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Architectural Acoustics for learning space

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Abstract - In general, the major acoustical problem arises due to the clubbing of two spaces of different acoustical needs. This research paper focuses on analyzing the complexity of the acoustical requirement of clubbed rooms. To research that a live case study has been performed. It begins with the acoustic survey of classrooms around the central multipurpose, Rangasthala at Reva University, Bengaluru. After extensive study, it's been found that the existence of multipurpose hall affecting adversely on the learning quality of classrooms around it. Room acoustical parameters such as Reverberation Time, Ambient Noise found to be deficient and affects the efficiency of learning in these classrooms. As a result, students find it difficult to concentrate while the Rangasthala is active, and the teachers also spend a tremendous amount of energy in teaching lessons. This paper also attempts to come up with efficient and economical solutions to have optimized acoustical quality for both the spaces simultaneously.

Keywords – Ambient noise, Attenuation, Damping, Decibel, Diffusion, Frequency, Noise reduction, Reverberation time, Sound level.

I. INTRODUCTION

Acoustics is a multidisciplinary subject related to physics, engineering, architecture, music, and neurology. It impacts various aspects of human life, such as education, health, art, culture, finance, and business. Acoustics deals with the quality of sounds and the elimination of noise for a space to make speech clarity and pleasant musical experiences. It enhances concentration and improves learning. Acoustics is an important issue at learning places as it affects the productivity of teachers, the learning abilities of students, and the health of students and teachers both. If a sound is above the tolerance level of an individual, it is classified as noise. Evidence suggests that learning outcomes for children in Indian schools are far below corresponding class levels in other countries. Program for International Student Assessment (PISA, 2012) places India second from bottom out of 73 countries. Besides that, a national survey conducted by the Annual status of education report (ASER, 2012) also corroborates the low levels of learning by children in schools.

II. BACKGROUND

Acoustics is fundamentally important to learning environments as learning is intrinsically linked with communication, and aural (sound) communication is acoustics. Teaching and learning are about concentration, and external noise is a major distracting factor in education.

According to World Health Organization (WHO) for a steady continuous noise, the noise level in outdoor living areas should not exceed 55 dB (A) to prevent the majority of people from being seriously annoyed.

The noise level should not exceed 50 dB (A) to protect the majority of people from being moderately annoyed.

The WHO also suggests that internal noise levels in dwellings during the daytime should be limited to 35 dB (A) to allow casual conversation.

In India, acoustics is considered the least important compared to other factors in the building. One of the examples where the acoustics has been given the least priority in learning is the Rangasthala at Reva University, a multipurpose hall surrounded by classrooms. We felt complication of the situation, and studied extensively to figure out the problems and came up with possible solutions.

Aim:

To maintain qualitative acoustics for two distinctive activities, cultural and learning space without affecting each other.

Objectives:

- To understand the necessity of acoustical correction in the classroom and its relationship with learning spaces.
- To study the optimal acoustical correction or treatment needed for clubbed rooms.
- To achieve an acoustical solution for a clubbed room with different acoustical solutions.

Scope:

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To enhance the deprived an ignore component of any teaching and learning environment through a live case study. It would also help in achieving adequate solution for the clubbed spaces, (i.e.) learning and multipurpose activities happening simultaneously.

III. LITERATURE CASE STUDY

BRAZILIAN PUBLIC SCHOOL – CLASSROOM'S ACOUSTICS

This literature study aimed to study the acoustical quality of classrooms standard 023 from FUNDEPAR, the Institute of Educational Development of the Parana state [1]. There are several studies of classroom acoustical quality [2, 3, 4, 5, 6], and this one will consider only the 023 standardized classrooms. The standard for this case has been compounded by a central circulation aisle with two classrooms on each side. Each edification, thus, has four classrooms. The aisle has a 6-m high zenithal skylight. The central aisle and the classroom walls are compounded by non-absorbing materials, which have increased the reverberating time in the classrooms.

Fig. 1 Central Aisle.

Room	dB (A)	NC
Library	35-45	30-40
Classroom	40-50	35-45
Aisle	45-55	40-50

Table -2 Noise levels for classrooms according to NBR – 10152. Lower value is for comfort, upper level is acceptable

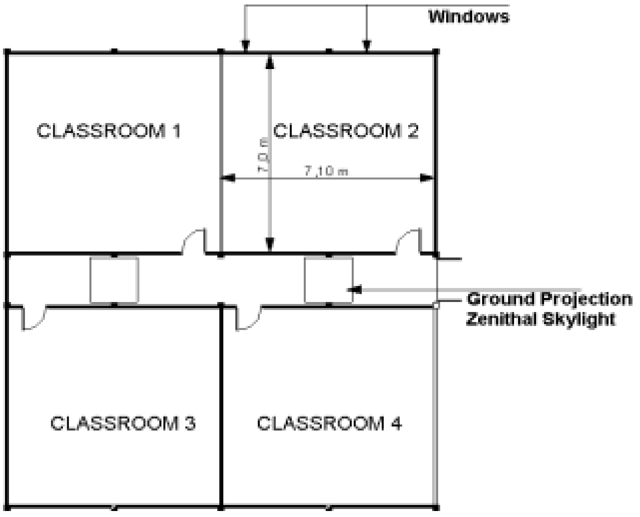

Fig. 2 Layout of 4 classrooms.

The Brazilian Standard NBR-10152 [7] states optimum reverberating times for several internal environments, along with the comfort and acceptable equivalent noise levels for these environment

Purpose:

- The goal of this study is to study the quality of the classrooms standard 023. In order to perform this, measurements of the reverberating time in several classrooms under different occupational ratios have been carried out, as well as equivalent noise level measurements. These levels have been compared to the Brazilian Standard 10152, which states about the comfort noise levels for different environments. The measurements have been done in only one school, because the same standard is applied to all of them.
- A second goal is to gather information on the perception of the students and teachers of the standard 023 by means of a questionnaire. Two models have been elaborated: one for the students and one for the teachers

For the reverberating time, the noise source has been placed where the teacher normally speaks. This measurement has been done in one of the classrooms under three conditions:

1. empty classroom (during a holiday),
2. 20 pupils and
3. 40 pupils (full).

An equivalent noise level measurement has also been carried out in the aisle with three full classrooms, and the background equivalent noise level has been measured in an empty classroom with all the other three under normal activities. The frequency range of the measurements has been from 100 Hz to 4000 Hz. The microphone has been positioned in three points inside the classroom, and for each position three measurements have been done.

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For the second objective of this study, two models of questionnaires have been elaborated, for teachers and students. A total of 15 teachers and 185 pupils have been interviewed.

Results:

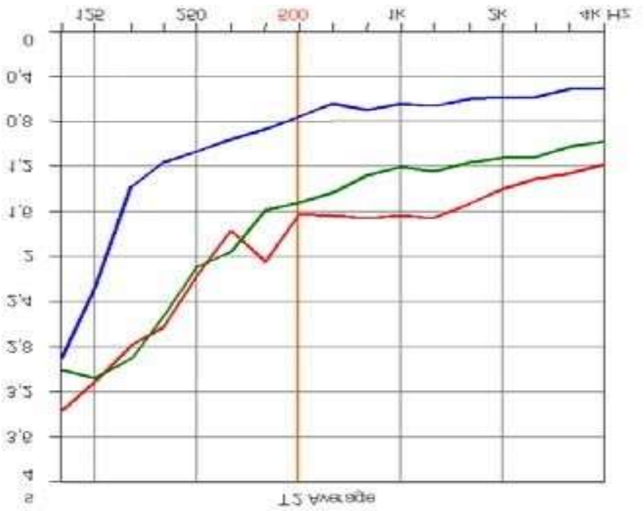


Figure 2 – Reverberating time for classroom 1 under empty, 20 pupils and 40 pupils' conditions.

The above values are the averages of all measurement points inside the classroom. For the frequency of 500 Hz the reverberating times were:

- Empty room: 1.65s;
- 20 pupils: 1.15s;
- Full room: 0.76s.

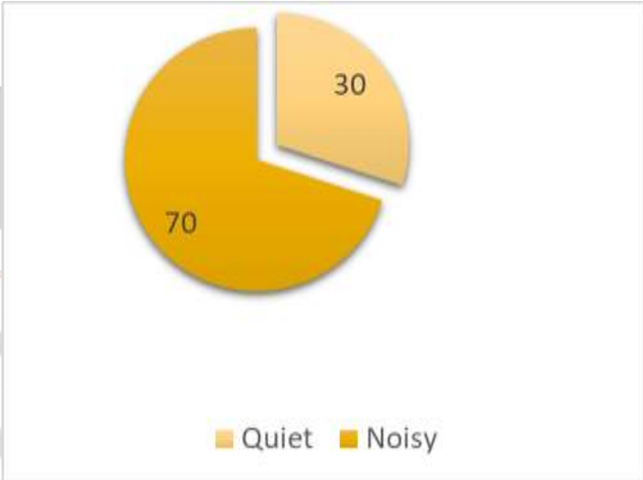
The reverberating time decreases with the increase in the number of people in the classroom. Under full room conditions, the reverberating time is close to the optimum reverberating time according to the Brazilian Standard NBR10152. Also, the World Health Organization recommends a reverberating time of 0.6s for a frequency of 500 Hz. The equivalent noise level measurements in the aisle have revealed a value of 70.3 dB (A). The Brazilian standard NBR-10152 states that circulating aisles should be in the 45 – 55 dB (A) range. The measurement of the empty classroom with all the other three under normal activities have shown a value of 63.1 dB (A) to 63.3 dB (A). The NBR10152 states that the comfortable background noise level for a classroom should be 40 dB (A), whereas the acceptable background noise level should be 50 dB (A).

For the questionnaire evaluations, teachers and pupils were asked to answer some questions by using an intensity scale, ranging from 0 (none) to 6 (extreme). When asked about the noise sources that caused annoyance, teachers have answered that the pupils of other rooms were the main source of annoyance.

	Other classroom students	Other classroom teachers	Noise from the same classroom	Traffic noise
Weighed answers	4.1	3	1.9	1

Table 3 – Weighted answers for the question "What noise sources bother you?"-

Table 3 shows that the main noise source is the noise generated in neighboring classrooms. Traffic noise is not a problem since the school is in a calm area of the city. The pupils were asked about their impression of the classroom regarding the external noise. A total of 30% of them have answered that they do not consider their classroom a noisy environment, whereas 70% of them have answered that they do consider their classroom a noisy environment



The classrooms belonging to the Standard 023 do not satisfy the acoustical requirements of the Brazilian Standard NBR10152. The reverberating time of the classrooms is high, reaching 1.65s for an empty room. The background equivalent noise level surpasses 60 dB (A) in an empty room, considering normal activities in the three other classrooms. And it surpasses 70 dB (A) in the aisle. All these results agree with the dissatisfaction degree of teachers and pupils, according to a questionnaire applied to them. The Standard 023 should be reviewed in order to improve the acoustical quality of the classrooms, such as adding absorbing materials on ceilings.

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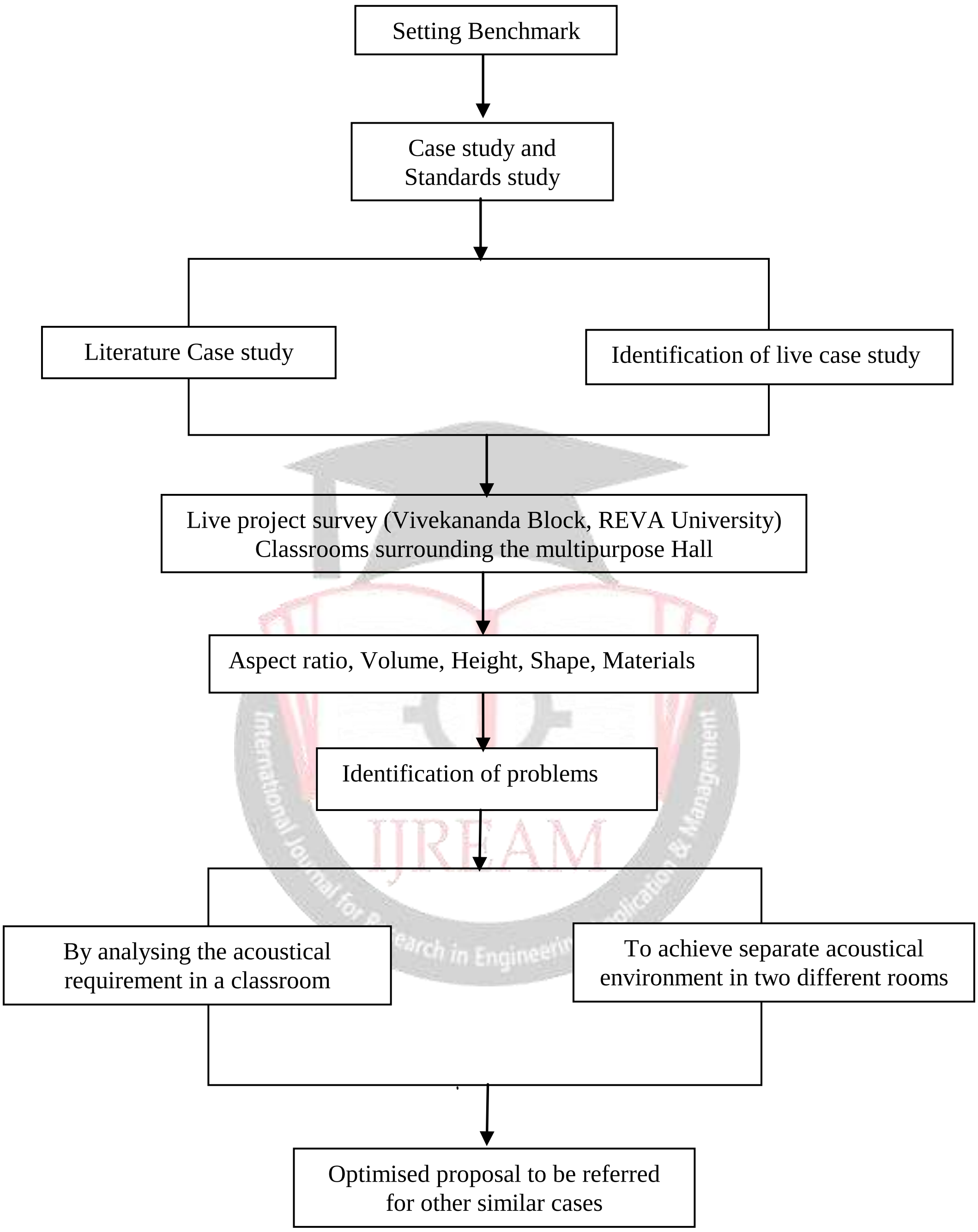
IV. METHODOLOGY

The research begins with the study of classrooms in foreign countries with better sensitivity towards classroom design. Followed by analyzing the flaws in learning classroom of specific live example. Further to categorization of several issue. At last thorough discussion for optimized proposal for acoustical correction so that clubbed spaces with different acoustical need s should not be affected by each other.

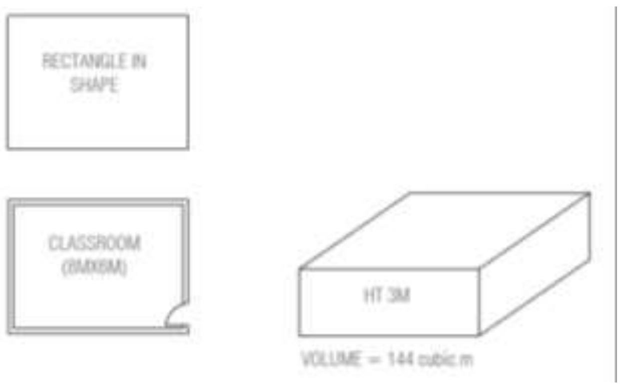


V. PRIMARY CASE STUDY

LOCATION: RANGASTHALA IN VIVEKANANDA BLOCK, REVA UNIVERSITY

It is G+8 academic block with an open auditorium at the Centre.

Survey is being conducted regarding how the noise generated in Rangasthala is affecting the surrounding classroom.



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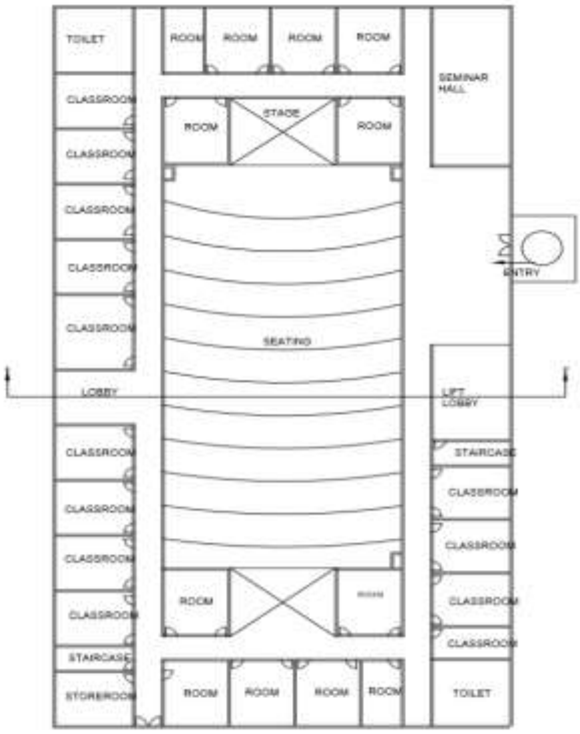
Capacity of 95 students

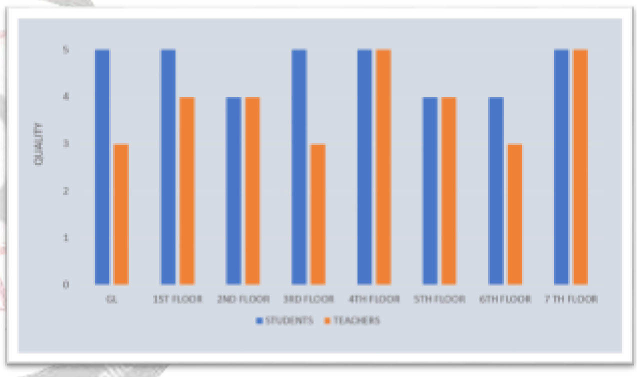
Corridor space

Rangastala stage

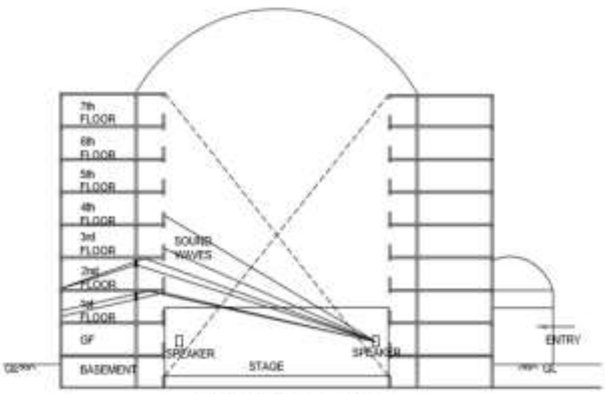


PLAN

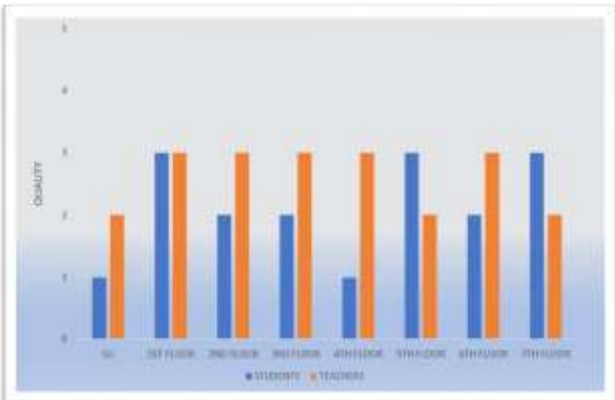
Observations:



Graph 1 Showing the survey result for "How important is acoustics in learning space"



SECTION AA'



Graph 2 showing the survey result for "Quality of listening with a performance in Rangasthala"

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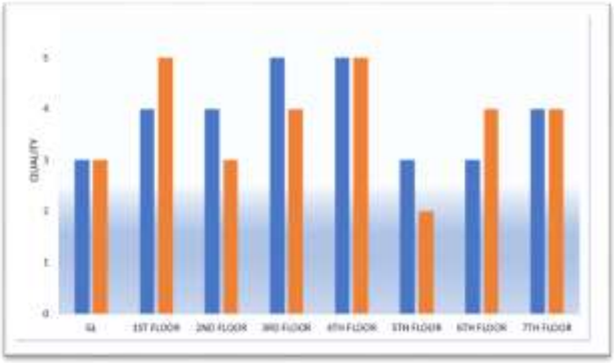

Graph 3 Showing the survey result for "Quality of listening without a performance in Rangasthala"

VI. PERFORMANCE ANALYSIS

For the questionnaire evaluations, teachers and students were asked to answer questions by using an intensity scale, ranging from 0(none) to (extreme).

- The sound generated during performance in Rangasthala is mostly affected to first five floors, least affected to the rest of the floors and in 8th floor it is negligible.
- The quality of listening with a performance is 3.
- Quality of listening without a performance is 4.
- It is observed that nobody liked to shift Rangasthala to some other place, because it is a matter of pride for them.
- Teachers are investing more energy to make students understand during a performance in Rangasthala.
- There is less disturbance from the corridors.

Based on analysis one can conclude that the Rangasthala is functioning properly and doesn't requires acoustical attention. But at the same time the learning spaces are getting hampered due the activities happening at Rangasthala, hence, it is necessary to treat classrooms and surrounding corridors with proper acoustics.

Proposals:

1. TREATMENT OF CEILING: It was observed from the survey that the ceiling over the corridor plays a key role in directing the sound (Noise) from the Rangasthala to the classroom. Hence, it is essential to treat the problematic ceiling (Fig. 1) to check on the unwanted reflections. Hence, absorptive materials such as spray Foam of NRC (0.8)

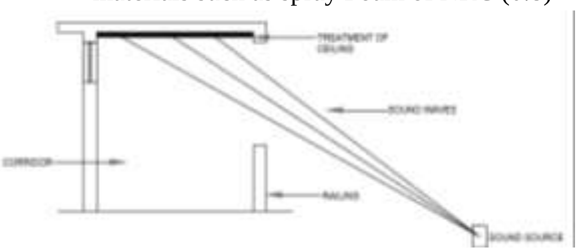

Fig. 1: showing the treatment on ceiling by spray foam.

2. FILTERING THE NOISE THROUGH THE VENTILATOR: One of the major openings in the class rooms are the continuous horizontal openings. These openings facilitates ventilation and provide abundance of natural light inside the classroom. But the same opening also causing problem on unwanted reflections. (Fig. 2) Hence, absorptive materials such as mineral wool as a louver could be added which will not obstruct light and ventilation and also can be used as absorbent.

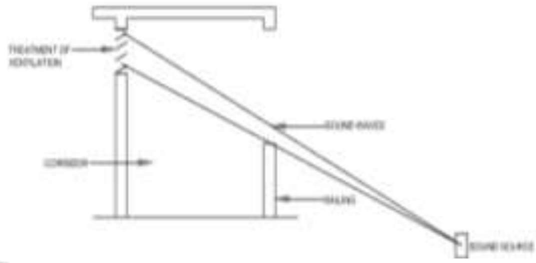

Fig. 2: showing the louvers from ventilators to obstruct noise From outside.

Fig 1. Showing installation of spray foam on ceiling.

Fig 2. Mineral wool.

VII. CONCLUSION

Theoretically, segregation of clubbed spaces for 2 different acoustical requirement could be done in 2 possible ways.

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1. Matching the RTs for both the space that means you have to maintain recommended RT whichever is low.
2. Acoustical isolation for both the spaces.

In the 1st case, matching RT will be expensive and will be spending on maintaining equal RT for no reason. It is better to follow 2nd option by isolating both the spaces of different RT requirement, it requires understanding of the source of sound, how it propagates and how sound is affecting space. We need to identify places to be treated to achieve desired acoustical quality.

VIII. APPENDIX

SOUND: It is a vibration that typically propagates as an audible wave of pressure, through a transmission medium such as gas liquid or solid.

FREQUENCY Vs WAVELENGTH

$$c = \upsilon \times \lambda$$

$$\upsilon \propto \frac{1}{\lambda}$$

Where, υ = Frequency

λ = Wavelength

c = Velocity of Sound (c = 343 m/s at 20°C)

REVERBERATION TIME: The interval between the initial direct arrival of a sound wave and the last audible reflected wave.

RT_{60}: It is the amount of time it takes for the reverberant energy in an enclosed space to drop by 60 dB from its initial, steady-state value after the original sound has ceased.

SABINE'S FORMULA:

$$RT60 = \frac{0.161V}{\Sigma S\alpha}$$

Where:

RT60 = reverberation time (sec)

V = room volume (m³)

S = surface area (m²)

α = absorption coefficient of material(s) at given frequency.

AMBIENT NOISE: It is any sound other than the sound being monitered. It is a form of noise pollution.

ATTENUATION: It is a measure of the energy loss of sound propagation in media.

DAMPING: It is the process of making machinery quieter by damping the vibrations to prevent them from reaching the observer.

DECIBEL: A unit to measure the intensity of the sound by comparing it with a given level on a logarithmic scale.

DIFFUSION: It is the efficiency by which sound energy is spread evenly in a given environment.

HEARING RANGE**:** 20-20000 Hz (for a healthy young person)

NOISE REDUCTION**:** It is a process of removing noise from a signal**.**

SOUND LEVEL: It is usually defined in terms of SOUND PRESSURE LEVEL (SPL). SPL is a ratio of absolute, sound pressure and a reference level. It is measured in dB

SOUND TRANSMISSION LOSS: It is the number of decibels that are stopped by a wall or other structure at a given frequency.

DESIRABLE REVERBERATION TIME:

The optimum reverberation time for an auditorium or room of course depends upon its intended use. Around 2 seconds is desirable for a medium-sized, general purpose auditorium.

Educational buildings	Recommended design sound level DB(A)		Recommended RT
Type of occupancy/activity	Satisfactory	Maximum	RT60
Teaching spaces Primary Schools	35	45	0.4 to 0.5
Teaching spaces Secondary Schools	35	45	0.5 to 0.6
Audio Visual areas	30	35	0.6 to 0.8
Art Studios	40	45	0.6 to 0.8

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Computer Rooms	40	45	0.4 to 0.6
Conference Rooms	35	40	0.6 to 0.7
Corridors & Lobbies	45	50	0.6 to 0.8
Libraries	40	45	0.4 to 0.6
Music Practice Rooms	40	45	0.7 to 0.9
Music Performance Room	40	45	1.0 to 1.5

Table 1- Showing recommended sound levels and desirable Reverberation time.

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