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Sound Insulation of Ventilation Partitions with Different Configurations

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ABSTRACT

Ventilation partition increasingly attracts researchers' interest because it allows noise reduction and natural ventilation simultaneously. A few ventilation partitions installed on the building façade can serve as an air supply system to alternatively replace the HVAC system, which helps to achieve low energy consumption in the context of green buildings. The paper shows the sound insulation performance of ventilation partitions in various configurations. The ventilation partitions consist of a two-panel partition with staggered openings on the two sides. Different acoustical treatments could be implemented in the cavity between the two panels to improve the noise reduction performance. In this paper, the sound transmission loss of the ventilation partitions without and with acoustical treatments were measured in laboratory conditions, and their corresponding sound transmission class (STC) was computed. The measurement results indicate that the STC of the ventilation partitions with acoustical treatments is between 22dB and 31dB, more than 11dB higher than that without any treatment.

Keywords: Sound transmission loss, Ventilation partition
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1. INTRODUCTION

High noise level ranks first among 23 most disliked aspects about living environment in HDB estates, according to the survey conducted by the Housing and Development Board (HDB)

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of Singapore [1]. Specifically, traffic noise is one of the major noise sources in high-rise high-density cities like Singapore and Hong Kong. For the residence near traffic roads or railways, one easy way to isolate external transportation noise is closing windows and doors facing roads and railways. But this blocks natural ventilation. To enhance noise isolation while maintaining natural ventilation at the same time, various solutions [2-8] have been proposed during the past decades. Some of them are discussed below in this section.

Active noise control (ANC) technique has been employed to mitigate noise transmission through conventional open windows [2, 3]. Secondary noise sources can be installed in the window frame to generate the out-of-phase sound to counter the incident sound, thus reduce the noise transmission through the window. However, the ANC technique is limited to noise reduction at low frequencies.

To control sound transmission for a wide frequency range, the plenum window which consists of two staggered glass panes was firstly proposed by Ford and Kerry [4]. Their measurement results indicated that the sound reduction index of plenum windows is about 9dBA better than that of open single windows for traffic noise. Based on such design, Tong *et al.* [5] carried out a full scale field measurement of sound insertion loss of plenum windows. The plenum window and conventional side-hung casement window were separately installed in two identical mock-up test rooms which were built side-by-side facing a busy road, the acoustical benefit from the plenum windows is between 7.1dBA and 9.5dBA. To improve the noise reduction performance of plenum windows, passive noise control techniques have been studied by many researchers. Kang and Brocklesby [6] installed transparent micro-perforated absorbers between two glass panes of a plenum window without sacrificing the transparency of windows. However, the improvement on noise reduction is not significant due to the low sound absorption performance of the transparent material. Later, Sondergaard *et al*. [7] tested the sound insulation of plenum windows with various configurations. The non-transparent sound absorbing sheets were placed on one glass pane, along with the window frame or on the vents. They found that the sound reduction index varies from 22dB to 30dB, as a baseline that an open single top hung window of the same size is 8dB. Besides, the perforated plates with back cavities installed along the window frame also help to enhance the noise reduction performance, where the reduction level depends on the perforation rate and the depth of cavities [8].

In fact, in order to improve the noise reduction performance of plenum windows without sacrificing light penetration, the spacing between two glass panes is made large so that sufficient space along the reveal of the window frame for acoustical treatments. Hence, most plenum windows with acoustical treatments are thicker than 200mm [5, 7, 8]. Thick window system means taking more available space from rooms or offices, which may not be acceptable by the users in practice.

This paper studies ventilation partitions consisting of two staggered panels. Without considering light penetration, ventilation partitions could be combined with many acoustic treatments, therefore better noise reduction performance could be achieved. In addition, ventilation partitions, being built flushed with a wall, will not take additional space of rooms and offices, which is one advantage from the point view of practical application.

The paper is organized as following. The second section will introduce measurement set-up in the sound transmission suite. Ventilation partitions without and with three kinds of acoustical treatments are presented in the third section, and their corresponding sound transmission loss were measured. The sound distribution in the cavity between two panels in different cases will be discussed as well. At the end, the paper will give conclusion and show future work perspectives.

2. Measurement set-up

Measured sound transmission loss (TL) performance has been used to evaluate the noise reduction performance of partitions in the paper. As shown in Figure 1, two reverberation rooms are coupled through a wall with a partition. Referring to ISO 140-3 [9], a pink noise source was generated by a noise generator and played by an omnidirectional sound source placed in a corner of the reverberation room, i.e., the source room. The receiving room is a similar but slightly larger room compared to the source room. With the averaged sound pressure levels in the source and receiving rooms L_s, L_r obtained, the sound transmission loss can be computed by

$$\mathrm{TL} = L_s - L_r - 10\log\frac{S}{A} \quad (1)$$

where S indicates the area of the test specimen, A is the equivalent sound absorption area of the receiver room measured according to ISO 345 [10].

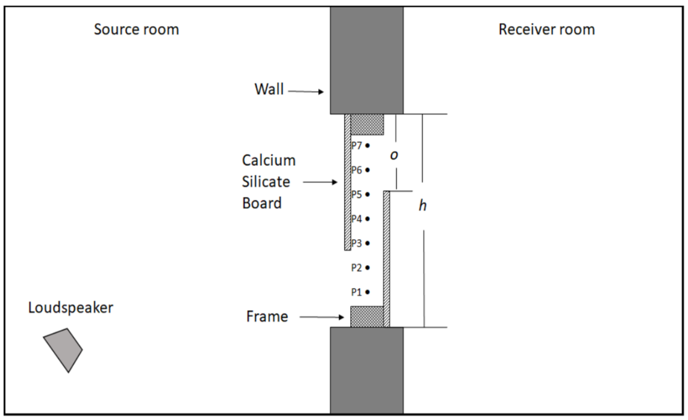

Figure 1: Measurement set-up

Figure 2: Front view of a tested ventilation partition from the receiver room.

3. Ventilation partition

3.1 Without acoustical treatments

The ventilation partition without any acoustical treatments consists of two staggered panels as shown in Figure 1, and the front view of a tested partition is shown in Figure 2. Throughout this paper, all the partitions are of width 1m and height 1.8m. The two staggered openings are of the same height 0.225m. The partition panel is calcium silicate board of thickness 9mm and mass density 1050 kg/m^3. The spacing between the two panels is 0.082m, therefore the total thickness of the ventilation partition is 0.1m.

The dash-dotted line in Figure 3 shows the sound transmission loss of the ventilation partition without any acoustical treatment (Case B0). As a reference, the sound transmission loss of a closed single-layered partition (Case B1) of width 1m and height 1.8m is plotted as the dashed line in Figure 3. In practice, we made the single-layered partition of the same calcium silicate board. We use the sound transmission class (STC) [11] which rates the sound transmission loss into a single value to alternatively compare noise reduction performance of various configurations. The STCs of Case B0 and B1 are 11dB and 31dB, respectively, as indicated in Table 1.

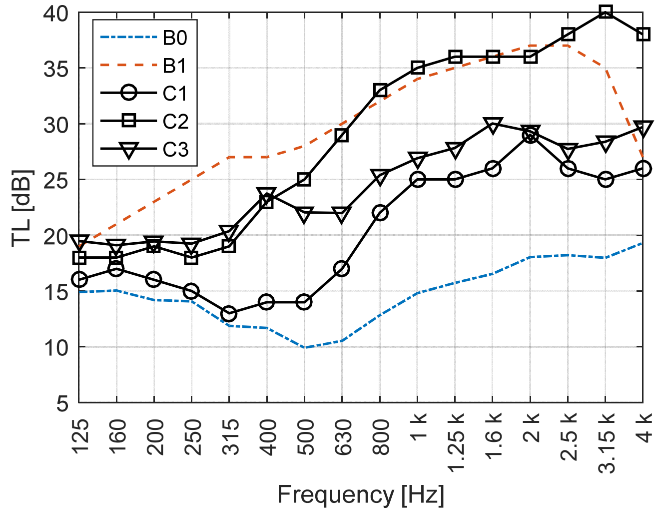

Figure 3: Sound transmission loss (TL) of ventilation partitions

Table 1: Description and STC of ventilation partitions with 5 different configurations

Cases	Description	STC
B0	Ventilation partition without any acoustical treatment	11dB
B1	Closed single-layered partition	31dB
C1	Fiberglass of thickness 25mm placed along the partition frame	22dB
C2	Fiberglass of thickness 25mm placed along the partition frame and layered on one panel.	31dB
C3	Fiberglass of thickness 25mm covering the top and bottom sides of the cavity; 10 triangle blocks of side size 200mm and thickness 82mm placed along the left and right sides of the cavity.	26dB

3.2 With acoustical treatments

To mitigate noise transmission through the ventilation partition, sound absorbers made up of fiberglass of density 80kg/m^3 were placed in the cavity, as shown in Figure 4. Detailed descriptions about the 3 configurations (Cases C1 – C3) are presented in Table 1. Concretely, the fiberglass of Case C1 only covers the frame, that of Case C2 covers both the frame and one of the two panels, and Case C3 also covers the frame but introduces thick triangle blocks along the reveals. In terms of the sound absorption coefficient of the fiberglass, we measure on the fiberglass of thickness 25mm and surface area 8.64m^2 in a reverberation chamber referring to ISO 354 [10], the result is plotted in Figure 5. The sound transmission loss of each case is illustrated in Figure 3 while the corresponding STC is presented in Table 1.

In Figure 3, the comparison of Case B0 to Cases C1, C3 demonstrates that the sound absorber placed on the window frame significantly increases the sound transmission loss, especially at middle and high octave-band frequencies. For instance, the sound transmission loss is increased by 11dB at the frequency 2k Hz due to the fiberglass covering the frame in Case C1. Furthermore, owing to the triangle blocks used in Case C3, the absorption area facing the cavity is larger than that of Case 1. Therefore, the noise reduction performance of Case C3 is better than that of Case C1 at all frequency bands.

Comparing Cases C2 and B1 in Table 1 and Figure 3, although the STCs of C2 and B1 are the same, the transmission loss of Case C2 is higher than that of Case B1 at some high octave-band frequencies. This means that the noise reduction performance of ventilation partitions with specific designs could be even better at high frequencies than a closed single-layered partition.

(a) C1, STC 22dB (b) C2, STC 31dB (c) C3, STC 26dB

Figure 4: Three ventilation partitions with acoustical treatments.

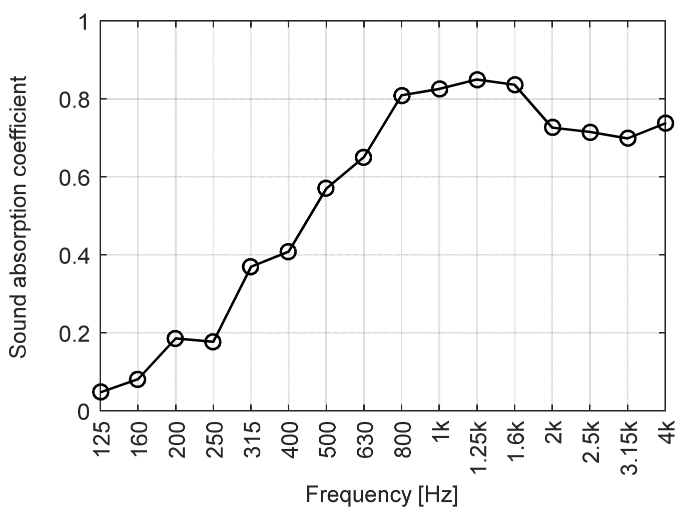

Figure 5: Sound absorption coefficient of the fiberglass.

3.3 Discussion

To determine the sound distribution within the cavity between the two partition panels, the sound pressure levels (SPLs) were measured at 7 measuring points (as marked in Figure 1) along a diagonal line placed in middle of the cavity between the two panels. The SPLs at the 7 points in Case B0 are plotted in Figure 6. The averaged sound pressure levels L_s and L_r in the source and receiver rooms are also shown as reference.

It can be seen that the SPLs at octave-band frequencies lower than 800Hz fluctuate around L_s and Point 1 facing the source room does not always present the highest SPL. For example, the SPL at Point 4 instead of Point 1 is the highest at the octave-band frequency 160Hz. Besides, at octave-band frequencies larger than 800Hz the SPLs at the 6 points apart from Point 7 (the point facing the receiving room) are almost equal. That is because the sound reflected from the cavity boundaries, mainly from the top and bottom boundaries, interferes with the incident sound. The sum of the incident and reflected sound waves makes the sound distribution in the cavity complex.

The SPLs of the 3 cases with acoustical treatment (Cases C1, C2 and C3) at the 7 points in the cavity were measured as well. Taking Case C3 as an example, Figure 7 presents that the SPL at the octave-band frequency higher than 400Hz decreases from Point 1 to Point 7, i.e., as the distance to the opening facing the source room increases. This phenomenon is much different from Case B0. This is because the sound absorption coefficient of the fiberglass at middle and high frequencies is high, so that there is rare sound reflection from the cavity boundaries. However at the lower octave-band frequencies, similar to Case B0, the SPLs at the 7 points also fluctuate around L_s due to the low absorption coefficient at lower frequencies. Generally, the fiberglass placed in the cavity changes the boundary conditions of the cavities, thereafter helps to improve the noise reduction performance of the ventilation partitions.

If we apply the configurations of Cases C1 or C3 in practice but replace the current panels by glass panes, the ventilation partitions become plenum windows which ensure light penetration and noise reduction at the same time. The questionnaire survey conducted in [12] demonstrated that the air supply provided by the plenum window is not sufficient for residents. We may involve a mechanical ventilation system in future to supply sufficient air. In fact, more configurations should be proposed to balance noise reduction, light penetration and air supply according to practical requirements.

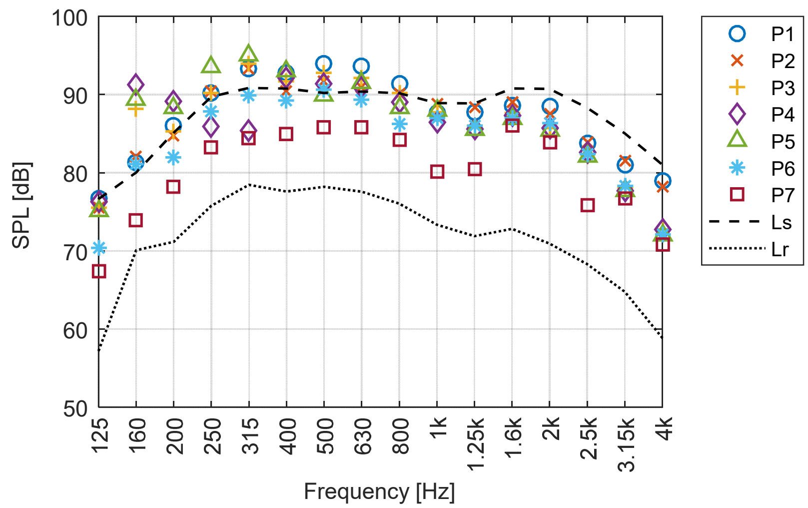

Figure 6: Sound pressure levels at 7 measuring points in the cavity for Case B0.

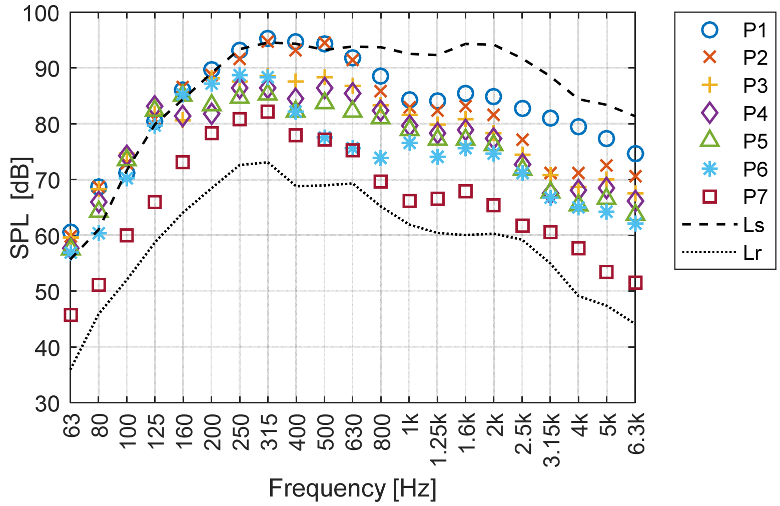

Figure 7: The sound pressure levels measured at the 7 points in the cavity for Case C3.

4. CONCLUSIONS

The paper presented sound transmission loss of the ventilation partitions without and with acoustical treatments. The ventilation partition without acoustical treatments consists of two partition panels (calcium silicate boards in the paper) with staggered openings. In terms of the three ventilation partitions with acoustical treatments, the fiberglass was placed between the two panels in various patterns, in order to enhance the noise reduction performance. The sound transmission loss of ventilation partitions were tested in laboratorial conditions. The measurement results show that the ventilation partitions with add-on fiberglass can achieve STC 22dB ~31dB, more than 11dB higher than that of the ventilation partition without any acoustical treatment. Apart from the noise reduction performance, the efficiency of air supply should be considered during the design stage of ventilation partitions in future.

5. ACKNOWLEDGEMENTS

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