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The preliminary study on subjective rating of different floors characterised by $L_{n,w}+C_{I,50\text{-}2500}$

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ABSTRACT

The problem of noise in dwellings is topic of large discussions nowadays. Not only airborne noise but also impact noise are responsible for decreased comfort of living. The subjective evaluation of impact noise sounds in dwellings are described in this paper. Listening tests based on method of adjustment (1) with statistically sufficient sample of tested subjects were performed in a listening test room in the laboratory of TGM where subjects compared the performance of acoustically presented floors. Impact noise stimuli were measured as the sound coming through various floor constructions with similar $L_{n,w}$ values, sorted into three main groups: (i) masonry concrete structure, (ii) cross laminated timber (CLT) structure and (iii) light-weight timber structure. Comparisons of listening test performance with calculated single number quantities for each construction were prepared in order to understand the perception of presented sounds by dwellers. The results from this preliminary study are meant as a basis for adjusting of currently applied reference curve also with particular focus on the low frequency range.

Keywords: Sound insulation of floors, sound transmission, impact noise, listening tests, psychoacoustic

1. INTRODUCTION

The impact sound with majority of sound energy in low frequencies, is nowadays perceived as one of the most unwanted noise sources in dwellings. The main reason is the serious impact of noise on human health (2-4). The disturbance of people by impact noise in dwellings was proved also in a large scale study in the framework of the Swedish research project AkuLite, which was running in the years 2009-2013. In one of the performed experiments, walking neighbours were identified as the most annoying noise sources (5). Various single number quantities (SNQs) assessing impact noise performance of floors has been proposed after the study of Bodlund (6) and some of them were introduced in ISO 717-2:2013 (7). Later, modified version of $L_{n,w}+C_{I,50\text{-}2500}$ with increased weight (importance) in frequencies below 50 Hz and above 400 Hz was introduced (8). The questions about subjective perception of impact noise have arisen in the last decade and in 2012 a study of Ljunggren et al dealt with matching of acoustic measurements with subjective judgements (9). In 2017 Kylliäinen

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et al performed an experiment aimed on the impact sound insulation of concrete floors. This experiment showed inconsistency of subjective perception of loudness of impact noise with calculated single number quantities which are standardized in ISO 717-2 – $L'_{n,w}$, $L'_{n,w}+C_I$, $L'_{n,w}+C_{I,50\text{-}2500}$ (10).

In this paper, results of a preliminary study are presented, that show the influence of low frequency content of sound signals on human's perception and judgement of loudness of sounds.

2. DESCRIPTION OF LABORATORY LISTENING TESTS

2.1 Tested subjects

Listening tests were performed by 45 listening subjects. The age of participants ranges between 14 and 63 years. (13 female and 32 male). None of them reported hearing problems. Each listener got the same instruction and explanation prior to the test to ensure the same conditions among them.

2.2 Stimuli used in listening tests

The stimuli were based on sounds recorded in receiving rooms, composed out of 6 steps of a walking person, coming through 9 different floor constructions. These constructions can be sorted into three different groups based on the main bearing structure as (i) heavy-weight concrete ceiling construction, (ii) floor construction based on cross laminated timber (CLT) panels and (iii) light-weight timber beam ceiling construction. The recordings were done under laboratory conditions in test stand for impact noise measurements at the facilities of TGM Vienna Acoustic Center Austria and in situ situations with low noise microphones placed 1 m from the ceiling: 1"-Condensermikrophon (Type Brüel & Kjaer 4179 with Preamp Typ 2660) recorded on a SQuadriga II (Code 330), from Head Acoustics. Reverberation time in receiving room was adopted (if necessary) by sound absorption material to mimic conditions of an ordinary living room, i.e. T_{30} = 0.36 s. List and description of all measured ceilings is shown in Table 1. The recordings were arranged into the pairs according to the similar performance in terms of parameter $L_{n,w}+C_{I,50\text{-}2500}$, with maximal difference of 1 dB, since the so called just noticeable difference of sound level for low levels does not exceed 1 dB (11). Frequency spectra of considered ceiling sorted into pairs are shown in Figure 1.

Table 1 – Ceiling constructions used as "filters" for sound recordings

Code	Type of construction	$L_{n,w}$ / dB	$L_{n,w}+C_{I,50\text{-}2500}$ / dB
CON1	Concrete Concrete standard floor with floating concrete floor with different kind of impact sound insulation material (polystyrene or mineral-wool) and gravel pouring	54	56
CON2		51	52
CON4		50	54
BSP1	CLT Cross laminated timber with different kind of floating floors (dry screed or concrete) with mineral-wool impact sound insulation slabs on gravel pouring, without suspended ceiling	50	56
BSP3		42	52
BSP4		50	53
HBD7	Light weight timber frame Light weight timber frame floor constructions with different kind of floating floors (concrete or dry screed elements) on mineral-wool impact sound insulation slabs and different kind of suspended ceilings	50	56
HBD8		43	52
HBDS		41	54

2.3 Description of room used for listening tests

Laboratory listening tests were performed in a silent environment in the listening test room at TGM – Die Schule der Technik, Vienna, Austria. To ensure the low background noise level the use of professional high-quality perception room is essential, since low level stimuli were presented during the listening test. The measured overall A-weighted background noise level inside the room was $L_{A,eq}$ = 17 dBA (measurement performed with Norsonic NOR 840 real time sound level analyser with a class 1 and B&K low-noise microphone). This room is furnished to be like a pleasant environment of a living room. All equipment which could possibly emit disturbing noise is placed outside in a neighboring control room – computer, second screen, etc. Thanks to that, the operator could stay outside of the room and was able to control the whole listening tests procedure. The 2nd order ambisonic loudspeaker system which allows to choose any combination of presenting loudspeakers is installed in this room.

2.4 Listening tests procedure

The performed listening tests were based on method of adjustment (1). The sound stimuli were presented via loudspeakers from the installed ambisonic system (EVE Audio SC204) to reproduce sound coming from the ceiling to tested subjects. The low frequency content of the played stimuli was presented via two low frequency loudspeakers (EVE Audio TS110) hidden behind the test person. During the listening test, pairs of signals were played and subjects were asked to adjust the loudness of a second stimulus to sound as loud as the reference signal. Altogether 13 comparisons were presented in one test set - six were formed by pairs according to the above described rule played in random order twice as A-B, B-A, to avoid a possible bias. An additional 7th pair contained two identical stimuli (HBD8) which were used for “calibration reason”, in other words, to understand the uncertainty of measurement by asking people to adjust two identical sounds to the same loudness.

Each test subject was seated inside the listening room and was able to control the whole test with a tablet connected to the computer in the control room using graphical user interface (GUI) of the prepared test routine showed in Figure2. Each test set took around 15-20 minutes. Each subject has performed the listening test only once.

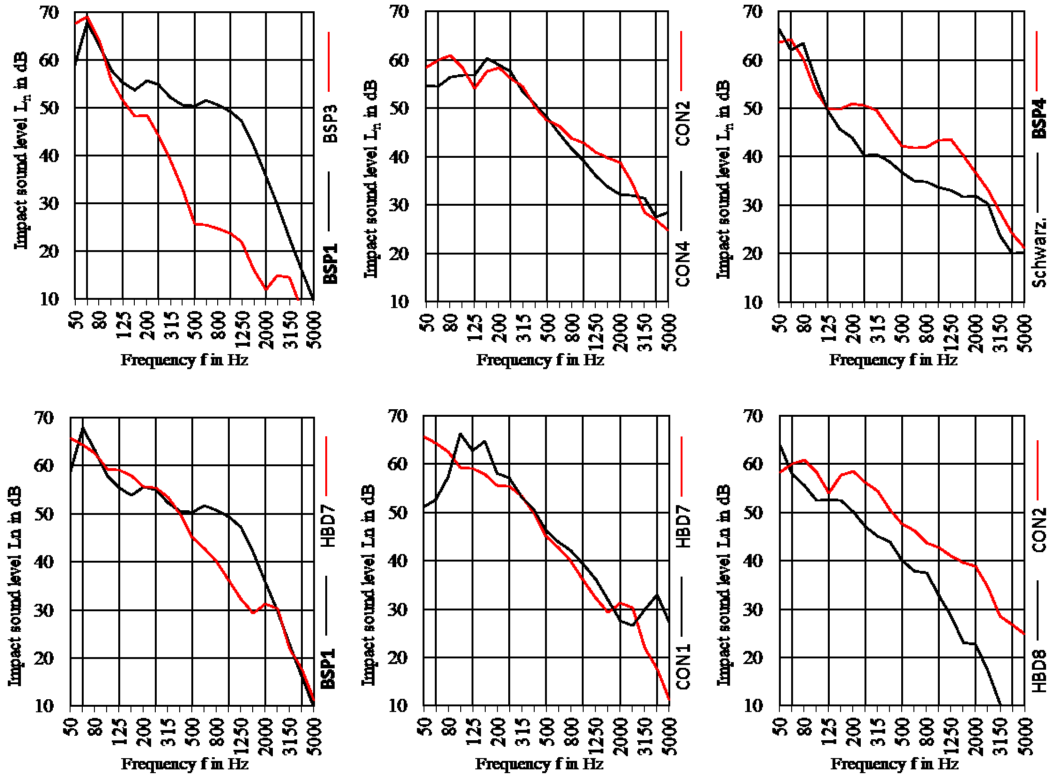

Figure 1 – Frequency spectra for impact sound level L_n of used floor constructions

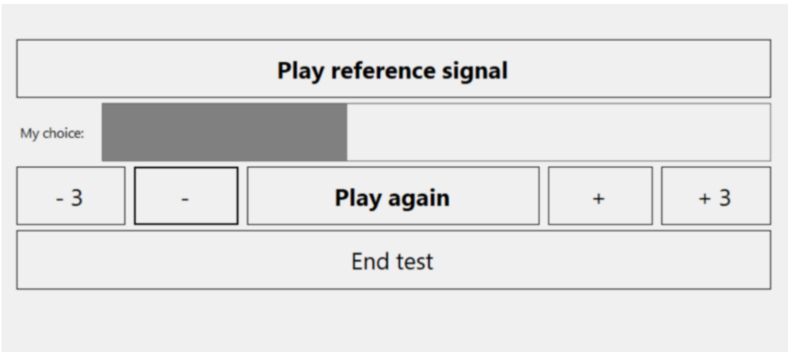

Figure 2 – Graphical users interface of listening test

3. RESULTS AND DISCUSSION

Distribution of answers obtained from listening tests shown below are expressed in percentage of given answers (Figures 3-5). The *x* axis shows values of sound pressure level in dB as following: The red line indicates the objectively measured value of $L_{n,w}+C_{I,50\text{-}2500}$ and the blue bars shows answers of subjects, obtained as adjusted sound level of given signal to reference signal (to be perceived equally loud). Data are analyzed per each pair (defined earlier in this paper) one by one.

Results for the so called “calibration pair” which consists of two identical stimuli (HBD8) are shown in the Figure 3. Ideally all answers should be identical with the red line, since the two sounds were equally loud. Based on the obtained answers it can be concluded, that the data form a nice gaussian distribution around the “correct answer” and a slight shift towards lower values is observed, which means that people have adjusted the signal slightly louder (in average 1-2 dB) than the reference signal. It can be concluded, that almost all subjects were able to set the loudness of the second stimuli almost correctly to $L_{n,w}+C_{I,50\text{-}2500}$ = 53 dB, with a deviation of max. 5 dB. Almost half of the people made an error less than 1 dB. Answers of all persons with error > 5 dB in the calibration test were excluded from the final analysis.

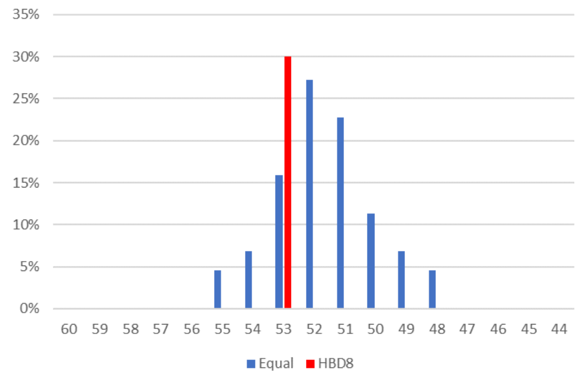

Figure 3 – Distribution of answers for “test” of test subjects which were taken into account for the analysis compared with calculated values of $L_{n,w}+C_{I,50\text{-}2500}$

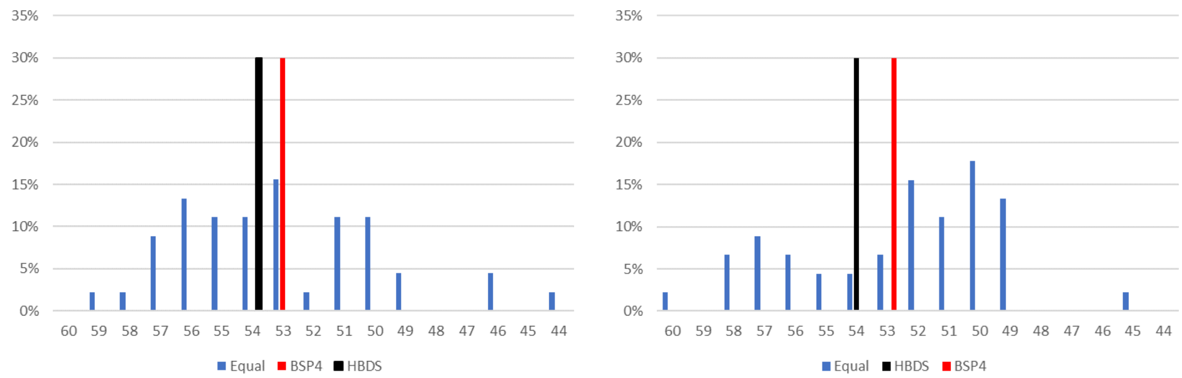

Figure 4 Left - Distribution of answers for pair BSP4 - HBDS compared with calculated values of $L_{n,w}+C_{I,50\text{-}2500}$, Right - example of HBDS – BSP4

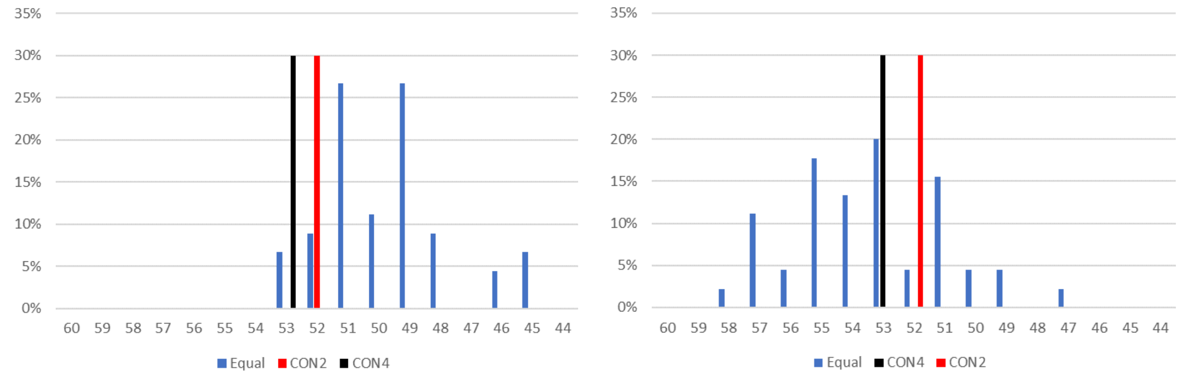

Figure 5 Left - Distribution of answers for pair CON2 – CON4 compared with calculated values of $L_{n,w}+C_{I,50\text{-}2500}$, Right - example of CON4 – CON2

When analyzing pairs one by one, different trends were observed. In several cases a large spread in data was seen.

The comparison between BSP4 and HBDS is given in the Figure 4. The reference signal (HBDS) $L_{\mathrm{n,w}}+C_{\mathrm{I,50\text{-}2500}}$ = 52dB is drawn in red and the sound signal that subjects were adjusting (BSP4) is indicated in black color. Answers of people are in blue.

Based on the obtained results, and the large spread of answers it cannot be concluded, that single number quanity $L_{\mathrm{n,w}}+C_{\mathrm{I,50\text{-}2500}}$ corresponds with subjective perception the best.

Furthermore a number of research questions arises, such as :

On which bases people take decision about the loudness of 6 consequently arriving impulsive sounds? Do they take the average value, or do they take the loudest step or the last they hear into comparison?

The statistical distribution of all answers (from all pairs) shows two groups of answers. First one from people who were deciding about the loudness level based on low frequency components and second one, that decided based on differences in high frequencies. Deeper analysis is therefore necessary in more detail, in which also individually recorded steps need to be analysed, maybe compared with recorded sound from standardized rubber ball.

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