Integration of Acoustic and Sound Control in the Design of a Centre for Performing Arts

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Abstract

*This study is focused on **acoustics**, interrelationship and design of performing spaces which is concerned with the production, control, transmission, reception, and effects of sound in spaces such as theatres, halls, auditoriums, etc. Through design guidelines, codes and standards with research studies to analyse the various characteristics of spaces for specific or multipurpose use and its relationship to the users of the facility. Hence this body of work is aimed at proposing a centre for performing arts in Port Harcourt city, Rivers State, Nigeria as a result of under development of such spaces for performing arts form. The prospect of a centre for performing arts in Port Harcourt city would revitalize the state, and project into a global platform through clearly defined spaces intended to house performing arts forms for both performers and spectators, this is necessary in sustaining the art forms and cultural heritage of the people of Port Harcourt. Also this research seeks to strike balance between the culture of the people and the international standard of performance spaces through articulate and architectural approach. In the course of this study, elements from existing performance spaces as that of for which the project is being planned will be studied through case studies, local and foreign case studies will be reviewed as guide for the development of this research. However, caution and careful considerations will be given as to the recommendations for this project with respect to environmental factors and climatic conditions. Finally, the expected outcome of this research work will be a purpose built centre for performing arts that is indigenous through architectural approach of optimizing and enhancing spatial configuration.*

INTRODUCTION

Acoustic is a word which pertain to hearing of sounds which may be pleasing or unpleasant to the hearer, and it take places especially, in a performance centre, as a matter of necessity should be checked properly.
Performance arts centre is aimed at achieving good intelligibility and music quality thereby creating an acoustic environment that is effective. To achieve the aforementioned, the following objectives need to be considered: Application of appropriate passive and active noise defense mechanisms in building design, appraisals of similar existing projects (post evaluation), and application of architectural acoustics design principles and criteria that impact the choice of acoustical control technologies, provision of sufficient room volume to allow the natural

development and support of sound. In today's architectural environment such as a performance centre, good acoustical design is not luxury – but a necessity.
Given that architecture involves the development and arrangement of forms and space in relation to users, space is one of the essential design elements. "Space is a prime material in the designer's palette and an essential element in interior design" (Ching D. K. 1943, page 10) refers to the unique kind of open space that an architect produces by giving it form, shape, and scale. The design of performing art venues, which are intended to accommodate certain activities like dance, music, theater, and other art forms, must be well thought out. The performance space's arrangement is a crucial component in optimizing other design aspects in respect to space for a positive user experience. The display layout depends on some main configurational properties such as control, connectivity and integration, as well as some qualities like hierarchy, symmetry and perspective. Different combinations of these properties result in three different display relationship strategies: objects enhancing space, space enhancing objects and fully autonomous independent space-display relation.

ACOUSTICAL MATERIALS AND CONSTRUCTIONS

Sound Absorbing Materials

On striking any surface, sound is either absorbed or reflected. The sound energy absorbed by an absorbing layer is partially converted into heat but mostly transmitted to the other side, unless such transmission is restrained by a backing of an impervious, heavy, barrier. In other words, good sound absorber is an efficient sound transmitter and consequently an inefficient sound insulator. Sound absorbing materials and constructions used in the acoustical design of auditoriums or for the sound control of noisy rooms can be classified as:

1. Porous materials
2. Panel or membrane absorbers,
3. Cavity resonators.

Porous Materials

The basic acoustical characteristic of all porous materials, such as fiberboards, soft plasters, mineral wools, and isolation blankets, is a cellular network of interlocking pores. Incident sound energy is converted into heat energy within these pores, while the remainder, reduced energy is reflected from the surface of the material.

Characteristics:

1. Their sound absorption is more efficient at high frequencies
2. Their acoustical efficiency improves in the low frequency range with increase in thickness and with distance from baking.

Categories:

1. Prefabricated units
2. Plaster and sprayed-on- materials
3. Blankets.
4. Carpets & fabrics

Prefabricated Acoustical Units

Various types of perforated, imperforated, fissured, or textured cellulose and mineral fiber tiles, lay in panels, and perforated metal pans with absorbent pads constitute typical units in this group.

Acoustical Plasters and Sprayed-On Materials

These acoustical finishes are used mostly for noise reduction purposes and sometimes in auditoriums where any other acoustical treatment would be impractical because of the curved or irregular shape of the surface. These are applied in semi-plastic consistency, either by spray gun or by hand troweling.

Acoustical Blankets

Acoustical blankets are manufactured from rock wool, glass fibers, wood fibers, hair felt, etc. Generally installed on a wood or metal framing system, these blankets are used for acoustical purposes for varying thicknesses between 1 & 5 in. Their absorption increases with thickness, particularly at low frequencies.

Carpets and Fabrics

These absorb airborne sounds and noises within the room, also reduce and in some cases almost completely eliminate impact noises from above and they eliminate surface noises.

Panel Absorbers

Any impervious material installed on a solid backing but separated from it by an air space will act as a panel absorber and will vibrate when struck by sound waves. The flexural vibration of the panel will then absorb certain amount of incident sound energy by converting it into heat energy. Among auditorium finishes and constructions the following panel absorbers contribute to low-frequency absorption: wood and hard board panels, gypsum boards, rigid plastic boards, windows, doors, glazing, etc.

Cavity Resonators

This consists of an enclosed body of air confined within rigid walls and connected by a narrow opening to the surrounding space, in which the sound waves travel. Cavity resonators can be applied 1) as individual units 2) as perforated panel resonators, 3) as stilt resonators.

Individual Cavity Resonator

These, made of empty clay vessels of different sizes, were used in medieval Scandinavian churches. Standard concrete blocks using regular concrete mixture but with slotted cavities, called sandbox units, constitute a contemporary version of sound resonators.

Perforated Panel Resonators

Perforated panels, spaced away from a solid backing, provide a widely used practical application of the cavity resonator principle. The air space behind the perforation forms the undivided body of the resonator, separated into bays by horizontal and vertical elements of the framing system.

Slit Resonators

In designing the auditoriums the desired acoustical effect can often be accomplished by using relatively inexpensive isolation blankets along the room surface. But these need protection against abrasion. Thus, opportunity to design decorative-surface treatment for protection is given. The protective screen can consist of a system of wood, metal or plastic salts, cavity blocks, with series of openings or gaps. This constitutes a stilt resonator.

Space Absorbers

When the regular boundary enclosures of an auditorium do not provide suitable or adequate area for conventional acoustical treatment, sound absorbing objects, called space absorbers, can be suspended as individual units from the ceiling. These are made of perforated sheets in the shape of panel, prisms, cubes, spheres, etc., are generally filled or lined with sound absorbing materials such as rock wool, glass wool, etc. their acoustical efficiency depends on their spacing. In order to achieve a reasonable amount of room absorption, it is essential that a large number of space absorbers be used within a space.

Variable Absorbers

For change in RT, various sliding, hinged, movable, and rotator panels have been constructed that can expose their absorptive or reflective surfaces. Draperies have been installed that can be spread out on walls or be pulled off into suitable pockets, thus arbitrarily increasing or reducing the effective absorptive treatment in the room.

Acoustical Constructions: *wall insulation: vertical barriers*

Wall construction used for sound insulation can be of three types:

1. Rigid and massive homogeneous walls: this consists of stone, brick or concrete masonry, well plastered on one or both sides. Their sound insulation depends on their weight per unit area.
2. Partition wall of porous material: these can be of rigid or non-rigid type. In the rigid partitions, insulation is 10% more.
3. Double wall partition: this consists of plasterboards or fiber boards or plaster on laths on both the faces, with sound absorbing blankets in between.
4. Cavity wall construction: this is an ideal construction from the point of view of sound insulation. The gap between two walls can be filled by air or some resilient material.

Floors and Ceiling Insulation: *Horizontal Barriers*

These act as horizontal barriers to both air-borne and impact noises. Main emphasis is given to the insulation against the impact noises. This may be done by:

1. Use of resilient material on the floor surfaces: this consists of providing thin concrete slab as the RCC floor slab, and then providing a soft floor finish material such as linoleum, cork, asphalt mastic, carpet, etc.
2. Concrete floor floating construction: in this an additional floor is constructed and isolated from the existing concrete floor.
3. Timber floor floating construction: this is done by employing mineral or glass wool quilt for isolation purposes. A further improvement in the insulation of such floors is achieved by employing a plugging or deadening material in the air gap between the wooden joists.
4. Timber floor with suspended ceiling and air space: the highest insulation can be achieved by using a very heavy ceiling, which are arranged to be independent of the floor by supporting it on resilient mountings.
5. Skirting: the larger the contact area a skirting provides between the floors and the walls, the lower would be insulation. For this the lower edge of the skirting is chamfered thus reducing the area of contact.

Acoustic Treatments

There are four primary goals of acoustic treatment:

1. To prevent standing waves and acoustic interference from affecting the frequency response of recording studios and listening rooms;
2. To reduce modal ringing in small rooms and lower the reverberation time in larger studios, performance centres, and auditoriums;
3. To absorb or diffuse sound in the room to avoid ringing and flutter echoes, and improve stereo imaging; and
4. To keep sound from leaking into or out of a room. That is, to prevent your music from disturbing the neighbours, and to keep the sound of passing trucks from getting into your microphones.

Wood Panels

Also called wave wood solution panels are one of the strongest ones as absorption and reflection control systems. It is a good solution where the aim is to get a balanced sound ambience that simultaneously controls the energy in a room. It maintains a living and a bright sound at the same time. This system presumes the optimal balance between the absorption area and the reflecting surface. It consists of acoustic foam and wood. It is ideal for conference rooms, lecture halls, distance learning rooms, recording and broadcastings studios, cinemas, home theatres etc. It is highly effective in the treatment of medium and high frequencies.

Wood can be used in different ways. One is the wood wool slabs. That is a panel product made of long thin strands of wood that are mixed with cement and compressed in a mould to bind them together. Wood wool slabs are mainly used for roof decks and wall cladding. The absorption factor grows as the plates get thicker. Thinner plates can give a good result if they are mounted with a cavity behind. Filling the cavity with wool gives an even better solution. Some plates have the ability to absorb the sound 100% in the frequency range over 500 Hz. Wood wool plates come both with rough and fine shingle.

This is the science of limiting and/or controlling noise transmission from one building space to another to ensure space functionality and speech privacy. The typical sound paths are room partitions, acoustic ceiling panels (such as wood dropped ceiling panels), doors, windows, flanking, ducting and other penetrations. An example would be providing suitable party wall design in an apartment complex to minimize the mutual disturbance due to noise by residents in adjacent apartments.

Interior Space Acoustics

This is the science of controlling a room's surfaces based on sound absorbing and reflecting properties. Excessive reverberation time, which can be calculated, can lead to poor speech intelligibility.

Sound reflections create standing waves that produce natural resonances that can be heard as a pleasant sensation or an annoying one. Reflective surfaces can be angled and coordinated to provide good coverage of sound for a listener in a concert hall or music recital space. To illustrate this concept consider the difference between a modern large office meeting room or Lecture Theater and a traditional classroom with all hard surfaces.

Interior building surfaces can be constructed of many different materials and finishes. Ideal acoustical panels are those without a face or finish material that interferes with the acoustical infill or substrate. Fabric covered panels are one way to heighten acoustical absorption. Finish material is used to cover over the acoustical substrate. Mineral fiber board, or Micro, is a commonly used acoustical substrate. Finish materials often consist of fabric, wood or acoustical tile. Fabric can be wrapped around substrates to create what is referred to as a "pre-fabricated panel" and often provides good noise absorption if laid onto a wall. Prefabricated panels are limited to the size of the substrate ranging from 2 by 4 feet (0.61 × 1.2 m) to 4 by 10 feet (1.2 × 3.0 m). Fabric retained in a wall-mounted perimeter track system, is referred to as "on-site acoustical wall panels". This is constructed by framing the perimeter track into shape, infilling the acoustical substrate and then stretching and tucking the fabric into the perimeter frame system. On-site wall panels can be constructed to accommodate door frames, baseboard, or any other intrusion. Large panels (generally, greater than 50 square feet (4.6 m^2)) can be created on walls and ceilings with this method. Wood finishes can consist of punched or routed slots and provide a natural look to the interior space, although acoustical absorption may not be great.

ACOUSTICAL DEFFECTS

Echo

Sound wave after originating in an enclosure spreads out and strikes the surfaces of ceiling, walls, floors and objects like furniture. Some of them are reflected back. These reflected waves get reunited and give rise to ECHOES. In other words, echo is an indirect or reflected voice heard just after the direct hearing of the voice coming from the same sound source.

The formation of echoes normally happens when the time lag between the two voices is about 1/17th of a second and the reflecting surfaces are situated at a distance greater than 15 m. This defect usually occurs when the shape of reflected surface is covered with smooth character.

Echoes cause disturbance and unpleasant hearing. These can be avoided by planning the shape and size of the room based on simple law of reflection, which state that the direction of travel of reflected sound should make the same angle with the wall as that of the incident sound.

Sound Foci

In case of concave shaped reflecting interior surfaces or domed ceiling of an enclosure, depending upon the curvature of these surfaces, there is possibility of reflected sound rays to meet at a point, called sound focus. This causes concentration effect for the reflected echoes and consequently creates a sound of large intensity. These spots of unusual loudness or intensity are called as sound foci. This defect can be eliminated providing suitably designed shapes of the interior faces or by providing the absorbent materials on focusing areas.

Whispering Galleries

The whispering gallery effect is due to high-frequency sound such as a whisper carried around by a curved surface with minimal sound absorption. A classic example of a whispering gallery is found in the Statuary Hall in the United States Capitol, Washington, D.C., but the effect will be found in any room with hard, concave curved walls. It is an acoustical oddity, but it is seldom a problem because it requires both a sound source and a receiver close to the wall. This problem can be solved in the same way as that of sound foci.

Dead Spots

This defect is an outcome as a side effect of the sound foci. Due to high concentration of the sound rays at some points, these spots of low sound intensity causing unsatisfactory hearing for the audience are known as 'dead spots'. This defect can be eliminated providing suitable diffusers, enabling uniform distribution of sound in the hall.

Long Delayed Reflection

This defect is similar to echo except that the time delay between the perception of direct and reflected sound is a little less.

Flutter Echo

This is usually caused by the repetitive inter reflection of sound between opposite parallel or concave sound reflecting surfaces. Flutter is normally heard as a high frequency ringing or bussing, It can be prevented by shaping to avoid the parallel surfaces, providing deep sound absorbing treatment, or breaking up smooth surfaces with splayed or scalloped elements A 1:10 splay (or >50 tilt) of one of the parallel walls with normally prevent flutter in small rooms.

Reverberation

We have already seen that reverberation is the persistence of sound in the enclosure, after the source of sound has stopped. Reverberant sound is the reflected sound, as a result of improper absorption. Excessive reverberation is one of the most common defects, with the result that sound once created prolongs for a longer duration resulting in confusion with the sound created next. However, some reverberation is necessary for good hearing. Thus, optimum clarity depends on correct reverberation time, which can be controlled by suitably installing the absorbent materials.

Insufficient Loudness

This defect is caused due to lack of sound reflecting flat surface near the sound source and excessive sound absorption treatment in the hall. The defect can be removed by providing hard reflecting surface near the source, and by adjusting the absorption of the hall so as to get optimum time of reverberation.

External Noise

External noise from vehicles, traffic engines, factories, cooling plants, etc. may enter the hall either through the openings or through even walls and other structural members having improper sound insulation. This defect can be removed by proper planning of the hall with respect of its surroundings and by proper sound insulation of exterior walls.

AIM AND OBJECTIVES

The aim of this research is to use an architectural approach to solve real life problems associated with the design such as sound production, light interference, etc. in performance spaces.

The objectives of this research include the following

- To provide parameters that enable effective design in performing art spaces for better performances and experience

- To improve research in related areas of performing arts hence create a socio-cultural environment for learning.
- Promote the need for performing arts center to enhance creativity and active participation in performance arts

RESEARCH METHODOLOGY

For the purpose of this research, the primary method deployed for the collection of data would be qualitative analysis which includes primarily research and other methods such as existing case studies, existing literature on the subject from other researchers through their writings in books, journals, articles, published and unpublished literatures, textbooks and other sources all relevant to the subject matter and the specific area of study. The collated raw information will be reviewed and used as the basis for analysis and guide on this research

DISCUSSION AND FINDINGS

The acoustics of a space are determined by its architecture -- its geometric shape, the way in which it is finished -- and by the number of people that occupy it at any given time. Sound waves travel in approximately straight lines, bouncing off hard surfaces or being absorbed or "soaked up" by soft ones before it dies out. Such a space is said to be reverberant or "live", and the sound bouncing around the room is called reverberation. Similarly, the sound from a person speaking in a room with soft walls (curtains, carpets, seat cushions, people, or acoustic tiles, etc.) will not bounce much at all before it dies out. It will take a lot of vocal effort to be heard over an equivalent distance in this non-reverberant or "dead" space, but the sound which does get through will be easier to understand. A good performance centre will have a good intelligibility rating. The set of minimum acoustic requirements that are met by event centre or performance centre starts with the direct sound from the speaker being loud enough, that means it replicates conversational sound levels. Sound from a person speaking in a very reverberant space will consist of one sound wave travelling in a straight line and a lot of sound waves that have bounced around the room for a long time. All of these sound waves will take different lengths of time to get to the listener, arriving at different times. (Arthur M. Noxon, (2009).

CONCLUSION AND RECOMMENDATION

Conclusion

This research has clearly shown the benefits of a centre for performing arts in any city. A well designed facility would bridge both social and international gap through the various theatrical activities (either local or international art forms). Hence the various factors that enhance good and effective spatial configuration must be considered in the design of a performing art center in other to enhance the quality of performance spaces for the users as well as create good user experience.

Recommendation

Architects, designers and other specialist in the design team need to recognize the fact that spaces used for either specific or multipurpose use should be designed to codes and standards that apply to the specific use and building type while keeping in view the environmental conditions that are prevalent. Hence it is recommended that proper calculation and attention is given to the minimum standard of the various factors involved in the optimization and enhancement of performing spaces such space size, space volume, seat layout, stage design choice, acoustic parameters, lightning angles, circulation, as well as other factors such as choice of material and finishes, building form.

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