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Are single number ratings for sound insulation requirements still up-to-date?

Reinhard O. Neubauer[1]
IBN Bauphysik GmbH & Co. KG
Theresienstraße 28
D-85049 Ingolstadt
Germany

ABSTRACT

In general, soundproofing requirements are given in form of a single number rating. Individual values are therefore singular, i.e. precise, so that no uncertainties are taken into account when checking the quality by measurement or calculation. A better description of the quality of sound insulation would be the formation of classes. In Europe requirements are mainly expressed as a weighted apparent sound reduction index R'_w*, or by specifying a certain weighted standardized level difference* $D_{nT,w}$*. Both quantities describe a quality that is not necessarily equivalent. The numerical comparison of the requirements is therefore not or only approximately possible. In light of this consideration requirements should be given therefore by classes. In this paper, the difference between a single number rating and a class rating is discussed.*

1. INTRODUCTION

Sound insulation is usually described using a single number. When calculating the sound insulation, an exact number is found, as is the case when the sound insulation is determined by measurement. Both quantities, however, are faulty. The obtained single numbers result with a certain uncertainty. ISO 12999-1 [1] describes the problem in their introduction as follows: "*An assessment of uncertainties that is comprehensible and close to reality is indispensable for many questions in building acoustics. Whether a requirement is met, a laboratory delivers correct results, or the acoustic properties of a product are better than the same properties of some other product can be decided only by adequately assessing the uncertainties associated with the quantities under consideration.*" This topic has been discussed in the literature [2-4] for a long time. As discussed in [4] problems occur also because of the measurement method uncertainty, and it is stated: "*This can be a problem when a measurement result has to be compared with a law limit value. In fact, for airborne sound insulation, to meet the regulations, the average value minus the chosen expanded uncertainty (with a one-side coverage factor) must be greater than the law limit value.*" This means that in practice, the test result of a construction to describe the quality as a singular number quantity contains an uncertainty that is not certified in the result. Instead of specifying a number with an uncertainty, e.g. (R'_w = 53 ± 2) dB, it is suggested to describe the numerical quantity with a class. Giving an average value of the sound insulation descriptor it might be reasonable to formulate a class with a certain class width. This could be a way out of the problem to formulate and compare the requirement and the measurement result as a single number with an uncertainty. If a class with a certain class width is specified

[1] dr.neubauer@ibn.de

as a result, the requirement and the measurement can be compared within a class. This paper proposes to specify the sound insulation in acoustic classes based on ISO/TS 19488 [5].

2. SINGLE NUMBER QUANTITY

Most European countries have sound insulation requirements and use a single number to describe airborne sound insulation. This is either the weighted apparent sound reduction index R'_w or the weighted standardized sound level difference $D_{nT,w}$. The biggest difference between these two quantities is that $D_{nT,w}$ is a measure that evaluates the sound heard while R'_w is related to the process of blocking airborne sound emerging a room [6]. Sound Insulation is therefore the ability of building elements to reduce sound transmission. ISO 16283-1 [7] describes the standardized level difference D_{nT} and provides a direct connection to the subjective impression of airborne sound insulation. On the other hand, ISO 16283-1 states that R' compared to D_{nT} has a weaker connection to the subjective impression of airborne sound insulation. This statement was confirmed in the literature [8,9]. It is therefore reasonable to use both quantities to define an acoustical class.

2.1. The linking of $D_{nT,w}$ and R'_w

The link between the two measures R'_w and $D_{nT,w}$ is in detail discussed in [10]. The relationship describing the link is revealed in Equation (1):

$$D_{nT,w} = R'_w + 10lg\left(\frac{V}{S_T}\right) - 4.95\ dB \tag{1}$$

were V being the room volume in m^3 and S_T the separation component area in m^2.

According to equation (1) a direct link between both quantities $D_{nT,w}$ and R'_w is only possible depending on the ratio of (V/S_T), that is a general equivalence of both quantities cannot thus be carried out [10]. As depicted and described in [10,11] if the separating area (S_T) deviates from the floor area (S_G), the difference (R'_w - $D_{nT,w}$) increases, and deviations of several decibels occur. If a difference (R'_w - $D_{nT,w}$) of ±1 dB and of ±2 dB is agreed, the graphical representation results as shown in Figure 1.

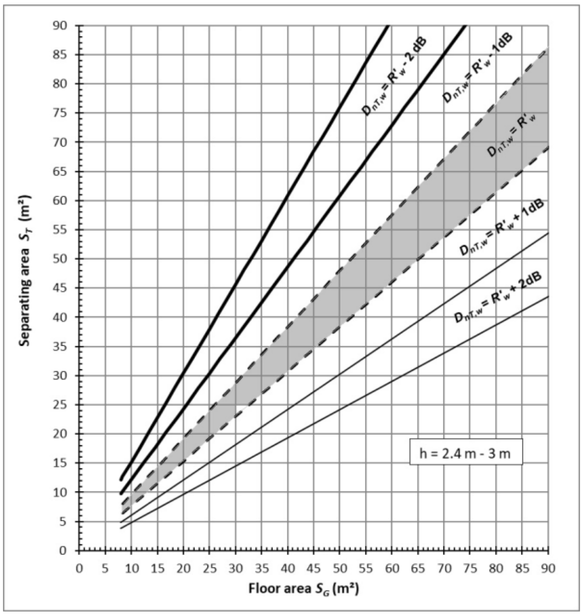

Figure 1: Differences of R'_w - $D_{nT,w}$ as a function of geometric conditions: S_T to S_G. The minimum floor area is 8 m^2. The room height is between 2.40 m and 3.0 m. The grey area indicates the equality of $D_{nT,w}$ = R'_w [11].

With variation of the volume and a constant separating area, the theoretically expected parameters were calculated in [8] and have been previously presented in [12]. Figure 2 shows the results.

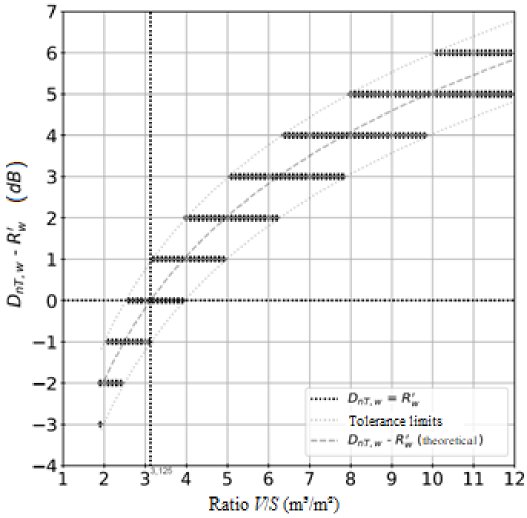

Figure 2: Theoretical differences ($D_{nT,w} - R'_w$) for the ratio (V/S_T). (Graphic from [8])

The dashed vertical line shown in Figure 2 represents the ratio of (V/S_T) = 3.125 m^3/m^2, where the numerical values of the two parameters R'_w and $D_{nT,w}$ are equal. From Figure 2 it is seen that with a maximum permissible difference of +2 dB, the (V/S_T)-ratio is 5 and with the assumed minimum parting component area of S_{min} = 10 m^2, the permissible volume is 50 m^3. Thus, a delimitation of the volumes with a minimum volume of V_{min} = 8 m^2 x 2.40 m = 19.2 m^3 and a "threshold volume" where the numerical values of the difference are equal to 31.25 m^3, as a "limit volume" of 50 m^3, where the maximum deviation is +2 dB, can be specified. The resulting volume intervals are then [11]:

$$19.2 \text{ m}^3 \leq V \leq 31.25 \text{ m}^3 \text{ and } 31.25 \text{ m}^3 < V \leq 50 \text{ m}^3.$$

2.2. Class formation

A class formation of both quantities ($D_{nT,w}$ and R'_w) is possible separately for each parameter alone without any problems. For example, Austria [13] has defined sound insulation classes from A to E and assigned a specific $D_{nT,w}$ to each class. Spain [14], on the other hand, has a classification system from A to F and ISO/TC 19488 also assigns so-called "class limits" from A to F to the standardized level difference. In all classification scheme, certain singular values corresponding to a certain class are always required. Fixed class boundaries and class widths are given. If a class with both quantities is composed, problems, however, arise. In [8] it was shown that two different classes could be formed, which is also discussed in [11]. On the one hand, a volume class was derived and, on the other hand, a separating area class. However, the relationships based on the volume classes and separating area classes are more complex. They have more comprehensive relationships regarding the limits of the respective classes and the expected difference values [8]. A distinction between dividing walls and dividing ceilings is useful in view of the results of the data analysis, but cumbersome for a generally applicable classification [11]. A useful class formation can be obtained based on the relationships between volume (V) and separating area (S_T) [12]. A classification can only be reasonably carried out if the deviations, i.e., the differences between the two parameters ($D_{nT,w}$ and R'_w), are defined.
To demonstrate a classification as an example, the following conditions are assumed:

- Room height: 2.40 m - 3.0 m.
- Room volume: 20 m^3 - 120 m^3.
- Separating surface: 10 m^2 - 40 m^2.

Equation (1) reveals that $D_{nT,w}$ is equal to R'_w only if the ratio (V/S_T) is equal to 3.125 m^3/m^2. Deviating ratios result in large dispersions in the difference between $D_{nT,w}$ and R'_w (see Fig. 2). In a first step, an area must be selected in which a certain deviation is accepted.
For example, if a deviation of ±2 dB is admitted, the permissible ratio of (V/S_T) can be determined according to Figure. 2. If the (V/S_T)-ratio is divided into a certain interval where a deviation of ±2 dB is accepted, two ranges results:

$$V/S_T\ [1.9;\ 5.0]\ \mathrm{m}$$
$$V/S_T\ [5.1;\ 12.0]\ \mathrm{m}$$

The following classification is based on ISO/TC 19488, where the classes are categorized from A to F and an additional "NPD class", i.e., NPD stands for: "no performance is determined" has been introduced. Where class A is the highest class and class F is the lowest class. The indication "NPD" can be used for dwellings where acoustic power is not required or intended, or where the performance does not meet the requirements of class F [5]. With the knowledge gained, particular with respect to results presented in Figure 2, sound insulation classes with an accepted deviation of for instance ±2 dB, can be designed. The smallest value for $D_{nT,w}$ is freely selectable and the R'_w values result from this. In Table 1 and Table 2 classes in dependence of the (V/S_T)-ratio are presented:

Table 1: Classes of V/S_T at intervals [1.9; 5.0] m. The bold represents the mean.

Sound insulation criterion	Sound insulation classes						
	V/S_T [1.9 - 5.0] m						
	NPD	F	E	D	C	B	A
Airborne sound insulation Nominal value $D_{nT,w}$	**≤45 dB**	46 **48 dB** 50	51 **53 dB** 55	56 **58 dB** 60	61 **63 dB** 65	66 **68 dB** 70	**> 70 dB**
Design value R'_w [dB]	43	48	53	58	63	68	70

Table 2: Classes of V/S_T at intervals [5.1; 12.0]. The bold represents the mean.

Sound insulation criterion	Sound insulation classes						
	V/S_T [5.1 - 12.0] m						
	NPD	F	E	D	C	B	A
Airborne sound insulation Nominal value $D_{nT,w}$	**≤45 dB**	46 **48 dB** 50	51 **53 dB** 55	56 **58 dB** 60	61 **63 dB** 65	66 **68 dB** 70	**> 70 dB**
Design value R'_w [dB]	39	44	49	54	59	64	66

The bold figure in Table 1 and Table2 indicating the airborne sound insulation ($D_{nT,w}$) represents the mean with a deviation of ±2 dB. The two tables Table 1 and Table 2 show that a jump of 4 dB occurs between the weighted apparent sound reduction index R'_w in a class (e.g., between classes F with R'_w = 44 dB and R'_w = 48 dB). This jump can also be deduced from Figure 2 and results from the specified spread of ±2 dB. If a different deviation or spread width is specified, there are other "jumps" in the determination of the value for the weighted apparent sound reduction index R'_w. For clarification, this is shown graphically in Figure 3.

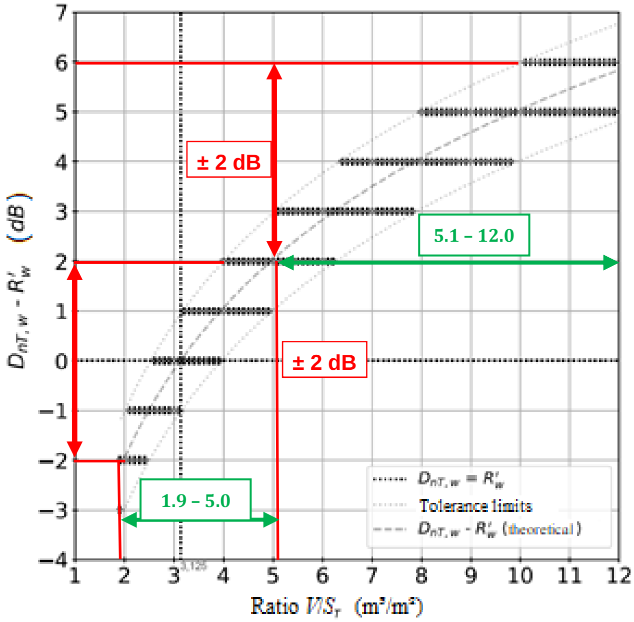

Figure 3: Grouping of the class as a function of the assumed difference (deviation ±2 dB).

3. FINAL COMMENTS AND CONCLUSIONS

A thorough inspection of Equation (1) reveals that both quantities, i.e. R'_w and $D_{nT,w}$ are rarely equal numerically and thus difficult to set equal in general, e.g. in a certain acoustical class. Both quantities are only in principle numerically equal at a ratio of (V/S_T) of 3.125 m^3/m^2. As discussed in [2-4] theoretically derived single-number quantities as well as results from field measurements have an uncertainty which have to be taken into account when judging and comparing results with some limit value. Particularly in legal proceedings, when sound insulation is complained and has to be proven with measurements, a comparison of results with uncertainties is very difficult. A decision which has to be made whether a certain limit value is achieved or not cannot be answered clearly with an uncertainty. It is therefore in some way reasonable to compare acoustic classes rather than single-number quantities. With a fixed spread in the class width, this procedure could also be viewed as taking into account the uncertainty of the singular value if the middle of a class represents the mean value. With the findings from the investigation of the relationships between R'_w and $D_{nT,w}$ and the practical application of limit value considerations, an acoustic class formation would be recommended instead of a single value evaluation.

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