Radiation Factor Correction when calculating Flanking Transmission

Heinrich A. Metzen

DataKustik GmbH, D-86926 Greifenberg, Germany; Email: h.metzen@datakustik.de

Introduction
The calculation scheme in EN 12354-1 is based on a 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]:

\[
R_{ij} = \frac{R_{i, situ} + R_{j, situ}}{2} + D_{v, ij, situ} + 10 \log \left( \frac{S_i}{S_j} \right)
\]

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:

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 excitation and for structures with not too high damping:

\[
\varphi^2 = \frac{1}{\eta_{tot, lab} \cdot k_B \cdot \max(a; b) \cdot \frac{2}{\pi}}
\]

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

\[
k_B = \frac{2\pi}{\epsilon_0} \cdot \frac{f}{\sqrt{f_c}}
\]

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

\[
R_{\text{non-res}} = -10 \log \left( \varphi \cdot 10^{\frac{R_{\text{res}}}{10}} \right) \text{ dB}
\]

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

\[
R_{\text{res}} = -10 \log \left( 10^{\frac{R_{\text{res}}}{10}} \cdot \varphi^2 \cdot \sigma_{\text{res}} \right) \text{ dB}
\]

Then, the predicted sound reduction index in laboratory is:

\[
R_{\text{lab}} = -10 \log \left( 10^{\frac{R_{\text{res}}}{10}} \cdot 10^{\frac{\varphi^2}{10}} \cdot \sigma_{\text{res}} \right) \text{ dB}
\]

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

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 \( R_y \).

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

\[
\tau_{ij} = \left[ \tau_1 \cdot \tau_j \cdot d_{ij} \cdot d_{ji} \cdot S_i \cdot S_j \cdot \frac{\sigma_{i, receive}}{\sigma_{i, source}} \cdot \frac{\sigma_{j, receive}}{\sigma_{j, source}} \right]^{1/2}
\]

Figure 1: Radiation factor correction (\( R_{\text{res}}-R_{\text{lab}} \)); a: 240 mm calcium silicate blocks (surface mass \( m'' = 452 \text{ kg/m}^2 \)); b: 80 mm gypsum blocks (\( m'' = 80 \text{ kg/m}^2 \)).
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 as gypsum board walls – the correction is reasonably higher. As it can be assumed that the overall flanking sound reduction index via path \( F_f \) 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 exited and radiating plate. Figure 2 shows the calculated result for a 12.5 mm gypsum board for two different plate sizes.

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 \( F_f \). 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 in this example were 4.6 m x 2.95 m.

Summary

Sound reduction indices originating from tests performed in transmission suites according to ISO 140 cause an underestimation 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 often 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