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Acoustic Design of an Auditorium – A Case Study

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A B S T R A C T

Acoustics is the science of sound, that is, wave motion in gases, liquids and solids, and the effects of such wave motion. Thus, the scope of acoustics ranges from fundamental physical acoustics to, say, bioacoustics, psychoacoustics and music, and includes technical fields such as transducer technology, sound recording and reproduction, design of theatre es and concert halls, and noise control. The aesthetically designed convention facility is a large air-conditioned place with audio – visual facility. Auditorium can be found in entertainment venues, community halls and theatres, and may be used for rehearsals, presentations performing arts productions, or as a learning space. There are two types of auditorium i.e. continental and multi aisle. The centrally and the most important visual comfort should be taken care under three considerations – sightlines, acoustics and room shaping. The auditorium should have good acoustics so as to cut noise pollution. The reverberation time should be properly calculated. The auditorium is place or room built to enable an audience to hear and watch Performance, lectures, shows at venues such as theatres. An auditorium includes any room intended for Classrooms, Meeting rooms, Theatres, Churches etc. The design of various types of auditoriums has become a complex problem, because in addition to its variation like aesthetics, functional, conflicting, artistic, economical, specious requirements for an auditorium often has to accommodate a large audience with proper privacy and space. This paper focusses on study of acoustics of modern and old auditorium.

Keywords: Acoustics, Intensity, Loudness, Reverberation Time, Seating arrangement

1. Introduction

A symbol for the culture that a city adorns i.e. Auditorium. It not only serves as a platform for showcasing cultural talent but also promotes social interaction. It started as a mere platform, pulpits and forums in early century has been morphed into large auditoriums of today. This gave birth to sound echo, seating and visuals etc. hence these had to be considered for planning of auditorium. Architectural acoustics is the study of how sounds are reflected in rooms. The indirect sound changes the quality of sound we hear in a room. The major factors affecting sound is the amount of sound absorbed by walls, ceiling, floors and also the shape and size of the room. The more sound is absorbed, the fewer sound reflections will lead to less indirect sound. Acoustics is the science with the production, control, transmission, reception and effect of sound or branch of physics concerned with the properties of sound.

2. Objectives of the Work

1. To understand the acoustical terminology and formulation of an auditorium.
2. To study of the shape of an auditorium.
3. To study of the finish materials of an auditorium.
4. To evaluate of the acoustic performance through site measurements.

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3. Various Design Concepts of Auditorium

The auditorium in which we listen to sounds has an important influence on what we hear. It is necessary to identify the principal means currently available for judging the quality of an auditorium. The important criteria for auditorium acoustics are: Provision of a reasonable level of acoustic gain, Provision of reverberation time and Avoid echoes. Other factors which affect acoustics are Shape of auditorium, Dimensions of auditorium, Layout of boundary surface, Seating arrangement, Audience capacity, Provision of clear and loud volume, Aesthetic view (Hearing conditions in any auditorium are considerably affected by purely based on architectural and structural considerations. Many researchers carried out the work on auditorium design. Barron M. (2019), in his research on Developments in Concert Hall Acoustics gave a possible explanation for RTs in halls being shorter than calculations predicted, the importance of early sound for the sense of reverberation (EDT), the nature of directional sensitivity, conditions for echo disturbance.Louena E.B.et al (2020), wrote an article on Acoustic Performance-Based Design: A Brief Overview of the Opportunities and Limits in Current Practice. In his article he explains role of acoustic consultants. Acoustic consultants are rarely involved since early design phases, and acoustic optimization and architectural design tend to be rather independent processes. The application of performance-based design in acoustics seems very promising to optimize design proposals in light of performance feedbacks obtained from acoustic simulation tools.Gou Z. and Lau S. (2019), Conducted performance simulation. They conducted research on Acoustic Design for an Auditorium Project – Using Building Performance Simulation to Enhance Architectural Quality. In their research they report a consultancy work for an auditorium project. The consultancy work considers four important acoustic design issues for auditoria: volume and seats; control of reverberation time (RT); diffusion of sound; elimination of defects.Vehviläinen S. et al (2018), wrote article on the acoustic design of a multipurpose hall. They presented the acoustic design of a 285-seat multipurpose hall at Kangasala Art Centre in Finland. The design goal was to create a multipurpose hall for different kinds of events varying from movies and theatre performances to acoustic and amplified music.Pradeepa C. and Ramachandraiah A. (2020), carried out Acoustical Study of Large Auditorium. They emphasized that an acoustical design of a large auditorium has been discussed. The study has been made through a simulation programme ODEON. Experiments have been conducted in the hall and the resulting RT values have been compared with simulated values which are in fairer agreement.Lu S huai and Yan Xiang (2014), carried out research on the parametric design of concert hall and its acoustics. Their work raised the idea of parametric design of concert hall, sketched out a rough prototype of it and demonstrated its validity by two implementation attempts. Specifically, how to obtain a user-friendly parametric model module that can automatically generate a wide variety of design schemas is the most challenging part.Ottobre R.D. et al (2016), worked on design and construction of six Multiplex cinema halls in the city of Mar del Plata. They concluded that the acoustic insulation performance highlighted that the design of the partitions between rooms, even without indoor air gap and reduced in thickness, comfortably achieved the required index R'w. The background noise level due to HVAC systems also comfortably reached the target.

Topa M.D. et al (2012), carried out experimental acoustic evaluation of an auditorium. They included the acoustical evaluation of an auditorium using an omnidirectional loudspeaker for sound source and linear sweep sine signal for excitation. Hall was evaluated for two source positions. For the evaluation of the reverberation time, a phonometer was also used for one source position.Kamisinski T. (2010), carried out acoustic simulation and experimental studies of theatres and concert halls. A deeper analysis of the acoustic properties of these interiors indicates a number of additional features significant for the architect and acoustician: in halls based on a rectangular plan, a modification of the rear wall is essential; in fan-shaped halls, reflective structures under the ceiling are significant, which compensate for the lack of side reflections.

4. Methodology

To understand the acoustic design of auditorium two auditorium in Ichalkaranji were selected for study. Multiplex, Ichalkaranji is latest and ultramodern cinema theatre and another theatre named Ichalkaranji Auditorium which is old one but modernised. Methodology followed as-

1. By case study or field visit
2. Study of reverberation time.
3. Understanding the Sound Distribution to achieve a good acoustic design.
4. To learn about the Sound Defects in auditorium design.

Field visits conducted-

1. Multiplex, Ichalkaranji
2. Ichalkaranji Auditorium, Ichalkaranji

Following points also considered in methodology for better understanding-

- By getting latest information of acoustic materials
- By studying material properties of latest of acoustic materials.
- By contacting the company Armacell India Private Limited, Pune who is involved in the acoustic designs of auditorium.

4.1 Study Pattern of an Auditorium design

In the acoustic study following pattern followed -

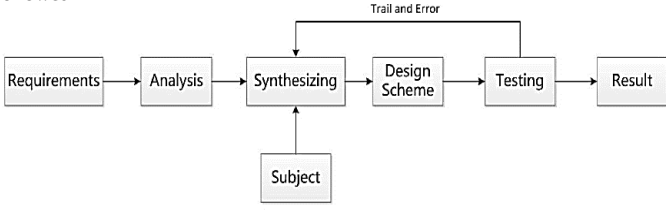

Fig 1: Study Pattern of an Auditorium design

4.2 Understanding the Acoustical terminology

1. **Intensity:** Amount of sound energy passing normally through unit surface, in unit time.
2. **Loudness:** Degree of sensation to ear depending on the intensity of sound (10 log I/Io dB). Echo: Echoes are heard when time interval between direct sound and reflected sound is more than 1/10th of the sound.
3. **Reverberation:** The persistence of sound due to multiple reflections, even after the source of sound is cut off is called reverberation.
4. **Reverberation Time:** The time taken to reduce intensity of sound by millionth of its original value. It is calculated by Sabine's formula.

4.3 Understanding the Formulation of an auditorium

1. **Focusing of walls:** Curved surfaces on the wall or ceilings focusing sound at a particular point causing uneven distribution of sound.
2. **Echelon effect:** Regular succession of echoes occur when sound is reflected from equally spaced reflecting surfaces like stairs or railings.
3. **Resonance:** When frequency of sound matches the natural frequency of window panes, doors, etc., they start vibrating with maximum amplitude causing damage.
4. **Seating arrangement:** Speaker or sound source should be at focus of parabolic reflecting surface. Seats should be arranged such that they are perpendicular to the direction of sound. Seats should be gradually elevated.
5. **Balconies and position of windows:** The balconies should have shallow depths and high openings. They should have railing bars instead of walls.

5. Field Visits Conducted

5.1 Modern Cineplex

In Modern Cineplex, management tried to make it logistically viable for nearby areas and this was the only best option for accessibility for all location and the most unique aspect is it always tends to nave a lively atmosphere. Every weekend anybody can witness events and activities.

Modern Cineplex is first of its kind in Kolhapur, this is the first three screen multiplex or the city with modern and hi-tech technologies like Dolby Atmos sound technology for use first time in western Maharashtra. Modern Multiplex came up with pushback seating capacities along with Recliner seats with 3 D Screens. R and S Pulz Speak-ers. 2K technology projector, with a seating capacity of 795 seats all together. Cineplex management enhanced concession menu with on -seat ordering facilities just tor the convenience to the customer.

Fig 1: view of Cineplex from screen side at Modern Multiplex

Fig 2: Acoustic, Heat and sound insulation material used at Modern Multiplex

5.2 Ichalkaranji Auditorium

Ichalkaranji Auditorium is one of the top Auditoriums in Ichalkaranji. Ichalkaranji Auditorium is the unique theatre in western Maharashtra. Seating capacity for 1200 persons. Fully air-conditioned theatre. This is the only air-conditioned theatre in south-west Maharashtra. It can be compared with the "Kalidas Theatre" in Nashik. The plans where prepared by Kirloskar consultants, Pune.

Fig 3: Comfortable chairs at Auditorium

6. Observations and Discussion

Comparative analysis of Multiplex & Auditorium is given in Table 1.

Table 1 Comparative analysis of Multiplex & Auditorium

Sr. No	Parameter	Multiplex	Auditorium
1.	Dimensions	58 ft x 110 ft	90 ft x 160 ft with Gallery
2.	Capacity	1. 381+20=401[silver screen] 2. 225+90=315[silver screen] 3. 162[normal screen]	1. For 1200 People [normal screen]
3.	Sound system	Dolby Atmos	Dolby Atmos
4.	Sound Absorbing Material Used	1. Ceiling- Framing plywood, foam, black cotton cloth 2. Wall- Cavity walls filled with sand, pop, glass wool, framing plywood, foam, black cotton cloth 3. Floor- Covered with carpet 4. Door- Glass wool 5. Chair- Foam	1. External wall- Perforated wall 2. Internal wall- Wooden acoustic panels 3. Ceiling- Wooden acoustic panels 4. Wall- Normal wall 5. Floor- Cement-tiles 6. Door- Thick wooden door 7. Chair- Husk
5.	Openings	1. Doors, with film room window	2. Stage entrances and 4 Doors
6.	Drawbacks	No drawbacks	1. Less effective sound proofing of auditorium walls. 2. Audio-visual issues form balcony No sound absorbing flooring
7.	Shape of auditorium	Rectangular	Rectangular
8.	Aesthetic view	Modern	Old

6.1 Absorption coefficient

The coefficient of absorption of a material is defined as the ratio of the sound energy absorbed by the surface to that of the total sound energy

6.2 Absorption coefficient = Sound energy absorbed by surface (Ia)/ total sound energy incident on the surface(I)

Unit of absorption is OWU (Open Window Unit)

Sound waves incident on open window are totally transmitted, hence it is called perfect absorber. Hence, absorption coefficient is the ratio of sound energy absorbed by the surface to the sound energy absorbed by open window of same area
Carpet-0.15 to 0.30, Ordinary chair-0.17, Human body-0.43 to 0.47, Open window-1

6.3 Working of sound absorbing materials of an auditorium:

Absorbent materials are usually elastic, not very dense and permeable. They are formed mostly by air. These are soft or fibrous materials containing fine channels interconnected with each other. They can absorb acoustic energy through two mechanisms: When they are soft materials, they absorb due to the deformation that occurs when the sound wave hits them. When they are porous materials, they absorb by the vibration of the air contained in its pores, which loses energy by friction against their edges. Table 2 shows sound absorbing materials used at both auditorium

Table 2 Sound absorbing materials used at both auditorium

Sr. no.	Sound absorbing materials	Sr. no.	Sound absorbing materials
1	Wood	12	Acoustic plasters
2	Glass wool	13	Acoustic tiles
3	Foam	14	Strawboard
4	Acoustic fiberglass	15	Pulp boards
5	Acoustic cotton	16	Compressed fiberboards
6	Acoustic foam	17	Compressed wood particle boards
7	Acoustic partitions	18	Perforated plywood
8	Hanging baffles	19	Wood wool board
9	Water resistant panels	20	Quilts
10	Echo absorber	21	Mats
11	Wooden panels	22	Human

7. Conclusion

The main acoustic phenomenon involved in auditorium planning is: acoustic absorption. A physical explanation of it has been done and the main points for their practical application have been summarized through comparative study of two auditoriums. For the improvement of the acoustic quality of a room, working on its internal surface materials and utilities is needed to control the sound absorption (avoiding excessive reverberation) and along with it, the construction of auditorium also plays important role ensuring good quality sound transmission.

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