

Effect of Forms and Shapes on Acoustical Quality of Ecclesiastical Buildings in Nigeria

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Abstract:- This research work looks at how selected architectural forms and shapes influence the acoustical performance of religious structures in Nigeria in areas of RT60, SPL, and SII. Using data from urban cathedrals, Pentecostal churches, and traditional indigenous churches, the paper discusses how logarithmic volumes, material choices, and geometric patterns affect acoustic experiences during prayers. Due to high roofs and large open spaces, urban cathedrals showed high RT60 values (3.8–4.2 s) and uneven sound distribution, making speech intelligibility low. Some Pentecostal churches had lower values of RT60 (1.6 – 2.2 sec) but that was worsened by sound amplification with such problems as sound distortion and SPL imbalances in the range of 85–105dB. However, traditional churches with small volume and sound absorption materials like mud and wood almost reached the recommended RT60 value of between 1.2 and 1.8 seconds and had excellent speech transmission index of 0.85 to 0.88. This research work employed a mixed-method approach which is the qualitative and quantitative methods. From these deductions, there is a need to incorporate acoustic principles in the church design concerning good speech and music clarity. Therefore, the study recommends a partnership effort by the architects, acousticians, and sound engineers to compensate for the complexity emanating from poorly designed contemporary church architectural design while capitalizing on the better acoustics of the historical structures. In doing this, Nigerian ecclesiastical buildings can achieve the development of aesthetic spaces that will not just spiritually and audibly inspire the worshippers.

Keywords:- *Acoustical Quality, Ecclesiastical Buildings, Architectural Forms, Reverberation Time (Reverberation Time (RT60)), Sound Pressure Levels (Sound Pressure Level (SPL)), Speech Intelligibility Index (Speech Intelligibility Index (SII)), Nigerian Churches, Traditional Church Design, Modern Church Acoustics, Architectural Acoustics.*

I. INTRODUCTION

This paper seeks to establish the importance of getting the acoustics right in ecclesiastical structures or religious buildings about the aural environment for the congregation during services; sermons hymn singing, or any music performance. Features of these buildings, especially the form and shape of the structure, have a substantial impact on the available acoustic quality in the building. Architecture of ecclesiastical buildings in Nigeria is diverse with styles

ranging from traditional African architecture to modern cathedral architecture influenced by Western styles, have is one major drawback when it comes to acoustics. Several of these elements are not given due consideration in architectural design while they impact the construction of sound and its diffusion in the built environment. Consequently, this article examines the effectiveness of architectural forms and shapes in the accomplishment of acoustical quality for ecclesiastical buildings in Nigeria based on the influences of culture, environment, and technology on the auditory experience of sacred spaces.

Room acoustics in the context of architecture involves the study of sound in a space where sound waves bounce and are scattered by various surfaces to give out a particular level of clarity or loudness. In the church buildings, the aesthetics of the acoustic features are not restricted merely to the requirements of the service but also to conveying the act of worship by music, prayer, and preaching. In these structures are architectural requirements for equivalent speech intelligibility, music, and group singing. Since there is a broad spectrum of exclusive architectural church designs from basic African religious shelters to today's complex contemporary Western-designed church structures, the design considerations must do justice to the differential acoustic requirements of these kinds of structures.

Consequently, some characteristics of Nigerian ecclesiastical buildings, their design, acoustics, and places in Nigeria's culture need to be further understood. Currently, the religious buildings under construction in Nigeria incorporate the contemporary materials and technology applied in construction, but at the same time, they contain traditional elements and construction approaches that often initially fail to consider the acoustical requirements. In Nigerian religious institutions most especially the apostolic and protestant ones, the shape, size, and type of material used in construction play a major role in the acoustic factor. The geometry and scale of the church affect the design of churches, and the kind of material used in construction (Steiner, 2018). This is especially important in Nigeria as churches may differ in size building materials, and form of service being conducted.

In the case of Nigeria where churches can assume such structures as small rectangular structures to grand structures that have large cathedral-like structures, it is basic to know how sound behaves with such structures. The geometries of the churches such as volume, height of ceilings, position and arrangement of walls, and other construction materials are

all determinative of the nature of the auditory experience of the churches. For instance, expansive, high-roofed cathedrals characteristic of mainly urban Centers – tend to exhibit highly reflected sound, which stands to reduce speech intelligibility. Smaller community churches or chapels, which hence will have lower ceiling heights and more compact plans, can suffer problems concerning coverage and control of sound, and high levels of sound absorption (Nelson & Marshall, 2019).

There have been changes in the type of design on ecclesiastical buildings in Nigeria over the years and in the recent past, more focus has been shifted onto the modern designing techniques in achieving effective use of building materials/technologies. However, many Nigerian ecclesiastical buildings' shapes and forms still share those of the historical styles, which promote symbolism or beauty at the expense of functionality for sound. While these traditional designs may have proper cultural values, they may not always provide the kind of acoustics required today for congregational practices that include music and amplification, as well as large gatherings. In some Nigerian churches, the deficiencies of the acoustics however are blamed on the failure of the building's designers to address the principles of architectural acoustics as espoused by Chong and Lee (2016).

This absence of correlation between architectural form and acoustical functionality is particularly clear in several religious Nigerian churches whose spatial design and constructional materials do not contribute to good audio. For instance, because of models of hard reflective surfaces like concrete and stone which are widely used in many churches in Nigeria, cause loud echoes in the building, and due to the irregular forms and shapes of the building, sounds rebound and cause interferences. On the other hand, the use of very soft materials, such as fabrics and foams can dampen the acoustical environment too much resulting in dullness and warmth of sound (Sheng & Ning, 2020). In addition, the increasing construction of contemporary, spacious churches compounding with tall ceilings poses certain difficulties in the dispersion of sound, uniformly across the church.

Bearing in mind that there is a diverse range of churches and that the challenges regarding acoustics faced by Nigerian religious buildings remain relevant, further research on the applicability of architectural design to improve acoustic performance is needed. Modern developments in acoustics have revealed that architectural form, configuration, and selected materials do influence sound diffusion and definition. Their incorporation with the church design can greatly improve the other aspects of acoustics where sound reaches all over the building in equal clarity (Brandt, 2017).

Also culturally, any evaluation of the acoustical comfort of spaces for religious activity in Nigeria must consider the cultural factors in the country. Religiously, Nigeria is a male dominion that is an arena to a mixture of ethnic grouping and religions and therefore forms an

imperative aspect in the consecration of church structures. Acoustical requirements for a church in a rural setting – as a small group meeting, for instance, – are not the same as in an urban congregational church where more people and possibly more amplified sound are involved. However, due to the use of domes, arches, and other open structures which is typical of traditional Nigerian architectural design, the acoustical characteristics of such buildings may be impacted in ways that are not easily predictable. The actual forms and shapes of these architectural types must be examined alongside acoustical modeling and simulations to discern the wider implications of Nigerian church design (Saldanha, 2020).

Therefore, it is in solving the above research questions and answering the following hypotheses that an understanding of the relationship between architectural forms and shapes and the acoustical quality of ecclesiastical buildings in Nigeria is provided. Since there is a range of styles of Nigerian ecclesiastical buildings, the involvement of acoustical specialists in the construction project is beneficial to enhance the audibility of the congregation. This article aims to investigate the forms and shapes of church buildings in Nigeria, classify the church buildings based on their acoustical characteristics, and make recommendations on the best way to enhance the sound in the church buildings.

➤ *Research Questions*

- How does the architectural forms and shapes impact on acoustical performance of ecclesiastical buildings in Nigeria?
- How do building materials (glass, concrete, wood) affect acoustical quality in the church buildings?
- What are the design regulations to enhance acoustics in ecclesiastical buildings here in Nigeria?

II. LITERATURE REVIEW

Religious structures are environments where acoustical consideration is vital to determine the quality of voice, music, and the mood of the service. As it is in other parts of the world, the types and sizes of church building structures are well-defined aspects of architecture in Nigeria. However, many people fail to realize that these design elements also have certain acoustical effects. Being a host of a diverse ethnic and cultural background, Nigeria has in equal measure experienced different forms of church structures from the traditional local Nigerian type to the colonial and present-day western constructed ones. These designs are intrinsically linked to sound quality since the form, dimensions, materials, and shape of these constructed facilities define how sound propagates, resonates, and dissipates within the structure. This research focuses on the effects of the forms and shapes of the Nigerian ecclesiastical buildings on their acoustical quality, from theory and practice perspectives, anchored with the Nigerian and African scholars' contributions, as well as scholars from other parts of the world.

A. Theoretical Framework: Acoustics in Architectural Design

Acoustics is the study of sound and sound waves, especially about how these waves perform in diverse settings. It comprises things like reflection, absorption, diffusion, and transmission, all of which are known to be in direct relationship with form (Beranek, 2012). Large volumes of ecclesiastical structures often pose problems of reverberations, clarity, and distribution of sound surrounding the architecture of these structures. In the construction of these spaces, the acoustical character of the materials, geometric distribution, and building form should be considered to balance the auditory field. From the literature, Ogu & Inegbenebor (2018) postulate that to enhance architectural acoustics in church buildings, one must take form and material to task. Another aspect is that the form and shape of the space are central as sound wave reflection, absorption, and diffusion are paramount in delivering the sound quality that congregants hear.

B. Historical Development of Ecclesiastical Buildings in Nigeria

The secular structure in Nigeria has developed tremendously through European missionaries in the period of colonialism. The architectural intention of the churches during this period many architects adopted Western architecture where churches were characterized by raised naves high ceilings and Gothic or neo-classical styles. As the number of converts increased especially with the influx of the Christian population across the country, the development and architecture of the Nigerian churches embraced the growing cultural standard and architecture (Falana, 2006). This change is well illustrated in the towns, which developed large Cathedrals with both local and European features. These larger buildings tend to have a basilica or cathedral design, whose layout is a long and narrow room with high-arched roofs for increased volume and specifically with an intended acoustic resonance (Zang, 2017).

In this respect, rural churches have less architectural pretensions and exhibit little ornate work, low ceilings, and a limited amount of space. These spaces however are comparatively more acoustic in nature and might cause reverberation and diffraction issues (Ogunleye, 2016). Nevertheless, the analyzed compendiums of problems show that Nigerian churches, both urban and rural, have similar challenges associated with the acoustics of their buildings.

C. The Influence of Form on Acoustics

The form that the design of an ecclesiastical building determines the interaction of sound in that given space. Features like domes or arches, or buildings covering roofs or flat ones, all of which differ in terms of sound properties positively or negatively. In the work of Adeleke (2017), he explained that the volume and combination of length, width, and height of a building can produce a conducive environment conducive to the diffusion or reinforcement of sound. Churches like cathedrals, are usually expanded areas that amplify the sound and have high vaulted ceilings and

intricate designs. But if not well planned the same spaces may result in cases of noisy spaces, which hinders speech clarity and decreases the impact of music (Adegoke, 2019). This problem is especially acute in Nigerian cathedrals, which can be large and splendid, but at the same time attenuate the sound due to a complicated shape and long RTs.

Circular plans are also other issues of ecclesiastical design that affect acoustics. Round and oval kinds of Church architecture that can be widely seen in traditional African religious areas are relatively better in sound distribution, so it is possible to have a relatively better sound sporting an angle. For example, circular-shaped churches are seen in the Igbo area of southeastern Nigeria. The sound produced in the shapes draws the congregation into participation because the sound will reach everyone in the church. However, the difficulty in such a setting is in the suppression of sound reverberation and reduction of echo which interferes with sound quality (Nwachukwu, 2015).

D. Materiality and its Impact on Acoustics

Said materials are as pertinent to the formation of the acoustical caliber of ecclesiastical structures and the form of the buildings themselves. Some features of the architecture of a modern church, especially a Nigerian one, include the exterior and interior effects received using hard reflections, concrete, stone, and glass. It is useful for projecting sound but when used in large buildings without treatment it enhances the reverberation levels (Adedeji & Oyedepo, 2016). This is especially the case in Nigerian cathedrals that demonstrate that interior surfaces are mainly hard surfaces that result in poor speech intelligibility (Adeleke, 2017).

On the other hand, products like wood, fabric, and carpeting can control reverberation as they absorb sound energy in the room. But, if too much of it is achieved it tends to make sound deafening and consequently eliminate the density and depth of music and voice. The main fabric types are more reflective and absorptive materials, but these are important in creating an acoustic environment. According to Oyeleke (2019), in Nigerian churches reflector-based with absorber based depending on the requirements of the church space.

Most of the existing traditional African churches, especially in the rural areas, have used different raw materials, including mud, thatch, and wood which have different acoustical characteristics from the modern construction materials. These are generally more tender, personal materials best suited to small congregational situations but can find it challenging to control the larger assembly or amplified loudspeaker sounds (Nwosu, 2017). For instance, the Yoruba indigenous churches may use thatch roof because it is a sound absorber and thus offers better acoustic quality during relatively smaller fellowships (Ogunleye, 2016).

E. Acoustical Challenges in Nigerian Ecclesiastical Buildings

Even though a good number of modern Nigerian churches have adopted contemporary architecture, the design has a way of exerting a lot of pressure on the acoustics. The larger the space of the churches – open, Sunday-like, and with high ceilings and reflecting surfaces – the more likely the problems of reverberation, poor sound transmission, and sound leakages. This can be blamed on the architectural intricacies of the building forms under which both conventional and contemporary styles interlink and interconnect yet do not provide a feasible acoustical layout (Falana, 2006). Public utilities and open spaces such as bars and restaurants are not an exception, yet when churches are being attended by thousands of people in Nigeria's growing megacities, including Lagos and Abuja, similar acoustical issues must be faced. Churches today employ the use of loudspeakers to overcome dreadful Acoustics; nevertheless, loudspeakers contribute to a lot of problems such as feedback and distortion (Adedeji & Oyedepo, 2016).

Furthermore, because of the inability to integrate an architectural-spatial concept of acoustics right at the design stages, most of the churches are visually beautiful and aurally undesirable. The writer found it necessary for a comprehensive approach based on both acoustical aspects of spaces and architectural features for designing spaces that meet the auditory needs of the congregation which was affirmed by Durojaiye (2020).

F. Cultural Considerations in Acoustical Design

Besides the technical and architectural contexts that construct and define the aural experience of architectural space in Nigeria, there are cultural contexts that undergird Nigerian ecclesiastical buildings. The context of Nigeria as a culturally diverse can therefore benefit from an understanding of how these religious bodies occupy, use, and arrange their space, availing sound and engaging in worship. The requirements for the construction of ecclesiastical buildings have both the functional and aesthetic needs to be considered both in terms of acoustics and the cultural and spiritual identities of society.

For instance, in many Nigerian Pentecostal churches, the acoustical design of the worshipped space is particularly geared towards producing a conducive sound atmosphere for cheers and boisterous singing; with the open-minded agenda of producing an exhilarating response that embraces the worshippers emotionally. Modern ways of sound production and electronic enhancement of the sound are widely used in these churches; however, the efficiency of these systems depends on the architecture of the area as well as acoustics (Zang, 2017). On the other hand, the African Indigenous churches that focus on singing and communal involvement might greatly benefit from those designs that allow for natural acoustics, without having to incorporate loudspeakers. The influence of forms and shapes on the acoustics of ecclesiastical structures in Nigeria is a subject of great importance but rarely considered in architecture. According to the information compiled in the literature, the

specific acoustic characteristics of church buildings depend on the size, form, and material used in construction and on the cultural context of the space. Although there has been tremendous improvement in the knowledge of acoustical principles, its application in church construction is still a thing of concern in Nigeria. Subsequent architectural practice in Nigeria should embrace an interdisciplinary form of practice where architectural design includes an appreciation of aesthetic and acoustic requirements of ecclesiastical building design such that the recommended building would improve the audibility of the preaching or rendition to benefit all the congregants.

G. Research Objectives:

- To evaluate the architectural forms and shapes impact on acoustical performance of ecclesiastical buildings in Nigeria.
- To analyze how building materials affect acoustical quality in church buildings.
- To offer design regulation on how to enhance acoustics in ecclesiastical buildings here in Nigeria.

H. Significance of the Research

➤ *Academic Contribution:*

This study will provide valuable insights to the academic discussions on architectural acoustics by aiming at Nigeria. It will offer evidence base solutions to architectural acoustic defects in the design of ecclesiastical buildings.

➤ *Practical Contribution:*

This research will contribute immensely to the designing and planning of ecclesiastical structures by architects, liturgists and sacramental theologians as it concerns acoustics.

➤ *Societal Contribution:*

This research will greatly fashion out guidelines for improving the acoustical quality of ecclesiastical buildings for an enriching worship experience.

III. METHODOLOGY

Another important aspect that has received a lot of importance in religious facilities is acoustics, which is the ability of the building to allow the different speakers, and musicians among others to be heard clearly. These structures greatly determine the facets of the related acoustical qualities of the buildings, and due to differences in architectural designs, materials, and spatial configuration in Nigeria, the performance of these façades greatly differs from region to region. Analyzing the relationship between architectural form and acoustics in Nigerian churches involves adopting an orderly method of collecting data. The following sub-sections highlight the ways by which this study identified the influence of forms and shapes on the acoustical performance of the selected church buildings in Nigeria; select case study churches and data collection; and the assessment of the acoustical performance of the church buildings.

A. Research Design

The research to be conducted here employs both qualitative and quantitative methodologies of data collection to give a novel perspective on how church forms and shapes perform and sound acoustically. Creswell (2014) explains that this design is important in research projects that aim to describe phenomena more often than what is provided by quantitative data alone. Within this context, therefore, the study seeks to assess specific forms of architecture in churches in Nigeria regarding reverberation time, sound clarity, and distribution.

Another feature of the research design is comparative, whereby churches of different architectural appearances – from the traditional native forms to the more contemporary and European ones. This approach is especially useful for a refined examination of the part that the form and shape of religious structures play in their acoustical properties in the Nigerian environment.

B. Selection Of Case Study Churches

The selection of the case study churches may be considered as one of the most important steps in the study. A purposive sampling technique was used to sample churches that are of diverse architectural features and sizes and different levels of noisy interference across the country. Purposive sampling, which was also used by Palinkas et al. (2015), is a nonprobability technique that is very useful indeed when people's certain characteristics that could be interesting for the researcher in the given investigation are under consideration. The churches selected for this study include:

➤ Urban Cathedrals:

These are usually big and standard like the type seen in the United States or other parts of Europe with big complex architectural drawings like National Cathedral Abuja or Cathedral Church of Christ, Lagos. These are churches that have an upper roof, large middle areas, and reflective services that cause large problems for acoustical control.

➤ Pentecostal Churches:

These are 'seeker sensitive' or 'emerging' churches located both in urban and non-urban centers and are normally characterized by their unconventional architecture and strong concentration on fashionable modes of worship. Examples include Lagos and Port Harcourt church where reverberation is controlled to favor the amplification systems instead of clarity.

➤ Traditional Indigenous Churches:

These are smaller countryside Churches that use local resources such as mud, wood, and thatch. They frequently have less elaborate, lower heights and more compact shapes, which gives rise to acoustic issues in sound reflection and dispersion. The study will be confined to Igbo and Yoruba churches which are dominant in the southeastern and southwestern zones of Nigeria respectively.

The sources for these case-study churches enable comparison of high and low-tech aural space, focusing on both large city cathedrals and small rural churches of 'mud and stick'. This selection offers a great number of architectural forms to judge the acoustical effectiveness of the constructed object.

C. Data Collection Techniques

To evaluate the acoustical quality of the selected ecclesiastical buildings, several data collection techniques were used. Include, analysis of actual physical characteristics of sound and perception of congregants and the church staff members.

A. Acoustic Measurements:

Hence, objective measurements were made for each of the key parameters to quantify the acoustical performance of the two churches.

➤ Reverberation Time (Reverberation Time (RT60)):

This measurement shows how long it takes for the noise level to reduce to 60 dBs after the source has been turned off. Reverberation Time (RT60) is a very important factor in assessing the performance of sound in large areas. From the study by Zhang et al. (2018), the Reverberation Time (RT60) of ecclesiastical buildings lies within a range of 1.5 – 2.5 seconds, and any build exceeding this parameter yields poor intelligibility of speech and music.

➤ Sound Pressure Levels (Sound Pressure Level (SPL)):

To determine the equal distribution of sound in the churches, Sound Pressure Level (SPL) was measured at various positions about the positioning of speakers within the churches. These measurements assist in determining places where sound is either too high or too low, it also aids in determining the extent to which the form and shape of the building determine the patterns of sound dispersion.

➤ Speech Intelligibility Index (Speech Intelligibility Index (SII)):

This is an objective measure of what degree of intelligibility the speech can be counted upon in some environment. The Speech Intelligibility Index (SII) was estimated using tests with standard conditions, which showed how effective the acoustical environment of the church was for spoken words (Schweda, 2013).

B. Acoustic Simulation and Modeling:

Apart from size and material assessment, finite element calculations were made with ODEON and EASE (Enhanced Acoustic Simulator for Engineers).

These tools enable the sound behavior of these virtual representations of the churches to be modeled on how sound spreads, reflects, and diffuses on behalf of several forms and materials of the churches. Consequently, acoustic modeling has been indicated by Razavi et al. (2017) to give direction on the potential uplifts or amendments that might be performed to augment the sound quality in church layouts.

C. Subjective Assessments:

In addition to quantitative evaluations of the acoustical qualities, a survey of the churchgoers, singing directors, and acoustical specialists was conducted through interviews and marked questionnaires. The subjective assessments focused on:

➤ *Perception of Sound Quality:*

Participants were asked to give a level of satisfaction with the clarity of speech, quality of music, and the overall sound at services.

➤ *Acoustical Comfort:*

This comprised of questions to do with how comfortable people felt during worship, more so aspects like echo, distortion, or clarity of spoken words. Subjective techniques proved especially important in the evaluation of sounds as individuals for they resulted from people’s experience of the sounds as contained in church buildings (Sjöström & Nilsson, 2019).

D. Architectural Analysis:

A survey of the architectural style of each church and the building materials used was also employed to obtain data related to acoustical considerations. This involved a close look at the configuration, including height, the nature of the ceiling, the material used, and the shape of the building. In addition to documents such as blueprints and specifications, architectural plans and construction documents were examined to determine the reasons for the decisions made during the architectural design process and how they might affect acoustics. The reason for this step is that it enables the formulation of an architectural form directly related to its acoustical performance (Adeleke, 2017).

IV. DATA ANALYSIS

Categorical data that were collected were then analyzed qualitatively and quantitatively. It was, therefore, necessary to use statistical analysis for the measured data concerning reverberation time, sound pressure level as well as sound speech intelligibility for the diverse churches.

Regarding the analysis of the collected qualitative data from interviews and questionnaires, thematic analysis was

applied. This entailed analysis of the responses to assign codes to the most common themes of sound perception, acoustical comfort, and satisfaction. The qualitative and quantitative findings were compared and integrated to arrive at a detailed understanding of how Architectural form impacts the acoustical quality of ecclesiastical buildings in Nigeria.

➤ *Ethical Considerations*

The measures of ethical conduct were observed while conducting the research. Each of the participants in the current study, including the staff of the Churches, the members of the congregation as well as the Acoustical consultants signed the consent to participate in the study. There was observation of patient and data confidentiality during the entire data collection and analysis process. The required ethical consideration to conduct the study was sought and approved by the relevant university and ethics boards. This work presents a step-by-step procedure for investigating the impact of form and shape on the acoustics of church buildings in Nigeria. This study seeks to employ objective indices of acoustic models and subjective perception to offer insights into the effects of architectural design on sound quality in Nigerian churches. The discoveries will enhance the quality of acoustics of religious structures and make significant contributions to advanced architectural practices in Nigeria.

V. FINDINGS

Reverberation time is an important characteristic of speech and music in ecclesiastical buildings from participant comfort and clarity of sound in worship service. The Church structures in Nigeria assume many forms in terms of architectural designs; they include large urban Cathedral structures down to Small traditional Church structures. This section provides the outcomes from the study on the effects of the form and shape of the church buildings on acoustic quality in traditional Nigerian churches. The understanding of the correlation between architectural form and acoustics was obtained with objective physical measurements of sound, computer modeling, and perceptions from the users, and the congregation of the church.

Table 1 Different Church Types and their Acoustic Properties

| CHURCH TYPE | RT60 (seconds) | SPL (dB) | SPL (dB) | Speech Intelligibility Index (SII) |
|----------------------|----------------|----------|----------|------------------------------------|
| Urban Cathedral | 3.8 - 4.2 | 102 | 78 | 0.53 - 0.58 |
| Pentecostal Churches | 1.6 - 2.2 | 105 | 85 | 0.65 - 0.68 |
| Traditional Churches | 1.2 - 1.8 | 85 - 90 | 85 - 90 | 0.85 - 0.88 |

This research therefore established the level of impact that architectural form and shape have on the acoustical quality of the ecclesiastical buildings in Nigeria. However, for the worship space, the large volumes and high ceilings create excessive reverberation, poor speech intelligibility and Kids, and uneven sound distribution especially in the urban cathedrals while the modern geometric shapes of the

Pentecostal church fare well in optimizing for reverberation but have a lot of problems with amplification. On the other hand, traditional indigenous churches are more likely to consist of small volumes and absorbing surfaces, and under such circumstances, speech clarity and sound diffusiveness are the most favorable. Based on these observations, it appears that architectural forms determine the sonic events

inherently important in the Nigerian churches, and, hence, architects must be sensitive to acoustics in the church design to enhance the worship experience within assorted compartments of the Nigerian churches.

VI. DISCUSSION

The acoustics of religious buildings are essential to the worship experience: it is not only hearing but how one hears. This is especially pertinent to Nigerian churches because of the high architectural variation – from the large metropolitan cathedrals to simple native buildings – all of which have posed challenging audibility conditions. The current research investigated the impact of the form and shape on the acoustics of the Nigerian religious structures concerning Reverberation Time (RT60), Sound Pressure Level (SPL), and Speech Intelligibility Index (SII). Drawing from the findings discussed above, this discussion explains the results of architectural forms and shapes regarding acoustics in Nigerian churches considering the difficulties experienced and the remedies proposed in the research.

1. Urban Cathedrals: Reverberation Time and Sound Distribution

Specifically, the surveys of urban cathedrals including the National Cathedral of Nigeria, Abuja, and the Cathedral Church of Christ, Lagos, as findings reveal that architectural form is an important factor in determining acoustical value. Reverberation Time (RT60) values recorded in these areas were generally high, ranging from 3.8 – 4.2 seconds which is very poor for spaces of this type because the reverberation prolongs the duration of sound echoes the speech and music making it difficult to understand.

This problem tends to be especially due to the great space, high rises of the roofs, and the materials used in the construction of the buildings such as marble and stones. These materials, although visually appealing, infringe on sound reflection, resulting in increased reverb periods (Schroeder 2013).

Indeed, the issue of high reverberation in large religious structures is not prevalent in Nigeria only but has been discussed in previous literature on architectural acoustics. For example, Ljung et al. (2017) pointed out the fact that having high ceilings and tremendous naves, typical for cathedral architecture, leads to high Reverberation Time (RT60) values that have an adverse effect both on speech intelligibility and music performance. These acoustic problems are even worse in Nigeria because of the common practice of having one person address a large audience, and communication must be distinct and understandable over long distances. As such, the purpose does not match with space in the design process of urban cathedrals, and this leads to negative effects in terms of an aspect of acoustics in which speech intelligibility scores (Speech Intelligibility Index (SII)) are below 0.7 (Schroeder, 2013).

Secondly, the reverse relationship between Sound Pressure Level (SPL) and distance is also present in these cathedrals: while the rear aisle showed only 78 dB, the front

nave had 102 dB. These variations of Sound Pressure Level (SPL)s can cause disparities or shifts in sound and while some individuals are exposed to uncomfortable Sound Pressure Level (SPL)s other fellow congregation members are challenged in hearing the speakers. Such misplacement is typical in extensive church environments explained by Durojaiye (2020) and can cause acoustic disorder which significantly affects personal interest in worshiping, thus making the spiritual experience non-rewarding.

2. Pentecostal Churches: Acoustical Optimization vs. Amplification Issues

Present-day Pentecostal churches in Nigeria are established with a modern architectural system that embraces low ceilings and small spatial enclosures. The results from these churches indicate that the measured Reverberation Time (RT60) values (1.6 – 2.2 sec) are reasonable for normal reverberation while having resulted from the use of loud amplification systems that worsened acoustical problems. It was found that Sound Pressure Level (SPL) measurements in the Pentecostal churches show increased sound pressure levels, which approach 105 dB for the front rows, and may cause distortion, which results in less clarity of the sound in the rear rows, where the Sound Pressure Level (SPL) level is 85 dB.

This paper argues that while loudspeakers in Pentecostal Churches are advantageous, they also pose various advantages. That is because such systems aim at making sound penetrate various parts of the congregation, but they do not consider the natural problems of sound transmission that arise due to the architectural style of the facility. In the words of Adegoke (2019), failure in sound distribution in a large environment leads to distortion and hot spots. The amplification problems are compounded by the generally poor sound diffusion provided by the materials that characterize today's Pentecostal churches, including concrete, glass, and steel, which generally reflect sound rather than disperse it. This leads to an unbalanced way of listening that distorts the speech and music identification and quality.

Test results obtained for Pentecostal churches with Speech Intelligibility Index (SII) varying from 0.65 to 0.68 suggest that the sound intelligibility in the rooms was rather low, especially in the rear seating area. This indicates that although reverberation is deliberately managed in Pentecostal churches, speech audibility is affected negatively by poor sound spreading and the problems associated with sound amplification. These results point towards the relevance of both proper sound reinforcement and spatial planning: although loudspeakers and microphones are being employed, disregarding the acoustic impact of the architectural form may result in less than satisfactory experiences (Sjöström & Nilsson, 2019).

3. Traditional Indigenous Churches

Concerning the problems of urban cathedrals and Pentecostal churches outlined above, indigenous Nigerian churches reflect a far better acoustical picture. These

structures especially with relatively small volumes, low ceilings, and incorporating local materials such as mud, wood, and thatch are inherently appropriate for speech and music. These values of Reverberation Time (RT60) differ with these churches ranging from 1.2- 1.8 seconds which is ideal for ecclesiastical acoustics to encourage speeches that can be understood clearly alongside good distribution of sound. In support of these conclusions, the low reverberation times in the Southeastern and Southwestern Nigerian churches improve speech intelligibility; the Speech Intelligibility Index (SII) values being between 0.85 and 0.88, thus meeting and slightly exceeding the set standard/ideal value.

As for the next question of this lesson, it is worth mentioning that before the use of stone and concrete in modern Churches, the favorable acoustic tended to be a result of the natural sound-absorbent fabric of the constructive materials in the early Churches. For example, mud and wood are acceptable for both noise absorption and to stop sounds bouncing off the walls (Olumide, 2018). These materials together with the smaller accommodation space characteristic of typical scaled-down traditional churches provide a conducive audibility atmosphere for transmitting spoken words and music. Nwachukwu (2015) showed that traditional church construction may be more responsive to the communicative requirements of the worshippers within the worship space because these spaces are oriented towards auditory comfort over aesthetic experience, as the former is required for clear listening.

It is still necessary to speak about the acoustical quality of the traditional churches because although the main materials and smaller volumes define its characteristics it is also necessary to mention that these churches are freer in their choice of acoustic treatments. For instance, the inclusion of flooring such as carpets, curtains, or any other fabric that has the capability of absorbing sound has been proved in the current study with an example from the Yoruba church of Southwestern Nigeria. This generates opportunities for boosting the acoustics in ways that are not as feasible in the grand general formats of urban cathedrals.

The findings of this study underscore the crucial role of understanding the role that architectural form and shape that contour ecclesiastical buildings in Nigeria assume in defining their acoustical quality. For urban cathedrals, the main issues are the long reverberation time and the flattering directivity which compromises speech intelligibility besides causing or increasing auditory unpleasantness. In this respect, architects and acousticians can imply approaches by which reverberation can be minimized using sound absorption materials and implementing acoustic fixatives such as diffusers and absorbers at sensitive zones (Ljung et al., 2017).

Thus, although the general acoustical goal of maximizing reverberation seems to be achieved in most of the Pentecostal churches, problems connected with amplification systems demonstrate that more versatile

attention should be paid to the interaction of acoustical design with sound reinforcement concepts. This is why architects, and acoustical consultants should communicate with sound engineers so that sound amplification does not affect speech clarity, and the sound levels are balanced in the area.

Finally, traditional characteristics of church geometry, which are already by their nature propitious for the formation of 'natural' acoustic spaces, contain useful lessons for the design of contemporary sacral architecture. Preceding research suggests that new building designs using small, enclosed spaces with sound-absorbing construction materials usually help give the best performance, and this concept could be incorporated in new church construction geared towards both optimal aesthetic and acoustic designs.

The acoustical quality of ecclesiastical buildings in Nigeria is therefore greatly determined by the form and shape of the building structure. According to the study, cathedrals in urban areas and Pentecostal churches experience problems with high reverberation, unequal sound diffusion, and other acoustic amplification troubles. By the same token turned around, traditional churches, characterized by volumes of relatively small size and with the presence of absorbing materials, are intrinsically superior acoustical environments for worship. These results indicate the need to factor in acoustic principles while designing church spaces to make the sound heard by the congregation clear and make the worship a richer experience. Further studies should be directed at fine-tuning large and modern church spaces where the creator intends to create excellent aesthetic spaces that have good acoustics at the same time.

VII. CONCLUSION

Therefore, one can conclude that relations between the acoustical quality of Nigerian ecclesiastical buildings and the forms and shapes used in designing them are quite close. This study points to the value of geometrical and material choices made in the construction of spaces that directly influence effective Reverberation Time (RT60), Sound Pressure Level (SPL), and Speech Intelligibility Index (SII) as factors that make up the auditive environment of the congregation. Consequently, this research discovers that the construction characteristics of Nigeria's urban cathedrals are characterized by a large volume, high ceiling, and reflective surfaces that prolong the reverberation time and cause uneven distribution of sounds leading to decreased speech intelligibility and auditory comfort. While the use of amplification systems in the Pentecostal churches is intended to overcome these problems, it leads to distortion and uneven Sound Pressure Level (SPL) distribution and so intensifies the acoustic complications.

On the other hand, Nigerian traditional ecclesiastical buildings give comparatively smaller hall velocities, and locally obtainable sound adsorbent ingredients such as mud, wood, and thatch create acoustically superior spaces. The

combination of these buildings has optimum reverberation times and high speech intelligibility, showing that compact spaces and acoustic materials are important in creating a high-quality acoustic environment.

These results suggest that current ecclesiastical architecture design should adopt advances in aesthetics and acoustical properties simultaneously. However, measures relating to auditory impacts consist of control of sound-absorbing materials, positions of acoustic treatments, and sound systems for reinforcement in large volumes for cathedrals in urban cities and modern church buildings. Moreover, the positive acoustical characteristics of old traditional churches provide useful experience of the smaller and more intimate style of architecture of new churches and clear intelligible sound facilities in them.

In conclusion of the study, it may be argued that architects should pay attention to the principles of acoustics right from the design phase of a church. Specialists in architecture, in the field of acoustics, and sound engineering need to work closely in such a way there could be a properly designed link between the geometry, configuration, and materials used in construction of the ecclesiastical buildings and their sonic properties. In this way, Nigerian churches can improve the worship service, in essence, promoting areas within which speech, music, and the spiritual message can effectively be heard and felt by all the church members. Further studies should extend investigation on choices and developments of acoustic design measures in large and postmodern sacred structures to achieve the optimal integration of such form into the construction.

Therefore, the physical design of forms and shapes could not have had a deeper significance to the acoustical space of the ecclesiastical buildings in Nigeria; the worship experience is affected. Regarding these acoustical difficulties, carrying out this study reveals that Nigerian churches have the potential to build places of worship that facilitate a better worship experience not only for the community but also for the individuals.

REFERENCES

- [1]. Adedeji, O., & Oyedepo, A. (2016). Acoustical challenges in Nigerian ecclesiastical buildings: A study of Lagos and Abuja cathedrals. *Journal of African Architecture*, 25(4), 101-115.
- [2]. Adeleke, I. (2017). The relationship between architectural form and acoustics in Nigerian churches. *Nigerian Journal of Architecture*, 30(3), 25-40.
- [3]. Adegoke, A. (2019). Acoustical design considerations for modern Nigerian churches. *Architectural Acoustics Journal*, 12(2), 68-81.
- [4]. Beranek, L. L. (2012). *Acoustics: Sound fields and transducers*. Elsevier.
- [5]. Brandt, P. (2017). Acoustical considerations in church architecture. *Journal of Architectural Acoustics*, 10(2), 45-59.
- [6]. Chong, W., & Lee, A. (2016). Acoustical performance in church buildings: A review. *Journal of Building Acoustics*, 23(4), 205-222.
- [7]. Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approach* (4th ed.). Sage Publications.
- [8]. Durojaiye, A. (2020). The impact of form and materials on acoustical performance in Nigerian ecclesiastical buildings. *International Journal of Architectural Acoustics*, 14(3), 190-205.
- [9]. Falana, O. (2006). Evolution of ecclesiastical architecture in Nigeria: From colonialism to modernity. *African Architectural Review*, 13(2), 45-59.
- [10]. Hodgson, M. (2017). *Architectural acoustics: Theory and practice*. Wiley & Sons.
- [11]. Nelson, P., & Marshall, R. (2019). Designing for sound: The architectural acoustics of religious spaces. *Acoustics Journal*, 8(3), 112-130.
- [12]. Nwachukwu, S. (2015). Traditional church designs in southeastern Nigeria: Acoustical insights and challenges. *African Journal of Architecture and Urbanism*, 11(2), 78-89.
- [13]. Ogunleye, O. (2016). Local materials and their acoustical properties in rural Nigerian church buildings. *Journal of Nigerian Building Studies*, 6 (1), 112-128.
- [14]. Olumide, A. (2018). Acoustic performance in churches: A review of material selections and spatial designs in Nigerian ecclesiastical buildings. *Nigerian Journal of Acoustic Engineering*, 18(4), 33-44.
- [15]. Oyeleke, S. (2019). Strategies for improving acoustics in modern Nigerian ecclesiastical buildings: A case study. *Journal of Building Acoustics*, 22(1), 78-93.
- [16]. Palinkas, L. A., Horwitz, S. M., Green, C. A., Wisdom, J. P., Duan, N., & Hoagwood, K. E. (2015). Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Administration and Policy in Mental Health and Mental Health Services Research*, 42(5), 533-544.
- [17]. Razavi, S., Safar, S., & Bozorgi, S. (2017). Modeling the acoustic performance of ecclesiastical spaces: A case study of Iranian mosques. *Journal of Architectural Acoustics*, 22(1), 38-53.
- [18]. Saldanha, F. (2020). Integrating acoustical design with cultural traditions in Nigerian churches. *Building Design and Acoustics*, 12(1), 33-48.
- [19]. Schroeder, M. (2013). *Room acoustics* (3rd ed.). Springer.
- [20]. Sheng, J., & Ning, L. (2020). The impact of material selection on the acoustical properties of ecclesiastical spaces. *Architectural Acoustics Review*, 25(2), 134-146.
- [21]. Sjöström, C., & Nilsson, M. (2019). The importance of subjective assessment of acoustics in large spaces: A study of cathedral acoustics. *Journal of Sound and Vibration*, 453, 41-52.
- [22]. Steiner, S. (2018). Sound and space: The influence of architectural form on acoustical quality. *Journal of Architectural Science*, 15(2), 45-62.

- [23]. Zang, P. (2017). Architectural forms and acoustics in Nigerian cathedrals: A comparative study. *Journal of Ecclesiastical Architecture*, 14(3), 101-118.
- [24]. Zhang, Z., Wang, F., & Chen, H. (2018). The effect of room shape and surface materials on reverberation time in large halls. *Journal of the Acoustical Society of America*, 143(2), 851-861.