STUDY OF ACOUSTIC ARCHITECTURAL MATERIALS FOR MUSIC HALL DESIGN

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CALEB UNIVERSITY, LAGOS

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A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE, COLLEGE OF POST GRADUATE STUDIES, IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELORS OF SCCIENCE (B.Sc.) DEGREE IN ARCHITECTURE, CALEB UNIVERSITY, LAGOS.

DECLARATION

We, **GBOLADE, OREOLUWA, ARCHIBONG, SHARON EJ** and **NKWOCHA, JESSE** of the department of Architecture, Caleb University, Lagos, hereby declare that this project is entirely our work and compositions. The work embodied in this project has not been submitted in candidature for any degree and is not concurrently being submitted for any other degree. All references made to the work of other persons have been duly acknowledged.

Signature and date

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Signature and date

ARCHIBONG, SHARON EJ

Signature and date

NKWOCHA, JESSE

CERTIFICATION

This is to certify that this project work was done **by GBOLADE, OREOLUWA Matriculation number: 17/3590, ARCHIBONG, SHARON EJ Matriculation number: 17/3773 and NKWOCHA, JESSE Matriculation number: 17/3853,** Department of Architecture, Faculty of Environmental Science, Caleb University, Lagos State.

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DEDICATION

We dedicate this project to the Almighty God for the grace, understanding and knowledge to care through to the end. We also dedicate this project to Our beloved parents Mr.& Mrs. Gbolade, Mr.& Mrs. Archibong and Mr. & Mrs. Nkwocha.

ACKNOWLEDGEMENTS

We would like to express our gratitude to our supervisor, Arc. Ibitoye for his valuable and constructive suggestions during the planning and development of this research work. His willingness to give his time so generously has been very much appreciated. We are indebted to you for your commitment, encouragement and assistance in keeping our progress on schedule. Our grateful thanks go to our parents and siblings for their support and encouragement in the course of our program at the university. Finally, we wish to express our thanks to all our course mates. Their moral support, advice and encouragement will forever be remembered.

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ABSTRACT

In the design of music hall, having good acoustics is indispensable. One of the ways to ensure that is to consider various architectural materials with acoustic properties. The acoustic architectural materials for music hall design are considered from sound absorbing materials/panels for walls, floors and ceiling. Various local and international materials have unique properties that are advantageous to music hall design. Materials such as sound absorption panels trap acoustical energy (sound) and prevent it from reflecting off of the surfaces they cover. This quality makes it very essential to the design of the music hall.

The aim of this research is to examine various acoustic friendly architectural materials in the design of a music hall.

The objectives of this research are:

1. Identify the acoustic friendly materials in the design of a music hall.
2. Explore the various forms or shapes of buildings suitable for effective acoustic function.
3. Explain the advantages and disadvantages of locally sourced acoustic friendly materials.

The research methodology used to carry out this study is qualitative research questionnaires and interviews were major element of the qualitative method of research.

At the end of this research, it is expected to understand that the case of auditorium in Caleb university and her environ were studied. Also, acoustics architectural materials for music hall design has a considerable effect on the hall's acoustic performance through sound reflection and diffusion. Therefore, to achieve the optimal acoustic performance of a music hall design this study of acoustics architectural materials is important.

With the amazing expertise and knowledge in the research of acoustics architectural materials in the music hall design, we expect to achieve a suitable space in the study area.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Acoustics can be described as the study of sound. It can also be described as the properties of a space, enclosed or open, to reflect sound waves in a way that produces distinct hearing throughout the space.

Architectural acoustics describes the interaction between people and sound, indoors and outdoors, and uses this information to develop acoustical design criteria for architecture and planning.

In order to produce sound, there are some factors that aid the production of quality acoustics. The factors include:

- The shape of the building
- The materials used for the finishes.
- Suspended reflectors
- Stage support
- The size of the room

There is a strong relationship between the properties of a material and how it reacts when exposed to sound. Depending on the material, it can either reflect or absorb sound. The knowledge of these unique acoustic properties of materials can aid in the design of a music hall. The type of materials used in the music hall design will determine how the audience perceives sound. This will also determine how those on the stage produce sound.

1.2 STATEMENT OF THE PROBLEM

Acoustics are greatly influenced by different factors. The choice of materials used in the design of a music hall is a major influence in the design of a music hall. The wrong use of materials for a music hall design could affect comfort and perception throughout the building. There is a need for a proper music hall design to aid the dissemination of information and sound.

A basic understanding of acoustic materials and their uses in the design of the music hall is very important in the planning and design of a music hall. A music hall which has not considered the properties of various materials will pose a threat to the audience and will become ineffective for the purpose it is meant to serve in the long run.

1.3 AIM AND OBJECTIVES

1.3.1 AIM

The aim of this research is to examine various acoustic friendly architectural materials and how it affects the design of a music/concert hall and also recommend the proper materials to be used in the design.

OBJECTIVES

The objectives are:

1. Identify the acoustic friendly materials in the design of a music hall.
2. Explore the various forms or shapes of buildings suitable for effective acoustic function.
3. Explain the advantages and disadvantages of locally sourced acoustic friendly materials.

1.4 RESEARCH QUESTIONS

The following questions guided this study:

1. Are there more halls in the study area?
2. What are the architectural materials that can be found in the music hall?
3. What work does local material play in the music hall?

1.5 SCOPE OF THE STUDY

The scope of the study is to give diverse information on building materials (how they react to sound and sound absorbing materials) and the blend of architectural design with acoustic design.

1.6 JUSTIFICATION OF THE STUDY

Acoustics in a music hall is very essential in music hall designs. The justification of this study is to show how acoustics friendly materials in a music hall will influence the design of the interior of buildings. These materials will produce properly disparse sound at suitable levels and with suitable aesthetic qualities for music and sufficient intelligibility for speech. It also shows how to control noise between a potentially disturbing sound source and a listener.

This research will contribute to the knowledge of Sustainable materials in the design of a music hall.

This research will promote broadening the understanding of acoustics by implementing the appropriate architectural materials in music hall design.

This research work will make sure that music hall design would take more values and consideration toward acoustics architectural materials.

1.7 DEFINITION OF TERMS

1. ACOUSTICS

Acoustics is the science that entails the study of sound and its production, transmission, and effects. An acoustician is a scientist or researcher who studies acoustics. An acoustic engineer is a person who studies acoustic technology. Acoustics is majorly studied to make sound and speech sound as good as it possibly can. It is achieved by decreasing the sound barriers and increasing the factors that aid proper dissemination of sound waves. Initially, acoustics was used only in industries which are based on sound like an auditorium, theatre but today, the application of acoustics has spread through many fields like medicine, warfare, architectural industries, etc.

2. MUSIC

According to Giang Nguyen, in theory, there is no exact definition of music. It depends on one's own point of view. Music is divided in many ways, typically by note, pulse and genre. These notes could be arranged horizontally which match on the same scale, or vertically which go up and down the scale. The pulse is the beat that runs in every piece of music. The genre is the kind of music including rock and roll, classical music. Most of the music is the product of working between composer and performer, while songs require a lyricist. A song sometimes can be used to create another one by keeping the tunes and changing the lyrics, which is best suitable for the performer. That is why different singers have different ways to sing a song. In addition, choosing the place to play music and considering who the audience will be are two keys to success of music. For example, a jazz fan will prefer a small smoky bar at late night instead of a large hall as a classical fan. Generally, music plays a role in human life and it can serve almost all sorts of listeners.

3. MUSIC HALL

According to Thom Andrews a music hall is a Theatre that is music driven (i.e., decisively linked to musical timing and organization) where, at the very least, music, language, vocalization, and physical movement exist, interact, or stand side by side in some kind of equality but performed by different performers and in a different social ambiance than works normally categorized as operas (performed by opera singers in opera houses) or musicals (performed by theatre singers in "legitimate" theatres").

4. ARCHITECTURE

According to [Vitruvius, 1692] in is his books De Architecture writes that, "Architecture is a science arising out of many other sciences, and adorned with much and varied learning; by the help of which a judgment is formed of those works which are the result of other arts. Practice and theory are its parents. Practice is the frequent and continued contemplation of the mode of executing any given work, or of the mere operation of the hands, for the conversion of the material in the best and readiest way. Theory is the result of that reasoning which demonstrates and explains that the material wrought has been so converted as to answer the end proposed"

5. MATERIALS

A large part of acoustical correction deals with the improvement of hearing conditions and the reduction of unwanted noise in rooms by reducing the energy of reflected sound. This is done mainly by the use of acoustical materials. Materials which have a substantially greater ability to absorb sound than such conventional ones such as wood, gins, hard plaster, or concrete.

The percentage of the energy absorbed by a material when a sound wave is reflected from, it is called the sound absorption coefficient, or acoustical absorptivity. This absorption

coefficient depends on the nature of the material, the frequency of the sound, and the angle at which the sound wave strikes the material.

6. DESIGN

According to Meriam webster dictionary, design is to create, fashion, execute, or construct according to plan.

CHAPTER 2

LITERATURE REVIEW

2.0 DEFINITIONS AND DESCRIPTION IN THE FIELD OF RESEARCH.

2.0.1 SOUND

According to Bleasy Cepeda Physical wave or a mechanical vibration, or simply a series of pressure vibrations, in an elastic medium. For airborne sound, the medium is air. For structure-borne sound the medium is concrete, steel, wood, glass and combinations of all of these.

For architects, we simply define sound as an audible signal. It simply means that the science of architectural acoustics is concerned with building occupants and sounds which he or she cannot detect are generally nor our concerns.

The physics of sound is called acoustics and the basic of sound includes the following:

- Frequency
- Pitch
- Loudness

2.0.2 REVERBERATION TIME

According to Wallace Clement Sabine, Reverberation is persistence of sound in an enclosure after the source of sound has stopped the stream of continuing sound is called reverberation. The rate of build-up of echo density is proportional to the square root of the volume of the room.

Reverberation Time (RT60) is the time it takes for a sound to decay by 60dB. It is governed by the absorption characteristics for the room in an enclosed environment sound can continue to reflect for a period after a source has stopped emitting sound. This prolongation of sound is called reverberation. the sound in a room to decrease by 60 decibels after a source stops generating sound. There are several reverberation formulae.

Sabine / Eyrings Formula for Reverberation Time:

RT60 =.049 V/a (0.16 V/a)

Where: RT60 = Reverberation Time

V = volume of the space (Cubic feet / Cubic meter)

a = sabins (total room absorption at given frequency)

k is a constant that equals 0.16 when the units of measurement are expressed in meters and 0.049 when units are expressed in feet

2.0.3 DECIBEL

In electronics and communications, the decibel (abbreviated as dB, and also as db and DB) is a logarithmic expression of the ratio between two signal power, voltage, or current levels.

In acoustics, the decibel is used as an absolute indicator of sound power per unit area.

(Mark, James E. (2007). *Physical Properties of Polymers Handbook*. Springer. p. 1025. Bibcode:2007ppph.book.....M. […] the decibel represents a reduction in power of 1.258 times)

2.0.4 AMPLITUDE

The **amplitude** of a periodic variable is a measure of its change in a single period.

(Knopp, Konrad; Bagemihl, Frederick (1996). *Theory of Functions Parts I and II*. Dover Publications. p. 3.)

2.0.5 ECHO

An *echo* is a repetition or imitation of sound. When sound waves hit a hard surface they might reflect, making the sound bounce and repeat.

2.0.6 VOICE

The faculty or power of uttering sounds through the mouth by the controlled expulsion of air; speech: to lose one's voice.

The sound or sounds uttered through the mouth of living creatures, especially of human beings in speaking, shouting, singing, etc.

2.0.7 OCTAVE

In music, an **octave** (Latin: *octavus*: eighth) or **perfect octave** (sometimes called the **diapason**) is the interval between one musical pitch and another with double its frequency. The octave relationship is a natural phenomenon that has been referred to as the "basic miracle of music", the use of which is "common in most musical systems". The interval between the first and second harmonics of the harmonic series is an octave.

(Duffin, Ross W. (2008). *What an equal temperament ruined harmony: (and why you should care)* (First published as a Norton paperback. ed.). New York: W. W. Norton. p. 163. ISBN 978-0-393-33420-3. Archived from the original on 5 December 2017. Retrieved 28 June2017.)

2.0.8 PUBLIC ADDRESS SYSTEM (PA-SYSTEM)

A **public address system** (**PA system**) is an electronic system comprising microphones, amplifiers, loudspeakers, and related equipment. It increases the apparent volume (loudness) of a human voice, musical instrument, or other acoustic sound source or recorded sound or music.

(Bruce Borgerson (November 1, 2003). "Is it P.A. or SR?". *Sound & Video Contractor*. Prism Business Media. Archived from the original on May 20, 2015. Retrieved May 19, 2015.)

2.1 HISTORY OF PHENOMENON STUDIED IN THE FIELD OF RESEARCH

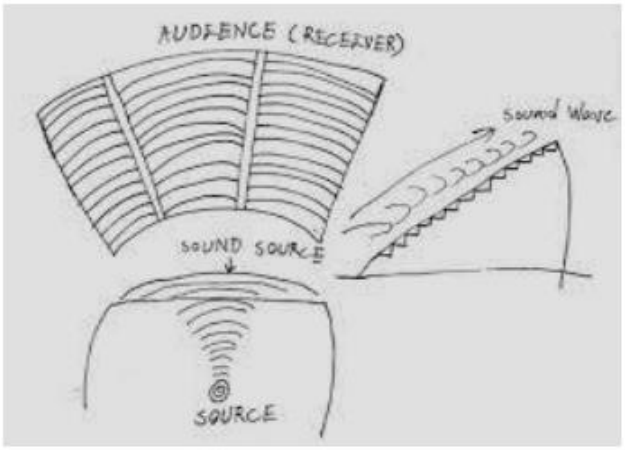
BUILDING ACOUSTICS: ANCIENT GREEK THEATER

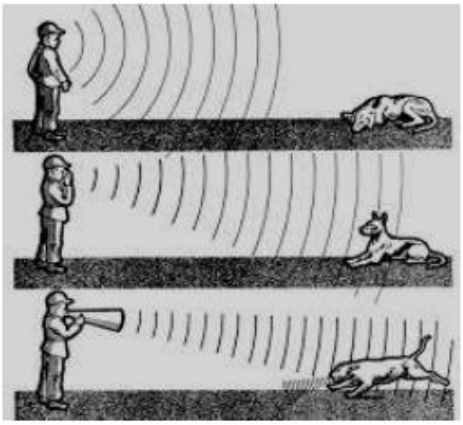
The Greek theatre history began with festivals honoring their gods. Actors were allowed to perform in each play. the chorus evolved into a very active part of Greek theatre. Music was often played during the chorus' delivery of its lines.

Greek Theatre buildings were called a *theatron*. The theaters were large, open air structures constructed on the slopes of hills. They consisted of three main elements: the orchestra, the skene, and the audience. For communicating to the crowds. (Both audio wise & vision wise communications) this became a very important design feature for theater building in the open air environments. As during those times no loud speakers were there. The seating visual angles for the arena area was very important. The actors had to use loud voices to become more effective communicators (see fig below) with focused blow of sound for attention of audience.

Skene: A large rectangular building situated behind the orchestra, used as a backstage. Actors could change their costumes and masks. Earlier the skene was a tent or hut, later it became a

permanent stone structure. These structures were sometimes painted to serve as backdrops behind all action scenarios.





2.2 PREVIOUS STUDIES CONDUCTED IN THE FIELD OF RESEARCH

LA FENICE – ACOUSTICAL PLANNING AND RECONSTRUCTION BY G. MULLERA AND J. REINHOLDA

The famous Teatro La Fenice in Venice was built in 1792. This typical Italian opera house burnt down in 1836 and again in 1996. Opera enthusiasts, musicians, critics as well as town officials demanded a precise reconstruction. They expected that thereby the well accepted "acoustics" of the famous opera could be achieved again. However, when starting any rebuilding, immediately modern requirements on security, stage machinery, air-condition and enlarging of the orchestra pit arise. The relatively high demands on the room acoustical quality of the house, the extremely limited space of the whole building complex in connection with the requirement of an increased number of rooms require a sophisticated room and building acoustical planning and realization.

The reconstruction requires a construction with the following architectural acoustics materials

• wooden beams made out of terrazzo which is typical of Venice.

• Terrazzo results in a relatively low noise protection which is typical of historical opera house.

• Due to the limited space the ventilation control had to be situated above the audience area. Because of fire protection and acoustical reasons, a reinforced concrete ceiling was necessary in contrast with the historical concept.

• For the Sale Apollinee a certain number of different types of wooden beam ceilings have to be reconstructed.

• As a Venetian distinctive feature, the ship traffic on the adjacent channels and on the bridges in the neighborhood must be taken into account. Big transportation cranes and the relatively short distance from the façades lead to relatively high acoustical requirements for the exterior construction elements.

2.3 RESEARCH GAP

1. According to a lot of Journals, poor understanding of acoustic architectural materials will cause noise and affect the ability of the audience and performers to perceive good sound.

2. Studies have shown that wrong use of acoustic materials could result in deafness when exposed to very high range.

3. Various acoustics Architectural materials have different absorption and diffusion properties to how they perceive sound, failure to understand this leads to poor planning and errors in the design of a music hall.

2.4 THEORETICAL FRAMEWORK TO THE FIELD OF RESEARCH

BLENDING ARCHITECTURAL & ACOUSTICS FACTORS IN DESIGNING A MUSIC HALL

A process of designing halls and theatres, in which the temporal and spatial design of architecture is demonstrated by the temporal and spatial factors of acoustics forms the theoretical framework.

Following a study which purpose was to investigate the acoustic factors that contribute to the overall acoustic quality of concert halls (Y.J. Choi and F.R. Fricke). The analysis was undertaken using Beranek orthogonal parameters who suggested six acoustical features that must be provided to achieving good acoustics. They are as follows:

I. EDT (Early Decay Time)

II. IACC (Inter-Aural Cross Correlation)

III. G_{mid} (the average intensity of the sound at mid-frequencies)

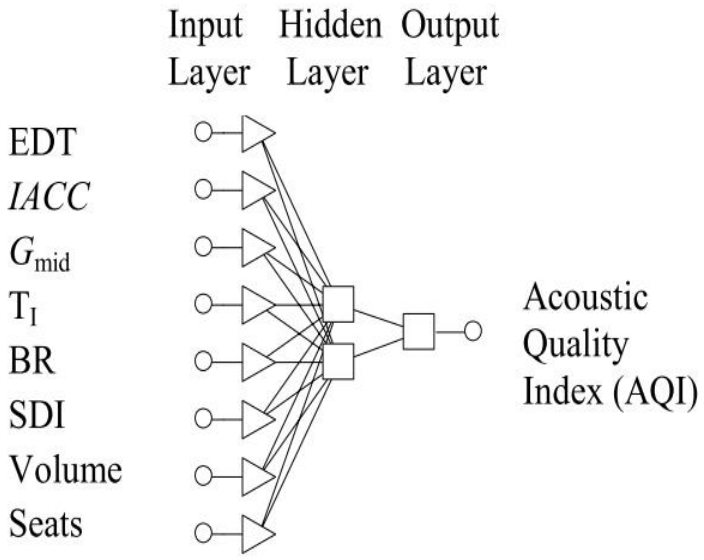
IV. T_i (Time to the first reflection)

V. BR (Bass Ratio)

VI. SDI (Surface Diffusivity Index).

The study was aimed at determining the combination of factors required for a good concert hall. As a first step, an independent evaluation of Beranek's approach was undertaken using Neural Network Analysis which is good at pattern recognition and as robust classifiers, with the ability to generalize in making decisions about imprecise input data. Also, a modified version of Beranek's theory that used a combination of some of Beranek's parameters with geometrical parameters, was examined to see whether this might give better results.

The following figure shows the neural network architecture of the research.



Both of architectural design and acoustic design were processed by temporal design and spatial factors. In order to blend architectural design and acoustic design, it is necessary to consider blending

the temporal factors of architectural design with those of acoustic design,

the spatial factors of architectural design with those of acoustic design,

the temporal and spatial factors of architectural design with those of acoustic design

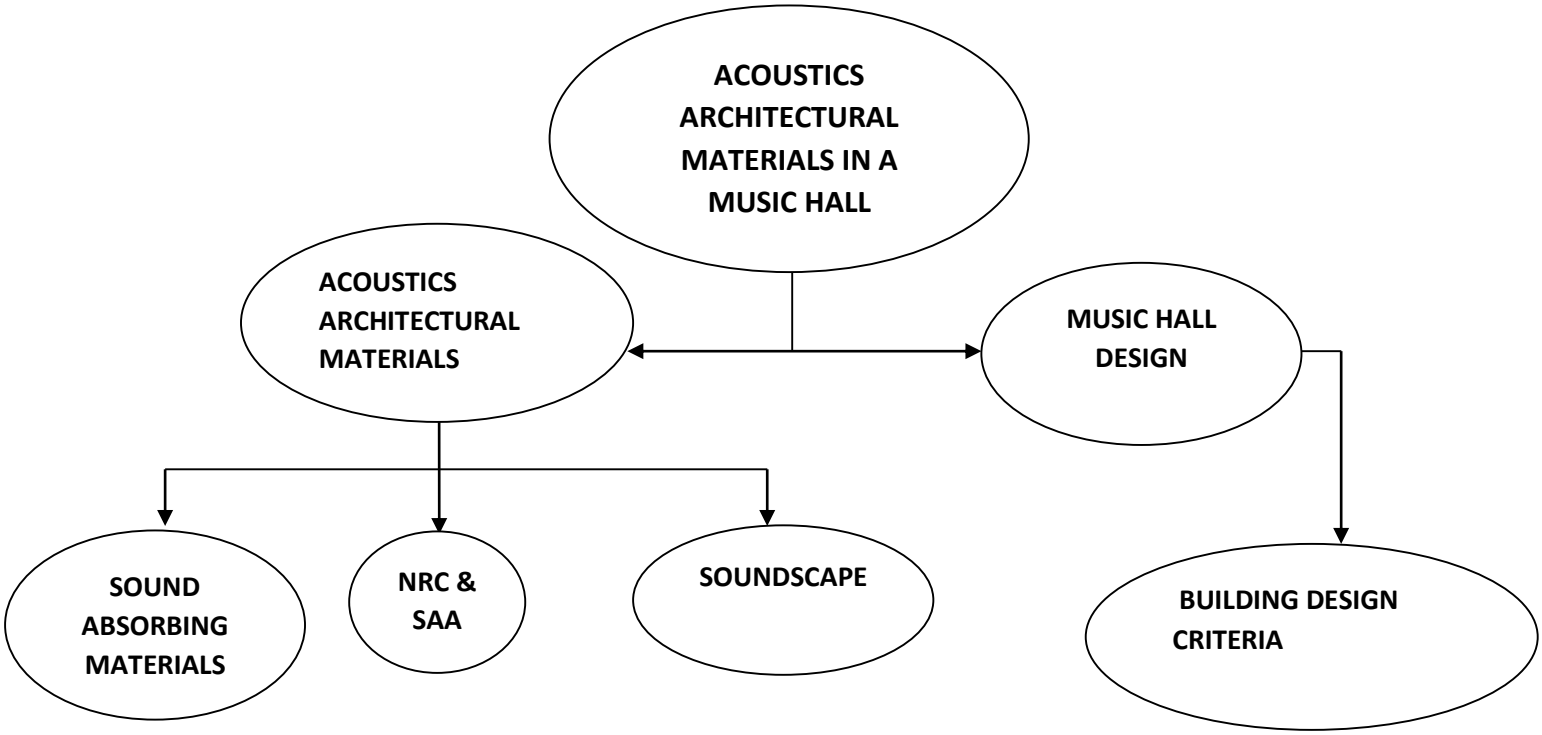
DESIGN PRINCIPLE FOR STAGE ACOUSTICS IN A MUSIC HALL

Among recording engineers and musicians there are complaints constructed concert acoustics is about stage acoustics at newly halls in Japan, such as “the unnatural”, “there is some lack of definition and clearness”, or “there seems to be a choked or stifled tone in feeling”, etc. Almost all of these concert halls have an end stage enclosed tightly with reflecting walls and

ceiling, in order not to lose the sound energy. It is considered that the complaints are brought about by the adverse effects of acoustic reflections from boundaries, such as a kind of booming or coloration caused by interference. Therefore, the control of acoustic reflections is very essential to give a good stage acoustics in a concert hall, especially in low frequency range. (Y. Hirasawa and Z. Maekawa, 1998)

Among room acousticians, it is said that the tone quality of a concert hall is depends almost entirely on the early reflection until about 100ms after the direct sound arrives. If so, the acoustics on a concert stage will be under the control of the reflections only from stage enclosure itself, since reflection from the audience space must be arriving later. Therefore, in order to study the tone quality of stage acoustics, it should be possible to use the stage enclosure only, without audience space.

2.5 CONCEPTUAL FRAMEWORK



ACOUSTIC ARCHITECTURAL MATERIALS

- **Sound Absorption Materials**

Sound absorbing materials will involve panels for floors, walls & ceiling. The sound absorption panels absorb acoustical energy (sound) and prevent it from reflecting or bouncing off of the surfaces they cover.

Absorption of Reflected Sound at various Frequencies						
Material	**125Hz**	**250Hz**	**500Hz**	**1kHz**	**2kHz**	**4kHz**
Brick	3%	3%	3%	4%	5%	7%
Carpet	8%	24%	57%	69%	71%	73%
Drapes	14%	35%	55%	72%	70%	65%
Drywall	29%	10%	5%	4%	7%	9%
Paneling	28%	22%	17%	9%	10%	11%
Plaster	14%	10%	6%	5%	4%	9%
Window Glass	35%	25%	18%	12%	7%	4%
Wood	15%	11%	10%	7%	7%	4%

NRC AND SAA

Specifications for materials used in sound absorption commonly include an NRC (Noise Reduction Coefficient) for simplicity, in addition to more detailed frequency versus amplitude charts.

The Noise Reduction Coefficient (NRC) and Sound Absorption Average (SSA) values are both single number ratings that indicate the level of sound absorption provided by the product being tested.

Soundscape

Soundscape is a sound or combination of sounds that forms or arises from a place. The study of soundscape is the subject of Ecology.

Soundscape can also refer to a performance of sounds that creates the sensation of experiencing a particular acoustic environment, compositions created using the instruments of an acoustic environment, either exclusively or in conjunction with musical performances (Prof Mukund).

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3. (Duffin, Ross W. (2008). What an equal temperament ruined harmony: (and why you should care) (First published as a Norton paperback. ed.). New York: W. W. Norton. p. 163. ISBN 978-0-393-33420-3. Archived from the original on 5 December 2017. Retrieved 28 June2017.)
4. (Bruce Borgerson (November 1, 2003). "Is it P.A. or SR?". Sound & Video Contractor. Prism Business Media. Archived from the original on May 20, 2015. Retrieved May 19, 2015.)
5. (Y. Hirasawa and Z. Maekawa, 1998)

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter aims to demonstrate the hypothetical assumptions that underpin this study, as well as the exploration method and associated experimental procedures.

This chapter contains the research methodology employed in this research. It includes the research design, study location, target population, sample and sampling techniques, instrument for data collection, validity and reliability of the instrument, method of data collection and method of data analysis.

3.2 RESEARCH DESIGN

This research adopts a qualitative method of research which includes observation, case studies and thorough review of journals. The descriptive nature of the study will be used various case studies to gain information about how architectural acoustic materials influence music hall design. This research work can, therefore, be categorized under the exploratory level of research as it seeks to investigate different architectural acoustic materials and the effect on the design of any music hall. In addition, a better understanding of existing materials and providing better materials that can help to create a better environment to enjoy music. The research to be carried out is qualitative because some primary research is employed.

3.3 SAMPLE SIZE

The proposed building to be used for this study is the Caleb university Auditorium, Lagos. The student population to be considered includes the undergraduate (100level – 400level) population.

Other buildings used as case studies sample size were taken into consideration.

3.4 SAMPLING TECHNIQUE

Random sampling technique was used in order to achieve a precise and more accurate result.

1. Photographs: Pictures of the current Caleb University, Lagos will be taken in order to get a clear view of the materials used in building it.
2. Tables/charts: Data gathered from this research will be put on tables and charts in order to study the trend.
3. Journals: various journal on previous studies will be assessed in order to gather enough
4. information on the research topic.
5. Sketches and notes: Drawings of the auditorium will be obtained and individual materials will be carefully analyzed.

3.5 SAMPLING PROCEDURE

The information used for this research will be gotten from the methodology used for data collection.

1. Visual study: This would be done by looking at the existing structure and looking into ways in which it could be improved.
2. Case study: Different case studies were used to carry out this research, modified to show acoustic properties locally and internationally.

3. Internet: The internet will provide enough information and insight on the research area.

3.6 ANALYSIS OF DATA

Information gathered from case studies and journals will be collated, described, distinguished and summarized.

3.7 ETHICAL CONSTRAINTS OF THE RESEARCH AREA

The Caleb university auditorium does not comprise all the qualities of a standard music hall, but it could be used as a case study, the reason being that it could be used to attain results that prove important to the study of architectural acoustic materials.

CHAPTER 4

DATA PRESENTATION AND ANALYSIS

4.1 INTRODUCTION

The discoveries from our methodology are to be talked about in this chapter, discussing findings from journals and case studies including their descriptions and analysis.

4.2 COLLATION OF DATA

4.2.1 CASE STUDY ONE: SALLE HENRY-LEBOEUF OF THE BRUSSELS PALAIS DES BEAUX-ARTS CONCERT HALL

- **Description**

The main Belgium concert hall, also called Salle Henry Le Boeuf of the Brussels Palais des Beaux-Arts has been inaugurated on October 19, 1929. The concept and the actual detailed design were led entirely by Architect Victor Horta.

Over the years, the hall has been transformed and new technology has been introduced. Its acoustics deteriorated: it became dry and lost its extraordinary bass qualities.

The main parameters are as follows:

- Number of seats: 2150
- Public area: 1300m2
- Stage: 186m2
- Total area: 1486m2
- Height of stage: 92cm above main floor, first row.

Fig 1: View of the stage at Salle Henry Leboeuf

4.2.2 CASE STUDY TWO: CALEB UNIVERSITY AUDITORIUM, LAGOS, NIGERIA.

- **Description**

The Caleb University Auditorium is an essential part of the university in which various activities involving the use of acoustics is performed. The auditorium is well shaped located at the center of the main Administrative and academic building of the university.

Its stage is made up of concrete block and it was finished with glazed tiles as well as the rest of the flooring in the hall. The auditorium has six different entrances and a lot of windows.

Fig 2: View of the Caleb University auditorium

4.3 INTERPRETATION OF DATA

4.3.1 CASE STUDY ONE: SALLE HENRY-LEBOEUF OF THE BRUSSELS PALAIS DES BEAUX-ARTS CONCERT HALL.

Materials used within the hall include the following;

- **CEILING**: 75 % of plaster placed on a metal grid, 20 % in heavy glass placed on heavy metal structures, damped by a wire mesh (cf. Horta), 5 % of light systems.
- **WALLS**: the walls are made of plaster placed on a brick residue; the walls are usually painted.
- **COLUMNS**: The columns are made of plaster placed on concrete.
- **MAIN FLOOR**: the main floor is made mostly of pine on 75 mm sleepers on concrete.

- **UPPER FLOORS**: the upper floors are made of pine glued directly on concrete.
- **STAGE FLOOR**: the stage is made of wooden floors on concrete floor (under the concrete floor Horta designed a large resonant cavity; originally the floor was made of pine with oak veneer as top layer).
    - **CARPETING**: A thick carpet on foam in the stalls, balcony and boxes (the original carpet was presumably thin or non-existent). The thick carpet will absorb the sound produced around the concert hall.
    - **SEATS OF THE STALLS, DRESS-CIRCLES, BALCONIES AND BOXES**: The seats enable absorption on all sides, thick seat and back, upholstered seats, thick wood layer under the seat and thin wood layer on the back.
    - **GALLERIES**: The galleries are made of upholstered seats; a thick wood layer is placed under the seat and thin wood layer is placed on the back.

The key element used in the reconstruction were:

1. The initial wooden stage for the orchestra was replaced in the early 70's by a concrete stage with a wooden floor on thin sleepers.
2. Openings all over the orchestra were eliminated.

4.3.2 CASE STUDY TWO: CALEB UNIVERSITY AUDITORIUM, LAGOS, NIGERIA.

The auditorium can be used for various activities using proper PA system which will enhance good acoustics. The wooden chairs do not aid good acoustics as sound is not been absorbed but deflected causing various distortion and echoes within the hall. One of its good qualities is its shape which helps good spread of sound waves.

4.4 ANALYSIS OF DATA BASED ON METHODOLOGY

The acoustics of Salle Henry-Leboeuf in Brussels was standard and renowned, but over the years poor maintenance and poorly planned renovations caused a lot of damage and negative effects to the acoustic sound production through the concert hall.

The materials within the Caleb University Auditorium includes the following; glass, concrete block wall, wood, steel and plaster of Paris (P.O.P), all of which react differently to high, mid and low sound frequencies. These materials react either by absorption, reflection and diffusion of sound waves.

4.5 PRESENTATION AND DISCUSSION OF FINDINGS

Several changes have been made to the concert hall in order to recover its standard and well renowned acoustics, these changes include extensive acoustics measurements, inventory of known modification and measurements before and after renovation.

At full capacity a person on the stage speaking with a PA system would not be properly head at the back because the hall is not designed with acoustic architectural materials that should aid that wholeness and clarity around the hall.

4.6 SUMMARY OF FINDINGS

At the end of this chapter, it was noted that clumsy renovations of music hall can permanently alter the acoustics. Knowledge of acoustics architectural materials and principles shows that it is possible to recover most of the original and essential features of acoustics, sited example from the Salle Henry-Leboeuf in Brussels concert hall.

It should also be noted that the use of a sophisticated PA system in a hall designed without properly incorporating acoustic architectural materials and design principles would not be sufficient enough to have standard and clear sound within the hall, example shown in the Caleb University Auditorium.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter presents the conclusions drawn and the recommendation made based on the findings from previous chapter. This chapter also presents the contribution to knowledge based on the findings of this research.

5.2 CONCLUSION

The acoustic architectural properties of materials are essential when considering the design of a music hall. It is very important to take architectural acoustic materials into consideration when designing a music hall. This study will enable individuals and performers to feel comfortable within a music hall. It will also provide optimal performance for music and speech production within the building. The use of materials such as oak and pine which are naturally sound absorbing in nature are generally required when considering music hall designs. Reduction of noise is indispensable as it diminishes disturbance, irritation or poor sound production within the space.

This research has shown that due consideration to acoustic architectural materials is an essential requirement for the design of an acoustically sound music hall design.

5.3 RECOMMENDATION

This research has proven that the use architectural acoustic materials cannot be overemphasized. The recommendations which can be drawn from this research

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