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THE EFFECT OF CRACKS ON VIBRATION TRANSMISSION

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1. INTRODUCTION

One of the difficulties of making accurate predictions of structure-borne sound transmission in buildings is that the theoretical model used to make the predictions will be idealised and is unlikely to exactly represent the actual structure. There are of course many reasons for such discrepancies. The material properties may not be exactly as specified or more likely were not specified and hence are not known. The method of construction and details of the assembly of the bricks and blocks that make up many structures may also have an effect on performance but cannot be modelled in any meaningful manner.

Once the structure is constructed cracks may occur and the result is that two parts of the structure that are supposed to be connected together may not be. Such cracks may occur in almost any part of the structure, however, they are found most commonly at structural joints. It is the effect of these cracks that are examined in this paper.

An example of such cracks occurs when non-loadbearing walls are built up to the underside of a floor as it is difficult to form a strong mechanical bond between the wall and the floor. When drying shrinkage occurs the wall will become smaller. The weight of the wall (many tonnes) will ensure that the wall rests on the floor below and any gap will occurs at the top of the wall. Of course wall decorations will usually cover such cracks, indeed plaster is usually mixed so that it is more flexible (weaker) and so covers up the crack. Nevertheless the crack exists and the thin layer of plaster will not transmit the sound and vibrations in the same manner as a firmly bonded joint.

Cracks and gaps can also occur in joints between concrete floor slabs depending on the method of construction and between walls particularly when new walls are added to old buildings without sufficient mechanical bonds.

The effect of such cracks and gaps is to decouple plates that are supposed to be connected at joints. This can be seen in Fig. 1. Disconnecting 1 plate makes a cross joint into a tee joint and tee joints become either in-line joints or corner joints. Disconnecting two or three plates will have an even greater effect. In each case a model based on the original design will be incorrect.

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Disconnecting a single plate will obviously prevent direct sound transmission from the disconnected plate to the other plates at the joint and so will decrease transmission. On the other hand there will be greater transmission between the remaining plates which will then lead to increased transmission. Overall, disconnecting a plate will not affect the total energy in the structure but will only change the distribution of that energy.

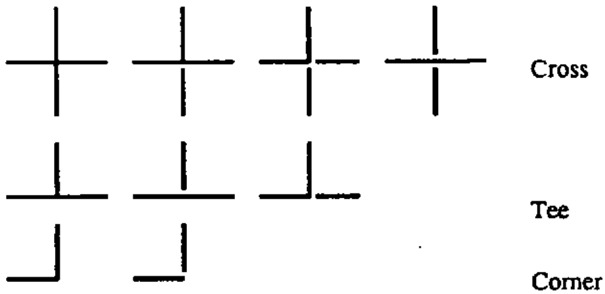

Fig. 1 Joint configurations when plates are disconnected from a joint.

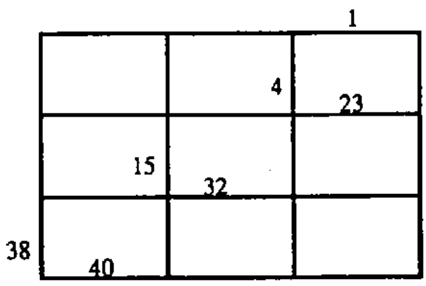

Fig. 2 Section through the test structure. (Numbers are subsystem numbers)

In small structures it may be possible, from a detailed examination, to account for such defects. In large models, where such analysis is not practical, they will result in errors in the model and hence in the predicted response.

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In a statistical energy analysis (SEA) model the effects of such defects in the structure can be predicted by changing the idealised theoretical model to more accurately reflect the actual construction. Such structural defects will, to a greater or lesser extent, affect all structures and have an effect on all theoretical models and so the results are of general interest.

2. TEST MODEL

In order to investigate the effect of cracks and defects on sound transmission a test structure was assembled. This is a very simple structure resembling part of a building and can be seen in Fig. 2. The actual model was constructed from 20 mm thick perspex. It was 2.4 m wide and 1.35 m high with an assumed internal loss factor of 0.03.

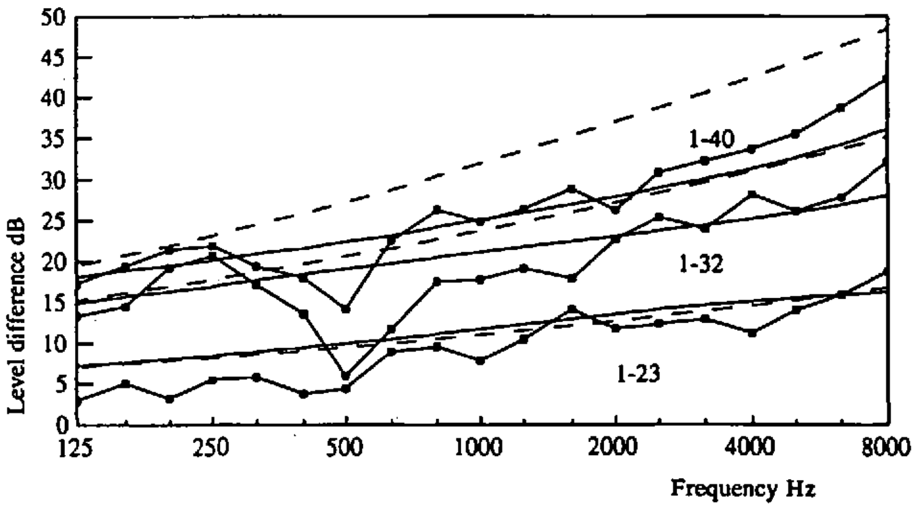

Fig. 3 Measured and predicted attenuation in the structure.
——□——, Measured; ———, Predicted with complete model;
——, Predicted with simple model.

3. VERIFICATION OF THE SEA MODEL

Prior to investigating the effect of cracks it was important to verify that the (idealised) SEA model accurately predicted the performance of the test structure. A structural source was used to excite plate 1 and the vibration of the structure was measured on plates 23, 32 and

40. Fig. 3 shows a comparison between the measured and predicted vibration level difference for these three subsystems. Two different theoretical models were used for the calculations. The simpler model assumed that only bending waves were generated at the joint and were present in each subsystem. This is a relatively simple model with 42 subsystems. The other model permitted the generation of longitudinal and transverse waves in the plates and so was modelled by 126 subsystems, (1 subsystem for each plate for each wave type).

It can be seen that there is good agreement between the measured and predicted results showing that the SEA model accurately models the basic structure. The two theoretical models are similar at low frequencies but at higher frequencies and for subsystems far from the source the more complex model, which includes in-plane vibration, gives better agreement with the measured results.

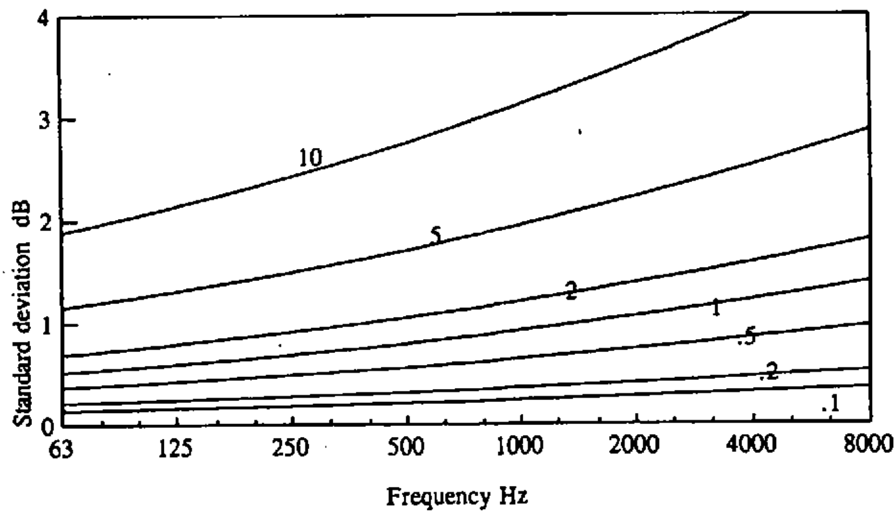

Fig. 4 Standard deviation of level difference 1-15 as different percentages of plates are disconnected. Numbers refer to the % probability of a single plate edge being disconnected from a joint.

4. EFFECT OF CRACKS

The effect of cracks and similar defects was determined by randomly disconnecting plate edges from joints and recomputing the performance. Each of the 168 edges (4 edges for each of 42 plates) was considered in turn. Using a random number generator a decision was made either to leave the edge connected at the joint or to disconnect the edge. Disconnecting 1% of the plates meant that there was a 1% chance that any plate edge would be disconnected from each joint and hence that 1% of all the edges would be disconnected. Thus disconnecting 1% on average disconnected 1.68 plate edges in the model.

After the plates had been disconnected the performance of the model was recomputed and the answers stored. This calculation was repeated many times so that the predicted spread of the vibration levels (standard deviation) could be determined.

The entire process was repeated for different percentages of disconnection.

For a typical plate in the centre of the structure, 15, the standard deviation of the level difference between the source subsystem, 1, and the test subsystem, 15, can be seen in Fig 4. The numbers refer to the % probability of a single edge being disconnected. It can be seen that as the percentage of plates disconnected increases so the standard deviation increases. Even for a relatively small percentage of cracks of around 1% there is a variation of between 0.5 and 1.5 dB.

As the frequency increases so the standard deviation increases. This is because the ratio of the internal losses to the coupling losses becomes larger (coupling loss factors become smaller at high frequencies) and attenuation with distance becomes greater. At low frequencies there are many long paths that contribute to sound transmission from one position to another so that disruption of a single path is less important.

For the same wall the spread of results is much less if the more complex model that includes in-plane waves is used as can be seen in Fig. 5. The additional paths introduced by the additional wave types decreases the effect of disruption caused by any single path and so decreases the standard deviation.

As the distance from the source increases so the standard deviation of the level difference increases. This can be seen in Fig. 6 which shows the standard deviation for the level difference from 1-4 where the distance is short, 1-15 as an average distance and 1-38 in which the distance is great. Close to the source only a few joints determine performance but as the distance increases so more and more joints can affect the performance resulting in greater variation.

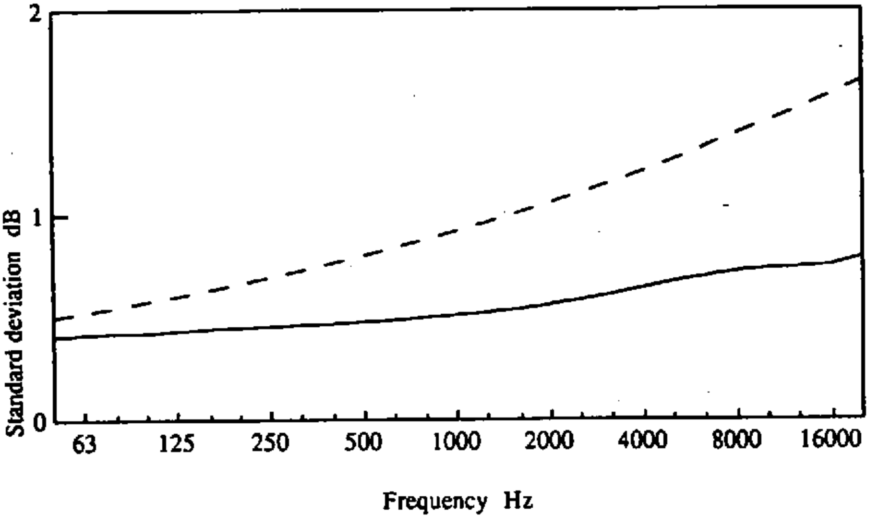

Fig. 5 Standard deviation of wall 15 for 1% disconnection for two different theoretical models.
———, simple model; — — — —, model with in-plane transmission.

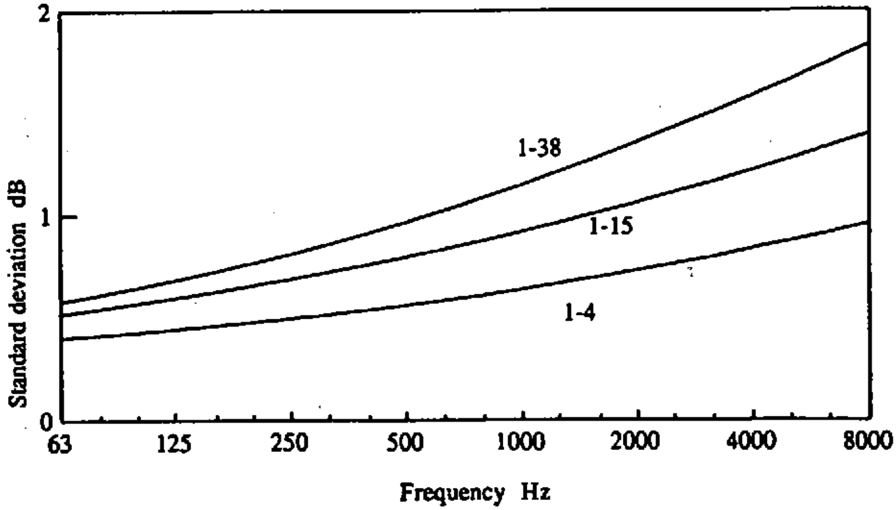

Fig. 6 Standard deviation at three distances from the source for 1% disconnection probability using the simpler model.

5. CONCLUSIONS

These results have shown that if even a few plates are disconnected from a joint there will be a measurable effect on the performance of a structure. For the structure that was tested disconnecting 1% of plates corresponded to only 1.7 plates disconnected (on average) yet resulted in a variation of 0.5 - 1.5 dB depending on the frequency. Such a variation is not large compared with other sources of error that can occur but nevertheless is large enough to be of interest.

Statistical energy analysis models are by their nature statistical. Usually it is the mean performance that is of interest. However, the spread of results that is likely to occur as a result of the assumptions made also needs to be considered. If the overall design of the structure is such that many joints can be disconnected without a significant change in the mean then the defects can be ignored. On the other hand if even a single joint completely changes the behaviour of the structure then more care must be taken both with the construction of the structure and with the data input into the model.