ONLINE ISSN 2069-7430
ISSN-L 1841-4737
PRO LIGNO
www.proligno.ro
Vol. 21 N° 4 2025
pp. 79-89

IMPROVEMENT OF THE AIRBORNE SOUND INSULATION ON WOOD FINISHED PARTITION WALLS

Chun-Hao FENG
Associate Professor, Department of Wood Science and Design
National Pingtung University of Science and Technology, Taiwan
E-mail: chunhao0111@hotmail.com

Fang-Ming LIN
Professor, Department of Wood Science and Design
National Pingtung University of Science and Technology, Taiwan
E-mail: fmlin@mail.npust.edu.tw

Hao-Ting HSU[*]
Ph.D. Student, Graduate Institute of Bioresources
National Pingtung University of Science and Technology, Taiwan
E-mail: shouting0320@gmail.com

Abstract:

Oriented Strand Board (OSB) features the natural texture and color of wood, making it a popular material for industrial-style interior design and decoration in Taiwan. This study investigated the airborne sound insulation performance of a wood-finished partition wall composed of OSB boards with wooden studs. The frequency characteristics of sound insulation performance were analyzed by comparing different wall construction compositions. The results indicated that increasing the wall cavity thickness in wall constructions can enhance sound insulation performance in the frequency range of 250 to 1600 Hz. Additionally, the sound insulation defect around 630 Hz can be improved by using cavity-filling materials. Finally, this study was to provide a reference for wood-finished partition wall constructions composed of OSB boards of wooden studs with resilient and filling material, which were for architectural designers engaged in the building interior environment design.

***Key Words**: Composite Wall, Interior Decoration, Sound Environment.*

INTRODUCTION

In 2017, the Forestry and Nature Conservation Agency designated the year as the “Year of Domestic Timber.” In light of global climate change, promoting the use of locally sourced forest products as substitutes for energy intensive materials has become essential. With effective forestry management, wood can be considered a sustainable material that poses no risk of scarcity, while being naturally degradable and reusable. As a construction material, wood requires relatively low energy for processing, produces limited carbon emissions, and generates minimal pollution. Moreover, wood meets the criteria for ecological green building materials under Taiwan’s Green Building Material Label. When bonded with adhesives containing low levels of toxic substances, it also satisfies the requirements for healthy green building materials. Furthermore, when incorporated into composite walls with enhanced airborne sound insulation performance, wood-based systems can qualify as high-performance green building materials, thereby contributing to improved sound environment quality.

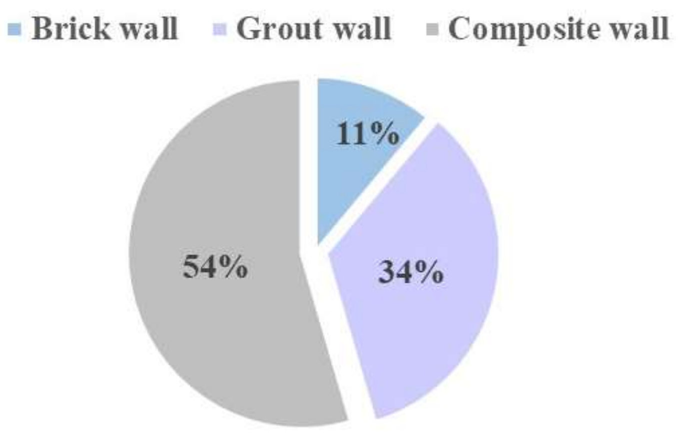
AIRBORNE INSULATION STANDARD OF BUILDING ELEMENT AND CURRENT CONSTRUCTION STATUS IN TAIWAN

Taiwan established regulations on airborne sound insulation performance in 2016. The regulations require a minimum R_w of 50 dB for separating walls and 45 dB for partition walls. As of November 2024, 70 constructions have met the sound insulation standards. These include composite walls, grout walls, and brick walls (Fig.1).

Although Taiwan has already set building performance regulations, but Taiwan’s declining birthrate and aging population have led to a shortage of construction labor. From 2024 to 2070, the working-age population in Taiwan is projected to decrease from 16.17 million to 6.97 million. Therefore, construction processes need to be adjusted. Designing high-efficiency and low-energy construction methods is a future trend in Taiwan.

---

[*] Corresponding author



a. Wall constructions in Taiwan that meet the building regulations requirement

b. composite wall

c. brick wall

Fig. 1.
Description of airborne sound insulation structures.

AIRBORNE INSULATION PROPERTIES OF WALLS

Wall constructions can be classified into single layer homogeneous walls and double layer composite walls. The sound insulation performance of single layer homogeneous is influenced by surface density, stiffness, and damping. According to the mass law, the higher the surface density, the greater its Transmission Loss (TL). However, walls with excessively high stiffness may experience structural resonance at specific frequencies, reducing their sound insulation performance; High damping can effectively absorb sound energy, thereby enhancing the airborne sound insulation. This effect is particularly notable near the resonance frequencies caused by excessively high stiffness.

Double-layer composite walls typically consist of two layers of facing materials separated by an air layer. The internal air layer and any infill materials also affect the airborne sound insulation. The air layer can cause the wall to exhibit resonance f_0 at low frequencies. At frequencies above$\sqrt{2}f_0$, the sound insulation is governed by the mass law. At higher frequencies, standing waves may develop between the wall board. The frequency range of structural vibration modes gradually intensifies and exhibit coincidence effects at the critical frequency f_c (Fig.2). Therefore, resonance frequencies affect the airborne sound insulation of double-layer composite walls.

$$f_0 = \frac{1}{2\pi}\sqrt{\left(\frac{1}{m_1}+\frac{1}{m_2}\right).\frac{\rho c^2}{d}} \qquad \text{(Equation1)}$$

In the equation, m_1 and m_2 are the surface densities of the two wall board; p is the air density (1.21 kg/m³ at room temperature); c is the speed of sound (344 m/s at room temperature) and d is the air layer thickness.

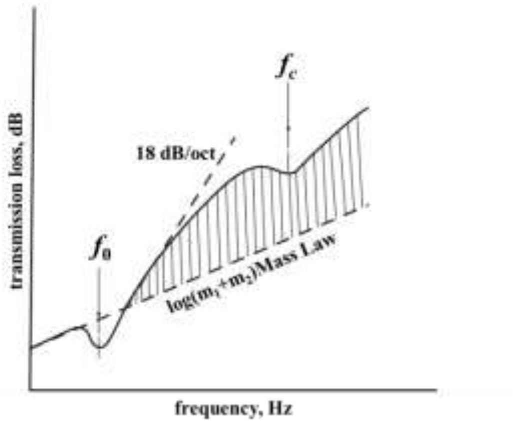


Fig. 2.
Airborne sound insulation properties of double layer composite wall.

(Wang *et al.* 2022) literature summarizes. The factors influencing airborne sound insulation in composite walls. The surface materials, internal materials, and structural form influence both the sound insulation performance and its frequency characteristics (Table 1).

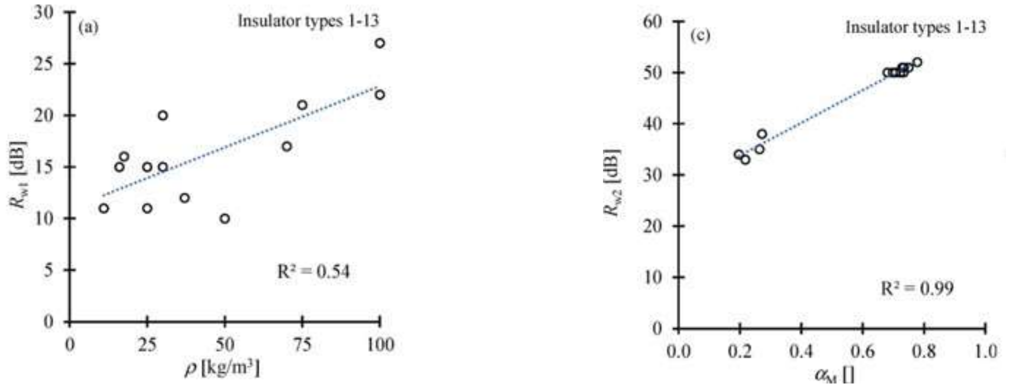
Table 1

The Influencing factor of airborne sound insulation of composite wall (Wang et al. 2022)

Itern	Factors
Surface material	material、weight、density、thickness、sealing
internal materials	material、sound absorption、thickness、weight、air layer
structural form	stud material、stud spacing、construction method

(Wang *et al.* 2022) discussed the effect of the number of gypsum board layers. The study found that each additional layer increases the R_w by 4 dB. The frequency characteristics also improve. Similar results were observed when the facing material was replaced with calcium silicate boards (Nurzynski.J 2022) conducted experiments using gypsum boards, gypsum fiberboards, and oriented strand boards. The airborne sound insulation measurement results indicate that two types of gypsum boards exhibited better performance. due to their higher surface density. The results indicate that the surface density of materials closely affects their sound insulation performance.

(Zeitler 2022) reported that using glass wool, rock wool, or other sound-absorbing materials in the air cavity can improve sound insulation performance, particularly at certain frequencies (Oliazadeh 2019) discussed the sound insulation performance of infill materials. The study found that using sound-absorbing infill materials in the air layer of composite walls does not increase the structural load while enhancing sound insulation performance (Hongisto 2022) discussed the sound insulation performance of partial filling, no filling, and complete filling with sound-absorbing materials. The results indicated that completely filling the cavity with sound-absorbing materials can reduce standing waves within the air layer. The correlation (R^2) between the density of the infill material and the R_w value was 0.54. The correlation(R^2) between the sound absorption performance of the infill material and the Rw value was 0.99 (Fig.3).



a. Correlation between density and R_w (Hongisto et al. 2022).

b. Correlation between sound absorption performance and R_w (Hongisto et al. 2022)

Fig. 3.

The correlation between the infill material and the R_w value.

(Wang *et al.* 2022) Investigated the air cavities of composite walls. After applying 90 mm of glass wool, the R_w increased by 5.3 dB. The results indicate that the use of internal infill materials improves airborne sound insulation performance.The spacing of the air layer also affects airborne sound insulation. (Van den Wyngaert *et al.* 2020) examined wall configurations with air cavity thicknesses of 50 mm 75 mm and 100 mm as the subjects of their study. The results showed an improvement of 1 dB~2 dB; Doubling the air cavity thickness can achieve an improvement of up to 4 dB.

Most current studies focus only on composite walls consisting of steel frames combined with gypsum boards or calcium silicate boards. This study focuses on the airborne sound insulation performance of timber-based composite walls. Considering the shortage of construction labor in Taiwan, Prefabricated construction methods are employed for both the structural frame and the surface materials. The objective is to reduce material waste and carbon emissions. This study investigates the airborne sound insulation performance using natural materials such as wooden frames and oriented strand boards (OSB). Based on the experimental results, an optimized design for wooden composite walls is proposed. The results are expected to meet Taiwanese building regulations or green building standards, serving as a reference for applications in the construction industry.

METHODS AND MATERIALS

The experimental site was located in the Acoustics Laboratory at National Pingtung University of Science and Technology. The measurement method used was ISO 10140-2, "Acoustics − Laboratory measurement of sound insulation of building elements − Part 2: Measurement of airborne sound insulation," published in 2021.

The experimental site was shown in Fig. 4 and 5. The experimental site was divided into two adjacent rooms: one for the sound source and the other for the sound receiving room. The volumes of the rooms were 115.0 m³ and 257.9 m³, respectively. A 10.2 m² opening was located between the two rooms to install the wall specimen.

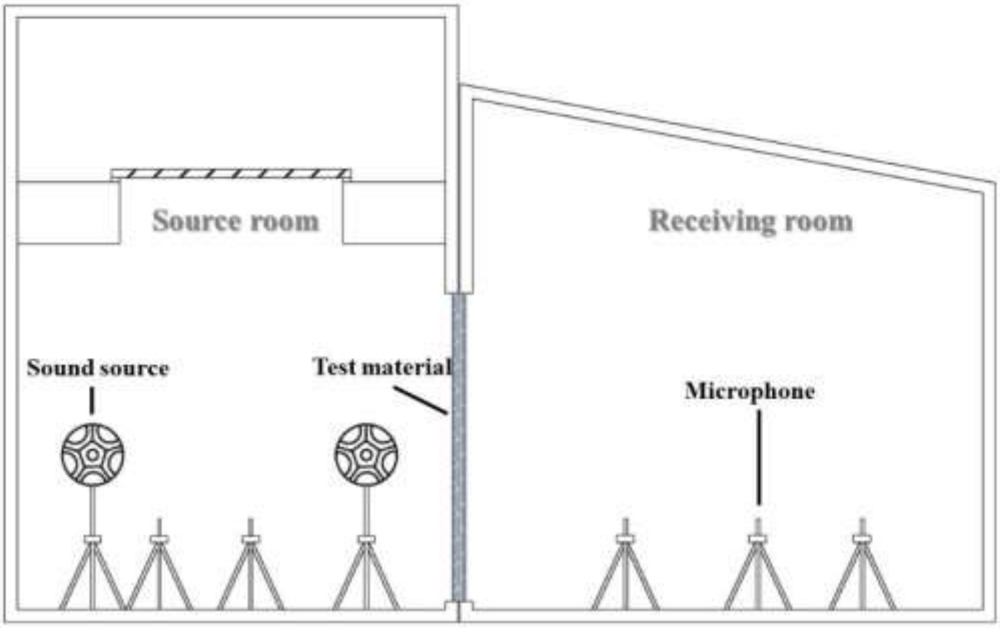


Fig. 4.
The acoustics laboratory of NPUST.

The measurement parameters included the energy average sound pressure level in the sound source room and sound receiving room, background noise and reverberation time of sound receiving room. The measurement frequency included 1/3 octave bands with a center frequency range of 100 ~ 3150 Hz.

During the experiments, a nondirectional loudspeaker generated a white noise signal. Five measurement positions were set up in both the sound source and receiving rooms, and sound pressure levels were recorded at the same time. We also measured the reverberation time and background noise of the sound source room. the apparent sound insulation index *R* of the wall specimen was calculated by Equation 2. In addition, the single-number rating $R_w$of airborne sound insulation was calculated in accordance with ISO 717-1.

$$R = L_1 - L_2 + 10log\frac{S}{A} \qquad \text{(Equation 2)}$$

In the equation, L_1 is the energy-averaged sound pressure level in the sound source room, in units of dB; L_2 is the energy-averaged sound pressure level in the receiving room, in units of dB; the test opening area of the installed wall specimen, in units of m²; A is the equivalent absorption area of the sound receiving room, in units of m². In this study, we primarily investigated the airborne sound insulation performance of a wood finished partition wall with wooden stubs as the wall structure. The wood finished partition wall construction combines different wallboards, filling materials, and an air layer. These assemblies could be regarded as a composite wall. Due to limited funding, the first phase of this study employed a 5.1 m² wall specimen to compare different variables. The second phase of the experiment utilized a 10.2 m² wall specimen to verify the airborne sound insulation performance and discuss the optimization of the wall design (Fig 5, Fig 6) (Table 2).

a. The specimen of composite wall of 5.1 m².
b. The specimen of composite wall of 10.2 m².
c. The wall specimen by wooden studs.

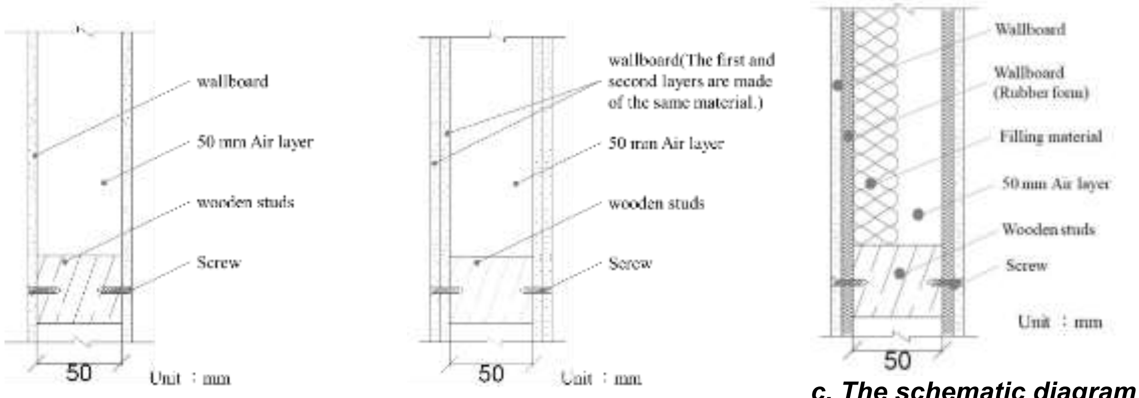
Fig. 5.
Wooden studs and wallboard of this study.

Table 2

Variables of composite wall

Number	Materials	specimen area(m²)	wooden stubs dimension(mm)
S1-CSB	single layer calcium silicate board on each side	5.1	600 x 300 x 50 (Length, width, and thickness)
S2-CSB	double layer calcium silicate board on each side		
S3-CSB	single layer calcium silicate board and rubber form on each side		
S4-CSB	single layer calcium silicate board and rubber form on each side, and infill filling material in wall cavity		
S1-OSB	single layer oriented strand board on each side		
S2-OSB	double layer oriented strand board on each side		
S3-OSB	single layer oriented strand board and rubber form on each side		
S4-OSB	single layer oriented strand board and rubber form on each side, and infill filling material in wall cavity		
L3- CSB	single layer calcium silicate board and rubber form on each side	10.2	
L3- OSB	single layer oriented strand board and rubber form on each side		
OSB (double layer)	single layer oriented strand board、rubber form and infill Filling material on each side + 4 cm wall cavity + single layer oriented strand board on single-sided		
S3-CSB (30)	single layer calcium silicate board and rubber form on each side	5.1	300 x 300 x 50 (Length, width, and thickness)

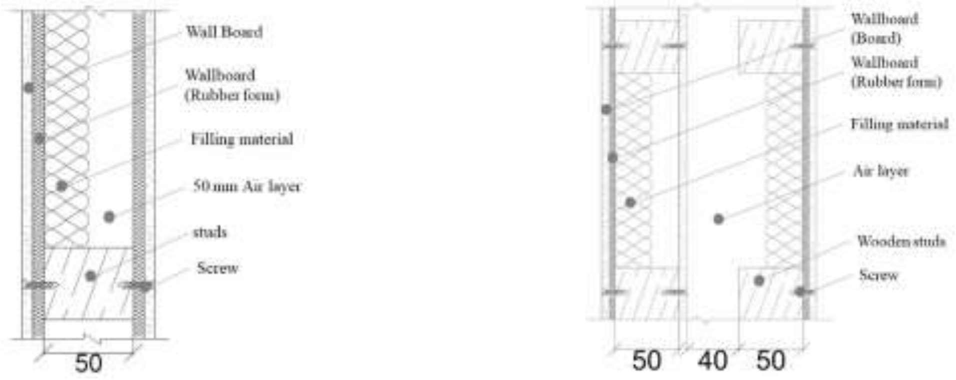
Note:
1. Calcium silicate board (thickness: 6.0 mm, surface density: 5.75 kg/m²) oriented strand board (thickness: 9.0 mm, surface density: 6.10 kg/m²); rubber form (thickness: 4.0 mm, surface density: 7.94 kg/m²; filling material (thickness: 25.0 mm, surface density: 7.71 kg/m²).
2. The wooden studs frame of S3-CSB (30) was 300 x 300 mm.



a. The schematic diagram of S1-CSB, S1-OSB.

b The schematic diagram of S2-CSB, S2-OSB.

c. The schematic diagram of S3-CSB、S3-OSB、L3-OSB, L3-CSB, S3-CSB (30).



d. The schematic diagram of S4-CSB, S4-OSB.

e. The schematic diagram of OSB (double layer).

Fig. 6.
The Schematic diagrams of different composite wall variables.

RESULT AND DISSCUSSION

Table 3

The single-number rating of different composite wall variables.

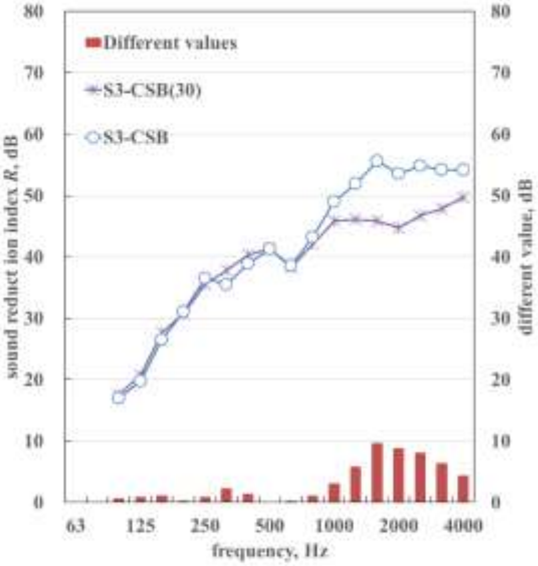
Number	S1-CSB	S2-CSB	S3-CSB	S4-CSB	L3-CSB	S3-CSB(30)
R_w(dB)	23	27	42	44	43	42
Number	S1-OSB	S2-OSB	S3-OSB	S4-OSB	L3-OSB	OSB(double layer)
R_w(dB)	24	30	43	44	45	51

SPACING OF FRAME BY WOODEN STUD

Fig. 7a showed a wall specimen of a wooden stub with a size of 300 × 300 mm, and Fig. 7b showed a wall specimen of a wooden stub with a size of 600 × 300 mm. Fig. 7c showed the airborne sound insulation measurement results of S3-CSB (30) and S3-CSB. The difference in the sound insulation R values of the two wall specimens was not significant below 800 Hz, but there was a difference of 3.2~9.7 dB above 800 Hz. The 300 × 300 mm wall (S3-CSB 30) specimen may transmit greater vibration energy due to the sound bridging effect generated by the structural framework.

a. The frame spacing was set at 300 × 300 mm.

b. The frame spacing was set at 600 × 300 mm.



c. The comparison of sound insulation values at each frequency for S3-CSB (30) and S3-CSB.

Fig. 7.
The effect of airborne sound insulation with different frame spacing.

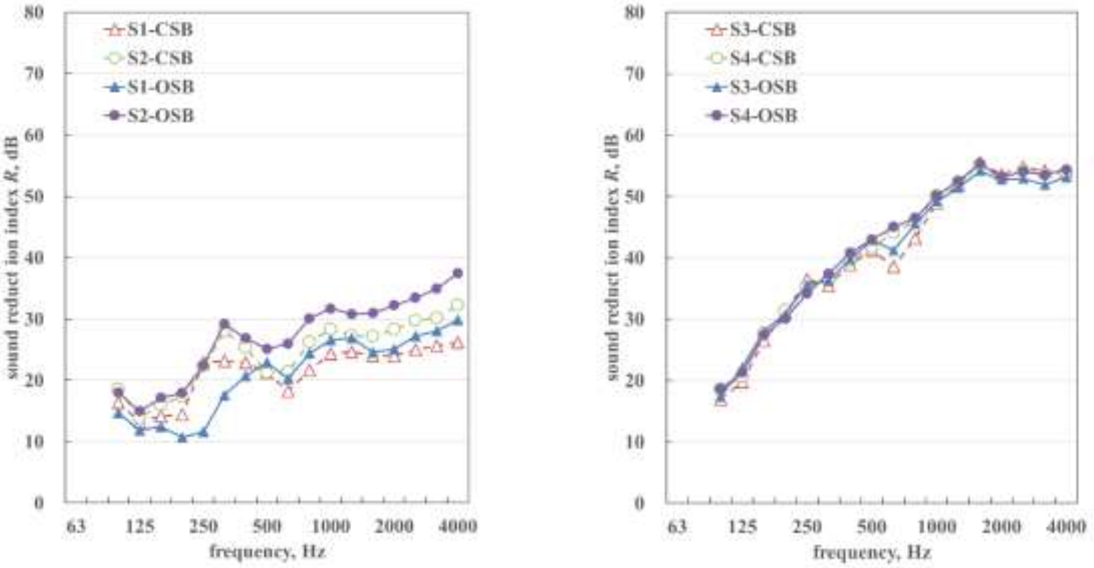
COMPARISON OF AIRBORNE SOUND INSULATION PERFORMANCE OF COMPOSITE WALLS

Composite wall was a common wall structure in Taiwan. Some studies showed that composite wall construction was widely used in various buildings due to it was advantages such as fast construction, clean construction site and light weight (Craik and Smith 2000). Because calcium silicate board, gypsum board or fiber cement board were the most commonly used wall surface materials in Taiwan, this study used CSB and OSB, combined with wooden stubs, to discuss the airborne sound insulation performance of walls with different combinations.

(Fig. 8a) indicated the measurement results of CSB and OSB under single layer and double layer construction conditions. The single number rating R_w of the CSB wall specimen increased from 23 dB to 27 dB. The single number rating R_w of the OSB wall specimen increased from 24 dB to 30 dB. When the number of surface material layers increased, the airborne sound insulation performance will increase by 4 dB, and then most frequencies showed a trend of increasing sound insulation. When using single layer CSB and OSB, the frequencies of 125 Hz and 630 Hz show resonance. Under the condition of double layer board, the resonance phenomenon at the frequency of 630 Hz moves to 500 Hz due to the increase in the surface density of wall board, but due to the limited increase, there is still an obvious phenomenon at the frequency of 125 Hz.

Fig 8b indicated the measurement results of adding a rubber foam to the single layer wallboard and adding a filler material to the wall cavity.

The R_w of the wall specimens of CSB and OSB after adding rubber foam was 42 dB and 43 dB respectively, after adding filling material to wall cavity, the R_w of both wall specimens increased to 44 dB. Because the rubber foam could provide the damping effect of the wall and solve the resonance of the frequency of 125 Hz. Adding filling material in the wall cavity could eliminate the 630 Hz resonance phenomenon.



a. The comparison of sound insulation values at each frequency for S1-CSB, S2-CSB, S1-OSB, S2-OSB.

b. The comparison of sound insulation values at each frequency for S3-CSB, S4-CSB, S3-OSB, S4-OSB.

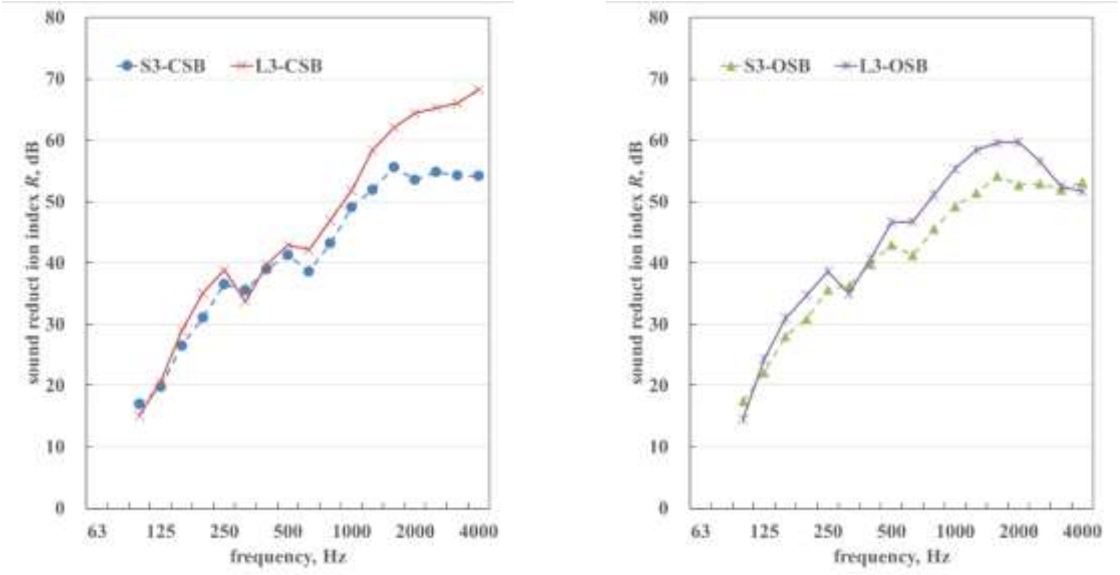
Fig. 8.
The effect of airborne sound insulation using different wallboard combinations and filling materials in composite walls.

To determine whether the test results of the 5.1 m² wall specimen are comparable to those of the standard 10.2 m² wall specimen, this study compared measurement results from wall specimens of different dimensions to verify the accuracy of the sound insulation performance of the 5.1 m² wall specimen.

Fig. 9a indicated that the sound insulation differences of CSB wall specimens with different sizes. The R_w of S3-CSB and L3-CSB was 42 dB and 43 dB respectively, which is not much different.

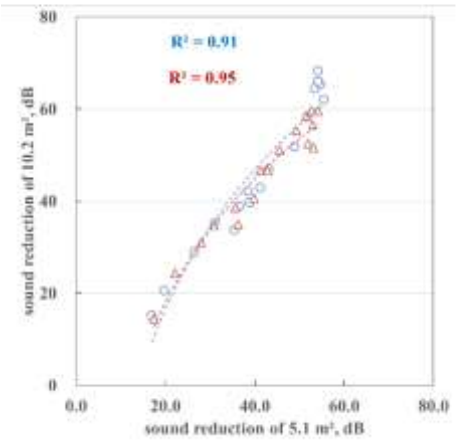
The frequency characteristics indicated that the sound insulation value of L3-CSB exceeded that of S3-CSB above 630 Hz, with a particularly pronounced difference at 1250 Hz, where the two wall specimens differed by more than 5 dB.

Fig 9b indicated that the sound insulation differences of OSB wall specimens with different sizes. The R_w of S3-OSB and L3-OSB was 43 dB and 45 dB respectively, which was 2 dB difference. The frequency characteristics indicated the results were the same as that of CSB, with obvious differences in sound insulation values above 630 Hz. Fig 9c indicated that the sound insulation values of wall specimens of different sizes of CSB and OSB showed high correlation, also demonstrates that, under limited financial resources, a 5.1 m² specimen was employed to investigate wall variation factors, and the resulting values can serve as a reference for further research.



a. The comparison of sound insulation values at each frequency for S3-CSB and L3-CSB.

b. The comparison of sound insulation values at each frequency for S3-OSB and L3-OSB.



c. The correlation of sound insulation value with different wall specimen dimensions.

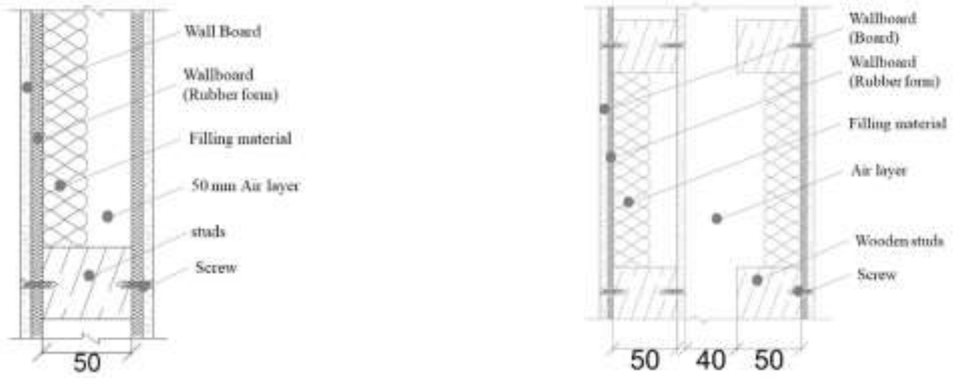
Fig. 9.

The effect of airborne sound insulation with different dimensions of composite wall specimen.

IMPROVEMENT OF AIRBORNE SOUND INSULATION OF OSB

This study examined the improvement of the sound insulation performance of OSB wall structures. Fig.10a showed the structure and sound insulation characteristics of S4-OSB. The results indicated that adding rubber foam to a single layer board effectively enhanced the sound insulation performance of the wall, while incorporating filler material into the air layer reduced resonance.

Fig.10b showed the structure of the OSB (double layer). The S4-OSB specimen was used as the foundation wall, and an optimized wall design was developed by incorporating a 4.0 cm air layer and a 600 × 600 mm wood stub combined with single layer boards and rubber foam. The improvement of sound insulation performance was further achieved through the double layer composite wall construction. Fig.11 showed the sound insulation measurement results of the OSB (double layer). The sound insulation performance was significantly enhanced, with an R_w of 51 dB. Compared with S4-OSB, an improvement of 3.3~24.1 dB was observed within the frequency range governed by the mass law, and no resonance phenomenon occurred below 1000 Hz. Although a coincidence effect appeared at 1600 Hz, it had little impact on the overall sound insulation evaluation of the wall.



a. The schematic diagram of S4-OSB.

b. The schematic diagram of OSB(double layer).

Fig. 10.
Single layer and double layer composite wall structures.

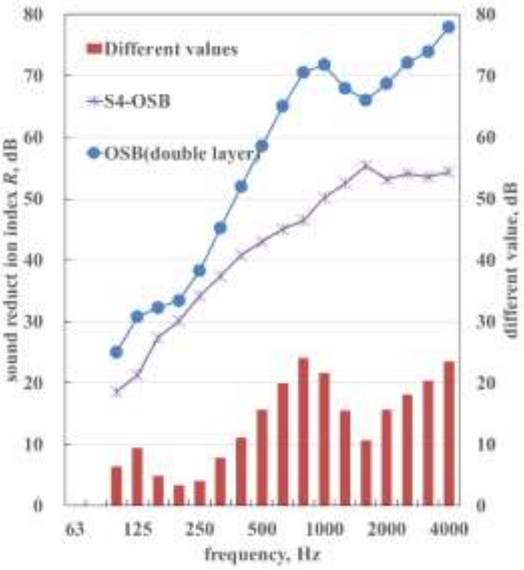


Fig. 11.
The comparison of sound insulation values at each frequency for S4-OSB and OSB(double layer).

CONCUSION

This study investigated the airborne sound insulation performance of wood finished partition wall made of CSB and OSB boards under the condition of wooden stubs. We investigated the sound insulation performance and frequency characteristics under different combination conditions, and the research results serve as a reference for the development of wood finished partition wall. The conclusions of this study were as follows:

(a) Although the composite walls exhibited similar R_w values under different wooden stud conditions, their frequency characteristics were influenced by the gap spacing.

(b) From the experimental results of airborne sound insulation of CSB and OSB composite walls, it was found that light partition walls can use high-damping materials to reduce the occurrence of low-frequency resonance frequencies, while filling materials can improve the standing wave phenomenon generated between the materials on both sides of the wall.

(c) The L3-OSB wall structure, consisting of two single layer OSB boards combined with rubber foam, achieved an R_w value of 45 dB. This level of sound insulation performance is comparable to that of brick walls or reinforced concrete structures. Furthermore, the composite wall of double layer OSB boards, with an R_w of 51 dB, not only complied with Taiwan’s building code requirements for airborne sound insulation of partition walls but also contributed to improved sound environment quality.

REFERENCE

Craik RJM, Smith RS (2000) Sound transmission through double leaf lightweight partitions part I: airborne sound. Applied Acoustics, 61(2):223-245.

Hongisto V, Saarinen P, Alakoivu R, Hakala J (2022) Acoustic properties of commercially available thermal insulators − An experimental study. Journal of Building Engineering, 54:104588.

ISO 10140-2 (2021) Acoustics - Laboratory measurement of sound insulation of building elements Part 2: Measurement of airborne sound insulation.

ISO 717-1 (2020) Acoustics - Rating of sound insulation in buildings and of building elements Part 1: Airborne sound insulation.

Nurzyński J (2022) Sound insulation of lightweight external frame walls and the acoustic effect of additional thermal insulation. Applied Acoustics, 190(1):108645.

Oliazadeh P, Farshidianfar A, Crocker MJ (2019) Study of sound transmission through single- and double-walled plates with absorbing material: Experimental and analytical investigation. Applied Acoustics, 145(1):7-24.

Van Den Wyngaert JCE, Schevenels M, Reynders EPB (2020) Broadband acoustic shape optimization of studs in double-leaf walls. Journal of Sound and Vibration, 485:115562.

Wang J, Du B, Huang Y (2022) Experimental study on airborne sound insulation performance of lightweight double leaf panels. Applied Acoustics, 197(2):108907.

Zeitler B (2022) Chapter 2.3 - Influence of internal thermal insulation on the sound insulation of walls. Energy-Efficient Retrofit of Buildings by Interior Insulation, pp. 193-218.