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Time to reconsider reverberation time

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ABSTRACT

The reverberation time (RT) is one of the best known variables in acoustics. Its value in the characterisation of concert halls is undisputed. In simple rooms like offices and dwellings the RT is used as such, and as a means to determine the amount of sound absorption, necessary in the process of measuring the sound insulation of façades, partitions etc. In voluminous rooms like large atria and sport halls noise control is the main reason for applying sound absorption; there the RT as such is a secondary quantity. Nevertheless the RT is often used as a criterion in such halls.

Problems can arise if the reverberation curve is not a straight line; this is not unusual. It will be argued that in such cases the (required) amount of sound absorption is a better criterion than the RT. An alternative method is necessary for the measurement of the amount of sound absorption. This method starts from the well known formula for the sound pressure level in the diffuse field, caused by a calibrated source.

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1. INTRODUCTION

The reverberation time (RT) plays a central role in the acoustics of enclosed spaces. It could already be measured before electronic equipment was available, without which sound pressure, power etc. could not be determined. Besides this historical aspect, it has the advantage of being expressed in an comprehensible measure (seconds), whereas the decibel scale is much harder to understand.

In the acoustics of rooms for music, auditoria etc. the RT is a very important criterion, but in many types of rooms the RT as such is not. This does not imply that sound absorption is irrelevant, because the effects of a lack of sound absorption are too well known: noisy, reverberating rooms, where speech intelligibility is poor.. A certain amount of sound absorption is needed to avoid those adverse effects and create an optimal acoustic climate.

We will focus on large enclosed spaces like atria, shopping malls, and sport halls where noise control is the main problem. In very large spaces air absorption may be relevant; here it will be neglected.

2. SOUND ABSORPTION VERSUS REVERBERATION TIME

W.C. Sabine gave his name to the law that links reverberation time (T) and the amount of sound absorption (A):

$$T = \frac{V}{6.\mathrm{A}} \quad (1)$$

Where V is the volume (in m^3). This relationship makes RT and amount of sound absorption almost interchangeable. Now the question should be asked: which criterion is best suited: RT or amount of absorption? It is a common experience that the noise level caused by the conversation of groups increases with the number of people; proportionally at first, when not many people are present yet, but even stronger if certain limits (noise level or number of people) are exceeded.

It is a realistic assumption, that the underlying reason is the intention of people to maintain conversation. An extensive (theoretical) approach is given bij Nijs et al [1]. A simple thought experiment is described in [2]. Based on the extensive literature on speech intelligibility, preferred speech levels etc. the effects of the number of occupants, trying to maintain or start their conversation, and the amount of sound absorption can be expressed in a model. .
The RT plays no role in this; it is only the amount of sound absorption that counts, more specific: the the amount of sound absorption per person present. From the dimensions and type of use of the room the number of people can be estimated, and the amount of sound absorption determined. Of course the volume of the room is known as well, so the required RT can be calculated by formula (1), as a derived quantity. In this way the derived RT can be used as a criterion for room acoustics, but only if Sabine's Law (1) is valid. Because this law presupposes a diffuse sound field, this condition is far from trivial: the room should have a more or less cube-like shape; the sound absorption coefficients of all elements of the envelope of the room should be approximately equal.

3. THE (?) REVERBERATION TIME

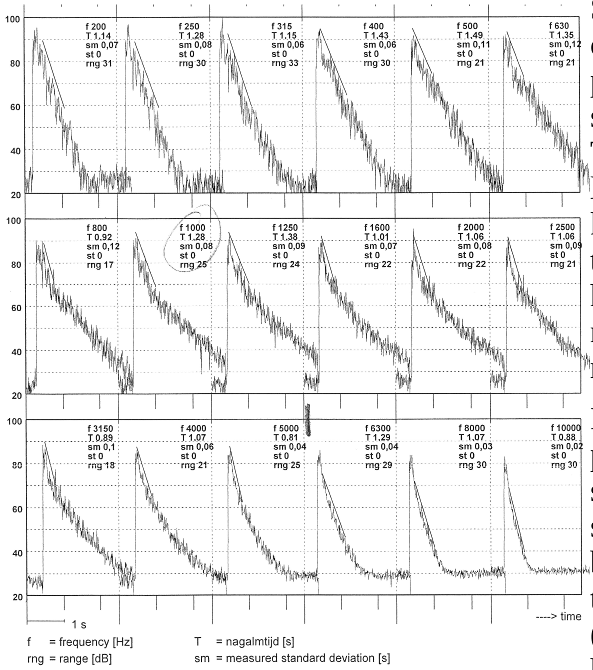

Figure *1: Decay curves in third octave bands; some are non-linear*

Sound fields in enclosed spaces can be very complex, mostly too complex to be handled in practice. A simple approximation is the diffuse sound field: homogeneous and isotropic. There, simple laws of energy conservation lead to exponential decay curves and the well-known formulas for RT and sound transmission between rooms. A diffuse field however is an ideal: even in reverberation rooms diffusers are necessary to create a reasonably diffuse field.

If the decay curve in a room, i.e. the sound pressure level as a function of time after switching off the sound source, is not a straight line (figure 1), the RT can no longer be determined without defining which part of the decay curve is used. In other words, a (small) family of RT's exists. Much attention has been paid in the past to reverberation in concert halls, and the question which member of the RT-family is best suited to describe the subjective impression of the acoustics of a a hall.

For the type of rooms discussed here, it is not the subjective impression of the hall that is important, but the effect on noise control. In rooms with non-linear decay curves, the RT is not defined, and the use of RT as a criterion can be ambiguous.

4. ALTERNATIVES ?

In noise control it is the amount of sound absorption that counts, and in rooms where it is not valid we should look for a method to measure that quantity, without using Sabine's Law. Therefore the equilibrium formula for the sound pressure level $L_{p,rev}$ in the reverberant field of a room with a constant sound source of known (calibrated) power level level (L_w) can be used:

$$L_{p,rev} = L_w + 10\, lg\, 4. \frac{(1-\alpha)}{A} \quad (2)$$

$$A = amount\ of\ sound\ absorption\, [m^2]$$

$$\alpha = average\ sound\ absorption\ coefficient = A/S$$

This can be rewritten as:

$$A = \frac{4}{10^{(L_{p,rev}-L_w)/10} + 4/S} \quad (3)$$

$$where\ S = total\ area\ of\ envelope\,(floor, ceiling, walls)\,[m^2]$$

In a perfect diffuse sound field the sound level $L_{p,rev}$ would be independent of the position in the room, at least at distances where the direct field is negligible. In practice the variation in sound level cannot be neglected, and an average value should be determined– not unusual in acoustics. As a consequence of Barrons correction [3] the preferred measurement area is a circle (better: a vertical cylinder) with a radius equal to the *mean free path (mfp)*, centered at the sound source. The value of the mean free path is:

$$mfp = \frac{4V}{S} \qquad (4)$$

In this way the amount of sound absorption can be determined in a different way, independent of the shape of the decay curve: by measuring the average sound level on a specified surface; the sound power level, the total area of the envelope of the room and its volume are the other required variables.

5. CONCLUSION

In the acoustics of enclosed spaces where noise control is paramount, the main a priori question is: how much sound absorption is needed, and where. In most cases the RT is not most suitable criterion, but the amount of sound absorption per person or per m^2. In rooms where the sound field is diffuse enough, the amount of sound absorption can be determined (a posteriori) via measurement of the RT and Sabine's Law. In the contrary case, measurement of the average sound pressure level caused by a source of known sound power level is an alternative.

6. REFERENCES

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