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A STUDY ON THE MEASUREMENT OF SOUND INSULATION OF A SMALL-SIZE WINDOW

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Abstract

In order to measure the sound transmission loss(STL) of a test specimen such as a window and a door, which is smaller than the test opening, a special partition is built into the test opening and the specimen is placed in that partition. This paper discusses how the measured STL of a small-size window is changed by the partition. Theoretical investigations are carried out to quantify the effect of the filler wall. The results reveal that the insufficient sound insulation of the filler wall lowers the measured value of the window's STL. How to obtain the more accurate STL of a small-size window even with the insufficient sound insulation of the filler wall is also introduced and discussed in comparison with the experimental results. The comparison shows the possibility of the proposed method in practical applications.

1. INTRODUCTION

The sound insulation is one of important acoustic properties of building elements such as walls, floors, doors and windows. According to standard test methods[1-2], the measurements are performed in laboratory test facilities that consist of two reverberation rooms and a test opening between two rooms. The area of the test opening is generally more than 10 m^2 in order to make an experiment with a specimen of large size. So, in case of small specimens such as windows and doors, a special partition of sufficiently high sound insulation is built into the test opening and the specimen is placed in that partition. How high is the sound insulation of the partition enough for that case? In this paper, simple investigations are theoretically carried out to quantify the effect of the filler wall. It is also introduced how we can obtain the more accurate STL of a small-size window even if the sound insulation of the partition is not sufficient. The comparison with the experimental data of ship windows shows that the proposed method can become a useful tool for practical applications.

2. THEORETICAL ANALYSIS

The STL measurement is performed in two reverberation rooms as illustrated in Fig. 1. From the sound pressure level measured in each room, the STL can be calculated as[1]

$$STL = \Delta L + 10\log(S / A), \tag{1}$$

where $\Delta L = L_S - L_R$, L_S and L_R are the averaged sound pressure levels in the source and receiving rooms respectively, S is the area of the test specimen, and A is the equivalent sound absorption area in the receiving room.

Let's consider a window whose size is smaller than that of the test opening. The window is installed in the free area of the filler wall that is built into the test opening. The measured STL of the window can be expressed from Eq. (1) as

$$STL_1 = \Delta L + 10\log(S_1 / A), \tag{2}$$

where the subscript 1 represents the window. If we substitute the total area of the test opening for the area S in Eq. (1), the STL of the total system that consists of the filler wall and the window can be also obtained as

$$STL_t = \Delta L + 10\log(S_t / A), \tag{3}$$

where the subscript *t* represents the total system. From Eqs. (2) and (3), the measured STL of the window can be rewritten as

$$STL_1 = STL_t + 10\log(S_1 / S_t). \tag{4}$$

By using the definition of the sound transmission coefficient[3] τ,

$$STL = -10\log(\tau), \tag{5}$$

the sound transmission coefficient of the total system can be expressed as[3]

$$\tau_t = (\tau_1 S_1 + \tau_2 S_2) / S_t, \tag{6}$$

where the subscript 2 represents the filler wall. Substituting Eqs. (5) and (6) into Eq. (4) leads to

$$STL_1 = -10\log(\tau_1) - 10\log(1 + \tau_2 S_2 / \tau_1 S_1). \tag{7}$$

In Eq. (7), the left-hand side is the measured value of the window's STL and the first term of the right-hand side is its true value. Therefore the accuracy of the STL_1 depends on whether the second term of the right-hand side is negligible or not. It is noteworthy that the measured STL is always lower than the true value and the higher sound insulation of the filler wall is required as the size of the window become smaller. For example, if the STL of the filler wall is 15 dB higher than that of the window ($\tau_2 / \tau_1 = 10^{-1.5}$) and the area ratio $S_2 / S_1 = 9$, the measured STL of the window become about 1 dB lower than its true value.

Sometimes a ship window of very small size such as a side scuttle (for example, its diameter is 410 mm) is required that its sound insulation capability is higher than STC 40. In this case, the STL of the filler wall has to be about 25 dB higher than that of the window. It is very difficult to construct the filler wall whose STL satisfies the 25 dB higher condition at any frequency. But if the measured STL of the filler wall and the total system meet the following condition,

$$STL_2 - STL_t > -10\log(S_t / S_2)\,, \tag{8}$$

where STL_2 is the measured STL of the filler wall without an opening, the true STL of the small-size window [$-10\log(\tau_1)$] can be calculated from Eqs. (4), (5) and (6) as

$$-10\log(\tau_1) = STL_1 - 10\log(1 - 10^{-(STL_2 - STL_t)/10} S_2 / S_t)\,, \tag{9}$$

3. EXPERIMENTAL VERIFICATIONS

In order to measure the STL of a small-size window, a bulkhead structure was built into the test opening whose size was 4.2 m × 2.4 m. Figures 2 and 3 illustrate the cross-section of the bulkhead structure and its opening part whose diameter is 410 mm, respectively. Two types of circular windows were installed in the opening part and their STL were measured. The inner structure of each window is as follows:

(1) Window A: 15 mm Glass + 12 mm A/G + 6 mm Glass,
(2) Window B: 15 mm Glass + 4 mm Glass + 12 mm A/G + 4 mm Glass + 4 mm Glass.

Figure 4 shows the measured STL of the bulkhead structures without the opening and with the opening or the windows; the area of the specimen is equal to that of the test opening (10.08 m^2). Figure 5 illustrates the measured STL of the opening and the windows, where the specimen area is 0.132 m^2. The measured STL of the free opening at the frequencies over 160 Hz is close to zero; the STL of the free area is theoretically zero. However the STL at 160 Hz and below is negative or very high. This may be due to the resonance related to the depth of the opening or unexpected reasons.

Figures 6, 7 and 8 represent the comparison between the measured STL and the results calculated form Eq. (9). In case of the free opening (see Fig. 6), the calculation agrees well with the experiment because the STL of the filler wall is high enough to neglect the last term of the right-hand side in Eq. (7) or Eq. (9). In case of the window A and B [see Figs. (7) and (8)], the calculated data are higher than the measurements. Particularly, the difference is more than 10 dB at the frequencies over 2 kHz in the case of window B. Based on the fact that the measured STL is always lower than the true STL, these calculated values may be closer to the true STL. In Fig. (7) and (8), we can find special frequencies below 400 Hz where the STL can not be evaluated using Eq. (9). This is because the measured STL of the total system is higher than that of the bulkhead in that frequency range (see Fig. 4). Note that STL_2 is assumed to be higher than $STL_t - 10\log(S_t / S_2)$ in Eq. (9).

4. CONCLUSION

In order to measure the STL of a small-size window, a special filler wall is inevitably built in the test opening whose size is lager than that of the window. The sound insulation of the filler wall affects the measured value of the window's STL. In this investigation, it was found that the measured STL of the window is always lower than its true value. It was also shown that the sound insulation of the filler wall necessary to neglect its effect depends on the area ratio between the window and the filler wall. The method to calculate the more accurate value even with the insufficient insulation of the filler wall was introduced and discussed in comparison with the experimental data of ship windows. In the case of the sufficient sound insulation of the filler wall, the result calculated using the method agrees well with the experimental one. On the other hand, the method gives the higher value than the measured data, which is lower than the true vale, in the insufficient insulation case. This comparison shows that the proposed method can become a useful tool for practical applications.

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[2] ASTM E 90-04:2004 Standard test method for laboratory measurement of airborne sound transmission loss of building partitions and elements.

[3] Leo L. Beranex, *Noise and Vibration Control, revised edition*, Institute of Noise Control Engineering, 1988.

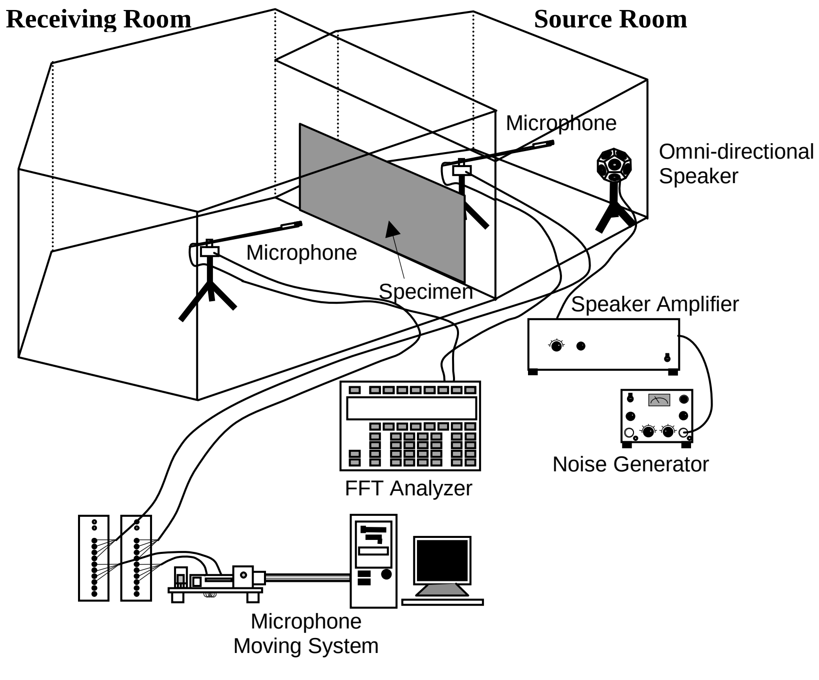

Figure 1. Schematic of measurement system.

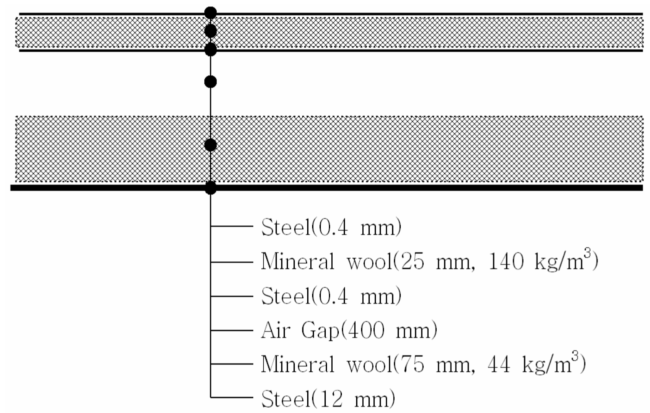

Figure 2. Cross-section of the bulkhead structure.

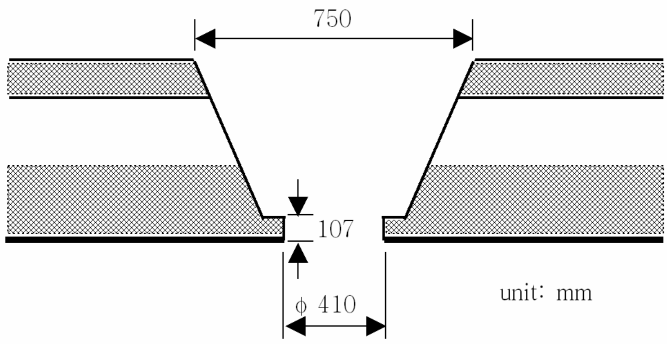

Figure 3. Cross-section of the opening part of the bulkhead structure.

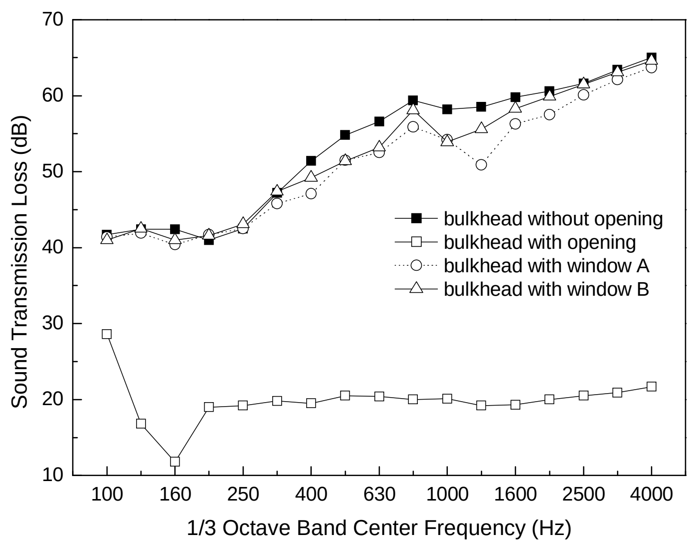

Figure 4. Measured sound transmission loss of the bulkhead structure.

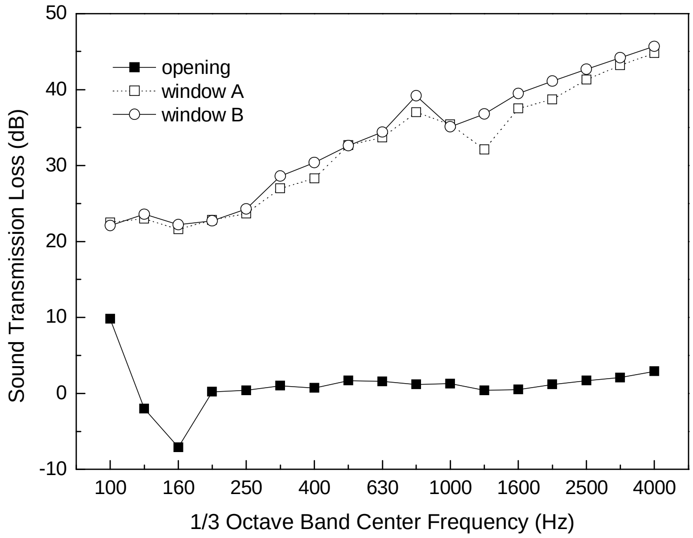

Figure 5. Measured sound transmission loss of the free opening and the windows.

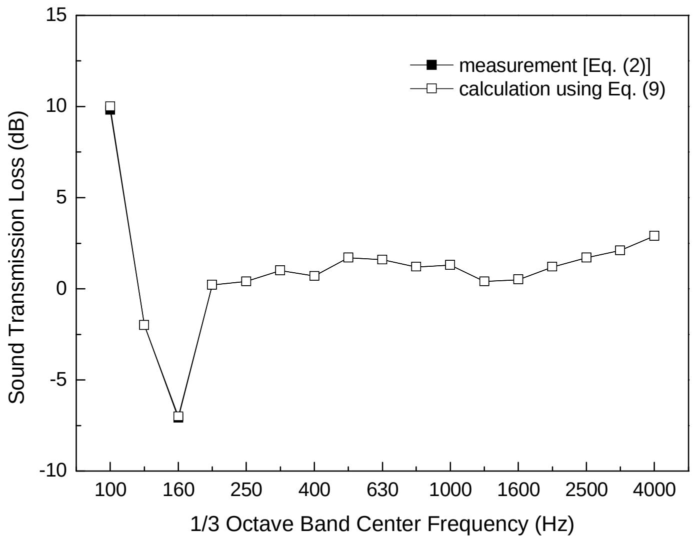

Figure 6. Comparison between the measured and calculated STL of the free opening.

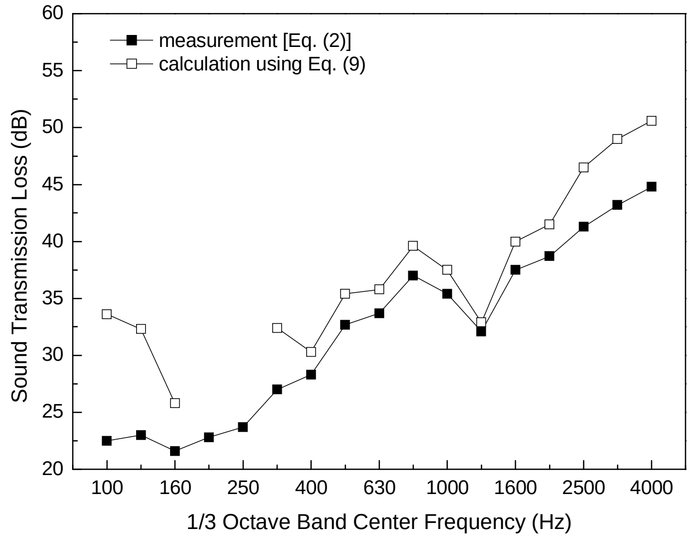

Figure 7. Comparison between the measured and calculated STL of the window A.

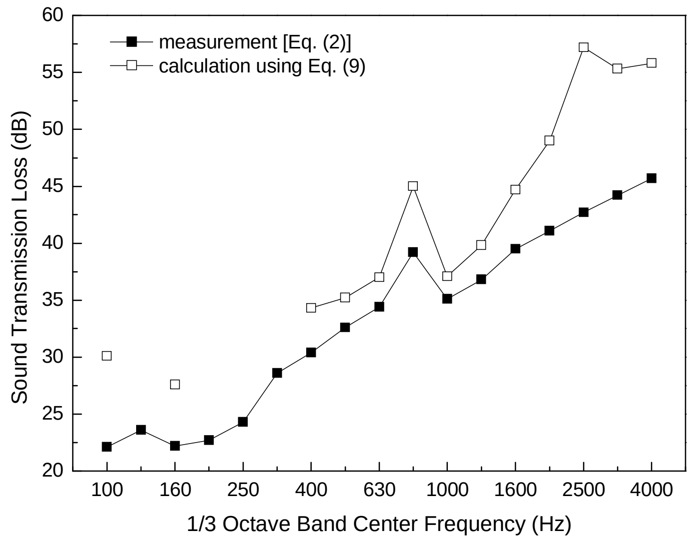

Figure 8 Comparison between the measured and calculated STL of the window B.