Structure-borne sound transmission in lightweight buildings

Robert J M Craik

Abstract: The move away from mass as a means of reducing sound transmission in buildings has led to the development of lightweight framed buildings. High levels of sound insulation are achieved by introducing discontinuities whilst retaining structural integrity. This increases the complexity of the design and hence any theoretical models used to predict sound transmission. For direct transmission through lightweight partitions the nature of the connection between the lightweight cladding and the frame determines the nature of the structural coupling. In most cases the coupling be modelled as either a series of point connections or as line connection.

If flanking transmission is included then the complexity of the model increases. The number of components (acoustic spaces, 2 dimensional plates and 1 dimensional beams) can be relatively large as is the range of possible designs. Some of the simpler cases can be well predicted whereas others cannot. In either case typical systems need to be studied to identify which components must be included and which can be ignored and to determine the best method of modelling the coupling.

INTRODUCTION

Acoustically, the simplest form of building construction is where walls and floors are made from homogenous components such as masonry walls and floors. Studies of sound transmission began with airborne transmission through single leaf walls and then developed to include double walls and flanking transmission. However, the construction industry has moved away from heavy masonry forms of construction towards lightweight construction where mass alone is not the means of reducing transmission. Instead a combination of materials are used in such a way that good sound insulation is achieved. Sound transmission can only be understood with both a detailed knowledge of the materials used (particularly density, stiffness and damping) and the way in which the various components are coupled together. Statistical frameworks such as statistical energy analysis (SEA) offer the best approach to these problems (1).

DIRECT TRANSMISSION

Lightweight constructions have always been used as internal partitions and are now widely used as party walls. The construction can take a variety of forms and a typical internal partition can be seen in Figure 1. Where good sound insulation is required then there will be absorption in the cavity and separate frames. In other cases a common frame may be present providing structural coupling.

FIGURE 1. Lightweight partitions are constructed from many components An SEA model may include structural coupling either as direct coupling between the plates or by including the frame as a subsystem.

FIGURE 2. Measured and predicted sound reduction index for transmission through a double leaf partition with added absorption and with the frame (modelled as a subsystem) connected by points to the cladding. —— measured; —— predicted; —— predicted at low frequencies.
The SEA model for the wall is also shown in Figure 1. If separate frames are used then there will be no structural coupling. If a common frame is used with widely spaced nails then the coupling can be modelled as point connections and the frame is included as an SEA beam subsystem. If there is a continuous line connection then the frame will provide direct coupling between the two plates but does not need to be included as a subsystem.

An example of the sound reduction index of a double leaf wall can be seen in Figure 2 and it can be seen that there is good agreement between the measured results and those predicted using SEA.

**FLANKING TRANSMISSION**

When both direct and flanking transmission are considered then the complexity of the system increases dramatically and it is increasingly difficult to give general guidelines as the range of design options increases. One design option is for the flanking element to be a masonry component. A common example of this is a timber floor supported by a brick or block wall or a partition built on a concrete floor. In a timber floor, if the floor joists are parallel to the wall, then it would not be expected that the floor would provide a barrier to vibration transmission from the wall of the room above to the wall of the room below. In practice, there will be some attenuation as can be seen in Figure 3. If the floor joists are built into the wall then it would be expected that they would form a greater barrier to the transmission of vibration on the supporting wall. An example of this (on a different wall) can also be seen in Figure 3. In this example, there were joists but no floor covering or ceiling. If these joists behaved independently then there should be little barrier to sound transmission especially at high frequencies where the spacing between the joists is large compared to the bending wavelength. In practice, there is considerable attenuation.

![Figure 3: Vibration level difference between two parts of a masonry wall divided by floor joists.](image)

If the flanking walls and floors are lightweight assemblies of beams and plates (similar to the partition) then the situation becomes much more complex. In some cases a single path or group of paths can be identified enabling sufficient simplifications to be made to enable the problem to be solved (3). In more general cases there may be many components with intersecting frame elements providing a structural shell and supporting lightweight plates such as plasterboard. In these cases it is less obvious which elements can be ignored to simplify the problem. Frame members will be connected at points and along their length both to other frame members and to the lightweight cladding. Many of these joints are not well understood and cannot be accurately modelled. However, the range of joints that is understood is expanding leading to an increased range of buildings for which sound transmission can be predicted.

**DISCUSSION**

It is likely that the trend towards lightweight buildings will continue as this results in cheaper buildings and simplifies the use of prefabricated components. Demand for good sound insulation is also increasing and standards at least as good as brick and concrete buildings are expected. The range of possible designs and materials will rule out lists of pre-approved constructions and so there is likely to be a shift towards verifying designs using numerical models.

**REFERENCES**