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Revising the EN12354 method of calculating the flanking sound reduction index of lightweight building elements

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Abstract: There is great interest worldwide in using the standard, EN12354 to predict the flanking sound reduction index of lightweight building constructions. However, there are several problems which must be overcome before the prediction method can be accurately applied to lightweight building elements. One problem is that the resonant component of the sound reduction index of lightweight elements must typically be determined for the predictions. Three methods of determining the resonant component which are being considered by COST Action FP0702 have been evaluated. The evaluation was conducted by comparing the predicted flanking sound reduction indices which were calculated using the different methods of calculating the resonant sound reduction index to the measured flanking intensity sound reduction index for a series of elements. The elements included single, homogeneous elements and double leaf elements. The determination of the resonant sound reduction index using a correction factor proposed by CSTB based on the radiation efficiencies of the elements is recommended.

Keywords: Flanking, Lightweight, Building

1. Introduction

One of the difficulties in applying the EN12354 (ISO 15712-1)^{1,2} method of predicting the flanking sound reduction index to lightweight building elements is that the resonant sound reduction index of the elements must typically be determined. The resonant sound reduction index R_R can not be measured and therefore must be either calculated theoretically or derived from measurement data. There have been a number of different methods of determining R_R proposed in the literature (for example, see Gerretsen³). However, each of the different methods of determining R_R results in a different value for R_R , which in turn, results in a wide range of predictions of the flanking sound reduction index R_{ij} . One of the objectives of the COST Action FP0702⁴ has been the adaptation of the EN12354 method to timber based, lightweight constructions. A result of the Action is that the number of methods of determining R_R under consideration has been reduced to three. However, only one method should be included in the revised EN12354 to ensure the uniformity of the predictions of R_{ij} .

The objective of the study described in this paper was to evaluate the methods of determining R_R which have been proposed by the COST Action. Since the true best estimate of R_R can not be determined directly, the accuracy of the different methods of determining R_R were evaluated by comparing the measured flanking intensity sound reduction index of different lightweight building elements to the values of the flanking sound reduction index predicted by the EN12354 method using the different methods of determining R_R .

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2. Determination of the resonant sound reduction index

The methods of determining R_R include:

2.1 Method Gerretsen

Method Gerretsen⁵ is based on the subtraction of the non-resonant sound reduction index from the total, measured sound reduction index such that:

$$R_{R, Gerretsen} = R_T - 10 \log \left[1 - \left(10^{\frac{-R_T}{10}} \right) 2\sigma_{NR} \left(\frac{2\rho_o c_o}{2\pi f \rho_s} \right)^2 \right] \quad \text{if} \quad \left[1 - \left(10^{\frac{-R_T}{10}} \right) 2\sigma_{NR} \left(\frac{2\rho_o c_o}{2\pi f \rho_s} \right)^2 \right] > 0.1 \quad (1)$$

$$R_{R, Gerretsen} = R_T + 10 \quad \text{if} \quad \left[1 - \left(10^{\frac{-R_T}{10}} \right) 2\sigma_{NR} \left(\frac{2\rho_o c_o}{2\pi f \rho_s} \right)^2 \right] \leq 0.1 \quad (2)$$

where R_T is the total, measured sound reduction index measured in the laboratory, σ_{NR} is the non-resonant component of the radiation efficiency, ρ_o is the density of air, c_o is the speed of sound in air, f is the frequency in Hz and ρ_s is the mass per unit area of the element. The limit for the calculation of $R_{R, Gerretsen}$ shown in Eq. 2 was required because the use of Eq. 1 without the limit can lead to values for $R_{R, Gerretsen}$ which can not be calculated.

2.2 Calculated Input Data Method

A correction factor which Gerretsen³ based on the equations found in Annex B of EN12354-1 is:

$$R_{R, CID} = R_T + 10 \log \left[1 + \frac{2\sigma_{NR}}{\sigma_R^2} \frac{(l_1^2 + l_2^2)}{(l_1 + l_2)^2} \eta_{tot} \sqrt{\frac{f}{f_c}} \right] \quad (3)$$

where l_1 and l_2 are the dimensions of the element, η_{tot} is the total loss factor of the element, σ_R is the resonant radiation efficiency of the element and f_c is the critical frequency of the element. It is important to note that Davy⁶ has found errors in the calculation of the radiation efficiency terms presented in Annex B.

2.3 CSTB Correction Factor

A correction factor proposed by CSTB⁷ which is based on the radiation efficiencies of the element is:

$$R_{R, CSTB} = R_T + 10 \log \left(\frac{\sigma_T}{\sigma_R} \right) \quad (4)$$

where σ_T is the total radiation efficiency. The total radiation efficiency includes both the resonant and the non-resonant components and is measured when an element is excited with airborne noise.

3. Measurements

3.1 Measured Values

L shaped panels constructed from two identical lightweight elements joined at the edges were mounted into an opening between a reverberant room and a semi-anechoic room. The flanking intensity sound reduction index of the L shaped panels was measured using sound intensity according to ISO15186-2.⁸

The velocity level differences of the L shaped panels were measured *in situ* in accordance with ISO 10848-1.⁹ The mechanically excited velocity level difference between the elements was measured in both transmission directions using a mechanical shaker as a excitation source. The loss factors of the

elements were measured *in situ* according to ISO 10848-1.

The resonant radiation efficiency σ_R of each of the elements was measured *in situ* by exciting element i and then measuring the velocity and sound intensity of panel j . In the case of the single leaf panels, this method of exciting the panels avoided the extra point force radiation contribution from the shaker. The airborne diffuse field excited radiation efficiency σ_T was measured by installing identical, single elements into the opening between the reverberation room and the semi-anechoic room and measuring the sound intensity and the time and space averaged mean squared normal velocity on the receiving room side.

3.2 Lightweight Building Elements Evaluated

The elements considered for the study were four sets of coupled, lightweight elements. Elements were joined together at one end to form L-shaped panels. The dimensions of each of the elements were 1.548m x 0.948m so that either side of the L-panel could be inserted into an opening between a reverberation room and a semi-anechoic room. A list of the panels is shown in Table 1.

Table 1: List of L-shaped panel constructions used for the study.

Elements	Leaf Material	Stud Material	Construction	Element thickness (m)
Single Leaf Panel	1.6 mm Steel	-	Panels spot welded to angle iron	0.002
Single Leaf Panel	4 mm MDF	-	Panels glued and screwed to a 1"x1" wood bar	0.004
Double Leaf Panel	10mm gypsum board	Metal	Studs crimped. Gypsum board screwed to studs.	0.091
Double Leaf Panel	4 mm MDF	Wood	Studs nailed. MDF glued and screwed to studs.	0.078

4. Calculations

The flanking sound reduction indices using the different methods of calculating the resonant component of the sound reduction index were predicted according to EN12354. The velocity level difference used for the calculations was for one direction only rather than the direction averaged velocity level difference. Although the EN12354 calculations require the velocity level difference to be direction averaged, the potentially large differences in the velocity level difference in each transmission direction can lead to uncertainty in the predictions. Therefore, this source of potential error was removed from the evaluation by considering one transmission direction only.

The radiation efficiency terms used for the calculation of Method Gerretsen and the Calculated Input Data Method were calculated according to Annex B of EN12354. Although there are other formulas for calculating the radiation efficiency terms, it seemed reasonable to assume that a person calculating the apparent sound reduction index using EN12354 would use on the equations presented in the standard. In addition, the CSTB Correction Factor was calculated using the radiation efficiency terms calculated according to the proposed revisions to the EN12354 standard.¹⁰

5. Results

The measured and predicted flanking sound reduction indices of the single, homogeneous, steel L-panel are compared in Figure 1. The error bars in the figure are the 95% confidence interval based on the standard deviation of repeatability of the measurements calculated according to GUM.¹¹

The Calculated Input Data Method is shown to over predict the flanking sound reduction index by up to 15.5 dB. The CSTB correction factor based on the measured radiation efficiencies was within 2 dB and a maximum of 6.9 dB of the measured value. The calculations using Method Gerretsen with the 10 dB limit was on average within 2 dB and a maximum of 4.8 dB of the measured value. However, a limit of 8 dB resulted in a more accurate prediction which was within 1.4 dB and a maximum of 2.8 dB of the measured value.

Figure 1 - Comparison for the steel elements.

Figure 2 - Comparison for the MDF elements.

The measured and predicted flanking sound reduction indices of the single, homogeneous, MDF L-panel are compared in Figure 2. The figure shows that both the Calculated Input Data Method and the CSTB Correction based on the revised Annex B over predicted R_{ij} below the 4000 Hz 1/3 octave band. Method Gerretsen also over predicted R_{ij} . A more accurate prediction using Method Gerretsen could be achieved by using a 3dB limit. However, the best prediction of the value of R_{ij} was achieved using the CSTB correction factor based on the measured radiation efficiency terms.

The measured and predicted flanking sound reduction indices of the double-leaf MDF L-panel are compared in Figure 3. The figure shows that both the Calculated Input Data Method and the CSTB Correction based on the revised Annex B over predicted R_{ij} . Method Gerretsen over predicted R_{ij} above the 500 Hz 1/3 octave band. A more accurate prediction using Method Gerretsen could be achieved by using a 4dB limit. The best prediction of the value of R_{ij} was achieved using the CSTB correction factor based on the measured radiation efficiency terms.

Figure 3 - Comparison for the double-leaf MDF elements.

Figure 4 - Comparison for the double-leaf gypsum board elements.

The measured and predicted flanking sound reduction indices of the double-leaf gypsum board L-panel are compared in Figure 4. The figure shows that both the Calculated Input Data Method and the CSTB Correction based on the revised Annex B over predicted R_{ij} above the critical frequency in the 4000 Hz 1/3 octave band. Method Gerretsen over predicted R_{ij} over much of the frequency range. A more accurate prediction using Method Gerretsen could be achieved by using a 0dB limit. The best prediction of the value of R_{ij} was achieved using the CSTB correction factor based on the measured radiation efficiency terms.

6. Discussion

The use of the Calculated Input Data Method systematically over predicted the value of the flanking sound reduction index. In the case of the double-leaf MDF panel, the over prediction was in excess of 29 dB. The results of this study have confirmed that the Calculated Input Data Method based on Annex B in its present form should not be used.

The CSTB Correction Factor based on the radiation efficiencies predicted using Annex B of the revised EN12354 is shown to over predict R_{ij} . The over prediction was caused by the errors in the calculation of the radiation efficiency terms which were carried into the proposed revision of the standard. The changes to the proposed revisions only include a calculation of the value of σ_T while the calculations of σ_{NR} and σ_R remained the same as those in the existing EN12354. Therefore, the equations presented in the proposed revision to Annex B should not be used for the determination of R_R .

The use of Method Gerretsen with the 10 dB limit tended to over predict the value of R_{ij} . The results for the lightweight elements evaluated in this study suggest that a lower limit (between 8 dB and 0 dB) would be better than the suggested 10 dB limit. More measurements are required for a range of elements to determine the best value for the limit on Method Gerretsen. However, the use of Method Gerretsen with any limit has been opposed by Davy.¹²

The use of the CSTB correction factor resulted in the best prediction of R_{ij} for the lightweight elements evaluated in this study.

7. Conclusions

The use of the formulas for calculating the radiation efficiencies found in Annex B of the current or the proposed EN12354 should not be used for the determination of the resonant sound reduction index. Method Gerretsen with the 10 dB limit was found to over predict the resonant sound reduction index. A different limit in the range of 0 dB to 8 dB may give better results. The CSTB correction factor was found to be the best method of calculating the resonant sound reduction index of lightweight elements.

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