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THE AIRBORNE SOUND INSULATION OF GLASS

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INTRODUCTION

With the increase of noise in the external environment more attention is being focussed on methods of improving the insulation of building facades. Although the first stage in a noise control programme should be the reduction of noise at its source, motor vehicles and aircraft are the main sources of noise in the external environment and the noise from them cannot, at present, always be reduced to acceptable levels. The second stage should be that of planning which can be divided into two aspects - town planning and architectural planning. Town planning can help to reduce noise nuisance by, for example, allocating land adjacent to motorways to buildings in which low noise levels are not required so that these buildings can act as noise barriers for other buildings. Where this is not feasible the more detailed architectural planning of the layout of rooms within a building can also help to reduce noise nuisance. The spaces in which quiet conditions are important should be on the side of the building away from the noise source and rooms where the noise levels are not critical located nearest the noise source.

Only after the possibilities of reducing noise exposure by planning have been examined or when site limitations necessitate building near to noise sources should attention be directed towards the insulation of the building structure. Since the insulation of windows has a considerable influence on the insulation of the building facade the factors which influence the insulation of glazed areas have to be considered. In order to establish the important factors and the areas in which further information is required a review of the currently available results on the sound insulation of glass and windows has been undertaken.

SINGLE GLAZING

The sound insulation of a single panel is determined by its mass, stiffness, edge conditions and dimensions provided that the perimeter of the panel is sealed so that its insulation is not governed by transmission through air gaps. According to the "mass law" the insulation of glass should increase by 6 dB when the thickness of the glass is doubled or when the frequency of the incident sound is doubled. However, measured insulation values differ from the mass law predictions in certain parts of the frequency range because the mass law is derived on the assumption that the panel is infinite and that its stiffness can be neglected. For example, the insulation of 6 mm glass predicted by the mass law at 500 Hz agrees, within a few decibels, with the measured values of transmission loss but at 2000 Hz the discrepancy between predicted and measured results can be as great as 20 dB. The divergence from the theoretically predicted value at this frequency is due to the "coincidence effect" which occurs when a frequency is reached at and above which the projected wavelength of the incident sound on the panel can equal the wavelength of free bending waves in the panel. In this region the transmission loss is reduced because of the efficient coupling between the panel and the air. For a given glass thickness the lowest frequency at which coincidence can occur is found for grazing incidence; this "critical frequency" decreases as the glass thickness is increased. The frequency of the coincidence dip can be easily calculated and the dip in the measured transmission loss curve for glass usually occurs within the same third octave band as that of the predicted frequency. The calculation of the magnitude of the transmission loss in the coincidence region is more complex since the bending stiffness including the damping or loss factor of the panel must be taken into account as well as the panel mass and the angle of incidence of the sound. The theory (1) for transmission loss in this region indicates that the transmission loss decreases as the angle of incidence of the sound is increased and increased as the panel damping is increased. Of the results reviewed only Utley and Fletcher (2) supplemented their insulation measurements with measurements of damping. They found that if the damping factor for glass alone was used to obtain a theoretical transmission loss curve the predicted insulation in the coincidence region was lower than that measured. There was a closer agreement between theory and experiment when the damping factor measured with the glass in a section of frame was used.

Attempts have been made to improve the insulation of panels in the coincidence region by the addition of damping layers. For glass the most practical way of adding damping is by lamination, this allows an increase in total thickness without the corresponding lowering of the critical frequency. Comparisons of the insulation of laminated glasses with homogeneous glass of the same thickness show that below the coincidence region of the latter the insulations of the two types of glass are similar but around and above this region the insulation of the laminated glass is markedly better than that of the homogeneous glass, as much as 10 dB better in some third octave bands. Measurements have not been made at sufficiently high frequencies to establish whether any reduction in insulation occurs at a frequency corresponding to the critical frequency of the glass in the laminate.

It has been suggested that damping at the edges of a panel can reduce the reflection of waves at its boundaries and lead to an improvement in the insulation of the panel. Eisenberg (3) investigated the effect of different mounting conditions on the sound insulation of a 6.5 mm thick sheet of glass at three angles of incidence. The difference between the mean sound insulation figures for the three types of edge fixing was only small, 1 dB for 45° incidence. More recent studies (2) show that when glass is flexibly mounted its insulation may be several decibels better in the coincidence region than when it is more firmly fixed.

A panel of finite size can resonate at certain frequencies depending on its size, mass, stiffness and edge conditions, these resonances can, like the coincidence effect, lead to a reduction in the transmission loss. Although the theory (1) indicates that for small thick panes of glass even the fundamental resonance can be within the frequency range of insulation measurements there is some disagreement between workers as to whether pane size has a significant effect on the transmission loss of windows. The expected effects of pane size are in the low frequency region where dips in the transmission loss curve corresponding to the resonance frequencies of the panes in the window should occur and in the coincidence region where the edge conditions will exert more influence on the insulation of a window composed of small panes. From currently available results it appears that the effect of pane size is of minor importance and that the major influences on the insulation of a single window are, firstly, the sealing and secondly, the glass thickness.

DOUBLE GLAZING

The insulation of double glazing is affected by the same factors as that of single glazing and by the following additional parameters: the width of the air space, the relative thickness of the two panes of glass, the mechanical linkage between them and the amount and type of absorbent material at the edges of the air space. The insulation of double glazing should increase more rapidly with frequency than that of a single panel of the same mass per unit area but in certain parts of the frequency range resonances associated with double panel construction can occur. At low frequencies the two panes are coupled by the air between them behaving like a spring and this coupling causes a reduction in insulation. The frequency of this "mass-air-mass" resonance is dependent on the total thickness of the glass and the width of the air space. Where possible the resonant frequency should be below 100 Hz, to attain this with, for example, a total glass thickness of 12 mm an air space width of at least 5 cm would be required. The reduction in insulation due to the "mass-air-mass" resonance is clearly shown in measurements of the insulation of narrow air space double glazing units. At high frequencies resonances caused by standing waves in the air space between the panels occur but because the dips due to these resonances are narrow their net effect is a reduction in the slope of the insulation curve.

The addition of absorbent material between the leaves of a double panel reduces the resonances within the cavity and thus increases the insulation. However, for double glazing the use of absorbent is limited to the edges of the cavity if the transparency of the window is not to be adversely affected. The majority of workers have only compared the insulation of double glazing with and without absorbent reveals and have not attempted to establish whether any relationship exists between the properties of absorbent materials and the resultant improvement in insulation. Ingemansson[4] measured the insulation of a double window with three thicknesses of absorbent at the edges of the air space, his results showed that the initial addition of absorbent was most important although the greatest thickness of absorbent, 10 cm, gave most improvement in insulation at low frequencies. The improvement in mean sound insulation obtained by lining the air space with absorbent is usually about 3 dB.

The coincidence effect can occur for each pane of a double glazing system so the use of panes of different thicknesses is often recommended. If panes of different thicknesses are used their coincidence frequencies are not the same and the dip due to coincidence should be less marked, insulation measurements confirm this. Another recommendation often made is to fix the two panes of a double window so that they are not parallel to each other. Although this has a firm theoretical basis there are few measurements to indicate that the amount of improvement which can be attained.

From the results of Oosting's[5] measurements the u·· of non-parallel panes does not appear to offer any practical advantage.

It has been suggested that double glazing in the same frame is of no value for sound insulation because of transmission through the frame and mechanical linkage between the panes of glass. This is not confirmed by the results available but the effect of separate frames and mechanical linkage has not been quantitatively established. In buildings double glazing in a single frame has the disadvantage that there may be a gap between the frame and surround which allows sound to leak through whereas with two frames the sound paths will be more tortuous and cause less leakage.

METHODS OF MEASUREMENT

Most experimenters have obtained their results on the insulation of glazing by the standard method, that is with the glass located between two reverberant rooms, but some Europeans [3][5] consider that the sound insulation of glazing should be measured at various angles of incidence because this corresponds more closely to practical conditions. Some agreement ought to be reached on which method is the most appropriate for measuring the insulation of glazing. However, laboratory measurements can only serve as a guide to the actual sound insulation which will be achieved with a particular system of glazing. The external sound field, the building construction and the amount of absorption in a room can all influence the effective insulation of a completed building.

CHOICE OF GLAZING

Glazing should be chosen in relation to the spectrum of the noise to be insulated and the noise levels required. Generally double glazing should be used for insulation against predominantly high frequency noise and, unless an air space of several centimetres can be obtained, single glazing should be used for low frequency insulation. The consideration of the internal noise levels is also important; for a given noise exposure the insulation of windows in say, a general office would not need to be as high as that of the windows in a private office or conference room.

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