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MEASUREMENT OF SOUND INSULATION IN BUILDINGS USING IMPULSE RESPONSE METHODS

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1. INTRODUCTION

Impulse response methods, as proposed by Louden, have been used for over twenty years in the assessment of the transmission characteristics of panels [1], and in the measurement of sound absorption in situ [2]. The method promises the following advantages and applications in the measurement of sound insulation:

(i) The standard methods of measurement and rating of sound insulation of usually internal panels and walls establish only that there has been a failure to comply with insulation requirements without indicating the mode of failure[3]. The impulse response method allows the contribution of the partition wall to be isolated from that due to flanking. Failure due to insufficient mass, bridging or air gaps might then be identified.

(ii) The standard methods are also used in the measurement of sound insulation of external walls and cladding but there remains a need for methods which are quick and accurate. There is a particular need for methods which allow a proper estimate of the sound insulation afforded by factory cladding.

Work on impulse response methods were initiated at Liverpool University about twelve years ago, where the original aim was the development of a simple and portable system for measurement of walls in situ [4]. More recently, the work received an impetus from the development and availability of relatively inexpensive fast Fourier analysers.

2. EXPERIMENTAL METHOD

The principle of the impulse response method can be simply stated. The method requires the separation of a direct short duration signal from subsequent scattered, diffracted, and reflected components to allow Fast Fourier Transformation. An anechoic condition is thereby simulated and the transmission or other characteristics of the system under test are assessed independently of the surrounding acoustic conditions. The time history of the signal at a microphone due to a short duration pulsed output of a loudspeaker where a reflecting surface is in close proximity is shown in figure 1. Correct time windowing of the direct component will eliminate the effect of the reflector

and subsequent frequency analysis will yield the anechoic frequency response.
If a free standing panel intersects the line between loudspeaker and microphone then an attenuated direct component results with subsequent larger diffracted and reflected components (figure 2). If the direct component is windowed and the spectrum obtained compared with that obtained without the panel in position then the level difference is the insertion loss of the panel; the effects of source and receiver frequency and directional characteristics and those of distance and air absorption are eliminated.
In figure 3 is shown a typical measurement system. The source is a moving coil loudspeaker of 120 mm diameter fitted at the end of a tube of 1.0 m in length. Back radiation from the cone is therefore delayed and does not mask the forward radiated component. The signal generator produces a rectangular pulse, the duration of which could be varied from 100 μs to 4 ms. The resultant loudspeaker response time was typically 1.5 ms and allowed panel sizes which resulted in a minimum path difference of 0.5 m between the direct and shortest diffracted paths. This could be achieved with panels of 1.0 m minimum dimension when the source-receiver distance is 1.0 m. The measurement system allowed the angle between the source-receiver axis and the panel to be varied.Signal capture and frequency transformation was made possible by means of a portable FFT analyser and signal-to-noise was improved by averaging.

3. SINGLE - LEAF WALLS

In figure 4 is shown the normal incidence insertion loss of a plywood panel; also indicated is simple mass-law prediction and the agreement can be seen to be promising. Figure 5 shows the normal incidence and oblique incidence insertion loss of a 13 mm perspex panel. The mass controlled and coincidence regions are clearly seen and agreement between measurement and theory is satisfactory.
In situ measurements have been performed on glass panels and masonry walls with a range of surface densities from 7- 500 kg/m^2 and satisfactory results were obtained for thin, low insertion loss panels. The isolation of a direct component of the transmitted signal proved difficult in the measurement of thick walls because of the appearance of a signal fluctuation which preceded the expected delayed diffracted component. In figure 6(a) is shown the direct component, precursor and diffracted components of a transmitted signal through 120 mm plastered brickwork at normal incidence. The precursor is the result of a forced bending wave, generated by the incident airborne sound, propagating freely after reflection at the edges of the wall. The resultant radiated sound arrives at the microphone position before the diffracted component and before the direct component is completed. The precursor effect, which was more severe for thick walls where bending wave velocities are high, was reduced by spatially averaging the unwanted fluctuations to a low level by changing the point of intersection of the panel and the line between loudspeaker and microphone. In figure 6(b) is seen

the reduction in unwanted fluctuation obtained by averaging eight positions. The resultant agreement between measurement and theory in figure 7 is fair.
In general the measurement method is limited to wall and panel constructions which allow adequate signal-to-noise and where the precursor effect can be adequately reduced. This was not possible for thick walls such as 220 mm plastered brickwork.

4. LIGHTWEIGHT CLADDING

The requirements of factory cladding has always been that it is relatively cheap, weatherproof and reasonably attractive. A recent requirement has been that it provide good thermal insulation (5), and even more recently that it also give adequate sound insulation. However, information on the sound reduction index of such cladding is not always available or is not in a form which allows the sound insulation in situ to be predicted. Again, the impulse response method might be employed to good effect. There are not likely to be problems in applying the method if the cladding is a thin, single-leaf isotropic panel. In figure 8 is shown the insertion loss of an aluminium panel at normal incidence and at 45^0 incidence, and again agreement is acceptable.
In figure 9 is shown the normal incidence insertion loss of a profiled steel panel. The results are less regular than for the previous case but a mass-law region is indicated with a plateau region above 1500 Hz. Such panels are orthotropic with two bending stiffnesses and two critical frequencies. It is thought that the spherical wave produced by the loudspeaker will result in non-normal incidence at the panel boundaries and therefore coincidence. An angle of incidence of 20^0 to the normal gives a lower coincidence dip at approximately 1.7 KHz (stiffer direction) and an upper coincidence dip at approximately 214 KHz, and the start of this range agrees reasonably well with the plateau region indicated.
Double skin cladding panels pose other problems to measurement in that the duration of the component of the transmitted signal is increased by multiple reflections in the cavity and will persist during the arrival of unwanted components, (figure 10). This problem is likely to be reduced when factory cladding of large area is measured when the arrival of unwanted signals is further delayed.

4. CONCLUDING REMARKS

1 Impulse response methods can be used for the measurement of insertion loss of single-leaf walls in situ. Mass-law characteristics and coincidence are clearly indicated for thin isotropic panels at oblique incidence.

2 The method promises a quick and inexpensive method for profiled and double-

leaf lightweight factory cladding but problems due to orthogonality and cavity reflections remain.

It will be appreciated that the method offers an in situ measurement, not an assessment of in situ performance. The results of normal or oblique incidence measurement would need to be used with the same caution as those obtained from standard reverberant transmission suite loss measurements since the sound field in a factory of extreme dimensions is not likely to be either predominantly normally incident or diffuse.

5. REFERENCES

1) M.M.Louden 1971 *Acustica* **25** ,167-172. The single-pulse method for measuring the transmission loss of acoustic systems.

2) J.C.Davies & K.A.Mullholland 1979 *Journal of sound and vibration* **67** (1), 135-149. An impulse method of measuring normal impedance at oblique incidence.

3) ISO 140 1978 *International Standards Organisation* Methods of measurement of sound insulation in buildings and of building elements.

4) J.C.Davies & B.M.Gibbs 1981 *Journal of sound and vibration* **74** (3),381-393. The oblique incidence measurement of transmission loss by an impulse method.

5) Building Regulations 1985 Part L Consideration of fuel and power L3 Resistance to the passage of heat.

SOUND INSULATION USING IMPULSE RESPONSE METHODS

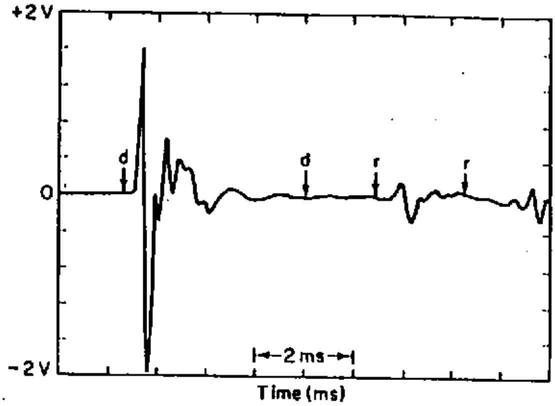

Figure 1 Direct (d-d) and reflected (r-r) components of a time history

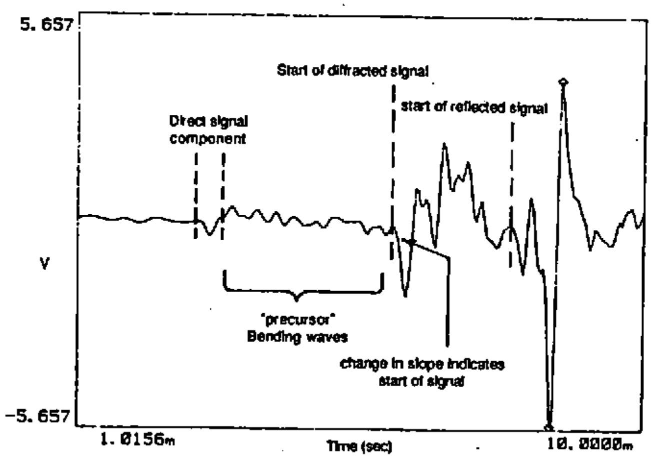

Figure 2 Time history with panel in place identifying separate signal components

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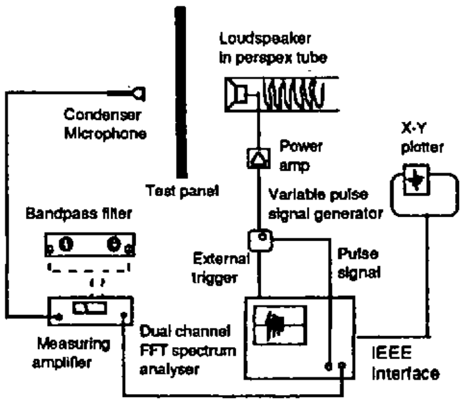

Figure 3 Instrumentation for impulse response measurements

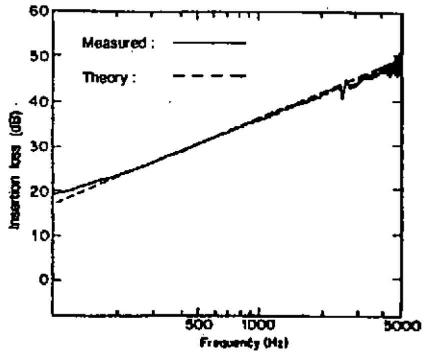

Figure 4 Normal incidence insertion loss for plywood

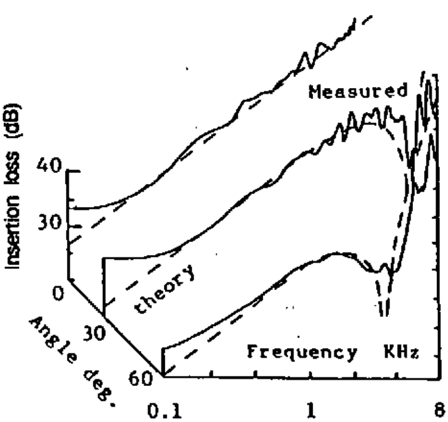

Figure 5 Normal and oblique incidence insertion loss

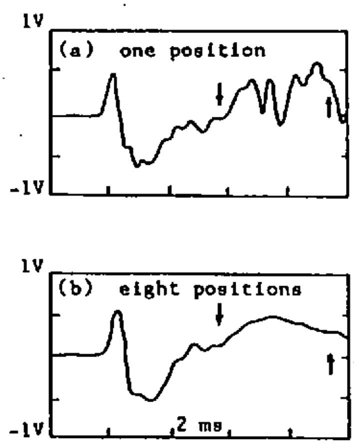

Figure 6 Elimination of precursor indicated by : ↑↓

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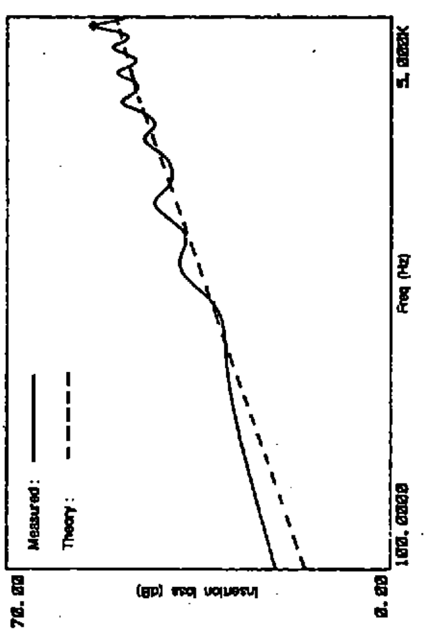

Figure 6 (a) Aluminium panel : Insertion loss at normal incidence

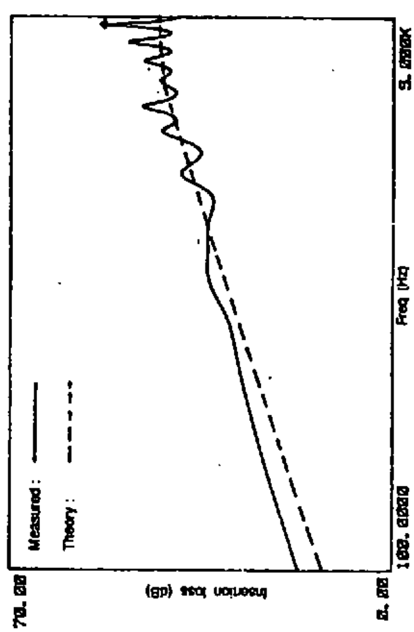

Figure 6 (b) Aluminium panel : Insertion loss at 45 degrees incidence

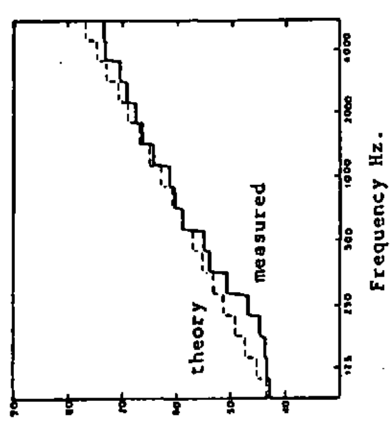

Figure 7 Insertion loss of brickwork

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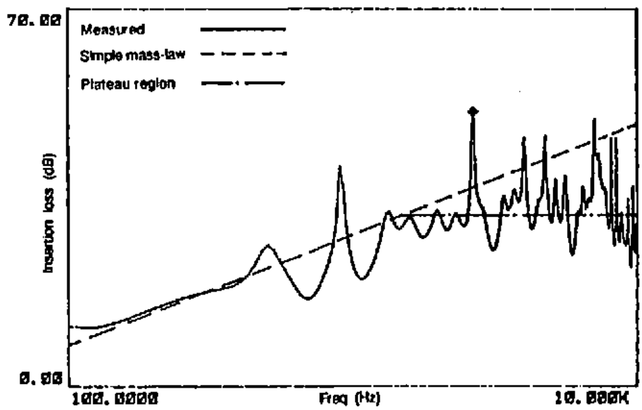

Figure 9 Profiled steel panel : Insertion loss at normal incidence

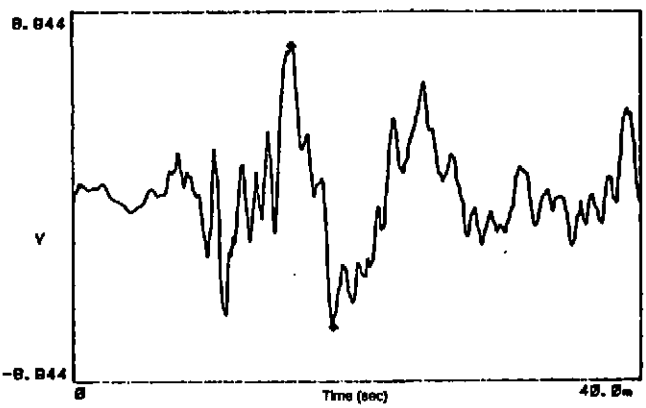

Figure 10 Lightweight cladding panel : Time history of signal at normal incidence