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Satisfaction with sound insulation in residential dwellings – The effect of wall construction

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ABSTRACT

Aim: The aim of this study was to compare the acoustic satisfaction in residential multi-storey buildings with different wall constructions with a similar weighted sound reduction index R'_w: Heavy construction (monolithic concrete walls) and Light construction (staggered double walls). Light constructions are known to have a lower sound insulation especially at low frequencies. Our research question was does this difference affect the overall acoustic satisfaction among occupants.

Materials and methods: Four and two residential multi-storey buildings were chosen to represent building types Heavy and Light, respectively. A questionnaire was distributed to each dwelling. Seventy-two and eighty-seven respondents were obtained, respectively, with response rates of 62% and 54%. Some sound insulation measurements were carried out for verification purposes.

Results: As expected, the airborne sound insulation was worse below 160 Hz in building type Light, while the R'_w values were nearly equal, 56–57 dB. The satisfaction with sound insulation did not differ between the two building types. All neighbour noise sources were rated equally disturbing in both building types. The building types did differ from each other with respect to the effects of noise on sleep.

Conclusions: The results suggest that when the airborne sound insulation is close to 55 dB R'_w, the construction type does not necessarily affect the acoustic satisfaction. The results also suggest that R'_w explains better the subjective rating of sound insulation than $R'_w + C_{50-3150}$.

1. Introduction

1.1. Sound insulation between dwellings

External noise in residential dwellings (later: dwellings) typically originates from a nearby environmental source (road, rail, airport, children in the yard, etc.), from other dwellings (impact and airborne sounds), from staircase (impact and airborne sounds) and from building services (air-conditioning, radiators, etc.).

This study focuses on the perception of the airborne sounds coming from neighbouring dwellings. The annoyance caused by neighbour sounds may be high even if the signal-to-noise ratio is low since they may contain large amounts of information and temporal variations, such as speech, which is more noticeable than most environmental noises which are usually more smooth [16]. At the same time, the means to control the neighbour noise are few.

According Levy-Leboyer and Naturel [25] the most annoying neighbour noises are those which are judged as being not normal, possible to avoid, occurring during the night and are described as being loud. Reactions towards the noise originators did not seem to be linked to the level of experienced annoyance but rather to the degree of control which the occupant felt over the situation and to the motives attributed to the person making the noise. As a result of these reasons, the individual differences in respect of the rating of sound insulation are large even if the sound insulation would be the same.

Maschke and Niemann [27] found an association between severe annoyance to neighbour noise and diagnosed hypertension, depression and migraine. The data was based on logistic regression analysis among 5101 adult residents from eight European cities. The causal relationship between neighbour noise and diagnosed diseases could not be shown but it is very probable that severe and long-term exposure to loud neighbour noises can increase the risk of these diseases. Unfortunately, their study did not include any

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quantitative information of the building types and their sound insulation values so the study cannot show whether the reason for severe noise annoyance was the poor sound insulation or the behaviour of the neighbours. Their study provides suggestive evidence that not only environmental noises, such as traffic noise, may cause health risks in homes but neighbour noises should also be taken into account.

1.2. Heavy versus light constructions

Sound insulation requirements between dwellings can be achieved by different construction types. The extreme examples are heavy (e.g. monolithic concrete walls and floors) and light (e.g. double-stud or staggered-stud plasterboard drywalls, wooden floors). The extremes differ significantly from each other in respect of the frequency dependence of sound insulation. Light constructions are usually significantly worse at low frequencies (below 100 Hz) because of the mass-air-mass resonance [17]. Light constructions may also have a weaker sound insulation above 2500 Hz because of the panels' coincidence frequency. Instead, heavy constructions behave more smoothly with frequency (Fig. 1, left).

Several studies have suggested that low frequency noise from the neighbours might be more annoying in buildings where light constructions are used instead of heavy constructions. Contrary to this, some researchers present evidence which suggests that the importance of low frequencies should not be over emphasised. In the following, a literature survey is presented to clarify these two different viewpoints.

Mortensen [28] carried out a listening experiment in laboratory conditions which compared light and heavy wall constructions with an equal weighted sound reduction index 57 dB R_w. The living noise from neighbours transmitted through a light wall was rated as more annoying. However, their study design was misleading since only one type of sound, i.e. music with a very strong bass content, was used to represent living sounds. In addition, music was played at an unrealistically high level of 100 dB (L_{Aeq}) in the neighbouring dwelling, which may overemphasise the hearing sensation of low frequencies based on loudness contours [23]. Normal levels in homes are very seldom above 85 dB ($L_{Aeq,15\ min}$, [1]). Therefore, Mortensen's study concerns only a specific type of living sound and it should not be used to draw general conclusions regarding the subjective differences of light and heavy constructions in residential dwellings.

Rasmussen [33] stated that "a trend towards lightweight building constructions has increased the low frequency problems, such as neighbours' music and footfall noise." However, the field evidence showing the prevalence of this problem among the population was not given. Anyway, this expectation is often presented among the researchers and consultants and this has inspired us to research the low frequency question.

Bradley [5] investigated the perception of neighbour noise between 98 adjacent apartments in row houses. The Sound Transmission Classes (STC) between apartments ranged from 39 to 60 dB. The sound reduction index at 160 Hz had the highest positive correlation with the subjectively rated sound insulation. In a larger study [6], Bradley investigated 300 party walls and 600 occupants in the related dwellings. Now, the sound reduction index of third octave bands 160–600 Hz explained best (R^2-values, coefficient of determination) the subjective ratings of sound insulation, annoyance of neighbour noises and hearing of neighbour noises. Unfortunately, the measurements in both studies were not made below 100 Hz. However, the R^2-value of the 100 Hz band was very low compared to the R^2-values of the bands 125–600 Hz, which might indicate that the R^2-values of the frequency bands below 100 Hz might not be very high. It is evident that Bradley's studies do not directly answer to the question regarding the importance of low frequencies.

Rychtáriková et al. [36] conducted a listening experiment with 40 subjects. The subjects listened to 64 different living sounds transmitted through two simulated wall constructions: a light construction (18 kg/m^2) and a heavy construction (305 kg/m^2). The R_w values were 69 and 52 dB. The $R_w + C_{50-5000}$ value was 52 dB for

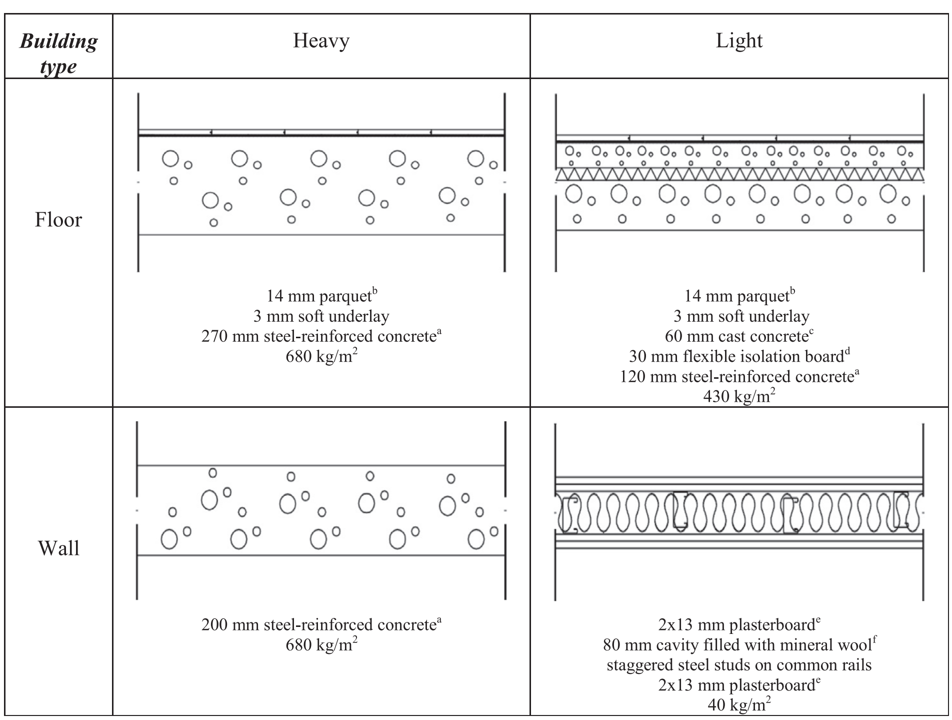

Fig. 1. The construction drawings of the floor and walls used between dwellings in the two *building types*. Approximate densities [kg/m^3] of the materials: [a] 2500 [b] 700 [c] 2000 [d] 50 [e] 700 [f] 30.