REVERBERATION & SOUND REDUCTION IN MASONRY CONSTRUCTIONS[1]

Masonry buildings in basic engineering principles had led to acoustically pleasing spaces, even though reverberation theory was not available as yet, in the same way that structural engineering was still at its infancy. Towards the end of the 19th century Sabine published reverberation theory, which is a property of how sound decays in a space, thus placing acoustics within an engineering field.

The discussion of aesthetics, proportion and acoustics can also guide today's structural engineer, given his expertise in numeracy. As Pevsner quotes in his Introduction *a bicycle shed is a building: nearly everything that encloses space on a scale sufficient for a human being to move in is a building.* Thus the maxim for structural engineers to design in elegance and economy, is relevant and certainly also in masonry.

If, for example, a structural engineer is commissioned to design an assembly hall of plan dimensions 6m X 10m. By applying the golden rule to the diagonal plan dimension (8m) an aesthetically proportioned building height is calculated to be at 5m. Having established the volumetric proportions of the designed space, the structural engineer can then, by undertaking simple reverberation checks, be in a position to advise his client on the sound suitability for the use of the space being designed for, whether a living room, warehouse, or assembly hall.

A short reverberation time in the region of 0.5sec - 1sec is more conducive to speech intelligibility, whilst a long reverberation time in the 2 sec region increasing to even 9 sec in Gothic Cathedrals improves on the quality of the music. If the reverberation time in a lecture hall is higher than 1sec, the listener will have to contend with multiple words at a time.

Figure 1: Early 15th century Bir Miftuh Chapel Malta – 6.7m span X 14.5m depth X 6.7m height.

The simple equation established by Sabine in the early 20th century notes the reverberation time as being directly proportional to the space enclosed and inversely proportional to the absorptive characteristics of the enclosed surfaces multiplied by a factor of 0.161. The more absorptive the materials used on surfaces together with the presence of an audience, the quieter the space becomes. Thus the above proposed assembly hall with an enclosed volume of $300m^3$ and enclosed surface area of 280 m^2, with an assumed average absorption coefficient for surfaces at 0.3 taken as at 500Hz, gives a reverberation time of:

$0.161 \times 300/(280 \times 0.3) = 0.575$sec.

Today various calculators are available online, whereby the reverberation time is calculated, with the various absorptive coefficients for the various wall or ceiling surfaces given, thus reducing the design time involved.

In the case of party walls WHO/Europe's guidelines for night noise, published in 2009, note annual average night exposure should not exceed 40 decibels (dB), corresponding to the sound from a quiet street in a residential area. Persons exposed to higher levels over the year can suffer mild health effects, such as sleep disturbance and insomnia. Long-term average exposure to levels above 55 dB, similar to the noise from a busy street, can trigger elevated blood pressure and heart attacks. If safety of ear damage from impulsive noise is to be considered, than any single impulsive noise should not exceed 140dB.

For airborne sound insulation assessment tests involve measuring the noise level created by a loud sound source in one room and comparing it with the resulting noise level in the adjacent receiver room. The 'sound reduction index' (in dB) *of* a sample is a measure of the ratio of the sound energy incident on the sample to that transmitted through it.

[1] Updated excerpt taken from paper: Malta's Heritage in Stone: from Temple Builders to Eurocodes 6/8, published in Journal of the International Masonry Society Masonry International Vol 31. No 2.

A wall separating sole occupancy units, or between a sole occupancy unit and a public corridor, plant room, lift shaft, stairway, hallway, should have a Weighted Sound Reduction Index (R_w) not less than 45. R_w ratings are determined measurements conducted in one-third octave bands over all frequencies between 100 Hz and 4000 Hz inclusive.

Where a habitable room such as a living room, dining room, family room, bedroom, study and the like, but not including the kitchen, in one sole occupancy unit is situated next to a bathroom, sanitary compartment, kitchen or laundry in an adjoining unit, the wall separating the units must have an R_w not less than 50. In addition, the dividing wall construction must provide a “satisfactory” level of impact sound isolation. With the typical background levels in most suburban areas, an R_w 45 wall construction, would usually ensure television, telephone ringing and conversation will sound "muffled", but still audible. Unless the background sound level within the receiving room is very low, the transmitted sound should from these sources not be intrusive.

The difference in noise level between source and receiving rooms is not just a function of the 'apparent sound reduction index' of the separating structure. If the receiving room contains a high level of sound absorptive material (eg carpets and a sound absorptive ceiling) then the difference in noise level between the two rooms will be greater than if the receiving room contained hard surfaces. The size of the connecting structure also has an effect. The larger the area of common structure, the greater the sound energy transmitted.

Therefore, with identical wall constructions, room finishes and room sizes, the difference in noise level between two rooms will be less if they adjoin by their long walls, rather than by their short walls.

For a wall to reach its optimum acoustic performance, the construction must be solid without gaps through which air, and therefore sound, cannot pass. Rendering one side, of a wall increases the R_w rating primarily because the render seals the fine pores in the brickwork and also eliminates partially filled and unfilled mortar joints. In addition, a layer of 13 mm render increases the mass of the wall and there will also be an increase in the acoustic performance. Once one side of a wall has been rendered, little acoustic benefit will be gained by rendering the other side.

A CSIRO technical study notes that **215 kg/m²** is the minimum mass per unit area required by an unrendered wall to ensure that an R_w of not less than 45 will be achieved when a layer of 13 mm render is applied to one side.

A simple rule of thumb that can be applied to materials to calculate their approximate transmission loss is the ‘mass law’ equation (33):

$$TL = 20 \log_{10} (mf) – B \quad (i)$$

Where: TL = transmission loss (dB)
m = surface mass (kg/m^2)
f = frequency (Hz) within a range of 100 -4000.
B = 48 dB (on average but can range from 45-53).

In Malta Globigerina masonry *franka* units at a dry density of 17.5kN/m^3, come in thicknesses of 230mm (395 kg/m^2) and due to the material’s acoustic property as gauged from equation (i), is normally utilised as party walls in dwellings, whilst the 180mm (315 kg/m^2) thickness is utilised for internal partitions, or else as double walling when used on the façade, with a bond stone tying the two leaves together. However according to the minimum mass at 215 kg/m^2 as specified above, both local thicknesses are adequate for the sound reduction awaited from a party wall.

The sound reduction achievable for the above 2 thicknesses as per equation (i) is now tabulated in table below, as calculated for various sound frequencies.

Frequency Hz thickness mm	**180mm**	**230mm**
100	37dB	39dB
500	51dB	53dB
4000	69dB	71dB

If the sound reduction for a party wall is taken at 45dB/50dB, it is noted that both thicknesses satisfy the criteria specified as per equation (i), except for sounds emanating in the 100Hz range. It is further to be noted that the party wall blocks are best to be solid, with hollow block construction being less acceptable.