EXPERIMENTAL EVALUATION OF NOISE REDUCTION EFFECTIVENESS OF SOUNDPROOFING PANEL SYSTEM

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Abstract

Measures to mitigate aviation noise at airports are increasingly critical, particularly for those near urban areas, requiring studies of effective noise reduction strategies. This article presents an experimental study evaluating and comparing the soundproofing efficiency of a 3 cm thick panel system made from different material combinations, including acoustic sonic felt, plywood, and black rubber. The study focuses on single-source noise with intensity levels equivalent to aircraft engine noise, measured at the noise measurement points recommended by ICAO. Through the shielding panel system, the noise level generated by the electrical blasting machine decreases linearly with the power of the noise source. The findings indicate that noise levels decrease proportionally as the power of the noise source is reduced. Among the tested configurations, the wood-felt-wood combination exhibited the highest sound insulation efficiency, reducing sound intensity levels by 9.48-7.58 dB, compared to 5.85-5.08 dB for the felt-wood-felt system and 5.42-3.14 dB for the uniform felt and black rubber system of the same thickness. These results provide an initial foundation for proposing effective soundproof panel combinations to mitigate both traffic and aviation noise.

Keywords: *Soundproofing panel; sound intensity level; aviation noise; electrical blasting device.*

1. Introduction

Noise pollution has become an increasingly critical research topic in Vietnam due to its adverse effects, including reduced work efficiency, hypertension, stress, tinnitus, hearing loss, and sleep disorders. According to Vietnamese and Russian standards, permissible noise levels in residential areas are 55 dB at night and 70 dB during the day [1], [2].

When studying and assessing noise intensity at airports, the International Civil Aviation Organization (ICAO) [3], [4] has recommended three noise monitoring points for different aircraft types, including jet aircraft, turboprop aircraft, and helicopters. These monitoring locations are generally positioned 120 to 650 meters from the runway centerline and threshold. However, noise measurement and evaluation at these locations are challenging due to aviation security and safety constraints. At these monitoring points, aircraft engine noise levels typically range from 80 dB to 108 dB, exceeding the recommended threshold of 70 dB for operational hours (06:00 - 21:00) in many countries worldwide [5].

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This presents a significant research challenge in determining noise intensity and developing mitigation solutions to reduce noise within airport infrastructure and surrounding areas. However, conducting frequent on-site noise intensity assessments at airports is highly challenging due to procedural, safety, and security requirements. Therefore, based on previous studies [6], the research team employed an electrical blasting device to generate single noise events with intensity levels equivalent to aircraft engine noise. A noise measurement model was developed, incorporating various shielding panels to evaluate the sound insulation effectiveness of different materials. This approach provides a foundation for researching aviation noise mitigation solutions in laboratory conditions, reducing costs and procedural complexities associated with airport-based experiments.

Studies on noise intensity attenuation and the development of noise maps have been conducted by various authors [7], [8]. However, research on aviation noise in Vietnam faces certain limitations due to challenges in equipment availability and experimental conditions. To address this, the research team has developed a laboratory-based experimental model to evaluate noise intensity attenuation patterns. This serves as an initial foundation for future field experiments on aviation noise mitigation solutions, aiming to minimize the impact on residential communities near urban airports.

2. Reducing of the sound intensity level (SIL) when encountering soundproof panels

As a form of sound vibration, transportation noise - particularly aviation noise - propagates as acoustic waves through the air. Its transmission characteristics depend on the physical and acoustic properties of the propagation medium.

The speed of sound propagation varies across different media and depends on the material properties of the medium, leading to differences in acoustic behavior.

When a sound wave encounters the surface of a structure or object, the incident sound energy (E_1) is divided into three components [9], each characterized by a specific coefficient (Fig. 1):

Reflected sound energy (E_2) is defined by the sound reflection coefficient;

Absorbed sound energy (E_a) is defined by the sound absorption coefficient;

Transmitted sound energy (E_3) is defined by the sound transmission coefficient.

The sound transmission coefficient T_θ is calculated using the following formula:

$$T_\theta = \frac{E_3}{E_1} \tag{1}$$

where E_1 is the incident sound energy (dB), E_3 is the transmitted sound energy (dB).

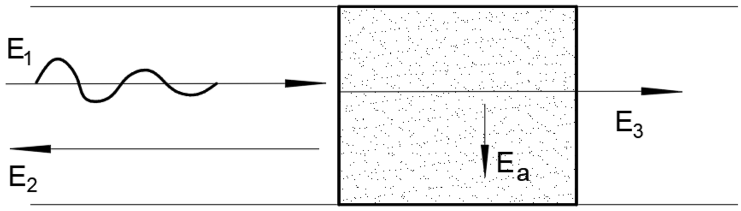

Fig. 1. Sound transmission process through soundproofing materials [9].

The sound insulation capacity of the material is then determined by the following formula [8], [9]:

$$R_\theta = 10\lg\left(\frac{1}{T_\theta}\right) \text{ (dB)} \quad (2)$$

The factors affecting sound insulation capability include the properties of the soundproofing material, the thickness of the soundproofing panel (E_a and E_3), and the power of the sound source (E_1).

Studies have shown that sound intensity levels depend on the acoustic power of the noise source, following a logarithmic - linear relationship [10]. To evaluate the sound insulation characteristics of various materials, we propose the following experimental model.

Soundproofing materials include sound-absorbing, sound-dampening, and sound-reflecting materials. Sound-absorbing and sound-dampening materials consist of black rubber, acoustic felt, various types of foam (PE, XPS, EPS), acoustic foam, acoustic fabric, fiberglass products, and cellulose-based products (Fig. 2).

a) Molecular structure of black rubber *b) Structure of Acoustic Sonic felt*

Fig. 2. Structure of sound-absorbing material.

Under experimental conditions, the research team utilized black rubber, acoustic sonic felt, and industrial wood (both separately and in various combinations) as a basis for studying soundproofing structures for buildings and barracks within airport areas to mitigate the impact of aviation noise.

3. Experimental model and equipment

3.1. Experimental model

The experimental model is set up as shown in the diagram (Fig. 3).

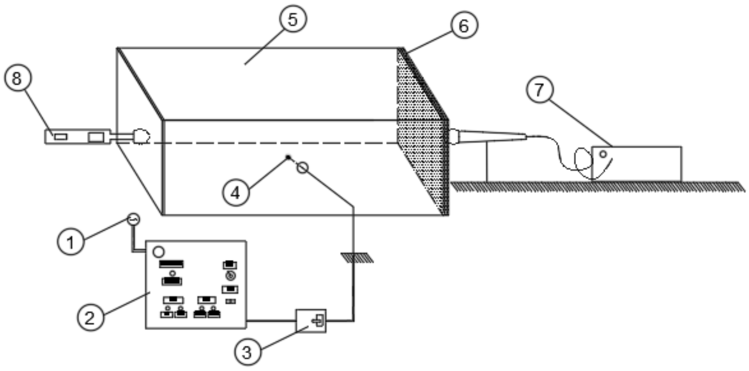

Fig. 3. Experimental setup diagram

1 - power source; 2 - electrical blasting device; 3 - circuit switch; 4 - electric detonator; 5 - soundproof box; 6 - soundproof panel; 7 - noise level meter 1; 8 - noise level meter 2.

3.2. Experimental equipment

- Soundproof box: The soundproof box is constructed from wood and lined by acoustic felt on the interior to ensure airtight sealing, maximizing soundproofing efficiency, minimizing sound reflections, and improving measurement accuracy. A mica window is installed on the top to observe the detonation process of the electric igniter generating noise (Fig. 4).

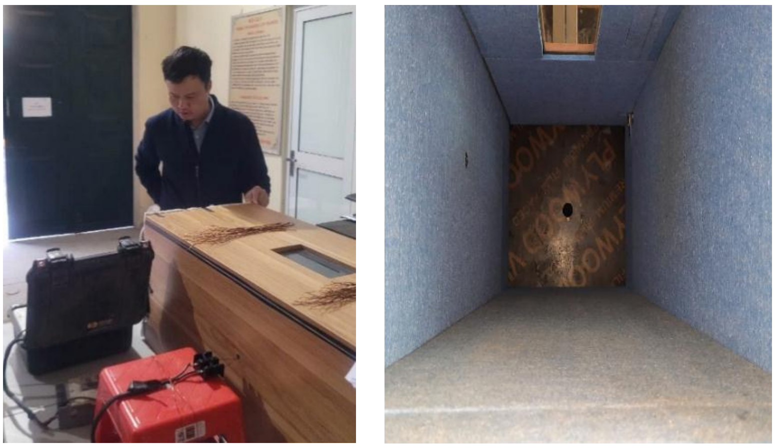

Fig. 4. Soundproof box.

- One end of the soundproof box is designed to accommodate interchangeable soundproofing panels. At this location, a noise level measurement system is installed to record sound intensity for each experiment.

- Electrical blasting device: This device operates based on the principle of physical detonation, generating pulsed energy analogous to that produced by conventional explosives. It is capable of delivering explosive energy at various levels, with a maximum capacity of up to 500 J [11], [12] (Fig. 5).

a) Electrical blasting device *b) Electric detonator* *c) Circuit breaker*

Fig. 5. Combination of electrical blasting device.

- Sound Level Meter: The Minimate Pro sound level meter from Instatel (Canada) and the Total TETSL01 handheld sound meter from China were used (Fig. 6). Due to experimental constraints preventing the use of identical sound level meter, the research team conducted tests to assess the consistency between the two measuring devices. The results showed that the average deviation between the two measurements - both with and without the soundproofing panel at the same distance - ranged from 0.5 dB to 1.0 dB. This deviation falls within the measurement uncertainty limits of the devices (±0.5 dB for the Minimate Pro and ±1.0 dB for the Total TETSL01).

a) The Minimate Pro sound level meter *b) The handheld sound meters Total TETSL01*

Fig. 6. Sound level meter.

The single noise intensity level value measured by the Minimate Pro sound level meter can be taken directly on the display screen or taken according to the maximum value in the graph stored in the device (Fig. 7). For the Total TETSL01 meter, the value must be recorded directly after each measurement.

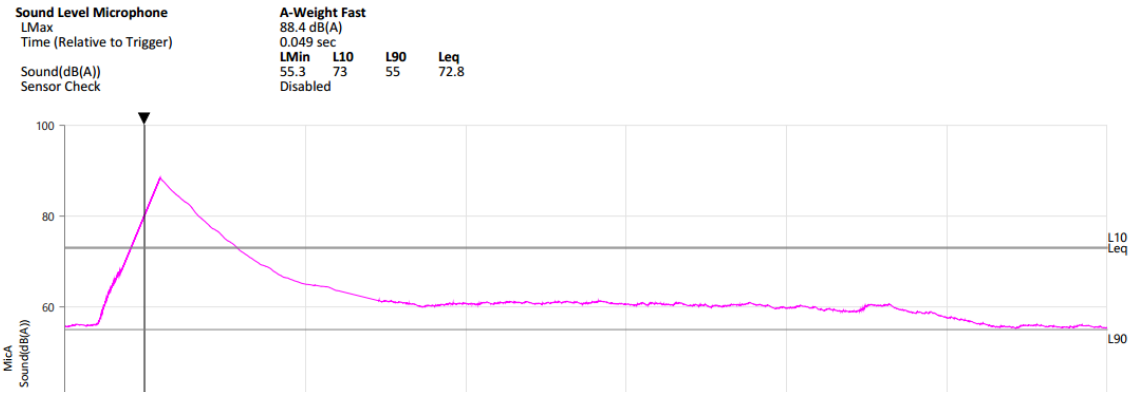

Fig. 7. Noise level graph from the Minimate Pro device.

3.3. Experimental order

During the experiment, the electric detonators were pre-fabricated from tinned copper wire. The order of steps from arranging the soundproof box, installing soundproof panels, checking the operating status of the devices, checking safety, setting the charging capacity, discharging, disconnecting the circuit, checking safety, and recording data were performed sequentially for each measurement (Fig. 8).

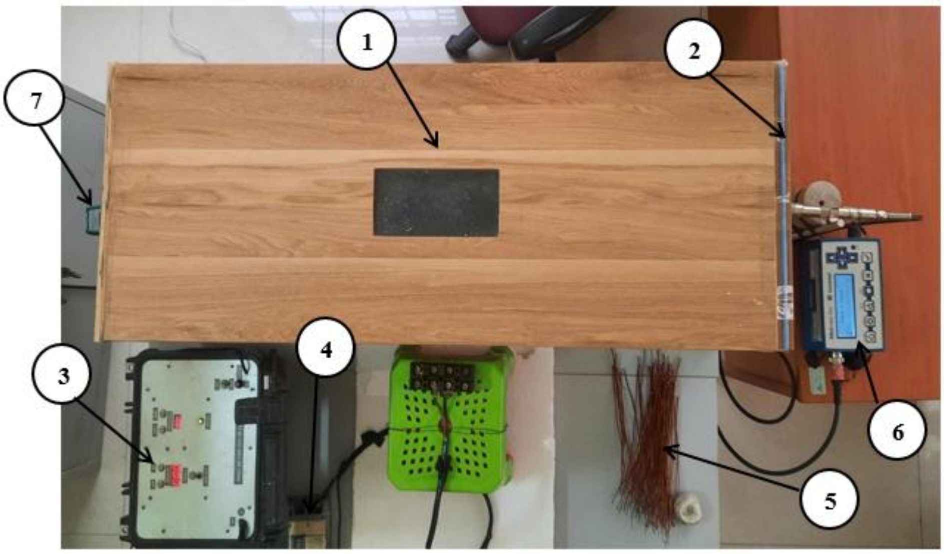

Fig. 8. Experimental model to determine noise reduction rules when using soundproofing panels
1 - soundproof box; 2 - soundproof panels; 3 - electrical blasting device; 4 - circuit breaker; 5 - electric detonator; 6 - Minimate Pro sound level meter; 7 - total TETSL01 sound level meter.

4. Experimental results and evaluation

The experimental noise level data were determined for each measurement corresponding to noise source power levels of 190 J, 290 J, and 390 J.

To evaluate the same type of soundproof panel system, the study used a system of 3 cm thick soundproof panels made from materials with sound absorption properties. The system consists of a three-layer thick black rubber system and a three-layer acoustic sonic soundproof felt system. The summarized results are presented in the following table.

Tab. 1. Noise intensity data were measured using the same type of soundproof panel combination

Power (J)	**Meter 1 (dB)**	**Meter 2 (dB)**	**Power (J)**	**Meter 1 (dB)**	**Meter 2 (dB)**	**Power (J)**	**Meter 1 (dB)**	**Meter 2 (dB)**
Combination of 3 cm thick acoustic sonic felt soundproofing panels								
190	90.5	87.4	290	92.4	87.4	390	94.6	89.8
190	90.1	84.5	290	91.4	86.9	390	94.3	88.4
190	90	84	290	91.3	87.8	390	94.9	91.2
190	90.8	83.9	290	92	86.4	390	93.4	91.4
190	90.4	84.5	290	92.7	88.7	390	94.7	89.3
Combination of 3 cm thick black rubber panels								
190	92	86.5	290	93.1	89.4	390	95	92.1
190	92.1	87.6	290	92.5	91.5	390	96	92.3
190	91.3	87.7	290	94.5	90.5	390	97.4	93.4
190	92.3	85.5	290	93.2	90.9	390	96.9	95
190	92.4	87.5	290	93.9	88.6	390	94.2	90.9

Based on the measured data, graphs were constructed to show the relationship between noise intensity level and noise source power for cases with and without soundproof panels, for each type of panel. The results are presented as follows:

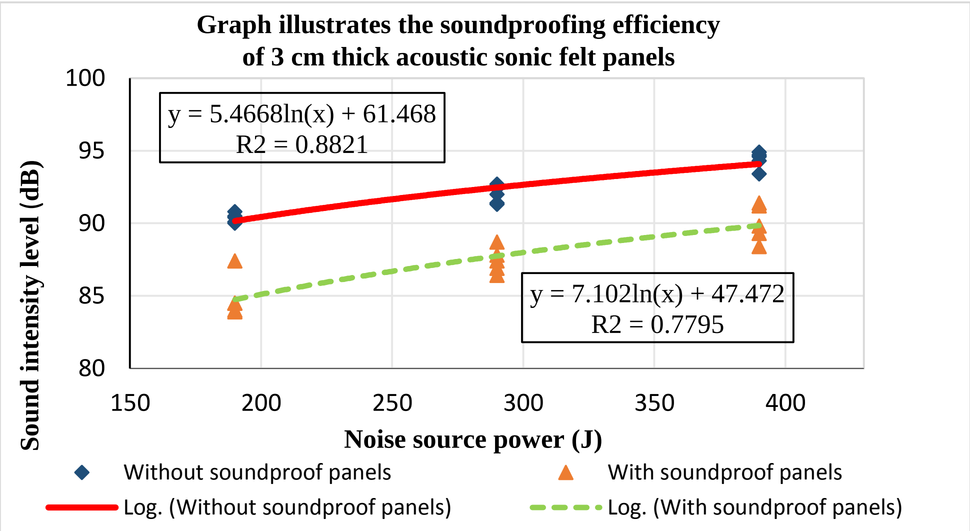

Fig. 9. Soundproofing efficiency graph of 3 cm thick acoustic sonic felt.

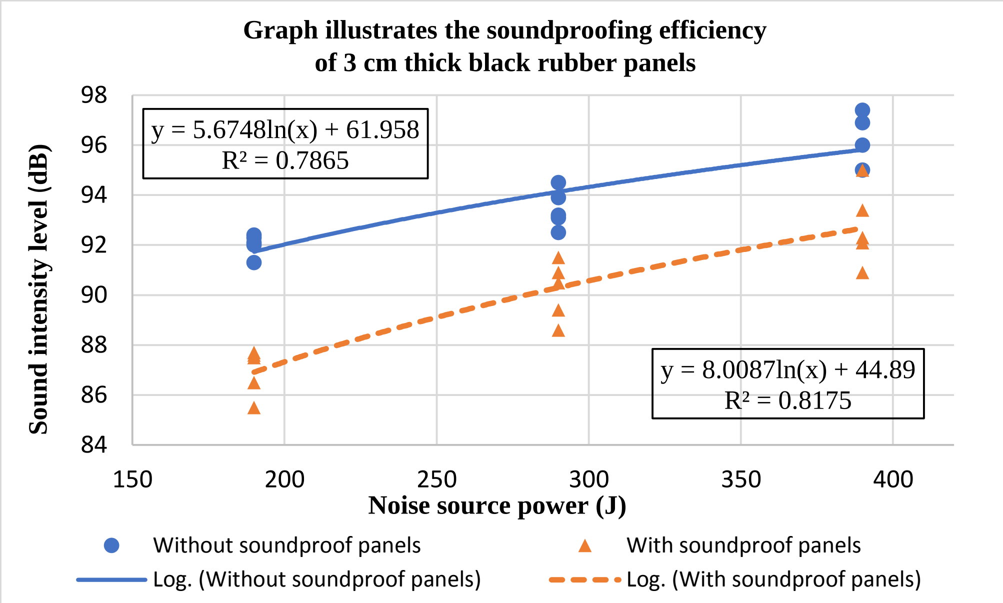

Fig. 10. Sound insulation efficiency graph of 3 cm thick black rubber panels.

A graph illustrates the soundproofing characteristics of the two types of systems as established in the following data:

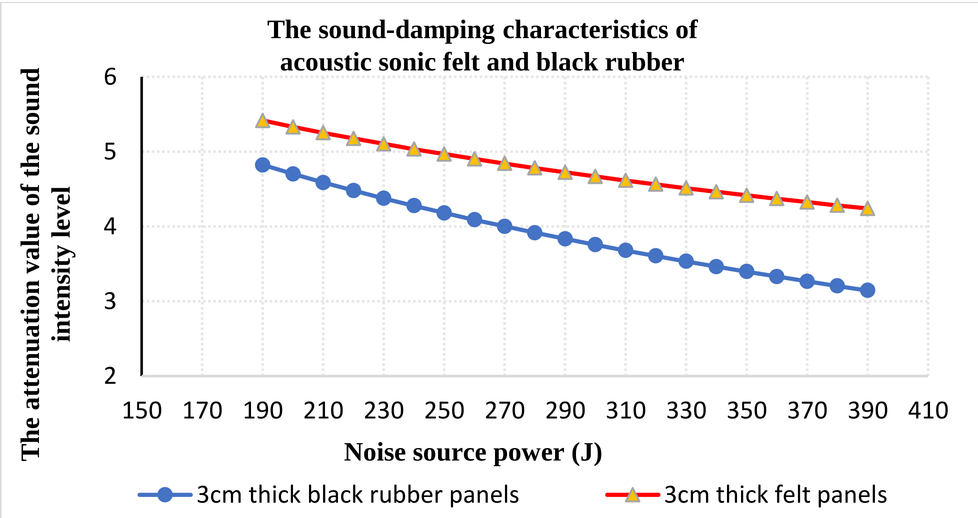

Fig. 11. The sound-damping characteristics of acoustic sonic felt and black rubber panels.

Based on the experimental results (Fig. 11), it is shown that as the noise source power increases (i.e., higher intensity and frequency), the sound insulation capacity of the acoustic sonic felt panel system decreases from 5.42 dB to 4.24 dB. Similarly, for the black rubber panels with the same thickness of 3 cm, the insulation capacity decreases from 4.82 dB to 3.14 dB.

To evaluate the sound insulation efficiency of a composite system incorporating wood panels with sound - reflecting properties, the study used acoustic sonic felt material combined with plywood in two configurations: (1) felt + wood + felt and (2) wood + felt + wood, both with a total thickness of 3 cm.

The following table summarizes the measurement data:

Tab. 2. Noise intensity data were measured using a combination of mixed soundproof panels

Power (J)	**Meter 1 (dB)**	**Meter 2 (dB)**	**Power (J)**	**Meter 1 (dB)**	**Meter 2 (dB)**	**Power (J)**	**Meter 1 (dB)**	**Meter 2 (dB)**
Combination 3 cm thick of felt-wood-felt panels								
190	89.7	84	290	92.3	85	390	93.5	89.2
190	90	84.2	290	91.8	87.5	390	94.3	89.4
190	89.3	84.1	290	91	85.8	390	94.2	88.4
190	90.7	84.9	290	91.6	87	390	96.8	93.4
190	90.3	83.7	290	92.5	85.5	390	92.2	87.9
Combination 3 cm thick of wood-felt-wood panels								
190	91.2	81.7	290	94.1	83.8	390	95.3	85.7
190	91.5	80.2	290	93.9	84.9	390	93.6	89.3
190	90.2	80.9	290	94.9	84.6	390	95.5	85.9
190	90.2	82.6	290	92.9	84.4	390	94.9	90
190	89.8	80.9	290	93.1	85.4	390	93.3	86

From there, a graph is constructed to evaluate the soundproofing efficiency of the two combinations, as shown below:

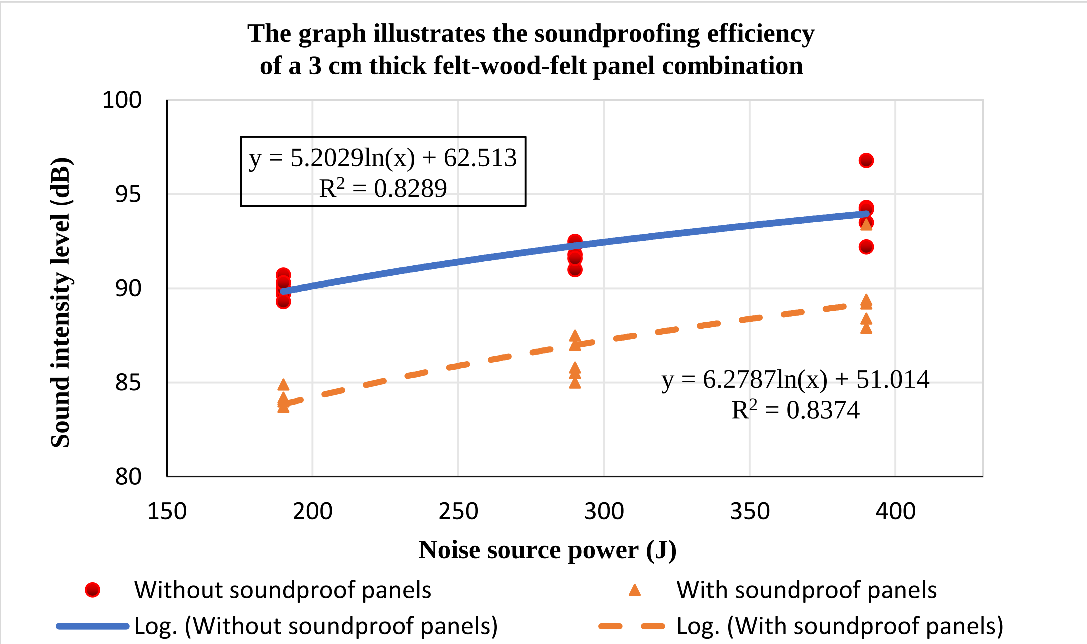

Fig. 12. Sound insulation efficiency graph of 3 cm thick felt-wood-felt combination.

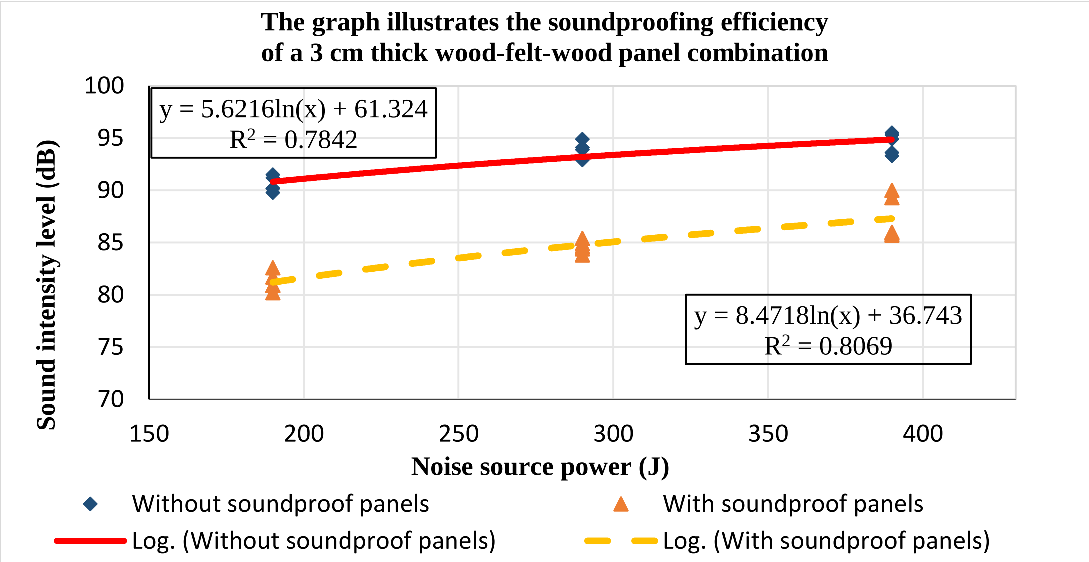

Fig. 13. Sound insulation efficiency graph of 3 cm thick wood-felt-wood combination.

From Figs. 9, 10, 12, and 13, we can establish a table of regression functions and a graph showing the sound reduction law of the studied soundproof panel systems as follows:

Tab. 3. Soundproof characteristic of the combination of soundproof panels

Order	Combination of soundproof panels (3 cm)	Regression function, coefficient of determination R^2, correlation coefficient R		Soundproof characteristic curve
		Without soundproof panels	With soundproof panels	
1	Acoustic sonic felt panels	$y = 5.467 \cdot \ln(P) + 61.468$ $R^2 = 0.8821$	$y = 7.102 \cdot \ln(P) + 47.472$ $R^2 = 0.7795$	$R_\theta = 13.996 - 1.635 \cdot \ln(P)$
2	Black rubber panels	$y = 5.675 \cdot \ln(P) + 61.958$ $R^2 = 0.787$	$y = 8.009 \cdot \ln(P) + 44.89$ $R^2 = 0.818$	$R_\theta = 17.068 - 2.334 \cdot \ln(P)$
3	Felt-wood-felt panels	$y = 5.203 \cdot \ln(P) + 62.513$ $R^2 = 0.829$	$y = 6.279 \cdot \ln(P) + 51.014$ $R^2 = 0.837$	$R_\theta = 11.499 - 1.706 \cdot \ln(P)$
4	Wood-felt-wood panels	$y = 5.622 \cdot \ln(P) + 61.324$ $R^2 = 0.7842$	$y = 8.472 \cdot \ln(P) + 36.743$ $R^2 = 0.807$	$R_\theta = 24.581 - 2.85\ln(P)$

In the graph in Fig. 14 below, it can be seen that the soundproofing efficiency of the combined system of shield panels gradually decreases as the noise source power increases, similar to the behavior of uniform shield panels.

Comparing the two mixed shield panel systems, we observe that using a sound-reflecting material on the outside and a sound-absorbing material in the middle is significantly more effective in reducing noise intensity, achieving a reduction of 9.62 to 7.58 dB, compared to 5.85 to 5.08 dB when using a sound-absorbing material on the outside and a sound-reflecting material in the middle.

This is the initial orientation to propose the structural and material combinations to reduce noise in the area of influence of the airport.

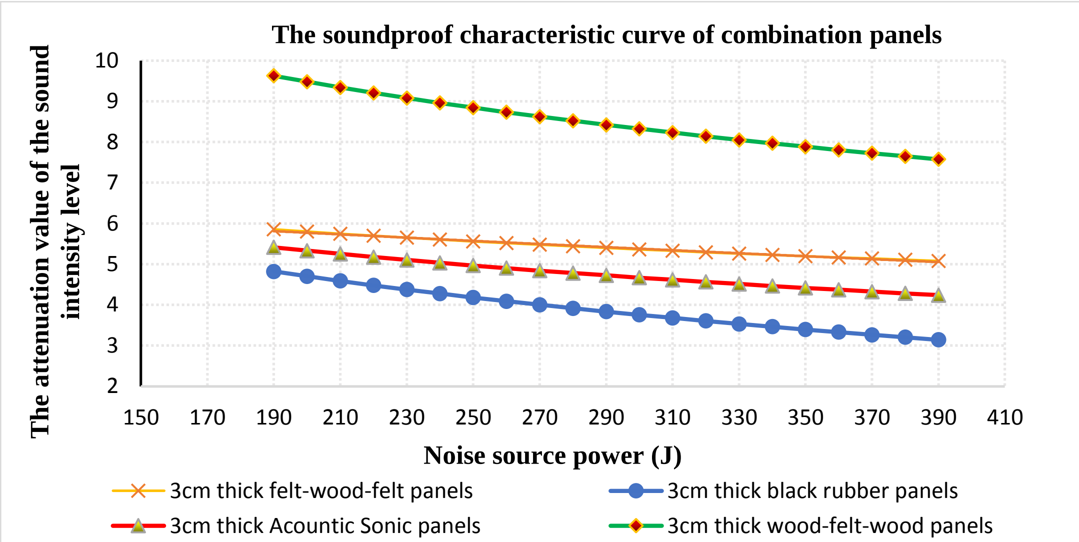

Fig. 14. The soundproof characteristic curve of combination panels.

5. Conclusion

Experiments with electrical blasting machines can produce noise at intensity levels comparable to aviation noise, enabling for the replication of complex field experimental conditions in a laboratory setting.

Different soundproofing materials exhibit varying soundproofing properties. As the power of the noise source increases, the effectiveness of these materials tends to decrease.

Under experimental conditions, the mixed wood-felt-wood panel system demonstrates better soundproofing performance than the felt-wood-felt system and outperforms homogeneous materials. Based on these findings, combining sound-reflecting and sound-absorbing materials is proposed as a strategy for designing noise reduction structures in areas affected by aviation noise at airports.

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ĐÁNH GIÁ HIỆU QUẢ GIẢM ỒN CỦA HỆ CÁC TẤM CÁCH ÂM BẰNG THỰC NGHIỆM

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Tóm tắt: Giải pháp giảm thiểu tiếng ồn hàng không tại các cảng hàng không ngày càng được quan tâm, đặc biệt tại các khu vực đô thị, đòi hỏi nghiên cứu các biện pháp hiệu quả. Bài báo trình bày nghiên cứu thực nghiệm đánh giá, so sánh hiệu quả cách âm khi sử dụng hệ thống tấm màn chắn có chiều dày 3 cm từ các loại tổ hợp vật liệu cách âm khác nhau gồm: nỉ Acoustic Sonic, gỗ ép, cao su đen cho tiếng ồn đơn, có mức cường độ tương đương mức cường độ tiếng ồn của các loại động cơ tàu bay tại các điểm quan trắc quy định của ICAO. Thông qua hệ thống tấm màn chắn, mức cường độ tiếng ồn khi tạo ra từ máy nổ điện có sự suy giảm theo quy luật tuyến tính với Power nguồn gây ồn, đồng thời, nghiên cứu cũng chỉ ra tổ hợp gỗ - nỉ - gỗ có hiệu quả cách âm tốt nhất với mức cường độ âm giảm từ 9,48 dB đến 7,58 dB so với mức cường độ âm từ 5,85 dB đến 5,08 dB khi sử dụng hệ nỉ - gỗ - nỉ và từ 5,42 dB đến 3,14 dB khi sử dụng hệ đồng nhất nỉ, cao su đen với cùng chiều dày. Kết quả nghiên cứu là cơ sở ban đầu để đề xuất dạng tổ hợp các tấm cách âm sử dụng trong công trình giao thông nói chung và sân bay nói riêng.

Từ khóa: *Tấm cách âm; mức cường độ âm; tiếng ồn hàng không; máy nổ điện.*

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