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Assessment of Acoustic Properties of Lecture Theatres in Ladoke Akintola University of Technology, Ogbomoso, Nigeria

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ABSTRACT: *Acoustic design is an important consideration in the design of lecture theaters (LTs); it has a significant impact on communication between students and instructors, their hearing comfort levels, lecture outputs and their overall performance. However, despite the significant role acoustic design plays in LTs, it has not received a significant attention both in design and literature in the developing countries especially Nigeria. This study is hence aimed at assessing the acoustic properties of lecture theaters in Ladoke Akintola University of Technology (LAUTECH) Ogbomoso with a view to establishing the design requirements for effective acoustic comfort in lecture theatres in Nigeria. Seven (58.33%) lecture theaters were randomly selected out of a total of 12 available in the study area and were objectively analysed. Shape of the lecture theaters, wall, floor, ceiling and furniture surface finishes were physically observed and their sound absorbing coefficients were evaluated and compared with data obtained from the Bureau of standards for the sound absorption coefficients, ISO 354 and literature. The total surface absorption coefficients of materials and surface area were used to calculate the Reverberation Time (RT) using Wallace Sabine model and results was compared with RT standard of between 0.5 and 1.0s recommended by scholars Odoh and Urenyang for LTs in Nigeria. The study observed that walls, floor and ceiling surfaces were treated with materials of low sound absorbing coefficients while only the ceilings were treated with high coefficient materials, the effect was observed in the RT values obtained. It was observed that only 3 (42.86%) LTs have their RTs within the recommended standards and hence are capable of providing good acoustic comfort for users while 4 (57.14%) LTs have excessive RT implying likely acoustic discomfort. The study recommended that materials with high sound absorbing coefficients be used for building component finishes and acoustic decisions should be taken right from design inception stage.*

KEYWORDS: acoustic design, lecture theatres, sound absorbing coefficients, reverberation time and surface finishes.

INTRODUCTION

Acoustic is the science of sound and has become a major concern of various professions such as Architects, Physics, Engineering, medicine, planning, education etc. this is majorly because it has a significant impact on the health, general wellbeing and performance of people (Huang, Chu et al, 2013).According the Physicians, (as cited by Adekalu and Halil, 2018), one of the most basic means of man and animal survival is hearing and speech is crucial to human sociocultural and economic development; hence, managing sound propagation is crucial.

Pumnia and Jain (2005) maintained that the management of sound propagation which involves promoting beneficial sound, maintaining its satisfaction for building occupants and minimizing unwanted sound otherwise called noise (which may impair occupant's comfort) can best be achieved by incorporating appropriate architectural acoustic design and construction techniques. These design techniques according to Ellie, William et al., (2020) would significantly enhance the acoustic comfort of occupants- Acoustic comfort is hence the perceived state of contentment with sound (acoustic) conditions in an environment.

Optimizing acoustic comfort involves putting essential measures that could optimise audible sound conditions in spaces in place, this could be achieved by adopting proper building form, and material finishes that could subdue and minimize the persistence of sound in spaces after they are produced and the time taken for such sound to decay otherwise called sound reverberation and reverberation time as well as echo (Ellie et al., 2020).Just like in every residential buildings, the studies of acoustic is essential in every educational setup (Castro-Martinez, Roa, Benitez et al., 2016) and this is in line with the submissions of Pumia and Jain (2005) who posited that in any educational set-up, the effectiveness of the lecture theatre spaces for teaching-learning could be achieved through good sightlines and speech intelligibility which affect visual clarity and hearing audibility respectively. However, acoustic effectiveness majorly as regards unwanted sound (noise) in lecture theatre spaces has been a major challenge to teaching and learning.

According to Woolner and Hall (2010), the problem of noise in the school environment especially in the lecture theatres is often associated with students struggling to get spaces with comfortable seats and choice of acoustic materials used in the design and construction of their buildings. Woolner et al (2010) further explained that effect of noise affects concentration of students in their various lecture spaces thereby hindering the outputs of learning.

Gilavand and Jamshidnezhad (2016), submitted that effective education depends on having a good physical and social environment, motivation of instructors and trainees and effective sound management of the learning halls and classes. Azar *et al*, (2020) affirmed that interactions among teachers and students in the lecture theatre should not be hindered by noise either from activities in classrooms or from outside and also, there must be a good acoustic comfort during these interactions; hence, adequate attention must be paid to the science of sound in educational places.

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Knauf, (2021) observed that in the developed countries like the United Kingdom (UK), Architects work with Acoustic engineers when they have commission for educational buildings; this is because adequate attention has been paid to the science of acoustics and effective legislation has been established to ensure that proper attention is paid on the acoustic properties of their educational buildings.

This is however not so in the developing countries like Nigeria. Ewekeye (2012) submitted that little attention is paid to the acoustic of buildings in Nigeria since the attention of architects and builders is to create structures with low budget and high aesthetical features. The resulting effect of this has however been low educational outputs and students poor performance. However, the high significance of acoustic science on education output has necessitated significant attention, hence, this study is aimed at examining the acoustic properties of lecture theatres in Ladoke Akintola University of Technology (LAUTECH), Ogbomoṣo with a view to assisting architects and other stake holders in their quest for enhancing acoustic (sound) properties of lecture theatres and other education buildings in Nigeria. The study would assess the noise levels of selected lecture theatres in the study area and examine the implications of the choice of the design decisions such as building shape, form, orientation and location as well as the choice of surface finishes (walls, floors, ceiling surfaces) adopted on the reverberation and reverberation time in each of the lecture theatres.It is hoped that this will contribute significantly to effective learning outputs in tertiary institutions in Nigeria as well as contributing significantly to the body of literature on acoustic science in the country.

Study Area

The study was carried out in Ladoke Akintola University of Technology, (LAUTECH) Ogbomoṣo, Oyo state, Nigeria. Situated on Longitude 8°8′0″N, and Latitude 4°16′0″E, the institution was established in April 1990 and has a Total land mass of 9880.771 Hectares. Apart from the post graduate school, the institution has a total of eleven faculties and twelve lecture theatres of diverse capacities.

Plate 1: Lautech imagery showing some Lecture Theatres
Source: Google maps, 2023

METHODOLOGY

The study employed objective approach for data collection; this involved taking physical measurements of the size, area, volume and height of each of the lecture theaters, and also directly observing their shape, wall and floor surface finishes, furniture materials and other acoustic architectural features.

Data obtained on the area of surfaces (floor, wall and ceiling) and volume were employed to calculate the Reverberation Time (RT) of sound using Wallace Sabin model of calculating RT of sound in spaces in order to understand the acoustic comfort levels of each of the lecture theaters, obtained parameters were compared with the recommended range of comfort of between 0.5 and 1 second recommended by Odoh and Urenyang (2012) for Nigeria; and data obtained through direct observation of the shape, surface finishes, furniture materials and other architectural features of the lecture theatres were compared with the acoustic requirements standards obtained from the Bureau of standards for the sound absorption coefficients and the data base of the widely accepted acoustic scholar Ingolf Bork referenced from the standard methods for material testing ISO 354 and the literature; their sound absorption coefficients were compared at the least expected frequency of 125 Hz and analyzed accordingly in other to examine the appropriateness of the design decisions taken and their effects on the acoustic properties of the lecture theaters. Seven lecture theatres (MKO, SIFAX, FAG, FET, FPASS, MGS and 250LT) were randomly selected; these represented 58% of a total of 12 lecture theaters identified in the study area.

FINDINGS

Shape

According to the Building Bulletin ‘93 on acoustic design of schools (2015), fan shape is the best in lecture theaters in terms of providing both acoustic and visual comforts concurrently; this was in response to the assertions of Pumia and Jain (2005) who affirmed that effectiveness of lecture theaters depends primarily on their visual and acoustic properties as they affects users’ visual clarity and hearing audibility. Fan shape was adjudged to be the best because fan shape aids good sightlines from the audience to the speaker and also ensure an even spread of sound while minimizing echo and reverberation. Three (3) types of shape was identified in the lecture theaters surveyed; they are rectangle, hexagon and fan shapes. However, four (4) lecture theaters representing 57.1% are fan shaped, two (2) representing 28.6% are rectangular in shape while only one (1) representing 14.3% have hexagon shape. This is an indication that majority (57.1%) of lecture theatres in the study area conform to the laid down standards regarding shapes of their buildings. See Table 1.

PARAMETER		250 LT	MKO LT	MGS LT	FAG LT	SIFAX LT	FPAS LT	FET LT	TOTAL
SHAPE	Fan	1(14.28%)	0	0	1(14.28%)	1(14.28%)	1(14.28%)	0	4(57.16%)
	Rectangular	0	1(14.28%)	1(14.28%)	0	0	0	0	2(28.56%)
	Others (Irregular Hexagon)	0	0	0	0	0	0	1(14.28%)	1(14.28%)
INTERNAL WALL	Emulsion Paint	1(14.28%)	1(14.28%)	1(14.28%)	1(14.28%)	1(14.28%)	1(14.28%)	1(14.28%)	7(100%)
FLOOR FINISH	Ceramic Tiles	0	0	1(14.28%)	0	0	0	1(14.28%)	2(28.56%)
	Terrazzo	1(14.28%)	1(14.28%)	0	1(14.28%)	1(14.28%)	1(14.28%)	0	5(71.42%)
SEAT FINISH	Leather	0	0	1(14.28%)	0	0	0	0	1(14.28%)
	Metal	1(14.28%)	1(14.28%)				1(14.28%)	1(14.28%)	4(57.16%)
	Wood	0	0	0	1(14.28%)	1(14.28%)	0	0	2(28.56%)
TABLE FINISH	Metal	1(14.28%)	0	0			1(14.28%)	0	2(28.56%)
	Wood	0	1(14.28%)	1(14.28%)	1(14.28%)	1(14.28%)	0	1(14.29%)	5(71.42%)
CEILING FINISH	Gypsum Board	0		1(14.28%)	0	1(14.28%)	0		2(28.56%)
	Asbestos	1(14.28%)	1(14.28%)		1(14.28%)	0	0	1(14.29%)	4(57.14%)
	PVC	0	0	0	0	0	1(14.28%)	0	1(14.28%)

Table 1.0: Physical Observation Schedule
Source: Authors Field Survey, 2021

Wall finishes

It was observed that all the lecture theaters were constructed with sandcrete block wall and are finished with emulsion paint on smooth plaster surface which has a low sound absorption coefficient of 0.01 Hz. While smooth wall rendered with pit sand mortar has the highest sound absorbing coefficient according to ISO 354 (0.08Hz), Akinayo, Ayandokun and Okah-avae (2007) recommended a minimum of smooth wall rendered with rough texcoat paint which has a sound absorbing coefficient of 0.03Hz for effective acoustic satisfaction in buildings. The implication of this is that all lecture theaters in the study area have their walls finished with poor acoustic decisions.

Floor

It was observed that 2 lecture theatres (28.56%) have their floors finished with ceramics floor tiles and 5 (71.42%) are finished with terrazzo floor finish; however, both of these floor finishes have a low sound absorbing coefficients of 0.01Hz compared to carpet underlay which was recommended by Olafisoye and Akomolafe, (2012) and which was observed by ISO 354 to have between 0.02 and 0.10 Hz (depending on type). Apart from the low sound absorbing coefficients possessed by these floor finishes, Olafisoye et al., (2012) also noted that they are major source of noise generation in spaces; it can hence be inferred that this is a wrong acoustic decisions.

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Chair/Table finishes.
Findings revealed that 1(14.28%) lecture theatre has leather surface chairs, 4 (57.16%) are of metal and 2(28.56%) are of wood; similarly, 2(28.56%) lecture theatres have their tables finished with metal and 5(71.42%) are finished with wood. The sound absorbing coefficients of leather, wood and metals are 0.40, 0.05 and 0.01Hz respectively; this implies that while good acoustic decisions were made in their choice of table finishes, poor acoustic decisions were taken in their choice of chair finishes.

Ceiling
It was observed that asbestos ceiling boards were used in 4 (57.16%) lecture theatres, PVC was used in 1(14.28%) and Gypsum board in 2(28.56%) lecture theatres. While asbestos ceiling board has a sound absorbing coefficient of between 0.4 and 0.7Hz, gypsum board has 0.45Hz coefficient and PVC has a coefficient of between 0.4 and 0.6 Hz. This implies that high sound absorbing coefficient materials were used for ceiling finishes in the study area.

However, the Bureau of Standard noted that it is not necessarily the case that high absorption coefficient materials would imply good acoustic comfort in spaces and hence advised that the sound reverberation time of rooms should be examined in line with the obtained results of the absorption coefficients; hence, the reverberation time of each of the lecture theaters were examined using the most popular Wallace Sabine model, results were as analysed below.

Assessment of reverberation time for acoustic comfort in the selected lecture theatres.
According to Nave 2017, reverberation time is strongly influenced by the sound absorption coefficients of the surface finishes and the volume; at lower volumes, reverberation time is shorter. Highly reflective surfaces also lengthen reverberation time and reverberation time has a direct consequences on acoustic comfort levels of spaces**.** Table 2.0 shows the results of reverberation time in the selected lecture theatres compared with the recommended value of reverberation time for lecture theatres obtained from the findings of Odoh and Urenyang (2012) is between 0.5s and 1.0s. The Reverberation time for each lecture theatre was calculated using Wallace Sabine model which is given as: $\frac{0.16v}{A}$ Where v = Volume of the lecture theatre,
A = Total Surface Absorption of the coefficients, A=$\sum(\alpha \text{ x } s)$; Where $\sum$= summation,
α = Absorption coefficient of finishes, **S =** Surface area of the finish (m^2).

Table 2.0: Comparison of reverberation time values of lecture theatres with recommended value

Lecture Theatre	Volume(v) m^3	Total Surface Absorption(A)	Reverberation Time (s) $\frac{0.16v}{A}$	Remark (Compared with range 0.5 - 1.0s)
250 LT	802.02	120.61	1.1	Slightly excessive
MKO LT	1815.71	313.93	0.93	Adequate
SIFAX LT	3234.68	711.38	0.73	Adequate
FAG LT	2559.3	381.68	1.1	Slightly excessive
FPAS LT	32277.72	105.19	4.99	Highly Excessive
MGS LT	5233.267	931.93	0.9	Adequate
FET LT	4092.183	458.65	1.43	Excessive

Source: Authors Field Measurement, 2021

As shown on Table 2.0, it can be deduced that 3 (42.86%) lecture theaters have their reverberation times within the normal range of 0.5-1.0s as submitted by Odoh and Urenyang (2012) while 4 (57.14%) have their reverberation times higher than the recommended range of comforts and hence excessive. This implies that there is a likelihood that majority of the lecture theaters in the study areas would not provide adequate acoustic comforts.

CONCLUSION AND RECOMMENDATIONS

Result shows that proper acoustic considerations have not been taken in the design of lecture theaters in the study area especially in the choice of materials selection for floors, walls chairs and tables where low sound absorbing materials were used. The effect of this was however seen in the reverberation time values obtained. It was observed that out of the total of 7 lecture theaters studied, only 3 (42.86%) has good reverberation times and hence is capable of providing god acoustic comfort for the users while 4 (57.14%) has excessive reverberation times and invariably poor acoustic comforts. It is hence recommended that materials with high sound absorbing coefficients should be used in future designs and acoustic design decisions should be taken from building design inception stage.

Conflict of interests

The authors have not declared any conflict of interests.

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