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# On the Relation between the Reverberant Sound Absorption Coefficient and the Normal Incidence Absorption Coefficient of Fibrous Materials

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So far, the relation between the reverberant and normal incidence absroption coefficient was investigated by Paris and London.[1] There, by using the normal acoustic impedance of the meterial, the absorption coefficient for oblique incidence was obtained and then this coefficisent was intefrated over all angles of incidence.

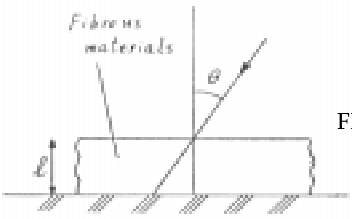


FIG. 1.

Now, we measured the normal incidence and reverberant absorption coefficient of fibrous materials. To explain th coerrspondence beetween these two coefficients, a new statistical method for random field was derived.

The reverberation chamber used for this research is the chamber of our institute, which was constructed in 1956. This chamber has a volume of 513 $m^3$ surrounded by nonparallel walls, and the reverberation time for the empty chamber is 22 sec at 500 cps.

It was shown experimentally that the assumption of a diffuse sound field would be nearly fulfilled in this chamber.[2] The normal incidence absorption coefficient was measured by the staionary wave method.

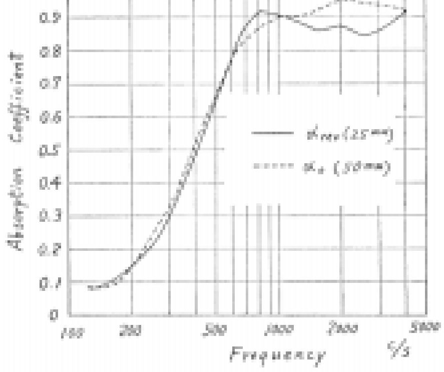


FIG. 2. Comparison of the reverberant absorption coefficient with the normal incidence absorption coefficient having a twofold thickness.

As shown in Fig.1, were consider the sound wave impinging from angle $\theta$ on the fibrous material of thickness $l$ which is placed on the rigid wall. If it is assumed that the sound wave propagates to the same direction even in the material, it seems reasonable to think that th ethickness of the material is expressed effectively by $l_\theta = l / \cos\theta$ .

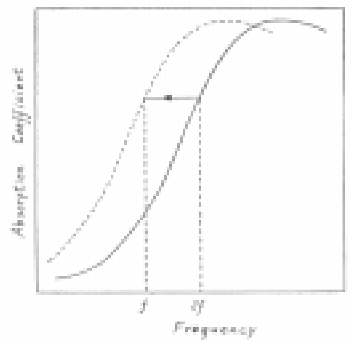


FIG. 3. Measured normal incidence absorption coefficient (solid line) at frequency $2f$ is translated to frequency $f$.

When the diffuse wound field is established in a reverberation chamber, an equal amount of sound energy will impinge upon the materials from all directions. Thus the statistical mean of the effective thickness of material was calculated for the case of random incidence.

The total solid angle between $\theta$ and $\theta + d\theta$ is $2\pi \sin\theta\, d\theta$ . Sound intensity impinging on the sample surface from this direction is proportional to $2\pi \cos\theta \sin\theta\, d\theta$ . Thus, when the fibrous material of thickness $l$ is placed in the random field, the effective thickness of material $l$ is given by the following formula:

$$\bar{l} = \frac{2\pi \int_0^{\pi/2} l_\theta \cos\theta \sin\theta\, d\theta}{2\pi \int_0^{\pi/2} \cos\theta \sin\theta\, d\theta}.$$

This becomes $\bar{l} = 2l$ . This formula represents the fact that the

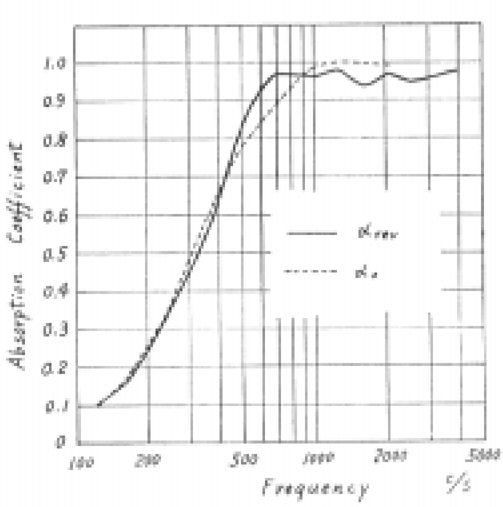


FIG. 4. Comparison of the reverberant absorption coefficient with the normal incidence absorption coefficient of the same thickness treated as in Fig.3.

thickness of material placed in the reverberation chamber is increased effectively twofold as compared with the case of normal incidence. Form this result, it seems reasonable to consider that the random inidence absorption coefficient will correspond to the normal incidence absorption coefficient of the same material when the thickness of material is increased twofold in the latter case. An example of the experimental results is shown in Fig.2 for the case of glass fib er of thickness 25 mm and 50 mm. This figure shows that the reverberant absorption coefficient for the case of 25 mm seems to coincide fairly well with the normal incidence absorption coefficient for the case of 50 mm.

Next, it is assumed that the attenuation of sound per cycle in the material is independent of the frequency of sound. On the basis of this assumption and the above formula, the normal incidence absorption coefficient for frequency $2f$ seems to correspond to the random incidence absorption coefficient at frequency $f$ in the case of the same thickness. Thus, the measured normal incidence absorption coefficient at frequency $2f$ was translated to the frequency (Fig.3), and this coefficient was compared with the absorption coefficient measured in the reverberation chamber (Fig.4).

In conclusion, for the case of certain fibrous materials, the reverberant sound absorption coefficient seems to correspond to the normal incidence absorption coefficient, considering that the effective thickness of material becomes twofold. This fact was verified in the case of fibrous materials for more than ten kinds.

[1] E.T.Paris, Pjol.Mag. **5**,489 (1928); A.London, J.Acoust.Soc.Am. 22,263-269 )1950).
[2] K.Sato and M.Koyasu, J.Acoust.Soc.Japan **13**,231-255 (1957).