Use of G and C_{50} for classroom design

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Introduction

Strength and Clarity have been proposed as measures of room acoustic response that relate directly to the conditions that we seek – namely speech intelligibility for listeners, SNR and control of background noise.

Theory

Theoretical methods to describe spatial variation of Strength and Clarity are presented, and compared with measured values in the Essex Study classrooms.

Barron's revised theory is used with an additional decay factor, ***fb***, to describe the spatial variation of the reverberant field ($Diff_{bar}$) in furnished rooms as:

$$Diff_{bar} = \frac{4(1-\alpha)^{fb.d/mfp}}{A}$$

From which Strength, G, is described as:

$$G = 31 + 10\,log\left(\frac{Q}{4\pi d^2} + \frac{4(1-\alpha)^{fb.d/mfp}}{A}\right)$$

Similarly, Clarity is defined as the difference between the Early (up to 50 ms) and Late (after 50 ms) sound:

$$C_{50} = L_{p,early} - L_{p,late}$$

With Barron's revised theory, modified again, this is calculated as:

$$L_{p,early} = L_{w,sp} + 10\,log\left(Dir + Diff_{bar}.\left(1 - e^{\frac{-0.69}{RT}}\right)\right)$$

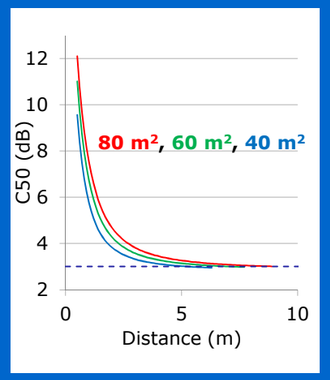
$$L_{p,late} = L_{w,sp} + 10\,log\left(Diff_{bar}.e^{\frac{-0.69}{RT}}\right)$$

Designing for Strength

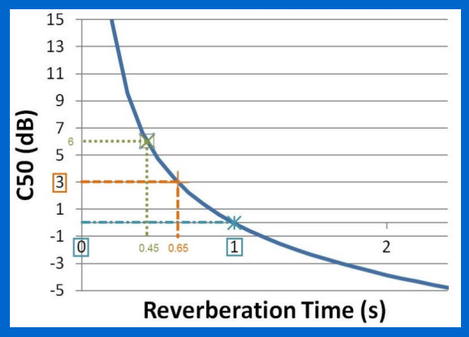
According to Sato and Bradley [1], SNR > 20 dB is required for most primary school children to hear most of the time. With a background noise of 35 dB(A), a minimum speech signal of 55 dB(A) is required.
If normal speech is 60 dB(A) @ 1 m, this will be 40 dB(A) @ 10 m in the freefield; the speech level in a room will be (40 + G) dB. Hence to achieve 55 dB(A), the minimum value for Strength at the back of the room should be G = 15 dB.

Designing for Clarity

Clarity may be plotted as a function of distance for a given reverberation time in rooms of different floor area, with a constant ceiling height of 3 m, as shown in the figure on the right. This demonstrates that the value at the back of the room is a function only of reverberation time, not room size.



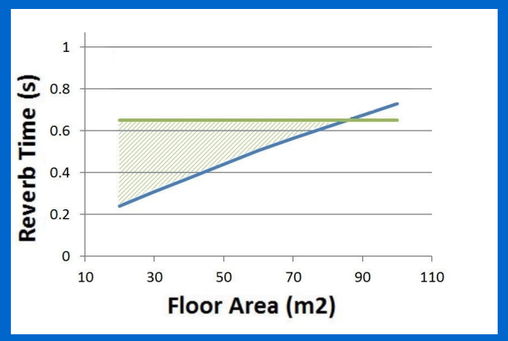
The figure below shows the value of Clarity with reverberation time at a distance D, where D is the square root of the floor area. To achieve a minimum value of 3 dB Clarity the maximum value of RT is 0.65 seconds.



Strength & Clarity

For the speech there is a minimum reverberation time requirement to ensure sufficient signal level at the back, which varies as a function of room volume and reverberation time. For Clarity, there is an upper limit for reverberation time to achieve particular level of Clarity at the back of the room.

Based on a room height of 3 m, the variation of reverberation time with floor area to achieve 15 dB G at a distance D is shown in the figure below.



The shaded area illustrates the design range that meets both criteria - Clarity and SNR - used in this example.

Conclusion

Although described in terms of reverberation time here, Strength & Clarity may be determined from room geometry and finishes. Room characterisation for a single value of Strength or Clarity requires spatial definition of the source and receiver positions.

Rooms can be designed for intelligibility & SNR. Strength also informs room gains from pupil noise; hence the minimum sufficient value is probably desirable. A better treatment is by Pelegrin [2] subsequent to writing this paper [3].

*[1] H. Sato, J. S. Bradley. "**Evaluation of acoustical conditions for speech communication in working elementary school classrooms",** JASA 123. 2064–2077. (2008)*
*[2] D. Pelegrin Garcia, B. Rasmussen, J. Brunskog, "**Classroom acoustics design for speakers' comfort and speech intelligibility: a European perspective**", FA 2014.*
*[3] J Harvie-Clark, F. Larrieu, D. Wallace, N. Dobinson, "**Use of G and C_{50} for classroom design**", Proc IOA Vol. 36 Pt 3, 2014*