Original Research Article

Determination of reverberation time and sound pressure level of selected lecture halls in University of Agriculture, Makurdi-Benue State, Nigeria.

ABSTRACT

***Aim**: Designing a lecture hall acoustics is a prestigious task which demands high accuracy of acoustical measures such as Reverberation time (T), Sound pressure levels (SPL) among other numerous parameters. In Nigeria however, little is considered about the acoustical environment on stages in lecture halls and how the design of environments are perceived by the users even though most international standards set optimum values of these parameters with respect to room volume and designed purposes.*

***Study Design:** This research has been conducted to examine the values of T and SPL of six selected unoccupied lecture halls in the University of Agriculture, Makurdi. Place and Duration: Department of Physics/ College of Science Federal University of Agriculture, P.M.B.2373 Makurdi-Benue State, Nigeria, between July 2017 to February 2018.*

***Methodology:** The linear dimensions (length,breadth and height) of each lecture hall and the surface areas of the absorbent materials per each lecture hall was measured using the measuring tape . The AutoCAD software was then used for volume computations.*
To measure the sound pressure levels (SPLs), equivalent sound pressure levels were registered at each selected point of the halls using a calibrated digital sound level meter (model Extech 407780) at wall distance of 1.00 m and intervals of 10 s in between.

***Results:** Reverberation Time values were calculated using Sabine's method. The mean value of T was found to be 1.66 s with a standard deviation of 0.36 s. The calculated SPL values were found to have a mean value of 76.07 dB (A) with a dispersion of 7.09 dB (A). In comparison with international guidelines, the reverberation time as well as SPL values found in these lecture halls were not within reference values of 0.40 ≤ T ≤ 0.80s and 40dB(A)≤ SPL ≤ 50dB(A) established by International Standard Organization (ISO) 3382, International Electro technical Commission (IEC) 60268 and World Health Organization WHO. Hence the results showed that the selected lecture halls do not meet the current standard of acoustic design set for public speech buildings.*

Keywords: reverberation time, sound pressure level, absorption coefficient.

1. INTRODUCTION

Reverberation time (T) is the period required by the reverberant sound to decay to one-millionth of its initial value. This naturally corresponds to a drop of 60dB [14]. The selection of correct interval of reverberation is called the optimum reverberation time and it depends on the use of the room [13]. If the reverberation time is too long, it results in overlapping of speech and if too short, it produces the effect of deadness [14]. Reverberation is caused by multiple reflections of sound waves from walls, ceilings, or windows. These reflections generate delays by slightly modifying or attenuating the spectral copies of the original source signal. This reduces and further degrades speech intelligibility in quiet and noisy situations [13]. Nowadays, most of the lectures in Nigerian Universities occur in lecture halls (enclosed spaces), where the sound waves are reflected from the walls, window panes, ceilings, and floor giving rise to the phenomena of reverberation [11]. Reverberation time varies between positions in a room, so it is usually measured at several positions. The average then gives an overall assessment which indicates the acoustic quality as a function of location [4]. In view of the significant benefits to acoustics of auditoria, reverberation time is strongly influenced by the absorption coefficients of the surfaces [6] as well as the volume of the room [1,2,3,7,13,14]. Reverberation time should be negligibly small in a good lecture hall. Previous research works showed that typical reverberation time ranges from about 0.4 s to 4.0 s in lecture halls and more in concert halls or churches [12]. Since architectural design in institutions of learning often do not consider these values, it is pertinent to investigate the acoustic parameters of lecture halls in University of Agriculture Makurdi, as these remotely affect the outcome of a learning process.

1.1 Sound Intensity

The intensity of sound is the flow of sound energy per unit of time through unit area. Frequency is a measure of the quality of sound energy. The intensity of sound is purely a physical quantity which can be accurately measured and is independent of ear of listener [14]. The intensity of sound is measured on a logarithmic scale due to its wide range of variations. Equation 1 gives the sound intensity in decibels.

$$m = 10 log_{10} (I_1/I_2) \quad (1)$$

where I is the sound intensity.

1.2 Sound Pressure Level

Sound pressure level (SPL) is the ratio of the absolute, sound pressure and a reference level usually the threshold of hearing. SPL is measured in decibels (dB), because of the incredibly broad range of intensities human can hear. The human ear cannot perceive low-and-high frequency sounds as they perceive sounds between 3000Hz and 4000Hz hence the reason that frequency response of human hearing changes with amplitude. Therefore, three weightings for measuring sound pressure levels have been set as A, B and C, where A - weighting applies to SPLs up to 55 dB, B-weighting applies to SPLs between 55 dB and 85 dB, while C-weighting applies to SPLs above 85 dB. In order to distinguish the different sound measures, a suffix is used: A-weighted SPL is written as dB (A) or LA, B-weighted SPL is written as dB (B) or LB, and C-weighted SPL is written as dB(C) or LC. Unweighted SPL is called “Linear SPL” often written as dB (L) or L. Other sound measuring instruments use “Z” to indicate linear SPL. In situations of ambient environmental measurements of “background” noise, distance need not be quoted as no single source is present. However, measurement of noise level of specific equipment needs distance specification. A minimum distance of 1.00 m from the source is commonly used. Thus, the equivalent SPL can be calculated using (2) [14].

$$L_{eq}=10\log\left[\frac{1}{n}\sum 10^{P_i/10}\right] \text{ dB} \qquad (2)$$

where L_{eq} is the equivalent sound pressure level in dB(A); P_i is the sound pressure level measured at each moment "i", in dB(A); n is the total number of measurements.

1.3 Theory of Reverberation Time

Reverberation time measurement is used to estimate the required time for the sound signal to "fade away". That is for the sound pressure to reduce by a predefined value. T_{60} is the standard reverberation time measurement and is defined as the time it takes for the sound pressure level to reduce by 60dB, measured from the moment the generated test signal is shortly ended [13] Reverberation time can be estimated using various methods such as; ray tracing method, Eyring's method, Sabine's Method among others. The famous Sabine's formula for estimation of reverberation time (T) in rooms [13] as used in this work is stated in equation 3.

$$T=\frac{0.16V}{\sum \alpha_i S_i} \qquad (3)$$

where v is the room volume (m^3), S_i is the absorbing surface area (m^2) and α_i is the surface absorption coefficient expressed as:

$\alpha = \frac{A}{S}$, A being the absorption amount.

2. MATERIALS AND METHODS

2.0 Materials

The materials used for measurements in this research work are:

Measuring tape (YUE BAO: 0-30 m), Samsung galaxy stops watch (model SM G920I), Sound level meter (Extech 407780-EN v 2.3), Clapping discs (0.12 m radius each), Microphones, Tripod, Thermometer (0-100□), AutoCAD software, D.C source (AAA 1.5 volts × 4), Global positioning system.

2.1 Study Area/Sample Space

The research was carried out in the Federal University of Agriculture, Makurdi using six (6) lecture halls. The selected lecture halls are listed in Table 1 with their respective location within the University.

Table 1: Selected Lecture halls in University of Agriculture, Makurdi

Code	Lecture Hall	Capacity (seats)	Location
L1	Science Lecture Theatre	1000	N 7.7677°, E 8.6218°
L2	Engineering Lecture Theatre	1000	N 7.7921°,E 8.6188°
L3	Engineering Auditorium	510	N 7.7903°, E 8.6201°

L4	Aper Aku Auditorium	811	N 7.8000°, E 8.6163°
L5	Block A91	180	N 7.7659°, E 8.6211°
L6	Block B19	154	N 7.7656°, E 8.6219°

2.2 Methodology

Volume and area measurements

To evaluate the volume of each lecture hall, measuring tape was used to measure their linear dimensions. The AutoCAD software was then used for volume computations.

Reverberation time computation

The reverberation time (T) in each hall was evaluated using (3): T= $\frac{0.16V}{\sum \alpha_i S_i}$

The respective absorption coefficients (α) of the material surfaces were adapted from ISO 3382-1, 2009 [14].

Measurement of sound intensity level

To measure the sound pressure levels (SPLs), equivalent sound pressure levels were registered at each selected point of the halls using a calibrated digital sound level meter (model Extech 407780) at wall distance of 1.00 m and intervals of 10 s in between. SPL was then calculated using equation (3).

Sound pressure level-SPL computation

The SPL values were measured in each lecture hall and equivalent SPL (L_{eq}) in each hall calculated using equation (2): L_{eq}=10log [$\frac{1}{n}\sum 10^{P_i/10}$] dB

3. RESULTS AND DISCUSSION

3.1 Results

In this section, the results of the measured items and computed values per each lecture hall selected are presented. Table 2 gives the summary of the measured surface areas, volumes and total absorptions in these halls.

Table 2: Selected lecture hall surface areas, volumes and total absorptions

Lecture hall	Volume/m^3	Volume/seat m^3	Absorption surfaces with their areas in m^2												Total absorption m^2-sabin
			Doors	Windows	Switches	White board	Table tops	Ceilings	Floor area	Lecture's stand	Walls	Distribution boards/change over	Speakers	Ventilators	
L1	4853.04	4.85	22.00	111.65	1.57	2.88	136.00	809.64	942.34	-	5654.04	0.58	-	-	394.2694
L2	4853.04	4.85	22.00	111.65	1.57	4.35	136.00	809.28	942.34	6.42	5654.04	2.54	0.41	-	391.0615
L3	2093.65	4.11	8.72	95.24	5.51	3.04	76.14	398.79	398.79	-	2392.74	12.52	0.41	-	191.9704
L4	8206.94	10.12	28.9	117.4	1.73	4.24	93.57	912.89	880.88	-	7419.49	-	0.74	8.79	712.9500
L5	547.73	3.04	7.05	36.68	0.28	2.88	54.08	182.58	182.58	9.59	479.7	-	-	-	91.5100
L6	354.83	2.30	3.78	21.96	0.19	2.88	35.36	104.36	104.36	6.42	349.28	2.88	-	-	39.4900

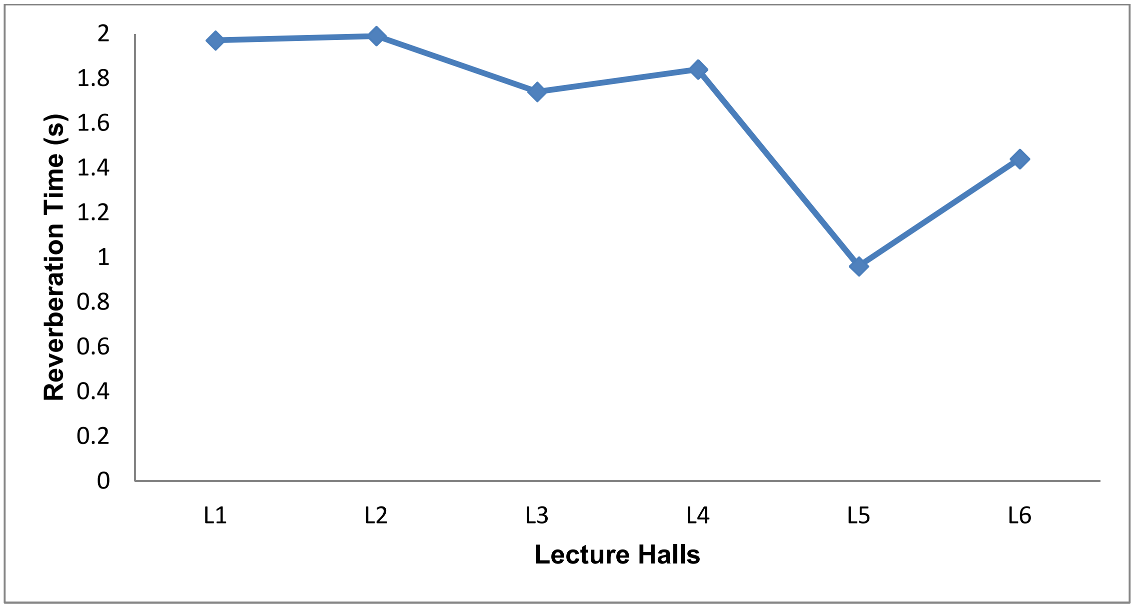

Figure 1: Reverberation Times calculated per Lecture Halls

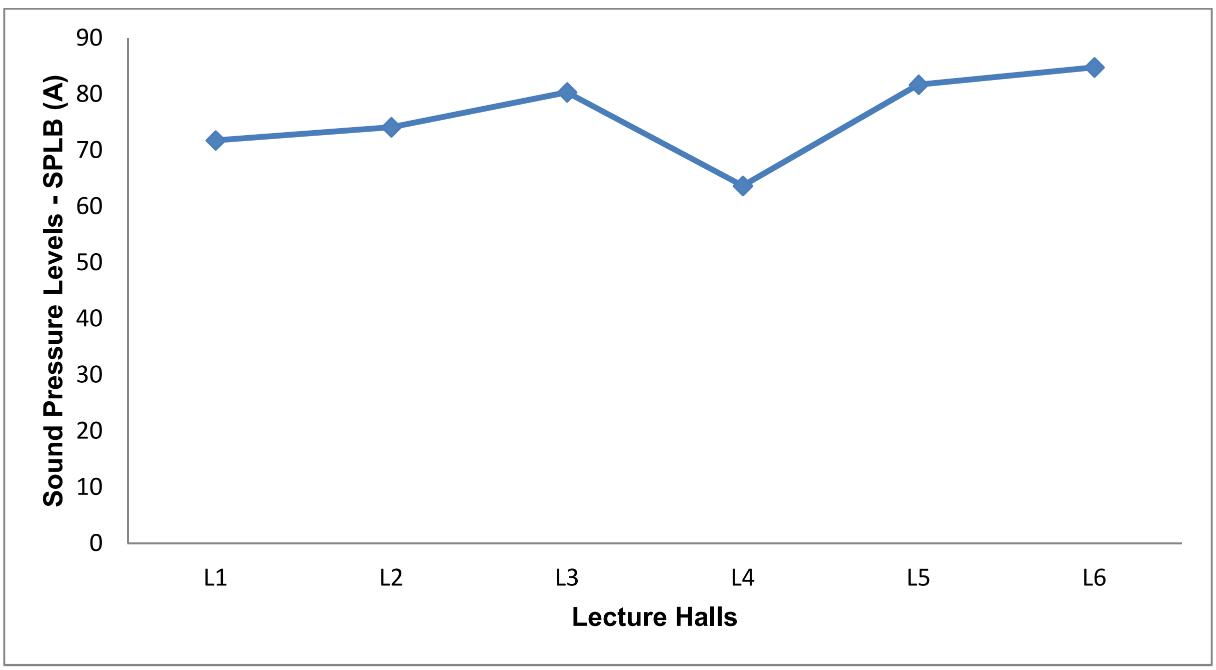

Figure 2: SPL measured in Lectures halls

3.2 Discussion

Figure 1 shows the reverberation time values in each selected lecture hall. These values were found to range 0.96 s and 1.99 s with L2 having the highest value of 1.99 s and L4 having the lowest value of 0.96 s. The mean value $\overline{T}$ of this range is 1.66 s and the standard deviation of 0.36 s was recorded indicating dispersion. These values are above the values set by ISO3382 and IEC 60268 for lecture hall design. The result also conform with similar works of [8] in which their study result gives the maximum value of reverberation time (T) as 1.29 s above the WHO range of 0.4 s – 0.8 s recommended standard values of T for lecture halls while evaluating the acoustic comfort of lecture halls in Lund University, Sweden. The mean value, 1.66s of T is also above [9] values of T which establishes the range 0.4 s- 0.6 s for 'good' intelligibility to normal speech and normal hearing to be achieved in lecture halls. Hence, these values provide a relative indication of poor listening conditions in these halls. Their value differences are attributed to high level of background noise and different absorbing materials employed.

The sound pressure level (SPL) results in Figure 2 show a range between 63.68 dB(A) and 84.79 dB(A) with a mean value of 76.07 dB(A) and standard deviation 7.09 dB(A). Therefore, regarding parameters set by ISO 3382, IEC 60268 and WHO; values of SPL found in each lecture hall were above the recommended set standard values in the range 40 dB(A) – 50 dB(A) for lecture hall environment.

4. CONCLUSION

In this work, lecture hall acoustic parameters relating to reverberation time (T) and sound pressure level (SPL) have been determined in six selected lecture halls of the University of Agriculture, Makurdi. The results obtained were compared to the design goal. The method of Sabine was used in computing reverberation time and from the results only L4 offers a relatively closer reverberation time of 0.96 s with respect to ISO3382 and IEC 60628. This is due to greater amount of absorbent materials employed in the surface finishing of L4 as compared to the other lecture halls. However, improvement in the absorption of materials still needs to be done in L4 and other lecture halls in order to meet the acceptable set range of 0.4 s – 0.6 s in lecture hall design [15]. Sound pressure levels (SPL) values found from this research in each lecture hall are all above the recommended values set by ISO 3382, IEC 60268, WHO and NBR 10150/2000 which establishes values in the range 40-50 dB(A) during day times in schools. This high level of unwanted background noise is the possible predominant cause of speech masking which decreases speech intelligibility in these lecture halls. Finally, the results obtained from this study show that the presence of acoustic treatment was not noted as of the time of designing the lecture halls in the Federal University of Agriculture, Makurdi as recommended by international standard bodies. However, the designers care much about ventilation since each lecture hall has wider window openings as our region is tropical.

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