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Research Article

Evaluation of Architectural Acoustics as a treatment in the design of Auditoriums

Uhiara F.E and *Emberga T.T

Department of Physics and Electronics, Federal Polytechnic Nekede, Owerri, Nigeria

*Corresponding Author E-mail: terhemba4sure@yahoo.com

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Abstract

Architectural acoustics is the potential to badly alter the comfort and dead sound that is supposed to be the end results to the listeners if not be researched and simulated before its applications to the design of auditoriums. Architecture in so many ways is interwoven with the ways of the people, it is employed to fulfill both practical and expressive requirements of civilized people and thus embraces both utilitarian and aesthetics ends. Music and speech eligibility plays a very important role in the ultimate decision that shapes the building form Architecture of a space. For a perfect building form for an auditorium, simulation, Visual survey and observation are key in conducting on-site survey for auditorium construction.

Keywords: Architectural acoustics, Auditorium, Reverberation time

INTRODUCTION

Theatre acoustics entails the putting in place of necessary measures that would help ensure that optimum audible conditions are created in spaces where speech and music are to be carried out with the help of the building form adopted in subduing reverberations and echoes. Various factors need to be considered of which the two most important are reverberation time and reflections (as a consequence of the primary and secondary structure of the space) (Baiche and Walliman, 2000). There is a need to get a grasp of key acoustic concepts and how it applies. The arts of music, drama, and public discourse have both influenced and are been influenced by the acoustics and Architecture of their presentation. Jacques (1990). Theorized that African music and dance evolved a highly complex rhythmic character rather than the melodic line of early European music to it being performed outdoors.

Auditoriums are venues where activities such as wedding receptions, meetings e.t.c are carried out in order to keep on the trend of one's culture by its performing arts, it can be obtained by ones cultural activities like songs, dance and the exhibitions of its materials and in so doing the need for proper planning and acoustic consideration to increase acoustic quality of the structure to facilitate a conducive amphitheatre for art performance. Acoustics is the science of sound. It deals with the production of sound, the propagation of sound from the source to the receiver, and the detection and perception of sound.

There are various perceptions to sounds, the disturbance in a medium that can cause disorder and an auditory sensation in the ear. (Thomas, 2007). Sound is explained by Donald(1997) as vibration in an elastic medium such as air and water

Cultural centre's have the problem of long reverberation times. This is so bad and terrible in an environment where users need to be attentive and also need to hear or listen to clearly exactly to what the performers are presenting. poor hall acoustics will make listeners suffer vestibular disorder and voices will be drowned out by echoes that will make music sound as noise virtually to the listeners, in solving this problem of reverberation, sound reflection will be brought to the minimal as bearable dead sound Transmission (flow) or prevention of transmission of sound, and conversion of energy to a non-audible form are the function of the kind of building form used. 1895 (Sabine,1922). He followed the earlier European examples, using a shoebox shape and heavy plaster construction with a modest ceiling height to maintain a reverberation time of 1.8 seconds. Narrow side and rear balconies were used to avoid shadow zones and a shallow stage enclosure, with angled walls and ceiling, directed the orchestra sound out to the audience. The deeply coffered ceiling and wall niches containing classical statuary provide excellent diffusion

REFLECTION OF SOUND ON DIFFERENT BUILDING FORMS

Reflection on Flat Surfaces

If a sound is activated in a room, sound travels radially in all directions. As the sound waves encounter obstacles or surfaces, such as walls, their direction of travel is changed, i.e., they are reflected. Reflections from Flat Surfaces plate1.0 illustrate the reflection of waves from a sound source from a rigid, plane wall surface. The spherical wave fronts (solid lines) strike the wall and the reflected wave fronts (broken lines) are returned toward the source. Like the light/mirror analogy, the reflected wave fronts act as though they originated from a sound image. This image source is located the same distance behind the wall as the real source is in front of the wall. This is the simple case, a single reflecting surface. In a rectangular room, there are six surfaces and the source has an image in all six sending energy back to the receiver. In addition to this, images of the images exist, and so on, resulting in a more complex situation. However, in computing the total sound intensity at a given receiving point, the contributions of all these images must be taken into consideration. Sound is reflected from objects that are large compared to the wavelength of the impinging sound.

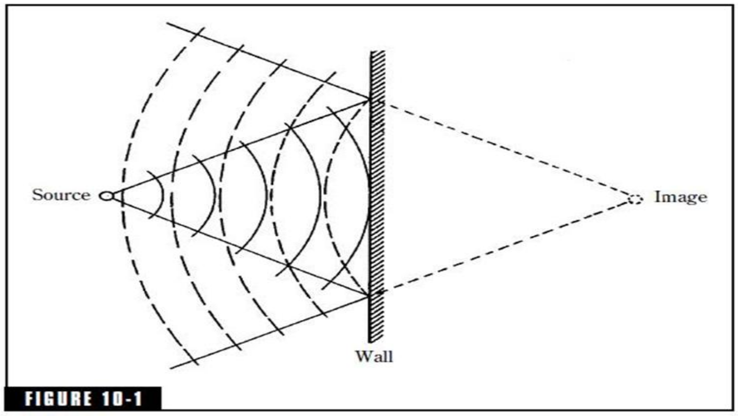

FIGURE 10-1

Reflection of sound from a point source from a flat surface (incident sound, solid lines; reflected sound, broken lines). The reflected sound appears to be from a virtual image source.

Figure 1: Reflection of sound on flat surfaces

Reflector for 10 kHz sound (wavelength about an inch). At the low end of the audible spectrum, 20 Hz sound (wavelength about 56 ft) would sweep past the book and the person holding it as though they did not exist, and without appreciable *shadows*. Below 300–400 Hz, sound is best considered as waves. Sound above 300–400 Hz is best considered as traveling in rays. A ray of sound may undergo many reflections as it bounces around a room. The energy lost at each reflection results in the eventual demise of that ray. Even the ray concept is an oversimplification: Each ray should really be considered as a “pencil” of diverging sound with a spherical wave front to which the inverse square law applies. The mid/high audible frequencies have been called the *specula* frequencies because sound in this range acts like light rays on a mirror. Sound follows the same rule as light: The angle of incidence is equal to the angle of reflection,

Doubling of Pressure at Reflection

The sound pressure on a surface normal to the incident waves is equal to the energy density of the radiation in front of the surface. If the surface is a perfect absorber, the pressure equals the energy-density of the incident radiation. If the surface is a perfect reflector, the pressure equals the energy-density of both the incident and the reflected radiation. Thus the pressure at the face of a perfectly reflecting surface is twice that of a perfectly absorbing surface. At this point, this is only an interesting sidelight. In the study of standing waves, however, this pressure doubling takes on greater significance

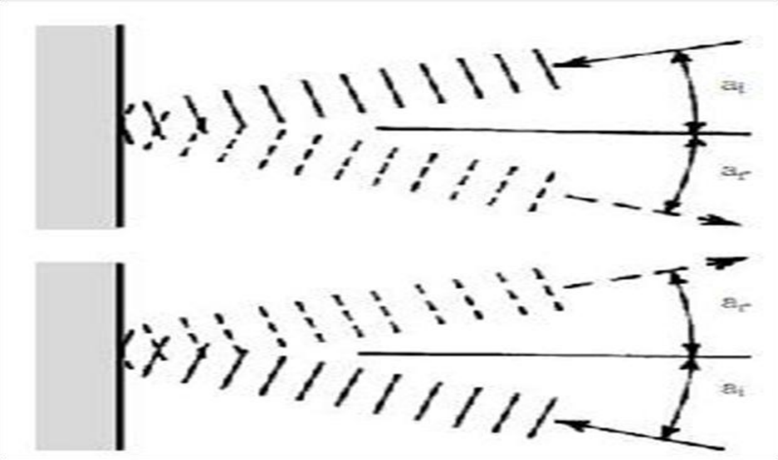

Figure 2. Angle of incidence of sound

Reflections from convex forms/surfaces

Spherical wave fronts from a point source tend to become plane waves at greater distance from the source. For this reason impinging sound on the various surfaces to be considered will be thought of as plane wave fronts. Reflection of plane wave fronts of sound from a solid convex Surface tends to scatter the sound energy in many directions as shown. This is to a diffusion of the impinging sound.

The poly cylindrical sound-absorbing system described in the previous chapter both absorb sound and contributes to much-needed diffusion in the room by reflection from the cylindrically shaped surface.

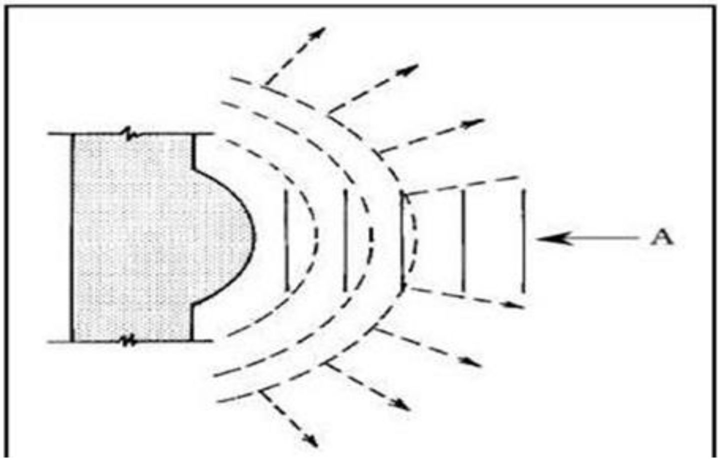

Figure 3: Reflections from concave forms/surfaces

Reflections from concave forms/surfaces

Plane wave fronts of sound striking a concave surface tend to be focused to a point as illustrated. The precision with which sound is focused to a point is determined by the shape of concave surfaces. The angle of incidence, *a*i, is equal to the angle of concave surface. Spherical concave surfaces are common because they are readily formed. They are often used to make a microphone highly directional by placing it at the focal point. Such microphones are frequently used to pick up field sounds at sporting events or in recording songbirds or other animal sounds in nature. In the early days of broadcasting sporting events in Hong Kong, a resourceful technician saved the day by using an ordinary Chinese wok, or cooking pan, as a reflector. Aiming the microphone into the reflector at the focal point provided an emergency directional pickup. Concave surfaces in churches or auditoriums can be the source of serious problems as they produce concentrations of sound in direct opposition to the goal of uniform distribution of sound. The effectiveness of reflectors for microphones depends on the size of the reflector with respect to the wavelength of sound. A 3-ft-diameter spherical reflector will give good directivity at 1 kHz (wavelength about 1 ft), but it is practically non directional at 200 Hz (wavelength about 5.5ft).

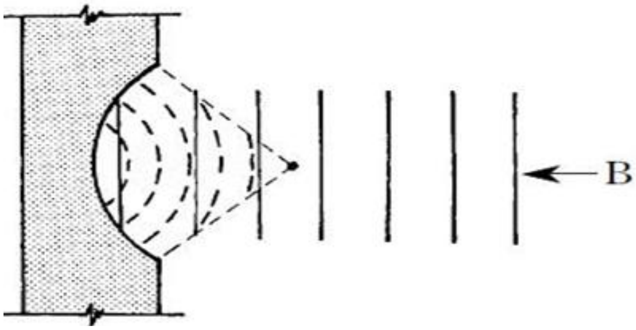

Figure 4: Reflections from parabolic surfaces

Reflections from parabolic surfaces

It is generated by the simple equation $y = x^2$. A very “deep” parabolic surface, exhibits far better directional properties than a shallow one. Again, the directional properties depend on the size of the opening in terms of wavelengths. Conversely, sound emitted at the focal point of the parabolic reflector generates plane wave fronts. This is demonstrated in the photographs of Fig below in which standing waves are produced by reflections from a heavy glass plate. The force exerted by the vibration of the air particles on either side of a node is sufficient to hold slivers of cork in levitation.

Space acoustics and applications

Room acoustics design begins with establishing basic size, shape and finish materials of a given space to achieve a certain room sound. These criteria are based largely upon the intended function and occupancy of the room Meyer and Good friend, 1957).

Specific criteria

- Cubic volume and reverberation time. RT60 is a recommended standard and indicates a time (RT) in a room that a sound takes to decay60 decibels from its original level when abruptly terminated.
- Room dimensional proportions (length-to-width and height-to-width ratios) and shaping.
- Type, location, orientation, and shaping of sound reflecting, absorbing and diffusing surfaces.

Acoustical materials

Beranek,(1996) on materials. Architectural surfaces need to be designed to reflect sound, absorb sound, or diffuse sound. Each type of surface has its own specific criteria and applications for being incorporated into a space.

I. Reflective surfaces

Are considered to be essentially flat or slightly shaped planes of hard building materials including gypsum board, wood, plywood, plaster, heavy metal, glass, masonry, and concrete.

- Should be of sufficient mass, thickness, and stiffness to avoid becoming absorbers of low-frequency sound energy where this is not desired (see discussion of Absorptive Surfaces below).
- Should be of sufficient dimension to reflect all frequencies of interest. since frequencies below 500 Hz are more omnidirectional in nature and not easily directed towards a specific location.
- Can create problems by being located and oriented such that sound generated a certain distance away can reflect back to its point of origin delayed in time and thus cause a discernible and troublesome echo.

II• Absorptive surfaces

Primarily used for the following applications:

- **Reverberation Control**: reduction of reverberant sound energy to improve speech intelligibility and source localization.
- **Sound Level Control**: reduction of sound or noise buildup in a room to maintain appropriate listening levels and improve sound isolation to nearby spaces.

- **Echo and Reflection Control**: elimination of perceived single echoes, multiple flutter echoes, or unwanted sound reflections from room surfaces.
- **Diffusion Enhancement**: mixing of sound in a room by alternating sound absorptive and sound reflective materials.

III. Types

As enumerated by Harris, (1994)

- Porous materials include fibrous materials, foam, carpet, acoustic ceiling tile, and draperies that convert sound energy into heat by friction. Example: fabric-covered 1 in. (2.5 cm) thick fiberglass insulation panels mounted on a wall or ceiling.
- Vibrating panels thin sound-reflective materials rigidly or resiliently mounted over an airspace that dissipates sound energy by converting it first to vibration energy. Example: a 1/4 in. (6 mm) plywood sheet over an airspace (with or without fibrous materials in the airspace).
- Volume resonators - materials containing openings leading to a hollow cavity in which sound energy is dissipated. Example: slotted concrete blocks (with or without fibrous materials in the cores).

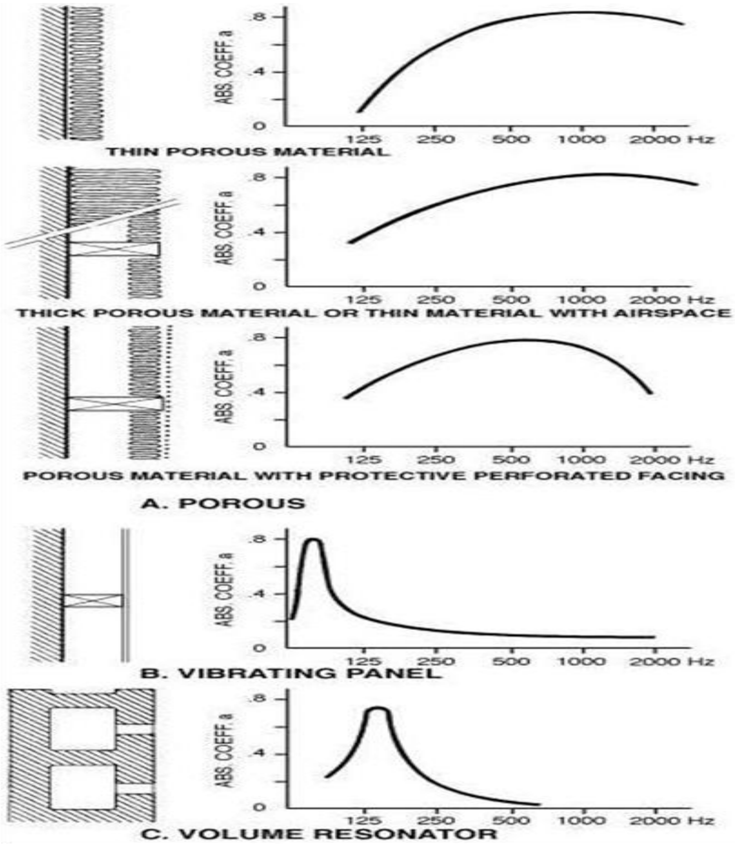

Figure 5: A graphical representation of the above types of sound absorbing materials along with typical levels of absorption versus frequency

Basic types and relative efficiencies of sound-absorbing materials

They are most efficient when applied in smaller panels distributed evenly on a room's boundary surfaces versus large panel areas concentrated on one or two surfaces.

IV. Diffusive Surfaces

These are materials having a non-planer shaping or random articulation that result in the redirection and redistribution of sound energy impacting their surfaces (Egan, 1988). They help to do the following:

- Promote diffusion, or even distribution, of sound in a room which creates in a listener the sense of being enveloped in a sound generated within the room.

- Are typically sound-reflective surfaces formed into convex splayed or randomly articulated shapes.

- Are not concave surfaces which can cause uneven focusing of sound energy.

See Figure 6 for the most common diffusive surface shapes.

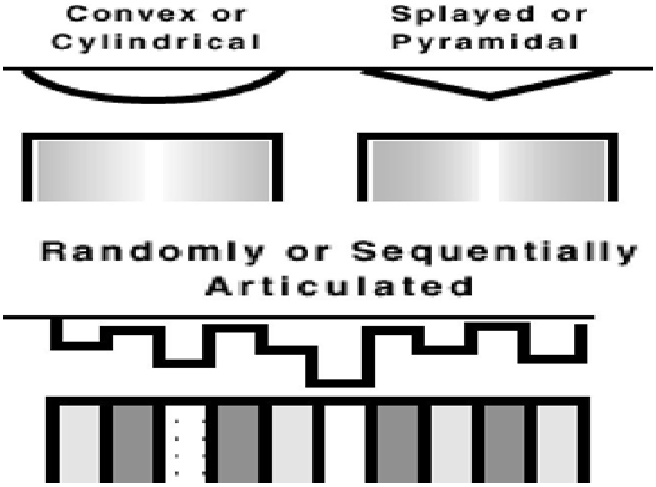

Figure 6: Common shapes that promote sound diffusion.

DISCUSSION

The acoustics of theaters are commonly judged by their reverberation evaluated from the sound level decay curves. The first, conventional Reverberation Time (RT) is defined as the time it takes for sound to decay by 60 dB after the sound source has stopped. It is usually determined by extrapolating the slope of a straight line fitted to the first part of reverberant decay curves as a function of frequency between -5 and -25 (RT20), or -35dB (RT30). The second indicator is the Early Decay Time (EDT), which is found to be a subjectively more relevant indicator than RT and is defined as the sound decay slope of a straight line fitted to the decay observed during the first - 10 dB. EDT values are more influenced by the Interior materials and finishes of theaters vary from one country to another. However, theaters walls are commonly finished with painted plaster. Wall wainscots are sometimes covered with marble tiles or wooden boards or panels tongued and grooved to compose a vertical pattern. The floor area is always carpeted. Plastered and painted concrete ceilings with simple to elaborate decorations and /or inscriptions are commonly used. Depending on the climatic conditions, the Theatre may be equipped with an air-conditioning system, in concert with some ceiling fans. Electro-acoustic sound reinforcement systems have also been installed in theaters of all sizes to improve the hearing conditions in the space, particularly when air-conditioning system is installed.

Simulation analysis was conducted on an hexagonal shaped building(theatre) form showed how effective an hexagonal building form can favour acoustics, the design has attempted to achieve a perfect dead sound to its listeners or users. This is reflected in the way and manner sound beams are radiated from a source and also converges it at a focal point to giving its users a feel of a dead sound in theatres.

Any artificial reproduction of sound or sounds intended to accompany action and supply realism in the theatre, radio, television, and motion pictures. Sound effects have traditionally been of great importance in the theatre, where many effects, too vast in scope, too dangerous, or simply too expensive to be presented on stage, must be represented as taking place behind the scenes. An offstage battle, for instance, can be simulated by such sounds as trumpet blasts, shouts, shots, clashing weapons, and horses' hooves. Certain dangerous effects, such as explosions, crashes, and the smashing of wood or glass, must also take place offstage. Sound effects must often be coordinated with actions on stage; when the hero pretends to punch the villain on the jaw, a sound technician backstage must provide a realistic “smack!”

Today most sound effects are recorded on records or tapes, which provide greater realism and allow for the production of an almost limitless range of effects with no need of bulky sound.

CONCLUSION AND RECOMMENDATIONS

The study aimed at analyzing the reflections of sound beams or rays in the design of a theatre The result showed that a theatre with hexagonal building forms tends to produce a perfect dead sound for her listeners therefore creating the harmony between the theatre and its users but also putting into consideration the use of material in such theaters for perfect absorption of sound to reducing reverberation time.

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