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REDUCING STRUCTURE-BORNE SOUND TRANSMISSION USING ELASTIC LAYERS

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INTRODUCTION

One method that is commonly used in buildings to reduce structure-borne sound transmission is to place elastic layers at critical joints. Layers such as rubber or cork can be placed under a partition, as can be seen in Figure 1, or between any two elements so as to reduce sound transmission. Often these layers are inserted on the basis that any improvement will help and it can do no harm. There is generally little in the way of design of the joint and no verification afterwards that any improvement has in fact been made.

These types of joints are also widely used in ship structures where again any design calculations are usually based on empirical results.

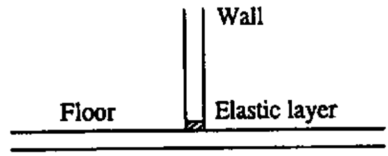

Figure 1. Section through a joint showing an elastic layer under a wall.

The effect of an elastic layer at a joint was first studied by Cremer [1] who presented calculations for elastic layers at junctions between plates. The work was restricted to normal incidence but included the effects of junction damping. This work was summarised in the later work by Cremer, Heckl and Ungar [2] and by Kurtze, Tamm and Vogel [3] who carried out measurements on perspex rods. More recently Wohle, Beckmann and Schreckenbach [4] showed how elastic layers could be introduced into a generalised model and Mees and Vermeir [5] have developed this theory to predict the performance of joints where there are elastic layers and have compared their results with measured data.

When an elastic layer is places in a joint it changes the way in which the joint behaves. For the simple case shown in Figure 1 the elastic layer reduces transmission between the floor and the wall. In a rigid joint the displacement of the wall in any direction must be the same as the floor at the joint. However with an elastic layer present the displacement of the wall can be different. In the same manner when the joint is rigid the entire joint must rotate as a single unit. If one element rotates then they all rotate. When there is an elastic layer the wall can rotate by a different amount. It is these differences in displacement and rotation that result in reduced transmission.

STRUCTURAL TRANSMISSION LOSS AT A JOINT

The predicted transmission loss for a structural joint like that in Figure 1 can be seen in Figure 2. The joint is a tee joint and the calculations are for a joint with a 200 mm concrete floor and a 100 mm concrete block wall built on top of it. The values given in the figure are for the structural transmission loss, *R*, defined as

$$R = 10Log\frac{1}{\tau} \qquad (1)$$

where τ is the structural transmission coefficient defined as

$$\tau = \frac{power\ transmitted}{power\ incident} \qquad (2)$$

and is a ratio of between 0 and 1.

The figure shows results for a bending wave incident on both a rigid joint and for a joint where there is an elastic layer between the floor and the wall. The layer was taken to be 15 mm cork and is typical of the type of layer that would be used in a building.

Results are given for a bending wave on the floor incident on the joint generating bending, longitudinal and transverse waves on the wall. The results for transverse waves are very similar to longitudinal waves and for clarity are not shown.

It can be seen that the inclusion of an elastic layer has resulted in a large increase in transmission loss to bending waves on plate 2, from 18 dB to over 40 dB. The peak at 250 Hz depends on the stiffness of the elastic layer. There is a smaller increase in transmission loss for transmission from bending to longitudinal waves with the largest benefit at high frequencies.

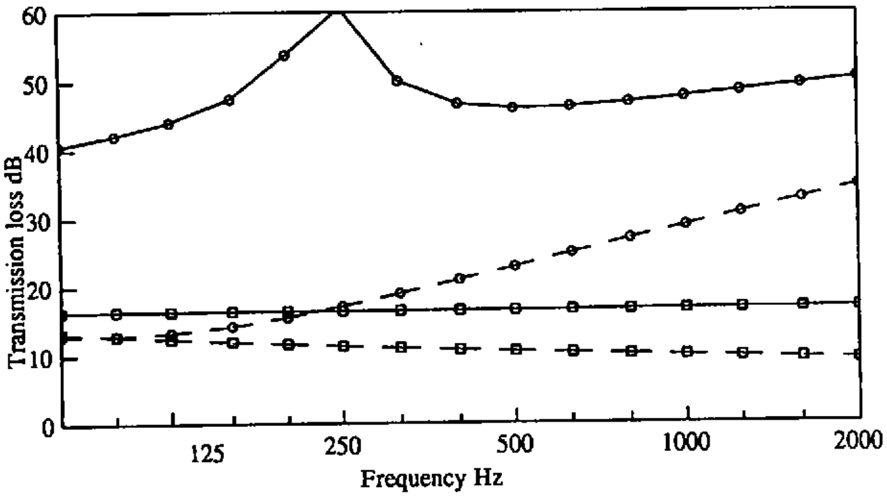

Figure 2. Structural transmission from a concrete floor to a concrete block wall at a tee joint. ————, Bending to bending; - - - -, Bending to longitudinal; □, Rigid joint; O, Joint with elastic layer.

Similar results can be seen in Figure 3 which shows results for the same joint but for an longitudinal wave on the floor incident on the joint. It can be seen that for transmission to bending waves there is almost no change in transmission loss at frequencies below 250 Hz. This is related to the peak in Figure 2. At higher frequencies there is an increase in transmission loss for both sets of curves.

From these results it can be seen that, as expected, there is a large increase in the transmission loss that should lead to a large reduction in transmission.

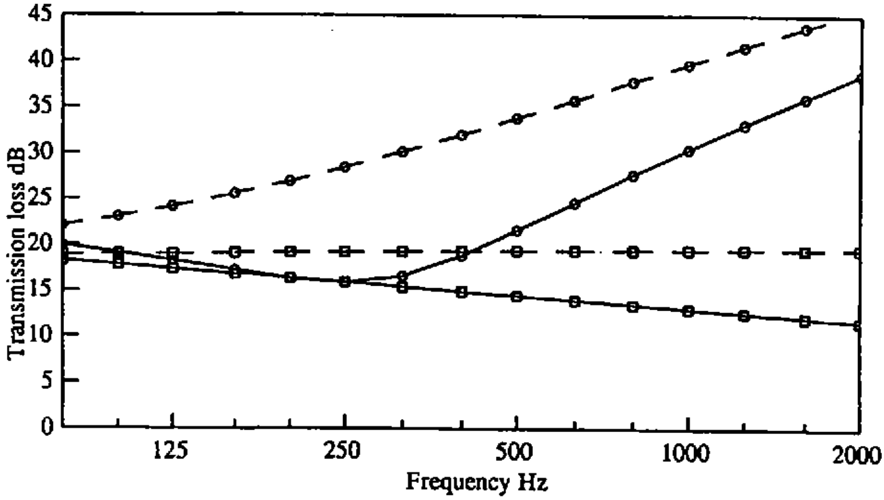

Figure 3. Structural transmission from a concrete floor to a concrete block wall at a tee joint. ————, Longitudinal to bending; - - - -, Longitudinal to longitudinal; □, Rigid joint; O, Joint with elastic layer.

RESULTS AT A JOINT

When these joints are used in a building then it is the level difference (the difference between the velocity of the floor and the velocity of the wall for a source on the floor) that is important. The level difference can be found by using the values of transmission loss in a statistical energy analysis model. This technique works well with buildings made from rigid joints [6] and can be readily used where elastic layers are used.

When the performance of rigid joints are being computed then the rest of the building has relatively little effect on the overall performance of an individual joint. This can be seen in Figure 4 which shows the predicted level difference between the floor and the wall for a source on the floor. There are three difference curves. The highest curve is the direct path transmission from the floor to the wall across the joint. Transmission by all other paths is excluded.

A more sophisticated model is to include the two sections of floor and the wall that together form the joint as three subsystems and to include the effect of wave conversion where bending energy is transferred to inplane energy and back again at boundaries. Including these effects increases transmission so reducing the level difference by about 4 dB. Finally the entire structure can be included in the model. In the measurement that were made the floor was part of a reverberant chamber which floated on springs. Including all of the rest of this chamber further reduces the level difference by about 1 dB at the higher frequencies.

It can be seen that for rigid joints the joint itself determines performance and that including the rest of the structure will reduce the level difference by a small amount. A reduction of 4 dB is not untypical though a value of 2-3 dB is more normal.

Results from similar calculations can be seen in Figure 5 where there is an elastic joint. In this case there is a very large difference between the three sets of curves. The direct path predicts a level difference of over 25 dB and follows the shape of the transmission loss curve closely. Modelling the two floor sections of floor and the wall as a three subsystem model reduces the level difference by up to 35 dB. Modelling all of the remaining structure can reduce the level difference by up to a further 15 dB. These results clearly show that the supporting structure has a very important part in the transmission of energy between the two plates. The performance of the system can only be determined from a knowledge of the whole structure.

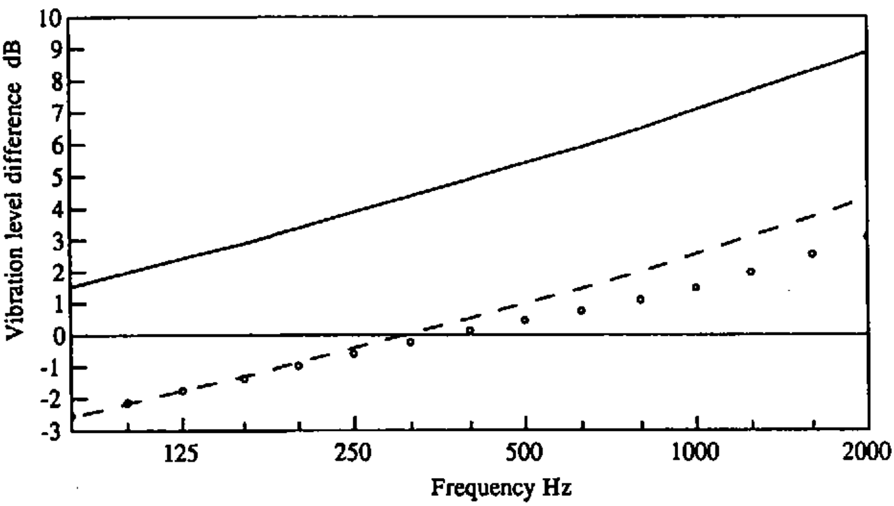

Figure 4. Predicted level difference for transmission from a floor to a wall connected by a rigid joint. ————, Direct path only; - - - - -, Sound transmission for a three subsystem model; · · · , Sound transmission involving all paths.

As expected there is an increase in the level difference by changing the rigid joint to an elastic joint. For the case examined the rigid joint results in almost no vibration level difference between the floor and the wall whereas the elastic joint results in a difference of over 10 dB.

A comparison between the predicted results and measurements can be seen in Figure 6 and shows transmission from the floor to the wall. There are two theoretical predictions, one for a rigid joint and one for the joint with an elastic interlayer. The measured results are for a 15 mm layer of cork used as an elastic layer. Two sets of measurements are included. In one set a tapping machine was used as a source and in the other a plastic headed hammer was used as a source. There is little difference between them.

It can be seen that the measured results agree with the model where elastic layer is included.

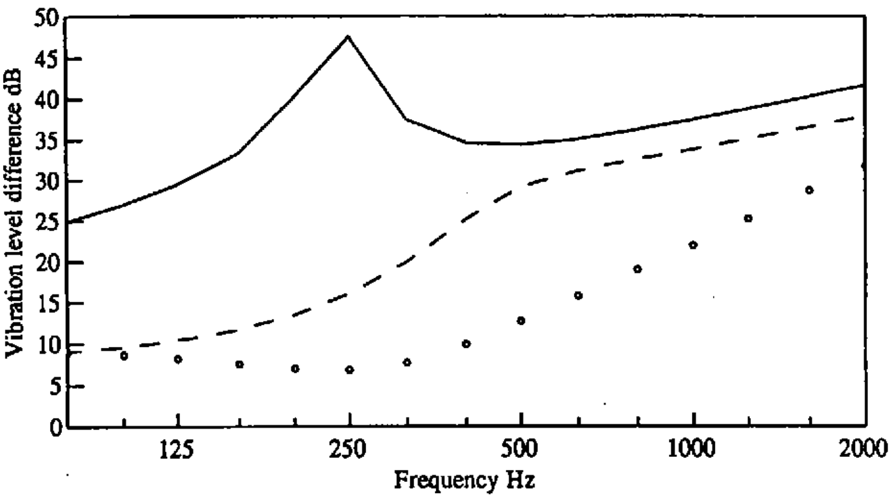

Figure 5. Predicted level difference for transmission from a floor to a wall connected by joint with an elastic layer. ————, Direct path only; - - - - -, Sound transmission for a three subsystem model; · · · · , Sound transmission involving all paths.

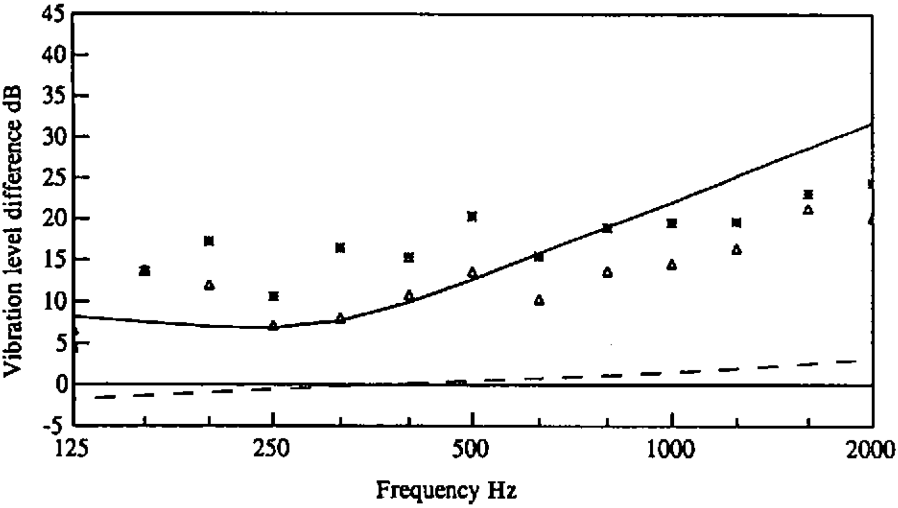

Figure 6. Measured and predicted level difference from a floor to a wall. *, Measured using a hammer as a source; ▵, Measured using a tapping machine as source; ————, predicted using elastic layer; - - - -, predicted for a rigid joint

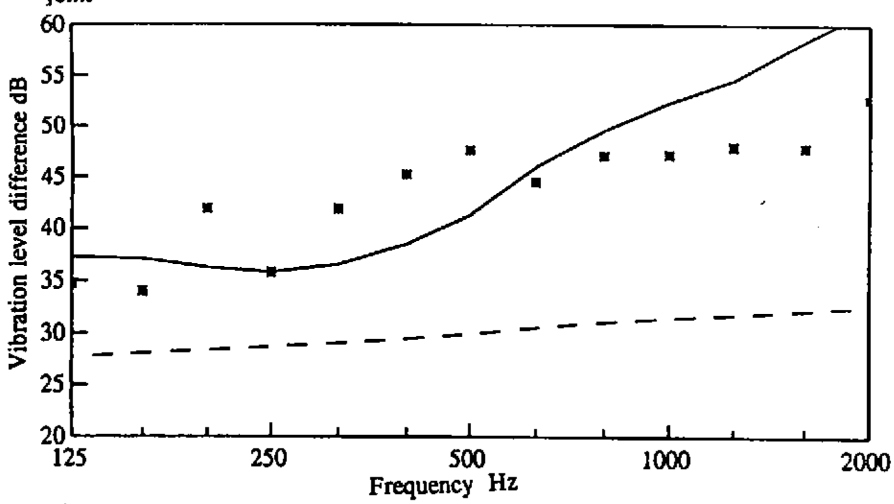

Figure 7 Measured and predicted level difference from a wall to a floor. *, Measured results; ————, Predicted using elastic layer; - - - -, Predicted for a rigid joint

Similar results are shown in Figure 7 for transmission from a wall to the floor. Again there is good agreement between the measured results and the theoretical model where the elastic layer is included.

CONCLUSIONS

From these results it can be seen that the theories for joints that predict performance at joints with elastic layers can be used in real buildings. These layers can bring significant improvements in performance by reducing sound transmission. However, the effect of the layer is not only to reduce transmission but also to change the nature of transmission. It is no longer enough to consider the one joint in isolation from the rest of the structure. Where elastic layers are used much more of the structure has to be included in the calculations.

ACKNOWLEDGEMENT

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