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Experimental Study on Practical Control of Floor Impact Sound for Nursery Schools

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ABSTRACT

Presently, in metropolitan areas in Japan, there are many problems of waiting children who did not enter nursery centers due to the number of people. In Japan, in April 2015, with the enforcement of "The Comprehensive Support System for Children and Child-rearing", small-scale childcare services became licensed nursery centers. With this system, it became possible to open even with a capacity of 6 to 19 people, and by having small-scale childcare services as licensed nursery centers, it was possible to open a nursery center using a vacant room of apartment or building. Based on the above background, the floor impact sound for children is an important theme in apartments and buildings. Also, not only in apartments and buildings but also in common two-story detached nursery centers, the problem of floor impact sound is important. In this study, we experimentally investigated the countermeasure method of the heavy-weight floor impact sound for the existing nursery centers. As a countermeasure, we installed a commercial product with the storage furniture with tatami on the floor. From the standpoint of vibration isolation and sound insulation, we improved the storage furniture with tatami and improved heavy-weight floor impact sound insulation performance.

Keywords: Noise, Impact, Floor
I-INCE Classification of Subject Number: 45

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1. INTRODUCTION

Following the establishment of "The Comprehensive Support System for Children and Child-rearing[1)]" in April 2015, small-scale authorized nursery centers are receiving recognition as a promising solution to the problem of long waitlists for nursery centers in urban areas and as a new template for rural areas affected by declining populations.

Traditional authorized nursery centers are required to meet certain standards, including having a capacity for 20 or more children and providing a certain amount of floor area per child. However, it can be difficult to obtain the required amount of space in urban areas, where the demand for nursery centers is high. This makes it difficult to open new nursery centers.

However, it is now possible to open new nursery centers for children between 0 and 2 years of age with a capacity of more than 6 and under 19 children. Small-scale nursery centers can be approved as authorized nursery centers and can be opened in vacant apartments or offices in office buildings.

However, sound emitted from nursery centers poses a serious problem. There have been multiple cases around the country in which plans for opening new nursery centers have been postponed or canceled owing to complaints from neighboring residents. Sound can become a key factor when deciding whether a new nursery center will be permitted to open. Considering the current state of affairs, it is necessary to be able to predict the sound environment before opening new nursery centers and to investigate countermeasures. The construction industry must overcome these issues as soon as possible.

In addition, the age limit for small-scale authorized nursery centers was raised to 5 years old in June 2017 under the National Strategic Special Zone Act. Compared to infants under 2 years old, children under 5 years old have more well-developed physical abilities and are more active. We anticipate that undertaking countermeasures to mitigate increased floor impact sound owing to the larger weight of the children and the sound of the children's voices (air sound) will become increasingly important for nursery centers that open in apartment buildings.

In this study, we investigate practical countermeasures against floor impact sound for small-scale nursery centers. Since small-scale nursery centers are often constructed within a short amount of time under limited budgets, we consider only low-cost commercially available products in this study. We investigated the performance of these products in reducing the levels of floor impact sound.

2. EXPERIMENT METHOD

2.1 Experiment facility

For the experiment, we used a reverberation room with an upper and lower floor (Japan Testing Center for Construction Materials). We measured the reduction of transmitted impact sound by floor coverings on a solid standard floor using standard heavy impact sources according to JIS A 1440-2[2)].

Fig. 1 (left: upper floor, right: lower floor) shows plan view as well as the excitation point and sound receiving point. We selected one excitation point in the center and five sound receiving points. The excitation was applied using the car-tire source with impact force characteristics (1) as specified in JIS A 1418-2[3)]. The car-tire source was dropped from a height of 85 cm. The excitation point is at Point 1 because, in this study, we applied excitation to the top of a piece of storage furniture with a tatami on top with a size of approximately 600 × 900 mm. We installed sound level meters (RION, NL-42), shown in L1–L5 in Fig. 1, at the sound receiving points. The height of the microphone is noted in the figure.

Fig. 2 shows a cross section of the slab. The thickness of the concrete floor was 150 mm.

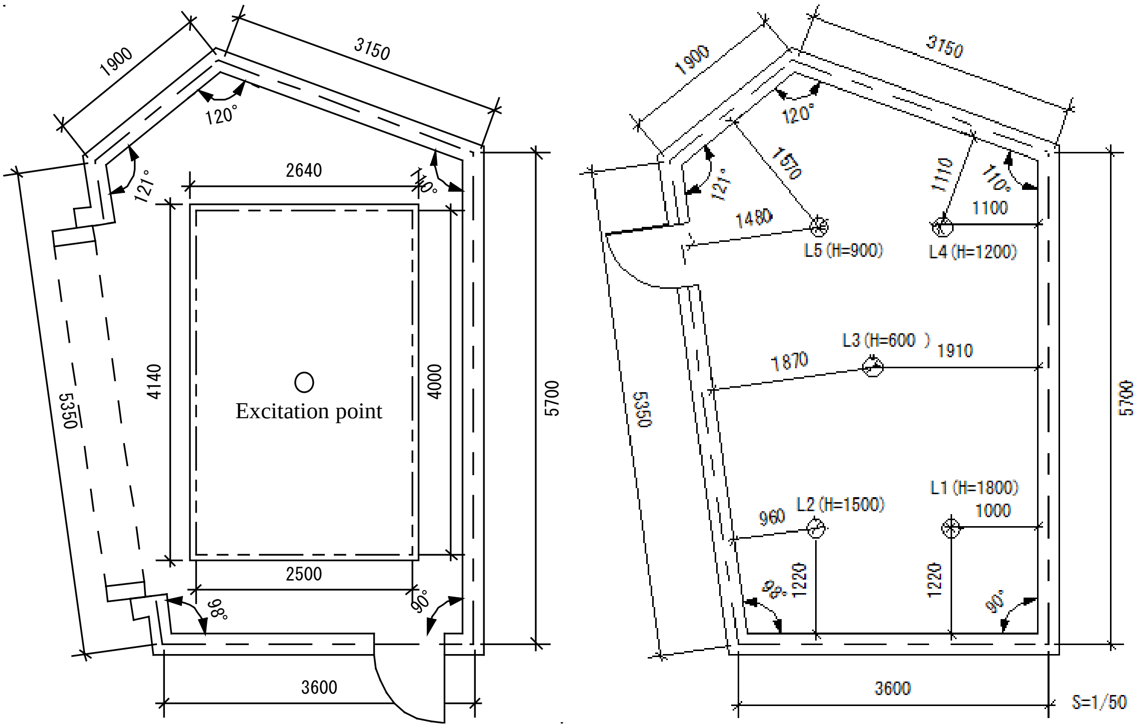

Fig. 1 – Plan of reverberation room.

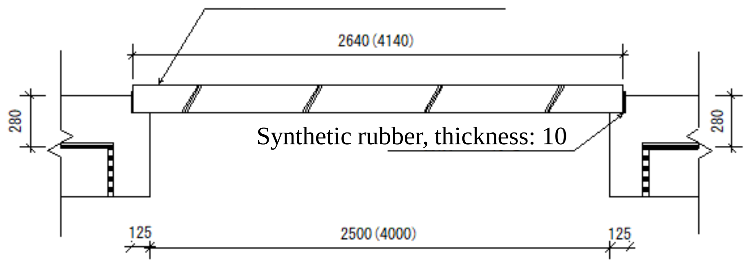

Fig. 2 – Cross section of floor slab.

2.2 Outline of experiment

Fig. 3 shows a diagram of the specimen, which was a piece of storage furniture with a tatami on top. We selected three variations of the specimen, labeled A–C. The size of specimen A was 600 × 600 × H450 mm (inner dimensions were 560 × 560 × H410 mm), and the mass was 10 kg. The size of specimen B was 600 × 600 × H315 mm (inner dimensions were 560 × 560 × H280 mm), and the mass was 8 kg. Specimen C was the same as specimen A except that one side was longer. The size of specimen C was 900 × 600 × H450 mm (inner dimensions were 420 × 560 × H410 mm × 2 places), and the mass was 15 kg.

Table 1 shows an overview of the 25 different variations of the experiment. Experiment No.1 was performed using the surface of a bare concrete slab.

In order to increase the amount of reduction of floor impact sound level owing to changes in the specifications for the specimen, we investigated (1) vibration control, (2) sound insulation, and (3) sound absorption methods. Furthermore, we considered the cost and ease of installation when investigating the specification changes as described earlier. In addition, although the height of the test specimen was 45 cm, the ceiling height in the nursery center was be sufficient since the height of the children was low.

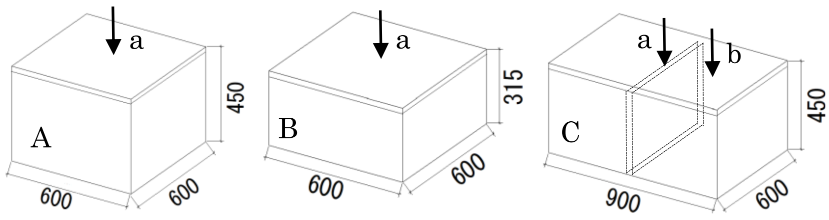

Fig. 3 – Storage furniture with tatami.

Table 1 – Outline of experiment pattern.

Experiment No.	Specimen	Furniture size (mm)	Furniture mass (kg)	Additional mass (kg)	Total mass (kg)	Vibration control rubber size (mm)	Sound absorption material	Sound insulation layers	Excitation point	Notes
1	0	-	-	-	-	-	-	-	a	-
2	A-1	600×600×450	10	-	10	200×200×12.5	-	-	a	-
3	A-2	600×600×450	10	-	10	200×200×25	-	-	a	-
4	A-3	600×600×450	10	-	10	200×200×25	8 layers (405 x 415 x 50 / 1 layer)	-	a	-
5	A-4	600×600×450	10	34	44	200×200×25	-	-	a	-
6	A-5	600×600×450	10	68	78	200×200×25	-	-	a	-
7	A-6	600×600×450	10	68	78	100×100×50	-	-	a	-
8	A-7	600×600×450	10	68	78	100×100×50	-	-	a	Slab reinforcement
9	A-8	600×600×450	10	34	44	100×100×50	-	2 layers (sealed end)	a	Slab reinforcement
10	A-9	600×600×450	10	34	44	100×100×50	-	2 layers (open end)	a	Slab reinforcement
11	A-10	600×600×450	10	34	44	100×100×25	-	2 layers (open end)	a	Slab reinforcement
12	A-11	600×600×450	10	34	44	-	-	2 layers (open end)	a	Slab reinforcement
13	A-12	600×600×450	10	-	10	-	-	2 layers (open end)	a	Slab reinforcement
14	A-13	600×600×450	10	-	10	-	4 layers (2 layers on top and bottom)(405 x 415 x 50 / 1 layer)	2 layers (open end)	a	Slab reinforcement
15	A-14	600×600×450	10	-	10	-	-	-	a	Slab reinforcement
16	A-15	600×600×450	10	-	10	-	-	-	a	-
17	B-1	600×600×315	8	-	8	-	-	-	a	-
18	B-2	600×600×315	8	68	76	100×100×50	-	-	a	Slab reinforcement
19	B-3	600×600×315	8	34	42	100×100×50	-	2 layers (open end)	a	Slab reinforcement
20	C-1	900×600×450	15	-	15	-	-	-	a	-
21	C-1	900×600×450	15	-	15	-	-	-	b	-
22	C-2	900×600×450	15	34		100×100×50	-	-	a	-
23	C-2	900×600×450	15	34		100×100×50	-	-	b	-
24	C-3	900×600×450	15	34		100×100×50	-	2 layers (sealed end)	a	-
25	C-3	900×600×450	15	34		100×100×50	-	2 layers (sealed end)	b	-

3. EXPERIMENT RESULTS AND DISCUSSION

3.1 Concrete slab bare surface

Fig. 4 shows the results for the bare surface. The data for the bare surface were calculated by taking the arithmetic mean of the floor impact sound pressure level results that were measured by applying excitation three times.

The measurement results for the floor impact sound pressure level, shown below, were calculated using the same method. The amount of reduction of floor impact sound pressure level was calculated by subtracting the floor impact sound pressure level that was measured when the specimen was present from the floor impact sound pressure level that was measured when the floor consisted of bare concrete. The background noise is the result of measuring the equivalent sound pressure level for 10 s. The sound pressure levels were 33, 34, 33, and 34 dB in the 63–500 Hz octave band.

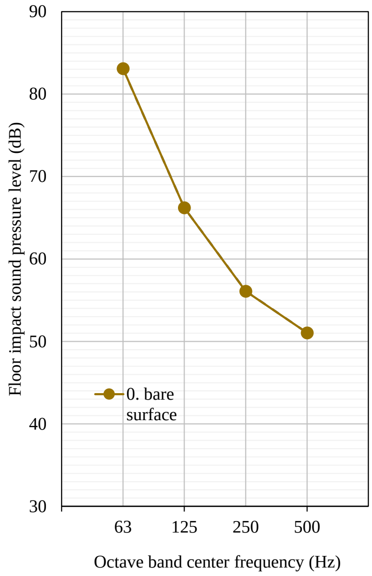

Fig. 4 – Concrete slab.

3.2 Vibration control measures

In order to apply vibration control, we used vibration control rubber. We used ether foamed polyurethane elastomer (0.16 g/cm^3) as the vibration control rubber. The spring constant of the vibration control rubber with a thickness of 12.5 mm was calculated and was found to be 4.3×10^3 (N/m). The specimen was installed at four support points.

Fig. 5 shows the experiment results for A-1 and A-2. The vibration control rubber was installed underneath, as shown in Fig. 6. Figure 5 shows that the oscillation was amplified in the 125–250 Hz octave band, and that the value was from -9 to 15 dB at 125 Hz octave band compared to that of the concrete slab. The floor impact sound pressure level was higher than the floor impact sound pressure level measured for the bare surface of the concrete slab.

Fig. 7 (1) shows the experiment results for A2–5. The results for A-2, 4, and 5 show that as the mass of the objects placed inside the storage area was increased from zero to 34 kg and 68 kg, the amount of reduction of floor impact sound pressure level also increased in the 63–250 Hz octave band. On the other hand, A-2 shows that there was no change in the 63 Hz or the 125 Hz octave band (which determine the heavy-weight floor impact sound insulation) compared to A-3, in which the storage area of specimen A was loaded with eight layers of sound absorption material (50 mm thickness) so that it was fully loaded. However, the amount of reduction of floor impact sound pressure level increased by 3–4 dB in the 250 Hz and 500 Hz octave band. These results show that using sound absorption material inside the pieces of furniture with tatamis on top, as was done in this research, has no effect on the heavy-weight floor impact sound insulation.

Fig. 7 (2) shows the results when varying the thickness of the vibration control rubber. A load of 68 kg was placed inside the storage area. The amount of reduction for A-6, in which the thickness of the vibration control rubber was increased by a factor of 2, improved by 3 dB in the 63 Hz and 125 Hz octave band compared to A-5. For A-7, we placed a sheet of plywood under the bottom slab in order to increase the bottom slab load resistance compared to A-6. However, the results show that there was almost no change in the amount of reduction of floor impact sound pressure level compared to A-6.

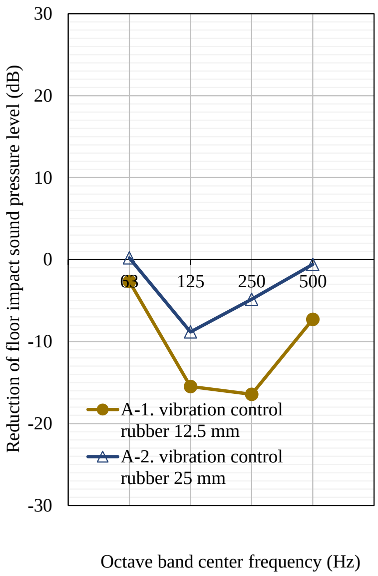

Fig. 5 – Change in thickness of vibration control rubber.

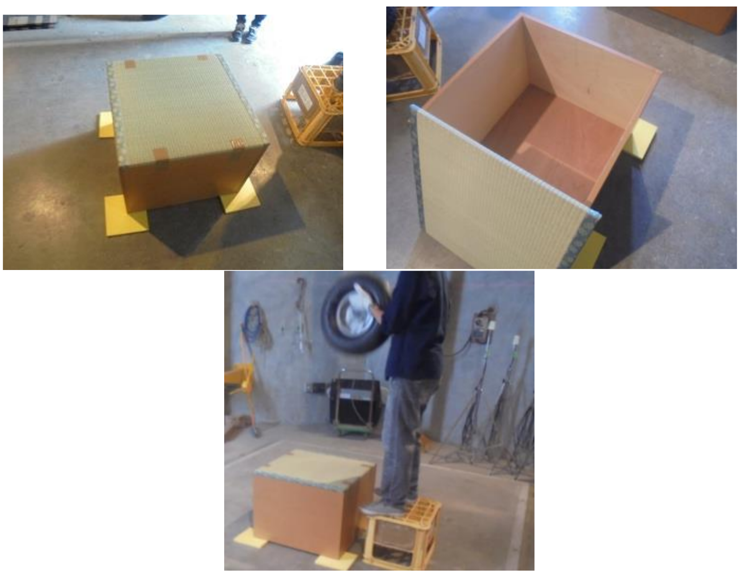

Fig. 6 – Installation status of vibration control rubber.

(1) Change in mass *(2) Change in thickness of vibration control rubber*

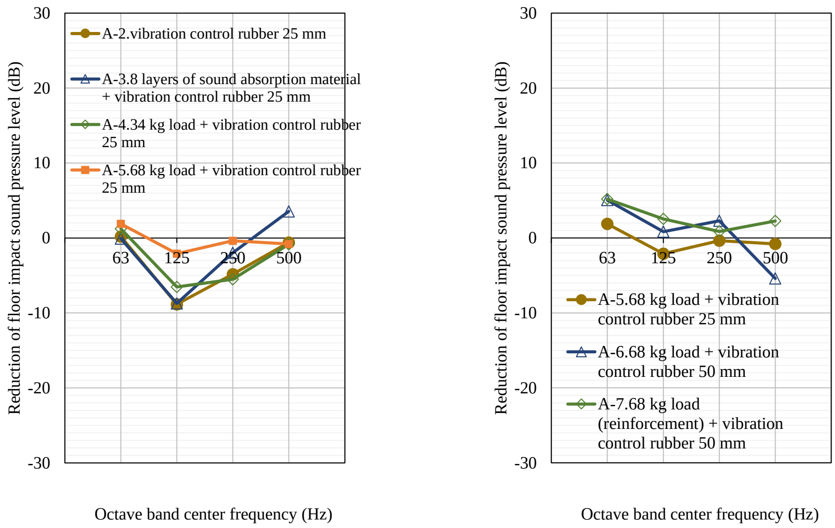

Fig. 7 – Change in mass and thickness of vibration control rubber.

3.3 Sound insulation measures

The interior of the specimen used in this study was an empty cavity. As a result, when an excitation was applied to the top of the specimen, internal sound pressure arose in the air inside and was transmitted to the floor below as floor impact sound. In order to control the sound pressure that arose owing to this air, we installed a sheet of lauan plywood (12 mm) as a separating board inside the specimen. The board was installed at a height that corresponded to the center of the specimen in the height direction. A lauan plywood sheet was installed on top of four pieces of rectangular lumber placed at the corners of the interior of the specimen. Using this setup, we investigated whether inserting separation plates in the air layer inside the specimen (which separated it into two layers) can improve the sound insulation.

Fig. 8 (1) shows the results for A-4 and A-10. The same conditions were used for the vibration control method. The difference is whether the air layer consisted of one or two layers. Note that in the case of A-10, the end was not sealed, and there was a gap of approximately 1 mm. The results show that the sound insulation effect of the separation boards improved the floor impact sound pressure level by 6 dB in the 63 Hz and 125 Hz octave band.

Fig. 8 (2) shows the results for A-8 and A-9. The conditions for the vibration control method were the same for both A-8 and A-9. We investigated the effect of the difference in the conditions regarding the end of the separation board between A-8 and A-9. The results show that sealing the end so that air does not flow through improved the sound insulation performance by 4 dB in the 63 Hz and 125 Hz octave band, as shown by A-8.

We applied both vibration control and sound insulation measures to A-8. The floor impact sound pressure level was reduced by 14 dB in the 63 Hz octave band for A-8. In order to achieve 14 dB improvement by increasing the slab thickness alone, it was necessary to increase the slab thickness by a factor of 2.24, which implied that it would be necessary to increase the thickness of 150 mm slab to 336 mm. Therefore, we believe that the countermeasure used in A-8 is more practical.

(1) Change in sound insulation layer *(2) Change in sealed and open end*

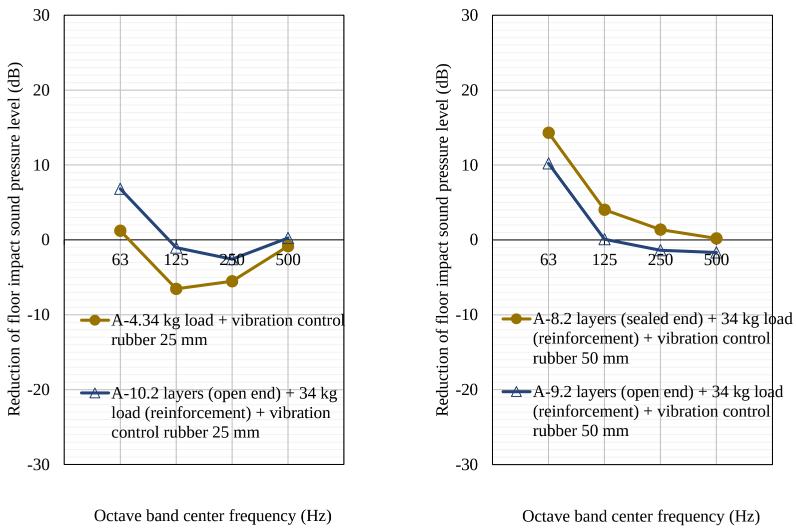

Fig. 8 – Change in sound insulation performance.

4. REDUCTION OF HEAVY-WEIGHT FLOOR IMPACT SOUND PRESSURE LEVEL USING PIECES OF STORAGE FURNITURE WITH TATAMIS

Table 2 shows an overview of the results of this research. The table shows the amount of reduction in the floor impact sound pressure level in the 31.5–500Hz octave band. The table is also sorted in descending order by the amount of reduction in the floor impact sound pressure level in the 63Hz octave band.

The pieces of storage furniture with tatamis on top that were used in this experiment were selected because they are easy to install in nursery centers. These pieces of furniture were able to achieve a maximum of 14 dB of performance improvement in the amount of reduction in the floor impact sound pressure level in the 63Hz octave band. A-8 represents the case in which vibration control measures were used, a separation board was placed in the center of the air layer inside the specimen, and the end was sealed. Additional mass was placed in only the lower portion of the air layer, and the upper portion was usable as storage.

Next, in cases in which the specimen was used without installing vibration control rubber under the specimen, the amount of reduction in the floor impact sound pressure level was -14 to -18 dB in the 125Hz octave band. Similarly, the amount of reduction in the floor impact sound pressure level was -14 to -18 dB in the 250–500Hz octave band. These results imply that using a separation board as a sound insulation layer does not result in improvement, and that vibration control measures are important when installing specimens such as these.

Table 2 – Experiment results of this research.

Experiment No.	Specimen	Excitation point	Reduction of floor impact sound pressure level (dB)					Reduction level in the 63Hz (dB)
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	
9	A-8	a	9.4	14.3	4.0	1.4	0.2	11～15
19	B-3	a	7.1	10.3	3.7	-1.6	-5.1	6～10
10	A-9	a	7.3	10.2	0.1	-1.4	-1.7	
18	B-2	a	6.2	9.3	4.5	1.7	-5.1	
11	A-10	a	4.9	6.8	-1.0	-2.6	0.2	
16	A-15	a	4.4	5.3	-15.3	-17.0	-16.9	1～5
8	A-7	a	5.0	5.2	2.5	0.9	2.3	
7	A-6	a	4.2	5.0	0.8	2.3	-5.4	
17	B-1	a	3.8	5.0	-16.4	-14.3	-14.9	
15	A-14	a	5.9	4.8	-18.2	-18.5	-18.9	
21	C-1	b	2.6	4.2	-13.6	-15.0	-15.9	
14	A-13	a	5.4	4.0	-14.5	-17.2	-19.7	
12	A-11	a	5.1	4.0	-17.3	-14.4	-14.6	
13	A-12	a	4.8	3.5	-16.7	-17.7	-18.8	
22	C-2	a	3.4	3.2	0.5	-4.3	-3.5	
25	C-3	b	5.4	2.8	-2.8	-3.6	-0.8	
24	C-3	a	3.7	2.7	-1.4	-8.7	-0.7	
23	C-2	b	4.8	1.9	-5.1	-5.6	-0.2	
6	A-5	a	3.1	1.9	-2.1	-0.4	-0.8	
5	A-4	a	2.4	1.2	-6.5	-5.5	-0.8	
3	A-2	a	1.5	0.2	-8.8	-4.8	-0.6	-4～0
20	C-1	a	0.3	0.1	1.1	-2.7	-2.0	
1	0	a	0.0	0.0	0.0	0.0	0.0	
4	A-3	a	1.3	-0.1	-8.7	-2.0	3.5	
2	A-1	a	1.1	-2.7	-15.5	-16.4	-7.3	

5. CONCLUSIONS

In this research, we investigated practical countermeasures against floor impact sound for small-scale nursery centers. In our experiments, we conducted an investigation of floor impact sound using low-cost commercially available products that can be installed in a short amount of time. We measured the amount of reduction in the floor impact sound pressure level caused by the car-tire source with impact force characteristics (1) as specified in JIS A 1418-2[3)] using a reverberation room with upper and lower floors. The results show the following:

(1) It was possible to improve the performance of the amount of reduction in the floor impact sound pressure level by a maximum of 14 dB in the 63Hz octave band when using pieces of storage furniture with tatamis on top by using appropriate vibration control measures and sound insulation measures that consisted of inserting separation boards inside the storage area.

(2) It is possible to achieve a reduction in the amount of floor impact sound pressure level of more than 5 dB by decreasing the spring constant of the vibration control rubber, even without using sound insulation measures.

Furthermore, we were able to summarize the specifications and results for reduction in the heavy-weight floor impact sound level in Table 1 and Table 2 in this report.

In the future, we plan to conduct practical experiments to investigate the effectiveness of combinations of multiple specimens at reducing the floor impact sound level based on the results of this experiment. We also plan to take measurements of the floor impact sound level for a variety of structures using actual buildings.

6. ACKNOWLEDGEMENTS

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