MODULE :03

ACOUSTICS

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Outlines:

- Acoustics design of a hall (Design of an auditorium)
- Factors affecting acoustics design of a hall or buildings

Acoustics design of a hall (Design of an auditorium)

- The sound from the source should be of adequate intensity.
- The sound should spread evenly and heard loud in any part of the hall.
- The sound of speech or music should be clear and words or musical notes must be distinctly audible.
- The structure of the wall, ceiling and floor should be designed for uniform focusing of sound through the entire hall.
- Any undesired or extraneous noise must be reduced so that it will not interfere with normal hearing of speech.
- The optional level of reverberation and echo should be measured and considered during the design of the hall.

Factors affecting acoustics design of a hall or buildings

There are several factors that determine the acoustical quality of a hall. We discuss here six major factors that are to be considered in the acoustic design of a hall.

(*i*) **Selection of Site:** A proper site with quite surroundings is to be selected for an auditorium. It should be away from the busy high-way vehicular traffic, rail traffic, airport or any other noisy location. The orientation of the hall should be such that the external noise is maintained at low level. Otherwise, the vibrations produced by the traffic will be conveyed into the hall through the structures which contribute to the noise in the hall. When air-conditioning is not provided the doors and windows are to be kept open during performance. When air-conditioning is provided, care should be taken to reduce the plant noise and grill noise.

Through an appropriate orientation, layout and structural design, the background noise level in the hall should be kept at around 45 dB.

(*ii*) **Floor Area calculation:** The floor area required for the auditorium may be calculated by multiplying the proposed number of seats by area required per person and then adding the required passageway space and the desired stage area. Generally, 0.6 m^2 to 0.9 m^2 space is required per person.

(*iii*) **Volume calculation:** The hall should be big enough so that sound intensity spreads uniformly over its entire area. Smaller rooms lead to irregular distribution of sound because of formation of standing waves. When the length of the hall is very large in comparison to the longest wavelength of sound, the sound spreads uniformly in the hall.

For a typical auditorium, the ratio of the length to width should be between 1.2 and 1.7 and height to width should be between 0.4 and 0.7 (Fig. 13.23).

Low ceiling restricts the sound to reach the people at the back of the room. In high ceiling rooms, the sound reflected from the ceiling arrives much later than the direct sound from the stage and affects clearness. An average height of 6 m for small halls and 7.5 m for large halls are usually adopted. It is desirable to provide slight increase in the height of ceiling near the center of the hall.

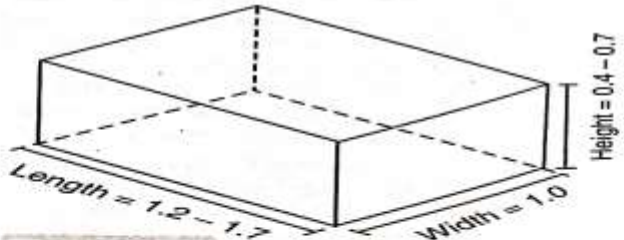

Fig. 13.23: Volume of Auditorium.

The recommended volumes for different types of auditoriums are as follows;

(*a*) Concert halls — 4.0 to 5.5 m^3/person
(*b*) Theatres — 4.0 to 5.0 m^3/person
(*c*) Public lecture halls — 3.5 to 4.5 m^3/person

For Western symphony orchestras, high values of reverberation times are specified; therefore, higher volume per person may be required. The sound level must be around 65 dB for easy and distinct listening conditions. Sound amplification would not be required if the volume of the hall is not more than 1500 m^3.

(iv) **Shape of the Auditoriums Plan:** The shape of the hall plays a very important role in determining its acoustical quality. Its shape should be such that acoustical defects such as echoes flutter, sound foci are avoided and at the same time beneficial sound reflections improve the sound level at remote places. Any shapes such as traditional cross, rectangles, squares, circles, fans, pentagons, hexagons, other polygons and various irregular shapes can be used for auditorium. A rectangular hall with splayed stage walls and a pitched reflecting ceiling is quite satisfactory and easy to construct. Fig. 13.24 shows a few shapes of auditorium.

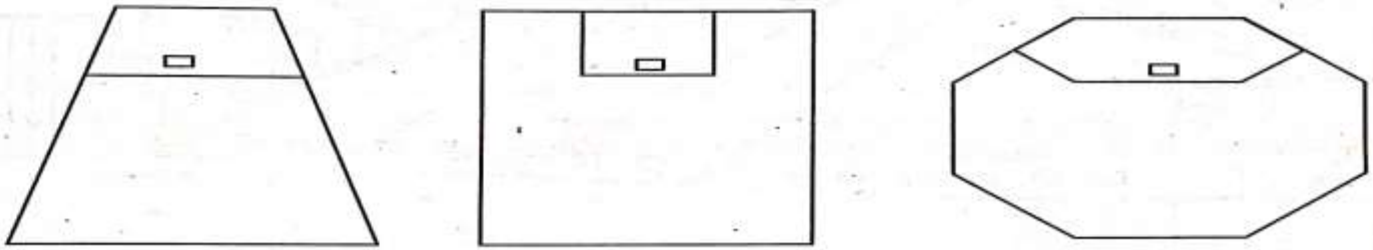

Fig. 13.24:
Shapes of auditorium.

The side walls and ceiling are potentially useful reflecting surfaces and should be carefully designed to maximize their usefulness. The rear walls and floors are potential sources of useless and harmful reflections which are to be avoided. Parallel hard walls create echo problems. Use of splayed side walls greatly reduce the problem and enhance the acoustical quality of the room. In view of this a fan-shaped floor plan (Fig. 13.25) is preferred. The side walls are arranged to have an angle of not more than 100° with the curtain line. The fan shaped plan provides favorable reflection of sound from sides. A concave surface within the hall is not desirable because it focuses sound reflections. Such surface must be broken up with smaller convex surfaces so that sound is diffused in all directions.

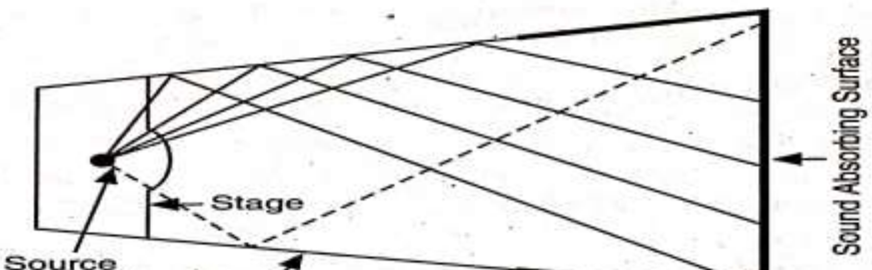

Fig. 13.25:
Fan-shaped floor plan.

The length of the hall should be less than 45 m. When it exceeds 45 m, persons at the rear notice delay between the movements of the actors and the sound coming from them. To avoid excessive length of the hall, a balcony is provided at the far end for additional capacity. When balcony is provided, its projection into the hall should not be more than twice the free height of opening of balcony recess. If balconies are too deep, sound shadow forms and the persons in the seats below the balcony do not receive ceiling reflections (see Fig. 13.26). Suitable sound reflectors should be positioned at appropriate places to get rid of this defect.

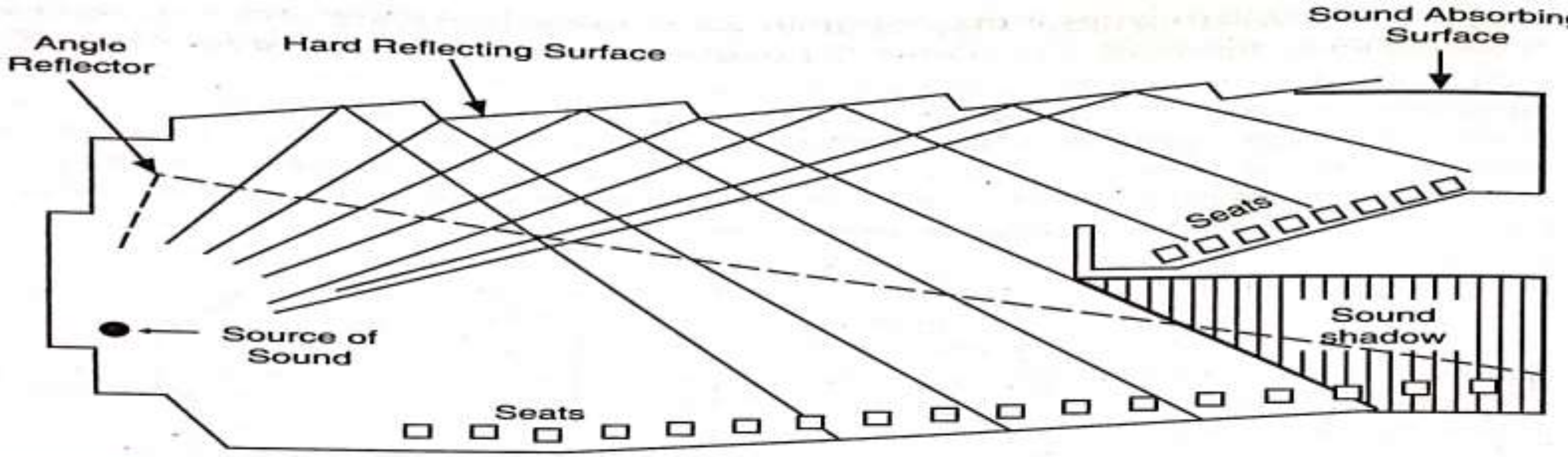

Fig. 13.26:
Ceiling reflections.

(v) **The Auditorium's Internal Geometry:** The angles of the walls, floors, balconies and ceilings significantly affect reflection of sound into areas that may be receiving less direct sound. The acoustically ideal room is one in which all seats receive the same sound level and frequency spectrum. But practically this is not possible due to the attenuation of sound with distance. A careful modeling of the internal angles of the auditorium helps to make the hall acoustically ideal. Fig. 13.27 shows an illustration of auditorium's Internal Geometry.

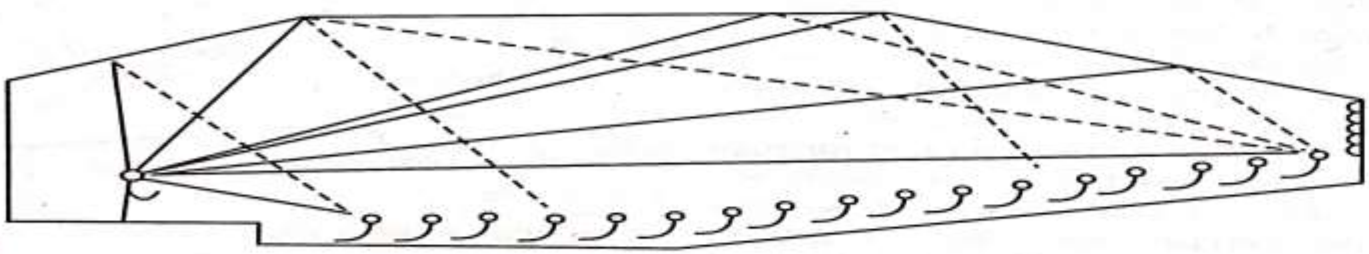

Fig. 13.27:
Auditorium's Internal Geometry.

These days, 3D computer modeling is available for showing the amount of direct and reflected sound for every seat in the auditorium. By adjusting interior wall and ceiling angles the level and concentrations of reflected sound versus direct sound can be determined, as well as the frequency spectrum of that sound.

(vi) **Reverberation Time:** A right reverberation time is essential for a hall to be acoustically good. The reverberation time should not be either too long or too short. A very short reverberation time makes a room 'dead' and a long reverberation time makes speech jumbled. A reverberation time of 0.5 s is acceptable for speeches and lectures, while a reverberation time of 1 to 2 s is satisfactory for concerts. In case of theatres, the optimum value varies with volume. 1.1 to 1.5 s is suitable for small theatres;

whereas for large theatres it may go up to 2.3 s. Table 13.4 shows reverberation time and acoustics; and table 13.5 shows the optimum reverberation time for halls.

Table 13.4: *Reverberation Time and Acoustics*

Reverberation time (seconds)	Acoustics
0.50 to 1.50	Excellent
1.50 to 2.00	Good
2.00 to 3.00	Satisfactory
3.00 to 5.00	Bad
> 5.00	Very bad

Table 13.5: *Optimum Reverberation Time for Halls*

Activity in Hall	Optimum Reverberation Time (in sec)	Audience Factor
Conference halls	1 to 1.5	One-third
Cinema theatre	1.3	Two-thirds
Assembly halls	1 to 1.5	Quorum
Public lecture halls	1.5 to 2	One-third
Music concert halls	1.5 to 2	Full
Churches	1.8 to 3	Two-thirds
Large halls	2 to 3	Full

Every material used in construction has an absorption coefficient and the amount of absorption varies with the frequency of sound. Carpets, drapes and curtains absorb mostly high frequencies while wood, sheetrock panels, and thin plaster on furring strips absorb lower frequencies. This must be considered in RT60 calculation. The amount of absorption in an auditorium should be fairly even throughout the frequency range. For an auditorium to be used mainly for speech needs a shorter RT60 than that mainly used for music. Contemporary music needs a very less RT60 value than orchestral music.

(*vii*) **Seating Arrangement:** The seats should be arranged in concentric arcs of the circles. Sloped floor seating is essential for a large audience to have good visibility and good acoustics. The successive rows of seats have to be raised over the preceding ones, with the result that the floor level raises towards the rear end. The rise in level may be about 8 to 13 cm per row. Further, the seats in each row should be staggered sideways in relation to those in front so that the line of sight of a person in any row is not obstructed by the person sitting in front of him. The back to back distance of chairs in successive rows should be at least 75 cm and this may be increased up to 106 cm for extra comfort.

The angle subtended with the horizontal at the front most observers, by the highest object to be seen on the stage, should not exceed 30°. On this basis, the distance of the first row should be about 4.5 m for movie watching and 3.6 m for theatres. In case of movies, synchronization of sound with lip movements is most essential; and in case of dramas, a person with normal vision should be able to discern facial expressions of the performers. In order to satisfy these conditions, it is recommended that the distance of the farthest seat from the curtain line should not exceed 23 m.

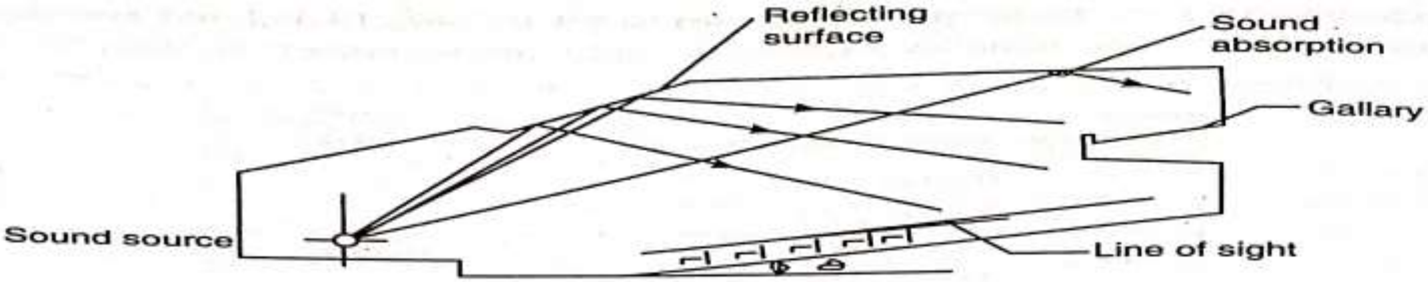

Fig. 13.28:
Seating Arrangement.

The floor of the hall should be inclined at not less than about 8 degrees to the horizontal. With normal spacing of seats this inclination ensures a clearance in sight of about 12 cm from two consecutive rows. This clearance helps in auditory reception also. The seats provide better audiovisual reception if staggered, and in that case the sight clearance may be reduced to about 10 cm. The slope of the balcony floor shall be such that the line of sight is not inclined by more than 40° with the horizontal.

The seats should be so arranged that they face towards the central portion of the stage. This is achieved by arranging them in concentric arcs drawn from a point located behind the curtain at a distance equal to that between the curtain and the rear wall which carries the balcony. Back to back distance between two rows should be 85 cm to 105 cm, and the width of each seat should be 45 cm to 55 cm. The observers in the front row should not be required to tilt the line of sight by 30° form the horizontal to look at the tallest object on the stage. The front row therefore should be placed at not less than 3.5 m from the curtain line. The larger the curtain, the greater the distance from the front row to obtain easily the full horizontal and vertical field of view. Fig. 13.28 shows an illustration of seating arrangement.

(*viii*) **Acoustic Treatment of Interior Surfaces:** The interior surface of the hall should be given utmost attention to make the hall acoustically satisfactory. If the side walls are parallel, they are to be covered with absorbent materials from a length of about 7.5 m from the stage (proscenium) end. As the reflections from the near wall are of no use, the rear wall should be covered with absorbents. In large halls, a false ceiling is usually provided. The false ceiling positioned near the stage should be constructed of reflective material and inclined in a proper way to help reflections of sound from the stage to reach the rear seats in the hall. Concave shaped ceilings in the form of dome should be avoided. The rear portion of the ceiling may be treated with sound absorbing material so that build-up of audience noise is prevented. The floor should be covered with a carpet. Carpet on the floor not only covers a useless reflecting surface but also greatly reduces audience noise.

Acoustical treatment with sound absorbing materials is generally needed on the rear portions of the ceiling and side walls, the rear wall and the balcony. This will eliminate (delayed reflections) echoes. Acoustical materials must be applied in patches, preferably of irregular sizes and distribution for better sound diffusion. All seats must be fully covered (upholstered). Two-thirds of the total seating capacity may be assumed to be present at any time for calculating the sound absorption provided by the occupied seats.

(*ix*) **Sound Reinforcement System:** A sound reinforcement system is the arrangement of microphones, signal processors, amplifiers, and loudspeakers that makes sounds louder. It is also used to improve the sound of the sources on the stage. A sound reinforcement system may be very complex or as simple as a small PA system. It is to be noted that the fitting of a sound system cannot fix all acoustic problems in an auditorium. A good sound engineer has to design the reinforcement system taking building acoustics into account.

Thanks