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ENERGY FLOW MEASUREMENT BETWEEN WALLS CONTAINING A WINDOW APERTURE

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1. INTRODUCTION

Openings such as windows or doors in flanking walls can be used to reduce the transmission of vibration between separating and flanking wall leaves and hence allow masonry flanking walls of low surface density to be used. This is advantageous because lightweight masonry inner flanking leaves can provide benefits in terms of thermal performance for flanking cavity masonry walls. Transmission of vibration between walls with a window aperture has been investigated using two different measurement methods.

2. MEASUREMENT METHODS

The test construction was a 90° corner junction between a separating wall and flanking wall in the BRE flanking laboratory. The flanking wall was $70kgm^{-2}$ aerated masonry and the separating wall was $166kgm^{-2}$ aggregate masonry. All walls were 100mm thick and had a plaster finish. A window aperture (920mm x 1050mm) was cut in the flanking wall at a distance of 250mm from the junction. Above the aperture was a steel lintel (1480mm x 143mm) covered with a plaster finish.

The spatial variation of vibration and structural intensity over the flanking wall was investigated using a measurement grid on the flanking wall surface. The separating wall was excited with a 0.45kg plastic headed hammer which was used to hit the wall approximately 5 times per second over a 20 second period. Source wall vibration was measured using two third octave filter dual-channel analysers to allow four accelerometer signals to be used in the calculation of the temporal and spatial average energy of the source wall. The four accelerometers were positioned at distances >0.5m from the boundaries and these positions remained fixed for the experiment. The source position was >0.5m from the boundaries and >0.8m from the accelerometers. Structural intensity measurements on the receiving wall were taken in the x and y direction simultaneously with two structural intensity probes using two third octave filter dual-channel analysers. Each structural intensity probe consisted of a two accelerometer linear finite difference array[1,2] using 50mm separation. Probe switching was carried out at each of the structural intensity measurement positions to remove low frequency phase mismatch error. The thin plate limiting frequency for the inner flanking leaf was 1187Hz and therefore measured structural intensity data was only valid below the 1.25kHz third octave band.

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The spatial average value for the Coupling Loss Factor (CLF) between the separating and flanking wall was determined using two different methods:

Method 1: The CLF was determined from measured wall vibration and structural intensity. This method calculates the CLF from the fundamental SEA equation.

$$\Pi_{12} = \omega\eta_{12}E_1$$

Structural intensity measurements in the x direction were used to determine the net power flow across a measurement line, parallel to the junction and at a short distance from that junction on the receive wall[3]. This method requires the measurement line to be sufficiently close to the junction to measure all coupling losses whilst remaining in the far-field to satisfy the structural intensity measurement assumption.

Method 2: The CLF was determined from measured wall vibration and damping. With knowledge of the Total Loss Factor (TLF) of the receiving subsystem and the Energy Level Difference (ELD) between the source and receiving subsystems it is possible to infer the CLF assuming that there is only one dominant transmission path, the direct path. By equating the power input to the receiving subsystem from the source subsystem, with the power lost from the receiving subsystem, the CLF can be calculated.

$$\eta_{12} = \eta_2 \frac{E_2}{E_1}.$$

The ELD was measured with a plastic headed hammer to provide a single impact as outlined in the draft CEN standard[4]. The integration time used for these single impact measurements was 2s. Structural reverberation times to calculate the TLF were measured using reverse filter analysis[5] with backwards integration. The CLF determined using Method 2 above the thin plate frequency limit takes account of coupling due to conversion of bending waves to in-plane waves and back to bending waves. Another advantage of Method 2 compared to Method 1 is that there is no upper frequency measurement limit due to thin plate bending wave theory which limits the use of the structural intensity probe. The disadvantage of Method 2 is that it does not discriminate against indirect transmission paths.

3. DISCUSSION

Measured structural intensity vectors on the flanking wall with and without the aperture in the 250Hz third octave band are shown in Figure 1 along with more detailed structural intensity data around the aperture.

On the flanking wall without the aperture there is clearly defined net energy flow away from the junction. This array of vectors then becomes more disordered in the region between the middle of the wall and the opposite wall junction with some energy flow towards the top of the wall. The boundary at the top of the wall is a straight junction which connects to another flanking wall of identical material and dimensions. All other boundaries are corner junctions connected to walls of different materials hence the straight junction provides the path of 'least resistance' for the flow of energy across the flanking wall.

On the detailed structural intensity vector map around the aperture there is clearly defined net energy flow below the aperture with less uniformity on the lintel.

The vibration contour plots for the flanking wall without the aperture indicated that there was a significant decrease in vibration level with increasing distance from the separating and flanking wall junction at frequencies above the 1.6kHz third octave band. The contour plot in Figure 2 shows the decrease in vibration level in the 5kHz third octave band in terms of the velocity level difference between the separating wall and the flanking wall. The measured vibration level for each column in the measurement grid was averaged and the reduction in vibration level across the flanking wall for third octave bands between 1.6kHz and 5kHz is shown in Figure 3. Above the 1.6kHz third octave band, the near-field was expected to be insignificant at all measurement grid positions. The decrease in vibration level with distance suggests that the propagating bending wave field is stronger than the reverberant field.

The measured and predicted decrease in vibration level data across the flanking wall in the 5kHz third octave band is shown in Figure 4. Predicted data was determined using thick plate theory with a Poisson's ratio value of 0.3 and Internal Loss Factor (ILF) values of 0.01, 0.02 and 0.03. For concrete aggregate, 0.01 is accepted as a typical value for the ILF, however, for the aerated concrete flanking wall, measured and predicted data showed closest agreement using an ILF of 0.03. The upper frequency limit for SEA subsystem size from Lyon[6] using an ILF of 0.03 was found to be in the 1.25kHz third octave band using bending wave thick plate corrected group velocity for the maximum flanking wall dimension 4.04m. The attenuation with distance implies that there may be an upper frequency limit to the applicability of SEA with plastered aerated concrete masonry walls of dimensions typical in dwellings. With spatial averaging this could be insignificant due to potential accelerometer fixing errors and material/construction variations at frequencies above the 1.25kHz third octave band.

The difference between CLF Methods 1 and 2 between the separating and flanking walls using the 95% confidence interval is shown in Figure 5 with and without the aperture. Between 100Hz and

630Hz the 95% confidence intervals overlap and Method 2 using structural intensity measurements near the boundaries can be considered valid. Between 800Hz and 1kHz the 95% confidence intervals no longer overlap and it is possible that the structural intensity measurement is in error due to the measurement positions being in close proximity to the wall and aperture boundaries.

Figure 6 shows the change in CLF due to the introduction of the aperture in the flanking wall using Method 2.The estimated change in CLF of -3dB was found by assuming that the aperture effectively decreases the wall junction coupling length by the height of the aperture. The estimation is reasonable when the distance between the junction and the aperture is less than a quarter of the bending wavelength on the flanking wall. This occurred at a frequency f_E (427Hz for the flanking wall) in the 400Hz third octave band. Below f_E measured data fluctuates around the -3dB estimate for the decrease in CLF. It is also noted that there are individual third octave bands where the CLF is significantly increased by the introduction of the aperture. Above f_E the decrease in CLF is significantly greater than the estimated value.

ACKNOWLEDGEMENT

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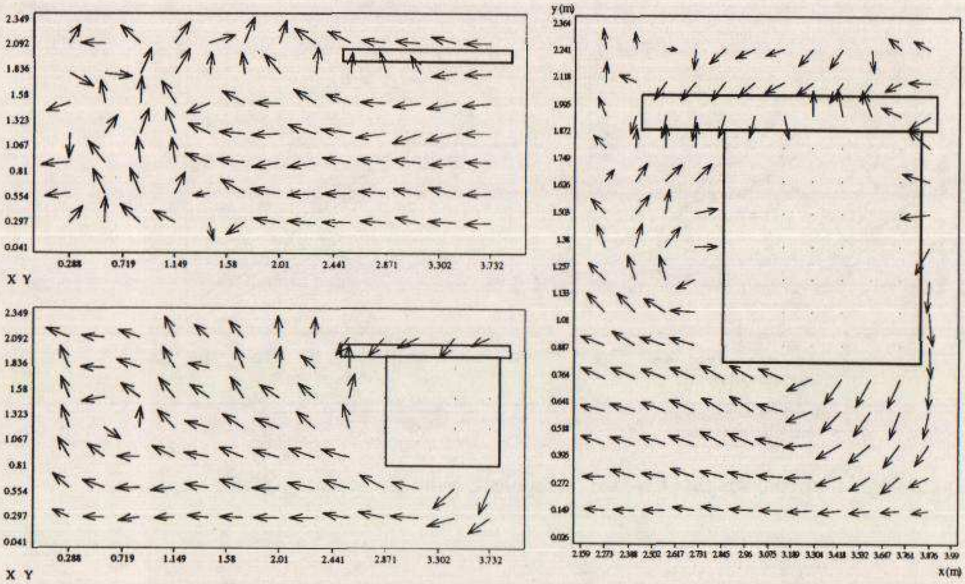

Figure 1: Measured structural intensity vectors (250Hz)

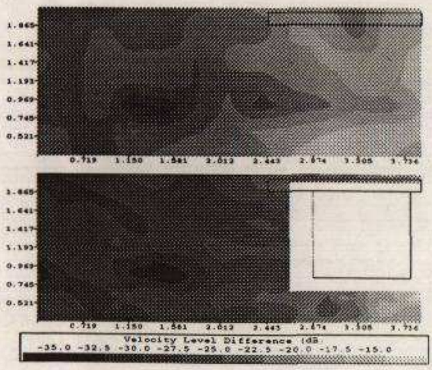

Figure 2: Vibration contour plot (5kHz) for the flanking wall with and without aperture

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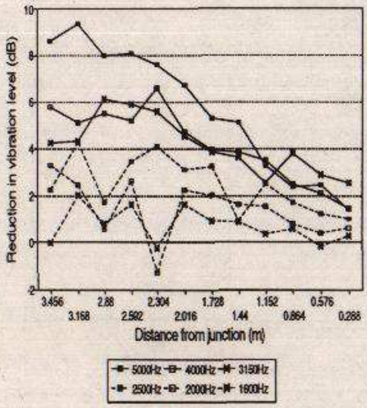

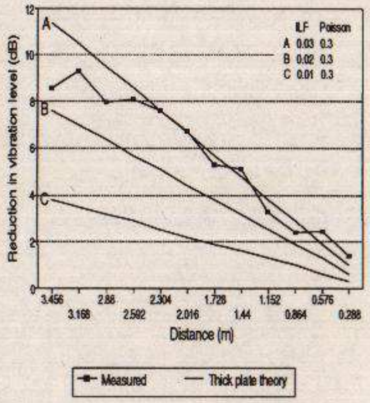

Figure 3: Vibration decrease (1.6-5kHz) Figure 4: Vibration decrease (5kHz)

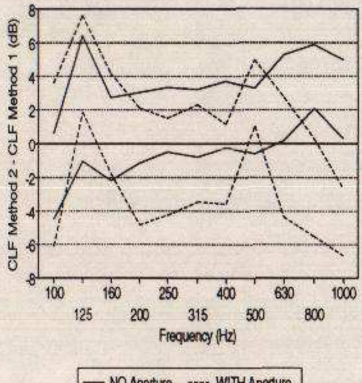

Figure 5: Difference between CLF measurement methods 1 and 2 (95% confidence intervals) Separating wall to flanking wall

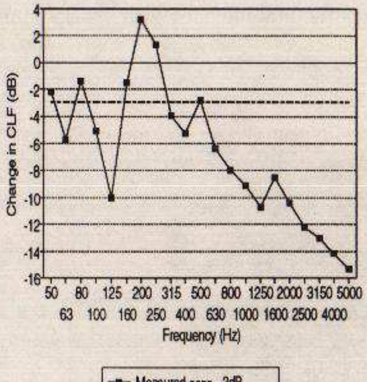

Figure 6: Change in CLF due to window aperture

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