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Subjective and objective acoustic performance ranking of heavy and light weight walls

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ABSTRACT

This study presents a comparison between heavyweight and lightweight walls, in terms of perceived loudness of pink noise transmitted through 10 different walls. The objective is to investigate whether the single number descriptor $R_{A,50-5000}$ adequately reflects the subjective perception of the acoustic performance of a wall and if the sound reduction index spectral behaviour affects the subjective rating. To perform the experiment, a Matlab® based digital tool was developed and a pairwise comparison listening test was performed in laboratory conditions with thirty three subjects. The sound samples consisted of only one stimulus – pink noise-, filtered by the sound reduction index spectrum of 5 heavy weight walls and 5 corresponding lightweight walls with the same $R_{A,50-5000}$ but different R_w.

The results were analysed and used to rank the walls from best to worst according to the perceived loudness of the sound samples. It has been shown that lightweight walls are better ranked than heavy walls, not only when compared to those with the same $R_{A,50-5000}$, but in some cases also when the $R_{A,50-5000}$ of the heavy wall is higher than the $R_{A,50-5000}$ of the lightweight one. Furthermore, the ranking obtained from the listening test results matches very well with the ranking made according to $R_w + C \approx R_{A,100-3150}$.

1. Introduction

In the last years, a scenario of renovation in the field of building acoustics resulted in the revision of many International Standards. Concerning laboratory sound insulation measurements, the revised ISO10140 series [1] was launched in 2010, and the in-situ sound insulation measurements series ISO 16283 [2,3] is almost finalized (part 3 to be published early 2016). Regarding sound insulation ratings, there was an intention to review the ISO 717 [4–6] aiming at optimizing the evaluation method at different levels: simplifying the calculation methods, reducing the amount of existing descriptors, identifying which single number ratings correlate better with the perceived annoyance, and taking into account the low frequency components of sound sources in households. Furthermore, this revision partly inspired the harmonization of sound insulation descriptors suggested by the European research and networking project COST Action TU0901 [7].

Nevertheless, given the lack of agreement among the participant countries and the need for more research, the standard proposal [8] was finally cancelled and the project postponed until more evidences in this field are available.

The idea of delivering better sound insulation ratings is a result of the interaction between new technical and social demands. The main characteristic desired is that descriptors *"should be better, or more accurate indicators of the acceptability of the sound insulation"* [9] by the people. To assess the acoustics performance of buildings and at the same time evaluate building occupants comfort using a unique single number rating is an important goal in the building acoustics research field [10–13].

One of the most controversial proposals of the extinct ISO/CD 16717 draft was to extend the frequency range used for airborne sound insulation assessment below 100 Hz. The proposed extension of the assessment frequency range intended to provide a better correlation between the objective acoustic performance of the construction solutions, and the subjective perception of the users, related to annoyance.

Over the last years important research has been initiated in this field [10,13–18]. Still there is no consensus on how to adequately

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include the lower frequency range in to the assessment of airborne sound insulation.

2. Objective

The main purpose of this research is to provide new evidence in the field of subjective perception of acoustic performance of different construction solutions.

The specific objective of the designed listening test is to investigate how people would rank ten different walls from best to worst based on perceived loudness and to compare such ranking to the one obtained using the objective sound insulation descriptor $R_{A,50-5000}$.

In this case study the set of walls consisted of five pairs of heavyweight and lightweight walls, each pair with the same $R_{A,50-5000}$ but different $R_{w,}$ similar to experiment performed in [19]. In the aforementioned paper, however, the comparisons were done only within pairs and not between pairs, and the main focus was placed on understanding the differences between temporal and spectral features of stimuli.

The subjective evaluation was carried out by listening tests performed in a laboratory. All the details related to the test are further described in Section 3.

3. Listening tests

3.1. Listening protocol

The participants were comfortably seated in a low background noise environment, a semi anechoic chamber. They listened to the audio stimuli through headphones.

The audio stimuli were obtained by filtering pink noise through the extended frequency spectrum of the sound reduction index (SRI) of 10 different partition walls (details in Section 5.1). This procedure assumes that, when listening, only direct transmission occurs.

The 10 different stimuli were presented to the participants in pairs, making all possible combinations in random order. The task of participants was to indicate which of the two presented sounds was louder. After validating the significance of the data and analysing them adequately, a ranking from best to worst sound insulation as perceived by subjects in terms of loudness was delivered.

3.2. Laboratory

The experiment took place at two different locations: the semi anechoic chamber at the Laboratory of Acoustics at KU Leuven, Belgium (from now on KUL) and the semi anechoic chamber of the School of Industrial Engineering of Universidad de Valladolid-Spain (from now on UVa).

Both at KUL and UVa tests, all the electronic equipment involved in the test was placed in an adjacent room, assigned as control room (Fig. 1). Inside the semi anechoic chambers there was only a screen, a mouse, a signal amplifier and the headphones, so there was no noticeable source of noise. According to measurements performed by the authors, the background noise level inside the semi-anechoic chambers was $SPL_{Background\ (UVa)} < 17$ dB and $SPL_{Background\ (KUL)} < 0$ dB. At the control room there was another screen and mouse so that the test tool could be operated/followed from both rooms. This allows the experimenter to set up the test, and to monitor the progress of the participant without entering the test chamber.

3.3. Equipment

The equipment used for both experiments is listed in Table 1. It should be noted that in both experiments, open-back headphones were used because of their particular characteristics. The perforated shells allow certain sound leakage, delivering a much wider sound spatiality, which is desirable for the purpose of the test.

Not only the headphones were selected based on quality requirements, but also all the other elements of electroacoustic chain. Precise equipment was necessary as some stimuli could be reproduced with a very low level (when the basic stimulus was filtered by walls with a high sound insulation performance), and electric noise from electroacoustic devices might be an issue.

A dummy head and torso were used for test calibration which is further described in Section 4.

3.4. Subjects

Thirty three normal hearing participants took part on the experiment: 11 at KUL – Belgium and 22 at UVa – Spain; 12 female, 21 male. Demographic data can be observed in Fig. 2. The participants are not representative of Belgian or Spanish population. The statistical analysis performed in Section 6.1 demonstrates the reliability

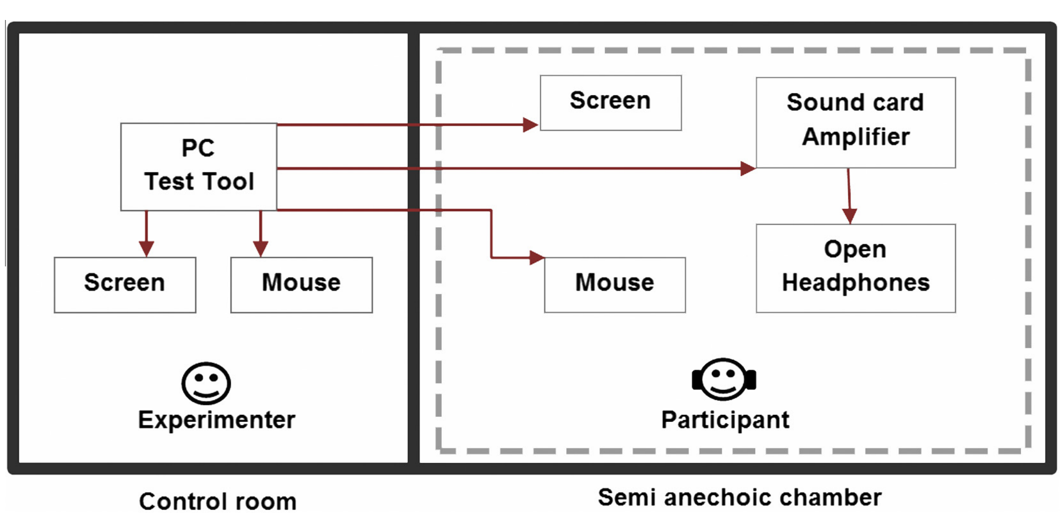

Fig. 1. Test set up.