Prediction of flanking sound transmission through gypsum board walls using SEA

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Introduction

In EN 12354-1:2000 a model is given for the prediction of sound transmission in buildings with "heavy", monolithic structures, like concrete or brickwork. Besides direct transmission through the partition the model also considers flanking transmission along first order paths.
In this paper a prediction model for flanking transmission through junctions of lightweight framed double leaf structures, like gypsum board walls, is derived using a statistical energy analysis (SEA) framework and validated experimentally at one test specimen.

Flanking sound transmission in terms of SEA

When sound transmission through a structure is considered in SEA, a system is defined and the structure is split up into a number of subsystems, like rooms, plates and beams, that represent a group of resonant modes. The resonant energy of the subsystems has to be distributed uniformly within the frequency bands considered and hence the modal properties of the subsystems have to fulfil a number of basic SEA conditions. The exchange of resonant energy between the subsystems and the losses in the subsystems are described by SEA loss factors that are either predicted or measured; power flow through the system is investigated.

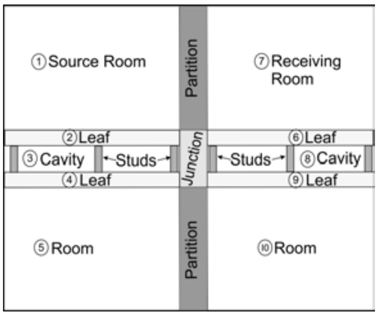

Figure 1: SEA system for flanking sound transmission through gypsum board walls (subsystems and denotations).

Figure 1 shows the SEA system for flanking transmission through gypsum board walls and the subsystems. Flanking transmission occurs between room 1 and room 7 through two gypsum board walls that are coupled at one junction. The leaves of the flanking walls are considered as single subsystems that only support bending modes. The cavities are resonant subsystems like the rooms and the studs are considered as structural coupling elements between the leaves that do not conserve resonant energy. The partitions between the rooms on the left and on the right side are not defined further and the junction is considered as "black-box" that couples the leaves of the two flanking walls only structurally.

In the frequency range of interest non-resonant and resonant energy components are induced in leaf 2 and leaf 4 because the flanking wall is excited by airborne sound in room 1 and the coincidence frequency of the gypsum board leaves is high. Therefore four different direct sound transmission paths through the flanking wall are considered below coincidence as it is indicated in figure 2. Along *path a* sound is transmitted non-resonantly through both leaves. Along *path b* and *path c* sound transmission is resonant through one and non-resonant through the other leaf. Finally, *path d* contains both leaves as resonant subsystems that are coupled fluid dynamically by the cavity and also structurally by the studs.

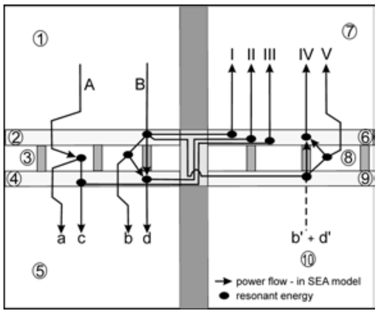

Figure 2: Considered power flow in the SEA system for flanking sound transmission through gypsum board walls.

Since at the junction only structural power flow is allowed, only the resonant energy components in the leaves on the source side couple across the junction with the leaves of the wall on the receiving side. Power flow between leaf 2 and leaf 6, between leaf 2 and leaf 9 and between leaf 4 and leaf 6 is considered in the following. Also sound is transmitted either resonantly or non-resonantly from leaf 9 to room 7. Hence below coincidence five flanking paths (path I to path V) and above coincidence three purely resonant flanking paths (path I, path II and path IV) are considered to occur through only two building elements that are coupled at a single junction.
The derivation of the expressions for the transmission paths will be shown elsewhere [2]. The reciprocity relationship holds if the paths are evaluated in opposite direction and the direction averaged flanking sound reduction index $\overline{R_{17,P}}$ for arbitrary path P is given in terms of acoustic quantities in equation (1) in a general form that is valid for all five flanking paths.

$$\overline{R_{17,P}} = \frac{\overrightarrow{R_P} + \overleftarrow{R_P}}{2} + \frac{D_{v,ij} + D_{v,ji}}{2} + 5\lg\frac{f_{c,j}\, m_i'^2\, \eta_i}{f_{c,i}\, m_j'^2\, \eta_j} + 5\lg\frac{S_S^2}{S_i\, S_j} \quad \text{[dB]} \quad (1)$$

Table 1: Input data for equation 1 for the flanking paths

	$\overrightarrow{R_p}$	$\overleftarrow{R_p}$	$D_{v,ij}$
Path I	$R_{13,R}$	$R_{31,R}$	$D_{v,26}$
Path II	$R_{15,d}$	$R_{51,d}$	$D_{v,46}$
Path III	$R_{15,c}$	$R_{51,c}$	$D_{v,46}$
Path IV	$R_{107,d}$	$R_{7\,10,d}$	$D_{v,29}$
Path V	$R_{107,c}$	$R_{7\,10,c}$	$D_{v,29}$

Equation (1) for the flanking paths is a function of the direct sound reduction indices R_P through the flanking wall, the resonant velocity level difference $D_{v,ij}$ of the gypsum board leaves, their coincidence frequencies f_c, their masses per unit area m', their total loss factors η and the surface areas S of the flanking walls and of the separating wall between the two rooms. The appropriate quantities of equation (1) are given for the paths in table 1. In this paper the direct sound reduction indices of table 1 are predicted like in [2] and the velocity level differences are measured.

Test set-up

The measurements have been carried out in the new NRC-IRC flanking test facility in Ottawa, Canada. A full-scale cross junction of wood frame walls and floors divides the facility into eight rooms with four on the two floors. In this paper only horizontal transmission through the wall junction on the first floor is investigated.

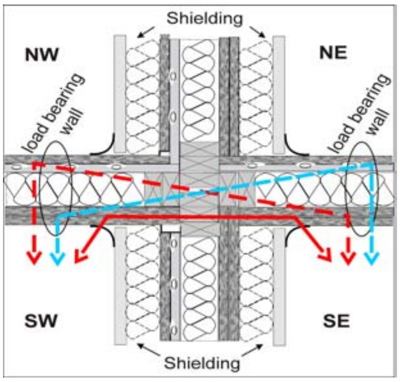

Figure 3: Junction of wood frame gypsum board walls and considered transmission paths

Test specimen

The junction is shown in figure 3 and flanking sound transmission is considered between room SW and SE. The coupled flanking walls are load bearing with a spacing of 0,40 m between the wood studs (38x89 mm²). In room SW and SE a double layer of 2x16 mm gypsum board is attached with screws to the frame and on the other side a single layer is mounted on resilient channels. The cavities are filled with 90 mm thick mineral wool bats. In front of the separating walls additional gypsum boards are placed on a layer of encapsulated mineral wool as shielding to suppress sound radiation or excitation of their surfaces by the sound field. All joints of the specimen and the shielding are taped or caulked to avoid sound leaks.

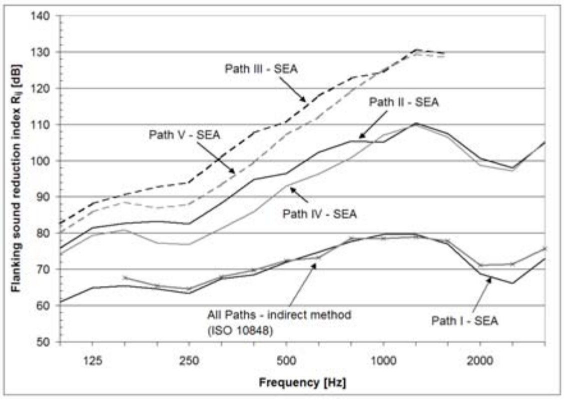

Figure 4: Predicted and measured flanking sound reduction indices for the considered paths

Applied measurement methods

First, the velocity level differences of table 1 are measured on the leaves with a scanning laser vibrometer in third-octave bands on a point grid with spacing of bigger than 0,20 m. On every leaf at least six driving points are randomly chosen for excitation with an electro-dynamic shaker. Second, the sound pressure level difference is measured between the rooms SW and SE for airborne excitation according to the indirect method of ISO 10848-1:2006 and the resultant flanking sound reduction index R_{17} of all paths through the considered flanking walls is determined.

Prediction versus experiment

In figure 4 the predicted flanking sound reduction indices are shown for all considered paths as well as the measurement results according to ISO 10848. The prediction for path I with coupling of the leaf 2 and leaf 6 agrees well with the measurement and the difference is less than 2 dB below coincidence. The predicted flanking sound reduction indices of the other paths that involve the second leaf of the flanking wall are at least 20 dB bigger in most of the frequency range and hence do not contribute to the overall transmission since the direct sound reduction indices as well as the velocity level differences are bigger that are used as input data than the one of path I. The difference between path II and path IV and between path III and path V is small since both coupled walls are equal and the junction is almost symmetrical.

Summary and conclusions

A simple prediction model for flanking transmission through gypsum board walls is derived in terms of SEA and validated. For flanking through two coupled flanking walls multiple transmission paths exist, but only path I is dominating the overall transmission. Transmission through the other paths is usually of smaller order and can be neglected but gives deeper insight in transmission at the junction.

Literatur

[1] Craik, R. J. M.: Sound transmission through buildings using SEA. Gower Publishing Limited, Aldershot, 1996

[2] Schoenwald, S.: Doctoral Thesis, Eindhoven University of Technology, exp. summer 2008