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Walking sound annoyance vs. impact sound insulation from 20 Hz

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ABSTRACT

There is a need to develop single number quantities (SNQ) of impact sound insulation that correlate better with walking sound annoyance. Previous research has indicated that impact sound insulation should be evaluated from 20 Hz in lightweight constructions, using modified spectrum adaptation terms. The purpose of our study was to verify whether frequencies between 20 and 50 Hz are important for perceived walking sound annoyance and to verify whether the proposed spectrum adaptation terms improve correlation with perceived walking sound annoyance. Binaural recordings of walking sound in one heavy and one lightweight construction were evaluated in a two-part listening test. The need to include frequencies from 20 Hz when evaluating lightweight constructions was verified. Both tested constructions achieved similar performance in terms of $L'_{nT,w}$ and $L'_{nT,w} + C_{I,50\text{-}2500}$, while a significant mismatch in the rated annoyance was observed. The correlation between SNQ and subjective response was considerably improved, when the impact sound insulation was evaluated from 20 or 25 Hz using a flat frequency-weighting factor.

1. Introduction

Due to fire risk, multifamily lightweight wooden dwellings higher than two stories were not permitted in Sweden until 1994. From that time, sound insulation requirements were stated from 100 Hz. However, impact sound insulation was identified as a serious low frequency problem in lightweight structures [1–3]. The national requirements were modified in 1999 to include frequencies down to 50 Hz, creating satisfactory design guidelines based on current knowledge at that time. The demand for lightweight wooden based multifamily dwelling houses have increased steadily for the last two decades. However, walking sound still tends to be rated as more annoying by residents of lightweight constructions compared to heavy constructions, even with identical single number quantity (SNQ) in an extended frequency range [3]. Thus, there is a need to develop new SNQs with stronger correlation between subjective rating of walking sound and weighted impact sound insulation that work both for lightweight and heavy constructions. The low frequency problem was treated in the Swedish research program AkuLite (2009–2013) [4], where common noise sources in Swedish dwellings were evaluated in a questionnaire survey. Walking neighbours was identified as the most annoying noise source, by margin. An extension of the frequency range down to 20 Hz regarding the evaluation of impact sound insulation was proposed. Ljunggren et al [5] suggested a modified version of $L'_{n,w} + C_{I,50\text{-}2500}$ with increased weight on frequencies below 50 Hz and above 400 Hz, in terms of $L'_{n,w} + C_{I,AkuLite,20\text{-}2500}$ resulting in a much stronger correlation with subjective annoyance. Consequently, evaluation from 20 Hz was in 2015 included in the Swedish standard [6] as a recommendation for higher sound classes in dwellings. An important difference between Ljunggren's method and the Swedish standard is that Ljunggren included normalisation of reverberation time between 20 and 40 Hz – a linear extension of ISO16283-2 [7], with reverberation time below 50 Hz measured in octave bands – whereas it was omitted in the Swedish standard.

Kylliäinen et al. [8,9] indicated that frequencies 50–100 Hz are important when determining the impact sound insulation in heavy constructions. They indicated a need for a new SNQ to improve the correlation between walking sounds with socks, and objective and subjective ratings respectively. These conclusions are also valid for lightweight constructions, which in general are more sensitive to low frequency performance compared to the investigated concrete constructions. In a Norwegian study by Milford, Hosoien et al. [10,11], a large database of 900 field measurements and 702 questionnaire respondents was used to correlate objective parameters with subjective responses. It was shown that walking sound and traffic noise were the most dominant sources of annoyance. They concluded that frequencies down to 50 Hz are essential to achieve good correlation between impact sound insulation and subjective response. Low frequency issues were apparent not only for lightweight constructions, but also for concrete constructions involving floating floors. These results are typical for the

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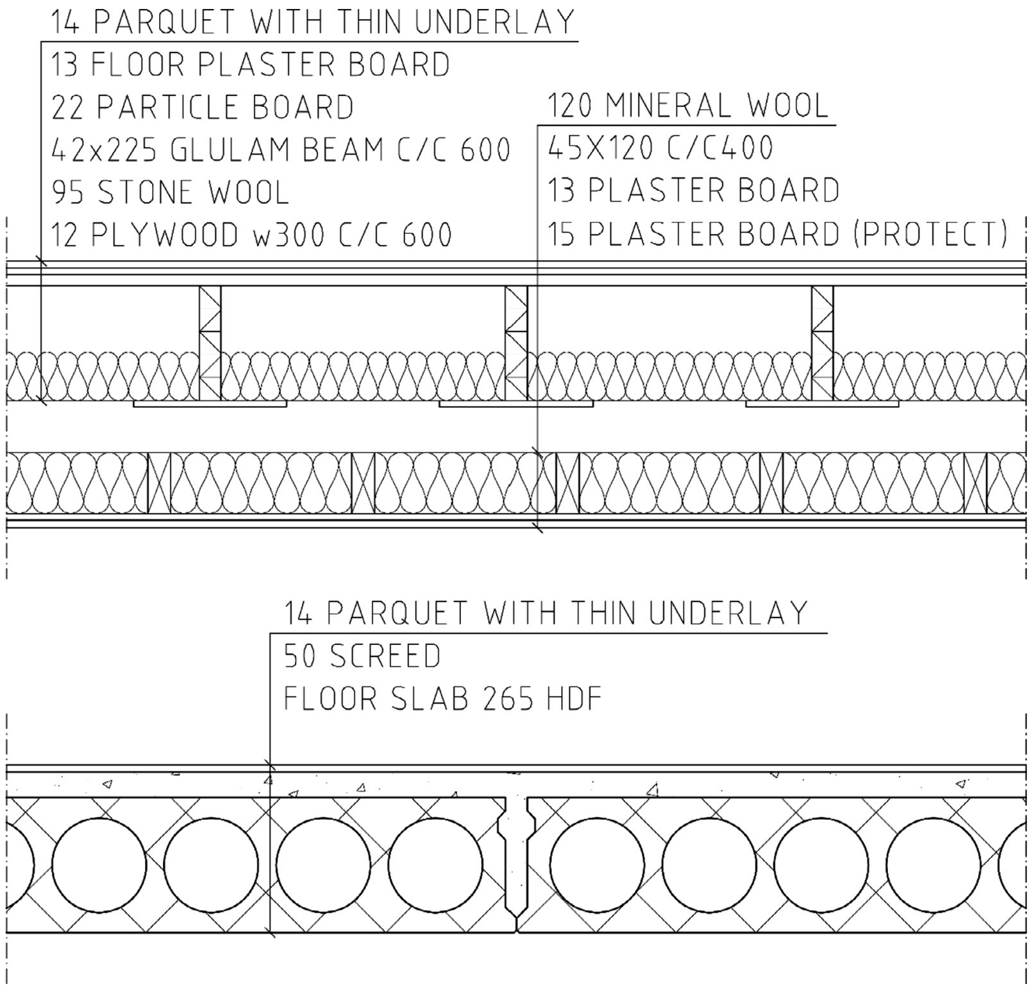

Fig. 1. Description of the two constructions used in the listening test. Top: wooden, Bottom: concrete.

Nordic countries, where walking without shoes is the norm at home. Blazier and DuPree [12], noted that sound detectability seemed to be more important to perceived annoyance, rather than relative loudness. Since low-frequency walking sounds are not masked by ordinary background noise, they are easy to detect. In lightweight constructions, low-frequency footfall noise is normally above the hearing threshold.

It is necessary to correlate objective and subjective data to develop better criteria for evaluation of impact sound insulation. Field measurements and questionnaires are important and can be complemented with listening tests. With laboratory listening tests, it is possible to expose the test subjects to exactly the same sounds under strictly controlled conditions. Subtle differences can thus be detected reliably. However, in listening tests dealing with sound insulation in dwellings there is always a risk that the test takes the character of a loudness test instead of an annoyance test. Sound annoyance has more components than simply loudness. For example, complaints on self-produced noise is rare compared to noise from neighbours even though the sound level of the latter is certainly lower in absolute terms. Mortensen [13] claimed that the annoyance rating varies with age and gender. Jeon et.al. [14] used a listening test with two groups of German and Korean subjects to show that culture could also be important for subjective annoyance in both heavy and lightweight constructions. Absolute scaling of annoyance is difficult to study in a listening test, as annoyance can develop for several months or years. Therefore, questionnaires are better suited to study the degree of absolute annoyance. These inherent advantages and drawbacks of building acoustic listening tests are thoroughly covered in [15].

The gait is another important factor for the walking sound level in the receiving room. A more flexible floor may make the walker walk harder on the heels, compared to a stiff, solid floor. This factor is relevant for comparisons of heavy and lightweight constructions. Blazier and DuPree [12] showed that different footwear was a significant factor on the low frequency content of the sound. Mortensen [13] concluded in a listening test that frequencies below 100 Hz are important for subjective evaluation of loudness of noise from neighbours (both impact and airborne sound), especially for lightweight constructions. A laboratory listening test was performed within AkuLite by Thorsson [16], to study the perceived annoyance and loudness of recorded walking sounds, for a lightweight and a heavy construction. It was concluded that walking sound includes important information below 50 Hz. Thorsson performed two equal tests, each evaluating perceived loudness and annoyance respectively. He could not identify any difference in subjective rating between his two choices of words. Other studies have also indicated that loudness and annoyance ratings provide similar information from subjects regarding airborne [17] and impact [9] sound insulation, although the latter study presented slightly higher ratings for annoyance compared to loudness. On the other hand, Rychtáriková [18] performed a listening test of airborne sound insulation through heavy and lightweight walls, evaluating perceived loudness of neighbour sounds. After the test, the subjects gave feedback using open questions, where 31 out of 39 subjects commented that they would sometimes have answered differently if they had been asked to rate annoyance rather than loudness. The choice of words can thus be critical for the outcome of a listening test.

1.1. Objectives

Our study takes off from the findings of AkuLite [5,16] and Aku20