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SCALE MODELS FOR DETERMINING THE PERFORMANCE OF BUILDINGS

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INTRODUCTION

Although scale models have been extensively used in Architectural Acoustics for modelling the sound within enclosures, there has been little application of models to Building Acoustics except in small laboratory models. At a time when large buildings are becoming more sophisticated and the demands on noise control more exacting, scale models offer a method of determining the performance of the building in cases when calculation methods do not exist or would prove very time consuming.

A scale model allows the performance of a building to be determined before the building has been constructed in the same way as with architectural scale models. However, for building acoustic models the requirements are less exacting since the aim is not to reproduce the sound field at each point in the model but only to determine the average sound level of each room or wall. The same answers could be obtained by calculations using statistical energy analysis methods, but for large structures the calculations are complicated and at the moment the cost of such a mathematical model would probably be prohibitive.

If it is assumed that only the average sound pressure levels in the rooms and possibly the vibration levels of the structural elements are required, then the actual construction of the model can be very simple. As with architectural models, all dimensions are reduced by a scale factor and the frequency of all measurements are increased by the same scale factor. The ratio of the wavelength to the dimensions is then the same for the full size building and the model. Furthermore, if the density and longitudinal wavespeed of each of the materials is the same in the model as for the corresponding materials in the full size building, then the mechanism of sound transmission in the model will be the same as in the full size building.

If the internal loss factor of the materials used is the same in the model, then for a given noise source the distribution of sound throughout the model will be the same as it would have been in the full building and measurements made in the model will give the same numerical values for the sound pressure levels and velocity levels. Often the main difficulty in producing a scale model is in obtaining suitable materials. However, for building acoustic models this is relatively simple. If the same material is used in the model, the material will have the same density and the same longitudinal wavespeed. Since the internal loss factor of most materials is more or less independent of frequency, then the use of the same materials will result in the same internal loss factor. The only difficulty in reproducing identical conditions in is in the rooms where it can be difficult to obtain a scaled down reverberation time. However, since this does not affect any other calculations, it is a relatively simple matter to correct the sound pressure level in each of the receiving rooms for the reverberation time.

When constructing the model, it is not necessary to model the finer points of the building as these have only a secondary effect on sound transmission. If a wall is to be built of concrete block, then slices of block can be cut from a large block. Such a wall would be considered homogeneous so it does not matter whether the parts that make up the wall are the same relative size as the blocks in the full size building and this can greatly simplify the construction.

THE SCALE MODEL

In order to test the accuracy of such models, a scale model of part of a building was constructed. The building that was studied had already been extensively tested and detailed measurements had been made of the sound distribution throughout the building for a number of different noise sources.[1] The building consists of three floors with four rooms on each floor. No special precautions were taken in constructing the model. The floors were made of thin concrete slabs with '9 mm down' aggregate and the walls were made of slices of the same concrete blocks that had been used in the original building. No attempt was made to scale down the size of these block slices so there were only 3 or 4 courses of blockwork on each floor.

RESULTS

Due to airborne flanking paths through the room in which the model was constructed, the model has been tested mainly for structure-borne sound transmission. Small shakers were attached to a wall or floor and the distribution of sound throughout the building was determined. The average wall and floor vibration levels were then compared with predicted values using a statistical energy analysis model and also with measurements made in the full size building.

Typical results can be seen in Figures 1 and 2. Each figure shows a section through the building showing the three floors. Against each wall or floor is shown the average equivalent octave band difference between the scale model results and either the full size results or the predicted results. The numbers shown underlined are the results for the walls seen in elevation. Figure 1 shown the comparison with the full size building. The results show that in the region around the noise source the agreement between the full size and scale model building are quite reasonable at 500 Hz (full size frequency). Similar results were obtained at other frequencies.

Similar results can be seen in Figure 2 which shown the comparison between the scale model results and the predicted results. Again the results are for the frequency 500 Hz (full size frequency) and for a point source on one of the walls. The agreement close to the noise source is good and the largest errors occur on the roof slab well away from the source.

These results are typical of the results that have been obtained for the scale model. The large errors for the roof are due largely to construction problems. There has been a tendency for the roof slab to lift free of the supports so that instead of a line contact between the walls and the roof there are only a few point contacts. This would account for the decrease in the roof vibration level that was measured.

These results have shown that scale models can be used as a means of determining the performance of buildings without the expense of performing the construction first and without detailed mathematical models. Modelling airborne paths has been found to be difficult and this may account for some lack of success in the past. However, for structure-borne sound the construction of the model is simple and few precautions are necessary.

REFERENCE

(1) R.J.M. Craik. The prediction of sound transmission through buildings using statistical energy analysis., J.S.V., Vol. 82, pp. 505-516, (1982).

ACKNOWLEDGEMENT

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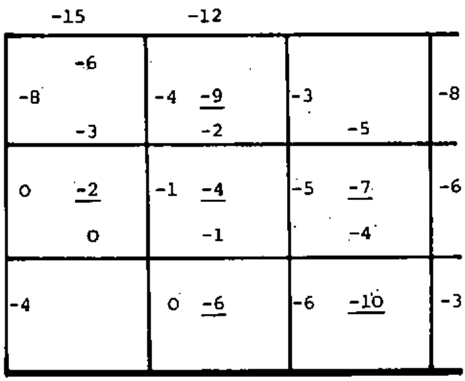
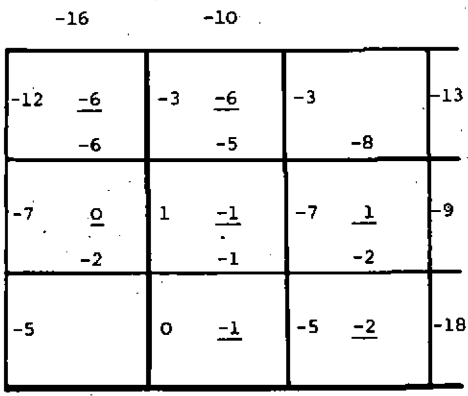


500 Hz octave band difference. Full size velocity minus scale model velocity for the same source

noise source

Figure 1. Difference between full size and scale model results.



500 Hz octave band difference Scale model velocity minus predicted velocity for the same source.

noise source

Figure 2. Difference between scale model and predicted results.