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IN SITU SOUND INTENSITY TECHNIQUE FOR DETERMINING SOUND TRANSMISSION THROUGH BARRIERS

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1. INTRODUCTION

There is some concern that timber noise barriers may leak sound especially after several years of exposure in the roadside environment. This loss of effectiveness may be due to warping and/or shrinkage of the timbers, the development of splits and cracks or vandalism.

The primary objective was to develop and validate a method of measuring the airborne sound insulation, or degree of sound leakage, in situ so that it would be possible to carry out a roadside survey of timber barriers to determine the nature and extent of any problem.

This paper describes the in situ sound intensity method and gives some results of measurements on timber panels located at two sites alongside the M25. The Paper also gives the results of testing the same panels in a laboratory in accordance with ISO 140/3 [1].

2. IN SITU MEASUREMENTS

Theory

At the ith one-third octave band frequency the airborne sound reduction index, R_i, is simply the difference between the average incident sound intensity $L_{I,o,i}$ and transmitted intensity $L_{I,t,i}$ levels measured normal to the barrier surfaces. ie

$$R_i = L_{I,o,i} - L_{I,t,i} \quad dB \quad \ldots \quad (1)$$

The average intensity flowing through a panel was obtained in situ by scanning with the sound intensity probe axis perpendicular to the plane of the panel. Because traffic is a time-varying noise source it was necessary to determine the incident intensity level $L_{I,o,i}$ simultaneously with measurements of the transmitted level $L_{I,t,i}$. It was possible to do this by continuous monitoring of the average sound pressure level, $L_{p,i}$, at the surface of a hard reflective plane. For a point sound source the value measured would be 6 dB higher than the normal component of incident intensity. For a line source such as traffic it can be shown that the sound pressure level is 8 dB above that of the normal component of intensity. Therefore the incident intensity from the traffic source, $L_{I,o,i}$, can be expressed as:

$$L_{I,o,i} = L_{p,i} - 8 \quad dB \qquad (2)$$

The predicted value of $L_{I,o,i}$ given by equation (2) was used in equation (1) to estimate the sound reduction index at various one-third octave band frequencies.

Method

The in situ technique adopted in this study was similar to that used by Carman et al [2] for measuring building facade attenuation. However in that study an external loudspeaker source was employed whereas in this study the traffic itself was used as the sound source.

The sound intensity incident on the traffic face of the barrier was estimated from the measurement of sound pressure levels using two 12mm diameter condenser microphones clamped in close contact with a hard, acoustically reflective surface. The microphone diaphragms were placed 0.3m from the edges of the panel enabling a reasonable sample of the sound pressure levels over the area to be obtained. The surface consisted of 0.9x0.9m chipboard 18mm thick overlaid with a hard plastic laminate. The reflective surface was suspended in contact with the traffic face of a barrier panel at approximately mid height. This arrangement was set up to one side of the position at which transmitted sound was measured.

Average sound pressure levels, L_{eq}, were measured using a portable PC based sound level measuring system. The levels at the two microphones were logarithmically averaged to obtain an estimate of the mean sound pressure level over the area of the panel. The sampling period for the sound pressure measurements was synchronised with the measurement of sound intensity using the scanning probe.

The sound intensity transmitted through the barrier was measured using a Bruel and Kjaer 4182 intensity probe and 2144 analyzer. The probe consisted of two phase matched microphones which were capable of resolving the very small differences in phase required to measure intensity. Clearly, to obtain the average intensity it was necessary to sample the intensity over the area being considered. For this purpose a grid covering an area 0.9x0.9m was constructed from a square metal frame with fine strings stretched across at 0.1m centres. The grid was suspended on the non traffic face of the barrier at the same height as the reflective surface used to estimate incident sound intensity. Scans with the probe were made in both vertical and horizontal directions as recommended in the draft guidelines [3]. Four scans were carried out with the probe perpendicular to the barrier face at a distance of approximately 100mm. Each scan took approximately 20s to complete. At each one-third octave band frequency from 100Hz to 5kHz the sound reduction index, R_i, was calculated using equation (1) above and an arithmetic average taken of the values obtained for the four scans.

After completing a set of measurements on one barrier panel the scanning grid was moved to the middle of an adjacent panel and again adjusted to be at the same height as the reflective panel on the traffic side. Measurements were then repeated so that over the two sites, A and B, measurements were made on a total of four panels.

3. LABORATORY MEASUREMENTS

The four barrier panels tested were demounted and tested according to ISO 140-3:1995. The panels were similar and were constructed from boards approximately 120mm wide and 20mm thick fixed with a single nail to each horizontal rail (see Figure 1). A gap of typically 15 to 20mm was left between adjacent boards. Cover strips approximately 60mm wide and 20 mm thick tapered down to 15mm were fixed centrally over the gaps and again attached by a single nail to the horizontal rails.

Tests were carried out by mounting the panels in an aperture 2.92 x 2.86m between two reverberant chambers. In one chamber a speaker provided a steady noise source with a continuous broad band spectrum from 100 Hz to 5kHz. A continually moving microphone was used to obtain an average of the sound pressure levels L_p in each room over a period of 64 s. A real time analyzer computed the one-third octave band sound pressure levels, $L_{p,i}$. Measurements were repeated with the speaker in a different position and the recorded levels were logarithmically averaged. The values of airborne sound reduction index, R_i, in each frequency band, i, were then calculated from the equation:

$$R_i = L_{p,1,i} - L_{p,2,i} + 10\log S/A \quad dB$$

where $L_{p,1,i}$ and $L_{p,2,i}$ were the average sound pressure levels in the source and receiving chamber respectively, S was the area of the test panel (m^2) and A was the equivalent absorption area in the receiving chamber (m^2).

Two panels, one from each site, were retested after being exposed to a suitable raised temperature in order to gauge the likely effect on sound transmission due to thermal expansion of the barrier elements in hot weather. To obtain an indication of the maximum temperatures achieved at the roadside, measurements of surface temperature of panels at each site were carried out on hot sunny days in July and August. The average panel temperatures recorded at site A and B were 46°C and 40°C respectively. In an attempt to reproduce these temperatures in the reverberation room a space heater was directed at the test panel prior to testing. During testing the average temperature for panel (i) was approximately 36°C (ie 10°C below that measured at site A) while panel (iii) was tested at a similar temperature to that measured at site B.

4. RESULTS

Figure 2 shows that good agreement, ie within approximately 2 dB, was obtained between measurements made in situ and in the laboratory in the frequency range 250Hz to 3.2kHz. This improved still further when the in situ results were compared with heated panels (see Figures 2(a) and (c)). The latter was a more valid comparison since the in situ measurements were all carried out on hot days in July.

There were some discrepancies at both high and low frequencies. At frequencies below 250Hz in situ measurements did not compare well with the laboratory measurements. This difference may be due to limitations in the intensity probe used in situ and measurement errors at low frequencies in the reverberation room. Above 3.2kHz some small adjustments to equation (2) are needed to allow for the lack of pressure doubling at the microphone surfaces on the traffic face of the barrier due to the fact that the centres of the microphone diaphragms were not exactly in the plane of the reflective panel surface. This was estimated to increase the measured sound reduction indices by approximately 1.6dB at 5kHz bringing it closer to the laboratory measurements for panel (i) from site A. At site B the measured sound intensity at 4kHz was relatively low and the pressure-intensity indicator for the sound field at the probe was too high indicating unacceptable measurement error for all but one of the scans. At 5kHz there was no net flow of sound intensity out of the panel and this precluded any measurement of the sound reduction index at this frequency. It is possible that the panels were slightly absorptive and extraneous noise from behind the barrier was entering the panel and producing a reversal of the intensity vector. For these reasons a full set of results are not given at 4 and 5kHz for site B (see Figures 2(c) and (d)).

The surface density was estimated to be approximately 10kg/m^2 which according to the Mass Law [4] should provide a sound reduction index of approximately 35dB at 1kHz. The measured values at this frequency were in the range 15-20dB. The reason for the reduced performance of the barriers was apparent on detailed visual inspection. In places gaps of several millimetres between the cover strips and the boards would have allowed sound leakage to occur.

5. CONCLUSIONS

1. The in situ sound intensity technique is considered to be an appropriate

method for determining the roadside performance of timber barriers.

2. The acoustic performance of the panels tested fell well short of the levels expected from a consideration of their surface density.

6. REFERENCES

[1] International Organisation for Standardardization, ISO 140-3, Measurement of sound insulation in buildings and of building elements - Part 3: Laboratory measurement of airborne sound insulation of building elements (1995).
[2] T.A.Carman, J.W.Sargent and L.C.Fothergill, Measurement of sound insulation of facades and facade elements - a comparison of the intensity technique with the traditional method, Proceedings of Noise'93, 53-58 (1993).
[3] International Organisation for Standardization, ISO/CD 140-5, Measurement of sound insulation in buildings and of building elements - Part 5: Field measurements of airborne sound insulation of facade elements and facades (1992).
[4] I.Sharland, Woods practical guide to noise control(Woods of Colchester, UK, 1992).

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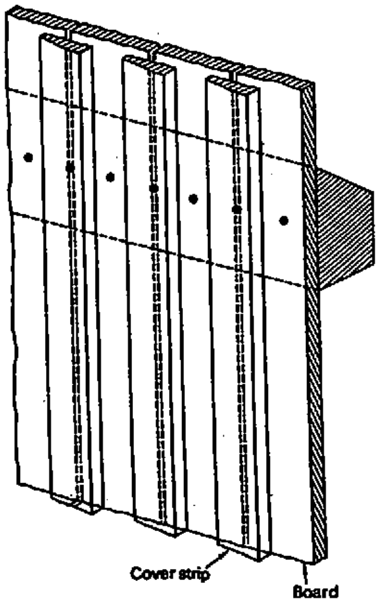

Figure 1: Construction of timber panels

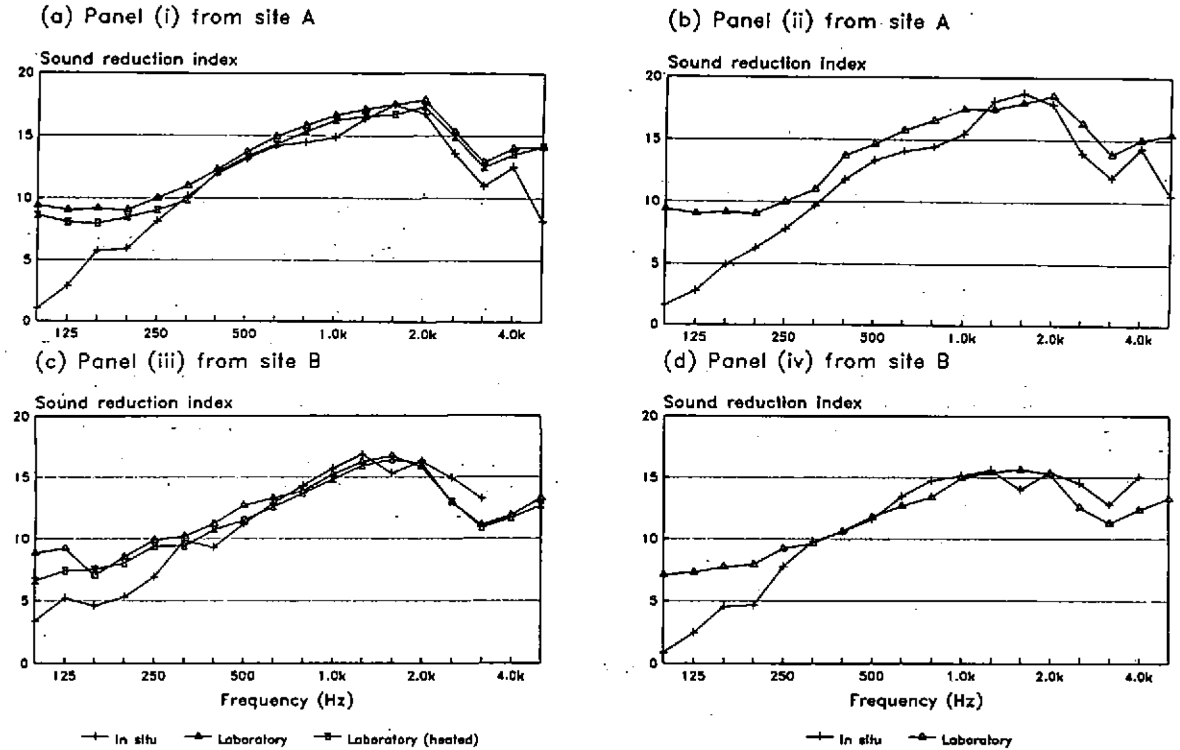

Figure 2: In situ and laboratory sound reduction indices