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Original Article

Establishing the Reciprocal Interpretation Amidst the Architectural and Acoustic Parameters of the British Colonial Church by Assessing its Acoustic Parameters

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Abstract - *This study examines the interdependent relationship between architectural parameters and acoustic performance of British Colonial churches through systematic measurement of both by exploring architectural features such as spatial geometry, materiality, structural features, decoration and their significant effect on acoustic parameters like reverberation time, sound clarity, and speech intelligibility in these buildings. The results add to architectural acoustics and cultural heritage conservation practice by presenting empirical evidence on the acoustic performance of colonial church buildings and its effect on restoration works and new church designs that will achieve historical authenticity while maintaining optimal acoustic performance. It is interdisciplinary and entails architectural history, acoustic engineering, and cultural heritage scholarship to understand how built environments are associated with hearing perception in religious settings. A sound and harmonious experience for congregational purposes such as worship, choir, and other activities is constructed based on this acoustical assessment. This includes varied field measurements, simulations, and objective determination of acoustical factors – Reverberation Time (RT), Sound Transmission Index (STI), and Background Noise (BN) measured at points in the church. Recommendations are provided for an equilibrium of acoustics and architecture, considering the church's historical and cultural limitations and sanctity. This is done by establishing optimum acoustics and boosting a spiritual community among its congregation.*

Keywords - *Church Acoustics, Reverberation, Background Noise, Speech Transmission Index and Congregation.*

1. Introduction

The increase in the necessity for comfortable acoustical conditions demands an analysis of how diversified sound messages can synchronize in church buildings and how the existing church conditions may be adopted for comfort in acoustics. The acoustics of a worship place profoundly impact the communicational – verbal, musical, and emotional – worship. This is mainly determined by its architecture and the geometric shape, the material used, and the people's occupancy at any given time (Babak, 2022).

The acoustical condition of ancient religious structures is a fundamental interface between architectural heritage and functional performance. However, this symbiosis is currently not well established for British Colonial churches in India. These church structures constructed between the 18th and 19th centuries were planned using European acoustic planning methods and building practices. However, high-density urbanization and infrastructural development around these cultural heritage sites have never challenged their modern-day acoustical condition.

A major research deficit concerns how modern-day urban encroachment influences British Colonial churches' original acoustic and architectural design objectives. As most literature has been dedicated to the acoustic properties of medieval European churches and religious architecture today, there has been a recent change within systematic reviews to recognize that whilst indeed much research has been carried out investigating soundscapes within religious heritage buildings, comparatively little empirical research has been undertaken to particularly analyze the unique acoustic issues of colonial-era churches in post-independence urban India. This ignorance is particularly evident in the quantitative assessment, in which external intrusion of noise upon the architectural form-acoustic function, two-way relationship in such heritage structures, as current studies of the acoustic environment of heritage buildings must be charting new directions (Li, Y. et al. 2022).

The problem is illustrated by exploring a 200-year-old British Colonial church adjacent to Chennai's Grand Southern Trunk Road, where the structure is subjected to severe acoustic degradation from varied contemporaneous noise pollution. The juxtaposition of the church to chock-a-block traffic movement on one of India's busiest national highways provides constant low-frequency noise intrusion superimposed over liturgical sermons and interrupting congregational worship, with Chennai city residents and commuters being exposed to noise levels from 74 to 85 dB(A) (Srinivasan, S. et al. 2024). In addition, the overhead Chennai Metro Rail imposes occasional high-intensity noise occurrences, further deleting this church's rectitude and acoustic integrity. To outshine that is the additional noise from aircrafts in the adjacent Chennai International Airport, promoting a multi-source environment that completely alters the church's inherent acoustic character in its most basic definition.

This convergence of transport infrastructure surrounding this old church is symptomatic of a broader urban heritage issue where this colonial structure cannot perform its intended acoustic purpose. The intensity of this problem is marked through the studies and analysis that have detected ambient noise levels in Indian urban silence areas, which are theoretically supposed to fortify the institutional buildings and their ambience to reach as high as 90 dB and day and night time noise levels to be outstanding the legitimate limits (Goswami, S. et al. 2014). The original architectural features—the vaulted ceilings, stone construction, permissible sound-absorbing material, and the judicious placement of windows—were designed to accommodate liturgical acoustics such as biblical sermons, choir singing, and congregational singing. The same features are now leveraged to enhance extraneous noise intrusion, creating an acoustic that obliterates the religious and cultural function of the building.

The research problem widens beyond noise pollution to include the degradation of cultural and religious heritage because the acoustics of these ancient sanctuaries also depict intangible cultural heritage (Ricciutelli, A. et al. 2024).

1.1. Purpose of Study

One cannot control the acoustical field alone by electro-acoustics. The task of the person who controls sound amplification is arduous in churches during sermons (Boren, 2021). Hence, it is intended to study the acoustics of the traditionally old church in Chennai.

1.2. Aim & Objectives of the Study

- This work aims to investigate the dynamism in acoustics inside the churches.
- STIs have to be measured and analytically investigated, along with the impact of background noise conditions, which are influenced by the existing mass traffic flow and the abutting transport facilities (Klepper, 2017).
- To examine the reverberation time, collect detailed architectural data, and critically analyze the materials and their acoustical impact in traditionally old churches (Zamarreno & Galindo, 2024).

1.3. Speech and Music

Architectural acoustics and sound amplification within a structure substantially shape a religious institution's well-being and deliver the Gospel's message with the highest clarity and precision. The congregation sings hymns, psalms, and other liturgical passages as part of the music, and there is also music that is played for the congregation (consisting of elements such as organ voluntaries, choir verses, anthems, and bell choir pieces) (Lonsdale, A.J. And North, A.C. (2011)).

1.4. Importance of Acoustic Design

The congregation, composed of many distinct individuals, will have varying requirements for a good listening experience based on language, age, and other characteristics (Elicio & Martellotta, 2015).

1.5. Architectural Acoustics

The performance of prayer –requires an uninterrupted space without intrusive background noise. Scripture readings and spiritual preaching demands coherence and accuracy in the speaker's voice. Thanksgiving, praises, and hymns are orchestrated through enchantments (Yan et al., 2015). The altar, choir, nave, aisle, and transept, with varied acoustical demands, are interlinked to set out numerous sacraments. The spatial form and the location of the sound regulate the expected acoustical performances of these allied spaces (Autio H, 2021).

1.6. Low-Background Noise

Dynamic range is the difference in interlinking the possible measurements of sound and the obvious background noise level. It should be large enough to serve as a buffer zone. (Omlin et al., 2011). Background noise is often associated with the surrounding external noises (Lim et al., 2008), which is also initiated by internal technical insertions (Xie et al., 2020). Here are the prescribed maximum BNL values that are practically framed and sustainable.

Table 1. Background noise of different spaces

1.	Sound Studio	15 - 20
2.	Concert Hall	20 - 25
3.	Theatre	25 - 30
4.	Cinema	30 - 35
5.	Classroom	35 - 40
6.	Office	35 - 40
7.	Conference Room	40 - 45

https://www.troldtekt.com/product-advantages/good-acoustics/advanced-acoustics/an-introduction-to-good-acoustics/

2. Church Details – The Case Study

Fig. 1 Church interior and exterior views

Standing upright majestically, just on the GST road is St. Thomas Garrison Church, established by the British Colonial Government for their army soldiers in the year 1830, under the approval of the Director of the East India Company. Positioned adjacent to Chennai's prime transit connectivity corridor, which houses the Chennai International Airport, the Metro Transit, and the Chennai Suburban Railway Network, the Grand Southern Trunk road is the paramount concatenation that clinches the Southern and Northern Chennai. Recognized by the Chennai Circle of the Archaeological Survey of India as a heritage monument, this traditional church is constructed using materials shipped mainly from Britain, phenomenally with a bomb-proof roof structure and iron railings running all around that are rust-proof.

Table 2. Architectural measurements

Year	1827
Church Name	CSI St. Thomas (Garrison) Church
Location	St. Thomas Mount
Seating Capacity	600
Volume (ft³)	289674
Area (ft²)	8778
Width (ft.)	66
Length (ft.)	133
Height (ft.)	33

Being a definite reflection of the St. Clement Danes located in London, the compound was constructed using bricks, mortar, and limestone with rust-proof iron railings upcycled from Tippu Sultan's discarded weapons, muskets, barrels, and pikes. The church has 20 windows, five doors, and Roman iconic pillars in the entrance verandah, a large prayer hall, a false ceiling with teak wood, a Bible, and a pipe organ. To abide by the Airport Authority of India (AAI) regulations, the multilevel church steeple with three tiers was cropped by a foot. It existed with a single spire, with the establishment of the airport in 1910 and land donated by the former Governor of Madras to serve primarily as a military base during World War II (History of Indian Airforce, 2023).

Fig. 2 GST road with metro rail

3. Methodology of Evaluation

3.1. Experimental Method - Sound Level Meter (Nor 132)

- The Reverberance Test was conducted using a Sound Level Meter, according to the ISO 3743-2 standard.
- The instrument is configured to measure reverberation time using impulse excitation (pistol shot, exploding paper bag or exploding balloon, which generates enough sound energy in the frequency). As soon as the instrument sees an incoming level in each octave or 1/3 octave band, it will initiate logging with time resolution at 5 ms. The instrument is calibrated before and after every measurement.
- A piston phone, which generates 114 dB, is used for calibration.

Fig. 3 Sound level meter NOR 132

3.1.1. Measurement of Background Noise

The existing Sound Pressure Levels in interior and exterior conditions were measured day and night in unoccupied conditions using the NOR 132 sound level meter positioned at 1.2 m from the ground. The observation was done for 1.5 minutes with an interval of a second to understand the impact of the external noises inside the church premises.

3.1.2. Measurement of Reverberation Time

A pertinent reverberation time is obtained: the reverberation time must be knitted to the specific room and its ordained objective, and an intelligently flat and uniform frequency spectrum of the reverberation time. The sole exception is the classical music concert halls, where the reverberation time can be greater towards the lower frequencies. There has been a myriad of proposals that interrelate the room size, function, and resulting reverberation time. **(**Furrer, 1948)

W. Furrer provided recommendations for appropriate Reverberation Times (RT) in various types of rooms to optimize acoustics, especially in the context of speech intelligibility and music clarity. His values are commonly referenced in architectural acoustics. Here is a summary of W. Furrer's recommended reverberation times for different room uses (typically given at mid frequencies such as 500–1000 Hz):

Table 3. Optimum RT values

Room Type	Recommended RT (RT60)
Classrooms (up to 200 m³)	0.6 – 0.8 seconds
Lecture Halls (200–500 m³)	0.8 – 1.0 seconds
Conference Rooms	0.6 – 0.9 seconds
Opera Houses	1.2 – 1.6 seconds
Concert Halls (for orchestral music)	1.8 – 2.2 seconds
Theatres (speech-focused)	1.0 – 1.2 seconds
Worship Spaces/Churches	1.5 – 2.0 seconds (up to 3.5s for large)

Note**:** These values vary depending on room size, material finishes, and purpose. Furrer emphasized balancing reverberation to support clarity (for speech) or richness (for music) without causing muddiness or echo. Below is the measured RT value using the sound level meter at various points in the church premises.

Table 4. In situ RT measurement

P	Frequency (Hz)							Avg. RT
	125	250	500	1000	2000	4000	8000	
1	3.41	3.03	3.00	2.36	2.04	1.75	1.35	2.42
2	3.36	3.06	2.93	2.36	1.97	1.80	1.35	2.40
3	3.34	3.28	2.97	2.37	2.10	1.82	1.44	2.47
4	3.43	3.09	2.91	2.45	2.11	1.85	1.46	2.47
5	3.55	3.12	3.07	2.44	2.09	1.83	1.46	2.51
6	3.21	3.09	3.01	2.43	2.05	1.76	1.40	2.42
7	3.47	3.06	3.10	2.45	2.08	1.82	1.43	2.49

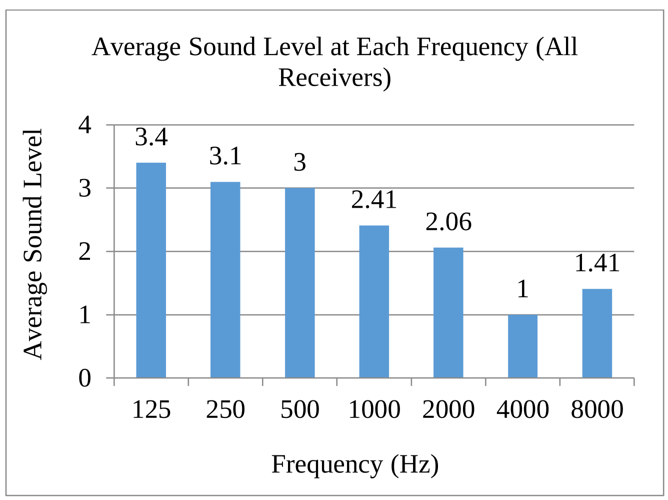

Fig. 4 Bar graph depicting the in situ RT (s)

3.2. Computer Simulations

- ODEON - Acoustics Simulation Software
- Considering the room geometry and surface properties, the ODEON software was employed to study the acoustics.
- The method employed is the image source method, along with ray tracing.
- The acoustical absorption of materials to various octave frequencies has to be appropriately chosen.

3.2.1. Simulation

All the 2D and 3D drawings were created from the in situ measurements using the CADD and Sketchup Pro Software. The simulation used ODEON Room Acoustic **so**ftware version 17—the ISO 3382-3_OMNI.SO8 directional pattern at 1.65 m above the floor level of the altar was the sound source to measure the reverberation.

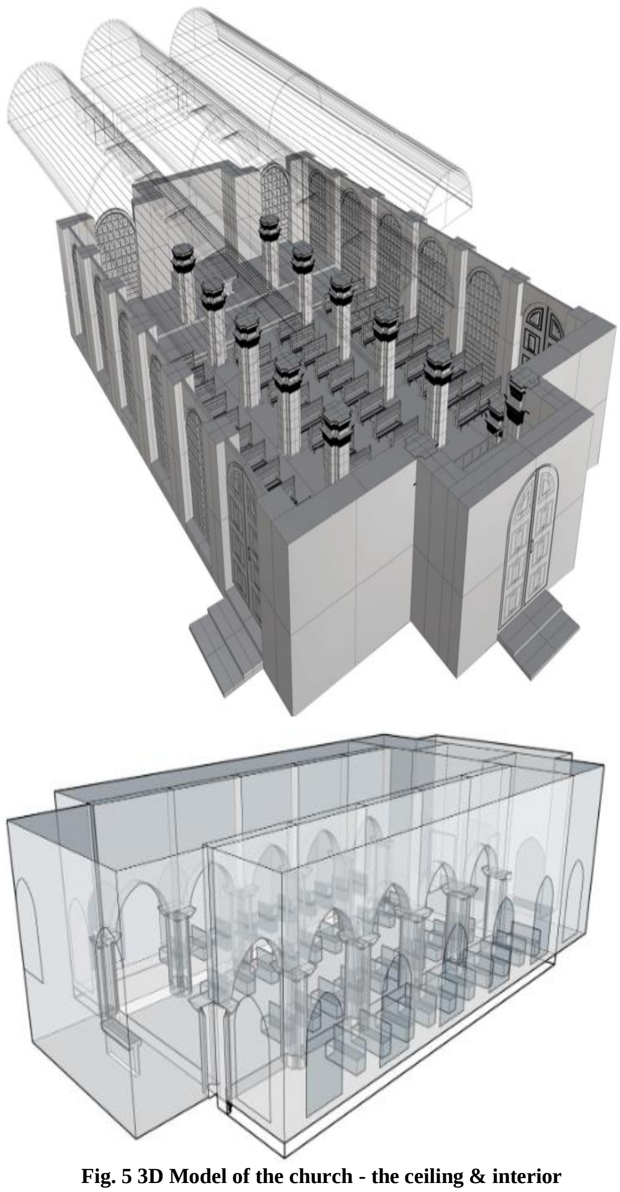

Fig. 5 3D Model of the church - the ceiling & interior

Table 5. Materials assigned in ODEON

Walls	Bricks, mortar, limestone
Flooring	Black and white granolithic tile finish
Ceiling	Vaulted ceiling finished with wooden panels.
Door	Polished Teakwood
Windows	Teakwood shutters and panels with steel grill
Seating	Polished Teakwood and wired.

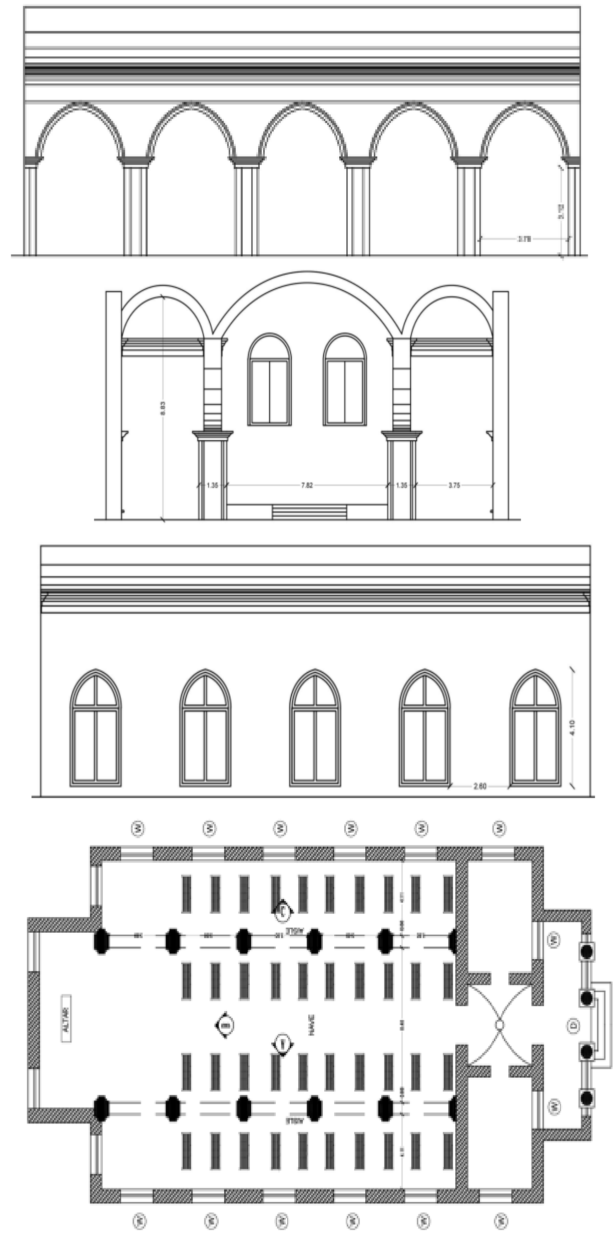

Fig. 6 Plan and interior elevations

4. Results and Discussion

Tables 6 and Figure 7 present the results of the RT for the closed and opened position of the church, respectively. The mean simulated RT was 2.76 seconds. It was demonstrated that the RT of St. Thomas Garrison Church is larger than the required maximum value of 2.5 seconds, especially in the mid-frequency range. The goal for reverberation time for the sanctuary should be a design target of 2.0 to 2.5 seconds in mid-frequency (500 to 1,000 Hz) for reasonable speech intelligibility and musical quality. The reverberation time in a space can be effectively controlled by the ratio of the sound-absorbing surface area to the sound-reflecting surface area. (MikeSorensen, 2012).

Table 6. Simulated reverberation time

Condition	Frequency (Hz)								Average All	Average 500-1000 Hz
	63	125	250	500	1000	2000	4000	8000		
Closed	2.77	2.48	3.01	3.29	4.02	3.10	2.22	1.21	2.76	3.65
Opened	3.09	2.83	2.89	2.72	3.07	2.40	1.82	1.09	2.49	2.89

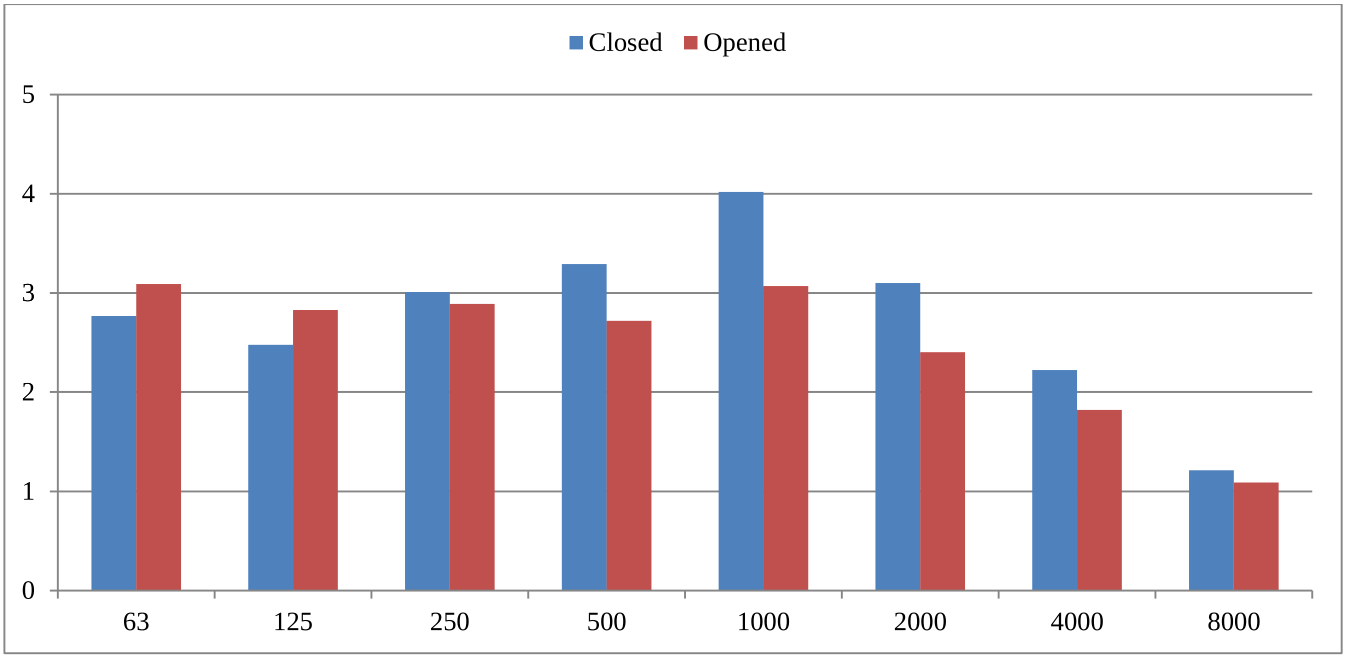

Fig. 7 Bar graph showing the RT - Closed & Opened conditions

Table 7. Existing background noise - door opened condition

Receiver	Frequency (Hz)								BN (dB)
	63	125	250	500	1000	2000	4000	8000	
1	43.8	31	21.5	21.4	27.7	28.1	26.1	21.9	**60.3**
2	44.4	48.2	48.9	52.5	54.9	53.9	51.5	37.2	**59.8**
3	44.6	49.4	51.9	53.6	56.6	55.6	54.3	41.8	**61.6**
4	44.5	49.2	53	52.7	54.6	55.6	52.9	38.2	**60.9**
5	45.3	49.4	53.1	54	56.3	58	49.9	39.2	**62**
6	43.9	50.6	52.4	52.1	55.1	56.5	54	37.7	**61.2**
7	45.2	48.6	51.2	52.7	54.4	54	48.7	35.6	**59.7**

Table 8. Existing background noise - door closed condition

Receiver	Frequency (Hz)								BN(dB)
	63	125	250	500	1000	2000	4000	8000	
1	37.6	40.7	43.6	43.7	45.2	42.2	43.6	28	**51**
2	39.5	42.8	43.8	45	47.4	44.9	40.2	27.4	**52.2**
3	37.6	41.9	43.7	43.8	43.9	42.7	41.3	28.5	**50.6**
4	39.2	41.1	42.5	44.6	45.1	44	39.6	26.7	**51.1**
5	40.6	41.9	44	43.2	42.8	42.2	40.9	25.7	**50.3**
6	39.3	43.9	43.8	42.1	47.2	42.7	46.6	26.6	**52.3**
7	40.5	43.4	44.8	45.3	46.2	44.4	41.7	26.7	**52.3**

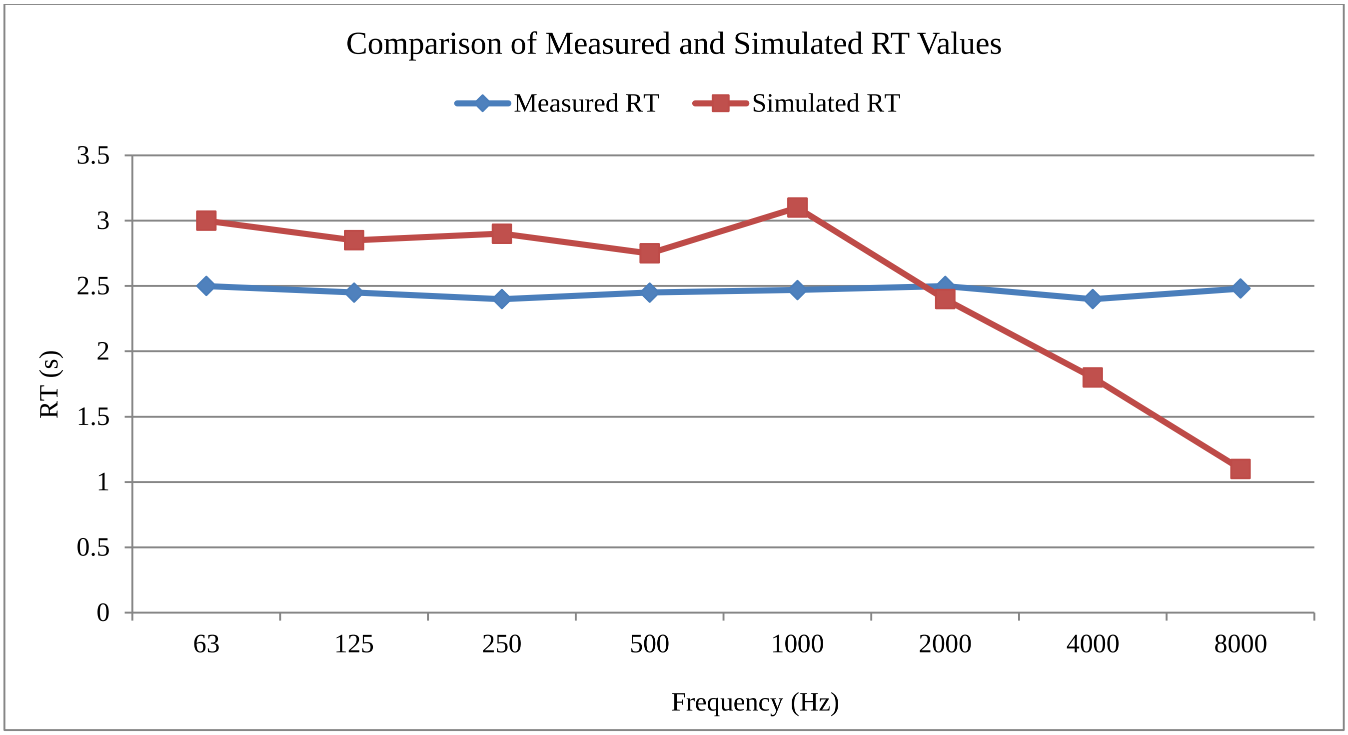

Fig. 8 Line graph comparing the Measured & Simulated RT

Tables 7 and 8 present the results of background noise level measurements taken in the closed and opened conditions, comparing the same. The data reveals that opened noise levels are noticeably higher than the closed conditions. This increase is primarily due to more heavy vehicles travelling on the nearby highway (GST Road). Unfortunately, none of the recorded levels meet the standards set by Indian noise pollution regulations. The actual background noise levels are measured using the simulation process based on the actual background noise levels measured and compared against lower noise criteria to assess their impact on STI performance.

The line graph compares the measured and simulated RT (Reverberation Time) values across 63 Hz to 8000 Hz frequencies. The x-axis uses a logarithmic scale to represent the frequency range better. It is evident from the above graph that the measured values remain relatively stable, while the simulated values decrease significantly at higher frequencies. The x-axis uses a logarithmic scale to represent the frequency range better. It is evident from the above graph that the measured values remain relatively stable, while the simulated values decrease significantly at higher frequencies.

With the aid of experimental measures, the acoustical study of the St. Thomas Garrison church located in St. Thomas Mount at Chennai has been developed, and the church's sensational acoustical efficacy is quantified uncomfortable for excessive reverberation. This is primarily caused by late reflections of sound that interfere with the direct sound, leading to reduced intelligibility. Reverberation time takes longer to achieve equilibrium because of the large room volume combined with the shape of the big arches, the hard materials used to construct the church, and the high ceilings. The simulated model is generated in line to capture the geometry and features of reality and maximize the accuracy of calculations identical to the existing acoustical conditions with the aid of ODEON Software.

With this model, further evidence has been extracted about the poor speech intelligibility experienced within St. Thomas Garrison Church and aimed at elucidating the acoustic behaviour of the church. For this, a proposal to achieve better acoustic results would allow the church to serve parishioners better and make the scene more acoustically ideal. Acoustic panels and soundproof curtains serve different purposes while offering practical solutions for sound control. By considering factors such as sound control requirements, aesthetic preferences, budget constraints, and the need for a temporary or permanent solution, soundproof curtains are designed to block sound from entering or leaving a room. (soundaway, n.d.) Acoustic curtains have been shown to reduce sound transmission by up to 29db. The performance may vary based on the materials' quality and specific application. Noise reduction is helpful in many locations, like theatres, churches, offices, and even enclosures for loud industrial machinery. (eNoise Control, n.d.)

According to Mike Sorensen's postulations, where treating the rear wall is a priority given the long confirmed delayed reflections creating an illusion that a sound source is located behind you, the church's rear walls will be treated by draping Polyester sound absorbing draperies with thickness thresholds of a minimum of 16". The drapery was selected based on the below criteria:

- High Sound Absorption Coefficients: rating between 0.65 – 0.90 depending on thickness and pleating.
- Broadband performance: operational across low-mid-high frequency ranges and clear for speech and music.
- Durable and maintainable: resistant to moisture and UV degradation, microbial growth - conducive to long-term installation
- Cost-efficient alternative - comparable low costs and little invasive installation.
- Aesthetic compatibility: available in custom colours and textures to align with the historic visual integrity of the church interior.

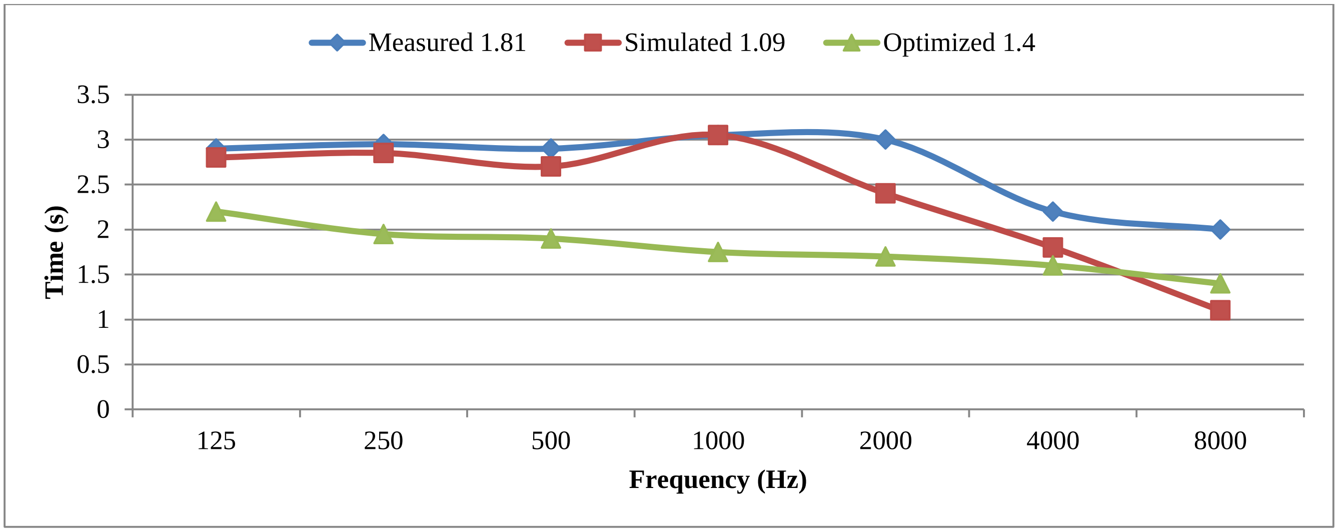

Fig. 9 Comparing the analysis with the proposal

Table 9. Acoustic parameters after the treatment

Metric	Pre-Treatment	Post-Treatment	Target
Reverberation Time (RT60, 1 kHz)	3.2 sec	1.7 sec	1.5–2.0 sec
Speech Transmission Index (STI)	0.42	0.65	≥0.60
Background Noise Level (dBA)	52 dBA	44 dBA	≤45 dBA

The locations have been designed in line with the simulated models and results to ensure that new materials can be implemented carefully without compromising the overall aesthetics or the spiritual ambience and that the changes made are as subtle as possible. Also, simulations conducted on the newly optimized model show significantly improved outcomes, including the desired reverberation time, enhanced clarity for musical performances, and a notable boost in speech intelligibility. Implementation of the suggested solution is, therefore, highly recommended.

5. Conclusion

The aim is to enhance the discourse on church acoustics and explain the intricate intertwining of architecture, sound, and spirituality while preserving our history and heritage. Additionally, this work included studying the delicate acoustic features of ancient churches in Chennai to provide vital information that can assist in constructing and altering religious edifices. The primary objective is to support these distinguished places in their efforts to maintain and enrich the cultural heritage through intensified devotion and optimized acoustics.

Integrating polyester sound-dampening draperies presents a practical and non-invasive solution to the acoustic challenges within St. Thomas Garrison Church. By optimizing reverberation, improving clarity, and reducing background noise, this intervention enhances both the spoken word and musical experience, ensuring the church continues to serve as a vibrant and acoustically pleasant space for generations. Possible future research on the application of noise barriers along the abutting expressway and enhancing the captivation of the sound is carried out extensively.

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