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STRUCTURE-BORNE SOUND TRANSMISSION THROUGH FRAMED BUILDINGS

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INTRODUCTION

Structure-borne sound transmission through regular buildings has been studied using statistical energy analysis (SEA) [1,2,3] with considerable success. However, sound transmission through framed buildings, incorporating columns, beams, preformed cladding panels and large floors, is a more complex problem. Transmission coefficients at structural joints between the members of such structures has been studied by Steel [4] and it was generally found that there was good agreement between measured and predicted results. This work has therefore been extended to include the prediction of the performance of entire buildings with this form of construction.

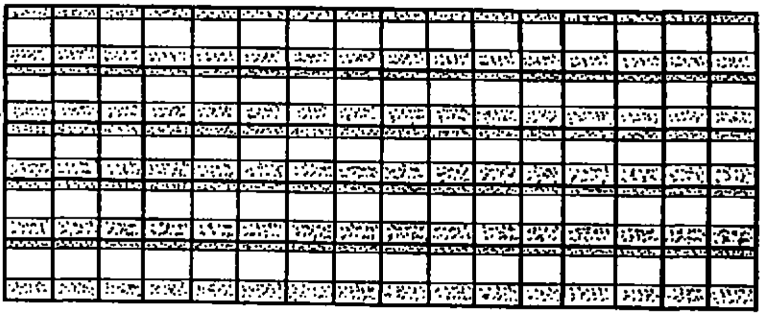
MODEL OF THE BUILDING

When modelling a building using SEA the building is divided into a number of subsystems. These subsystems correspond more or less to the structural elements with each wall, floor, and column being a separate subsystem. The boundaries of these subsystems are then well defined. In this work only transmission of bending waves is considered so each physical element is a single subsystem.

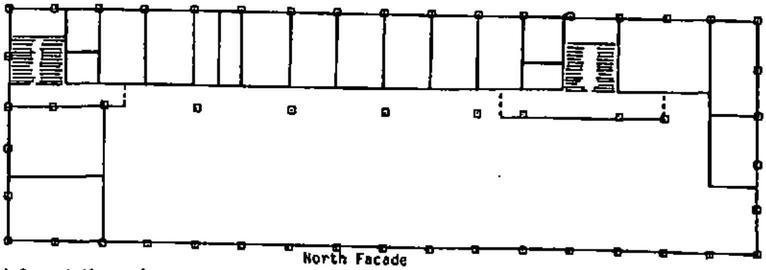
The building that was examined is shown in Fig. 1 and consists of a total of approximately 1000 subsystems. The building has five storeys with an open plan office layout. There are some small offices on the south facade. The floors columns and external cladding panels are constructed of concrete.

As the SEA model of the whole building was too large to be solved on a personal computer the model was reduced to the 300 most important subsystems. The smaller model excluded the South, East and West facades of the building, and also the stairwells, ground floors and roof but included all of the subsystems involved in the measurements. The differences between the results of the two models are less than experimental fluctuations for the frequencies considered in this work.

All of the concrete elements in the building were assumed to have a density of 2500 kg/m³, a longitudinal wave speed of 3500 m/s and a Poissons ratio of 0.3. Floors are 200 mm thick cladding panels are 2.7 long 1.7 m high and 0.125 m thick. The columns in the external facade were approximated to a square cross section of 0.3 x 0.3 m and are 2 m long.



a) Elevation showing the north facing facade.



b) Second floor plan.

Figure 1. Plan and Elevation of the Building.

EXPERIMENT

Measurements of vibration transmission from a source subsystem (excited by a hammer) to a number of receiving subsystems were carried out. Transmission from columns floors and cladding panels was measured.

The energy level difference, ΔL, was computed from the acceleration levels from the equation,

$$\Delta L = 10\log\left(\frac{m_1 a_1^2}{m_2 a_2^2}\right) \tag{1}$$

where the subscripts 1 and 2 represent the source and receiving subsystem respectively, m is the subsystem mass and a is the acceleration of the subsystem.

When the source and receiving subsystems are connected together then an estimate of the energy level difference can be made by considering transmission along the first path only which gives the level difference as

$$\Delta L = 10\log\frac{\eta_2}{\eta_{12}} \tag{2}$$

where η_2 and η_{12} are the total and coupling loss factors respectively.

RESULTS

In the SEA models of the building the large floors were initially modelled as one subsystem. This means that the vibration level at one location of the floor is the same as every other location and that there is therefore no attenuation across the floor. In practise there is significant attenuation across the floor. As a result of this attenuation it is unlikely that there will be significant amounts of sound entering the floor from one side, due to excitation by a wall, that will cross the floor and be reflected back to the other side in order to excite adjacent wall panels.

In order to allow this property of the building to be incorporated into the SEA model the internal loss factor of the floors were set to 10^6 so that transmission paths through the floors were effectively eliminated.

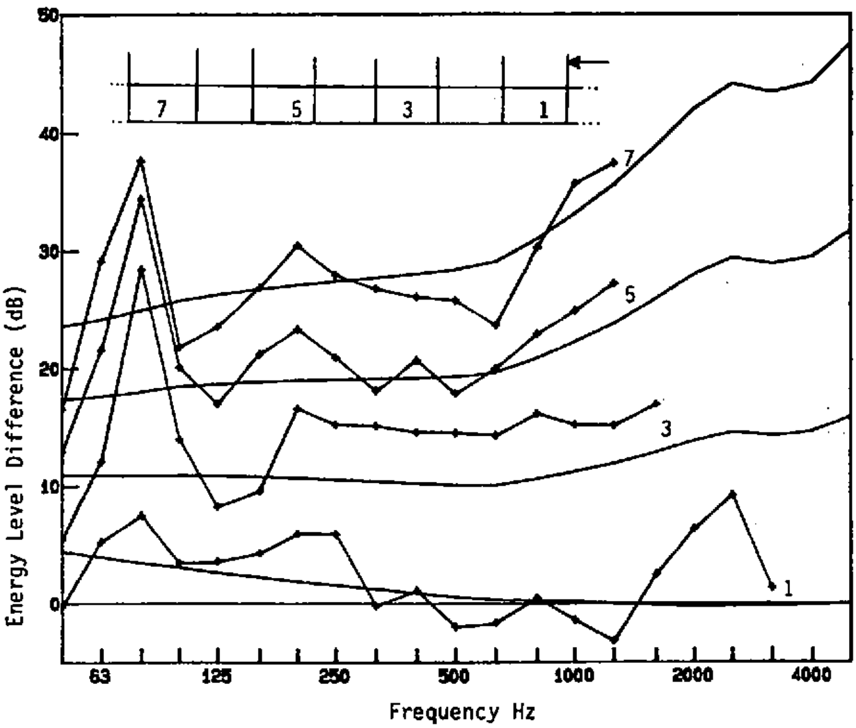


Figure 2. Measured and Predicted Energy Level Difference For Transmission from a Column to Panels on the North Facad. —+—+— Measured; ——— Predicted.

Fig. 2 shows measured and predicted energy level differences on the north facade of the building for a source exciting a column of the building. Although there is some discrepancy the agreement is generally good. The measured results for transmission to the panel marked as number 3 are the worst being greater than expected.

In the same way columns in the north facade were excited and coupling to the cladding panels directly below was measured. The results, shown in Fig. 3, generally fall with increasing frequency. Strong flanking paths give predictions which can be as much as 5 dB less than the direct path and the prediction including flanking paths shows better agreement with measured results.

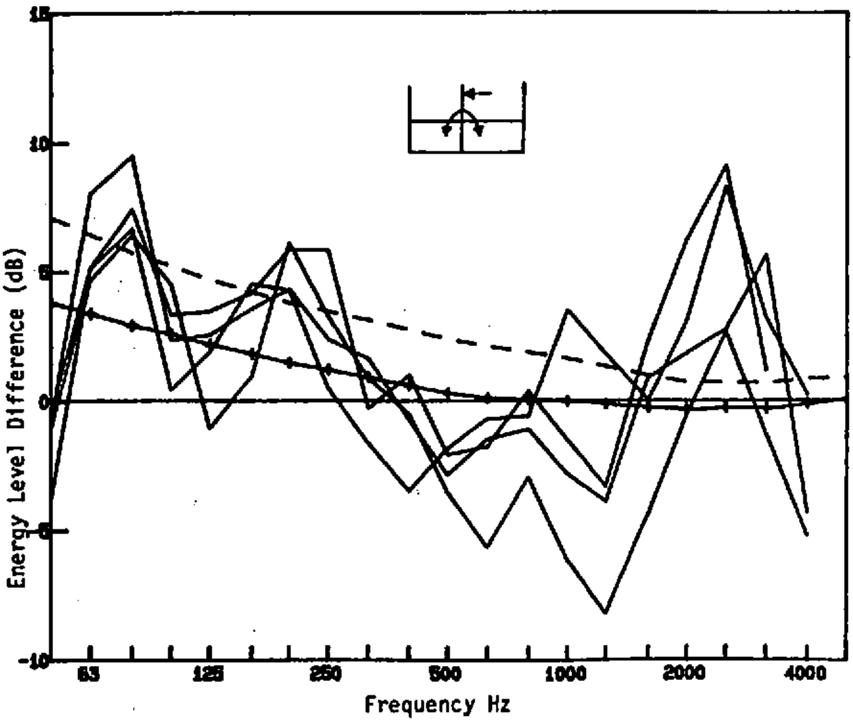


Figure 3. Measured And Predicted Energy Level Difference For Transmission From A Column Down To A Panel. ——— Measured; +—+—+ Predicted using 300 subsystem model; – – – Predicted for direct path only.

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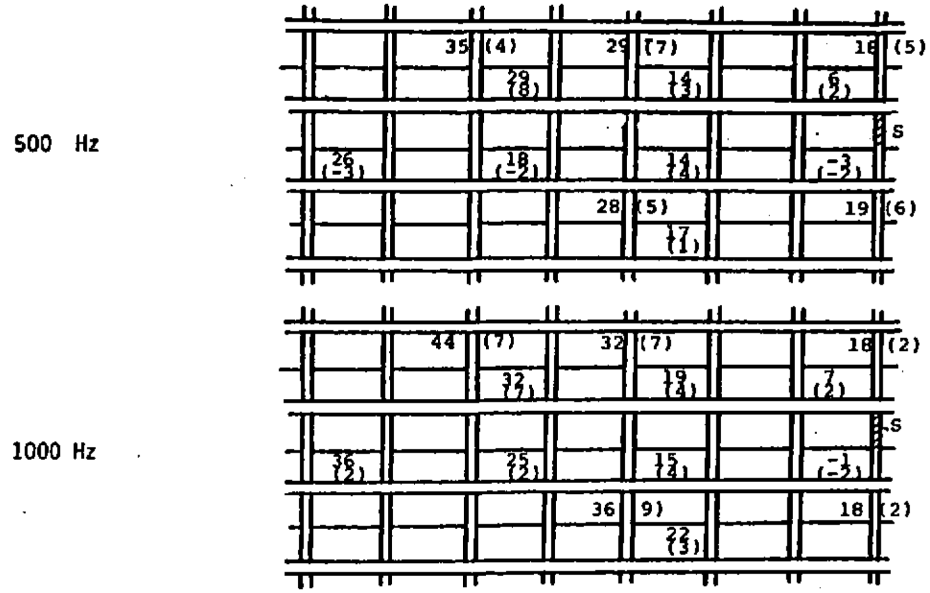

Figure 4. Measured and predicted Energy Level Difference for a Source On a Column. ** measured; (**) measured minus predicted.

Fig. 4 shows the distribution of energy throughout the building for a source on a column on the second floor level. Against each subsystem is shown the actual measured level difference and in brackets () the difference between the measured and predicted level differences.

At both frequencies shown (500 and 1000 Hz) the measured level difference increases as the receiving subsystem becomes more distant from the source, as would be expected. There is greater attenuation in the vertical direction than in the horizontal direction due to the strong coupling between adjacent wall panels. The largest differences between measured and predicted results occur on subsystems close to the source at the third floor level and the largest difference is 8 dB at 1000 Hz. In general there is good agreement.

DISCUSSION AND CONCLUSIONS

The results have shown that the model of the building can be used to predict sound transmission through the building over considerable distances. Although it has been assumed that sound was transmitted principally by bending waves in-plane waves should probably also be included if transmission over longer distances is to be considered.

The modelling of the vibrational characteristics of large span floors which incorporate supporting beams requires further consideration before a complete SEA model of the building can be produced. Tests carried out on this building suggest that at high frequencies there is no significant reverberant sound field produced in the floors. This places difficulties in modelling such buildings and may limit the use of SEA for predicting performance.

Where comparison between measured and predicted results is possible there has been generally good agreement and SEA techniques can be applied successfully to framed building structures.

ACKNOWLEDGEMENTS

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