Study for the applicability of the prediction method according to prEN 12354-5 and correlated laboratory measurement methods (CEN TC 126 / WG 7) in lightweight building construction

– Abridged Report –

Abbreviated: Installation noise in lightweight building construction

Christoph Kling, Volker Wittstock, Heinrich Bietz

Physikalisch-Technische Bundesanstalt, 38116 Braunschweig,
christoph.kling@ptb.de, volker.wittstock@ptb.de, heinrich.bietz@ptb.de

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1 Introduction

The standard EN 12354 provides a method to predict the sound transmission in buidlings. By this, architects and civil engineers are able to account for the demands of the building authorities just when planning a building. Part 5 of the standard [1], which is currently a draft, deals with noise of domestic installations such as sanitary installations, lifts, air conditioning systems etc.. Up to now, the draft comprises solid constructions such as walls of concrete or sand lime bricks. To an increasing degree, lightweight constructions are used especially with sanitary constructions. These constructions such as wooden or metal post-and-beam constructions have different characteristic properties compared to heavy walls. The applicability of the existing draft of the standard and corresponding laboratory measurement methods to lightweight building construction was investigated in a project promoted by the Bundesamt für Bauwesen und Raumordnung (BBR).

The investigations focused on several points. Firstly, it had to be determined if the assumptions used in the standard are fulfilled in lightweight construction. Furthermore, a series of sanitary installation noise measurements were performed for in-situ situations. These served as comparison values for laboratory measurements. Moreover, these measurements showed which are the relevant sources in practise.

The standard EN 12354 virtually splits the sound source from the receiving structure and characterises both separately. According to the prediction method, the sound power which is introduced into the building must be calculated for each combination of a sound source and a receiving element anew. A substantial part of the project was therefore to characterise lightweight construction elements as receiving structures.

It turned out that the characterisation of sound sources is more extensive compared to solid building construction. In the course of the project, a recent suggestion in research literature was picked up, modified to a method for detailed source characterisation and applied to a wastewater pipe which is the most affecting sanitary source.

This abbreviated report restrictes itself to the main issues of the project and especially goes into the characterisation of sanitary installation sources and receiving construction elements.

2 Installation measurements

In the past, a test facility for studying sanitary installation noise in lightweight wooden construction was designed at PTB in collaboration with the Bundesverband Deutscher Fertigbau e.V. (BDF). In the meantime, different installation sets were built in by ten manufacturers which are organised in the BDF and the installation noise was measured. Additionally, comparative measurements were performed in finished buildings.

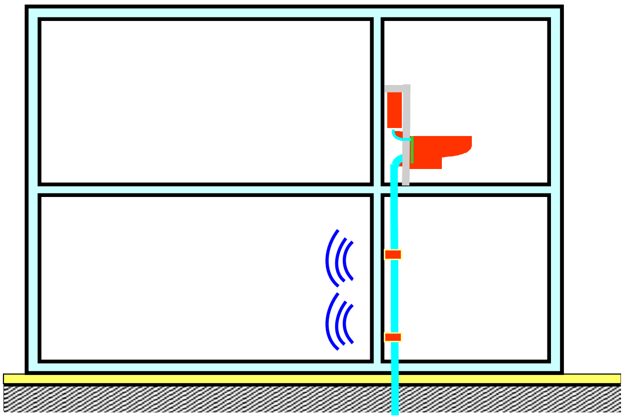

Figure 1: Sketch of the wooden sanitary installation test facility.

In the scope of this short report, it shall only be mentioned that the wastewater pipe behind a toilet, which is the most important source, is the dominant part of the installation. From the judicial point of view, this is a diagonal transmission but technically seen, it is a horizontal transmission because the actual noise source – the wastewater pipe – is located in the same floor as the room to be protected. Many of the constructional systems exceeded the standardised boundary values for installation noise. To illustrate this, figure 2 shows the mean values and the deviation range of the installation noise in the case of diagonal transmission. On the left side, the loudest measured levels are given. The right diagram shows the levels derived from the outlet noise only. It can be seen that the installation noise is clearly dominated by the outlet. The reason is that the wastewater pipe is directly coupled to the room to be protected. The flush is loud because the greatest flow rate (about 2-3 liter/s) is reached in this time interval – at least for short periods of time.

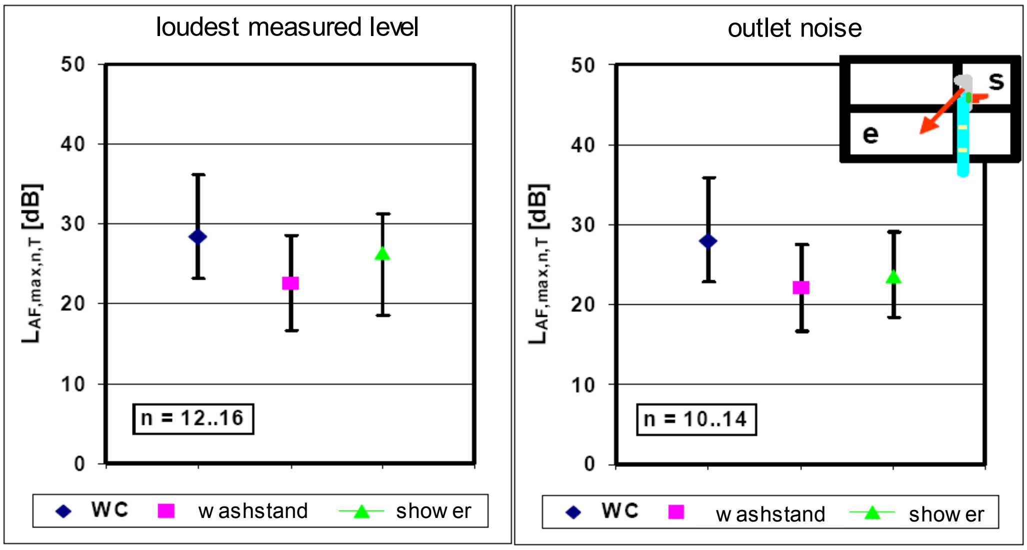

Figure 2: Comparison of installation noise with diagonal transmission.

3 Characterisation of structure-borne sound sources

The installation noise measurements showed that the wastewater system is the most important source affecting the next room to be protected [2]. That's why, this sound source was chosen for further investigations.

At first, it was examined if different water fillings affect the impedance. For this purpose, pipes of different masses per length unit (from HT-pipes to cast pipes) were closed at both ends and filled with different amounts of water. The impedance was measured by use of an impedance head directly at the standard clamp. The impedance was found to be in the range of about 0 dB (see figure 3). It is influenced by different filling levels only at low frequencies, whereas the impedance varies irregularly with the filling level. At frequencies above 100 Hz, the deviation range is lower than 5 dB. The heavier the pipe the less is the influence of the filling level. Obviously, the elastic layer in the clamp leads to decoupling so that the filling levels can hardly be seen in the impedance curves.

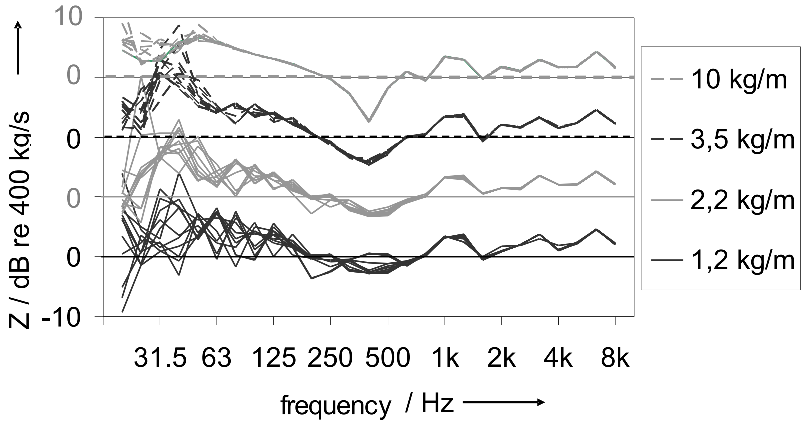

Figure 3: Measured input impedance of wastewater pipes with different masses per length with filling levels from empty to half-full.

Afterwards, a wastewater pipe system was installed in a test facility at PTB. With a constant flow rate of 2.8 liter/s, the structure-borne sound power introduced to different receiving plates was measured. In accordance with the 2-plate method [3], three different plates were used: a 120 mm thick sand-lime brick wall as a heavy element, a freely supported 12 mm thick plasterboard plate and a freely supported 5 mm plywood plate as a very lightweight element. Comparing the results of the heavy wall with the results of the two lightweight plates, the free velocity and source impedance – as the two source quantities – could be calculated (figure 4). Additionally, the impedance was measured with an impedance head at the two clamps as well as the free velocity by uncoupling the receiving wall. The results of the direct measurement agree qualitatively well with the results of the 2-plate method. Unfortunately, the requirements for the 2-plate method are not met for all frequencies. Moreover, the analysis can be based on impedance or mobility. Due to fact that the curves are displayed in third-octave bands, this leads to deviations between the results.

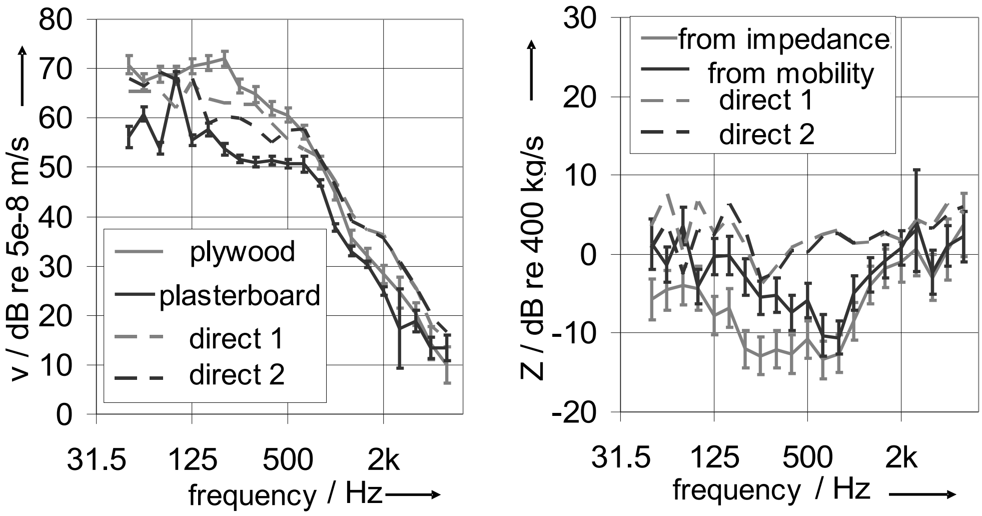

Figure 4: Source quantities of the wastewater pipe system directly measured and measured according to the 2-plate method; left: free velocity; right: source impedance.

4 Lightweight construction parts as receiving elements

If the input impedance of lightweight construction elements are in the same range as the source impedances, this quantity must be known for the predictive calculation. Furthermore, the question arises if lightweight constructions can be considered as homogeneous in regard to their input impedance. To answer these questions, the following lightweight constructions were studied systematically:

- A wooden post-and-beam construction, covered on each side with 13 mm chipboard and 12 mm plasterboard (GKB)
- The same wall with an additional layer of 7 mm ceramic tile on receiving side
- A metal post-and-beam construction Knauf W112, covered with 2x12 mm GKB (Knauf Piano) on both sides
- A timber joist floor (type 1 from DIN EN ISO 140-11)
- A timber joist floor with screed (40 mm concrete screed + 52 mm insulating layer)

In the predominant part of the measurements, a shaker and an impedance head were used. The impedance head cannot be used for measurements with the heavy timber joist floor. Separate force and acceleration transducers were applied here. The connection to the element was usually performed with bee glue on the wall surface but screwed connections were applied, too. A lot of excitation points were used on every measurement object to gain information about the homogeneity.

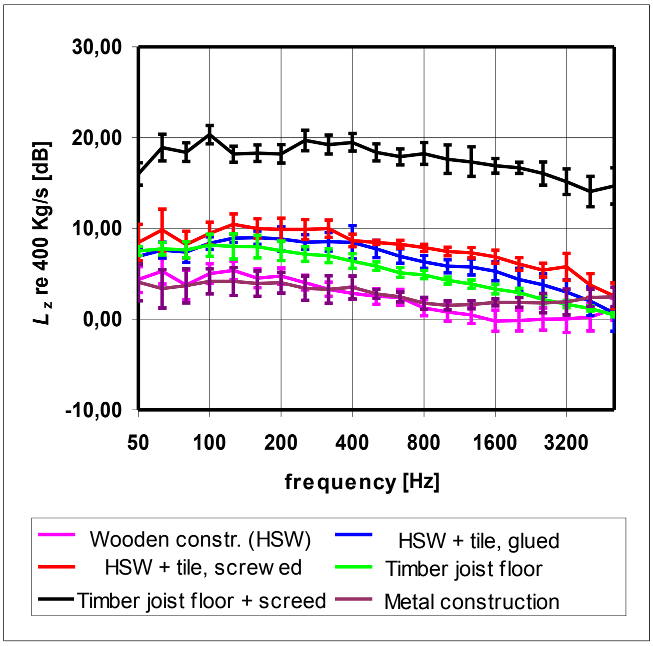

Figure 5: Typical input impedances of lightweight construction elements.

Figure 5 summarises the averaged input impedances of the studied objects. It is found that indeed all constructions – except the heavy floor – have impedances in the range of the examined structure-borne sound source. Moreover, the additional layer of ceramic tiles increases the impedance for about 6 to 7 dB. This agrees very well with the values found in the in-situ measurements.

Concerning the homogeneity, it shall only be mentioned here that only a small influence of the supporting frame was observed, especially with several covering layers and glued coupling of the transducers. The deviation between different excitation points increases if the transducers are screwed or if the frame work is only simply covered.

5 Conclusions

The input impedance of not extra-covered lightweight construction elements was found to be about 0 to 10 dB. The frequency dependence is only small. The impedance of the studied source system is about the same and cannot be neglected as usually done in solid structure buildings. The applicability of the prediction standard to lightweight construction is more extensive but basically possible.

6 Acknowledgements

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7 References

[1] EN ISO 12354-5 DIN EN 12354-5 *Building Acoustics - Estimation of acoustic performance of buildings from the performance of elements* - Part 5: Sound levels due to service equipment; German version prEN 12354-5:2007

[2] Bietz, H. Wittstock, V., Scholl, W. *Prüfstand zur Bestimmung von Installationsgeräuschen im Holz-Fertigbau – neue Messergebnisse und Entwicklungen*. Tagungsband der DAGA 06 auf CDROM, Braunschweig

[3] Gibbs, B.M.; Qi, N.; Moorhouse, A.T.: *A Practical Characterisation for Vibro-Acoustic Sources in Buildings*. Acta Acustica united with Acustica, Volume 93, Number 1, January/February 2007 , pp. 84-93