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B.Sc (Part-I) Hons
Paper-I

Sabine's formula for reverberation time.

The Sound produced by a speaker in a room or a hall suffers successive reflections from the walls, the ceiling and the flooring of the hall so that in addition to the direct sound a series of sound waves pass the listner's ear producing a sort of rolling sound. This gives the listner the impression of prolongation or persistance of sound for some time after the original sound has ceased. This is called reverberation.

Causes of Reverberation!— (i) The intensity of sound produced by the speaker decays exponentially and takes a long time to fall to zero value. The time depends upon the absorption of sound, being large if the absorption is small. Hence the presence of absorbing materials like open windows, audience, curtain etc. reduces reverberation.

(II) The reverberation is called by reflection of sound waves from the walls, ceiling and floor of the hall because the sound persists for some time due to reflection.

(III) As all the sound waves reaching a particular point in the hall are not in phase, these produce interference, thereby causing reinforcement or destruction of sound waves as the case may be. This gives rolling effect to sound waves.

Reverberation time:— The time interval is taken by a sustained or continuous sound to fall in intensity to one millionth of its original value i.e. fall by 60 decibels in loudness is called reverberation time.

The relation connecting the reverberation time with the volume of the hall, the area, and absorption coefficient of surface is known as Sabine's formula.

The absorption coefficient for the material of a surface is defined as the ratio of the sound energy absorbed by the surface of the sound energy absorb by an equal area of a perfect absorber such as an open window. The standard unit of absorption is called a sabine and is the sound energy absorbed by one square foot an open window. Hence the effective absorbing area A for a surface having a total area S and absorption coefficient α is given by

$$A = \alpha S$$

If $\alpha_1, \alpha_2, \alpha_3, \alpha_4$, ----etc. are the absorption coefficient at each reflection of the surfaces having total area S_1, S_2, S_3, ----etc. in a room, then the average value of the absorption coefficient α is

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

or, $\alpha = \frac{\Sigma \alpha_i S_i}{S}$, where S is the total area of all the surface.

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Let I be the average intensity at any instant and ∂I the fall in intensity due to absorption in a small interval of time ∂t, then

$$\partial I = -\alpha n I \partial t \quad \text{--- (1)}$$

Where α is the mean absorption coefficient of all absorption surface in the room and n the number of reflections of sound waves per second.

By statistical method Jaeger showed that sound travels an average distance $\frac{4V}{S}$ between two successive reflections where V is the volume of the hall and S the total area of the reflecting surface. If v is the velocity of sound, then

The time between to successive reflection $= \frac{4V}{Sv}$

∴ Average number of reflections per second $n = \frac{Sv}{4V}$ --- (2)

Substituting n in equation (1), we get

$$\partial I = -\alpha \frac{Sv}{4V} I \partial t$$

or $$\frac{\partial I}{\partial t} = -\alpha \frac{Sv}{4V} I$$

in the limiting case

$$\frac{\partial I}{I} = -\alpha \frac{Sv}{4V} \partial t$$

If I_0 is the steady value of the intensity at the instant the source is cut off and I_t its value at a time t latter then

$$\int_{I_0}^{I_t} \frac{dI}{I} = -\int_0^t \frac{\alpha Sv}{4V} dt$$

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or, $\log_e\left(\frac{I_t}{I_0}\right) = -\frac{\alpha S v t}{4V}$

or, $\frac{I_t}{I_0} = e^{-\frac{\alpha S v t}{4V}}$ ——— (3)

According to the definition of reverberation time $\frac{I_t}{I_0} = 10^{-6}$

∴ From eqn (3), we have

$$e^{-\frac{\alpha S v t}{4V}} = 10^{-6}$$

$$\therefore e^{\frac{\alpha S v t}{4V}} = 10^{6}$$

$$\therefore \frac{\alpha S v t}{4V} = \log_e(10^{6})$$

If T be the reverberation time, then

$$\frac{\alpha S v t}{4V} = 6 \log_e(10)$$

$$\therefore \frac{\alpha S v t}{4V} = 6 \times 2.3026$$

Taking the velocity of sound approximately at room temperature as 350 m/s

$$\therefore T = \frac{6 \times 2.3026 \times 4}{350} \times \frac{V}{\alpha S}$$

$$\therefore T = \frac{0.158 V}{\alpha S}$$ ——— (4)

This equation is called Sabine's formula.

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