24th INTERNATIONAL CONGRESS ON SOUND AND VIBRATION
23–27 July 2017, London

SUBJECTIVE EVALUATION OF HEAVY/SOFT IMPACT SOUND

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Child running and jumping sound are one of the major noise sources in heavy structured apartment building. It was reported that physical characteristics of rubber ball (heavy/soft impact sound) was similar with child's running and jumping. As a standard impact source, rubber ball was standardized in ISO 10140 series and ISO 16283-2. However, evaluation method of rubber ball was not proposed in ISO standard. In order to propose the single number quantity of rubber ball which has good relationship with resident's responses, subjective evaluation was conducted. Rubber ball impact sound were recorded with multi-channel system in nine apartment buildings. Recorded sound sources were reproduced through multi-channel speaker system with subwoofer in a test chamber. More than 100 apartment building residents were participated. Subjective loudness and annoyance were investigated.

Keywords: Heavy/soft impact sound, Single number quantity, Subjective evaluation, Loudness, Annoyance no more than five words

1. Introduction

One of major low-frequency sound, which is generated in dwellings, is floor impact sound. When children run and jump in their houses floor impact sound radiated into the lower unit. It was reported that the rubber ball impact sound is similar with real children's running and jumping sound even adult's walking sound [1]. Also, Jeon et.al reported that physical properties and subjective impression of rubber correlates well with of real heavy/soft impact sound in residential buildings [2]. Subjective loudness evaluation was conducted with rubber ball impact sound which was recorded in concrete structure apartment building and the results were compared with several single number indices [3]. Ryu et, al conducted subjective annoyance experiments with rubber ball impact sound which was measured in Japanese wooden houses, and propose arithmetic mean and Zwicker's percentile loudness and a single number indices [4]. Jeong[5] also compared subjective loudness experiment result with several single number rating method and propose arithmetic mean from 63 Hz to 500 Hz in octave band and $L_{A,FMax}$ as single number quantity of rubber ball impact sound.

In order to measure and evaluate low-frequency floor impact sound, heavy/soft impact sound source; rubber ball, was standardized in ISO 10140-3, 5[6. 7] and ISO 16283-2[8]. Some Asian countries use rubber ball impact source for the development of floor impact sound isolation material, which is specialized in reducing low-frequency impact sound [9, 10]. However, evaluation method such as single number quantity (SNQ) was not proposed and standardized in ISO. In order to propose SNQ of rubber ball impact sound, the proposed SNQ should be well correlated with subjective responses of residents.

In this study, more than 120 subject evaluated subjective loudness and annoyance of rubber ball impact sound recorded in typical Korean apartment unit. Subjective loudness and annoyance results were compared with six single number quantities.

2. Rubber ball impact sound

2.1 Recording of rubber ball impact sound

Rubber ball impact sounds which were used for subjective experiment were recorded in typical reinforced concrete structured Korean multi-story apartment buildings. The area of apartments units were from 59 m^2 wide to 129 m^2 wide. In the apartment unit, resilient materials; from 30 m to 60 mm thick, for the isolation of floor impact sound were installed. All of the rubber ball impact sounds were recorded in living room, because most of children run and jump in living room.

Rubber ball impact sound was recorded using 5 microphones considering multi-channel reproduction system through B&K Pulse recording system. 5 microphone were located in the centre of living room and 4 corner positions. Figure 1 shows frequency characteristics of rubber ball impact sounds. As shown in Figure 1, frequency characteristics of rubber ball impact sound was changed by the resilient material and structural conditions.

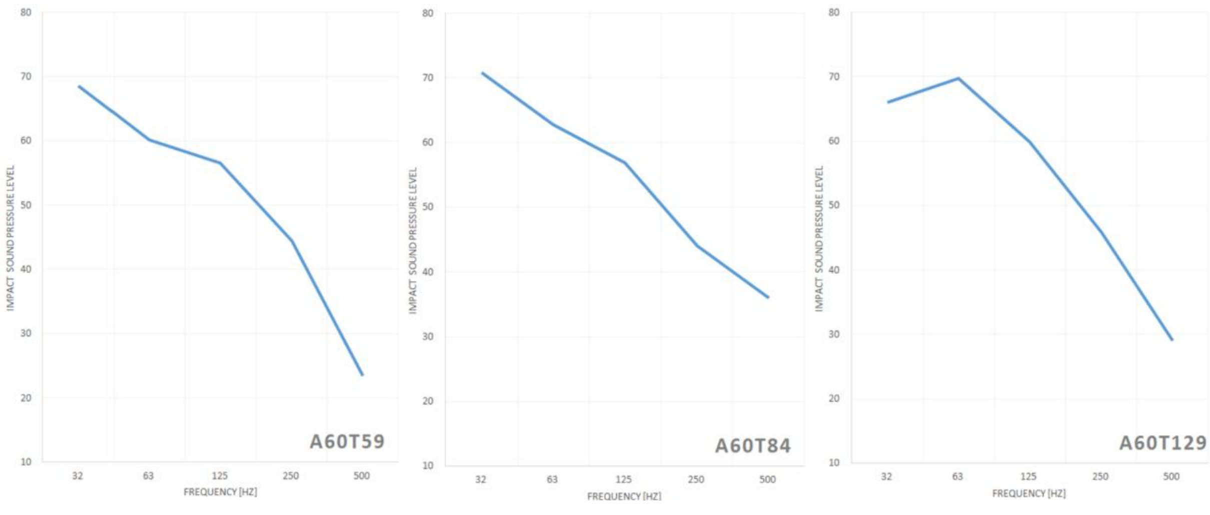

Figure 1: Frequency characteristics of rubber ball impact sounds

2.2 Reproduction of rubber ball impact sound and subjective experiment

For the subjective experiment, multi-channel reproduction system was installed in the about 30 m^2 wide listening room (see Figure 2). Multi-channel reproduction system was consisted with 2 subwoofers and 5 loudspeakers. In order to simulate living room condition in real apartment unit, sofas, lug and TV set was placed in the listening room. 4 or 5 people participated in the subjective experiment at the same time. Reproduced rubber ball impact sounds were recorded and analysed at each position of participants. Reproduced rubber ball impact sound pressure level was distributed from 25 dB to about 70 dB in $L_{A,Fmax}$.

Figure 2: Listening room where subjective experiment was conducted.

Subjective loudness and annoyance were evaluated by participants using 7 point rating scale. 120 subjects were participated in the experiment. All of the subjects were from 20's to 50's and lived in multi-story residential buildings in Seoul and Gyeonggi-do. In order to compare relationship between subjective responses and single number quantities, 6 single number quantities were analysed. 6 single number quantities were arithmetic mean from 63 Hz to 500 Hz level in 1/1 octave band, $L_{A,Fmax}$, $L_{C,Fmax}$, $L_{,Fmax}$, $L_{i,Fmax,AW}$ and L-Number.

3. Results of subjective experiment

Relationship between subjective loudness and six single number quantities were analysed. As shown in Figure 3, arithmetic mean shows the best correlation performance with subjective loudness. The next best single number quantity was $L_{A,Fmax}$. $L_{i,Fmax,AW}$ which is used in Korea as a single number quantity for bang machine shows relatively lower correlation performance.

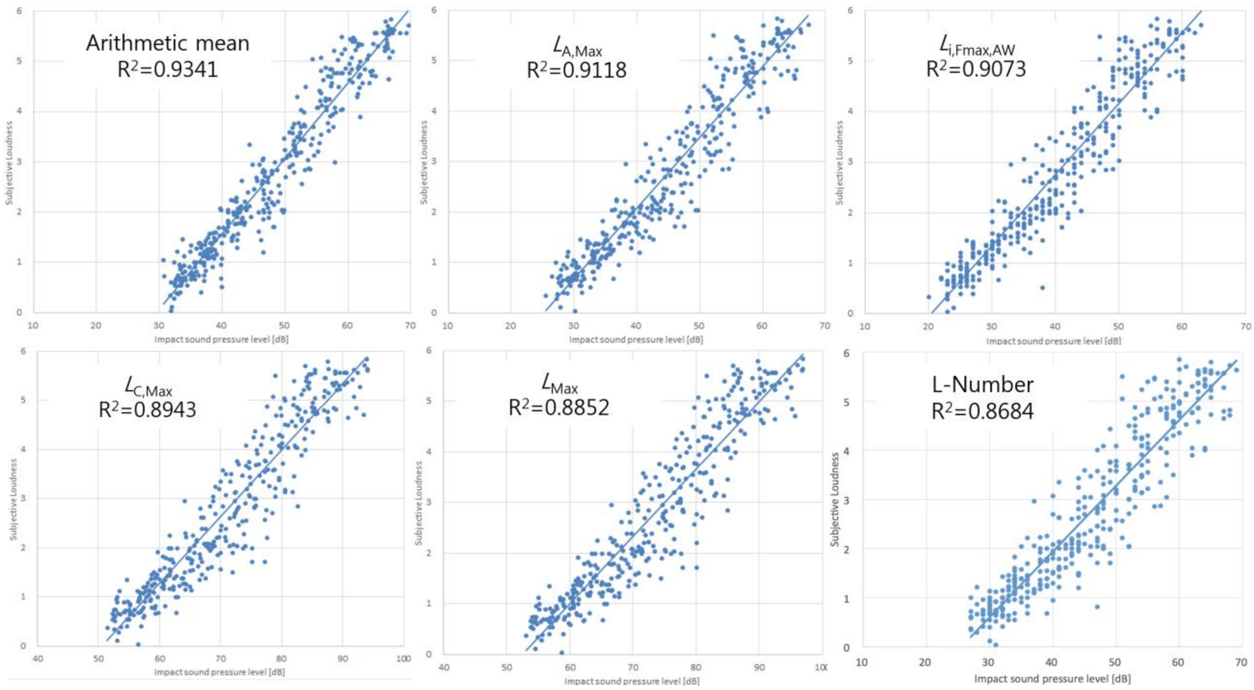

Figure 3: Relationship between subjective loudness and six single number quantities

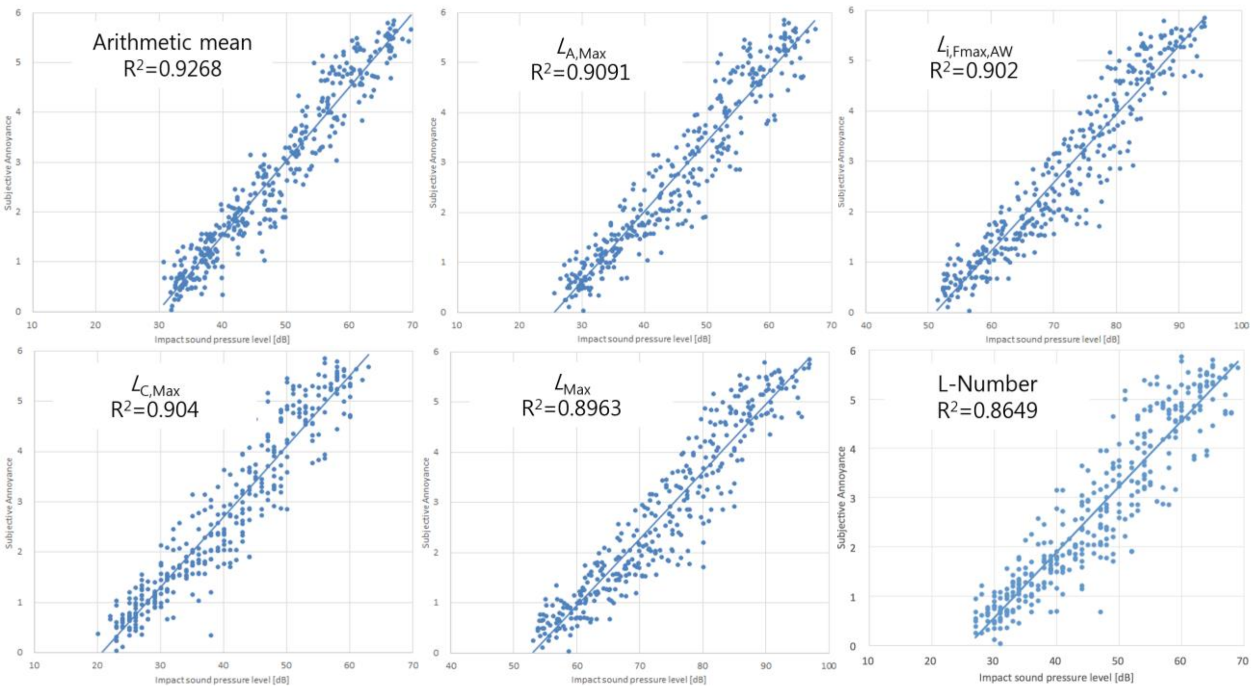

Figure 4: Relationship between subjective annoyance and six single number quantities

Relationship between subjective annoyance and single number quantities were analysed. As shown in Figure 4, arithmetic mean also shows the best correlation performance with subjective annoyance. The next best single number quantity was $L_{A,Fmax}$. L-number which is used in Japan as a single number quantity for bang machine shows lower correlation performance.

4. Conclusions

In this study rubber ball impact sounds from the concrete structured multi-story residential building in Korea were subjectively evaluated using 7 point rating scale. 120 subjects who were lived in multi-story residential building participated in the subjective experiment. Subjective responses; loudness and annoyance, were compared with 6 kinds of single number quantities of rubber ball impact sound. Subjective loudness and annoyance are well correlated with arithmetic mean and $L_{A,Fmax}$. Results of previous studies [3, 4],also show that arithmetic mean and $L_{A,Fmax}$ correlated well, however, the best single number quantity was 5 or 10 percentile Loudness. Recent subjective experiment using frequency component varied rubber ball impact sound also shows that arithmetic mean and $L_{A,Fmax}$ correlate well with subjective loudness [11]. From the results of this study and previous studies, it can be concluded that arithmetic mean and $L_{A,Fmax}$ could be used as single number rating method for rubber ball impact sound in reinforced concrete buildings.

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