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Low-Cost Alpha Cabin Like Test Box Proposal for the Development of New Acoustic Sound Insulation Materials

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Highlights

- Analysis of acoustic values of materials with Alpha Cabin test-room method
- Portable measuring box for sound absorption and insulation tests of materials
- Inexpensive test box for the production of healthy, natural, exportable, acoustic materials
- Design of multiple, inexpensive, fast and accurate measurements equipment with non-parallel surfaces
- Quick and easy measurements of materials without frequency band absorption analyzes in the market.

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Abstract

Experimental criteria for sound insulation material recommendation and design have an important share in indoor acoustic control. Among these criteria, laboratories with devices such as impedance tubes, alpha cabins and reverberation rooms used to measure and analyze parameters such as sound transmission loss and sound absorption coefficient have been investigated. In literature, it has been observed that there are studies on acoustic materials and the tests applied to these materials, but the application is more limited. According to research data, an Alpha Cabin model system design that can be used to develop new types of acoustic sound materials has been proposed. In addition to the fact that a large number of experimental measurements can be performed at lower costs using the designed Alpha Cabin model system, many tests can be performed easily for different material designs in a very short time. To perform these tests, the Alpha Cabin system has been designed based on noise and sound insulation. For example, floating flooring, ribbed connection, and so on. Afterward, different insulation materials were used for insulation purposes and standards were achieved. The Alpha Cabin test system, which was designed and developed, overlaps the experimental and theoretical data for 500, 2000, and 4000 Hz when compared with the values of 29.1 dB for 500 Hz, 38.6 dB for 2000 Hz, and 49 dB for 4000 Hz measured in the Acoustic Facade Panel Test Room, and it has been observed that it can be used in the development of new sound insulation materials.

1. INTRODUCTION

Technological and industrial developments in recent years provide important gains for human beings, but also cause some problems. One of these problems is noise. Noise is an unwanted sound and negatively affects human health. It also significantly reduces the working efficiency. Noise also causes some health problems such as hearing loss. For this, some institutions and organizations, by taking advantage of the sound absorption properties of different fibers, automotive, construction, etc. and architectural acoustics, as well as working to reduce noise. The World Health Organization (WHO) and the International Labor Organization (ILO) define health as a mental and physical condition. He states that environmental noise is a negative threat to public health. For this reason, international organizations such as WHO, ILO, US EPA (US Environmental Protection Agency) have conducted scientific research to determine harmful noise levels and produce solutions in order to protect human health. Based on these data, WHO published guidelines for noise in various environments in 1999 [1].

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Experimental criteria have an important role in acoustic sound insulation material proposal and design. Among these criteria, laboratories with mechanisms such as impedance tube, alpha cabin, and reverberation chamber, which are used to measure and analyze parameters such as sound transmission loss and sound absorption coefficient, were investigated. Studies may be limited due to many reasons such as not being widespread in laboratories, imported and expensive professional alpha cabinet systems, and inability to measure every material due to the dimensions of the impedance tube. Due to the sensitivity of the impedance tube, stones, etc., hard materials can damage the impedance tube and sensitivity. In addition, it has been seen that the existing systems are not easy to use and the high experimental costs make the researches difficult. To evaluate the results as statistically healthy, there is a need to perform multiple tests from a sample. Depending on this need, the measurement and reporting costs of these measurements reach very high values. Before making more precise experimental measurements, the Alpha Cabin model system is proposed for preliminary selections in this study. Numerous experimental measurements can be made at a lower cost using the Alpha Cabin model system. In addition, many experiments and measurements of immovable materials (for example, large samples) are carried out in a much shorter time with this system. In this direction, to reduce the sound transmission loss, floating floor, ribbed connection, etc., are primarily used in the system. Detailed studies based on the data obtained as a result of the tests carried out, a material proposal with the lowest cost and the closest results to the similarity are given.

In the literature research on Alpha Cabin, which is one of the mechanisms used to determine acoustic properties such as sound transmission loss and sound absorption coefficient, there are examples of different designs made for cheap alpha cabin production in some countries. Of these, the experimental setup was designed in the study on recycled raw materials with a mixing ratio of 50% Polypropylene, 20% Polyethylene Terephthalate (PET), and 30% Hollow PET and samples with needle densities of 250, 300, and 400 [2]. In another study on natural fibers, they designed a mechanism and carried out experimental procedures to determine the sound absorption capabilities of samples prepared from wood powder, rice husk, rice straw, and their mixtures [3]. They carried out the study, which includes another design example in this field, using materials such as felt, silicone-applied felt in the frequency range of 200-1600 Hz. For these studies, they performed the tests with the setup they designed for sound absorption measurement [4].

In another study, small resonance rooms (small Alpha Cabin), especially as used in the automotive industry, especially for the sector of 1.2 m^2 as it allows the testing of samples of the size is stated that advantageous. Accordingly, samples were prepared with polyester carpet and felt and tested in the designed small Alpha Cabin, and the results were analyzed [5]. In this context, in another study, it was seen that a large resonance chamber of 10 m2 was developed using new solutions with low cost and using less material. By preparing porous and sound absorbing samples smaller than the sample size specified in the ASTM E 1050 standard, the advantages/disadvantages are explained by comparing the tests performed in the large-scale reverberation chamber and the developed small-sized echo chamber [6]. In another study, designed with a small volume, it has been observed that the reverberation chamber is useful in determining the sound absorption coefficients of the finished parts in the automotive industry and that there is a strong correlation between the large reverberation chamber and the small reverberation chamber [7]. In another related study, the Alpha Cabin is defined as a test box with non-parallel walls and used to measure the random sound absorption coefficient (RSAC). It has been stated that at certain frequencies, high sound insulation is provided to keep background noises low [8].

In the literature, there are many studies to determine the sound absorption coefficients of various materials in the developed Alpha Cabin systems and currently used devices. Examples of these studies can be given as follows.

In a study of Bansod, Teja and Mohanty, it is stated that significant gains have been achieved in noise control engineering due to the low cost, environment-friendly, and easy production of natural materials and sound-absorbing materials in industrial and architectural applications, and the sound absorption coefficients of felt samples made of jute of different thickness and densities were measured. It has been determined that the sound absorption coefficient is improved when the thickness of the jute felt is increased to the range of 25-50 mm and supported with MPP [9]. In a study of Aygün, to determine acoustic performance, it was stated that porous materials are widely used for noise control. Felt and carpet were preferred as material.

Measurements were made with an impedance tube to investigate the acoustic performance of woven (carpet) and nonwoven (felt) materials made of wool using a traditional technique. As a result, at frequencies above 1250 Hz, it was observed that the sound absorption coefficient of the felt was higher than that of the handmade carpet. It has been determined that the felt reduces the sound pressure level to the range of 1 dB-10 dB [10]. In another study on how the absorbance of felts varies according to which factors, some special factors such as pore diameter, fiber mixture, and the effect of the surface structure were emphasized in particular of the felt material [11].

In a study on the importance of acoustic requirements in the interior; acoustic requirements is defined as absorbing unwanted sounds indoors, excluding unwanted sounds coming from the outside, and ensuring that the sound spreads correctly in the space under the function (music, speech, sound recording, etc.). For this reason, in the study, the importance of using textile surfaces in the interior was emphasized, and it was stated that the use of these materials as acoustic barriers could be made in terms of color, surface, and shape, by undergoing some processes and making a difference in architecture [12]. In the study on the production of wall fabrics that provide sound and heat insulation to use them for insulation purposes in buildings, samples were created from ducted polyester fiber nonwoven surface, plain patterned surfaces woven with textured yarns obtained from polypropylene, and hollow polypropylene fiber. In this study, the sound absorption coefficients and heat transmission coefficients of the surfaces obtained by different surface forming techniques from 100% PP (polypropylene) and 100% PET (polyester) fibers were determined [13].

In the study, the porous materials preferred in the automotive industry were modeled with material modeling programs, and the values obtained as a result of the tests were compared with the physical results, the sound absorption coefficients, and sound transmission losses of 125-4000 Hz of the samples prepared in different diameters were measured. Then, the test and model results of the 20 mm thick polyurethane sponge and the test and model results of the 16 mm polyester felt were found to be close to each other which presents the accuracy of the material modeling [14].

In another study, in which it was stated that the sound absorption coefficient is a parameter that is widely used to characterize the acoustic properties, a test with a volume of 2 m^3 was carried out regarding acoustic sponges for the measurement method that can be made in the frequency range of 5000 Hz to 50000 Hz of the sound absorption coefficient of acoustic materials. A study was carried out to determine the sound absorption coefficient of an egg-shaped acoustic sponge in the frequency range of 5000 to 50000 Hz in the room. Consequently, reverberation times at 31500 Hz is 0.20 s in the empty room, approximately 0.08 in the polyurethane acoustic sponge, and approximately 0.02 for 4 measurements in the center of the test room in the sample made of mineral wool [15]. Materials with different properties are preferred. In porous materials, the behavior at high frequency is expressed by the three parameters tortuosity, viscous and thermal, which define the structure shape factor. Tortuosity has been determined as one of the important criteria for determining acoustic properties in porous materials [16].

Computer programs have also an important place. For example, in a study on the improvement of the absorption coefficient in sound absorbing materials, optimization was conducted with the MATLAB computer program in order to investigate the structural parameters of the fiber and sponge sound absorber materials. The parameters optimized were structure form factor, shear modulus, porosity structure, thickness of the material, radius of the fiber, flow resistance, etc. As a result of the study, it was observed that the sound absorption coefficient of sound absorbing materials increased from 0.82 to 0.92 at a frequency of 1500 Hz. It has been stated that the optimal results of this situation can set an example for the development of new materials [17].

Another study on the importance of acoustic comfort was tried to obtain and interpret the sound transmission loss and sound absorption coefficient of insulation materials used in vehicles. Insulation materials were selected in different weights and thicknesses and the relationship between weight, sound transmission loss and sound absorption coefficient was examined [18].
In the experimental study, using different models in 11 different materials, 1/3 octave band analysis was performed according to the standards ISO 12354, ISO 10140 and ISO 717. In these models used, while calculating the sound attenuation index R for monolayer panels, the panel dimensions used and the

thickness, density, elasticity modulus, porosity, internal loss factor and sound air velocity were taken into account. As a result, materials whose R values corresponding to different frequencies used through experimental studies were simulated using different sound insulation models, and the effectiveness of the sound insulation models used was determined by comparing the results [19].

Noise is important at different environments. Today, interior noise has an important place in the brand preference of vehicles. Due to the changing needs and the ongoing competition between the manufacturers, the continuous development of insulation materials shows parallelism. In this sense, different methods are applied to determine the sound absorption coefficients of insulation materials. For this reason, in the study, the sound absorption coefficients of five insulation materials with different thickness and structural properties were determined by the impedance tube method in a certain part of the automobile. In addition, the effects of sample thickness on the sound absorption coefficient were also investigated [20].

In work of Zent and Long, they used a test room called “Alpha Cabin” with a volume of $6.44m^3$. While performing the experiments in the reverberation room, measurements were made in the absence and presence of absorbing material in the room in order to detect the decrease in the sound field. Sounds in the 1/3 octave band between 250 Hz and 10000 Hz were produced by three speakers, measurements were recorded with 5 microphones in the room and the results were averaged. In the field of sound transmission and noise reduction, materials such as cotton fiber blends and microfibers with different pores and thicknesses have been developed. In their study, they stated that the effectiveness of the absorption is directly related to the thickness of the material, and that sound absorbers are more effective at high frequencies. When all samples were examined, they concluded that the thinner the sample, the higher the flow resistance required to ensure good sound absorption. In their study, they stated that the effectiveness of the absorption is directly related to the thickness of the material, and that sound absorbers are more effective at high frequencies [21].

Sound absorption coefficient, which is a value measured according to international standards, is generally shown in octave bands between 125 Hz and 4000 Hz. This coefficient depends on parameters such as frequency, material properties, mounting method of the material, geometry and dimensions of the indoor space, the location of the material in the space, and the sound absorption coefficient in a closed space obtained by calculating [22].

In one study have developed a sound reduction box as an alternative to an anechoic chamber for laboratory measurement of the sound insulation properties of materials or structural elements. The methods used in their work are based on ISO 15186-1 and ISO 717-1. They used 2 cm and 4 cm thick wood materials. Measurements were made using a sound intensity analyzer. It has been determined that the device they developed can be used as an alternative for testing acoustic materials [23].

In another study, they prepared samples such as guadua, acustifibra, panel, panel guadua, panel acustifibra and measured the sound absorption coefficients in the frequency range of 250-2000 Hz. They obtained close results for Guadua fiber and acustifibra samples. They found that the panel made of Guadua fiber can be efficient in acoustic conditions [24].

In the literature, it has been seen that there are researches [2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, 23, 24] about what acoustic materials are and what tests are applied to these acoustic materials, but the application is more limited. Due to its limitations, it was not encountered to evaluate their performance in terms of the mathematical model and to implement various variations in practice.

In this study, the Alpha Cabin model system designed for preliminary selections has been proposed for experimental studies on acoustics. By using this system, a large number of experimental measurements can be made at lower costs.

2. NOISE

It can be defined as unwanted sound. In TS 5960, noise is defined as sounds or sound groups with incompatible frequencies and disturbing intensity [25]. A person can suffer permanent hearing loss when exposed to noise [26].

When sound waves hit the pores in materials with a porous structure, sound waves contact the pores due to irregularly positioned pores. Therefore, frictions occur, and heat energy is released as a result of these frictions. Briefly, at low frequencies, porous elastic materials convert sound energy into heat energy and absorb it. This is known as an isothermal process [27].

Since most porous materials are fibrous, they trap air between them. It can be produced in different ways according to its mechanical and acoustic properties. Fibers are classified as natural (cotton, hemp, linen, etc.) and synthetic (glass wool, mineral wool, graphite, ceramic, polyester, polypropylene, kevlar, etc.). Their views are given below in Figure 1 [28].

Cellular Fibre Granular

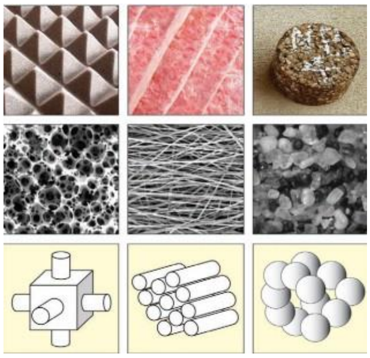

Figure 1. *Microscopic views of physical models of porous materials which indicate their swallowing mechanisms [28]*

The frequencies to which the human ear is sensitive have been investigated and a table called equal volume contours has been developed [29]. The Fletcher-Munson Loudness Curves plot is given in Figure 2 [30]. It is known that an important factor related to speech transmission index (STI) is also related to the objective parameter of speech clarity for voice transmission channels. In this sense, sound ergonomics studies gain importance especially for "Special buildings" sensitive to sound characteristics. The private building is divided into 4 groups depending on its behavior and effectiveness against sound. In [AG1]: "keyboard buildings" whose main function is directly related to sound are represented, in [AG2]: the main function is not related to sound, but it is used as warning and guidance, in [AG3]: the sound is considered as ambient noise, and in [AG4]: the area is very sensitive to sound. It is stated that the control of the sound level should be provided with special techniques, and frequency analysis is very important for noise control in such buildings. In this article, buildings are divided into 5 groups for vibration [31].

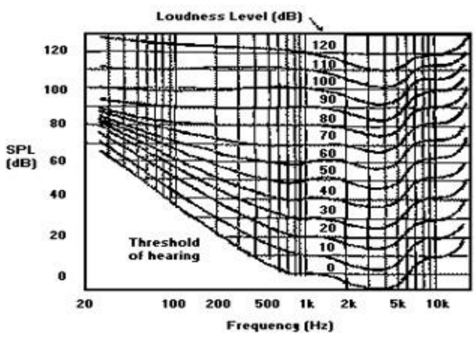

Figure 2. *Fletcher-Munson Loudness Curves [30]*

The Fletcher-Munson Loudness Curves shown in Figure 2 shows the human ear's perceptual capacities of sound pressure levels at different frequencies. For sound and vibration transmission from the ground, the acceleration and deceleration period of Ankara Metro Railway according to the frequency, noise and vibration sound pressure level (SPL) difference is analyzed and given in Figure 3 [32].

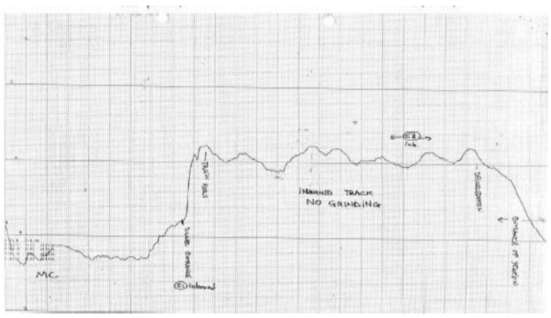

Figure 3. *SPL differences in terms of acceleration and deceleration period with respect to noise and vibration [32]*

The graph of the vibration and noise effects on the side buildings of the Ankara Metro Rail System and the ANKARAY Light Rail system line and the high noise and vibration caused by the subway rails at the entrance to the tunnel is given in Figure 3, 3a, 3b. In this sense, especially for the train horn, while the noise and vibration increase for the acceleration period, the noise and vibration decrease for the deceleration period [32].

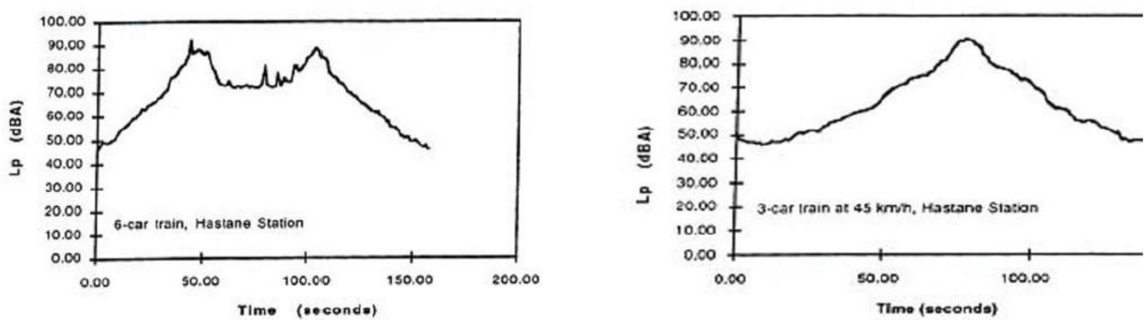

Figure 3a; 3b. *The subway rails cause high noise and vibration at the entrance of the tunnel, and especially the train horn accelerates the noise and vibration, but the noise and vibration also reduce for the deceleration period [32]*

Algorithms have been proposed in experimental studies on the distortion of audio signals by impact sound. Consequently, efficient results can be obtained especially for low noise rates [32].

3. SYSTEMATIC OF THE DESIGNED ALPHA CABIN MODEL

As a new approach in this study, the Alpha Cabin simulation model system, which is seen in Figure 4a and Figure 4b, has been developed. In this designed model system, base dimensions of 60*120*60 cm (length*width*height) and the volume of approximately 0.392 m^3 type was used. During the measurement, it is foreseen that there will be no parallelism on all surfaces to avoid nodes (sound nodes) in the measurement box. To prevent the sounds originating from outside the test box and reaching inside of the test box, isolation was provided by making detailing. For this reason, sound pressure levels (SPL, Sound Pressure Level) were tried to be measured between the inside and outside of the box by covering the inside and outside surfaces and the lid of the experiment box with different materials (such as fleece, carpet flex, and styrofoam). The image of the designed Alpha Cabin model system for its cover is closed and open is given in Figure 4. (a) and (b). The results revealed that the designed and proposed Alpha Cabin System can be used in the tests of acoustic sound-absorbing materials.

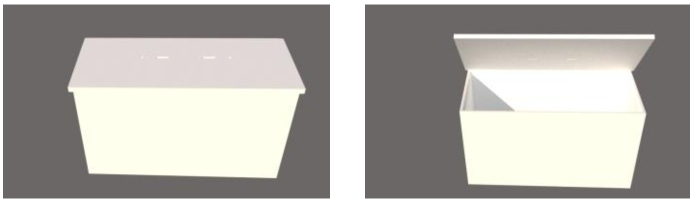

Figure 4. (a) *The cover of the designed Alpha Cabin model system is closed and* ***(b)*** *The cover of the designed Alpha Cabin model system is open*

Figure 4. It is seen in (a) and (b) that the surfaces are designed so that they are not parallel to each other. The loudspeaker used as a sound source and the microphone used as a receiver are placed in the openings on it and measurements are made. The representation of the dimensions of this Alpha Cabin is given in Figure 5.

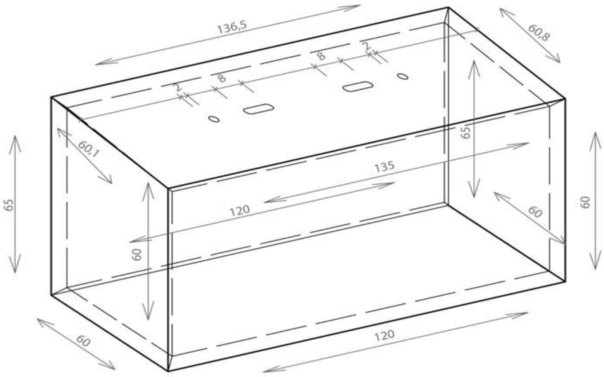

Figure 5. *Representation of the dimensions of the designed Alpha Cabin model system*

The illustration in Figure 5, is given in Figure 6 in unfolded form.

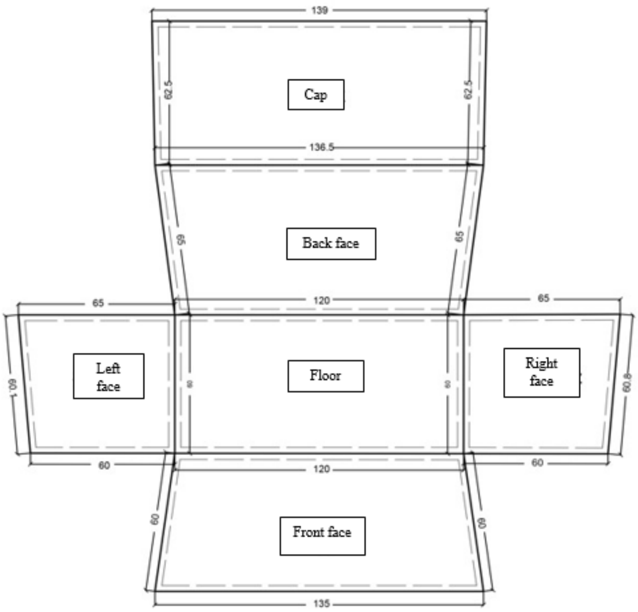

Figure 6. *Explanation of the designed Alpha Cabin model system*

4. MATERIAL AND METHOD

After coating with each sound insulation material, the "White Noise Free" program for sounds such as white noise and pink noise received in the range of 500-16000 Hz (we test the mid-frequency range of the human voice), "Sound meter- Decibels" for the measurement of sound pressure levels. and noise meter" program, "Frequency Generator" program for frequency measurement, have been installed on devices used separately as sound source and receiver. One of these devices is placed inside the designed Alpha Cabin model system and the other is placed on this model system. To prevent vibrations, cotton-containing insulation material and felt are placed under the sound source and receivers. Then, when white noise was given from another sound source, the sound pressure levels seen on the screens of the receivers inside and above the model system were recorded. The same process is repeated for pink noise. Accordingly, a tabulated analysis of the background sound levels made in the Designed Alpha Cabin model system using different insulation materials on different dates is given in Table 1.

Table 1. *Tabulated analysis of background sound levels in the designed Alpha Cabin model system*

Tabulated Analysis of Background Sound Levels in the Designed Alpha Cabin Model System						
		White noise		**Pink noise**		**Explanation**
Date	**Values**	**Outside the box**	**Inside the box**	**Outside the box**	**Inside the box**	Carpet was used as the first insulation material under the Alpha Cabin. There is a textured insulating surface (cotton) under the devices to prevent vibration when measuring.
28.01.2021	Minimum	41	30	45	42	Carpet was used as the first insulation material under the Alpha Cabin. There is a textured insulating surface (cotton) under the devices to prevent vibration while measuring.
	Average	46	41	52	44	
	Maximum	52	73	70	59	
29.01.2021	Minimum	47	29	30	29	At the bottom of the box, there is a carpet, which is the first insulation material, and a double-layered blanket as the second insulation material. In addition, fleece as a soft-touch woven product was used as the third insulation material for the inside of the box and the cover sections, and a hard-touched rug was used for the 4. insulation material around the box. There is a textured insulating surface (cotton) under the devices to prevent vibration while measuring.
	Average	54	32	52	33	
	Maximum	61	72	66	58	
31.01.2021	Minimum	32	30	30	28	There are the first and second insulation materials at the bottom of the box. In addition, a third insulation material was used inside the box, and a double-layered blanket, which was the second insulation material, was used on the back of the box and on the top of the cover. There is a textured insulating surface (cotton) under the devices to prevent vibration while measuring.
	Average	44	34	42	32	
	Maximum	57	53	45	52	
06.02.2021	Minimum	33	30	33	29	Styrofoam is placed on the bottom edges of the outer surface of the box and on the joints as a 5th insulation material. 0.5 mm thick felt as the 6th insulation material and fleece, the 3rd insulation material, were placed on the inside of the box, and the cover was wrapped with this fleece. 10 mm thick felt is placed on the inside of the upper edges of the box to prevent sound escapes when the lid is closed. There is a non-woven insulating surface (felt) under the devices to prevent vibration while measuring.
	Average	51	36	49	35	
	Maximum	56	52	67	53	

Since it was thought that the isolation processes in Table 1 and the measurements made with the primary sound source might not be sufficient in terms of sound level, the Extech HD600 device was used as another sound source and as a receiver (Sound Pressure Level SPL, measuring device). In the designed Alpha Cabin model system, the outer surface of the box is covered with a non-woven surface (Ductliner) containing glass wool, with a density of 32 dns and a thickness of 15 mm, and the upper part of the lid is closed. To prevent sound escape through the openings in the cover, a glass wool-containing non-woven surface and felt (Resilient materials) are used around the end of the sound source cable (speaker cable) and the receiver (SPL measuring device). First, the sound pressure level of the sound generating source was measured. In addition, according to whether the source (sound generator) and receiver are inside or outside of the designed Alpha Cabin model system, 5 tests were performed. The measurement results are given in Table 2.

Table 2. *Measurement results according to whether the sound source and receiver are inside or outside of the designed Alpha Cabin model system*

SQUENCE NO	SOUND SOURCE (Loudspeaker)	dB MEASUREMENT DEVICE	WHITE NOISE AVERAGE (dB)	PINK NOISE AVERAGE (dB)	EXPLANATION			
1	Inside the assembly	Inside the assembly	100	96	When the sponge at the end of the meter is not attached			
2	Inside the assembly	Outside the assembly	58,6-59,3	57,6-59,9	When the sponge at the end of the meter is not attached	The difference between with and without the sponge attached		
3	Inside the assembly	Outside the assembly	59,5-59,6	58,5-60,3	Sponge attached to the end of the measuring device			
4	Outside the assembly	Outside the assembly	97,6-101,3	95,8-96,8	When the sponge at the end of the meter is not attached	The difference between with and without the sponge attached		
5	Outside the assembly	Outside the assembly	99,9-100,7	95,4-96	Sponge attached to the end of the measuring device		Sponge attached	Without sponge attached

According to the data in Table 2 the loudspeaker is determined as the sound source and gives a sound of approximately 100 dB. Then, a sound source (speaker) that can give an average of 110 dB sound was used. The visual of the designed Alpha Cabin model system, insulated with a glass wool-containing nonwoven surface, is given in Figure 7.

Figure 7. *The visual of the designed Alpha Cabin model system, isolated with a glass wool-containing nonwoven surface*

While the Alpha Cabin model system, designed as in Figure 4, is insulated with the duct liner, the sound source was placed inside the box. When the sound pressure level outside the box was measured with the SPL measuring device, it was understood that there was an average difference of 40 dB. Since different samples would be placed in the experimental setup and measurements would be made, it has been named as L_1 and L_2 chambers to make controlled (Transmission Loss/Sound Transmission Loss) measurements. Regarding the measurements, the measurement system defined in ISO 15186, ISO 140-3, and ISO 140-5 standards have been taken into account. The image of the source room and the receiving room related to these measurements is given in Figure 8 [33].

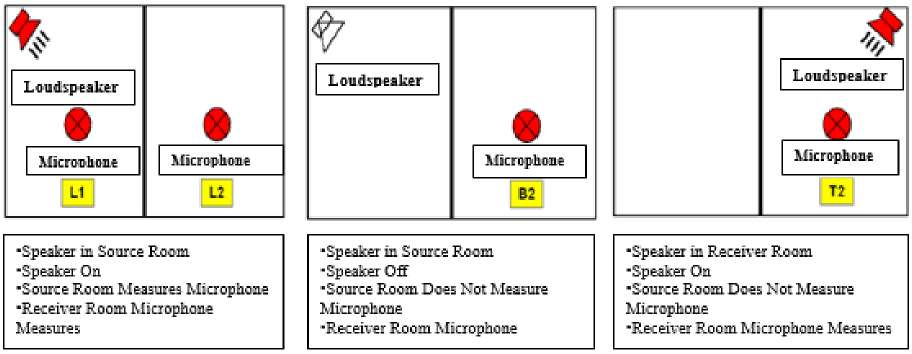

Figure 8. *Image of the source room and the receiving room [33]*

While testing the designed Alpha Cabin model system, the measurement principle shown in Figure 8 was taken as reference (sound source is loudspeaker and receiver is microphone). To measure the performance of this system, measurements were made for each of the three different properties such as Acoustic Wall

Panel, Izobozz Felt, and Acoustic Foam. Among these samples, Acoustic Facade Panel and Izobozz Felt have sound transmission loss and sound absorption coefficients, measured in laboratory conditions within the scope of standards. These materials were placed one by one to form a panel in the inner middle section of the experimental setup and experiments were carried out. In the measurements, the speaker (sound resource) and receiver (SPL measuring device), were made and recorded separately according to their placement in the L_1 and L_2 chambers. The sound source was placed under the cover of the device from the inside, and its cables were taken out through the opening in the cover and its connection to the computer was provided. The receiver, on the other hand, is in such a way that it hangs from the hole in the cover of the assembly to the chambers. According to this; respectively; Sound source and receiver in L_1 room, sound source in L_1 room, receiver in L_2 room, sound source and receiver in L_2 room, sound source in L_2 room and receiver in L_1 room. In each of these processes, first, the noise level in the room and the background noise inside the box were checked with the help of the SPL device. Then from the source, giving white noise and pink noise, L_2 from the opening of the chamber onto the corresponding measuring device suspended from the SPL value shown on the display are stored. Then, the frequency generator program was opened, 8 bands of sound were sent at frequencies between 125-16000 Hz (125, 250, 500, 1000, 2000, 4000, 8000, and 16000), respectively. The values taken from the SPL measuring device were recorded. After this was completed, the sound source was placed in L_2 chamber, and SPL meter placed in L_1 chamber as before. Pictures of the samples and their layout in the designed Alpha Cabin model system are given in Figure 9.

Figure 9. *Pictures of the samples and their placement in the designed Alpha Cabin model system*

The measurement results of the samples shown in Figure 9 are given in Table 3.

Table 3. *Measurement results of Acoustic Facade Panel, Izobozz Felt and Acoustic Foam*

	Measurements of the 80 mm Acoustic Facade Panel								Measurements of the 15 mm İzobozz Felt								Measurements of the 55 mm Acoustic Foam							
	Perforated Surface				Flat Surface																			
Location of sound source and receiver	Sound Source at L1, Receiver at L1		Sound Source at L1, Receiver at L2		Sound Source at L2, Receiver at L2		Sound Source at L2, Receiver at L1		Sound Source at L1, Receiver at L1		Sound Source at L1, Receiver at L2		Sound Source at L2, Receiver at L2		Sound Source at L2, Receiver at L1		Sound Source at L1, Receiver at L1		Sound Source at L1, Receiver at L2		Sound Source at L2, Receiver at L2		Sound Source at L2, Receiver at L1	
Back-ground noise in the box	46		52,3		49,3		39,6		46		52,3		49,3		39,6		46		52,3		49,3		39,6	
Back-ground noise İn the room	39,6		39,7		39,9		39,8		39,6		39,7		39,9		39,8		39,6		39,7		39,9		39,8	
Minimum (Min.), Maximum (Max.)	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
White noise	97,2	98,8	81,6	82,4	107	107,7	81,6	82,3	97,2	98,8	81,6	82,4	107	107,7	81,6	82,3	97,2	98,8	81,6	82,4	107	107,7	81,6	82,3
Pink noise	94,8	95,6	81,1	84,7	104,8	105,2	82	83,1	94,8	95,6	81,1	84,7	104,8	105,2	82	83,1	94,8	95,6	81,1	84,7	104,8	105,2	82	83,1
	SOUND PRESSURE LEVELS (dB)																							
Frequency (Hz)	Sound Source at L1, Receiver at L1		Sound Source at L1, Receiver at L2		Sound Source at L2, Receiver at L2		Sound Source at L2, Receiver at L1		Sound Source at L1, Receiver at L1		Sound Source at L1, Receiver at L2		Sound Source at L2, Receiver at L2		Sound Source at L2, Receiver at L1		Sound Source at L1, Receiver at L1		Sound Source at L1, Receiver at L2		Sound Source at L2, Receiver at L2		Sound Source at L2, Receiver at L1	
	In-side	Out-side	In-side	Out-side	In-side	Out-side	In-side	Out-side	In-side	Out-side	In-side	Out-side	In-side	Out-side	In-side	Out-side	In-side	Out-side	In-side	Out-side	In-side	Out-side	In-side	Out-side

125	92,1	60	76,5	69	98	76	77,7	70	90	72	95,8	77	91,5	51	92,1	71	92,1	60	76,5	69	98	76	77,7	70
250	108,3	75	98,3	74	109,7	82	97,6	84	104,5	85	103,4	85	107,9	80	96,4	79	108,3	75	98,3	74	109,7	82	97,6	84
500	101,9	58	84,3	58	108,9	71,00	81,90	75	100,7	69	107,2	75	102,90	71,00	104,3	69	101,9	58	84,3	58	108,9	71,00	81,90	75
1000	101,5	53	72,1	71	110,9	75	88,2	77	110,1	66	106,8	66	99,2	63	108,5	65	101,5	53	72,1	71	110,9	75	88,2	77
2000	103,1	44	82,7	62	115,2	69	79,8	72	112	69	107,3	67	105,4	57	104,2	64	103,1	44	82,7	62	115,2	69	79,8	72
4000	102,3	36	73,6	50	109,9	62	67	74	99,6	61	98,9	56	106,2	49	92,5	54	102,3	36	73,6	50	109,9	62	67	74
8000	110,5	35	78,4	43	119,9	27	84,3	41	110,5	38	102,6	41	99,9	38	106	41	110,5	35	78,4	43	119,9	27	84,3	41
16000	67,9	33	46,8	24	78	20	42,2	23	57,7	23	68,7	31	74,1	24	61,2	24	67,9	33	46,8	24	78	20	42,2	23
	Sound Source at L1		**Sound Source at L2**						**Sound Source at L1**		**Sound Source at L2**						**Sound Source at L1**		**Sound Source at L2**					
Frequency (Hz)	**Reverberation Time (sn)**								**Reverberation Time (sn)**								**Reverberation Time (sn)**							
250	0,33		1,11						0,33		1,11						0,33		1,11					
500	0,25		0,33						0,25		0,33						0,25		0,33					
1k	0,14		0,17						0,14		0,17						0,14		0,17					
2k	0,1		0,01						0,1		0,01						0,1		0,01					
4k	0,44		0,05						0,44		0,05						0,44		0,05					
Average	0,19		0,25						0,19		0,25						0,19		0,25					

The graph is given in Figure 10 according to the results of the first measurement made from the perforated surface regarding the Acoustic Facade Panel, which is one of the samples in Table 3.

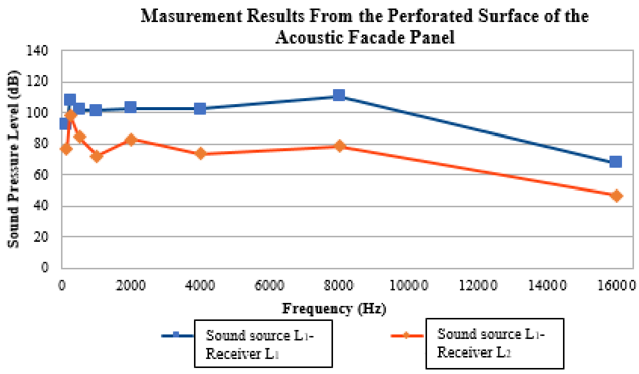

Figure 10. *Graph according to the measurement result of the perforated surface of the Acoustic Facade Panel*

The graph is given in Figure 11 according to the first measurement result made from the flat surface regarding the Acoustic Facade Panel.

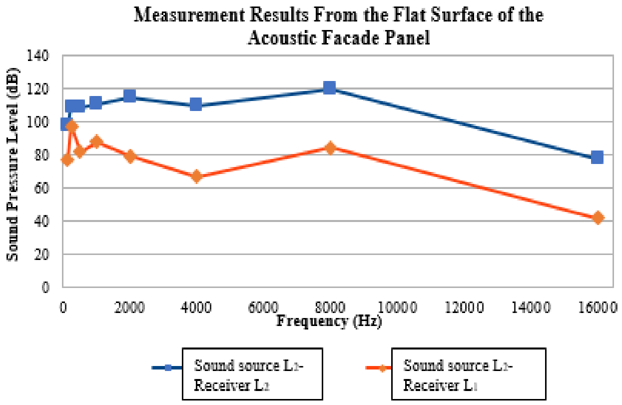

Figure 11. *Graph according to the first measurement result made from the flat surface of the Acoustic Facade Panel*

The data seen in Table 3 and Figures 10 and 11, which were created accordingly, are the values obtained as a result of the measurement according to the 8 band frequencies in the literature. However, as a result of the analyzes made according to these values, it has been determined that the results would not be sufficient since the wave sizes at these frequencies are longer than the box dimensions due to the dimensions of the box. For this reason, the data in Table 4 are the values obtained as a result of the measurements made in the frequency ranges of 250-5000 Hz. In addition, in the designed Alpha Cabin model system, both the use of a single material to reduce the cost and the glass wool-containing non-woven surface used for the outer coating of this system were seen to be more effective in sound insulation, so the felt on the upper inner edges was removed and glass wool insulation material was used instead. Accordingly, a second measurement was made from the perforated surface of the Acoustic Facade Panel, and the results and the values measured in the Acoustic Facade Panel test room are given in Table 4.

Table 4. *Second measurement results from the perforated surface of the Acoustic Facade Panel*

MEASUREMENTS MADE FROM THE PERFORATED SURFACE of 80 mm ACOUSTIC FACADE PANEL				
Location of sound source and receiver	**Sound Source at L_1, Receiver at L_1**		**Sound Source at L_1, Receiver at L_2**	
Background noise in the box (without sample)	38		38	
Background noise in the box (with sample)	38,8		38,4	
Background noise in the room	39		39	
Minimum and Maximum	**Minimum**	**Maximum**	**Minimum**	**Maximum**
White noise	101,5	102,3	76,3	77,1
Pink noise	98,2	99,1	77,1	78
Frequency (Hz)	**Sound Source at L_1, Receiver at L_1**	**Sound Source at L_1, Receiver at L_2**	**The value we achieve in the designed Alpha Cabin system (dB)**	**Value measured in acoustic wall panel test room (dB)**
250	103,5	90,2	13,3	25,6
315	106,2	91,7	14,5	27
400	99,9	83,7	16,2	28,1
500	98	78	20	29,1
630	105,8	86,4	19,4	30,1

800	103,4	81,6	21,8	30,5
1000	94,7	68,9	25,8	26,3
1250	108,7	82	26,7	27,4
1600	105	70	35	32,8
2000	107,2	72,8	34,4	38,6
2500	100,9	68,7	32,2	40,7
3150	102,7	68,1	34,6	44,1
4000	100,5	59,3	41,2	49
5000	110,5	67,9	42,6	50,5

The graphical view of the Acoustic Facade Panel in Table 4, according to the results of the second measurement made from the perforated surface, is given in Figure 12.

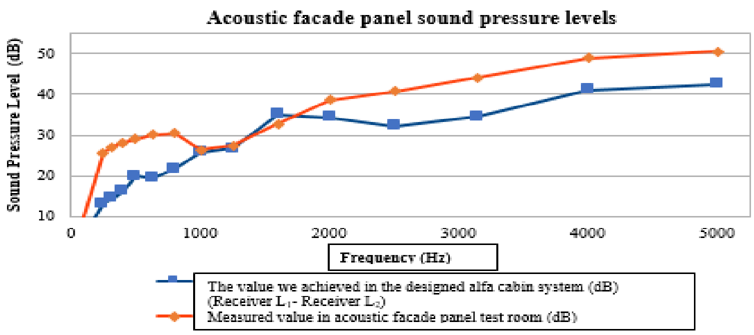

Figure 12. *Second measurement results from the perforated surface of the Acoustic Facade Panel*

When the data obtained in Figure 9 is analyzed, it is seen that more efficient results are obtained after 500 Hz, and therefore, the designed Alpha Cabin model system is more suitable for indoor acoustics compared to its dimensions.

The formulas used to calculate the sound transmission loss value for 500 and 2000 Hz frequencies of the Acoustic Facade Panel are given in Equations (1) and (2), respectively [34]. Here, the calculations were made with the usage of the values in Table 4 and the test results.

$$R=0,161\frac{V}{\sum SA} \quad (1)$$

$$R=L_1 - L_2 + 10.\log(S/A)$$
(2)

L_1 : Average sound pressure level in the source room (dB)
L_2 : Average sound pressure level in the receiver room (dB)
S : Surface area of test material (m^2)
A : Equivalent absorption area in the receiver room (m^2)
The data taken from Table 4 in the mentioned calculations are given in Table 5 as a summary.

Table 5. *Data used in the calculation and comparison of the sound transmission loss*

Frequency *(Hz)*	**Sound Source in L_1, Receiver in L_1**	**Sound Source in L_1, Receiver in L_2**	**The Value We Achieve in the Designed Alpha Cabin System (dB) (Receiver L_1- Receiver L_2) *(dB)***	**Value Measured in Acoustic Wall Panel Test Room (dB)**
500	98	78	20	29,1
2000	107,2	72,8	34,4	38,6
4000	100,5	59,3	41,2	49

The reverberation times measured for frequencies of 500, 1000, 2000, and 4000 Hz are given below in Table 6.

Table 6. *Reverberation times (sec) measured at 500, 1000, 2000, and 4000 Hz frequencies*

Frequency *(Hz)*	**Sound Source at L_1, Measured Reverberation Times *(second)***			
	1. measurement	**2. measurement**	**3. measurement**	**4. measurement**
500	0,28	0,26	0,27	0,28
1k	0,15	0,13	0,13	0,14
2k	0,1	0,1	0,1	0,1
4k	0,05	0,04	0,05	0,09
Average	**0,21**	**0,2**	**0,2**	**0,21**

According to the data in Table 6, these values are taken as approximately 0.3 s for 500 Hz, 0.1 s for 2000 Hz, and 0.06 s (average) for 4000 Hz. The area of the sample is approximately 0.3105 m^2. Calculations according to these values are given below

$0{,}30 = 0{,}161\frac{0{,}192}{\sum SA}$ from the equation $\sum$ SA= $0{,}10$ is taken.

According to the values in Table 5,
for 500 Hz;
R=$98 - 78 + 10.\log(0{,}3105/0{,}10)$
R=$24{,}9$ dB is.

for 2000 Hz;
$0{,}1 = 0{,}161\frac{0{,}192}{\sum SA}$ approximately equal to $\sum SA = 0{,}31$ is taken.
R=$107{,}2 - 72{,}8 + 10.\log(0{,}3105/0{,}31)$
R=$34{,}4$ dB is.

for 4000 Hz;
$0{,}06 = 0{,}161\frac{0{,}192}{\sum SA}$ approximately equal to $\sum$ SA= $0{,}51$ is taken.

R=$100{,}5 - 59{,}3 + 10.\log(0{,}3105/0{,}51)$
R=39 dB is.

The comparison of the values obtained in the designed Alpha Cabin model system, Acoustic Facade Panel Test Room, and Theoretical calculation are given in Table 7.

Table 7. *Comparison of the values obtained in the designed Alpha Cabin model system, Acoustic Facade Panel Test Room, and Theoretical calculation*

Frequency *(Hz)*	**Sound Source in L_1 Receiver in L_1**	**Sound Source in L_1, Receiver in L_2**	**The Value We Achieve in the Designed Alfa Cabin System (dB) (Receiver L_1-Receiver L_2) *(dB)***	**Value Measured in Acoustic Wall Panel Test Room (dB)**	**Value Obtained in Theoretical Calculation *(dB)***
500	98	78	20	29,1	24,9
2000	107,2	72,8	34,4	38,6	34,4
4000	100,5	59,3	41,2	49	39

According to Table 7, the values measured in the designed Alpha Cabin model system are 20 dB for 500 Hz, 34.4 dB for 2000 Hz and 41.2 dB for 4000 Hz, the values measured in the Acoustic Facade Panel Test Room are 29.1 dB for 500 Hz, 38 for 2000 Hz. It is seen that these values coincide with the values obtained with the theoretical calculation as 24.9 dB for 500 Hz, 34.4 dB for 2000 Hz, and 39 dB for 4000 Hz. The comparison graph of the values we obtained in the designed Alpha Cabin model system, Acoustic Facade Panel Test Room, and Theoretical calculation is given in Figure 13.

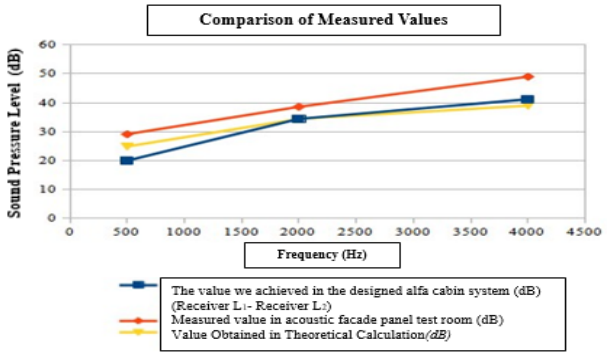

Figure 13. *Comparison graph of the values obtained for the designed Alpha Cabin model system, Acoustic Facade Panel Test Room, and Theoretical calculation*

According to Figure 13, it can be seen that there is serious parallelism between the compared value.

5. RESULTS and DISCUSSION

In the low-cost and easy-to-manufacturable Alpha Cabin test box proposal, it was tried to spread the material recommendations. Firstly, while measuring the background sound levels, isolation was done with different materials, and the material that could be effective in sound insulation was tried to be determined for the test results to be efficient. Secondly, to prevent the sounds originating from outside the test box and reaching the inside of the test box, isolation was provided by making detailing. As a result, it has been observed that the nonwoven surface material containing glass wool is effective. Then, sound transmission loss measurements were made with different samples such as Acoustic Facade Panel, Izobozz Felt and Acoustic Foam to measure the parameters such as sound transmission loss and sound absorption coefficient and to determine the adequacy of the performance. Regarding these measurements, the measurement system defined in ISO 15186, ISO 140-3, and ISO 140-5 standards has been taken as reference. Sound pressure levels of 3 different samples selected according to 8 frequency bands in the literature were recorded and analyzed, and sound transmission loss was tried to be determined in the frequency ranges of 250-16000 Hz (mid-frequency range used in building acoustics with the onset of the human voice) with the Acoustic Facade Panel. These values 20 dB for 500 Hz, 34.4 dB for 2000 Hz and 41.2 dB for 4000 Hz were measured in the later designed Alpha Cabin model system, and 29.1 dB for 500 Hz, 38.6 dB for 2000 Hz were measured in the Acoustic Facade Panel Test Room. The values for 49 dB and 4000 Hz are compared. It is seen that these values coincide with the values obtained in the theoretical calculation as 24.9 dB for 500 Hz, 34.4 dB for 2000 Hz, and 39 dB for 4000 Hz.

6. CONCLUSION

The Alpha Cabin like test box which we are working on is designed using plywood and straw materials, with base dimensions of 60*120*60 cm (width*length*height) and a volume of approximately 0.392 m3. In terms of sound insulation, straw was placed between two plywood on all surfaces and production was carried out without using any metal during the assembly phase. Many materials can be tested in this model system developed. It was observed that realistic results can be obtained by comparing the tests performed in the Alpha Cabin test box with the tests performed in the original Alpha Cabin test room. It is not possible to produce as many test materials as possible during researches and to carry out multiple tests of these materials due to the high production transportation and measurement costs. The advantage and importance of this test box is that it allows for multiple tests that can be performed before being sent to the original test room. Thanks to the reproduction of alternatives due to the cost of production transportation and measurement, it has allowed for different natural sound insulation material research that will not disturb the air quality we are working on. The results obtained from the tests provide the possibility of comparison in original test rooms. It is expected that it will also enable many future tests and that the results obtained especially at high frequencies will be true and lead to new studies.

Added Value:
More than one test can be done in a shorter time and at a lower cost. A cheap and effective Alpha Cabin system design has been proposed, which many commercial organizations can easily do their testing.

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CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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