Certified Sound insulation of different building elements

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Introduction

In building acoustics there exist this problem: You can get a certificate for a product based on results of field measurements- but …using a product in the field is only allowed after the product is certified. And this is the problem in a nutshell: wwhich came first: the chicken or the egg. In the EG this problem is nowadays solved by a combination of using results of laboratory measurements and calculating the sound insulation according to EN 12354 part 1, 2 and 3. In this paper some practical solutions for this problem, as used since 1980 in The Netherlands were presented and discussed in the case of non bearing inner walls, roof elements, complete building systems and floor systems.

Statistical principles

In the 80's of the last century the principles for getting certificates were :

1. The results of at least 10 field measurements;
2. Statistical processing in order to get reliable results for the whole population based on the results.

Statistical procedure

In case of certificates it is of crucial importance that a certificate gives reliable information about the product performance. For this purpose are used [1] or [2]. For building acoustics this is realised

$R_{practise} > R_{requirements} > R_{measured} - ks_p$ dB (1)

$R_{requirement}$ = the required sound insulation through legislation [dB]

$R_{measured}$ = the measured averaged sound insulation [dB]

k = a factor which depends on the reliability (p), consumer risk (r) and the number of measurements (n)

s_p = product variance is equal to $s_p^2 = s^2 - s^{m2}$

s = the total variance from the measurements

s_m = the variance caused by measurement uncertainty

For the situation p = 80 %, r = 20 % and n = 10 then k= 1.2 For p= 95 % r = 5 % and n= 10 then k = 3. In order to reduce the over dimensioning the following choices were made :

P = 80 %, r = 20 % . n= 10, also because of the fact that k does not change very much by increasing n.

Application to building elements

Because of the different places of building elements in a building every building element has a special treatment with respect to acoustics. In the following paragraphs not bearing inner walls (with a mass below 100 kg/m²), roof elements, building systems, concrete floors and mufflers and glass were treated.

Non bearing inner walls

The acoustical problem is the airborne sound insulation between rooms in the same dwelling. In this situation not only the sound transmission through the partition wall is important but also the indirect sound transmission via doors . Initially there was little information available about the latter transmission. Therefore very often the first floor of a dwelling was chosen as a standard in which all measurements had to be made. see figure 1. Additional measurements were done in such a situation[3] to get information about the indirect sound transmission via doors.

Very remarkable for this type of measurements is that the s_p was determined at an averaged value of 0,6 dB, which is very low in respect to measurements between dwellings (1,1 to 2,5 dB).

Because all measurements must be carried out in the same plan with special dimensions of the door configuration, the results give a good impression of the mutual quality of the sound insulation of the walls. Because the sales of this type of walls did not change over the last 15 years, this type of measurements has not been performed since that time.

Roof elements

The prefabricated roof element is a typically Dutch developement which started at the beginning of the 70-ties of the last century. Initially it was an element with a length of 4 till 6 m and a width between 1 m and 1,25 m. Nowadays the width can be up to 3 m, so that with two complete elements (except tiles) a whole roof can be constructed. The types are :

- sandwich-elements: two wooden or chipboard sheelds with PIR, PUR and EPS insulation in between Typical values of the sheelds are 3, 5, 7, 8, 10 and 12 mm. Thickness of insulation 65 - 117 mm;
- single leaf elements with PUR (65 - 117 mm), EPS (60 – 200 mm) or Mineral wool (100 -190 mm);
- double leaf elements with mineral wool insulation.

As alternative for mineral wool sheepwool or cellulose are used.

For this type of elements the main sound transmission is the Ff flanking path which is independant of the partition wall. One special part of this path, is the sound transmitted via the cavity between the roof elements and the roof tiles. This transmission can be decreased by means of the mineral wool barrier. (figure 2) Also the direct sound transmission is important. At first most measurements were performed in the field. (chicken and egg problem). To avoid this problem several ‘field-laboratories‘ were made (see figure 3). Two rooms, one with a length of 2,78 m and one of 4,88 m, seperately placed on „Langsdäm-bügel“. The so built cavity wall gives a direct sound transmission of R_A = 65 dB, so that the Ff-sound transmission of most roof elements can be measured. The airborne sound transmission is measured according to NEN 5077. One of the assumptions is that there is a linear decline of the acceleration level on the roofconstruction . To determine the reduction of acceleration perpendicular of the partition wall, the acceleration levels on the roof elements were maesured. In formulas:

$A(x) = -Mx + N$ dB [dB] (2)

With

$A(x)$ = acceleration level on the roof element inside[dB]

X = distance to partition wall [m]

N = constant [dB]

M = linear coëfficiënt in [dB/m]

With this linear relation the total sound transmission via the roof elements is conform formula 3.

$$D_{nT\,r} = C - 10\lg\left(\frac{10}{Mb}\left[1 - 10^{\left(\frac{-Mb}{10}\right)}\right]\right) + 10\lg\left(\frac{V}{3S_r}\right)$$

$[dB](3)$

with

D_{nTr} = the standardised level difference caused by the roof [dB]

C = constant [dB] determined from measurements, corrected with ks_p as in formula (1)

b = length perpendicular to the partition wall [m]

V = Volume of the receiving room [m³]

S_r = total roof surface in the receiving room [m²]

The acceleration is measured with an accelerometer. As mounting method for the accelerometer a very thin double sided adhesive tape was used.

The measurements show a variation in M from 1,3 to 5,5 dB/m, The low values correspondent with hard thermal insulation materials as EPS and PUR, the high values for the mineral wool.. In this manner a clear interpretation method of the measurement results was created independent of the value of M.

The cavity between the tiles and the upper part of the partition wall gives easy sound transmission between the roof elements at each side of the partition. Especially this is the case with roof elements with hard insulation materials. (EPS, PUR or PIR). This transmission leads to 6 to 10 dB lower values than when this open room is filled with a so-called mineral wool barrier (figure 4). To fulfil the requirements all roof elements with hard insulation material need the mineral wool barrier. Also other separation systems are available, but not often used. Roof elements with mineral wool as thermal insulation do not need such a barrier to fulfil the Dutch requirement. They are in most cases only necessary to reach 5 dB higher levels than the requirements.

Especially for the roof-elements with soft thermal insulation materials with a possibility to reach much higher sound insulation figures a value of 5 dB higher than the minimum requirements is introduced.

In the certification document a table is presented with different types of partition walls, and combined values of V/S_{wall} and the minimum V/S_r that fulfil the requirements between living and sleeping rooms, a value of 5 dB lower (for other rooms) and for 5 dB higher. With this application table architects, consultants, suppliers, manufacturers and contractors can choose the proper roof element.

Sometimes a contractor thinks that a roof element is always applicable when it has a certificate. This is not the case as is shown in the application table. Sometimes this leads to values 10 dB lower than the requirements. Not every roof element is appropriate in every case. With the By a correct use of the table such errors can be avoided.

Prefabricated building systems

This type of building elements are prefabricated concrete systems with ground floors, partition walls, storey floors and facade-elements. Also prefabricated timbre wood element.

For this type of building systems the certification process starts with an advisory report from an acoustic consultant that gives a prognosis of the sound insulation between dwellings and within the same dwelling. If the certifying organisation, the acoustic consultant and the manufacturer agree about the constructions to use and the details, the system gets a preliminary certificate with the condition that within a certain time field-measurements must prove that the system fulfils the requirement in accordance with formula 1.

Especially with new higher requirements in the Dutch building Code it is difficult to determine the new dimensions and details. To get such information special investigations were made as illustrated in [4]

In Dutch legislation also the sound transmission to rooms which are not adjacent to the sending room, must be incorporated in the result. For stony and concrete constructions this leads in most cases to a correction of 0.5 to 1,5 dB. The certification measurements in timber wood construction gave such results that the flanking transmission to not-adjacent rooms is much lower, so that this correction is not needed. Because stony and concrete constructions are in the majority, the correction of 0,5 to 1,5 dB must also be used for timber wood constructions according to NEN 5077:1997.

For most common building systems, such as stone or concrete, there is a Dutch Code of Practise NPR 5070:2005. In this code conservative estimates are used. In building systems with specially tuned elements, things are possible that are generally not possible.

Large amounts of measurements in prefabricated concrete systems show smaller s_p values than in not prefabricated systems. (s_p = 1.1 d B vs s_p = normally 1,5 or 2,5 dB) see also [5] and [6].

Floor elements

In this type of element a different starting point is chosen. The examples for floor elements as used in the Dutch code of practise NPR 5070:2005 are copied. The mass of the floor element inclusive the covering floor and the type of junction (flexible or rigid) with the partition wall determine this sound transmission. In this case the same certainty is given as in NPR 5070:2005.

Ventilation grids and Mufflers

In sound insulation of facades the acoustical and ventilation quality of mufflers are very important. In certification the ventilation capacity q_v has to be measured conform NEN 1087:2001 in a special laboratory situation. The sound insulation properties are determind in a laboratory measurement according tot ISO 140 part III. These two parameters are necessary for input in the calculation procedures according to EN 12354 part 3[7] and the Dutch code of practise. The official quantity D_{neA} is in computer programs mostly recalculated to a R_{qA}, a quantity that standardises the sound insulation with respect to the ventilation capacity conform formula(4).

$$R_{qA} = D_{neA} - 40 + 10\log(q_v) \quad \text{dB} \quad (4)$$

with

q_v = Ventilation capacity per unit length according to NEN 1087:2001 [dm³/(sm)]

D_{neA} = Normalised sound level difference for small elements according to ISO 140 part 3 [dB]

Glass

For the calculation of the $R_{A,tr}$ of different types of single and double glazing there is special software. Recent developements in different types of glass cannot be calculated with that program. Laboratory measurements according to ISO 140 part III are therefore necessary. The results have to be deminished with a term ks_p. For glass this value of ks_p is determined at 1 dB [7] .

Conclusion

Certifying sound insulation of building elements leads to different approaches, specially adapted to the place of the element in the building. So the conditions, characteristic for the various building elements are different but the statistics are the same.

In the future calculations according to EN 12354 part 1 – 6 will maybe play a more important part then nowadays. However measurements must decide if the situation fulfils the requirements. As the English say : “The proof of the pudding is in the eating“.

References

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[5] R van Schie, M. Vercammen en W.G.M. Beentjes ‘*Quality of the sound insulation in dwellings*’ NAG publication 175/4 **2006** (in Dutch)

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[7] EN 12354 part 3

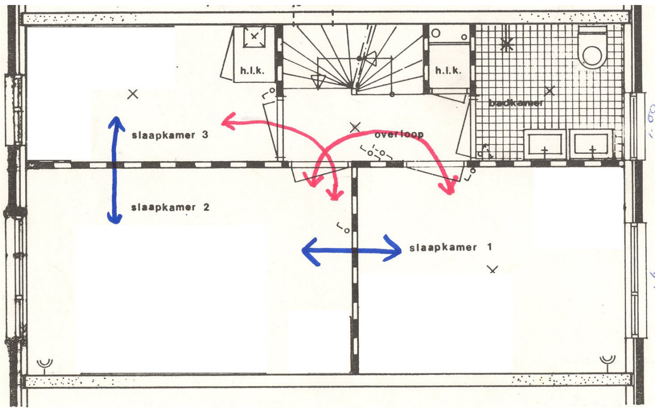

Figure 1: Standard plan for field measurements of non-bearing inner walls. Blue arrows: direct tranmission, Red arrows : indirect transmission via doors.

Figure 2: The mineral wool barrier of glass wool between the tile-laths above the partition wall.

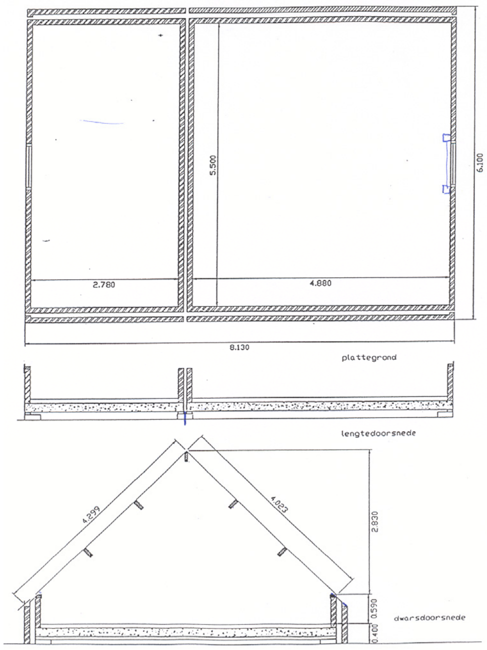

Figure 3: „Field“laboratory for testing the sound insulation of roof elements.

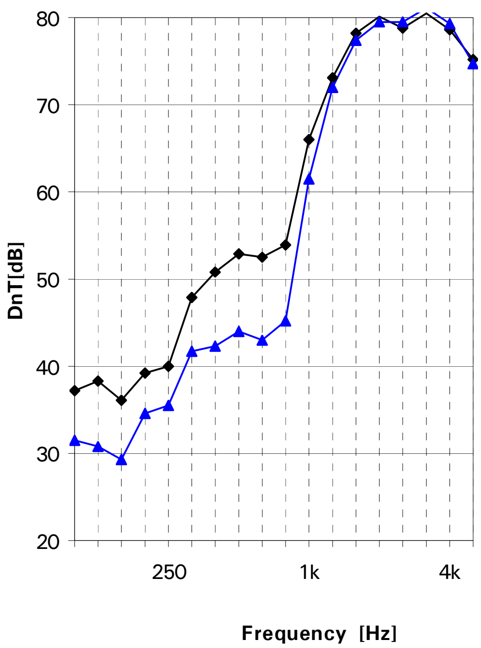

Figure 4 Typical sound insulation characteristics of a sandwich-element (8 mm chipboard, 85 mm EPS-15 and 8 mm chipboard): a resonance frequency of ca 160 Hz, caused by the sandwich-element , the air-cavity and the roof tiles and a double resonance frequency at 800 Hz caused by the sandwich-element itself as well in the sending as in the receiving room,. The last resonance frequency leads to an increase of the sound insulation more than 24 dB/octave. Also the effect of the mineral wool barrier is shown: the upper black line is with barrier and lower blue line without barrier and leads to an increase of $D_{nT;A}$ with 7 dB.