Architectural Acoustic

Prepared By :-
Rushit Patel

What is acoustic?

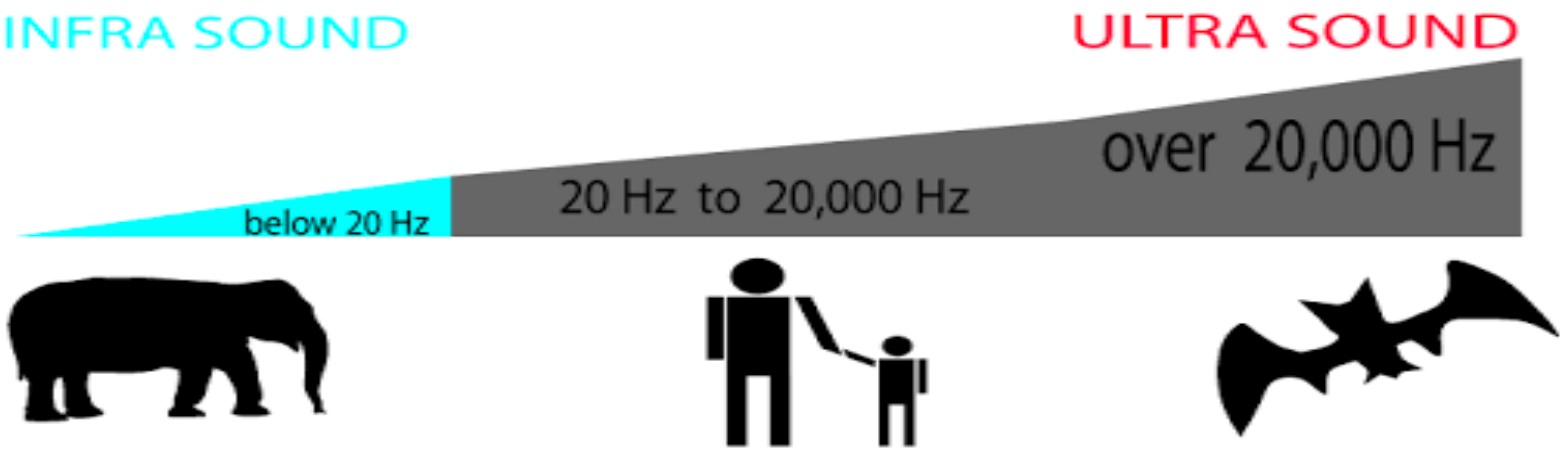
- Acoustic is the science of sound which deals with the properties of sound waves.

- Some of the important applications in the field of engineering are electro-acoustics, design of acoustical instruments and architectural acoustics.

Classification of sound

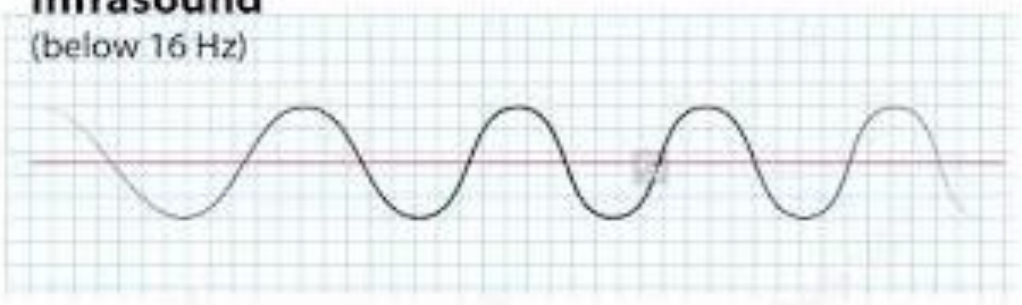
- Sound waves are classified in 3 types.

1. Infrasound (f<20 kHz)
2. Audible sound (20 Hz<f<20 kHz)
3. Ultrasound (f>20 kHz)

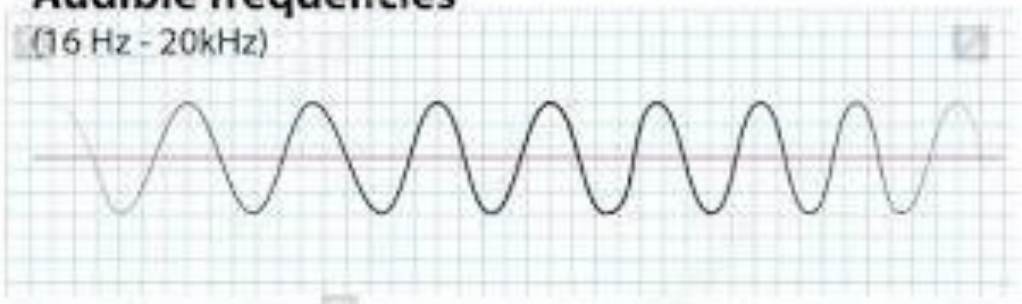


SOUND WAVE

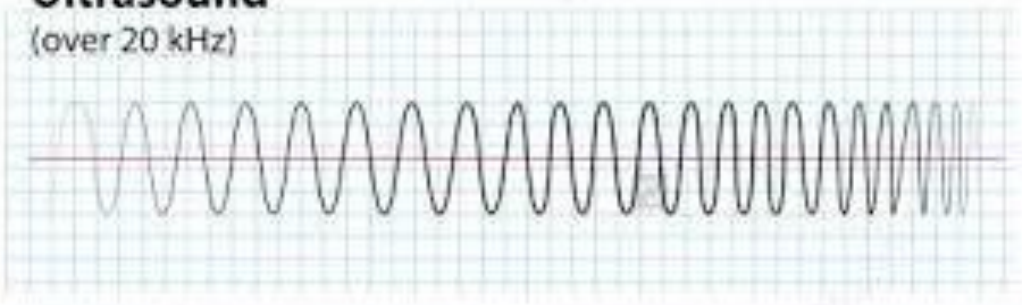
Infrasound
(below 16 Hz)



Audible frequencies
(16 Hz - 20kHz)



Ultrasound
(over 20 kHz)



❖Classification of audible sound

- Audible sound is classified in two types.

(1) **Musical sound :**

- The sound which produces pleasing effect on the ear is called musical sound.
- Example : Sitar, violin, flute, piano, etc.

Properties of musical sound

- The musical sound waveforms are regular in shape.
- they do not undergo a sudden change in amplitude.

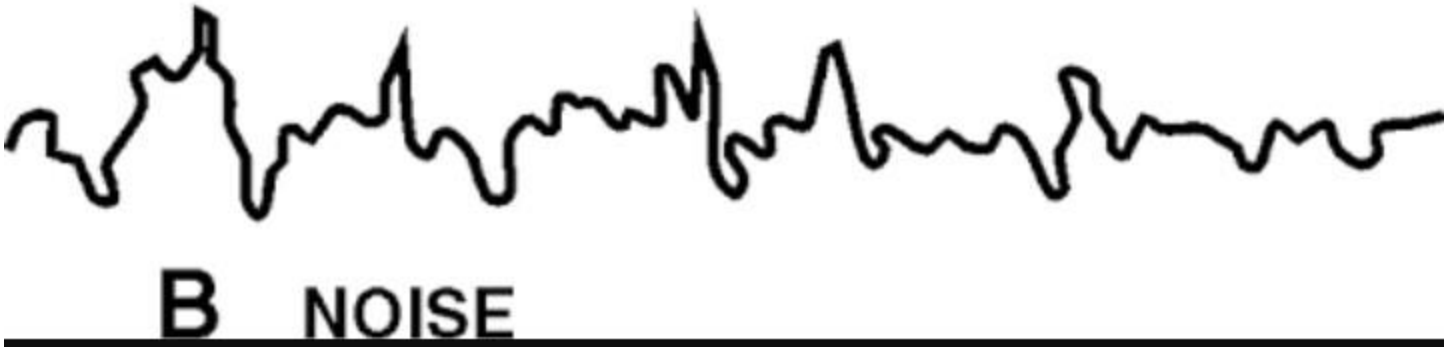
A MUSICAL NOTE

(2) Noise

- The sound that produces a jarring effect on the ear is called nose.
- Example:-Sound of airplane ,road traffic ,crackers ,etc.

Properties of noise

- The noise waveforms are irregular in shape.
- They undergo a sudden change in amplitudes.



❖Characteristics of musical sound

- **The characteristic of musical sound are:**

1) **Pitch-** Related to frequency of sound.
2) **Loudness-** Related to intensity of sound.
3) **Timber-** Related to quality of sound.

❖ INTENSITY

- Intensity I of sound wave at a point is defined as the amount of sound energy Q flowing per unit area in unit time when the surface is held normal to the direction of the propagation of sound wave.
- i.e. $I = Q/At$

$$I = 2\pi^2 f^2 a^2 \rho v$$

Where ;

f= Frequency

a=Amplitude

ρ=Density

v=velocity

<u>UNIT</u>:- W/m²

Intensity Level

- The intensity level of a sound is defined as the logarithmic ratio of intensity I of a sound to the standard intensity I.

$$I_L = \mathbf{10} \log_{10} (I / I_0)$$

❖Absorption coefficient

1. The sound absorption coefficient ‘a’ of a material is defined as the ratio of sound energy absorbed by it to the total sound energy incident on it.

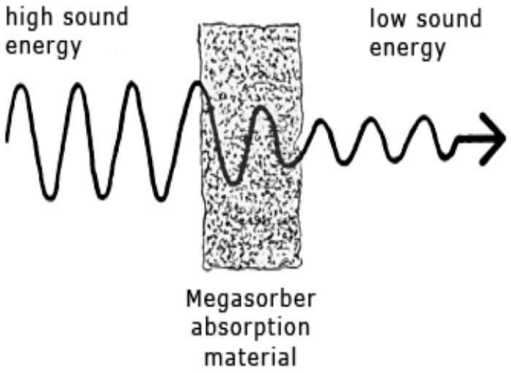
2. Absorption coefficient a=$\frac{\text{Sound energy absorbed by the surface}}{\text{Total sound energy incident on it}}$

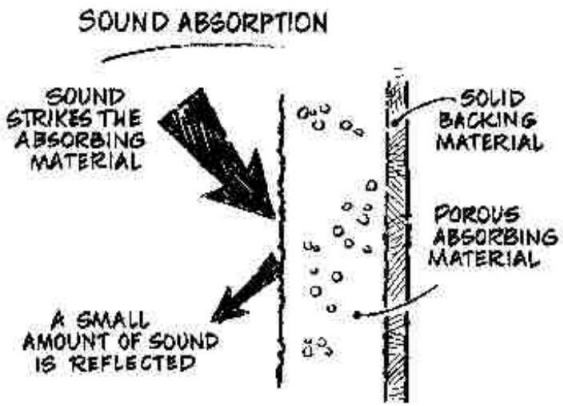
3.

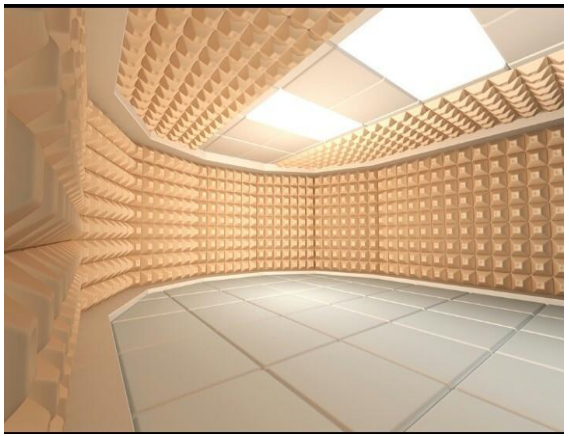
2. It is defined as the reciprocal of the area of the sound absorbing material which absorbs the same amount of sound energy as that of 1 m^2

❖ SOUND ABSORBING MATERIALS

- The special materials used to increase the absorption of sound waves or to reduce the reflection of sound waves in a room or a hall are known as sound absorbing materials.







Sound Absorbing Material Properties :

- It should have high sound absorbing efficiency.
- It should be easily available , cheap, easy to fix, durable, Light in weight, good looking etc.
- It should be water proof and must have good resistance to fire.
- It should be efficient over a wide range of frequencies.
- It should have sufficient structural strength.

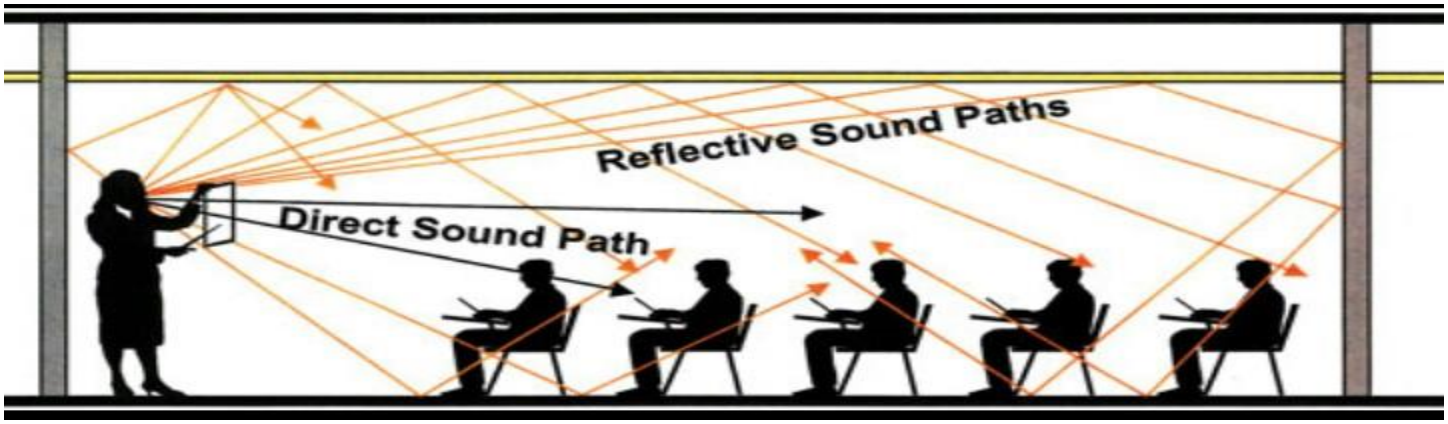
Types of sound Absorbing Materials

- The sound absorbing material are broadly classified into the following four categories.

1. Porous absorbents
2. Cavity resonators
3. Resonant absorbents or panel absorbers
4. Composite absorbents.

Reverberation

- This prolongation of sound in a hall even though the source of sound is cut off is called ***reverberation.***
- A sound produced in a hall undergoes multiple reflections from the walls, floor and ceiling before it becomes inaudible.



Reverberation Time

- **The time taken by the sound in a room to fall from its average intensity to inaudibility level is called the reverberation time of the room.**
- **Reverberation time is defined as the time during which the sound energy density falls from its steady state.**

Sabine's Formula

•Subine defined the reverberation time as the time taken by the sound intensity to fall to one millionth of its original intensity after the source stopped emitting sound.

$$T = \frac{0.161V}{\sum_{1}^{N} \alpha_n \ S_n}$$

or $$T = \frac{0.161V}{\alpha_1 S_1 + \alpha_2 S_2 + \alpha_3 S_3 + ... + \alpha_n \ S_n}$$

Factors Affecting Acoustics of Buildings

(1) (1) Reverberation Time

- If a hall is to be acoustically satisfactory, it is essential that it should have the right reverberation time.
- The reverberation time should be neither too long nor too short.
- A very short reverberation time makes a room `*dead'*. On the other hand, a long reverberation time renders speech *unintelligible*.
- The optimum value for reverberation time depends on the purpose for which a hall is designed.

Remedies

- The reverberation time can be controlled by the suitable choice of building materials and furnishing materials.
- Since open windows allow the sound energy to flow out of the hall, there should be a limited number of windows. They may be opened or closed to obtain optimum reverberation time.
- In order to compensate for an increase in the reverberation time due to an unexpected decrease in audience strength, upholstered seats are to be provided in the hall.

(2) Loudness

- Sufficient loudness at every point in the hall is an important factor for satisfactory hearing.

- Excessive absorption in the hall or lack of reflecting surfaces near the sound source may lead to decrease in the loudness of the sound.

Remedies

- A hard reflecting surface positioned near the sound source improve the loudness.
- Low ceilings are also of help in reflecting the sound energy towards the audience.
- Adjusting the absorptive material in the hall will improve the situation.
- When the hall is large and audience more, loud speakers are to be installed to obtain the desired level of loudness.

(3) Focussing

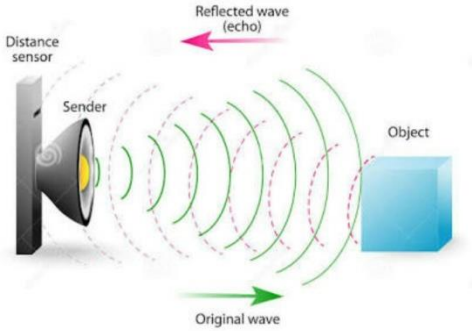
- Reflecting concave surfaces cause concentration of reflected sound, creating a sound of larger intensity at the focal point. These spots are known as *sound foci*.
- Such concentrations of sound intensity at some points lead to deficiency of reflected sound at other points.
- The spots of sound deficiency are known as *dead spots*. The sound intensity will be low at dead spots and inadequate hearing.
- Further, if there are highly reflecting parallel surfaces in the hall, the reflected and direct sound waves may form standing waves which leads to uneven distribution of sound in the hall.

Remedies

- The sound foci and dead spots may be eliminated if curvilinear interiors are avoided. If such surfaces are present, they should be covered by highly absorptive materials.
- Suitable sound diffusers are to be installed in the hall to cause even distribution of sound in the hall.
- A paraboloidal reflecting surface arranged with the speaker at its focus is helpful in directing a uniform reflected beam of sound in the hall.

(4) Echo

- When the walls of the hall are parallel, hard and separated by about 34m distance, echoes are formed. Curved smooth surfaces of walls also produce echoes.



Remedies

- This defect is avoided by selecting proper shape for the auditorium. Use of splayed side walls instead of parallel walls greatly reduces the problem and enhance the acoustical quality of the hall.
- Echoes may be avoided by covering the opposite walls and high ceiling with absorptive material.

5) Echelon effect

- **If a hall has a flight of steps, with equal width, the sound waves reflected from them will consist of echoes with regular phase difference. These echoes combine to produce a musical note which will be heard along with the direct sound. This is called *echelon effect*. It makes the original sound unintelligible or confusing.**

Remedies

- **It may be remedied by having steps of unequal width.**
- **The steps may be covered with proper sound absorbing materials, for example with a carpet.**

(6) Resonance

- **Sound waves are capable of setting physical vibration in surrounding objects, such as window panes, walls, enclosed air etc. The vibrating objects in turn produce sound waves. The frequency of the forced vibration may match some frequency of the sound produced and hence result in *resonance phenomenon*. Due to the resonance, certain tones of the original music may get reinforced that may result in distortion of the original sound.**

Remedies

- **The vibrations of bodies may be suitably damped to eliminate resonance due to them by proper maintenance and selection.**

(7) Noise

- Noise is unwanted sound which masks the satisfactory hearing of speech and music.
- There are mainly three types of noises that are to be minimized.
- They are (i) air-borne noise,
  (ii) structure-borne noise and
  (iii) internal noise.

(i) Air-Borne Noise

- **The noise that comes into building through air from distant sources is called *air-borne noise*.**
- **A part of it directly enters the hall through the open windows, doors or other openings while another part enters by transmission through walls and floors.**

Remedies

- **The building may be located on quite sites away from heavy traffic, market places, railway stations, airports etc.**
- **They may be shaded from noise by interposing a buffer zone of trees, gardens etc.**

(ii) Structure-Borne Noise

- **The noise which comes from impact sources on the structural extents of the building is known- as the *structure-borne noise*. It is directly transmitted to the building by vibrations in the structure. The common sources of this type of noise are foot-steps, moving of furniture, operating machinery etc.**

Remedies

- **The problem due to machinery and domestic appliances can be overcome by placing vibration isolators between machines and their supports.**
- **Cavity walls, compound walls may be used to increase the noise transmission loss.**

(iii) Internal Noise

- *Internal noise* is the noise produced in the hall or office etc.
- They are produced by air conditioners, movement of people etc.

Remedies

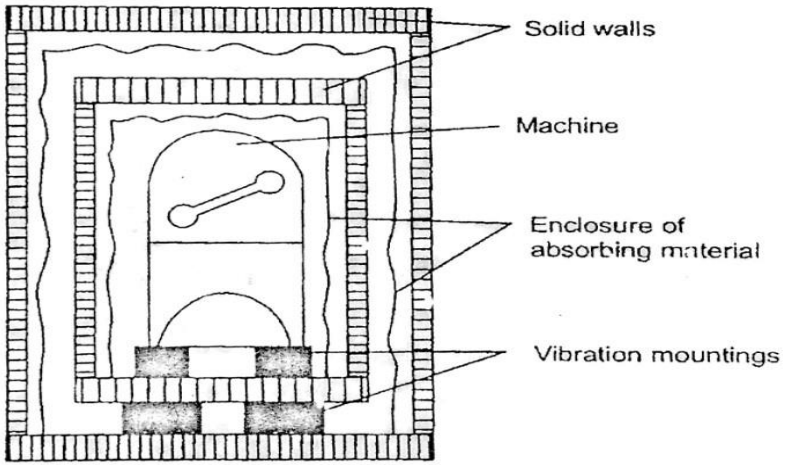
- The walls, floors and ceilings may be provided with enough sound absorbing materials.
- The gadgets or machinery should be placed on sound absorbent material.

❖ NOISE CONTROL MACHINE

- Noise control may be effected by one or more of the following methods.

1. Sound absorbent materials may be installed near noise source.
2. The source of sound may be redesighed for quieter operation.
3. The source may be isolated with sound reducing housings.
4. Workers may use ear muffs and ear plugs.

ILLUSTRATION OF NOISE CONTROL IN A MACHINE :



- The machine is made to rest on soft vibration mounts kept beneath the machine.
- It is enclosed by an absorbing material.

Thank you