Classification Criteria of Heavy/Soft Impact Sound

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Summary

Low frequency impact sound is one of the major noise sources in dwellings. In order to measure low frequency impact sound, heavy/soft impact source; rubber ball, was standardized in ISO 10140 series and ISO 16283-2. Previous studies reported that rubber ball has similar physical and subjective characteristics with real floor impact sound such as children's running and jumping. Also, as a single number quantities, $L_{A,Fmax}$ and arithmetic average from 63 Hz to 500 Hz octave bands were proposed. In this study, subjective evaluation on the satisfaction were conducted to propose classification criteria of heavy/soft impact sound. More than 130 people who live in multi-story residential buildings participated and multi-channel loud speakers and subwoofers were used to represent heavy/soft impact sounds which were recorded in various multi-story residential buildings. Subjective evaluation results was analyzed considering classification scheme standardized in ISO/DIS 19488.

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1. Introduction

Low frequency noises from the mechanical equipment, home theatre and foot step in residential building have been increasing. In the case of Korea, the major low frequency sound in apartment buildings is impact sound such as walking, running and jumping. The results of several social survey on floor impact sound shows, low frequency impact was major noise in residential buildings [1]. Social survey results which was conducted in 2006 showed that about 63 % questionnaire was not satisfied on heavy/soft impact sound isolation performance of their apartment buildings [2].

Three kinds of impact sources are now using to evaluate floor impact sound isolation performance. Tapping machine is the most widely used source, simulating high-heel drop. As heavy/soft impact sources rubber ball is used. It was reported that the rubber ball has similar characteristics with child's running and jumping [3].

Heavy/Soft impact source; rubber ball, was included as standard impact source in ISO 10140 series and ISO 16283-2. The rubber ball is now using for test and evaluation of low frequency impact sound isolation performance. Single number quantity and classification on heavy/soft impact sound need to be proposed in ISO standard. In order to propose single number quantity of heavy/soft impact sound, relationship between single number quantity and response on rubber ball impact sound should be checked.

2. Previous studies on subjective responses of rubber ball impact sound

Subjective loudness on rubber ball impact sound was evaluated in Korea using rubber ball impact sounds which were recorded in reinforced concrete structured buildings [4]. Recorded rubber ball impact sound sources were presented through headphone in small listening booth. Subjective responses were compared with 6 kinds of single number quantities. Loudness shows the highest correlation coefficient. A-weighted maximum impact sound pressure level and arithmetic mean value; arithmetic mean of maximum impact sound pressure level from 63 Hz band to 500 Hz band in 1/1 octave band, show good relationship with subjective loudness

Similar study was conducted in Japan [5]. In the case of Japanese study, rubber ball impact sound which was recorded in Japanese wooden houses. They presented recorded impact sound in anechoic chamber using 4 subwoofers. Subjective annoyance was asked to subjects. Japanese study shows the loudness is the best single number quantity and the next was A-weighted maximum sound pressure level. The results of both studies commonly showed that arithmetic mean value and A-weighted maximum impact sound pressure level showed good correlation performance with subjective results in concrete and wooden houses.

Recent studies [6] on subjective responses on rubber ball impact sound show that subjective loudness and annoyance also correlated well with A-weighted maximum impact sound pressure level. In the case of artificially frequency characteristics changed rubber ball impact sound sources, A-weighted maximum impact sound pressure level and arithmetic mean value show good relationship with subjective loudness [7].

Figure 1 Listening room where subjective experiment was conducted

3. Subjective evaluation of rubber ball impact sound

In order to verify previous studies, subjective evaluation of heavy/soft impact sound was conducted. For the subjective evaluation of heavy/soft impact sound, heavy/soft impact sounds were recorded in typical Korean reinforced concrete apartment buildings. Impact sound mainly recorded in the living-room of each unit. The area of each

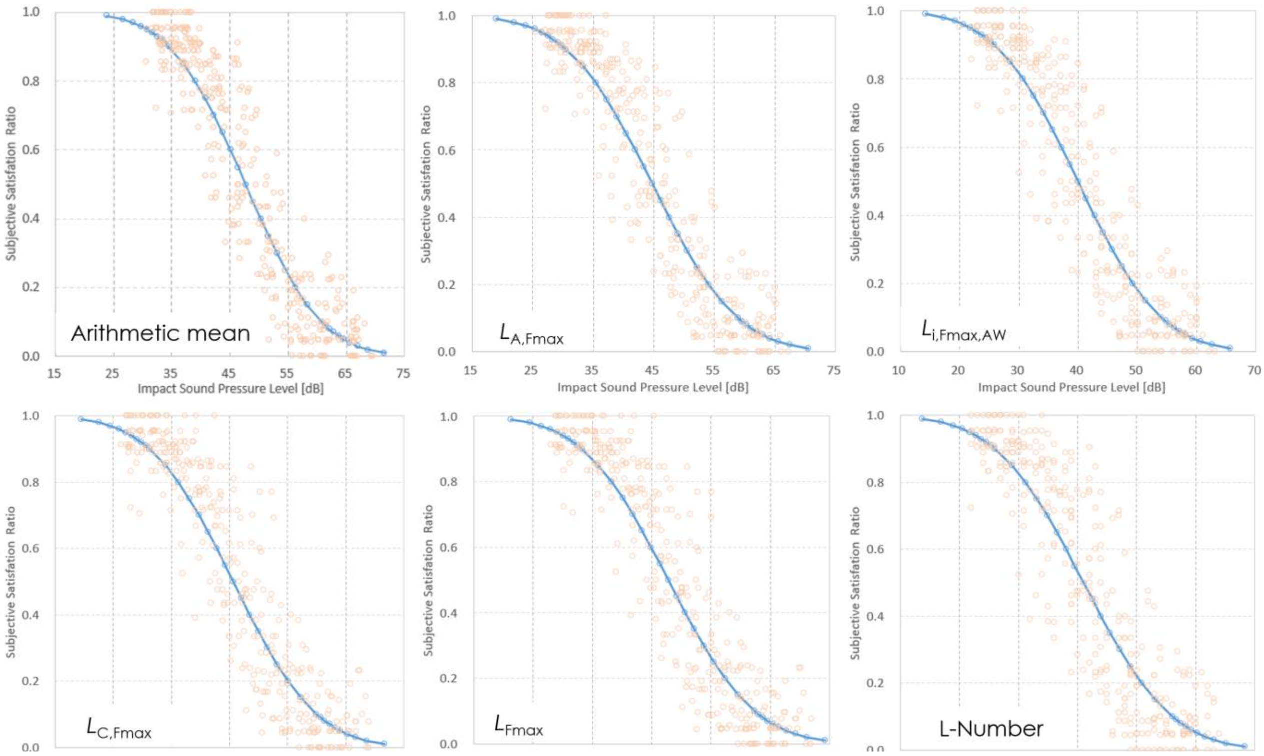

Figure 2 Probit analysis results between subjective satisfaction and six single number quantities

units was from 59 m^2 to 129 m^2. In Korean apartment units, 30 mm and 60 mm thick resilient material was installed to reduce floor impact sound. Rubber ball impact sounds were recorded with 5 microphone positions simultaneously according to KS. Recorded rubber ball impact sound sources were presented in listening room. The listening room was designed and equipped similar with typical living room of Korean apartment. Sofas, table and TV set was placed in the listening room. For the reproducing of low frequency sound 2 subwoofers was used in corner positions. 5 loudspeakers used for presentation of directional feeling of heavy/soft impact sound. 4 or 5 people participated in the subjective test at the same time (See Figure 1). Presented rubber ball impact sound sources were recorded and analyzed at each position. In the experiment, subjective satisfaction was evaluated using 7 point scale method and Yes or No method. 130 subjects participated. Most of the subjects were lived in apartment building. Age of subjects was from 20s to 50s, but mainly in 30s and 40s. For the comparison of subjective responses with single number quantities, 6 kinds of SNQs were calculated. 6 single number quantities were arithmetic mean value, $L_{\mathrm{i,Fmax,AW}}$, $L_{\mathrm{A,Fmax}}$, $L_{\mathrm{C,Fmax}}$, L_{Fmax} and L-Number. Correlation coefficient with subjective satisfaction shows similar result with loudness and annoyance.

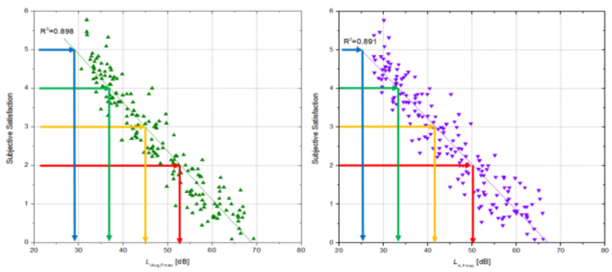

Figure 3 Classification class of rubber ball impact sound based on 7 point scale responses

Table I Impact sound pressure level of each classification class of rubber ball impact sound

Satisfaction	Grade A (5, Very much)	Grade B (4, Quite)	Grade C (3, Relatively)	Grade D (2, A little bit)
Arithmetic mean value	29 dB	37 dB	45 dB	53 dB
$L_{\mathrm{A,Fmax}}$	26 dB	34 dB	42 dB	50 dB

In the case of Yes or No responses, Probit analysis was applied. Six kinds of single number quantities with Yes or No responses were analyzed. As show in Figure 2, arithmetic mean value and A-weighted maximum impact sound pressure level show relatively small dispersion of subjective responses.

From the results of subjective evaluation results using 7 point scale, classification of rubber ball impact sound was calculated (see Figure 3). For the calculation of classification, arithmetic mean and A-weighted maximum impact sound pressure level results was used. In the 7 points scale, subjective satisfaction starts from 2 point. From 2 point to 5 point, 4 grade can be proposed.
2 point means “a little bit satisfy”,
3 point “relatively satisfy”
4 point “quite satisfy”
5 point “very much satisfy”
As shown in Table 1,
Minimum level was 53 dB in arithmetic mean and 50 dB in A-weighted maximum impact sound pressure level. The level difference between grades was 8 dB.

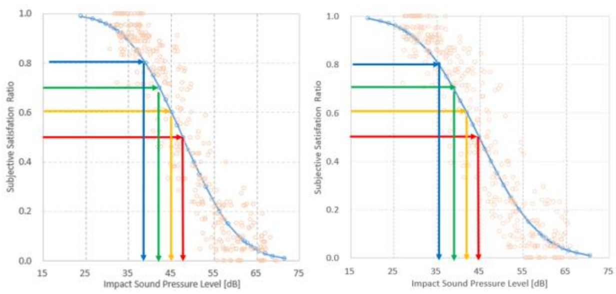

Figure 4 Classification class of rubber ball impact sound based on Yes or No responses

Figure 4 shows the classification from Probit analysis. From these results, we can calculation subjective satisfaction percentage. Minimum grade was 50 % percentage satisfaction. And 60 %, 70 %, and 80 % satisfaction was used. In this case, 50 % satisfaction was 48 dB in arithmetic mean value and 45 dB in A-weighted maximum impact sound pressure level. Both of them had 3 dB difference.
Also, the results from 7 point scale compared in this table. 2 point was estimated as 30% satisfaction. 3 point was 60 %, 4 point was 85 % or 84 %. 5 point was 96 % satisfaction.

4. Conclusions

In this study, subjective evaluation on the satisfaction were conducted to propose classification criteria of heavy/soft impact sound. More than 130 people who live in multi-story residential buildings participated and multi-channel loud speakers and subwoofers were used to

Table II Combined impact sound pressure level and subjective satisfaction of each classification class

Satisfaction	96 % (Very much)	85 ~ 84 % (Quite)	80 % (A)	70 % (B)	60 % (C, Relatively)	50 % (D)	30 % (A little bit)
Arithmetic mean	29 dB	37 dB	39 dB	42 dB	45 dB	48 dB	53 dB
$L_{A,Fmax}$	26 dB	34 dB	35 dB	39 dB	42 dB	45 dB	50 dB

represent heavy/soft impact sounds which were recorded in various multi-story residential buildings. Arithmetic Mean value and A-weighted maximum impact sound pressure level correlate well with subjective responses; Loudness, Annoyance and Satisfaction.
Table 2 shows the combined results of 7 point scale and Yes or No experiments. The satisfaction of rubber ball impact sound was started from 50 dB in A-weighted maximum impact sound pressure level, where about 30 % of subjects satisfied and “a little bit satisfied” in 7 point scale. 50 % satisfaction was set to D grade, 45 dB in A-weighted maximum impact sound pressure level. If the rubber ball impact sound pressure level reduced to 35 dB in A-weighted maximum impact sound pressure level, it can be anticipated from Table 2 that about 80 % of residents will satisfy on the rubber ball impact sound isolation performance of their houses. In order to construct more than 95 % of residents satisfying dwelling, rubber ball impact sound should be reduced to 26 dB.
The results in this paper is on the rubber ball impact sound recorded in reinforced concrete structured apartment buildings in Korea. Similar subjective experiment using rubber ball impact in wooden structured dwelling need to be conducted. Also a comparison on the subjective response between Asian subjects and European subjects need to be checked.

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