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THE N_{10} – A COMPARISON VALUE FOR SPEECH SOUND ABSORPTION FOR OBJECTS

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ABSTRACT

Since the introduction of the weighted sound absorption coefficient in ISO 11654:1997 [1], it has been used extensively to describe sound absorption for all products. The standard for rating sound absorption of furniture, ISO 20189:2018 [2], introduces the concept of sound absorption per object. The possibility to measure sound absorption per object is already included in the existing measurement standard, ISO 354:2003 [3], but is not so often used. The advantage of presenting the sound absorption per object instead of the absorption factor is twofold: 1. It is possible to describe the sound absorption for irregularly shaped objects, and 2. The influence of object size is directly coupled to its sound absorption. One problem with object sound absorption is however that it is cumbersome to compare the sound absorption for two different objects. This paper proposes a measure that can be used for such comparisons, the N_{10}. N_{10} is a single number that evaluates a product's sound absorbing efficiency for speech sound as described in ISO 3382-3:2022 [4]. In words, N_{10} is the number of objects required to obtain 10 square meters effective sound absorption area for speech.

Keywords: *Sound absorption, Furniture absorption, Comparison value*

1. INTRODUCTION

Even though professionals in acoustics think it is essential to include frequency information in all measurement results, manufacturers of products with acoustic performance often have difficulties in handling frequency data. The problem is especially true for clients who want to compare products from different manufacturers, or salespersons trying to describe their products' positive aspects. The need for simple comparison values for the complicated acoustic measurement results is evident. A single-value number is usually preferred since comparisons between products, and thus sorting of them, are simple and straight-forward.

Regarding sound absorption of large surfaces, such as absorbing ceilings or large wall absorbers, such a comparison value has been in use since 1997 through the standard ISO 11654:1997 [1]. The weighted sound absorption factor, α_w, is today a well-known and often used comparison value for sound absorption, often through the sound absorption class. A similar one-figure value is described in the standard ASTM C423-23 [5], namely the *SAA* (Sound Absorption Average) and also its predecessor *NRC*. The drawback for all of these comparison values is that they are only applicable for large and flat surfaces. For small surfaces, or for 3D objects with complicated shapes whose surface areas are difficult to measure, there is no available comparison value. An additional difficulty arises for objects with two-sided sound exposure, e g office screens. It is not clear in all standards if the one-sided or two-sided surface area should be used in the evaluation.

The advantage of presenting the sound absorption per object instead of sound absorption per square meter surface (i e the absorption coefficient) is that the sound absorption includes the object's size. A larger object of the same material has a larger absorption area, a fact that has a evident pedagogic value.

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2. MEASUREMENT OF OBJECT SOUND ABSORPTION

In the current version of the ISO measurement standard for sound absorption, ISO 354:2003 [3], it is described how the sound absorption of objects can be performed. One should remember that the absorption coefficient is actually measured through measuring the total equivalent absorption area of the 10 m^2 of absorbent, and afterwards calculating the absorption coefficient by dividing the absorption area with the geometrical area.
The instructions in the standard on how to measure object sound absorption are however not specific on what could be treated as an object, or how different types of objects should be arranged in the reverberation room. The standard ISO 20189:2018 [2] has been developed with these shortcomings in mind, and is essentially a list of descriptions of how different furniture should be measured and evaluated.
A consequence of object sound absorption instead of absorption coefficient is that a product available in different sizes have different absorption values. To overcome the large work amount to measure all sizes for a product the ISO 20189:2018 standard has introduced the possibility to interpolate sound absorption for intermediate sizes. The largest and smallest sizes are measured, and then chosen intermediate sizes. The sound absorption area for the rest of the sizes are interpolated.
The object sound absorption should be reported as the object's absorption area in the octave bands between 125 and 4000 Hz. The ISO 20189:2018 standard thus lacks a single number comparison value, and measurement results using this standard are difficult to compare.

3. THE N_{10} VALUE

3.1 General about single number values

Two main procedures are used in standards that describe evaluations of single number ratings;

1. Evaluations using comparisons with a reference curve where only numbers on one side of the reference curve are counted.
2. Weighting procedures where the raw measurement data is weighted with a specific frequency spectrum.

Examples of the first procedure are the comparison values α_w, R_w or L_{nw}, and examples of the second procedure are R_w+C, $L_{nw}+C_I$ or $DL_{\alpha,NRD}$. The standards that describe the evaluations are (in the same order as the single numbers) ISO 11654 [1], ISO 717-1 [6], ISO 717-2 [7] and EN 1793-1 [8] respectively.

3.2 Acoustic context for the N_{10} value

Furniture that is covered by the ISO 20189:2018 [2] standard are primarily used in offices or schools. The most common sound exposure in those built environments is speech. A comparison value for furniture should thus be based on speech in order to be a relevant measure. The obvious starting point for a relevant measure is thus to weight an object's sound absorption area with the sound power spectrum of speech. Speech spectra from the standards ISO 3382-3:2022 [4] (equivalent to the speech spectrum in ANSI S 3.5-1997, R 2007 [9]) and IEC 60268-16:2020 [10] are used in this paper. The spectra are presented in Table 1. The IEC 60268 spectrum in the table is calculated to a unisex spectrum as the energetic mean of male and female spectrum.

Table 1. A-weighted frequency spectra (*DL*) of speech from standards. The values in the table are dB values that sum energetically to 0 dB(A).

f (Hz)	ISO 3382	IEC 60268
125	-23.6	-16.1
250	-11.7	-4.3
500	-2.6	-4.5
1k	-5.4	-7.7
2k	-11.4	-12.8
4k	-17.6	-16.6

It is clear in Table 1 that there are significant differences between the standards. The speech-weighted absorption area is calculated according to Equation 1,

$$A_{speech} = \sum_{i=1}^{6} A_i 10^{\frac{DL_i}{10}} \quad (1)$$

where i denotes the frequency band index ($i = 1$ corresponds to the 125 Hz octave band and $i = 6$ corresponds to the 4 kHz octave band). However, in the ISO 3382 spectra the 500 Hz octave band is significantly stronger than all other bands. In the IEC 60268 spectra the 250 Hz and 500 Hz are almost identical. These facts can possibly be used to simplify the evaluation. Figure 1 shows the correlation between the weighted absorption calculated according to Equation 1 and just by using the strongest octave band for each standard respectively. In the graphs, measured absorption areas for 196 products are used, data provided by the company Acoustic Facts. Acoustic Facts certifies laboratory measurements and publish product data on their website.

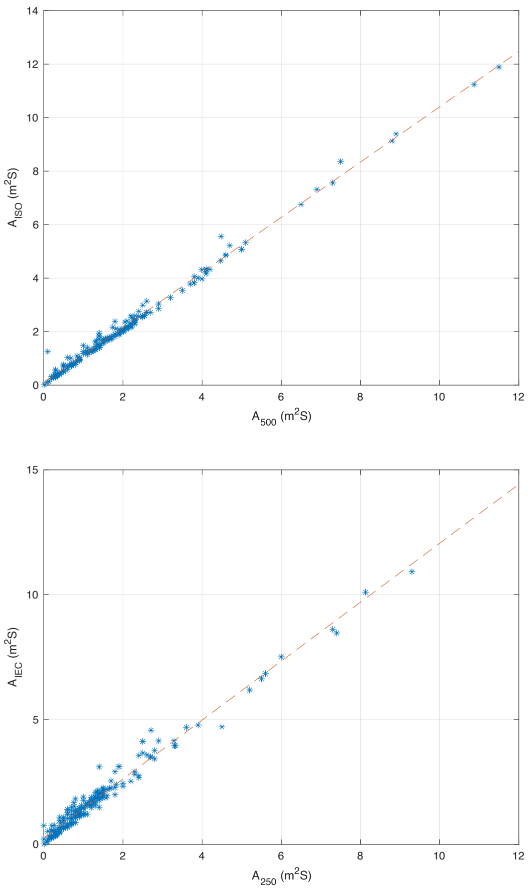

Figure 1. Correlation between full speech spectrum calculation and a simplified calculation with only the strongest frequency band.

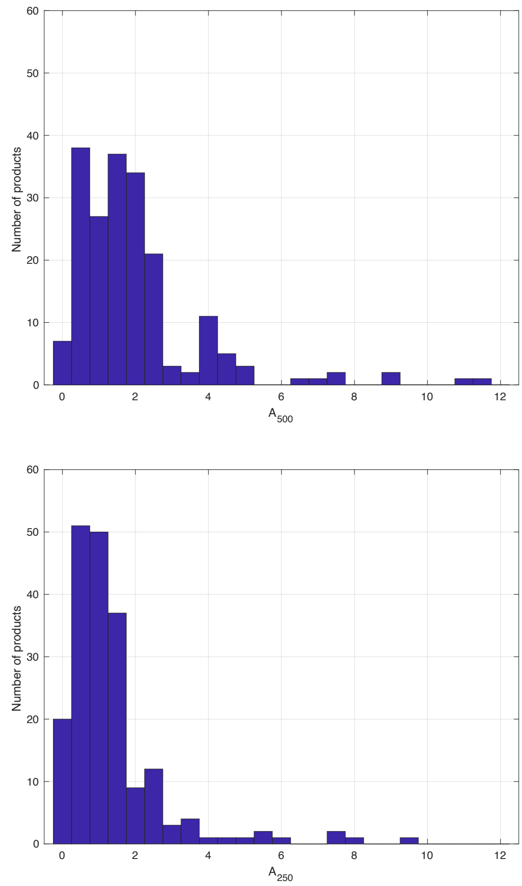

Figure 2. Distribution of the products for 500 Hz and the 250 Hz octave band respectively.

The company was started as an initiative from the Swedish furniture industry, who were asking for a relevant way to declare furniture sound absorption.
From the graphs it is clear that it seems to be sufficient to evaluate the speech sound absorption from the strongest octave band of speech.
From the two used standards, the ISO standard is chosen in order to get as much dynamics as possible in the final measure. The dynamics using the 500 Hz band is larger than the dynamics using the 250 Hz band, see Figure 2 where the 500 Hz band results in more even distribution of products. The 250 Hz band results in a denser population at lower values than the 500 Hz band. This means that it is more probable that an absorption performance difference between two products is more probable by using the 500 Hz octave band than the 250 Hz octave band. The conclusion is here that the speech spectrum in ISO 3382-3, and thus also in ANSI S 3.5, is better suited for a comparison measure.

3.3 Description of the N_{10} value

The aim for the N_{10} measure was to get a speech absorption comparison measure, and that this measure would be possible to use for product choice. This implicitly means that the N_{10} most probably also will function as a design measure in product development. With this in mind, it is dangerous to have a measure that is based on one octave band only. The probable outcome is that we would see many products that are optimized for sound absorption in the 500 Hz octave band, and those products are not very effective for speech absorption. An additional requirement was added to the effective sound absorption to overcome this; the absorption

area of the product should not be less than the value in the 500 Hz band in any higher octave band. If so, the smallest absorption area should be used.
There are so many different absorption values used today with different meanings, so the idea came up if it would be more easier to understand by the intended users (i e the furniture industry) to use an alternative unit. The alternative unit chosen here is to use amount of products (N), and more specifically the amount of products (of a specific size) that would be needed to obtain 10 m^2 of speech absorption. The reason for using 10 m^2 as a normative size is that this specific size is already in use in several acoustic standards, e g when normalizing sound pressure level difference (D_n) or normalized impact sound level (L_n).
The final definition of the proposed N_{10} comparison measure is as follows.

$$N_{10} = \frac{10}{A_{500}} \qquad (2)$$

A_{500} is the object sound absorption area in the 500 Hz octave band. If the sound absorption area is lower in any octave band between 1 kHz and 4 kHz, that value should be used in the N_{10} calculation according to Eq 2. The N_{10} value should be given with two value figures, i.e. with one decimal for N_{10} values below 10, and with integers for values of 10 and above.

4. COMMENTS ON THE USAGE OF N_{10}

Even though its definition is very simple, as is shown in the previous section, the N_{10} value has a clear empiric basis as it is built on standardized values of speech spectrum. As shown in Figure 1 it has a strong correlation to absorption of the A-weighted sound.
One should remember that the N_{10} value is designed to be a comparison value; it is not intended to be used as a design parameter in room acoustics.
The original initiative from the Swedish furniture manufacturers was the result from experiences with badly formulated procurements, and the evaluation of the procurement replies. There was simply no rules on how furniture's sound absorption should be evaluated or presented. This was experienced as especially sensitive for the large-scale governmental procurements issued by the Swedish Legal, Financial and Administrative Services Agency (Kammarkollegiet). It was very important for the furniture manufacturers that relevant procurement rules regarding sound absorption were included in those procurements. The manufacturer was not allowed to sell acoustic products to any governmental institution if it did not passa the procurement. On the other hand, frivolous manufacturers that did pass the procurement with irrelevant or very unspecific acoustic documentation could sell their furniture at a lower cost. For instance, office screens could pass the procurement with absorption measurements for a similar material as in the screen filling but measured as a suspended ceiling with 200 mm air gap behind. One other example was that sound absorption for the screen filling was documented as absorption coefficient in a ISO 354 Type A mounting, but the screen filling was covered by perforated wooden sheets with less than 10 % perforation. We all know that these are not the same. The procurements did really not work in practice, and the final customers could get products with more or less any absorptive quality.
Today, Kammarkollegiet issue procurements with N_{10} requirements for the sound absorption for table screens, floor screens and wall absorbers. Kammarkollegiet also recommends the use of N_{10} requirements when governmental institutions issue their own procurements. This system has been in place since 2019, but it has been in use for a longer time period.
As is said in this paper, any measure which is used to set requirements will also be used for product development. The introduction of N_{10} as requirements in procurements has triggered much product development among many manufacturers. In itself, this has increased the knowledge about and attention to acoustics, not only for the manufacturers but also for other professional groups.

5. CONCLUSIONS

To set relevant requirements on the sound absorption of furniture has been a difficult task in the past. However, since 2019 a specific evaluation system has been in place in governmental procurements in Sweden using the comparison value N_{10}. This value is based on standardized frequency spectrum of speech, and mean the amount of a specific product (with a specific size) that is needed to give 10 m^2 of speech-relevant sound absorption.
The N10 value is only intended as a comparison value and not for room acoustic design.

6. REFERENCES

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