Characterization of a water drainage pipe using the EN 14366 and EN 15657 methods

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Summary

Structure-borne sound generated by waste water installations can be measured in the laboratory following EN 14366. In this standard, the characteristic structure-borne sound pressure level is defined as the normalized sound pressure level radiated by a reference wall made of 10 cm of concrete. This approach assumes a force source behavior of the pipe and may thus not be adapted for pipes installed in lightweight buildings. The new version of EN 15657 can be used to determine the structure-borne sound power injected by a piece of equipment installed in any type of construction, from characteristics of the source and of the supporting wall or floor. In this work, the source characteristics defined in EN 15657 – i.e. equivalent blocked force and free velocity levels and equivalent mobility – are determined experimentally. The equivalent mobility of the supporting wall (concrete, 10 cm in thickness) is used to calculate the installed structure-borne sound power. The normalized flanking sound pressure level of the wall for a unit power (1 W) is also measured and used to calculate the normalized sound pressure level in the adjacent room. The result is then compared to the characteristic structure-borne sound pressure level measured following EN 14366. Results for various water flow rates are presented and discussed.

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1. Introduction

Water drainage pipes are regularly designated as annoying sources of noise by building occupants. Proper design is a key point in order to meet performance requirements in terms of sound pressure levels generated on site. To that end, airborne and structure-borne sound from drainage pipes can be characterized in the laboratory following EN 14366 [1]. In this method, specific for water evacuation systems, acoustic measurements are conducted in the source room – to characterize the total noise composed of the airborne and structure-borne components – and in the adjacent room – where only structure-borne sound is supposed to be radiated. Results are expressed in terms of normalized sound pressure levels, which cannot be directly transposed to the field situation. These sound pressure levels can be used as input data in the model of EN 12354-5 [2] to predict sound pressure levels in situ by taking into account the receiving room absorption, the characteristics of the supporting and radiating elements and of the junctions between them.

One limit to this approach based on acoustic measurements is that the results are often close to background noise when considering structure-borne noise, especially for the most silent products. Aiming at improving the accuracy of the method, standardization working group CEN/TC126/WG7 is currently considering a new way of characterizing drainage pipes in terms of sound power levels. The new standard EN 15657 [3] could be used as a basis to determine the structure-borne sound characteristics from vibration measurements. This would also help reduce the risk of confusion between sound pressure levels in the laboratory and in situ, as well as harmonize practices for all service equipment types.

In this work, a straight drainage pipe is characterized in the laboratory following both approaches. The normalized structure-borne sound pressure level L_{sn} is measured following EN 14366. The structure-borne sound characteristics are also determined following EN 15657 and the normalized sound pressure level in the adjacent room is calculated, using the normalized flanking sound pressure level of the separating wall. This new calculation method is presented in detail in [4] for different building and equipment configurations. Results from the two approaches are then compared together in order to evaluate the impact of modifying the characterization method in the frame of a future revision of EN 14366.

2. Methods

First, a straight plastic pipe with a nominal diameter of 110 mm is characterized following EN 14366. Two mounting conditions (with rigid or resilient connectors) and various water flow rates (from 0.5 to 4 L/s) are considered. The structure-borne normalized sound pressure level L_{sn} is measured using a rotating microphone in the room adjacent to the source room. No structural sensitivity correction is applied.

The resulting normalized sound pressure level can also be predicted from the installed structure-borne sound power level L_{Winst} according to the following relationship.

$$L_{n,pipe} = L_{Winst} - L_{W0} + L_{ne,0,all,i} \quad (1)$$

In equation 1, L_{W0} = 120 dB re. 10^{-12} W is the power level corresponding to a reference power of 1 W and $L_{ne,0,all,i}$ is the normalized equipment sound pressure level (in dB re. 2.10^{-5} Pa) of the separating wall to which the pipe is connected, including all transmission paths, for the reference unit power.

Since the separating wall is made of 10 cm thick solid concrete blocks, a force source assumption can be made. The installed structure-borne sound power level can be approximated as follows.

$$L_{Winst} \approx L_{Fb,eq} + 10\lg\left(Re\left(Y_{R,eq}\right)\right) \quad (2)$$

where $L_{Fb,eq}$ is the single equivalent blocked force level (in dB re. 10^{-6} N) of the pipe and $Y_{R,eq}$ is the single equivalent mobility (in m/(N.s)) of the separating wall.

In this section, the methods to obtain the characteristics of the pipe and of the separating wall are presented. These quantities can then be used to estimate the normalized sound pressure level according to equation 1 and compare the results to the values of L_{sn}.

2.1. Properties of the pipe

The single equivalent blocked force level of the pipe is determined for all the considered mounting conditions and water flow rate values. Indirect measurements are performed using the reception plate method as proposed in EN 15657. The single equivalent blocked force level is estimated from the structure-borne sound power level $L_{Ws,low}$ injected into the separating wall of the laboratory, considered as a low mobility reception plate.

$$L_{Fb,eq} \approx L_{Ws,low} - 10\lg\left(Re\left(Y_{R,low,eq}\right)\right) \quad (3)$$

In equation 3, $Y_{R,low,eq}$ is the single equivalent mobility of the reception plate. The injected power is deduced from the vibration velocity level averaged over the reception plate area using the power substitution method, as illustrated by equation 4. An impact hammer is used as calibrated source. The power level injected by the hammer L_{Wcal} can thus be determined from the force and velocity signals at the excitation point. 5 calibrated source positions and 6 accelerometer positions are used.

$$L_{Ws,low} = L_{v,low} + 10\lg\left(\frac{1}{N}\sum_{i=1}^{N} 10^{\frac{L_{Wcal,i}-L_{vcal,i}}{10}}\right) \quad (4)$$

2.2. Properties of the supporting wall

The single equivalent mobility – i.e. point mobility averaged over the contact points – of the separating wall is measured directly with an impact hammer in order to be used in equations 2 and 3.

The normalized flanking equipment sound pressure level of the wall is measured following the method described in ISO 10848-1 [5]: the wall is mechanically excited at 4 different locations with an impact hammer. At each excitation position k, the injected power level $L_{W,k}$ is calculated. In parallel, the sound pressure level in the receiving room is measured using 5 fixed microphone positions. Remark: the excitation positions considered here are different from those used during the power substitution method (see section 2.1). The transmission function $D_{TF,k}$ is calculated as in equation 5, where $L_{av,k}$ is the average sound pressure level in the room.

$$D_{TF,k} = L_{av,k} - L_{W,k} \quad (5)$$

The normalized average transmission function is then calculated as in equation 6, where A is the equivalent sound absorption area in the room and $A_0 = 10$ m². Here, the equivalent sound absorption area of the room is deduced from reverberation time measurements.

$$D_{TF,av,n} = 10\lg\left(\frac{1}{K}\sum_{k=1}^{K} 10^{\frac{D_{TF,k}}{10}}\right) + 10\lg\left(\frac{A}{A_0}\right) \quad (6)$$

Finally, the normalized flanking equipment sound pressure level of the wall is calculated according to equation 7.

$$L_{ne,0,all,i} = D_{TF,av,n} + L_{W0} \quad (7)$$

3. Results

The normalized structure-borne sound pressure spectra of the pipe measured according to EN 14366 are represented in Figure 1. Single number values (A-weighted levels) are given in the legend. Squares represent the values considered as limit of measurement under the terms of the standard, i.e. when the sound pressure level increases by 6 dB or less when the pipe is attached to the separating wall, by comparison to the pipe being detached (assimilated to background noise). It can be observed that many values correspond to this limit of measurement, especially in the high frequency range, and even for the higher water flow rate. Therefore, the results seem to converge in this frequency range.

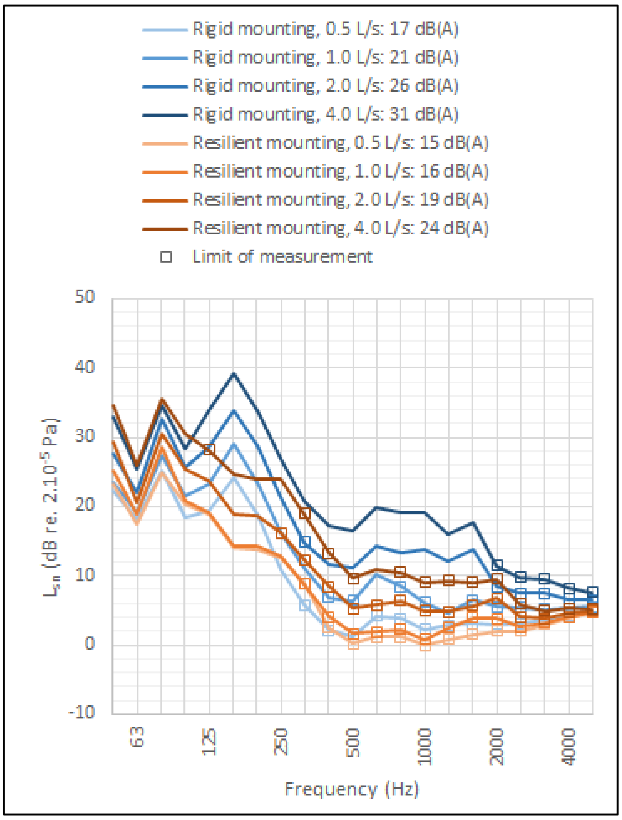

Figure 1. Normalized sound pressure level of the pipe

The single equivalent blocked force spectra of the pipe measured according to the procedure described in section 2.1 are represented in Figure 2. It can be observed that fewer results are affected by background noise with this method. Plus, even at high frequencies, results for the different water flow rates and mounting conditions considered can be clearly distinguished, as the single equivalent blocked force level decreases following a rather regular slope.

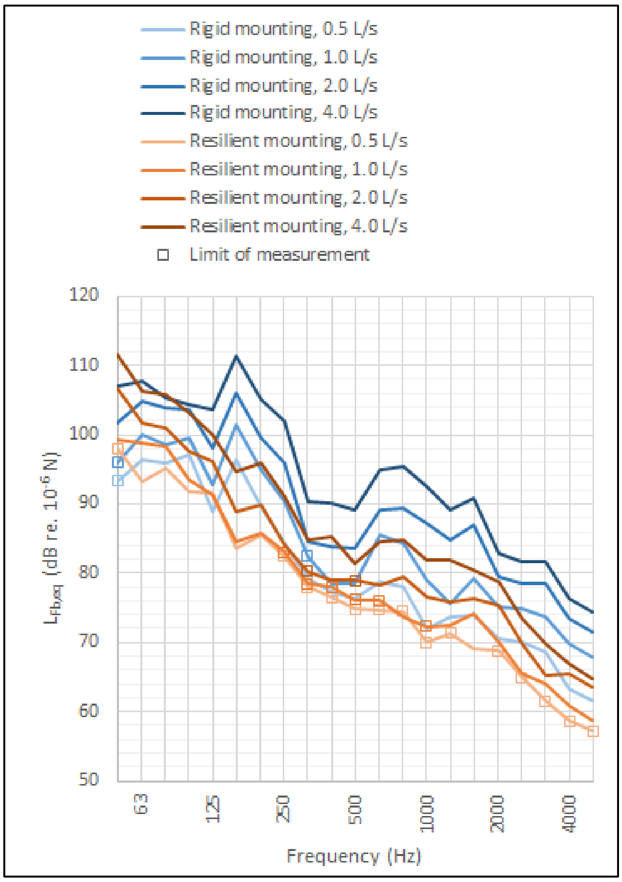

Figure 2. Single equivalent blocked force level of the pipe.

The single equivalent mobility of the separating wall is represented in Figure 3. These values are close to the characteristic mobility of 10 cm of concrete (approximately 5.10^{-6} m/(N.s)).

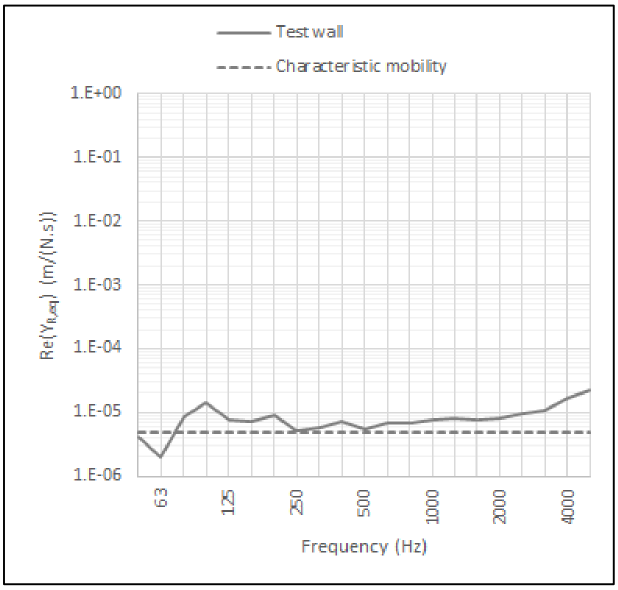

Figure 3. Single equivalent mobility of the wall.

The normalized flanking equipment sound pressure level of the wall measured according to the procedure described in section 2.2 is represented in Figure 4.

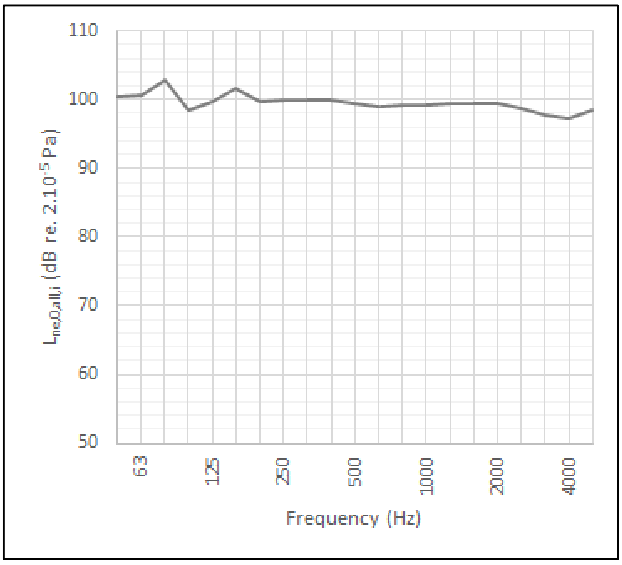

Figure 4. Normalized equipment sound pressure level of the wall for all transmission paths.

The normalized sound pressure level calculated from the pipe and wall properties according to equation 1 are now compared to the results presented in Figure 1. The differences $L_{n,pipe} - L_{sn}$ are represented in Figure 5. Differences on A-weighted values are specified in the legend.
On average, the differences in sound pressure level are close to zero between 125 and 1000 Hz. However, some important discrepancies (up to 8 dB at 100 Hz for the pipe rigidly mounted) are

observed at lower frequencies. At 250 and 315 Hz also, up to 6 dB discrepancies are observed for the pipe mounted with rubber lined brackets. As shown in Figures 1 and 2, some of these measurement results are affected by background noise. In addition, it should be noted that a standard deviation of repeatability of 3 dB in each third octave band can be expected from the single equivalent blocked force level measurements, as specified in EN 15657. No accuracy information is available in the current version of EN 14366.

From 1000 Hz, L_{sn} values are almost always higher than the calculated $L_{n,pipe}$ values. This is particularly obvious for the lower levels, i.e. for the pipe with resilient mounting and for the lower water flow rates, with 15 dB differences for the higher frequency bands. The measurement method of EN 14366 can explain these differences, as most L_{sn} values are influenced by background noise in this frequency range.

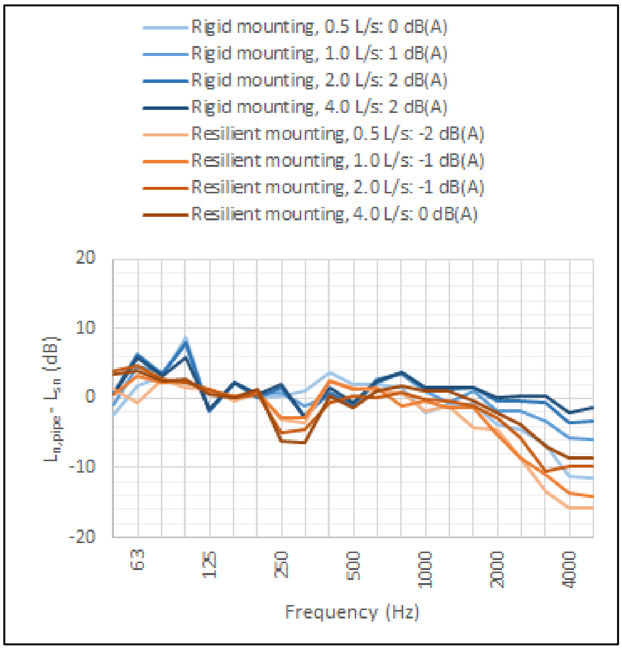

Figure 5. Level difference between the two tested characterization methods.

4. Conclusions

This study aimed at assessing the possible impacts of a change in the way structure-borne noise from waste water pipes is characterized in the laboratory. Normalized sound pressure levels generated by a straight plastic pipe were measured following the current method described in EN 14366. The results were compared to calculated values obtained from the single equivalent blocked force level of the pipe – determined from vibration measurements on the supporting wall according to EN 15657 – as well as from the transmission function of the wall – measured according to ISO 10848-1. Such comparisons were made for the pipe being either rigidly fixed to the wall or mounted with vibration isolators. Different constant water flow rates were considered.

Measurement results tend to show that the alternate method based on the single equivalent blocked force level of the source performs better at characterizing low levels, more particularly encountered at high frequencies. Indeed, the accuracy of the acoustic measurements is more likely to be limited by background noise. Therefore, the impact of the intended change of method on the characterization results can be important in this frequency range.

At lower frequencies, the differences in sound pressure levels are close to zero on average, despite some significant discrepancies on individual results.

When looking at the single number ratings, differences of -2 to +2 dB(A) are observed for the considered water drainage system.

Acknowledgement

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References

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