Study on the influence of stagger joint structure on acoustic transmission loss of partition wall

Ping Liu 1, a, Wenhua Zhang 2, 3, b, Xiaoming Dai 1, Fayuan Wu 1, Rui Xu 1

1 State grid of Jiangxi electric power research institute, Nanchang, China
2 Nanchang Institute of Technology, Nanchang, China
3 Nanchang Institute of Technology, Jiangxi Province Key Laboratory of Precision Drive and Control, Nanchang, China

a Liuping_dky@163.com, b Zhangwenhua_610@163.com

Abstract. The existence of gap has always restricted the improvement of sound insulation performance of traditional partition wall structure. The sound transmission loss of partition wall under the slit existence condition was studied. The effects of the staggered slit depth and the staggered slit distance on the sound transmission loss of partition wall were analyzed. The experimental results showed that the sound insulation property of the plasterboard whole component with the staggered slit was better than one with the straight slit. The effect of the staggered slit depth depended on the variation of surface density of partition wall structure and sound wave propagation path. The When the staggered slit distance was equal to the partition wall thickness, the sound insulation property of the partition wall is best. The reason can be explained is that the transmission level of sound energy through the wall is equivalent to that through staggered slit. It makes up the “short board” of slit transmission in partition wall structure.

Keywords partition wall, sound transmission loss, slit depth, straggled slit distance, impedance tube.

1. Introduction
As one of the four major pollutants harming the environment, noise has a serious impact on people’s work, study and physical and mental health. Long-term exposure to noise will damage hearing and vision, induce diseases, affect sleep, and seriously cause cardiovascular diseases[1-3]. In industrial cities with dense population and developed transportation, in order to reduce the impact of noise on residents' life, people have increasingly higher requirements on the sound insulation effect of the housing partition wall. According to the code for sound insulation design of civil buildings (GB50118-2010), the household wall separating bedrooms and living rooms (hall) should have A sound insulation volume greater than 45 dB(A). The sound insulation of the floor plant used for division between residential and non-residential spaces shall be greater than 51 dB(A)[4]. At present, the evaluation requirements related to sound insulation belong to one of the evaluation criteria of green building in both public and residential buildings in China[5].
Under strict standard requirements, Japan developed double layer gypsum board partition with sound insulation of 64 dB, three-layer gypsum board partition with sound insulation of 86 dB and four-layer gypsum board partition with sound insulation of 90 dB[6]. A. Uris[7] et al. studied the influence of rock wool density on acoustic insulation of partition wall, and found that when frequency is below 1250Hz, increasing the rock wool density can increase the sound insulation quantity, but over 1250Hz, the rock wool density has no effect on the sound insulation quantity. A. Uris[8] et al. studied the influence of the built-in board on the sound insulation of components, and found that adding gypsum board into the cavity of the gypsum board partition wall can improve the sound insulation of 100-200 Hz low-frequency band by about 6-7 dB. Bravo J M[9] et al. studied the influence of the air layer between gypsum board and the sound absorber on the sound insulation volume of the partition wall, and found that the existence of the sound absorber can increase the weight sound insulation volume by about 2 dB, and the air layer several millimeters thick will instead cause resonance, thus reducing the sound insulation volume of components.

The propagation of sound wave in the partition system includes the propagation through the partition members and the propagation through the leakage site, where leakage includes regular gaps, irregular gaps and holes, etc. [10]. Study shows that if the acoustic leakage cannot be completely eliminated, the improvement of the sound insulation of the wall structure on the whole components is not much[11]. As the most commonly used building partition material at present, gypsum board is widely used for all kinds of indoor partition. As a result, it is generally a Mosaic structure, and there are inevitable gaps between its Mosaic surface and ceiling, floor and wall, which greatly reduces the overall sound insulation of the gypsum board partition structure. Thus, this study took double-layer gypsum board as the object of study. Through the preparation of staggered joints with different depths and distances, the experimental test was conducted to study the impact of staggered joints on the sound transmission loss of the whole structure.

2. Design of experiment principle, instrument and method

2.1. Experiment principle
The propagation path of sound wave in the wall is shown in Fig. 1. When sound waves hit the wall surface, the magnitude of transmitted sound energy is related to the sound insulation ability of the wall. Part of sound energy transmission is transmitted through local vibration of wall, that is, air sound causes solid vibration and then air sound. The other part is transmitted through the wall gap.

![Fig. 1 Sound transmission through the wall structure](image)

2.2. Experiment instrument and method
As shown in Fig. 2, the acoustic transmission loss of gypsum board slit structure was studied by impedance tube test. he impedance tube test system includes: impedance tube SW422 (diameter 100 mm, frequency range 100-1600 Hz), 4-channel data collector, 1/4 inch microphone, power amplifier, etc.
In order to explore the influence law of partition wall gap structure on acoustic transmission loss, the research object adopts single-layer gypsum board with diameter of 100 mm, thickness of 9.5 mm, 12 mm and 15 mm respectively to form double-layer gypsum board structure. And a 2 cm long and 2 mm wide gap (about 0.5% of the total area of the partition plate) is opened on each side of the single-layer gypsum board, and the gap of the upper and lower plates is staggered (as shown in Fig. 3). The position of the staggered joint is set at 0, 5, 7.5, 10, 12.5, 15 and 17.5 mm from the center line (that is, the staggered joint is 0, 10, 15, 20, 25, 30 and 35 mm).

3. Results and analysis

3.1. Comparison of sound insulation between staggered joints and straight joints

In the construction of the plasterboard partition wall installation, there are inevitable gaps. The conventional way of treating the gap is the overlap of the material, that is, the staggered joint is more conducive to the overall sound insulation of the structure. In order to understand the influence of staggered joints and straight joints on the sound insulation performance of the whole structure, the average sound insulation quantity measured by double-layer gypsum board with different thickness (gap depth) and different gap distances between 100-1600 Hz bands is listed in table 1 below.

| staggered slit distance (mm) | 0 (straight slit, mm) | 15 | 20 | 25 | 30 |
|-----------------------------|-----------------------|----|----|----|----|
| 19 mm thick                 | 17.6                  | 19.2| 21.5| 20.0| 18.6|
| 24 mm thick                 | 18.6                  | 20.7| 21.4| 22.1| 19.8|
| 30 mm thick                 | 19.4                  | 24.9| 25.7| 23.9| 27.6|

Fig. 3 the sketch map and photo of plasterboard staggered slit structure
It can be seen from table 1 that the sound insulation of staggered joints is greater than that of straight joints. When the straight seam structure is transformed into the staggered seam structure, the average sound insulation of the whole structure will increase by at least 1 dB. This is because the setting of staggered joint avoids the phenomenon of "direct penetration" of sound energy in straight joint structure, especially the low-frequency sound wave, and avoids the occurrence of diffraction phenomenon. In addition, the staggered joint structure makes the sound wave inevitably contact the wall surface in transmission, increasing the loss of sound energy.

3.2. Influence of stagger depth on sound insulation of partition structure
The stagger depth of this study is the thickness of the double gypsum board. Therefore, gypsum board structures with the same gap distance and different gap depth were selected to test the acoustic transmission loss. The test results are shown in Fig. 4.

It can be seen from figure 4 that the sound insulation of gypsum board structures with different stagger depths increases with the increase of frequency. The deeper the stagger joints, the greater the sound transmission loss. This can be explained by changes in the overall surface density of the partition wall and acoustic propagation path: On the one hand, the increase of stagger depth is the increase of the thickness of the whole structure of gypsum board, the quality of the whole structure per unit volume increases, and the sound insulation performance of the whole structure is improved according to the law of mass action. On the other hand, the increase of stagger joint depth is the extension of acoustic wave's transmission path in the gap, which increases the frictional energy dissipation between acoustic wave and the gap wall, and thus attenuates the transmission sound energy of the overall structure of the partition wall.
Fig. 4 Effect of staggered slit depth on the sound insulation property of the double plasterboard baffle structure (a,b,c,d)

3.3. Influence of the gap distance on the sound insulation of the partition structure
The study took the double-layer gypsum board of 19 mm, 24 mm and 30 mm thick as the test object. The sound transmission loss of partition wall structure under different gap distances was tested, as shown in Fig. 5.

Fig. 4: Effect of staggered slit depth on the sound insulation property of the double plasterboard baffle structure (a,b,c,d)

Fig. 5: Effect of staggered slit distance on the sound insulation property of the double plasterboard baffle structure

As shown in Fig 5, the sound insulation amount of gypsum board structure with different stagger distance increases with the increase of frequency. It can be seen from the analysis of gap gap gap distance, as the gap gap distance increases, the sound insulation performance of the overall structure of the partition wall increases gradually, and decreases after reaching a maximum value. When the sound insulation structure has the greatest sound insulation performance, the gap distance and the thickness of the double gypsum board are the closest. Table 1 shows the calculated average sound insulation amount of the double gypsum board partition wall structure with different staggered joints, which also verifies the above statement. According to the analysis, this may be because when the gap gap gap distance is less than the thickness of the partition wall, sound wave can easily pass through the gap. When the gap gap gap is larger than the thickness of the partition wall, the sound wave can easily pass through the wall. Only when the gap gap gap distance is close to the thickness of the partition wall, the transmission difficulty of sound wave through the wall and the gap is equal, which makes up for the sound penetration "short board” of the gap in the partition structure, and improves the overall sound insulation effect.
4. Conclusion
In the installation and construction of the plasterboard partition wall, it is inevitable that there is stitching, that is, straight and staggered joints. In this paper, the crack of double gypsum board partition wall structure is studied respectively by the measured impedance tube. The results show that the setting of staggered joints improves the sound insulation performance of the overall structure of the partition wall. The greater the depth of staggered joints, the sound insulation of the wall structure is also large. When the gap distance is close to the thickness of the partition wall, the transmission of sound wave through the wall and the gap is relatively difficult, thus making up for the sound penetration "short board" of the gap in the partition structure, and improving the overall sound insulation effect. The results of this study can provide scientific basis for the design and treatment of gap acoustic insulation of double layer and multi-layer partition structure in the future.

If you follow the “checklist” your paper will conform to the requirements of the publisher and facilitate a problem-free publication process.

Acknowledgements
This work was supported by the Research Project Foundation of State grid of Jiangxi Electric Power Company[52182016000X], the Scientific and Technological Research Project Foundation of Jiangxi Education Department [GJJ161121], the National Natural Science Foundation of China [21603093] and the Scientific and Technological Research Project Foundation of Jiangxi Education Department [GJJ151132]. Scientific.

References
[1] W-S Zhang, H Zhou, L-W Xiao. etc. Study on correlation between hearing loss of noise workers and blood pressure and hypertension[J]. Chinese journal of occupational diseases, 2012,30(70): 517-520
[2] Passchier-Vermeer W, Passchier W F. Noise exposure and public health[J]. Environmental health perspectives, 2000, 108(Suppl 1): 123-131.
[3] Willich S N, Wegscheider K, Stallmann M, et al. Noise burden and the risk of myocardial infarction[J]. European Heart Journal, 2006, 27(3): 276-282.
[4] The ministry of housing and urban-rural development of the People's Republic of China. GB 50118-2010 Specification for sound insulation design for civil buildings[S]. Beijing China construction industry press, 2010
[5] The ministry of housing and urban-rural development of the People's Republic of China. GB/T 50378-2014 Green building evaluation standard [S]. Beijing China construction industry press, 2010
[6] Matsumoto T, Uchida M, Sugaya H, et al. Development of multiple drywall with high sound insulation performance[J]. Applied acoustics, 2006, 67(6): 595-608.
[7] Uris A, Llopis A, Llinares J. Effect of the rock wool bulk density on the airborne sound insulation of lightweight double walls [J]. Applied Acoustics, 1999, 58(3): 327-331.
[8] Uris A, Bravo J M, Gomez-Lozano V, et al. Sound insulation of double frame partitions with an internal gypsum board layer [J]. Applied Acoustics, 2006, 67(9): 918-925.
[9] Bravo J M, Sinisterra J, Uris A, et al. Influence of air layers and damping layers between gypsum boards on sound transmission[J]. Applied Acoustics, 2002, 63(10): 1051-1059.
[10] Asakura T, Sakamoto S, Sakimoto Y, et al. Leak transmission characteristic of slit-shaped apertures and effect of porous type absorption on reducing propagating sound[J]. Acoustical science and technology, 2009, 30(2): 147-150.
[11] Hongisto V, Keränen J, Lindgren M. Sound insulation of doors—Part 2: comparison between measurement results and predictions[J]. Journal of sound and vibration, 2000, 230(1): 149-170.