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Floor Impact Sound Insulation Using Perforated Gypsum Board Ceiling

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ABSTRACT

Apartments in Korea are structured with reinforced concretes, and the noise due to the floor impact sound causes serious problems between neighbors. As a way to reduce the floor impact sound in existing houses, this study applied perforated gypsum boards to apartments ceiling and analyzed a level of floor impact sound. The ceiling structure consisted of perforated gypsum board, glass wool and air layer. To analyze the effective perforated shape of the gypsum board, experiments of sound absorbing coefficient were conducted in the reverberation chamber according to the perforation diameter and spacing and whether the glass wool was present or not. Based on the analysis results, a material that exhibited 0.99 of sound absorbing performance at the 160 Hz band was selected. The floor impact sound was compared when a perforated ceiling structure was installed and general ceiling structure which is consisted of air layer and gypsum board. For the lightweight impact sound, the single number quantity($L'_{n,AW}$) did not improve. The heavyweight impact sound ($L_{i,Fmax,AW}$) showed a reduction of bang machine by 1 dB and rubber ball by 2 dB.

Keywords: floor impact sound, perforated gypsum board, ceiling structure, apartment, residential building
I-INCE Classification of Subject Number: 51

1. INTRODUCTION

Apartments in Korea accounts for 60 % of all houses, an apartment is the most preferred housing type in Korea. However, the noise in apartments has caused social problems between neighbors, creating conflicts and even violence between neighbors. Apartments are structured with reinforced concretes, and most noise sources are from heavyweight impact sound occurred during residents running or walking in the floor. A floating structure, which installs a resilient material on 210 ㎜ thick slab, is employed in

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recently built apartments to reduce the floor impact sound. However, it is necessary for already built apartments to improve the insulation performance of floor impact sound from portions other than the floating structure. It is also necessary to improve the insulation performance of floor impact sound through constructions within a short period of time. A ceiling is the most likely portion to meet the above requirements.

Newly built apartments are structured with finish materials such as 200 ㎜-thick air layer and gypsum board beneath the slab. Here, the heavy impact sound is amplified at a range of 63 to 125 Hz band due to the air spring in the air layer [1] [2].To reduce this phenomenon, this study installed a perforated ceiling structure to reduce the amplification of the heavyweight impact sound due to the air layer. The perforated ceiling structure consisted of perforated gypsum board and glass wool.

A sound absorbing frequency band may differ according to the perforation diameter or spacing in the gypsum board. The sound absorbing performances of the ceiling structures with different perforation shape in the gypsum board and glass wool behind the gypsum board were tested in the reverberation chamber, and the best performance ceiling structure was applied to the model test laboratory of real apartment to analyze the improvement effect of sound insulation performance from the floor impact sound.

2. Perforated Ceiling and Measurement Method

2.1 Perforated ceiling

The sound absorbing frequency band varies depending on the perforation diameter or spacing in the gypsum board. Five types of gypsum board with different perforation shapes are shown in the Fig.1. The thickness of the gypsum board was 9.5 ㎜. The perforation diameter and spacing were set to 5 - 10 ㎜, and 15 - 30 ㎜. The perforation diameter and spacing were designed by referring to the sound absorption coefficient data of materials whose sound absorbing performance was high in the low frequency band in the market. The perforation diameter was set to a size considering the maintenance convenience of actual apartments when the gypsum board was installed.

(unit : ㎜)

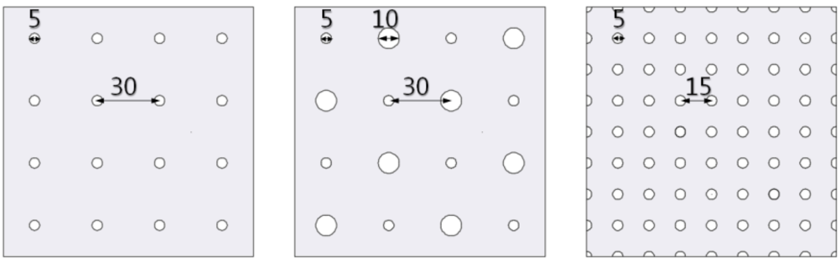


Fig. 1 Perforated gypsum board

2.2 Sound absorption measurement method

The sound absorption coefficient in the reverberation chamber was tested according to KS F 2805 [3]. The area of the reverberation chamber was 260m^3 and the test temperature and humidity were 15-20 ℃ and 60~70 %, respectively. As presented in Table.1, the size of perforated gypsum board was 3m x 4m was installed above the 200 ㎜ air layer configured with a frame. In addition, the sound absorbing performance was analyzed when glass wool was put behind the perforated gypsum board. The thickness of the gypsum board was 9.5 ㎜, and the thickness and density of the glass wool were 50 ㎜ and 40kg/m^3.

Table. 1 The sound absorption coefficient measured perforated ceiling structure

Test overview	Ceiling structures (three types) with the perforated gypsum board	Ceiling structures (three types) with the perforated gypsum board and glass wool
Structure	Perforated gypsum board (9.5 ㎜)	
	Air layer 200㎜	Glass wool 50㎜ (40 kg/m^3)
		Air layer 150 ㎜

2.3 Floor impact sound measurement method

The floor plan of the experimental household is shown in the Fig.2. The size of the target room was 3.5 m x 2.4 m x 2.3 m. The upper household's floor structure is consisted of 210㎜ concrete slave, 30 ㎜ of expanded polystyrene (EPS), 40 ㎜ of lightweight foamed concrete, and 40 ㎜ of finish mortar. Below the slab, 200 ㎜ of air layer and 9.5 ㎜ of gypsum board were placed, which is generally applied to newly built apartments. The floor impact sound levels are compared with "air layer (200 ㎜) + gypsum board (9.5 ㎜)" and "air layer (150 ㎜) + glass wool (50 ㎜) + gypsum board (9.5 ㎜)".

The lightweight and heavyweight impact sounds were tested in accordance with KS F 28010, and single number quantities(SNQ) were analyzed according to KS F 2863 [4] [5]. Bang machine and rubber ball were used to measure the heavyweight impact sound. Fig. 3 shows the floor impact sound level when the ceiling structure is configured with "air layer (200㎜) + gypsum board (9.5㎜)". The SNQ($L'_{n,AW}$) of the lightweight impact sound was 40 dB, which was high due to the sound pressure level at the 125 Hz band. The SNQ($L_{i,Fmax,AW}$)of the heavyweight impact sound was 55 dB when measured with bang machine, and 49 dB when measured with rubber ball. The sound pressure level was high at the 63 Hz band when using bang machine and at the 125 Hz band when using a rubber ball.

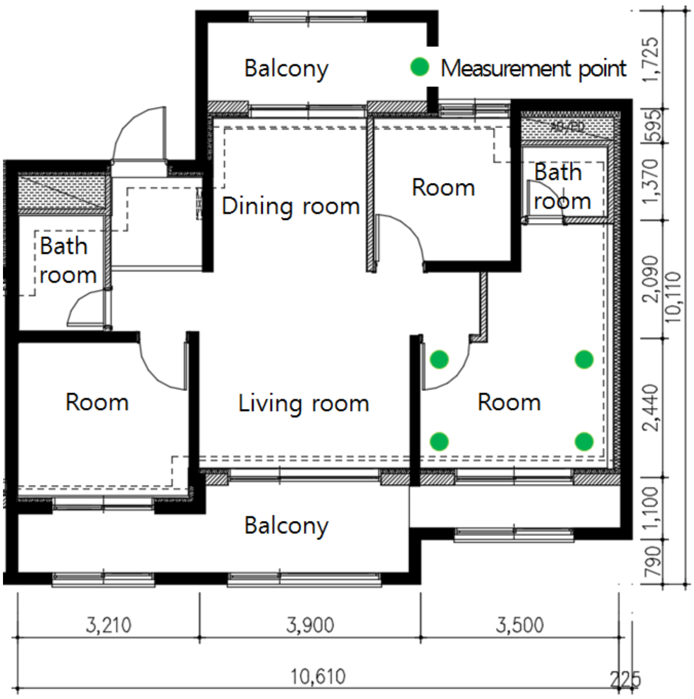


Fig. 2 Floor impact sound measured household

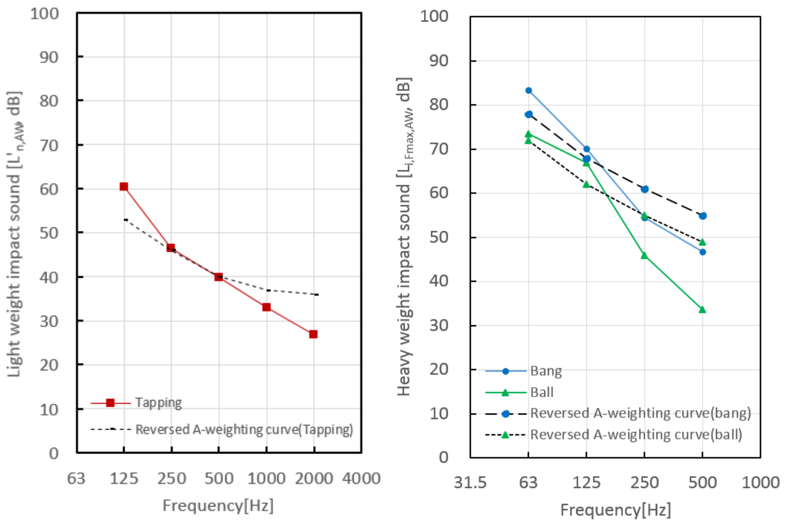


Fig. 3 Insulation performance of floor impact sound at general ceiling structure (air layer 200 ㎜ + gypsum board 9.5 ㎜)

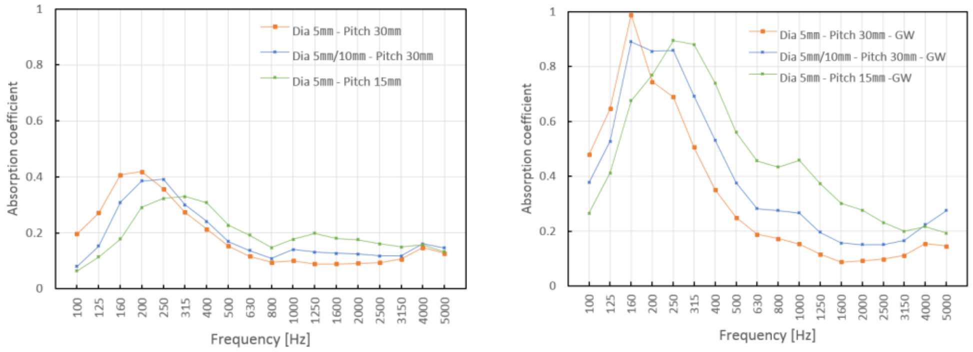
3. Result

3.1 Sound absorption coefficient

The test result of the sound absorption coefficient in the ceiling structure with "perforated gypsum board (9.5 ㎜) + air layer (200 ㎜)" is shown in Fig. 4 (a). The sound absorption coefficient was relatively high at a range of 125 to 500 Hz although it varied depending on the perforation shape. The perforated gypsum board, which was regarded to have the best sound absorption coefficient in the 63-500 Hz, was a gypsum board perforated with "5 ㎜ of diameter and 30 ㎜ of spacing". This gypsum board structure showed the best sound absorption coefficient in the 200 Hz band as well as better performance was revealed in the lower frequency bands than those of other perforated gypsum boards. The frequency band that showed the largest sound absorbing performance in the gypsum board that had the same diameter (5 ㎜) and 15 ㎜ spacing, was 315 Hz. This result indicated that the perforation spacing was narrower, the maximum sound absorbing frequency band became higher. The sound absorbing performance was higher at the 315 Hz or higher frequency bands. The maximum sound absorbing frequency band in the gypsum board with "5 ㎜ of diameter and 30 ㎜ of spacing" was moved to the high frequency bands compared to that of gypsum board with "5 ㎜ of diameter and 30 ㎜ of spacing".

The sound absorption coefficient of the ceiling structure with "perforated gypsum board (9.5 ㎜) + glass wool (50 ㎜) + air layer (150 ㎜)" is shown in Fig. 4 (b). When structured only with the gypsum board, the maximum sound absorbing performance was 0.42 whereas it was increased up to 0.99 when glass wool was installed in the behind the gypsum board. When glass wool was applied, the sound absorbing performance at 100 to 500 Hz was improved by 1.6 to 4.8 times. Furthermore, when glass wool was installed, the frequency band that exhibited the maximum sound absorbing performance was moved to the low frequency band. Both of the ceiling structures with "5 ㎜of diameter and 30 ㎜ of spacing" and "5 ㎜ and 10 ㎜ of diameter and 30 ㎜ of spacing" had the best sound absorbing performance in the 160 Hz band. However, the ceiling structure with "5 ㎜ and 10 ㎜ of diameter and 30 ㎜ of spacing" had better sound absorbing performance in wider frequency bands.

The ceiling structure to be developed aimed to reduce the air spring action in heavyweight impact sounds. Thus, this study selected the ceiling structure that showed better performance in the 100 to 125 Hz band. As a result, this study aimed to analyze the improvement of sound insulation performance against floor impact sound by installing a perforated gypsum board with “5 ㎜ of diameter and 30 ㎜ of spacing” and glass wool.

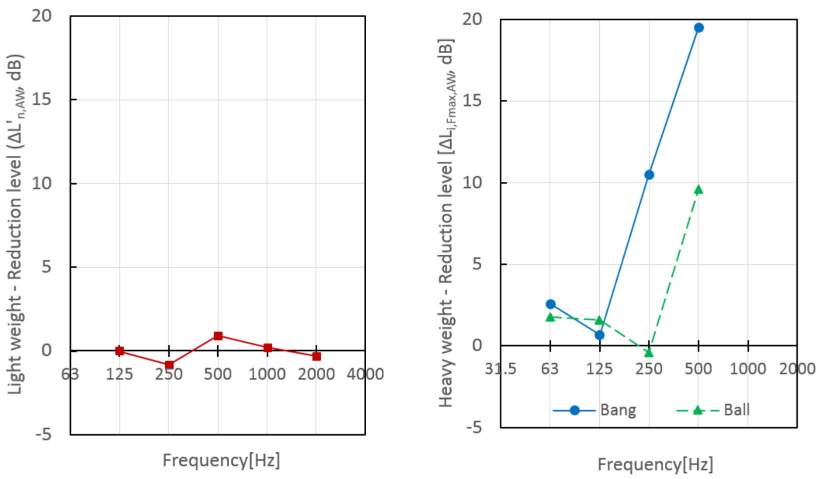


(a) Perforated gypsum board (b) Perforated gypsum board and glass wool

Fig. 4 Sound absorption coefficient

3.2 Floor impact sound

The ceiling structure with “5㎜ of diameter, 30㎜ of spacing perforated gypsum board (9.5 ㎜) + 50㎜-thick glass wool + 150 ㎜-thick air layer”, which was selected through the sound absorption coefficient test, was applied to the room in the apartment. The insulation performance of floor impact sound was improved compared to that of general ceiling structure, “gypsum board (9.5 ㎜) + 200 ㎜-thick air layer”, which is shown in Fig. 5. For the lightweight impact sound, the variation was less than 1 dB in the 500 Hz band, and the SNQ($L'_{n,AW}$) was 40 dB, which had no difference. For the heavyweight impact sound, the reduction when using bang machine was 2.5 dB in the 63 Hz band, 10.5 dB in the 250 Hz band, and 19.5 dB in the 500 Hz band, and the SNQ($L_{i,Fmax,AW}$) was 54 dB, which was reduced by 1 dB. When using a rubber ball, the reduction was 1.6 to 1.8 dB in the 63 to 125 Hz band and 9.6 dB in the 500 Hz band. The SNQ was 47 dB, which was reduced by 2 dB. The large reduction was exhibited in the 250 to 500 Hz band for bang machine, and 500 Hz band for rubber ball, but no significant effects were found in the SNQ($L_{i,Fmax,AW}$).



(a) Light-weight impact sound (b) Heavy-weight impact sound

Fig. 5 Reduction of floor impact sound compared to general ceiling structure

4. CONCLUSIONS

This study was conducted to reduce the floor impact sound by applying perforated gypsum board on ceiling of an apartment. The perforated gypsum board and glass wool showed superior sound absorbing performance in the 125 Hz band to reduce the sound amplification. The results shows no significant changes were found on the lightweight impact sound. But the heavyweight impact sound show 1~2 dB of sound reduction compared to general ceiling structure (200 ㎜-thick air layer + 9.5 ㎜-thick gypsum board). The study results could be utilized as a method to improve the floor impact sound in already built apartments.

5. ACKNOWLEDGEMENTS

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