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Parameters for Acoustic Design in Auditorium

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Abstract*: The clarity of communication in any auditorium is closely associated to the quality of acoustic treatment of that space. This quality is characterized by various parameters in acoustic designing. This research paper aims to explain the acoustical phenomenon and defects that becomes the basis of acoustical designing and material selection. The paper includes the basic guidelines and techniques for an auditorium acoustics designing, including fundamental thumb rules for selection of materials with respect to NRC values required in a space. The paper attempts to explain the NRC values that are generally considered on various surfaces of an auditorium to achieve the most efficient sound distribution in the space. Recommendations for surface finish have been conferred to achieve the required acoustical effect in an auditorium.

Keywords: Acoustic, Auditorium, Noise reduction coefficient, Acoustic material

I. INTRODUCTION

An auditorium is a multidimensional space used generally for performing arts or presentations. It enables the audience in general to watch & hear a performance. Acoustics plays an important part in designing such spaces. A badly designed acoustics in an auditorium leads to incommunicable noises. Hence, it is required to acoustically design the space in a way that the speech can be clearly understood. The minimum acoustic requirements that is required for an auditorium starts with the sound source from the speaker being loud enough, that means it produces communicable sound levels. Also, the background noise in the enclosure should not interfere with the main activity. Defects like echo and late reflections should be checked and be nil. One of the major requirements for a good auditorium is that it must be free of reverberations to avoid masking of various sounds generated one after the other.In order to avoid undesirable sound, unfavorable conditions must be provided for the production, transmittion, and reception of the disturbance and hence shall be avoided. In order to achieve such, the surface treatment must be done carefully to allow the correct intensity of the sound to generate at the source and the sound must be uniformly distributed avoiding any dead spots or sound foci. Also, the transmission path must be cautiously designed with sound reflectors and barriers as per the need and seating design of the auditorium to achieve crisp & clear sounds.

II. PROPOSED METHODOLOGY

STEP 1 -UNDERSTANDING OF ACOUSTICAL PHENOMENONS IN ENCLOSURE

In order to understand the correct strategies for designing such space, the first step is to understand the basic criterions and phenomenon attached with the acoustical designing. Some are generally discussed in this section.

A. Reflection

The phenomenon of reflections helps in distributing and amplifying sound generated at the source. In order to determine the behavior of sound reflection, shape of the surface plays an important part. A flat surface is effective in distributing sound if positioned correctly and the surface area is large enough whereas a concave surface causes concentrated reflection instead of dispersion. This causes an abundance of reflection to be heard by the listeners in the focal point. Whispering galleries is an effect generated due to concave surface or parabolic surfaces [1]. To achieve the best sound distribution, researchers have concluded that convex surfaces are the best as they provide a wide spread of reflected sound. Figure 1 shows the sound distribution pattern on various surface shapes.

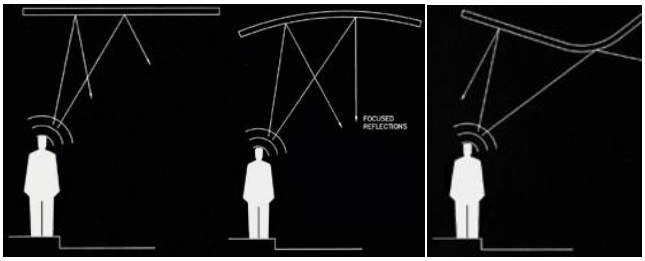

Figure 1: Reflection on various types of surfaces: Flat, concave, convex

B. Refraction

When the direction of propagation of sound wave changes it is said to be refracted from one medium to another, as the velocity of propagation is different in different materials. The amplitude of the sound wave decreases as the density of the medium increases. [2]

C. Diffraction

Sometimes we are able to hear others speaking from the adjacent room around the corners due to diffraction of sound waves around obstacles. Another example of such phenomenon can be understood as,

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if someone is standing outside the auditorium one can still hear the sounds from inside because the sound would spread out from the small opening as if it were a localized sound source and move to another space for proliferation. Figure 2 shows the diffraction pattern along the corners and at the opening in an enclosed space. [2], [3]

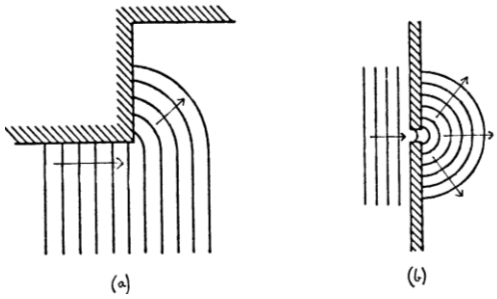

Figure 2: Diffraction along corners and opening

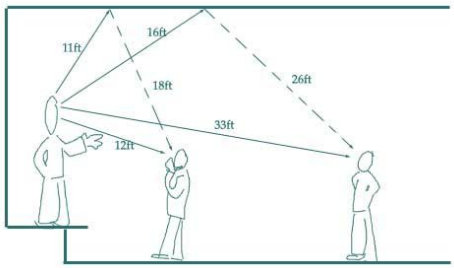

Figure 3: Ray diagram analysis

D. Diffusion

When sound wave hits a complex surface it causes multiple reflections and diffractions which are called as diffusion. Repeated reflections and diffraction within a space result in good diffusion. Diffusion of sound is important in concert halls, classrooms, studios etc to avoid dead spots, places where the sound is weak or cannot be heard clearly [3].

E. Absorption

Absorption of sound is caused when the sound energy is converted to heat energy by the material of the surface where it strikes thereby reducing the intensity of sound [2]. Vibrations in the particles of the absorbing material are caused due to sound waves. The friction caused between the particles due to vibration generates heat and thus sound absorption is accomplished by way of energy to heat conversion. Hence fibrous materials are better sound absorbers [1].

STEP 2- UNDERSTANDING THE ACOUSTICAL DEFECTS

It is important to understand, identify and remedy acoustical defects in order to achieve the best acoustically designed space. Following are some of the defects discussed.

F. Echo

Echoes are formed when the time interval between the two sounds is about 1/17th of a second and the sound reflecting surfaces are located at a distance greater than 15 m [2]. The surface of a material plays an important part. For example, smooth surfaces echo more due to reflection of sound. A preliminary way of identifying if a room will echo or not is by using a ray-diagram analysis. By charting sound wave rays from speaker to listener in key points around the room, one will be able to tell if a room will have a strong echo or not. Figure 3 shows the ray diagram. In order to understand it more clearly, an example is explained in detail pointing out the procedure for the same.

The first step is to plot the direct and reflected rays line-of-sound wave for each listener on the drawing (architectural section) of the auditorium. For example, if there are 2 listners in a room at 12ft and 33ft from the source,the first marking should be direct lines of 12ft & 33 ft towards the listerners. The second step is to mark the reflected rays, which add up to a distance of (11+18 = 29ft) and (16 + 26 = 42 ft). If we find the difference of these numbers, they end up being 17ft for the closer person, and 9 ft for the far away person. A table of sound-path difference is then referrred to find out the permissible ranges of echo (table 1)[4].

Table 1: Sound path difference

S.No.	Sound-path difference	
	Difference	***Sound quality***
1	Less than 28	Excellent for speech
2	28-40	Good for speech
3	40-50	Marginal
4	50-68	Negative
5	Greater than 68	Strong Echoes
6	Less than 28	Excellent for speech
7	28-40	Good for speech

G. Reverberation

Achieving the correct reverberation time becomes very critical in acoustic designing to achieve an optimum tonal balance. Long RT means that the previous sound has not yet decayed and the next sound has arrived. This can lead to difficulty in understanding of speech. Reverberation Time varies for building typologies. For example, cinema hall should have RT of 1.3 sec whereas large convention halls can have it up to 3 sec to allow audibility to the farthest seating people.

H. Sound foci and Dead spot

Sound foci mostly happen with concave surfaces where the reflected sound meets at one point generating a high intensity of sound at that point. This can be eliminated by selecting correct roof profile and sound absorbing material.Dead spots are an outcome of sound foci. They can be eliminated by providing suitable diffusers enabling uniform distribution of sound.

I. Sound shadow

This phenomenon is observed in case of auditorium is designed with large projecting balconies where the sound does not reach under the balcony area. In order to avoid this type of defect, the depth of such projection should not be twice the height of the space under the balcony.

III. RESULT ANALYSIS

This section of the paper discusses the characteristics and feel of a space when designed with righteous acoustic material properties.

•If the sound gives the impression of being performed in a small hall the auditorium is said to have acoustical intimacy. If the initial time-delay gap is shorter than 20 millisec and the direct sound is not too faded, the room will be characterized to be acoustically intimate. [5]

•If an auditorium has a large volume relative to its audience capacity with predominant sound-reflective enclosures, it is said to be 'live'. A live hall has a relatively long RT, giving a long sustained tone.

•A hall which has a relatively small volume compared to its audience capacity with enclosures which are highly sound absorptive, is said to be 'dead' or 'dry'. A dry hall has a short RT and hence when the music is played in it, the sound will be dull.[3]

•When the room has a relatively long RT at the lower frequencies, it is said to have fine acoustical quality of 'warmth' resulting in rich bass of the sound.

•If the RT is adequately controlled, a pleasant 'fullness of tone' will be noticeable in an auditorium space. Excessive fullness of tone makes the sound blurred and unenjoyably.

•If the sound of the different musical instruments is easily distinguishable, and if every sound within a rapid passage is heard separately, the room is said to possess 'clarity'.

•If reflected sound waves approach the listener from every direction in approximately equal amount, the result is 'diffusion'. A relatively long RT and ample wall and surface irregularities promote diffusion, a highly desirable characteristics in auditorium for music.[5]

Acoustic treatment in an auditorium based on NRC values:

After understanding the various phenomenon and characteristics of good acoustically designed auditorium, it is necessary to understand the various critical areas and basic criteria for preliminary designing and material selection.

The most important areas of acoustic treatment in an auditorium are the ceiling, side walls, back walls, on stage and floor. It is very important to optimize the distribution of sound in a space. In order to do so, noise reduction coefficient is the key factor which has been kept in mind while designing. It is the measure of the intensity of sound allowed to pass by a surface after being reflected. NRC ranges from 0 to 1. 0 means no reflection and 1 indicated complete absorption of sound [6]. Conceptually speaking the surfaces near sound sources shout have lower NRC value to allow sound distribution.Following are the basic criterion considered for a preliminary designing and material selection for an auditorium of around 800 capacities:

1. Achieving NRC (noise reduction coefficient) of 0.8 to 0.9 from main auditorium side walls / back wall
2. Achieving NRC of 0.7 to 0.85 for ceiling
3. Achieving NRC of 0.5 to 0.6 for floor
4. Achieving NRC of 0.25 to 0.3 for stage flooring
5. Achieving NRC of 0.7 to 0.8 for stage side / back wall.
6. Achieve overall reverberation time (RT60) for auditorium to be around 1.3 seconds.

In order to achieve the above mentioned NRC values for optimizing the sound quality, different materials are applied to different surfaces. Few of the suggestions for the choice of material are as below:

1. For Auditorium walls:
   a. Side walls are designed in order to both reflect and absorb sound. Up to the door level, the walls must reflect the sound and wall above the door level should absorb the sound. So generally, wooden paneling are great option up to door level as the smooth surfaces are good reflectors of sound. As for above the door level where absorption is required, it should be designed with materials giving NRC value of 0.8-0.9. Examples for same are fabric finished wood wool panels and vertical wooden slats to achieve better absorption rates.
   b. Back walls are also designed to absorb most of the sound in an auditorium. Highly absorbing perforated gypsum panel finish gives an NRC of 0.85-0.9.
   c. The final wall finish can be done with Blazer Cloth or non-woven carpet pasted over Acoustic treatment.
2. Ceiling
   a. Stage ceiling must absorb maximum sound as most of the sounds are generated there only. Best materials for the same can be gypsum perforated boards which are painted black or Absorber gypsum with glass wool backing and final layer in black (painted).
   b. False ceiling in the main seating area of the auditorium shall be a combination of fabric covered plywood, POP based ceiling with surface affixed with glass fiber fabric, or micro perforated plaster board, plaster board absorbing type with glass wool backing.
3. Flooring- Floor should be carpeted to achieve at least 50% absorption.
4. Balcony seating- Wooden vertical slats with gap in between.

IV. CONCLUSION

In order to achieve a good acoustical design for a space or an auditorium various factors plays an important role. Each factor and criterion has to be tandem and one has to find correlation between designing, material, their reverberation times and clear undistorted sound. The goal of this paper was to put forward the important aspects and technical knowhow of an auditorium in acoustical terms. It is important to have a superlative acoustic signature that would minister best cogent transmission of amplified and unamplified sounds.It is observed that as the material applied on any surface becomes fibrous, the absorption level increases and as the surface becomes smooth the sound reflection intensifies. It becomes important to understand and strike the correct balance between material selection and NRC value to achieve an overall required effect in an auditorium. NRC value acts as a measurable physical attribute of sound that must be understood, at least in conceptual way, in order to understand the basic procedures for controlling sound in a space.

REFERENCES

1. Architectural Acoustics, By Marshall Long, pp 247-249
2. Foundations of Engineering Acoustics, 1st edition, by Frank J. Fahy, pp 140-145
3. Architectural Acoustics: Principles and Design, Madan Mehta, James Allison Johnson, Jorge Rocafort, 1999, pp 35-54
4. ffden-2.phys.uaf.edu › 211_fall2002.web.dir › Quinton Harris acoustic.html
5. Auditorium Acoustics and Architectural Design, Michael Barron, 2nd edition, section-1,pp 10-15
6. Architectural Acoustics Illustrated, Michael Ermann, Ch 2, pp 36-38
7. Acoustic Design for an Auditorium Project Using Building Performance Simulation to Enhance Architectural Quality, zhonghua gou, ASA2017 Wellington, 2017
8. The acoustical design of the new lecture auditorium, Faculty of Law, Ain Shams University, Ahmed Elkhateeb Ain Shams Engineering Journal 3(3):219–235 · September 2012

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