SOUND INSULATION OF FACADE AND THE EVALUATION OF THE TOLERANCES OF STANDARD PREN 12354-3

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Abstract

European standard prEN 12354-3 describes calculation models designed to estimate the reduction of outdoor sound by facades of buildings. The accuracy of the prediction depends on the accuracy of the input data, the type of elements involved, the geometry of the situation, etc. The facade elements of the buildings are normally defined according to the temperature conditions of the environment. For this reason they are dissimilar in different countries. In the standard, it is therefore not possible to specify the accuracy in general for all types of situations and applications. In this paper the tolerance of the method is studied by comparing the calculation results to the laboratory measurement results of different types of facades and sound fields of source room. Some examples of the comparison results are presented and the possible reasons for the discrepancies are discussed. The obtained accuracy of the predictions is satisfactory for airborne sound insulation.

1 Introduction

The European standard prEN 12354-3 [1] describes a calculation model designed to estimate the reduction (sound insulation or the sound pressure level difference) of outdoor sound by facades or other external surfaces of buildings (especially dwellings), on the basis of data which characterises the sound reduction index (or alternatively element normalized level difference) of the relevant building elements. Those elements are usually windows, doors, walls, roofs or ventilation equipment. The facade elements of the buildings are normally defined according to the temperature conditions of the environment. As an example of this, in the Nordic countries, the windows are typically 3-glazed and thus acoustically complicated. Thermal insulation is the most important single property also for other facade elements. The accuracy of prediction depends on the accuracy of the input data, the type of elements involved, the geometry of the situation, etc. In the standard, it is therefore not possible to specify the accuracy in general for all types of situations and applications and thus no specific accuracy values of the method are presented. There is thus a need to gather data on the accuracy by comparing the results of the model with a variety of laboratory and field measurement situations. The aim of this paper is to compare the prediction model and the laboratory measurement data of those elements typically used in the Nordic countries. The tolerance of the method is studied by comparing the calculation results to the laboratory measurement results of different types of facades and sending room sound fields. 2-glazed and 3-glazed window types are included into the consideration. The comparison procedure allows to evaluate, at least for the examined building elements, the accuracy of the method which can be applied, for example, as a safety margin when evaluating the sound insulation value of a facade in an official supervision.

2 Facade building elements

The most important single factor, which has an influence to the properties of the building elements of a facade, is the weather conditions such as temperature, wind and rain. The building regulations of thermal insulation, based on energy consumption, regulate the properties of the building and the available building elements. The Nordic countries are situated on the borderline of the northern arctic winds and southern warm winds where the low pressures are usual. Because of the requirements of thermal insulation the usual value for the weighted sound reduction index of the wall construction is about 60 dB. Acoustically the most inadequate facade elements are thus the ventilation equipment, windows and balcony doors. The windows are typically triple-glazed with two separate casement frames. Very often one of the casement frames includes insulating double glazing (3-12-3 mm) and the other one 3 or 4 mm glazing. The typical weighted sound reduction index value is about 42 dB. The increment in the depth of the double construction strengthens the natural convection and increases both thermal and sound insulation. A depth larger than 50 mm of the cavity does not enhance the thermal insulation of the construction even if the sound insulation increases. The sound insulation properties of balcony doors are usually quite consistent with those of windows. A typical weighted element normalized level difference value of ventilation equipment, which is installed into the frame of the window, is about 43 dB. For equipment, which is installed into the wall, the value is respectively about 50 dB. In Central Europe, when building regulations concerning the thermal insulation are strict, the weighted sound reduction index of the wall construction is equal to that in the Nordic countries. Window constructions are usually insulating double-glazed with one casement frame. The material of the pane may also be PVC. Typical facade ventilation elements are wall outlets. The facade elements examined in this study are presented in Table 1.

3 Principles of the calculation model

The main quantities which express the performance of the building facade are the apparent sound reduction indexes R'_{45} and $R'_{tr,s}$ as well as the standardized and normalized level differences $D_{2m,nT}$ and $D_{2m,n}$. The dominating exterior sound fields in measurement conditions influence the values achieved. The diffuse incident sound field is assumed to be the most representative one in most cases and thus the calculated value is the apparent sound reduction index which enables calculation of other quantities and which is comparable to values R measured under laboratory conditions. Airborne sound transmission through the facade is due to the sound transmission by each of the facade building elements from which the facade is constructed and it is assumed that the transmission for each element is independent from the transmission of the other elements. The evaluation method of the acoustical performance of the facade is thus based on the known performance of the facade building elements which the quantities, sound reduction index R and element normalized level difference $D_{n,e}$, express. For the calculation additional information concerning the shape of the facade, sealing type and quality for slits and connections as well as total facade area may be necessary. The facade area means the whole outer surface of the room. The method enables the evaluation of the direct and flanking transmission of sound. However only determination of direct transmission is considered here, because the flanking transmission contribution is negligible in laboratory conditions. The apparent sound reduction index of the facade for diffuse incident sound is calculated thus by adding the sound power directly transmitted by each of the building elements

$$R' = -10 \cdot \lg\left(\sum_{i=1}^{n} \tau_{e,i}\right)$$

where

$$\tau_{e,i} = \frac{A_0}{S} 10^{-D_{n,e,i}/10} \quad \text{or} \quad \tau_{e,i} = \frac{S_i}{S} 10^{-R_i/10}.$$

A_0 is the reference equivalent sound absorption area (10 m^2 for dwellings), $D_{n,e,i}$ is the element normalized sound level difference of element i, S is the total area of the facade (outer surface of the room), R_i is the sound reduction index of element i and S_i is the area of element i.

4 Measurements

In the first phase of the present study, which this paper introduces, the airborne sound insulations of the building facades are studied in well determined sound fields in laboratory conditions [2, 3, 4]. The weighted sound reduction indexes and weighted element normalized level differences of single facade elements have first been measured (see Table 1). After that the elements have been installed into the dividing wall of the source and receiver room and the sound reduction index of the wall has been measured (see Table 2). The sound fields of the field conditions have been emulated by removing the roof of the sending room, leaving the door of the sending room open, installing sound absorption material on the floor of the sending room and by installing a parapet wall of balcony to the front of the balcony door. Table 1 presents the properties of the facade elements considered and their weighted sound reduction index R_w or weighted element normalized level difference $D_{n,e,w}$ values.

No	R_w dB	$D_{n,e,w}$ dB	Facade element	Area m^2
1	67	-	test wall; depth 400 mm	12
2	43	-	window 1; 170 mm frame, 3-12-4 and 5 mm glass panes	1.5
3	34	-	window 2; 130 mm frame, 3-12-4 and 3 mm glass panes	1.5
4	30	-	window 3; 4-12-4 mm glass panes	1.5
5	32	-	window 4; 170 mm frame, 4-12-4 and 4 mm glass panes	1.5
6	41	-	balcony door 1; 4-12-4 and 4 mm glass panes	1.9
7	43	-	balcony door 2; 4-12-4 and 4 mm glass panes	1.9
8	-	57	wall outlet 1; ∅160/60 mm, length 400 mm	10 (ref.)
9	-	46	wall outlet 2, ∅100/60 mm, length 400 mm	10 (ref.)
10	-	45	outlet in window frame 3; 600·170·12 mm	10 (ref.)
11	-	39	outlet in window frame 4; 300·170·12 mm	10 (ref.)
12	-	47	wall outlet behind radiator 5; ∅160/100, length 400 mm	10 (ref.)

Table 1. Measured airborne sound insulation data for the considered facade elements

5 Comparison between measured and calculated results

A large number of comparisons were made between the measured and calculated results for different types of facade building elements and different types of sound fields of source room (Tables 1 and 2, Figures 1 and 2). Calculations were carried out for one-third octave bands and single number ratings. The frequency range for the one-third octave bands is 100 - 3150 Hz. The single number rating has been deduced from these results according to EN-ISO 717-1

[5]. Table 2 presents the facade element combinations and the calculated and measured values for R'_w when the sound field has been diffuse and the facade plane facade. The mean and standard deviation of the difference between the calculated and measured values is 0.3 ± 0.4 dB. In general, the difference between calculated and measured sound insulation values seems not to be depending on the types of elements involved.

No	Facade elements (see Table 1)	Calculated R'_w/dB	Measured R'_w/dB
1'	1, 2, 8	50.9	51
2'	1, 2, 9	45.6	46
3'	1, 2, 10	44.8	45
4'	1, 2, 11	39.5	40
5'	1, 2, 12	46.4	47
6'	1, 2, 6	47.2	47
7'	1, 2, 6, 8	46.9	47
8'	1, 2, 6, 9	44.0	44
9'	1, 2, 6, 10	43.4	44
10'	1, 5, 6	40.4	41
11'	1, 3, 8	42.9	44
12'	1, 3, 9	41.5	42
13'	1, 3, 10	41.2	41
14'	1, 3, 11	38.1	38
15'	1, 4, 9	38.4	39
16'	1, 4, 10	38.2	39
17'	1, 4, 6, 11	36.3	36

Table 2. Measured and calculated sound insulation values for facade element combinations

The variations in sound reduction indexes of facades are presented in Figures 1 and 2 in one-third octave bands, when the sound field of the source room has been varied. The dashed lines present the sound reductions of the facades measured in diffuse field conditions and the solid lines present the mean of the sound reductions of the facades when the sound field of the source room has been modified by removing the roof of the source room, leaving the door of the source room open, installing sound absorption material on the floor of the source room or by installing a parapet wall of balcony to the front of the balcony door. The ranges in solid lines present the standard deviations of the sound reduction indexes when the source room sound field has been modified. The means and standard deviations of weighted sound reduction indexes of three and four element facades are 41.2 ± 0.5 dB (in diffuse field the value is 41 dB) and 43.2 ± 0.8 dB (in diffuse field the value is 42 dB), respectively.

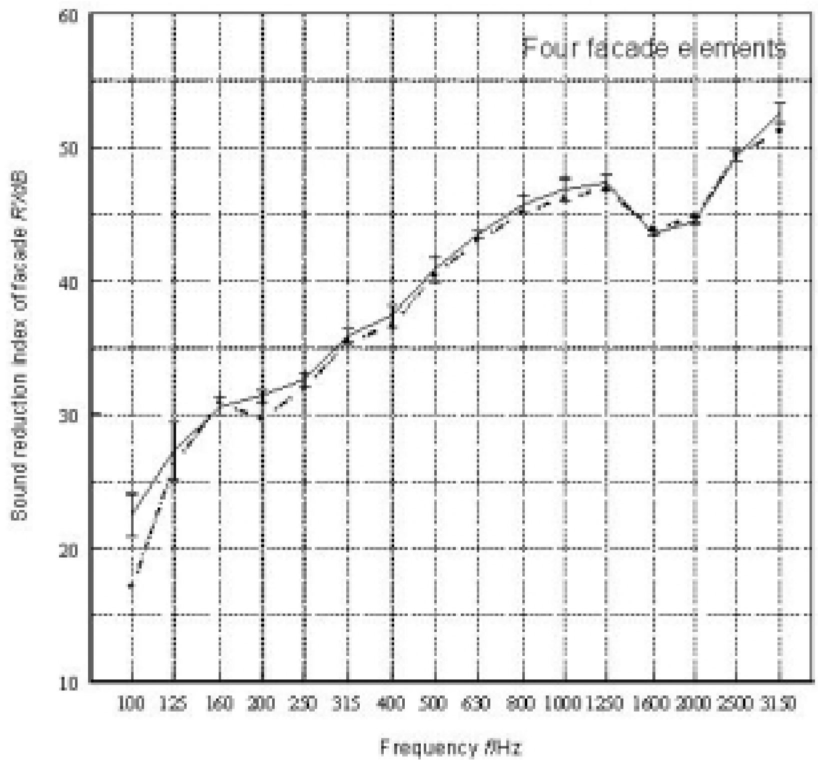

Figure 1. Variation in sound insulation, combination (1, 3, 6, 8)

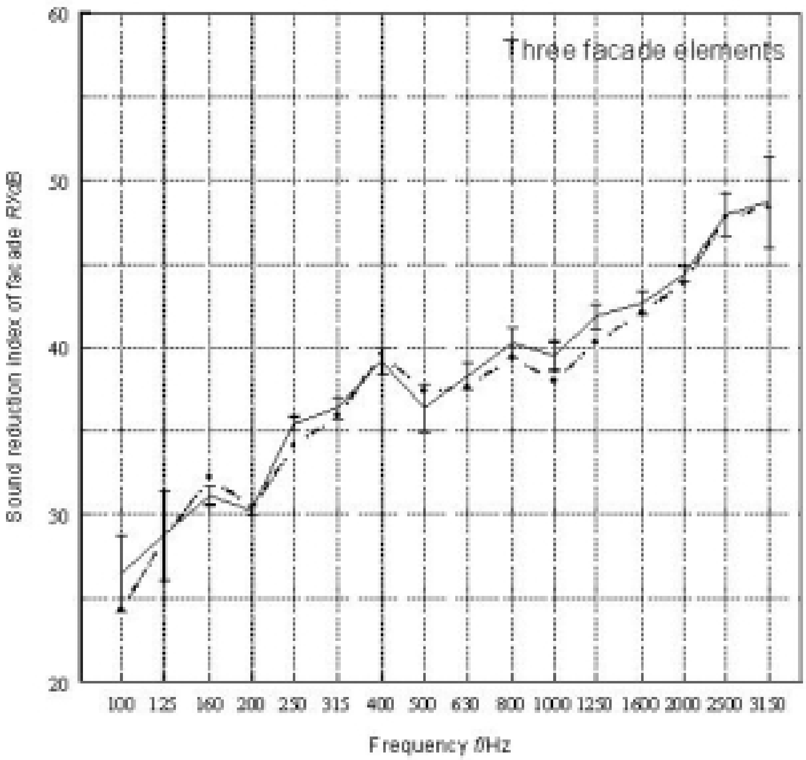

Figure 2. Variation in sound insulation, combination (1, 5, 6)

6 Conclusion

The obtained accuracy of the predictions is satisfactory for airborne sound insulation. For the weighted sound reduction index of facade for diffuse incident sound field the mean and standard deviation of the difference between the calculated and measured values is 0.3 ± 0.4 dB in laboratory conditions. The modification of the source room sound field or the profile of the facade has not influenced considerably to the measured weighted sound reduction index values of facade. Evaluation of the accuracy of the method will be continued later in field conditions.

REFERENCES

[1] *EN 12354-3 Building Acoustics - Estimation of acoustic performance of buildings from the performance of elements, Part 3: Airborne sound insulation against outdoor sound.*

[2] *EN-ISO 140-3 Acoustics - Measurement of sound insulation in buildings and of building elements Part 3: Laboratory measurements of airborne sound insulation of building elements.*

[3] *EN-ISO 140-1 Acoustics - Measurement of sound insulation in buildings and of building elements Part 1: Requirements of laboratory test facilities with suppressed flanking transmission.*

[4] *EN-ISO 140-10 Acoustics - Measurement of sound insulation in buildings and of building elements Part 10: Laboratory measurements of airborne sound insulation of small building elements.*

[5] EN-ISO 717-1 Acoustics - Rating of sound insulation in buildings and of building elements Part 1: Airborne sound insulation.