance tube, which is a sensitive device, may limit the ability to carry out studies for many reasons. Due to the sensitivity of the impedance tube, hard materials such as stones can damage the impedance tube and its sensitivity. It has been observed that the lack of easy use of existing systems and the high cost of experiments make research difficult. For statistically sound evaluation of the results, there is a need to perform a large number of tests from a sample. Due to this need, the costs of measurement and reporting of these measurements reach very high values. For this reason, Sound Transmission Loss values were calculated by testing single-layer samples with natural materials. As a result, composite structures were created from samples with Sound Transmission Loss values of 30 dB and above, and testing procedures were carried out.

In the study, when the data obtained as a result of the experiments were analyzed, it was determined that composite samples can be effective in reducing noise.

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Institutional Review Board Statement

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Informed Consent Statement

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Data Availability Statement

Not applicable.

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There isn't an acknowledge that I want to highlight.

Conflict of Interest

Declaration of conflict of interest.

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