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Research on Airborne Sound Insulation Performance of Lightweight Steel Gauge and Lightweight Concrete Partition Wall

Weibin WU[1]; Guojun YAN[2]; Jie LIN[3]

[1, 2, 3] China Academy of Building Research, China

ABSTRACT

To investigate the airborne sound insulation properties of lightweight steel gauge and lightweight concrete partition wall, we have measured different configurations of walls in CABR Acoustics Laboratory in accordance with ISO 10140-2:2010. The basic structure consists of lightweight steel gauge, fiber cement panels mounted on each side as permanent formwork, and cast-in-place lightweight concrete of different thickness and density. Test results show that sound reduction index of walls with and without concrete casting differs greatly in frequency characteristic, and increment of concrete density provides a better improvement in sound insulation than that of thickness. Then we attached plasterboards on both sides of walls therein and got diverse results. For lighter walls, additional plasterboards contribute to better sound insulation, while for heavier walls, weighted sound reduction index decreases due to resonance of plasterboards. Finally, we measured multilayer walls of heavy-heavy, heavy-light and heavy-light-heavy structure, where heavy and light mean cavity filled with concrete and mineral wool respectively. Multilayer structure is a good way to improve sound insulation, but symmetrical configuration should be avoided to prevent overlap and magnification of acoustics defects.

Keywords: Sound insulation, lightweight steel gauge, lightweight concrete
I-INCE Classification of Subjects Number(s): 33

1. INTRODUCTION

Lightweight steel gauge and lightweight concrete partition wall is a kind of composite wall consists of lightweight steel gauge, permanent formwork and lightweight concrete. Based on the traditional structure of lightweight double leaf partition and integrated with the application of cast-in-place lightweight concrete, it presents the advantages of lightweight, integrity, soundness, durability, etc. The lightweight steel gauge and wall panels can be prefabricated in factory, and assembled on site together with the lightweight concrete pouring. Its simplicity and high building efficiency can nicely meet the requirements of building industrialization.

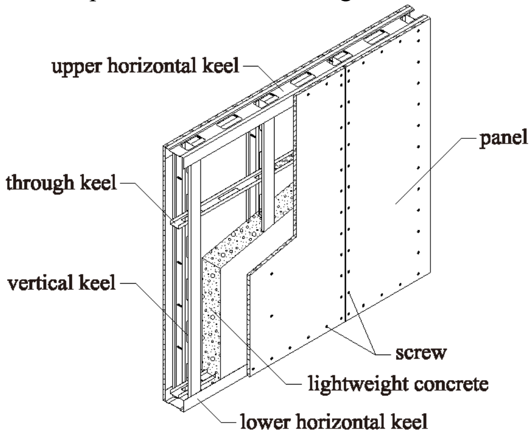

Figure 1 – Structure of lightweight steel gauge and lightweight concrete partition wall

[1] bin_cabr@foxmail.com
[2] yanguojun@126.com
[3] l_jie_bj@aliyun.com

Acoustically speaking, the sound insulation characteristics of lightweight steel gauge and lightweight concrete partition wall are ill-defined due to the interaction between the lightweight steel gauge and lightweight concrete structurally. Therefore, we intend to find out the sound insulation properties and key factors by conducting a series of measurements for different configurations of walls, which will be contributive to the design and construction in future projects.

2. MEASUREMENT SETUP

2.1 Facilities and Equipment

All the measurements were carried out in Acoustics Laboratory of China Academy of Building Research. The test chambers consist of source room and receiving room, which are structurally isolated from each other to avoid flanking transmission. The volumes of source room and receiving rome are about 69m^3 and 55m^3 without filler wall. The area of full-sized test opening is about 3.67m(W)×3.00m(H), 11.0m^2. Panel absorbers are installed in both rooms to achieve appropriate reverberation time in accordance with ISO 10140-5:2010.

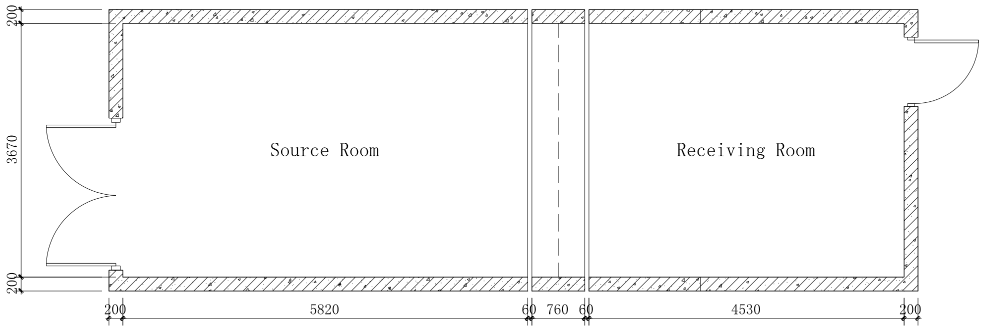

Figure 2 – Sound insulation test chambers

The equipment used to perform the tests is listed in Table 1.

Table 1 – Equipment list

Device	Manufacturer	Type
PULSE Analyzer Platform	B&K	LAN-XI Type 3160
Microphone	B&K	Type 4190
Preamplifier	B&K	Type 2669-B
Sound Calibrator	B&K	Type 4231
OmniPower Sound Source	B&K	Type 4292-L
Amplifier	Crown	XTi 4000
Rotating Microphone Boom	B&K	Type 3923

2.2 Test Specimen

The basic structure of the partition walls under test is composed of lightweight steel gauge as supporting framework, 10mm fiber cement panels mounted on both sides as permanent formwork, and cast-in-place expanded polystyrene concrete inside the cavity, which we call the concrete core. By changing the density and thickness of EPS concrete, attaching plasterboards to the walls, and adding extra cores filled with EPS concrete or mineral wool, we have measured 10 walls of different configurations in all.

2.3 Reference Standards

All the measurements were performed under the instructions of ISO 10140-2:2010. The weighted sound reduction index R_w were calculated in accordance with ISO 717-1:2013.

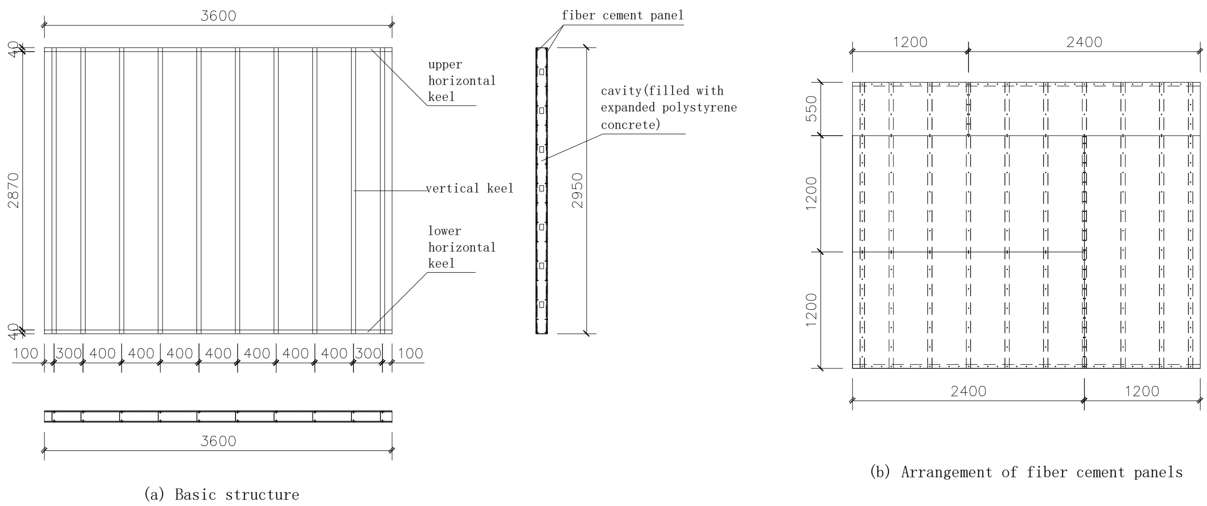

Figure 3 – Basic structure of the specimen

3. RESULTS AND DISCUSSION

3.1 Effect of Concrete Density

EPC100(400) and EPC100(800) are of the same dimension and configuration but filled with EPS concrete of 400kg/m^3 and 800kg/m^3 respectively. For comparison, we also measured the wall EPC100(0) leaving the cavity empty.

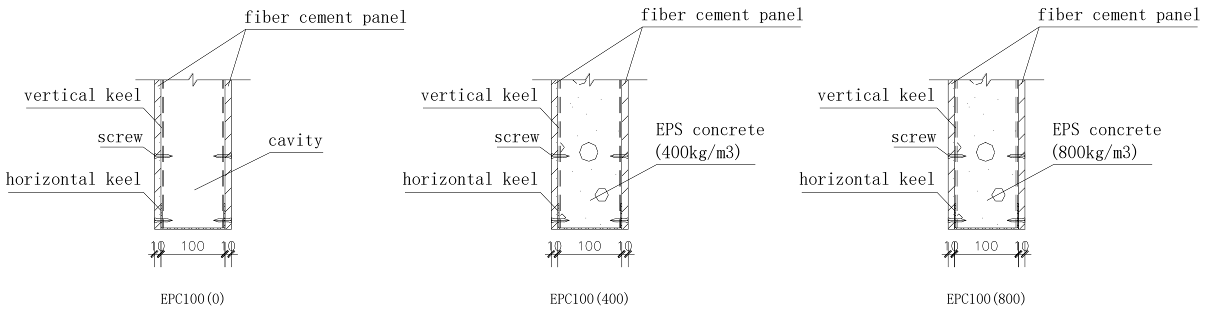

Figure 4 – Structure of walls with different concrete density

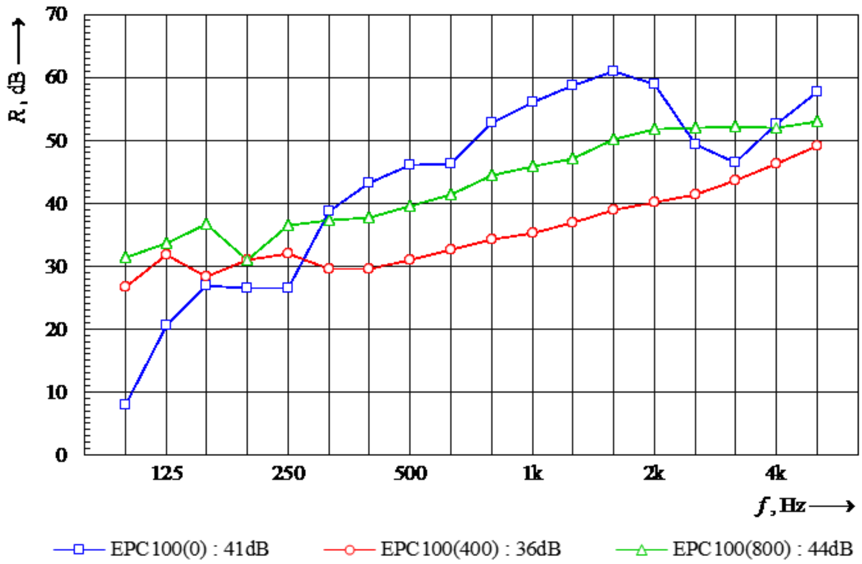

Figure 5 – Sound reduction index of walls with different concrete density

As no concrete was cast inside the cavity, EPC100(0) forms a typical lightweight double leaf partition wall. Sound reduction index outperforms that of EPC100(400) and EPC100(800) in medium frequency range, providing an intermediate R_w between them. A deep pit occurs around 3150Hz due to coincidence effect of the panels, and R declines drastically in low frequencies due to its light weight as well as resonance of the double leaf.

For EPC100(400) and EPC100(800), the whole structure acts like a single wall because of the consolidation of concrete. R increases by approximately 5dB per octave above the critical frequency around 200Hz~250Hz, which is mainly determined by the concrete core. Furthermore, we get an improvement of 8dB in R_w by doubling the density of EPS concrete, better than the theoretical value of 6dB from Mass Law. This deviation shows that EPS concrete of 400kg/m^3 is neither massive enough like brick wall to provide a considerable insulation, nor damped enough like glass fiber to attenuate the transmitted sound, making it of little value in practice.

3.2 Effect of Concrete Thickness

EPC75(800), EPC100(800) and EPC200(800) are filled with EPS concrete of the same density of 800kg/m^3 but differ in concrete thickness from 75mm to 200mm.

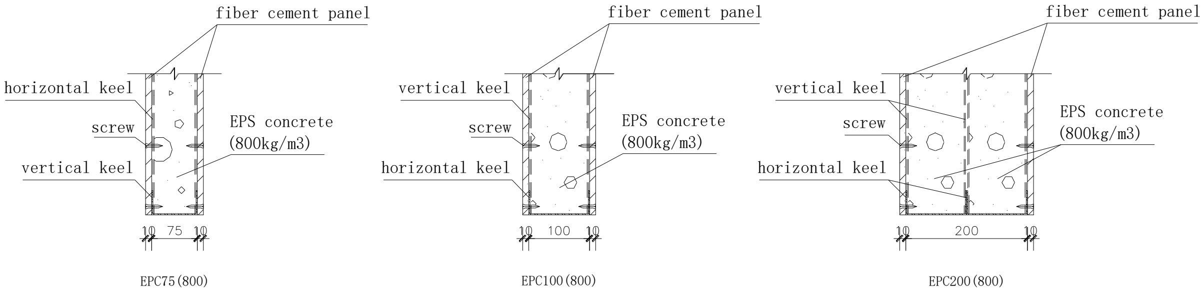

Figure 6 – Structure of walls with different concrete thickness

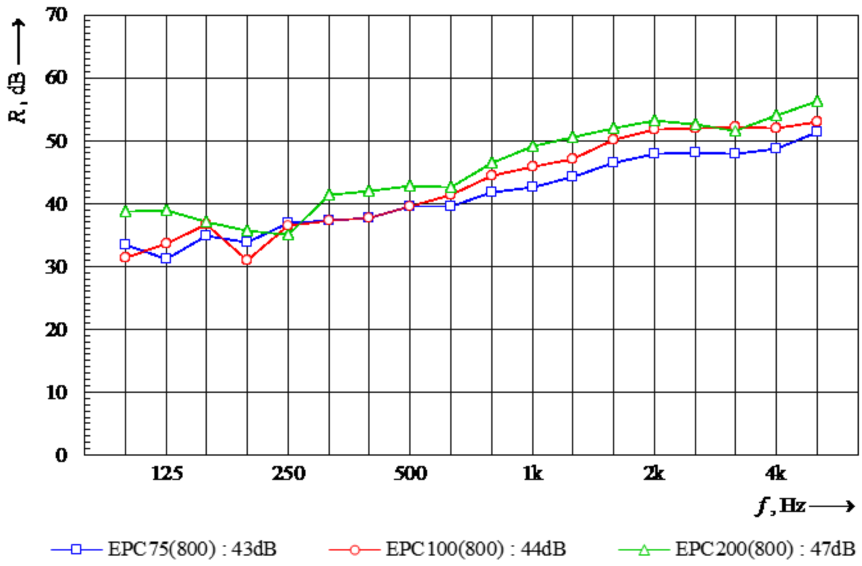

Figure 7 – Sound reduction index of walls with different concrete thickness

Test results show that the overall sound insulation performance improves meagerly as the concrete thickness increases. R_w rises only from 44dB to 47dB with the concrete thickness doubled from 100mm to 200mm, far below the 8dB derived by doubling the concrete density from 400kg/m^3 to 800kg/m^3. This phenomenon might be due to the structural connections of the lightweight steel gauge, through which vibration is able to transmit more easily. Besides, though the panels bond with the concrete tightly, they could still vibrate slightly due to the low tensile strength of the concrete. The mild dip around 3150Hz~4000Hz, which is in accord with the coincidence frequency of the panels, could prove the existence of the tiny vibration. As a result, vibration transmitted through the lightweight steel gauge and sound radiated from the panels will dominate the transmission of sound energy through the whole wall, which limits the improvement of sound insulation.

3.3 Effect of Attached Plasterboards

Intending to improve the sound insulation performance in a quick and easy way, we attached plasterboards to the outside surfaces of EPC100(400) and EPC200(800). However, we got opposite results for the two walls.

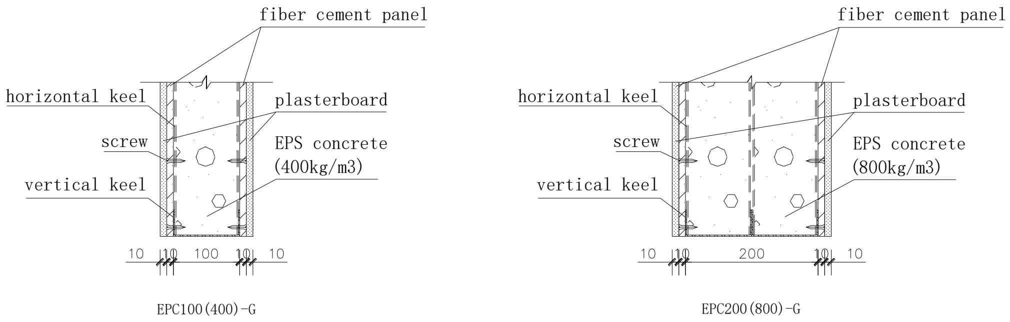

Figure 8 – Structure of walls with attached plasterboards

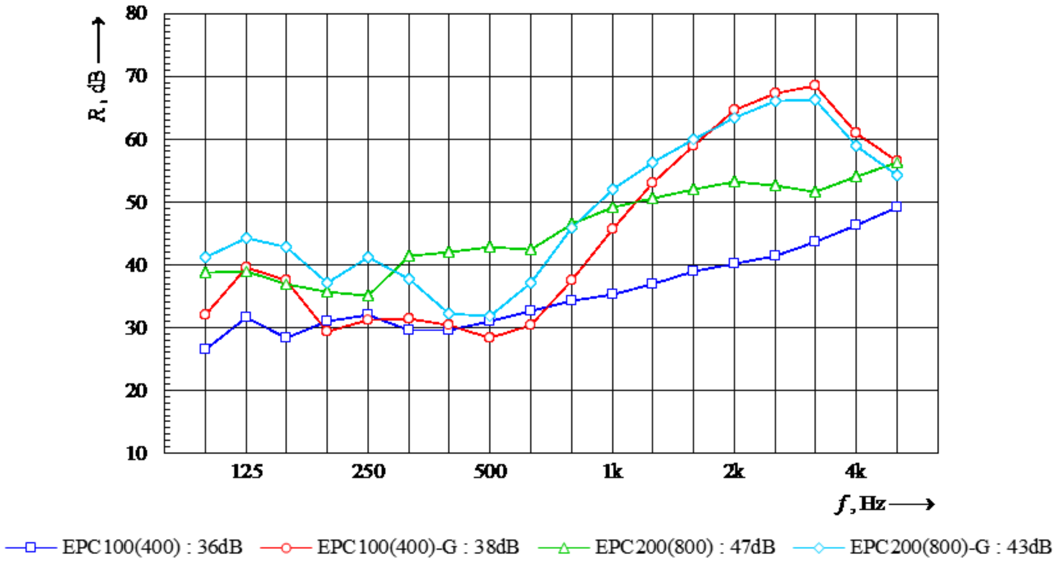

Figure 9 – Sound reduction index of walls with and without attached plasterboards

For the lighter wall EPC100(400)-G, additional plasterboards do help increase R significantly in high frequency range, and R_w rises from 36dB to 38dB as well. However, the irregular dip around medium frequency should merit attention.

For the heavier wall EPC200(800)-G, insulation performance improves in high frequency range as EPC100(400)-G does. However, R drops drastically around 315Hz~630Hz compared with EPC200(800), similar to that of EPC100(400)-G, resulting in a decline of R_w from 47dB to 43dB. Since the plasterboards are attached on the panels by self-tapping screws with low damping, they will resonate by the excitation of incident waves and radiate secondary noise concentrated around the resonance frequencies. When the sound insulation is weak for the basic wall, the secondary noise appears to be insignificant. Once the basic wall is soundproof enough, this defect will come out to be apparent, degrading the sound insulation performance of the whole wall. Therefore, such treatment would not work efficiently if the plasterboards are attached onto the partition wall without appropriate damping.

3.4 Effect of Multilayer Structure

Because of the dissatisfactory improvement we got in Section 3.3, we then soundproofed the partition walls by installing another cavity and filling it with EPS concrete or mineral wool, composing a multilayer construction. First we added a 75mm concrete core to EPC100(800) to form a heavy-heavy structure. Second we added a 50mm mineral wool core to EPC75(800) to form a heavy-light structure. Sequentially, we added another 75mm concrete core to it, forming a hamburg-like heavy-light-heavy structure.

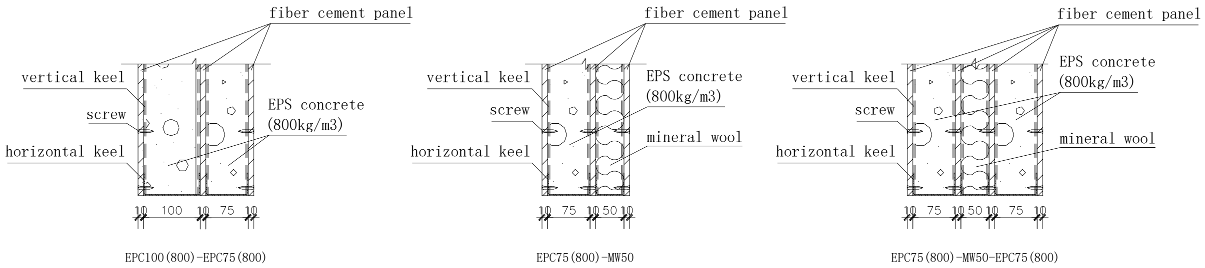

Figure 10 – Structure of multilayer walls

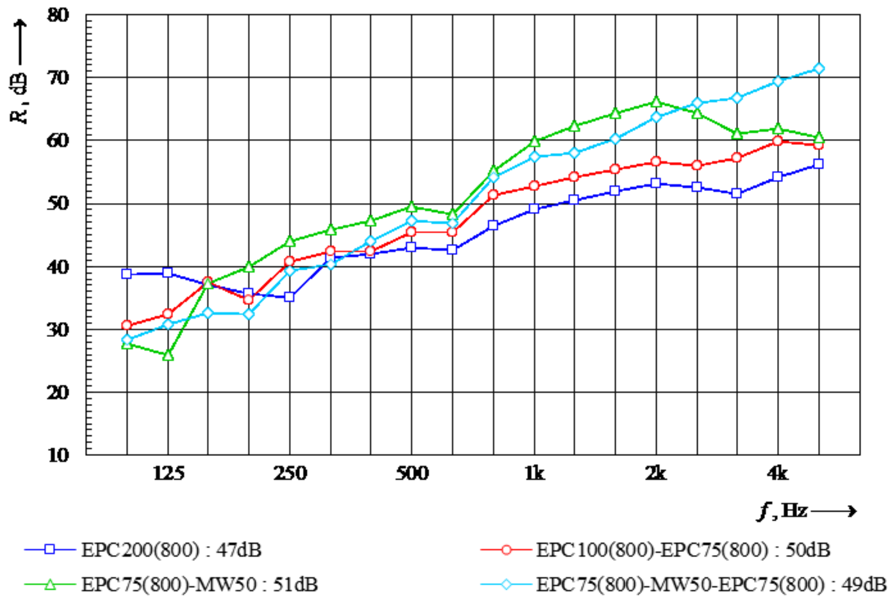

Figure 11 – Sound reduction index of multilayer walls

For EPC100(800)-EPC75(800), though sharing approximate thickness and weight with EPC200(800), its R improves moderately covering medium and high frequency range, and R_w increases from 47dB to 50dB. Such improvement indicates that the interpretation in Section 3.2 is acceptable. The existence of the internal panel, which acts like a barrier disconnecting the lightweight steel gauge on both sides, tends to attenuate the vibration transmitted through it.

EPC75(800)-MW50 is of the best soundproof among all the testing walls, yielding an R_w of 51dB. Though thinner and lighter than EPC200(800), it has a higher R within the whole testing frequency range except below 125Hz. That is to say, combination of multi-core with separated mass is a more effective and economic way to provide better insulation performance than simply increasing the weight of the single heavy core.

EPC75(800)-MW50-EPC75(800) is the thickest and most complicated wall in our test. However, its R_w degrades by 2dB compared with EPC75(800)-MW75 in spite of the additional concrete core. This might be blamed for its symmetrical structure, which would lead to overlap and magnification of the acoustics defects of the double leaf.

4. CONCLUSIONS

According to the test results, EPS concrete of 800kg/m^3 is much more suitable than that of 400kg/m^3 for the lightweight steel gauge and lightweight concrete partition wall in terms of sound insulation. However, due to the limitation of the potential vibration transmitted through the lightweight steel gauge, simply increasing the concrete thickness performs inefficiently compared with the added cost. Besides, extra plasterboards should be attached to the wall with adequate damping, otherwise the resonance of the plasterboards would be harmful to the sound insulation performance. A better solution is to install additional porous material to the partition wall, forming a multilayer structure with separated mass cores. Anyway, symmetrical configuration should be avoided to prevent the overlap and magnification of the acoustics defects.

REFERENCES

1. China Academy of Building Research, Institute of Building Physics. Handbook of Architectural Acoustics. Beijing, China: China Architecture & Building Press; 1991.
2. Tor Erik Vigran. Building Acoustics. Abingdon, Oxon, UK: Taylor & Francis; 2008.
3. ISO 10140-2:2010, Acoustics – Laboratory measurement of sound insulation of building elements – Part 2: Measurement of airborne sound insulation.
4. ISO 717-1:2013, Acoustics – Rating of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation.