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# PRACTICAL ASPECTS OF THE SITE MEASUREMENT OF SOUND ABSORBERS FOR NOISE ABATEMENT

D C Hothersall and D H Crombie

Department of Civil Engineering, University of Bradford, Bradford, W. Yorkshire, BD7 1DP

## 1. INTRODUCTION

In outdoor situations, where reflection from surfaces increases the environmental noise levels it is sometimes possible to reduce the problem by introducing surfaces constructed from sound absorbing materials. An example of this concerns road traffic noise barriers. Where parallel barriers are constructed to protect both sides of the road the back reflection of sound from the barrier on the opposite side, can reduce the attenuation expected for a single barrier. To overcome this problem the surfaces of the barriers facing the traffic can be made absorbent [1]. When a barrier is sited very close to a road, similar degradation in the performance of a barrier is observed when high sided vehicles are passing. This is due to reflection effects between the barrier and vehicle and the problem can be reduced by using an absorbing noise barrier [2].

Many different types of noise absorbers are commercially available. The two most basic forms are Helmholtz resonator types (eg. blocks with cavities) and homogeneous porous materials (eg. solid wood or stone chips in a lean mix binder matrix, or compressed fibrous material). Propriety panel absorbers usually combine a perforated hollow box with a fibre panel in-fill. The use of natural absorbing materials is attractive. Earth mounds, sometimes reinforced to reduce their width and maintain stability are commonly used. These can be covered with grass or other plantings.

## 2. METHODS OF MEASURING THE PERFORMANCE OF ABSORBERS

Manufacturers of absorbing materials usually provide a spectrum of the random incidence absorption coefficient over a suitable range of frequencies. The results are generally obtained using a standard method for the measurement of random incidence sound absorption [eg. 3]. The material is introduced into a reverberation room and the absorption coefficient can be simply calculated from the change in reverberation time. This method will produce a good standard measure of absorption for practically any type of absorber provided, of course, that it can be properly installed in the reverberation chamber.

The absorption coefficient for normally incident plane waves can be determined in an impedance tube [eg. 4]. This provides good standard data, but is only useful for fine grain, homogeneous or layered absorbing materials. Again a specimen of the material in a suitable form is required. A more detailed description of the performance of an absorber is obtained if the surface impedance is measured. Using this method the effect on both the phase and amplitude of a reflected wave is obtained. Many methods have been developed for the measurement of impedance, and while it is possible to obtain experimental results as a function of angle of incidence the meaning of such results for absorbers of complex construction is difficult to interpret. Most research in this area has been restricted to the examination of layered homogeneous materials. [Reviews in [5] and [6]].

With the increasing sophistication of the modelling methods used to predict environmental noise conditions using boundary element and ray techniques it is becoming increasingly necessary to have information about the impedance of surfaces. Methods of describing the effects on the phase and amplitude of more complex types of acoustic absorbers, on incident waves as a function of angle of incidence are still not well developed.

## 3. SITE MEASUREMENTS

In several situations it is not possible to use the impedance tube or reverberation chamber method of determining absorption coefficient. This is obviously the case for earth mound, retained earth, or willow wall noise barriers which must be investigated on site. Also, for proper quality control it is useful if the absorption coefficient of every type of absorbing surface can be measured on site. This enables the performance of newly constructed installations to be checked by the customer and contractor. It also enables the long term performance to be monitored by measurements of the installation over a period of years.

Thus a requirement exists for a robust and efficient in-situ measurement method of monitoring absorbing materials on site. Requirements of a suitable method are:

i. The method should involve equipment which is easily deployed, straightforward and quick to use.
ii. The method should be capable of monitoring surfaces of fairly small dimensions (say 2m x 2m) with other reflecting surfaces nearby. Ideally an 'average' result over a reasonable surface area should be produced, so that small scale variations in the structure do not strongly affect the results.
iii. The method should be operable in conditions with significant levels of background noise (eg. near a road).
iv. When the method is used for noise barriers it would be useful if it could be simply adapted to also measure the transmission characteristics of the barrier.

It is possible to determine the absorption coefficient by suitably configured measurements of sound intensity [7, 8]. A second method is to determine the response of the absorbing surface to an acoustic impulse. This general approach is well known and its use has been reported in a practical system for monitoring the performance of porous road surfaces [9]. It has also been applied to noise barriers using an explosive source in a French Standard [10]. The impulse response can also be determined using a source activated by a signal comprising pseudo-random sequences of maximum length [11] and the application of this (MLS) method to this specific problem has recently been reported [12]. Practical aspects of the application of the impulse method to absorbing noise barriers using a pulsed loudspeaker source are considered in the next section.

## 4. EXPERIMENTAL METHOD

The sound source was a tweeter driven by a delta function signal. The basic requirements of the source are repeatability of the acoustic pulse and short enough duration to resolve the direct and reflected pulses without detecting scattered waves from the edges of the specimen surface or reflections from other surfaces nearby.

Although signal theory predicts that a pulse of duration, T has a high spectral content at all frequencies below 1/T the shorter the duration of the signal the lower the power, if the amplitude remains constant. At low powers signal to noise problems are encountered, particularly at low frequencies. It is necessary in using impulse methods in which broad band spectral response is to be studied to balance these two effects.

Geometries used to carry out measurement of absorption coefficients of a noise barrier 2m in height are shown in Figure 1.

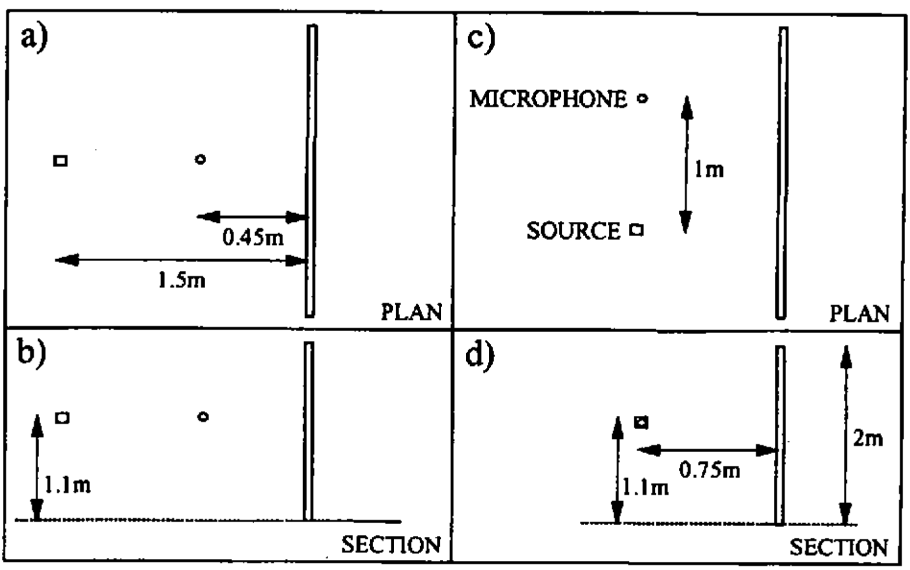


*Figure 1 - Source and receiver positions for impulsive measurement of a noise barrier a) and b) at 0° and c) and d) 34° angle of incidence.*

In Figure 1a) and b) plan and elevation respectively for measurements at normal incidence are shown. In Figure 1c) and d) the angle of incidence is 34°. These configurations are similar to those proposed in [10]. They allow approximately 3ms between the incidence of the direct and reflected pulse at the microphone. A similar time decay occurs between the pulse reflected from the barrier and the scattered waves from the upper edge of the barrier and also the pulse reflected from the ground. The time interval between the direct and reflected pulses is reduced as the angle of incidence increases and is about 2ms when the angle of incidence is 34°. These time intervals are the maximum achievable for this type of measurement. However signal processing techniques have been developed [13] which enable signals which overlap significantly to be analysed. Signal processing is straight forward with any modern signal analyser. In this case a Bruel & Kjaer twin channel narrow band analyser was used. 200 pulses were averaged in the time domain. Direct and reflected pulses were isolated using a time window and the amplitude spectra obtained. A second approach in which the path lengths do not require adjustment and in which movement of the source and microphone is unnecessary is to install a plane rigid screen immediately in front of the surface of the absorber. The measurement is then repeated with the rigid screen removed. This method produced good results for the materials where the screen could be introduced close to the surface, but with the willow wall barrier this was not possible.

The transmission through the rigid screen must be negligible. For sound frequencies of 500Hz and greater a wooden screen of 15mm thickness was adequate. For lower frequencies a more substantial screen would be necessary, which would be difficult to install and any increased thickness would increase inaccuracies due to the change in the length of the path of the reflected ray with and without the presence of the screen.

Since direct and reflected pulses have travelled different distances from the source the spectra obtained are not directly comparable. If spherical spreading from the source is assumed a single constant adjustment can be applied. However since this assumption may not be valid it was found to be more convenient to determine the direct pulse in a prior experiment in which the source to microphone distance was the same as the reflected path length from source to microphone via the absorbing surface. In this case direct division of the two spectra provides the pressure reflection coefficient for the surface ($R_p$), The absorption coefficient ($\alpha$) is given by

$$\alpha = 1 - R_p^{\,2}$$

## 5. EXPERIMENTAL RESULTS

Figure 2 shows the normal incidence absorption coefficient determined at 1/3 octave centre frequencies for a hard backed sample of wood and cement material, 100mm in thickness with a surface profiled to a depth of 25mm. It was clear during the measurements that results below about 500Hz were unreliable due to inadequate resolution of the signal from the background noise. These results of the impulse method are compared with measurements carried out in an impedance tube on the same material. Agreement between the two methods is reasonable. The differences between the results of the two methods can be attributed to the profiling of the surface of the sample. The scale of the profiling made it impossible to produce a fully representative sample for the impedance tube measurement.

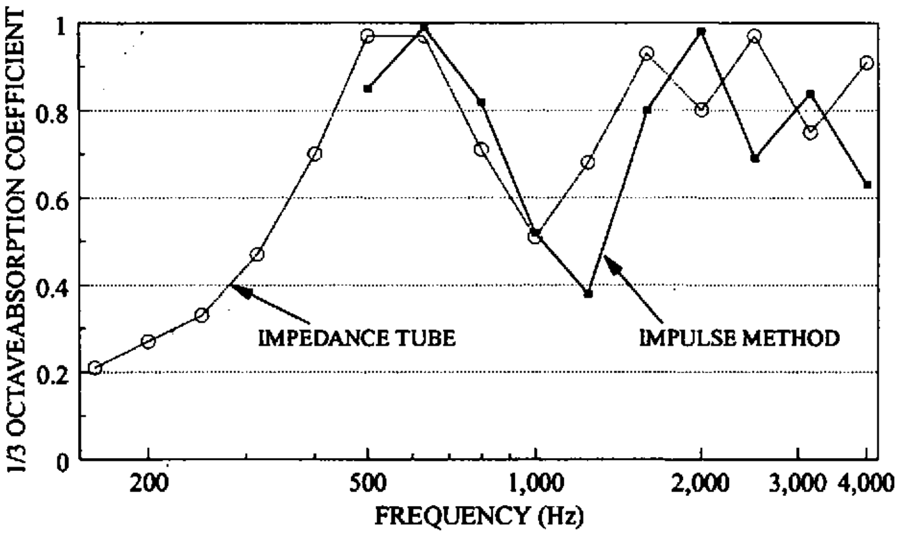


***Figure 2 - Normal incidence absorption coefficient for a wood and cement composite material measured by the impulse method and impedance tube method.***

Figure 3 shows results of the impulse method for a commercial volume absorber type barrier at 0° and 34° angle of incidence. The narrow band spectrum was combined into 1/3 octaves. The absorption coefficient changes with angle of incidence, as expected for a complex absorber of this type. However, the results were similar to the random incidence absorption coefficient provided by the manufacturer.

The impulse method has also been tried on a barrier with larger scale changes in structure; in this case a willow wall noise barrier. For this material results obtained were much less consistent and depended upon the surface character in the vicinity of the reflection point. For this type of construction this ranged from deep cavities through areas covered in fine twigs and leaves to closely woven areas.

Measurements were carried out at eight different positions over the surface. The 1/3 octave normal incidence absorption coefficient averaged over the eight positions is shown in Figure 4.

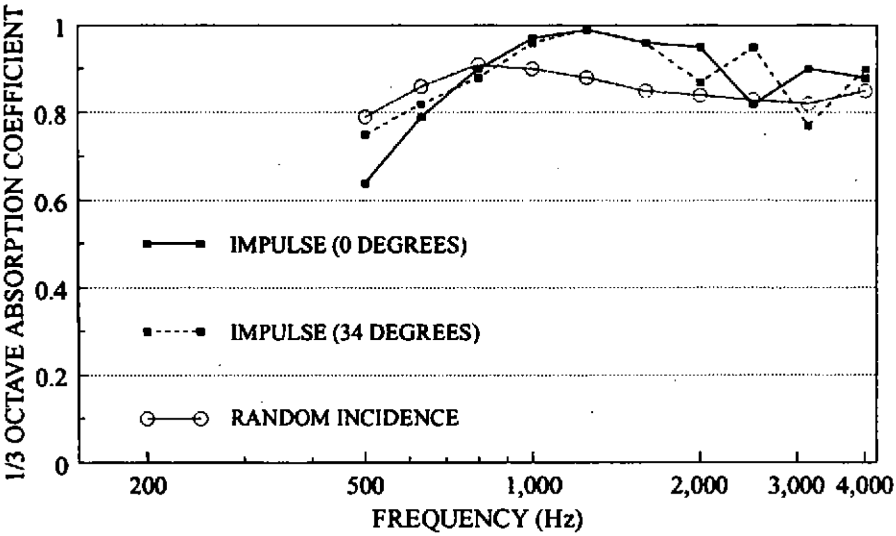


***Figure 3 - Absorption coefficient of a commercial volume absorber noise barrier measured at 0° and 34° angle of incidence.***

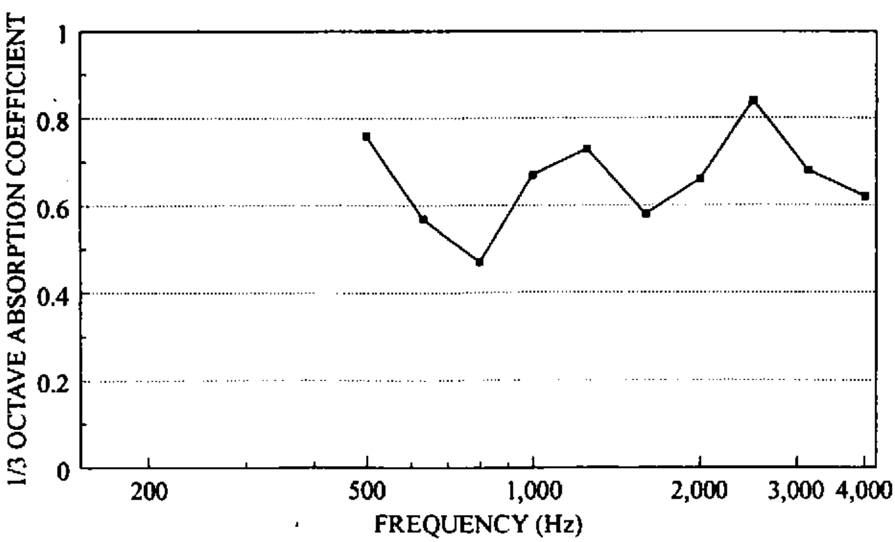


***Figure 4 - Mean absorption coefficient of a willow wall noise barrier measured at normal incidence.***

## 6. CONCLUSIONS

The need has been considered for a standard method of measuring the properties of absorbing materials on site. A method using an impulsive source of sound has been investigated. Using this particular method unreliable results for the absorption coefficient were obtained at frequencies below about 500Hz.

There are several important differences in results for absorption measured using the standard laboratory measurement in reverberation room and the impulse method.

a) The random incidence absorption coefficient is measured in the reverberation room method, were as the impulsive method determines the result for a specific angle of incidence.
b) Laboratory measurements provides an average value over the area of absorber installed. Results of the impulse method are related to a localised area around the reflection point.
c) Absorbers with profiled faces (eg. volume absorbers consisting of perforated metal bodes) scatter the incident sound in addition to absorption. The laboratory test measures energy extracted by the absorbing surface. The impulse measurement includes the scattered sound as an energy loss (or gain).

There is scope for further investigation and development of all the methods mentioned in this paper. However, it is not yet clear which method offers the most promise in terms of robustness, accuracy and breadth of application to form the basis of an acceptable international standard.

## 6. REFERENCES

[1] G R WATTS, 'Acoustic performance of traffic noise barriers: a state of the art review', Reference Book of the Eurosymposium on the Mitigation of Traffic Noise in Urban Areas, Nantes, 1992, pp223-250.

[2] D H CROMBIE, A T PEPLOW AND D C HOTHERSALL, 'Efficiency of absorbing screens in the presence of high sided vehicles, Proceedings of the Institute of Acoustics, 14(4), pp659-666, 1992.

[3] INTERNATIONAL ORGANISATION FOR STANDARDISATION, ISO-354-1985. Measurement of sound absorption in a reverberation room, 1985. Also BS 3638.

[4] W T CHU, 'Impedance tube measurements - a comparative study of current practices. Noise Con. Eng. J, 37(1), pp37-44, 1991.

[5] C HOWORTH, 'Sound propagation over rigid porous layers, PhD Thesis, Open University, 1991.

[6] D C WADDINGTON, 'Acoustical measurement using a two-microphone transfer function technique, PhD Thesis, University of Salford, 1990.

[7] M S ATWAL AND M J CROCKER, 'Measurement of the absorption coefficient of acoustical materials using the sound intensity method, 2e Congres International Sur L'Intensimetrie Acoustique. CETIM, Senlis, France, 1985, pp495-502.

[8] C CHARLES, D ABRAHAM AND J C PASCAL, 'Mesure in-situ de l'impedance acoustique des materiaux en fonction de l'angle d'incidence. 2e Congres International sur l'Intensimetrie Acoustique. CETIM, Senlis, France, 1985, pp495-502.

[9] P PICHETTI, R BRASCHI AND G BERO, 'Etude pour l'amelioration des proprietes phone-abosrbantes des tapis drainants et avec agile expansee et systeme automatique de mesure in-situ. Porte session reference book, Eurosymposium on the Mitigation of Traffic Noise in Urban Areas, Nantes, 1992, pp61-67.

[10] L'ASSOCIATION FRANCAISE DE NORMALISATION, 'Code d'essai pour la determination de characteristiques d'ecrans installes en champ libre, NF S 31-089, July 1990.

[11] M R SCHROEDER, 'Integrated impulse method measuring sound decay without impulses', J. Acoustic. Soc. Amer., 66, pp497-500, 1979.

[12] M GARAI, 'Measurement of the sound absorption coefficient in situ: the reflection method using periodic pseudo-random sequences of maximum length, Applied Acoustics, 39, pp 119-139, 1993.

[13] J S BOLTON AND E GOLD, 'The application of cepstral techniques to the measurement of transfer function and acoustical reflection coefficients', J. Sound Vib., 93 (2), pp217-233, 1984.