Acoustic classification with the descriptor of the weighted Standardized Level Difference $D_{nT,w}$ and of the weighted Apparent Sound Reduction Index R'_{w}. Are the classes the same?

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***Abstract* — Building regulations specifies technical requirements to sound insulation performance. This will be often done by using a single number rating like the weighted apparent sound reduction index R'_w or the weighted standardized level difference $D_{nT,w}$. A better description of the quality of sound insulation would be the formation of classes. If acoustic classes are provided, the question arises to what extent are R'_w and $D_{nT,w}$ the same. Can a sound insulation class be equal with both descriptors R'_w and $D_{nT,w}$? This paper compares the two parameters and presents the class formation of both descriptors.**

Keywords—Airborne sound insulation, classification, single number rating, building acoustics.

I. INTRODUCTION

The classification of airborne sound insulation as a conceptual quantity is often used. Various European countries have established classification systems, partly as parameters of soundproofing (e.g., $D_{nT,w}$) and partly as parameters of sound insulation (e.g., R'_w) [1]. In this article it will be shown how a classification of soundproofing, with reference to the descriptive parameter $D_{nT,w}$ and backed by the parameter of the sound insulation R'_w, is possible. And it compares the two parameters and presents the class formation of both descriptors.

II. 2. SOUNDPROOFING AND SOUND INSULATION

In this context a distinction in general must be made concerning "*soundproofing*" and "*airborne sound insulation*". The biggest difference between soundproofing and airborne sound insulation is that soundproofing is a process of a heard sound while airborne sound insulation is related to the process of blocking airborne sound emerging a room [2]. Sound Insulation is therefore the ability of building elements to reduce sound transmission. ISO 16283-1 [3] describes the standard sound level difference D_{nT} and provides a direct connection to the subjective impression of airborne sound insulation.

A. Standardized level difference $D_{nT,w}$

The standardized sound level difference D_{nT} is defined by the sound pressure level difference between the transmitting and receiving rooms using a reference reverberation time T_0. The sound level difference is measured by spatial and temporal averaging of the respective sound pressure levels depending on the frequency. The frequency dependent reverberation time determined in the receiving room is normalized to the reference reverberation time and thus considers the room acoustic properties of the receiving room. The standardized sound level difference is calculated according to Equation 1:

$$D_{nT} = L_1 - L_2 + 10 \log(T/T_0) \quad [\text{dB}], \qquad (1)$$

where T_0 is the reference reverberation time, in s.

The standard sound level difference is frequency dependent. To obtain a single number of the frequency dependent standard sound level difference, the weighted standardized level difference $D_{nT,w}$ is determined with the help of a reference curve according to ISO 717-1 [4].

B. Sound insulation measure R'_w

The sound insulation value R is defined by ten times the decadal logarithm of the ratio of the sound power that hits a separating component in the transmission chamber and radiates from the separation component in the receiving room. If all transmission paths involved in the sound transmission are included, apparent sound reduction index R' results and is calculated according to Equation 2:

$$R' = L_1 - L_2 + 10 \log(S_T/A) \quad [\text{dB}], \qquad (2)$$

with L_1 and L_2 denoting the energy-average sound pressure levels measured in the source and receiving room, in dB. S_T is the area of the partition between the sending and receiving rooms, in m², and A is the equivalent sound absorption area in the receiving room, in m².
The calculation of the equivalent sound absorption area A in the receiving room is based on the measured reverberation time T using Sabine's equation assuming a diffuse sound field [5] according to Equation 3.

$$A = 0.16\ V/T \quad [\text{m}^2], \qquad (3)$$

To obtain a single number of the frequency dependent apparent sound reduction index R', the weighted apparent sound reduction index R'_w is determined with the help of a reference curve according to ISO 717-1 [4].

III. THE LINKING OF $D_{nT,w}$ AND R'_w

The equation for the determination of the sound insulation, expressed as R'_w, it is seen that the sound insulation value is determined by the sound pressure level difference ($D = L_1 - L_2$) and the correction term: 10 lg(S_T/A). On the other hand, the weighted standardized sound level difference $D_{nT,w}$ is also determined by the sound pressure level difference (D) and a correction element: 10 lg(T/T_0). Therefore, the sound pressure level difference (D) between the transmitting and receiving rooms is common for both parameters $D_{nT,w}$ and R'_w. Both quantities coincides numerically if the ratio of room volume (V) to separation component (S_T) corresponds to the value of 3.125 m. The link between the component-related measure R'_w and the reverberation time-related measure $D_{nT,w}$ is shown in detail in [6]. It becomes obvious that a flat-rate conversion, without reference to the geometric ratios of room volume (V) and separation component area (S_T) under consideration of a given scattering, or an accepted difference, is not possible. This is illustrated by Equation (4) for airborne sound insulation given below.

$$D_{nT,w} = R'_w + 10 \log(V/S_T) - 4.95 \text{ dB} \quad [\text{dB}], \qquad (4)$$

According to equation (4) a direct link between both quantities $D_{nT,w}$ and R'_w is only possible depending on the ratio of (V/S_T). A general equivalence of both quantities cannot thus be carried out. As shown in [6], the geometric ratio of room volume to separating surface (V/S_T) can basically be resolved in such a way that this results in either a functional dependence on the room width (w), the room length (l) or the room height (h). If a floor area of $S_G \geq 8$ m² and room heights between 2.40 m and 3.0 m is assumed, the following results for the case distinction: $R'_w = D_{nT,w}$, i.e., the numerical uniformity of both measures, shown in Figure 1 below.

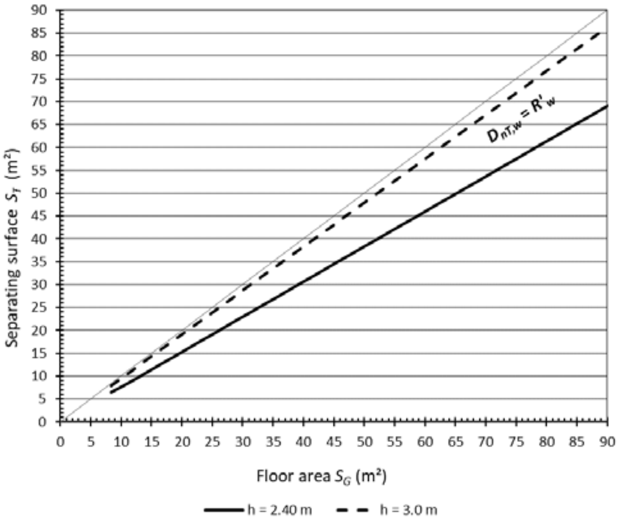

Fig. 1. Depicted is the difference: $R'_w - D_{nT,w} = 0$ depending on the geometric ratios: separating surface S_T and floor area S_G. The minimum floor area is 8 m². The room height is between 2.40 m and 3.0 m. The diagonal drawn in grey indicates the equality of $S_T = S_G$.

Figure 1 shows that mathematically based on equation (4) the equality of R'_w and $D_{nT,w}$ is always given if the floor area (S_G) is not larger than the separating surface (S_T). If the separating surface deviates from the floor area, there are differences between R'_w and $D_{nT,w}$. If a difference ($R'_w - D_{nT,w}$) of ±1 dB and of ±2 dB is allowed, the graphical representation results as shown in Figure 2.

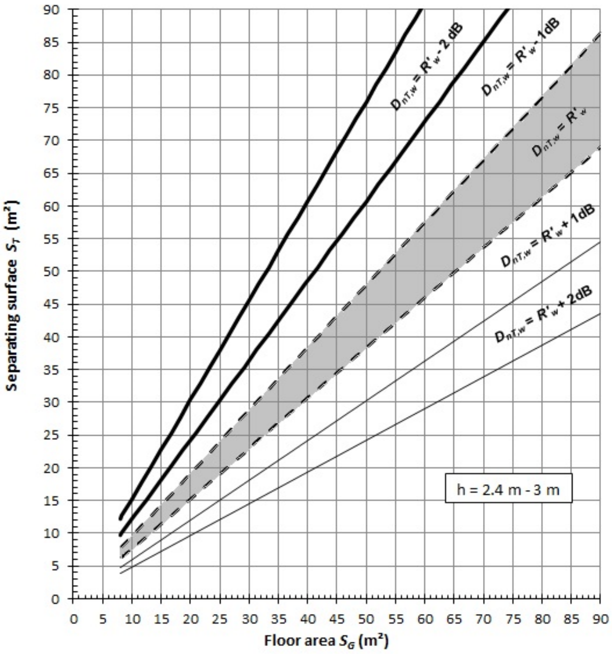

Fig. 2. Differences of $R'_w - D_{nT,w}$ as a function of geometric ratio: separating area S_T to floor area S_G. The minimum floor area is 8 m². The room height is between 2.40 m and 3.0 m. The grey area indicates the equality of $D_{nT,w} = R'_w$.

If the separating surface (S_T) deviates from the floor area (S_G), the difference increases, and deviations of several decibels occur. These deviations result from the geometric conditions and are not "acoustically" conditioned. From Figure 2 it is seen that a floor area, e.g., rooms between 10 m² and 20 m², the difference between $D_{nT,w}$ and R'_w is mathematically not greater than +2 dB. The standard sound level difference only becomes smaller when the separating surface (S_T) becomes larger than the floor area (S_G).

IV. 3. CLASS FORMATION

A class formation of both quantities ($D_{nT,w}$ and R'_w) is possible separately for each parameter singly without any problems. For example, Austria [7] has defined sound insulation classes from *A* to *E* and assigned a specific $D_{nT,w}$ to each class. Spain [8], on the other hand, has a classification system from *A* to *F*. ISO/TC 19488 [9] also assigns so-called "class limits" from *A* to *F* to the standard sound 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 to be made, difficulties arise in the way. In [2] it has been shown that there could be two different classes built. On the one hand, a volume class was derived and, on the other hand, a separating surface class. However, the relationships based on the volume classes and separating surface classes are more complex. They have more comprehensive relationships regarding the limits of the respective classes and the expected difference values. 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. A useful class formation can be obtained based on the relationships between volume (V) and separating surface (S_T). 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.

With variation of volume and a constant parting surface, the theoretically expected parameters are calculated depending on frequency and an evaluation of the frequency-dependent quantities is plotted graphically as a function of the ratio (V/S_T) using the evaluation method according to [4] and the difference ($D_{nT,w}$ - R'_w). The ideal frequency response of the sound level difference was iteratively subjected to several variations. Figure 3 summarizes the theoretically expected difference values ($D_{nT,w}$ - R'_w) as a function of the ratio (V/S_T) including the tolerance limits [10].

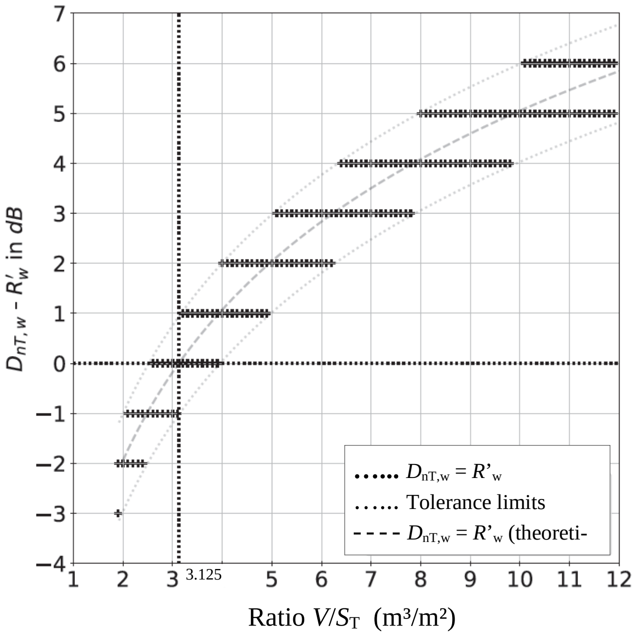

Fig. 3. Theoretical differences ($D_{nT,w}$ – R'_w) for the ratio (V/S_T). (Graphic from [10]).

The dashed vertical line shown in Figure 3 represents the ratio of V/S_T = 3.125 m³ /m² , where the numerical values of the two parameters R'_w and $D_{nT,w}$ are equal. Accordingly, for ratios smaller than this threshold, the weighted apparent sound reduction index R'_w is always greater than the weighted standard sound level difference $D_{nT,w}$ and always smaller for larger ratios. From Figure 3 it can be further deduced 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 m², the permissible volume is then 50 m³. Thus, a delimitation of the volumes with a minimum volume of V_{min} = 8 m² x 2.40 m = 19.2 m³ and a "threshold volume" in which the numerical values of the difference are equal to 31.25 m³, as well as a "limit volume" of 50 m³, where the maximum deviation is +2 dB, can be specified. The resulting volume intervals are then:

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

To show a classification as an example, the following conditions are assumed:

Room height: 2.40 m - 3.0 m
Room volume: 20 m³ - 120 m³
Separating surface: 10 m² - 40 m²

Equation (4) shows that $D_{nT,w}$ is equal to R'_w only if the ratio V/S_T is equal to 3.125 m³/m². Deviating ratios result in large dispersions in the difference between $D_{nT,w}$ and R'_w (see Fig. 3). 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 allowed, the permissible ratio of V/S_T can be determined according to Figure. 3. If the V/S_T ratio is divided into a certain interval where a deviation of ±2 dB is accepted, two ranges results:

$$V/S_T \ [1.9; 5.0] \text{ m}$$

$$V/S_T \ [5.1; 12.0] \text{ m}$$

The following classification is based on ISO/TC 19488 [9], 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*. With the knowledge gained, particular with respect to results presented in Figure 3, sound insulation classes with an accepted deviation of for example ±2 dB, can be designed. The smallest value for $D_{nT,w}$ is freely selectable and the R'_w values result from this. In Tab. 1 and Tab. 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

NPD: No performance determined.

Table 2. Classes of V/S_T at intervals [5.1; 12.0] m. 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

NPD: No performance determined.

The bold figure in Tab. 1 and Tab. 2 indicating the airborne sound insulation ($D_{nT,w}$) represents the mean with a deviation of ±2 dB. The two tables Tab. 1 and Tab. 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 3 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 4.

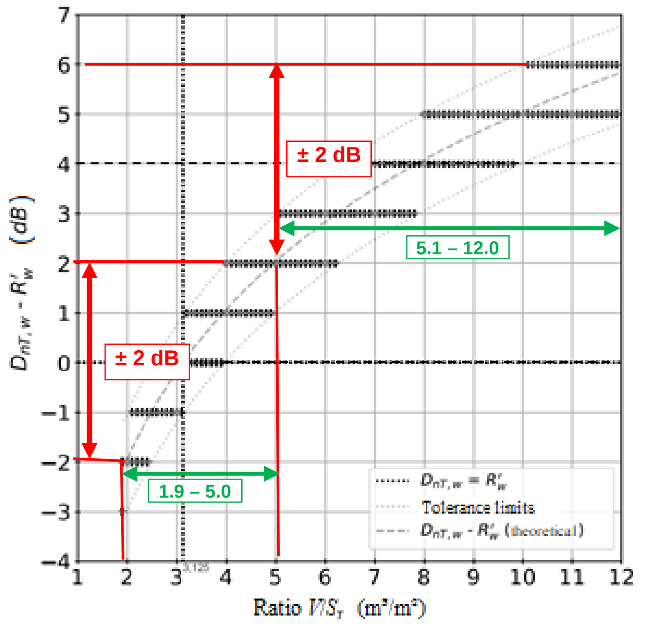

Fig. 4. Depiction of the grouping of the class as a function of the accepted difference (deviation ±2 dB).

V. Summary

Soundproofing, expressed with the weighted standardized level difference $D_{nT,w}$, is in general not equal to the sound insulation, expressed with the weighted apparent sound reduction index R'_w. Only if the ratio of V/S_T = 3.125 m³/m², the numerical values of R'_w and $D_{nT,w}$ are equal. All other geometrical variations lead to a deviation between R'_w and $D_{nT,w}$. A general classification of soundproofing or sound insulation is, however, possible and can help to be able to make quick and targeted divisions. The advantage of a representation in classes is a simpler estimation of the expected differences of the two parameters $D_{nT,w}$ and R'_w. However, the simplified relationships based on the volume classes and separating surface classes are more complex due to the conditions and assumptions described. They have broader relationships regarding the boundaries of the respective classes and the expected difference values [2]. However, from the ratio of volume (V) and separating surface (S_T), a meaningful class formation can be obtained. A classification is, however, only possible if the deviations, i.e., the differences between the two descriptors ($D_{nT,w}$ and R'_w), are defined. If, in addition to a deviation limit (spreading width), a class width is also specified, it is possible to form a class depending on the ratio (V/S_T). For a fixed class, a certain V/S_T ratio must always be considered to comply with the agreed error limit. A direct comparison of R'_w and $D_{nT,w}$ is only allowed with a fixed V/S_T ratio and always leads to a difference (dispersion), except for V/S_T = 3.125 m³/m². Depending on the size of the separating surface and the room volume, the spreading width can be -3 dB to +6 dB [2].

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