A SEMINAR REPORT
ON
"ACOUSTICS IN AUDITORIUMS"

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CH-1 INTRODUCTION

ACOUSTICS:

"Acoustics" is a science of sound, which deals with origin, propagation and auditory sensation of sound, and also with design & construction of different building units to set optimum conditions for producing &listening speech, music, etc.

While our forefathers lived in relative tranquility, we are subjected to an incredible increase in the sources of noise and noise intensity both inside & outside our buildings, often with serious and harmful effects. At the same time, it has become an accepted practice to replace the conventionally thick and heavy building construction with thin, light, prefabricated, sometimes even movable building elements. There is also a growing demand for considerably improved hearing conditions. The knowledge of this science is essential for proper functioning of theaters, auditoriums, hospitals, conference halls, etc. also buildings are becoming increasingly mechanized. Use of A.C., work machines, appliances like: vacuum cleaners, typewriters, etc., noise pattern of building has increased, leading to greater need of noise control.

All these elements have contributed to make " ARCHITECTURAL ACCOUSTICS " an essential discipline in the control of interior & exterior environment.

AUDITORIUMS:

An auditorium includes any room intended for listening to music, including theaters, churches, music halls, classrooms, and meeting halls. The design of various types of auditoriums has become a complex problem in contemporary times, because in addition to its various, sometimes conflicting, aesthetics, functional, technical, artistic and economical requirements, an auditorium often has to accommodate an imprecedentedly large audience. These are nowadays being used as multipurpose rooms in almost every field, stating from a small school to official buildings.

Hearing conditions in any auditorium are considerably affected by purely architectural considerations like - shape, dimensions and volume, layout of boundary surfaces, seating arrangements, audience capacity, surface treatment and materials used for interior-decoration. Seeing to the increasing use of auditoriums in present scenario, the study of acoustical concepts in "AUDITORIUM DESIGN" is a necessity.

AIMS AND OBJECTIVES:

1) To study characteristics and behavior of sound in an enclosed space.
2) To study concept of noise and defects of sound in an enclosure.
3) To study the types and functional implification of acoustical materials.
4) To study acoustical tests and measurements.
5) To study the design considerations for planning auditorium w.r.t acoustics.
6) Identifying the spaces in auditoriums, which need acoustical treatment.
7) Study the practical implication of acoustical design through case studies in Jaipur and Ahemadabad.
8) Drawing out the conclusions regarding ideal "Auditorium design" through above relative studies.

SCOPE AND LIMITATIONS:

1) The study deals with basic properties of sound and acoustics.

2) The study deals with auditoriums acoustics only.
3) The study deals with only the properties of acoustical materials and doesn't include their manufacturing process.
4) The study only introduces the basic working of acoustical devices.
5) Inferences derived are w.r.t. the case studies done.

CH-2
SOUND - BASIC THEORY

two definitions of the word sound are:

1) Physically speaking, it is a fluctuation in pressure, a practical displacement in an elastic medium, like air. This is objective sound.
2) Physiologically it is an auditory sensation evoked by the physical fluctuation described above. This is subjective sound. The speed of the sound wave at 200c is about 1,130 ft per sec (344 m per sec).

The purpose of sound control is to provide an acoustically satisfactory environment with in the given space. The objective may be the complete elimination of audible sound, an acceptable noise level, or acoustically correct auditorium or room for speech/music.

INTENSITY AND LOUDNESS:

Intensity of sound is defined as the amount or flow of wave energy crossing per unit time through a unit area taken perpendicular to the direction of propagation. Intensity is proportional to its amplitude square.

Loudness of a sound corresponds to the degree of sensation depending on the intensity of sound and the sensivity of eardrums, and does not increase proportionally with increase of its intensity but more nearly to its logarithm. Phon is the unit of loudness level. If I_0 and I represent the intensities of two sounds of particular frequency, and L and L_0 be their corresponding measures of loudness, we have

$L = k \log_{10} I$

$L_0 = K \log_{10} I_0$

The difference in loudness of the two, technically known as intensity level L between them, is given by:

$L = k \log_{10} I/I_0$

FREQUENCY & PITCH:

Frequency is defined as the number of cycles, which a sounding body makes in each unit time. The unit of frequency is hertz.

The attribute of an auditory sensation which enables us to order sounds on a scale extending from low to high frequency is called pitch. It is a measure of the quality of a sound. It is that characteristic by which a shrill sound can be distinguished from a grave one, even though the two have same intensity. A sound sensation having pitch is called tone. Pure tone is a sound sensation of a single frequency, characterized by its singleness of pitch. Complex tones are sound sensations characterized by more than one frequency.

A normal ear responds to sounds within the audio-frequency range of about 20 to 20,000 Hz. The frequencies most commonly used in acoustical measurements are 125, 250, 500, 1000, 2000& 4000 cps. Additional frequencies are generally used for determining sound attenuation factors of partitions and floors.

WAVELENGTH:

The distance a sound wave travels during each complete cycle of vibration, that is, the distance between the layers of compression is called wavelength.

WAVELENGTH = SPEED OF SOUND/FREQUENCY.

Where wavelength is expressed in feet (or meters), speed of sound in feet per sec (or meters per sec), and frequency in hertz.

OCTAVE BANDS:

For convenience, the audible frequency range is divided into octave bands, each band having range of one octave. The upper frequency limit is therefore twice the value of lower limit. A large % of total speech intelligibility is provided by the fifth, sixth, seventh bands.

VELOCITY OF SOUND:

Sound waves travel at a speed of approx. 1120fps, 763 mph. This speed is the same regardless of pitch or loudness of sound. A sound therefore travels a mile in about 4.7 seconds.

SOUND PRESSURE:

The average variation in atmospheric pressure above or below the static pressure due to a sound wave is called the sound pressure. The unit of SP is the microbar, which is the pressure of 1 dyne/sq cm or approx. one millionth of the normal atmospheric pressure. The standard scale used to measure sound pressure in physical acoustics extends over a wide range, which makes it awkward to deal with. Furthermore, it does not take into account the fact that the ear does not respond equally to the changes of sound pressures at all levels of intensity. For these reasons, sound pressures are measured on a logarithmic scale, called decibel scale.

SOUND POWER:

Sound power or acoustic power of a source is the rate at which it emits sound energy. This power may be; 1) the total power radiated by the source over its entire frequency range; 2) the power radiated between limited frequency range; 3) the power radiated in each of the series of frequency bands.

HUMAN EAR AND HEARING:

The minimum sound pressure level of a sound that is capable of evoking an auditory sensation in the ears of an observer is called the threshold of audibility (0). When the pressure level of the sound is increased, it eventually reaches a level of sound, which stimulates the ear to the point at which discomfort gives way to definite pain; this level of pressure is the threshold of pain (130 db).

INVERSE SQUARE LAW:

Under free field conditions of sound radiation, sound intensity is reduced by 1/4th each time the distance from the source is doubled i.e.:

I1/I2 = D22 /D12

CH-3
NOISE

SPEECH, MUSIC AND NOISE:

Sound may, and usually does, have several frequencies at the same time. The lowest frequency is called the fundamental, and all others are called overtones. Speech sound also contains a fundamental frequency or pitch, which is produced by the vocal chords. This depends on individual. The fundamental frequency of men is 125cycles, and of women is 250 cycles. Noise is defined as unwanted sound. Physically a noise differs from a musical sound in not having a definite frequency or a series of simply related frequencies.

SOURCES OF NOISE:

Sources of noise can be classified as those originating outside and those originating inside a building.

OUTSIDE NOISE:

Motor traffic and airplanes are major sources of noise. The exhaust of big jet can develop 120db or more. Other sources are power lawnmowers, children playing, etc. Even the weather- the whistle of the wind and rain- can be the source of noise.

INSIDE NOISE:

Motor driven appliances are the principle source. These are dishwashers, refrigerators, vacuum cleaners, exhaust, Ac, radios, TV's, etc.

Table-

Acceptable indoor noise levels

Type of building	Noise level range DB
1) radio & t.v. station	25-30
2) music room	30-35
3) hospital & auditorium	35-40
4) apartments, hospitals & homes	35-40
5) conference room, offices & lib.	35-40
6) court room & class room	40-45
7) public offices, banks & stores	45-50
8) restaurants	50-55

BACKGROUND NOISES:

This comes from outdoor sources such as motor vehicles and street traffic, and indoor noises as the various motor driven appliances.

The noise may alternatively be classified as: 1) air born 2) structure born or impact sound

AIR BORN NOISE:

These are the noises which are generated in air & which is transmitted in air directly to ear. Such a sound travels from one part of the building to the other, or from outside of the building to inside by 1) openings like doors, windows, ventilators, key holes, etc. 2) forced vibrations set up in walls, ceilings, etc. Air born noises processes power, continues for long duration, and is confined to places near its origin.

STRUCTURE BORN / IMPACT NOISES:

These are the sound, which originate and progress on the building structure. These are caused by structural vibrations originated due to impact. The common sources of this sound are: footsteps, movement of furniture, dropping of utensils, hammering, drilling, operation of machinery, etc. These are more powerful, propagate over long distances and persists for a very short duration.

The difference between the air born and structure born noise is related to the origin of noise in relation to the receiver room only. In a three story building, washing of cloths on the middle floor will be heard as impact noise for the room below and air born for the above floor.

TRANSMITTION OF NOISE:

Noise is transmitted in the following ways:

1) Through air.
2) By vibrations of structural members
3) Through structural members.

Transmission of noise through air is more common. In this sound waves travel through openings of doors, windows, etc. When the source of sound is very near, sound wave impinge or strich on thin structural member such as partition walls, membrane walls, etc. These structural membranes vibrate and in turn set up secondary sound waves to the other side. The third type of transmission takes place when elastic wave motions, consisting of compression & rarefactions of sound, are transmitted from particle to particle of the structural member, in the form of pressure impulses. Such a mode is prevalent where mechanical vibrations are caused, such as factories, workshops, etc.

TRANSMITTION LOSSES:

When sound is transmitted from the source or the origin to the adjoining room/area, reduction in sound intensity takes place, this is known as transmittion loss. It is numerically equal to the loss in the intensity of sound expressed in decibels.

PSYCOLOGICAL & PHYSIOLOGICAL EFFECTS OF NOISE:

The consequences of excessive noise range from the merely annoying, unpleasant psychological effects to harmful physiological effects

PSYCOLOGICAL EFFECTS:

The psychological effects of noise embrace those conditions where the noise is primarily disturbing, distracting, irritating, unpleasant or annoying. Noise quieting for psychological reasons is recommended when the noise level and reverberation are sufficient to cause annoyance or discomfort or difficulty of communication between persons. Spaces requiring noise quieting for this purpose include offices, restaurants, hospitals, school, shops, corridors of public building, apartments and hotels.

PHYSIOLOGICAL EFFECTS:

Sustained exposure to noise is a contributing factor in impaired hearing, chronic fatigue, neurasthenia, increased blood pressure, and decreased mental and working efficiency. Noise may even induce nervous fatigue. Occupational hearing loss is the most widely recognized type of injury due to exposure to continuous noise.

ANALYSIS OF NOISE CONTROL PROBLEMS:

These are sometimes considered to be composed of three parts:

1) The source,

2) The path,
3) The receiver.

For undesirable sound, unfavorable conditions must be provided for the production, transmittion, and reception of the disturbance. Measures must be taken to suppress the intensity of the noise at the source; an attempt must be made to move the noise as far as possible from the receiver. The effectiveness of the transmittion path must be reduced as much as possible, probably by the use of the barriers which are adequately sound or vibration proof, and the receiver must be protected or made tolerant to the disturbance using masking noise or background music. All these belong to the realm of noise control.

CH - 4

ACOUSTICAL PHENOMENON IN ENCLOSURE & ACOUSTICAL DEFFECTS

ACOUSTICAL PHENOMENON IN AN ENCLOSURE:

Studying the behavior of sound in a room can be simplified if the outwardly traveling layers of compression and rarefaction are replaced by imaginary sound rays perpendicular to the advancing wave front, traveling in straight lines in every direction within the space, quite similar to the beams of light.

SOUND REFLECTION:

Hard, rigid and flat surfaces, such as concrete, brick, stone, plaster or glass, reflect almost all-incident sound energy striking them. Convex reflecting surfaces tend to disperse and concave surfaces tend to concentrate the reflected sound waves in the room.

SOUND ABSORPTION:

Sound absorption is the change of sound energy into some other form; usually heat, in passing through a material or striking a surface. The speed of the traveling sound wave is not affected by absorption. How efficient the sound absorption of a material is at a specified frequency is rated by the sound absorption coefficient. The sound absorption of a surface is measured in sabins, formerly called open-window units.

Sound absorption coefficients and measurement of absorption: The ratio of the sound absorbed by one square meter surface to that absorbed by one square meter of open window is called coefficient of absorption for that surface. The absorption of a surface is the product of the area of the surface multiplied by its absorption coefficient and is expressed in m^2 sabins.

Table-

Sound absorption data for common building materials and furnishings.

Materials	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
Walls						
1) Brick, unglazed	.02	.02	.03	.04	.05	.07
2) Brick, unglazed & painted	.01	.01	.02	.02	.02	.03
3) Glass, heavy	.18	.06	.04	.03	.02	.02
4) Glass, ordinary	.35	.25	.18	.12	.07	.04
5) Plaster on brick	.01	.02	.02	.03	.04	.05
Floors						
1) Concrete or terrazo	.01	.01	.02	.02	.02	.02
2) Marble or glazed tile	.01	.01	.01	.01	.02	.02
3) Wood	.15	.11	.10	.07	.06	.07
4) Carpet, heavy on concrete	.02	.06	.14	.37	.60	.65
5) Carpet heavy on foam rubber	.08	.24	.57	.69	.71	.73
6) Gypsum board, ½ in thick	.15	.10	.05	.04	.07	.09
7) Plaster on	.14	.10	.06	.05	.04	.03

lath						
8) Plywood, 3/8 in	.28	.22	.17	.09	.10	.11
Furnishing						
1) Fabric well upholstered seats	.19	.37	.56	.67	.61	.59
2) Audience seated in upholstered seats	.39	.57	.80	.94	.92	.87

SOUND DIFFUSION:

If the sound pressure is equal in all parts of an auditorium and it is probable that sound waves are traveling in all direction, the sound field is said to be homogeneous, in other words, sound diffusion or sound dispersion prevails in the room. Adequate sound diffusion is necessary acoustical characteristic of certain types of rooms

(Concert halls, radio stations, etc.) Because it promotes a uniform distribution of sound, accentuates the natural qualities of music & speech, and prevents the occurrence of undesirable acoustical defects.

SOUND DIFFRACTION:

Diffraction is the acoustical phenomenon, which causes sound waves to be bent or scattered around such obstacles as corners, columns, walls and beams. This is more pronouncing for low frequency than for high. Experience gives ample evidence that deep galleries cast an acoustical shadow on the audience underneath, causing a noticeable loss in high frequency sound which do not bent around the protruding balcony edge. This condition creates poor hearing conditions under the balcony. Diffraction, however, reduces this acoustical defect, but only in the lower portion of audio frequency range.

REVERBERATION:

When a steady sound is generated in a room, the sound pressure gradually builds up, and it takes some time for it to reach its steady state value. Similarly, when the source of sound has stopped, a noticeable time will elapse before the sound will die away to inaudibility. This prolongation of sound as a result of successive reflections in an enclosed space after the source of sound is turned off is called reverberation.

The importance of reverberation control in acoustical designs of auditoriums has necessitated the introduction of a relevant standard of measure, the reverberation time (RT). This is the time for the sound pressure level in a room to decrease 60 db after the sound is stopped.

The Sabin formula, for the simplified calculation of the reverberation is:

$$RT = 0.05V/a + xV$$

Where, RT = reverberation time, sec

V = room volume, cu ft,

A = total room absorption, sq-ft,

x = air absorption coefficient.

The air absorption coefficient depends on the temperature and humidity of the air and also on the frequency of sound.

Table-

Optimum reverberation time

Type of building	Optimum reverberation Time in secs	Audience factor
1) Cinema theaters	1.3	Two-thirds
2) Churches	1.8-3	Two-thirds
3) Law courts, conference hall	1-1.5	One-third
4) Large halls	2-3	Full
5) Music concerts	1.6-2	Full
6) Assembly hall	1-1.5	quorem
7) Public lecture hall	1.5-2	One-third

ROOM RESONANCE:

An enclosed space with sound reflective interior surfaces undesirably accentuates certain frequencies, called the normal modes of vibration of the room. Rooms have large number of normal modes, depending on their shapes and dimensions. The deleterious effect of the normal modes is particularly noticeable at the lower frequencies, where these modes are unequally distributed. This is known as resonance, which is unwanted for good acoustics.

ACOUSTICAL DEFFECTS:

ECHO:

Sound wave after originating in an enclosure space 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.

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.

REVEBERATION:

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.

CH-5
ACOUSTICAL TESTS AND MEASUREMENTS

WHY MEASURE?

Under many circumstances, the interaction of speakers with the acoustical environment can completely negate the very best electrical engineering. Therefore it becomes obvious, that to fully engineer the sound system the characteristics of space where it will be used must be considered.

WHAT TO MEASURE?

For getting good listening conditions, basic tests are to be done. There are four basic conditions that need to be measured and subjected to control. These are:

1) Quietness
2) Proper reverberation
3) Useful and adequate loudness
4) Proper distribution

QUITENESS:

A sound system is planned in the first place because either the program material needs help in overcoming the noise present, or the distances involved make acoustical gain necessary. Usually system planning must take both these into consideration.

You need to know two things about the noise present: its total sound pressure level (SPL) 7 its distribution by frequency.

PROPER REVEBERATION:

Sound must "hang on" long enough to allow to sound natural, and yet not long enough to allow one word to blur the next word during the normal speech. It is often desirable to have low frequencies to reverberate longer than higher frequencies in the same space.

Here also two factors should be considered: How long it takes sound to decay it the room & how the decay time varies with frequencies.

USEFUL AND ADEQATE LOUDNESS:

Useful & adequate loudness must be achieved if the audience is to here. Failure to achieve useful loudness can be attributed to:

(1) No uniform frequency response,
(2) High distortion of the signal,
(3) Improper polar response characteristics,
(4) Incorrect high /low cutoff frequencies,
(5) Improper equalizations.

PROPER DISTRIBUTION:

The entire audience in a listening area needs to hear clearly. Good listening in one seat must not be at the expense of marginal listening elsewhere. No seat should be located in the dead spot. Graphic level recorder, random noise generator, and tunable 1/3-octave filter have made it possible to quickly & economically search the entire audience area for changes in acoustical level.

SPECIFIC MEASUREMENTS:

Basic environmental and system parameters that can be measured during an acoustical survey are:

1) Ambient noise level

2) Reverberation times of the environment

3) Distribution of sound

(All at 1/3 octave band interval)

At the listeners seat:

1) Frequency response

2) Total harmonic distortion

3) The relative direct to reflected sound differences of amplitude and time.

<u>INSTRUMENTATION FOR ACOUSTICAL TESTS:</u>

A list of equipment comprising a typical acoustical measuring chain can be compiled as:

1) A sound level meter with interchangeable microphones, weighing scales, & recorder output battery operated & capable of meeting ASA standards: It is a very sensitive audio- frequency voltmeter with a calibrated attenuator. It measures sound pressure level using formula:

$$SPL = 20 \log10 \, p/0.0002$$

Where,

Spl is the sound pressure level in db,

p is measured pressure in dynes per sqcm.

Although it gives an accurate reading in decibels, it does not give pressure distribution.

2) A calibrated condenser microphone system: General characteristics of these are:

Ruggedness, low internal noise, sensitivity, wide dynamic range, smooth frequency response, extended frequency response, low distortion. All the qualities do not exist in same microphone. General compromise is to use calibrated ceramic microphone.

3) A constant percentage bandwidth wave analyzer: A wave analyzer, connected to the output of sound level meter, indicates in detail the frequency distribution of any signal. These are of three basic types: constant bandwidth, band rejection filter, and constant percentage bandwidth. Once the frequency is known, wavelength is calculated by:

$$W = V/F$$

Where, W is wavelength in feet,

V is velocity of sound in feet per second,

F is frequency in cycles per second.

4) A high-speed graphic level recorder: In case of reverberation time measurements, automatic recording is mandatory. Servo operated ac-recording voltmeters suitable for acoustic work is called graphic level recorders. This can be operated in either forward or reverse direction, thus allowing a resonance in space to be approached from either direction frequency wise.

5) A calibrated x-y oscilloscope: Amplitude, frequency, and time can be measured with more than adequate accuracy using a combination of sound level meter, a wave analyzer, and a graphic level recorder. With the addition of a calibrated oscilloscope and an oscilloscope camera, signal waveforms can be seen and phenomena recorded that are of too short a duration to be written down accurately by a graphic level recorder.

6) An oscilloscope camera.

7) A sound level calibrator: It is to calibrate the entire chain of instruments this is used. Once the chain of appliances is set, a known acoustical signal must be applied to bring all readings into agreement. Sound level calibrator does this.

8) A tape recorder: In many instances it is desirable to store data for later evaluation or to record transient signals for repetitive analysis. Recorder is used for this purpose.

9) All of the following are the sound sources used:

A random noise generator.

A pink noise filter.

A beat frequency oscillator.

An audio burst keyer.

10) Power amplifiers & speakers: All signal sources require electronic amplification and conversion to acoustical energy. This is done by the amplifiers & speakers.

11) A barometer.

12) A sling psychometre.

CH-6

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 fibreboards, 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 semiplastic 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, glazings, 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 soundblox 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 fiberboards 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.

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AUDITORIUM DESIGN

BREIF HISTORY:

The auditorium, as a place for listening, developed from the classical open-air theaters, but there is little evidence that the Greeks and Romans gave particular consideration to acoustical principles when they selected natural sites and built open-air theaters.

The first reference to architectural acoustics in recorded history is made by Vitruvius (first century B.C.). In his book, he describes sounding waves as being used in certain open air theaters, but no evidence exists that the few vases found near the theaters were used for acoustical purposes.

After the fall of Romans, the only type of auditorium built during the middle ages was church hall. Middle ages is the council room. Middle of sixteenth century, strolling professional actors in England used the round, square, or octagonal courtyards of inns as playhouses. In subsequent centuries, a remarkable number of theaters were built. In seventeenth century, the horseshoe shaped opera house with a large stage area and stage house, and with ring of boxes, or tiers, on top of each other, stacked to the ceiling. But in all these no specific steps taken. The first scientific work was in Athanasius Kircher's, appeared in seventeenth century. Before the twentieth century, only one audi was acoustically treated.

It was not till twentieth century, that professor W.C. Sabin, did his pioneer work on room acoustical design. He first designed the coefficient of sound absorption and arrived at a simple relation between the volume of a room, the amount of sound- absorbing material in it, and its reverberation time.

DESIGN: FROM THE STANDARDS:

OUTLINE OF ACOUSTICAL REQUIREMENTS:

1) There should be adequate loudness in every part of the auditorium particularly the remote seats.
2) The sound energy should be uniformly distributed in the room.
3) The audience and the most efficient presentation of the program by the performers should provide optimum reverberation characteristics in the auditorium to allow the most favorable reception of the program material.
4) The room should be free of such acoustical defects as echoes, long delayed reflections, flutter echoes, sound concentrations, distortion, sound shadow, and room resonance.
5) Noises and vibrations which would interfere with listening of performing should be excluded or reasonably reduced in every part of the room.

ADEQUATE LOUDNESS:

The problem of providing adequate loudness, particularly in medium and large-sized auditoriums, results from the energy losses of the traveling sound waves and from excessive absorption by the audience and room contents. Sound energy losses can be reduced and adequate loudness can be provided in the following ways:

1) The auditorium should be shaped so that the audience is as close to sound source as possible.

2) Sound source should be raised high.
3) The floor where audience is seated should be properly racked. It should not be more than 1in 8.
4) The sound source should be closely and abundantly surrounded with large sound reflective surfaces. Initial time delay gap between direct and first reflective sound should be relatively short, possibly not more than 30 milliseconds.
5) Parallelism between opposite sound reflective boundary surfaces, particularly close to the sound source, should be avoided.

DIFFUSION OF SOUND:

Two important points must be considered in the effort to provide diffusion in a room : the surface irregularities elements, (coffered ceilings, serrated enclosures, protruding boxes sculptured surface decorations, deep window reveals, etc) must be abundantly applied and should be relatively large.

CONTROL OF REVERBERATION:

In the acoustical design of an auditorium, once the optimum RT is at the mid frequency range has been selected and the RT vs frequency relationship below 500 Hz decided upon, the reverberation control consists of establishing the total amount of room absorption to be applied by acoustical finishes, occupants, room contents, etc., in order to produce the selected value of RT. In almost every auditorium the audience provides most of the absorption, about 5 ft^2 sabins per person. Therefore to have good hearing conditions even in audience absence, the seats should be upholstered, with underneath side of them also absorptive. Sound absorbing materials should be all along the boundary surfaces. The acoustical treatment should go first on the rear wall, then on those portions of the sidewalls, which are farthest from the source or along the perimeter of the ceiling.

ELIMINATION OF ROOM ACOUSTICSAL DEFECTS:

1) **Echo**: echo occurs if a minimum interval of 1/25 sec to 1/10 sec elapses between the perception of the direct and reflected sounds originating from the same source. Since the speed of sound is about 344 m/sec, the critical time intervals specified above corresponds to path difference of min. 24 m for speech or 34 m for music between direct and reflected sound. A sound reflective rear wall, opposite the sound source, is a potential echo-producing surface in the auditorium unless it is treated or is under deep balcony.
2) **Flutter echo:** a flutter echo consists of a rapid succession of noticeable small echoes and is observed when a short burst of sound, such as a clap or shot, is produced between parallel surfaces. Elimination of parallelism between opposite reflecting surfaces is one way to avoid flutter echoes.
3) **Sound concentration:** sound concentrations, sometimes referred to as hot spots are caused by sound reflections from concave surfaces. If large concave surfaces cannot be avoided or acoustical treatment is not feasible, these concave surfaces should be laid out in such a manner that they focus in space outside or above the audience area.
4) **Coupled spaces:** if a auditorium is connected to an adjacent reverberant space by means of open doorways, the two rooms will form open spaces. The undesirable effect of coupled spaces can be overcome by adequate acoustical separation between the coupled spaces, by providing approximately the same RT in both spaces or by reducing the RT of both.

Sound shadow: the phenomenon of sound shadow is noticeable under the balcony that protrudes to far into the air space of an auditorium. Such under spaces, with the depth exceeding twice the height, should be avoided