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Improvement of the Floor Impact Noise of the Concrete Slab Using Latex Modified Mortar

Chan-Hoon Haan(1), Won-Hak Lee(2), Chan-Jae Park(3)

(1) (3)Department of Architectural Engineering, Chungbuk National University, Cheongju, Korea.
(2) Korea Institute of Construction Technology, Korea.

ABSTRACT

The present study aims to reduce the floor impact noises of multi-story housing using latex polymer modified cement mortar. A method of construction to reduce both light-weight and heavy-weight impact noises was sought. In order to achieve the noise reduction efficiency, the structure was designed to substitute the mortar layer, the closest to the impact source, as latex modified polymer mortar which can directly attenuates floor impact noise and vibration. The optimum mixing ratio was determined by material tests and after all 7 % SBR latex modified mortar and 5% of low Tg latex mortar were prepared to investigate the effect of SBR latex on floor impact noise reduction. Acoustic experiments were undertaken to four specimens with different latex polymer ingredient. Results show that while specimen 2 (i.e. latex-modified mortar laminated) shows better noise reduction performance for light-weight impact noise, specimen 3 & 4 (i.e. low Tg latex polymer mortar laminated) have effects of noise reduction for heavy-weight impact noises. Remarkable reduction was occurred when rubber powder was mixed with low Tg latex polymer (i.e. specimen 4) with the sound source used as impact ball. Li,Fmax,Aw was 37dB while general floor system has 45dB. The light-weight and heavy-weight impact tests demonstrated that the SBR latex-modified mortar generally gives better noise reduction characteristics than the unmodified mortar over the full range of frequencies and the benefit become outstanding as the frequency reaches above 125 Hz.

1. INTRODUCTION

Recently in Korea, demands for the improvement of indoor acoustical environment have been raised. The people have appealed on the noise and vibration which becomes serious environmental factor and the percentage of complain on the floor impact noises have been continuously increased.[1] So, optimization of the indoor acoustical environment are need to be achieved if the residential spaces can be constructed with the consideration of the acoustical comfort of indoor spaces.

Most of the apartments in Korea have been made with reinforced concrete and have radiant floor heating system. Moreover, Koreans customarily do not wear shoes in the house and heel to toe, for this reason, heavy-weight impact noise caused by foot walk becomes a major source of indoor noises. However, there have been not satisfactory regulations yet concerning sound insulation of apartments in Korea. The lack of restrictions on residents living environments has worsened the aural situation. And frequent disputes have been occurred among residents and between occupants and building contractors. As the results, many insulation materials have been developed for reducing impact floor noises. However, it was revealed that flexible insulation materials and floating floor systems have little effect on the heavy-weight impact sound.

On this research, modified cement mortar using latex polymer was applied as a noise reducer which is layered on top of the concrete floor systems of the typical existing apartments. As engineering properties of mortar has been modified by SBR latex on this study.[2-3] Acoustic experiments using latex modified mortar were undertaken to find the effects of new materials on the impact noises.

2. ACOUSTIC EXPERIMENTS

2.1 Test Specimens

In order to investigate the floor impact noises, four mock-up specimens of floor system were made to carry out the acoustic experiments. Two SBR polymers were used with different glass transition temperature(Tg) which have different chemical features.

The thickness of concrete slab of mock-up models is 150mm which has been used for typical apartments built before 2004. So, theses specimens were made to investigate the possibility of controling the impact noises for remodeling apartments as well as new buildings. The upper layer of concrete slab consists of thermal insulation and light-weight foaming concrete and cement mortar of which total thickness was 110mm. All the mock-up models have the deviation within ±3mm for total layers including slab, insulation, foaming concrete and mortar.

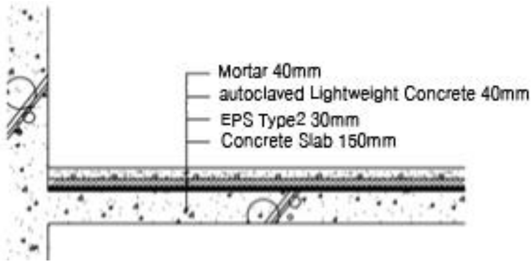
The detail sections of four mock-up test specimens are illustrated in figure 3. Model 1 is the layout of current floor structure with ordinary cement mortar. Otherwise, cement mortar was replaced with SBR polymer mixed mortar in specimen 2. Also, low Tg SBR was used in specimen 3 and specimen 4 has low Tg SBR and rubber powder in cement mortar layer.

2.2 Acoustic Experiments

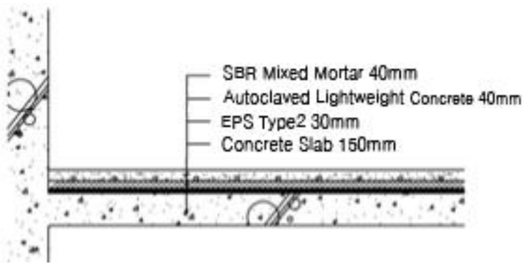
Acoustic experiments were undertaken following the Korean standard KS F 2865 for the light-weight impact noise and KS F 2810-2 for the heavy-weight impact noise. Reverberation time was measured as a pre-condition which was adjusted about 4.2 sec (±0.04). Four measurement positions were selected which are at least 50cm apart from each wall, ceiling and floor. Also, each measurement positions are apart from at least 70cm each other.

Floor impact noise measurements were carried out in a reverberation chamber with the volume of 87.7m3 which has KS standard. Tapping machine was used as the light-weight impact sound source and, for heavy-weight impact sound sources, bang-machine and impact ball were used. Figure 2 shows the upper plan of the measurement chamber with the experimental outlet of the devices.

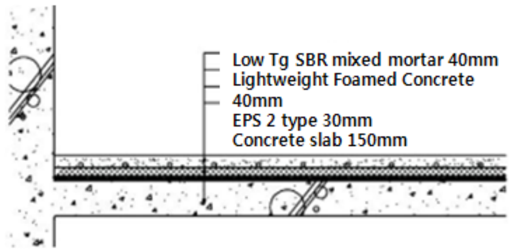
The mortars were casted under the proportions that were calculated previously. Casting the mortar with the dimension of 4.3x2.8x0.4 m were made and density and compressive strength of cement mortar were measured under ASTM C 109[4].



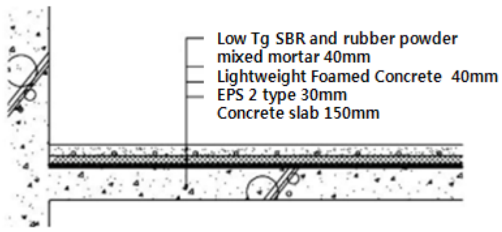
a) specimen 1



b) specimen 2



c) specimen 3



d) specimen 4

Figure 1. Detail sections of four floor specimen structures as tested in present study

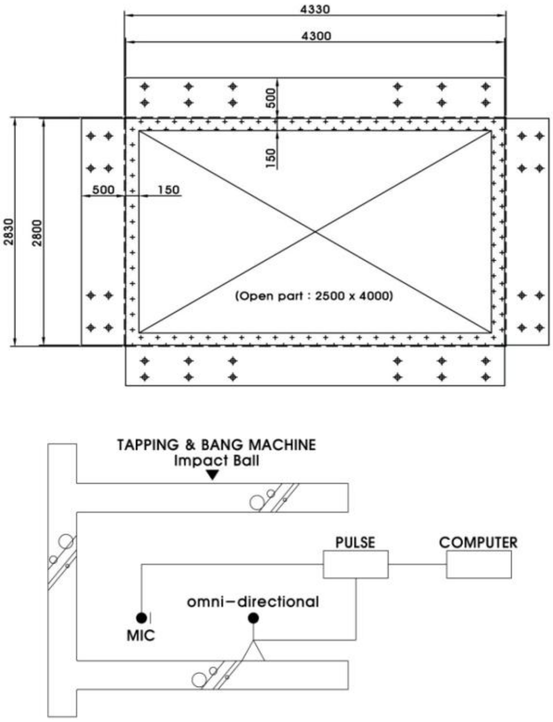


Figure 2. Test facility and experiment method

3. RESULTS

3.1 Light-weight impact noise

Light-weight impact noises were calculated with standardized floor impact sound levels which consider background noise level. Light-weight impact noises were analyzed at the frequency band from 125Hz to 2000Hz.

The results of light-weight impact sound levels measured at the 1/3 octave band are listed in table 1 and figure 3. Generally, specimen 2 seems to has a low light-weight impact noises in overall frequencies comparing other specimens. Results show that SBR latex modified mortar has the effects on reducing high frequency noises. Ignoring specimen 4 which has rubber powder, specimen 2 & specimen 3 which have latex modified mortar have 3dB lower sound level at 125Hz and 2dB lower at 500Hz in comparison with specimen 1 which has not latex modified mortar.

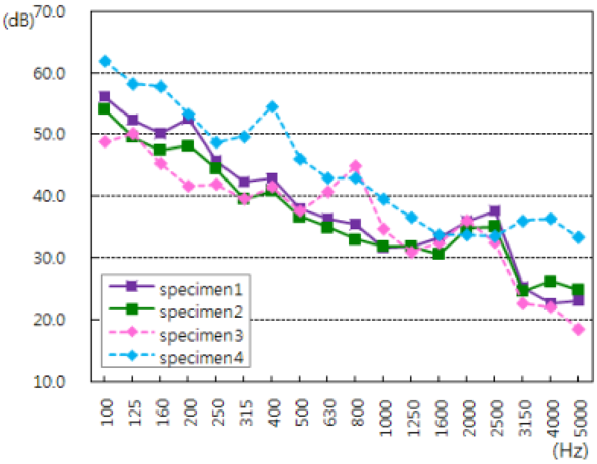


Figure 3. Comparison of Light-weight impact sound level of each specimen

Table 1. Light-weight impact sound levels of each specimen (dB)

Contents	1st Experiment		2nd Experiment	
	specimen 1	specimen 2	specimen 3	specimen 4
Additive	Ordinary Mortar	Latex Mortar	Low Tg Latex	Low Tg Latex & RP
Mortar Type	Wet Type	Wet Type	Wet Type	Wet Type
100	56.1	54.1	48.8	62.0
125	52.4	49.6	50.1	58.3
160	50.1	47.5	45.3	57.9
200	52.5	48.2	41.6	53.4
250	45.8	44.5	41.9	48.8
315	42.4	39.6	39.6	49.7
400	42.9	40.9	41.5	54.6
500	38.0	36.7	37.6	46.1
630	36.4	35.0	40.7	43.0
800	35.4	33.1	44.9	43.0
1000	31.7	31.9	34.7	39.6
1250	31.9	31.9	30.9	36.6
1600	33.3	30.6	32.4	33.8
2000	35.9	34.8	36.0	33.8
2500	37.6	35.1	32.5	33.6
3150	25.2	24.6	22.7	36.0
4000	22.6	26.2	22.1	36.4
5000	23.1	24.8	18.5	33.4
L'n, AW	**44**	**41**	**43**	**49**
Grade	**2nd**	**1st**	**1st**	**3rd**

Table 2. Heavy-weight impact sound levels of each specimen using bang-machine (dB)

Contents	1st Experiment		2nd Experiment	
	specimen 1	specimen 2	specimen 3	specimen 4
Additive	Ordinary Mortar	Latex Mortar	Low Tg Latex	Low Tg Latex & RP
Mortar Type	Wet Type	Wet Type	Wet Type	Wet Type
50	78.5	84.3	78.7	80.5
63	78.2	78.1	70.1	69.4
80	64.0	63.9	59.6	61.3
100	62.0	58.9	57.1	61.5
125	48.7	48.1	50.7	51.4
160	42.3	40.4	45.4	48.2
200	42.1	39.4	41.9	45.9
250	33.5	33.9	39.9	39.2
315	27.4	27.0	33.4	34.5
400	26.0	27.5	28.9	34.0
500	21.8	20.9	25.8	28.2
630	17.5	19.1	24.1	27.7
800	16.5	17.5	22.1	25.3
1000	14.8	15.4	17.9	24.3
1250	15.0	15.9	17.0	22.0
1600	12.2	13.9	13.9	19.7
2000	11.5	12.5	13.2	19.3
2500	11.8	14.4	12.5	17.7
Li,Fmax,AW	**51**	**56**	**49**	**50**
Grade	**Out of grade**	**Out of grade**	**4th**	**4th**

3.2 Heavy-weight impact noise (Bang Machine)

The measured heavy-weight impact noises at the 1/3 octave band are listed in table 2 and displayed in figure 4. As shown in figure 4, the reduced sound level of heavy-weight impact noises is an insignificant difference comparing with the light-weight impact noises. The results show that specimen 2 with SBR mortar has 0.5dB lower sound level than Specimen 1 at the frequency band from 63Hz to 200Hz.

Especially, specimen 3 has much less sound levels at the low frequency band from 63Hz to 100Hz. This may resulted from the lower Tg polymer mortar which has lower compressive strength. However, there is no particular reduction in any other frequency bands.

The results denotes that low Tg SBR polymer modified mortar has good effect on the reduction of impact floor noise at the low frequency bands below 500Hz.

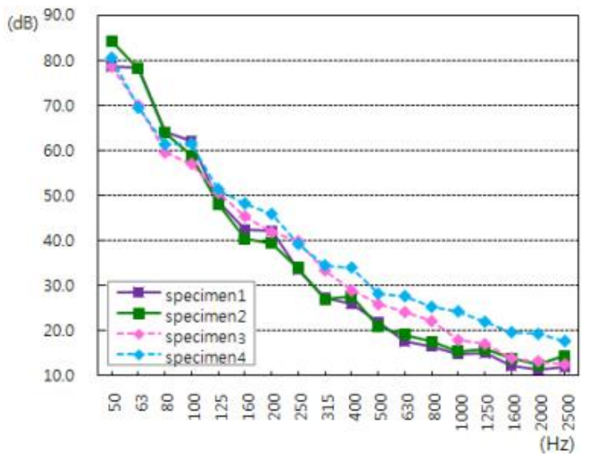


Figure 4. Comparison of Light-weight impact sound level of each specimen using bang machine

3.3 Heavy-weight impact noise (Impact ball)

According to the papers of J.Y. Jeon et al. [3], compared with the impact force of children jumping and running that is the main impact sounds occurred in the apartment in Korea, bang machine appeared higher at 63Hz band, and the impact force of impact ball was lower than that of bang machine, which was similar to the impact force caused by the child in fact. The impact force of bang machine is appox. 3,000 N higher than the impact ball which eventually results in 5dB higher floor impact sound levels. Thus, impact ball was used as an alternative impact source of floor impact noise tests.

The measured heavy-weight impact noises using impact ball are listed in table 3 and displayed in figure 5. The results show that specimen 3 has lower overall heavy-weight impact sound level than specimen 1. It reveals that low Tg latex modified mortar has an effects of reducing heavy-weight impact sound level at the frequency band from 63Hz to 100Hz.

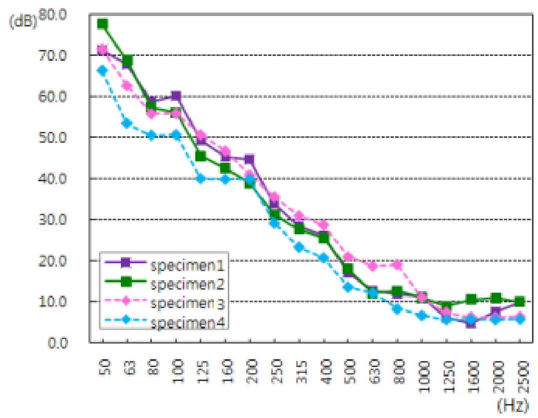


Figure 5. Comparison of heavy-weight impact sound level of each specimen using impact ball

Especially, specimen 4 has much less sound levels at the most of frequency bands. This implies that low Tg modified mortar with rubber power has particular effects of reduction of heavy-weight impact noises.

Comparing the impact sound levels at 63 Hz, it is shown that sound level of bang machine is about 10dB higher than the sound level of impact ball. Meanwhile, only 3dB reduction was occurred at the 125Hz and 250Hz.

This means that the use of impact ball as the heavy-weight sound source is very important for the evaluation of floor impact noise levels because sound level at the 63Hz is most significant for the heavy-weight impact noises.

Table 3. Heavy-weight impact sound levels of each specimen using impact ball (dB)

Contents	1st Experiment		2nd Experiment	
	specimen 1	specimen 2	specimen 3	specimen 4
Additive	Ordinary Mortar	Latex Mortar	Low Tg Latex	Low Tg Latex & RP
Mortar Type	Wet Type	Wet Type	Wet Type	Wet Type
50	71.3	77.6	71.6	66.2
63	67.8	68.7	62.7	53.4
80	58.6	57.4	55.8	50.5
100	60	56	55.9	50.6
125	49.4	45.5	50.7	40
160	45.3	42.5	46.8	39.8
200	44.7	38.9	40.9	39.8
250	33.9	31.3	35.6	29.2
315	28.5	27.7	31	23.4
400	26.2	25.5	28.8	20.8
500	17.1	18	21	13.7
630	12.7	12.2	18.7	12.3
800	12	12.7	19.1	8.4
1000	11.5	11	11	6.8
1250	6.2	9.1	7.5	5.8
1600	4.9	10.6	6.3	5.9
2000	7.7	11	6.2	5.8
2500	10.1	10.1	6.4	5.9
Li,Fmax,AW	**45**	**48**	**43**	**37**

4. CONCLUSIONS

Three different SBR latex modified cement mortar layers were examined to have effects on the reduction of the floor impact noises in comparison with the ordinary cement mortar layer. Followings are the results of the acoustic experiments conducted to examine the impact sound pressure levels.

1) Concerning the results using tapping machine, it was shown that SBR latex modified mortar structures decrease the light-weight impact sound level.

2) Regarding the heavy-weight impact noise, SBR latex modified mortar structures has effects on reducing sound levels at the frequency band from 63Hz to 200Hz.

3) It was also, revealed that low Tg SBR polymer modified mortar has good effect on the reduction of impact floor noise (appox. 2-3dB) at the low frequency bands below 500Hz.

4) Remarkable reduction was occurred when rubber powder was mixed with low Tg latex polymer (i.e. specimen 4) with the sound source used as impact ball. Li,Fmax,Aw was 37dB while general floor system has 45dB.

5) The use of impact ball as the heavy-weight sound source is very important for the evaluation of floor impact noise levels because it is very similar to the impact force caused by the child in fact.

The light-weight and heavy-weight impact tests demonstrated that the SBR latex-modified mortar generally gives better noise reduction characteristics than the unmodified mortar over the full range of frequencies and the benefit become outstanding as the frequency reaches above 125 Hz.

5. DISCUSSIONS

The increase of water cement ratio affects the thermal conductivity value. Thus, the decrease of the thermal conductivity is due to two factors: the polymer and water content. The water/cement ratio increases the amount of capillary porosity in hydrated cement. When the water escapes from the capillaries, it leaves behind free, semi-dry space. This is most likely the addition of water reduces the thermal conductivity.

In this research, we have not identified yet a flexible (Low Tg) polymer emulsion, which is compatible with the surface acting agents for cellular cement mortar. We can assume that a flexible (a low Tg) polymer will be more efficient in reducing the impact sound transmission, than a higher Tg polymer. Thus, We are getting a sample of SBR latex, with Tg-16℃ (compatible with Portland cement) shortly and will run the mechanical test.

6. ACKNOWLEDGEMENTS

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