

# Loudness evaluation of frequency component varied heavy/soft impact sound

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## Abstract

Floor impact sound is one of the most annoying noise sources in multi-story residential building. People usually do not wear shoes in a floor-heated house, in such cases children's running, jumping and adult walking generate low frequency impact sound. In order to simulate and test low frequency impact sound in multi-story residential buildings, heavy/soft impact source (rubber ball) was standardized in ISO 10140-3, 5 and ISO 16283-2. However there is no single number quantity (SNQ) to evaluate rubber ball impact sound. For the proposition of SNQ on rubber ball impact sound several subject tests were conducted. The most of subjective test focused on level variation.

In this study, frequency component of rubber ball and real impact sound, which were recorded in typical Korean residential building, were varied and presented to the subjects using headphone. Subjective loudness were evaluated and compared with several SNQ such as  $L_{AF,Max}$ ,  $L_{iF,avg,Max}$  and  $L_{iFmax,AW}$ . It was found that  $L_{iF,avg,Max}$  shows higher relationship than other SNQs.

## 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. 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 [1, 2] and ISO 16283-2 [3].

It was reported that the rubber ball impact sound is similar with real children's running and jumping sound even adult's walking sound [4]. 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 [5]. However, evaluation method such as single number quantity (SNQ) was not proposed and standardized. 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, 28 subjects evaluated subjective loudness of rubber ball impact sound recorded in typical Korean apartment unit, which was artificially varied in 1/1 octave frequency band. The subjective loudness was compared with several single number quantities.

## Rubber Ball Impact Sound Recording and Subjective Evaluation

The recording and measurement of the rubber impact sound for the subjective experiment were conducted in the living room of the apartment unit (see Figure 1). When the rubber ball impact sound was recorded, lower unit was fully furnished and upper unit was not furnished. The dummy head was used to record at the center of the living room of lower unit and at the center of the living room of upper unit was impacted.

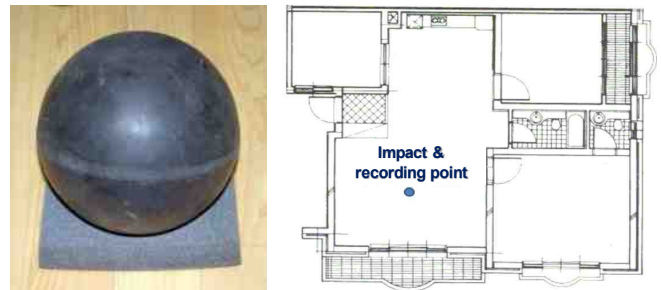


Figure 1: Rubber ball and floor plan of apartment unit where rubber ball impact sound recorded

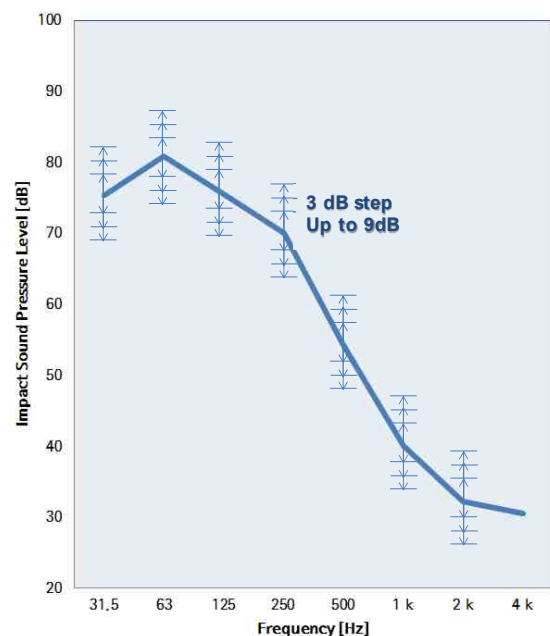


Figure 2: Frequency spectrum of rubber ball impact sound and level variation range in 1/1 octave frequency band

As shown in Figure 2, the level of the octave band of the rubber ball impact sound was varied by 9 dB in 3 dB increments. Loudness was assessed by the subjects'

subjective responses. In order to maintain the reproducibility of the sound source recorded with the dummy head, the sound source was presented to the subject using headphones in a small listening chamber

28 subjects were participated in subjective experiment, all of the subjects were University students and office workers in their 20's. Subjective loudness responses were collected using ME(Magnitude Estimation) method. In order to compare the subjective responses with SNQs, five SNQs was calculated. Five SNQs are as follows. All of the SNQs were based on the maximum impact sound pressure level with Fast time weighting.

- Arithmetic mean (63 Hz ~ 500 Hz in Octave band,  $L_{iFavg,Fmax}$ )
- $L_{iFmax,AW}$
- $L_{AFmax}$
- $L_{CFmax}$
- $L_{Fmax}$

### Results of Subjective Loudness Evaluation

The correlation coefficients between the subjective loudness evaluation results and the five SNQs were analyzed and compared. The results of subjective loudness evaluation on the rubber impact sound evaluation test are shown in Figure 3 ~ 7. The horizontal axes of Figures 3 to 7 are subjective loudness evaluation results, and the vertical axes represent the respective single numerical evaluation values.

As a result of subjective loudness and five SNQs, the arithmetic mean method shows the highest correlation performance( $R^2 = 0.8273$ ). The next best SNQ for rubber ball impact sound was  $L_{A,Fmax}$ ( $R^2 = 0.8135$ ). Relationship between subjective responses and  $L_{i,Fmax,AW}$  was the lowest among these three SNQs( $R^2 = 0.7965$ ).  $L_{CFmax}$  and  $L_{Fmax}$  showed relatively low correlation.

Ryu et al.[6] evaluated subjective annoyance with rubber ball impact sound recorded in Japanese wooden frame residential building and compared with several SNQs. In this study, arithmetic mean and  $L_{A,Fmax}$  correlated well with subjective annoyance. Jeong[7] also reported that both SNQs correlated well with level vaired rubber ball impact sound recored in reinforced concrete structured apartment buildings.

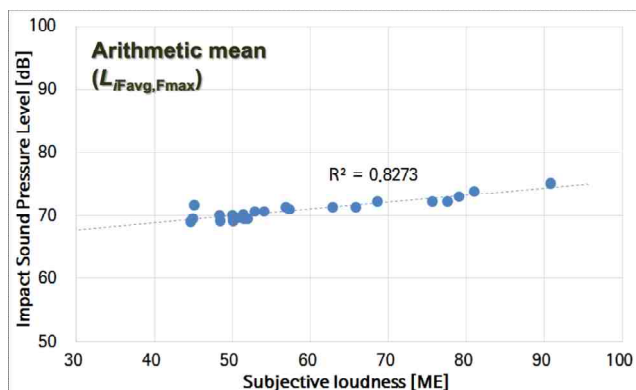


Figure 3: Relationship between Subjective loudness and arithmetic mean value

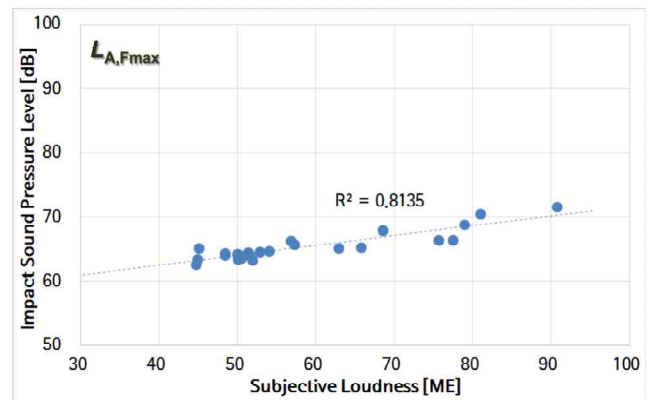


Figure 4: Relationship between Subjective loudness and  $L_{A,Fmax}$

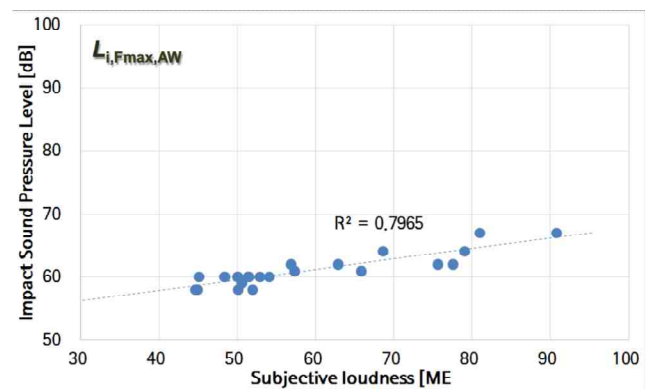


Figure 5: Relationship between Subjective loudness and  $L_{i,Fmax,AW}$

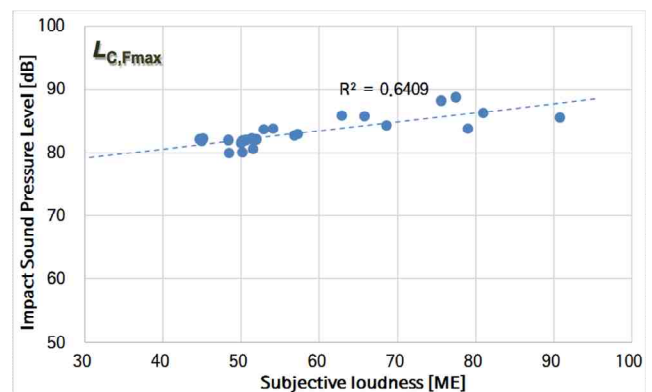


Figure 6: Relationship between Subjective loudness and  $L_{C,Fmax}$

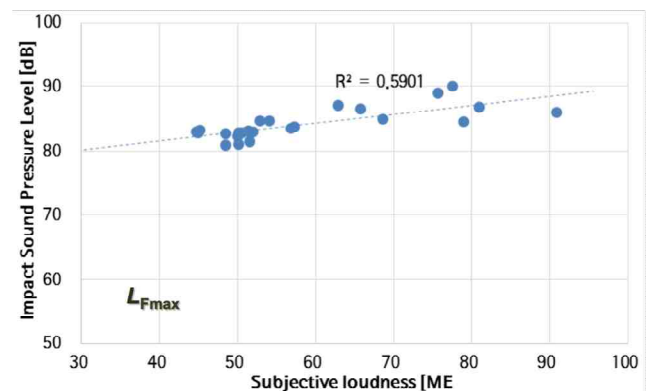


Figure 7: Relationship between Subjective loudness and  $L_{Fmax}$

From the result of this study and previous studies, it can be concluded that arithmetic mean of maximum impact sound pressure level from 63 Hz band to 500 Hz band in octave band and  $L_{A,Fmax}$  show the best and next best correlation performance with subjective loudness and annoyance responses.

## **References**

- [1] ISO 10140-3 Acoustics - Laboratory measurement of sound insulation of building elements - Part 3: Measurement of impact sound insulation
- [2] ISO 10140-5 Acoustics - Laboratory measurement of sound insulation of building elements - Part 5: Requirements for test facilities and equipment
- [3] ISO 16283-2 Acoustics - Field measurement of sound insulation in buildings and of building elements - Part 2: Impact sound insulation
- [4] J. Y. Jeon, J. K. Ryu, J. H. Jeong and H. Tachibana: Review of the Impact Ball in Evaluating Floor Impact Sound. *Acustica* 92 (2006) 777-786.
- [5] J. Y. Jeon, J. H. Jeong, M. Voländer and R. Thaden: Evaluation of Floor Impact Sound Insulation in Reinforced Concrete Buildings. *Acustica* 90 (2004) 313-318.
- [6] J. K. Ryu, H. Sato, K. Kurakata, A. Hiramitsu and T. Hirota: Relation between annoyance and single-number quantities for rating heavy-weight floor impact sound insulation in wooden houses. *J. Acoust. Soc. Am.* 129(5) (2011) 3047-3055.
- [7] J. H. Jeong, Evaluation method of rubber ball impact sound , Euro-Noise 2015.