Multi-row perforated concrete wall board with built-in sound insulation material

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Abstract. The multi-row perforated concrete wallboard with built-in sound insulation materials studied in this paper is a new type of lightweight sound insulation wall. With reference to the authorized utility model wall, this work performs sound isolation tests on walls with different internal structural parameters cast on multiple sections, using the experimental method of sound insulation room. Based on the experiment, COMSOL numerical simulation software is used to establish a sound-solid multiphysics model to achieve the numerical solution. Three kinds of changing parameters are studied with respect to the effect of the sound transmission on the wall panel. The optimal cross-section combination structure discovered is a foam concrete wall panel with a 15mm thick sound insulation layer, multiple rows of 30 mm diameter holes and a large flow resistance.

1. Introduction

With the development of modern construction technology, the walls used in building construction are required to be light in weight and high in strength. The requirements for noise suppression between various areas outside the building are also becoming more and more demanding. In existing civil buildings, the wall is usually simply light-weight wall tiles, or a number of round holes are provided in the middle of the wall to reduce weight and built-in steel bars to increase strength; in the construction process of buildings, noise isolation is usually adopted with sound insulation by using the soundproof glass effect glass door or glass window.

2. Analysis of existing specifications and lightweight sound insulation wall panels

The sound insulation of buildings is deeply related to all aspects of daily life such as privacy, work, and quality of life. Therefore, problems such as noise pollution in cities are becoming increasingly serious. According to a large number of surveys and studies, the sound insulation of light-weight partition walls must reach at least 45dB to satisfy the residents.

In addition to observing the law of mass, sound waves propagate in solids, and are also affected by the resonance phenomenon in the low frequency band (100 ~ 500 Hz) of the acoustic frequency and the high frequency band (≥3000 Hz) anastomosis effect [1]. In these two frequency bands, sound insulation performance of the Lightweight board will be greatly affected. How to achieve an excellent combination of light weight and sound insulation performance is the main purpose of experiments and simulations.

3. Wallboard design and production

Draw inspiration from scholars at home and abroad, this experimental design wall is a double-layer, multi-row, built-in sound insulation layer made of foamed concrete. Foamed concrete is a lightweight,
heat-insulating, fire-resistant, sound-proof and frost-resistant concrete material. The slurry can be self-leveling, self-compacting, good construction and easy to pump and level, has good compatibility with almost all other building materials, and the strength also can be adjusted [2]. Acoustic materials, such as polyvinyl chloride (PVC), aluminum foam, plywood, fiberglass fabric, and glass rock wool materials, all have good sound insulation performance and are widely used in various fields. In addition, multi-row holes are evenly distributed on both side of the built-in sound insulation material. The schematic diagram of the cross section of the wall is shown in Figure 1.

Fig.1 Double-layer multi-row hole sound insulation wall

Fig.2 Sound insulation laboratory section

The mix ratio of the poured foam concrete is 0.25 kg of JDL-2 foam concrete foaming agent, 70 kg of 42.5 portland cement, 6 kg of sand and 22 kg of water. The foaming agent is diluted in water at a ratio of 1:24 and placed in a high-speed disperser. Fully contact with air, foam until the foam is stable, then pour into a clay mixer and mix with cement, water, water reducing agent and sand, then cast 1m × 0.8m × 0.12m wall template and 100mm × 100mm × 100mm cube mortar test block. After two days, the mold is removed and moved into the curing room, and the standard curing can be tested after 28 days.

4. Basic situation of sound insulation template and test process
A variety of structural walls are selected for the test of the sound insulation test in the laboratory. The sound insulation laboratory profile is shown in Figure 2. Among them, the size of the sound source room is 1.0m × 1.0m × 0.8m (length × width × height) and the plane area 1.0m². The receiving room size is 1.0m × 1.0m × 0.8m (length × width × height), and the plane area is 1.0m². The four wall sizes are 1.0m × 0.12m × 0.8 m (length × width × height), as shown in Table1. The hole size is set to radius r = 15mm, sound insulation layer thickness h = 15mm. Use HS6288B Type noise spectrum analyzer for testing. The testing is based on the standard reference. Five 1/1 octave center frequencies are used to measure the sound insulation performance of the wall, and the center frequencies are 125, 250, 500, 1000 and 2000 Hz.

5. The wall sound insulation calculation
The measured sound insulation of the 4 types of walls is shown in Table 1. The single value of the sound insulation of the wall indicates that it is determined by the measured sound insulation frequency characteristic curve and according to the method prescribed by national standards, which is called weighted sound insulation $R_w$. The values are as follows: 1. LXB-1 41dB; 2. LXB-2 59 dB; 3. LXB-3 56 dB; 4 LXB-4 57dB.

| Hole | Sound insulation material | 1/1 octave band sound insulation |
|------|---------------------------|---------------------------------|
|   | Center frequency / Hz     | LXB-1 | LXB-2 | LXB-3 | LXB-4 |
| 125 | No                        | 16.4  | 38.7  | 35.6  | 36.3  |
| 250 | No                        | 32.9  | 49.3  | 46.4  | 47.2  |
| 500 | No                        | 42.6  | 59.2  | 56.8  | 57.7  |
| 1000| Have                      | 49.0  | 63.4  | 61.3  | 62.1  |
| 2000| Have                      | 52.7  | 66.2  | 64.1  | 65.3  |
6. Test Conclusions
Sound insulation materials can greatly improve the sound insulation volume. Compared with foam concrete, sound insulation materials have more excellent sound insulation performance. Although part of the strength is sacrificed, the sound insulation effect has increased significantly. It should be fully applied in sound insulation wall panels.

Multi-row holes and holes to optimize the surface density of the wall panel. Setting multiple rows of holes in the sound insulation wall panel can reduce the area density by 19.6% under the loss of 5% of sound insulation, and also reduce the amount of concrete while ensuring the bearing capacity of the wall.

7. Basic Model of Multiphysics
The COMSOL Multiphysics software is used to establish an acoustic-solid coupling model based on experiments. The boundary element model of the sound barrier often uses a two-dimensional boundary element model to simplify the boundary element model of the sound barrier [3]. The foam concrete sound insulation wall board is actually poured. Establish the geometric model to set the size, and refine the free triangle meshing, as shown in Figure 3. Using COMSOL to analyze the multiphysics coupling problem can avoid some loose coupling solutions to solve the multiphysics problem error, and achieve multiphysics Process coupling, the numerical solution of the obtained physical process is more accurate [4].

![Fig.3 Finite element model for acoustic analysis of sound insulation wallboard](image)

Set the incident and outgoing power of the sound insulation wall panel. The equation solved by the model is the modified Helmholtz equation, Among them, $\rho$ is the density, $c$ is the speed of sound, and $\omega$ is the angular frequency. Since the density of different materials is different, the equation must include density.

The following equation defines the incoming and outgoing wave power of the sound insulation wall board, as shown in Table 2. The acoustic-structural multiphysics model, solid mechanics, and pressure acoustics module are established in COMSOL. Because the foamed concrete is porous, it is good for sound absorption. The sound absorption coefficient is high, and the acoustic model of porous media can be established in pressure acoustics. The Delany-Bazley single-parameter empirical model can be used. The acoustic-structural boundary is delimited in the multiphysics field. The internal holes and the air boundary are set as the internal hard sound field boundary. Compared with the finite element method, the boundary element method reduces the dimension, which reduces the degree of freedom, and simplifies the problem. The boundary element method is a study of sound barriers Insertion loss numerical tool [5]. Set different parameterized scans according to different research objects.

| name   | expression                                | description         |
|--------|-------------------------------------------|---------------------|
| $p_0$  | 1 [Pa]                                    | Inlet sound pressure|
| $p_{in}$ | $\text{intop\_in}(p_0^2/(2*acpr.rho*acpr.c))$ | Incident wave power |
| $p_{out}$ | $\text{intop\_out}(p*\text{conj}(p))/(2*acpr.rho*acpr.c))$ | Outgoing wave power |
| TL     | $10*\log_{10}(w\_in/w\_out)$             | Sound loss          |

Tab.2 Sound insulation wall panel simulation parameter setting
8. Single factors affecting sound transmission loss of multi-row porous foamed concrete wall
In order to investigate the influence of related structural parameters of multi-row porous foam concrete wallboard on its sound transmission loss, the double-layer and multi-row porous hole radius, foam concrete flow resistance, the distance between multi-row porous holes and sound insulation layer, and the thickness of sound insulation layer were studied respectively. And the effect of ordinary concrete on the sound transmission loss of wall panels.

Double row Hole radius. Keep the other parameters of the original multi-row foamed concrete wall panel unchanged, and set the double-layer multi-row hole radii of 10 mm, 15 mm, and 20 mm in the parameterized scan. Using COMSOL software to calculate the shown in Figure 4. The relationship between the sound transmission loss of the wall plate and the noise frequency under different multi-row hole radii shown in Fig. 4 shows that the effect of the hole radius on the sound transmission loss of the wall plate in the low frequency area is not obvious, but with the increase of frequency When it reaches more than 3000Hz, the effect of the hole radius and the sound transmission loss gradually increases, but the gap between them does not exceed 5dB. The smaller the hole radius, the better the sound insulation performance, but the change of the hole radius size has little effect on the sound transmission loss. It was calculated that the radii of the double-layer multi-row holes were 10mm, 15mm and 20mm, respectively, and the sound transmission losses were: 63.0db, 62.0db and 59.5db.

Flow resistance of foam concrete. Flow resistance is a parameter that reflects the difficulty of saturated fluid around the rigid skeleton of a foamed concrete material when passing through the material. To investigate the relationship between flow resistance and sound transmission loss, the material parameters of foam concrete can be set as 1000p_a s/m² and 10000p_a s/m². Using COMSOL software to calculate the sound transmission loss of the wall plate, the relationship between the sound transmission loss of the wall plate and the noise frequency under different foam concrete flow resistances as shown in Fig. 5 is obtained. The sound loss gradually shows a difference of about 10 dB, When the end of the curve slides down, the coincidence effect occurs. The magnitude of the flow resistance in the middle and high frequency bands has a greater impact on the sound insulation performance of the wall panel. The acoustic loss is 53.3dB when the flow resistance is 1000p_a s/m². The acoustic loss is 74.4dB when the flow resistance is 10000p_a s/m². Sound insulation performance increased significantly.

Distance from multiple rows of holes to sound insulation layer. Keep the other parameters of the original multi-row foamed concrete wall panel unchanged, and set the distance from the circular tangent point of the double-layer multi-row hole near the sound insulation layer to: 0mm, 5mm, 10mm, and 15mm. Calculated using COMSOL software The sound transmission loss of the wall plate, as shown in
Figure 6, is the relationship between the sound transmission loss of the wall plate and the noise frequency at different multi-row holes from the sound insulation layer distance. It can be seen that the four curves basically coincide, only at 2000 Hz. The left, right, and high frequency sections are different, but they can be ignored. There is no obvious difference in the stress, sound pressure, and sound pressure level cloud diagram of the wall panel model. Therefore, changing the distance between the multiple rows of holes and the sound insulation layer will not affect the sound insulation of the wall panel. Impact on performance.

Built-in sound insulation layer thickness. Keep the other parameters of the original multi-row foamed concrete wall panel unchanged, and set the thickness of the double-layer multi-row hole spaced acoustic layer to be 8mm, 15mm, 25 mm, and 35 mm. Using COMSOL software to calculate the sound transmission loss of the wall panel, get As shown in Figure 7, the relationship between the sound transmission loss of a wall panel and the noise frequency under the same thickness of the sound insulation layer is calculated. According to the calculation, the thickness of the sound insulation layer is 8mm, 15mm, 25mm and 35mm, respectively. The time-transmission sound loss is 56.0dB, 60.9dB, 64.8dB and 66.7dB. When the thickness of the sound insulation layer is 8mm, the acoustic wave has a curvature increase similar to that of other thicknesses in the low frequency band, but a trough occurs at 3300Hz, and the anastomosis effect occurs. Increasing the thickness of the sound insulation layer can increase the sound transmission loss, but compared to other wall panels, the parameters are minimal. Thickening the thickness of the sound insulation layer will weaken its longitudinal load capacity when the wall panel thickness is fixed.

Foam concrete and ordinary concrete. Keep the other parameters of the original multi-row foamed concrete wall panel unchanged, set the wall panel concrete parameters, the density of foam concrete is 904kg / m3, and the density of ordinary concrete is 2300kg / m3. The foam concrete is porous, which is larger than ordinary concrete. The porosity and sound absorption coefficient are about 4 times that of ordinary concrete at different frequencies. Therefore, sound mainly exists in the form of acoustic waves in foamed concrete, and exists in the form of stress in ordinary concrete.

The COMSOL software was used to calculate the sound transmission loss of the wallboard, and the relationship between the sound transmission loss of foam concrete and ordinary concrete wallboard as a function of noise frequency was obtained as shown in Figure 8. The huge gap in density, the sound insulation performance of ordinary concrete in the low frequency band was significantly stronger For foamed concrete, the gap gradually narrows in the middle and high frequency bands. At this time, the main effect of sound insulation performance is no longer the density of the wall. It is calculated that the sound transmission loss of foamed concrete is 60.9 dB and that of ordinary concrete is 68.5 dB. With huge differences, the transmission loss is within reasonable control.
9. Comsol simulation conclusion

According to the characteristics of porous media of foamed concrete and experimental basic data, based on multiphysics coupling, an acoustic-solid multiphysics model that can be calculated using COMSOL is proposed. The effect of double-layer and multi-row pore radius, foam concrete flow resistance, The spacing between multiple rows of holes and the sound insulation layer, the thickness of the sound insulation layer, and ordinary concrete on the sound transmission loss of the wallboard were stimulated. The biggest impact is the flow resistance of the foam concrete, followed by the size of the multiple rows of holes. The distance of the layers has no effect. Considering the surface strength of the wall panel in use, it is advisable to fit multiple rows of holes and sound insulation layers. The optimal combination of lightweight sound insulation wall plates is a 15mm thick sound insulation layer and the multi-row hole diameter is 30 mm. The flow resistance is large form concrete wallboard.

Compared with ordinary concrete, foam concrete has a density reduction of only 39% of ordinary concrete at a reduction of 7.6dB in the manufacture of lightweight wall panels, and the sound transmission loss at high frequencies is almost the same, but it is disadvantageous for the purpose of manufacturing lightweight sound insulation wall panels.

Combining the above five single-factor comsol acoustic-solid coupling simulations and room for further research on other factors, the sound insulation of such double-layer multi-row cellular foam concrete in lightweight sound-insulating wall panels is superior to most of the market. The sound insulation wall panel is hoped to promote its industrialized production and apply it to actual projects in the future.

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