Filed survey method using Origami impulse source for sound insulation measurements

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ABSTRACT

We have developed a new easy-to-use impulse source, which we refer to as the Origami impulse source (OIS). The OIS can generate impulses easily and repeatedly over short time intervals. We are currently using the OIS effectively for measuring reverberation time. In the present study, we proposed a survey method using the OIS for sound insulation measurements in the field. In order to identify the capabilities of the OIS method, two types of field measurements were performed. First, the sound insulation of a concrete wall between rooms was measured. Next, the sound insulation of window sashes under various conditions was measured. In these field measurements, the effect due to the microphone arrangement was examined. For the purpose of comparison, measurements by the conventional method using a loudspeaker were also performed. As a result, no variation was observed for different microphone arrangements, and these results were in good agreement with the results obtained by the conventional loudspeaker method. The feasibility of using the OIS for field survey measurements has been confirmed.

Keywords: Sound insulation measurement, Impulse source

1. INTRODUCTION

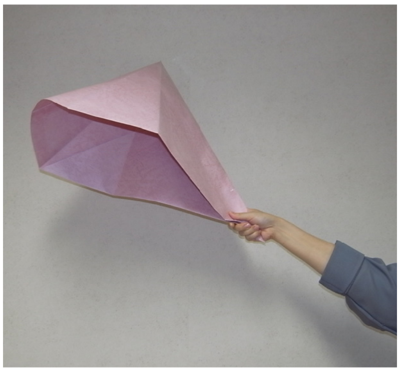

Figure 1 – Origami impulse source

We have developed a new easy-to-use impulse source, referred to as the Origami impulse source (OIS), which is shown in Figure 1. The radiation directivity characteristic was confirmed to be almost omni-directional, and the repeatability was higher than that of conventional impulse sources [1]. Therefore, the OIS is considered to be useful for acoustic measurements, especially as a survey method in the field. For example, the OIS has been applied to reverberation time measurements in place of the general method using a loudspeaker. In the present study, we applied the OIS to sound insulation measurements in the field. In general, the loudspeaker is used as a sound source in measuring the sound insulation. In this case, the average sound pressure levels on the source side and the receiving side are measured at several microphone positions, either simultaneously or one after another. Based on the reciprocity theorem, the sound propagation characteristics between the source point and the receiving point do not vary, even if their positions are reversed each other. Consequently, it is assumed that the average sound pressure levels can be similarly measured by at least two microphones (one on each side) when the sound sources are operated in many positions. This assumption can be achieved using the OIS which can generate impulses easily and repeatedly over short time intervals. According to this technique, it is expected that field measurements can be performed more conveniently and effectively than the loudspeaker method. In order to prove the feasibility of using the OIS for the sound insulation measurements, two types of field measurements were performed. The accuracy of OIS was compared with the conventional method involving the use of loudspeakers.

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2. SOUND INSULATION BETWEEN ROOMS

2.1 Measurement method and conditions

Sound insulation measurements using the OIS were performed in test rooms that simulated field conditions found in ordinary rooms. The test specimens were a concrete wall (100 mm, 240 kg/m^2). The average sound absorption coefficient of these test rooms was adjusted between 0.10 and 0.15 at the frequency range of interest. Figure 2 shows the arrangement of the sound sources and the microphone positions. The OIS was manipulated at ten different source positions. At least two microphones were needed (one in each room) because the level differences between rooms were measured. In order to examine the effect due to the microphone positions, three different microphone arrangements (the layout of the two microphones: Mic.1-2, Mic.1-3, and Mic.1-4) were compared. The single event sound exposure levels $L_{p\mathrm{E}1,i}$ (at the source side) and $L_{p\mathrm{E}2,i}$ (at the receiving side) were measured at ten different source positions. From the i-th set of $L_{p\mathrm{E}1,i}$ and $L_{p\mathrm{E}2,i}$, the level difference D_i is calculated as follows:

$$D_i = L_{p\mathrm{E}1,i} - L_{p\mathrm{E}2,i}\,. \tag{1}$$

The average level difference D is calculated as follows:

$$D = \frac{1}{N}\sum_{i=1}^{N} D_i\,. \qquad N:\ \text{number of source positions} \tag{2}$$

According to ISO 140-4 [2], which specifies the field measurements of the sound insulation between rooms, the apparent sound reduction index R' is expressed as follows:

$$R' = D + 10\lg\frac{S}{A}\,, \tag{3}$$

where S is the area of the test specimen, and A is the equivalent sound absorption area of the receiving room.

For the purpose of comparison, general field measurements using the loudspeaker according to ISO 140-4 were also carried out. As shown in Figure 3, two sound sources and ten fixed microphone positions were used.

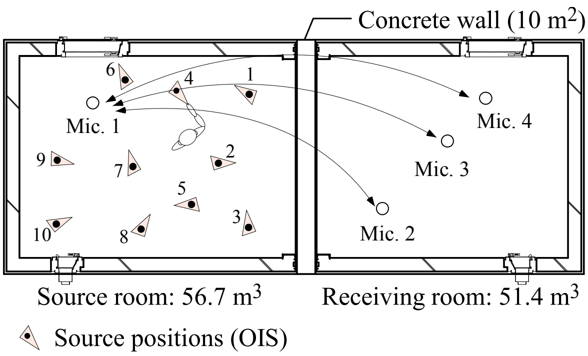


Figure 2 – Test arrangement of measurements using the OIS

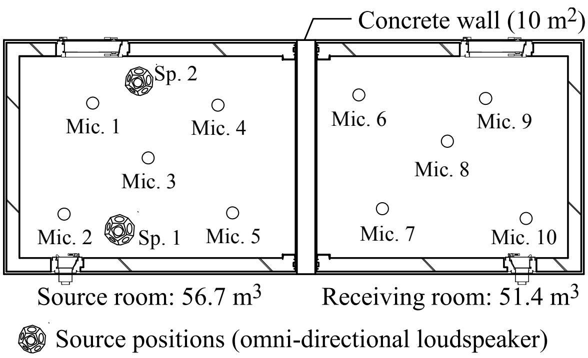


Figure 3 – Test arrangement of measurements according to ISO 140-4

2.2 Results

Figure 4 shows the results of apparent sound reduction index measured using the OIS and the loudspeakers. The results obtained using the OIS at 4 kHz are shown for reference purposes only because the sound level was not sufficiently high at 4 kHz. No variation was observed for the various microphone arrangements. These results were in good agreement with those obtained using the ISO 140-4 method, except at low frequencies. The level differences D_i measured at Mic.1-2 are shown in Figure 5. Variation occurred particularly among the results of ten measurements at low frequencies. In order to improve the precision of the measurements at low frequencies, it is necessary to significantly increase the number of source positions. However, the differences at low frequencies are not too remarkable for the field survey method. These results reveal that the measurements performed using the OIS have sufficient accuracy, as compared to the conventional field measurement.

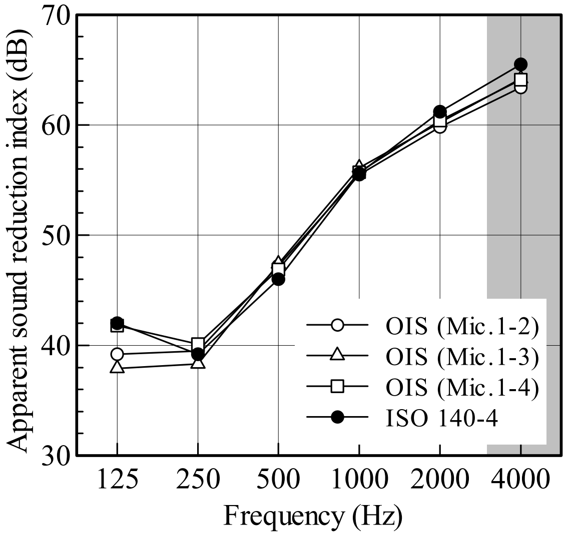


Figure 4 – Comparison of apparent sound reduction index measured using the OIS at different microphone arrangements and using loudspeakers according to ISO 140-4

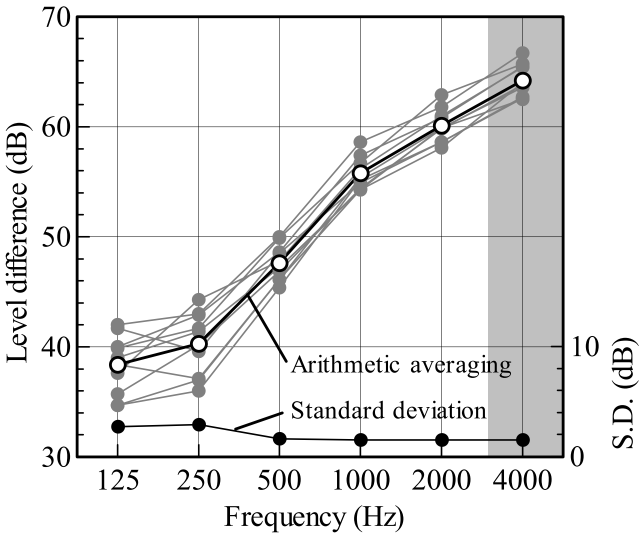


Figure 5 – Level differences D_i measured at Mic.1-2

3. SOUND INSULATION OF THE WINDOW SASH

3.1 Measurement method and conditions

The sound insulation of window sashes was measured in the field using the OIS. The two measurement conditions are shown in Figure 6. The specimens were sliding window sashes with a single pane of 3-mm glass (Case 1) and double glazing: 5 mm + 12 mm air layer + 5 mm (Case 2). As shown in Figure 6, the test arrangements (locations of sound sources and microphones) were decided based on the indoor source method specified in the Japanese Industrial Standard JIS A 1520 [3]. The test arrangement of JIS A 1520 is illustrated schematically in Figure 7. The average sound pressure level in the source room $\overline{L}_{in}$ is measured by five evenly distributed microphones, and the sound pressure level on the outdoor side $\overline{L}_{out}$ is measured by four microphones on the measurement surface at a distance of 250 mm away from the specimen. According to JIS A 1520, the quasi transmission loss TL_q is expressed by the following simple equation:

$$TL_q = \overline{L}_{in} - \overline{L}_{out} - 3\,. \tag{4}$$

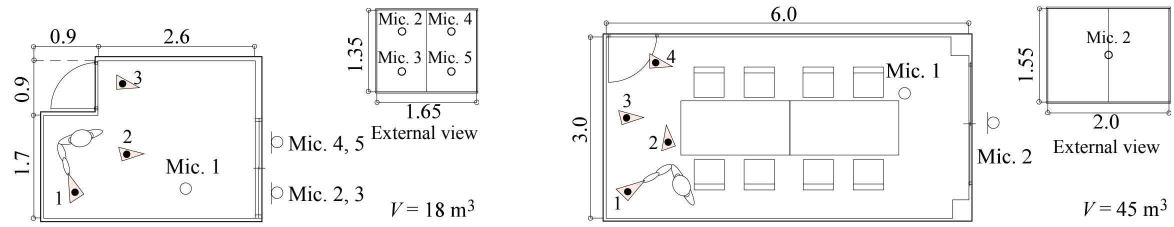
The correction term in this equation (-3 dB) is determined by empirical adjustment in order to make this term equivalent to the sound reduction index.

When using the OIS, the level differences of the single event sound exposure level in each side are similarly calculated by Equations (1) and (2), and the quasi transmission loss $TL_{q,\mathrm{OIS}}$ is expressed as follows:

$$TL_{q,\mathrm{OIS}} = D - 3 \,. \quad (5)$$

Since the sound pressure levels on the outdoor side are influenced by dominant sound leakages around the window frame, four different microphone arrangements (the layout of the two microphones: Mic.1-2, Mic.1-3, Mic.1-4, and Mic.1-5) were compared in Case 1.

For the purpose of comparison, measurements were also performed according to JIS A 1520. In Case 2, the apparent sound reduction index measured by the sound intensity method according to ISO 15186-2 [4] were also compared. This method is popular for measuring the sound insulation of small building elements in the field. (A detailed description is not presented herein.)



(a) Case 1 (b) Case 2

Figure 6 – Test arrangements of sound insulation measurements of window sashes

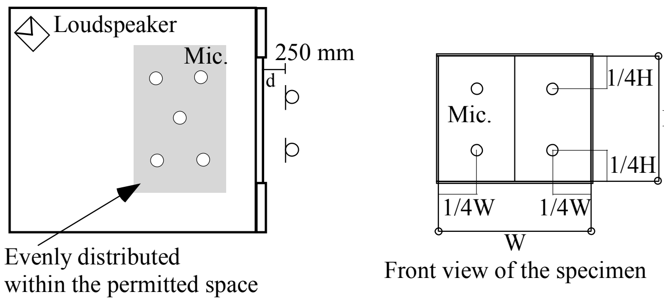


Figure 7 – Illustration showing conceptual arrangements of the measurement according to JIS A 1520

3.2 Results

Figure 8 shows the results for Case 1. As compared with the results obtained by the JIS A 1520 method, the results obtained using the OIS clearly indicated variations among the different microphone arrangements at high frequencies. This indicates that the sound leakage from the left side window sash is dominant. Under these conditions, the number of microphone positions outside the room must be increased in order to improve the measurement accuracy.

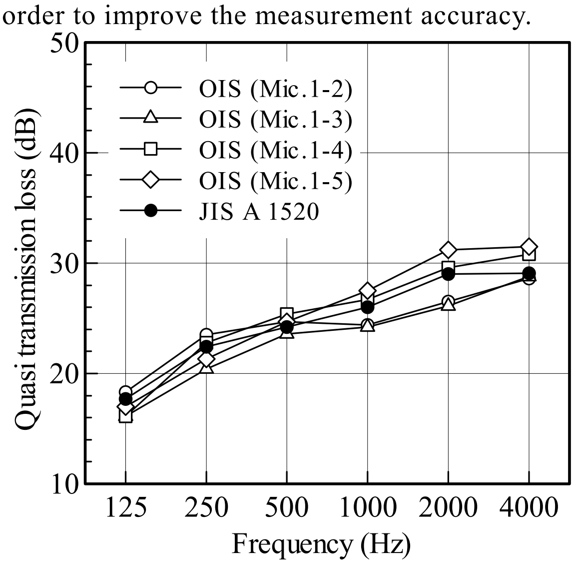


Figure 8 – Comparison of the results obtained using the OIS at different microphone arrangements and the JIS A 1520 method

Figure 9 shows the results for Case 2. The results obtained by the OIS and the JIS A 1520 method generally agreed well. In this case, there was no dominant leakage from the gap between the window sash and frame. The results obtained by the ISO 15186-2 method tended to be slightly larger than those obtained by the other methods at high frequencies. Since the discrepancies were less than 2 dB for the entire frequency range, there is no significant variation among the three methods. Sound insulation measurements of the window sash can be performed with sufficient accuracy using the proposed OIS method.

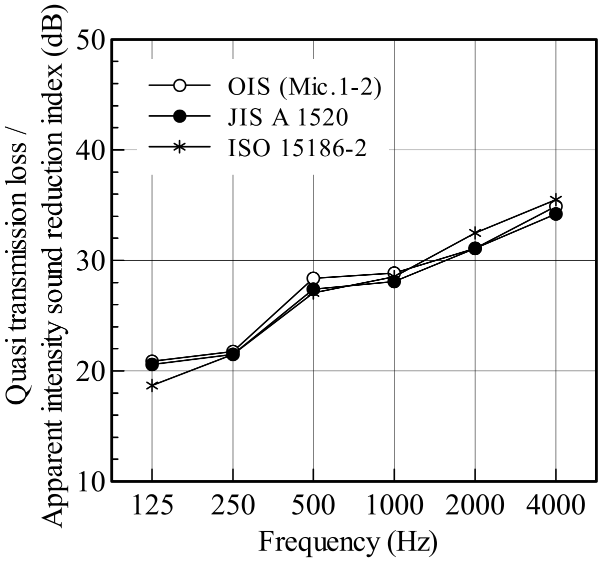


Figure 9 – Comparison of the results obtained using the OIS and the JIS A 1520 method and the ISO 15186-2 method

4. CONCLUSIONS

The OIS has been applied to sound insulation measurements in the field. In the measurements between rooms, there was no variation for various microphone arrangements, and the obtained results were in good agreement with the results obtained by the conventional loudspeaker method. Therefore, the accuracy of the proposed method using the OIS is sufficient as a field survey method. The measurement of window sashes can be also performed with sufficient accuracy. However, it is necessary to arrange several microphone positions outside the room when the window sashes have dominant sound leakage. As a result, the feasibility of the survey method using the OIS for sound insulation measurement has been established.

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