DESIGNING BUILDINGS INSIDE OUT

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1 INTRODUCTION

Modern building regulations and legislation can be very prescriptive, giving set criteria for factors such as sound insulation, indoor ambient noise level, reverberation time etc. The assumption and implication is that all these factors are necessary for the successful operation of a building and the comfort of its occupants.

But are all these factors always necessary? It may also not always be possible to fully comply with criteria, due to constraints of a particular building, overriding design factors (e.g. thermal comfort), not to mention budgetary constraints (which are tighter now than ever). Does one set of criteria really fit all and, if these criteria are not met to the letter, does the building fail to operate successfully?

Living and working in the so-called Austerity Decade, we can not afford to stipulate criteria for the sake of it, or because that is what we have always done. Everything must be traceable, provable and provide the developer, owner and occupier with best value. There is a significant shift towards refurbishment and remodeling of existing buildings, even adaptation of existing buildings for purposes other than those they were originally constructed for. As practitioners, we need to make sure that we are offering the best advice to our clients, based around their needs, expectations and budgets and the constraints of the buildings they are developing.

2 WHAT ARE BUILDINGS FOR?

With the exception of buildings for music, the acoustic requirements of most buildings can be distilled down to the fundamental concepts of communication and privacy: do people want others to be understood or not? This requirement may well differ across different parts of the same building, in which case this will need to be taken into account.

2.1 Residential dwellings

In residential dwellings, Building Regulations define the minimum levels of sound insulation between dwellings that is required to provide a reasonable standard of privacy. For example, the particular rating $D_{nT,w} + C_{tr}$ attempts to quantify what is reasonable for party walls and ends up with a figure of 45 dB to divide new-build dwellings but only 43 dB for a material change of use and ‘rooms for residential purposes’. Is this suggesting that the requirements of people who live in a converted mill are less than those in a new house, or that they are somehow less deserving of the same level of sound insulation? Or is it an acknowledgement that site constraints play a significant part in the practicalities involved in providing sound insulation?

Residential occupation is extreme in its requirement for sound insulation. It is commonly accepted that speech, both at normal and raised levels, should not be audible between dwellings. The C_{tr} correction is intended to provide protection against low frequency noise also, to variable levels of success in actual applications.

Code for Sustainable Homes acknowledges that it is more ‘sustainable’ to provide enhanced levels of sound insulation, up to 8 dB better, and rewards developments if this can be accommodated.

It would be difficult to argue that these levels of attenuation are required in a non-domestic, e.g. commercial, environment.

2.2 Commercial Applications

In the case of commercial applications such as offices and community buildings, is it really necessary to not be able to hear anything that people in the adjacent space are doing? Providing the basic rudiments of speech privacy can be employed where necessary, do occupants need anything greater? Certainly in many applications, co-workers need to be able to understand what each other are saying as this is fundamental to the tasks they are carrying out.

Documents such as BS 8233: 1999 have recognised that lower (when compared with residential) levels of attenuation are suitable in an office environment, suggesting D_w 38 dB for general applications and D_w 48 dB or greater when increased privacy is required. The same document also introduces us to the concept of privacy being a function of background noise level in addition to airborne sound insulation, as did the now-superseded HTM 2045 (1996). This has been taken up by the Association of Interior Specialists' Acoustic Guide for Offices (2011) which gives advice on varying levels of privacy values in the context of varying background noise level and sound insulation (this is picked up later in this paper). BS 8233 suggests that the arithmetic sum of the D_w and background noise in dB(A) should be greater than 75 for a reasonable standard of privacy; by implication therefore, a D_w 38 dB partition can give acceptable levels of general privacy in background noise levels as low as 37 dB(A), a little over NR30.

The difference between residential provision of $D_{nT,w} + C_{tr}$ 45 dB (which can be approximated to 53 $D_w/D_{nT,w}$ for a lightweight stud partition) and D_w 38 dB in an office is profound in terms of its physical magnitude and the required construction to facilitate it.

But what does this all mean in terms of the physical and subjective impact on privacy? How good or bad is office sound insulation compared to that expected in dwellings? Are modest levels of sound insulation sufficient, or even too high?

Also, when we consider the need for co-working, what are the requirements to enable this to happen successfully?

3 PRIVACY AND COMMUNICATION

As discussed above, we will consider both speech privacy and communication in terms of Speech Transmission Index (STI). This measure is generally well understood and related to. STI is defined as numbers between 0 (total unintelligibility) and 1 (perfect intelligibility); in reality, neither of these extremes will be experience between adjacent spaces or areas, therefore it is the regions in between that we need to be concerned with. The common scale for STI is as below, defined by Houtgast and Steeneken:

STI Score	**0 to 0.3**	**0.3 to 0.45**	**0.45 to 0.6**	**0.6 to 0.75**	**>0.75**
Description	Bad	Poor	Fair	Good	Excellent

Table 1 - STI scoring

The regions of the scale that are most appropriate for everyday speech are therefore <0.4 (where intelligibility is Poor and privacy is therefore good) and >0.6 (where intelligibility is Good and privacy is therefore poor). It is interesting to note that the region in between these two thresholds is quite narrow and the implication is that it does not take much change in a signal or physical characteristics of a room to tip the balance either way. It is also interesting to note that documents such as BS 5839: Pt 8 deem that a RASTI of >0.5 is acceptable for voice alarms in emergency situations, even though this is technically only Fair; this is surely more to do with the physical difficulties of achieving a better score in large, often reverberant spaces, rather than a condoning of mediocrity.

The physical constraints of a space play a large part in the determination of STI. As defined in BS EN 60268 Pt 16: 2003, STI is a function of Signal to Noise Ratio (SNR) and reverberation time (RT).

It is worthwhile noting the constraining factors that affect STI, which also highlight the shortfalls in STI as an assessment tool. Using the formulae for STI given in BS EN 60268 Pt 16: 2003, RT can be shown to have the following influence, even when the SNR is very high:

RT / seconds	STI impact
>4.0	Bad
2.0 to 3.9	Poor
1.0 to 1.9	Fair
<0.9	Good
0	Excellent

Table 2 – RT impact on STI

When the SNR is low then this has a significant contributory factor, changing these rules.

What can be inferred from this exercise is the following:

- In large spaces with a high RT (i.e. over 2.5 seconds) then STI can only ever be Poor. We know this to be the case from personal experience, when someone shouts in a swimming pool or railway station.
- The only way to achieve Excellent STI is to be on-axis in virtually anechoic conditions (i.e. outdoors) or otherwise in the near field of a speaker where the reverberant field is significantly below the direct signal (e.g. at least 10 dB).

As discussed above, the extremes are not representative of most commercial situations where STI would be used in design, but an appreciation of these factors is very helpful.

3.1 Privacy

As discussed in section 2.2 above, BS 8233: 1999 adopts a Privacy figure of 75, which is to be the addition of in-situ sound insulation through to an adjacent space and the background noise level in dB(A). This has also been included in BREEAM 2008 for Offices (Credit Hea 13) and BREEAM 2011 (Credit Hea 05). It can be inferred from this that varying the Privacy figures will give varying degrees of privacy; the AIS' A Guide to Office Acoustics (www.acousticguide.org) has developed this in graphical form, as shown below:

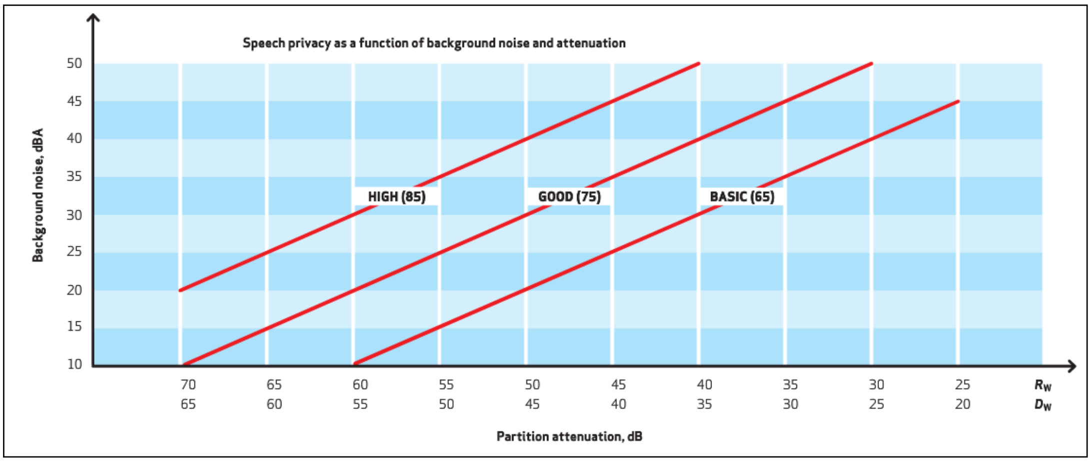

Figure 1 – AIS Privacy Chart

This Guide assumes a further two levels of Privacy: Basic at 65 and High at 85. Using the same formula as BS 8233 and BREEAM, values are then suggested for sound insulation and accompanying background noise level, graphically showing the relationship between the factors.

Based on what we have considered above, it would be helpful to consider how this relates to STI in a typical office scenario. For the purposes of this study we will assume a moderate-sized cellular office having a reverberation time of 0.8 seconds across the frequency range, for background noise levels of NR25 (or 30 dB(A)) for a typical chilled ceiling/beam or quiet fan coil unit, and for NR20 (or 25 dB(A)) for displacement ventilation or natural ventilation (where external noise is low).

We will consider these scenarios with varying levels of sound insulation, from D_w 15 dB (for an open plan scenario as described in BS 8233, having significant levels of acoustic absorption from the ceiling and half-height partitions), in increasing 10 dB increments up to D_w 45 dB (for a robust stud partition). For the purposes of this assessment, a number of assumptions have been made, as follows:

- For sound insulation figures, an octave band spectrum equivalent to the weighting reference curve given in ISO 717 Pt 1: 1997 has been used
- The same reverberation time (0.8 seconds) has been assumed in all octave bands
- Raised speech effort as defined in 'Guidance on computer prediction models to calculate the Speech Transmission Index for BB93 – Version 1.0' has been used as the source spectrum
- Calculations of STI have been carried out using the algorithms given in BS EN 60268 Pt 16: 2003 have been used

Values of STI for varying levels of D_w and background noise level are shown in the Table below:

Background noise level / dB(A)	D_w / dB	Privacy	STI (Verdict)
30	15	45	0.60 (Good)
	25	55	0.53 (Fair)
	35	65	0.40 (Poor)
	45	75	<0.40 (Poor)
25	15	40	0.60 (Good)
	25	50	0.59 (Fair)
	35	60	0.47 (Fair)
	45	70	<0.40 (Poor)

Table 3 - Transmitted STI with low background noise

As can be seen from the Table above, to achieve a Poor speech intelligibility, based on raised vocal effort, levels of sound reduction (D_w) of 35 and 45 dB are required for background noise levels of 30 and 25 dB(A) respectively. For moderately low noise background noise levels of 30 dB(A) / NR25 then this suggests only moderate sound insulation, below that suggested in BS 8233 is required. It should be noted, however, that this refers to Poor STI only, and for total speech privacy and security, higher values of attenuation will be required, preferably accompanied by higher levels of background noise for masking purposes.

If we develop this further for much higher internal noise levels, but still in line with the upper limit of acceptability for BREEAM, the results follow a logical progression but give interesting results for even open plan situations. In practice, this level of noise would not normally be used as a design parameter for mechanical ventilation but could be experienced when a building is naturally ventilated via opening windows and there is a busy road outside:

Background noise level / dB(A)	D_w / dB	Privacy	STI (Verdict)
50	15	65	0.40 (Fair/Poor)
	25	75	<0.40 (Poor)
	35	85	<0.40 (Poor)
	45	95	<0.40 (Poor)

Table 4 - Transmitted STI with high background noise

What this shows is that, when the background noise level is consistently high, Poor STI (and therefore good privacy) is achieved even at low levels of sound insulation, as provided in an open plan situation with moderate internal finishes. The related factor to this is that when background noise levels are high then speech communication is generally poor.

4 PRACTICAL IMPLICATIONS

As can be seen from the Sections above, even moderate levels of sound insulation between adjacent spaces, such as D_w 38 dB suggested by BS 8233, can yield good levels of speech privacy where the source is raised vocal effort, even with moderate levels of background noise. Speech privacy increases in effect proportionally with sound insulation and/or background noise.

Where this comes in useful is in refurbishment situations, such as are becoming more prevalent in the construction industry. Often in older (and some more recent) buildings, levels of sound insulation of existing partitions is relatively low; if a building is in an urban environment where external noise levels are high and the primary source of ventilation is via opening windows, internal conditions can provide perfectly reasonable acoustic criteria in terms of speech privacy for offices or even education requirements. In such circumstances it could be argued that expensive upgrades to meet the exact requirements of BREEAM, BB93 etc. may not be necessary, especially if the budget is not available. It could even be argued that maintaining these moderate levels of sound insulation is more sustainable than removing/supplementing existing partitions and installing extensive attenuation against external noise – the definition of sustainability being to provide good standards for the present without compromising the opportunities of future generations.

There are limitations to this study though, which include the following:

- This relates to speech *privacy*, the requirements of which will be different to those of speech *security*. Generally, for security purposes where virtually no transmitted speech signal can be tolerated, significantly higher levels of sound insulation will be required
- When background noise level is used as a masking source, it must be reasonably constant without significant fluctuations either upwards or downwards. If levels fluctuate downwards then the privacy will not be maintained, whereas fluctuations upwards can result in distraction
- Where externally generated (e.g. road traffic) noise is the primary background noise source then lapses in privacy must be expected in lulls in traffic. Similarly, external events such as emergency vehicles and overhead aircraft may cause unacceptable levels of disturbance to building occupants

In times when construction budgets are at an all-time low, Acousticians can not afford to be accused of putting unnecessary constraints on developments. The earlier that an Acoustician gets involved in a design process, the more likely that a satisfactory solution can be obtained by good communication across all members of a design team. In many cases, the very first questions that need to be asked are: 'What is the building for? What are its primary purposes? What do its occupants need in terms of speech privacy and communication?'. When the answers to these questions are known we can begin to design buildings from the inside out.