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# Floor Impact Sound Characteristics of a Damping Floor Structure Using MSK2

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## ABSTRACT

**Floor noise in multi-story, public housing such as apartments has long been a key cause of disputes and public grievances. In particular, among floor noises, heavy weight impact sounds are an area wherein no clear-cut solution has been identified. In similar research, the author has proposed a means of reducing floor noise through the new material MSK (Mikro Shnicht Kaltasphalt) (B.S. Lee et al., 2017). Mock-up testing has demonstrated that it is possible to reduce heavy weight impact sounds by approximately 3dB. Building on such previous research, the present study employees MSK2 material, having mechanical properties modified from those of MSK, and proposes a damping floor structure providing increased reduction of heavy weight impact sounds. 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 24dB compared to a bare slab structure according to a single-number evaluation metric, while heavy-weight impact sounds(impact ball) are reduced by approximately 3~5dB. This is thought to be attributable to the superior floor impact sound attenuation performance of the newly adopted material.**

**Keywords:** Floor impact Noise, public housing, Mikro Shnicht Kaltasphalt,
**I-INCE Classification of Subject Number:** 30

## 1. INTRODUCTION

The wall-slab structure is one of the most common structural systems applied to the construction of multi-dwelling housing in Asia, and around 100,000 housing units are built each year using this structural system in Korea alone. However, when it comes to the wall-slab structure, the floor slab and wall are shared between the upper and lower housing units and the adjacent units, respectively, resulting in noise transmission. Unlike the Western life style, an *ondol* (heated flooring) system is typically used in Asia, and this has been the cause of endless complaints regarding floor impact noise. 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

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the floor structure. However, no solutions have been proposed yet, indicating many challenges ahead.

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 effective 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 is 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).

Thus, in relation to this issue, the researchers of this study have proposed measures to reduce floor impact noise using a new material called Mikro Schicht Kaltasphalt (MSK) in a previous study (B.S. Lee et al., 2017), where it was verified that heavy-weight impact noise could be reduced by approximately 3dB based on a mock-up test. This paper, in particular, proposes a buffer-based floor structure aimed at boosting the degree of heavy-weight impact noise reduction using MSK2, which is an improvement from MSK in terms of properties. The newly applied MSK2 has excellent attenuation performance and greatly lowers the vibration response from the center of the slab. With such characteristics, it is expected to have a positive impact on floor impact noise abatement.

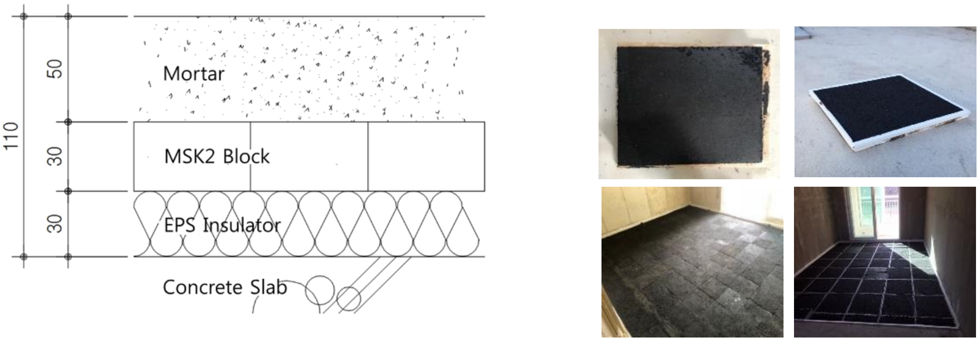
## 2. BUFFER-BASED FLOOR STRUCTURE USING MSK2

The buffer-based floor structure using MSK2 is designed to reduce heavy-weight impact noise by enhancing the impact absorption performance as a way to improve the attenuation characteristics in each dominant frequency band of the floor structure. Also, even with respect to the installation method, MSK2 is fabricated in blocks, instead of applying the conventional stacking, casting or depositing method, in order to improve constructability. Two types of MSK2 blocks were initially proposed. In the first experiment, only MSK2 was fabricated as blocks for installation, while in the second experiment, an integrated block combining MSK2 with an insulation material was fabricated for installation. As for the integrated block, the EPS material used as the insulation layer was in the form of a ribbed vessel to hold MSK2, and this helped promote the effectiveness of fabrication and installation at the same time. Fig. 1 shows a cross-section of the buffer-based floor structure and its installation, and Table 1 shows the properties of MSK2.

*Table 1. Properties of MSK2*[1)]

| | Stone chip A | Stone chip B | Elastic chip A | Elastic chip B | Latex | Additive | Retardant | Total |
|---|---|---|---|---|---|---|---|---|
| Amount of input per product Unit (kg) | 1.44 | 2.7 | 1.62 | 0.81 | 0.81 | 0.09 | 1.12 | 8.59 |
| Weight ratio (%) | 16.8 | 31.5 | 18.9 | 9.4 | 9.4 | 1.1 | 13.0 | 100 |

1) Product size : 500mm (L) x 500mm (W) x 30mm(H)



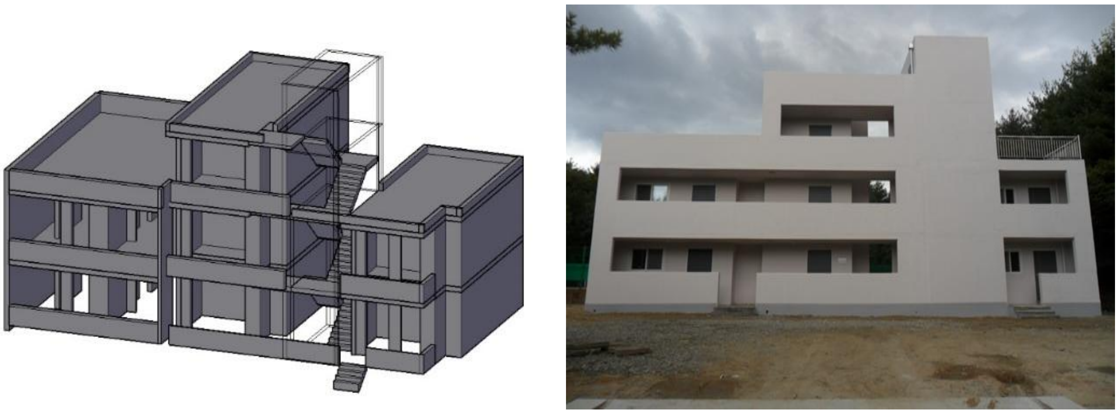
*(a) The buffer-based floor structure* *(b) MSK2 Installation*

*Figure. 1 Improving attenuation characteristics floor structure with MSK2*

## 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. It was set up to enable the application of diverse buffer-based floor structure (propose) with a floor slab thickness of 210mm/180mm. Fig 2 shows the floor plan, elevation and three-dimensional drawings of the housing units subject to the mock-up.

(a) *Floor plan* (b) *Section*



(c) *Three-dimensional drawing* (d) *Mock-up picture*

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

The first and second experiments were carried out in the living rooms of the 36 $m^2$ and 46 $m^2$ models, and the thickness of the floor slab was 210mm. The dimensions of the sound receiving rooms for the 36 $m^2$ and 46 $m^2$ models were 4,200mm (L) × 3,500mm (W) × 2,800mm (H) and 3,560mm (L) × 3,020mm (W) × 2,800mm (H), respectively. Each had a ceiling with a depth of 200mm, and the internal walls were left unfinished.

## 4. TEST METHOD

In the vibration test performed to determine the natural frequencies of the mock-up slab, an impact hammer was used as the impact source. The vibration acceleration was measured at 20 equidistant intervals of on top of the floor slab in order to measure the natural frequency at each vibration mode. 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, and the maximum noise level was measured for each of the 1/3 octave band central frequencies of 125, 250, 500, 1000, and 2000Hz for light-weight impact noise and 63, 125, 250, and 500Hz for heavy-weight impact noise, in accordance with the related standards, KS F 2810-1 and KS F 2810-2. The measurements were evaluated based on the single number quantities obtained 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*

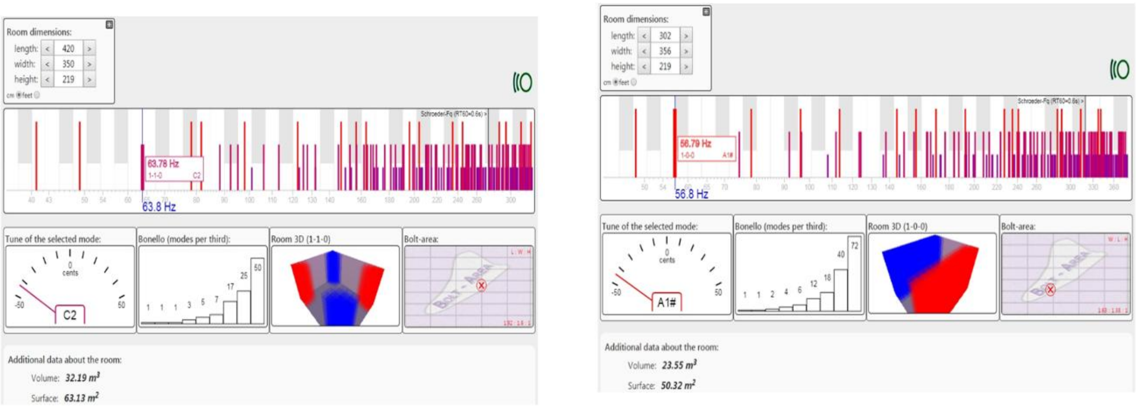
## 5. TEST RESULT

### 5.1 Results of Measuring Natural Frequencies

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. As shown in the table and the figure, the floor structure for the $36m^2$ model had a high likelihood that the 63Hz central frequency band, which causes the biggest problem in relation to heavy-weight floor impact noise, and the secondary harmonic component would be in resonance. Also, in the room mode, the same frequency band component was detected, indicating disadvantageous conditions for floor impact noise abatement. In the case of the floor structure for the $46m^2$, however, the secondary mode was found to be near the 63Hz central frequency band, and a 56.8Hz component was detected in the room mode. Thus, it was expected that there would be a need for control with respect to the primary mode.

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

| | Natural frequencies (Hz) | | | |
|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th |
| $36\ m^2$ | 31.3 | 36.9 | 43.1 | 60.6 |
| $46\ m^2$ | 55.6 | 61.1 | 78.8 | 99.4 |



Room dimensions:
length: 420
width: 350
height: 219
cm ● feet ○

Additional data about the room:
Volume: 32.19 $m^3$
Surface: 63.13 $m^2$

Room dimensions:
length: 302
width: 356
height: 219
cm ● feet ○

Additional data about the room:
Volume: 23.55 $m^3$
Surface: 50.32 $m^2$

*(a) $36\ m^2$* *(b) $46m^2$*

*Figure. 4 The room mode of the sound receiving room(amroc, [7])*

### 5.2 Results of Measuring Floor Impact Noise

The results of measuring the floor impact noise in the first experiment ($36m^2$ model) are presented in Table 3. Fig. 5 shows the results of the floor impact noise test on the bare slab, basic buffer structure, and buffer-based floor structure fabricated using MSK2 that were applied to the $36m^2$ model. The results of measuring the floor impact noise showed that compared with the bare slab, the MSK2-applied floor structure resulted in noise abatement of approx. 16dB for light-weight impact noise and approx. 5dB for heavy-weight impact noise (Impact ball) in the single evaluation index. It also resulted in approx. 3dB lower light-weight impact noise and 1dB lower heavy-weight impact noise (Impact ball) compared with the basic buffer structure. On the other hand, there were little to no differences observed for heavy-weight impact noise produced by the bang machine from the bare slab and buffer structure, and this was deemed to be due to the resonance of the dominant frequency (63Hz) of the impact of the bang machine and the harmonic component of the natural frequency of the buffer-based floor structure, as described earlier.

*Table. 3 Floor impact noise experiment results ($36m^2$)*

| Title | Test name | Composition1) (mm) | Light-weight impact sound(dB) | Heavy-weight impact sound(dB) | |
|---|---|---|---|---|---|
| | | | | Bang machine | Impact ball |
| NS | Bare slab | BS 210 | 62 | 50 | 49 |
| BS | Basic buffer structure | BS 210+EPS 30<br>LC 40+Mortar 40 | 49<br>(-13) | 50<br>(±0) | 45<br>(-4) |
| MSK2-1 | MSK2 floor structrue | BS 210+EPS 30<br>MSK2 30+Mortar 50 | 46<br>(-16) | 51<br>(+1) | 44<br>(-5) |

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

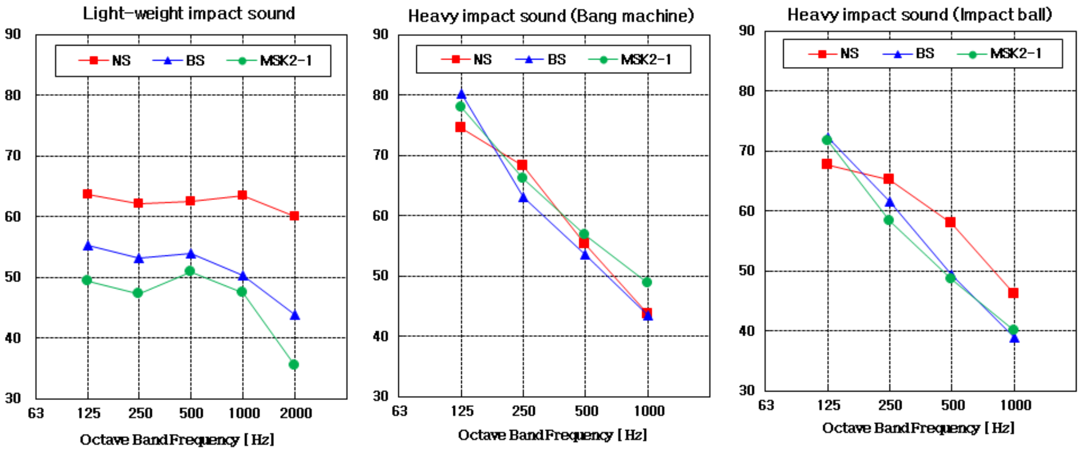


*Figure. 5 Floor impact noise experiment results ($36m^2$)*

The results of measuring the floor impact noise in the second experiment ($46m^2$ model) are presented in Table 4. Fig. 6 shows the results of the floor impact noise test on the bare slab and buffer-based floor structure fabricated using MSK2 that were applied to the $46m^2$ model. The results of measuring the floor impact noise showed that even the MSK2-2 floor structure resulted in noise abatement by approx. 24dB for light-weight impact noise and approx. 3dB for heavy-weight impact noise (Impact ball) compared with the bare slab in the single evaluation index, but little to no abatement with respect to the impact noise from the bang machine. These results prove the impact absorption performance of MSK2, and it is expected that field application will be possible if the heavy-weight floor impact noise abatement measures for bang machines are improved.

*Table. 4 Floor impact noise experiment results (46m$^2$)*

| Title | Test name | Composition1) (mm) | Light-weight impact sound(dB) | Heavy-weight impact sound(dB) | |
|---|---|---|---|---|---|
| | | | | Bang machine | Impact ball |
| NS | Bare slab | BS 210 | 64 | 53 | 52 |
| MSK2-2 | MSK2 floor structrue | BS 210+EPS 30<br>MSK2 30+Mortar 50 | 40<br>(-24) | 52<br>(-1) | 49<br>(-3) |

1) BS : Bare slab

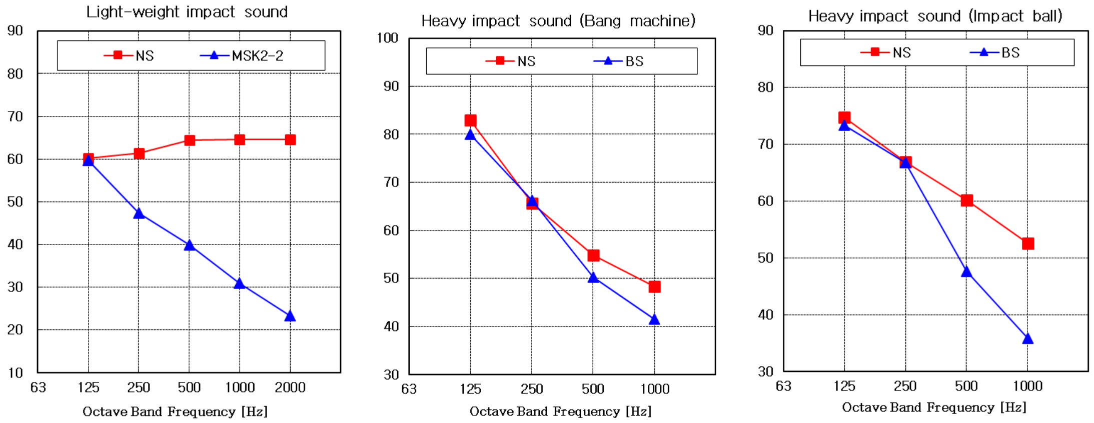


*Figure. 6 Floor impact noise experiment results (46m$^2$)*

## 6. CONCLUSIONS

In this study, a buffer-based floor structure made with MSK2, which was produced by improving the properties of the existing MSK, as part of the measures to reduce heavy-weight floor impact noise by enhancing the impact absorption performance of the floor structure without altering its natural frequency. The performance of the newly developed material was verified using a mock-up. Floor impact noise was measured using the mock-up, and the results showed a decrease of 13~24dB in light-weight floor impact noise and a decrease of 3dB(Impact ball) in heavy-weight floor impact noise transmitted by the MSK2-integrated floor structure compared with bare slab. It was deemed that the vibration response in all the frequency bands decreased, thereby affecting floor impact noise abatement. It is expected that it will be possible to apply the MSK2-integrated block, with greatly improved construability, in the field.

## 7. ACKNOWLEDGEMENTS

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