Radiation Factor Correction when calculating Flanking Transmission

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Introduction

The calculation scheme in EN 12354-1 is based on an reciprocal approach when calculating the contribution of each flanking path ij resulting in the sound reduction index R_{ij} via each flanking path (ignoring additional layers) [1]:

$$R_{ij} = \frac{R_{i,situ} + R_{j,situ}}{2} + \overline{D_{v,ij,situ}} + 10\lg\frac{S_S}{\sqrt{S_i S_j}} \tag{1}$$

with the direction averaged velocity level difference $D_{v,ij,situ}$ based on a reciprocal definition.

The standard states that the sound reduction indeces R_i resp. R_j of each element should relate to resonant transmission only. Calculations according to the above formula can be considered to be correct only above the critical frequency f_c. With respect to heavy building elements such as masonry or concrete walls and floors this is considered to be not a rather strong restriction. However, this is a severe restriction to the range of application of the standard with lightweight elements having a high critical frequency. Thus, the most relevant parts of the frequency range – with regard to the single number rating describing performance - are dominated by the non-resonant (forced) transmission. The difference is due to different radiation efficiencies on sending and receiving side of the flanking path under consideration:

$$\tau_{ij} = \left[\tau_i \ \tau_j \ d_{ij} \ d_{ji} \ \frac{S_i \ S_j}{S_0^{\ 2}} \frac{\sigma_{i,\,receive} \ \sigma_{j,\,receive}}{\sigma_{i,\,source} \ \sigma_{j,\,source}} \right]^{1/2} \tag{2}$$

Correction of radiation efficiency

Following the calculation model given in EN 12354 the input data for elements to calculate the flanking transmission should relate to resonant transmission [1]. Due to the dominant excitation of free bending waves this assumption holds above the critical frequency. Below the critical frequency the airborne sound insulation index measured according to ISO 140-3 with airborne sound excitation is too low because the forced transmission governs the sound reduction index. For elements with a critical frequency well above the lower limit of the frequency range this may - when using data measured in a direct transmission suite according to ISO 140-3 - result in a too low flanking sound reduction index R_{ij}.

An approach to correct for the radiation efficiency has been published by *Sonntag* in 1965 [2]. The relation between the surface velocity of the resonant to the non-resonant modes has been derived for broad band exitation and for structures with not too high damping:

$$\varphi^2 = \frac{1}{\eta_{tot,lab} \cdot k_B \cdot \frac{\max(a;b)}{2}} \tag{3}$$

with the size dimensions a, b and the bending wave number:

$$k_B = \frac{2\pi}{c_0} \cdot \sqrt{\frac{f}{f_c}} \tag{4}$$

with the speed of sound c_0 and the critical frequency f_c. With the sound reduction index for forced excitation (non-resonant transmission):

$$R_{non-res} = -10\lg\left(\tau_{45°}\right) \quad \mathrm{dB} \tag{5}$$

an the sound reduction index for free excitation (resonant transmission):

$$R_{res} = -10\lg\left(\tau_{45°} \cdot \varphi^2 \cdot \sigma_{res}\right) \quad \mathrm{dB} \tag{6}$$

Then, the predicted sound reduction index in laboratory is:

$$R_{lab} = -10\lg\tau_{45°}\left(1 + \varphi^2 \cdot \sigma_{res}\right) \quad \mathrm{dB} \tag{7}$$

The correction (R_{res} - R_{lab}) is applied below the critical frequency ($f < f_c$) while for the higher frequency bands its value is set to 0 dB.

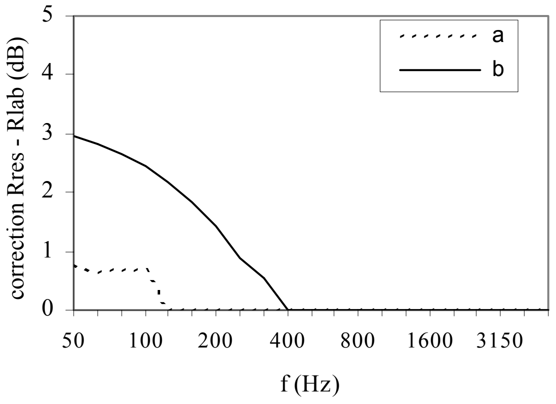

Figure 1: Radiation factor correction (R_{res}-R_{lab}); a: 240 mm calcium silicate blocks (surface mass m“ = 452 kg/m²); b: 80 mm gypsum blocks (m“ = 80 kg/m²).

Application to heavy elements

For heavy flanking elements the correction results in an increase of the flanking sound reduction index R_{ij} in single third-octave bands of 1-3 dB which is in practice of minor relevance when predicting the performance between rooms expressed by a single number rating (e.g. weighted sound reduction index R'_w). Figure 1 illustrates the correction for two monolithic walls made from calcium silicate and from gypsum blocks (wall dimensions 4 m x 2,5 m).

Application to lightweight elements

For lightweight elements with high critical frequency used as flanking constructions – such als gypsum board walls – the correction is reasonably higher. As it can be assumed that the overall flanking sound reduction index via path Ff is dominated by the transmission along the internal cladding across the junction the correction of the radiation factor is applied just to the gypsum board as exitated and radiating plate. Figure 2 shows the calculated result for a 12.5 mm gypsum board for two different plate sizes.

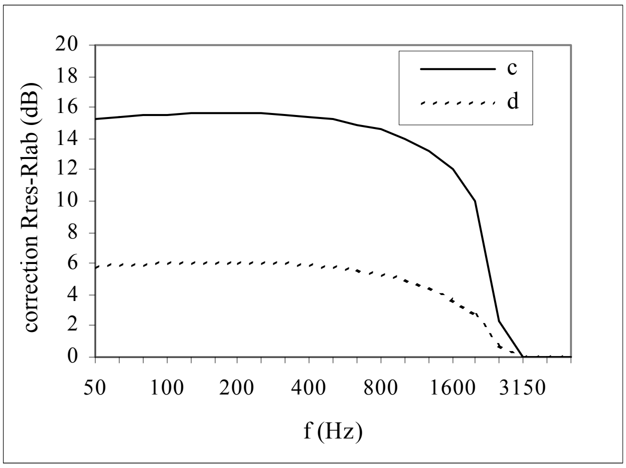

Figure 2: Radiation factor correction (R_{res}-R_{lab}) for 12.5 mm gypsum board; c: for dimensions 4 m x 2.5 m Total width); d: for dimensions 0.6 m x 2.5 m (studs width).

With lightweight constructions mounted on a frame or on studs the size of the radiating plate is a relevant parameter. Some authors have stated that the surface velocity level decreases rapidly along the plate on sending and receiving side while others found no relevant decrease of the velocity level on the receiving side [3, 4]. However, in both cases the average velocity level and thus the radiation is dominated by the resonant modes (i.e. free bending waves).

Comparison with measured data

Figure 3 shows a test result of a lightweight double wall on metal studs with 12.5 mm gypsum board cladding on either sides installed as a flanking wall in a 4-room flanking test facility [5]. The flanking sound reduction index R_{Ff} has been measured and compared with the calculated one making use of the measured direct sound reduction index R and the measured junction transmission index K_{ij}. The difference R_{meas}-R_{calc} is mainly due to different radiation factors when applying the direct sound reduction index R to calculate the transmission via flanking path Ff. The proposed correction of the radiation factor increases the accuracy of the prediction of the flanking sound reduction index R_{Ff}. The plate dimensions assumed n this example the dimension were 4.6 m x 2.95 m.

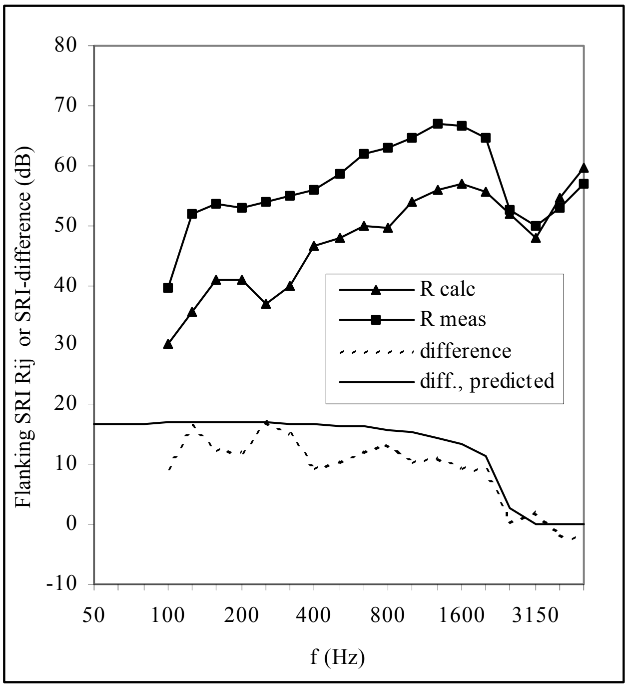

Figure 3: Increase of the flanking sound reduction index due to the radiation factor correction for a double light-weight wall, cladding 12,5 mm gypsum board.

Summary

Sound reduction indeces originating from tests performed in transmission suites according to ISO 140 cause an under-estimation of the flanking sound reduction index R_{ij} calculated according to EN 12354-1. Reasons for this discrepancy are that diffuse field conditions in the transmitting plates are oftenly not met and the difference of the radiation factor for forced and free bending waves is not taken into account. The proposed correction enables to correct for this effect with reasonable increase of accuracy of the predictions. However, further investigations are required to confirm this approach in the range of applications required.

References

[1] EN 12354-1: Airborne Sound Insulation between Rooms, 2000.

[2] Sonntag, E.: Die Anregung freier Biegewellen auf Platten bei Luftschalldämmung, Hochfrequenztechn. u. Elektroakust. Leipzig 74 (1965), S. 173-181.

[3] Weber, L.; Scholl, W.: Stoßstellendämmung bei Leichtbauwänden, DAGA Oldenburg, 2000.

[4] Saß, B.; Schumacher, R.: Längsschalldämmung und Stoßstellen-dämmung im mehrgeschossigen Holzbau, DAGA Aachen, 2002.

[5] Weber, L.: Berechnungsverfahren für die Schall-Längsleitung im Leichtbau, Akustik-Forum Raum und Bau, Fraunhofer-Institut für Bauphysik (IBP), Stuttgart 3./4.02.2004.