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The insulation of dwellings against external noise

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This paper provides information on the noise reduction achieved in dwellings that are exposed to road traffic noise and have different types of window. The various methods currently used to quantify noise reduction are explained. The paper also considers ventilation requirements and methods for maintaining ventilation while achieving the required noise reduction. It will be of interest to architects, designers, planners and environmental health officers.

INTRODUCTION

The main path by which external noise enters a room in a dwelling is usually the window. This is the case even where double windows are fitted, except when the facade is of lightweight construction or there is some weak point such as a door or an air brick. For aircraft noise, transmission via chimneys and roofs may also contribute. A considerable amount of data has been published on the sound insulation of glass and windows in the laboratory (eg by Marsh[1] and Quirt[2]), but field data are scarce. Laboratory conditions differ in many respects from those found in practice. While laboratory studies are useful for determining how performance depends on various design parameters, they may give only a poor guide to actual performance in buildings.

This paper presents noise reduction data obtained for dwellings subject to noise from road traffic. The dwellings were fitted with a range of types of window including single casements, replacement thermal double glazing, and double windows formed by adding a secondary inner pane to the existing window. The results are presented over the frequency range 63 Hz to 3150 Hz and also in terms of three single-figure descriptors which are often used to rate sound insulation performance. The way in which the value of each single-figure descriptor is obtained is described.

In addition the paper gives some data about the noise reduction provided by windows in schools and offices, and also points out the need to provide alternative means of ventilation where windows need to be kept closed to keep out noise.

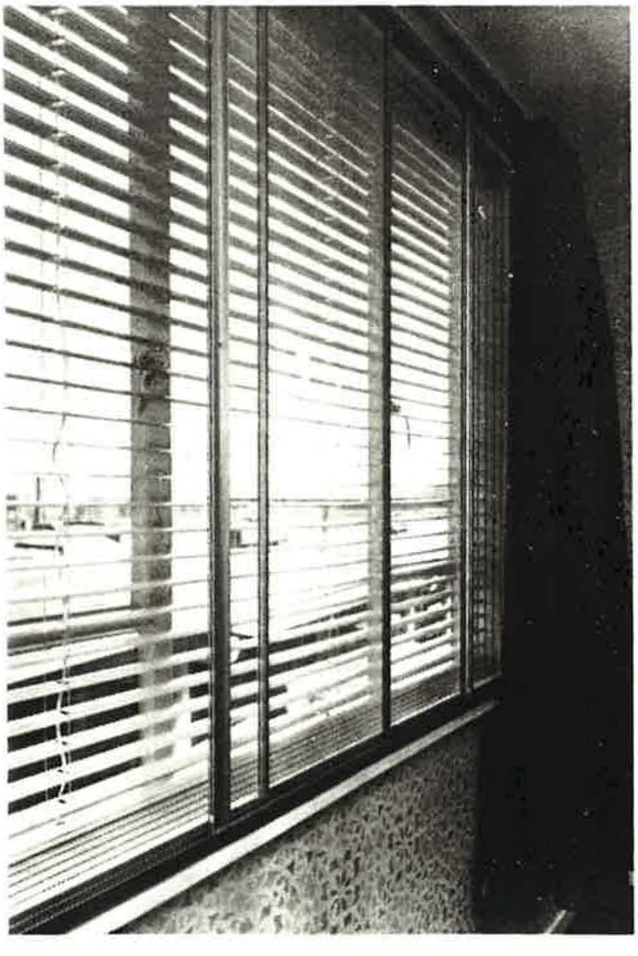

Figure 1 Secondary double windows with mid-pane venetian blinds

FACTORS AFFECTING SOUND INSULATION

The major factor which influences the sound insulation of any single wall or partition is its mass. Stiffness and damping of materials also have an effect. The sound insulation of a window increases with increasing frequency until a dip occurs due to the coincidence effect. (This effect is described in BRE Digest 337[3] but, briefly, it is the matching of the velocity of sound in air and in the glass.) For 3 or 4 mm glass the coincidence effect occurs at the top of the frequency range of interest. In practice the effect may be obscured by the presence of direct air paths around the frames of openable lights which also reduce sound insulation at high frequencies[4]. Where thicker glass is used, the coincidence effect can reduce the benefits of increased mass because the dip in the insulation curve moves towards the centre of the frequency range of interest.

A method of improving sound insulation without using heavier glass is to use a double-leaf construction (Figure 1). The sound insulation of double windows also depends on the thickness and overall damping of the glass but is affected as well by resonances associated with the double-leaf construction. The inclusion of sound absorption capability in the cavity by suitable treatment of the reveals is beneficial, but the most important resonance — the 'mass-spring-mass' resonance — will probably not be affected by such treatment. It has a frequency which is the same as that of two rigid bodies with the same mass as each leaf, connected by a spring with a stiffness equal to that of the air in the cavity. Typically for a double window the resonance frequency might be at or below 100 Hz. An advantage of double windows is that their sound insulation performance is less critically dependent on the efficiency of the seals around the openable sections when closed.

METHODS FOR DESCRIBING INSULATION PERFORMANCE

Sound insulation is normally measured in each of 16 one-third-octave bands, the centre frequencies of which range from 100 to 3150 Hz, or sometimes in octave bands from 125 to 2000 Hz.

A number of different ways of specifying sound insulation are in common use and this can lead to confusion.

1 **Standard laboratory measurements**
In laboratory tests to British Standard BS 2750: Part 3[5] the difference in sound pressure levels between the source and the receiver room is corrected, or 'normalised', to take account of the area of the building element under test, and the sound absorption and volume of the receiving room. The sound insulation is then referred to as the **sound reduction index.**

2 **Standard field measurements**
For field measurements to British Standard BS 2750:Part 5[6] the difference in sound pressure levels between the source and the receiver room may be normalised as in the laboratory, but it is more usual to normalise only for the amount of sound absorption in the receiving room, and the resultant quantity is then referred to as a **normalised (or standardised) level difference.**

3 **Building performance measurements**
When field measurements are made to show the sound insulation actually achieved by the facade of a building, the **unnormalised level difference** may be quoted, as is the case with all the insulation data presented in this paper.

While the third-octave values provide the fullest indication of performance, it is often convenient to use a single-figure value for the sound insulation, particularly when comparing the performance of different constructions. The following three methods of determining a single-figure value are often used.

1 **Average insulation (D_{AV})**
This is calculated by arithmetically averaging the 16 one-third-octave values.

2 **Weighted standardised level difference (D_w)**
This is described in British Standard BS 5821: Part 3[7] and involves comparison with a reference curve. The reference curve is shifted up or down in 1 dB steps until the sum of the unfavourable deviations is as large as possible without exceeding 32 dB. The weighted standardised level difference is the level of the shifted reference curve at 500 Hz.

3 **A-weighted sound level difference (D_A)**
This is the difference in A-weighted sound levels measured outside and inside the building. The advantage of using the A-weighted level difference is that it enables account to be taken of the differences in spectra for the different external sources. However, because of this dependence on the incident spectrum, when quoting a value of the descriptor the shape of the noise spectrum which has been used should be indicated.

NOISE REDUCTION RESULTS

In dwellings

The results of measurements[8] in dwellings subjected to road traffic noise and having single, replacement double-glazed or secondary double windows are shown in Figure 2.

The curve for single windows is an average of data for wood and metal casement windows and wood sash windows. At frequencies below 100 Hz there was little difference in the noise reduction performance for the three types of frame. At higher frequencies both wood and metal casement windows showed dips in the insulation curve, though at different frequencies. It has been shown that these dips arise from a Helmholtz resonator effect associated with the cavities around the edge of the opening casements when they

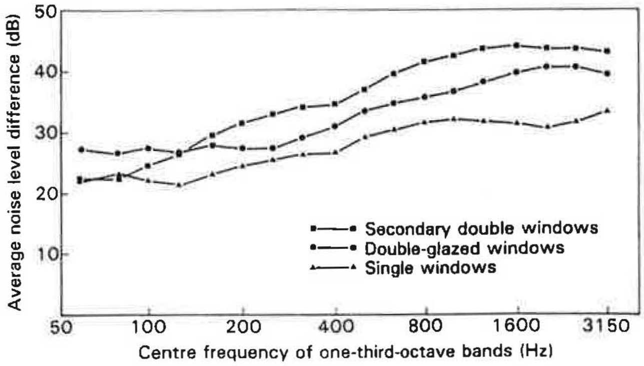

Figure 2 Comparison of average noise level differences for three window types in dwellings

are closed. The sash window frames, which do not have these cavities, had an insulation curve without dips at high frequencies.

The secondary double windows were installed under the Noise Insulation Regulations[9] and therefore had air gaps in the range 150 – 200 mm. These windows gave the highest noise reduction over most of the frequency range; the replacement double-glazed windows gave the greatest reduction at 100 Hz and below. Mass-spring-mass resonance has a major influence on noise reduction at low frequencies. For the secondary double windows the frequency of this resonance was about 70 Hz and at that frequency the noise reduction was no better than that for the single windows. For the double-glazed windows the resonance frequency was much higher, about 280 Hz, because of the narrower cavity between the panes. At the resonance frequency the noise reduction of the double-glazed windows was only slightly above that of the single windows but at low frequencies the level difference remained constant, which eventually led to the double-glazed windows having the greatest noise reduction as the resonance frequency for the secondary double windows was reached.

A study[10] of dwellings which were fitted with secondary double windows showed that the windows not only gave a satisfactory reduction in noise levels but also led to a considerable reduction in vibration disturbance. This probably occurred because the new inner pane reduced the sound of window rattling which is known to be an important component of vibration disturbance.

The performances of the three types of window in terms of single-figure values are given in Table 1. To obtain the values of D_A an input traffic noise spectrum was used. The variability of the results is quite high but not unusually so for sound insulation data obtained in buildings. It reflects differences in performance due to different construction details and standards of workmanship as well as measurement variability which will be higher than that found in the laboratory. Examples of the effect of constructional details on sound transmission are shown in Figure 3.

The values given in Table 1 show that the double-glazed windows had only a slightly lower value of D_A for traffic noise than did the secondary double windows. This arises because of the relatively good performance of the double-glazed windows at the lowest frequencies. It is possible that the performance of the double-glazed windows may have benefited from the fact that they were all replacement windows and fairly new.

Table 1 Average single-figure sound insulation values (unnormalised) (dB) (standard deviations in brackets)

	Window type		
	Single	Double glazed	Secondary double window
D_A	28.6 (2.9)	33.3 (3.0)	34.0 (3.0)
D_W	30.2 (3.1)	35.1 (3.3)	40.6 (2.8)
D_{AV}	28.3 (2.7)	33.6 (3.0)	37.1 (2.6)

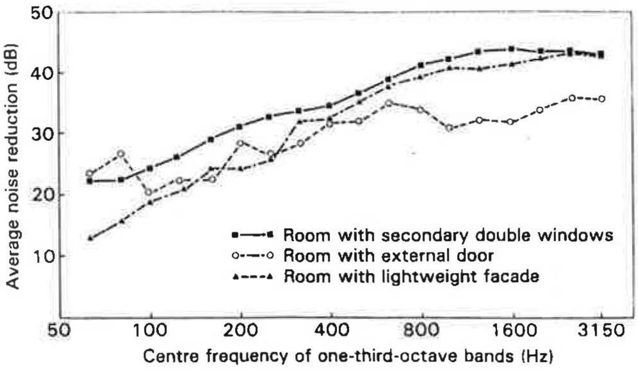

Figure 3 Influence of constructional details on noise reduction in dwellings

The influence of the input spectrum can be seen when the average performance curves in Figure 2 were used to determine D_A for both road traffic and aircraft noise. With aircraft noise, the value of D_A for the secondary double windows was at least 3 dB higher than that for the double-glazed windows compared with a difference of only 0.7 dB for road traffic noise.

In other buildings

Because the data given above for dwellings are not normalised they cannot be used for other types of building where window sizes and room absorptions are very different from those found in dwellings. BRE has data on the noise reduction of single windows in unoccupied offices and classrooms which indicate an average level difference for road traffic of about 20 dB(A). The difference between this value and the value of over 28 dB(A) found for dwellings can be largely explained in terms of greater window areas and lower sound absorption in offices and classrooms.

VENTILATION

In buildings without mechanical ventilation systems, windows are the main means of providing ventilation. Even when windows are closed, cracks around openable sections provide adventitious ventilation (or 'infiltration'). The installation of double windows will in most cases reduce this adventitious ventilation, while opening the windows will seriously reduce the sound insulation potential of the double windows.

There are three main reasons for supplying fresh air in a dwelling: the control of odour and condensation, the maintenance of comfortable conditions in summer, and the functioning of combustion appliances. Sufficient air for the control of odour and condensation will in general be obtained by the infiltration of air through adventitious openings with opening of windows in bathrooms and kitchens during periods of moisture generation. Much higher ventilation rates may be required to maintain comfortable conditions in summer. For certain combustion appliances it is necessary to supply fresh air for combustion and also, in the case of flueless appliances, to dilute the combustion products in the room.

The solution adopted for the package installed under the Noise Insulation Regulations was to fit a powered ventilator unit and a permanent vent in each room. The latter was provided to reduce the back pressure on the powered ventilation which would be created in a well sealed room and which would tend to reduce its efficiency. A study of the acceptability of this package indicated that many residents continued to open windows, possibly when rooms were unoccupied. This finding indicates that the use of fixed windows in dwellings would prove unacceptable to residents even if alternative means of ventilation were provided.

Another solution which is sometimes proposed involves 'staggering' the openings of the double window, with the outer and inner panes open on different sides. The results of one study suggest that it may be possible to obtain a ventilation rate of two to three air changes per hour under certain conditions while maintaining a sound insulation of about 27 dB(A). Unfortunately the ventilation obtained with such an arrangement, relying as it does on natural pressures, will depend critically on wind conditions, temperature differences between inside and outside the building and whether there is the opportunity for significant cross ventilation within the building. A BRE Digest[11] discusses the mechanisms that govern natural ventilation. It is unlikely that the use of double windows with staggered openings would provide sufficient ventilation to maintain thermal comfort consistently but it may be an acceptable option for rooms with low ventilation requirements, such as north-facing bedrooms.

CONCLUSIONS

1 The average noise reduction for dwellings exposed to road traffic noise is 28.6 dB(A) for those with closed single windows and 34 dB(A) for those with closed secondary double windows.

2 Dwellings fitted with replacement doubled-glazed windows have a noise reduction against road traffic noise of 33.3 dB(A).

3 For dwellings exposed to aircraft noise the noise reduction provided by secondary double windows would be about 3 dB(A) higher than that for double-glazed windows.

4 The average noise reduction of small offices and classrooms with single closed windows is about 20 dB(A) when unoccupied.

5 In situations where windows need to be kept closed to keep out noise it will often be necessary to provide alternative means of ventilation. Even where such means are provided in dwellings residents may still wish to open windows and thus the provision of fixed windows would prove unacceptable.

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