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Study and Simulation of Acoustics: A Case Study at St. George Basilica Church

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Abstract— This case study was undergone at church, for studying the acoustical nature by analyzing the reverberation time. This work consist of three phases. In first phase, collecting all the data from the project site. This phase, the collection of all the datas about the materials and the acoustical problem faced in the church. These were collected through observations and questionnaires. The second phase composed of experimental studies at the project site by ON-OFF method. Here the acoustical parameters, that decide the acoustical characteristics of a building, were calculated for further studies and analysis. And the third phase consists of the analysis of collected datas and drawing inferences. This project is completely done on the MATLAB platform. This work presents the acoustical characteristics of a building and how the material inside the site effects the sound propagation and the audibility inside. By analyzing the acoustical parameter, reverberation time, acoustical nature of the building can be predicted. This project is a case study which reveals the acoustical problems inside the site and suggesting a solution for the problem.

Index Terms— **Acoustics, Acoustic nature of room, Reverberation time, ON-OFF Method.**

I. INTRODUCTION

Acoustics is the science, deals with the study of mechanical waves in gases, liquids, and solids and about the vibrations of sound. The science of acoustics has applications in music, medicine, architecture, industrial production, warfare. Science of sound, deals its production, transmission, and effects, including biological and psychological effects and the qualities of a room that, together, determine its character with respect to auditory effects [1]-[2]

II. PROBLEM DEFINITION

This project presents the acoustic problem encountered in the project site st, George Basilica church. There is a severe acoustical problem in this site. The audibility of speech is different for different parts of the church. The speech delivered by the priest is not clear to the worshippers [4]-[6].

III. METHODOLOGY

The project site St.George Basilica church is visited prior to the investigation for the data collection. Here the datas are collected through the observation and the questionnaires

Circulated among the priest and worshippers. Personnel interview is taken from the priest and the office staffs .For the experimental studies, ON-OFF method is used which measures the impulse responses of a room.

A. *Primary Observation*

The St. George Basilica of Angamaly is the largest basilica in South India with a built up area of 24000 sq. ft. The main altar is 2000 sq ft roofed with a dome of about 185 ft. Crucified Christ along with St. Mary and St. John and an array of grand and solemn statues of holy men are placed in the Main altar. The windows of the dome bear portraits of Apostles and pictures of the holy men and instances from the new and old testaments are imprinted on the other windows of the church.

B. Site Features

The most important thing is the shape of the church. When analyzing the shape, we could see the zigzag structure throughout the walls and the roof. The peculiarity of the church is the way its altar is created.

(i) Altar

The altar is made as a flute structure. And it is completely created by the reflecting material called the Italian crystal glasses. The flute structure of the altar creates new sound forms by the reflection several times.

(ii) *Dome*

The dome is very attractive. The 12 window paintings of the saints on the dome causes high reflection .And the star like cutting on the end of the doom again creates the refection. From the primary inspection we can conclude that the altar is the worst.

(iii) Front side of the altar

The front part of the altar is made up of stones, and it is in zigzag structure in construction. There are windows which are also made of reflecting glasses.

C. Diary Observation

The diary report gives the clear idea about the project site. It includes the construction materials of the church and the collected datas from the worshippers.

Prior to experimental studies, observing the components and materials inside the church, which has a crucial role in absorbing the sounds. Looking inside the church and listing out the materials inside the church reveals that it is composed of full reflecting materials like glasses.

These reflecting materials play a role in propagation of the sounds inside the church. Based on their absorbing coefficients, it will reflect or absorb the sound signals or transmitting the sound signal to the audiences

TABLE I: MATERIALS LISTED INSIDE THE CHURCH

Materials	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz
Floor Materials					
Marble or glazed tile	0.01	0.02	0.06	0.15	0.02
Seating materials					
Wooden chairs(empty)	0.01	0.09	0.08	0.08	0.08
Reflecting wall materials					
Concrete pillars	0.36	0.44	0.31	0.29	0.39
Stones	0.03	0.03	0.03	0.04	0.05
Wooden doors	0.1	0.07	0.05	0.04	0.04
Statues(plaster of Paris)	0.29	0.1	0.06	0.05	0.04
Reflecting glasses	0.18	0.06	0.04	0.03	0.2

Data Collection through Questionnaires

Datas are collected through circulating the questionnaire. This helps to draw the problem more clearly. A questionnaire is circulated between the worshippers, which is shown below.

IV. EXPERIMENTAL STUDIES

The church is divided into 8 parts for the purpose of doing experimental study. A sketch of the church helps for the experimental purpose. For measuring the acoustics parameters, impulse response method is used. In each of the segment, room impulse is measured and calculates the acoustic parameter called reverberation time

A. Impulse Method

Impulse response method [8]-[12] is used here. In this method. the basic source of information about the audible properties of the sound field in a room is the impulse response signal. When recorded with a multichannel technique to preserve the information about direction of incidence it contains all available information for a given source and receiver location.

B. Reverberation Time

Reverberation time [7] refers to the amount of time required for the sound field in a space to decay 60dB, this refers to the amount of time it takes for sound energy to bounce around a room

before being absorbed by the materials and air.

Reverberation time (in seconds) =.05 x volume of room/sabins (1)

One Sabin the amount of absorption of one square foot of perfectly absorbing surface. Sabin equation for calculating reverberance

$$RT_{60} = \frac{24 \ln 10}{C_{20}} \frac{V}{Sa} \approx 0.01611 sm^{-1} \frac{V}{Sa} \quad (2)$$

where c_{20} is the speed of sound in the room, V is the volume of the room in m³, S total surface area of room in m², a is the average absorption coefficient of room surfaces, and the product Sa is the total absorption in sabins.

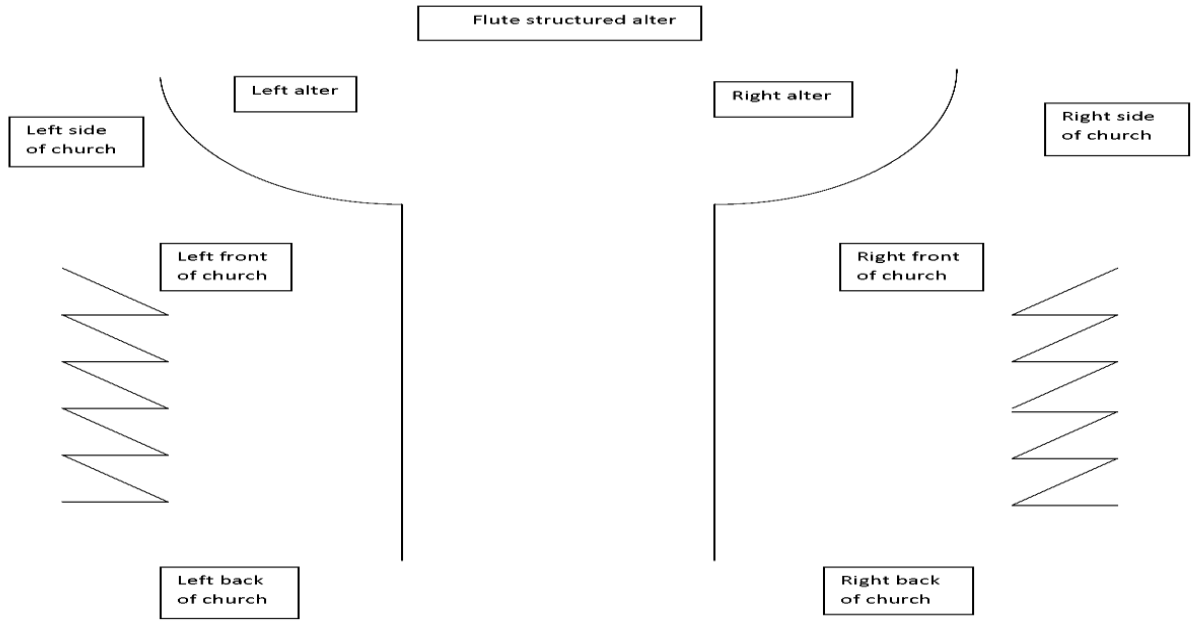

Fig. 1. Inside sketch of the church,by diving into parts for experimental purpose

C. *Experimental Procedure*

The experiment [13]-[15] is done at each and every part of the church as in the sketch. In order to measure the impulse response of the room, adopted the source ON-OFF method. In this method, Sound system first produce sound wave and record the reflected wave after the 8 seconds while it is in OFF mode. A sine wave with sampling frequency is 8000 Hz is generated using the MATLAB software. The sound source is kept at different parts of the church, do the ON-OFF method. The sound recorder is 2m away from the source. From the recorder data, the reverberation time is calculated as per the definition.

V. EXPERIMENTAL RESULTS

The collected 5 samples for each of the frequencies are analyzed using MATLAB software. The room impulses are as shown in below. The reverberation time is calculated after filtering the recorded data.

Input level: 1 V

Sampling frequency: 8000Hz

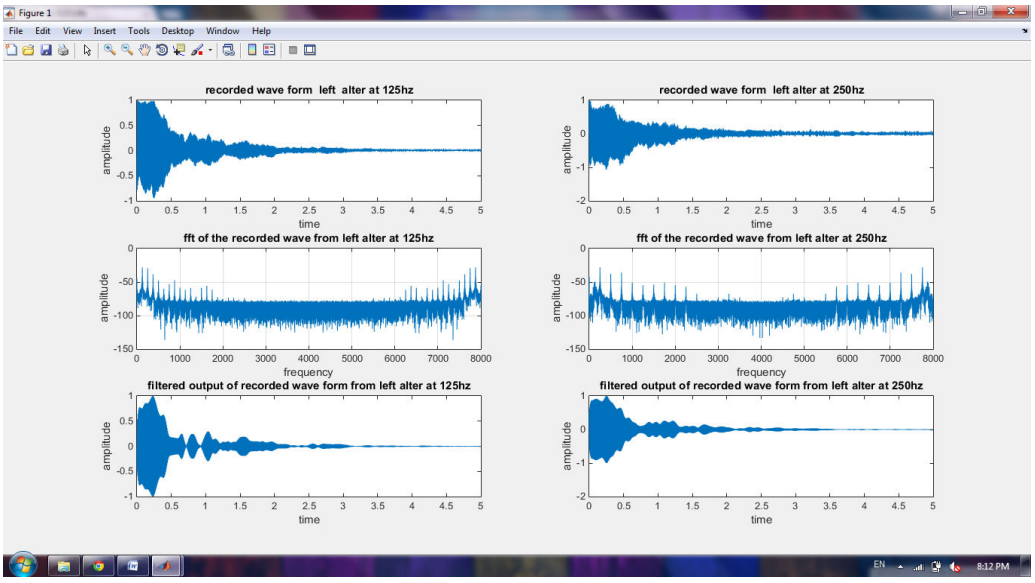

Fig. 2. Impulse response at 125 Hz and 250 Hz

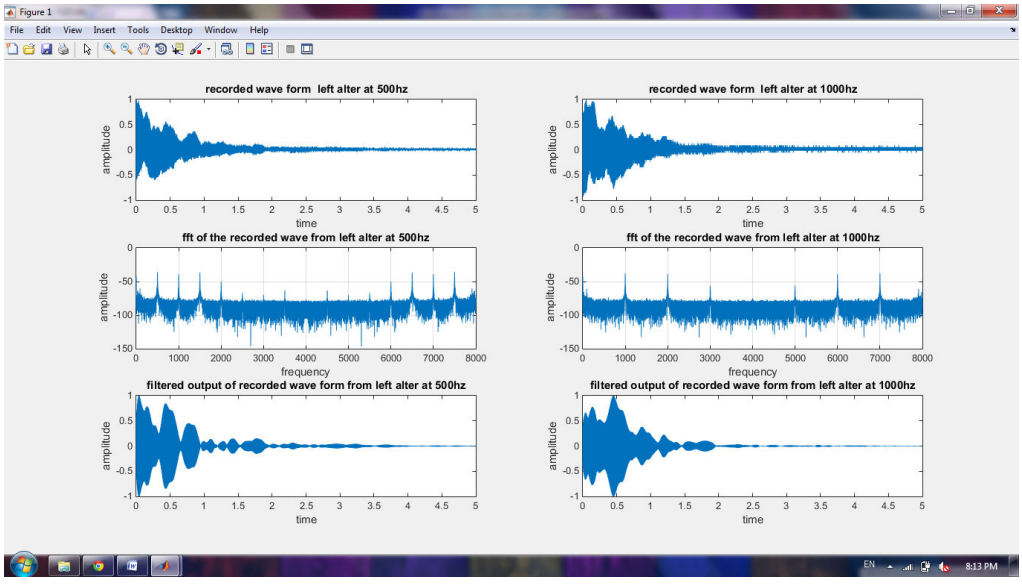

Fig.3. Impulse response at 500 Hz and 1000 Hz

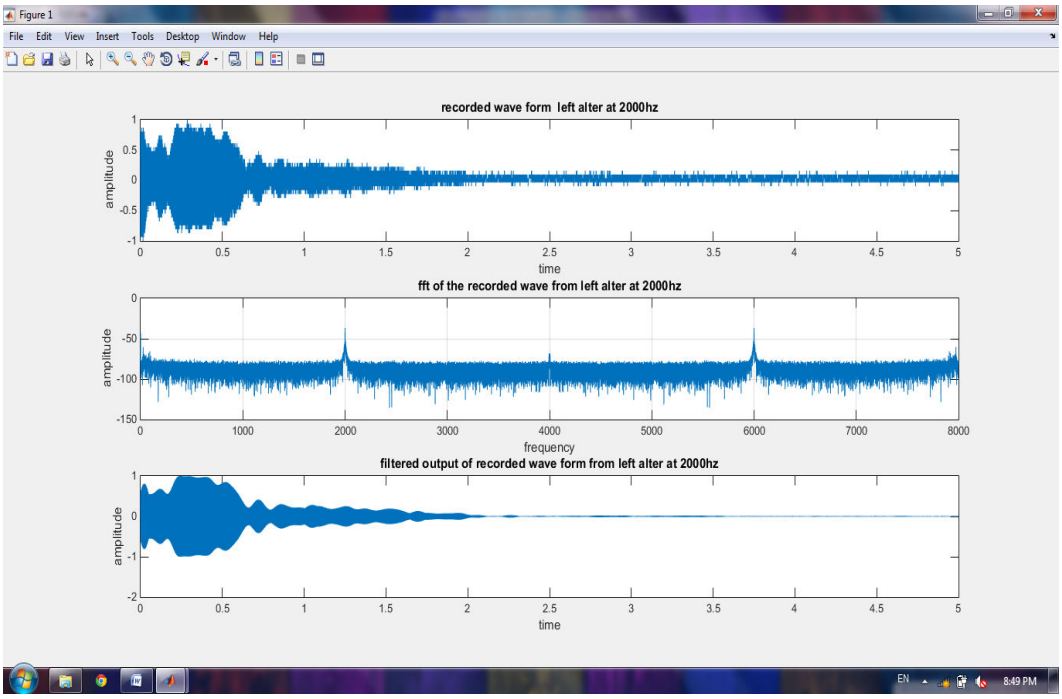

Fig. 4. Impulse response at 2000 Hz

The collected samples for different frequencies is analyzed and calculated as the reverberation time to decay to 60 db of the original sound amplitude .Different parts of the church have the different reverberation time. As the reverberation time increases the time to decay the sound inside the room also increased. So the delivered sound is still there inside the room, effects the new sound arriving. All the existing sounds (new arriving and the previously existing one) combined to form a damaged sound.

Analyzing the reverberation for different frequencies at different parts of the church is listed in table. It shows the reverberation time is less for less frequencies and higher frequencies. It's high for medium frequencies. This is because at higher frequencies the absorption is high.

TABLE II: REVERBERATION TIME AT DIFFERENT FREQUENCIES FOR DIFFERENT PARTS

frequency samples	*125 HZ*	*250 Hz*	*500 Hz*	*1000 Hz*	*2000 Hz*
Left altar	3.5	3.56	5.8	4.2	2.32
Right altar	2.85	3.36	5.4	4.32	3.3
Left front	2.7	3.36	4.8	3.2	2.8
Right front	3.65	3.95	4.1	2.8	2.6
Right side of church	1.8	3.35	4.55	4.2	3.2
Left side of church	4.4	4.2	5.1	4.18	3.7
Right back	2.9	3.3	2.9	3.9	2.5
Left back	3.3	3.9	4.2	3.9	2.7

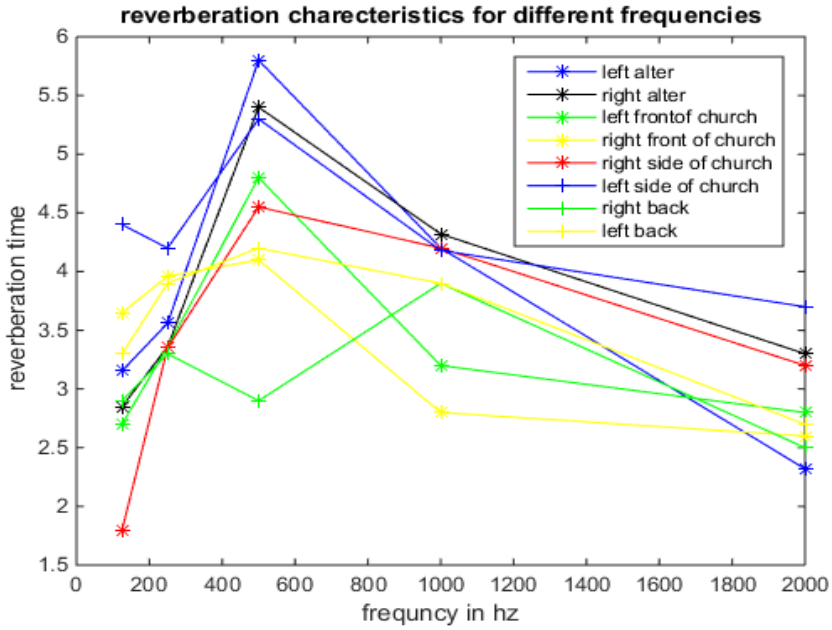

Fig. 5. Comparison of reverberation time at different parts of the church

VI. CONCLUSION

Here the acoustical problem in the project site St.George Basilica church is studied through the impulse response method. Through this method impulse response of the room is collected by using source ON-OFF method. The impulse response contains both directed wave and the reflected wave. Impulse response is taken for different frequencies. From the impulse response, measured the reverberation time for different frequencies. From the observation, reverberation time is low for both low and high frequencies while it is high for medium frequency. The absorption by the building materials for medium frequencies is less and this cause the higher reverberation time. The reverberation time is higher for altar side, since it is

composed of any reflecting materials like glasses and reflecting surfaces. And the low reverberation time for back of the church, since it contains many sound absorbing materials (wooden doors, benches etc.)

The reverberation time is depends upon the material distributed inside the room. Depending upon the absorbing coefficient, the material absorbs or reflect the sounds and produces damaged sound when it is getting reflected.

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