THE ROLE OF ACOUSTICS IN THE CONTEXT OF GREEN BUILDINGS

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INTRODUCTION

The Green Building Council of South Africa (GBCSA) recognises good acoustics as a point of merit under the Indoor Environment Quality category of its rating tools. While good acoustics definitely has its place in design, what is its role in the greening of buildings?

The concept of green building is most commonly thought of as a drive to decrease the carbon footprint of development and minimise the depletion of natural resources. However, this is only part of the motive. While we advocate saving the planet, in truth we are striving to save ourselves, mankind. The Green Building Council makes the statement that "building green is an opportunity to use resources efficiently and address climate change while creating healthier and more productive environments for people to live and work in" (Green Building Council South Africa, n.d.). In other words, building green is as much about the sustainability of the environment as it is about supporting the sustainability of people and businesses. What would be the point of building highly-rated green buildings if they were terrible spaces to occupy?

INDOOR ENVIRONMENT QUALITY

The GBCSA, as well as other green building councils around the world, factor Indoor Environment Quality (IEQ) into their rating systems in pursuit of this human aspect of development. The term "sick building syndrome" (SBS) has long been used to describe a range of negative health effects experienced by building occupants that can be associated with time spent in a poor building environment. The World Health Organisation recognised the adverse health effects of sick buildings as early as 1982 (World Health Organization, 1982). Symptoms may include chest tightness and difficulty with breathing, eye irritation, dry throat, headaches, tiredness, irritation or concentration difficulties and even fever (Bluyssen, 2009). While this condition is primarily related to the air quality in a building, it is also associated with other aspects of the indoor environment, such as poor lighting, thermal discomfort and noise (Bluyssen, 2009).

The impact of a poor indoor environment extends beyond the direct physiological and psychological effects on the occupants, influencing productivity. Research has shown that the building itself can influence productivity by up to 17% (Clements-Croome, 2006), with associated economic impacts.

Since the green movement is as much about creating healthy, productive environments as it is about resource efficiency, the IEQ category in the Green Star rating system can be justified. More specifically, though, the reason for including acoustics needs to be understood and justified. For this, it is important to first understand the nature of sound and the definition of noise.

SOUND AND NOISE

Sound is energy in the form of a wave of vibrating particles with an amplitude and frequency. The amplitude of the wave determines the loudness, described as a sound level in deciBels [dB]. The frequency can be described as the pitch, measured in Hertz [Hz]. The range of human hearing is 0 dB to about 130 dB at frequencies between 30 Hz and 20 kHz. Hearing damage can occur due to exposure to certain frequencies, prolonged exposure to sound above 90 dB or short-term exposure to sound above 120 dB. However, these thresholds do not necessarily define noise. Rather noise is defined as unwanted sound and is very subjective.

Noise can have two basic kinds of effects on humans. Firstly, it can have auditory effects that lead to hearing damage, as mentioned above. Secondly, and more importantly for this discussion, are the non-auditory effects. This cannot be measured empirically and results from noise that is not necessarily excessively loud but rather noise that interferes with activities or disturbs attitudes. Non-auditory effects include performance effects, such as disrupted work or rest, and physiological effects, such as increased heart rate and blood pressure (Canadian Centre for Occupational Health and Safety, 2007). The World Health Organization (WHO) lists cognitive impairment, annoyance and cardiovascular disease amongst the effects of noise on people (World Health Organization, 2011). From this it is easy to see how noise influences health, happiness and productivity.

In non-industrial buildings, the source of this kind of noise is typically building services (such as noisy ventilation systems), traffic, talking, alarms, or media. Recommended ambient noise levels for various types of spaces are listed in the WHO *Guidelines for community noise* (Berglund, et al., 1999) and *SANS 10103 The measurement and rating of environmental noise with respect to annoyance and speech communication* (South African National Standards, 2008), providing a useful reference for design.

In working and living environments, the common criteria for good acoustics are speech intelligibility, speech privacy and non-distractibility. One of the most important aspects of acoustics to be controlled in order to achieve these requirements is reverberation. This refers to the amount of time it takes for a sound to die down by 60 dB. A room that has a long reverberation time becomes very noisy as sound 'bounces' around and speech becomes unintelligible, making productivity and communication difficult. There are no standards for reverberation time in different types of spaces, though some useful recommendations are listed in the table below.

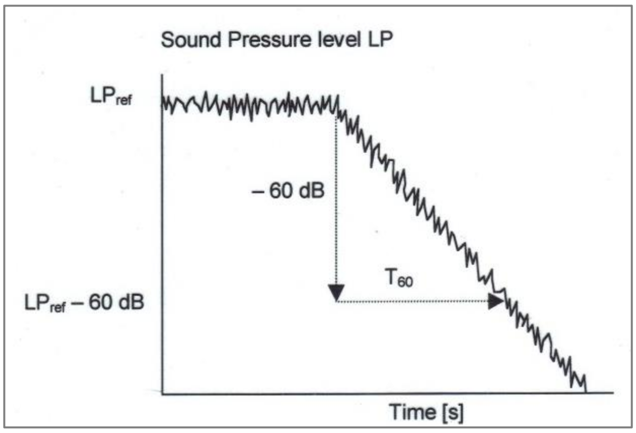

Figure 1: Graphic representation of reverberation time

Internal Space	Reverberation Time (T_{mf}) - Seconds
Private Office	0.6 – 0.8
Open Plan Office	0.8 – 1.2
Secondary School Classroom	< 0.8
Primary School Classroom	< 0.6
Atrium	1.5 – 2.0
Restaurant	0.8 – 1.2

Table 1: Recommended reverberation times for internal spaces (Clarke Saunders Associates Acoustics, 2014)

Reverberation is influenced by the geometry of the room and the materials of the room. The geometry will influence the way in which the sound waves reflect and which frequencies become most amplified. The materials of the room will determine how much of the sound is absorbed, rather than reflected. The frequency of the sound is relevant because different materials will absorb different frequencies. It is therefore important to understand which frequencies are likely to exist in a space and which of these needs to be removed or amplified to achieve appropriate acoustic conditions.

The frequency of human speech lies in the mid- to high frequency range of about 150 Hz to about 4 kHz. The vowel sounds are produced at frequencies at the lower end of the spectrum while most consonants are produced at the higher frequencies. In order to achieve speech privacy, only the higher frequencies of the speech spectrum need to be removed as speech without consonants becomes unintelligible, though audible. At the same time, lack of clarity means that overheard conversations are less distracting.

Fortunately, higher frequency sound energy can quite easily be absorbed and dissipated by open-cell materials. When sound waves strike a surface, a portion is reflected and a portion is absorbed and transmitted. Sound energy entering an open cell material can be converted to heat and dissipated. The amount of energy that is absorbed depends on the frequency of the sound and the size of the open cells. Different materials have different sound absorption properties at different frequencies.

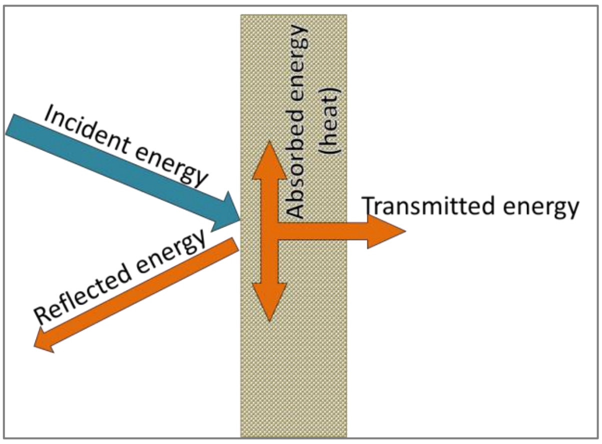

Figure 2: Diagrammatic illustration of the reduction of sound energy in a material.

The noise reduction coefficient (NRC) of a material is a single figure (between 0 and 1) indicating the absorptive properties of a material at different frequency bands. This can be used to assess the effectiveness of a particular product or material (the closer the NRC value is to 1, the better the absorption).

ACOUSTIC CHALLENGES IN GREEN BUILDINGS

To create an indoor acoustic environment that it conducive to occupant health and productivity is very often a challenge in green buildings since many of the other IEQ and energy-efficiency factors can easily contribute to sound transmission rather than attenuation. Post occupancy surveys have indicated that in many cases, the acoustic environment in green buildings is worse than in conventional buildings (Muehleisen, 2011). Some of the factors of green building design that seem to present problems for acoustics are daylighting and external views, natural ventilation, and passive thermal design.

DAYLIGHT AND EXTERNAL VIEWS

Maximum penetration of natural daylight and provision of external views is promoted as an aspect of green buildings to improve the indoor environment. In order to achieve this, it is often necessary to have large open-plan spaces. The lack of partition walls enables the free transmission of sound throughout the space.

Large open spaces such as open plan offices tend to have a very long reverberation time as reflected sound waves travel a longer distance. Large glazed surfaces also contribute to the reverberation since they do not absorb much sound energy but rather reflect it back into the space, as well as allowing the transmission of outdoor environmental noise.

NATURAL VENTILATION

In a similar way, natural ventilation design can also create acoustic problems. Interior divisions are avoided to allow cross ventilation but at the same time allows sound transmission across a space. Often a central atrium is used in multi-story buildings to create a chimney effect. This not only means that sound can travel across a floor but also between floors.

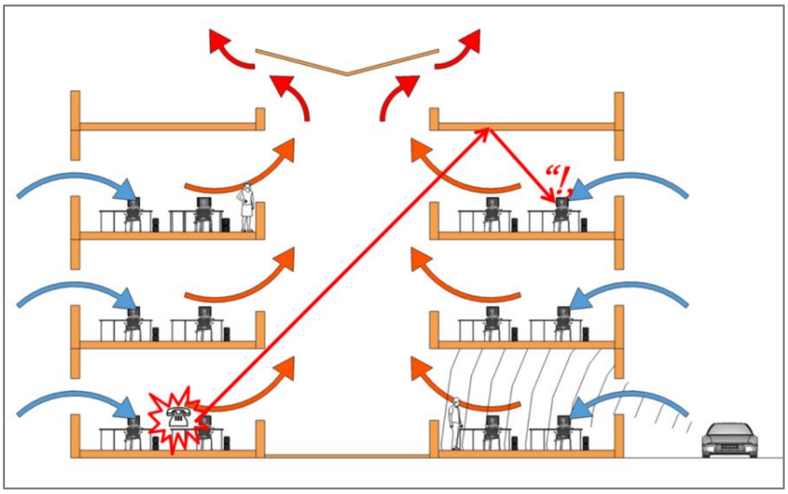

Figure 3: Diagrammatic illustration of noise transfer in passively ventilated atrium building.

Furthermore, natural ventilation essentially requires openings in the building envelope, allowing the transmission of outdoor noise to the interior, which needs to be addressed correctly.

THERMAL COMFORT

Passive thermal comfort solutions can also compromise acoustics. The thermal properties of mass elements in a building, such as masonry walls and concrete slabs, can be used for the retention and transfer of heat, thus decreasing the load on mechanical heating and cooling systems. However, this concept requires mass elements to be exposed to the interior. This has resulted in a trend to omit ceilings, exposing the concrete slab above. One problem for acoustic comfort in this type of design is that exposed hard surfaces, like the concrete slab, do not absorb sound well and instead reflect it, resulting in a high reverberation time. Another potential problem to be aware of when ceilings are omitted that there is less opportunity to attenuate noise generated by exposed services, such as exposed ducting or water pipes.

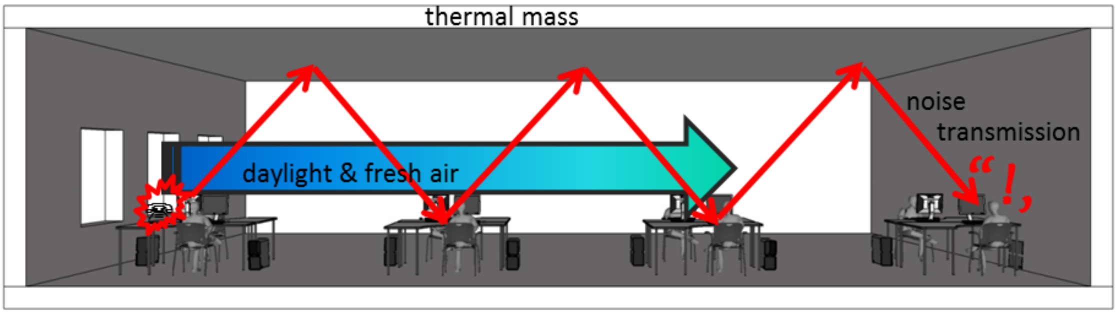

Figure 4: Illustration of sound transmission in open plan office.

ACOUSTIC SOLUTIONS

Good acoustics, however, need not be incompatible with these factors of indoor comfort.

OPEN PLAN, EXPOSED MASS

Where an open plan design is desired for the benefit of maximising daylight penetration, views and natural ventilation, sound transmission and reverberation can be most easily controlled through the installation of acoustically absorptive materials. This will reduce the amount of sound energy in the space and thus decrease the effect of reverberation.

Any soft finishes and furnishings, such as carpets and upholstering, can provide absorption will also aid in reducing the reverberation time. The effectiveness is dependent on the area and composition of the textiles. Absorptive textiles may be covered with perforated panels to give them structure or to suit the building aesthetics. The perforations can be in any design that provides at least 20% of the absorptive area to be exposed.

Acoustic panels composed of suitably absorptive materials of almost any shape, form, dimension and orientation can be installed. These can be merely decoratively or used to demarcate functional zones. A good rule of thumb is that the absorption area should be equivalent to at least 20% of the surface area of the room to be noticeably effective. This leaves a large percentage of the thermal mass exposed. Acoustic panels need not be directly against the structure and can be creatively positioned in such a way as to minimise interference with daylight and ventilation. An example is the use of floating ceiling islands of acoustic panels, which correctly positioned, could also provide a plane for the reflection of light deeper into the space. Another example would be to clad internal structural elements, such as columns, that do not contribute to the thermal mass in acoustic panels.

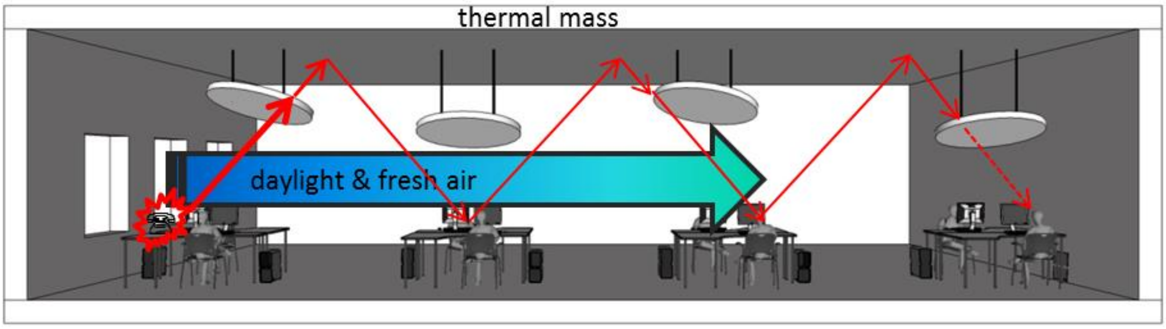

Figure 5: Illustration of acoustic solution using ceiling islands in open plan office.

THERMAL INSULATION

Thermal comfort achieved through the use of thermal insulation, rather than thermal mass, is extremely compatible with acoustics since most thermal insulation materials also provide good acoustic absorption. For example, a 100mm non-woven thermal blanket offering a thermal resistance (R-value) of 2 m^2K/W could also have a noise reduction coefficient (NRC) of around 0.75. Care should be taken, however, not to make assumptions in this regard as some thermal insulators, such as EPS, do not provide good acoustic absorption.

It is important to remember that different materials absorb different sound wave frequencies. It would be futile, for example, to hope to absorb low frequency base sound by installing a non-woven insulating blanket in the wall panelling as it would only absorb higher frequencies. However, it may be ideal for creating speech privacy.

Masking & ventilation

Sound masking is the concept of using background noise to 'cover' disturbing or distracting noise. Sometimes white noise is generated electronically to mask conversations and very often the sound of mechanical ventilation provides a making effect. Running water or simply music playing can also provide sound masking, though care should be taken that the masking sound does not become a disturbing noise.

When considering natural ventilation, the open sections in the building envelope allow outdoor noise to penetrate the interior space. This noise can create a masking effect, provided it is not too loud or disturbing. Outdoor noise can additionally establish a sense of connection with the outdoors, which is beneficial in the same way as views to the outside is. Features, such as running water, can be artificially created near open windows to enhance this effect.

Material selection

There are many products and materials available on the market that can provide sound absorption. When selecting acoustic products, the specifier must ensure that the materials used do not compromise any other aspects of green building, having a low carbon footprint, low toxicity, and being resource efficient.

Many acoustic products are made from recycled plastic or glass fibres, offering a responsible solution, provided the VOC content is low. These products can be used in conjunction with steel or timber panels to create the desired aesthetic, for example, as a backing to a perforated steel plate.

Material must be used efficiently, only using acoustic material where it is necessary and effective. A comprehensive understanding of the sound frequencies that need to be addressed will help inform the material choice. Considering that only around 20% of the area of a room needs to be absorptive to make a noticeable difference, anything in great excess of this could be considered wasteful.

Conclusion

Acoustics in buildings, like any other aspect of design, only becomes problematic when the designer neglects to consider it from conception. As an after-thought acoustic installations can compromise the intended aesthetic and functioning of a design but when correctly incorporated, it can provide excellent opportunities for creative and complementary interior solutions.

While the basic principle laid out here is to increase the area of absorptive materials in a space, acoustic design can be very much more complex and consultation with an expert may be necessary. A good starting point when considering acoustics in design is to determine the basic requirements of a space by asking whether sound needs to be kept in, kept out, or controlled within the space and whether the need is to create privacy, clarity or quietness. Then, since acoustic solutions are frequency-dependent, one must identify the type of sound to be addressed (such as speech, music, traffic, or machine noise). Once this basic understanding of acoustic requirements has been established, decisions regarding design, material choice and the complexity of the solution can begin to be addressed sensibly.

Designers play a significant role in determining how human, environmental and economic resources are invested in buildings. Neglecting to address a single aspect can potentially ruin the investment, wasting resources. A sensually holistic approach to design is thus essential in the design of sustainable buildings.

Resources

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