MADRID
inter.noise 2019
June 16 - 19
NOISE CONTROL FOR A BETTER ENVIRONMENT

Effect of sound absorbing material above the suspended ceiling on heavyweight floor impact sound

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ABSTRACT

This study investigated the effect of sound absorbing materials above the suspended ceiling on heavyweight floor impact sound through measurements in reverberation chamber and test building. In the reverberation chamber, a suspended ceiling system and a speaker inside the suspended ceiling were installed for experiment, and specimens with and without glass wool of various thickness and density inside the ceiling were tested and compared with each other. Heavyweight floor impact sound recorded in the field was then reproduced from the speaker and its sound pressure level was measured in several receiving positions of reverberation chamber. Result showed that glass wool inside the ceiling reduced floor impact sound pressure level by 2 dB in singe number quantitation ($L_{i,Fmax,Aw}$). It was also found that reduction in heavyweight floor impact sound pressure level due to glass wool increased with increasing thickness. In the measurement in test building, it was also found that glass wool reduced by 3 dB of heavyweight floor impact sound pressure level in single number quantity.

Keywords: Sound absorbing material, Suspended ceiling, Heavyweight floor impact sound
I-INCE Classification of Subject Number: 51

1. INTRODUCTION

Floor impact sound is one of irritating noise sources in the residential building. Technologies such as floating floor with resilient material has been developed, but their sound insulation performance were not perfectly proved for heavyweight floor impact sound such as children's jumping and adult's footstep. Because typical Korean residential building has suspended ceiling below structural slab, floor impact sound is transmitted to

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room of the lower floor through the suspended ceiling with air gap. Therefore it is important to examine how the suspected ceiling and air gap affect floor impact sound. Several studies [1-8] investigated the influence of the suspended ceiling on floor impact sound. Air gap between slab and suspended ceiling was found to resonate heavyweight floor impact sound below 100 Hz, and the degree of resonance was varied with the thickness of the air gap [2-3]. It was also found that perforated ceiling panel and components such as side molding reduce heavyweight floor impact sound level [6-7]. In addition, suspended ceiling designed as resonator absorber had influence on reduction of heavyweight floor impact sound level. However, there is no empirical study on influence of sound absorption material in the air gap between slab and suspended ceiling on floor impact sound until now.

In this study, the effect of sound absorbing materials above the suspended ceiling on heavyweight floor impact sound was explored through experiments in reverberation chamber. Mock-up ceiling system was first constructed in the reverberation chamber. Simulated floor impact sound measurement were conducted for several suspended ceilings with and without glass wool of various thickness and density. Reduced heavyweight sound level due to glass wool was analysed and compared with each other for test specimen. In addition, floor impact sound measurement in test building was conducted for the suspended ceiling with and without glass wool in order to confirm the result in the reverberation chamber

2. MEASUREMENT IN REVERBERATION CHAMBER

2.1 Methods

2.1.1 Mock-up of suspended ceiling system

Mock-up of suspended ceiling system for simulated floor impact sound measurement was constructed in the reverberation chamber (volume: 209 m^3) as shown in Figure 1 and 2. Suspended ceiling (area: 10.5 m^2 =3.0 m x 3.5 m) consists of eight gypsum boards (thickness: 9.5 mm), steel stud and pipe, and was connected to side frame wall. Thickness of air gap between floor of reverberation chamber and ceiling panel was 180 mm. A speaker to reproduced heavyweight floor impact sound was installed under floor of reverberation chamber, and two ply of gypsum boards (thickness: 9.5 mm) was also installed on sides of the speaker using wooden frame.

2.1.2 Test specimen

Table 1 shows specification of each suspended ceiling type for the measurements. In the present study, various thickness and density of glass wool above the suspended ceiling panel were tested to investigate the influence of sound absorbing materials on floor impact sound. As shown in Table 1, type A is gypsum board (thickness: 9.5 mm) without glass wool, and used to compare with one with glass wool. Type B, C, and D consist of gypsum board (thickness: 9.5 mm) and glass wool with 24 kg/m^3 of density and thickness of 25, 50, and 75 mm, respectively. Type E, F, and G also consist of gypsum board (thickness: 9.5 mm) and glass wool with and thickness of 25 mm and 48, 64, and 80 kg/m^3 of density, respectively.

2.1.3 Measurement method

In the present study, floor impact sound measurement was simulated by using speaker to reproduce heavyweight floor impact sound. Heavyweight floor impact sound source was recorded in living room of apartment building with reinforced concrete structure, which is typical type in Korea. In the field recording, bang machine with tire

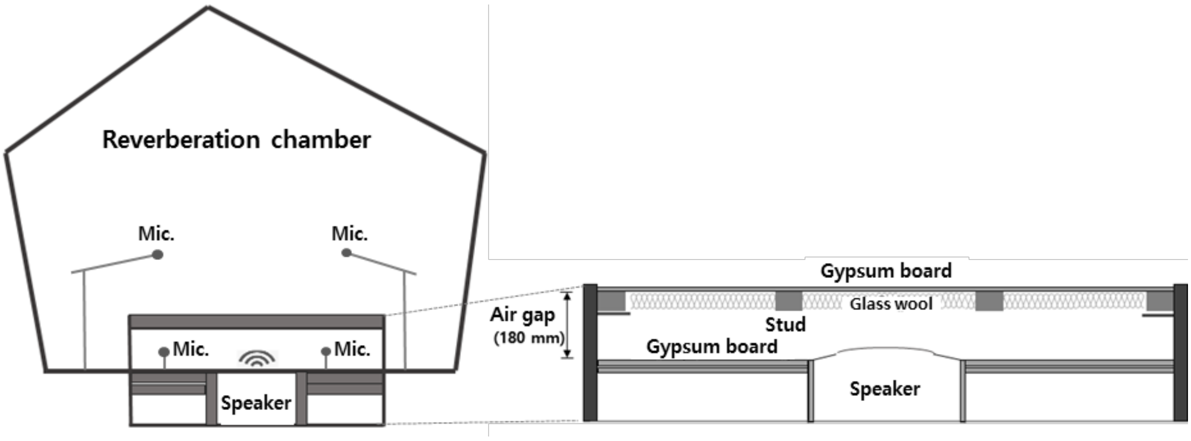

Figure 1. Mock-up of suspended ceiling for simulated floor impact sound measurement in the reverberation chamber

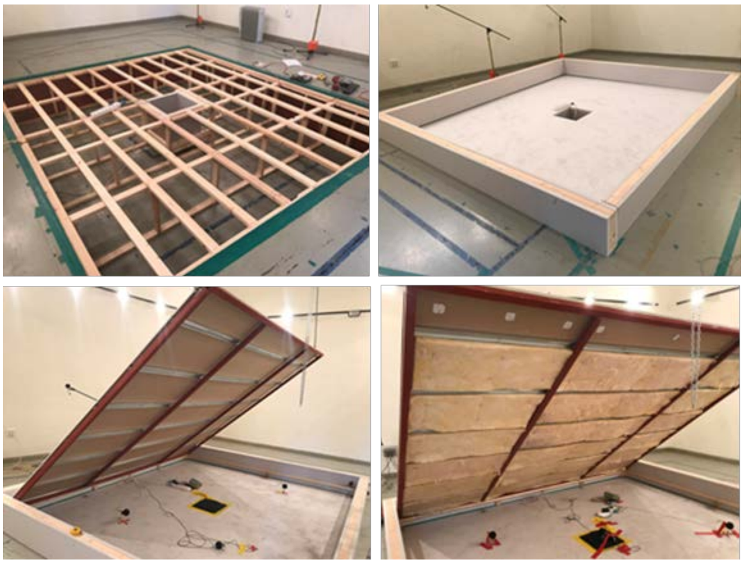

Figure 2. Installation of mock-up ceiling system and glass wool in the reverberation chamber

[9] was utilized as impact source, and impact and sound receiving position was at centre of upper and lower floor, respectively. The speaker used in the measurement reproduces sound from 50 Hz and 630 Hz, which is frequency range for heavyweight floor impact sound in standard [9]. Heavyweight floor impact sound was reproduced from a speaker under floor of reverberation chamber, and measured in six positions of reverberation chamber including the center position. Heavyweight floor impact sound level was then averaged over the six positions. Height of microphone was 1.2 m. Three microphones were also positioned inside air space between suspended ceiling and floor.

Table 1. Specification of each suspended ceiling type for the measurements

Type	Specification
A	Gypsum board 9.5 mm
B	Gypsum board 9.5 mm + Glass wool (24 kg/m^3, 25 mm)
C	Gypsum board 9.5 mm + Glass wool (24 kg/m^3, 50 mm)
D	Gypsum board 9.5 mm + Glass wool (24 kg/m^3, 75 mm)
E	Gypsum board 9.5 mm + Glass wool (48 kg/m^3, 25 mm)
F	Gypsum board 9.5 mm + Glass wool (64 kg/m^3, 25 mm)
G	Gypsum board 9.5 mm + Glass wool (80 kg/m^3, 25 mm)

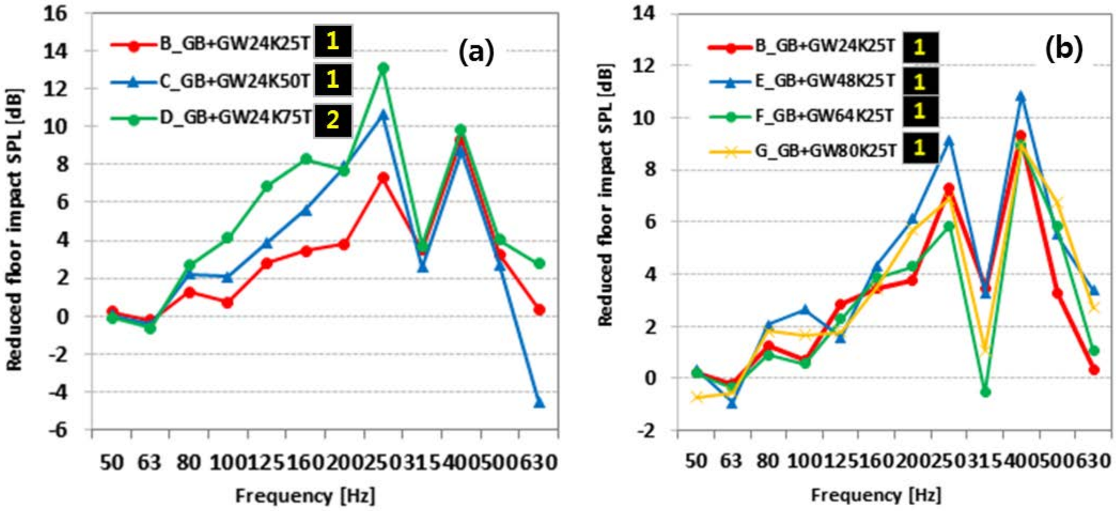

Figure 3. Reduced heavyweight floor impact SPL due to glass wool for various thickness (a) and density (b) in the reverberation chamber; Number in black box indicates reduced single number quantity

2.2 Results

Figure 3 shows reduced heavyweight floor impact sound pressure level (SPL) due to glass wool for various thickness and density. In the figure, number in black box indicates reduced single number quantity ($L_{iFmax,Aw}$) [10]. As shown in the figure (a), floor impact SPL was reduced in the frequency range over 80 Hz for all thickness of glass wool. In particular, most significant reduction of floor impact sound was found in 250 Hz and 400 Hz octave band. However, reduction in 315 Hz octave band was not significantly great for all thickness. In terms of single number quantity, Type D with most thick glass wool reduced by 2 dB of floor impact sound. Type B and C also reduced by 1 dB of floor impact sound. Consequently, the floor impact sound level was more greatly reduced with increasing thickness of glass wool.

As shown in the figure (b), floor impact SPL was reduced frequency range over 80 Hz for all density of glass wool. Similarly to result for thickness, most significant reduction of floor impact sound level was found in 250 Hz and 400 Hz octave band. In addition, sound level reduction in 315 Hz octave band was not significantly great for all density. In terms of single number quantity, all types reduced by 1 dB of floor impact sound. However, influence of increasing density of glass wool on the reduction in floor impact sound level was not clearly found.

3. MEASUREMENT IN TEST BUILDING

3.1 Methods

Floor impact sound measurement was conducted in a wall structure test building (structure: box-frame constructed with reinforced concrete, slab thickness: 120 mm, wall thickness: 150 mm, floor area: 3.5 m × 5.8 m). Same specimens as those in reverberation chamber was installed in the test building as shown in Figure 4. Floor in the test building consisted of 120 mm slab concrete, 30 mm isolation material, 40mm light-weight foamed concrete, 40mm mortar, and floor finishes. Type A (gypsum board: 9.5 mm) and Type C (Gypsum board: 9.5 mm + Glass wool: 24 kg/m^3, 50 mm) was tested. The measurement was based on standardized methods [9] using bang machine for heavy-weight impact source. Five positions including center of room was employed for impact and sound receiving position.

Figure 4. Installation of mock-up ceiling system and glass wool in the test building

3.2 Results

Figure 5 shows reduced heavyweight floor impact SPL due to glass wool (24 kg/m^3, 50 mm) in reverberation chamber and test building. In the figure, number in black box indicates reduced single number quantity. As shown in the figure, frequency spectrum of floor impact sound level in the test building was highly correlated with one in the reverberation chamber (correlation coefficient: 0.88, $p<0.01$). Floor impact sound level in the test building was reduced after installing glass wool in all frequency range. In addition, sound levels in 250 Hz and 400 Hz octave band were greater than those in other octave band. This result was similar as one in the reverberation chamber. Sound level reduction in frequency range below 100 Hz in test building was greater than those in the reverberation chamber. This sound level reduction resulted in greater reduction of single number quantity than in the reverberation chamber. Consequently, glass wool installation in test building reduced by 3 dB of floor impact sound in the single number quantity.

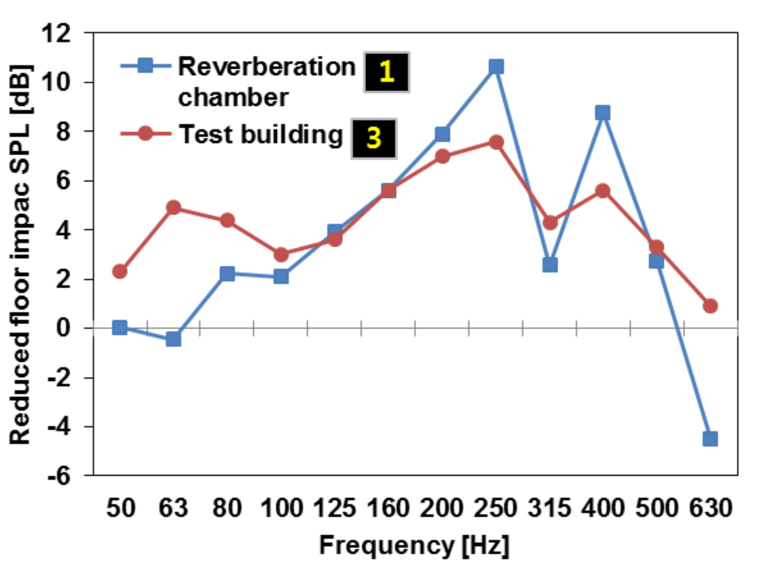

Figure 5. Reduced heavyweight floor impact SPL due to glass wool (24 kg/m^3, 50 mm) in reverberation chamber and test building; Number in black box indicates reduced single number quantity

4. CONCLUSIONS

In the presented study, the effect of sound absorbing materials above the suspended ceiling on heavyweight floor impact sound was investigated through measurements in reverberation chamber and test building. Results showed that glass wool (24 kg/m^3, 75 mm) above suspended ceiling reduced by 2 dB in single number quantity of heavy weight floor impact sound in simulated measurement in the reverberation chamber. In addition, more thick glass wool showed greater reduction of heavyweight floor impact sound level. Measurement in the test building also showed that glass wool (24 kg/m^3, 50 mm) above suspended ceiling reduced by 3 dB in single number quantity of heavy weight floor impact sound. More analyses about comparison with non-ceiling floor and relation among sound absorption and floor impact sound level in receiving room and air-space above suspended ceiling will be conducted in the future.

5. ACKNOWLEDGEMENTS

This research was supported by a grant (19RERP-B082204-06) from Residential Environment Research Program funded by Ministry of Land, Infrastructure and Transport of Korean government.

6. REFERENCES

1. J. Jeon, J. Jeong, M. Vorländer, R. Thaden, "Evaluation of floor impact sound insulation in reinforced concrete buildings," Acta Acustica united with Acustica 90 (2004) 313–318.
2. K. Kim, J. Kang, S. Lee, K. Yang, "Floor impact sound isolation performance by composition of ceiling and wall," Transactions of the Korean Society for Noise and Vibration Engineering, 15(4) (2005) 465-473.
3. Architectural institute of Japan, "Isolation design of floor impact sound in building". Gibodo Press, Japan, 63-66, 2009.
4. C. K. Hui, C. F. Ng, "Improvement of lightweight floating ceiling design with optimum stiffener and isolator locations," Journal of Sound and Vibration 327 (2009) 333 – 353.
5. A. Hiramitsu, "Effect of ceiling specification on floor impact sound insulation of wood-frame construction," Proc INTER-NOISE 2012; New York, USA, 2012
6. J. Ryu, K Kim, "Effect of perforated ceiling structure on floor impact sound," Proc INTER-NOISE 2015; San Francisco, USA, 2015.
7. Kim I, Ryu J, Go J., "Effects of finishing materials in wall and ceiling on floor impact sound", *Proc INTER-NOISE 2016*; 21-24 August 2016; Hamburg, Germany 2016.
8. J. Ryu, H. Song, Y. Kim, "Effect of the suspended ceiling with low-frequency resonant panel absorber on heavyweight floor impact sound in the building," Building and Environment, 139 (2018), 1–7.
9. KS F 2810 (2012), Method for Field Measurement of Floor Impact Sound Insulation. Part 1&2: Method Using Standard Heavy Impact Sources (Korean Standards, Seoul, Korea)
10. KS F 2863-2 (2007), Rating of Floor Impact Sound Insulation for Impact Source in Buildings and of Building Elements. Part 2: Floor Impact Sound Insulation Against Standard Heavy Impact Source (Korean Standards, Seoul, Korea)