Evaluation of impact noise in wooden buildings

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Introduction

Buildings with wooden floor constructions and wooden buildings, like prefabricated single family houses, have a long tradition in Germany. From the middle of the 1990s, additionally, multi-storey houses of wood construction have been allowed in many European countries. In general, those multi-dwelling houses have to fulfil the same acoustic requirements as concrete buildings. Especially the impact noise requirements can be difficult to meet. Even when they are fulfilled, the main complaints in wooden buildings are due to low frequency impact noises.

The weighted impact noise level does not take into account frequencies below 100 Hz, and the spectrum adaption term C_I can only consider frequencies down to 50 Hz. It is not clear, if subjective judgements are influenced by frequencies below 50 Hz. It is obvious, that the weighted impact noise level does not agree to subjective judgements. Additionally, the tapping machine has a different excitation characteristic than real walking people and other sources of impact noise.

In the research project "AcuWood", the impact noise of wooden floor constructions are investigated. By measurements, listening tests and questionnaires it is intended to find descriptors for impact noise, which highly correlate to the subjective evaluation.

Laboratory measurements

In a first step, recordings and measurements of impact noise were performed at a laboratory wooden beam floor (DIN EN ISO 10140-5, floor C1 [1]). The floor has a sound reduction index R_w = 46 dB / $C_{50\text{-}3150}$ = -5 dB and a weighted impact sound level of $L_{n,w}$ = 74 dB / $C_{I50\text{-}2500}$ = 1 dB. In general, such floors are equipped with a dry floating floor. In our case we used a 18 mm gypsum floor laminated on 10 mm wood fibre board, giving R_w = 54 dB / $C_{50\text{-}3150}$ = -5 dB and $L_{n,w}$ = 68 dB / $C_{I50\text{-}2500}$ = 0 dB for the combination. Additionally, representing real situations, different floor coverings of laminate, parquet, tiles and carpet were also applied and measured. As sources the tapping machine, the modified tapping machine, female and male walkers, the Japanese rubber ball falling from a height of 1 m and a chair drawn across the floor was used.

Measurement results of the floor with floating floor and different sources are shown in figure 1. Both rooms were equipped with absorbers and had low reverberation time. Results were gained by averaging 6 microphone positions in the receiving room below and are given as L_{nT} values, for the ball drop as $L_{max,nT}$. The tapping machine and modified tapping machine was placed on 4 different positions. The chair was pulled and the ball was dropped at the same 4 positions repeatedly at each position 10 times and averaged. The walkers were walking at a speed of two steps per second in a circle.

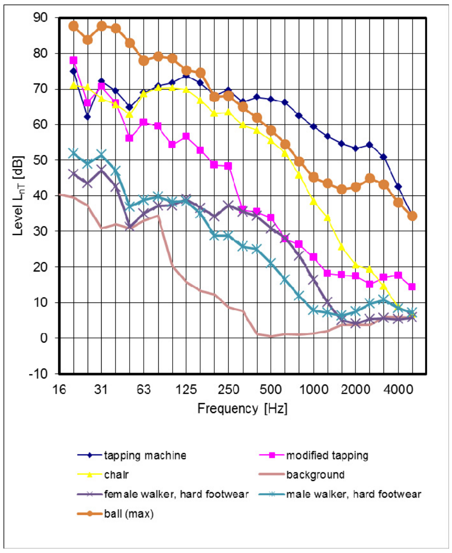

Figure 1: Level L_{nT} of different sources and $L_{max,n,T}$ of the ball, in the receiving room below the floor with floating floor.

Results for the tapping machine in figure 1 show, that the spectrum is much more broadband than for all other sources. At very low frequencies up to 50 Hz, the levels of the tapping machine, the modified tapping machine and the chair are similar and about 20 dB higher than the walkers. The walker signals at very low frequencies are above background noise, but possibly below the hearing threshold. Both sources, the modified tapping machine and the ball, have a similar spectrum as the male walker with hard footwear, but are shifted to higher levels. The main advantage of the ball might be the high levels, which enables measurements in noisy environments and on better floor constructions.

Influence of the floor coverings

For all different floors, the standardised impact sound level was compared, shown in figure 2. The main reduction of impact noise is caused by the dry floating floor. It reduces the impact sound at frequencies between 50 and 1000 Hz, with a main reduction at 125 Hz of more than 10 dB. Therefore, $L'_{n,w}$ is reduced from 74 to 68 dB. Further, the different floor covers have not a great additional influence; they tend to reduce levels at higher frequencies above 250 Hz. At lower frequencies only tiles give slightly lower values, and the carpet gives a slightly shifted response to lower frequencies. The values of $L'_{n,w}$ / $C_{I50\text{-}2500}$ at the floor with dry floating floor of 68 dB / 0 dB are reduced to 65 dB / + 2 dB for the laminate and parquet, and to 63 dB / +2 dB for tiles and 61 dB / +4 dB for carpet.

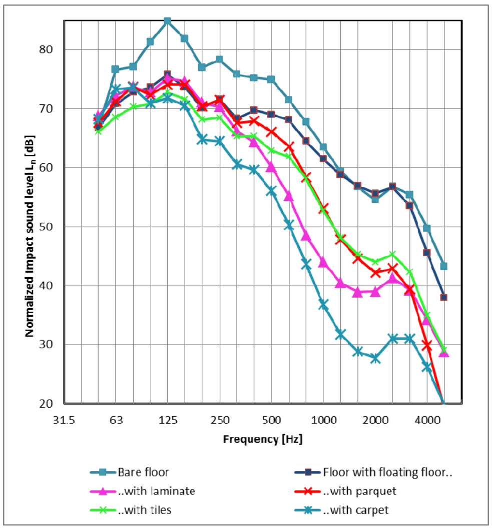

Figure 2: Standardised impact sound level of tapping machine on different floors.

A-weighted levels

A very common and human hearing related measure is given by the A-weighted levels in the receiving room. For comparison of the different floor covers, for each source the A-weighted level $L_{n,T,A}$ was calculated. For the male walker the spectra are shown in figure 3.

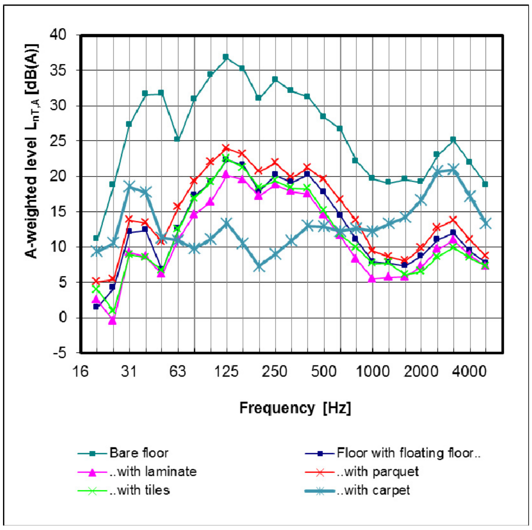

Figure 3: A-weighted level $L_{n,T,A}$ of the male walker on different floor covers.

The results show that the bare floor gives the highest levels with a maximum at 125 Hz, but still has high levels around 50 Hz. The main reduction of the levels is due to the dry floating floor, with a reduction of more than 10 dB. For all walkers, differences between the floor covers were quite small, except for the carpet with somewhat different spectrum. Summing up levels from 50 to 2500 Hz gave values of $L_{n,T,A,50\text{-}2500Hz}$ of 43.5 dB, 29.8 dB, 27.8 dB, 31.6 dB, 29.2 dB and 26.1 dB for the bare floor, the floor with floating floor, the laminate, the parquet, the tiles and the carpet, respectively.

Listening tests

With the recorded signals of the above mentioned measurements, listening tests concerning the loudness and annoyance were performed. The sample was 23 persons, 9 female and 14 male, ageing between 20 and 32 years old. As recordings were made by dummy head and microphone, the differences between both types of signals were addressed. The listening tests were performed with calibrated headphones. Results for the annoyance of the signals are shown in figure 4.

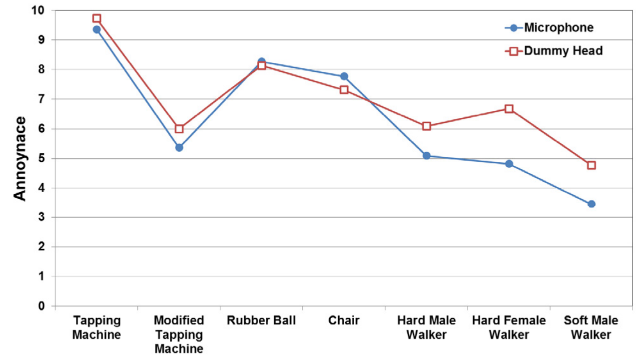

Figure 4: Annoyance rating for microphone and dummy head recordings of the different sources. The results for the different floor constructions are averaged.

The tapping machine is rated most annoying, the soft male walker (with socks) least. For steady sources like the tapping machine or rubber ball, the annoyance of the microphone and dummy head signals are rated similar, for the walkers, where localisation of the moving source with the dummy head recordings is possible, the signals where distinctively rated more annoying. The pattern of results for the loudness rating was similar to the annoyance rating. The annoyance and loudness ratings for laminate, parquet and tiles were similar, for carpet they were slightly lower.

Further work

Shown above are first interim results of the project AcuWood. The work will continue with similar tests on a concrete floor (with concrete floating floor), to evaluate the differences to typical German floor constructions. Further, other wooden floor constructions will be investigated, partly in real buildings. For all cases, listening tests will be conducted to get data for the subjective evaluation and to find physical descriptors, which highly correlate to subjective ratings. Additionally, questionnaires will be used to gain an overview of user perception of quality aspects in buildings, including impact sound.

Literature

[1] EN ISO 10140-5:2010: Acoustics – Laboratory measurements of sound insulation of building elements – Part 5: Requirements for test facilities and equipment.

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