Classification scheme of floor impact sounds with the standard rubber ball in dwellings

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ABSTRACT

This study presents results of subjective judgments to simulated floor impact sound to create classification scheme of heavy weight impact sound with standardized rubber ball. The floor impact sound samples were recorded in a wood-frame test house with different floor configurations and were reproduced in an anechoic chamber. Using the relationship between subjective rating and physical indices, an example of classification scheme for rubber ball impact sound measurement will be presented.

Keywords: Impact transmission, Classification, Subjective rating

1. INTRODUCTION

The COST action in Europe initiated discussion in ISO/TC 43/SC 2 to create classification scheme of sound insulation performance of dwellings. Although some of the countries are interested in heavy weight floor impact sound with standardized rubber ball, little data were provided and evaluation scheme with the measurement result is still in discussions.

The specification of standardized rubber ball is presented in ISO 10140-5 [1] and originally defined in JIS A 1418-2 [2]. However, relationship between measurement result with the rubber ball and annoyance of daily life is still in discussion. COST TU0901 [3] presents reports of social surveys and results of measurements in several countries. These reports are based on results of questionnaire surveys. There is little information the relationship between result of surveys and objective measurements.

The intention of this study is based on the message of COST TU0901 report, that is "Listening tests and more detailed interviews with residents should be made to find out what reasons there might be behind large discrepancies concerning subjective responses and objective sound insulation properties of the buildings." Based on authors' previous study and some of the studies held in Japan, this paper will present the relationship between complain ratio and single number quantities to evaluate sound insulation performance for heavy weight floor impact sounds.

2. LABORATORY LISTENING TEST TO RATE ANNOYANCE OF FLOOR IMPACT SOUNDS

2.1 Measurement of annoyance response in a living room situations [in2013]

Heavy-weight floor impact sounds were recorded in a mock-up building [4] constructed with wood frame. Different insulation treatments were installed in the floors of each room and walls separating rooms. The tire, the rubber ball, and the jumping by adult with 67 kg weight were utilized

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for heavy-weight floor impact sources. Impact source was driven at the center of the upper floor and at the height of 75 cm for Tire, 100 cm and 10 cm for rubber ball, and about 10 cm for jumping. Total of 56 floor impact sounds were used in the subjective rating.

Forty subjects rated their annoyance ("KININARU" in Japanese) by floor impact sounds presented in random using Japanese 5 category scale [5] with verb at each category; 1. MATTAKU-NAI (not annoy at all), 2.AMARI-NAI (not annoy), 3.TASHO (moderately annoying), 4. DAIBU (very annoying), 5.HIJOUNI (extremely annoying). Subjects were asked to image the situation; "Floor impact sounds were heard from upper unit when you are reading book comfortably in your living room." Measured values were transformed to distance scale. Following two indicators are employed to present the results:

Noticeable Ratio of Annoyance (NRA): This value is calculated as a ratio of sum of "moderately" to "extremely" annoying to all responses. Sum of category 3 to 5.

Complain Ratio (CR): This value is calculated as a ratio of sum of "very" to "extremely" annoying to all responses. Sum of category 4 to 5.

2.2 Measurement of annoyance response in bedroom situations [4]

Two of impact sounds ("A", "B") measured by rubber ball dropped from 1 m height at different impact position on same floor were used. Additionally, one of the impact sounds ("B3") was presented continuously three times at once. Presentation level of these three stimuli were controlled 30 to 64 dB in $L_{iA,Fmax.}$ Thirty stimuli were used in the experiment in total and presented to subject with randomly controlled intervals from 6 s to 9 s in random order for each trial. Seventeen subjects were participated and rated 5 times for each stimulus.

2.3 Measurement of annoyance response in rooms with various structures [6]

The stimuli consists of 32 sounds recorded in buildings, which are reinforced-concrete construction, wood-framed construction and light-weight steel construction, by using binaural recording technique [6]. A tire, a rubber ball, and walking and running by adult were utilized for heavy-weight floor impact sources. Procedure of listening test was more less the same as described in section 2.1 except the number of category of judgments. Fifteen young subjects in their 20s participated in the experiment. The result is presented as unsatisfied ratio, which is same as NRA.

2.4 Relationships between A-weighted maximum sound pressure levels and annoyance responses

Ryu et al. suggested that Zwicker's loudness and previous study presented that A-weighted maximum sound pressure level is well correlated with Zwicker's loudness [7]. Because AIJ is trying to encourage using A-weighted maximum sound pressure level, this study uses $L_{iA,Fmax}$ as physical index.

Number of impact heard at once differentiate annoyance response in bedroom. Result of previous study for wood-frame construction is quite similar to annoyance response of Hamada's study [6] with various structures. Both NRA and CR can be presented with same psychometric function with different shifting factor (7.3 dB shift).

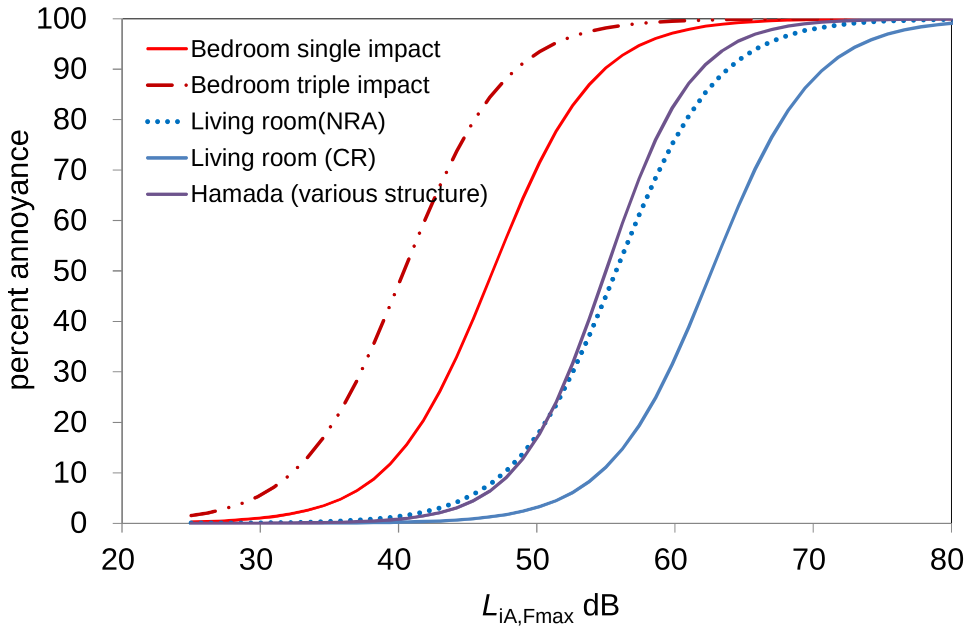

Figure 1 – Relationships between A-weighted maximum sound pressure levels and annoyance responses

3. RELATIONSHIP BETWEEN FLOOR IMPACT SOUNDS MEASURED WITH ISO STANDARD TAPPING MACHINE AND RUBBER BALL.

3.1 Source of data

Field data was obtained from reference literature [8] produced by Urushido et al.. Measurements at 38 points in a building with more than 20 stories multi dwelling RC building. The receiving room had volume of 20 m^3 to 80 m^3 .use as living and dining room or bedroom. The floor construction was 220 mm thick concrete slab covered by wooden floating floor. Two of data from the multi dwelling houses constructed steel-flame building that has three stories. The room volumes of receiving were about 20 m^3 to 30 m^3. In these field measurement, the absorption performance of receiving room has been determined the level indicator L_{abs} of sound absorption area using a reference sound source, that was described in JIS A 1418-1 [9]. The receiving room condition was unfurnished in each room.

Laboratory data was measured in the floor-test rooms at Kobayasi institute of physical research. The receiving room volume is 60 m^3, one test room has 150 mm thick concrete slab and another has 200 mm thickness. The reverberation time of receiving room has been adjusted in 1 s. to 2 s. over 50 Hz to 2000 Hz that is in field use. Some type of floor coverings were used, i.e. 3 mm-vinyl sheet, 7 mm-tile carpet and wooden floating floor with 150 mm air-space.

3.2 Relationship between $L'_{nT,50}$ and $L_{iA,Fmax}$

A single number quantity i.e. $L'_{nT,50}$ was calculated from normalized sound pressure level in the receiving room in one third octave band levels from 50 Hz to 2500 Hz [10]. A-weighted maximum sound pressure level $L_{iA,Fmax}$ was, however, directly measured using sound level meter. Though the highly correlation between direct measured value and converted value from one third octave band levels had made sure by the reference [8], the value of Y-axis was indicated the former values, because for the listening tests described in Chapter 2 took it account.

In Figure 2, the filed data was indicated by the circle symbols (○, ●) and the laboratory data was by the triangle symbols (△, ▲). The unoccupied circles used for the multi-dwelling houses constructed reinforced concrete building, filled circles for steel-flamed building. The unoccupied triangles indicate the impact sound performance of floor coverings, however, the filled triangle for bare slave do not indicate the real situation in dwellings, but it was just in the bottom performance of floor coverings.

The relationship between them was scattered but range of values is similar.

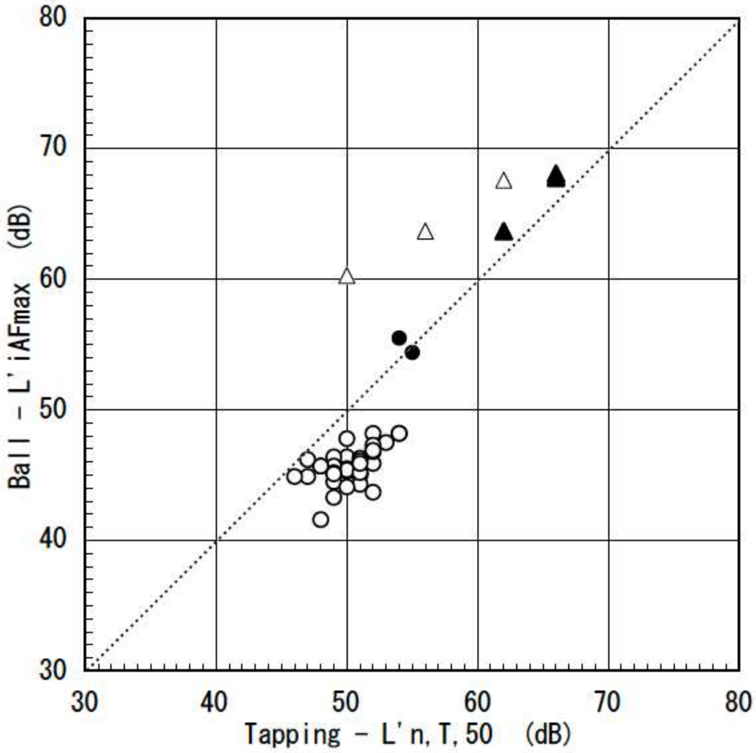

Figure 2 – Relationships between A-weighted maximum sound pressure levels and single number quantity $L'_{nT,50}$.

4. CLASSIFICATION SCHEMES

4.1 AIJ committee proposal of classification scheme for floor impact sound

AIJ (Architecture Institute of Japan) establishes the committee to create AIJ-ES (AIJ Engineering Standard) to evaluate sound insulation performance of multi dwelling houses. In this proposed standard, as described in section 2.4, $L_{iA,Fmax}$ is proposed to be used for evaluation of heavy-weight floor impact sound as single-number quantity [6].

Table 1 – Proposed rating class for heavy weight floor impact sound of dwellings in AIJ

Class	$L_{iA,Fmax}$	Description
1	40	High performance for special requirement
2	45	Recommended performance for usual use
3	50	Acceptable limit for usual use

4.2 Proposed classes in COST-TU0901

COST report presents the basic concept of judging sound insulation performance in terms of human response. Table 2 presents the proposed classes and their descriptions. If these classes would be used in ISO standard, number of classes and percent judgment to create criteria should be well discussed. This study tentatively uses the numbers to show the example to create classification scheme with annoyance responses with laboratory data.

Table 2 – Description of classes for sound insulation performance (from COST Report [3])

Class	General Description	Sound insuration judged poor
A	A quiet atmosphere with a high level of protection against sound	less than 5%
B	Under normal circumstances a good protection without too much restriction to the behaviour of the occupants	around 5%
C	Protection against unbearable disturbance under normal behaviour of the occupants, bearing in mind their neighbours	around 10%
D	Regularly disturbance by noise, even in case of comparable behaviour of occupants, adjusted to neighbours	around 20%
E	Hardly any protection is offered against intruding sounds	around 35%
F	No protection is offered against intruding sounds	50% or more

5. DISCUSSION

5.1 AIJ Class and annoyance rates

Table 3 presents relationships between $L_{iA,Fmax}$, results of experiments and AIJ proposed class presented Table 1. Because Class 1 is for special required case, it suits only for bedroom situation and over quality rating for usual use. Class 1 corresponds Class A for living room and Class D for bedroom in COST report. Class 2 corresponds to Class A for living room and Class E for bedroom in COST report. Class 3 corresponds to Class D for living room and Class F for bedroom in COST report. It is found that “Class” should be situation dependent variable. It is also found that COST Class covered quite wider range than AIJ Class.

Table 3 – AIJ class and annoyance ratio

AIJ Class	$L_{iA,Fmax}$ measured with a JIS rubber ball correspond to AIJ Class	Unsatisfied ratio (%) (Hamada et al.)	NRA(%) in living room situation	NRA(%) in bedroom situation with single impact
1	40	1	1.4	14
2	45	4	6	38
3	50	18	18	71

5.2 COST Class and noticeable ratio of annoyance

In this discussion, the hypnosis, which is that $L'_{nT,50}$ and $L_{iA,Fmax}$ presents same annoyance if both number would be equal. It might be reasonable because range of both indices were almost the same as Chapter 3 presented.

Table 4 presents COST-Class and corresponding NRA in living room and bedroom situations. Table 2 shows that COST-Class ranges 4 to 90 % annoyance range of floor impact sound in living room situations. On the other hand, COST Class A may still presents annoyance to residence in bedroom situation. It can be said that COST is better to have $L'_{nT,50}$ numbers for classification of a bedroom.

Table 4 – COST-Class and corresponding NRA in living room and bedroom situations

Index		Class A	Class B	Class C	Class D	Class E	Class F
(A)	COST Class limits $L'_{nT,50}$ (dB) (Tapping machine)	≤ 44	≤ 48	≤ 52	≤ 56	≤ 60	≤ 64
(B)	NRA(%) in a living room corresponds to (A) (Rubber ball)	≤ 4	≤ 11	≤ 27	≤ 52	≤ 76	≤ 90
(C)	NRA(%) in a bedroom corresponds to (A) (Rubber ball)	≤ 32	≤ 58	≤ 80	≤ 92	≤ 97	≤ 99

6. CONCLUSIONS

The classification scheme of floor impact sound was discussed and following points were revealed:

1) Listening test to rate annoyance response in various situations is essential to discuss about classification scheme.
2) $L_{iA,Fmax}$ measured with rubber ball could be represent annoyance response.
3) COST-Class and $L'_{nT,50}$ presents enough variation to classify floor impact sound with rubber ball if impact sound with tapping machine and that with rubber ball presents same annoyance when their numbers are identical.
4) Relationship between physical numbers and annoyance response varies with situation.

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REFERENCES

[1] ISO 10140-5: 2010, “Acoustics−Laboratory measurement of sound insulation of building element−Part 5: Requirements for test facilities and equipment,” (International Organization for Standardization) Geneva, Switzerland (2010).
[2] JIS A 1418-2: 2000, Acoustics−Measurement of Floor Impact Sound Insulation of Buildings−Part 2: Method Using Standard Heavy Impact Sources (Japanese Industrial Standards, Tokyo, Japan).
[3] COST Action TU0901 "Integrating and Harmonizing Sound Insulation Aspects in Sustainable Urban Housing Constructions -Building acoustics throughout Europe Volume 1: Towards a common framework in building acoustics throughout Europe-," European Corporation in Science and Technology (2014).
[4] Hiroshi SATO, Tomohito HIROTA, Atsuo HIRAMITSU, and Manabu TANAKA, "Subjective evaluation of floor impact sound of wood-frame construction dwellings in different living situation," Proc. INTER-NOISE 2013; 15-18 September 2013; Innsbruck, Austria 2013. paper #1215.
[5] T. Yano, J. Igarashi, J. Kaku, K. Kanda, T. Kaneko, S. Kuwano, Y. Nii, T. Sato, M. Sou, I. Yamada, Y.

Yoshino, “International joint study on the measurement of community response to noise: construction of noise annoyance scale in Japanese,” J. Acoust. Soc. Jpn., 58(2), 101-110, (2002).
[6] Yukio Hamada, Tomotaka Hiramatsu, Shinji Nakazawa and Katsuo Inoue, "Evaluation of heavy-weight floor impact sounds with maximum A-weighted sound pressure level," INTER-NOISE 2011; 4-7 September 2011; Osaka, Japan 2011.
[7] Jongkwan Ryu, Hiroshi Sato, Kenji Kurakata, Atsuo Hiramitsu, Manabu Tanaka, and Tomohito 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), 3047-3055 (2011).
[8] Y. Urushido and M. Abe, “Study on measurement and the calculation method of A-weight floor impact sound level derived from octave band or one-third-octave band measurements (part 2) ,” Proc. of Architectural Acoustics meeting, AA 2014-22, in Japanese.
[9] JIS A 1418-1:2000, Acoustics−Measurement of floor impact sound insulation of buildings−Part 1 : Method using standard light impact source (Japanese Industrial Standards, Tokyo, Japan).
[10] ISO 717-2: 2013, “Acoustics−Rating of Sound Insulation in Buildings and of Building Elements−Part 2: Impact Sound Insulation," (International Organization for Standardization) Geneva, Switzerland (2013).