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Influence of suspended ceiling type of residential building on heavyweight floor impact sound

Hansol Song[1]; Jongkwan Ryu[2]; Inho Kim[3]; Yonghee Kim[4]

[1,2] Chonnam National University, Korea

[3] POSCO E&C, Korea

[4] Korea Conformity Laboratories, Korea

ABSTRACT

This study investigated the influence of suspended ceiling type of residential building on heavyweight floor impact sound through floor impact sound measurements in test building using rubber ball. In general, gypsum board is suspended using hangers for the ceiling finishing in the Korean residential building, and air space between slab and the suspended ceiling thus occurs. Three types of the suspended ceiling (perforated, sound absorbent, and resonator ceiling) were tested to explore reduction of floor impact sound level in comparison with general gypsum board. Results showed that three suspended ceilings significantly reduced by 3 to 4 dB in single number quantity for rating heavyweight floor impact sound insulation. It was also found that dominant frequency band of the reduction depended on the suspended ceiling types.

Keywords: Heavyweight floor impact sound, Suspended ceiling, Residential building

1. INTRODUCTION

In Korea, floor impact sound such as children's jumping and running sounds, which has dominant sound energy in the low frequency, has been perceived as most irritating noise in apartment building [1,2] and causes social problems such as murder and arson case. Several surveys [3,4] in European country also reported that the sound insulation in the lightweight as well as heavyweight building is an important factor for comfortable living environment. This floor impact noise problems in Korea is due to fact that there are too many apartment buildings over 60 % of all housing types, which has relatively thin slab with 120–150mm thickness. Another reason is that people inside home do not wear shoes and cause easily footstep noise with their bare feet. Accordingly, Korean government forced to have legal minimum slab thickness (210mm) and floating floor for apartment building with RC (Reinforced Concrete) structure since 2005. Several studies on the floating floor with resilient materials to reduce floor impact sound have been carried out [5–12]. However, the floating floor with the resilient material resonates low-frequency sound below about 100 Hz especially for heavyweight floor impact sound in box-frame reinforced concrete structure [5,9]. In addition, the several studies [13–22] have been conducted for acoustical treatments on suspended ceiling panel with air gap under structural slab, which is usually used in Korea as well as the other countries. Previous studies [16,18,21] on the suspended ceiling found that air gap between slab and ceiling panel resonates low-frequency sound below 150 Hz, which is due to air-spring effect. The degree of sound resonance in low-frequency ranges varied with air gap thickness [16,18]. It was also reported that the suspended ceilings have limitation on sound insulation because of the bending resonance frequency [13,14]. To control the amplification of floor impact sound that occurs when installing ceiling, this study proposed

[1] shs206203@naver.com
[2] jkryu@jnu.ac.kr
[3] kiminho21@gmail.com
[4] yhkim@kcl.re.kr

three suspended ceiling types which are perforated ceiling, sound absorbent ceiling, and resonator ceiling. The present study analyzed the reduction performance of floor impact sound by the three suspended ceilings in comparison with general gypsum board through floor impact sound experiments in test building using rubber ball.

2. PERFORATED CEILING

2.1 Methods

In the ceiling, the general and perforated gypsum boards both with and without the sound absorbent sheet (non-woven fabric, thickness: 1 mm) were suspended by timber hangers. The thickness of the air gap between the slab and the gypsum board was 70 mm and 200 mm in the center and side areas of the coffered part, respectively. The perforated gypsum board (thickness: 12.5 mm and mass per unit area: 8.7 ~ 9.7 kg/m^2) consists of several holes of diameter 12 mm, and the percentage of perforated area was about 13 %. Suspended ceilings were installed below the structural slab. The perforated gypsum board with absorbent sheet attached under the gypsum board was constructed. The heavyweight floor impact sound measurements were carried out for ceiling panel with perforated panel (absorbent sheet 1 mm + perforated gypsum board 12.5 mm). The measurement was also made for not only ceiling with general gypsum board (thickness 12.5 mm) but also slab without the suspended ceiling, and results were compared one another. The floor impact sound measurements were conducted in a test building (structure: box-frame constructed with reinforced concrete, slab thickness: 120 mm, wall thickness: 150 mm, floor area: 3.5 × 5.8 m^2, height: 2.6 m) for the cases of both with suspended ceiling. The measurements were based on the standardized methods [23,24], such as using a rubber ball for heavy-weight impact source. The impact source and the microphone was placed at the center position and four corners, totaling five positions. The microphones were located at a height of 1.2 m from the floor and at 0.75 m from wall. In the case of heavyweight floor impact sound, the maximum impact SPL ($L_{i,Fmax}$), which is the maximum SPLs measured by the fast time constant, was measured. The single number quantity (SNQ) for impact sound insulation rating (rubber ball: $L'_{i,Fmax,AW}$) was also calculated according to the procedure for evaluating SNQ in the standardized methods [25]. All the measurements were made for the conditions of no finishing material above the structural slab, and no finishing material over the walls and floors of the receiving room.

2.2 Results

Figure 1 (left) shows floor impact sound pressure level ($L_{i,Fmax}$) in 1/1octave band and SNQ ($L'_{i,Fmax,AW}$) by rubber ball for gypsum board and sound absorbent ceiling. The 1/1 octave band analysis was used to calculate the SNQ and compare easily with results of specimen. As shown in Figure 1, floor impact sound by rubber ball exhibits a dominant low frequency component, and no significant difference in SPL was observed for 32 Hz and 63 Hz octave bands, but in the 125, 250, and 500 Hz band, $L_{i,Fmax}$

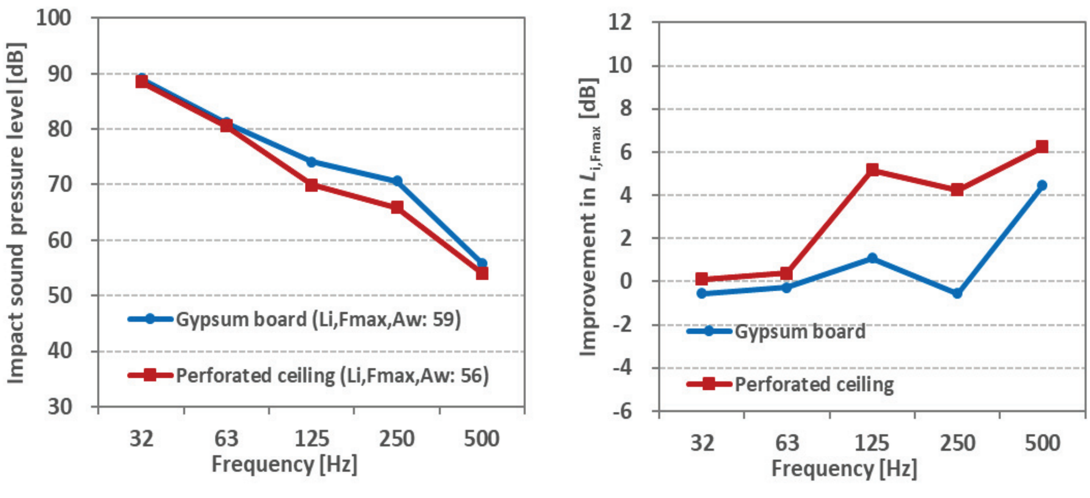


Figure 1 – Floor impact sound pressure level ($L_{i,Fmax}$) (left) and improvement in floor impact sound pressure level by installing the suspended ceiling (right) for perforated ceiling

of perforated ceiling are lower than those of gypsum board. The SNQ of perforated ceiling by rubber ball is 3 dB lower than gypsum board. Figure 1 (right) shows the improvement in floor impact sound pressure level ($L_{i,Fmax}$) by installing the suspended ceiling. Gypsum board ceiling showed the amplification of sound in 32 Hz, 63 Hz, and 250 Hz octave band in comparison with case without ceiling. These amplification were reduced in the case of perforated ceiling. Perforated ceiling exhibited the maximum reduction of 5 dB in the 250 Hz band compared with the gypsum board ceiling.

3. SOUND ABSORBENT CEILING

3.1 Methods

Heavyweight floor impact sound measurements were also carried out in a test building for sound adsorbent ceiling panel (absorbent gypsum board 15 mm with mass per unit area of 10 kg/m^2 + 25 mm glass wool with 24 kg/m^3). The NRC (Noise Reduction Coefficient) of the absorbent gypsum board is 0.21. The measurement was also made for not only ceiling with general gypsum board (thickness 9.5 mm) but also slab without the suspended ceiling, and results were compared one another. Figure 2 shows installation of the sound adsorbent ceiling panel in the test building. Sound absorbent ceiling panel were respectively suspended using steel hanger, carrying channel and T-bar with 60 mm air gap between structural slab and ceiling. The test building is a box type RC structure with 180 mm thick concrete slabs, 150 mm thick concrete walls (three sides), and a window (one side). Additionally, a room of the test building has an area of 24.9 m^2 (4.7 m × 5.3 m) and a height of 2.7 m. Heavyweight floor impact sound measurements were conducted using a rubber ball. There were five impact and sound receiving points including the center position. Microphones were positioned at the center and four corners at height of 1.2 m above floor. The 1/1 octave band analysis and calculation of a SNQ ($L'_{i,Fmax,AW}$) were conducted according to KS F 2863-2 [25]

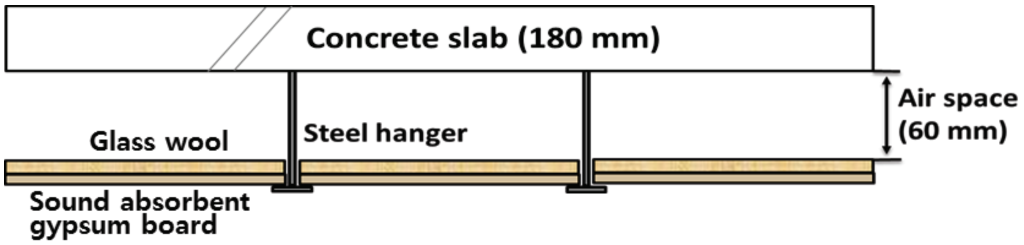
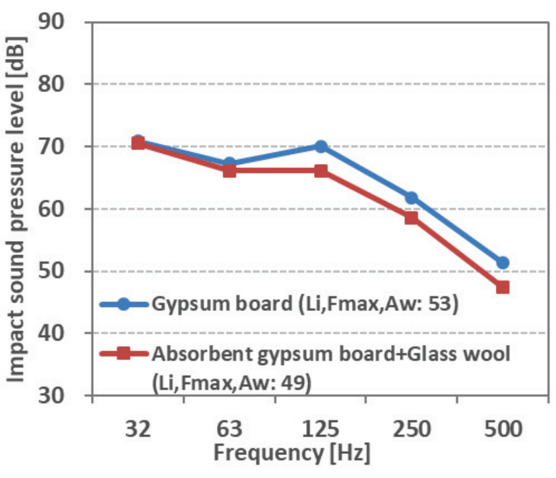


Figure 2 – Structure of sound absorbent ceiling (absorbent gypsum board and glass wool)



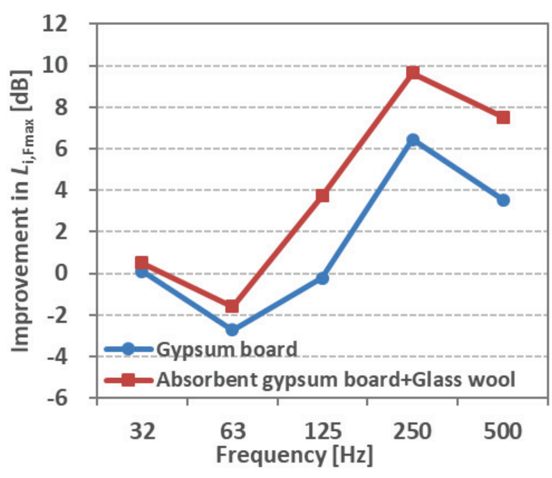


Figure 3 – Floor impact sound pressure level ($L_{i,Fmax}$) (left) and improvement in floor impact sound pressure level by installing the suspended ceiling (right) for sound absorbent ceiling

3.2 Results

Figure 3 shows floor impact sound pressure level ($L_{i,Fmax}$) in 1/1octave band and SNQ ($L'_{i,Fmax,AW}$) for gypsum board and sound absorbent ceiling. As shown in Figure 3 (left), $L_{i,Fmax}$ of sound absorbent ceiling was significantly lower in the octave band over 32 Hz than those of gypsum board. The SNQ of sound absorbent ceiling was thus 4 dB lower than gypsum board. Figure 3 (right) shows the improvement in floor impact sound pressure level ($L_{i,Fmax}$) by installing the sound absorbent ceiling. As shown in Figure 3 (right), it is clearly observed that gypsum board ceiling resonated the sound in 63 Hz band. This resonance was diminished by sound absorbent ceiling, but there was still a resonance in 63 Hz band.

4. RESONATOR CEILING

4.1 Methods

Heavyweight floor impact sound measurements were additionally carried out in a test building for resonator ceiling with resonant panel absorber (hole 50 mm + hole interval 450 mm + air gap 50 mm with 50 mm glass wool). The measurement was also made for not only ceiling with general gypsum board (thickness 9.5 mm) but also slab without the suspended ceiling, and results were compared one another. Figure 4 shows installation of the suspended ceiling with resonant panel absorber in the test building. Resonant panel absorber was suspended using steel hanger, carrying channel and M-bar with 110 mm air gap between structural slab and ceiling. Resonant panel absorber was connected to M-bar, which is arrayed at every 30 cm using screw. The measurement method is same as section 3.1.

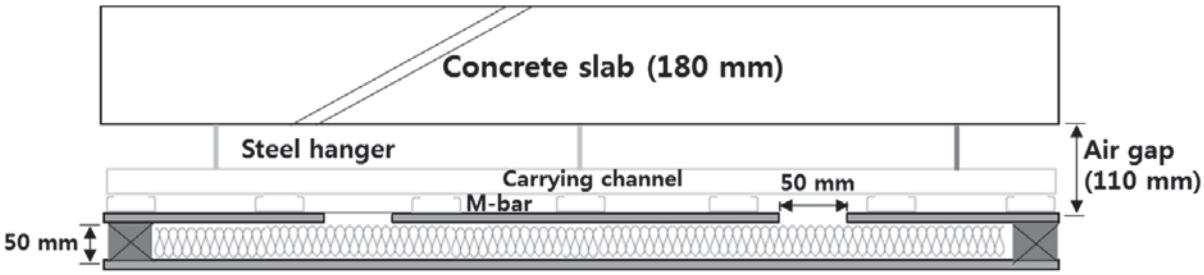


Figure 4 – Structure of the suspended ceiling with resonant panel absorber

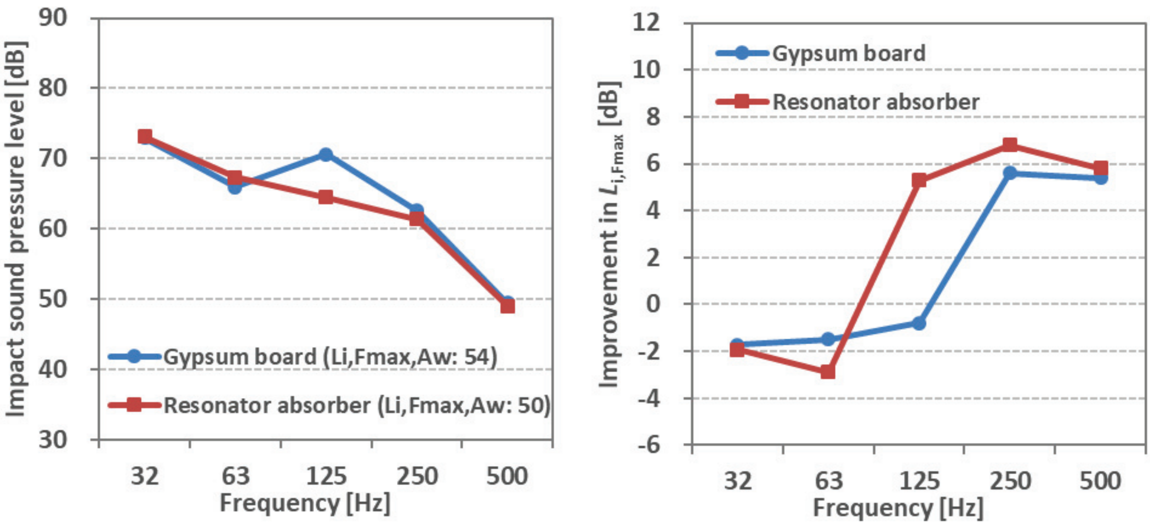


Figure 5 – Floor impact sound pressure level ($L_{i,Fmax}$) (left) and improvement in floor impact sound pressure level by installing the suspended ceiling (right) for resonant panel absorber ceiling.

4.2 Results

Figure 5 shows floor impact sound pressure level ($L_{i,Fmax}$) in 1/1octave band and SNQ ($L'_{i,Fmax,AW}$) for gypsum board and resonant panel absorber ceiling. $L_{i,Fmax}$ of ceiling with resonant panel absorber is slightly higher than gypsum board in the 63 Hz band, but in the 125 and 250 Hz band $L_{i,Fmax}$ of ceiling with resonant panel absorber are lower than those of gypsum board. The SNQ of ceiling on resonant panel absorber is 4 dB lower than gypsum board. As shown in Figure 5, reduced impact $L_{i,Fmax}$ by resonant panel absorber is most large 6 dB in the 125 Hz band. This result is due to the fact that large absorption coefficient coefficient of resonant panel absorber was shown in 100 – 125 Hz band and the ceiling with resonant panel absorber absorbed heavyweight floor impact sound. Figure 5 (right) shows the improvement in floor impact sound pressure level ($L_{i,Fmax}$) by installing the suspended ceiling. As shown in Figure 5, it is observed that resonator absorber resonated the sound in 63 Hz band. In the case of gypsum board, sound below 125 Hz octave band was resonated. The resonator ceiling showed a 6 dB reduction in the 125 Hz band compared with the regular ceiling.

5. CONCLUSIONS

This study investigated the influence of suspended ceiling type (perforated, sound absorbent, and resonator ceiling) heavyweight floor impact sound through floor impact sound measurements in test building using rubber ball. It was found that the three types of suspended ceiling enhance heavyweight floor impact sound insulation in comparison with normal gypsum board ceiling. The three suspended ceilings significantly reduced by 3 to 4 dB in SNQ ($L'_{i,Fmax,AW}$) for rating heavyweight floor impact sound insulation. In addition, the improvement in heavyweight floor impact sound insulation by three suspended ceilings was found in octave bans over 63 Hz. Especially, perforated and sound absorbent ceiling slightly reduced the sound resonance, which was found for gypsum board ceiling. Further research to increase the improvement in heavyweight floor impact sound insulation in 63 Hz octave band is needed in the future.

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