Master's Science in Engineering

Floor Impact Sound Insulation Performance by Physical Characteristics of Access Floor Resilient Materials

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Floor Impact Sound Insulation Performance by Physical Characteristics of Access Floor Resilient Materials

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Abstract

Floor Impact Sound Insulation Performance by Physical Characteristics of Access Floor Resilient Materials

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At present, apartments in which more than 70% of the Korean population live in are vulnerable to noise and vibration due to the characteristics of RC wall structure. The resulting inter-layer noise complaints increase year by year and are becoming serious social problems. The government introduced the recognized floor structure to solve the interlayer noise problem by improving the floor structure, but mostly it is limited to the wet standard floor structure and development of new floor structure is required.

As an alternative, the dry access floor is more likely to reduce the floor impact sound than the wet floor structure, and has additional advantages such as ease of maintenance and shortening the construction period. However,

sufficient sound insulation performance and analysis are insufficient compared to the possibility, so there are many difficulties to apply to real apartments.

Therefore, in this study, the resilient material was applied as a method to improve the floor impact sound insulation performance of the access floor and the dynamic characteristics of the resilient material, dynamic modulus and loss factor, were used as variables and the correlation between the floor impact sound reduction and the non- parametric statistical and Spearman correlation coefficients was analyzed.

As a result of analysis, it is analyzed that the sound insulation performance is obtained by applying the resilient material to the access floor, and the loss factor is analyzed in the light-weight floor impact sound and the dynamic modulus coefficient is higher in the heavy-weight floor impact sound.

Particularly, in obtaining the dynamic modulus and the loss factor, it is found that the value obtained according to DIN 53513, which measures the physical characteristics of the resilient material itself, is more suitable for analyzing the correlation with the floor impact sound insulation than the KS F 2868 standard for measuring the resilient properties of the currently floated floor structure.

Accordingly, it is necessary to present a new standard for the development of an additional floor structure including the access floor in addition to the existing floor structure. And the relationship between the physical

characteristics of the resilient material and the insulation performance of the floor impact sound can be used as a basis for the development of resilient materials.

Further research is needed on the relationship between the measurement method and the appropriate range of the physical characteristics of the access floor resilient material and the floor impact sound insulation performance.

Keyword : Interlayer noise, Floor impact sound, Resilient material, Dynamic modulus, Loss factor, Natural frequency, Apartment, Access floor

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Chapter 1. Introduction

1.1 Research Background

1.1.1 Increase of Apartment Residents in Korea

In the middle of the 20th century, urbanization of the population caused by industrialization occurred in Korea. As a result, housing in the form of an apartment through the verticalization of the buildings has developed in order to accommodate the population rapidly flowing into the city and to accommodate many people by utilizing limited land.

More than 70% of the population in Korea is living in apartment(Population and Housing Census) and more than 50% of the nation's housing is occupied by apartments which are increasing steadily(Ministry of Construction and Transportation).

1.1.2 Interlayer Noise Problem due to Characteristics of Apartment

These walled residential units are preferred because of the efficiency of space use, economic efficiency, and construction. However, this structure allows each generation to share walls and slabs, and thereby differentiates the generations. Therefore, it is vulnerable to noise and vibration, which are the causes of noise generation between adjacent generations.

Most of the apartments in Korea have RC type wall structure. Such concrete is a heavy material due to the characteristics of the material and has a good insulation performance against air transmission sound transmitted through the air medium such as speech, TV sound and the like because it is sealed. However, in the case of the solid propagation sound generated when an impact is applied to the concrete surface, the concrete has a characteristic of being easily transmitted to the adjacent generation since its own vibration resilient ability is very small(Moon and Park 2014).

According to the Ministry of Environment(2015), the interlayer noise complaints are increasing every year from 7021 in 2012, 14,555 in 2013, 16,370 in 2014 and 15,519 in 2015, and is becoming a serious social problem.

1.1.3 Governmental Institutional Efforts to Solve the Interlayer Noise Problem

In order to solve the interlayer noise, the Korean government announced the standard floor structure in accordance with the "Standard for Recognition and Management of Floor Impact Noise Canceling Structure in Apartment", and the floor structure in the apartment house secured the minimum sound insulation level(Ministry of Land, Infrastructure and Transport 2004). In addition to this, the government intend to expand the possibility of improving the floor structure by introducing a recognized floor structure that has been recognized by related organizations.

However, most users have only used the standard floor structure already developed, and there is a lack of development for the new recognized floor structure.

This phenomenon deteriorates the development to improve the floor impact sound insulation performance. Even the studies conducted for securing the floor impact sound insulation performance have been limited to the development of the resilient material within the range of the standard floor structure, so that there is a difficulty in improving the floor impact sound insulation performance.

The autonomous introduction through the development of the recognized floor structure is limited, so the government abolished the standard floor structure in 2013, and only the recognized floor structure is defined as the floor structure standard(Ministry of Land, Infrastructure and Transport 2013).

1.1.4 Limitations of Currently Used Wet Floor Construction

Approximately 70% of the currently recognized structures are occupied by wet type structures similar to standard floor structures(Yoo 2012).

However, the wet floor structure is a cause of the interlayer noise because the floor slab etc. are integrated with the structure to transmit the solid sound to the lower layer. In addition, the construction method is complicated, the air is long, and there is a problem such as waste of heat storage for preheating(Kim & Sohn 2006). Furthermore, there are limited factors such as the difficulty of maintenance in the case of drowning in resilient materials and limitations of remodeling.

1.1.5 Dry Floor Structure Presented as an Alternative to Wet Floor Construction

As an alternative to the wet floor structure in which these drawbacks exist, a dry floor structure is emerging. The basic dry floor structure refers to a method in which foamed concrete and finished mortar are removed. Depending on the type of heat source, it could be classified into electric type and hot type, and it can be classified into full dry type and semi-dry type according to the construction method of the finish layer. Also, it can be divided into pipe separation type and pipe integral type depending on the type, and it is classified into a new type of expansion type and a new type of renewal type depending on the use(Kim, 2005).

Such a dry floor structure is advantageous because it has advantages such as structure separation, resource recyclable materials use, and shortening of construction period.

However, in order to apply the dry floor to the apartment where the interlayer noise is a big problem, sufficient floor impact sound insulation performance should be secured. However, the dry floor structure is still insufficient to analyze the sound insulation performance according to the constitution and the materials, and there are not enough data on it, so there is a great difficulty to apply to the actual apartment.

Among them, the access floor, which is a typical dry floor structure, is a panel type floor structure constructed by floating on a bottom structure such as a reinforced concrete slab, and the floor structure of a floor of an office building.

In recent years, there has been an attempt to increase the applicability of a floor unit for a house by increasing the sound of a vehicle by attaching a resilient material to the lower end of the support floor of the access floor. In addition, there is a technical possibility to introduce a variable system in a residential apartment building, such as that used in offices, by installing facility piping in the space between the slab and the floor panel, thereby enhancing the flatness of the inside of the main building.

1.2 Research Objective and Scope

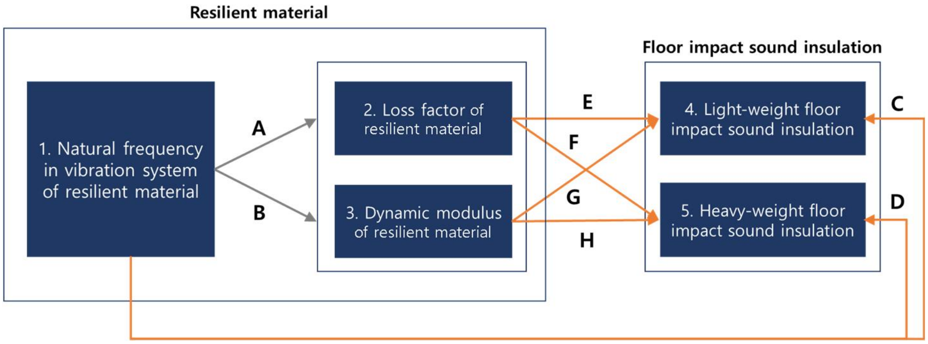


Figure 1-1. Research Objective

In this study, the effect of floor impact sound insulation performance on the access floors, which is a typical dry floor structure will be investigated and the correlation between the physical characteristics of the resilient material and the floor impact sound insulation performance.(Figure 1-1)

The physical characteristics of the resilient material are known to affect the floor impact noise insulation performance. However, the impact of the floor impact noise insulation performance of the access floor is still lacking. Therefore, in this study, it is aimed to find out which of C ~ H is most related to floor impact noise insulation performance.

The purpose of this study is to present the basic data for enhancing the applicability of the access floor to the apartment by analyzing the interlayer noise insulation performance of the access floor with the application of the resilient material.

The characteristics of the Korean interlayer noise problem, the light-weight and heavy-weight impact sound insulation performance, which are determined by using two standard impact sources, tapping machine and impact ball are applied as the dependent variables of the experiment.

In addition, for the resilient material that can be easily applied to the access floor, the experiment is conducted by setting two physical characteristics, dynamic modulus and loss factor, which are considered to be highly related to the interlayer noise insulation performance, as dependent variables.

1.3 Research Process

The research process is as follows.

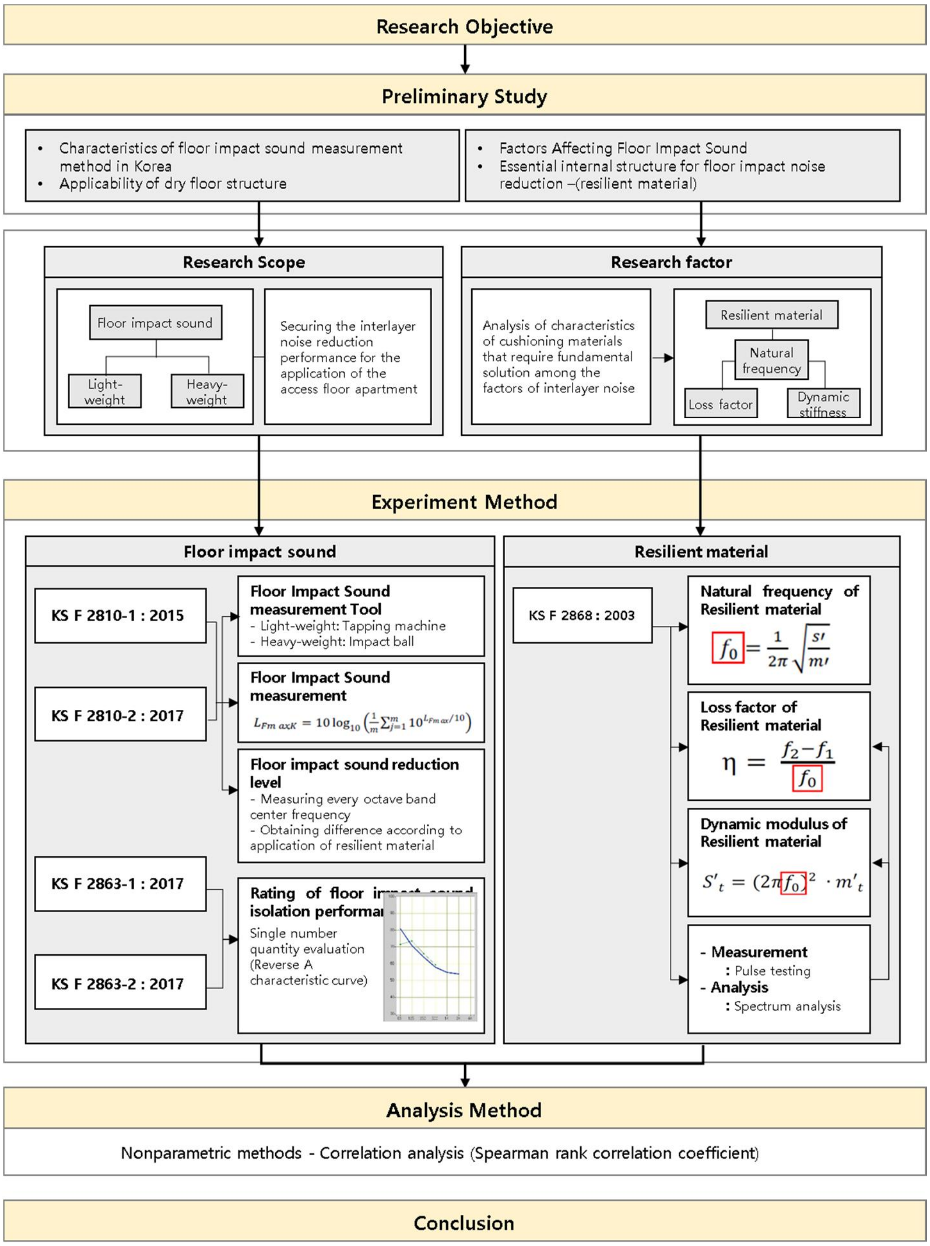


Figure 1-2 Research Process

Chapter 2. Preliminary Study

In this chapter, the characteristics of the interlayer noise problem in Korea and the influence factors of the floor impact sound is investigated. In addition, through literature review, derive the factors for the floor impact sound insulation performance and establish the experiment plan based on these factors.

Since preliminary studies conducted so far have been based on the current law, most of them are not out of the range of the standard floor structure, which is a wet structure, and can be roughly divided into four directions.

- Characteristics of Floor Impact Sound Measurement Method in Korea
- Factors Affecting Floor Impact Sound
- Essential Internal Structure for Floor Impact Noise Insulation
  - Resilient Material
- Applicability of Dry Floor Structure

2.1 Characteristics of Floor Impact Sound Measurement Method in Korea

Compared to the western stand-up meal life, Korea has a relatively high ratio of apartment housing, and social problems due to interlayer noise due to oriental sedentary life(Park 2015).

Because of this cultural background, ISO and Western used a tapping machine, which is designed to simulate the sound of a floor impact sound, as a lightweight standard impact source.

However, in Korea, where most of the activities are sedentary and barefoot, it is necessary to evaluate the heavy-weight impact source with the evaluation of the light-weight impact source(Yeon 2010; Hwang 2015; Shin 2011).

Impact balls are mainly used for Bang machine and Impact ball. Among them, Impact ball is known to be similar to real human steps and children's beats.

Accordingly, a light-weight impact sound will be measured by a tapping machine, and a heavy impact sound will be measured by using an impact ball.

2.2 Factors Affecting Floor Impact Sound

The main factors influencing the floor impact sound could be summarized in two ways; form of structure and components between the impact room floor and the sound ceiling.

2.2.1 Form of structure

Kim(2008) argued that the heavy weight impact sound is more effective in reducing the frame structure than the wall structure. And Park(2008) argued that separation type plan is more effective in reducing heavy-weight and light-weight impact sound than linear type plan due to the difference of space arrangement. In addition, Ham(2013) argued that there is a structural error between apartment houses and laboratories in this study.

However, since the shape of the plane is determined at the basic design stage, and the frame and structure types are determined at the structural design stage, these two factors are difficult to consider as a universal mitigation measure. Therefore, a more fundamental solution is needed by securing the sound insulation performance of the floor structure itself.

2.2.2 Components between Floor of Excitation Room and Ceiling of Sound Receiving room

Jung and Lee(2003) argue that floor slab thickness and weight increase the effect of reducing floor impact sound, and Yoon(2003) argues that the effect of floor impact sound insulation is higher in the case of the total flooring finishing material and foam layer is thick. Also, it is generally known that the thicker the thickness of the wet flooring, the higher the sound insulation performance and the difference in sound insulation performance depending on the type and shape of the resilient material.

However, the floor finish and the ceiling structure are factors requiring client’s preference as the exterior material, and the degree of freedom should be secured. Therefore, it is often the case that the resilient material insertion is the only method, which improves the impact sound performance separately from the external environment without changing the structure(Moon 2014).

2.3 Essential Internal Structure for Floor Impact Noise Insulation - Resilient material

2.3.1 The Characteristics of Resilient Materials

In the wet floor structure, the resilient material is placed between the built-in floor and the slab so that the impact energy applied to the built-in floor is not directly transferred to the slab.

The dynamic modulus and the loss factor, which represent the dynamic characteristics of the resilient material, have the most significant meaning(Lee et al., 2003; Park and Lee 2005)

Particularly, in the case of the wet bottom structure, it has been found that the smaller the dynamic modulus of the resilient material the greater the insulation effect of the floor impact sound. However, the effect of the floor impact sound insulation effect is limited to the light impact sound, and the opinion about the heavy impact sound is different.

Kim(2008) argue that the lower the number of dynamic modulus in the resilient material, the higher the sound insulation performance. However, Oh and Sohn(2010) argues that the dynamic modulus of the resilient material is not correlated with the heavy-weight impact sound. In addition, Seo(2003) argues that the resilient material acts as a stiffness element of the bottom structure, generating resonance in the low frequency band, thereby increasing the noise caused by the heavy-weight impact source.

Based on these studies, it can be concluded that the difference of the results is caused by the difference of interpretation according to the frequency band. In the case of the wet bottom structure, the light-weight impact sound occurs in the high frequency band, and the lower the number of dynamic modulus of the resilient material, the greater the sound insulation performance.

However, it is difficult to find the correlation with the dynamic modulus of the resilient material. In some low-frequency bands, noise is amplified due to resonance.

Analysis of dynamic modulus and loss factor is essential in applying the resilient material to the access floor. Also, it is suggested that separate analysis according to frequency band is needed for experiment and analysis.

2.3.2 Characteristics according to The Types of Resilient Material

Materials used as resilient materials include EPS(Expanded Polystyrene), EPP(Expanded Polypropylene), EVA(Ethylene Vinyl Acetate), EPE(Expanded Polyethylene), PU(Polyurethane). Among them, EPS(Expanded Polystyrene) and rubber are mainly used. In recent years, there has been an attempt to utilize PU having high impact absorbing ability and excellent restoring force for building materials. At present, PU is used as vibration insulation material for large structures, and it is used to improve noise and vibration insulation ability through the integrated method called aerocon(Cement + Polyurethane foam + admixture + water).

As such, PU(Polyurethane) is likely to be applied as a resilient material for floor structure based on high sound insulation and vibration insulation performance characteristics.

However, in order to use PU as a resilient material, it is necessary to analyze the correlation between the physical characteristics of PU and the sound insulation performance, and to provide concrete grounds.

2.4 Applicability of Dry Floor Structure

2.4.1 Dry Floor Structure as an Alternative to Wet Floor Construction

As an alternative to the wet floor structure, efforts have been made to develop heat insulation performance, walking feeling, and floor impact sound insulation performance to apply the dry floor structure with various advantages to apartments(Ryu et al. 2013).

Several researchers have conducted research on the floor impact sound insulation performance of floor impact sound by changing the material of the dry panel(Oh et al. 2010) and the hardness of the supporting rubber(Yeon 2013).

However, it is still difficult to secure the insulation performance of the floor impact sound, in particular, the insulation performance of the heavy impact sound, which makes it difficult to apply the actual dry floor structure.

2.4.2 Improvement of Sound Insulation Performance for the Application of Dry Floor Construction

There have been previous studies analyzing the floor impact sound insulation performance according to the material.

Choi(2010) analyzed the dynamic modulus of the resilient material as a key factor in determining the effect of reducing the impact sound of flooring.

Especially, the samples of EPP and EVA materials have a large change in dynamic modulus with time, so they should be measured considering the load for a certain period of time. Also, it was found that the difference in dynamic modulus of EVA material occurs depending on the presence or unevenness of the lower part of the buffer material.

In the analysis of the correlation between shape and dynamic modulus of the EPS and EVA materials and the performance of the floor impact noise insulation, Jeong(2014) revealed that the material with irregularities has low dynamic modulus and high floor impact sound insulation performance .

Therefore, in order to secure the sound insulation performance of the access floor, it is necessary to analyze the correlation between the physical characteristics of the resilient material applicable to the access floor and the floor impact sound insulation performance.

Particularly, selection of materials is very important because the number of dynamic carbon materials changes depending on the shape of resilient material, the time of the load, and the type of material, and the floor impact sound insulation performance varies depending on the dynamic modulus of resilient material.

2.5 Summary

Previous studies related to floor impact sound are summarized in four ways.

First, due to the oriental sedentary life of Korea, it is necessary to consider heavy-weight floor impact sound as well as light-weight floor impact sound. Therefore, it is measured by tapping machine and impact ball in the floor impact sound test.

Second, the influence of the floor impact sound is the form of the apartment structure, the form of structure, the components between the floor of the excitation room and the ceiling of the sound receiving room. However, we will focus on the resilient material because it can improve the floor impact sound insulation performance separately from the external environment without changing the structure.

Third, it is known that the dynamic modulus and the loss factor of the resilient material affect the floor impact sound insulation performance. In order to apply the resilient material of the PU material with high sound insulation and vibration insulation performance, concrete basis should be presented.

Fourth, in order to apply the dry floor structure proposed as an alternative to the wet floor structure to the apartment, it is necessary to secure the sound insulation performance firstly. Further analysis is needed to improve the sound insulation performance through the resilient material.

Chapter 3. Resilient Material Affecting Floor Impact Sound

In this chapter, the experiment according to the purpose of the study is conducted(Figure 1-1).

Through experiments, it is possible to measure the natural frequency of the vibration system according to the resilient material, 2)the loss factor of the resilient material, and 3)the dynamic modulus. Therefore, we confirm the relationship between 1)the natural frequency of the vibration system, 2)the loss factor of the resilient material, and 3)the dynamic modulus of the resilient material.

Floor impact sound is divided into 4)light impact sound and 5)heavy impact sound. And the sound insulation performance of the floor impact sound is assumed to be 2)the loss factor of the resilient material, 3)the dynamic modulus, and each factor is considered as a dependent variable.

The purpose of this study is to investigate the relationship(A~H) between the resilient material and the floor impact sound insulation performance through correlation analysis based on two related relationship(A, B) by including the natural frequency of the vibration system as a common coefficient.

Specifically, by correlation analysis, correlation between the natural frequency of the resilient material’s vibration system and the insulation performance of the light-weight impact sound(C), between the natural frequency of the resilient material’s vibration system and the insulation performance of the heavy-weight impact sound(D), the loss factor of the resilient material and the insulation performance of the light-weight impact sound(E), the loss factor of the resilient material and the insulation performance of the heavy-weight impact sound(F), the dynamic modulus of the resilient material and the insulation performance of the light-weight impact sound(G), the dynamic modulus of the resilient material and the insulation performance of the heavy-weight impact sound(H) will be intended to derive

3.1 Experiment Method

In order to analyze the correlation between the floor impact sound and the physical characteristics of the resilient material, derive the numerical value of each element.

First, to determine the floor impact sound isolation performance, the floor impact sound level of the access floor is measured according to the experimental method according to KS F 2810-1, 2 by applying five resilient materials.

Next, in order to evaluate the floor impact sound insulation performance, a single numerical evaluation value of the access floor using the man slab and the resilient material according to KS F 2863-1, 2 is obtained and the difference value is derived.

Measure the dynamic modulus of elasticity(MN/m^3) and the loss factor of the resilient material according to KS F 2868 standard for the five resilient materials with dynamic modulus(N/mm^2) and loss factor measured according to DIN 53513.

3.2 Measurement of Floor Impact Sound Insulation Performance

3.2.1 Laboratory Design

For this study, a two-story reinforced concrete structure was constructed. The specific conditions are as follows.

Table 3-1 Laboratory Information

Laboratory Size	2800(w) x 4000(l) x 2690mm(h)
Thickness of Slab	210mm
Thickness of Wall	200mm
Concrete Strength	24Mpa

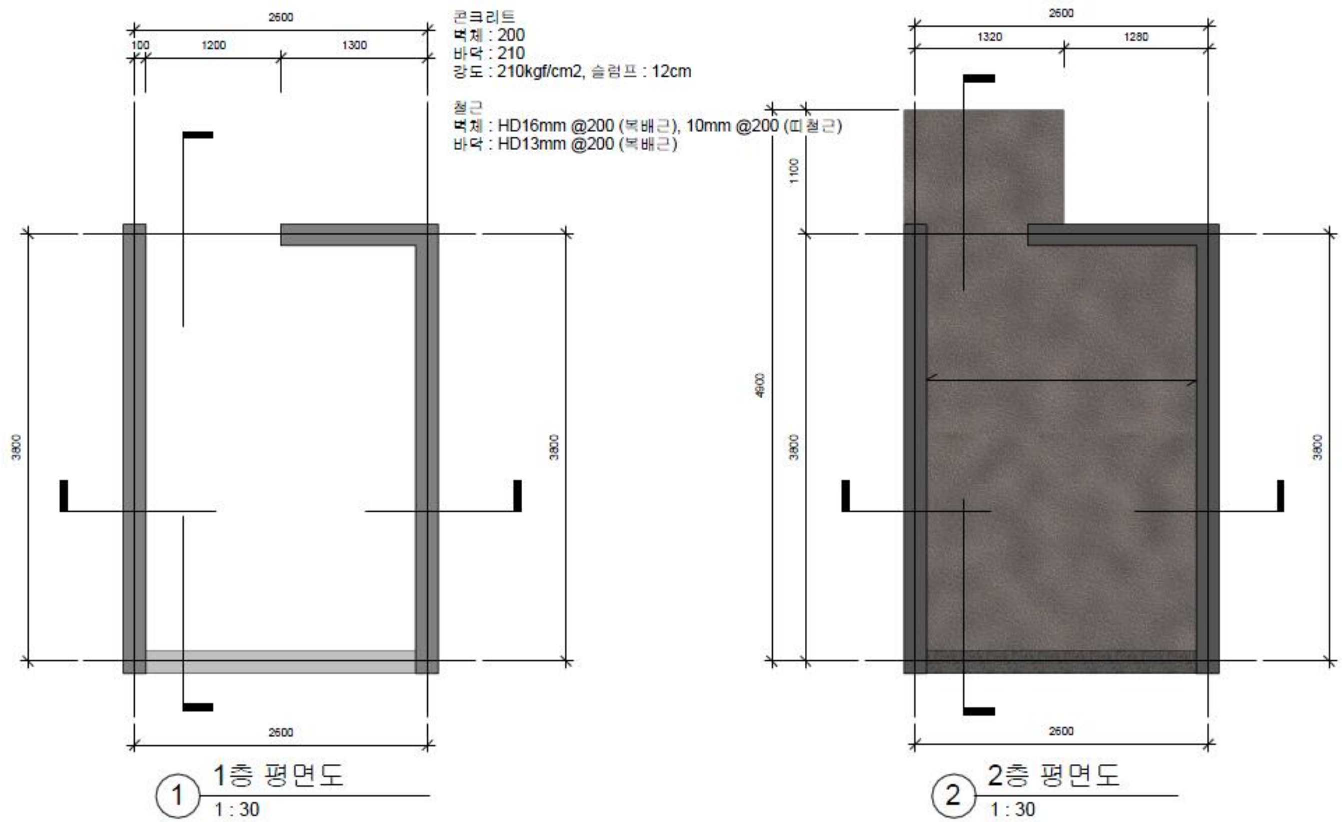


Figure 3-1 Laboratory Plan

3.2.2 Measuring and Evaluating Floor Impact Sound Insulation Performance

According to KS F 2810-1, 2, an average energy value of the maximum sound pressure level measured at all measurement points is calculated for each excitation point at every octave band center frequency.

$$L_{Fmax,k} = 10\log\left(\frac{1}{m}\sum_{j=1}^{m} 10^{L_{Fmax,j}/10}\right)[dB] \qquad (1)$$

$L_{Fmax,j}$: Measured value of the maximum sound pressure level at the jth measuring point
m : Number of measurement points

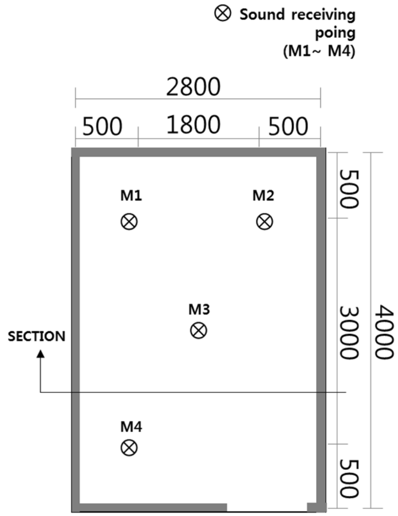
Of the two layers of the experiment, room on the second floor is excitation room which the excitation is applied. The location of the impact source is 4 points on the bottom plane spaced 0.5m from the walls of the excitation room and 5 points including the center point.

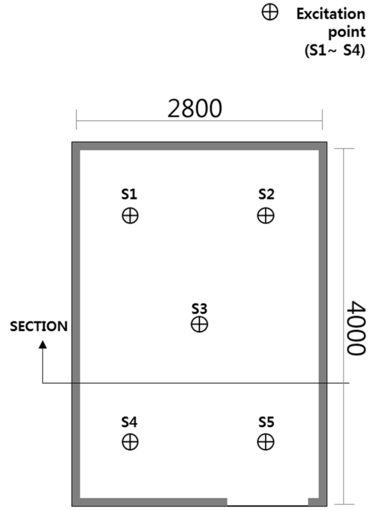
The room on the first floor is used as a sound receiving room to measure the impact sound transmitted by the impact source. The sound receiving point shall be 4 points including 3 points on the bottom plane and 0.5m apart from the wall and including the center point.

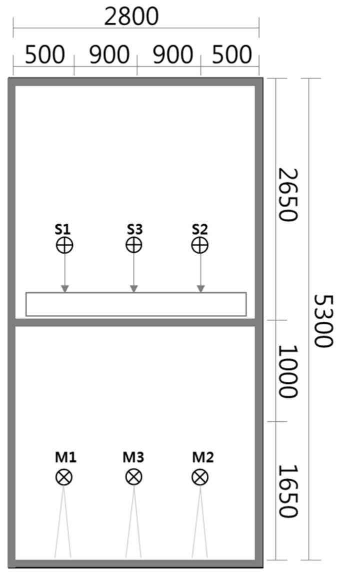
The floor impact sound is measured by using a tapping machine with a standard light-weight floor impact and an impact ball with a standard heavy-weight floor impact to account for both light impact sound and heavy impact sound.

In addition, the floor impact sound is measured for each center frequency of the octave band, light-weight impact sound is in the range of 125Hz to 2,000Hz, and heavy-impact sound is in the range of 63Hz to 500Hz.

Table 3-2 Experiment Design in Laboratory







<table>
<tr><td colspan="2">PLAN</td><td>Section</td></tr>
<tr><td>1F
Sound Receiving Room</td><td>2F
Excitation Room</td><td>1F / 2F</td></tr>
</table>

According to KS F 2863-1,2, the graph obtained by connecting the levels of the octave bands obtained above and the reverse A characteristic reference curve are compared to obtain a single numerical value of floor impact sound insulating performance.(Figure 3)

Table 3-3 Reverse A Characteristic Value

Frequency(Hz)	Standard value(dB)
63	83
125	73
250	66
500	60
1000	57
2000	56

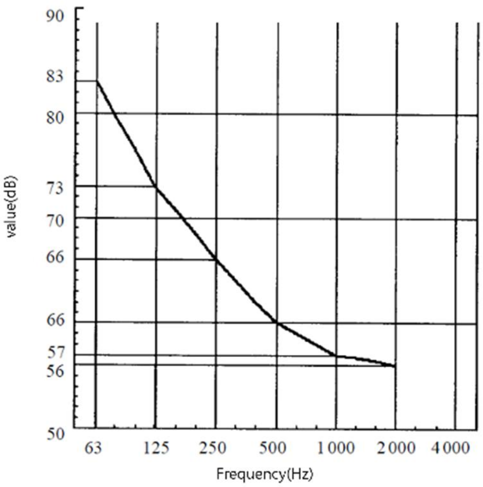


Figure 3-2 Reverse A Characteristic Curve

The floor impact sound insulation performance is obtained by comparing the single number quantity with the reference value of the reverse A characteristic curve based on the value results of the octave band measurement

$$\boldsymbol{X_{1/1}} = \mathbf{10\,log}\left(10^{X_{1/3,1}/10} + 10^{X_{1/3,2}/10} + 10^{X_{1/3,3}/10}\right)[\boldsymbol{dB}] \qquad (\mathbf{2})$$

$\boldsymbol{X_{1/1}}$: $Octave\ band\ value\ (dB)$
$\boldsymbol{X_{1/3,1}}$, $\boldsymbol{X_{1/3,2}}$, $\boldsymbol{X_{1/3,3}}$: $Level\ value\ of\ three\ octave\ bands\ included\ in\ the\ octave\ band\ (dB)$

The weighted floor impact sound level insulation amount is obtained through the difference of the weighted standard impact sound level before and after the access floor and the resilient material is installed on the slab.

$$\boldsymbol{L_{n,r} = L_{n,r,O} - \Delta L} \cdots\cdots \qquad (3)$$

$$\boldsymbol{\Delta L = L_{n,r,O,W} - L_{n,r,W}} \qquad (4)$$

$\boldsymbol{L_{n,r}}$: Normalized floor impact sound levels with the floor finish and floor resilient structure resting on the rare slab
$\boldsymbol{L_{n,r,O}}$: Normalized floor impact sound level of defined base floor
$\boldsymbol{\Delta L}$: Floor impact sound level attenuation measured according to KS F 2865
$\boldsymbol{L_{n,r,W}}$: Weighted normalized floor impact sound levels with floor finish and floor resilient structures resting on the rare slab
$\boldsymbol{L_{n,r,O,W}}$: The values obtained from $L_{n,r,W}$

3.3 Physical characteristics of Resilient Materials

3.3.1 Given Physical Characteristics of Resilient materials

Table 3-4 Physical characteristics of resilient materials

Type	Resilient material		Thickness	Dynamic modulus		Loss factor
	Material	Name		Given value	Converted value	
1	Polyurethane	PU 1	12.5 mm	0.172 N/mm^2	13.76 MN/m^3	0.25
2		PU 2	12.5 mm	0.611 N/mm^2	48.88 MN/m^3	0.16
3		PU 3	12.5 mm	2.54 N/mm^2	203.2 MN/m^3	0.13
4		PU 4	12.5 mm	5.04 N/mm^2	403.2 MN/m^3	0.11
5		PU 5	12.5 mm	0.9 N/mm^2	72 MN/m^3	0.07

3.3.2 Derivation of physical characteristics of Resilient Materials through experiments

1) Natural Frequency

The natural frequency is the free vibration frequency of the system, expressed as Equation (5).

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{s'}{m'}} \quad [Hz] \qquad (5)$$

s' : The dynamic elastic modulus per unit area of the test specimen
m': Mass per supported area

The natural frequency of the vibration system is obtained by analyzing the waveform of the free vibration part in the vibration velocity response waveform obtained by the pulse excitation method.(Figure 3-3)

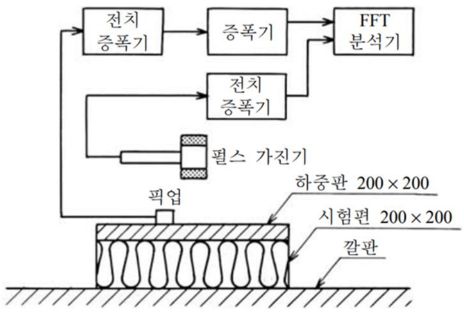


Figure 3-3 Measurement scheme by pulse excitation method

2) Loss factor

The loss factor is the ratio of the energy lost by attenuation over one cycle to the maximum strain energy that an object under dynamic loading can store for one period.

The loss factor of the resilient material is obtained by taking the frequency f1, f2, which is 3 dB away from the peak level of the natural frequency of the vibration system obtained by the pulse excitation method, and calculating the loss factor from equation (6).

$$\boldsymbol{\eta} = \frac{\boldsymbol{f_2 - f_1}}{\boldsymbol{f_0}} \quad (\boldsymbol{f_1 < f_2}) \qquad (6)$$

3) Dynamic modulus

The dynamic modulus represents the ratio of the dynamic displacement to the dynamic load, and equation (7) is used to obtain the dynamic modulus per unit area.

$$\boldsymbol{S'_t = (2\pi f_0)^2 \cdot m'_t} \qquad (7)$$

$\boldsymbol{S'_t}$: Dynamic modulus per unit area [MN / m3]
$\boldsymbol{f_0}$: Basic fundamental frequency of the vibration system [Hz]
$\boldsymbol{m'_t}$: Mass per unit area of the load plate [kg / ㎡]]

3.4 Summary

In this chapter, the experimental method and the calculation formula for analyzing the correlation between the physical characteristics of the resilient material and the floor impact sound insulation performance are described.

The floor impact sound insulation performance can be evaluated by first measuring the floor impact sound level according to KS F 2810-1, 2 and by calculating a single number quantity according to KS F 2863-1, 2 and comparing the numerical values.

The dynamic modulus and the loss factor of the resilient material are measured in accordance with KS F 2868 standard and measured values are measured according to German DIN 53513 standard.

Chapter 4. Results and Analysis

4.1. Analysis Method

In this study, the relationship between the physical characteristics of the resilient material and the floor impact sound insulating performance(A~H) will be investigated by analyzing the correlation between numerical values derived from experiments and calculations according to the purpose of the study.(Figure 1-1)

However, due to the characteristics of the experiment, it is difficult to obtain sufficient samples and it is difficult to assume that the population has regularity. Therefore, it is analyzed using nonparametric statistics which do not need to consider the parameters of the population.

In addition, nonparametric regression analysis using the Spearman(1904) rank correlation coefficient and the method proposed by Theil(1992), which can be easily computed and used as a nonparametric method, is used to determine the correlation between two populations Find the correlation coefficient between the population.

4.1.1 Nonparametric Statistics

Nonparametric statistics is a method of calculating probabilities directly from data, regardless of the type of population.

Nonparametric statistics are a method of statistical processing without assuming the population's aptitude, that is, the normal distribution.

Therefore, if the distribution of the population is not considered to follow a specific probability distribution function, or if the data is given as an ordinal scale and the data is given as a relative size, or if there is no assumption about the distribution type, use nonparametric statistics that relax the assumptions and do not mediate parameters.

The statistical results are not as robust as the parametric statistics, but they can be used more prominently when the number of samples is small. Also, it can be used when the observation value is inaccurate and the observation value is simply ordered or classified. However, some nonparametric methods are inefficient when the sample size is large because of the large amount of computation.

4.1.2 Spearman Rank Correlation Coefficient

Correlation coefficients can also be calculated using nonparametric methods, and the rank correlation coefficients proposed by Spearman(1904) are mainly used because of simplicity of calculation. In this method, two variables X and Y are listed in order of magnitude, and then the correlation coefficient is obtained using the order.

4.2 Result Analysis

4.2.1 Floor impact sound insulation performance analysis

1) Single-number quantity for impact sound insulation rating derived from octave band measurements

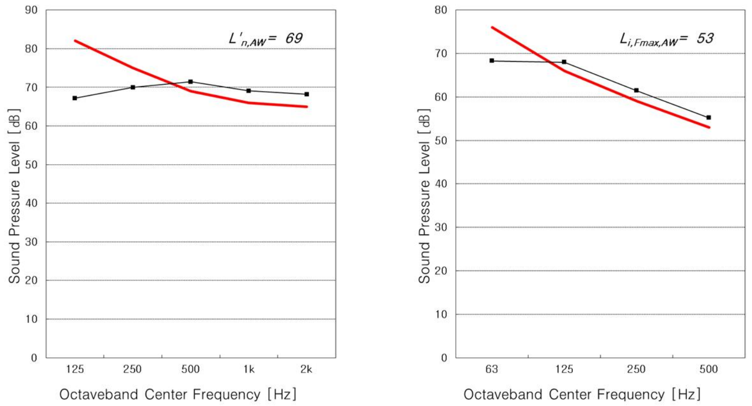


Figure 4-1 Single Number Quantity –Light-weight Impact Sound(L), Heavy-weight Impact Sound(R)

According to the criteria of KS F2863-1, 2, to derive the weighted insulation in impact sound pressure level of the floor to which the access floor was applied, find the single number quantity for floor impact sound insulation performance of rare slab(Figure 4-1) and the slab to which apply access floor(Table 4-1, Table 4-2). Although it is difficult to confirm the exact numerical value by frequency band, it is possible to evaluate simple sound insulation performance by representative numerical value.

Table 4-1 Single Number Quantity of Light-weight Floor Impact Sound Insulation Performance

Single number quantity(dB)							
Floor Impact Sound		Light-weight					
Floor structure		Access floor 1		Access floor 2		Bare slab
Value		(A1L)	(BL)-(A1L)	(A2L)	(BL)-(A2L)	(BL)
Resilient material	PU 1	43	26	37	32	69
	PU 2	42	27	34	35	
	PU 3	40	29	37	32	
	PU 4	40	29	37	32	
	PU 5	39	30	32	37	

Table 4-2 Single Number Quantity of Heavy-weight Floor Impact Sound Insulation Performance

Single number quantity(dB)						
Floor Impact Sound		Heavy-weight				
Floor structure		Access floor 1		Access floor 2		Bare slab
Value		(A1H)	(BH)-(A1H)	(A2H)	(BH)-(A2H)	(BH)
Resilient material	PU 1	54	-1	53	0	53
	PU 2	53	0	50	3	
	PU 3	52	1	51	2	
	PU 4	53	0	53	0	
	PU 5	53	0	50	3	

By using the access floor with resilient material, the floor impact sound level insulation was increased compared to the rare slab.

Compared with the rare slab, a insulation of the minimum impact noise of 26(dB) to a maximum of 37(dB) was confirmed for light-weight impact sound. In the case of heavy-weight impact sound, it was confirmed that the floor impact sound level of 3(dB) was reduced.

In addition, both the light-weight impact sound level and the heavy-weight impact sound level show values below the criterion, thereby satisfying the floor sound impact blocking performance recognition standard(Table 4-3).

In particular, the weight impact sound level insulation was small, while the light weight impact sound level insulation was large and the performance was equivalent to the first grade of the floor impact sound standard.

As a result, the floor impact sound insulating performance is improved by applying the resilient material to the access floor.

Particularly, it is judged that the performance of reducing light-weight impact sound is better than that of heavy-weight impact sound.

2) Weighted Insulation in Impact Sound Pressure Level

Since a single numerical evaluation value is used to judge the sound insulation performance, it is difficult to confirm accurate values by frequency band, but simple sound insulation performance evaluation is possible.

Compared to the standardized floor impact sound level values in Table 4-3, all access floors with resilient materials are included in the standard.

Table 4-3 Standard of normalized floor impact sound level

Grade	Reverse A Characteristic Weighted Floor Impact Sound Level	
	L'n,Aw (Light-weight Impact Sound)	L'i,Fmax,Aw (Heavy-weight Impact Sound)
1st	L'n,Aw ≤ 43	L'i,Fmax,Aw ≤ 40
2nd	43 < L'n,Aw ≤ 48	40 < L'i,Fmax,Aw ≤ 43
3rd	48 < L'n,Aw ≤ 53	43 < L'i,Fmax,Aw ≤ 47
4th	53 < L'n,Aw ≤ 58	47 < L'i,Fmax,Aw ≤ 50

The floor impact sound insulation value of the access floor using the resilient material was compared with rare slab.

Although the resilient materials of PU1~5 are the same polyurethane material, they have different physical characteristics and have different effects on floor impact sound insulation performance.

Also, even when the same resilient material was used, it was found that there was a difference in floor impact sound insulation performance depending on the type of access floor.

It can be seen that the floor impact noise insulation performance of the access floor using the resilient material is confirmed. The floor impact sound insulation performance differs according to the type of the access floor and the physical characteristics of the resilient material.

It can be seen that the floor impact sound insulation performance of the access floor using the resilient material differs depending on the type of access floor used and the physical characteristics of the resilient material.

However, it is difficult to confirm the detailed relationship between the floor impact sound insulation and the physical characteristics and frequency band of the resilient material by using only a single floor impact sound evaluation value. Therefore, more detailed floor impact sound insulation performance analysis is needed.

3) Box Plot

Based on the analytical limitations of the single number quantity, the floor impact sound insulation performance of the resilient material is analyzed using the Box Plot. The Box Plot shows the floor impact sound insulation by the octave band center frequency. Therefore, it is possible to analyze by frequency band differently from the evaluation by deriving the single number quantity.

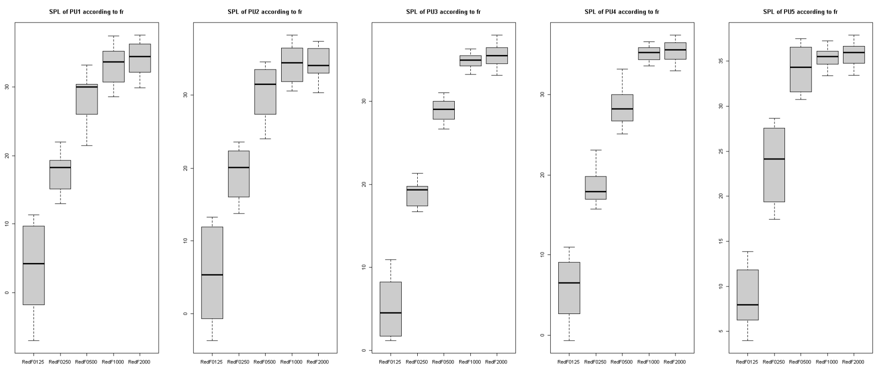


Figure 4-2 Insulation in Light-weight Impact Sound Pressure Level of Resilient Material According to Frequency

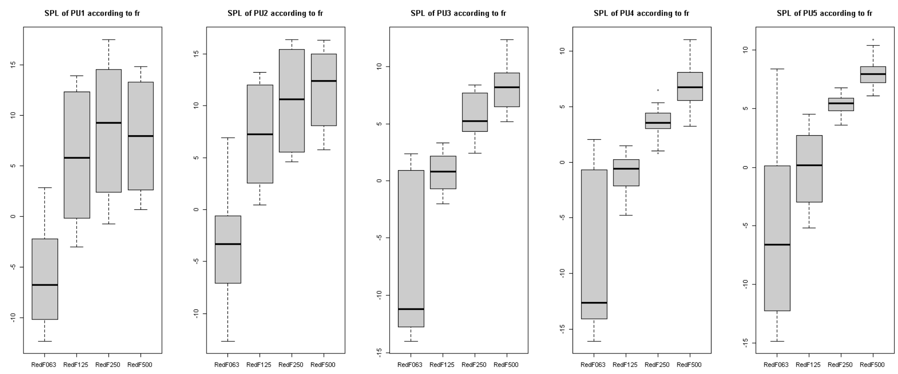


Figure 4-3 Insulation in Heavy-weight Impact Sound Pressure Level of Resilient Material According to Frequency

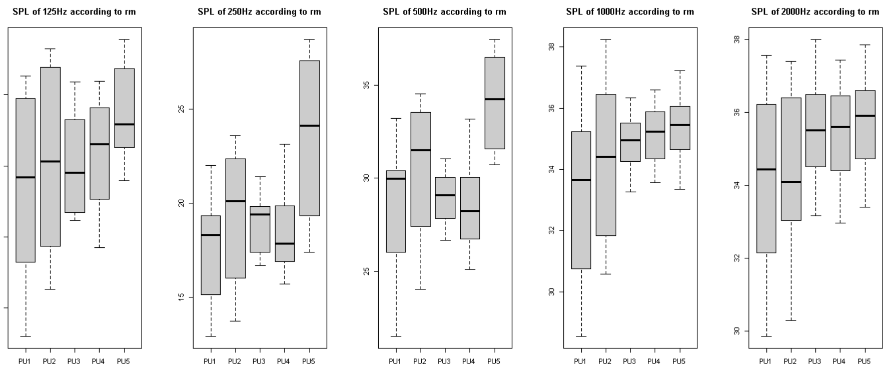


Figure 4-4 Insulation in Light-weight Impact Sound Pressure Level at Frequency Band according to Resilient Material

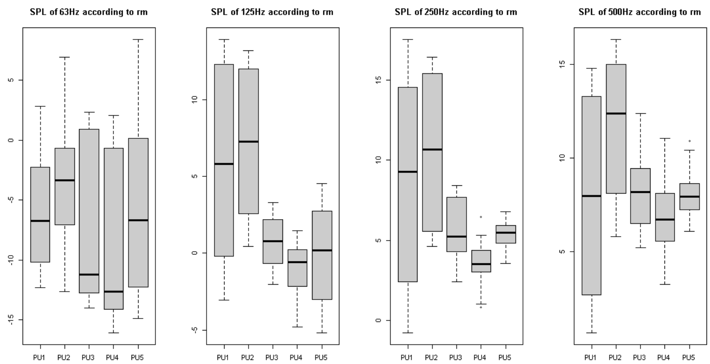


Figure 4-5 Insulation in Heavy-weight Impact Sound Pressure Level at Frequency Band according to Resilient Material

Figure 4-2, Figure 4-3, Figure 4-4 and Figure 4-5 show the distribution and median value of the floor impact sound insulation by resilient material and frequency band in light-weight and heavy impact sound.

It is considered that the floor impact sound insulation performance increases with the increase of the frequency band in the access floor using the resilient material in terms of the distribution of the floor impact sound insulation values as a whole, which shows the same pattern in both the light-weight impact sound and the heavy-weight impact sound.

It can be expected that the resilient material exhibiting high performance in one frequency band of the light-weight impact sound shows a high sound insulation performance even in the frequency band of the other light-weight impact sound, .Also, it is analyzed that the sound insulation performance of light-weight impact sound and heavy-weight impact sound have different effects on the sound insulation performance of heavy-weight and light-weight impact sound depending on the characteristics of the resilient material.

4.2.2 Relationship between Physical Characteristics of Resilient Materials and Floor Impact Sound Insulation Performance

1) Physical Characteristics of Resilient Materials

The dynamic modulus of the physical characteristics of the resilient material is calculated using the natural frequency (5). Since the variable *m'(*mass per unit area of the load plate) in the formula is measured using the same load plate for the characteristics of the experiment, it is treated as a constant, and as a result, the natural frequency and dynamic modulus of the resilient material have a correlation of 1. Since the frequencies $f1$ and $f2$, which are 3dB away from the peak level of the natural frequency, act as variables, the loss factor of the resilient material has a correlation of 1 or less. In this study, the rho value of 0.7 and the low p-value of less than 0.05 are considered to be highly correlated between the natural frequency and the loss coefficient of the resilient material.(Table 4-4)

Table 4-4 Correlation among Physical Characteristics of Resilient Material

Correlation		p-value	rho
Natural frequency	Dynamic modulus	< 2.2e-16	1.0
Dynamic modulus	Loss factor	0.0015	-0.7
Natural frequency	Loss factor	< 2.2e-16	-0.7

Based on these results, this study deal with the relationship between only dynamic modulus and loss factor in resilient material's physical characteristics and the floor impact sound insulation performance.

Table 4-5 Physical Characteristics of Resilient Materials

Type	Resilient material		Thickness	Natural frequency	Dynamic modulus	Loss factor
	Material	Name				
1	Polyurethane	PU 1	12.5 mm	64.58 Hz	32.99 MN/m3	0.53
2		PU 2	12.5 mm	66.25 Hz	34.65 MN/m3	1.34
3		PU 3	12.5 mm	81.67 Hz	52.62 MN/m3	0.58
4		PU 4	12.5 mm	85.42 Hz	57.96 MN/m3	0.77
5		PU 5	12.5 mm	86.67 Hz	59.61 MN/m3	1.24

Table 4-6 Comparison of Physical Characteristics of Resilient Materials

Type	Resilient material	Thickness	Dynamic modulus		Loss factor	
			Given value	Measured value	Given value	Measured value
1	PU 1	12.5 mm	13.76 MN/m3	32.99 MN/m3	0.25	0.53
2	PU 2	12.5 mm	48.88 MN/m3	34.65 MN/m3	0.16	1.34
3	PU 3	12.5 mm	203.2 MN/m3	52.62 MN/m3	0.13	0.58
4	PU 4	12.5 mm	403.2 MN/m3	57.96 MN/m3	0.11	0.77
5	PU 5	12.5 mm	72 MN/m3	59.61 MN/m3	0.07	1.24

The physical characteristics of the resilient material are given in Table 4-5, given in accordance with KS F 2868 in the present study and given values measured in accordance with DIN 53513 standard in Germany. As a result, it was confirmed that the values of dynamic modulus and loss factor derived from each standard are different.(Table 4-6)

DIN 53513 in Germany and KS F 2868 in Korea differ in the method of measuring the dynamic modulus and the loss factor, and the values derived from the differences are also different. Therefore, it is required to analyze whether the numerical value derived from a certain criterion has a higher correlation with the floor impact sound insulation performance.

2) Analysis of Correlation between Physical Characteristics of Resilient Material and Floor Impact Sound Insulation Performance - Spearman Correlation Coefficient

The correlation between dynamic modulus and loss factor, which are physical characteristics of resilient material, and floor impact sound level insulation, was analyzed by using Spearman correlation coefficient according to frequency band and type of access floor.

RedF in the table indicates the floor impact sound insulation compared to the rare slab in the corresponding frequency band. RedF125 refers to the floor impact sound insulation compared to the rare slab in the 125Hz band.

The P-value represents the significance probability and is the value calculated under the assumption that the null hypothesis is true. This means the probability that the test statistic will show evidence to reject the strong hypothesis that is stronger than the observed test statistic. Therefore, if the p-value is small, there is evidence to reject the hypothesis.

rho is the Spearman correlation coefficient, which indicates the correlation between variables in the sequence scale when using the nonparametric method. Correlation coefficient rho is a value between 0 and 1, and when rho> 0, there is a positive correlation. When rho<0, a negative correlation is obtained. When rho=0, there is no correlation. In addition, the closer the rho is to 0, the lower the correlation, and the closer to rho the absolute value 1, the higher the correlation.

Table 4-7 and Table 4-8 show the correlation between dynamic modulus, loss factor and floor impact sound insulation according to DIN 53513 standards and Table 4-9 and Table 4-10 show the correlation between dynamic modulus, loss factor and the floor impact sound insulation. According to the table, it is difficult to find a meaningful relationship between the dynamic modulus and loss factor derived from KS F 2868 and the floor impact sound insulation, because the p-value is high and the rho value is low.

On the other hand, the relationship between the dynamic modulus and loss factor derived from DIN 53513 and the floor impact sound insulation is more significant in relation to the criteria of KS F 2868.

Table 4-7 Correlation Analysis–Light-weight Floor Impact Sound(KS F 2868)

Correlation		All		Access Floor 1		Access Floor 2	
		p-value	rho	p-value	rho	p-value	rho
Dynamic Modulus	RedF125	0.0435	-0.1847	0.0236	-0.2919	0.0098	-0.3311
	RedF250	0.0521	-0.1778	0.1607	-0.1834	0.0068	-0.3457
	RedF500	0.0000	-0.3867	0.0005	-0.4352	0.0001	-0.4859
	RedF1000	0.6003	-0.0483	0.8405	-0.0265	0.5385	-0.0810
	RedF2000	0.6035	-0.0479	0.5198	-0.0847	0.7004	-0.0507
Loss Factor	RedF125	0.0020	-0.2797	0.0000	-0.6955	0.0125	-0.3205
	RedF250	0.0003	-0.3248	0.0172	-0.3066	0.0000	-0.6098
	RedF500	0.0000	-0.3746	0.0003	-0.4515	0.0000	-0.5267
	RedF1000	0.0015	-0.2861	0.8405	-0.0265	0.5385	-0.0810
	RedF2000	0.0162	-0.2190	0.5198	-0.0847	0.7004	-0.0507

Table 4-8 Correlation Analysis–Heavy-weight Floor Impact Sound(KS F 2868)

Correlation		All		Access Floor 1		Access Floor 2	
		p-value	rho	p-value	rho	p-value	rho
Dynamic Modulus	RedF125	0.0435	-0.1847	0.0236	-0.2919	0.0098	-0.3311
	RedF250	0.0521	-0.1778	0.1607	-0.1834	0.0068	-0.3457
	RedF500	0.0000	-0.3867	0.0005	-0.4352	0.0001	-0.4859
	RedF1000	0.6003	-0.0483	0.8405	-0.0265	0.5385	-0.0810
	RedF2000	0.6035	-0.0479	0.5198	-0.0847	0.7004	-0.0507
Loss Factor	RedF125	0.0020	-0.2797	0.0000	-0.6955	0.0125	-0.3205
	RedF250	0.0003	-0.3248	0.0172	-0.3066	0.0000	-0.6098
	RedF500	0.0000	-0.3746	0.0003	-0.4515	0.0000	-0.5267
	RedF1000	0.0015	-0.2861	0.8405	-0.0265	0.5385	-0.0810
	RedF2000	0.0162	-0.2190	0.5198	-0.0847	0.7004	-0.0507

Table 4-9 Correlation Analysis–Light-weight Floor Impact Sound(DIN 53513)

Correlation		All		Access Floor 1		Access Floor 2	
		p-value	rho	p-value	rho	p-value	rho
Dynamic Modulus	RedF125	0.0435	-0.1847	0.0236	-0.2919	0.0098	-0.3311
	RedF250	0.0521	-0.1778	0.1607	-0.1834	0.0068	-0.3457
	RedF500	0.0000	-0.3867	0.0005	-0.4352	0.0001	-0.4859
	RedF1000	0.6003	-0.0483	0.8405	-0.0265	0.5385	-0.0810
	RedF2000	0.6035	-0.0479	0.5198	-0.0847	0.7004	-0.0507
Loss Factor	RedF125	0.0020	-0.2797	0.0000	-0.6955	0.0125	-0.3205
	RedF250	0.0003	-0.3248	0.0172	-0.3066	0.0000	-0.6098
	RedF500	0.0000	-0.3746	0.0003	-0.4515	0.0000	-0.5267
	RedF1000	0.0015	-0.2861	0.8405	-0.0265	0.5385	-0.0810
	RedF2000	0.0162	-0.2190	0.5198	-0.0847	0.7004	-0.0507

Table 4-10 Correlation Analysis–Heavy-weight Floor Impact Sound(DIN 53513)

Correlation		All		Access Floor 1		Access Floor 2	
		p-value	rho	p-value	rho	p-value	rho
Dynamic Modulus	RedF125	0.0435	-0.1847	0.0236	-0.2919	0.0098	-0.3311
	RedF250	0.0521	-0.1778	0.1607	-0.1834	0.0068	-0.3457
	RedF500	0.0000	-0.3867	0.0005	-0.4352	0.0001	-0.4859
	RedF1000	0.6003	-0.0483	0.8405	-0.0265	0.5385	-0.0810
	RedF2000	0.6035	-0.0479	0.5198	-0.0847	0.7004	-0.0507
Loss Factor	RedF125	0.0020	-0.2797	0.0000	-0.6955	0.0125	-0.3205
	RedF250	0.0003	-0.3248	0.0172	-0.3066	0.0000	-0.6098
	RedF500	0.0000	-0.3746	0.0003	-0.4515	0.0000	-0.5267
	RedF1000	0.0015	-0.2861	0.8405	-0.0265	0.5385	-0.0810
	RedF2000	0.0162	-0.2190	0.5198	-0.0847	0.7004	-0.0507

These results indicate that the criteria of DIN 53513 are more appropriate than the criteria of KS F 2868 for measuring the physical characteristics of the resilient material applied to the access floor, due to differences in the method of measuring the physical characteristics of the resilient material is analyzed.

The present resilient material criterion of floor structure according to KS F 2868 suggests the method of measuring the dynamic modulus and loss factor of the resilient material used in the floating floor. In the standard, the dynamic modulus of elasticity is in the range of 10 to 30 and the loss factor is in the range of 0.1 to 0.3. Experiments have also shown a general trend between the dynamic modulus of elasticity and the lightweight impact sound insulation in floored structures.

According to the measurement method proposed in the standard, the load of the components stacked on the upper part of the buffer material in the actually floating floor is applied by measuring the load plate made of a rigid body of 200kg/m^2 on the test piece.

However, this measurement method is inadequate to measure the physical characteristics of the resilient material used in the actual dry access floor, as limited to a wet floor structure.

As the load applied to the resilient material increases, the changing dynamic modulus value does not show a constant change amount or rate of change. Therefore, the dynamic modulus of the resilient material itself may be different from the dynamic modulus of the resilient material itself.

As a result of this study, it was found that the correlation between dynamic modulus measured by applying a relatively high load of 200kg/m^2 according to KS F 2868 standard of Korea and the floor impact sound insulation performance is higher than the correlation between dynamic modulus obtained from the physical characteristics of the material itself measured through the deformation of the resilient material in accordance with German DIN 53513.

It is considered that it is more appropriate to analyze the relationship between the physical characteristics of the material itself without load and the floor impact sound insulation because the mass per unit area of the access floor stacked on the resilient material is relatively low at 40kg/m^2. Unlike the wet floored structure in which the resilient material and the upper structure are supported by the faces and the load is distributed and transmitted, the access floor is supported by the lower pillars(legs) so that the concentrated loads would generate.

The dry access floor, which emerged as an alternative to the wet floor, has a very high possibility of reducing the floor impact sound in addition to the convenience of maintenance. However, current resilient material measurement and application criteria are limited to the range of wet floored structures, and there is no standard for resilient materials to be applied to access floors.

As a result of this study, unlike the standard for floating floors, floor impact sound insulation performance suited to the standard was shown even in the range of dynamic modulus of 40MN/m^3 or more in the access floor,. In the case of lightweight impact sound, the loss coefficient is more correlated with the floor impact sound insulation than the dynamic modulus of the resilient material, while the loss coefficient is also correlated with the heavy impact sound.

Accordingly, it is required to establish standards for research and development of new floor structures, including access floors, and for additional considerations.

Analysis of the correlation between the physical characteristics of the resilient material derived in accordance with DIN 53513 and the insulation in floor impact sound shows that the dynamic modulus of the resilient material and the floor impact sound insulation are largely negatively correlated in the light impact sound relationship.

This phenomenon is caused by the light-weight impact sound, which is considered to be due to the fact that the sound transmitted to the air(air transmission sound) is larger than the floor impact sound due to the application of the resilient material.

In this case, relatively low p-value and high rho value are shown in relation to the loss factor of the resilient material and the floor impact sound insulation rather than the relation between the dynamic modulus of the resilient material and the insulation amount of the floor impact sound.

Therefore, the insulation of the floor impact sound in the light-weight impact sound is analyzed to have a higher correlation with the loss coefficient of the resilient material than the dynamic modulus of the resilient material.

In the case of the heavy-weight impact sound, negative rho value is shown between the dynamic modulus of the resilient material and the floor impact sound insulation, and it is analyzed as having a negative correlation. By showing the positive rho value between the loss coefficient of the resilient material and the floor impact sound insulation, Positive correlations were found.

In contrast to the light-weight impact sound, the p-value and the rho value are relatively low in relation to the dynamic modulus of the resilient material and the floor impact sound insulation, rather than the relation between the loss factor of the resilient material and the insulation effect of the floor impact sound.

Therefore, the floor impact sound insulation in the heavy impact sound is analyzed to have a higher correlation with the dynamic modulus of the resilient material than the loss coefficient of the resilient material.

4.3 Summary

By applying the resilient material to the access floor, it is possible to reduce floor impact noise and to expand the utilization.

It was confirmed that the dynamic modulus of elasticity and loss coefficient measured according to DIN 53513 standard in Germany are higher than those of KS F 2868 in Korea.

It is analyzed that there are differences in the amount of load applied to the upper part of the resilient material and the load transmission method in the floored structure and the access floor.

As a result of analysis of the correlation between dynamic modulus, loss factor and floor impact sound insulation, it was confirmed that the lower the dynamic load factor and the higher the loss factor, the higher the sound insulation performance. Especially, it is found that the loss factor is higher than the dynamic modulus of the light-weight impact sound, and the dynamic modulus is higher than the loss factor of the heavy-weight impact sound.

The correlation between the dynamic modulus of the resilient material and the loss factor and the floor impact sound insulation is found to be larger in the heavy-weight impact sound than in the light-weight impact sound. It can be seen that it acts as a more meaningful indicator in the transmitted sound.

In this analysis, light-weight impact sound, which occupies a large part of the air transmission sound, can be expected to reduce additional light weight impact sound by taking advantage of the effect of the air layer below the access floor, together with consideration of window and ceiling finishing materials to reduce air transmission sound.

In addition, according to the resilient material standard of the current floating floor structure, the dynamic modulus is recommended to be higher than $10MN/m^3$ considering the walking sensation and occurrence of crack, and it is suggested to be less than $40MN/m^3$. The loss factor is shown as 0.1~0.3. However, as a result of the experiment, rather than $40MN/m^3$, the sound insulation performance is higher.

Chapter 5. Conclusion

5.1. Conclusion

In this study, experiments have shown that by applying a resilient material to the access floor, the floor impact sound insulation performance met the criteria. Therefore, it is possible to confirm the possibility of applying the access floor to the apartment, and it is necessary to consider the difference in sound insulation performance caused by the type of the resilient material and the access floor.

Currently, the wet floor structure is being applied to most apartment buildings in Korea, so the resilient material standard is also limited to the floating floor structure. As a result, there is no known method for deriving the physical characteristics of the resilient material applied to the access floor, and it is difficult to grasp the relationship between the resilient material and the floor impact sound insulation performance.

In this study, through the experiment, it was confirmed that the method of deriving the physical characteristics of the resilient material according to DIN 53513 standard of Germany is more suitable than the KS F 2868 standard, and the correlation is analyzed.

Correlation analysis showed that the loss factor of the light-weight impact sound and the dynamic modulus of the heavy-weight floor impact sound have a higher correlation with the floor impact sound insulation performance. Also, it is analyzed that the sound insulating performance is higher in the range of the dynamic carbon number of $40MN/m^3$ or more.

As a result, it is necessary to present a new standard for the development of new floor structure including access floor. It is necessary to define the relationship between the physical characteristics of the resilient material and the floor impact sound insulation performance and the characteristics of the resilient material.

5.2. Contribution

Currently, most floor structures used in apartments are wet floors, but researches and developments are needed to use alternative access floors with various advantages such as maintenance and interlayer noise insulation potential.

In this study, the applicability of the access floor is verified by satisfying the floor impact sound insulation performance criteria by applying the resilient material to the access floor.

In addition, by analyzing the correlation between the physical characteristics of the resilient material and the floor impact sound insulation performance in order to apply the resilient material to the access floor, it can be used as a basic data for the development of the resilient material.

In addition, it is expected that the possibility of developing a resilient material applied to an access floor can be expected by explaining the inadequacy of the method of measuring the physical characteristics of the resilient material and suggesting other measurement methods.

In addition, the experiment suggests that the resilient material with dynamic modulus in the range outside the current standard exhibits higher sound insulation performance, suggesting a new standard.

5.3. Limitation and Further Study

In this study, there is a limitation that it is difficult to confirm the significance of the correlation because the number of samples is insufficient due to the characteristics of the experiment and the analysis is performed using a non-parametric method. Also, since analysis is conducted based on rankings, it is difficult to grasp the exact relationship of numerical values. Therefore, a more accurate analysis should be made by ensuring a sufficient number of samples

And there is a limitation that it cannot provide accurate criteria and scope of measurement of resilient materials. Therefore, further studies should be conducted to specify the appropriate range of dynamic modulus and loss factor of resilient materials to increase the applicability of access floors.

In addition, In order to improve the performance of the light-weight impact sound insulation of the access floor, additional study is needed to reduce the air transmission noise such as window, ceiling structure and finishing material. In addition, in order to improve the insulation performance of heavy impact sound, it is necessary to consider parameters such as mass in addition to dynamic modulus and loss factor.

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국 문 초 록

현재 우리나라 인구의 70% 이상이 거주하는 공동주택은 RC조의 벽식구조라는 특성으로 인해 소음과 진동에 취약한 특징을 가진다. 이로 인해 발생되는 층간소음 민원은 매년 증가하여 심각한 사회적 문제로 대두되고 있다.

정부는 바닥구조를 개선하여 층간소음 문제를 해결하기 위해 인정바닥구조를 도입하였지만, 대부분 습식 표준바닥구조에 한정되어 있으며, 새로운 바닥구조의 개발이 요구되는 실정이다.

이에 대안으로 제시되는 건식 액세스플로어는 습식바닥구조에 비해 바닥충격음 저감 가능성이 높고, 유지보수의 용이성 및 공기단축과 같은 추가적인 장점을 가진다. 하지만, 가능성에 비해 충분한 차음성능 확보 및 분석이 미흡해 실제 공동주택에 적용하기에는 많은 어려움이 존재한다.

따라서 본 연구에서는 액세스플로어의 바닥충격음 차단성능 향상을 위한 방법으로 완충재를 적용하였으며, 완충재의 물리적 특성인 동탄성계수와 손실계수를 변수로 설정하고, 비모수 통계학과 Spearman 상관계수를 이용해 바닥충격음 저감량과의 상관관계를 분석하였다.

분석 결과, 액세스플로어에 완충재를 적용함으로써 차음성능을 이끌어냈으며, 경량충격음에서는 손실계수가, 중량충격음에서는 동탄성계수가 더 높은 상관성을 가지는 것으로 분석된다.

특히, 동탄성계수와 손실계수를 구함에 있어서, 현재 뜬바닥 구조의 완충재 특성을 측정하기 위한 KS F 2868 기준보다는, 완충재 자체의 물성을 측정하는 DIN 53513 기준에 따라 구한 값이 바닥충격음 저감량과의 상관성을 분석하는 데 더 적합한 것으로 확인된다.

이에 따라, 기존의 바닥구조 외에 액세스플로어를 포함한 추가적인 바닥구조의 개발을 위해서는 새로운 기준의 제시가 필요하다고 판단되며, 앞서 밝힌 완충재의 물리적 특성과 바닥충격음 저감성능간의 관계는 완충재 개발의 기초자료로 이용될 수 있다.

이후, 액세스플로어 완충재의 물리적 특성에 대한 측정방법 및 적정 범위, 그리고 관계에 대한 추가적 연구가 요구된다.

키워드: 층간소음, 바닥충격음, 완충재, 동탄성계수, 고유진동수, 손실계수, 공동주택, 액세스플로어

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