Title: **Characteristic and Evaluation of Floor Impact Sound for High-rise Apartment Buildings**

Authors: Sang-Gon Cha, Researcher, Kyonggi University
Gab-Chul Jeong, Daewon Plus Construction
Sang-Woo Lee, Professor, Kyonggi University

Subjects: Interior Design
Social Issues

Keyword: Residential

Publication Date: 2004

Original Publication: CTBUH 2004 Seoul Conference

Paper Type:
1. Book chapter/Part chapter
2. Journal paper
3. **Conference proceeding**
4. Unpublished conference paper
5. Magazine article
6. Unpublished

Characteristic and Evaluation of Floor Impact Sound for High-rise Apartment Buildings

Sang-gon Cha[1], Gab-chul Jeong[2], Sang-woo Lee[3]

[1] Research staff, Graduate school of Architectural Engineering, Kyonggi University.
San 94-6 Ieu-Dong, Paldal-Gu, Suwon City, Kyonggi-Do, Korea
[2]Daewoo Institute of Construction Technology
60 Songjuk-Dong, Jangan-Gu, Suwon City, Kyonggi-Do, Korea
[3]Professor, Dept. of Architectural Engineering, Kyonggi University.
San 94-6 Ieu-Dong, Paldal-Gu, Suwon City, Kyonggi-Do, Korea

Abstract

In South Korea, high-rise apartment buildings were constructed in the suburbs of Seoul city to solve the overpopulation in Seoul area in earlier 1990 s. In this study, the floor impact sound are measured and analyzed for high-rise apartment buildings to investigate the insulation performance of floor impact sound with the type(P'yong) and the number of stories. The following conclusions can be drawn from the results of this study.

Keywords: High-rise apartment buildings, Floor impact sound, Reverse A characteristic curve

1. Introduction

In South Korea, high-rise apartment buildings were constructed in the suburbs of Seoul city to solve the overpopulation in Seoul area in earlier 1990 s. At that time, these buildings were up to only 30-story buildings due to the skyline. However, because of high-rising of the mixed use and office buildings, these buildings were up to 60-70 story buildings in earlier 2000 s and these trends will be accelerated in the future. High-rise apartment buildings located in downtown area are exposed to various noise more than the one of low-rise apartment buildings because of local feature and height. The noise pollution is an important evaluation standards to estimate the quality and price of the buildings. Therefore, the noise prevention and isolation in high-rise apartment buildings are an environmental factor to control the comfortable life. In May 2003, the amendment for *'The Provisions for the Housing Construction Standards - The Ministry of Construction and Transportation'* is pass the vice-minister's meeting and the enforcement will be scheduled in April 2004 considering the cabinet council and term of validity. This amendment emphasises on the improvement of life quality. And, it regulates the introduction of noise grade, obligation of grade indication of inter-story noise, and application of lowest criteria of noise.

The main objective of this study is to suggest the improvement of sound performance fixing the weight of the buildings and reducing the propagation of noise in high-rise apartment buildings. To accomplish the main objective, the floor impact sounds are measured and analyzed in high-rise apartment buildings. The target buildings of measurement are selected considering the area of floor, type of building, and type of structures for high-rise apartment buildings constructed in the suburbs of Seoul city. The degree of noise is measured and analyzed with size of floors and number of stories to quantify analyze the factors of floor impact sound of the selected buildings.

2. Measurement and Evaluation of Insulation Performance of Floor Impact Sound

2.1. Introduction

To consider the degree of noise with the size of floors and number of stories for the slab system in high-rise apartment buildings, 'A' reinforced concrete frame structures are selected as an objective buildings of measurement located in Seocho-gu, Seoul city. Table 1 showed the profile of the objective buildings of measurement, and Figure 1 illustrated the cross section of the slab. This building is 5-stories below ground, 37-stories above ground and floor area is 39-94 P'yong (126.4-304.6 m^2). The thickness of

Contact Author
Sang-woo Lee
Professor staff, Dept. of Architectural Engineering,
Kyonggi University.
San 94-6 Ieu-Dong, Paldal-ku, Suwon City, Kyonggi-Do,
Korea
Tel: +82-31-249-9729 Fax: +82-31-249-6300
e-mail: swlee@kuic.kyonggi.ac.kr

reinforced concrete slab is 180 mm and finishing layer is consist of vinyl sheet(20 mm), light weight cellular concrete(50 mm), polyethylene film (0.08 mm) and light weight adiabatic materials (20 mm).

Table 1. profile of the objective buildings of measurement

No	Type (P'yong)	Thickness of slab [mm]	Area ofmeasurement room[㎡]			Measurement point
			Living room	Master's room	Room 1	
1	58 (187.9 m^2)	180	98	58.1	37.9	Each 5 Point
2	63 (204.1 m^2)		126.5	47.5	37.7	
3	79 (256.0 m^2)		131.0	54.0	51.6	

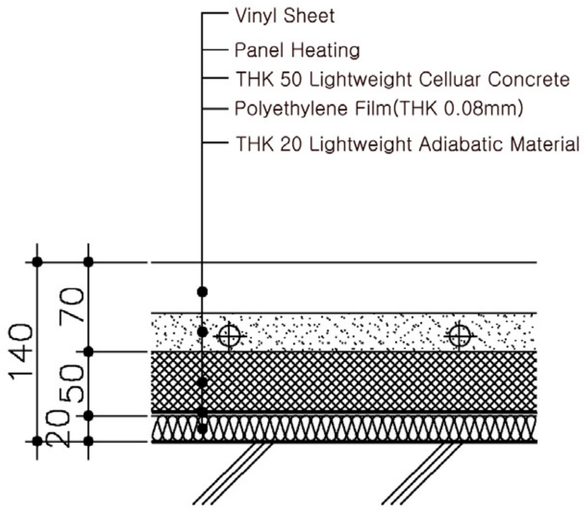

Fig. 1. Cross section of the slab

2.2. Measurement and Evaluation

2.2.1. Measurement Method

The light-weight and heavy-weight impact noise were measured at living room, master's room and room 1 to investigate the degree of noise with size of floors and number of stories. Figure 2 illustrated the floor plan and measurement point of the objective building.

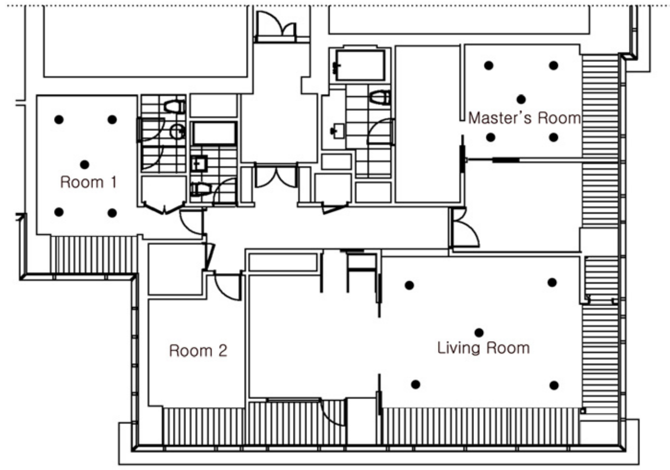

Fig. 2. Floor plan and measurement point of the objective building

The equipments used in measurement and analysis are shown in Table 2.

Table 2. Equipment used in measurement

Equipment	Model	Company
Precision Sound Level Meter	NA-29E	RION
1/3 Octave Band Real-Time Analyzer	SA-27	RION
Tapping Machine	-	-
Bang Machine	FI-02	RION

2.2.2. Evaluation Method

The evaluation method for insulation performance of floor impact noise are legislated by an Korea Standards (KS) in 2002. The KS F 2863-1 regulates the '*Evaluation Method of Insulation Performance of Floor Impact Noise for Light-weight Noise*', and KS F 2863-2 regulates the '*Evaluation Method of Insulation Performance of Floor Impact Noise for Heavy-weight Noise*'. The reverse A characteristic curve for light-weight and heavy-weight noise are used as a reference value of insulation performance of floor impact noise. The measurement results for light-weight impact noise are evaluated from reverse A characteristic curve regulated in KS F 2863-1. The measurement quantity used in evaluation are applied by the standard floor impact noise level regulated in KS F 2810-1. The sound absorbing power in receiving room are modified using reverberation time. The measurement results for heavy-weight impact noise are evaluated from reverse A characteristic curve regulated in KS F 2863-2, and the measurement quantity used in evaluation are applied the standard floor impact noise level regulated in KS F 2810-2.

3. Results of Measurement and Analysis

3.1. Analysis of Insulation Performance of Floor Impact sound

The evaluation results of single-value quantity using the reverse A characteristic curve for light-weight floor impact sound shows that $L'_{n,AW}$ = 46～50 at living room, $L'_{n,AW}$ = 46～55 at master's room, and $L'_{n,AW}$ = 44～49 at room 1, respectively. The evaluation results of single-value quantity using the reverse A characteristic curve for heavy-weight floor impact sound shows that $L_{i,Fmax\,AW}$ = 43～48 at living room, $L_{i,Fmax\,AW}$ = 47～50 at master's room, and $L_{i,Fmax\,AW}$ = 44～50 at room 1, respectively. It is evaluated that insulation performances of floor impact sound for measurement buildings are satisfied the code values which are prescribed below 58 dB for light-weight impact sound and below 50 dB for heavy-weight impact sound regulated in *'The Provisions for the Housing Construction Standards - The Ministry of Construction and Transportation'* and the enforcement will be scheduled in July 2005. This results indicated insulation performances of floor impact sound are superior to code value, that is, 8～12 dB at living room, 3～12 dB at master's room, and 9～14 dB at room 1 are superior to code value for the light-weight noise and 2～7 dB at living room, 3 dB at master's room, and 6 dB at room 1 are superior to code value for the heavy-weight noise. Figure 1 and 2 show the single value quantity for measurement buildings compared with code values for heavy-weight and light-weight, respectively.

Table 3. Insulation performance of floor impact sound

type (P'yong)	location	single-value quantity $(L'_{n,AW})$	single-value quantity $(L_{i,Fmax,AW})$	L-value	
				Light -weight	Heavy -weight
58 (187.9 m^2)	Living room	48	48	53	53
	master's room	50	48	55	53
	room 1	47	49	52	54
63 (204.1 m^2)	living room	49	45	54	50
	master's room	48	49	53	54
	room 1	45	45	50	50
79 (256.0 m^2)	living room	48	47	53	52
	master's room	48	48	53	53
	room 1	47	46	52	51

According to previous studies, the insulation performance of living room of relatively large area was inferior to those of master's room and room 1 in the wall-type apartment buildings.

However, these results was contrary to previous studies showing that the insulation performance of living room is relatively large area was superior to those of master's room and room 1 in the reinforced concrete frame structures. Table 4 shows the previous studies and code values for insulation performance of floor system.

Table 4. comparison for insulation performance of floor system

		Results		previous studies 1)	code value 2)	Architectural Institute of Japan
		L-value	Single-value quantity			
light-weight	living room	53-54	48-49	light－weight L－70	$(L'_{n,AW})$ = 58	unpleasant
	Mas-ter's room	53-55	48-50			unpleasant
	room 1	50-52	45-47			satisfied
Heavy-weight	living room	50-53	45-48	heavy－weight L－50	$(L_{i,Fmax,AW})$ = 50	satisfied
	Mas-ter's room	53－54	48－49			unpleasant
	room 1	50－54	45－49			unpleasant

These results satisfied the provisions criteria which was newly revised and the previous study suggested through noise measurement, questionnaire, and noise test for the reinforced concrete apartment buildings. Also, these results correspond to the 'unpleasant' in the '*relationship between degree of insulation and life sensitivity*' which was used the fundamental data of classification of noise for floor impact sound in Architectural Institute of Japan.

3.2. Floor Impact Sound Level and Characteristic of Frequency with Each Type

1) Heavy-weight Impact Sound

To investigate the reduction effect of floor impact sound for the each type, the characteristics of frequency with each rooms are examined.

In case of 58 P'yong (187.9 m^2), the floor impact sound level shoowed the most high value at 63 Hz and the more high frequency, the less low level, that is a typical characteristic of frequency for the heavy-weight impact sound. In comparison with each rooms, floor impact sound level for living room with relatively large area have higher reduction effects than those of master's room and room 1 showing that 1.8 dB and 6 dB are low at 250 Hz and 1.0 dB and 6 dB are low at 500 Hz, respectively. In results from single-value quantity of heavy-weight floor impact sound for each rooms, it shows that floor impact sound level for living room have higher reduction effects than those of master's room and room 1 about 1-2 dB showing that $L_{i,Fmax\,AW} = 47$ at the living room, $L_{i,Fmax\,AW} = 48$ at the master's room, and $L_{i,Fmax\,AW} = 49$ at the room 1.

In case of 63 P'yong (204.1 m^2), the floor impact sound level for living room which is relatively large area showed higher reduction effects than those of master's room for all frequency range, and it showed the reduction effects about maximum 6.6 dB at 500 Hz. However, the floor impact sound level for living room have lower reduction effects than those of room 1 showing that 1.3 dB is high at 125 Hz and 1.2 dB is high at 250 Hz, respectively. In results from single-value quantity of heavy-weight floor impact sound for each rooms, floor impact sound level for living room and room 1 are equal to $L_{i,Fmax\,AW} = 45$, thus, there are no reduction effects of floor impact sound level between two rooms. However, floor impact sound level for master's room is equal to $L_{i,Fmax\,AW} = 49$, this implies that living room have higher reduction effects than master's room about 4 dB.

In case of 79 P'yong (256.0 m^2), the floor impact sound level for living room have higher reduction effects than those of master's room on 500 Hz about 3.2 dB, and than those of room 1 on 250 Hz about 1.7 dB. However, the floor impact sound level for living room have lower reduction effects than those of room 1 on 63 Hz about 1.9 dB. From results of single-value quantity of heavy-weight floor impact sound for each rooms, it show that $L_{i,Fmax\,AW} = 47$ at the living room, $L_{i,Fmax\,AW} = 48$ at the master's room, and $L_{i,Fmax\,AW} = 46$ at the room 1. Therefore, it shows that living room have higher reduction effects than master's room about 1 dB, however, lower reduction effects than room 1 about 1 dB.

Table 5. Insulation performance of floor impact sound (heavy-weight)

Type	Location	Octave Band Central Frequency (Hz)				Single-value quantity
		63	125	250	500	
58 (187.9 m^2)	Living room	75.9	62.6	48.5	40.2	47
	Master's room	76.8	62.1	50.3	41.2	48
	room 1	76.1	64.3	54.5	46.2	49
63 (204.1 m^2)	Living room	74.4	59.4	45.8	35.6	45
	Master's room	79.3	61.3	49.2	42.2	49
	room 1	74.3	58.1	44.6	35.6	45
79 (256.0 m^2)	Living room	76.9	59.0	45.7	37.2	47
	Master's room	79.5	59.3	48.1	40.4	48
	room 1	75.0	58.5	47.4	38.7	46

2) Light-weight Impact Sound

The characteristics of frequency of floor impact sound level for each type have a maximum value on 125 Hz which implies low frequency level.

In case of 58 P'yong (187.9 m^2), floor impact sound level for room 1 which is relatively small area have higher reduction effects than those of living room for all frequency ranges showing at maximum 1.5 dB is low at 250 Hz. Also, floor impact sound level for room 1 have higher reduction effects than those of master's room for all frequency ranges showing the maximum 4.3 dB is low at 1 kHz. From the results of the single-value quantity of light-weight floor impact sound for each rooms, it shows that $L'_{n,AW} = 48$ at the living room, $L'_{n,AW} = 50$ at the master's room, and $L'_{n,AW} = 47$ at the room 1. Therefore, it shows that room 1 have higher reduction effects than living room about 1 dB, and than master's room about 3 dB.

In case of 63 P'yong (204.1 m^2), floor impact sound level for room 1 have higher reduction effects than those of living room showing the maximum 6.3 dB is low at 125 Hz. Also, the floor impact sound level for room 1 have higher reduction effects than those of master's room for all frequency ranges showing that maximum 5.7 dB is low at 500 Hz. In results from single-value quantity of light-weight floor impact sound for each rooms, it shows that $L'_{n,AW} = 49$ at the living room, $L'_{n,AW} = 48$ at the master's room, and $L'_{n,AW} = 45$ at the room 1. Therefore, it shows that room 1 have higher reduction effects than living room about 4 dB, and than master's room about 3 dB.

In case of 79 P'yong (256.0 m^2), the results of frequency analysis show that floor impact sound level for room 1 have higher reduction effects than those of living room showing that maximum 4.8 dB is low at 63 Hz. Also, floor impact sound level for room 1 have higher reduction effects than those of master's room showing the maximum 1.3 dB is low at 500 Hz. However, the floor impact sound level for room 1 have lower reduction effects than those of living room and master's room showing the maximum 1.2 dB and 2.4 dB are high at 2 kHz, respectively. In results from single-value quantity of light-weight floor impact sound for each rooms, it shows that $L'_{n,AW} = 48$ at the living and the master's room, and $L'_{n,AW} = 47$ at the room 1. Therefore, it shows that room 1 have higher reduction effects than living and master's room about 1 dB, respectively.

3.3. Characteristic of Frequency of Floor Impact Sound Level with the Number of Stories

1) Heavy-weight Impact Sound

The impact sound level was measured for the floor system to investigate the reduction effects with the number of stories for high-rise apartment buildings. The evaluation of floor impact sound level

Table 6. Insulation performance of floor impact sound (light-weight)

Type	Location	Octave Band Central Frequency (Hz)					single-value quantity
		125	250	500	1000	2000	
58 (187.9 m^2)	Living room	61.9	55.4	51.4	45.9	43.6	48
	Master's room	61.3	56.0	54.1	49.5	43.8	50
	room 1	61.4	53.9	50.2	45.2	42.7	47
63 (204.1 m^2)	Living room	64.4	58.8	51.1	44.5	32.0	49
	Master's room	59.3	57.0	53.2	42.6	29.2	48
	room 1	58.1	51.3	51.9	41.1	27.5	45
79 (256.0 m^2)	Living room	62.3	55.7	51.4	46.0	38.7	48
	Master's room	58.3	54.0	52.5	47.0	37.5	48
	room 1	57.5	53.2	51.3	47.1	39.9	47

with the number of stories was studied for the 5-story(lower story), 14-story(middle story), and 29-story(upper story).

The characteristic of frequency shows that the floor impact sound level of heavy-weight have the most high value at 63 Hz and the more high frequency, the less low level, that is a typical characteristic of frequency for the heavy-weight impact sound.

The characteristic of frequency of floor impact sound level for living room with the number of stories shows that floor impact sound level for living room of the 29-story have higher reduction effects than those of the 5-story and the 14-story showing that 1.3 dB and 1.2 dB are low at 125 Hz and 0.9 dB and 1.1 dB are low at 250 Hz, respectively. In results from single-value quantity of heavy-weight floor impact sound for each stories, it shows that floor impact sound level for living room of the 29-story have higher reduction effects than those of the 5-story and the 14-story about 1-2 dB showing that $L_{i,Fmax\,AW}$ =47 at the 5-story, $L_{i,Fmax\,AW}$ =48 at the 14-story, and $L_{i,Fmax\,AW}$ =46 at the 29-story.

The characteristic of frequency of floor impact sound level for the master's room with the number of stories shows that floor impact sound level for master's room of the 29-story have higher reduction effects than those of the 5-story and the 14-story showing that 3.1 dB and 3.5 dB are low at 63 Hz, respectively. However, the floor impact sound level for master's room of the 29-story have lower reduction effects than those of the 5-story and the 14-story showing that 2.1 dB and 1.0 dB are high at 125 Hz, respectively. In results from single-value quantity of heavy-weight floor impact sound for each stories, it show that $L_{i,Fmax\,AW}$ =48 at master's room of the 5-story, $L_{i,Fmax\,AW}$=49 at master's room of the 14-story, and $L_{i,Fmax\,AW}$=47 at master's room of the 29-story. Therefore, it show that floor impact sound level for master's room of the 29-story have higher reduction effects than those of the 5-story and the 14-story about 1-2 dB

The characteristic of frequency of floor impact sound level for room 1 with the number of stories show that floor impact sound level for room 1 of the 29-story have higher reduction effects than those of the 5-story and the 14-story showing that 2.5 dB and 1.5 dB are low at 63 Hz, respectively. In results from single-value quantity of heavy-weight floor impact sound for each stories, it shows that $L_{i,Fmax\,AW}$ =48 at room 1 of the 5-story, $L_{i,Fmax\,AW}$ =50 at room 1 of the 14-story, and $L_{i,Fmax\,AW}$ =45 at room 1 of the 29-story. Therefore, it shows that floor impact sound level for room 1 of the 29-story have higher reduction effects than those of the 5-story and the 14-story about 3dB and 5dB, respectively.

Table 7. Insulation performance of floor impact sound with the number of stories (heavy-weight)

Location	No. of stories	Octave band central frequency (Hz)				Single-value quantity
		63	125	250	500	
Living room	5-story	76.5	60.3	47.1	38.8	47
	14-story	76.4	62.1	47.3	37.9	48
	29-story	75.2	59.5	46.2	37.8	46
Master's room	5-story	79.1	60.9	48.4	41.1	48
	14-story	79.5	61.9	49.3	42.2	49
	29-tory	76.0	59.6	50.3	39.7	47
Room 1	5-story	76.4	61.0	50.6	43.4	48
	14-story	75.4	62.4	49.8	40.1	50
	29-story	73.9	59.5	49.5	40.1	45

2) Light-Weight Impact Sound

The characteristic of frequency shows that the floor impact sound level of light-weight have the most high value at 63 Hz and the more high frequency, the less low level, similar to the characteristic of frequency for the heavy-weight impact sound.

The characteristic of frequency of floor impact sound level for living room with the number of stories shows that floor impact sound level for living room of the 29-story have higher reduction effects than those of the 5-story and the 14-story showing that 1.6 dB and 0.6 dB are low at 500 Hz, respectively. However, floor impact sound level for living room of the 29-story have lower reduction effects than those of the 5-story and the 14-story showing that 2.8 dB and 1.2 dB are high at 2000 Hz, respectively. In results from single-value quantity of light-weight floor impact sound for each stories, it show that floor impact sound level for living room of the 29-story and the 14-story have higher reduction effects than those of the 5-story about 1.0 dB showing that $L'_{n,AW}$ =49 at the 5-story, $L'_{n,AW}$ =48 at the 29-story and the 14-story.

The characteristic of frequency of floor impact sound level for master's room with the number of stories shows that floor impact sound level for master's room of the 29-story have higher reduction effects than those of the 5-story and the 14-story showing that 2.9 dB and 1.3 dB are low at 250 Hz, respectively. However, the floor impact sound level for master's room of the 29-story have lower reduction effects than those of the 5-story and the 14-story showing that 1.7 dB and 2.0 dB are high at 2000 Hz, respectively. In results from single-value quantity of light-weight floor impact sound for each stories, it shows that floor impact sound level for master's room of the 29-story have higher reduction effects than those of the 5-story and the 14-story about 4.0 dB and 1.0 dB showing that $L'_{n,AW}$ =51 at the 5-story, $L'_{n,AW}$ =48 at the 14-story and $L'_{n,AW}$ =47 at the 29-story.

The characteristic of frequency of the floor impact sound level for room 1 with the number of stories shows that floor impact sound level for room 1 of the 29-story have higher reduction effects than those of the 5-story and the 14-story showing that 1.6 dB and 3.1 dB are low at 250 Hz, and 3.6 dB and 1.8 dB are low at 500 Hz, respectively. However, floor impact sound level for room 1 of the 29-story have lower reduction effects than those of the 5-story and the 14-story showing that 1.6 dB and 1.5 dB are high at 1000 Hz, and 5.1 dB and 1.6 dB are high at 2000 Hz, respectively. In results from single-value quantity of light-weight floor impact sound for each stories, there are no reduction effects of floor impact sound level for the room 1 with the number of stories showing that $L'_{n,AW}$ =48 at the room 1 of the all story.

Table 8. Insulation performance of floor impact sound with the number of stories (light-weight)

Location	No. of stories	Octave band central frequency (Hz)					Single-value quantity
		125	250	500	1000	2000	
Living room	5-story	62.7	56.3	52.1	45.5	38.6	49
	14-story	62.3	56.1	51.1	46.0	40.2	48
	29-story	62.1	55.5	50.5	46.0	41.4	48
Master's room	5-story	60.6	56.6	55.8	49.2	38.6	51
	14-story	61.3	55.0	51.4	46.0	38.3	48
	29-story	57.0	53.7	51.4	46.3	40.3	47
Room 1	5-story	58.4	53.3	52.5	45.0	36.9	47
	14-story	60.1	54.8	50.7	45.1	40.4	47
	29-story	59.8	51.7	48.9	46.6	42.0	47

4. Conclusions

In this study, the floor impact sound are measured and analyzed to investigate the insulation performance of floor impact sound with the type(P'yong) and the number of stories for high-rise apartment buildings. The following conclusions can be drawn from the results of this study.

1) The evaluation results of single-value quantity using the reverse A characteristic curve for light-weight floor impact sound shows that $L'_{n,AW}$ =46～50 at the living room, $L'_{n,AW}$ =46～55 at the master's room, and $L'_{n,AW}$=44 ～ 49 at the room 1, respectively. And, the evaluation results of single-value quantity using the reverse A characteristic curve for heavy-weight floor impact sound show that $L_{i,Fmax\ AW}$ =43～48 at the living room, $L_{i,Fmax\ AW}$ =47～50 at the master's room, and $L_{i,Fmax\ AW}$ =44～50 at the room 1, respectively. It is evaluated that insulation performances of floor impact sound for measurement buildings are satisfied the code values which are prescribed below 58 dB for light-weight impact sound and below 50 dB for heavy-weight impact sound. According to previous studies, the insulation performance of living room, for relatively large area was inferior to those of master's room and room 1 in the wall-type apartment buildings. However, the results from this study were contrary to previous studies showing that the insulation performance of living room for relatively large areas was superior to those master's room and room 1 in the reinforced concrete frame structures.

2) For heavy-weight floor impact sound, the insulation performances of floor impact sound level for living room which is relatively large area has higher reduction effects than those of master's room and room 1 in all frequency ranges. However, for light-weight floor impact sound, the insulation performance of floor impact sound level for room 1 which is relatively small area has higher reduction effects than those of living room and master's room.

3) The insulation performance of floor impact sound for the each rooms with the number of stories are investigated that the 29-story which is relatively higher story have higher reduction effects than those of the 5-story and 14-story for heavy and light-weight impact sound in all frequency ranges.

Acknowledge

This research**(03R&D 10A1040001-03A0204-00310**) was financially supported by the Ministry of Construction & Transportation of South Korea and **Korea Institute of Construction and Transportation Technology Evaluatio and Planning** , and the authors are grateful to the authorities for their support.

References

1. Korea National Housing Cooperation, A study on the criteria of Indoor noise(I)-Criteria of insulation performance of floor impact sound, 1990.9

2. Sangwoo Lee, Deaup Jeong, Sooyeul Lee, Sangon Cha, A study on the sound insulation performance of steel-structured apartment buildings(I), The korean society for noise and vibration engineering, 2000, 6

3. Sho Kimura, Katsuo Inoue. Practical calculation of floor impact sound by impedence method, Applied acoustics 26(1989), p. 263-292

4. Jaehee Jang, Byung hun Lim, Sang Woo Lee, System Developmemt to reduce Floor Impact Sound in Apartment Houses, JASA, Vol 105, 1999, 2