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Applying EN 12354-5 for estimating sound levels due to service equipment in buildings

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ABSTRACT

Standard EN 12354-5 is new and contains a frame work within which the subject of sound levels due to service equipment in buildings can be treated. This paper presents the application of this standard to predict sound levels due to sources such as whirlpool baths, flushing boxes or waste water pipes for which laboratory measurement standards already exist (respectively EN 15657-1 and EN 14366); both airborne and structure borne transmission through building constructions are considered. Several aspects of the problem are discussed: particularly the need of rather new input parameters such as plate input mobility or plate radiation efficiency, which have to be estimated, the need of a frequency range extended down to 50 Hz, and the inevitable limitations due to the still limited data or scientific knowledge available.

1. INTRODUCTION

Standard EN 12354-5 [1] is new and contains a frame work within which the subject of sound levels due to service equipment in buildings can be treated. This paper presents the application of this standard to predict sound levels due to sources such as whirlpool baths, flushing boxes or waste water pipes for which laboratory measurement standards already exist (respectively EN 15657-1 [2], also very new and EN 14366 [3]); both airborne and structure borne transmission through building constructions are considered: the approach used for airborne sound sources is presented in section 2 and the one for structure borne sound sources presented in section 3. Several aspects of the problem are discussed: particularly the need of rather new input parameters such as plate input mobility or plate radiation efficiency, which have to be estimated, the need of a frequency range extended down to 50 Hz, and the inevitable limitations due to the still limited data or scientific knowledge available. Practical examples will be presented at the conference.

2. AIRBORNE SOUND SOURCE

The airborne sound source is located in situ in a room (source room; see Figure 1); the source is supposed to be characterized by its sound power level L_{Wa} measured in laboratory (several well known standards are available).

A. Sound level in the source room

The normalized space averaged sound level in the room is readily obtained from the source sound power level:

$$L_{na} = L_{Wa} - 4 \qquad (1)$$

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The corresponding standardized sound level in the room can be obtained using:

$$L_{nT} = L_{na} + 10\,lg(A_{ref} .T_{ref} / 0.16V) \text{ where } A_{ref} = 10m^2 \text{ and } T_{ref} = 0.5s \qquad (2)$$

Note that the directivity of the source is usually not known; estimating the direct field in the source room is therefore not that easy.

B. Sound level in the receiving room

The normalized space averaged airborne sound level $L_{na,ij}$ radiated in the receiving room for each transmission path i,j can be calculated [1]:

$$L_{na,ij} = L_{Wa} + D_{si} - R_{ij,ref} - 10\,lg(S_i / S_{ref}) - 10\,lg(A_{ref} / 4) \qquad (3)$$

where $D_{si} = 10\,lg(S_i / A_s)$ is a sound transmission term, $R_{ij,ref}$ the flanking sound reduction index used in standard EN 12354-1 [4] (airborne sound insulation between rooms) with reference to a separating element of area $S_{ref} = 10\,m^2$ and S_i the area of the element *i* considered in the source room. Note that the combination of L_{Wa}, D_{si} and $-10\,lg\,S_i$ leads to the incident diffuse intensity in the source room.

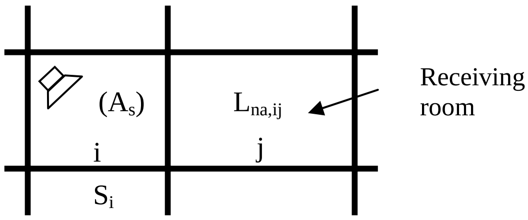

Figure 1: Airborne sound transmission; sketch

Equation (3) can be simplified by using the normalized sound level difference $D_{n,ij}$ for path *i,j* as:

$$L_{na,ij} = L_{Wa} + D_{si} - D_{n,ij} - 10\,lg(S_i / 4) \qquad (4)$$

The total airborne sound level transmitted through all the paths (the same as the paths used to calculate the sound insulation in EN 12354-1) can then be calculated:

$$L_{na} = 10\,lg \sum_{i,j} 10^{L_{na,ij} / 10} \qquad (5)$$

A few remarks can be made: *(i)* if the source is enclosed, (waste water pipe in a shaft for example), the source sound power is attenuated by the sound power insulation D_W (measured in laboratory) of the enclosure: $L_{Wa} = L_{Wa,source} - D_W$; *(ii)* waste water pipe are characterized using standard EN 14366, where the output quantity is directly expressed in terms of normalized sound level L_{na}; equation (1) is then not necessary anymore; *(iii)* the case of airborne sound sources located close to a wall or a floor is very common ; the incident airborne sound field is then no longer diffuse and the approach has to be modified ; this case can lead to either dominant grazing incidences in front of the element considered or a localized airborne excitation, similar to mechanical excitation [5]; more work is needed to solve this case.

3. STRUCTURE BORNE SOUND SOURCES

The structure borne sound source is mounted in situ in a room (source room; see Figure 2) and mechanically connected to a certain number of elements depending on the source type (a whirlpool bath is usually connected to the floor and 2 walls for example). The receiving elements must be heavy, with low mobility compared to the source mobility (the connection to lighter elements is under study at European Standardization level). The source is supposed to be characterized in laboratory by up to three levels $L_{Wsn,i}$ of characteristic reception plate power (one for each receiving element *i*) according to standard EN 15657-1. Note that the power injected by a source to a receiving structure depends on the receiver input mobility; the laboratory output quantity $L_{Wsn,i}$ represents the power injected by the source to a infinite concrete plate of thickness 10 cm of mobility $Y_{\infty,rec} = 5\ 10^{-6}\ m/Ns$.

A. Sound level in the receiving room

The normalized space averaged sound level $L_{ns,ij}$ radiated in the receiving room for each transmission path *i,j* can be calculated [1] as:

$$L_{ns,ij} = L_{Ws,inst,i} + D_{sa,i} - R_{ij,ref} - 10\,lg(S_i / S_{ref}) - 10\,lg(A_{ref} / 4) \quad (6)$$

This approach corresponds to a 3 step method:

- step 1: estimation of the installed power; $L_{Ww,inst,i}$ is the installed power injected to element *i* and calculated from the characteristic reception plate power $L_{Wsn,i}$ obtained in laboratory using:

$$L_{Ws,inst,i} = L_{Wsn,i} + 10\,lg(Y_{\infty,i} / Y_{\infty,rec}) \quad (7)$$

where $Y_{\infty,i} = 1/8\sqrt{m_i B_i}$ is the characteristic mobility of element *i* (with m_i mass per unit area and B_i bending stiffness).

- step 2: $D_{sa,i}$ is an adjustment term to estimate the incident airborne sound power generating the same vibrational energy in the receiving element i.

- step 3: standard EN 12354-1 can then be used through the flanking sound reduction index $R_{ij,ref}$ to estimate the structure borne sound level transmitted to the receiving room, from the equivalent incident airborne sound power.

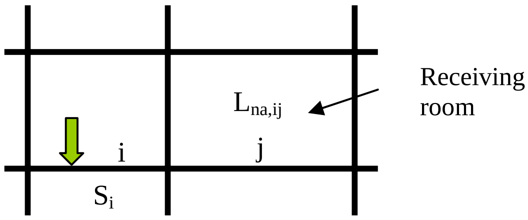

Figure 2: Structure borne sound transmission; sketch

As before, equation (6) can be simplified by using the normalized sound level difference $D_{n,ij}$ for path *i,j* as:

$$L_{ns,ij} = L_{Ws,inst,i} + D_{sa,i} - D_{n,ij} - 10\,lg(S_i / 4) \quad (8)$$

$D_{sa,i}$ can be estimated [1] from the R index, loss factor η and radiation efficiency σ of element *i* as:

$$D_{sa,i} = -R_i - 10\,lg\,\eta_i - 10\,lg(2\pi f\, m_i / \rho c) - 10\,lg\,\sigma_i \quad (9)$$

Note that among all the parameters needed, several are already known and used in EN12354-1: mass per unit area (used to estimate the vibration reduction index of junctions), loss factor (used to estimate field data from laboratory data) and R index. But, two are new: radiation efficiency and characteristic mobility (directly related to bending stiffness); however both can be roughly estimated from the mass per unit area of the (heavy) elements considered, treating homogeneous and hollow elements separately.

Remark: waste water pipes are characterized in laboratory according to standard EN 14366. In this standard, only acoustic quantities (airborne and structure borne sound) are measured and the output is a characteristic structure borne sound level L_{sc}. However, the installed power used in equation (8) can be deduced [1] from this characteristic sound level using:

$$L_{Ws,inst,i} = L_{sc} + 8\lg f - 10\lg Y_{\infty,i} + 53.5 \quad (10)$$

Like before, the total structure borne sound level transmitted through all the paths can then be calculated:

$$L_{ns} = 10\lg \sum_{i,j} 10^{L_{ns,ij}/10} \quad (11)$$

However, this time, *i* corresponds to the only element(s) in the source room which the source is connected to, and *j* to the elements in the receiving room linked through only one junction to element *i* (because of the simplified first order SEA used in the EN 12354 series). Figure 3 below shows some examples of transmission paths.

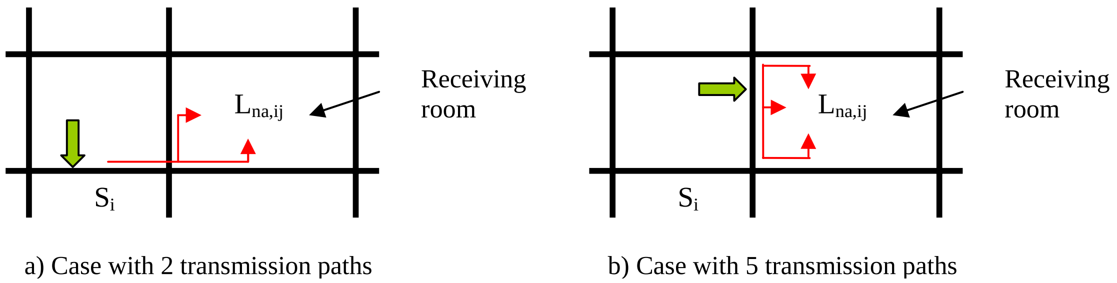

Figure 3: Structure borne sound transmission; examples of transmission paths

B. Sound level in the source room

This case is similar to the case described in Figure 3b with a source inside the "receiving room" and will be treated the same way; 5 transmission paths are involved.

4. PREDICTION AT LOW FREQUENCIES

The frequency band considered in standard EN 15657-1 is limited to the twenty one 1/3 octave bands from 50 Hz to 5000 Hz; laboratory data of airborne and structure borne sound source power are therefore already available in this frequency range. However this paper has shown that the prediction of service equipment noise in buildings is linked to the prediction of sound insulation between rooms (as described in EN 12354-1), which involves input parameters (such as the R index) usually not known below 100 Hz (at least in France), in spite of the possibility of extending the frequency range down to 50 Hz given in EN ISO 140-3. Prediction down to 50 Hz is therefore not possible yet.

5. CONCLUSIONS

The technical content of the new standard EN 12354-5 which allows the prediction of noise generated in buildings by service equipment, from laboratory data measured according to the also new standard EN 15657-1 has been presented in this paper, as well as the difficulties encountered and the limitations due to the still limited data or scientific knowledge available. The presentation will be illustrated by practical examples at the conference.

REFERENCES

1. EN 12354-5:2009, Building acoustics – Estimation of the acoustic performance of buildings from the performance of the elements – Part 5: Sound levels due to the service equipment.

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