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Repeatability Evaluation of Rubber Ball Impact Sound in a Reverberation Chamber

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ABSTRACT

The rubber ball was known as the most similar impact source with real impact sound such as child's running and jumping in the apartment buildings. For this reason, rubber ball had been standardized as the only heavy/soft impact source in the ISO standards, and single number quantity for the rubber ball impact sound is standardizing. However, it is necessary to check the repeatability of the rubber ball drop from 1m height when the rubber ball was dropped by the test person and automated rubber ball drop device. In this study, repeatability of rubber ball drop was evaluated in the reverberation chamber. As a result of the repeatability test for the rubber ball, the difference of floor impact sound pressure level among operators was very small. In the case of using the automated rubber ball drop device, the repeatability of the drop device was highest in the low-frequency band except for the 80 Hz band. In the case of dropping the rubber ball, it is considered to be useful for improving the test quality in the test of the test room. Also, it can be used in the field conditions where it is easy to move and for checking impact force exposure level of a rubber ball.

Keywords: Rubber Ball, Floor Impact Sound, Repeatability
I-INCE Classification of Subject Number: 73

1. INTRODUCTION

The rubber ball is known to be an impact source that generates similar impact sound to the impact sound generated in actual apartment buildings [1, 2]. For the evaluation of low-frequency impact sound in apartment houses, the rubber ball was standardized as a heavy/soft impact source in the ISO standards [3-5]. Rubber ball impact sound is generated by free drop of rubber ball at 1 m height by test person. Since a rubber ball is dropped by the test person, the repeatability of the same test person dropping several times and when the different test person drops a rubber ball needs to be checked. In order to minimize the variation caused by the test person during the measurement of

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the rubber ball impact sound, the use of an automated rubber ball drop device was continuously proposed. This makes it possible to minimize the deviations caused by dropping the rubber ball by the test person, thereby enabling reliable test results to be derived. Patents for a dropping device for a rubber ball impact sound has been registered, and an automated rubber ball drop device has been developed based on the patent in Korea recently. In this paper, the difference in repeatability between test persons and an automated rubber ball drop device was compared.

2. REPEATABILITY EXPERIMENT

In this study, a repeatability experiment was conducted on three test persons and automated rubber ball drop device under the conditions of the reverberation chamber in which a 150mm thick slab was installed (see Figure 1). The information on three test persons who participated in the experiment was shown in Table 1. Test person A has a general knowledge of rubber ball with more than 10 years of testing experience in the field of building acoustics, and test person B has conducted repetitive tests without knowledge on the rubber ball. Test person C has more than 10 years of experience in testing and research in the field of building acoustics and had knowledge and research experience on the rubber ball. When test persons made the rubber ball free drop, they used an aid device to maintain the drop height (1 m) specified in the standard. The automated rubber ball drop device was designed by moving the rubber ball to the prescribed drop height of the jig, as shown in Figure 1, then opening the black jig on which the rubber ball is located and dropping it to the floor surface.

Table 1 Experience of three rubber ball impact source operators on building acoustic test field

Test person	Test experience on building acoustics	Knowledge on rubber ball impact source
A	More than 10 years	Middle
B	None	None
C	More than 10 years	Enough

The device was constructed as quickly move the jig downward by the motor system and hold the rebounded rubber ball after impact the floor surface. This series of actions can be operated continuously, but in this study, the settings have been changed so the device can be operated only once when the switched on. The repeatability test of rubber ball impact was conducted on a 150 mm thick concrete slab (size 4.2 m × 3 m) installed in the reverberation chamber which was connected vertical direction. The floor of the upper reverberation room was impacted with a rubber ball and the impact sound pressure level was measured by applying a fixed microphone method at five points in the lower reverberation chamber. At five measurement points, the microphone height from the floor surface was 1.2 m and the floor of the lower reverberation room was designed as slopes so that the vertical distances from the bottom of the slab to the microphone were arranged differently. The centre part of the slab was impacted to evaluate the repeatability of the rubber ball impact source. The maximum sound pressure level ($L_{i,Fmax}$) of the floor impact sound for one impact was measured ten

Figure 1 Automated rubber ball drop device

times in each experiment with three test persons. The results of five microphone measurements were compared by arithmetic mean.

2. RESULT OF REPEATABILITY EXPERIMENT

Figure 2 shows the results of 10 measurements using an automated rubber ball drop device. When using the device, the level difference due to the impact of 10 times was small as shown in Figure 2. The level difference in the 50 Hz to 80 Hz band was found to occur somewhat. However, the floor impact sound levels in the 50 Hz to 80 Hz range are lower than those in the other bands.

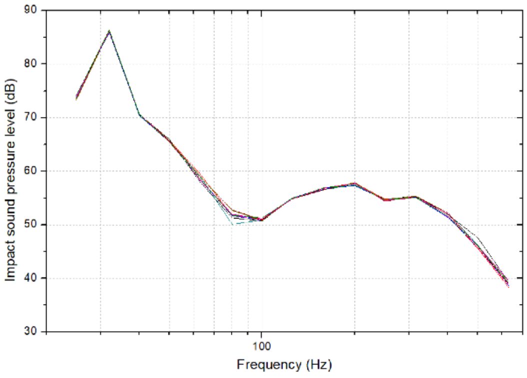

Figure 2 Rubber ball impact sound spectra using automate rubber ball drop device

Figure 3 ~ Figure 5 show the result of 10 rubber ball impact tests for three teste persons. Figure 3 shows the average result of five microphones measured as a result of the test person A. At this time, the test person A was impacted ten times without maintaining the falling direction of the rubber ball constant.

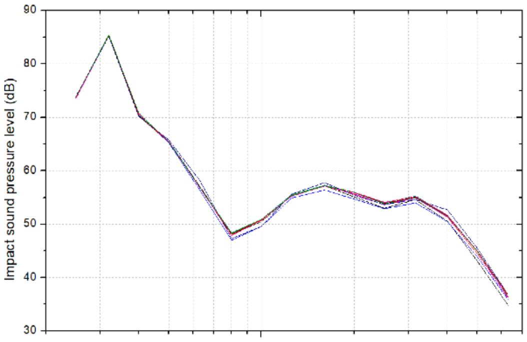

Figure 3 Rubber ball impact sound spectra of operator A

Figure 4 shows the measurement results for the test person B who had no experience in building acoustics test and knowledge of the rubber ball. The results of test person B were found to be relatively narrower than those of test person A. Experimental results of Experiment B show that the level difference in the 250 Hz to 400 Hz band is relatively large compared to the other bands.

Figure 5 shows the result of the repeated experiment of the test person C. Test person C has experience in the building acoustics and has knowledge on the rubber ball. He keeps constant height when rubber ball impact drops and always try to drop the rubber ball in a constant direction. The results showed the narrowest level distribution among the three test persons. In the 200 Hz band, the level distribution is relatively large, but it is considered to have the narrowest level distribution when compared with the distribution of other test persons.

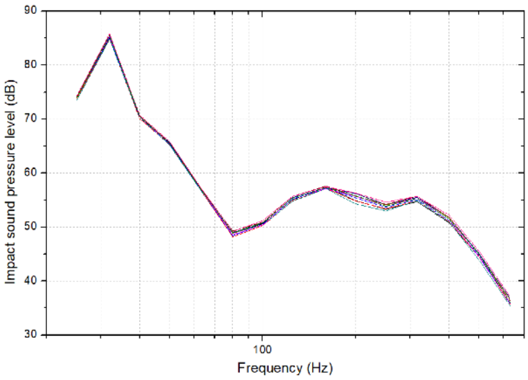

Figure 4 10 Rubber ball impact sound spectra of operator B

As a result of repeated experiments on the rubber ball impact for the three test persons, it is important to try to keep the falling direction of the rubber ball constant at a constant height when the rubber ball is impacted. Even if there is no experience with the rubber ball as in the case of the ball test person B, it is possible to achieve a certain degree of repeatability by following the precautions in the impact of the rubber ball. Figure 6 compares the mean spectra of 10 rubber ball impact sound levels measured by three test persons and an automated rubber ball drop device. The correlation coefficient between the results of three experiments and the result of the automated rubber ball drop device was 1.000 ** (significant at 0.01 level (both sides)).

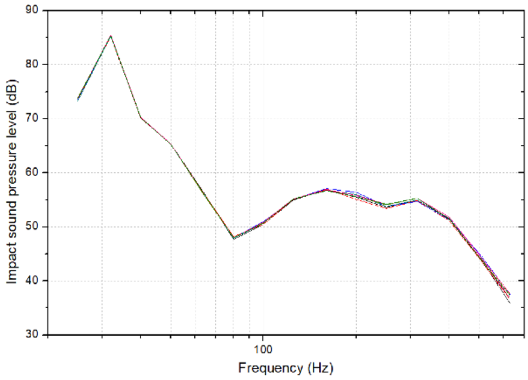

Figure 5 10 Rubber ball impact sound spectra of operator B

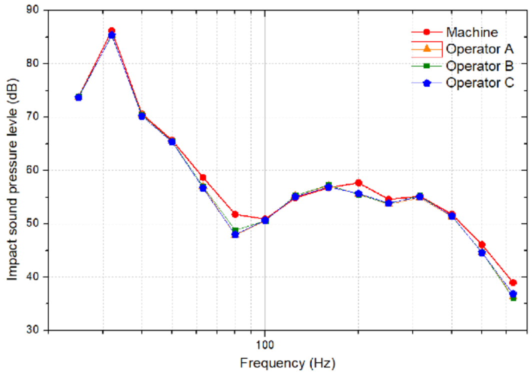

Figure 6 Comparison of rubber ball impact sound pressure level spectrum between 3 operators and rubber ball dropping machine

The frequency characteristics of the experimental results were similar to 0.996**. In the case of using the automated rubber ball drop device, the rubber ball impact sound pressure level in the 63 Hz, 80 Hz and 200 Hz bands was higher than the test results of the test persons. This is caused by the effect of the downward motion of the automated rubber ball drop device to catch the rebounding rubber ball immediately, the difference in the position of the fixed load applied to the slab such as the position of the test person.

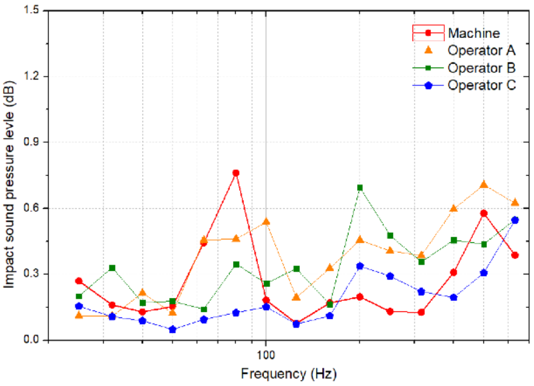

Figure 7 Comparison of standard deviation on rubber ball impact sound pressure level between 3 operators and rubber ball dropping machine

Table 2 A-weighted floor impact sound pressure level on the repeatability test

No.	Machine	Test person		
		A	B	C
1	55	54	54	54
2	55	54	54	54
3	55	53	54	54
4	55	55	54	54
5	55	54	55	55
6	55	55	55	54
7	55	55	55	55
8	55	55	55	55
9	55	55	55	55
10	55	54	55	54
Stdev.	0.000	0.699	0.516	0.516
Average	55.0	54.4	54.6	54.4

Figure 7 compares the standard deviations of repeatability test results of three test persons and automated rubber ball drop device by frequency band. The standard deviation of each frequency band tends to increase with increasing frequency band. However, as the frequency band increases, the rubber impact sound pressure level is lowered, and the impact on the single numerical quantity is less. The standard deviations for the repeatability test in lower than 200 Hz bands, which mainly affects the single number quantity of the rubber ball impact sound, were found to be less than 0.4 dB.

Test person A did not pay much attention to keep the falling direction of the rubber ball constant and showed a higher standard deviation than the other test persons. In the case of the automated rubber ball drop device, the standard deviation was less than 0.2 dB in the band below 300 Hz bands excluding the 63 Hz and 80 Hz bands. 63 Hz, and 80 Hz band have higher standard deviations than the results of the test person's, which is considered to be influenced by the operation of the automated rubber ball drop device.

Table 2 shows the calculation results of the single number quantity of the repetition test of the rubber ball impact sound. Table 2 shows the calculated A-weighted floor impact sound level ($L_{iA,Fmax}$) proposed by ISO / NP 717-2 as a single number quantity of the impact sound of a rubber ball. As shown in Table 2, the standard deviations of the single numerical quantities were small when the automated rubber ball drop device was used. For the test persons, the drop in height and direction was the smallest standard deviation, and there was no significant difference between the test persons who did not experience the use of rubber ball.

4. RESULTS

As a result of the repeatability test for the rubber ball, the rubber ball impact sound pressure level was very similar to that of the test person. The repeatability of the test person was slightly different due to the skill of the test person and the attention to the dropping the rubber ball such as the direction of the drop. In the case of using the automated rubber ball drop device, the repeatability of the device was better in the low-frequency band except for the 80 Hz band. In the case of dropping the rubber ball, it is considered to be useful for improving the test quality in the test of the test room. Also, it can be used in the field conditions where easy to move the device.

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