Dynamic stiffness characteristics of resilient materials for remodeling of the aged apartment buildings

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ABSTRACT

This study investigates dynamic stiffness characteristics of floor resilient materials for reduction of floor impact noises in remodeled aged apartment buildings. Since the aged apartment buildings built in before 2005 have too thin floor structure system, relatively thinner thickness less than 30 mm with lower dynamic stiffness is required for resilient materials to secure the maximum inner height of the room. In addition, dynamic stiffness in after-heating condition should be also examined because resilient materials are exposed to repeated thermal variations due to the Korean-style floor-heating system. Common resilient materials with various thickness and component such as EPS or EVA were collected, then dynamic stiffness was measured according to KS F 2868 and ISO 9052-1 before and after 48 hours heating with 70 degrees Celsius. As results, range of dynamic stiffness values of resilient materials in before- and after heating conditions was derived as a function of materials' thickness and composition. Base on the measurement results, the suitable range of dynamic stiffness and composition were suggested according to thickness range. In addition, time dependent tendencies of dynamic stiffness of resilient materials in after-heating condition were discussed for improving standard test procedure.

Keywords: Dynamic Stiffness, Transmission   I-INCE Classification of Subjects Number(s): 45

1. INTRODUCTION

In Korea, more than 60 % of families live in the apartment houses, including town houses and multiplex houses (2014 statics in Korea). These types of houses have serious problem, floor impact noise between adjacent houses because they are sharing the walls and slabs. The floor of apartment consist of slab, resilient material, light weight evaporated concrete and finishing mortar. To reduce the floor impact noise of the apartment house, most of construction companies are using the resilient materials. Commonly, expanded polystyrene (EPS) and ethylene vinyl acetate (EVA) are used for resilient materials in Korea.

The dynamic stiffness is the one of the major property of resilient materials which influences to the floor impact noise of apartment. As the dynamic stiffness decrease, the floor impact noise from light weight impact source is reduced. The Korean government sets the limitation of the dynamic stiffness of resilient materials less than 40 MN/m^3 in 2005. After then, many kinds of resilient materials with low dynamic stiffness, less than 5 MN/m^3, are applied to improve the performance of reducing the floor impact noise.

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More than 30 % of apartment houses are passed over 15 years after constructed. They were not followed the regulation about resilient materials, but also slab thickness, because there were no regulations about them at that time. So, these houses has more severe problem with the floor impact sound than houses constructed recently. Recently, many aged apartments which have passed more than 15 years are being remodeled. However, most aged apartments have too thin floor structures with less 150 mm slab thickness and low indoor height. It is hardly to secure the inner height of the room with improved performance of the floor impact noise. So, it is important that the thin resilient materials with low dynamic stiffness are used to reduce the floor impact noise at aged apartment.

In this study, dynamic stiffness of resilient materials was measured as their thickness and material components. And appropriate range of the dynamic stiffness and thickness of resilient materials was investigated. The dynamic stiffness as loading time is also investigated.

2. STANDARDS AND REGULATIONS

2.1 Measurement Standards

The dynamic stiffness can be measured in accordance with ISO 9052-1 and KS 2868 standards. The set-up for pulse exciting measurement consist of base plate, specimen, load plate, pick-up, pulse exciter and FFT analyzer, see Figure 1. The steel load plate has dimension with 200 mm × 200 mm and mass with 8 kg ± 0.5 kg. The measured specimen should be made larger than load plate.

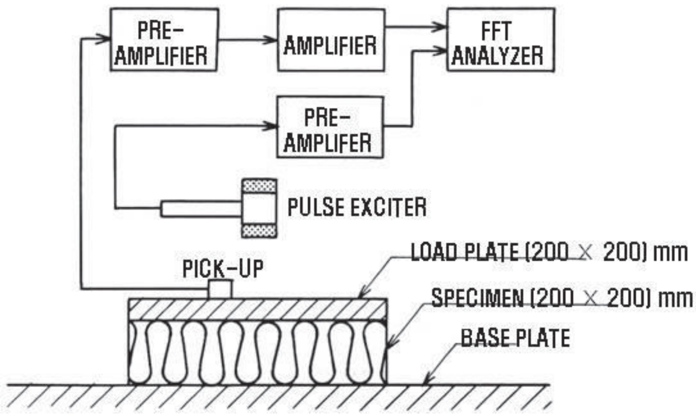


Figure 1 – Pulse exciting dynamic stiffness measurement scheme

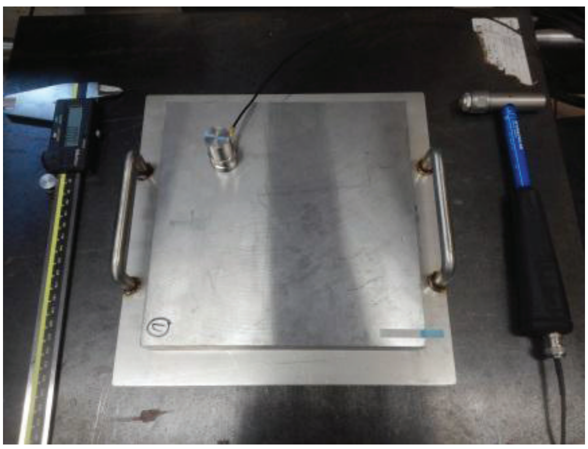


Figure 2 – Pulse exciting dynamic stiffness measurement equipments

After hitting the center of the load plate with pulse exciter (impact hammer), the acceleration level is measured with pick-up (accelerometer). The resonance frequency can be obtained by analyzing the frequency response of vibration system with this equation.

$$s'_t = (2\pi f_r)^2 \cdot m'_t$$

where, s'_t is dynamic stiffness, in MN/m^3
f_r is resonance frequency, in Hz
m'_t is mass per unit area, in kg/m^2

2.2 Regulation for Resilient Materials

The Korean regulation about measurement methods and limits of resilient materials for insulating floor impact noise was modified in 2014. The dynamic stiffness of resilient materials should be measured after loading the load plate about 48 hours over in accordance with notification of Korean government. And, after heating about 48 hours with load plate the dynamic stiffness should be measured. The limitation, on the regulation, of the dynamic stiffness before heating is 40 MN/m^3, and after heating is no 20 % more than before heating results.

At the real apartment floor structure, resilient materials affected by heating with "Ondol" and loading with upper structure like as light weight aerated concrete and finishing mortar. So, heating and loading time is very important during measurement of dynamic stiffness.

3. MEASUREMENT

3.1 Measurement of Dynamic Stiffness

The dynamic stiffness of diverse resilient materials was measured. Three test samples of each resilient material were selected and measured in accordance with ISO 9052-1, KS 2868 and notification of Korean government. After more than 48 hours with loading plat on the test samples, dynamic stiffness was measured. And then, they were heated with 70 ℃ for 48 hours with loading on top of samples. Lastly, dynamic stiffness of test samples was measured again. 51 types of resilient materials were tested. There were 22 types of expanded polystyrene (EPS) materials, 7 types of ethylene vinyl acetate (EVA) materials and the others. These test materials were supplied from many manufactures or construction companies.

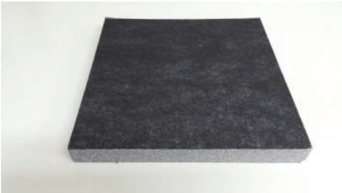
3.2 Dynamic Stiffness Tendency

The tendencies of dynamic stiffness as loading time were also confirmed using some kinds of resilient materials.

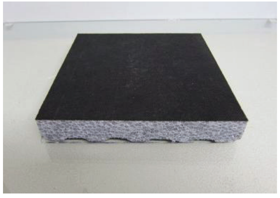
To confirm the differences of dynamic stiffness between the components of resilient materials, 3 kinds of materials were prepared, expanded polystyrene (EPS), ethylene vinyl acetate (EVA) and polyethylene (PE). Also differences as thickness and bottom shape of resilient materials are investigated.

Table 1 – Test specimen samples

Material	Size	Thickness	Shape
EPS	(200×200) mm	30 mm	Flat
		20 mm	Flat
		30 mm	Uneven
EVA	(200×200) mm	30 mm	Uneven
PE	(200×200) mm	30 mm	Flat

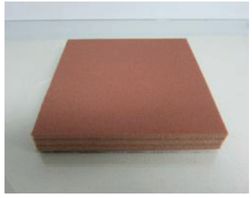


EPS-flat



EPS-uneven

EVA-uneven



PE-flat

Figure 3 – Test samples of resilient materials

4. RESULTS

4.1 Dynamic Stiffness of Common Resilient Materials

Usually, after-heating dynamic stiffness of resilient materials is higher than before-heating. Figure 4 shows the average before- and after-dynamic stiffness of each kind of resilient materials. The test results of EPS test samples after-heating increased than before-heating. EVA or PE resilient materials are usually used as multi-layered type and weak with heating high temperature over 70 ℃ and test was conducted within one minute as notification. So, during the heating time, air gabs between each layers are disappears and lower layers are depressed with pressure from upper layer. The measurement results of EVA and PE resilient materials are decreased after heating, because the component of EVA and PE materials became soft with heating.

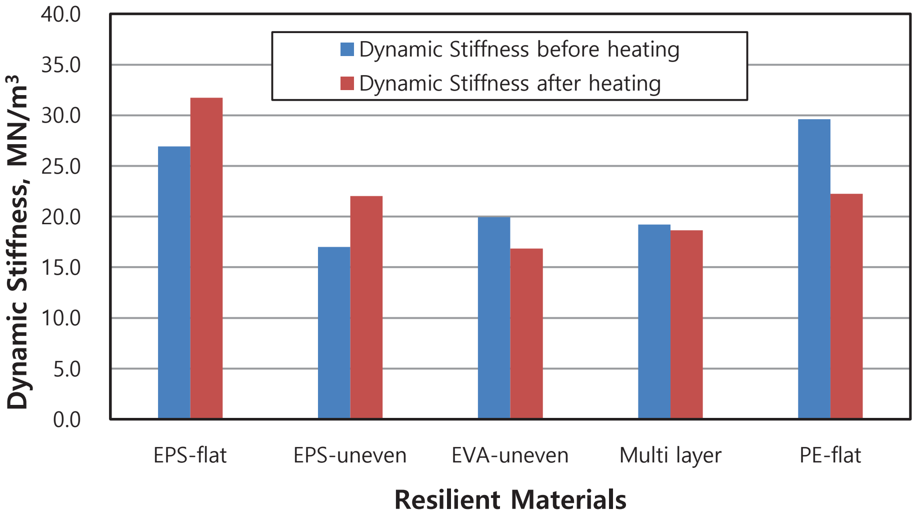


Figure 4 – Average dynamic stiffness of each type of resilient materials

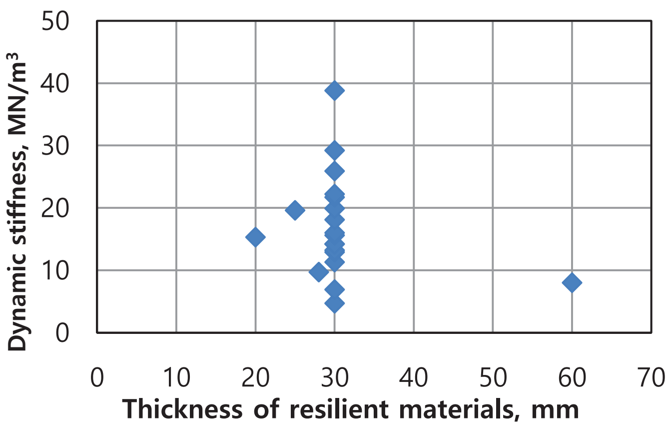


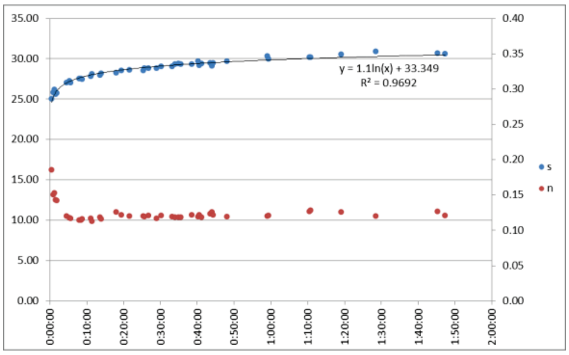
Figure 5 – Dynamic stiffness as thickness of EPS resilient materials with flat bottom

The resilient materials with 30 mm thickness are used most commonly for reducing the floor impact noise at the apartment construction. The results of resilient materials with less 20 mm thickness should be collected to investigate the relationship between dynamic stiffness and thickness of materials.

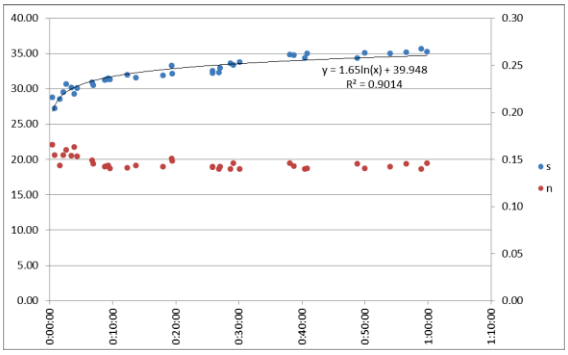
4.2 Dynamic Stiffness Tendency

Figure 5 shows the measurement results for changes in the characteristics of the dynamic stiffness with an increase in the loading time of the load plate. The dynamic stiffness of all 5 kinds of materials was increased as loading time with load plate and the correlation equation has high determination coefficient. Especially, in the case of EPS materials with flat bottom shape show the results of over 0.9 determination coefficients.

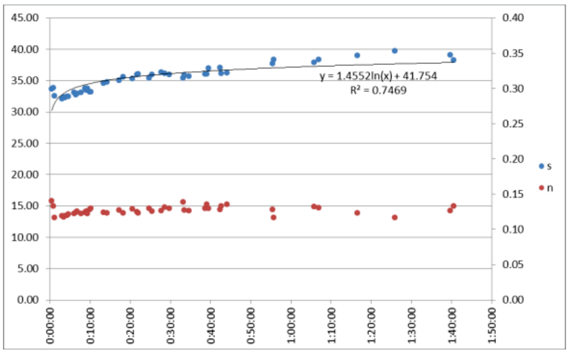
As notification of Korean government, the dynamic stiffness after 48 hours of resilient materials used for reduction of floor impact noise is limited strictly as no more than 40 MN/m^3. If the deviations of results with correlation equation are low and the correlation coefficient is high, the final dynamic stiffness at the time after 48 hours could be predicted.



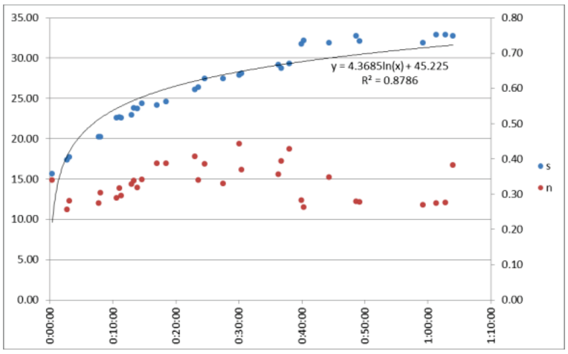
EPS-flat 30 mm



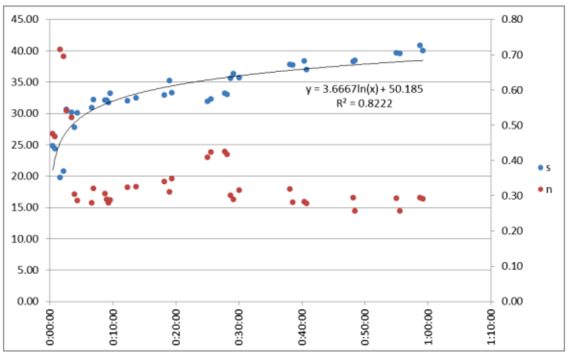
EPS-flat 20 mm



EPS-uneven 30 mm



EVA-uneven 30 mm



PE-flat 30 mm

Figure 6 – Dynamic stiffness and loss factor tendency before-heating of each type of resilient materials

5. CONCLUSIONS

In this study, dynamic stiffness of diverse resilient materials used reducing floor impact noise was investigated as components of materials, thickness and bottom shapes. And changes of the dynamic stiffness of increase characteristics as loading time with the load plate also measured.

The measured results with EPS test samples after loading before heating is less than the results after heating. At the measuring time after heating, EVA and PE resilient materials became soft, so they have low dynamic stiffness than the results before-heating.

The resilient materials with 30 mm thickness are used most commonly for reducing the floor impact noise at the apartment construction. The results of resilient materials with less 20 mm thickness should be collected to investigate the relationship between dynamic stiffness and thickness of materials.

The measurement results for changes in the characteristics of the dynamic stiffness with an increase in the loading time of the load plate. The dynamic stiffness of all 5 kinds of materials was increased as loading time with load plate and the correlation equation has high determination coefficient. Especially, in the case of EPS materials with flat bottom shape show the results of over 0.9 determination coefficients.

If the deviations of measured results with correlation equation are low or the correlation coefficient is high, the dynamic stiffness after 48 hours loading time could be predicted. Then the preparing time for measurement could be reduced.

ACKNOWLEDGEMENTS

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