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ABSORPTION OF SOUND PULSES BY POROUS MATERIAL

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1.00 INTRODUCTION

This paper describes the development of a technique and its use to measure the absorption coefficient of acoustic ceiling tiles at normal and oblique incidence. Previous work, by Louden, 1974, using a 0.5 m sec duration pulse, Cho et al, 1959, Rogers et al, 1960, Cops et al, 1973, and Yuzawa, 1975, using tone bursts of 1 to 5 m sec duration, has shown that the absorption of sound by porous materials is generally a function of only two characteristics of the incident sound field: its frequency spectrum and angle(s) of incidence. I.e., some correlation between impulse derived absorption coefficients and steady state incident field derived results has been found.

The results given in this paper, using a much shorter pulse than hitherto used, show a substantial discrepancy to results derived using the impedance tube.

2.00 EXPERIMENTAL TECHNIQUE

A very short 0.2 m sec duration pulse is produced by a 0.22 blank cartridge fired by a simple device constructed from a household mousetrap. The technique is a modification of that described by Lewis and Smith, 1978. A 4-channel FM tape recorder is used to capture the incident and reflected pulses on separate channels. The first microphone is placed between source and sample, the second is placed in the same vertical plane and source and first microphone but in a position to capture the geometric reflection off the sample.

It will be appreciated that at normal incidence one microphone can be used to capture incident and reflected pulses, because measurements are now axial as opposed to planar at oblique incidence. The microphone is positioned with its axis perpendicular to the measurement axis so that both signals are captured at 90° microphone directivity.

The sample under test was laid out on hardboard sheets, to facilitate easy moving, on a concrete floor in an 8 x 3 tile matrix. This area of sample has calculated to be greater than that required to ensure the reflection was totally off the sample. I.e., no edge effects distorted the reflection. It was found to be better to move the sample, on its hardboard, with the microphone booms and source set for a particular angle of incidence. Thus reducing the number of microphone position changes, and hence, the experimental error in position measurement, to a minimum.

The constraint applied to the sample area is also minimized at normal incidence. The minimum area is a circle who radius is a function of source sample and receiver sample distances. When, at oblique incidence, the measurement axis is extended to a measurement plane the minimum area required is extended from a circle to an ellipse. The distortion or eccentricity of the ellipse will increase with increasing angle of incidence.

The high crest factor of the pulse used meant that care had to be taken on recording. Bruel and Kjaer, type 2606, measuring amplifiers were used to amplify the microphone output; these amplifiers have a theoretical crest factor capability of 40. In practice it was found that no crest factor distortion was evident if the gunshot barely moved the meter needle of the 2606 with Impulse Hold Setting.

3.00 THE ANALYSIS PROCEDURE

Individual pulse trains were replayed from the tape recorder to a B and K Digital Event Recorder. Its facility of memory recycling enables analogue 'real time' frequency analysis to be carried out. To remove unwanted reflections from the recorded signal the event recorder memory was recycled through a B and K Tape Signal Gate. This is a device which applies a variable width gate or window to the recording so that only the signal appearing in the window is transmitted. The TSG is triggered from the event recorded so that the gate position is fixed relative to the event recorder memory. A delay may then be applied from the TSG to position the window at the correct pulse in the memory. Positioning of the gate is done visually by comparing the gated and ungated signals on an oscilliscope.

Frequency analysis is carried out by passing the analogue output from the gate to a 1/3 octave Real Time Analyser.

4.00 THEORY

Using the Real Time Analyser the sound pressure level, L dB, can be measured for any 1/3 octave frequency band, i.e., the mean sound pressure in that band is given by:

$$p = 10^{L/10} . p_o \qquad \text{where } p_o \text{ is the reference pressure}$$

The energy in the band is proportional to the mean square pressure, therefore for a measured incident pulse SPL of D dB the energy is given by:

$$E_D = K(10^{D/10} . p_o)^2 \qquad \text{where K is the constant of proportionality}$$

And similarly, for the reflect pulse SPL of R dB, the energy in a band is given by:

$$E_R = K(10^{R/10} . p_o)^2$$

The absorption coefficient is given by:

$$\alpha = 1 - E_R/E_D$$
$$= 1 - 10^{(R - D)/10}$$

A correction is made to the reflected sound pressure level because of the extra distance covered, assuming inverse square law attenuation this correction y dB is given by:

$$y = 20 \log_{10} \frac{\text{source - receiver distance}}{\text{source - sample - receiver distance}}$$

Therefore $\alpha = 1 - 10^{(R + y - D)/10}$ ... (1)

R and D being the measured SPLs of reflected and incident pulses respectively in any 1/3 octave frequency band.

5.00 RESULTS AND DISCUSSION

Measurements were carried out on (a) five types of acoustic ceiling tile: two ceramic, two mineral fibre and one wood fibre, and (b) 90 mm medium density polyurethane foam. The results obtained for pulse and impedance tube methods, at normal incidence, and pulse method only at oblique incidence are given together with estimates of the 95% confidence range for each value.

It is evident that, whereas the results obtained with the impedance tube show a variation with absorption with frequency, which is typical of that generally associated with porous materials, the absorption characteristic found with the pulse technique do not. This contrasts with the situation mentioned earlier in this paper where the results of other workers using transient signals, particularly tone bursts, have found results which correlate, to some degree, with the steady state derived results.

The principle difference between the pulse derived values and those derived using steady state incident fields is that the former is found to be largely independent of frequency whereas the latter, the standing wave tube results, have a substantial frequency dependence. The repeatability of the measurements on each sample and the consistancy of the pattern found across all samples rule out the possibility that there are chance results.

The observed behaviour must, therefore, be associated with the gunshot pulse itself. The implication is that the energy loss processes which take place within porous materials when excited by a continuous sound field or a tone burst do not operate in the same way when excited by a short duration gunshot pulse. However, further work is needed to establish the nature of the absorption processes and the conditions under which non-linearity in the behaviour commences.

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