USING SOUND INTENSITY MEASUREMENTS TO DIAGNOSE THE CAUSES OF POOR SOUND INSULATION

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1. Introduction

When new buildings or conversions fail to meet the sound insulation required by the Building Regulations there is a need to identify which walls or floors require remedial works in order to rectify the situation.

BRE Acoustics Centre has developed a field test method using sound intensity to identify which walls and/or floors are the cause of poor sound insulation. This method then allows decisions to be made on specific remedial works to achieve the required sound insulation.

This paper describes a method of assessing sound intensity measurements that are used to investigate sound insulation in the field through use of the parameter ΔE. The paper then presents results from consultancy work as a case study to show how sound intensity measurements can be used to provide sufficient information to rectify the causes of poor sound insulation.

2. Objectives

In the laboratory, one of the objectives with sound intensity is to obtain values of the sound reduction index, R of a separating element with suppressed flanking transmission.

In the field, the objective is not to obtain precise single number quantities for sound insulation, but to identify which wall and /or floor elements contribute significantly to the sound field in the receiving room. Sound intensity measurements are often complicated by (i) the reverberant field in the receiving room (ii) radiation from other surfaces (iii) influence from outside sources such as traffic and (iv) practical considerations when attempting to reduce the effects from (i) to (iii) above. However, in the majority of cases, sound intensity measurements yield sufficient information to make decisions on the appropriate remedial treatment.

3. Field Indicator F_{pI} and the measurement environment

A measure of the accuracy of intensity measurements in a reverberant space can be obtained by using the surface pressure-intensity indicator (field indicator) F_{pI}, defined in [1] as shown in Equation 1.

Equation 1

$$F_{pI} = L_p - L_{In}$$

where L_p is the time averaged sound pressure level and L_{In}, is the time averaged normal sound intensity level. Theoretically, intensity measurement of a plane wave propagating in the direction of measurement in a non-reverberant space, with zero phase mismatch between the probe microphones should give an F_{pI} of 0dB. However, this is unlikely to occur in practice.

The laboratory standard [1] states that an intensity measurement is not satisfactory if F_{pI} > 10dB for a sound reflecting test specimen. This criterion can often be satisfied in the field for at least two surfaces when there is sufficient absorption in the receiving room. Although it is often difficult to satisfy this criterion at all frequency bands, careful measurements can still yield sufficient information to identify the dominant radiating surfaces.

4. Assessment of intensity measurements

The scanning intensity method used in the field measurements is adapted from the new laboratory standard BS EN ISO 15186-1:2000 Acoustics - Measurement of sound insulation in buildings and of building elements using sound intensity - Part 1: laboratory conditions [1].

In the field it is necessary to ensure that all dominant radiating surfaces have been measured. This can be achieved by calculating the difference between the sound energy in the room derived from intensity measurements with that obtained from sound pressure measurements [2]. This difference is denoted ΔE in dB and is given by Equation 2. When ΔE is zero this indicates that all significant radiating surfaces have been included and the intensity measurements are accurate.

Equation 2

$$\Delta E = \left[10\lg\sum_{i=1}^{N}10^{\frac{L_{w,i}}{10}} + 10\lg\left(\frac{4}{A}\right)\right] - \left[L_2 + 10\lg\left(1+\frac{S_T\lambda}{8V}\right)\right]$$

where:
$L_{w,i}$ is the sound power level radiated by surface i (dB re 10^{-12}W)
A is the equivalent absorption area in the receiving room (m^2)
S_T is the total area of all the boundary surfaces in the receiving room (m^2)
λ is the wavelength of sound in air (m)
V is the room volume (m^3)
L_2 is the sound pressure level in the receiving room (dB re 20μPa)

In order to assess typical ΔE values in the field, it is useful to compare field data with measurements made under laboratory conditions in the BRE flanking laboratory at frequencies between 50Hz and 3150Hz obtained using the criterion $F_{pI} \leq 10$dB. Figure 1 shows the mean, 95% confidence interval and the range for ΔE data from fourteen tests carried out in the BRE flanking laboratory along with individual results from recent field measurements. (N.B. The results from the BRE flanking laboratory tests have been submitted for inclusion in the draft intensity standard "ISO/CD 15186-2:2001. Acoustics - Measurement of sound insulation in buildings and of building elements using sound intensity - Part 2: In-situ conditions")

The laboratory results show that in the presence of flanking transmission, when all significantly radiating surfaces have been measured, ΔE is typically -1dB ±1dB between 400Hz and 3150Hz. In theory a value of 0dB should be achieved when all surfaces have been measured, but this seldom occurs. A negative bias occurs at higher frequencies when some of the remaining surfaces cannot be measured, due to (i) the radiated sound power from other surfaces and (ii) the reverberant field. A bias may also occur at lower frequencies in a non-diffuse sound field, where the Waterhouse correction term does not apply.

The field results tend to have a large scatter in comparison with the BRE flanking laboratory data. At frequencies above 400Hz, time constraints in the field often prevent measurement of all the radiating surfaces, which gives rise to increasingly negative ΔE data as shown in Figure 1.

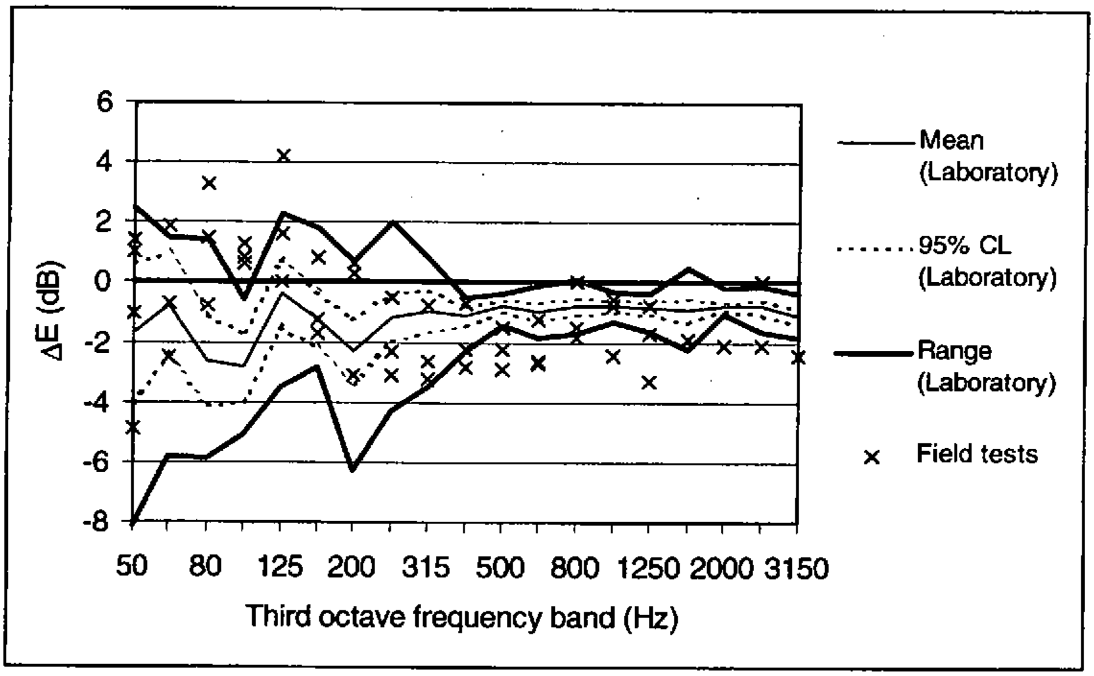

Figure 1: ΔE data from the BRE flanking laboratory and field measurements.

5. Case Study

In this case study, a separating wall had been tested to ISO140 [3] and was found to have poor sound insulation. A company had tried to rectify the problem by treating the separating wall on one side using a plasterboard laminate with a resilient layer. However, further tests revealed that the construction was still under-performing. BRE Acoustics Centre were then called in to specify suitable remedial treatments to improve the sound insulation.

The frequencies which primarily affected $D_{nT,w}$ lay in the region 160Hz to 500Hz. Several surfaces (Figure 2) were scanned using an intensity probe fitted with a 50mm spacer. After having measured each of the selected walls and also the window area, a calculation of ΔE indicated that not all of the significantly radiating surfaces had been measured. A plot of the measured sound power levels from each surface (Figure 3) passing the criteria given in [1] shows how the rating of the sound insulation was being governed primarily by the ceiling (S6), as well as the flanking cavity wall (S2). It is useful to note that an initial aural assessment did not identify the ceiling as a main source of transmission. Due to the sensitivity of the ear at high frequencies, attention was drawn towards the flanking wall, which radiated sound in this frequency region. Treatment of this wall alone is unlikely to have sufficiently improved the sound insulation.

BRE Acoustics Centre recommended treating the ceiling with an independent lining and filling part of the flanking wall cavity with mineral fibre (the latter was due to a restriction from the client that the floor area was not to be reduced, which prevented the flanking wall from being lined). Due to an obstruction in the cavity caused by a concrete pillar (See Figure 2), the cavity could only be filled in an area to the left of the pillar (when facing the wall from inside). Much of the radiated sound power from the flanking wall was found to be concentrated in the area to the right of the pillar (See Figure 2, area a). Improvements in high frequency sound insulation were therefore limited.

Figure 4 shows the sound insulation curves of two flats (Flats A & B) prior to treatment and in two flats (Flats C & D) after treatment of the ceiling and the cavity. These results clearly demonstrate the significant improvements in sound insulation at low frequencies where the ceiling was radiating significantly, and at high frequencies where the flanking wall was radiating significantly.

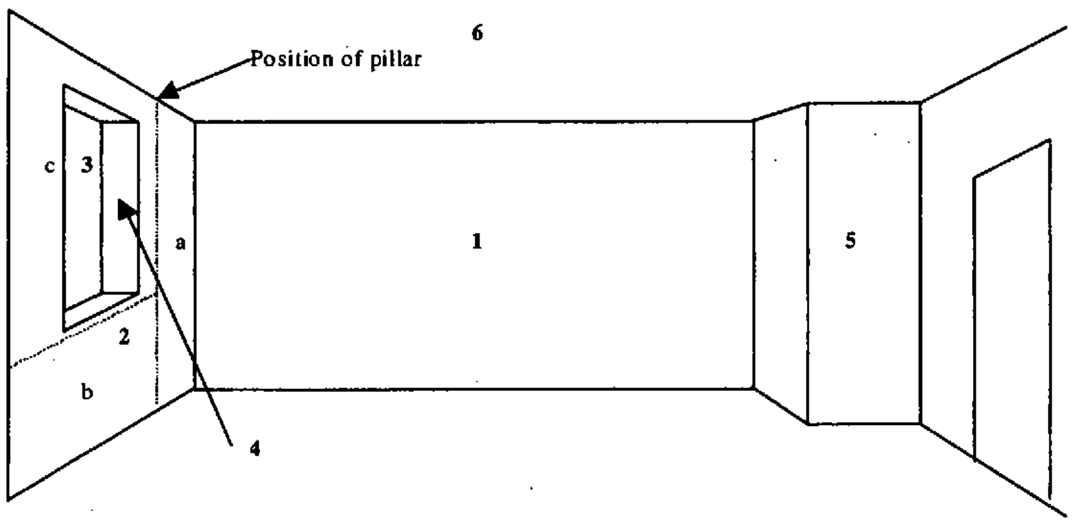

Figure 2: Case study: Surfaces 1 – 6.

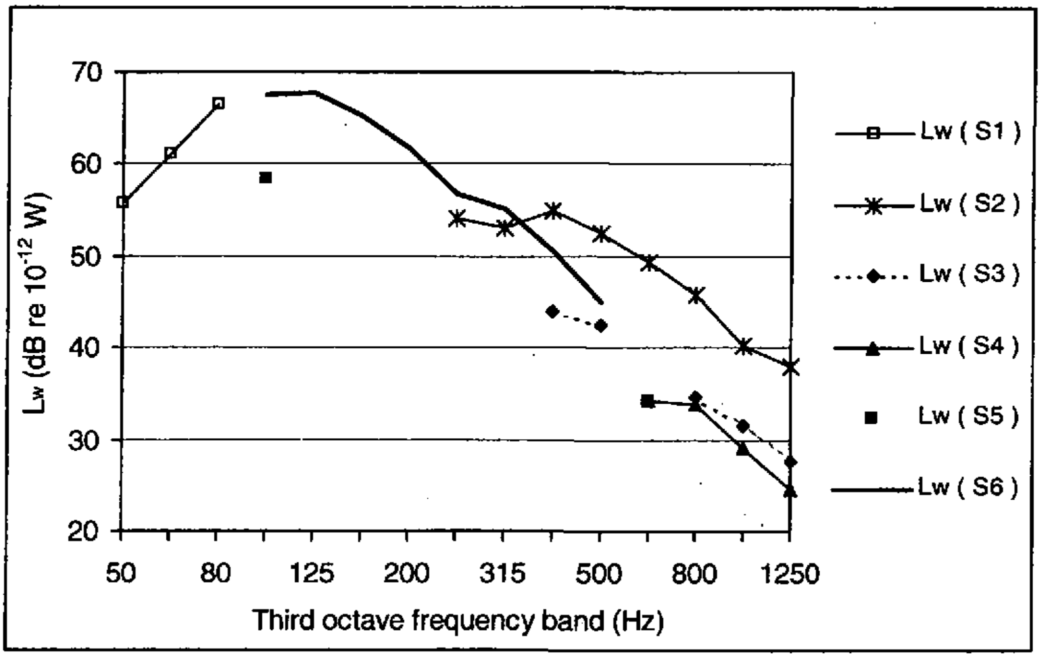

Figure 3: Case study: Sound power levels measured using sound intensity.

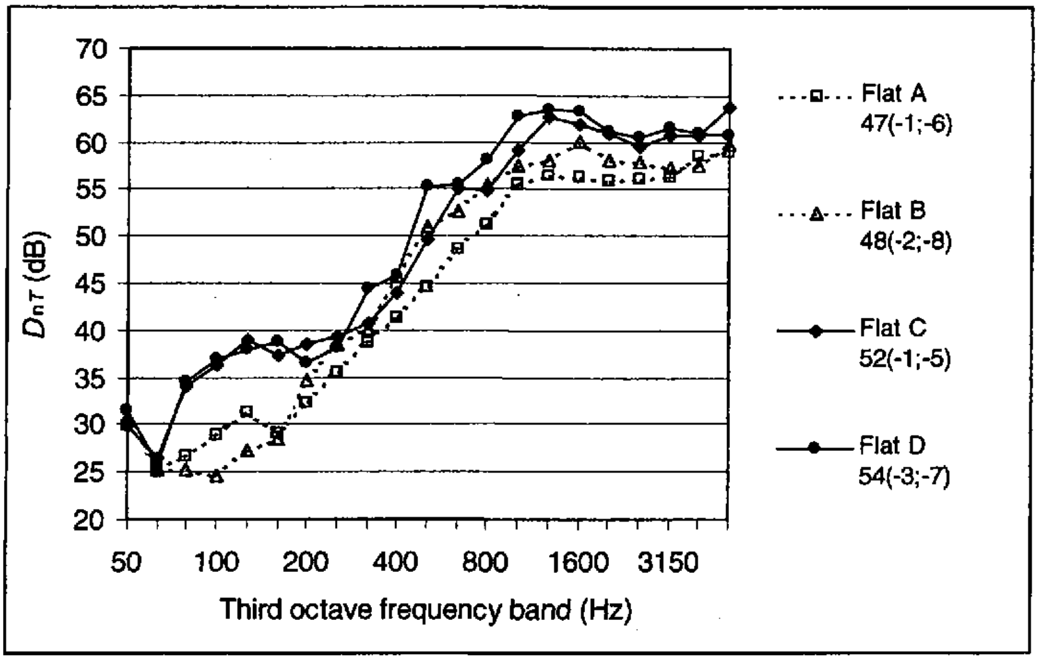

Figure 4: Case study: Airborne sound insulation measurements to ISO 140-4.

6. Conclusions

It is crucial to be able to assess sound intensity measurements that are used to investigate sound insulation in the field. This can be achieved through use of the parameter ΔE.

A case study on consultancy work carried out by BRE Acoustics Centre demonstrates how sound intensity measurements can be used to provide sufficient information on which to rectify the causes of poor sound insulation in the field. This allows targeted application of remedial treatments on walls and/or floors, which is particularly beneficial in terms of cost.

7. References

1. **BS ISO 15186-1:2000**. Acoustics- Measurement of sound insulation in buildings and of building elements using sound intensity - Part 1: laboratory conditions
2. **C. Hopkins and T. Emmanuel.** Sound intensity measurements for building acoustics. Institute of Acoustics Bulletin. July/August 1996.
3. **BS EN ISO 140-4:1998,** Acoustics - Measurement of sound insulation in buildings and of building elements - Field measurements of airborne sound insulation between rooms.