

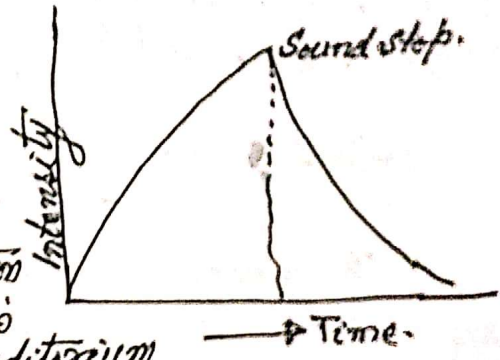
Q. 110: - Acoustics of Building

According to the Sabine a hall is good for speech and music which have.

- (1) The sound heard must be loud in every point of the hall.
- (2) The syllable must not overlap.
- (3) There should be no echoes, ~~to fulfill these~~

To fulfill the above demands the following conditions are to be secured.

(a) Optimum Reverberation: - When a continuous sound is sounded in a hall it takes time to reach its max^m intensities due to reflection and refraction from the object and wall of the hall. Similarly as the sound is stopped, the energy takes some time to reach its min^m audibility. This dying sound is k/a Reverberation. The dying time of sound is k/a Reverberation time. According to Sabine this reverberation time for good auditorium



$$T = \frac{0.16V}{A}$$

Where, V = Volume of hall, A = Total absorption of the sound

(b) Adequate Loudness: - This can be achieved by placing large wooden board near and behind the speaker

(c) Uniform distribution: - For uniform distribution of the sound the hall should not have curved surface because they focus the sound at some places. A parabolic ceiling is helpful for this purpose.

(d) Absence of echelon effect: - The echelon effect is minimized by using Hair Carpet

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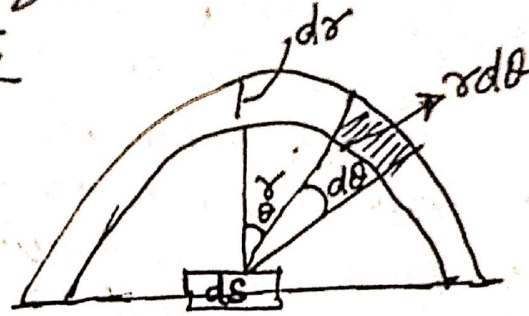
SABINE'S FORMULA: Growth and decay of sound.

Assumption (1) The distribution of energy is same throughout the room.

- (A) There is no interference between sound wave
 (B) The absorption coefficient of the surface is independent of sound intensity.

Let us consider an element is at a plane of the wall. Let us consider two spheres of radii r and $r + dr$.

Let us consider a small area $r d\theta \cdot dr$ between the sphere. If the whole figure is rotated by an angle $d\phi$ such that it travels a volume.



The sound energy in unit solid angle

$$= \frac{E}{4\pi} r^2 \sin\theta d\theta dr d\phi$$

The energy in solid angle $\frac{ds \cos\theta}{r^2}$

$$= \frac{E}{4\pi} r^2 \sin\theta d\theta dr d\phi \frac{ds \cos\theta}{r^2}$$

$$= \frac{E ds}{4\pi} \sin\theta \cos\theta d\theta dr d\phi$$

The energy received by ds in one second:

$$= \frac{E ds}{4\pi} \int_0^{\pi/2} \sin\theta \cos\theta d\theta \int_0^{2\pi} d\phi \int_0^{\infty} dr$$

$$= \frac{E ds}{4\pi} \frac{1}{2} \cdot V \cdot 2\pi$$

$$= \frac{E ds V}{4}$$

If ' α ' is the absorption coefficient of ds then, energy absorbed per second

$$= \frac{E V ds \alpha}{4}$$

The total energy absorbed by the room per second.

$$\frac{dE}{dt} = \frac{1}{4} EV \int adS$$

$$= \frac{1}{4} EVA$$

The rate of energy supply by the source is equal to the sum of rate of energy growth in space and rate of energy absorbed by the wall.

$$P = V \cdot \frac{dE}{dt} + \frac{1}{4} E \cdot AV$$

$$\text{or, } \frac{dE}{dt} + \alpha E = \frac{4P}{VA}$$

$$\text{or, } \left(\frac{dE}{dt} + \alpha E\right)e^{\alpha t} = \frac{4P}{VA} e^{\alpha t} \text{ or } \frac{d}{dt}[E e^{\alpha t}] = \frac{4P}{VA} e^{\alpha t}$$

$$\text{Integrating we get; } E e^{\alpha t} = \frac{4P}{VA} e^{\alpha t} + C \quad \text{--- (A)}$$

$$\text{(i) At } t=0, E_0 = 0 \Rightarrow C = -\frac{4P}{VA}$$

$$\therefore E = \frac{4P}{VA} (1 - e^{-\alpha t}) = E_{\max} (1 - e^{-\alpha t}) \quad \text{--- (B)}$$

$$\text{(ii) If source is cut off } P=0 \text{ at } t=0 \text{ and } e = E_{\max}$$

$$\therefore E e^{\alpha t} = E_{\max}$$

According to Sabine, the reverberation time T is the time during which the steady energy density falls to 10^{-6} of its max. value.

$$\text{or, } \frac{E}{E_{\max}} = 10^{-6} \Rightarrow 10^{-6} = e^{-\alpha t}$$

$$\Rightarrow \alpha T = \lg_e 10^6 = 6 \lg_e 10$$

$$T = \frac{6 \times 2.303}{\alpha}$$

$$= \frac{6 \times 2.303 \times 4 V}{VA}$$

$$= \frac{6 \times 2.303 \times 4 V}{330 \cdot A}$$

$$\therefore T = \frac{0.16 V}{A}$$

