Sound Insulation Performance Analysis of New Energy-saving Lightweight Wooden Wall

Xinghua Min¹, Ming Chen¹ and Ting Qu²,3*

¹Nanjing Research Institute of Ecological and Environmental Protection, Nanjing 210013, China
²School of Architecture, Southeast University, Nanjing 210096, China
³Key Laboratory of Urban and Architectural Heritage Conservation of Ministry of Education, Southeast University, Nanjing 210096, China

*Email: 230198012@seu.edu.cn

Abstract. In this paper, a kind of light energy-saving prefabricated building high sound insulation wood wall is designed, and its sound insulation performance is experimentally studied in practical housing applications. Firstly, an energy-saving wood wall is designed on the basis of a sound insulation calculation with weighted sound transmission loss of 44.0 dB. Secondly, the energy-saving wood wall is implemented in practical house applications and the corresponding sound insulation of the wall is measured for evaluation. Measurement results show that the actual weighted sound transmission loss of the wall is 24.0 dB. Further analysis indicates that the gaps of the plates and rigid connections are the main causes of the sound insulation decrease in the actual application of this lightweight wall. This paper provides the design method of lightweight walls for new energy-saving light prefabricated houses, and indicates the importance of optimizing the construction details to guarantee the overall sound insulation performance of energy-saving light prefabricated houses.

1. Introduction

Walls are important parts of buildings. In recent years, requirements for green and energy-saving buildings in China have been increasing, and buildings are developing in the direction of high-rises and large spaces. As a modern new type of wall material, lightweight partition wall has the advantages of increasing the building area, reducing the weight of the wall itself, improving the function of the wall, reducing the comprehensive cost of building construction, and improving the efficiency of building construction operations. However, the lightweight and thin thickness of lightweight wall panels result in poor sound insulation performance of lightweight wall panels. The average sound insulation is around 40dB, which is difficult to meet the minimum requirement on sound insulation of 45 dB in "Civil Building Sound Insulation Design Code GB50118-2010" [1].

In recent years, more and more researchers have paid attention to the sound insulation of lightweight walls. Due to the sound insulation of the single-layer board of the same material, the sound insulation performance is far worse than that of the composite panel, and the existing research is mostly concentrated in the in-situ of composite panels. Chen Jihao et al. [2], Zhong Xiangzhang et al. [3], Wu Tao et al. [4], and Wang et al. [5] conducted investigations on the sound insulation performance of the wall, FC lightweight composite wallboard, GRC lightweight sound insulation composite wallboard and V-shaped corrugated sandwich panel were studied. Xin Fengxian et al. carried out sound insulation experiments on lightweight metal sandwich panels and found that the sandwich panel has the best sound insulation effect on vertically incident sound waves [6]. Cui
Chengxun conducted experiments on different combinations of panels and found that the sound insulation effect of the double-layer of "board-air-sound-absorbing material-board" structure is relatively good [7]. The above studies have investigated methods to improve the sound insulation performance of lightweight panels from different perspectives, such as filling cavities with sound-absorbing materials, adding spring damping connections, and changing the configuration of the panel. Based on the above research, this paper designs a light wood composite wall and analyzes its sound insulation performance.

2. Design of the lightweight wooden wall
The wooden wallboard construction method designed in this paper is shown in Figure 1. From the inside to the outside, the finished wood veneer is 18 mm, the base board is 15 mm, the XPS insulation board is 40 mm, and there is a 60 mm thick air layer in the middle. 40mm XPS insulation board, aluminum keel and outdoor surface layer are wrapped with aluminum XPS insulation board, the total thickness of the wall is 216mm, and the surface density is 32.5kg/m2. The wallboard integrates heat preservation and load bearing.

3. Sound insulation performance prediction
In order to predict the sound insulation effect of the design scheme more effectively, INSUL sound insulation simulation software is used to simulate the scheme. INSUL, a sound insulation simulation software produced by Marshall Day Acoustics, can quickly evaluate the sound insulation performance of new materials and systems and modify existing designs as required [8]. The comparison of experimental data shows that the most reliable predicted value of INSUL is less than 3dB from the measured parameters. However, like other estimation and simulation tools, the simulated results of INSUL cannot be equal to the actual measurements.

During INSUL simulation, related parameters of XPS insulation board of the wall panel refer to the data [9-10], and parameters of other materials are consistent with common market parameters. INSUL simulation results obtained are shown in Fig. 2, with weighted sound insulation \(R_w = 44.0\) dB.

4. In-situ experimental measurement

4.1. Measurement object introduction
The wallboard designed in this paper has been applied in the dream house of Green building Expo Park in Jiangsu Province. For light equipment capacity of type Siheyuan, Dream house adopts the modular production, construction of the ultra-high speed assembly way and removable repeated construction of the turnover use way, which is a concentration of photovoltaic power generation, sewage treatment and other green technology of low carbon buildings. Through the green building design logo formal and building energy consumption evaluation grade certificate, it has important
demonstration significance to realize the sustainable development of urban and rural construction and plays a milestone role in the industrialized construction of buildings and the development of mobile housing. In order to verify the sound insulation effect of the lightweight wall, the acoustic performance of the in-situ experimental measurement and analysis of the results, to find out the problems and further put forward the optimization scheme.

4.2. Experimental measurement

The measured room is a regular living room on the west side of the dream house. The length, width and height of the room are 6.0m×6.0m×3.0m respectively, and the volume of the room is about 108m³.

In the experiment, the French 01DB-Symphonic two-channel acoustic test and analysis system was used to measure the sound insulation performance of the building wall. Firstly, the indoor and outdoor sound pressure levels and indoor reverberation time were measured according to the Code for Building Sound Insulation Measurement GBJ 75-84 [11] and Code for Indoor Reverberation Time Measurement GBT 50076-2013 [12].

According to the specification code [11], the speaker noise measurement method is used to measure sound insulation. The arrangement of measuring points is shown in Fig. 3, in which sound source S, outdoor reference sound pressure level measurement point A1 and indoor measurement point B1~B3 are shown. The sound source S is 0.4 m away from the ground, the outdoor reference sound pressure level measuring point A1 is 2.2 m away from the ground, and the relative distance between the two is 2.5 m. The equivalent sound pressure level measuring point A2 is located in an open place 2.5 m away from the sound source. The indoor and outdoor sound pressure levels obtained are shown in Table 1, and the in-situ measurement photos are shown in Fig. 4 and Fig. 5.

![Figure 3](image1.png)

**Figure 3.** Schematic diagram of the plane of the experimental measuring room and the distribution of sound source points and measuring points (Floor plan)

![Figure 4](image2.png)

**Figure 4** In-situ photos of experimental measurements

![Figure 5](image3.png)

**Figure 5** In-situ photos of experimental measurements
Table 1. Test the indoor and outdoor sound pressure levels of the wall

| Measuring point | Outdoor equivalent | B1 | B2 | B3 | Indoor average |
|-----------------|--------------------|----|----|----|----------------|
| Sound pressure level (dB) | 90.7 | 67.3 | 65.4 | 65.4 | 66.0 |

In this measurement, the interrupted sound source method [12] was used to measure reverberation time. The measurement equipment was B&K4224 active loudspeaker, and the microphone was GRAS-26CA type free in-situ microphone. During the measurement, the generation and interruption of sound signals were controlled by the French 01DB-Symphonie double channel acoustic test and analysis system. In order to accurately test the reverberation time of the room, a total of 4 measuring points were set up in the experiment process, and the average value was taken as the effective reverberation time of the room. The reverberation time of the in-situ measurement $T_{60}=0.53s$.

According to Eq. 2.4.4 and 4.3.2 of sound insulation of building components stipulated in the code [11], the above measurement results are put into the calculation formula, and it is obtained that the weighted sound insulation of the wall panel in the in-situ experiment is $R=24.0$ dB, which is smaller than 44.0 dB of sound insulation simulation analysis.

5. Result analysis and discussion

According to the above simulation and measurement results, the sound insulation of the lightweight wall simulated by INSUL is 44.0 dB, and the sound insulation effect is relatively good. In in-situ experiments, the sound insulation is 24.0 dB, and the sound insulation effect is poor. There is a big difference between the in-situ measurement results and the simulated calculation results of the same plate, the difference is 20.0 dB. The main reasons for this situation are as follows: on the one hand, due to the existence of holes or gaps in the construction process, the sound insulation volume is reduced, and the connection between plates is directly connected by bolts, which has adverse effects on the sound insulation effect. On the other hand, because the construction with a whole is used in light panels, the floor and roof of the light panels on the accurate measurement of wall insulation has a certain degree of interference.

6. Conclusions

In this paper, a kind of light wood wallboard is designed for light equipment residential and applied to the construction of dream house. In order to have an accurate understanding of the sound insulation performance of the wallboard, the sound insulation performance is predicted in the design stage and good preliminary results are obtained, and then the in-situ experimental measurement is carried out. The results show that the measured results are far different from the simulated ones. Although dream house has passed the green building design identification and building energy consumption assessment grade certificate, the actual sound environment feeling of the building has not reached satisfactory results, and the actual measurement data also verified the subjective feeling. Based on the simulation of the sound insulation performance of the wall and the in-situ experiment measurement, the following suggestions are put forward according to the analysis of the results and the experimental investigation:

1) In the process of site construction, try to control the emergence of holes or gaps, and use tongue-and-groove joints or joints with better tightness at the connection between plates, so as to avoid the appearance of flat joints. At the same time, rigid connection should be avoided. The method of bolt direct connection is adopted in this scheme, although the sound insulation performance of the

2) In addition to the wall panels, the roof, floor and other maintenance structures of the building also adopt lightweight structures, which will cause certain interference to accurately measure the sound insulation of the wall panels on site. In order to more accurately measure the sound insulation of lightweight wall panels, this situation should be avoided as far as possible.

3) Although the experimental data show that the most reliable predicted value of INSUL is less than 3dB from the measured parameters, INSUL, like other estimation tools, cannot replace the actual
measurement. In the implementation process of engineering scheme, the on-site measurement results should prevail, because the on-site measurement results are closer to people's subjective feelings.

References
[1] GB 50118-2010 Code for Sound insulation design of civil buildings. [In Chinese]
[2] Chen Jihao, JI Zhijiang, Wang Jing, et al. Research on sound Insulation performance of Lightweight Composite Wall Environmental Engineering, 2012(S1): 9-12. [In Chinese]
[3] Zhong Xiangzhang, MO Fangshuo. Sound Insulation performance of FC lightweight Composite Wall board. New Building Materials, 2001(10): 7-8. [In Chinese]
[4] Wu Tao, CAO Maju, TANG Xiangyang, et al. Construction of GRC lightweight sound insulation composite wallboard and its sound insulation performance test. Building technology, 2005,36 (09): 665-666. [In Chinese]
[5] Wang Zhijin, XU Qinghua. Journal of vibration engineering, 2006,19 (01): 65-69. [In Chinese]
[6] Xin Fengxian, Lu Tianjian, Chen Changqing. Research on sound insulation performance of lightweight metal sandwich plate. Acta acustica (Chinese edition), 2008,33 (04): 340-347. [In Chinese]
[7] Cui Chengxun. Experimental study on sound insulation of double-layer lightweight slab structure. Building science, 2011,27 (10): 63-69. [In Chinese]
[8] Wang Qi. Application of Sound insulation and sound absorption Simulation software in industrial noise prediction. Taiyuan, Shanxi, China. 2015. [In Chinese]
[9] HuoYi. Performance Analysis and comparison of EPS and XPS boards. Construction Science and Technology, 2011(09): 68-69. [In Chinese]
[10] Shen Jiao, Li Deying, Jie Pengfei. Performance Analysis and Application of XPS Plate. Energy Conservation, 2009(08): 13-15. [In Chinese]
[11] GBJ75-1984 Code for measurement of sound insulation in buildings. [In Chinese]
[12] GBT50076-2013 Indoor reverberation time measurement Specification. [In Chinese]