Proceedings of The Institute of Acoustics

THE MEASUREMENT OF SOUND TRANSMISSION AT CORNERS BY IMPULSE TECHNIQUES.

B.M.GIBBS University of Liverpool

J.C. DAVIES University of Aston

Introduction

In the transmission of structure-borne sound throughout large buildings useful attenuation results from the reflections which occur at structural discontinuities. Using simple bending wave theory Cremer (1) was able to calculate the reduction in vibration levels which occurs at changes in cross-section, material or direction. The application of this analysis to finite plates poses problems when describing vibration power flow between the plates. The problem can be circumvented by assuming that the wave fields on the plates are diffuse and that all angles of incidence of a bending wave at a junction are equally likely. The development of statistical energy analysis (S.E.A.) techniques (2) has allowed the incorporation of angular averaged transmission coefficients, calculated by the methods of Cremer (1) and Kihlman (3), into power flow equations. Methods exist which allow measurement of the normal incidence transmission coefficients of bending and longitudinal waves. Use is made of model structures consisting of rods or of rods and plates where all free ends are non-reflective terminations (4). This approximates to the semi-infinite structures described by Cremer.

Impulse methods

The method adopted in this investigation involved recording the time history of the plate response to an impulsive vibration source. By isolating the direct response signal from the delayed signals resulting from reflection at free edges the junction investigated can be considered as that of semi-infinite plates. Impulse methods have been applied here to a study of the transmission of bending waves at a corner junction of light-weight concrete plates. The velocities of sound waves that propagate on such plates are greater than that of sound in free air. This, coupled with dimensions of the order of a few metres, which are typical of building structures, makes signal separation difficult. The problem is further complicated when dealing with more than one wave field. The dispersive nature of bending waves could also appear to complicate the method of measurement. However, the relative small shifts in phase which occur in the path lengths investigated did not prove a problem. All information concerning frequency dependence of bending wave transmission was preserved.

Bending wave transmission at a corner

Curve (a) of figure 1 shows the variation at 500Hz of bending wave transmission coefficient with angle predicted using a modification of the theory of Cremer. Curve (b) gives the variation from similar theory derived from the work of Bhattacharya (5). Here each wave is considered individually and it is assumed that the component of in-plane displacement, parallel to the junction on each plate, is zero. So far the discussion has been in terms of reflected and transmitted energy intensity. Any measurement will be in terms acceleration, velocity or displacement amplitudes of the travelling waves and, close to the junction, these include the quasi-stationary near fields. Figure 2 shows the ratio of amplitudes squared calculated at the junction and also at a distance of 50mm (curves a) and b), respectively), at a frequency of 500 Hz. At a distance of 50mm (curve b) the influence of the near field is much reduced due to the field decaying with distance. The angular variation is much less obvious.

Any attempt to measure directly the ratio of square amplitudes should be able to:
a) measure the angular variation of vibration level on the reception plate,
b) measure level difference as a function of angle,
c) indicate total reflection of the transmitted bending wave,
d) show discontinuities corresponding to angles of total reflection of the in plane waves.

Experimental procedure:

Measurement was of a corner junction cast in lightweight concrete. The two plates forming the junction were cast in situ and were monolithic. The plates were constructed as thin as was practicable in order to produce slow bending waves. This, combined with relatively large plate dimensions, ensured adequate time delays. Thus on the 25mm plate the bending wave velocity is approximately 400m/sec at 1kHz and on the 400mm wall the corresponding velocity is approximately 500m/sec. An estimate is therefore given of the duration of signal that can be analysed, with one metre being equivalent to 2 milliseconds. The experimental arrangement is shown in figure 3, the main component of which is an event recorder. Transient signals can be recorded and stored in the digital memory and either replayed in analogue form or analysed on a digital computer using Fast Fourier Transform routines. The vibration source used was a speech coil from a loudspeaker bolted directly to the source wall. An amplified single square pulse was applied to the coil the duration of which was approximately 0.07 milliseconds. The system response was measured by means of accelerometer transducers. A number of methods of fixing were investigated. Best results in terms of reproducibility of both level and signature were obtained by means of a hand held probe screwed to the base of the accelerometer. Measurement was reproducable within $\pm$ 1dB with the additional advantage of good spatial resolution. In typical impulse responses it was found that reflected signals arrived before the time history of the initial pulse has finished. On introducing a low pass filter the time window between direct and reflected signals is increased. The filter used had a 3dB point at 1.25kHz and a roll off of 36dB/octave. Figure 4 shows a typical resultant response signal.

Results and Discussion

The following measurements were made:
1) The variation in level, on the reception plate with increased distance along a normal to the junction.
2) The variation in level on the reception plate as a function of angle.
3) The variation in level difference across the junction as a function of angle.

Measurements were made on both source plate and reception plate at the junction, thus eliminating time delays between the incident and reflected wave on the source plate and ensuring the maximum path difference between direct signals and signals reflected from free edges on both plates. A disadvantage is that the quasi-stationary near fields exert maximum effect at the junction and, as predicted by theory, are out of phase with the travelling waves. The resultant levels were therefore low. In measurement of angular variation, limits are set by the plate geometry. The ratio of plate thickness and the plate dimensions were such that the angle of total reflection (approximately 55^{o}) of bending waves could be included.

Figure 5 shows measured level on the reception plate at 500Hz as a function of angle. Measurements were made on a line parallel to the junction at a distance of 50mm and the angle was calculated from ray propagation. There is an obvious decrease in level with increased angle. Despite good angular resolution no clear indication is given of the discontinuities in the curve corresponding to total reflection of longitudinal and transverse waves. Figure 6 shows the variation in measured level difference as a function of angle, at a distance of 50mm from the junction. Also shown in the predicted level difference at a distance of 625mm from the neutral axis. Although theoeretical and measured values are of the same order of magnitude and, despite there being no obvious discrepancy, no clear indication is given of the dip in the curve corresponding to totals reflection of the inplane waves.

Conclusion

Measurements have been made of level both as a function of distance from the junction and a function of angle of incidence. Comparison of experimental results and theoretical predictions agree in general terms. The observed variation of level with distance from the junction is explained in terms of interference of travelling waves and decaying near fields. The variation of level as a function of angle of incidence shows trends which agree with the predictions of the theoretical work, however, there was not sufficient resolution to verify the predictions of variation of level due to total reflection of in-plane waves. Plane wave theory has at this stage been used to describe a circular wave from a point source. Problems are still being encountered in the separation of the reflected wave on the plate from the incident wave, and greater angular resolution must be introduced in order to investigate angles of total reflection of inplane vibration waves.

REFERENCES

(1) L. CREMER 1948 Department of Scientific and Industrial Research, Report No.1, Ser.B. Propagation of structure-borne sound.

(2) R.H. LYON and E. EICHLER 1964 JASA, 36 (7), 1344-54. Random vibration of connected structures.

(3) T. KIHLMAN 1970 J. Sound. Vib. 11 (4) 435-445. Sound transmission in building structures of concrete.

(4) G. KURTZE, K. TAMM and S. VOGEL 1955 Acustica 5, 223-233.

(5) M.C. BHATTACHARYA 1970. Ph.D. Thesis, The University of Liverpool.

The Measurement of Sound Transmission
at Corners by Impulse Techniques.

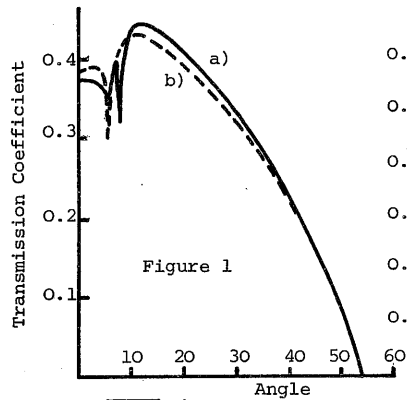

Figure 1

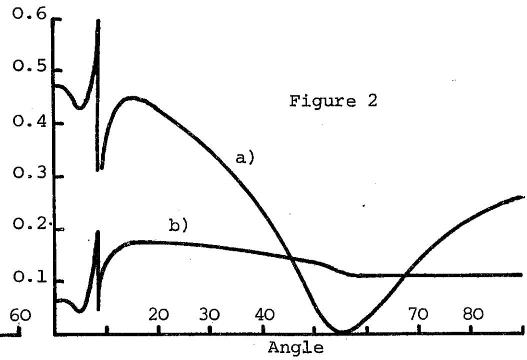

Figure 2

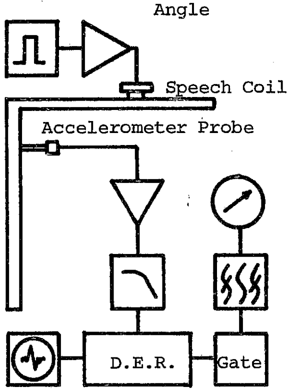

Figure 3

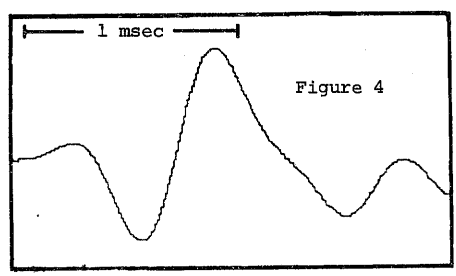

Figure 4

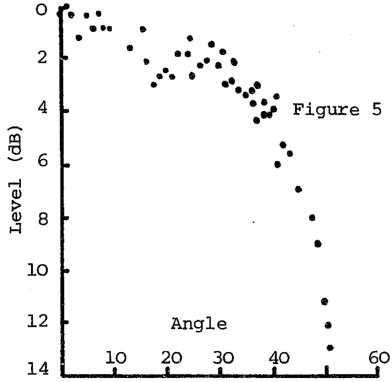

Figure 5

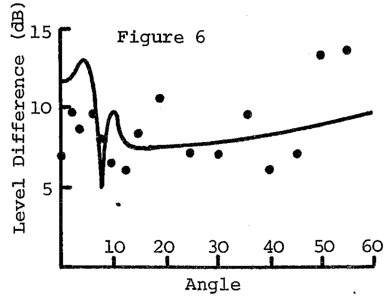

Figure 6