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Development of sound absorption materials made from recycled glass

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ABSTRACT

In recent years, Taiwan's government has been promoting a circular economy for industrial renovation. To enhance the value of building materials made from recycled resources, researchers carried out a project connecting recycled glass to high-performance materials with the objective of developing sound absorption materials for interior design.

In this paper, we adopted a ceiling system that included panels of expanded metal mesh and infill of glass wool or foamed cement bricks made from recycled glass as study objects. The sound absorption performance was tested in a reverberation room of an architectural acoustics laboratory via ISO 354 and ISO 11654, and we studied the combination of various panel thicknesses and aperture shapes of the expanded metal mesh, as well as the thickness of the air gap in the back side.

The results demonstrated that glass wool with non-woven cloth had good sound absorption performance, and its low frequency absorption was improved when combined with expanded metal mesh. Finally, we were able to propose two kinds of ceiling panel products that provided various sound absorption and flameproof features for interior design.

Key word: Circular economy, Recycling material, Expanded metal mesh.
I-INCE Classification of Subject Number: 35, 51

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1. INTRODUCTION

In recent years, Taiwan's government has been promoting a circular economy for industrial renovation. To enhance the value of building materials made from recycled resources, researchers carried out a project connecting recycled glass to high-performance materials with the objective of developing sound absorption materials for interior design.

In this research project, we proposed a ceiling system with panels of expended metal mesh (EMM) and sound absorption infill. In the ceiling system, the porous infill provides high-frequency sound absorption performance, while the EMM panel with the inner air gap provides the low-frequency performance. As for the infill elements, recycled glass was first made into glass wool and then covered by non-woven cloth and fiber cloth to make it long-lasting and ensure human safety. In contrast, recycled glass was also ground, stirred with cement, and put into foaming process to make a foamed cement brick.

Many previous studies have pointed out that porous materials have a high-frequency sound absorption ability. Bucciarelli et al. [1] used multi-layer micro perforated panels (MPP) at low frequency to theoretically and experimentally demonstrate that ability through an impedance tube. Dengke et al. [2] used a perforated plate with extended tubes to increase the absorption band on low frequencies. Duan et al. [3] presented porous zeolite material and found that a thicker material increased low frequency and absorbing bandwidth. Vasina et al. [4] presented a systematic method for studying acoustic and non-acoustic properties of consolidated porous samples of expanded clay granulate. Sakagami et al. [5-6] have recognized MPP as the next generation of porous sound absorbing material.

In order to find the combination of EMM panel types and air gap and infill material thicknesses, which can potentially improve the market of recycled materials, a research and development project between manufacturers and our university was initiated.

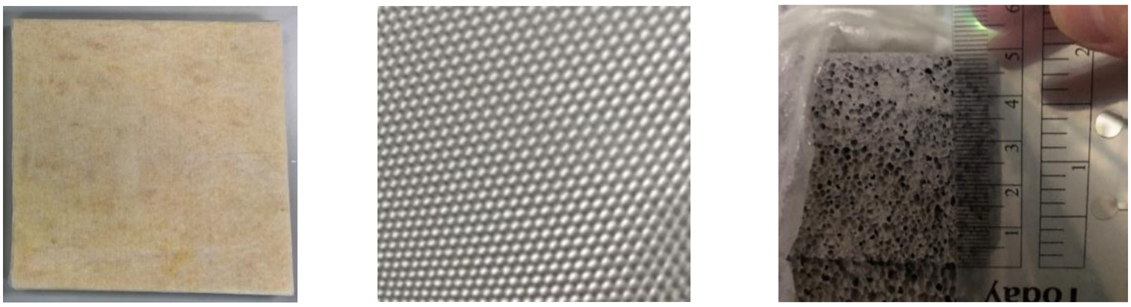
2. METHODOGY

In this study, we carried out a two-step proto-typing process via experiments. In the first step, the sound absorption coefficients of the infill materials were studied. In the second step, the ceiling system with the two best infill materials were tested in the laboratory. All experiments were performed according to ISO 354 and ISO 11654 standards in the architectural acoustic laboratory at National Cheng Kung University.

2.1 Test specimen of infill materials

Figure 1 shows pictures of glass wool with non-woven cloth and fiber cloth, as well as a foamed cement brick. Glass wool, which had a density of 24 kg/m^3, and a foamed cement brick, which had a thickness of 50 mm and a density of 270 kg/m^3, were adopted in the study. Each infill material unit was 60 cm × 60 cm and was implanted on the floor. The glass wool was covered by two different types of cloth, flame-retardant non-woven cloth and fire-resistant fiber glass cloth.

The characteristics of the infill material experiments are shown in Table 1, and the pictures of the measurement are shown in Figure 2. We performed the measurements in a reverberation chamber with a volume of 211.6 m^3 according to the process set forth by ISO 354. The total area of the test specimen was 10.8 m^2 (3 m × 3.6 m), and we utilized the interrupted noise method to measure reverberation time using white noise.



(a) glass wool with non-woven cloth (b) glass wool with fiber cloth (c) foamed cement brick

Fig. 1. Pictures of the infill materials

Table 1. Characteristics of the infill material experiments

No.	Recycle material	Cover material	Density	Thickness (mm)	Implanted
1	Glass wool	None	24 kg/m^3	50	floor
2		Non-woven cloth			
3		Fiber cloth			
4	Foamed cement brick	None	270 kg/m^3		

Fig. 2. Absorption coefficient measurements of the test specimens.

2.2 Test specimens of the ceiling system

In this study, we used four kinds of EMM with different thicknesses and mesh shapes for the experiments, as shown in Figure 3. The thicknesses, mesh widths, and mesh lengths are listed in Table 2.

For the experiment, the ceiling system was installed reversely on the floor, as shown in Figures 4 and 5. The infill materials were implanted on the floor, which means that the infill was placed under the floor close to the slab. In total, we studied 24 cases with different combinations of EMM types, infill materials, and air gap thicknesses, as shown in Table 2. Note that the thickness of the air gap included the thickness of the infill material.

Figure 6 shows the aperture shape of EMM. The mesh's width and length are 1 mm × 2 mm and 2 mm × 4 mm.

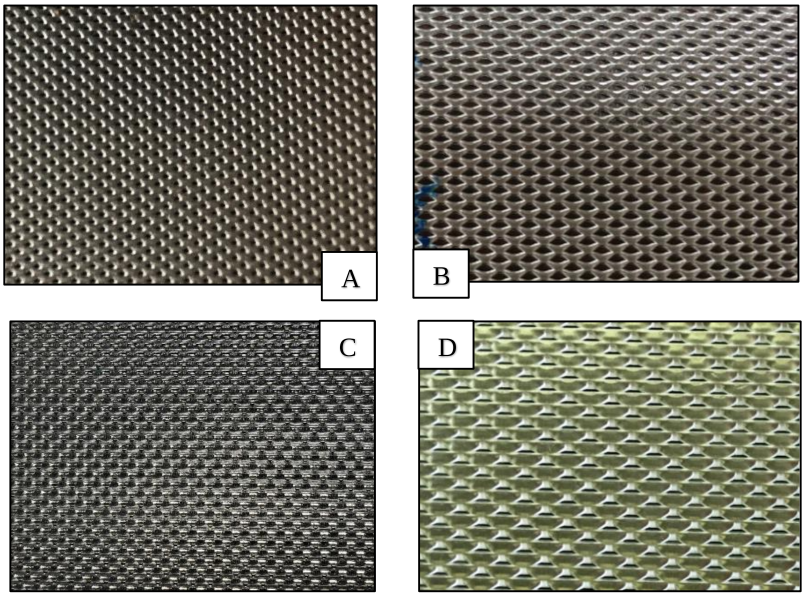


Fig. 3. Pictures of the EMM

Table 2. Cases of sound absorption coefficient measurements.

Case	Type	Air gap thickness (mm)	Mesh thickness (mm)	Mesh width (mm)	Mesh length (mm)	Infill material implanted
A1	A	210	0.5	1	2	On floor
A2						None
A3		260				On floor
A4						None
A5		460				On floor
A6						None
B1	B	210		2	4	On floor
B2						None
B3		260				On floor
B4						None
B5		460				On floor
B6						None
C1	C	210	0.6	1	2	On floor
C2						None
C3		260				On floor
C4						None
C5		460				On floor
C6						None
D1	D	210		2	4	On floor
D2						None
D3		260				On floor
D4						None
D5		460				On floor
D6						None

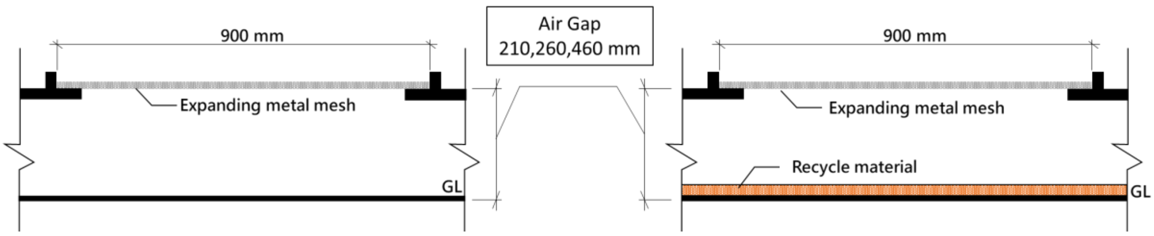


Fig. 4. Sections of the ceiling systems in the experiments

Fig. 5. Pictures of the ceiling systems with different air gaps.

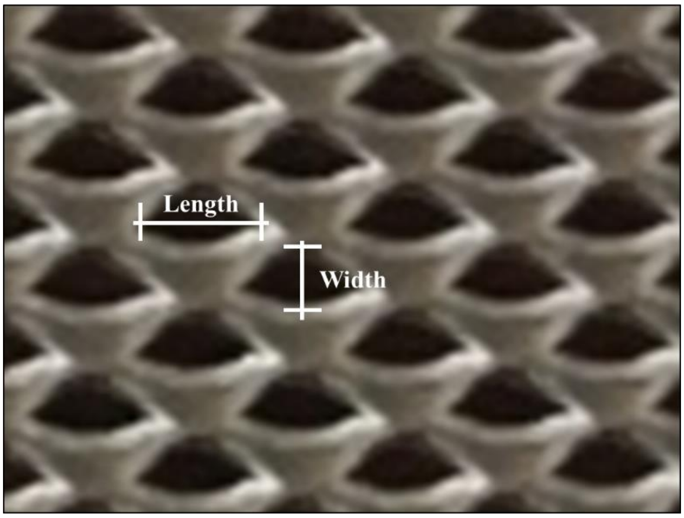


Fig. 6. Aperture shape of the expanded metal mesh.

3. RESULTS

3.1 Results of the infill materials

Figure 7 shows the sound absorption coefficient results of the infill materials. No cover material (No. 1) demonstrated the best sound absorption coefficient value, exceeding 0.8 at frequencies greater than 500 Hz. With the non-woven cloth (No. 2), the performance was reduced but still exceeded 0.8 at frequencies greater than 1000 Hz. The glass wool covered by fiber cloth had a pick at 630 Hz and decreased at high frequencies. The absorption coefficient of all frequencies was under 0.8, thus demonstrating the worst sound absorption performance.

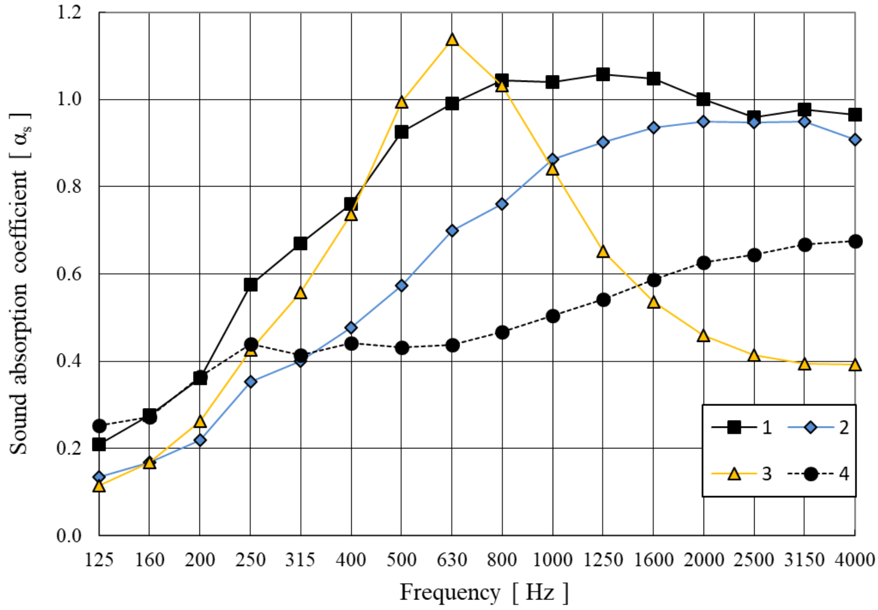


Fig. 7. Results of infill materials.

3.2 Results of the ceiling system

Figure 8 shows the sound absorption coefficient of Type A. The cases with infill materials (A1, A3, and A5) showed better performance than the cases without infill materials (A2, A4, and A6). The air gap of 21 cm (A1) and 26 cm (A3) had a better sound absorption coefficient than 46 cm (A5), especially at frequencies between 250~400 Hz.

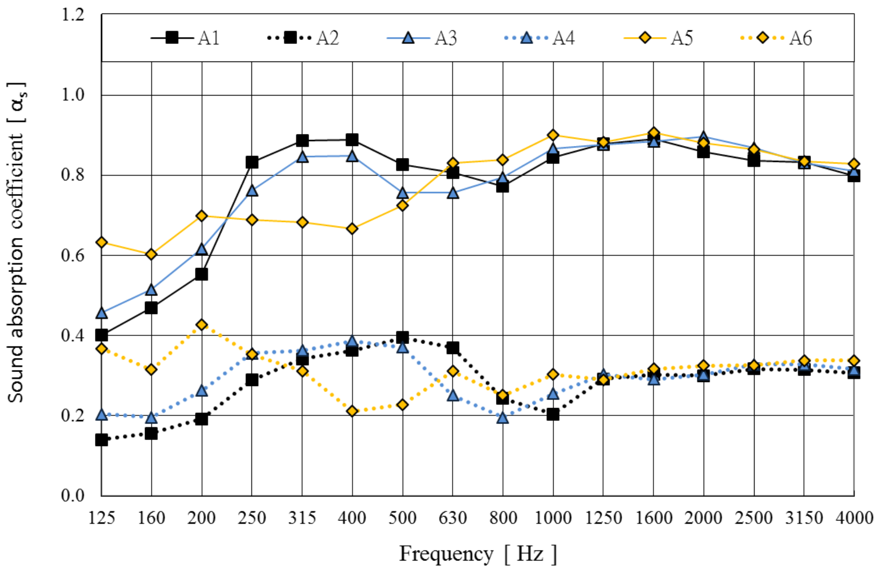


Fig. 8. Sound absorption coefficient of Type A

Figure 9 shows the results of Type B. With the aperture shape of 2 mm × 4 mm, the absorption coefficient of the ceiling system without any infill material had values under 0.2, a significant drop in performance. The system with infill materials showed similar performance, even with different air gap conditions.

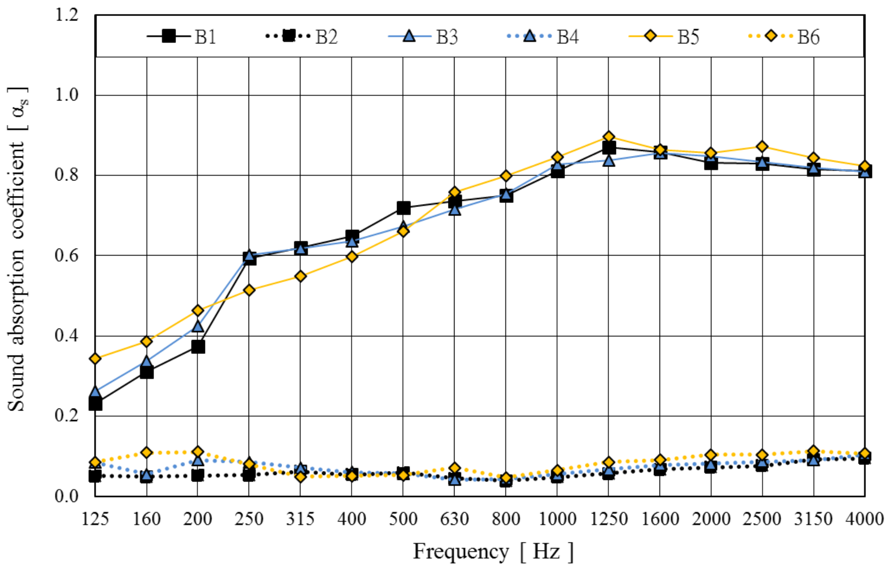


Fig. 9. Sound absorption coefficient of Type B

Figure 10 shows the results of Type C. Compared with Type A, increasing the thickness of the EMM panel from 0.5 mm to 0.6 mm revealed little benefit on sound absorption performance. The curves of the sound absorption coefficient of Type A and Type C are similar at all frequencies. Figure 11 shows the results of Type D, which demonstrates a small increase in performance over Type B and little benefit from changing thickness.

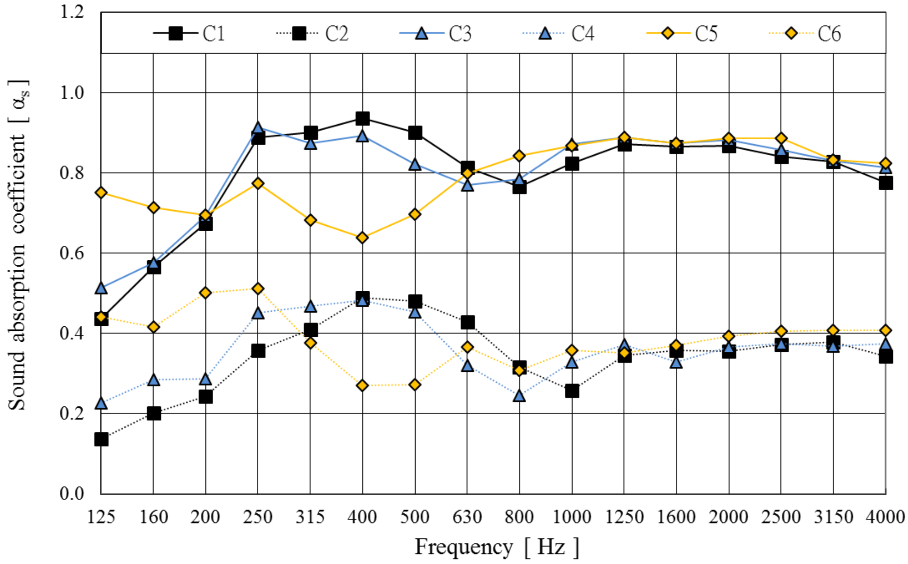


Fig. 10. Sound absorption coefficient of Type C

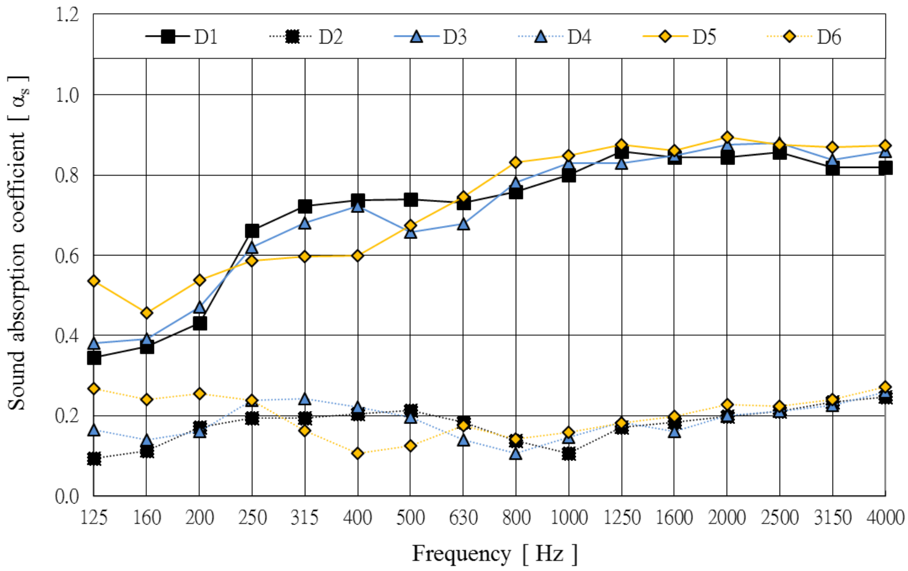


Fig. 11. Sound absorption coefficient of Type D

4. CONCLUSIONS

In this paper, a ceiling system that included EMM panels and infill materials made from recycled glass was studied according to ISO 354 and ISO 11654 standards. The combination of infill thickness, EMM perforation rate, combination of panel thickness and aperture shape of expanded metal mesh, and air gap thickness in the back side were studied. Our results revealed glass wool with non-woven cloth to have the best sound absorption performance. Regarding a ceiling system with better performance, we proposed two kinds of ceiling products with the aperture shape of 1 mm × 2 mm and a panel thickness of 0.5 mm (A1, A3, A5) and 0.6 mm (C1, C3, C5) for interior design.

5. ACKNOWLEDGEMENTS

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