BRITISH ACOUSTICAL SOCIETY

70/115

MODEL STUDIES IN AC...

NOVEMBER 12th 1970

THE ROLE OF INTERNAL DAMPING OF MATERIALS IN SCALE-MODEL MEASUREMENTS OF SOUND TRANSMISSION

C.L.S. Gilford and B.M. Gibbs (University of Aston in Birmingham)

The general conditions of similarity in models will have been described by other authors in this symposium. The simplest scheme is to build the model of the same materials as the full-sized structure and to scale up all frequencies in the same ratio as the linear reduction of the model. It is assumed that all the physical properties of the material will be the same at the elevated as at the original frequencies.

This assumption is justified in the case of the density, and the elasticity of most materials, and hence the velocities of longitudinal and bending waves are unchanged. The absorption coefficients of surfaces do not remain constant but scaled absorbing materials can be devised to reproduce the characteristics of most normal materials at the scaled frequencies. Such materials are, in general, of similar construction but smaller thickness than the originals. Harwood and his colleagues at the B.B.C. have accurately scaled all the constructions used in their studios. Absorption by the air in an enclosure does not scale, but the humidity can be maintained at a low value at which the scaled absorption is correctly related to the original over most of the frequency range.

When we come to the applications of model techniques to the propagation of sound through solid materials, the difficulties become less tractable. The resistances of solids appear, if anything, to increase with frequency and it is more difficult to remove than to add resistance to the model. We must, therefore, examine the significance of internal losses in sound propagation and devise reliable and accurate means of measuring them over a frequency range of at least 20:1.

The Significance of Internal Losses in Sound Transmission

(a) Direct Transmission through partitions.

The effects of internal resistance in the materials have been treated by several authors. Westphal (1954) showed that the radiation efficiency of a laminar material at and above its critical frequency was considerably reduced by damping, though below this frequency it was somewhat increased. The range of damping considered was up to 10 dB/wavelength. Price and Crocker (1970) give calculated curves showing an improvement of 5-10 dB in the T.L. of a double leaf wall due to damping within the normally encountered range. Internal losses, therefore, have a considerable significance for airborne sound transmission and should be closely controlled.

(b) Transmission along building elements.

As one recedes from the source the intensity of structure-borne sound is reduced by several factors.

(i) Losses in the material itself. The attenuation along a material of loss factor η amounts to 13.6 η dB per wavelength. If we assume a frequency of 500 Hz and a typical loss factor of 0.01 for building materials, the attenuations will range from 0.08 dB/m for 200 mm thick concrete to 0.7 dB/m for 3 mm plywood.

(ii) Loss by radiation from the surface. The sound power radiated from unit area of a large vibrating surface, assuming piston radiation, is $V^2\rho c$ where V is the r.m.s. transverse velocity. The ratio of radiated to absorbed power is $\rho\lambda/2\pi m'\eta$ where m is the mass per unit area. For the 200 mm concrete, this is a ratio of about 1/40 while even for the plywood it is about 0.6 and we may thus conclude that radiation is not an important factor in the damping.

(iii) Reflection from transverse elements. This depends in a complicated way on the relative properties of the two structures and on the angle of incidence of the sound on the discontinuity. Cremer (1953) and others have, however, shown that it is a very important factor, accounting for more than the attenuation figures quoted in (i) and (ii).

(iv) Spreading out of the sound energy. (Cf.Inverse Square Law) This effect contributes an attenuation of the order of 6-8 dB by the time the structure-borne sound has travelled the length of a room in a subdivided building.

The internal losses in normal building materials, therefore, play a little part in the attenuation of flanking transmission; scale model experiments are likely, with present materials, to be a more reliable guide for structure-borne transmission than airborne sound transmission.

Measurement of Loss Factors

(i) Measurement of free decay rates. The sample is set into free vibration by an impact or an electromagnetic driver. The reverberation time of the system is then $2.2/\eta f$, and the logarithmic decrement is $\pi\eta$. This method has been used by Mason and Leventhall (1970) up to the 22nd mode of bending vibration.

At low frequencies the times of decay are long enough for direct measurement. At higher frequencies, and with lossy materials, the decay can be recorded at a high tape speed and then replayed at a low tape speed. Leventhall and Mason (1969) have devised an automatic electronic device for measuring decrements on a few cycles and we are developing a logarithmic amplifier suitable for the same purpose.

(ii) Generation of admittance diagrams around a resonance. (Kennedy and Pancu (1947)) The in-phase and quadrature components of the response to a sinusoidal excitation are plotted as X and Y co-ordinates for a series of driving frequencies surrounding a resonance, giving a circular admittance diagram with the real axis as diameter. The loss factor can be derived directly from the diameter of the admittance circle and the rate of change of the real component with frequency. The specimens are flat strips suspended by thin wires from one end and excited electromagnetically through a single layer coil wound on a thin aluminium alloy former. The components of the output of the measuring accelerometer are measured by means of a Solartron Resolved Components Indicator.

The admittance diagram method gives the most accurate and controllable measurements, but is only applicable conveniently to specimens in which the resonances are clearly separated. For many practical structures the resonances are closely spaced and determination of the loss factors must be measured from decrements.

Results

Measurements have been made on steel, wood and concrete; measurements on brickwork and other building materials are in progress. Initial measurements showed that with all methods of clamping, the results varied with the mode of oscillation, presumably due to varying power flow into the mounting and by radiation into the air. All the results quoted here are, therefore, with wire suspensions.

Where results on different samples of the same material vary, it has been assumed that the lowest results represent the actual internal losses and variations from this are due to unwanted losses, either by radiation into the air, the clamping of the specimen, or the driver and accelerometer positions.

Fig. 1 shows a typical experimental arrangement adapted for the measurement of loss-factor by the admittance method. This method will not be universally applicable to building structures, and we therefore compared these results obtained with those produced by the decay-time method.

Fig. 2 shows results obtained from a model concrete beam using the two methods; they are seen to be in reasonable agreement.

Fig. 3 shows the collected results for steel strips of the same thickness. It is thought that this very lightly damped material (the loss factor increases from approximately 5.10^{-4} at 100 Hz to 2.10^{-3} at 2 KHz.) is highly susceptable to losses other than internal. In this case, the peak value of 10^{-2} between 2.5 KHz and 7 KHz might be due to radiation around the critical frequency, calculated to be approximately 6 KHz.

Fig. 4 shows results similarly plotted for wood (deal). As in steel, the natural frequencies of resonances scaled correctly with several forms of suspension and specimen shapes. The results show an increase of loss factor from $1.8 \cdot 10^{-2}$ at 100 Hz to 4.10^{-2} at 10 KHz with an average value of approximately 3.10^{-2}.

Fig. 5 compares loss factors of concrete, lightweight concrete, breeze block and brick work.

Conclusions

Scale-model measurements on the transmission of sound depend on correct scaling of the losses in the materials used. For ordinary building materials, the losses do not greatly influence the attenuation of sound in longitudinal members, but are likely to influence airborne sound transmission significantly. Measurements of loss are by no means easy and misleading results can be obtained more easily than correct ones. Methods described in this paper appear to be giving results of the right order and are being further developed.

References: Kennedy C.C. and Pancu C.D.B. (1947) J. Arc. Sc. 14 Vol. p. 603.

Mason J.A. and Leventhall H.G. (1969) J.S.I. Ser. 2 Vol. 2 p. 1104

Mason J.A. and Leventhall H.G. (1970) B.A.S. Reprint No. 70/64.

Ref. Cont. Price A.J. and Crocker M.J. (1970) J.A.S.A. 47 p. 687

Fig. 1