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MEASUREMENT OF THE SOUND INSULATION OF FACADES AND FACADE ELEMENTS - A COMPARISON OF THE INTENSITY TECHNIQUE WITH THE TRADITIONAL METHOD

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1. INTRODUCTION

Much research has been carried out into the use of the sound intensity technique for measuring sound insulation of partitions [1-5], but less has been published on the use of the technique for the measurement of facade insulation. This paper describes some experiments which have been carried out to compare measurement of window and facade sound insulation using the intensity technique and the sound pressure method. In each case the experimental methods are described, and the results of the investigations are presented.

2. PRINCIPLES OF THE TWO METHODS

The sound insulation of a window is usually described in terms of its sound reduction index, which is defined as ten times the common logarithm of the ratio of the sound power W_1 incident on the window to the sound power W_2 transmitted through the window. It is denoted by R:

$$R = 10\ lg\left(\frac{W_1}{W_2}\right)\ dB \tag{1}$$

2.1 Traditional Sound Pressure Measurement Method

The traditional method of measuring the sound insulation of a window is to obtain the incident and transmitted sound power by measurement of the sound pressure outside the window and in the receiving room. In the field the sound power measured in the room will be the total sound power W_3 transmitted into the receiving room (not just the sound power transmitted through the window) and so the measured sound insulation is called the apparent sound reduction index and is denoted by R'.

$$R' = 10\ lg\left(\frac{W_1}{W_3}\right)\ dB \tag{2}$$

The noise source may be road traffic or a loudspeaker. The formula to calculate R' from sound pressure level measurements depends on the noise source that has been used and the position where the incident pressure is measured. A different subscript is added to the R' in each case to indicate which measurement method has been used. The general form of the formula is:

$$R'_{subscript} = L_1 - L_2 + 10\ lg\left(\frac{S}{A}\right) - X\ \ dB \tag{3}$$

where L_1 is a measurement of the incident sound pressure level,
L_2 is the mean sound pressure level in the receiving room
S is the area of the test specimen,
A is the equivalent absorption area of the receiving room, calculated from measurements of reverberation time, and
X is a correction arising from the different possible noise sources and measurement locations.

2.2 Sound Intensity Method
The principle of the sound intensity method is to obtain the sound power transmitted by the whole facade or a facade element by direct measurement of the sound intensity being radiated by it. Using this method, the sound reduction index of the window alone can be measured in the field. Measurements of the sound reduction index for a facade can also be carried out by measuring the sound intensity radiated by the whole facade, i.e. wall and windows.

To use this technique to measure the sound reduction index of a window, the noise source is a loudspeaker directed at 45° to the window (the intensity technique cannot be used with traffic noise as the source and receiving levels cannot be easily synchronised). The sound pressure level incident on the window is measured in order to calculate the incident sound power as before, and the mean normal intensity is measured over a surface enclosing the window, to calculate the sound power transmitted by the window. The sound reduction index of the window is then given by [6]:

$$R_{I_{45^\circ},c} = L_s - 7.5 - \left(L_{I_n} + 10\ lg\left(\frac{S_m}{S}\right)\right) + 10\ lg\left(1 + \left(\frac{S_{b_2}\lambda}{8V_2}\right)\right)\ \ dB \tag{4}$$

where L_s is the average sound pressure level on the surface of the window,
L_{I_n} is the average normal sound intensity over a measurement surface enclosing the window,
S_m is the area of the measurement surface,
S is the area of the window
S_{b_2} is the area of all the boundary surfaces in the receiving room,
V_2 is the volume of the receiving room
λ is the wavelength of the midband frequency.

The last term in the equation is a room correction which is used in order to simulate the result given by the traditional laboratory method. It arises from the fact that in the traditional method measurements are made only in the central region of the rooms, and the increase in pressure near the walls in both rooms is assumed to cancel out [5].

The intensity method can also be used in the opposite direction, using a loudspeaker inside the room as the noise source, and measuring the sound intensity radiated by the window to calculate the transmitted sound power. The incident sound power is calculated from measurements of the sound pressure level in the room. The sound reduction index of the window is then given by [6]:

$$R_{I,e} = L_{p_1} - 6 - \left(L_{I_n} + 10\ lg\left(\frac{S_m}{S}\right)\right) + 10\ lg\left(1 + \frac{S_{b_1}\lambda}{8\ V_1}\right)\ dB \qquad (5)$$

where L_{p1} is the average sound pressure level in the source room
S_{b1} is the area of all the boundary surfaces in the source room,
V_1 is the volume of the source room.

Since the room correction for the receiving room can no longer be used, the room correction for the source room is used instead [5].

3. INVESTIGATIONS

3.1 Laboratory simulation of field measurement.

The first investigation was carried out as part of a laboratory simulation of field measurements of the sound insulation of windows.

The experiment was carried out between an anechoic chamber where the sound field was a free field, simulating outdoor conditions, and a reverberant chamber where the sound field was diffuse, simulating ideal indoor conditions. The rooms were separated by a thick double leaf dense concrete wall containing a $14m^2$ aperture. A typical external cavity wall was constructed in the aperture, consisting of one leaf of 100mm brickwork and one leaf of 100mm blockwork, separated by a 50 mm cavity, with a wooden-framed single-glazed window. Removable secondary glazing was also installed and tests were carried out with and without the secondary glazing.

At the start of the investigation it was discovered that the insulation of the test wall was not good enough for the sound transmitted through the wall to be insignificant compared with that transmitted by the window, and so the two techniques could be compared directly only by considering the whole facade.

The experimental methods used were based on methods set out in a committee draft of the revision of ISO 140 part 5: Field measurements of airborne sound insulation of facade elements and facades [6].

3.1.1 Sound Pressure Method. A loudspeaker producing broadband noise was suspended in the anechoic chamber, directed at the centre of the window at an angle of incidence of 45°. The sound pressure level on the surface of the window was measured at six positions by microphones fixed vertically on to the window, connected to a Norsonics NE830 real time analyser. In addition sound pressure level measurements were made on the surface of the wall. The average surface sound pressure level L_{1s} was obtained by taking the mean of these measurements. The sound pressure level in the receiving room (the reverberant chamber) L_2 was measured by microphones suspended at six positions throughout the room. Measurements of the reverberation times in the receiving room were also made at the same six positions. The sound reduction index of the facade was calculated using the formula:

$$R'_{45^\circ} = L_{1_s} - L_2 + 10\ lg\left(\frac{S}{A}\right) - 1.5 \quad dB \tag{6}$$

The area S was taken to be the area of the whole facade (14.0 m²).

3.1.2 Intensity Method. The noise was produced in the anechoic chamber and measured on the surface of the facade in exactly the same way as for the sound pressure method. The sound intensity radiated into the reverberant chamber by the window and surrounding wall was then obtained using a B&K type 3519 sound intensity probe with a 25mm microphone spacing to measure the mean intensity level L_{In} over a measurement surface enclosing the whole test facade. Acoustic foam blocks were placed behind the operator to reduce the reverberant field.

The facade was mounted within a wooden surround which formed a niche enclosing it on four sides. The measurement surface was chosen to be a flat surface within the niche opening, 150 mm from the facade. The measurement surface was divided into sub-areas of 1 m², and the probe was scanned over each sub-area 4 times, twice horizontally and twice vertically, using a scanning speed of about 0.2 m/s. The separation of the scanning lines was about 0.15 m. A measurement for the mean intensity over each area was obtained by comparing both horizontal scans with both vertical scans for that area and taking the average of the horizontal and vertical scan with the smallest deviation at each frequency.

The mean intensity over the measurement surface was obtained by taking the average of the values for each sub-area. The sound reduction index for the facade was then calculated from Eq. (4), where S, the area of the facade, and S_m, the measurement area, were equal.

3.1.3 Results. Fig 1 shows the sound reduction index of the facade with the single glazing only. It can be seen that there is very good agreement between the results obtained with the two measurement methods over the whole frequency range. Fig 2 shows the results when the secondary glazing was added, and again it can be seen that the agreement is very good. The weighted sound reduction indices were calculated for both measurement methods and the results are given in Table 1. In both cases there was only 1 dB difference between the two values.

Fig. 1 Sound reduction index of facade with single glazing installed

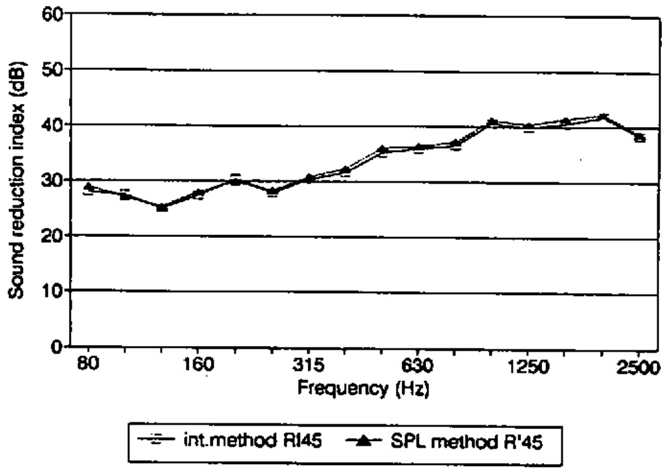
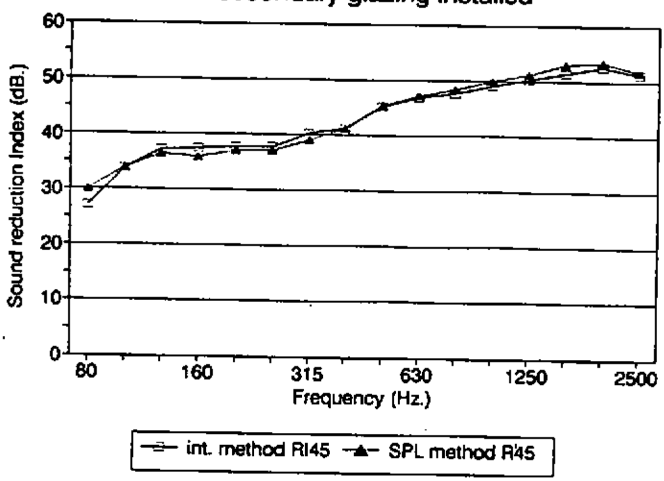


Fig.2 Sound Reduction Index of a facade with secondary glazing installed



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3.2 Field investigation

This investigation was to compare the sound reduction index of a window measured in the field, using the two techniques. The window was 4 mm single glazing in a wooden frame and the facade wall was solid brick, 23 cm thick, facing a residential road.

3.2.1 Intensity Method. The intensity measurements were carried out in the reverse direction to the laboratory investigation, with the noise source being placed inside the room, and the intensity measurements being made on the outside of the facade. The facade (wall and window) was divided up into sub-areas and the mean intensity was measured for each sub-area, using the four-scan technique. The measurements were made using a Norsonics 216 intensity probe connected to the Norsonics 830 real time analyser. In addition an enclosed surface was measured around the window only. As the measurements were being made outside, no foam blocks were required, however care had to be taken to ensure that the measurements were not affected by noise from passing vehicles.

It soon became clear that the sound radiated from the wall was insignificant compared with the sound radiated by the window and the measurements of the intensity radiated by the wall were unreliable as the field indicator was too high. Calculations were therefore carried out using only the mean intensity level measured over the surface enclosing the window (L_{In}).

The sound pressure level in the source room (L_{p1}) was obtained from measurements at six positions in the room, and the sound reduction index was calculated for the window alone from Eq. (5).

3.2.2 Sound Pressure Measurement. The window to be measured faced on to a road, and so road traffic was used as the noise source. As it had been shown that the wall did not contribute significantly to the sound transmitted by the facade, it was acceptable to use this method to measure the sound reduction index of the window alone.

Three sets of simultaneous measurements were made, using a microphone attached to the external surface of the window, and a microphone inside the room, both connected to the NE830 real time analyser. The microphone positions were changed between each measurement and it was ensured that each measurement period included at least fifty vehicles.

The mean sound pressure level on the window (L_s) and inside the room (L_2) due to road traffic was calculated and the apparent sound reduction index was obtained from:

$$R'_{tr,s} = L_s - L_2 + 10\ lg\left(\frac{S}{A}\right) - 3\ \ dB \qquad (7)$$

3.2.3 Results. Fig 3 shows the sound reduction index of the window as measured using the intensity technique (R_I) and the sound pressure method with traffic noise ($R'_{tr,s}$). It can be seen that the agreement between the two sets of results is reasonable. The intensity method gives about 2dB higher insulation between 200 Hz and 400 Hz and also above 2000 Hz. At other frequencies the agreement is very good. The weighted sound reduction indices are given in Table 1 and again they differ by only 1 dB.

Fig 3. Field measurement of the sound reduction index of single glazed window

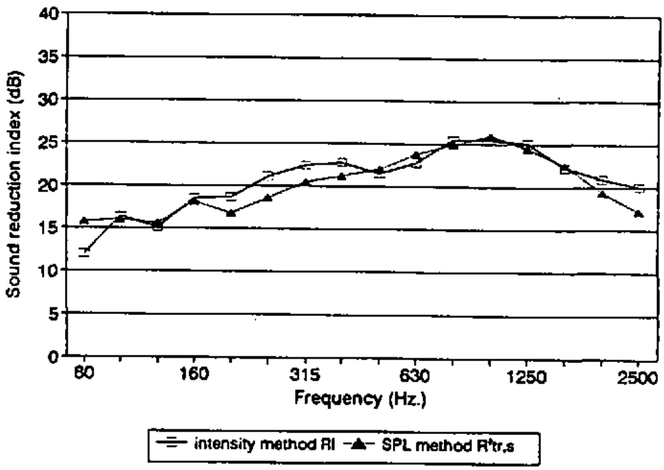

Table 1. Weighted sound reduction indices calculated from measurements obtained using the intensity method and the sound pressure method.

Investigation	Intensity method	Sound pressure method
Single glazing in facade between anechoic and reverberant chambers	$R_{I45',w}$ = 38 dB	$R'_{45,w}$ = 37 dB
Secondary glazing in facade between anechoic and reverberant chambers	$R_{I45',w}$ = 47 dB	$R'_{45,w}$ = 48 dB
Field measurement of single glazing	$R_{I,w}$ = 23 dB	$R'_{tr,s,w}$ = 22 dB

4. CONCLUSIONS

It has been shown that intensity measurements can be used successfully to measure the sound insulation of windows and facades. The technique has been compared with traditional methods of using sound pressure measurement and good agreement has been achieved between the methods both in the laboratory and in the field.

5. REFERENCES

1. M.J.Crocker, P.K.Raju, B.Forssen, "Measurement of Transmission Loss of Panels by the Direct Determination of Transmitted Intensity.", Noise Control Engineering Vol. 17 (1), 1981. p6-11

2. A.Cops and M.Minten, "Comparative Study Between the Sound Intensity Method and the Conventional Two-Room Method to Calculate the Sound Transmission Loss of Wall Constructions.", Noise Control Engineering Journal Vol. 22 (3), 1984 p 104-111.

3. R.E.Halliwell and A.C.C.Warnock, "Sound transmission loss: Comparison of conventional techniques with sound intensity techniques.", Journal of the Acoustical Society of America 77(6), June 1985 p2094-2103.

4. A.Cops, M.Minten, H.Myncke, "Influence of the Design of Transmission Rooms on the Sound Transmission Loss of Glass - Intensity Versus Conventional Method."Noise Control Engineering Journal Vol. 28 (3) 1987, p121-129

5. H.G.Jonasson,"Measurements of sound reduction index with intensity technique. Nordtest Project 746-88" Swedish National Testing and Research Institute. SP report 1991:23.

6. Committee Draft ISO/CD 140-5 "Acoustics - Measurements of sound insulation in buildings and of building elements - Part 5: Field measurements of airborne sound insulation of facade elements and facades" 1992-05-11.