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THE REVERBERATION TIME AND CONGREGATIONAL RESPONSE TO THE ACOUSTICS OF SOME LARGE CHURCHES IN THE JOS METROPOLIS

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ABSTRACT

This paper investigates why some very expensively built church auditoria turn out to be below standard as far as good acoustics and sound intelligibility is concerned. The study included the physical aspects –measurements of the dimensions of the auditoria and other physical parameters that would affect the acoustics on the one hand, and obtaining the responses of the congregation on the auditoria acoustics on the other hand. Reverberation time for the enclosures considered was calculated from the slope of the sound as plotted by a sound level recorder and the Sabine's formula. There is a correlation between the complaints of the users of the auditoria and the results obtained.
Keywords: *Intelligibility, Reverberation Time (RT) and Acoustics of Large Church Auditoria*.

INTRODUCTION

There is presently an ongoing revolution in the sizes of churches in Nigeria. We are witnessing a paradigm shift from small enclosures to very large auditoria: however, little attention is being paid to the acoustics of such buildings. Paradoxically these buildings are solely for either church activities or musical concerts where the production, transmission and reception of sound should be of utmost importance. It has been observed that after these auditoria have been constructed: obtaining a good sound becomes a huge problem due to the fact that there was a negligence of acoustical implications at the outset. Designing an auditorium is to a significant degree a process of creating an acoustic space that eliminates late reflections, especially echoes, for all listeners.www.churchacoustics.com (2008) Reverberation is the ongoing part of sound in a large hall that gradually decays away, a totally chaotic lingering presence of a previous direct sound, a sonic afterglow, a remembrance. Excessive reverberation means that the lyrics become more difficult to understand and musical detail is lost (Steeneven and Houtgast 1985), (Baranek, 1996).We instinctively connect what we hear with what we see in order to gain a deeper understanding of our environment. When we do, it is well known that we actually hear better (Sumby and Pollack, 1954), (Massaro and Stork, 1998).(Sumby and Pollack, 1954).Acoustics isn't about sensory deprivation; it's about getting good sound. And we get it by working hard to corral, train and manage those errant reflections, 99.9% of the sound emitted from the loudspeaker. Auditorium acoustics is about getting the best use out of all the sound that missed the people on its first pass.

Apart from dimensional ratios, the Plan shape of the room also needs to be considered in the preliminary design stage. Numerous Plan shapes have been used in auditorium design, from the traditional cruciform to rectangles, squares, circles, fans, pentagons, hexagons, other polygons and various irregular shapes.The temptation to depart from acoustically tried and tested shapes in search of something unique that runs the risk of favoring form over function must be resisted.home1.gte.net/mjarzo

After dimension ratios and plan shape, the next most important acoustic parameter to consider is the relationships between the auditorium's internal angles or its internal geometry. The angles of the walls, floors, balconies and ceilings greatly affect how sound from the stage or platform is reflected into other areas that may be receiving less direct sound. The acoustically ideal room is one in which all seats receive the same sound level and frequency spectrum. This is never wholly possible due to the attenuation of sound with distance, but by carefully modeling the internal angles of the auditorium, the reflected sound can be "aimed" at those areas that need it and kept away from those that don't. Churches offer an extreme example of the multipurpose space due to the several conflicting acoustical requirements during the same event. The acoustics during the service can't be altered to meet the acoustical requirements both for organ and choir on one hand, and speech intelligibility, on the other.

Calculated Rooms

In this work, eleven enclosures were considered based on the scope which the paper covers. Churches with volumes>2000m^3 were considered. Table 1 gives an overview of the data used for the estimation of the reverberation time while Table 2 gives an overview of the acoustical characteristics of the auditoria and their reverberation time values.

Calculation Method

Basically two methods were employed in this work: they include the use of the Sabine formula in its classical form. The value of the reverberation T time was calculated from the total absorption area A $[m^2]$ and the volume$v[m^3]$ of the auditorium as;

$T = \frac{0.161}{V}(1)$

Secondly, the use of a graph level recorder was employed. A 50db sound level recorder potentiometer was plugged into position. The rectifier response, writing speed and paper speed were adjusted to values that will enable the stable and smooth pen functioning. A half inch B&K microphone was fixed on a stand 1.5m above the ground level. Subsequently, the microphone was connected to the preamplifier input of the graphic level recorder. The pen drive and the paper drive of the sound level recorder was switched on. A loud sound was made in each of the enclosures with the aid of a knockout banger. The rise and decay level of the sound was recorded by the graphic level recorder. From the slope of this decay curve the decay rate and the reverberation time of the different enclosures were obtained.

S/N	Name of Church	Volume of Auditorium(m^3)	Floor Area Floor Material (m^2)	Ceiling Area Ceiling Material (m^2)	Wall Area Wall Material (m^2)	Window Area Window Material (m^2)	Door Area Door Material (m^2)	Area of rug & curtains (m^2)
1.	ST. LUKES CATHEDRAL	3958.54	688.0 Concrete	734.2 ____	414.3 Concrete	10.71 Glass	8.88 Glass	188.42 ____
2.	UNITED BAPTIST CHURCH	4429.9	762.54 Concrete	631.9 Wood	113.92 Concrete	111.67 Glass	16.6 Glass	____ ____
3.	ECWA CHURCH BISARA II	2716.8	320.6 Concrete	368.1 Asbestos	716.58 Concrete	____ ____	19.68 Wood	47.6 ____
4.	CHURCH OF ETERNAL LIFE	23291.8	6989.4/279.9 Concrete/Tile	154.9 Aluminum	1357.5 Concrete	78.69 Glass	6.69 Wood	4.83 51.98
5.	CHURCH OF FAITH	3482.1	459.1 Terrazzo	2072.1 Aluminum	308.2 Concrete	85.88 Glass	26.26 Glass	____ ____
6.	REDEEMED CHRISTIAN CHURCH OF GOD	34017.4	2072.07/768 Cemented/Tiles	2072.07 PVC	577.9 Concrete	696.2 Glass	63.55 Glass	18.58 326.68
7.	SHEKINAH CHURCH	14170.3	699.1/543.94 Cemented/Bare	1243.01 Aluminum	579.4 Concrete	163.9 _____	31.68 _____	55.2 _____
8.	LIFE & POWER CHURCH	5078.92	725.56/157.5 Concrete/Tiled	725.56 Aluminum	672 Brick	35.26 Glass	18.3 Glass	45.26 22.84
9.	ECWA GOODNEWS CHURCH OLD	2684.5	315.11 Concrete	566.2	566.2 Concrete	50.96 Glass	12.97 Wood	_____ _____

10.	ECWA GOODNEWS CHURCH NEW	6498.84	862.93	444.92 Acoustic Ceiling	362.93 Concrete	81.99 Glass	8.9 Wood	_____ 17.89
11.	CHURCH OF GOD MISSION	5925.3	944.5 Terrazzo	303.77 PVC	633.97 Concrete	7.86 Glass	45.84 Glass	128.1 _____

Table 1 Data for Estimation of Reverberation Time

Table 2. An Overview of The Acoustical Characteristics of Auditoria and Their R.T Times

Names of Auditorium	Basic Shape	User's Assessment	Volume (m^3)	Total Surface Areas m^2	Reverberation Time (s)	
					Classical	**Experimental**
ST LUKES CATHEDERAL	Cruciform	Poor retention of sound	3958.54	3305.28	1.9	1.7
UNITED BAPTIST CHURCH	Diamond Square	Satisfactory	4429.90	2604.82	5.9	1.9
ECWA BISHARA II	Rectangle	_____	2716.80	1132.66	7.2	3.4
CHURCH OF ETERNAL LIFE	Dome	Too much echo	23291.83	8762.63	19.3	3.8
THE CHAPEL OF FAITH	Fan	Severe interferences	3482.04	879.40	4.9	3.3
JESUS HOUSE	Rectangle	Poor intelligibility	34017.42	9518.37	5.8	3.1

SHEKINAH CHURCH	Octagon	Poor retention of sound	14170.30	2815.63	1.1	2.1
LIFE AND POWER CHURCH	Rectangle	Fairly Okay	5078.92	1676.75	2.0	3.4
ECWA GOOD NEWS CHURCH [OLD]	Square	Poor intelligibility	2684.47	945.24	2.9	2.8
ECWA GOOD NEWS CHURCH [NEW]	Diamond Square	Poor Intelligibility	6498.34	923.21	3.6	2.5
CHURCH OF GOD MISSION	Hexagon	Delay in sound transmission	5925.33	2114.73	2.8	3.1

Table 3 Reverberation Time (R.T) Values for Full Capacity Audience

S/N	NAMES OF AUDITORIA	VOLUME(m^3)	RT FOR FULL HALL(S)
1	ST. LUKES CATHEDRAL	3958.5	1.1
2	UNITED BAPTIST CHURCH	4429.9	1.9
3	ECWA CHURCH BISHARA II	2716.8	2.0
4	CHURCH OF ETERNAL LIFE	23291.3	2.5
5	CHAPEL OF FAITH	3482.1	1.8
6	REDEEMED CHRISTIAN CHURCH OF GOD	34017.4	1.9
7	SHEKINAH CHURCH	14170.3	0.6
8	LIFE AND POWER CHURCH	5073.9	1.2
9	ECWA GOODNEWS CHURCH OLD	2684.5	1.4
10	ECWA GOODNEWS CHURCH NEW	6498.3	1.6
11	CHURCH OF GOD MISSION	5925.3	1.4

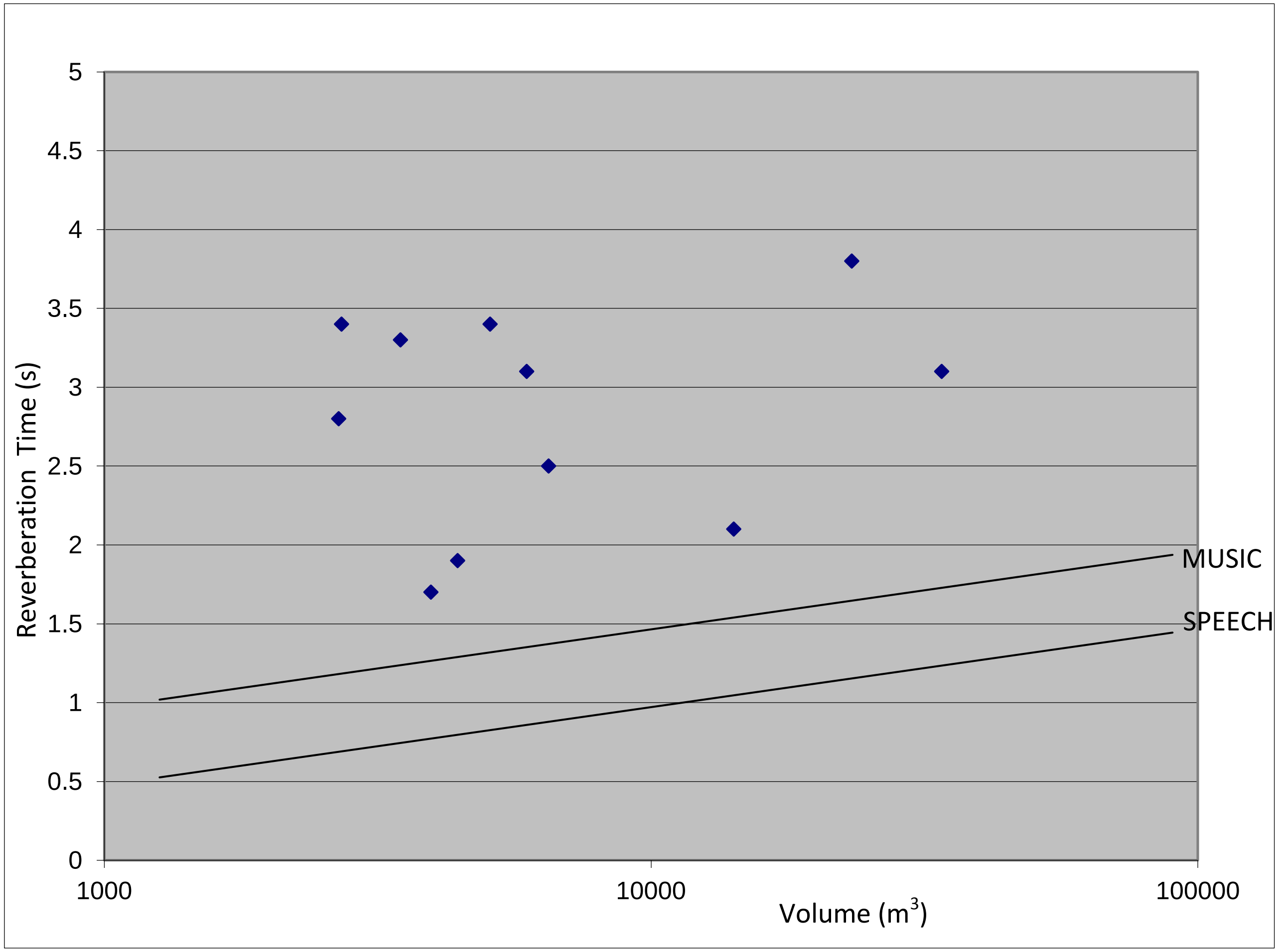

Fig. 1 A graph of Experimental Reverberation time(s) Values Vs Volume (m^3).

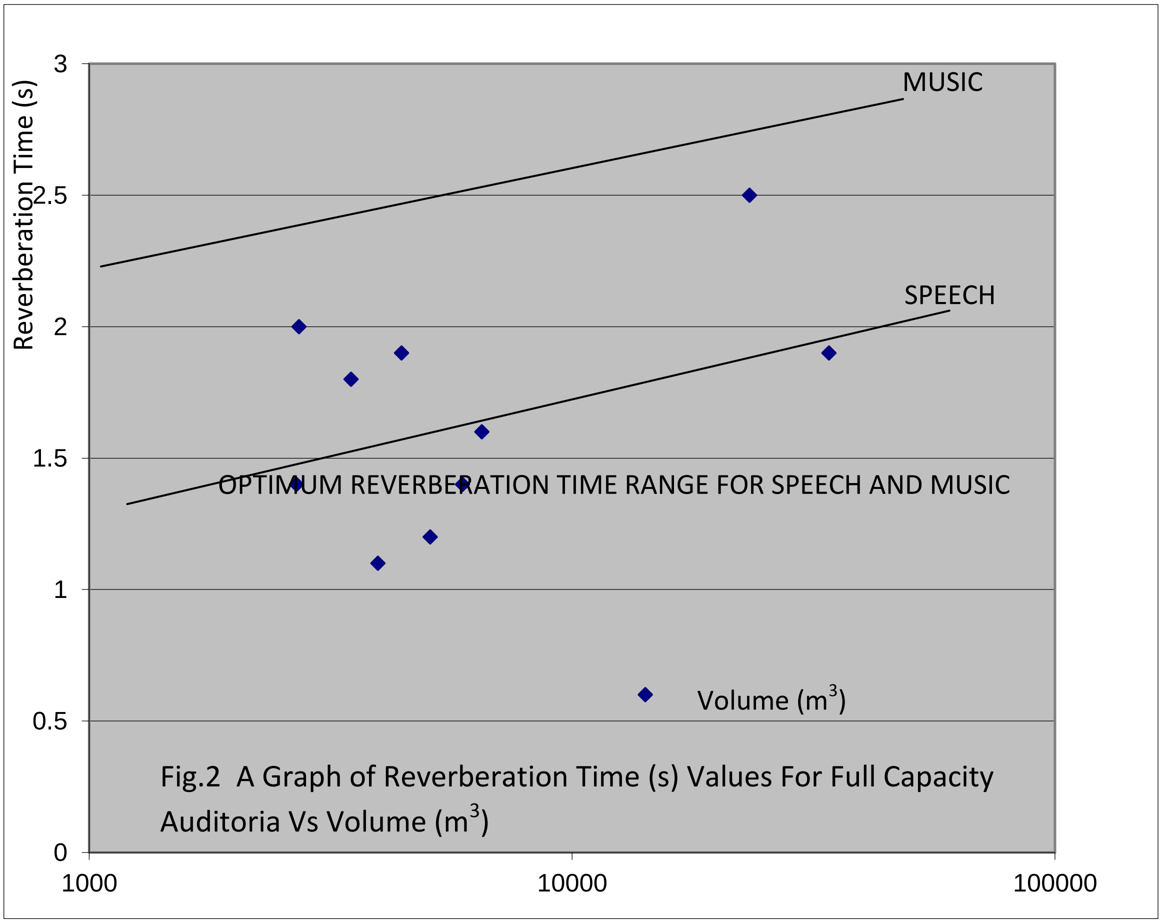

Fig.2 A Graph of Reverberation Time (s) Values For Full Capacity Auditoria Vs Volume (m^3)

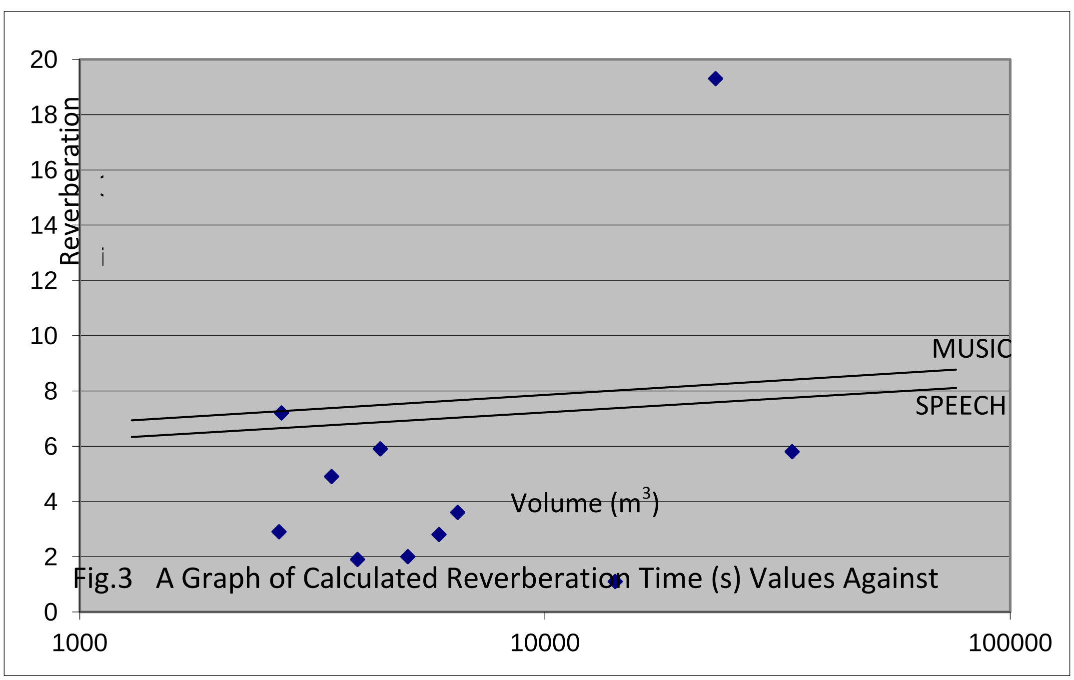

Fig.3 A Graph of Calculated Reverberation Time (s) Values Against

RESULTS

Calculated and Measured Values of Reverberation Time

A plot of the reverberation time versus the volume of the auditoria showed that the church auditoria under investigation were not within the optimum reverberation time range for both speech and music (fig 1 and 3); it was however observed that for the experimental values three of these auditoria were a bit close that is the ST Lukes, United Baptist and Shekinah church. Fig 2 is a graph of predicted optimum reverberation time when these auditoria have a full congregational participation, it was observed that six of these auditoria namely: ST Lukes Cathedral, Jesus House, Life and Power church, ECWA good news church (old), ECWA good news church (new) and Church of GOD missionhad reverberation time of 1.1s, 1.9s, 1.2s, 1.4s, 1.6s and 1.4s respectively which is within the optimum reverberation time range. From the foregoing it can be inferred that the congregational response as illustrated in table (2) was correct. This further explains why most of the church users complained about the intelligibility of sound produced in their auditoriums because most of these huge auditoria are hardly occupied to their full capacities during church activities.

From the foregoing it is evident that most of these enclosures have some acoustical faults: Some of these faults which have been established in the literature include:

1. The use of poor absorbent materials as finishes on floors. It was observed that tiles and terrazzo with absorption coefficients of 0.015 at 500 Hz were used in most of the halls.
2. The shape of some of the enclosures could also be a major contributory factor; dome shape and cruciform are known to be very problematic.
3. The ratio of the number of occupants in such enclosures to their volumes; most of the church auditoria are not usually full to capacity during church activities therefore reducing sound absorption in the auditoria.
4. Most of these enclosures were completely without ceilings and even where ceilings were fixed, it was quite obvious that they were not ceilings of high acoustic absorption.

The essence of acoustics in large church auditoria cannot be overemphasized: in order to avoid building acoustically non-functional auditoria the acoustical implications should be taken into account from the outset. As it can be seen from this research, for a church auditoria to perform its function to an optimum capacity the expertise of an acoustician cannot be undermined.This paper recommends the introduction of increased absorption within the churches either in the form of acoustic ceilings which many lacked – or carpeting as more often than not they were not used at full capacity. For the five out of the eleven churches in which the reverberation times were above the optimum values definitely these need more treatment with absorbers.

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