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STUDY ON THE SOUND ABSORPTION PERFORMANCE OF ULTRA-MICROPOROUS HONEYCOMB ALUMINUM PANELS

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Abstract: In order to reduce the impact of intensive noise on personnel comfort in multi-functional exhibition halls, based on the micro-perforation theory, this paper systematically analyzes the sound insulation and sound absorption properties of ultra-microporous honeycomb aluminum panels. By establishing an acoustic finite element model, simulation technology was used to explore the sound insulation and sound absorption coefficient of ultra-microporous honeycomb aluminum panels in the range of 100Hz to 5000Hz. At the same time, the sound insulation amount and sound absorption coefficient were experimentally measured by combining the reverberation chamber method and the standing wave tube method. The results show that the simulation results of ultra-microporous aluminum honeycomb panels are highly consistent with the experimental data. The weighted sound insulation is 27.0dB (experimental value 26.8dB), and the sound absorption coefficient NRC reaches 0.63, which is significantly better than ordinary aluminum honeycomb panels. Research shows that ultra-microporous honeycomb aluminum panels have good noise reduction effects, help improve the acoustic environment in large spaces, and improve personnel comfort.
Keywords: Ultra-microporous honeycomb aluminum plate; Sound absorption performance; Sound insulation; Finite element simulation; Reverberation chamber method; Standing wave tube method

INTRODUCTION

In large indoor spaces such as modern multi-functional exhibition halls, the presence of noise seriously affects personnel comfort and activity experience. Traditional aluminum honeycomb panels are widely used in interior decoration due to their simple structure and light weight. However, their sound absorption performance is relatively poor, especially in the low-frequency area [1,2]. In recent years, ultra-microporous honeycomb aluminum panels, a new sound-absorbing material based on micro-perforation theory, have shown great potential in improving sound absorption effects due to their unique pore structure and porous layer design [3]. However, the specific sound absorption performance of ultra-microporous aluminum honeycomb panels and its comparison with traditional aluminum honeycomb panels have not been fully studied. Therefore, this article aims to systematically explore the sound insulation and sound absorption properties of ultra-microporous honeycomb aluminum panels through a combination of simulation and experiment, in order to provide a theoretical basis for its optimization in practical applications.

1 RESEARCH MATERIALS

1.1 Conventional Honeycomb Aluminum Plate

Conventional honeycomb aluminum panels are composed of two layers of thin aluminum plates and lightweight aluminum honeycomb core materials bonded through an adhesive to form a layered composite structure. The honeycomb core material is a regular hexagonal hole with a side length of 8mm, a material thickness of 0.08mm, and a height of 18mm.

1.2 Ultra-Microporous Honeycomb Aluminum Plate

As a new type of sound-absorbing material, ultra-microporous honeycomb aluminum plate is composed of micro-perforated aluminum plate, perforated aluminum plate non-woven fabric and aluminum honeycomb core material. The specific structure is as follows: behind the plate is a micro-perforated aluminum plate with a thickness of 1mm. The hole shape is an isosceles right triangle, the length of the hypotenuse is 0.4mm, the hole center distance is 2.2mm, and the perforation rate is 0.65%; a layer of 0.2mm thick is attached underneath it. Non-woven porous sound-absorbing material; the bottom of the board is a perforated aluminum plate with a thickness of 1mm, a hole diameter of 2.5mm, a hole center distance of 4.5mm, a perforation rate of 23.8%, and a layer of non-woven porous sound-absorbing material with a thickness of 0.2mm. ;The middle aluminum honeycomb core material is the same as ordinary aluminum honeycomb panel. These can be seen in Figure 1-4.

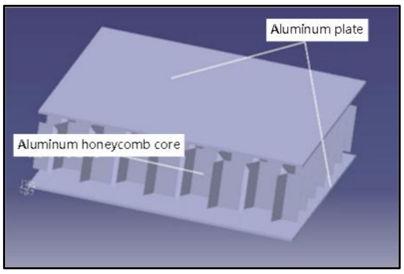

Figure 1 Ordinary Aluminum Honeycomb Panel Structure

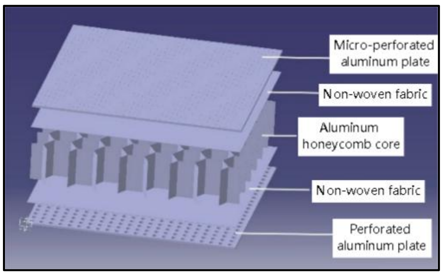

Figure 2 Ultra-Microporous Aluminum Honeycomb Panel Structure

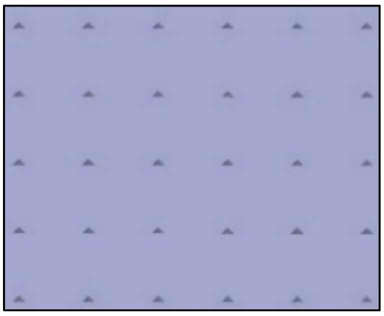

Figure 3 Micro-Perforated Aluminum Plate

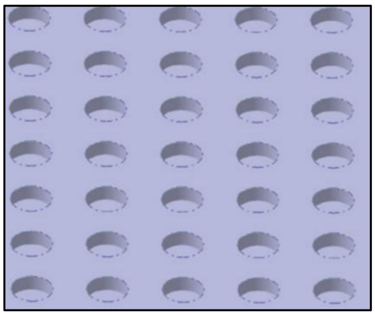

Figure 4 Perforated Aluminum Plate

2 SIMULATION ANALYSIS

As shown in Figure 5 and 6, for the ultra-microporous honeycomb aluminum plate, the acoustic finite element model of the air on the sound-emitting side and the receiving side was established. During the model pre-processing process, the material properties and grid properties of the structure were defined, and fixed constraints were placed around the ultra-microporous honeycomb aluminum plate. Furthermore, the acoustic fluid material and its properties are defined, and a field point grid equivalent to a microphone is set up for monitoring sound pressure.

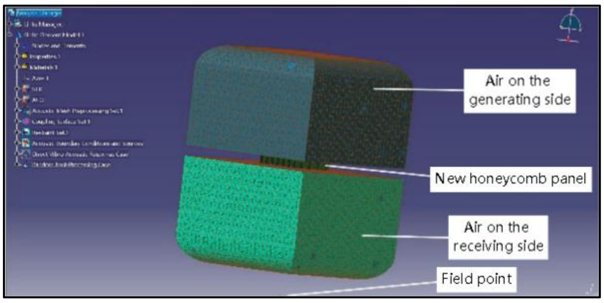

Figure 5 Sound Insulation Simulation Model

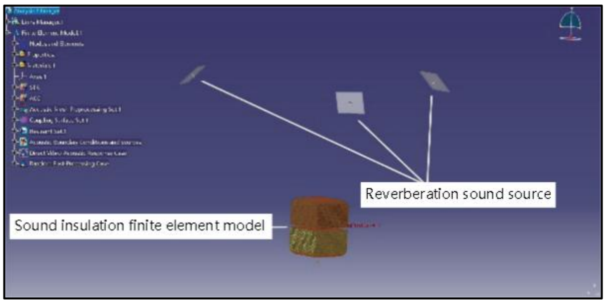

Figure 6 Reverberation Sound Source

The Direct-Acoustic Response Analysis Case is used to perform direct acoustic-vibration coupling calculations on ultra-microporous honeycomb aluminum panels. Subsequently, the coupling response was synthesized into a random calculation response using the Random Post-Processing Case, and a 1/3 octave sound insulation curve in the range of 100Hz to 5000Hz was obtained (see Figure 7). The simulation results show that ultra-microporous honeycomb aluminum panels have poor sound insulation performance at low frequencies (200Hz and 315Hz), but above 800Hz, the sound insulation capacity increases significantly as the frequency increases. The weighted sound insulation is 27.0dB.

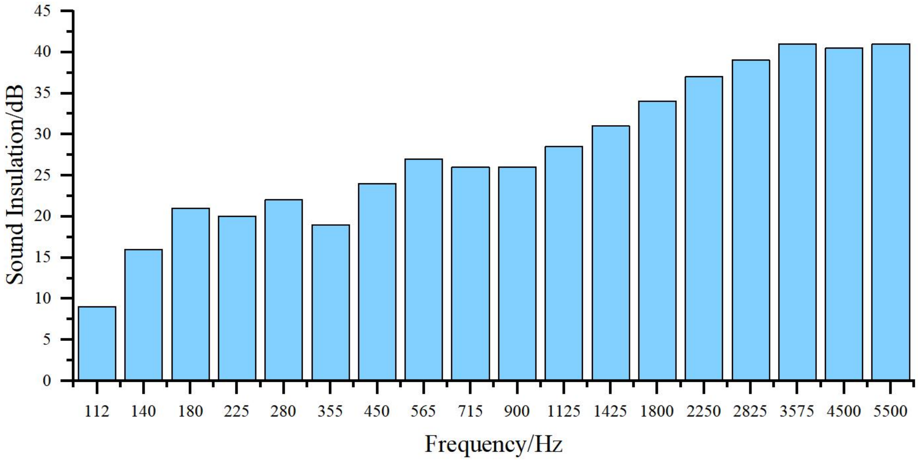

Figure 7 Changes in Sound Insulation

In Figure 8, it can be seen from the simulation calculation results that the low-frequency sound insulation performance of the ultra-microporous honeycomb aluminum plate is poor. The sound insulation amount is significantly reduced at 200Hz and 315Hz. After 800Hz, the sound insulation amount increases with the increase of frequency. The weighted sound insulation amount of the simulation results is calculated. is 27.0dB.

Furthermore, an acoustic finite element model of the impedance tube was established for the ultra-microporous honeycomb aluminum plate, and the acoustic grid was pre-processed. Define the material and grid properties of the structure, define the acoustic fluid material and properties, define a plane sound source on the other side of the air column, and set up two field point grids 1 and 2 equivalent to microphones for monitoring.

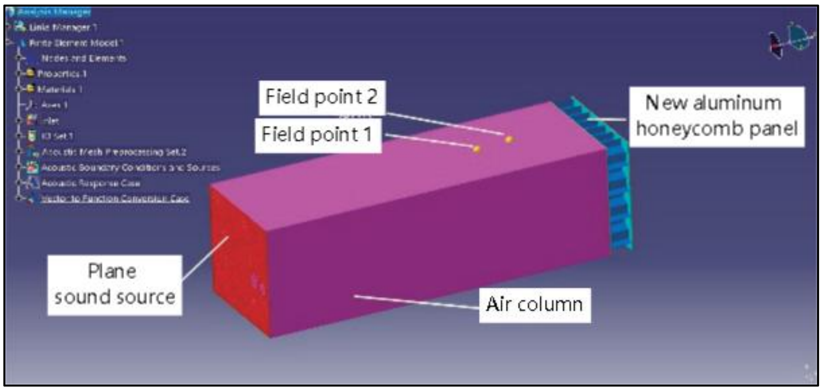

Figure 8 Sound Absorption Simulation Model

Use the Acoustic Response Analysis Case to calculate the acoustic response, then use the Vector to Function Conversion Case to obtain the sound pressure frequency response function at the two field points, and process the data to obtain the sound absorption coefficient curve. Changes in sound absorption coefficient can be seen in Figure 9.

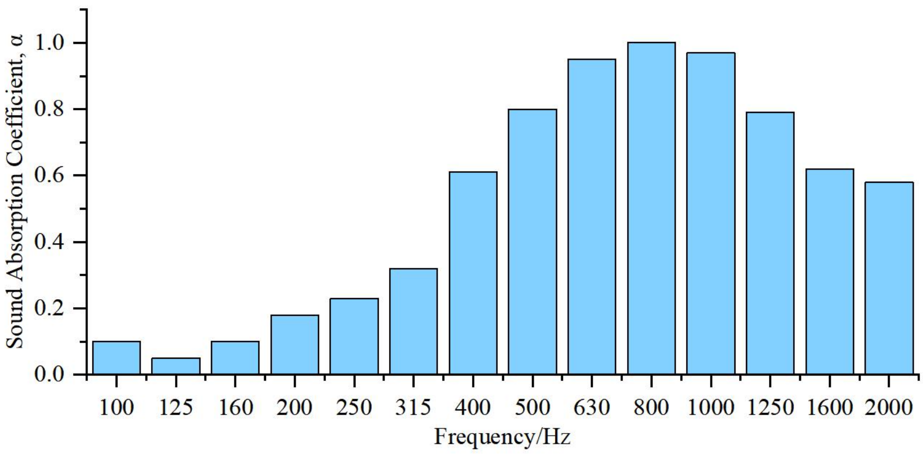

Figure 9 Changes in Sound Absorption Coefficient

It can be seen from the simulation calculation results that the ultra-microporous honeycomb aluminum plate has poor low-frequency sound absorption effect. The sound absorption coefficient reaches the maximum value of 0.99 at 800Hz, and the sound absorption coefficient is greater than 0.6 between 400Hz and 1600Hz. In engineering, the sound absorption coefficient NRC is often used as an index to measure the comprehensive evaluation of sound energy absorption of a material in a closed space. NRC is the arithmetic mean of the sound absorption coefficient of the material at the four frequencies of 250Hz, 500Hz, 1000Hz and 2000Hz. It is calculated The NRC of the simulation results is 0.64.

3 EXPERIMENTAL ANALYSIS

As shown in Figure 10-12, the sound insulation of ordinary aluminum honeycomb panels and ultra-microporous aluminum honeycomb panels was measured using the reverberation chamber method (according to GB/T19889.3-2005 and GB/T 50121-2005 standards). The specimen is fixed in the middle of two adjacent reverberation chambers, a speaker is placed on the sound-emitting side, and microphones are used to collect the acoustic signals on the sound-emitting side and the receiving side. The data is recorded through the test system and processed by computer to obtain the changes in sound insulation. The experimental results show that the weighted sound insulation of the ultra-microporous honeycomb aluminum plate is 26.8dB, which is basically consistent with the simulation result of 27.0dB, verifying the accuracy of the simulation model.

Figure 10 Sound Emitting Side

Figure 11 Receiving Side

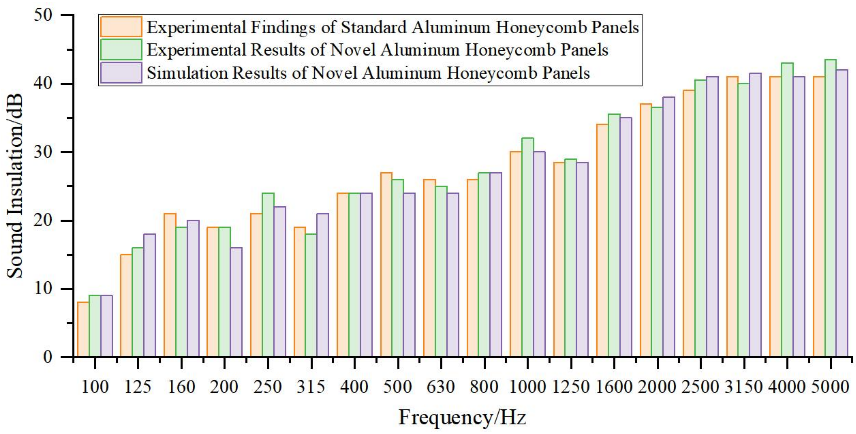

Figure 12 Comparison of Sound Insulation

The standing wave tube method is used to determine the normal incidence sound absorption coefficient of sound-absorbing materials. The test specimen is placed at the end of the standing wave tube, and the signal generator emits plane sound waves of different frequencies through the speaker at the other end to form a standing wave. The microphone measures the sound pressure at different positions in the tube, and the data is processed based on the transfer function method to obtain the change in sound absorption coefficient. Experimental results show that the sound absorption coefficient of ultra-microporous aluminum honeycomb panels is 0.63, and that of ordinary aluminum honeycomb panels is 0.17. Obviously, the sound absorption performance of ultra-microporous aluminum honeycomb panels is far superior to that of ordinary aluminum honeycomb panels, and is highly consistent with the simulation result of 0.64. Sound absorption coefficient comparison curve can be seen in Figure 13.

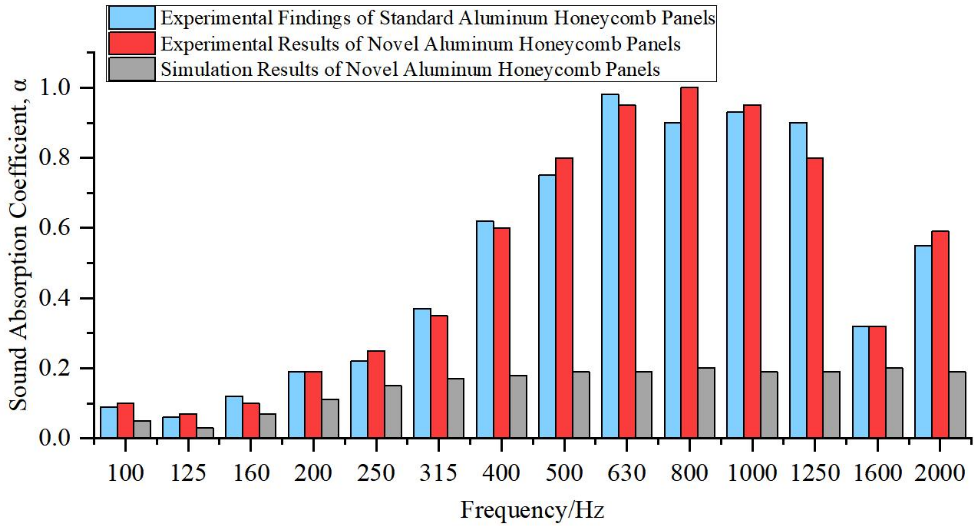

Figure 13 Sound Absorption Coefficient Comparison Curve

4 CONCLUSION

Based on the above-mentioned research on the sound absorption performance of ultra-microporous aluminum honeycomb panels, simulation and indoor testing were combined to conduct a comparative analysis of the sound insulation capacity and sound absorption coefficient of ordinary aluminum honeycomb panels and ultra-microporous aluminum honeycomb panels. The results showed that compared with ordinary aluminum honeycomb panels, the sound insulation capacity of ultra-microporous aluminum honeycomb panels is not much different, but the sound absorption performance of ultra-microporous aluminum honeycomb panels is significantly improved, with the sound absorption coefficient NRC reaching 0.63. When the NRC reaches above 0.5, the noise that the human ear can feel will be significantly reduced. It can be seen that the ultra-microporous honeycomb aluminum plate has a good noise reduction effect, which is beneficial to improving the complex indoor sound environment in large spaces and improving crowd comfort. Future research can further optimize its structural design to improve low-frequency sound absorption performance and expand its application prospects in more fields.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Li Miaoping. Construction technology of self-cleaning aluminum metal composite roof. Construction Technology, 2013, 42(16): 90-92.

[2] Liu Bin. Effect of damping materials on sound insulation performance of subway vehicle floors. Urban Rail Transit Research, 2018, 21(11): 133-135+139.

[3] Zhang Keshu, Xu Qing, Ma Weilian, et al. Simulation and testing of sound insulation and absorption performance of new micro-perforated aluminum honeycomb panels. China Building Materials Technology, 2020, 29(06): 36-39.