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Study on Acoustics in Buildings

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Abstract: Acoustics in buildings is that part of science in which importance has been given to the sound quality in building, which enables a proper understanding of the different factors influencing the same. Acoustics being one of the important factor which enables in reduction of transmission of noise and enable a better sound quality in the room. But however either very less or insufficient amount of work has been put in considering the scope of the subject. Some other limitations are builders either do not give priority to that aspect due to lack of information or the improper design and poor implementation. Also The Indian Standard Codes in this area are too old and need updation considering the Modern Scenario and Modern Construction Practices. So efforts have been made to consider this situation and find the best practices, recent innovations and methodologies which could help in maintaining proper Acoustics in Buildings, Halls, Auditorium's etc. And what role could a Civil Engineer play in elimination of this problem.
Keywords: Acoustics, Buildings, Material Properties

I. INTRODUCTION

Acoustics in one of the very important parameters to ensure proper living conditions in the room or a building. But however, much importance is not being taken for that field during the design of buildings. The reasons for this include either no proper building guidelines or Acoustics as a whole is never looked at because India being A developing In the country due though to very mass constructions are done not much emphasis is being given to the field of acoustics. Some of the advanced countries have given importance to this field during construction process. So now an attempt has been made to understand the importance of acoustic parameters and emphasis has been given to the recent innovative methodologies available and how those methodologies could be more appropriate in calculating and analysing the sound quality parameters in buildings. So, for the proper understanding it has been divided into various segments of research where firstly proper emphasis is giving the sound measuring methodologies compared to those in the IS codes and their efficiency respectively. Nextly the usage of different acoustic materials and their orientation has been given importance. On the basis of all the data available for different material and respective materials properties the usage has been recommended based on some of the international standards. Then a model has been drafted where buildings are classified based on their usage, Importance and working and steps to be followed are recommended.

II. SOUND QUALITY PARAMETERS

A. Reverberation Time

The Reverberation is the phenomenon of persistence of sound after it has been stopped as a result of multiple reflections from surfaces such as furniture, people, air, etc. within a closed surface. These reflections build up with each reflection and decay gradually as they are absorbed by the surfaces of objects in the space enclosed. It is the same as the echo, but the distance between the source of the sound and also the obstacle through which it gets reflected is less in case of this reverberation. The quantitative characterization of the reverberation is mainly done by using the parameter called reverberation time. Reverberation time is usually defined as the length of the time when the sound decays by about 60 decibels starting from the initial level. In the process of reverberation, the time delay is said to be not less than 0.1 second i.e. the reflected form of the wave reaches the observer in more or less than 0.1 seconds. Hence, this delay in the perception of the sound and also the original sound is said to be very less and whereas the original sound will be still in the memory when this reflected sound is heard. Reverberation time is the time required for the sound to “fade away” or decay in a closed space. Sound in a room will repeatedly bounce off surfaces such as the floor, walls, ceiling, windows or tables. When these reflections mix, a phenomenon known as reverberation is created.

Reverberation reduces when the reflections hit surfaces that can absorb sound such as curtains, chairs and even people. The reverberation time of a room or space is defined as the time it takes for sound to decay by 60dB. For example, if the sound in a room took 10 seconds to decay from 100dB to 40dB, the reverberation time would be 10 seconds. This can also be written as the T60 time. However, it is often very difficult to accurately measure the T60 time as it may not be possible to generate a sound level that is consistent and stable enough, especially in large rooms or spaces.

To get around this problem, it is more common to measure the T20 and T30 times and to then multiply these by 3 and 2 respectively to obtain the overall T60 time. The T20 and T30 values are usually called "late reverberation times" as they are measured a short period of time after the noise source has been switched off or has ended.

III. METHODOLOGIES AVAILABLE

Reverberation Time is the time taken for a sound level to decay by 60 dB after the excitation stops. However, it is not practical to measure 60 dB in 'real life' rooms so the decay is usually measured over the first 20 dB and then extrapolated to the full 60 dB range. This procedure is in accordance with BS EN ISO 3382 and the results are labelled RT60 (T20). EDT - Early Decay Time is measured over the first 10 dB decay by acousticians, interested in clarity and the direct sound field. Early reflections that reach the listener within 50 metres integrate with the direct sound and can improve speech clarity - The Haas Effect. Reverberation Time is measured in 1/1- or 1/3-octave frequency bands, some of which may be averaged to provide a single- number result for the most significant bands.

Reverberation Time may range from 0.1 seconds (or less) in anechoic chambers, to 10 or more seconds in large public spaces. Reverberation Times vary between positions in a room, so it is usually measured at several positions. The average for all positions gives an overall assessment, and the position results may be used to indicate the acoustic quality as a function of location.

Reverberation Time can be measured using either Impulsive Excitation (Schroeder method), such as from a pistol or balloon burst or by using Interrupted Noise, with the built-in noise generator. Impulse Excitation Method - all you need, for this method, is a B&K 2250 or a NTXL2 reverberation time meter, a tripod and a balloon (or other impulsive source, such as a starting pistol). After you pop the balloon, meters start measuring, analyse the decay and present the reverberation time as well as the decay curves for all frequency bands. They will also display the average reverberation time for the bands you select. Interrupted Noise Method - When using a power amplifier and loudspeaker sound source both the B&K 2250 and the NTi-XL2 will measure and display the reverberation time spectrum and decays. The measurement can be in octaves or 1/3- octaves in parallel over a selectable frequency range, allowing you to focus sound power on the relevant range. In each frequency band, the decay is sampled 200 times each second, for reverberation times as long as 20 seconds.

1) Standardised Reverberation Times are used in Sound Insulation Rating measurements.
2) Reverberation Time Instruments : B&K 2250 or the Norsonic 118+ and the NTi XL2.

IV. METHODOLOGIES CONSIDERED

Over the years a large number of parameters have been defined in order to describe and evaluate acoustical properties of a certain space.

Nevertheless the reverberation time has always been the basic indicator of acoustical behaviour. In the professional work of an acoustician, it is often required to measure the reverberation time in spaces with very different sizes, shapes and intended purposes. As a par of this large scale research on the measurements of reverberation time, an attempt was made to determine the best possible measurements which will provide the most reliable results. Over the years, a number of different methods for measuring the reverberation time has been developed and implemented, the most common being:

1) The interrupted noise method
2) The filtered burst method implemented by Bruel and Kjear
3) Integrated Impulse Response Method
4) The method of Recording the Room Response to an impulsive source

A. *Reverberation Time Calculated By Different Methodologies*

The requirements that have to be met when performing a reverberation time measurement are stated in and can be summarized as:

1) The source, either a loudspeaker or, if nothing else is available, an impulsive source of some kind, should have an omni-directional radiation pattern (or as close to it as possible).
2) The sound pressure level must be high enough to provide a minimum required dynamic range to perform a reverberation time measurement, to be more precise, at least 45 dB for methods that do not apply synchronous averaging.

It is quite clear that an omni-directional source has to be used in order to excite the measured space uniformly in all directions. All our measurements have been performed using the omni-directional loudspeaker or impulsive sources, for both of which it was assumed that their radiation pattern approaches the ideal one, thereby fulfilling the requirement on omni-directivity.

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Nevertheless, a small number of measurements were made using directional loudspeaker in order to examine the influence of the directional properties of the source on measurement results. Several parameters can actually be measured and calculated from the energy decay curve obtained from reverberation time measurements. The RT30 parameter is considered to be the most accurate and the goal is to be able to measure it whenever possible. If this is not the case, the RT20 parameter is used as the indicator of reverberation time. The EDT is only used when all else fails, however, it should be noted that it is not a true measure of reverberation time because it can and often does differ a lot from RT20 and RT30.

V. ROOMS CONSIDERED FOR ANALYSIS

A. Room 1

Listening Room located at Department of electroacoustics of Faculty of EE and Computing in Zagreb
Dimensions :- Length of the room is 10.2m, width 7.1m and height is 3.2m and has a room volume of 320 m3

Fig 1 The Interior of Room 1

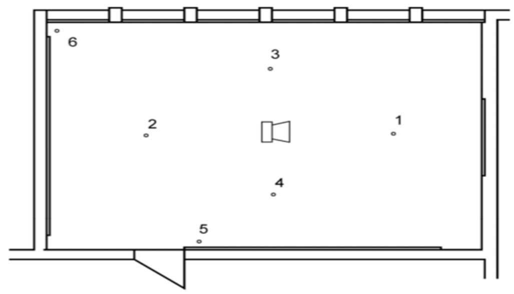

Fig 2 The Floor Plan of Room 1

B. Room 2

Hall Way in one the buildings of Faculty of EE and Computing In Zagreb
Dimensions :- Room Volume of approximately 800 m3

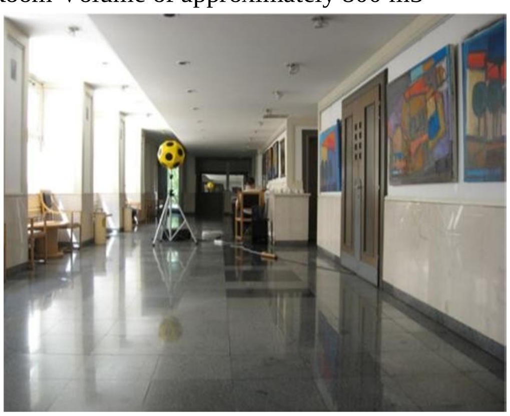

Fig 3 The Interior of Room 2

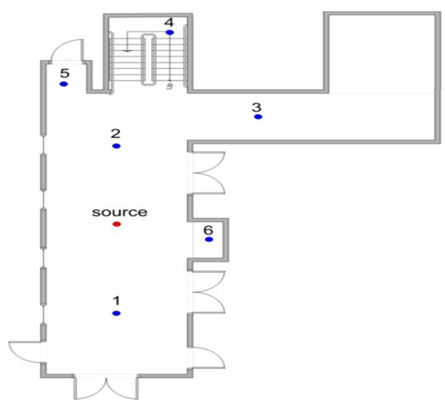

Fig 4 The Floor Plan of Room 2

C. Room 3

High Voltage laboratory located at the facility of EE and computing in Zagreb.
Room Volume of approximately 2000 m3 with all surfaces made of concrete and no acoustic treatment whatsoever

Fig 5 The Interior of Room 3

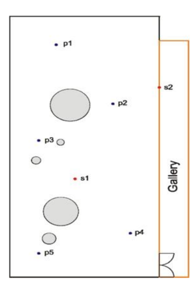

Fig 6 The Floor Plan of Room 3

D. Room 4

Drama Theatre in Zagreb

Dimensions :- Length of about 23.2 m, width 15.6 m and has a room volume of 3130 m3 and the theatre has about 218 seats.

Fig 7 The interior of Room 4

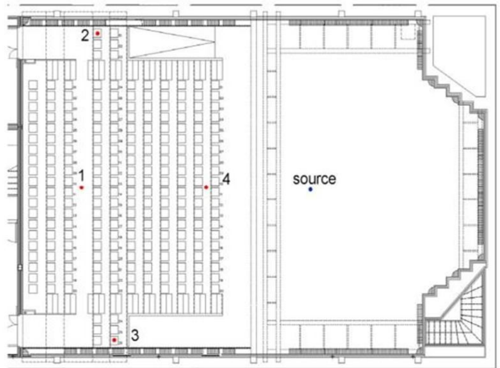

Fig 8 The Floor Plan of Room 4

VI. ANALYSIS OF THE RESULTS

A. In Room 1

The below are two graphs showing the relation between Reverberation Time and Frequency

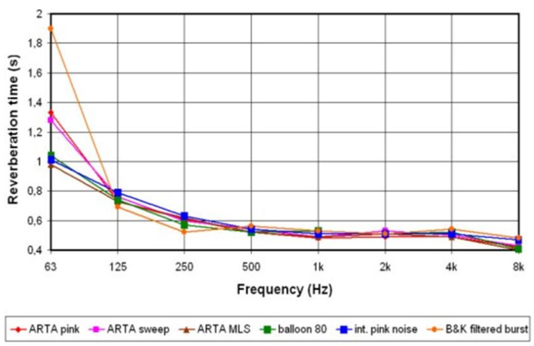

Fig.9 RT60 measured in room 1 at position 1.

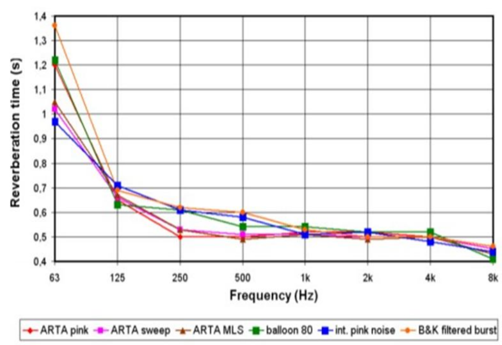

Fig.10 RT60 measured in room 1 at position 2.

B. Room 2

Relation between Reverberation Time (in Seconds) and Frequency (Hz)

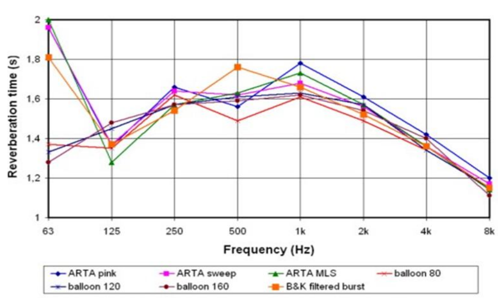

Fig.11 RT60 measured in room 2 at position 1.

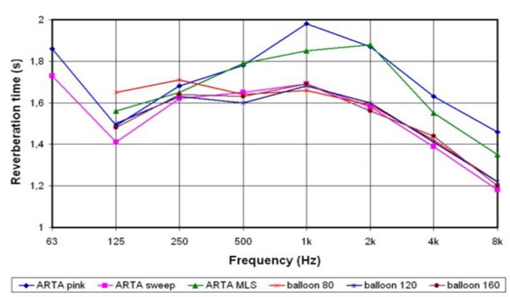

Fig.12 RT60 measured in room 2 at position 3.

1) *Observations:* In room 1 all methods provide results that are in very good agreement, unlike in room 2, as shown in Figs.11 and 12. One explanation could be the different acoustical properties of both rooms. On one hand, room 1 is acoustically dampened space of an ordinary shape, while room 2 is quite the opposite, a space with highly reflective surfaces and an exceptionally irregular shape. The results also show the best agreement at high frequency octave bands, while the dispersion of results becomes evident as the frequency decreases. At low octave bands, however, the decay curve loses its smoothness because of room modes and usually has more than one slope, so it can be difficult to determine the right one.

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C. Room 3

Relation between Reverberation Time (in Seconds) and Frequency (Hz)

In room 3 the omni-directional source and the balloon were positioned at position S1 indicated on the floor plan of the room, while the small loudspeaker, being a part of a permanent sound reinforcement system installed in the room, is placed at position S2. The resulting reverberation times are shown for position 1 in Figs.13 and 14. The measurements performed using the integrated impulse response method utilized the sine sweep as the excitation signal, while the method of recording the room response to an impulsive source used balloons as the source of excitation. The comparison of results shown in Figs.11 and 14 reveal that the choice of the sound source is much more critical in smaller rooms where the sound field is never truly diffuse. The differences become larger at lower frequencies due to the smaller room dimensions and more emphasized room modes.

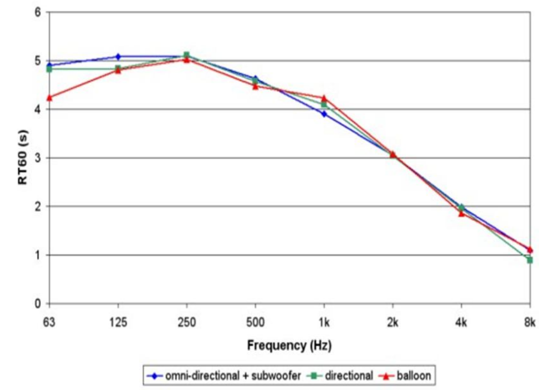

Fig.13 RT60 measured in room 3 at position 1 using different sound sources.

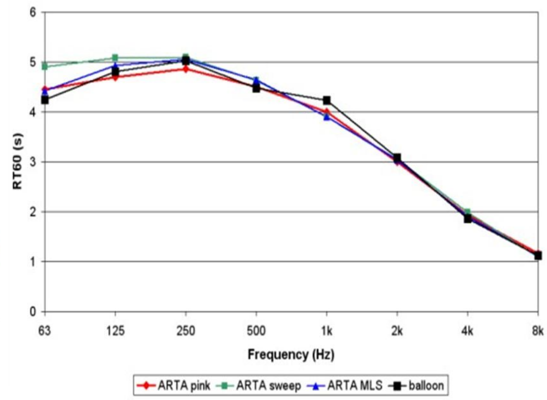

Fig.14 RT60 measured in room 3 at position 1 using different methods.

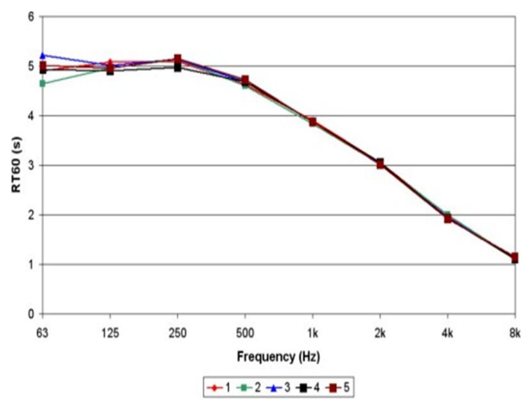

Fig.15 RT60 measured in room 3 at all positions.

Furthermore, these results suggest that the choice of measurement method is not critical in room 3, whereas in room 2 it is important as the results obtained using different methods are significantly different. Other authors suggest that the integrated impulse response method using the sine sweep is preferred due to the best S/N ratio and low sensitivity to harmonic distortion. Fig.15 shows the measurement results in room 3 for all positions using the integrated impulse response method with the sine sweep as the excitation and the omni-directional sound source coupled with the subwoofer as the sound source. These measurement results are in much better agreement then the ones in room 2 because the shape and interior of room 3 do not allow the forming of standing waves. Furthermore, the size and non-existence of acoustic treatment in room 3 lead to a very small room radius. As a consequence, all microphone positions are deeply in the diffuse sound field.

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D. Room 4

Relation between Reverberation Time (in Seconds) and Frequency (Hz)

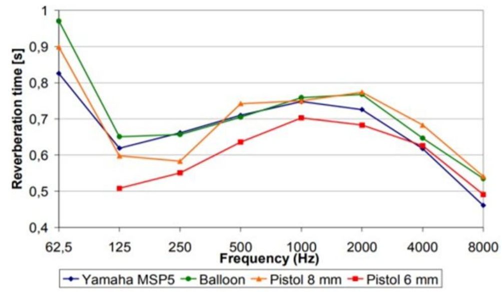


Fig.16 RT60 measured in room 4 at position 1.

Finally, Fig.16 shows the results of reverberation time measurements in room 4 at position 1. It is obvious that the results differ very much due to the difference in directivity of the sources, and the small dynamic range of pistol shots compared to the range obtained using the integrated impulse response method.

E. Conclusions

The reverberation time was measured in two reverberant and two rather damped rooms of different size and shape. Although the reverberation time measurements are standardized demanding an omni-directional sound source and repeatable measurement method to be used, the shown results suggest that other types of sound sources and measurement methods can be used with almost no influence on the final result if the measured room is large and reverberant. However, this conclusion is valid if the sound field in the room is diffuse. The basic conditions that have to be met are that the room has no emphasized room modes in the frequency band of interest and that its shape and acoustic finishing leads to sufficiently long reverberation time. If the room is large enough, its dominant modes form at frequencies below the frequency range of interest. On the other hand, if the room is of irregular shape and/or smaller size, much more attention should be paid to the choice of appropriate measurement method and excitation source. Furthermore, measurement positions and their number should be carefully chosen as the resulting reverberation time will be merely the average of the results measured at different positions.

F. Recommendations

The first issue that has to be analysed is the question of available dynamic range each method is able to provide, given that the measurement setup is always the same.

1) The energy decay curves indicate that the integrated impulse response measured using the swept sine signal and a balloon burst provide by far the greatest available dynamic range, thereby ensuring the maximum commodity in the process of calculation of reverberation time.
2) On the other hand, the integrated impulse response measured using the pink noise and the MLS signal are not able to provide the required dynamic range, but they can still be utilized if certain precautions are taken.
3) Finally, the interrupted noise method provides a dynamic range so small, compared to other methods, that the results obtained from it cannot be considered as reliable.

G. Reverberation Time Calculation

The first step to calculate the reverberation time is to calculate the Sabins with the below equation.

1) Formula for Total Absorption

$$\mathbf{a = \Sigma\, S\, \alpha}$$

Where:

Σ = sabins (total room absorption at given frequency)

S = surface area of material (feet squared)

α = sound absorption coefficient at given frequency or the NRC

After we calculate a, we can then use the Sabine Formula to calculate the reverberation time.

2) Sabine Formula

RT60 = 0.049 V/a

Where:
RT60 = Reverberation Time
V = volume of the space (feet cubed)
a = sabins (total room absorption at given frequency)

In an existing room, one can go on site and measure the reverberation time using a loud speaker and a sound level meter. And can also calculate the reverberation time using the Sabine's Formula created by Wallace Clement Sabine. This equation is based on the volume of the space and the total amount of absorption within a space. The total amount of absorption within a space is referred to as sabins. It is important to note that the absorption and surface area must be considered for every material within a space to calculate sabins. To obtain the Sabin values, we use the volume (length x width x height) of the room and the materials of the Resurfaces. The table below provides the sabins at each octave band frequency for common construction materials.

Sabins at Octave Band Frequency for Common Construction Materials

Sabins at Octave Band Frequency for Common Construction Materials							
Location	Material	Absorption Coefficient (a) or Sabins Octave Band Center Frequencies					
		125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
All Walls	Gypsum Board	0.29	0.10	0.06	0.05	0.04	0.04
Ceiling	Metal Deck	0.05	0.04	0.03	0.03	0.02	0.01
Floors	Concrete Painted	0.01	0.01	0.02	0.02	0.02	0.02

VII. FORMULATION METHODOLGY

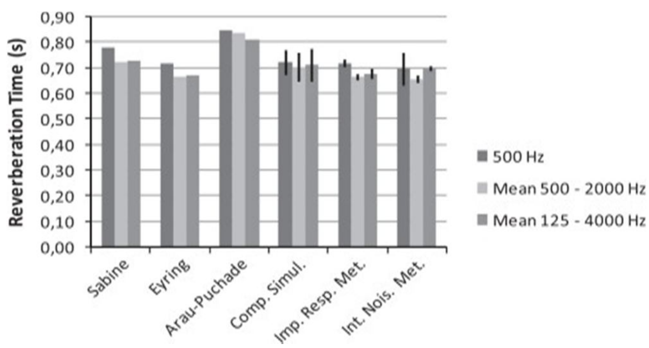
The literature on room acoustics indicates that researchers are not entirely satisfied with existing formulas for calculating reverberation time RT. Sabine's formula assumes that sound energy diffuses equally through a room (homogeneously and isotopically). In fact, however, this condition is rarely met since the large areas in a room are characterized by diverse absorptions. Eyring states that Sabine's formula is invalid when there is considerable absorption in a room. In his article, he points out that Sabine's formula should be used for ''live" rooms and claims that reverberation time depends on the shape of the room. Eyring presents a revised theory and derives a formula of the RT equation which is more general than Sabine's formula. Eyring's formula is based on the medium of unhindered propagation between reflections characterized by a diffuse sound field. Another formula for calculating reverberation is that of Arau- Puchades, which should be used in rooms with asymmetric distribution of absorption. Arau- Puchades assumes that reverberation decay is a hyperbolic process. This decay is the superposition of three contributions: early decay, first and second linear portion of the decay, and third linear portion of the decay.
For rectangular rooms, Arau-Puchades defines an absorption coefficient based on Eyring's model for each parallel surface and each direction of the space. Bistafa and Bradley found that in spaces where the total sound absorption is high, prediction of the reverberation time using Sabine's formula results in longer values than those found by means of Eyring's formula, but the difference diminishes as the total sound absorption decreases. In studies conducted by these same authors, the reverberation times calculated in a classroom with a volume of 153 m3 by means of Sabine and Eyring's formulas were practically the same. On the other hand, Arau- Puchades' formula resulted in longer reverberation times. A study by Dance and Shield found that the precision of Eyring and Sabine's formulas is the same when suitable absorption coefficients are used. Eyring and Sabine's formulas proved to be a reasonable choice for calculating the reverberation time in a classroom. The results obtained by Bistafa and Bradley did not justify the use of more complex analytical expressions for the prediction of reverberation time, since generally they did not yield a more accurate result.

Moreover, according to these authors, a large variety of results can be obtained when the user has a free choice of coefficients of absorption. These formulas for determining reverberation time are only some of the ones that exist for this calculation. Other formulas are those of Fitzroy, Tohyama and Suzuki, Kuttruff, Pujolle, Nilsson. Thus, there are many doubts about which formula should be used. These formulas produce better results according to the characteristics of the room in question. The importance of evaluating reverberation time in classrooms lies in the fact that reverberating environments affect concentration ability and speech intelligibility, forcing teachers to speak louder, considering that this will contribute for the understanding of the teacher s speech by the students. However, speaking louder does not improve intelligibility in excessively reverberant conditions. In the present work, in addition to calculating reverberation time by means of several formulas and computer simulation of this parameter, in situ measurements were taken using two methods, the interrupted noise method and the integrated impulse response method. The main objective of this work was to evaluate different procedures for determining reverberation time in a classroom of approximately 250 m3.

A. Statistical Analysis of the Data

The data obtained from the measurements and simulations were analysed statistically, using the MINITAB 14 statistical package (Minitab Inc.). The analysis involved the values of reverberation time at the frequency of 500 Hz, of the mean RT between the frequencies of 500, 1000 and 2000 Hz and the mean RT between the octave-band frequencies of 125–4000 Hz. Astolfi et al. have also evaluated average RT in classrooms, across 500 Hz–2 kHz, and across 125 Hz–4 kHz.

The measurements and computer simulations yielded five values corresponding to the five points where microphones were located, generating repeatable data that were evaluated by analysis of variance (ANOVA). The calculated values did not show repeatability and were therefore evaluated based on the confidence interval of the previous data. The graph in Figure below presents the calculated, measured and simulated values of reverberation time RT used for the statistical analysis of the data.



The application of the analysis of variance using the simulated RT data at the frequency of 500 Hz, the integrated impulse response measurement and the interrupted noise measurement resulted in a p value of 46%. Because the value of p is higher than 5%, the null hypothesis (H0) that the values of reverberation time obtained by the three methods (simulation, integrated impulse response measurement and interrupted noise measurement) are statistically equal is accepted. The analysis of variance of the mean RT values obtained at the frequencies of 500, 1000 and 2000 Hz resulted in a p value of 1.6%, i.e., lower than 5%. Thus, the null hypothesis (H0) is rejected and the alternative hypothesis that at least one of the methods is different is accepted. To determine which of the methods is different, a multiple comparison was made using Tukey’s multiple comparison method.

This comparison revealed a significant difference between the values obtained by computer simulation and by the interrupted noise method. In contrast, it was found that the values obtained by computer simulation and by the Integrated impulse response measurement did not differ significantly. In addition, the two methods of measurement generated statistically equal results. The analysis of variance of the mean RT values obtained at the octave-band frequencies of 125–4000 Hz yielded a p value of 8.7%, indicating that that all the methods are statistically equal. As for the values obtained by means of the RT calculation formulas, a comparison was made with the calculated confidence interval using the measured and simulated RT values. Table 5 presents the confidence intervals of the RT values obtained by the two measuring methods and the computer simulation of the RT values at 500 Hz frequency, the mean RT at 500–2000 Hz octave- band frequencies, and the mean RT at 125–4000 Hz octave-band frequencies. This table also compares the RT values calculated with the Sabine, Eyring and Arau-Puchades formulas and the confidence intervals (= indicates within the confidence interval, while – indicates outside the confidence interval). An analysis of the table reveals that most of the RT values calculated by Eyring’s formula lie within the confidence intervals calculated for the measurement and computer simulation methods.

The calculated value falls outside the confidence interval only when one compares the RT value calculated by this formula for the octave-band frequencies of 125–4000 Hz and the RT value in the same frequency range measured by the interrupted noise method. A comparison of the RT values obtained by measurements and computer simulations against the RT values obtained with the Arau-Puchades formula indicates that in all the compared cases, methods and frequency ranges, the RT values calculated with this formula fall outside the confidence interval. Astolfi et al. evaluated eight classrooms with volumes ranging from 160 to 466 m3 , and found that ‘‘the Odeon 6.5 soft-ware and the Sabine formula yielded the most accurate results for RT in empty classrooms”. A comparative analysis of the RT values obtained in this study using Sabine’s formula and those obtained by computer simulation (Table) indicates that the values obtained by this formula fall within the confidence interval calculated by computer simulation. However, a comparison of the RT values calculated through this formula against the measured RT values indicates that the values calculated by the formula are outside the confidence interval of the measured RT. Based on these data, it can be concluded that the most suitable formula for calculating the RT in this classroom is that of Eyring, while the least suitable formula to determine the RT in this room is that of Arau-Puchades.

B. Conclusions

The comparison of the results of the procedures to determine the RT based on the relative difference and on the statistical analysis clearly showed a statistical difference when the relative difference exceeded 5%. An example of this is the statistical difference between the data of mean RT at 500– 2000 Hz octave-band frequencies measured by the interrupted noise method and the simulated RT data, which showed a relative difference of 7% between these methods. When the relative difference was compared with the calculated values and confidence interval between the mean and simulated RT values, a relative difference higher than or equal to 4% already yielded RT values outside the confidence interval. The statistical analysis demonstrated that there is no significant difference between the two measurement methods, interrupted noise and integrated impulse response. These findings are in agreement with Astolfi et al. With regard to computer simulation using the Odeon software, there was no difference between this method and the two measuring methods when the RT was evaluated at the frequency of 500 Hzand the mean RT at octave-band frequencies of 125– 4000 Hz. However, when the mean RT at 500, 1000, and 2000 Hz frequencies was evaluated, simulated values differed from the values measured by interrupted noise method. According to Bork, the accuracy of the data simulated in the computer is in general influenced by and actually dependent on several parameters besides those directly considered by the software. A very relevant parameter for the precision of a computational simulation is the precision of the values attributed to the coefficients of absorption of the materials inside the room under study. It is normally very difficult to identify the absorption coefficient of the materials in existing buildings. The values used in this work are standard ones and therefore do not take into account the wear and particularities of the materials in the room.

According to Christensen, in addition to the coefficients of absorption, the imprecision of scattering coefficients inserted in computer simulations is one of the main sources of error. In the present work, similarly to what was reported by Bistafa and Bradley, the reverberation times calculated by Sabine’s formula were slightly longer than those calculated by Eyring’s formula, but were still very similar, while Arau-Puchades’ formula resulted in much longer reverberation times. The accuracy of the calculated values was much greater when the first two formulas were used, without the need to use more complex formulas such as that of Arau-Puchades. Therefore, Arau-Puchades’ formula proved to be the least suitable for calculating the RT of the room of this study. The values obtained with Eyring’s formula were very similar to those obtained by the two measurements and by the computer simulation.

C. Eyring’s Reverberation Time Formula

The Sabines Formula only works up to the absorption coefficient value of 0.2. Sabines formula Works for Large Enclosures.
However, it leads to paradox for highly absorptive surfaces.
But, the Eyrings Formula proved be more effective and accurate in majority of the cases as disscussed above

$$T_r = -0.163 \frac{V}{S \ln(1-\overline{\alpha})}$$

Where, S = Area of the Surface in m2
$\bar{\alpha}$ = Absorption Coefficient of Surface
But, however the Absorption Coefficient also changes with different values of the frequency of Sound.
Suppose if the Absorption Coefficient is small then this approximates to a different form

$$T_r = 0.163\frac{V}{S\bar{\alpha}} = 0.163\frac{V}{A}$$

D. Innovative Practices which can be Implemented

Usage of Volume Diffusers, Grid Diffusers, Labyrinth Diffusers for Optimum Reverberation Time proved to be effective
To reduce Reverberation

1) Using materials with Better Absorption Coefficient.
2) Value of attenuation (alpha Constant)
3) Using Correct material and in Adequate Positioning and Proportioning
4) Adding Sound Absorbing Materials which includes Carpets, Textiles, Drape,
5) Curtains, Books and this includes people too !! But However adding too much of the sound Absorbing Materials, this could Render the room With “Dead” Sound Quality.
6) Usage of Large Number Acoustic Panels to reduce Large number of Reflecting Surfaces.
7) Installing Gypsum Boards
8) By Proper Wall and Ceiling Diffusion
9) Porous materials such as mineral wool and fiberglass are examples of such absorbents. As the sound waves penetrate mineral wool, sound energy gets converted to heat through friction.

E. Scope of Research

1) Increasing Reverberation Time Using Diffusers: An Acoustic Design for More Sustainable Halls
2) Achieving Optimal Reverberation Time in a Room, using Newly Patented Tuning Tubes

F. Loudness

In general terms , loudness is the subjective perception of sound pressure. According to American Standards Association it is defined as “That attribute of auditory sensation in terms of which sounds can be ordered on a scale extending from quiet to loud.” In different industries loudness has different measurements and different measurement standards. For example in the broadcasting industry by ITU BS 1770.3 relative loudness of different segments of electronically reproduced sounds, such as for broadcasting and cinema are measured. Some other methods have a general scope to measure and help to characterize a few common observations like Environmental noise are Steven’s loudness and Zwicker's loudness More modern standards, such as Nordtest ACOU112 and ISO/AWI 532-3 (in progress) take into account other components of loudness, such as onset rate, time variation and spectral masking.

Loudness is the subjective perception and cannot be measured directly. So loudness will be measured by considering typical human perception in mind.

G. Terminologies

1) *Sound Pressure:* Root mean square value of variation of air pressure measured in pascal (Pa) above and below atmospheric pressure caused by sound.
2) *Sound Pressure Level :* Quantity of sound pressure in decibels expressed by the formula

SPL (dB) = 10 log10(p2/p 2)
Where p - root mean square pressure in Pascals
po- reference sound pressure (20 µPa) Tables and Recommendations:
With respect to loudness of sound there are many codes which cover about the same which are all covered under NBC 2016 where various tables deal with various aspects of loudness at various places like roads, railways, airports, broadcasting stations, industrial buildings, non industrial buildings etc. Tables and recommendations for various aspects of loudness was derived from several codebooks and is summated together in NBC 2016. Acoustics of the building is covered in Volume 2, Part 8 (Building Services), Section 4 (Acoustics, Sound insulation and Noise control of Buildings) of NBC 2016.

The codes which are used for acoustics of the buildings are as follows :-

a) IS 1950 : 1962 Code of practice for sound insulation of non-industrial buildings
b) IS 3483 : 1965 Code of practice for noise reduction in industrial buildings
c) IS 4954 : 1968 Recommendations for noise abatement in town planning
d) IS 11050 (Part 1) : Rating of sound insulation in buildings and of building elements
e) IS 11050 (Part 2) : Rating of sound insulation in buildings and of building elements: Part 2 Impact sound
f) BS 8233 : 2014 Code of practice for sound insulation and noise reduction for buildings

VIII. HOW LOUDNESS EFFECTS THE SOUND QUALITY IN BUILDINGS

A. External Factors

1) The level of traffic noise fluctuates continuously and the way it does, has a considerable effect on the nuisance caused.
2) Aircraft noise may disturb sleep, rest and communication, and as such may be considered potentially harmful to health. It is important that no new development is carried out within areas where the expected noise levels will cause mental and physical fatigue or permanent loss of hearing.
3) Railways are a very serious source of noise in built up areas in both day and night and the effect of the noise on people will be profound. Underground transportation system can be a major cause of disturbance for the neighbouring community. Very high noise levels are propagated to long distances by the underground high speed railway, as a result of wheel-rail interaction. Both airborne noise and ground or structure- borne vibrations are potential sources of complaints
4) Convoys of long distance heavy trucks at night moving past through built-up areas cause serious noise complaints. On busy roads, the noise of continuous traffic may be a worse nuisance than that of railways.
5) Construction noise due to stationary and moving equipments will be a big nuisance to the neighbouring areas and will affect people in the vicinity a lot
6) Noise because of regular activities which happen outside the house like vendors selling food.

B. Internal Factors

1) Industrial Building: Source of noise will be mostly from the industrial equipment inside the industry. External noise contribute to a small amount in Industrial Buildings.
2) Non Industrial Buildings: Internal factors will be a significant source of noise.

C. Some Of Them Are

1) Conversation of the occupants
2) Footsteps
3) Banging of doors
4) Shifting of the furniture
5) Operation of the cistern and water closet
6) Playing of radio
7) Television
8) Music system
9) Cooling and ventilation machinery

D. Effect of Loudness in Sound Quality

Effect of loudness can be broadly fit in three factors

1) Physical Characteristics of Sound

a) Sound can transmit into rooms through airborne sound or through building structure vibrations.
b) This disturbs the atmosphere inside the building.
c) Loudness in external places like road, railway and airport can seriously disturb the uniform distribution of loudness within a building which in long term can cause health issues in people too.

2) Human Related Factors

a) Perception of different loudness varies with age, gender, occupation of people etc.

b) Loudness in the building will be perceived in various ways by various people and the sound quality overall will be perceived by different people.

3) Social Factors

a) Social event loudness will be perceived by different people in the same society on various aspects

b) The group of people who participate in the event would feel that the loudness is one essential aspect in the event while the other part of society at that same time may perceive it as noise which affects the sound quality in their place.

IX. PREVENTIVE MEASURES

A. Aircraft Noise

1) As the problems caused by aircraft noise have become more acute, a number of methods have been devised for evaluating noise exposure in the vicinity of airports. They all combine many factors into a single number evaluation. A commonly used criterion is the noise exposure forecast (NEF). The NEF is used primarily to develop noise contours for areas around airports. It has been accepted generally that noise exposure forecast levels greater than NEF 40 are unacceptable to people while levels less than NEF 25 are normally acceptable. Levels between NEF 25 and 40 may lead to subjective complaints.

2) While it is theoretically possible to provide sufficient insulation to achieve an acceptable indoor noise environment in the area of very high outdoor noise, there is a level above which aircraft noise seriously affects living conditions no matter how much sound insulation has been applied to the dwelling unit. For this reason it is recommended that no residential development be allowed beyond the NEF 35 level.

3) During summer months, the windows are normally kept open for adequate ventilation. In view of this, no matter how much sound insulation is provided for the building structure, the noise level inside the room can never be less than 10 dB below the outdoor noise level. For very critical buildings, such as buildings necessary for maintaining and supplementing the airport services, and for commercial development, such as hotels, it is possible to provide sealed windows and to centrally air condition the entire building. However, it is not feasible for most of the residential developments in the country. In such cases proper zoning regulations and siting of vulnerable buildings away from aircraft noise are of vital importance.

B. Railways

1) Railway cuttings reduce the spread of noise, whereas embankments extend it. The elevated railway on viaducts or embankment is very common in built-up areas. The elevation increases exposure to noise but in addition the construction of the viaduct may affect the propagation of noise. In this respect solid embankments are preferable to built-up arches, which tend to act as sound boxes.

2) Wherever possible, no residential or public building zone should abut onto railway lines, especially on the marshalling yards which is particularly objectionable because of the shrill, clanging and intermittent noise they generate, often at night. The appropriate zones alongside railway lines are industrial and commercial buildings other than office buildings. Where these precautions are not practicable and housing has to abut on to railway lines, every attempt may be made to house as few people as possible in the vicinity of the railway lines.

3) For underground transport, noise control methods should be considered in the following

a) In stations, where high noise levels are produced at the arrival and departure of trains

b) In tunnels, during high speed train movement

c) Where an underground rail transit system passes close to existing structures or high rise buildings, adequate attention should also be paid to the problem of ground vibration transmitted to the building, and proper isolation should be provided for critical areas

d) Wherever elevated railway tracks are provided, adequate measures should be taken to avoid the spread of noise in the surrounding built up areas

e) In transit cars, where sound insulation is of vital importance to provide comfortable conditions for the commuters

C. Roadways

1) Precautions may, therefore, be taken in the planning of dwellings in relation to arterial and trunk roads as with railways. Care may be taken that local housing roads do not provide shortcuts for heavy traffic through residential areas. Hilly roads present the additional noise of gear changing. Trees with heavy foliage planted on both sides of the carriageway help slightly to muffle the noise, provided the foliage extends for a considerable distance (30 m or above).
2) For zoning and planning of new buildings in urban areas, it is recommended that external LA10 be limited to a maximum of 70 dBA when the dwellings are proposed to have sealed windows and 60 dBA when the dwellings are proposed to have open windows. Indeed it is desirable to confine major new residential development to locations subject to LA10 levels substantially lower than those given above.
3) It is recognized, however, that within the large urban areas, the use of sites where the external LA10 is greater than 60-70 dBA cannot always be avoided. In that case it is suggested to utilize such design solutions as barrier blocks in order to reduce external LA10 noise levels to at least 60-70 dBA at any point 1.0 m from any inward looking façade. When the orientation of the site and the density of development are such that this cannot be fully achieved some form of dwelling insulation will have to be provided. It should be appreciated that where open windows are necessary, the occupants would have to put up with discomfort if the above conditions are not met.

D. Highway Barriers

1) Barriers are often the most effective means of reducing traffic noise around residential areas. They have the great advantage that they generally protect most or all of the site. In nearly all situations, a well-designed barrier of even a modest height (say 3 m) can at least ensure that all areas of open space are free from excessive noise levels.
2) There are two types of barriers that can be built to protect sites; one which are built solely for the purpose of reducing noise and the other which form part of the building complex (barrier blocks). Free standing walls and artificial mounds are typical examples of the first type while single and multi-storeyed utility buildings and garages are the most common form of the second.
3) Of the two types, laying out barrier blocks of a complex in an appropriate fashion is a better option because they are cheaper and also tend to form a more effective barrier overall because of their greater height and width. Barrier walls or mounds are more limited in their effect than barrier blocks for they protect little more than the area of the site close to ground level essentially because of the lack of height, as continuous walls much higher than 3 m are often difficult to construct.

E. Construction Noise

1) Noise control can be done at the source or in the noise propagation path. While it is preferable to adopt noise control at the source, it may not be practically possible to implement it for some of the construction equipment. Given the diversity of noise sources, mitigation strategies in case of construction noise have to be dealt with appropriately depending on the spectral characteristics of sources.
2) Source noise control strategies include providing acoustic enclosures for sources like diesel generators, choosing less noisy construction machinery and selecting alternative construction practices which involve lesser noise generation.
3) Noise control in the propagation paths primarily involves provision of noise barriers around the construction sites. Positioning of major fixed construction equipment/ installations such as batching plants and diesel generators have a significant impact on the noise spectrum and its impact.
4) Also, time of operation and duration of noisy construction activities have significant impact on the resultant annoyance.

F. Residential Buildings

1) Site Planning: The most desirable method is to locate the residential buildings in a quiet area away from the noisy sources like the industrial areas, rail tracks, aerodromes, roads carrying heavy traffic, etc.

a) To minimise ground reflection, the dwellings should be surrounded by the maximum amount of planting and grassed areas and the minimum amount of hard surfacing. This applies particularly to high density areas. Where for maintenance reasons a large amount of hard paving is necessary, it should be broken up by areas of planting and grassing. Narrow hard paved courts should be avoided between adjacent tall buildings.

b) Roads within a residential area should be kept to a minimum both in width and length, and should be designed to discourage speeding. Area-wise planning, with zones from which vehicular traffic is altogether excluded will greatly help to reduce noise. Roads with through traffic should be excluded from residential areas, but where sites have to be developed adjacent to existing major roads the same principles should be observed in the siting of blocks as with railway lines

c) Play areas for older children should be sited as far away from dwellings as possible. Special care should be taken with old peoples' dwellings. They should not be placed immediately adjacent to service entries, play spaces, or to any entrances where children may tend to congregate.

2) *Internal Planning:* The orientation of buildings in a locality should be planned in such a way as to reduce the noise disturbance from neighbourhood areas. The non-critical areas, such as corridors, kitchens, bathrooms, elevators and service spaces may be located on the noisy side and the critical areas, such as bedrooms and living space, on the quiet side.

G. Educational Buildings

1) *Site Planning:* Where outdoor noise nuisance exists from local industry, busy roads, railway, airfields, sport grounds or other sources beyond the control of the school authority, school buildings should be sited as far away from the sources of noise, as possible.

a) Rooms should be planned in a manner so that the minimum amount of glazing is placed on the side facing the external noise.

b) Noises arising from the activities of a school and from the use of the buildings after school hours may constitute a nuisance to occupants of surrounding property; therefore, it is desirable to place playgrounds, workshops, swimming pools, music rooms, assembly halls and gymnasia as far away as possible from buildings which require a quiet environment.

H. Internal Planning

The following principles should be observed in the detailed planning of educational buildings: Grouping Noisy rooms should be separated from quiet ones, if possible. In general, it is desirable that rooms should be grouped together in accordance with the classification. Windows and ventilators Windows of noisy and quiet rooms should not open on to the same courtyard or be near to one another. Skylights and ventilators over noisy rooms should be avoided, if they are likely to be a source of nuisance to adjacent upper floors. Doors Swing doors into rooms should only be used where no problem of sound transmission exists. Reduction of insulation between rooms and corridors due to doors shall be borne in mind. The type and method of fitting of doors is important and necessary care shall be paid in this respect. Sliding partitions, if used, should be acoustic operable partitions. Pass-through doors, if provided, should be acoustic doors with drop seals. Open planning and circulation areas Where open planning is used to permit spaces, such as assembly halls, dining rooms or entrance halls to be used in association with each other or for circulation, the degree of disturbance caused by interfering noise to teaching areas needs careful consideration; traffic through such areas should be strictly controlled; full use should be made of sound absorbent treatments to reduce the spread of noise from one space to another. If rooms have large glazed panels or ventilation openings facing directly on the circulation areas, human traffic passing by the rooms should be controlled. Preferably a baffled ventilation system or double windows should be used. Fan-lights over doors should be fixed and glazed. Furniture In all educational buildings, regardless of the character of the floor finish, rubber buffers should be fitted to the legs of chairs and tables.

I. Sound Insulation

1) Suppression of noise at source:

2) All items of equipment that are potentially noisy should be selected with care.

3) Water closet cisterns should not be fixed on partitions next to bedrooms or living rooms.

4) Plumbing pipes should be isolated from the structures.

5) Lift motors should be mounted on resilient supports.

6) Access doors from machine rooms to internal staircases should be well fitting and of solid construction.

7) Special noise control measures may be required for electrical and mechanical services such as diesel generators, outdoor air conditioning units, cooling towers, etc.

8) Reduction of airborne noise transmitted through the structure

9) Reduction of airborne noise requires the use of rigid and massive walls, or acoustically designed dry walls, without any openings.

10) Openings are the major cause of penetration of noise through a barrier.

11) While designing it should be borne in mind that all components should provide a sound transmission compatible with that of the rest of the barrier so that an equivalent amount of sound energy is transmitted through each portion of the barrier.
12) Ventilating ducts or air transfer openings where provided should be designed to minimise transmission of noise.
13) For this purpose, sound attenuating devices having necessary insertion loss may be installed in these openings.
14) All partitions should be sealed effectively where they butt against the rest of the structure.
15) All doors and windows should be properly gasketed where a high degree of sound insulation is desired.
16) Reduction of structure borne noises:
17) This requires the use of discontinuous or nonhomogeneous materials in the construction of the structure.
18) Reduction of impact noise:
19) The floor of a room immediately above the bed room or living room shall result in an impact sound pressure level (L'nT,w) not greater than 60 dB. Typically, a 150 mm thick concrete floor with thick carpet (12 mm) covering would satisfy this requirement.
20) The floor of a room immediately above the bed room or living room shall result in an impact sound pressure level (L'nT,w) not greater than 60 dB. Typically, a 150 mm thick concrete floor with thick carpet (12 mm) covering would satisfy this requirement.

J. Echo

In acoustics, Echo is a reflection of sound that arrives at the listener with a delay after the direct sound. This can be heard when the reflection returns with sufficient magnitude and delay to be perceived distinctly. The delay is directly proportional to the distance of the reflecting surface from the source and the listener. The human ear cannot distinguish echo from the original direct sound if the delay is less than 1/10 of a second. The velocity of sound in dry air is approximately 343 m/s at a temperature of 25 °C. Therefore, the reflecting object must be more than 17.2m from the sound source for echo to be perceived by a person located at the source.

K. Remedy

1) An echo can be avoided by covering long distance walls and high ceiling with suitable sound-absorbing material.
2) Install carpet throughout the room for complete coverage.
3) Install a new floor with sound-dampening underlays.
4) Install a new floor that's made of cork.
5) Install mass loaded vinyl if you want to cover all walls completely.
6) Add insulation to help with temperature at the same time.

L. Echelon Effect

The process of combination of multiple echoes and forming of a new sound is known as echelon effect. A set of railings or rectangular surfaces is said to produce echelon effect. This echelon effect affects the original quality of sound.

1) *Remedy:* To minimize echelon effect in acoustics of building, stair type construction in the hall should be avoided. If it is necessary, then the spacing between the stairs must be unequal or stairs may be replaced by a ram. The steps of stair case should be covered with carpet.

X. NOISE

A. Objective

The objective is to detail a potential significant noise impact that could result the proposed action. To identify and quantify any such potential impact from the action, a noise analysis is designed and conducted and consist of three parts:

1) A screening analysis to determine location where traffic generated by the proposed action would have the potential to cause significant noise impact.
2) A detailed analysis at any location where traffic generated by the proposed action would have the potential to results in significant adverse noise impact to determine the magnitude of increase in noise level.
3) An analysis to determine the level of building attenuation necessary to ensure that interior noise level in proposed buildings satisfy applicable interior noise criteria.

B. Reducing Noise Levels in Buildings

The process of noise control revolves around three crucial categories for interiors: sound absorption, airborne sound transmission, and impact-sound transmission.

1) *Sound Absorption:* Sound absorption is the capability of a surface, or building material, to absorb sound instead of reflecting it. Sound waves will continue to bounce around a room for a time after they are created if the majority of surfaces in a room is reflective. Surfaces that absorb sound better will not allow for reflections to bounce around as much, and will deaden the sound wave more quickly. Many common building materials, such as gypsum board, wood, concrete, brick and tile, are fairly reflective and do not absorb much sound. Softer materials, such as carpet, foam padding, and fiberglass insulation, are far better at absorbing sound. The use of absorptive materials can be helpful in controlling sound. Fiberglass insulation is very absorptive and can be usedwhere sound control is a concern. Thick carpet with padding is also very absorptive, and acoustical ceiling tiles are designed to absorb rather than reflect sound. Even in cases where these options are not viable, absorptive materials can be added to finished rooms in other ways: furniture with thick cushioning is extremely absorptive, as are thick and heavy curtains and drapes. Items such as these can be added or arranged in ways that will allow for greater sound absorption. Acoustical baffles with absorptive materials can be purchased for use in areas where sound is a major concern, and most are designed to be unobtrusive and visually nondescript so as to allow for installation without drastically altering the aesthetics of a room.

Requirements of a good acoustic material

a) Should have high absorption power
b) It should be able to absorb a wide range of frequencies
c) Should be cheap and easily available
d) Should look attractive after fixing it
e) It should be fire resistant
f) Should have adequate structural strength
g) Should be non- hygroscopic.
h) It should be insects and termites free

2) *Airborne Sound Transmission:* Airborne sound transmission in interiors deals with how well sound is controlled from room to room, and from the outdoors to indoors (or vice versa) through walls and ceilings. Sound transmission loss is the decrease in sound energy when it passes through a building element. Different materials provide different levels of transmission loss and, thus, different levels of diffusion of sound. Dense, heavy materials increase the mass of floors and walls, allowing less sound to pass through. De-coupling can also be used to control sound, in this case. A break in framing or a resilient drywall connection breaks the path of vibration for the sound wave, causing it to halt. This is the most effective method for controlling strong, low frequencies, which are the hardest to block. Blocking airborne sound from leaking through gaps and cracks by sealing them is also effective.
3) *Impact-Sound Transmission:* After an impact noise is transmitted through a floor or ceiling assembly, the airborne sound that has made it through is the impact-sound transmission. The sound of someone stomping around on the floor above you is an impact sound transmitted through the ceiling to the room you are in. As with airborne sound transmission and sound absorption, the media of building materials used in construction come into play. Wood joist floor-ceiling systems transmit a lot of impact sound. Adding fiberglass insulation will improve their capability of blocking impact sound, as will decoupling by using a wire-suspended drywall ceiling. Lightweight concrete flooring is generally good at reducing airborne sound transmission, but it does not do as well blocking impact sound. De-coupling is crucial to improving impact sound control in this instance. Resilient underlayment's beneath floating floors can isolate the finished flooring from the concrete slab.
4) *Sound Insulation:* Sound insulation/sound proofing is a method used to subdue the level of sound passing through the insulating building component. People generally confuse sound absorption and sound insulation to be the same. The two are very different from each other. Sound absorbents which are mostly pours materials absorb thus reduce the sound which is reflected from surfaces. On the contrary sound insulating construction reduces sound passing through it. Sound absorbers, are poor sound insulators. While hard material used for sound insulation are inferior sound absorbers. Impact Insulation- is a rating of how well a building floor reduces the impact of sounds, such as footsteps.

XI. SOUND INSULATING MATERIALS

1) *Non Porous Rigid Partitions:* The sound insulation of non-porous rigid constructions such as plastered solid brick masonry walls varies. It depends upon the weight per unit area. There is a point when it requires major increase in thickness to provide small increase in sound insulation.
2) *Porous Rigid Materials:* Porous concrete masonry and cinder concrete are some examples of porous rigid materials. They provide 10 percent higher insulation as compared to non-porous rigid partitions due to their sound absorptive quality. To enhance the results of insulation it is recommended that porous partitions should be plastered on at least one side and if possible then on both sides.
3) *Flexible Porous Material:* These materials provide low insulation. Even lower than rigid materials. Flexible porous materials consists of mineral wool, quilt etc. To increase insulation rigid materials and porous absorbers can be combined together and then applied. This will produce better insulation per unit area.

A. Wall Insulation

Walls are a vertical barrier of sound. Proper construction of walls can increase the level of sound insulation. Construction of walls for sound insulation can be of four types –

1) *Rigid Homogeneous Walls:* Stone, brick or concrete masonry constructions come under this section. The sound insulation in these walls depends upon their weight per unit area. Sound insulation in these increases if the thickness of wall increases. Due to this these walls become uneconomical and bulky after a certain limit.
2) *Partition Walls of porous materials:* These can be rigid or non-rigid. Rigid porous materials such as porous concrete masonry, cinder concrete etc. increase insulation about 10.%. While partition walls of non rigid porous materials provide very low sound insulation. However they can be used if combined with rigid materials.
3) *Double Wall Partition:* A double wall partition comprises of Plaster boards Or fibre boards or plaster on laths on both sides. With sound absorbing cushion in between. Rough wooden blocks are provided to support the cushion. Double wall partition is a wall of rigid as well as non–rigid porous materials.
4) *Cavity Wall Construction:* This is said to be the most adequate wall construction from the sound proofing point of view. In this two walls are made with a gap of minimum 5cm between them. This gab can be left air filled as we know sound travels the slowest in air or can be filled with some flexible material, like quilt etc. On the surface of the wall Celotex or other insulating board may be fixed.

B. Floor And Ceiling Insulation

Like walls are vertical sound barriers similarly floor and ceiling are horizontal sound barriers. The materials used for the construction of floors and ceiling i.e. R.C.C, stone etc. provide great insulation again air borne noise but do not function well for structure and impact borne noise. The target of sound proofed floors is to provide insulation against impact and structure borne noise.

1) *This Can Be Achieved By The Following Ways:* Applying resilient surface materials on floor – In this a thin concrete layer is provided as R.C.C floor slab. On top of this then a soft floor finish or covering is applied. This finish or covering can be of linoleum, insulation board, cork, carpet, etc. this helps in reducing impact noises.
2) Concrete floor floating construction: This is similar to Cavity wall construction as discussed earlier. In this method we construct an isolated floor from the existing concrete floor. Then a resilient or porous material like glass wool is laid on the R.C.C flooring. On top of this a water proof sheet is put and then a 5cm thick layer of concrete is given. This kind of construction provides complete insulation against impact sounds.
3) Timber floor floating construction – In case of wooden flooring the problem of sound insulation is even more. This process is similar to concrete floor floating construction. The only difference is that mineral or glass wool quilts are used for isolation purpose. At times sand or ashes are also used for isolation.

C. Specialty Construction Materials for Sound Control

There are a number of specialty materials available for sound control. These are designed to provide strategic advantages over traditional materials, and are designed for use in situations where controlling sound or noise levels is of great concern. Many of these materials can be used during an initial build or installed at a later date, if the situation necessitates it.

D. Some Common Examples are Listed here.

1) Mineral-fibre insulation is a special, denser type of insulation that can be used to improve a room's level of soundproofing. Its density is much higher compared to traditional fiberglass insulation, which makes it far more effective at stopping the transmission of sound from one room to another. Mineral-fibre insulation also has a much higher burning point than standard fiberglass insulation, as well as a lower rate of moisture absorption.
2) Sheets of limp mass, dense vinyl sound barrier are available for covering flat surfaces. The sheets are flame-retardant, and easy to install with plastic-cap nails or staples, or one can use trowel-applied, multi-purpose vinyl flooring adhesive. They are also available with an adhesive backing for even easier installation. These coverings are safe, inexpensive, and easy to work with. They can be cut with a standard utility knife or scissors.
3) Floor de-couplers can be used to "float" a floor. De-coupling a floor is an effective way to minimize sound transmission. These floaters can be placed between the existing floor and a new level of flooring installed on top of them. They are inexpensive and will allow for the additional level of flooring to be removed at a later date, returning the floor to its original state.
4) Resilient channels are pieces of metal made in a special shape that gypsum board or any type of drywall can be attached to in order to minimize sound transmission. One side of the resilient channel is attached to the stud, and the drywall is attached to the other side. Drywall that is isolated from framing in this manner will transmit far less sound than drywall mounted directly to studs. Optimal control of noise in buildings can be achieved by understanding the basics of how sound moves through solid objects and air. Building materials will have the most impact on controlling sound in interiors, but strategic placement of absorptive materials in finished areas can also be very effective. Many of the materials listed above can be incorporated into a build when the situation calls for it, or installed at a later date, if it becomes necessary.

XII. MODERN APPROACH

The recognition of noise as a serious health hazard is a development of modern times. Too much noise obviously impairs our physical and mental existence and therefore it is reasonable to pursue Technology Assessment concerning noisy technologies. In other words, noise has turned into one of the most important among the environmental factors on which industry sets down a big part of its efforts and concerns. The conflicts of interest associated with noise that arise from the operation of airports are well known. Recently, passive mediums have been used extensively in the industry to reduce noise.

Acoustical sustainable materials, either natural or made from recycled materials, are quite often a valid alternative to traditional synthetic materials. The production of these materials generally has a lower environmental impact than conventional ones, though a proper analysis of their sustainability, through Life Cycle Assessment procedures, has to be carried out. Airborne sound insulation of natural materials such as flax or of wool. Many natural materials (bamboo, kenaf, coco fibres) show good sound absorbing performances; cork or recycled rubber layers can be very effective for impact sound insulation. These materials also show good thermal insulation properties, are often light and they are not harmful for human health. Furthermore, many of these materials are currently available on the market at competitive prices. Noise reduction techniques can be broadly classified as passive and active methods. Passive control involves reducing the radiated noise by energy absorption, while the active method involves reducing source strength or modifying acoustic field in the duct to obtain noise reduction. Active noise control is being used only at low frequencies. At middle and high frequencies, active noise control is hard to implement because there are different phenomena of sound propagation. Thus, the main purpose of the active sound control is to provide higher noise reduction at low frequencies. While at higher frequencies standard solutions are applied, and they are based on the application of absorbing properties of the materials. The absorbing materials, as such, are passive mediums that lower noise by disseminating energy and turning it into heat.

Acoustic absorption depends on the frequency of the sound waves.

A. Sound Absorbing Materials (Based on IS:2526-1963)

The materials generally used may be broadly classified into the following categories:

1) Acoustic plaster (a plaster which includes granulated insulation material with cement};
2) Compressed cane or wood fibreboard, unperforated and perforated;
3) Wood particle board;
4) Compressed wood wool);
5) Mineral/glass wool quilts and mats;
6) Mineral/compressed glass wool tiles;
7) Composite units of perforated hardboard backed by perforated fibreboard;

8) Composite units of perforated board (hardboard, asbestos board or metal sheet) backed by mineral or glass wool quilt or slab; and
9) Special absorbers constructed of hardboard, teak ply, etc, backed by air.

XIII. ACOUSTIC MATERIALS PROPERTIES AND ORIENTATION

Acoustical materials are a variety of foams, fabrics, metals, etc. used to quiet workplaces, homes, automobile , and so forth to increase the comfort and safety of their inhabitants by reducing noise generated both inside and outside of those spaces. Acoustical materials are used in two major ways: as soundproofing, by which noise generated from outside a given space is blocked from entering the space; and, as sound absorbing, where noise generated within a space is reduced inside the space itself. As an example of soundproofing, a school might construct a special wall to isolate the music room from a general classroom next door. As for sound absorbing, a machine shop might install barriers to block and absorb the acoustic energy of a noisy air compressor.

A. Measures Of Acoustical Materials Effectiveness

There are several specifications of the acoustic properties of acoustical materials that are measured and delineated by manufacturers and which are used to quantify the effectiveness of the material for handling sound or noise. The most common of these include

1) Absorption Coefficient
2) Specific Acoustic Impedance
3) Noise Reduction Coefficient
4) Sound Transmission Class
5) A-weighted Sound level Scale

The absorption coefficient, or sound absorption coefficient, is defined as the portion of sound energy incident on a material’s surface that is not reflected. The specific acoustic impedance is defined as the product of a material’s density and its acoustic velocity. The effectiveness of acoustic material to absorb sound energy depends upon the frequency of the sound, with the mid-to-high ranges being more effectively muted by most materials than the lower frequencies. A so-called noise reduction coefficient establishes a material’s average absorption coefficient at frequencies of 250, 500, 1000, and 2000 Hz., and is useful for comparing a material’s effectiveness at absorbing noise in general. In special applications, such as recording studios, the noise reduction coefficient is less useful because it does not cover the lower base range frequencies which tend to present the biggest problem. In these situations, using the absorption coefficient at the frequency in question can make a better determination of a material’s effectiveness; unfortunately, noise reduction coefficients for various commercial materials are often published whereas the absorption coefficients generally are not. Materials used for soundproofing are given an STC, or Sound Transmission Class, a rating which quantifies how well a material blocks transmission at frequencies associated with speech. Like the Noise Reduction Coefficient associated with absorptive materials, the STC rating does not give a good indication of a material’s effectiveness at blocking low- or high-frequency sounds, such as mechanical noise or music. Sound for human-occupied environments is measured by an A-weighted sound level scale, which reduces the impact of high and low frequencies to better match the human ear’s response to the middle ranges. This scale, with units of dBA, is sometimes referred to as noise level and is a selectable feature of most sound meters.

B. Acoustic Foam

Acoustic foam does not block sound. It is used in sound absorption applications such as gymnasiums to reduce reverberations as noise travels and bounces off reflective surfaces. To block sound, acoustics specialists rely on mass primarily, while eliminating any gaps in walls where sound can leak through and eliminating, as well, any mechanical couplings between inner and outer walls.

Soundproof sheetrock, mass loaded vinyl barriers, and sound isolation clips are some of the products used for soundproofing. Sometimes laminated materials are used to reduce the transmission of sound through walls by disrupting the resonant frequencies of like materials. There are also specialized products available for use in construction such as soundproof windows, sound reduction windows, and sound resistant doors. The standard unit of sound absorption, or Sabin, is based on the amount of absorption a 1 ft-square section of material will achieve over a frequency range of 125-4000 Hz. It is often impractical or undesirable to completely cover a room with acoustic material. In these instances, discrete placement of material in small patches proves more effective than placing it all in one spot. Likewise, placing material asymmetrically—on non-parallel walls, for instance—usually achieves a greater quieting effect, as does locating the material near corners and edges rather than in the centers of walls. Situations like these can often be tricky to quiet, and often the advice of an acoustical contractor or an architect familiar with acoustical construction can be helpful.

C. Specific Material Properties

1) *Soundproofing:* Commercially available soundproof drywall, or pre- damped drywall, achieves its reduction in sound transmission by sandwiching a layer of viscous damping glue between two sheets of usually dissimilar materials of unequal thickness. Manufacturers claim a several-times reduction in sound transmission over ordinary drywall. Installation of these materials has to abide by the manufacturers' instructions to achieve their maximum effectiveness. Sometimes obtain good results by mimicking the idea behind pre-damped drywall. Acoustic caulk or other forms of sound dampening sealants, marketed under a number of tradenames, are available for this purpose. Other forms of materials can be applied to help deaden or dampen sound including Liquid Applied Sound Deadeners (LASD) or sound dampening liquid coatings. Mass loaded vinyl is a generic term for several commercial products which use heavy vinyl sheeting installed behind sheetrock as a means of blocking sound transmission. By being loosely draped between stud attachments, the material flexes as sound waves impinge upon it, prohibiting the transfer of their energy to the more-rigid interior walls. Again, the materials must be installed according to manufacturers' instructions to be effective; keeping the product behind sheetrock maintains a structure's fire resistance. Another method is lead-sheet soundproofing, also referred to as acoustic or acoustical lead, which, given the material's high density, proves an effective method of reducing sound transmission through walls. In many applications, the lead is bonded to foam on both sides and then adhered to sheetrock. Sound isolation clips provide a mechanical means of decoupling inside walls from exterior structures. Usually consisting of rubber-fitted mounts that hold nailing strips, these clips provide a convenient method of isolating a room from external noises. As with any of these soundproofing methods, clips are designed only to work on airborne sound. Noise coming through structures, plumbing, etc. will remain unmuffled by their use. Soundproofing is used in many other settings besides buildings. Aircraft, for example, are soundproofed to protect crew and passengers from engine noise and high- frequency flight noise. Aircraft insulation soundproofing often has thermal resistance as well to insulate cabins and cockpits from extreme outside temperatures. Vendors also supply materials for general aviation aircraft. Automobiles are fitted with a variety of soundproofing materials to protect passengers from engine, airflow, and road noise.
2) *Absorbers:* Sound absorption materials come in a variety of styles allowing them to integrate aesthetically to indoor offices and the like. They are also available in special laminated versions for industrial applications such as machinery enclosures, automobile headliners, etc. Acoustic foam is usually of the open cell variety as closed-cell structures tend to reflect sound rather than absorb it. Foam surfaces can be flat or topological—the familiar "egg-crate" pattern being representative of the form. One popular product in these applications is melamine foam, which can often be purchased as composite sheets and as 2 x 2 ft. squares and 2 x 4 ft. rectangles in thicknesses of 1 and 2 inches. The material is usually applied to the walls of enclosures, etc. with adhesive. A variety of spray- applied acoustical insulations are available as well which can be applied over large interior walls as a way of reducing reverberation while producing a finished interior surface. Acoustical foams are available in many bulk forms, including sheets and rolls, and also as tape. Melamine foam is manufactured from thermosetting melamine resin which produces a very fine, open cell, fibre-less structure which is fire resistant and easily die-cut, routed, or sliced to produce an abundance of shapes. There are instances where syntactic foam has been used for noise attenuation, and even aluminium foams have been applied for noise control. For interior spaces, the primary objective is reducing the echoes produced as these make hearing speech difficult. Absorption is the principal method for doing this. Studies have shown that a general inhabited space, one not devoted to sound recording, for instance, can be made too quiet which is uncomfortable for many people. That is where combining absorptive shapes with shapes that diffuse sound has proven effective. Acoustical absorbers are available both as hanging acoustical baffles and as sound dampening room dividers. Sometimes referred to as sound abatement panels, these come in an array of designs and constructions to complement the décor of the spaces in which they are installed. They can be flat, permanently installed dividers or moveable, soundproof accordion room dividers. When it comes to sound absorption in machinery enclosures, server rooms, etc., a variety of materials and methods are available. Acoustical blankets are used in industrial settings to set up noise absorption around loud machinery and are typically rated to withstand the high temperatures so often associated with industrial operations. These can serve as temporary or permanent noise absorbers. The same blankets, which are usually made of some combination of acoustical foam for absorption and mass loaded vinyl for blocking, can be built as full, custom enclosures to completely surround offending machinery. Pipelines can also be covered with similar materials to minimize the transference of noise through them. OSHA has specific guidelines for manufacturing plants, among them that the continuous noise exposure in an 8-hour shift should not exceed 90 dBA (a time-weighted average, or TWA), and the highest impact or percussive noise exposure should not exceed 140 dBA. Where high- frequency noise in plants generated by turbine-driven pumps and compressors can be controlled with barriers, many reciprocating machines produce low-frequency vibrations

which are harder to attenuate with absorbent barriers: very often these vibrations are transmitted into the floor and the structure of the building. This noise is best attacked by isolating the machines from the structure with resilient pads or isolation mounts.

D. Considerations

There are a few subjective measures associated with sound, among them loudness and quality. Loudness is expressed in units of phons to provide a qualitative measure, a phon being defined as the pressure level in dB of a 1000 Hz. tone against which a person compares another pure or complex tone. Another measure, the sone, is defined as the loudness of a 1000 Hz., 40 dB tone. A relationship can be plotted between phons and sones. Quality is the subjective measure of the pleasantness or unpleasantness of sound which can make sounds of the same loudness appear more or less disturbing. Music typically combines fundamentals and harmonics to produce a pleasing sound, whereas in the case of noise, the frequencies are irregular and random. Among the attributes used to describe sound quality are pitch and timbre. Pitch is determined mainly by frequency, then intensity and wave shape while timbre is determined mainly by wave shape, then by intensity and frequency. It is these differences that enable us to distinguish the same note played on a brass horn and a woodwind as coming from different instruments. Stylized acoustic wall panels soften the hard, reflective surfaces of interior spaces. As mentioned, sound can find its way through the smallest gaps in an otherwise impenetrable barrier, a phenomenon known as “flanking. Penetrations through walls for piping and ductwork will also permit sound to pass, as will the pipes themselves, and these gaps should be properly sealed. Where barrier walls adjoin other walls or floors, a sealant can be used as well to close up any gaps. A few rules of thumb apply to soundproofing and sound absorbing. Usually, doubling the mass of a wall will produce a noticeable reduction in the level of sound coming through it. When adding sound absorption to a room, usually it takes a 3 dB reduction in sound levels to affect a perceptible difference. Most of the material described herein relates to common industrial sound and noise problems found in offices, factories, etc. There are special cases where the acoustics of a room are important from the standpoint of being able to hear the sounds without losing their liveliness: concert halls, recording studios, etc. Here is where diffusors come into play. They create a sense of spaciousness in a room by scattering sound waves to reduce echo and standing waves, giving the sound better clarity.

E. Resources

In addition to organizations that sponsor standards for industrial noise control such as OSHA and ANSI, the following organizations can provide useful information on various aspects of acoustic materials.

1) Acoustical Society of America’s homepage
2) The site for Institute of Noise Control Engineering
3) Noise Reduction Materials for Tractor, Excavator, and Bulldozer Cabs

F. Acoustic Materials

When the sound intensity is more, then it gives the great trouble or nuisance to the particular area like auditorium, cinema hall, studio, recreation centre, entertainment hall, college reading hall. Hence it is very important to make that area or room to be sound proof by using a suitable material called as ‘Acoustic material’. It is measured in decibels (dB). Acoustic material play a vital role in the various area of building construction. In studio, class room, reading hall, cinema theatre, more concentration is required to listen, hence the acoustics treatment is provided so as to control the outside as well as inside sound of the various building until such that sound will be audible without any nuisance or disturbance.

1) Types of Acoustic Material

a) Acoustic plaster
b) Acoustic tiles
c) Perforated plywood
d) Fibrous plaster
e) Staw board
f) Pulp board
g) Compressed fibre board
h) Hair felt
i) Cork board slabs
j) Foam glass
k) Asbestos cement boards

2) *Properties of Acoustic Materials*
a) Sound energy is captured and adsorbed.
b) It has a low reflection and high absorption of sound.
c) Higher density improves the sound absorption efficiency at lower frequencies.
d) Higher density material help to maintain a low flammability performance. Hence acoustic material should have higher density.
e) It controls the sound and noise levels from machinery and other sources for environmental amelioration and regulatory compliance.
f) Acoustic material reduces the energy of sound waves as they pass through.
g) It suppresses echoes, reverberation, resonance and reflection.

3) *Uses of Acoustic Materials*
a) Acoustic materials can be used for noise reduction and noise absorption.
b) It makes the sound more audible which is clear to listen without any disturbances.
c) It suppresses echoes, reverberation, reflection and resonance.
d) Important specifications for noise reduction and noise absorption products include noise attenuation and noise reduction coefficient.
e) A vinyl acoustic barrier blocks controls airborne noise (street traffic, voices, music) from passing through a wall ceiling or floor.
f) Acoustic foam and acoustic ceiling tiles absorb sound so as to minimize echo and reverberation within a room.
g) Sound proof doors and windows are designed to reduce the transmission of sound.
h) Building techniques such as double wall construction or cavity wall construction and staggering wall studs can improve the sound proofing of a room.
i) A sound proof wall (treated by an accurate material) can incorporate sound proofing and acoustic materials to meet desired sound transmission class (STC) values.

G. *Acoustic Materials Available In The Market*
1) *Basotect:* Basotect® is a light weight open cell foam, which is made from melamine resin. It is flexible, easy to handle. It is easy to cut and install. It is available in sheet form and also available in pre-cut or profiled to size and shape. The natural colour of the foam is light grey, although it is also available in a range of functional or decorative facings and fabrics that can he sprayed with flexible PVC coating. It is designed for use in thermal and acoustic insulation applications.
a) *Properties of Basotect®*
- It is flame resistant.
- It has high sound absorption.
- It is heat resistant.
- It has light weight.
- It has good thermal insulation.

b) *Applications of Basotect®*
- It is used in building services like arid ceiling panels for office and conference suit etc.
- It is extensively used in recording studios for the work of wall panels, ceiling tiles and anechoic wedges.
- It is used in engine room and accommodation areas of marine ship.
- It is used in automotive for car trim engine and under bonnet panels.
- It has industrial applications and used as enclosure linings and suspended absorbers.

2) *Sound Fibre Rock:* Sound fibre rock is made from non-combustible rock fibre. It is available in four different thickness. It is supplied in slabs of size 1000 x 600 mm. The slabs can also be supplied as part of an acoustic composite product with lead or polymeric barries.
a) *Properties of sound fibre-rock*
- It is resistance to high temperature.
- It has excellent sound and thermal qualities.
- It is simple to cut and install.

b) Applications of sound fibre- rock

- Since it has excellent sound and thermal qualities, making it an ideal choice for cavity wall, floor and ceiling insulation.
- Sound fibre rock slabs are particularly suitable for acoustic infill in partitions and ceilings, provided a high level of control of both airborne and structure born sound.
- It is also suitable for acoustic absorption in the linings of buildings, with the 600 N /m3 slabs being particularly good in sound studios.
- The 450 N/m3 slabs can also be used to firestop small voids, in particular the gap under pitched roof in dwellings.

3) *DMP2 Damping Mat:* DMP2 damping mats are light in weight and PVA- based, visco-elastic polymer. It is designed for use in acoustic applications where a high level of vibration damping is required. These type of material come with a self- adhesive backing. It is available in standard sheet sizes of 1600 x 1000 mm or die- cut to shape.

Applications of DMP2 damping mats

a) It is extensively used to reduce vibration in sheet metal and other resonant surfaces such as vehicle body parts, machine panels, steel sinks and table etc.

b) DMP2 damping mats are particularly suitable for clean- room environments.

4) *Damping mats (DM3, DM5, DM5A, DM 10):* Damping mats are manufactured from bitume with added mineral fillers and synthetic rubber forming a highly visco-elastic product. It is available in four standard grades. Damping mats come with self-adhesive backing.

Applications of damping mats

- Barrier mats are used to reduce vibration in sheet, metal and other resonant surfaces such as vehicle body parts, machine panels, steel sinks and table etc.
- It improves the sound insulation by adding mass to the structure.

5) *Sound Fibre-Poly:* It is manufactured from non-irritating water repellent polyester fibres. It is designed for use in acoustic and thermal insulation applications. It can be supplied in sheet form in packs 10 or cut to a specific size and shape. It can also be supplied in fabric wrapped form for architectural applications or with other performances enchanting facings.

a) Properties of Sound fibre-poly

- It is rot proof, odourless, non-hygroscopic , will not sustain vermin.
- It will not encourage the growth of fungi or bacteria.
- It is dimensionally stable under varying conditions of temperature and humidity.
- For long term protection, it should be stored in a dry well ventilated area.

b) Applications of sound fibre-poly

- Sound fibre-poly sheets are particularly suitable for architectural building applications such as wall or ceiling panels.
- It is also used in low temperature heating and ventilation equipment.

6) *Insulation Blankets:* There are two types of insulation blankets with a name of SCL and SCP. There are noise insulation quilted blankets. SCL and SCP can be supplied in standard sheet size of 2000 x 1200 mm or can be supplied as individually tailored parts to suit for particular application. Blankets can be stitched and edge bound and can also be supplied with eyelets or Velcro for fixing. SCl and SCP are also available with other higher performance facings. SCL is manufactured from two layers of quilted glass fibre and a lead core with hardwearing PVC coated glass cloth material on outside. SCP is manufactured from two layer of quilted glass fibre and a polymer barrier core with hardwearing PVC coated glass cloth material on the outside. These are high performance blankets offer a cost effective alternative to SCL.

a) Properties of Insulation Blankets

- They are extremely flexible with a high degree of durability.
- They are fire resistant and also resistant to most common fluids, mineral oil and petroleum.

b) Application of Insulation Blankets: SCL are high performance insulation blanket which are designed for under bonnet vehicle installations, plant equipments, agricultural vehicles and industrial pumps.

7) *Barrier Mats:* It consist of thermoplastic polymer with phthalate esters and mineral fillers, making it an extremely durable and flexible product. It is available plain, self-adhesive backed or with a reinforced class '0' foil facing. It is available in thickness of 2.5 mm and 4.5 mm.

a) *Properties of Barrier Mats*
- It is black in colour.
- Its density varies from 50 N/m2 to 100 N/m2.
- Its hardness is 90°.
- It is resistant to fire.
- Its operating temperature is 90°C for extended period and 120°C for short period.

b) *Application of Barrier mats: Barrier* mats are designed to add mass and reduce noise transmission on various products, including mechanical and electrical equipment, automotive components and extensively within the building industry on walls, floors and ceilings etc.

8) *Sound Lag:* Sound lag L and P are the two types of noise insulation blankets. Sound lag L is manufactured from two layers of glass fibre with a lead core and a reinforced class `0′ foil, vapour barrier outer coverings. The inner layer of glass fibre is quilted with a scrim backing to prevent fibre breakout. Sound lag P is a cost effective, flexible polymeric barrier mat, faced with class '0' foil vapour barrier and non-irritant polyster fibre inner layer.

Applications of sound lag

a) It is designed to control noise breakout from ducting and pipe work by extremely wrapping to contain the noise within the duct.
b) It enjoy a decoupled mass technique i.e. heavy barrier layer isolated from the duct or pipe surface by a resilient layer of insulation acting like spring.
c) Sound Lag L is used in applications requiring a high level of thermal insulation and improved sound absorption.
d) It has a good acoustic performance.

9) *Sound foam, S:* It is a flexible open cell polyurethane foam, offering excellent sound absorbing qualities over a wide range of frequencies. It is available plain or self- adhesive backed. It is easy to handle and to cut and install. It can be available in sheet form from 6 mm to 100 mm thick, or it can also be available die – cut to size and shape. It can also be available as part of acoustic composite product with lead polymeric barriers or damping sheets.

a) *Applications of sound foam S*
- It is a self-extinguishing acoustic foam.
- It is used extensively in the motor industry for vehicle and compressors, generators, enclosures.

10) *Sound Foam:* It is flexible open cell polyurethane foam, offering excellent sound absorbing qualities over a wide range frequencies. It is available plain or self- adhesive backed. It is easy to handle and to cut and install. It is a black non- flammable acoustic foam. It is impregnated with fire retardant chemicals which enables the material to achieve class '0' fire rating as defined by the building regulations.

a) *Application of sound foam 0:* It is extensively used in air conditioning and air handling system, ducting and also compressors, generators, enclosures and other applications.

XIV. SITE SELECTION

The acoustic design of a building starts with the selection of the site. The acceptance of any given sound depends on many factors that vary according to the type of building, the type of activity being performed, and the social and cultural habits of the occupants. The quality of sound in any given indoor space is determined by the sources of the sound or noise and quality of the building envelope including:

1) Exterior noise (nearby traffic, neighbours...)
2) Interior noise (music, phone conversations...)
3) Impact noise (footsteps...)
4) Sound vibrations through the structure
5) Equipment noise (ventilation systems, electronic equipment, pipes, elevators...)

A. Noise

A satisfactory indoor acoustical environment actually starts by knowing what is going on outdoors. Building acoustics can help to mitigate the effects of noise disturbance which can have negative effects on health, wellbeing and general quality of life. Noise disturbance has become a more common problem as a result of industrialization, urbanization and the rapid increase in the number of household appliances, devices, equipment and alarms. However, greater awareness in planning and improved standards of construction can help mitigate potential noise problems. The Noise pollution is defined as:

1) *Environmental Noise:* Which includes noise from transportation sources.
2) *Neighbour Noise:* Which includes noise from inside and outside buildings.
3) *Neighbourhood Noise:* Which includes noise arising from industrial and entertainment premises, trade and businesses, construction sites and noise in the street.

B. Assessment Of External Noise And Vibration

If the noise measurement survey shows that the ambient external noise levels on the site are below 45 dB LAeq,30min, and prediction work shows that they will remain below 45 dB LAeq,30min in the future, no special measures are likely to be necessary to protect the buildings or playing fields from external noise. However, consideration should be given to any potential increases in noise levels due to future developments (e.g. increases in traffic flows, new transport schemes, changes in flight paths). The local highway authority should be able to advise whether significant changes in road traffic noise are expected in the future. This is likely to be relevant for developments near new or recently improved roads. Where road traffic noise levels are likely to increase, it is reasonable to base the sound insulation requirements on the best estimate of noise levels in 15 years' time. Similar information is likely to be available from railway operators and airports. The prediction of future external noise levels should be carried out by an acoustics consultant.

C. Noise Control

Follow these guidelines when selecting a site for an building or educational facility:

Avoid sites in high noise areas—airfields, highways, factories, and railways.

Ensure compatibility with existing facilities—do not site a school in an industrial area, for example.

Determine what else is planned for the site in the future. Your building may be the first one built, but if future buildings are acoustically incompatible with yours, significant remediation measures may be necessary to return the interior sound environment to an acceptable level.

When the site is predetermined and is too noisy for a building or educational facility:

1) Incorporate appropriate sound control measures
2) Avoid through-the-wall, package terminal air conditioners (PTAC)
3) Orient quiet spaces away from outside noise sources.

To protect the spaces in a building from noise from a nearby highway or railway, lay out the building so that restrooms, mechanical and electrical equipment rooms, and other less noise-sensitive spaces are adjacent to the roadway. When designing a campus near high noise activity, locate gymnasiums and other less noise-sensitive facilities closer to the noise source and place buildings needing quiet surroundings in the shadow of those facilities. As always, while siting for noise control, incorporate sustainable site planning into the decision-making process. It is more likely for a project to remain within budget if opportunities are sought to apply a single design approach to achieve multiple design objectives. For example, an earth berm with low-growth, drought-tolerant plants can act as a noise barrier from highway traffic, can meet sustainable development principles, and can help meet security requirements for standoff distance from buildings.

D. Acoustic Comfort

Considering the types of noise and architecture, noises can either be transmitted through the air or through the building fabric itself (through the envelope), vertically (from floor to floor), or laterally (through internal partitions). Acoustic comfort in a building is dependent on the acoustic characteristics of the building fabric, as regards acoustic transmission and absorption. When designing for acoustic comfort today, we must take into account a variety of external and architectural factors:

1) The types of noise to be managed, from protecting the building's users from incoming levels of noise, but also perhaps from polluting the environment with noise produced from the building, as well as managing the internal noise within the building.
2) The spectrum of noise to be managed (low or high frequencies
3) The construction system and materials the building's activity : sleeping, working, teaching or healthcare

XV. DESIGN DEVELOPMENT

Including acoustic solutions in a project begins during the design phase. There are a wide variety of soundproofing solutions on the market for office buildings, apartment complexes and homes. If you're including soundproofing solutions in your design plan, it's a good idea to have a few sound specifications. Notes on maximum sound penetration and ideal decibel levels for building systems can help engineers and contractors during the building process. Acoustic specifications might include customized wall or ceiling shapes, like the use of angled acoustic ceiling panels in a theatre.

These specifications might also include:

1) Details of floating doors
2) Sketches for acoustic windows
3) Location and sizes of speakers
4) Preliminary room finish options
5) Size and location of ducts
6) Placement of heating and cooling vents

All of these will have an impact on the user's listening experience.

A. Construction Documentation

If you've developing construction documentation, it's a good idea to provide specifics for any acoustic solutions you've suggested. Many contractors don't take the acoustic properties of materials into account when they're building, so include the required specifications here. For building systems, it can be helpful to specify a maximum decibel level instead of a range. For example, instead of specifying HVAC equipment with a decibel level between 25 and 35, specify a decibel level of 25.

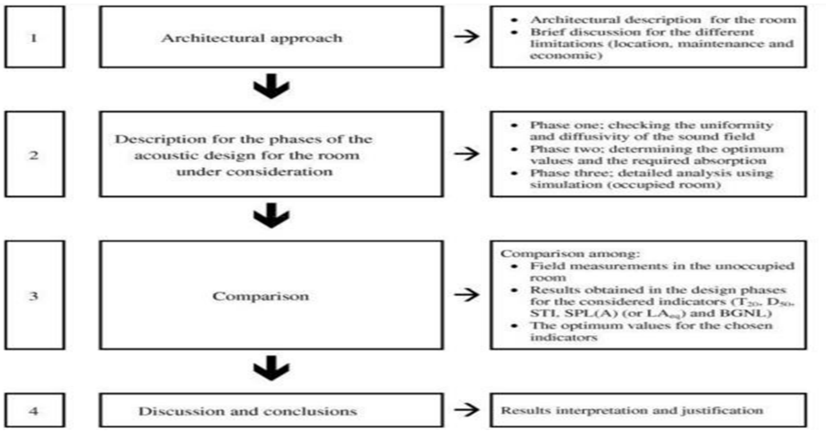
Including soundproofing specifications in the construction documentation is particularly important for noise dampening kits, floor underlayments and in-wall equipment like rails and pads. Documentation might include specific manufacturers, or simply how much soundproofing the materials should provide.

B. Construction Administration

Many contractors aren't experienced with acoustic design. Site visits during construction will help ensure soundproofing materials are being installed correctly, and that building systems aren't too noisy. On-site follow-up is particularly important if you've specified the use of sound isolation rails or decoupling the drywall from the framing as a way to dampen sound. It's common for contractors to screw drywall to the framing and to the noise dampeners, which defeats the purpose of decoupling the drywall.

General Practices for Soundproofing

1) Watch out for sound reflections. These straight, flat spaces tend to reflect or echo sound. Noises tend to sound muddy as a result. These can affect concentration in office spaces, understanding in classrooms and TV viewing in homes.
2) Be aware of the sound of other building systems. HVAC systems in particular can be conflicting noises in a building.
3) To maximize clarity of sound, keep objects out of the way of the desired sound path. High-frequency sounds will be absorbed by obstructions, while low- frequency sounds will bend around them. This all means the sound people hear will be distorted.
4) Be aware of the acoustic properties of furniture that will be placed in the room. For instance, in theatres or auditoriums, many types of seating have absorptive qualities. Even people have absorptive qualities. A presentation in a room with a full audience sounds very different than one in the same room with just a few people.
5) If noise carries from another room or outside, consider ways to dampen the sound. Noise- dampening insulation can help with this. It's also possible to decouple the drywall from the framing.
6) Select floor materials and wall coverings carefully. Different materials provide different sound reflections. There are an increasing number of materials, like microperforated wood, that provide absorptive qualities with a more traditional aesthetic.
7) Consider developing a customized ceiling shape or wall to optimize sound in theatres, arenas or public venues. Acoustic consultants use a variety of tools to create the optimum shape for a listening experience.



C. Design Objectives

The acoustical environment for an auditorium project can be enhanced in following respects (Barron, 1993): The floor area and volume of the auditorium should be kept at a reasonable minimum for adequate loudness in every part of the auditorium. Optimum reverberation characteristics should be provided in the auditorium to facilitate whatever function is required. The sound energy should be uniformly distributed within the room. The room should be free from acoustical defects (distinct echoes, flutter echoes, picket fence echo, sound shadowing, room resonance, sound concentrations and excessive reverberation). First of all, there should be adequate loudness in every part of the auditorium, especially in remote seats. The problems of providing adequate loudness result mainly from the inverse square law and excessive absorption by the audience attenuating the direct sound before it reaches the listener (Egan, 1988). Above all, the floor area and volume of the auditorium should be kept at a reasonable minimum, thus shortening the sound paths. The following table details recommended Volume-per- seat values for various auditoria (Table 1). The volume for the DBS auditorium is 7,324 m3 (The calculation was conducted in SketchUp 8.0). The total number of seats is 800. So, the Volume-per- Seat is 7,324 m3 /800 = 9.2 m3 . The value falls into the range for Concert Halls. For other criteria, the authors conducted building simulation to verify its performance.

XVI. BUILDING SIMULATION

A. Reverberation Time

Reverberation is the persistence of sound in a particular space after the original sound is removed (Meyer, 1978). Reverberation Time (RT) is the time required for reflections of a direct sound to decay by 60 dB below the level of the direct sound (Knudsen, 1932). For acoustic design, RT remains a prime consideration. Historically values between 1.0 and
1.5 seconds have prevailed (Olson, 1967). For the fullness of instrument playing, RT for symphony concert hall is usually higher than 1.5. For a concert hall, the RT should be between 1.4 and 1.7. The choice of appropriate RT for a recital hall is at the same time more difficult but less critical than for a full symphony concert hall. In a small hall, reflections arrive earlier and this means that maintaining satisfactory clarity should be less of a concern. The suitable choice of reverberation time, as it affects loudness, should therefore be less stringent in the smaller hall (Ham, 170 F.A. Last name, S.B. Last name and T.C. Last name 1987). For symphony concert halls, the recommended reverberation time is a function of programme only. Different sources in the literature give different recommendations and the final selected values should be influenced by experience of individual halls, as well as the acoustic intentions of the designers (Beranek, 2004). A shorter reverberation time will enhance musical definition. A long reverberation time will give a more sumptuous sound with better blend but less clarity.

B. Methodology

Odeon 5.0 was used to estimate RTs in the DBS auditorium. The method estimates a mean absorption coefficient, which is inserted in the Sabine, Eyring and Arau-Puchades formulas to give an estimate of the reverberation time (Christensen, 2009). Instead of simply taking the areas of the surfaces and multiplying by the corresponding absorption co-efficient to obtain the total absorption in the room, Odeon also sends out ‘particles’ from the source, assuming diffuse conditions thus reflecting them in random directions, keeping a count on how many times they hit each surface.

Surfaces that are hit very often then carry greater weight in the overall mean absorption coefficient of the room. Surfaces, which are not detected at all in the ray-tracing process, are left out of all calculations and surfaces which are hit on both sides are included twice in the calculation. As a result the estimated reverberation time corresponds to the sub- volumes in which the selected source is located. Note however that if a part of the area of a surface, which is present in the sub-volume, is located outside that sub-volume (e.g. if two sub- volumes share the same floor surface) then area and surface estimates for the statistical calculations may not be entirely correct. In Odeon, two mean absorption coefficients are inserted in the Sabine and Eyring formula to calculate reverberation times. The mean absorption coefficients used for the Arau- Puchades formula are derived in similar ways except that separate values for surface hits, area and the corresponding mean absorption coefficient are calculated as projections onto each of the main axis of the room. The DBS model was based on the architects' design scheme and the principle of material selection is to minimize the sound absorption (Figure). The condition was the auditorium occupied (audience on the wooden chairs); one speaker was located in the center of the stage. The result was shown in Figure 4 (estimated RTs) and 5 (absorption sources). The estimated RT for the DBS auditorium at the mid-frequency (500 Hz) cannot fall in to the range 1.4 - 1.7 seconds. The RTs at the high- frequencies (1000 Hz, 2000 Hz etc.) are even lower than 1.0 seconds. Undoubtedly, the audience absorbed the largest part of sound; the ceiling in the wake of the audience. Considering the absorption due to audience that is hard to change, efforts should be made on the ceilings.

C. Sound Distribution

Averagely distributing sound energy is of importance to achieve a good acoustic design. In an enclosed space, the direct sound decreases in level in the same way as outside. Most of the sound energy we receive in enclosed spaces has been reflected by walls and ceiling surfaces. The geometries of reflection for light and are identical.

The reflected wave behaves as if it had originated from the image position (Schultz and Watters, 1964). But, for sound, much larger surfaces are required owing to the much longer wavelengths involved. An acoustic mirror is a large, plane, massive surface of, for instance, concrete or timber. Sound reflected by one surface will continue to be reflected between the room surfaces, until its energy is removed by absorption. "3D Billiard" in the Odeon software was used to simulate the sound energy propagation and distribution. Figure shows the result. One of outstanding issues is that the upper part of the stage obstructs the sound propagation to the audience. The direct sound (deep red balls) has not yet reached the rear wall, but some balls have been reflected eight times (green balls) in the stage. It means that the outlet of the stage needs acoustic treatment. Reflectors should be considered.

D. Sound Defects

Any time the surfaces of a room focus the sound which is reflected from them, they create spots of high intensity and other spots with low intensity. This is generally undesirable in an auditorium since we want a uniform, evenly dispersed sound to all listeners (Andrade, 1932). The "3D Billiard" again, is used to display sound effects such as scattering, flutter echoes or sound focusing. A number of billiard balls are emitted from the source and reflected by the surfaces in the room. To visualize any sound effect, a large number of billiard balls (10,000 balls) were used. The results are shown in Figure 7. As expected, the real walls of the stage contributed to a sound focusing in the front of the auditorium. The focused sound energy will cause sound distortion, which should be avoided. The main reason is that the real wall is concave. This form should be avoided in auditorium design.

XVII. CONSTRUCTION PRACTICES

A. The Double Stud Wall Assembly

Double Stud framing is the most effective way to decouple a wall. Best at Low-Frequency isolation, the Double Stud wall also offers a structural wall to hang very heavy elements such as cabinets, equipment, speakers, etc. A drawback of this solution is space efficiency. With it, you are basically building two walls, which requires a significant amount of space.

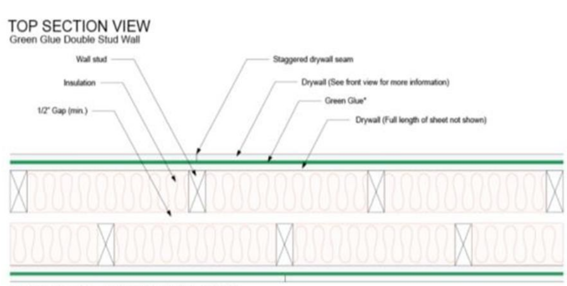


Figure representing assembly of Double Stud Wall

B. *Cavity Wall Construction*

A cavity wall or hollow wall consists of two separate walls called leaves-or skins with a cavity gap in between. The cavity wall construction is an effective method of damp prevention in which main wall of a building is shielded by an outer skin wall, leaving a cavity between the two. The cavity walls are often constructed for giving better insulation to the building. It also prevents the dampness to enter and acts as sound insulation. The cavity extends vertically all along the height of the wall, except at the openings, where it discontinued. The cavity should terminate near coping in case of flat roofs with parapet walls and upto or near eaves level in case of sloping roof. In the foundations, the cavity should start near the ground level or 150 mm below the D.P.C level.

1) *Construction of Cavity Wall:* As you can see in the picture the construction of cavity wall includes 2 walls i.e 2 leaves. outer leaf and inner leaf. The thickness of both the walls is usually same, but in some cases the thickness of inner leaf may be greater than the outer leaf, totally depending upon the structural requirement. Generally 2 slender half brick skins are not as strong as one brick thick solid wall. Therefore to overcome this advantage cavity walls are interconnected by one another by means of wall ties. These wall ties are usually made up of steel. It is mandatory to place 5 wall ties per square meter construction of cavity wall. Maximum horizontal spacing of the wall ties is restricted to 900 mm and vertical spacing is estricted to 450 mm. The width of cavity or the open space between the 2 walls should should range in between 40 mm – 100 mm. During the construction of cavity walls, the openings made for doors and windows should be sealed with damp-proof course, so that there is no entry of moisture through it.
2) *Cavity Wall Insulation:* In order to meet building regulation cavity walls which are built of 100 mm facing bricks and 100 mm blocks has to be well insulated between the two walls. This simple method can increase the thermal insulation qualities of the building. Generally cavity walls insulation is adopted to reduce heat loss through cavity wall. It is generally done in cold areas where the climate is cold during most of the months all around. It prevents the convention and keeps the house warm by making sure less heat is lost through the wall. It is done by insulating the cavity walls by filling the open space between the 2 walls by insulation materials such as polyurethane, glass fiber wool, rock wool panels etc. The insulation of cavity walls is not only done for heat loss but also to make the structure sound proof or to reduce noise transmission. This is done by same method as mentioned above but the insulation material used is different. Here cellulose insulation material is used. It is low conductive material used to make the building sound proof. This type of insulation is generally adopted by the structures such as theatres, auditoriums etc.
3) *Partition Wall:* A partition wall may be defined as a wall or division, provided for the purpose of dividing one room or portion of a room from another. Partition walls may be built of bricks, studding, glass or other such material. Generally, the partition walls are designed as a non-load bearing walls. But it can be load bearing walls. Load bearing partition wall is designed in such a way that they can take the load which acts on it. The partition wall may be constructed on any floors, it may be ground floor or upper floor. It rests on a concrete floor or on beams spanning between main walls in case of the ground floor. In the case of the upper floor, it rests on beams spanning between two columns. The most functional use of partition wall is privacy from consideration of sight and sound both. Partitions may be broadly divided into the following two categories:

a) Those that are made of blocks, slabs and laid in suitable mortars.
b) Those that are made of boards or of sheet materials.

Partitions made by Burnt clay blocks, cement blocks, lightweight concrete blocks, gypsum blocks, Wood wool slabs etc. are of category

- While partitions made from wooden panels, plywood, gypsum boards, lathe and plaster, hard and soft boards,metal sheets etc. are of category
- Requirements of an ideal partition wall
  - It should be as thin as possible.
  - It should be sound proof.
  - It should be light proof.
  - It should be easy in construction.
  - It should be economical.
  - It should provide adequate privacy.

4) *Types of Partition Walls*

Following are the 11 types of partition walls:

a) Brick partitions.
b) Hollow clay block partitions.
c) Cement concrete partitions.
d) Glass partitions.
e) Timber partitions.
f) Metal partitions.
g) Plasterboard partitions.
h) Straw-board partitions.
i) Wood wool slab partitions.
j) A.C. or G.I. sheet partitions.
k) Plastic board partitions.

5) *Cement Concrete Partitions:* When cement concrete is used to make the partition wall is known as cement concrete partition, and it is easy to construct. Cement concrete may be used in the form of hollow blocks or in from of solid thin concrete slab. Hollow blocks are constructed jut like a hollow clay block (1: 3 cement mortar is used in block masonry). Partition of cement concrete may be either precast or caste-in-situ. In the case of precast concrete work, plain cement concrete slabs are prepared in a suitable size and they are secured to the precast poles erected at suitable intervals. Slabs are secured in grooves of the poles. Sometimes, L or T shaped units may be prepared and used to form a partition wall. The thickness of the solid concrete slab is about 40 mm. In the case of cast-in-situ work, concrete walls are casted about 75 mm thick. These walls may or may not be provided with any intermediate concrete pole. If additional stability is required, then reinforcement is provided at the centre of the thickness. This reinforcement should be provided both in vertical and horizontal directions.
6) *Plasterboard Partitions:* When the partition wall made by plasterboard is known as a plasterboard partition wall. Generally, the thickness of the plasterboard is around 50 mm to 100 mm. There are different types of plasterboard are available in the market.
7) *Plasterboard Partition Wall:* Plaster of Paris or gypsum is used for the manufacture of these board. When gypsum is used for the manufacture of the plasterboard then it is called ‘gypsum plasterboard’. This types of plasterboard are mostly used for partition walls as well as for false ceiling work. In order to reduce the density, sawdust or some other fibrous material can be added to the gypsum. Plaster slabs are manufactured in moulds of iron or timber. The surface of the plasterboard may be rough or smooth. If the partition is to be finished with plaster, its face surfaces are manufactured rough. If they are not to be plastered their surface should be finished. Plater board may be fixed in wooden frames provided with grooves.

8) *Advantages*

Following are the advantages of Plasterboard partition walls:

a) It is light in weight
b) Easy of installation
c) Lightproof
d) Easy to handle
e) well in fire-resistant

C. Additions On Walls

1) *Staggered Stud Wall Construction:* A well-built staggered stud wall increases the sound damping of a wall. Basically, this involves staggering 2x4 boards along alternate edges of the top and bottom frame. In existing walls, this includes the addition of furring strips to bring the outside frame to 2x6. When completed, the result is, effectively, two separate wall surfaces in one wall, which keeps sound from reverberating through the studs the way they would in a single stud construction. Its not advisable to use of this wall. Insulation is generally compressed, the top and bottom plates transfer a lot of energy, etc. The red boards are 2x1 furring strips we cut down to run around the perimeter of the wall. Add Soundproofing IB-1 Clips Adding Soundproofing Clips improve sound isolation by decoupling drywall from your room framing. Install Soundproofing Clips directly to ceiling or wall framing using standard screws. Snap 7/8" Drywall Furring Channel into Soundproofing Clip to decrease the conduction contact area and increase the flexibility. Fasten standard drywall following local building codes. The combination of increased resilience and the mass from the drywall create a powerful ally against noise.

2) *Resilient Channel Wall Assembly:* It is not suggested installing Resilient Channel walls. They test well in the lab but when installed in the field they are seriously prone to malfunction. Our purpose for posting this data is so you have a point of reference. Resilient Channel was the standard in soundproofing in the past, but has become obsolete.

XVIII. CONSTRUCTION RECOMMENDATIONS FROM BS 8233:2014

Types Of Wall And Floor Construction For Sound Insulation

A. *Introduction*

Wall and floor constructions which can be done to insulate the sound to the range required is given in this document. The range is taken in Weighted Standardized level difference which is measured in Decibels.

The following guidelines are general guidelines and can change with respect to many external factors which need to be kept in consideration time and again.

B. *Wall And Partitions*

1) *Sound Insulation Range:* 26 to 33 dB

a) 1 mm steel sheet panels fixed to steel frame members to form demountable partition units 50 mm overall thickness. Mineral wool cavity insulation

b) Plywood or wood fibre board 12 mm thick nailed both sides of 50 mm × 50 mm timber framing members spaced at 400 mm centres

c) Paper faced strawboard or wood wool 50 mm thick panels plastered both sides

d) Chipboard hollow panels 50 mm thick tongued and grooved edges, hardboard faced. Joints covered with wood trim

2) Sound Insulation Range: 33 to 37 dB

a) Lightweight masonry blockwork. Plaster or drylining on at least one side. Overall mass per unit area not less than 50 kg/m2

b) Laminated plasterboard at least 50 mm thick fixed to timber perimeter framing, any suitable finish. Approximate mass per unit area 35 kg/m2

c) Timber stud partitions any size timbers greater than 50 mm × 50 mm, 400 mm centres, cross noggins, 9.5 mm plasterboard lining on both sides, any suitable finish

d) Metalstud partition, 50 mm studs 600 mm centres, clad both sides with 12.5 mm plasterboard, joints filled and perimeters sealed. Approximate mass per unit area 18 kg/m2

e) 50 mm lightweight masonry blockwork, plastered both sides to 12 mm thickness or drylined with 9.5 mm plasterboard.

3) *Sound Insulation Range:* 37 to 43 dB

a) Lightweight masonry blockwork, plaster or dry lining on at least one side. Overall mass per unit area not less than 75 kg/m2

b) Metal stud partition, 50 mm studs 600 mm centres, clad both sides with 12.5 mm plasterboard, joints filled and perimeters sealed. 25 mm mineral fibre quilt hung between studs. Approximate mass per unit area 18 kg/m2

4) *Sound Insulation Range :* 43 to 50 dB

a) Masonry wall, joints well filled. Either plaster or dry lining on both sides. Overall mass per unit area not less than 150 kg/m2

b) 100 mm metal stud partition, ‘C’ section studs not greater than 600 mm spacing, not less than nominal 50 mm web depth. Clad on both sides with two layers of plasterboard of not less than 25 mm combined thickness. Mineral fibre quilt hung between studs. Approximate mass per unit area 35 kg/m2

c) 75 mm × 50 mm timbers framing using staged studs at 300 mm spacing with 25 mm stagger forward and back. Frame clad with two layers of 12.5 mm of plasterboard on both sides. Mineral fibre quilt hung between studs. Approximate mass per unit area 36 kg/m2

d) 50 mm × 25 mm timber stud partition to form a 25 mm cavity, clad on both sides with minimum 38 mm wood wool slabs having their outer faces screeded or plastered

e) Solid autoclaved aerated concrete block 215 mm thick plaster or dry lined finish on both sides, blockwork joints well filled. Overall mass per unit area not less than 160 kg/m2.

5) *Sound Insulation Range:* 50 to 54 dB

a) Two separate frames of timber studs not less than 89 mm × 38 mm, or boxed metal studwork with 50 mm minimum web depth Studs at 600 mm maximum centres. A 25 mm mineral wool quilt suspended between frames. Frames spaced to give a minimum 200 mm overall cavity. Clad on outside of each frame with a minimum of 30 mm plasterboard layers (for example 19 mm plus 12.5 thickness). Approximate mass per unit area 54 kg/m2

b) Either in-situ or precast concrete wall panel not less than 175 mm thick and not less than 415 kg/m2. All joints well filled

c) Brick wall nominal 230 mm thickness, weight (including plaster) not less than 380 kg/m2 . Plaster or dry-lined finish both sides. Brickwork joints well filled)

d) 'No fines' concrete 225 mm thickness, weight (including plaster) not less than 415 kg/m2 . Plaster or dry-lined finish both sides

e) Cavity lightweight aggregate block (maximum density of block 1600 kg/m3) with 75 mm cavity and wall ties of the butterfly wire type. Dry lined finish on both sides. Joints in blockwork are well filled. Overall mass per unit area is not less than 300 kg/m2

f) Dense aggregate concrete block cavity wall with 50 mm cavity and wall ties of the butterfly wire type. Dry lined finish on both sides. Joints in block work well.

6) *Sound Insulation Range :* 54 to 60 dB

a) Two separate frames of timber studs not less than 100 mm × 50 mm spaced at 600 mm maximum centres. A 50 mm mineral wool quilt in each frame between studs. Frames spaced to give a minimum 300 mm overall cavity. Each frame clad on outside with three layers of 12.5 mm plasterboard nailed to framing. Approximate mass per unit area 51 kg/m2

b) Two separate frames of boxed 'C' section galvanized nominal 150 mm steel studs 100 mm apart with a 400 mm overall cavity. 50 mm mineral wool quilt fixed to the back of one frame each frame clad on the outside with three layers of 12.5 mm plasterboard by self drilling or tapping screws. Approximate mass per unit area 47 kg/m2

c) Solid masonry with an overall mass per unit area of not less than 700 kg/m2 fully sealed both sides

d) Dense aggregate concrete block solid wall 215 mm thick plaster finish to both surfaces. Overall mass per unit area not less than 415 kg/m2

e) Cavity lightweight aggregate block (maximum density of block 1600 kg/m3) with 75 mm cavity and wall ties of the butterfly wire type. Plaster finishes on both sides. Joints in blockwork are well filled. Overall mass per unit area not less than 300 kg/m2

f) Dense aggregate concrete block cavity wall with 50 mm cavity and wall ties of the butterfly wire type. Plaster finishes on both sides. Joints in blockwork are well filled. Overall mass per unit area not less than 415 kg/m2

C. *Floor Construction*

1) *Sound Insulation Range :* DnT,w = 49 to 54 dB

a) A concrete floor having mass per unit area not less than 365 kg/m2 , including any screed or ceiling finish directly bonded to the floor slab; together with a floating floor or resilient floor covering equivalent to rubber or sponge rubber underlay or thick cork tile (for example carpet and underlay or sponge rubber backed vinyl flooring)

b) A solid floor consisting of,

- A solid slab; or
- Concrete beams and infilling blocks; or
- Hollow concrete planks; together with a floating floor. A ceiling finish is required for a beam and block floor. In each case the slab should have a mass per unit area of at least 300 kg/m2 , including any screed or ceiling finish directly bonded to it.

Where a floating floor is laid over a floor of beams and hollow infill blocks or hollow beams along the top of the structural floor, it should be sealed and levelled before the resilient layer is put down. It is also essential to have due regard for conduits and pipework which should be laid and covered so as to prevent any short circuit of the floor's isolating properties. If precast units are used as a structural floor, it is essential that the joints are filled to ensure that the sound insulation performance is maintained. The resilient material is laid to cover completely the structural floor and turned up against the surrounding wall along all edges. The resilient layer is usually of mineral fibre, or a special grade of expanded polystyrene. When the screed is laid, it is important that none of the mix finds its way through the resilient layer to the structural floor, as this will short circuit the isolation between the two decks and significantly reduce the sound insulation *c)* A floor consisting of boarding nailed to battens laid to float upon an isolating layer of mineral fibre capable of retaining its resilience under imposed loading. With battens running along the joists, a dense fibre layer can be used in strips. The ceiling below to be of metal lath and plaster not less than 29 mm thick, with pugging on the ceiling such that the combined mass per unit area of the floor, ceiling and pugging is not less than 120 kg/m2. This construction will only give values for DnT,w of 50 to 53 dB, and a value for L' nT,w of 75 Db

d) A floor consisting of 18 mm tongued and grooved chipboard on 19 mm plasterboard laid on battens running parallel to the joists and supported on 25 mm thick mineral wool of about 90 kg/m3 to 140 kg/m3 density; 100 mm of fibre absorbent (as used for insulation in roof spaces) laid between the joists on top of the plasterboard ceiling

e) A floor consisting of 18 mm tongued and grooved chipboard on 19 mm plasterboard floating on a 25 mm thick mineral wool layer of about 60 kg/m3 to 80 kg/m3 density; this on a 12.5 mm plywood platform; 100 mm of fibre absorbent laid between the joists on top of the plasterboard ceiling.

2) Sound Insulation Range: DnT,w = 32 to 36 dB

Timber joist floor consisting of 22 mm tongued and grooved floor boarding or equivalent fixed directly to floor joists. Ceiling of 12.5 mm plasterboard and skim with no floor covering.

XIX. PROPOSED IDEOLOGY / MODEL

Much focus has been given to all the aspects right from the start, how different factors are responsible on the different sound quality parameters, and arriving for at the most accurate and appropriate methodologies has been extensively discussed. The design methodologies, construction practices available and some the recommendations from the British Standard Codes giving more emphasis on Indian Codal Provisions.

For the purpose easy distinction the buildings have been classified based on their purpose and usage into three categories

A. High Priority Buildings

Under this category all the buildings such as Conference halls, Auditoriums where Acoustics are a prime factor are included in this category. And the other requirement is that they are still in the planning stage. In such a case importance has to be given to all the stages i.e. site selection, Design Methodologies, Acoustic Materials, and Construction conforming to the recommendations and appropriate standards like the BS:8233-2014 and IS: 2526 – 1963.

Emphasis to be given on I, II, III, IV, V, VI sections already discussed.

B. Relatively Less Important

All those buildings where a decent amount of acoustic parameter is sufficient are included in this category. The other requirement is that the building is still in planning stage, in a already specified location/site. Such a case requires little focus on the sound quality parameters. Though it is essential to maintain the parameters conforming to the codal provisions. Some stages such as a sophisticated design especially for acoustic design might not be recommended seeing the budget constrains. But however appropriate acoustic materials and construction practices conforming to the codal provisions is recommended.

Emphasis given to II, V, VI sections that are already discussed.

C. Constructed Buildings But Require Modifications / Acoustic Treatment

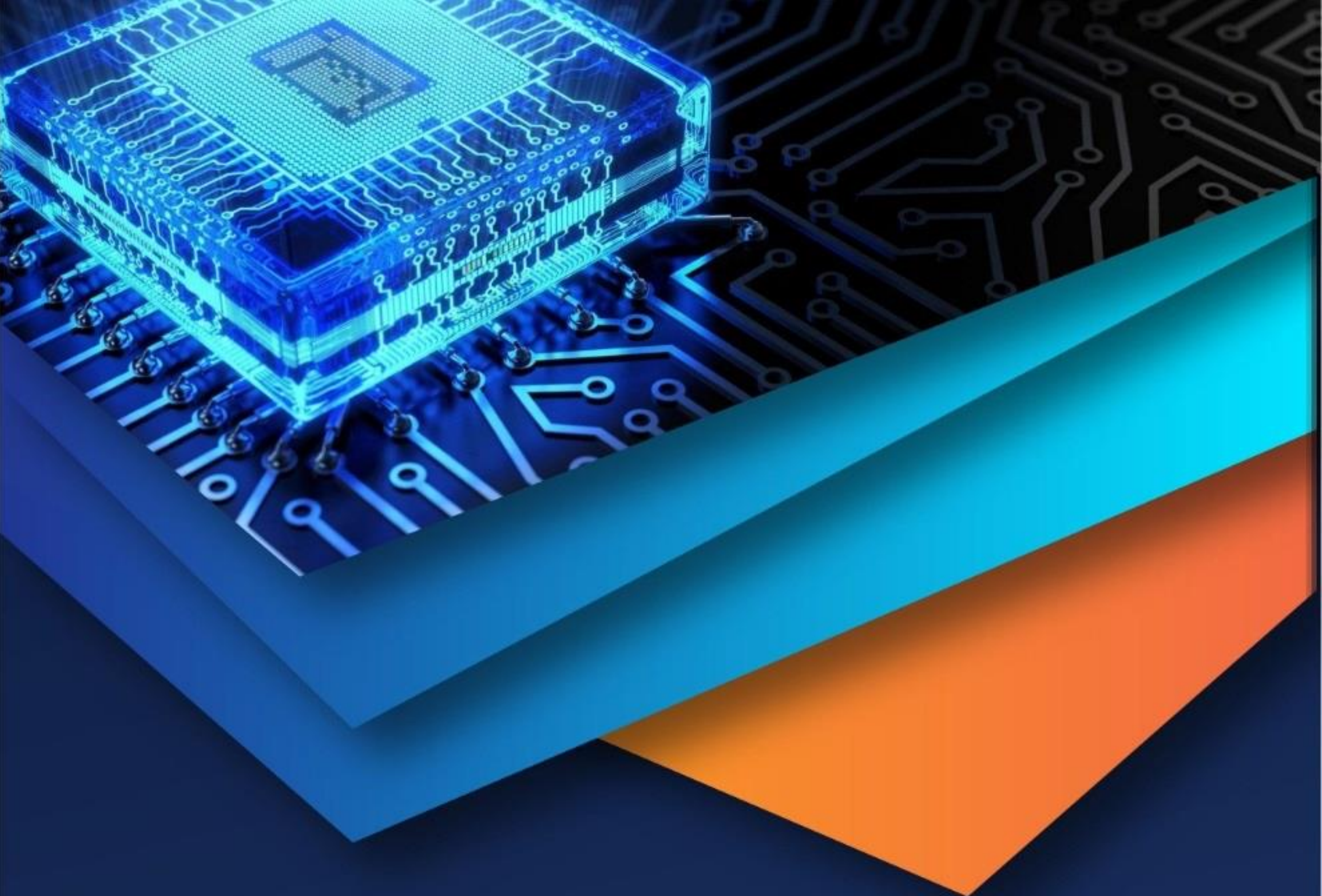
As the name implies all those buildings, which are not given acoustical importance during their construction stage but need some acoustical treatments for the optimum values of sound quality parameters such the room could be considered as a acoustically sound room. In such a case importance has to be given in determining the sound quality parameters and their optimum values for the a sound functioning.

Emphasis to be given to I, II sections that are already discussed.

The ideology mentioned above can be used a guiding parameter which provides us with necessary recommendation and guidelines in adopting either construction practices or acoustic treatment so as to ensure acoustically sound room. The parameters considered for this classification as mentioned earlier involve the building usage and as well providing a substantial importance to the economy and feasibility. Any of the practices could be adopted based on the requirements and should be conforming to the codal provisions. This ideology as a means provides the necessary clarity for a Civil Engineer, such that the building designed, constructed is not only structural strong but also acoustically sound.

BIBILOGRAPHY

[1] Statistical Comparison of Reverberation Time – Carolina Reich Marcon Passero, Paulo Henrique Trombetta Zannin
[2] Reverberation Time Measuring Methods - K. Jambrosic, M. Horvat and H. Domitrovic Faculty of EE and Computing, Unska 3, Department of Electroacoustics, HR-10000 Zagreb, Croatia
[3] Sound Absorption by a Helmholtz Resonator – M. A. Mironov
[4] Spectrographic Study on a Echo – IEEE Archived Research Paper
[5] Acoustic Properties of Materials - ICA(International Commission for Acoustics)
[6] Acoustic Properties of Building Materials - Federal University of Technology, Akure
[7] Acoustic Material Data - www.cern.org
[8] IS:2526 – 1963 Code of Practice for Acoutical Design of Auditoriums and Conference Halls
[9] British Standards BS 8233 : 2014 Sound Reduction and Noise Insulation in Buildings



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