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Transmission of Airborne Noise in Buildings

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Introduction

Airborne sound insulation is normally regarded as the reduction of airborne sound by a structural member such as the wall or floor of a building. Clearly while passing through that member the energy is contained within the structure. It does not have to re-appear directly on the other side of the member but can travel through the building structure and then be radiated as airborne sound again perhaps several floors away. Nevertheless, the term structure-borne noise is usually reserved for vibrational energy which passes directly into the structure from impacts or from machinery even though it may subsequently appear as airborne noise.

Considering only airborne sound insulation, interest is limited to the behaviour of lightweight constructions. Traditional materials, such as 9" plastered brick walls or 8" reinforced concrete floors, have a superficial mass of about 90 lb/ft^2, give an average insulation of about 50 dB over the frequency range 100 to 3150 Hz and generally prove satisfactory. The current tendency to use lighter constructions often leads to inadequate sound insulation and consequently acoustical requirements must be given very serious consideration at the design stage.

Insulation of single walls

The simplest way of understanding how a single wall provides sound insulation is to regard it as a mass which moves under the influence of a sound pressure wave and in moving radiates sound on the far side. Unfortunately, the stiffness cannot be totally ignored because at certain frequencies the stiffness and mass cancel each other and the resonance is controlled by the damping in the system. The consequent poor insulation occurs in two separate regions. At low frequencies overall modes of vibration predominate while at high frequencies local bending waves give rise to coincidence transmission. Low stiffness is usually associated with a low mass panel, say 5 lb/ft^2, and stiffness effects occur outside the frequency range of interest. Increasing the mass increases the stiffness and the resonance effects creep into the range of interest from both ends. Consequently the average insulation which is achieved in practice is less than that calculated considering only the mass of the wall and the discrepancy increases as the mass of the wall is increased. This has given rise to the empirical mass law based on many test results which relates the average insulation to the wall mass. This is shown in figure 1. It is possible to increase the mass of a wall without increasing the stiffness when sheet materials are being used. For example two half-inch sheets of plasterboard laid one on top of another and not glued weigh the same as a one-inch sheet of plasterboard but give a better insulation because the bending stiffness is less.

Insulation of cavity walls

Figure 1 shows that light walls weighing 5 to 10/lb ft^2 can be expected to give an average insulation of about 35 dB and that the mass is being used reasonably efficiently. For a higher insulation it is necessary to go to much heavier thicker walls in which case the mass is not being used efficiently. This is clearly of no use for lightweight structures and the solution is found in the cavity wall.

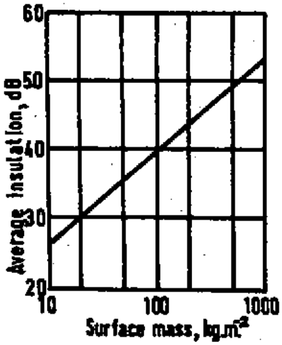

Figure 1

Here two separate leaves are used with varying degrees of structural linkage and the separating air gap may contain some loose fibrous material which acts as a sound absorbent. In general, any weakness in the single leaf, such as coincidence transmission, will appear when the leaf is used in the cavity construction but there are additional effects which mean that the insulation of the two leaves is not equal to the arithmetic sum of the insulations of the individual leaves. At low frequencies the two leaves act as masses and the entrapped air acts as a spring which leads to the mass-spring-mass resonance. By either making the masses large or by making the cavity large this resonance can be kept below 100 Hz but in practice weight or space requirements often mean that this resonance impairs the low frequency insulation. At mid-frequencies, say between 200 and 1000 Hz, two-dimensional standing waves are set up within the cavity and these also impair the insulation. Any form of resonance can be controlled by increasing the damping and so the inclusion of some absorbent in the cavity leads to a considerable improvement in that the standing waves are damped and to a lesser degree the mass-spring-mass resonance is damped. Coincidence transmission is also a resonant phenomenon and an absorbent infill also leads to some improvement in the coincidence region. The overall improvement is more noticeable in light walls than heavy ones and the first half-inch or so of absorbent quilt does the most good, the inclusion of further material producing much less benefit. The precise placing of the material seems to have little importance and it is usually hung from the top of the cavity. The other very important aspect is the transmission of energy through stud linkages and around the edges of the wall. The degree to which this flanking transmission impairs the insulation depends upon the stiffness and mass of the linkage and it is only possible to generalise. It is usually the high insulation values which are affected most and these normally occur at high frequencies. Three different categories are illustrated in figure 2 and it is suggested that stud linkage is acceptable for an average insulation of less than 40 dB while total isolation is required for an average insulation of more than 50 dB. There are exceptions to this, of course, and it has been shown that very flexible metal channel studding may be used in partitions having an average insulation of 45 dB.

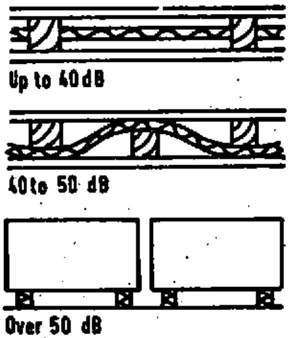

Figure 2

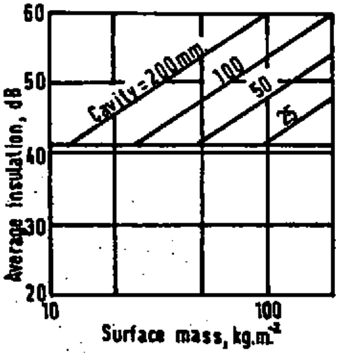

Figure 3

There is no satisfactory theory for predicting the average insulation of a cavity wall. There is, however, an empirical relationship which is illustrated in figure 3. It is based on tests utilising woodwool slabs but has now been shown to be reliable for several other materials. It is assumed that there is some absorbent in the cavity and that the rules for avoiding flanking transmission outlined in figure 2 have been followed.

Insulation of floors

Even in buildings of lightweight construction the floors are often of thick concrete and then there is usually no airborne sound insulation problem. The provision of a floating floor, consisting perhaps of a concrete screed laid on a glass fibre mat, is usually to improve the impact sound insulation, although that could often be achieved by the alternative method of using a resilient floor covering.

Lightweight floors, such as those used in dwellings, might consist of timber joists with a plasterboard ceiling and a tongue and groove or plywood floor. Under these circumstances the rules laid down for cavity walls are generally applicable. A floating floor improves both airborne and impact sound insulation and mineral wool (providing absorption) or sand (providing mass) should be laid between the joists.

Conclusions

If weight is a problem then to get satisfactory sound insulation it is better to use a double leaf cavity construction. The use of an absorbent is desirable and precautions must be taken to avoid flanking transmission. An empirical relationship may be used to predict the average airborne sound insulation of a cavity wall with reasonable accuracy.

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