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Floor Impact Sound Characteristics of a Floor Noise Preventing Structure Having an Impact Damping Layer in the Central Portion of a Slab

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ABSTRACT

Floor noise has long been a key cause of disputes and public grievances. In recent times, with increasing demand for higher quality of living, floor noise has become a major social issue. However, heavy weight impact sounds are an area wherein no clear-cut solution has been identified. The present study is an extension of research aimed at resolving this problem. The present study proposes a new construction method wherein an empty space is formed at the center of a slab when forming a damping layer to reduce floor impact sound, causing an impact at the center of the slab to be transmitted through the sides of the slab instead of being transmitted downward through the central portion of the. Assessment of floor impact sounds using a mock-up employing the newly proposed damping floor structure shows that light weight impact sounds are reduced by 13dB compared to a bare slab structure according to a single-number evaluation metric, while heavy weight impact sounds are reduced by approximately 3dB. This is thought to be the impact had by reduced vibration response at the central portion of the slab on reducing noise impact sound.

Keywords: Floor impact Noise, public housing, Noise preventing damping layer
I-INCE Classification of Subject Number: 30

1. INTRODUCTION

Apartments in Asia are built with a wall-slab structural system, which exposes the residents to noise transmitted via the shared walls and floors. In recent years, there has been increased demand for improved quality of life and living standards among apartment dwellers, and the problem of noise traveling via walls and floors has been causing a great deal of disputes and complaints among neighbors to the extent that it has become a social issue. Among the various types of floor impact noise, heavy-weight floor impact noise caused by children running or jumping on the upper floor has become a major cause of complaints in Asia, necessitating an urgent improvement of the floor structure. However, the related problems have been ongoing, without any real

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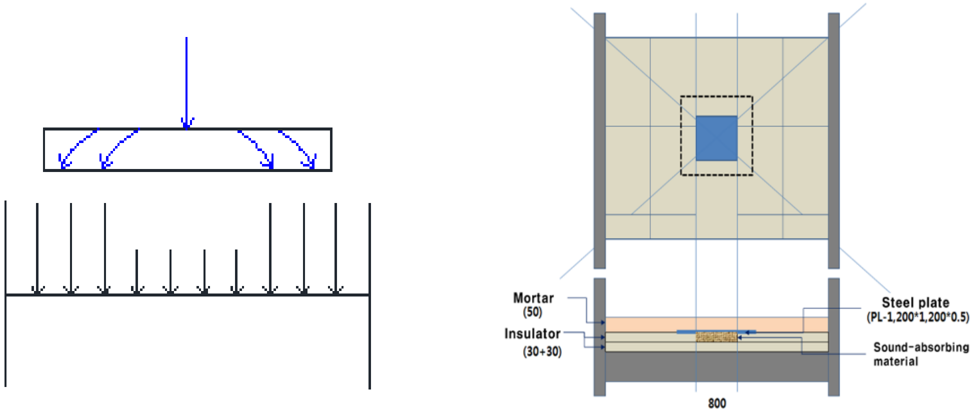
solutions proposed. The current approach to reduce floor impact noise is to increase the thickness of the slab or to create a buffer structure above the slab. In previous studies, the actual concrete strength, mass density and thickness of the slabs significantly affected the floor impact noise and vibration(G.O. Beak, 2015; Y.J. Lee and Y. Jeong, 2016). Although the former method has been proven somewhat effectiveness in previous studies, it has limitations in that increases the overall weight of the building, thereby raising the earthquake load and the volume of the foundation, which are disadvantageous for real-life application in construction. On the other hand, the method of applying a buffer structure has failed to abate heavy-weight impact noise (Bang et al., 2013; Chun et al., 2015). This study was conducted as part of the research to resolve this problem with the aim of proposing a new construction method that can reduce the vibration response and impact noise of floor slabs by creating an empty space in the center of the slab when forming a buffer layer so that the impact force is transmitted via the sides, instead of being directly transmitted through the center of the slab. Experiments were carried out in order to verify the effectiveness of this design.

2. Floor Structure with Impact Buffer Layer in the Center of the Slab

Heavy-weight floor impact noise is characterized by structure-borne sound generated as the vibration of the structure in question causes the surrounding air to vibrate. Therefore, the loudness of heavy-weight floor impact noise is closely associated with the vibration of the floor slab. As seen in the results of measuring noise in the field, the magnitude of impact noise response is the highest in the center of the floor slab, where the vibration response is the greatest. Based on this property, this study proposed creating an empty space in the center of the slab when forming a buffer layer so that the impact force is transmitted via the sides of the slab, instead of being directly transmitted to the bottom through the center, which would help reduce the vibration response and the impact noise. Fig. 1 shows the installation drawing and cross-section of the buffer-based floor structure (hereinafter referred to as the “CN floor structure”) with a buffer layer in the center of the slab.

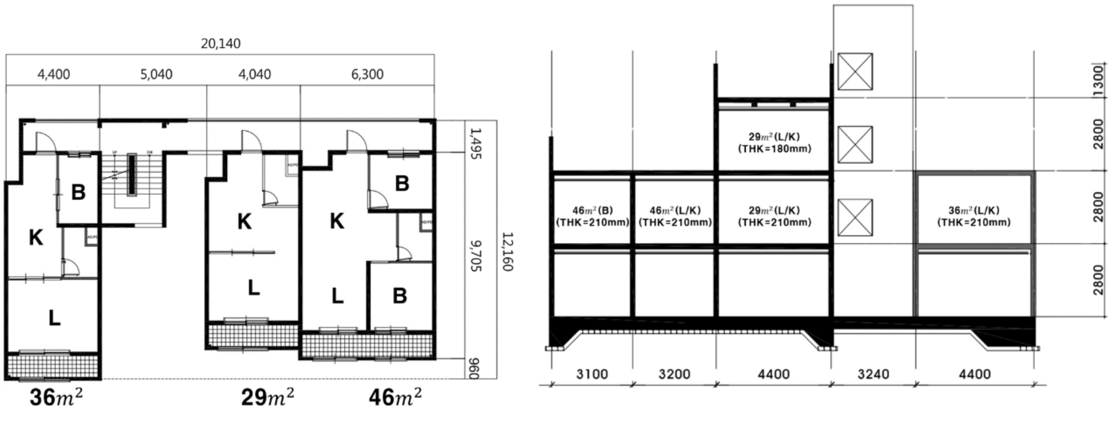


(a) Conceptual diagram *(b) Floor plan and cross-sectional diagram*

Figure. 1 CN Structure with buffer layer in the center of the slab

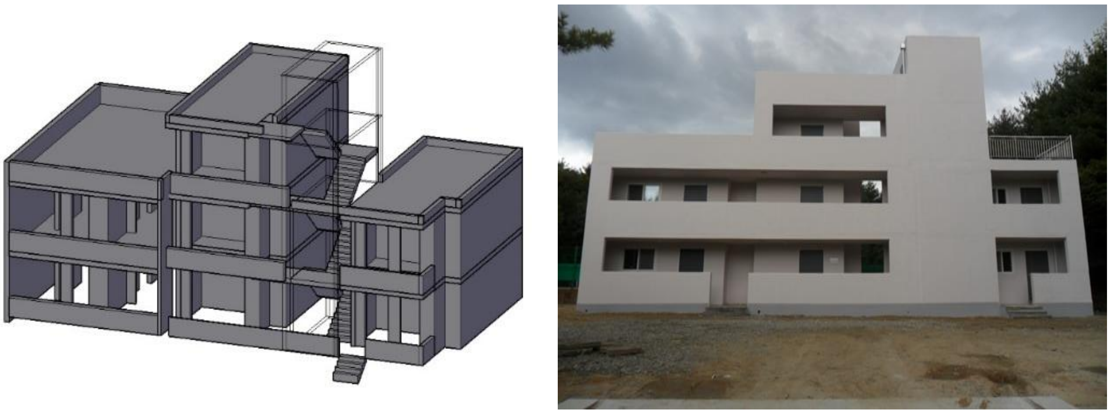
3. MOCK-UP STRUCTURE

A mock-up was built for the purpose of checking the performance of the buffer-based floor structure proposed in this study in floor impact noise abatement. The mock-up was comprised of two to three floors of seven housing units, each with a floor area of $29m^2$, $36m^2$, or $46m^2$, which are the standard floor area of multi-dwelling housings built with wall-slab structures in Asia. The experiment was carried out in the living room of the 29m^2model among the mock-up buildings. The thickness of the floor slab was 210mm. The dimensions of the sound receiving room were 4,220mm(L) ×3,240mm(W)×2,800mm(H), with a ceiling measuring 200mm in depth and unfinished internal walls.



(a) *Floor plan*

(b) *Section*



(c) *Three-dimensional drawing*

(d) *Mock-up picture*

Figure. 2 Planar and three-dimensional drawings of the mock-up

4. TEST METHOD

In the floor impact noise test, a light-weight impact noise source (tapping machine) and heavy-weight impact noise sources (Characteristic 1: bang machine, Characteristic 2: impact ball) were used in measuring the maximum noise level for each of the 1/3 octave band central frequencies. For the measurement of the response vibration resulting from the light- and heavy-weight impact noise generation, five points were designated at the same locations where noise meters were installed, and an accelerometer was installed at each of these points on the ceiling of the sound receiving room to measure the acceleration of vibration. The measurements were evaluated based on the single number quantities obtained using from the inverse A-weighting curve of KS F 2863-1 and KS F 2863-2. Fig. 3 shows a photograph taken during the test.

(a) Natural frequency measurement *(b) Bang machine*

(c) Impact ball *(d) Measurement at receiving point*

Figure.3 Vibration and floor impact noise measurement

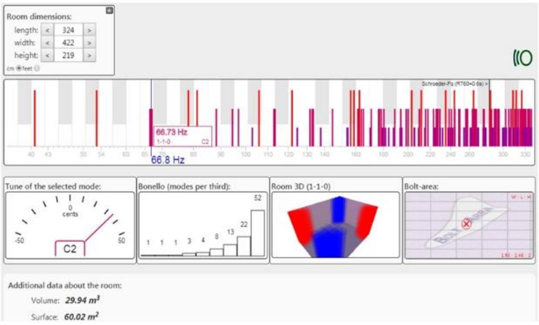
5. TEST RESULT

5.1 Results of Measuring Natural Frequency

Table. 2 and Fig. 4 show the measurements of the natural frequencies of the mock-up slab at each mode and the room mode of the living room.

Table. 2 Results of measuring the natural frequencies of mock-up slabs by mode

	Natural frequencies(Hz)			
	1st	2nd	3rd	4th
$29m^2$	45.6	65.6	96.3	140.0



Room dimensions:
length: 324
width: 422
height: 219

Additional data about the room:
Volume: 29.94 m³
Surface: 60.02 m²

Figure. 4 The room mode of the sound receiving room(amroc, [7]) As shown in the table and the figure, the floor structure for the $29m^2$ model had a low likelihood that the primary vibration mode and the 63Hz central frequency band, which causes the biggest problem in relation to heavy-weight floor impact noise, would be in resonance. Also, the room mode was found to consist of components away from the same frequency band. Therefore, it is expected that effective floor impact noise control will be possible by creating a buffer structure that does not impact the vibration mode.

5.2 Results of Measuring Floor Impact Noise

The measurements of floor impact noise in the experiment are shown in Table 3. Fig. 5 shows the results of the floor impact noise test on the bare slab and the CN floor structure applied to the $29m^2$ model. The results of measuring the floor impact noise showed that the CN floor structure recorded lower noise levels compared with the bare slab structure by 27dB in the case of light-weight floor impact noise, based on the single evaluation index, and by 4dB in the case of heavy-weight floor impact noise produced by an impact ball. This was deemed possible because the buffer structure, which included the dual structure of the EPS and the sound-absorbing material of the central part, significantly contributed to the impact noise reduction in the high-frequency range. On the other hand, the heavy-weight impact noise generated by a bang machine and transmitted by the CN floor structure was 3dB higher than the level recorded by the bare slab.

Table. 3 Floor impact noise experiment results ($29m^2$)

Title	Test name	Composition1) (mm)	Light-weight impact sound(dB)	Heavy-weight impact sound(dB)	
				Bang machine	Impact ball
NS	Bare slab	BS 210	66	50	52
CN	CN floor structure	BS 210+EPS 30 EPS 30 (include buffer layer in center of slab) +Mortar 50	39 (-27)	53 (+3)	48 (-4)

1) BS : Bare slab, LC : Light-weight foamed concrete

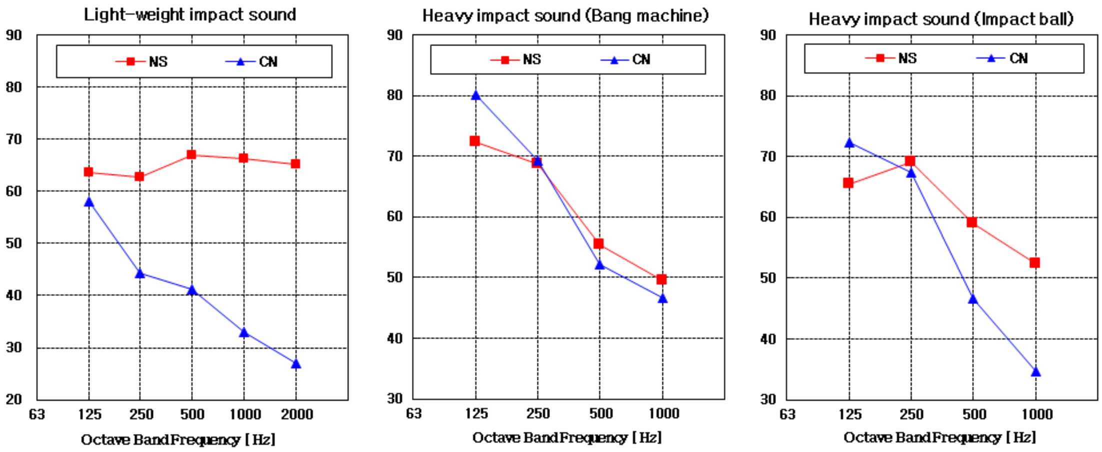


Figure. 5 Floor impact noise experiment results ($29m^2$)

This was deemed to be due to the sound-absorbing material installed in the center of the slab failing to contribute to the absorption of low-frequency sounds and the air layer acting as an air spring and amplifying the low-frequency impact noise. Also, it was deemed that the total height of the buffer layer was not sufficient for the reduction of the vibration response and impact noise of the floor slab, which was intended to be achieved by creating an empty space in the center of the slab to redirect the impact force to be transmitted through the sides, instead of straight down the center.

6. CONCLUSIONS

In this study, a buffer-based floor structure designed to redirect the impact force exerted at the center of the slab to be transmitted via the sides, rather than directly down the center of the slab, in order to reduce the vibration response and impact noise of the floor slab, and its performance was verified using a mock-up. The results of measuring the floor impact noise using the mock-up showed that the proposed structure recorded a noise abatement of approx. 27dB for light-weight floor impact noise, based on a single evaluation index, and a noise abatement of approx. 4dB for heavy-weight floor impact noise (impact ball), compared with the bare slab. This was deemed to be the result of the buffer structure, which includes the dual structure of the EPS and the sound-absorbing material of the central part, significantly contributed to the impact noise reduction in the high-frequency range.

7. ACKNOWLEDGEMENTS

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