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Use of acoustic materials in design of cultural centres.

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ABSTRACT

A good knowledge of acoustic materials is essential for achieving noise control in the design of cultural centers spaces in this case an enclosed space (the auditorium). The areas susceptible to noise in the auditorium are the walls, floors and ceiling as well as the materials the seats of the auditorium is made of. The paper is on the use of acoustic materials in design of cultural centres which are used to handle acoustics issues such as; appreciate reverberation time, uniform sound distribution, appropriate sound level, low background noise and echo etc. and by means of Analysing relevant data and appropriate case study this paper seeks to research into the characteristics and composition of acoustic materials suitable to handle these issues. The final results will be appropriate choice of materials for auditorium design and by extension their applications, this paper will further more serve as a basis for further research on acoustics and issues that concern acoustics materials in the design of cultural centers in Nigeria.

Keyword: Architectural Acoustic, Auditorium, Acoustic Problems, Acoustical Materials.

1. INTRODUCTION

Without a good knowledge of acoustical materials, cost-effective control of noise becomes more a matter of chance than of intelligent design. In the design of cultural centers there are acoustics issues which includes; appreciate reverberation time, uniform sound distribution, appropriate sound level, low background noise and echo etc. And in confronting the problems of the program space steps can been taken to handle the acoustics issues which includes; adopting of the coupled space concept, use of appropriate choice of materials and the auditoria design and geometry to achieve optimal and even sound distribution throughout the hall. The interest of this paper is on the choice of materials for the auditorium design in the walls, floor and ceiling as well as the materials the seating are made up of.

Acoustical materials ranges from traditional synthetic materials to natural or made from recycled materials and mixed and composited materials as alternative for sustainability because their production generally has a lower environmental impact than conventional ones, though a proper analysis of their sustainability, through Life Cycle Assessment procedures, has to be carried out. However they all show good airborne sound insulation, good thermal insulation properties, impact sound insulation as well as good sound absorbing performances. Airborne sound insulation of natural materials such as flax or recycled cellulose fibres, rock or glass wool, soundproofing material made out of wood. Many natural

materials (bamboo, kenaf, sisal, coco fibres) show good sound absorbing performance, while cork or recycled rubber or polymers layers can be very effective for impact sound insulation.

Source: A Review of Sustainable Materials for Acoustic Applications by F. Asdrubali, S. Schiavoni and K. V. Horoshenkov

Architectural Acoustics

''*Architectural acoustics is the management process of how airborne sound and impact is transmitted and controlled in a building design. While virtually all materials in a room affects sound levels or another, wall partitions, ceiling systems and floor / ceiling assemblies are the main elements that designers use to control sound.*'' (James.D. Janning, AIA).

Acoustic in architecture simply refers to improving of sound in an environment.

Acoustic Issues

Reverberation time: The reverberation time is approximately the time needed for decay and stops to a level that is not heard after a hard sound source is turned off. At the point when a source makes a sound wave in an auditorium, spectators hear not just the sound wave proliferating straightforwardly from the source but also in addition the heap reflections from the walls, floor, and ceiling.
Uniform sound distribution: it is a term that talks about the probability of sound distributing evenly.
Appropriate sound level: talks about the level of sound being within the average for the particular purpose and it is measured in decibels (dB)
Low background noise: is a noise pollution or interference that's not being monitored
Echo: it is caused when the sound in a room is reflected from several surfaces and it reaches the receiver at different times

Measures of Acoustical Materials Effectiveness

There are several specifications of the acoustic properties of acoustical materials that are measured and delineated by manufacturers and which are used to quantify the effectiveness of the material for handling sound or noise. The most common of these include:

Absorption Coefficient

The absorption coefficient, or sound absorption coefficient, is defined as the portion of sound energy incident on a material's surface that is not reflected.

Specific Acoustic Impedance

The specific acoustic impedance is defined as the product of a material's density and its acoustic velocity. The effectiveness of acoustic material to absorb sound energy depends upon the frequency of the sound, with the mid-to-high ranges being more effectively muted by most materials than the lower frequencies.

Noise Reduction Coefficient

A so-called noise reduction coefficient establishes a material's average absorption coefficient at frequencies of 250, 500, 1000, and 2000 Hz. and is useful for comparing a material's effectiveness at absorbing noise in general. In special applications, such as recording studios, the noise reduction coefficient is less useful because it does not cover the lower base range frequencies which tend to present the biggest problem. In these situations, using the absorption coefficient at the frequency in question can make a better determination of a

material's effectiveness; unfortunately, noise reduction coefficients for various commercial materials are often published whereas the absorption coefficients generally are not.

Sound Transmission Class

Materials used for soundproofing are given an STC, or Sound Transmission Class, a rating which quantifies how well a material blocks transmission at frequencies associated with speech. Like the Noise Reduction Coefficient associated with absorptive materials, the STC rating does not give a good indication of a material's effectiveness at blocking low- or high-frequency sounds, such as mechanical noise or music.

A-weighted Sound level Scale

Sound for human-occupied environments is measured by an A-weighted sound level scale, which reduces the impact of high and low frequencies to better match the human ear's response to the middle ranges. This scale, with units of dBA, is sometimes referred to as noise level and is a selectable feature of most sound meters. The dB refers to decibels, which is logarithmic versus linear scale. Table 1 below illustrates the relationship between the decibel scale and the corresponding energy. Note that every 10 dB change adds an order of magnitude (factor of 10) to the energy level.

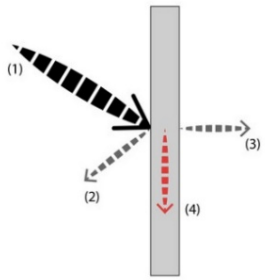
Thomasnet.com/articles- overview of acoustical materials

2. ACOUSTIC SOLUTIONS

Acoustic solutions can be categorized in terms of function which are either to soundproof which means less noise or treatment which means better sound.

Soundproofing

To reduce the noise coming in to the auditorium and going out, the structural mass of the walls, floors and ceiling should be considered. And the sealing of air gaps surrounding doors and windows, and also the openings for mechanical and electrical outlets. The extent of the measures taken will depend on how much noise is outside, and how much is to be reduced inside.



(1) Incident sound (2) reflected sound (3)transmitted sound (4)absorbed sound
Source: keys to improve architectural acoustics: sound absorption and diffusion by Eduardo souza

All building materials have the potential to absorb, reflect or transmit sound when it hits them.

Sound Absorption: the incident sound that strikes a material that is not reflected back is known as sound absorption. The more fibrous the materials, the better Absorbent quality it has and the denser the less absorbent. Absorbers sucks energy out of the sound waves so they can't bounce all around the space.

Table 2 Materials and structures for noise control

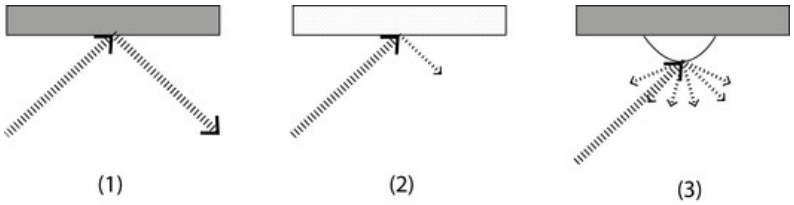
`Category	Description of	Purpose of	Representative uses of
Absorptive materials	Relatively lightweight; porous, with interconnecting passages; poor barrier	Dissipation of acoustic energy, through conversion to minute amounts of heat	Reduction of reverberant sound energy; dissipation of acoustic energy in silencer
Silencers	Series or parallel combination of reactive elements	Dissipation of acoustic energy in the presence of steady flow	Duct silencers in inlet and exhaust silencers for engines, fans, turbines
Barrier materials	Relatively dense, nonporous	Attenuation of acoustic energy	Containment of sound
Damping treatments	Viscoelastic materials with relatively internal losses	Dissipation of vibratory energy	Reduction of acoustic energy
Vibration isolators	Resilient pads; metallic springs	Reduction of transmitted forces	Mounts for fans, engines, machinery

Source: Acoustical Materials – Sound Absorbing Materials Made of Pine Sawdust, April 2018

Table 2 show absorptive barrier materials, silencers, damping treatments and vibration isolators and their major characteristics for each of these categories are. The first three categories function is to absorb or attenuate airborne sound waves. In other words, some vibrating object in contact with a medium has created sound waves whose propagation through the medium is to be minimized. The fourth category function– damping treatments - is to reduce the amplitudes of resonant vibrations that generate airborne sound and or to minimize the transfer of vibratory energy at panel edges or attachment points to adjoining structural elements. The last category function; vibration isolation is to minimize the transmission of shaking forces into a floor or other solid structure.

Acoustic treatment

Sound treatment is are used to improve the quality within an environment, example for the whole audience to hear the performer in the auditorium. When sounds are reflected they cause an increase in the overall echo and reverberation levels in a space. Treating an interior space reduces reverberation levels and echo and the two methods are sound absorption and diffusion, however the best strategies combine both.



Source: keys to improve architectural acoustics: sound absorption and diffusion by Eduardo souza

(1) Reflective surface (2) absorptive surface (3) diffusive surface

Diffusion: this a method of acoustic treatment that spreads sound energy with a diffuser to improve the sound in a space. Basically diffusers breaks sound waves up and scatter them across the frequency spectrum. Diffusion does not only spread the reflected sound an interior

space but also reduces the effects of echo and reverberation. An example is a curved panel with a fabric cover, which can be placed on walls and ceiling of the space. The density and thickness of the material affects the frequency and sound absorption amount. Other factors influence acoustic performance for example an air space incorporated behind an acoustic ceiling or wall panel improves low frequency performance.

Acoustical Materials

Soundproofing Materials

There are different types of Soundproofing Materials scenarios. Each of these acoustic materials falls into one of these categories: Sound Absorbing, Sound Insulation, Sound Dampening, and Decoupling.

- *Architectural Soundproofing – This group includes anything used in the structure of a building, such as soundproof windows, soundproof walls, doors, and decoupling products used to install them.*
- *Acoustic Foam – This material, commonly called Studio Foam, has a distinctive wedge or pyramid shape that is highly effective at absorbing sound. They attach to walls as panels, hang from ceilings as baffles, or sit in corners as bass traps.*
- *Sound Insulation – Sound insulation are batts made of mineral wool, rock wool, and fiberglass, designed to fit in between the studs of walls. The batts fit snugly between studs to take up airspace that can transmit sound.*
- *Acoustic Fabrics – Acoustical fabrics are thicker and heavier than other fabrics and used in theatre curtains, blackout curtains, and studio blankets.*
- *Acoustic Coatings – Materials like Mass Loaded Vinyl (MLV) is a dense rubber like material, the mass of the material acts as a sound barrier.*
- *Floor Underlayment – Soundproofing a hardwood or tile floor requires the decoupling of the flooring surface and the subfloor to reduce the noise transmission. Cork rolls, felt, and polymers are commonly used as underlayment materials.*
  Source: https://www.soundproofingtips.com/soundproofing-materials/

Sound Absorbing Materials

Rather than reflecting noise, sound waves are absorbed into this type of material, softening echo and reverberation to improve the sound in a room. One useful material is fabrics, used for heavy acoustic curtains and blankets. The most popular though is acoustic foam, a special material designed with special cell structure and density to deflect, dampen, and absorb unwanted sounds. They are commonly used in studios, theatres, and entertainment centers.
Source: https://www.soundproofingtips.com/soundproofing-materials/

Materials	Properties	Pictures
1. Acoustic Curtains (Utopia Thermal Blackout Curtains)	Blackout curtains are good for reducing the noise coming in or getting out from windows and doors. A typical acoustic curtain uses quality, heavyweight, plush fabrics combined soundproofing materials like mass loaded vinyl to dampen sound and reduce echo.	 Source:https://www.soundproofingtips.com/soundproofing-materials/
2. Moving Blankets (Sure Max Heavy Duty)	Best Use: Good, thick moving blankets can be used for some sound absorption. Max blankets are made from plush cotton batting and polyester backing and weigh over 5 pounds each. They don't have grommets for easy hanging.	 Source:https://www.soundproofingtips.com/soundproofing-materials/
3. Door Sealing Gasket & Sweep Kit	Best Use: Foam gaskets are a great cheap material for filling in space on door frames where noise loves to leak in and out of rooms. Gaps between the door jam and door are prime paths for unwanted noise to travel. Compressible foam gasket material helps seal up the gap and absorb some of the sounds. The door sweep portion is to seal up the floor section of the door, especially on hard floors.	 Source:https://www.soundproofingtips.com/soundproofing-materials/

Soundproofing Insulation

Soundproofing insulation is used in buildings and homes to reduce the amount of sound transmitted to other parts of the building. Mineral wool and fiberglass are the most common materials. It's a relatively easy and cost-effective way to improve the soundproofing of a room.

Materials	Properties	Picture
4. Mineral Wool (Rockwool Rock board)	Sizes: 24” x 48” x 2”-4” thick Uses: Rock board is a rigid, fire-resistant mineral wool insulation used for both acoustic and thermal insulation. Mineral wool is a natural material.	 Source:https://www.soundproofingtips.com/soundproofing-materials/
5. Soundproof Fiberglass (Owens Corning 703)	Density: 3 lb/ft^3 Uses: Owens Corning 703 fiberglass boards are commonly used for making acoustic panels for home studios, commercial buildings, churches, and theaters.	 Source:https://www.soundproofingtips.com/soundproofing-materials/

Sound Dampening Materials

The mass and density of these materials dissipate sound and reduces the amplitude and energy of the noise. Sound damping materials come in the form of mats, rolls, sprays, and paints and help kill vibrations, rattles, and overall dissipation of noise.

Materials	Properties	Picture
6. Mass Loaded Vinyl (Dynamat Xtreme)	Uses: Rolls of MLV can be used to noise-proof cars, machinery, and appliances. Their flexible nature and adhesive backing make it easy to cover almost any surface. Reduces road noise Kills vibration and rattles Enhances high-end stereo performance	
7. Floor Underlayment (Roberts Super Felt)	Size: 360 sq. feet, Thickness: 4 mm Uses: Use a quality underlayment to reduce sound transmission of hardwood and engineered floors. Roberts Super Felt underlayment is an excellent choice for noise proofing a floor, especially with laminates, hardwoods, and engineered wood. The felt is made from recycled fibers, compressed and heat treated to form a rich sound absorbing material.	 Source:https://www.soundproofingtips.com/soundproofing-materials/
8. Sound Deadening Spray (DEI	Coverage: 20 sq ft This sound deadening spray is the liquid spray version of mass loaded vinyl sheets, and DEI	

Boom Mat)	Boom Mat is one of the best. One container covers up to 20 square feet and is perfect for covering those difficult to access areas of doors, trunks, and compartments. Spray those areas the mats can't reach for the ultimate car soundproofing performance.	 Source:https://www.soundproofingtips.com/soundproofing-materials/
9. Sound Deadening Paint (Acoustic coat Paint)	Soundproof paint has been called "a myth", but let's look at this group of soundproofing materials and you can decide. Soundproofing paints on the market can be rolled on, or sprayed on. Paints can only be applied in thin layers, so spraying will allow a thicker coat and is the recommended method of application.	 Source:https://www.soundproofingtips.com/soundproofing-materials/

Sound Decoupling Products

To soundproof a room or any other structure, you need to decouple the materials that transmit the sound, such as the walls, ceiling, floors, and doors.

Materials	Properties	Pictures
10. Noise proofing Compound (Green Glue)	Green Glue products are all the rage in soundproofing materials. Green Glue Compound and Green Glue Sealant come packaged in the familiar caulking style dispensing tube. It is used as a sound dampening material in the construction of soundproof walls. When applied between layers of drywall, it can dissipate the sound vibrations that pass-through walls and floor. Green Glue Sealant is used to seal holes, seams, and gaps in walls, ceilings, and open spaces like around electrical boxes, fixtures, and screw holes.	 Source:https://www.soundproofingtips.com/soundproofing-materials/
11. Resilient Channel	Resilient Channels are specially designed sheet metal rails that are mounted across the studs of walls and ceiling joists. They lay over the soundproofing insulation, and the drywall is attached directly to the resilient channels.	 Source:https://www.soundproofingtips.com/soundproofing-materials/
12. Soundproof Drywall	Soundproof drywall is like sheetrock on steroids. It combines multiple layers of gypsum board, and layers of material like steel, to increase its mass and density and thereby blocking sound.	

13. Soundproof Windows	These specially designed windows are constructed of several thick panes of glass, usually with a layer of air or inert gas trapped in between to prevent sound waves from leaking indoors. Soundproof windows are most often installed right over the top of the existing window, using spring-loaded frames on tracks	

Acoustic treatment

Acoustic Panels/Boards – These are decorative versions of sound insulation and sound absorbing foam. Acoustic foam does not block sound. It is used in sound absorption applications to reduce reverberations as noise travels and bounces off reflective surfaces. The acoustic panels are available for wooden grooved acoustic panels, perforated acoustic panels, polyester acoustic panels, fabric covered acoustic panels, wood wool acoustic panels, art acoustic panels, acoustic diffusers, sound absorbers, acoustic foam, etc.

material	Properties	Pictures
Wooden Acoustic Panels	wooden acoustic panels are E1 level eco-friendly and fireproof, and are widely used in multi-purpose halls, conference rooms, cinemas, auditoriums, hotels, auditoriums, airports, etc. Wooden groove acoustic panel is a mature sound-absorbing material.	 https://www.leeyinacoustics.com/acoustic-panels/
14. Acoustic Foam (Auralex Studio foam Wedges)	Size: 12”x12”x2” It is used improving the sound in small to medium rooms, like recording studios, control boardrooms, and even small home theatres. Studio foam Wedges have an NRC rating of 0.8 and the anechoic wedge can significantly cut down reverberation, slap, and flutter.	 Source:https://www.soundproofingtips.com/soundproofing-materials/
Polyester Fiber Sound Absorption Panel	Polyester fiber material has various densities and good air permeability, and is an ideal product in sound absorbing and heat insulating materials. The highest sound absorption coefficient is above 0.8 in the noise range of 125~4000HZ. Used as indoor sound absorbing material, it can effectively shorten the reverberation time, absorb excess reverberation sound, improve hearing adjustment, and improve language clarity. Polyester fiber panel is made of 100% polyester	 https://www.leeyinacoustics.com/acoustic-panels/

	fiber. Size: 1220mmx2420mm Standard thickness: 9mm/12mm/24mm Density: 1200g-3700g/sqm	
Fabric Wrapped Acoustic Panels	Fabric covered acoustic panel is featured by wide absorption spectrum and high sound absorption coefficient, and has excellent sound absorption for low, medium and high frequency noises. At the same time, fabric wrapped acoustic panels are flame retardant,flexible, no dust pollution, strong decoration and simple construction, which are widely used in conference room, multi-purpose hall etc. Substrate:80kg/m3 Owens high density glass fiberboard Finish: Class A/B/C acoustic cloth (ink painting is available) Conventional thickness:25mm,50mm Regular corner shapes: Right angle. bevel Frame: High strength lightweight aluminum alloy one piece frame specifications: 600*600mm,600*1200mm,800*600mm,1200*1200mm,1200*2400mm	 https://www.leeyinacoustics.com/acoustic-panels/
Wood Wool Acoustic Panels	Wood wool sound absorbing panel has unique appearance and good sound absorption, the surface can be painted and sprayed for up to six times.The sound absorption can reach up to 1.0. Wood wool acoustic panel has many functions such as sound absorption, impact resistance, fireproof, moisture proof and mildew resistance, which can be widely used in sports venues, theaters, conference rooms, churches, factories, schools, libraries, swimming pools, etc. Thickness:15/20/25mm Specifications:600x600mm,600x1200mm,1200x1200mm,1200mmx2400mm	 https://www.leeyinacoustics.com/acoustic-panels/
Sound Absorber	The most important is its sound absorption performance, which can prevent echo defects in large halls, and effectively reduce the reverberation time. The acoustic absorbers are available in a variety of shapes such as plate, square, cylinder, cone, and sphere. Among them, the plate-like structure is the simplest and is the most commonly used sound absorber. Finish: Flame retardant acoustic glass fiber cloth Weight: 3.8kg/㎡, 6.8kg/㎡, 12kg/㎡ Installation method: Horizontal hanging. vertical hanging Conventional specifications: 600x1200mm, 600x2400mm, 1200x1200mm, 1200x2400mm Fireproof performance: Class A Structure: One piece aluminum alloy frame, filled with custom broadband sound-absorbing foam, foam surface is composited with environmental	 https://www.leeyinacoustics.com/acoustic-panels/

	sound absorption felt, the surface wrapped in a fire-retardant non-combustible sound-absorbing cloth.	
Acoustic Ceiling	Fiberglass ceiling is made of fiberglass and acoustic transparent wrappage.The fiberglass ceiling has good noise absorption effect and good decoration effect. Material Torrefaction Compounded High Density Fiberglass Wool Face. Special Painted Laminated With Decorative Fiberglass Tissue- Fire-Resistant: Class A (En13501-L-2007+Al:2009) Thermal-Resistant >0.4 Enviromental Impact Tiles And Packings Are Fulfy Recyclable Safety Limit Of Radionuclides In Building Materiab Specific Activity Of 226ra:Iracl0	 https://www.leeyinacoustics.com/acoustic-panels/
Sound Diffuser	acoustic diffusers, including pyramid acoustic diffusor, QRD acoustic diffuser, QRS acoustic diffuser, 3D triangular acoustic diffuser, solid wood stepping acoustic diffuser, solid wood strip acoustic diffuser, beveled triangular pyramid acoustic diffuser, which are widely used in concert halls, multi-purpose halls, auditoriums, recording studios, home theaters, etc. Flame retardant performance: B1 level Diffusion frequency range: Full frequency	 https://www.leeyinacoustics.com/acoustic-panels/

3. EXPERIMENTAL

CASE STUDY CYPRIAN EKWENSI CENTRE FOR ARTS AND CULTURE

This theatre for art and culture is owned by the Federal Government but is been named after Cyprian Ekwensi the head of features at the Nigerian broadcasting cooperation (N. B. C) and also a writer, which is located in the federal capital territory of Nigeria commissioned in 1991 by Gen. Ibrahim Badamassi Babangida who was the then head of state.

The following facilities comprise the cultural centre; an administrative unit, theater, gallery, recreational area, museum, ceramic and studio, community hall and a graphic and painting studio.

Architectural Form: The walls in the front façade have motives which were taken from the culture of various regions within Nigeria; even on the columns mosaic designs were used.

The Cyprian Ekwensi centre for art and culture plan is rectangular in shape and consist the following functions, auditorium, stage and it back-stage and conveniences.

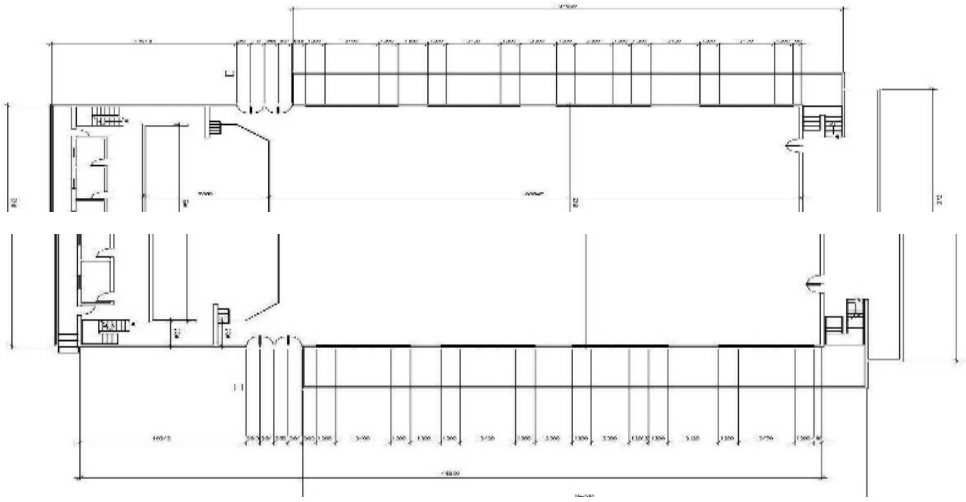


Figure 2.21: Rectangular Theater for Cyprian Ekwensi Art and culture centre Abuja

Source: Guardian.com .ng- Tribute to Ekwensi. 2015

Entrance to the Facility.

Source: Guardian.com .ng- Tribute to Ekwensi. 2015

This picture shows the entrance to the theatre where functions like wedding receptions, drama cultural arts are been carried out, and on its walls we have cultural displays of arts works and painting.

Building Construction Materials

Walls: Reinforced concrete, and mosaic designs depicting cultural plays, sand screed blocks are the major materials used for the construction of the super structure.

Interior wall finishes: It was finished using cement screed and painted with emulsion paint, which does not enhance the treatment of acoustic.

Construction Technology: use of sustainable design elements like wood for the struts and framework as well as glass for the interior skin and concrete depicts an art center are not completely present.

Roof: Aluminium roofing over steel were used for the roofing of the building.

Acoustic considerations

The gallery of its theater and the use of materials do not favours acoustics, due to the nature of its building form and the use of hard wall surfaces and ceiling materials, which causes reverberation during musical performance.

Material used as acoustical treatment on the wall, but not covered all around the wall. At the Cyprian Ekwensi Art and Culture, Sound and vibration sources are usually speech and sounds

of normal human activity—music, mechanical equipment sound and vibration, traffic, and the like.

Sound is not been heard in its dead form, instead it's been heard after so many reflections before it gets to its users.

Interior for Cyprian Ekwensi Theatre.

Back Stage for rehearsals.

Source: Guardian.com .ng- Tribute to Ekwensi. 2015

These are gases (usually air); denser fluids (water, steam, oil, etc.); and solids (building materials themselves) were not considered, .instead, a space to just carry people for functions which, during sound transmission in the theater, building, some of the sound energy dissipated, virtually all is been reflected from various surfaces, and is not been transmitted through the building materials and furnishings.

Materials used in the Theatre.

Source: Guardian.com .ng- Tribute to Ekwensi. 2015

Case study of a cultural center and the materials used

4. CONCLUSION AND DISCUSSION

Being in an interior space such an auditorium that has inadequate acoustics consideration can be extremely unpleasant and has direct influences on the environmental comfort of a space, human behaviour and productivity. Architects do not necessarily need be experts in every technical aspect of a design project, even in acoustic knowledge. It can be good to call on acoustic engineers to carefully review the technical specifications of a design program and to recommend the best materials to improve the acoustics of the space. However, it is very important to have the basic idea of issues relating to acoustics which will make informed decisions for incorporating better sound within the project's design, to achieve good sound user experience.

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Guardian.com .ng- Tribute to Ekwensi. 2015