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How to reduce uncertainties for building acoustic measurements in test facilities?

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Abstract

Measurements in building acoustics are performed for very different purposes. One main purpose is to determine the acoustic properties of building elements in test facilities. For these measurements, a small uncertainty is desired by manufacturers and laboratories to discriminate between products. To achieve small uncertainties, test conditions are more and more specified, e.g. by defining the test geometry with glazing and windows. This approach has the disadvantage that the sound insulation in different geometries will distinguish from the one under specified conditions. Another approach to reduce the uncertainty is to define reference objects for specific types of building elements. The acoustic property of this reference object is then measured in a laboratory. When the measurement result is within specified tolerances, the laboratory is permitted to report an uncertainty smaller than the general uncertainty stated in ISO 12999-1. Both approaches and their implications are discussed in the contribution.

Keywords: uncertainties, measurements, building acoustics, test facilities

How to reduce uncertainties for building acoustic measurements in test facilities?

1 Introduction

The acoustic properties of building elements and materials are usually determined experimentally in special test facilities. Measurement results are used for very different purposes, e.g.

- for the declaration of product properties,
- to obtain input data for the prediction of a building's acoustic performance from the acoustic properties of the structural members,
- for the comparison of different products and
- for optimising the acoustic properties of building products.

A fair competition requires, that measurements are performed according to internationally harmonised and widely accepted standards. A major part of a measurement is the determination of the uncertainty which is attributed to the measurement result.

Traditionally, uncertainties are scarcely taken into consideration in building acoustics. Nevertheless, accreditation or similar processes often require laboratories to report uncertainties in their test reports. Therefore and for several other reasons, uncertainties became a major issues in the building acoustic community in the last years.

The consideration of uncertainties in building acoustics generated the feeling that the uncertainties are generally large. Therefore the question arose whether these uncertainties can be reduced. This contribution gives an overview on the current approaches in this respect using airborne sound insulation as an example.

2 Uncertainties derived from round robin results

The airborne sound reduction index is defined in ISO 80000-8 [1] as 10 times the common logarithm of the ratio between the incident and the transmitted sound power. For measurements according to ISO 10140-2 [2], this definition is transferred into a measurement equation using the diffuse field assumption. Thereby, the measurement of the incident and transmitted sound powers is performed by sound pressure measurements in the sending and receiving rooms and a determination of the sound absorption in the receiving room. The step from the definition of the quantity to the measurement equation already adds a certain amount of uncertainty which can't be predicted for a given situation with a reasonable effort. This is one main reason why uncertainties can't be calculated from a model equation today. Therefore, round robin results are used to determine the uncertainties [3]. The results of this analysis are standardised in ISO 12999-1 [4] and are the best estimates for the uncertainties in building acoustics today.

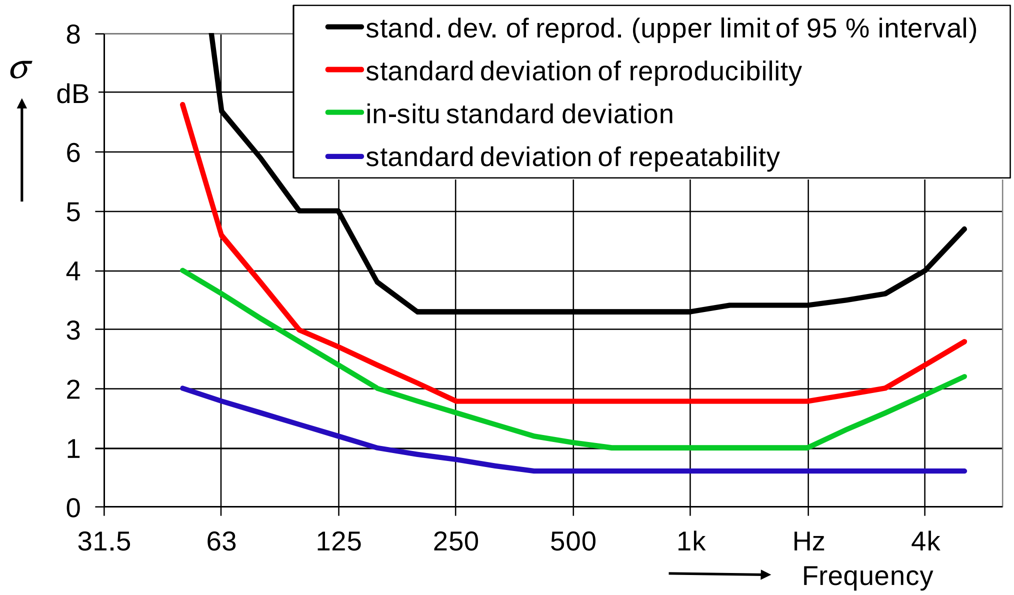

Figure 1: Standard deviations for different test conditions in one-third octave bands as given in ISO 12999-1 [4]

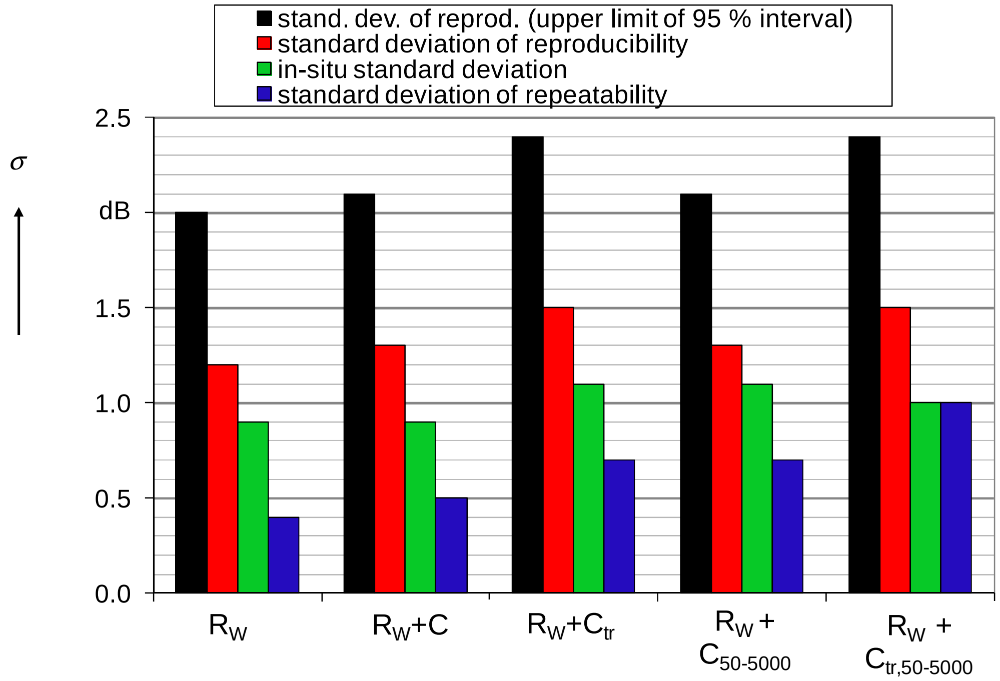

Figure 2: Standard deviations of some selected single-number quantities for different test conditions as given in ISO 12999-1 [4]

One consequence following directly from this approach is that the standard deviation of reproducibility, which characterises the spread of the laboratory results, covers at least two aspects. The first is the measurement uncertainty, as desired, but the second is that the tested element may really have a different sound reduction index in different situations. The latter is not really a part of the measurement uncertainty. But, being inseparably linked to the standard deviation of reproducibility, it is an inherent part of the standardised figures. It is therefore more appropriate to refer to *uncertainties* than to *measurement uncertainties* in building acoustics.

For airborne sound insulation, the currently standardised uncertainties are given in Figures 1 and 2. The standard deviation of reproducibility, which is the best estimate for the uncertainty of laboratory results is nearly two dB at medium frequencies and increases considerably towards lower frequencies (Figure 1). For the different single number descriptors, this figure is between 1.2 and 1.5 dB. The confidence interval which contains a large fraction of the values which can be reasonably attributed to the measurand has thus a width of at least 2.4 dB for 68 % coverage, or 4.8 dB for 95 % coverage. It is totally understandable that these large uncertainties are under discussion and that measures to reduce these uncertainties are highly welcome.

3 Reducing uncertainties by stricter specifications of test conditions

One obvious approach which is applied in many technical fields is to increase the strictness of test conditions. This approach will be discussed here as a thought experiment on the example of the sound reduction index of a wall construction.

Starting point is the sound reduction index of this particular wall construction in different laboratories (Figure 3). When the laboratories meet the current specifications [5], only certain aspect ratios of the wall are permitted. The size has to be about 10 m². Also, sending and receiving rooms must have different volumes, and there are several further requirements. The probability density function for the weighted sound reduction index measured in laboratories is then characterised by a standard deviation of 1.2 dB which is the standard deviation of reproducibility as given in [4]. The expected value is chosen arbitrarily to be 46 dB.

The interesting question is now what the probability density function of this particular wall construction will be in real buildings. For the standard deviation, a tentative value of 3.0 dB seems to be appropriate. This is due to the very different sizes and aspect ratios as well as due to the very different airborne sound fields in the receiving and sending rooms. Even more interesting is the behaviour of the expected value. One aspect had been quantified in the past which is the question of different room volumes on the sending and receiving sides in laboratories. In real buildings, symmetries are observed very often which means that the rooms on both sides of the wall construction are of the same shape and size. In this case, the weighted sound reduction index will be about 1 dB smaller than in laboratories [6]. The expected value is therefore assumed to have a value of 45 dB (Figure 3).

Standardisation thus succeeded in reducing the standard deviation considerably by defining the test conditions in laboratories. One side effect of this is the shift of the expected value, which is assumed to be about 1 dB considering one effect only.

One could think of even tighter requirements for laboratories in the future. As an extreme thought one could prescribe everything, the material of the wall test facility, the exact dimensions of the rooms and the test specimen and so on. Then, the standard deviation could be reduced to a value of about 0.9 dB which is the in-situ standard deviation given in [4]. Nevertheless, it is impossible to predict the expected value for this scenario. But it must be assumed that the expected value is shifted by a certain amount (Figure 3).

In general, the amount of the shift of the expected values will be different for different choices of the laboratory specifications and for different test objects. It is thus not sufficient to focus on a small standard deviation of reproducibility when developing test conditions. One also has to consider possible shifts of the expected values.

In view of the purposes of a laboratory measurement mentioned in the introduction it is not obvious that tighter test conditions are a good proposal for the future development of measurement techniques in building acoustics.

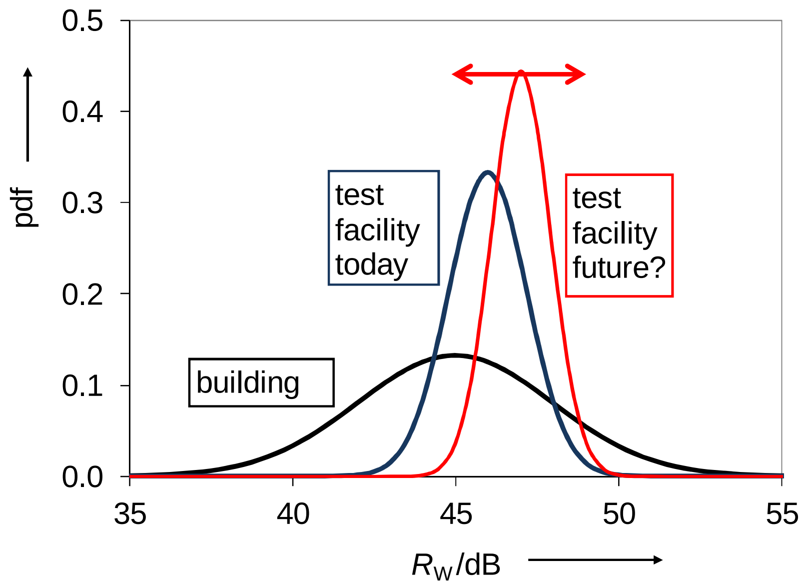

Figure 3: Assumed probability density functions for different test conditions of the nominal identical object using the weighted sound reduction index as an example

4 Reducing uncertainties by using reference objects

Another attempt to reduce uncertainties is the use of reference objects of certain types, e.g. window panes or plaster board walls. Starting point for this approach is a dedicated round robin for which typically one or two test objects from the same product family are used. The standard deviation derived from the round robin results according to ISO 5725-2 [7] is then used to define qualification ranges. A laboratory that yields measurement results within this range is then permitted to report smaller uncertainties for products of this family, e.g. window panes or plasterboard walls.

The thinking behind this approach is, that the results for different specimens of the same product family are correlated. This means that one particular laboratory always yields weighted sound reduction indices for one particular product family which have a certain offset to the mean value of the round robin. Only then, a laboratory with results within the qualification range for the round robin object can be expected to deliver results within the narrow uncertainty range for all other products of the same family.

The assumption of correlation was tested for different specimens using the round robin data base at PTB. Results of product A were plotted as a function of the results for product B. Each dot represents the two results from one laboratory. For an ideal correlation, all points should lie on a straight line. The test for the heavy lime-brick walls [8], [9] once with clamped and once with elastic mounting conditions reveals no correlation (Figure 4). The same is the case for the gypsum board walls [10], (Figure 4), the windows [11] (Figure 5) and the glasing and the metal sheet [12] (Figure 5). The latter shows the best correlation from the chosen examples. Nevertheless the correlation is not sufficient to derive a dedicated small uncertainty for the weighted sound reduction index of window panes from the fact that the measured sound reduction index of the metal sheet is within a certain tolerance range. It is important to note here that the correlation is not better for more recent round robins.

It must be mentioned here that the use of reference objects for a general qualification of laboratories is highly recommended. But, using reference objects for reducing the uncertainty of laboratory results needs further discussion due to the lack of correlation.

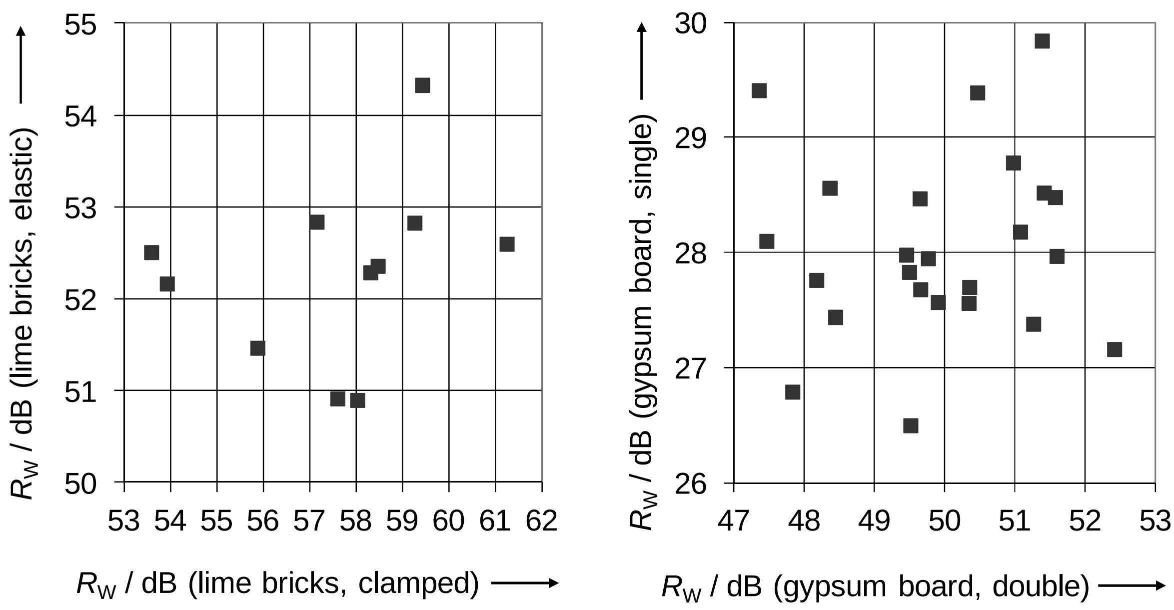

Figure 4: Weighted sound reduction indices of two different specimens measured in the same set of test facilities [8], [9], [10]

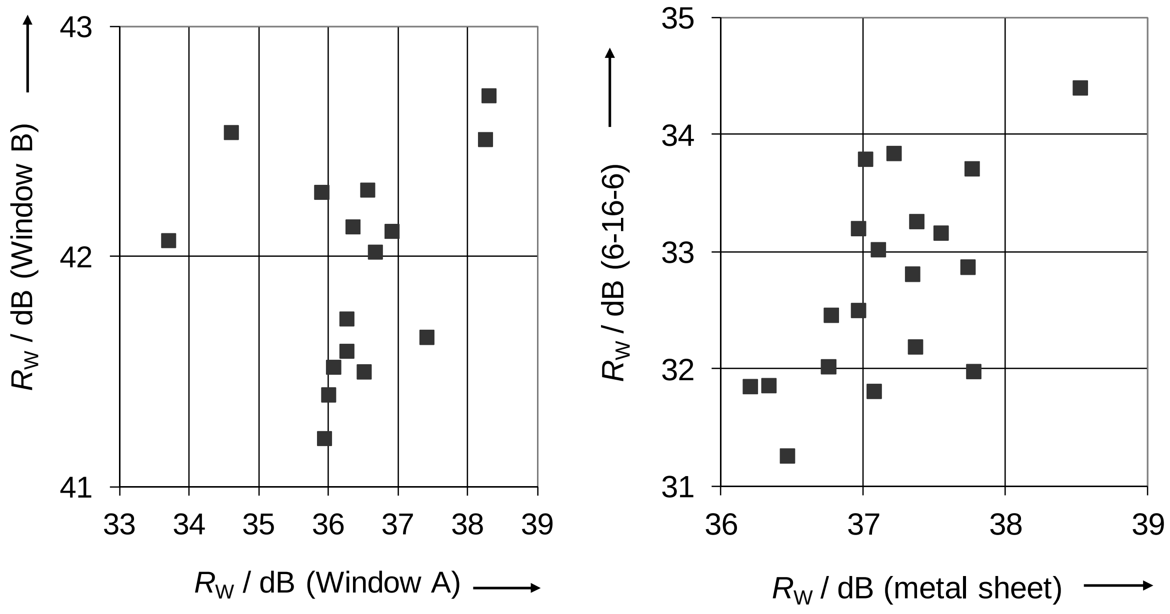

Figure 5: Weighted sound reduction indices of two different specimens measured in the same set of test facilities [11], [12]

5 Conclusions

Both methods for reducing the uncertainty - using reference objects as well as tighter specifications of test conditions - have presumptions and implications which must be clearly addressed in view of the purposes of laboratory measurements. Both methods suffer from the fact that uncertainties today include the contribution of measurement uncertainty as well as the fact that the ratio between incident and transmitted sound power really is different for different laboratory or field situations for the same specimen. This becomes more important for lower frequencies and is reflected by the huge uncertainties below 100 Hz. To overcome this, a more appropriate definition of the sound reduction index has to be developed which may in future lead to a derivation of detailed uncertainty models.

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