A First Step towards Auralisation of Impact Noise

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Introduction

The acoustic quality of floor constructions is described by the normalised impact sound level measured in the receiving room using a standardised source (tapping machine, bang machine, etc.). Depending on the floor construction, the single number quantity, however, does not always show a good correlation with the annoyance of impact sound. Several other parameters play an important role like the type of source (walker, jumping children), time of day, current activity etc. Instead of listening tests using time consuming recordings in real buildings, an auralisation of the receiving room signal would be preferable. For practical use, the auralisation should be based on the typically available data of a construction. In a first approach, an auralisation algorithm is developed using the normalised impact sound level and geometric dimensions of the construction. The dynamic interaction between source and structure is neglected. Thus, only heavy-weight constructions are valid for this model. To demonstrate the effects of different sources and impedances, however, constructions with low impedances are taken into account, too.

The Model for Auralisation

The sound propagation between the force source in the source room and the listener's ears in the receiving room can be described by an impulse response. The objective of the model is to calculate this response which can be considered as a room acoustical binaural impulse response describing the path between a source and a receiver. It contains a direct sound part which travels directly from the sound emission points in the receiving room to the listener. Furthermore, it contains reflections from the walls which form the reverberant part of the impulse response. The force source in the source room excites the radiating walls in the receiving room. The sound emission points are considered as point sources in the middle of the radiating walls. The "reverberation tail" represents the room acoustical properties of the receiving room. The expression "binaural" means that an impulse response for both ears of the listener is calculated. This takes the direction of the sound sources into account and results in a natural hearing impression.

In short, the sound pressure in the receiving room can be obtained by

1. dividing the normalised impact sound level by the force spectrum of the tapping machine
2. multiplying the result with the force spectrum of the chosen force source (e.g. a walking person)
3. modelling the sound field in the receiving room (reverberation etc.) in an appropriate way

The modelling of the receiving room and the necessary equations for modelling the force sources is described in detail in [1].

Auralisation

To carry out the auralisation, the force of the tapping machine and the sources to be auralised must be known. For the measurements, a set-up was used consisting of a 15x15cm honeycomb sandwich slab resting on three force transducers which are mounted on a solid ground. The advantage of the honeycomb sandwich slab is the small weight and extremely high stiffness. This is necessary since resonances of the slab in the interesting frequency range can spoil the measurement result. With this set-up, the first resonances arise at frequencies beyond 2 kHz.

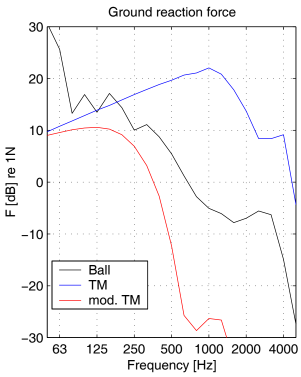


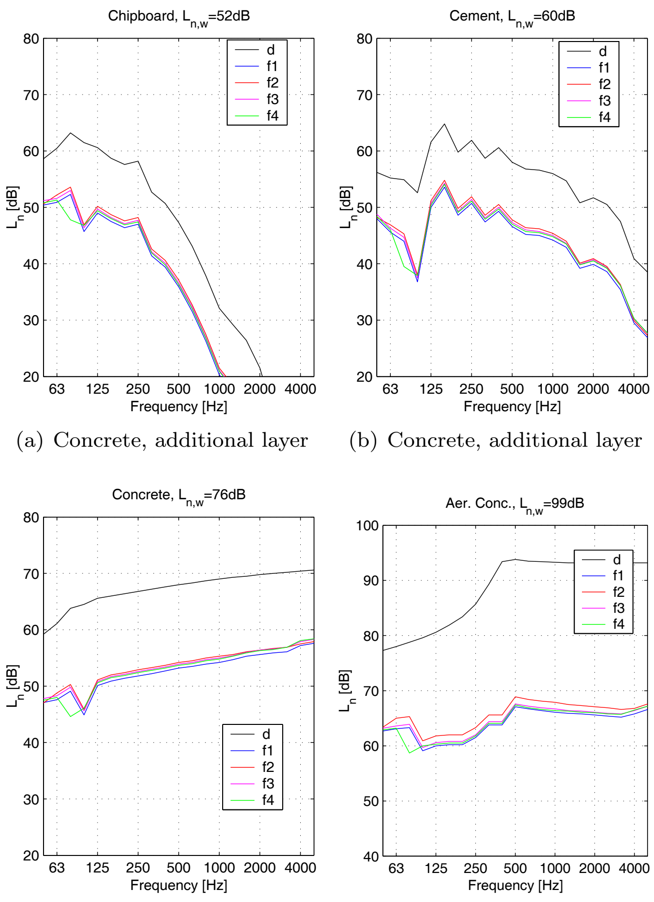
Figure 1: Measured forces of the tapping machine, the modified tapping machine and the Japanese rubber ball in one-third octaves

Figure 1 shows the one-third octave spectra of the measured forces of the tapping machine, the modified tapping machine, and a rubber ball according to prEN ISO 140-11. The spectra of the tapping machine and the modified tapping machine are equal at low frequencies. Then, above 125Hz the force of the modified tapping machine gets significantly smaller due to the rubber layer between hammer and floor. It should be remarked that due the elasticity of the used sandwich slab's surface, the measured force of the tapping machine seems to be too low above 1kHz. For use in auralisation of common sources, this is not a problem since this frequency range can be neglected.

For the auralisation, a force-time signal of the necessary length is constructed from a few force signals of the source. As an example, from two or three force pulses of one hammer of a tapping machine, a force-time signal is constructed by appending the pulses at an interval of 0.1 seconds. To make the signal sound more naturally, jitter in time and amplitude can be introduced. In a first try, an auralisation of the four room situations shown in figure 2 was carried out. The situations were modelled in a building acoustics software which delivers the normalised impact sound levels to be used for the auralisation. The impact sound levels of the auralised signals were calculated from the resulting audio files by software. They were, then, compared to the normalised impact sound levels obtained by the modelling software which were used as input parameters for the auralisation. At first, the levels of the auralised signals are not absolutely calibrated. Only the differences between the room situations are considered. For a better comparison, the measured levels are referenced to the room situation with the highest $L_{n,w}$. The results are shown in table 1.

Input parameters		Auralisation results	
Floor / Covering	$L_{n,w}$	Level TM	Level mod. TM
Chipboard	52dB	58dB	54dB
Cement	60dB	64dB	55dB
Concrete	76dB	75dB	58dB
Aer. concrete	99dB	99dB	76dB

Table 1: Impact sound levels from auralisation



(a) Concrete, additional layer (b) Concrete, additional layer

(c) Concrete (d) Aerated concrete

Figure 2: Normalised impact sound levels for four room situations

Discussion

From the results in table 1 it can be seen that for bare floors the signals auralised from the tapping machine have the same level differences as the $L_{n,w}$ values. Further, the level differences for the floors with additional layers do not match the $L_{n,w}$ values. Looking at the levels resulting from the auralisation of the modified tapping machine, one notices that completely different results are obtained not only in absolute levels but also in differences between the situations.

This can be explained by considering the force of the modified tapping machine. Whereas the tapping machine contributes energy in a wide frequency range, only frequencies up to app. 400Hz contribute a significant part for the modified tapping machine. Thus, only this frequency range has to be considered in the impact sound levels shown in figure 2 as for higher frequency ranges there is no excitation. It can be seen that situation a) - c) show similar impact sound levels in this region whereas situation d) has a significantly higher level. Thus, also in the auralisation, nearly equal levels result for a) - c) and a much higher level for situation d). It has to be investigated if the auralisation is valid for using additional layers since the dynamic interaction, normally, can not be neglected. The impedances of the source and the structure must be considered. This is especially important if the source impedance is not small compared to the structure impedance as it may be the case for a tapping machine used on light-weight constructions or additional layers. This can explain the mismatch in the results for the floors with the additional layers auralised with the tapping machine. For the modified tapping machine, however, the source impedance is normally small compared to the normal tapping machine and thus the results of the auralisation may be valid.

Conclusions

An algorithm for auralisation of impact sound insulation was developed. Force-time signals of typical sources and data of the receiving room are used. In a first approach, the dynamic interaction between source and structure was neglected. The forces of 3 different kinds of sources - the tapping machine, the modified tapping machine, and the Japanese rubber ball - were measured. Four different types of floor constructions were auralised and their normalised impact sound levels were compared to the results of the auralisation. It was found that for bare floors with high impedances, reasonable results are obtained. This has to be validated by investigating more room situations. For floors with low impedances, the results of the auralisation with the tapping machine differ from the impact sound levels of the construction. It has to be proven if a consideration of the source and structure impedances gives better results.

Acknowledgements

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References

[1] R. Thaden. Auralisation of impact sound insulation. In *Proceedings of the ICA*, Kyoto, Japan, 2004.