(6) ACOUSTICS. (1)

Acoustics

It is the branch of science which deals with the study of sound.

Reverberation.

→ when sound is produced in a hall, the listener hears a series of reflected sound in addition to direct sound. So sound remains in the listener's ear for a long time, even after the source stops the production of sound.

→ The persistance of sound even after the source of sound is stopped is called Reverberation.

Reasons for Reverberations :-

a) Intensity of sound decreases exponentially, not suddenly.

b) Multiple reflection from different materials.

c) Sounds reaching at a particular point are not in phase, it causes constructive and Destructive interference.

Reverberation Time.

→ It is the time taken for a sound to decrease in intensity to 10^{-6} of it's initial intensity, after the source stopped the production of sound.

→ It is the time taken for the intensity of sound to decrease by 60dB, after the source stopped the production of sound.

→ It is represented by 'T'

→ It is given by $T = \frac{0.163V}{A}$ secs.

Absorption coefficient :-

→ It is the ratio of sound energy incident on a surface to the sound energy absorbed by that surface.

→ unit of absorption is Sabine.

→ ~~One~~ "Sabine" is the sound energy absorbed by one square foot of an open window.

→ For a surface having area "S", absorption coefficient "α", the equivalent absorbing Area "A" is given by

$$\boxed{A = \alpha S}.$$

→ If a hall contains different materials having surface Area $S_1, S_2, S_3 \ldots$ etc having different absorption coefficients $\alpha_1, \alpha_2, \alpha_3 \ldots$ etc. Then the average value of absorption coefficient is given by,

$$\alpha = \frac{\alpha_1 S_1 + \alpha_2 S_2 + \alpha_3 S_3 + \cdots}{S_1 + S_2 + S_3 + \cdots}$$

$$= \frac{\Sigma \alpha_1 S_1}{\Sigma S_1}$$

$\Sigma \alpha_1 S_1 \rightarrow A$, total absorbed energy

$\Sigma S_1 \rightarrow S$, Total surface Area.

Imp

SABINE'S FORMULA

→ The expression for reverberation time is derived on the basis of some assumptions. They are.

(a) The distribution of sound energy and the intensity of sound is uniform inside an enclosure.

(b) Dissipation of energy in air is negligible.

(c) Absorption coefficient of materials are independent of intensity of sound.

(d) The phenomenon of interference and formation of stationary waves are supposed to be absent.

(e) Rate of emission of sound energy is constant.

[H]

→ Consider a hall of volume V. Source emits sound and it is reflected from different objects.

→ After a particular time, an equilibrium condition is attained.

→ At t=0, the source stopped production of sound. E_0 be the intensity at that time.

→ After 't' secs 'E' be the energy. Energy decreases exponentially.

→ $E = E_0 e^{-AVt/4V}$

A → Total energy absorbed
V → velocity of sound
V → volume of hall
t → Time.

→ Intensity of sound is proportional to Energy, for a given frequency. Let I_0 be the intial intensity and I be the intensity after "t secs"

$$I = I_0 e^{-AVt/4V}$$

$$\frac{I}{I_0} = e^{-AVt/4V}$$

At time $t = T$ (Reverberation Time), $\frac{I}{I_0} = 10^{-6}$

$$10^{-6} = e^{-AvT/4V}$$

ie; $$10^{6} = e^{AvT/4V}$$

$$\log_e 10^6 = AvT/4V$$

$$\frac{AvT}{4V} = 2.303 \log 10^6 = 2.303 \times 6 \log 10 = 2.303 \times 6 \times 1$$

$$\frac{AvT}{4V} = 2.303 \times 6 \times 1$$

$$T = \frac{2.303 \times 6 \times 4V}{Av}$$

But $v = 340 m/s$, velocity of sound, Then

$$\boxed{T = \frac{0.163V}{A} \text{ secs.}}$$

This is sabine's formula for reverberation time.

Imp **Significance of Reverberation Time:**

→ The value should not be too small or too large, It should be an optimum value.

→ For a lecture hall value of reverberation time should be small. Then only the decay of notes takes

for better clarity.

→ For a musical hall the value will not be too high or too low. It should be much greater than a lecture hall.

→ If it is too small for a musical hall continuity between successive notes will not be obtained.

→ If it is too high for a musical hall overlapping between notes takes place.

→ for a hall of volume 10000 cubic feet, the reverberation time is 1.03secs for a speech.

Loudness & unit of Loudness.

→ Loudness is the characteristic property of sound by which we can distinguish two sounds of same frequency.

→ Loudness is proportional to the logarithamic value of intensity of sound.

→ If I_0 & I be the intensity of two sounds of same frequency. Their Loudness are L_0 & L respectively. Then.

$$L_1 \propto \log_{10} I_1$$

ie, $L_1 = K \log_{10} I_1$ and $L_0 = K \log_{10} I_0$

Difference in Loudness $L = L_1 - L_0 = K \log_{10} \frac{I_1}{I_0}$

$$\boxed{L = K \log_{10}\left(\frac{I_1}{I_0}\right)}$$

where $I_0 = 10^{-12}$ watts/m^2.

Bel

Unit of Loudness is Bel.

$$L = K \log_{10}\left(\frac{I_1}{I_0}\right)$$

When $K = 1$

$$\boxed{L = \log_{10}\left(\frac{I_1}{I_0}\right) \text{ Bel.}}$$

Decibel (dB)

Bel is a large unit. $1/10^{th}$ of Bel is called decibel.

$$\boxed{L = 10 \log_{10}\left(\frac{I_1}{I_0}\right) \text{ dB}}$$

(For more, Refer Text

PHON.

→ In the case of Bel or dB main assumption is that if intensity of sound is same Loudness is also same for all frequencies.

→ But limits of audibility varies between 20Hz-20kHz

→ So if even if intensity is same, Loudness will be different for different frequencies.

→ Based on this a new unit is introduced called "phon".

Imp Determination of Absorption Coefficient:-

→ For determination of absorption coefficient reverberation chamber is used.

→ It is an enclosure which contains large number of microphones at the inner surface.

→ The surfaces are highly reflecting.

→ At first using the empty reverberation chamber, reverberation time T_1 is noted.

→ Then the material whose absorbtion coeficient is determined is placed inside the chamber. Source produces sound. ~~and~~ Reverberation time T_2 is noted.

$$T_1 = 0.163\frac{V}{A}, \quad \frac{1}{T_1} = \frac{A}{0.163V}$$

$$T_2 = \frac{0.163V}{A+\alpha S}, \quad \frac{1}{T_2} = \frac{A+\alpha S}{0.163V}$$

$$\frac{1}{T_2} - \frac{1}{T_1} = \frac{\alpha S}{0.163V}$$

$$\boxed{\alpha = \frac{0.163V}{S}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)}$$

Factors Affecting Acoustics of Buildings & their Remedy.

(Refer Text, Imp Qns & Answers from this area
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1. Reverberation:-

(please refer the explanation of Reverberation)

2. Reflection of echo:-

Echo is produced when the time interval between direct sound and Reflected sound is 1/10 sec.

→ thick contains, walls coated with sound-absorbing materials.

3. Focussing of sound waves.

— If the hall contains spherical, concave like areas sound signals are focussed at certain points after reflection from these surfaces. So Intensity will be maximum at ~~certain~~ same points and minimum at other points.

4. Adequate Loudness:—

5. Resonance effect:—

Some times the hall contains Hollows, and cavities etc. The air molecules present at this cavities @ vibrates with respect to the forced vibration by sound signal. This produce resonance and causes unpleasantness.

6. Echelon effect:—

It is the unpleasantness from regularly spaced structures in the room like spacing of stairs etc. This produce an unpleasantness in the form of Musical Note.

7. Extraneous noise & sound insulation:—

unwanted sound is called Noise.

(a) Air born noise (b) structural Noise

(c) In born Noise.

[For Remedies Refer Text]