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REDUCING THE HEAVYWEIGHT IMPACT SOUND LEVELS IN REINFORCED CONCRETE STRUCTURES USING VISCOELASTIC DAMPING MATERIALS

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Abstract

Floating floors with resilient isolators inserted between the structural slab and the upper layer of the floor structure have been generally used because of their effectiveness in lightweight impact sound isolation. However, these isolators often amplify low-frequency sounds below 100Hz. Therefore, a new damping viscoelastic material has been developed to reduce heavyweight impact sound levels in box frame-type reinforced concrete structures. The viscoelastic materials can be embodied between the concrete slab and the upper layer of the floor structure as a constrained layer and the energy from floor impacts is absorbed with shear and or compressional damping characteristics.

1. INTRODUCTION

According to a recent survey, more than 40% of Koreans (a total of 45 million people) live in apartment buildings and are therefore exposed daily to floor impact noise. Apartment residents are often troubled by heavyweight impact sounds caused, for example, by children's jumping or running, which produces mostly low-frequency noise [1].

Most apartment buildings in Korea are box frame-type structures built with reinforced concrete. Because their walls bear the structural load, box frame-type structures do not require columns or beams, thereby offering the advantages of reduced structural height, enlarged room space, and reduced sound transmission. In addition, box frame-type structures maintain a complex floor structure composition due to Ondol, the most common under-floor heating system. This combination of complex floor structure and box frame-type construction facilitates the propagation of structure-borne noise from a unit to the unit below.

Several treatments, such as elastic surface layers, floating floors, and double ceilings, are used to reduce floor impact sound [2]. Floating floors, in which resilient isolators are inserted between the structural slab and the upper layer of the floor, are generally used because of their effectiveness in controlling structure-borne and airborne noise [3]. However, according to recent studies, these isolators amplify low-frequency noises (those below 100 Hz), which are generally produced by heavyweight impacts. Viscoelastic damping materials are widely used to reduce noise in settings such as vehicles, ships, and machinery; however, there has been no report of their use in apartment building floor slabs for reducing floor impact sounds [4].

In this study, a means of effectively utilizing viscoelastic damping materials for reducing heavyweight impact sounds in box frame structures was proposed. We investigated and compared the effects of typical resilient isolators and viscoelastic damping materials in reducing floor impact noise.

2. EXPERIMENT: TESTING DAMPING MATERIALS

2.1. Floor Structures

In this experiment, we analyzed vibration and noise characteristics, which are produced by the standard heavy-weight impact source at living room and bedroom of four units in typical high rise apartment buildings. Three of the floor systems contained damping materials and the other one, for comparison, contained a resilient isolator in the A floor system as listed in Table 1.

The damping material used in this experiment was viscoelastic material. The damping material in bulk was used in the B floor system. And the PE honeycomb with damping material was used in the C and D floor systems as shown in Figure 1.

Table 1. Floor system detail in the apartment building

Type	Floor System Composition
A	Concrete slab (150mm) + Resilient isolator (20mm) + Lightweight concrete (40mm) + Finishing mortar (50mm)
B	Concrete slab (150mm) + Damping material (15mm) + Lightweight concrete (45mm) + Finishing mortar (50mm)
C	Concrete slab (150mm) + Damping material (3mm) + PE honeycomb structure (12mm) + Lightweight concrete (45mm) + Finishing mortar (50mm)
D	Concrete slab (150mm) + Lightweight concrete (45mm) + Damping material (3mm) + PE honeycomb structure (12mm) + Finishing mortar (50mm)

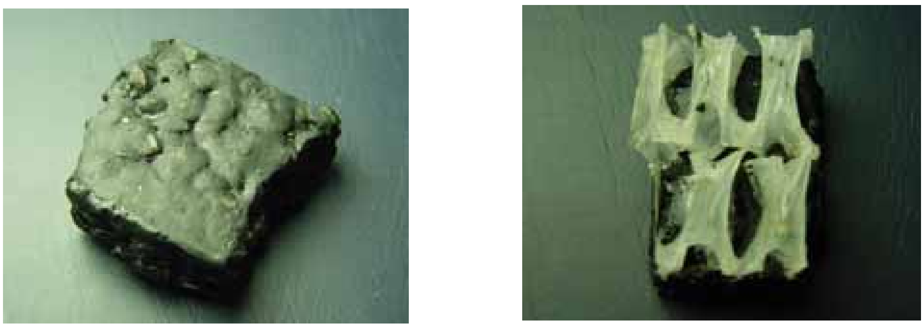


Figure 1. Viscoelastic damping materials (Left: THK 15mm, Right: THK 3mm & PE Honeycomb)

2.2. Measurement Method

To measure lightweight impact sound transmission through floors, the International Standards Organisation (ISO) suggests the use of a tapping machine with five steel-faced hammers, each weighing 0.5 kg, that strike the floor 10 times per second from a height of 40 mm [5]. Recently, the ISO 140-11:2005 standard has adopted a measurement using a modified tapping machine to emulate a walking person and a heavy-soft impact source to emulate human footsteps or children jumping.

However, the new standard is for laboratory measurement of lightweight reference floors. Research has shown that the rating of floor materials tested by the tapping machine does not rank them as reliably as a human observer would. Carpeting apartment floors often ensures a good rating in the standard test but does little to attenuate low-frequency impact sound [6]. This is why the Japanese Industrial Standard (JIS A 1418-2) has been used in Korea to evaluate low-frequency impact sound. In the Japanese test (the “banging” test), a small automobile tire is dropped from a height of 0.85 m onto the test floor, and the resulting sound-pressure levels are measured in the room below. Bang machine as a heavy weight impact source in the banging test, is the standardized machine, which has been recognized as reproducing the dominated characteristics of the low frequency impact force, such as children’s jumping and running. The measuring method of impact force level of the bang machine is described in the JIS [7].

The levels of sound and vibration produced by the bang machine were measured through transient signal analysis. On the receiving floor, 4 microphones were installed at 1.2 m above the floor to measure the sound pressure levels. The measured data was evaluated according to the single numeric rating method using inverse A-weighting floor impact noise level. The bang machine impacting on the center of the driving room produced the heavy-weight impact with the characteristics of impulse signal. As shown in Figure 2, an accelerometer was installed on the driving point (center of the concrete floor) to get the trigger signal (reference signal). The vibration acceleration was then measured at the central points in ceiling of the receiving room.

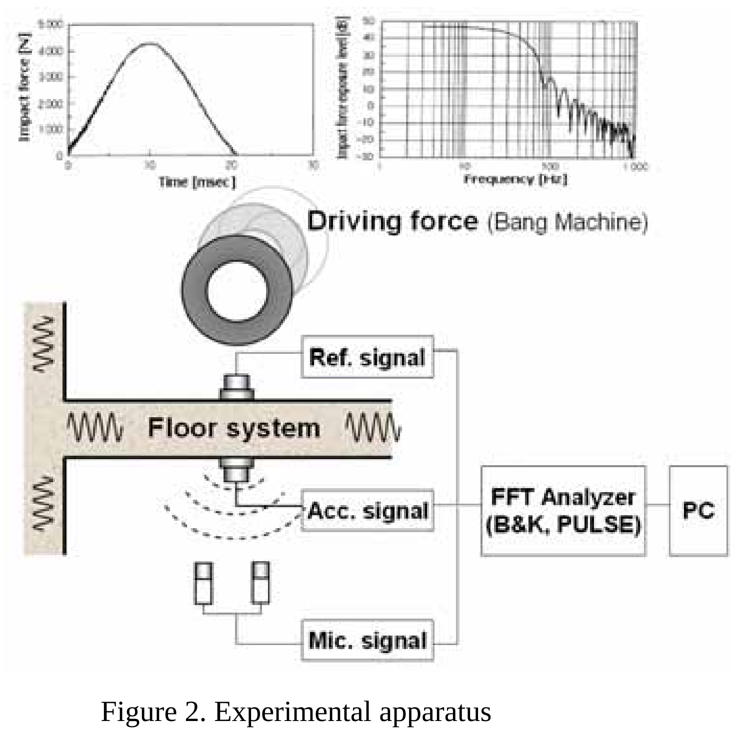


Figure 2. Experimental apparatus

2.3. Results

Figure 3 shows the frequency response of the vibration acceleration level for each floor system and bare concrete.

As shown in Figure 3(a), the resilient isolator decreases the resonance frequency and it was not effective in reducing the vibration acceleration level. On the other hand, Figure 3(b)-3(d) show that the use of the viscoelastic material increases the resonance frequency and decreases the vibration acceleration level. Also the effect of the 3mm thick damping layer is the same as that of 15 mm thick damping layer, and there is no difference effect between the C and D floor system compositions.

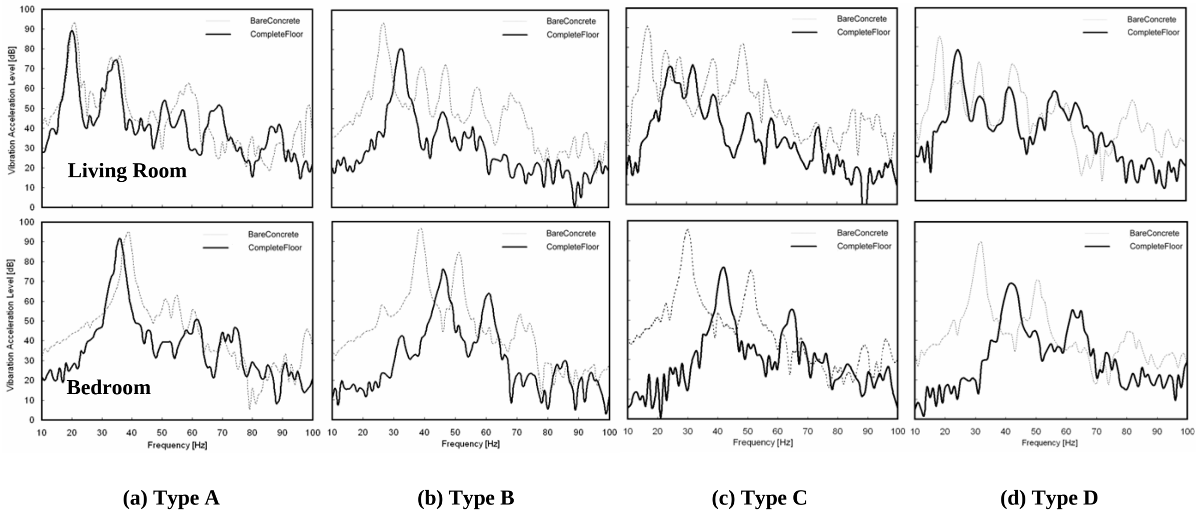


Figure 3. Comparison in terms of frequency response of the vibration acceleration level

Figure 4 shows the time response of the vibration acceleration. The floor systems with damping materials show a shorter time response and smaller amplitude. These results are due to the impact energy absorption of the damping material.

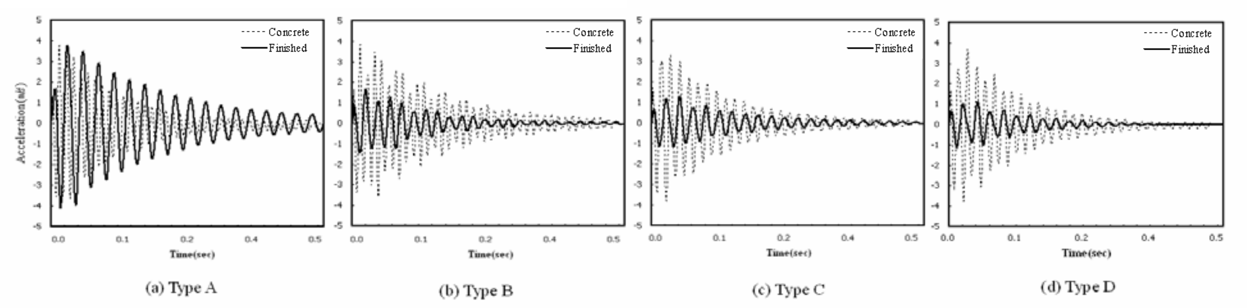
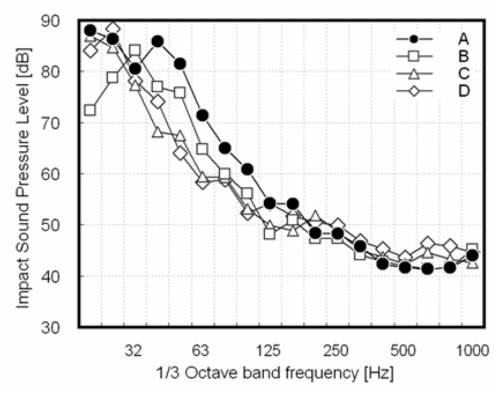


Figure 4. Time response spectrum of each structure in bedroom

Figure 5 shows the heavyweight impact sound spectrum. The sound pressure levels produced by the bang machine were at the 1/3 octave band frequencies. The dominant frequencies are below 80 Hz and the sound pressure level has a peak around 50 Hz. The floor structure using resilient isolators has a much higher sound pressure level at low frequencies. Both for living room and bedroom, the structure using damping materials increases the resonance frequency and reduces the vibration acceleration level, thus sound pressure level is also decreased.



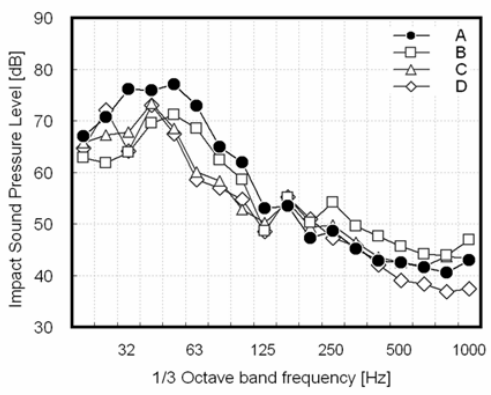


Figure 5. The Heavy-weight impact noise spectrum (Left: Living room, Right: Bedroom)

3. CONCLUSIONS

The damping materials are more effective than resilient isolators in reducing heavy-weight impact sound levels. This is because resilient isolators function as a separator so that the concrete slab and the upper layers act independently in a rigid body mode. This is in contrast to the floor systems with damping material. In these systems the concrete slab and the upper layers along with damping layer act as a single body. So the impact energy is absorbed in the damping layer. For the sound insulation mechanism, the impact sound level produced by a heavy-weight impact source can be reduced by increasing the resonance frequency of the floor system.

The viscoelastic materials can be embodied at any position between the concrete slab and the upper layer of the floor structure as a constrained layer and the energy from floor impacts is absorbed with shear and or compressional damping characteristics. There is a need for developed discussion about viscoelastic damping materials on the structural slab of reinforced concrete box frame-type structures. It is also necessary to investigate the optimum thickness and the position of the damping materials according to each construction method and sectional design.

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