Investigation of the sound transmission through double-leaf separating walls with respect to incomplete separation

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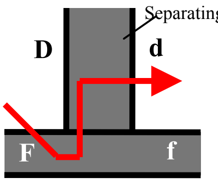
Introduction

The separating walls between attached row and twin houses usually are of heavyweight cavity construction in order to avoid annoyance caused by noise from adjacent houses. Although it is known that the sound reduction index is higher than for single-leaf walls with the same mass at present it is not possible to quote by number the sound reduction that can actually be achieved for certain situations. Since the actual state concerning this matter is unsatisfying a research project in cooperation with the industrie was started. The main aim is to find a way for prediction of the sound transmission through double-leaf separating walls including the flanking transmission which is compatible to the CEN-calculation model [1].

Approach

Complete separation

In [2] an approach to extend the CEN-calculation to heavy double walls as separating (and flanking) elements for complete separation was presented. Complete separation means that there is no effect of bridging of the two wall leafs by the ground plate which is approximately given one level above the ground plate. The basic idea of [2] is picked up here.



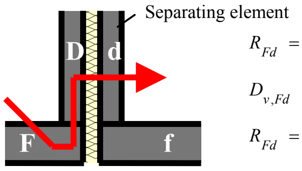
$$R_{Fd} = R_F + 10\lg\frac{\sigma_F}{\sigma_d} + D_{v,Fd} + 10\lg\frac{S_D}{S_d} \quad (1)$$

$$R_{Fd} = R_{dF} = \frac{R_F}{2} + \frac{R_d}{2} + \overline{D_{v,Fd}} \quad (2)$$

$$\overline{D_{v,Fd}} = k_{Fd} - 10\log\frac{l_{Fd}}{\sqrt{a_{F,situ}\cdot a_{d,situ}}} \quad (3)$$

Figure 1: **single-leaf situation e.g. path Fd (other paths analogue)**

The basic principle of [1] is to calculate the sound transmission via each transmission path and sum up all paths to the overall transmission. For example the transmission on path Fd (Figure 1) can be calculated according to equation 1. This equation corresponds to a direction dependent calculation. Input values are the sound reduction index of the flanking element and the velocity level difference of the flanking and the separating element. For a direction dependent calculation also the radiation coefficients are needed. The radiation coefficients are eliminated by using reciprocity how equation 2 is received. As input values the sound reduction indices of the elements that form the junction and the direction averaged velocity level differences are needed. $\overline{D_{v,Fd}}$ can be calculated according to equation 3 from the junction transmission index K_{Fd} and the equivalent absorption lengths. This data can be received from Annex E of [1]. The capability of this method has been proved for single-leaf situations, input data is available.



$$R_{Fd} = R_F + 10\lg\frac{\sigma_F}{\sigma_d} + D_{v,Fd} + 10\lg\frac{S_D}{S_d} \quad (4)$$

$$D_{v,Fd} = D_{v,FD} + D_{v,Dd} \quad (5)$$

$$R_{Fd} = R_{dF} = \frac{R_F}{2} + \frac{R_d}{2} + \overline{D_{v,FD}} + \overline{D_{v,Dd}} \quad (6)$$

Figure 2: **double-leaf situation e.g. path Fd (other paths analogue)**

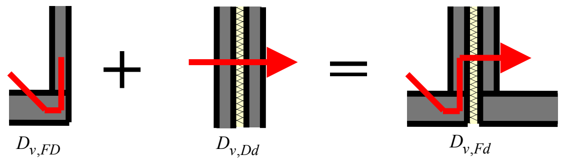


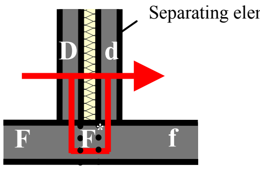
Figure 3: **addition of velocity level differences e.g. path Fd (other paths analogue)**

For double-leaf separating walls the transmission paths are basically the same (Dd, Df, Ff, Fd) but the transmission through the cavity constitutes a fundamental difference which has to be taken into account. This is done by defining a velocity level difference $D_{v,Dd}$ for the two wall leafs. In Figure 2 is shown how the transmission e.g. on path Fd can then be described. For a direction dependant calculation equation 4 applies which is similar to equation 1 but the transmission through the cavity is contained in $D_{v,Fd}$. The approach is to split up the velocity level difference $D_{v,Fd}$ into $D_{v,FD}$ for the junction built by flanking and separating element and $D_{v,Dd}$ for the two wall leafs. If the (simple) addition of velocity level differences for the junction and the two wall leafs is applicable the CEN calculation model with its basic requirements could simply be extended to double-leaf separating walls. In order to find out if the addition of velocity level differences for T- / L-junctions and for the two wall leafs is applicable a field measurement was carried out. In Figure 5 the velocity level difference of the two wall leafs is shown. The result of the addition of $D_{v,FD}$ and $D_{v,Dd}$ is exemplary shown in Figure 6 for the ceiling as flanking element. The addition results in a very good agreement with the measured $D_{v,Fd}$ which is also the case for other flanking elements. Therefore it can be stated that the addition of the velocity level differences as described is possible and so the basic requirement of the presented approach seems to be given. Using reciprocity equation 6 is received. The required input data then is the same as for single-leaf situations -

R_d / R_D can be calculated the same way as R_f / R_F - except $\overline{D_{v,Dd}}$ which can either be calculated or based on measurements. In further steps the accuracy has to be checked when using calculated input data for 1.) $\overline{D_{v,FD}}$ according to Annex E of [1] and 2.) $\overline{D_{v,Dd}}$ with available calculation methods.

Incomplete separation (in the ground floor)

For stability reasons the two leaves of the wall in most cases are structurally linked, particularly by the ground plate. This bridging increases the sound transmission of the cavity wall and also the flanking transmission in the ground level. Since recently more and more row and twin houses are built without basement a prediction method for this situation is needed. In order to describe the transmission according to the CEN-calculation model in principle the same approach as for complete separation is possible but many more transmission paths have to be considered (Figure 4).



$$\tau_d = \tau_{Dd} + \tau_{DF^*d} + \tau_{FDd} + \tau_{FF^*d} \tag{7}$$

$$\tau_f = \tau_{FF^*f} + \tau_{FDdf} + \tau_{Ddf} + \tau_{DF^*f} \tag{8}$$

Figure 4: **double-leaf situation for incomplete separation**

In addition the bridging of the walls by the ground plate (junction transmission of 2nd order) obviously can't be modelled easily. At this point it is conceivable to calculate the transmission as for complete separation and add a correction term considering the effect of the not interrupted ground plate. In case of a floating floor on the ground plate it can be assumed that mainly the transmission via path Dd ($\tau_{Dd} + \tau_{DF^*d}$) is increasing the sound transmission compared to the situation of complete separation. The effect of the ground plate can be evaluated by comparison of the measured velocity level difference of the two wall leafs for complete and incomplete separation (1st floor / ground floor). As an example the result of a measurement is shown in Figure 7. While $D_{v,Dd}$ is increasing with frequency, in the ground floor the increase stops at a certain frequency and remains in a plateau. This affects the sound reduction index as shown in the right graph. In order to quantify this effect further investigations have to be carried out.

Summary and outlook

A prediction method for the transmission through double-leaf separating walls is needed. An approach to extend the CEN-calculation model based on investigations of [2] was presented. First measurements indicate that the basic requirement of the approach – the possible addition of velocity level differences for T-/L-junctions and the cavity built by the two wall leafs – is given. In consideration of the achievable accuracy of predictions according to the presented approach for complete separation further investigations have to be carried out. In particular the effect of a not interrupted ground plate (incomplete separation) has to be investigated.

Field measurement

The separating and flanking walls are of aerated concrete, ceilings are of reinforced concrete. In the 1st floor the velocity level differences were measured for each transmission path separately.

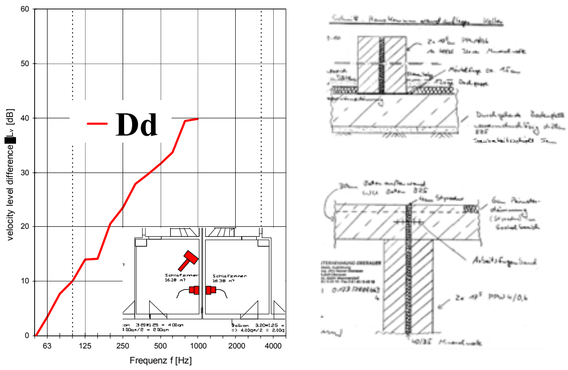


Figure 5: **graph: velocity level difference $D_{v,Dd}$ in the 1st floor draft: connection of sep. wall and ground plate / outer walls**

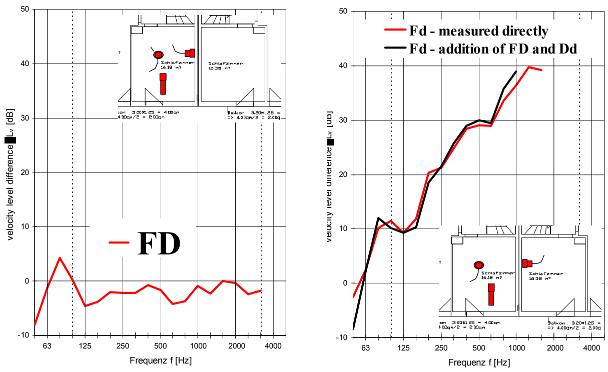


Figure 6: **comparison of the addition of measured velocity level differences $D_{v,FD} + D_{v,Dd} = D_{v,Fd}$ with measured $D_{v,Fd}$ in the 1st floor. Flanking element: ceiling**

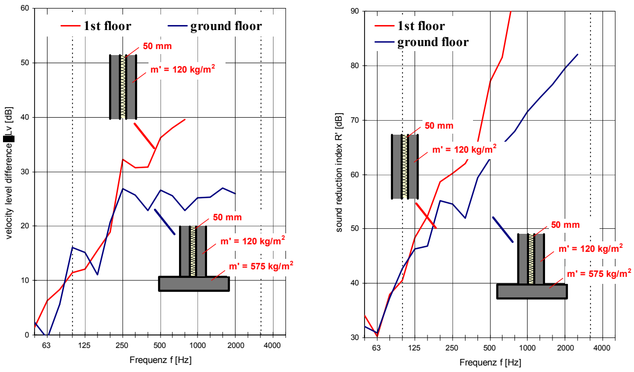


Figure 7: **comparison 1st floor / ground floor left: velocity level differences for the two wall leafs right: sound reduction indices**

References

[1] CEN/TC 126 N 237, pr EN 12354-1: Building acoustics – Estimation of acoustic performance of buildings from the performance of elements - Part 1: Airborne sound insulation between rooms, April 2000

[2] H. A. Metzen; D. B. Pedersen; E. Sonntag, ‚Extending the CEN-Calculation model for sound transmission in buildings to heavy double walls as separating and flanking walls', Forum acusticum Sevilla 2002