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STRUCTURE-BORNE SOUND IN FRAMED BUILDINGS

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INTRODUCTION

Many industrial and commercial buildings, built with a frame and lightweight cladding, are highly serviced with many noise sources and at the same time require high acoustic performance. These structures may be characterised by having thin beams and columns supporting large unbroken floor areas.

For transmission over long distances structure-borne sound transmission is important and therefore if these types of building are to be understood it is necessary to investigate the mechanisms of transmission between columns, beams and floor slabs.

Statistical energy analysis (SEA) has been used with success for studies of domestic type buildings and is ideally suited to the study of large buildings. In this paper sound transmission through the frame of a building is examined. Measured and predicted results for sound transmission are presented and some of the difficulties of modelling large floor slabs are discussed.

SEA techniques require the response of an element to be controlled by resonant modes, but building elements such as beams and columns cannot always be considered to be multi-modal at low frequencies and therefore may not lend themselves readily to study within a SEA model. However recent studies, [1][2], indicate that SEA techniques can be successfully used in frequency regions where there may be as few as one mode per frequency band, making studies of framed buildings quite feasible. However, as will be seen there are other difficulties that still remain to be overcome

THEORY

In SEA notation the power flowing between two elements, W_{12}, is defined as,

$$W_{12} = E_1 \omega \eta_{12} = E_2 \omega \eta_2 \qquad (1)$$

where E is the energy in a subsystem, η_{12} is the coupling loss factor (CLF) and η_2 is the total loss factor of the second subsystem.

Lyon [3] gives the CLF between a column and floor, η_{cf}, where both elements are made of the same material and thickness, as

$$\eta_{cf} = w/4L \tag{2}$$

where w and L are the column thickness and length respectively. If the elements are not made of similar materials then the coupling loss factor can be approximated to

$$\eta_{cf} = B_c / 4LB_f \tag{3}$$

where B is the bending stiffness.

The CLF from a floor to a column can be found from

$$\eta_{fc} = \eta_{cf} n_c / n_f \tag{4}$$

where n_c and n_f are the modal densities of the column and floor respectively [3].

When the floor slabs are large then the reverberant sound field is not large compared to the direct sound field. In such cases the sound is not uniformly distributed throughout the floor. Even where the floor is not particularly large non-uniformity can be caused by reinforcement beams, structural joints between precast floor slabs and other inhomogeneities.

In such cases when sound is transmitted from a column to a floor there will be a concentration of sound energy around the point of intersection which is also the point of excitation for the floor. The sound is then attenuated with distance from this point.

For this type of excitation the power balance equation given in equation (1) cannot be used. Instead the power flow from the column to the floor can be found by measuring the energy density close to the column where the direct field dominates. The power flow from the point of excitation will then be

$$W_{12} = E_1 \omega \eta_{12} = Ed.2\pi r.Cg \tag{5}$$

where Ed is the energy density of the floor at the distance r & Cg is the group velocity.

For transmission from the floor to the column the usual SEA theory can be used providing the energy density in the entire floor is taken as being that which surrounds the point of contact between the floor and column.

RESULTS

The floor/column system under investigation consists of a concrete slab floor with a surface area of $194m^2$ and 0.125m thick, supported by 8 steel beams, and a column which is 6.5m long of composite construction using a 0.2 x 0.2m universal column surrounded by 0.09m thick concrete blocks.

The distribution of energy within this floor is difficult to predict due to the stiffening effects of the beams and attenuation of vibrations across beams and joints.

Figure 1 shows the results of measurements made on the floor at approximately 1.5m, 4m and 6m from a tapping machine which was used as a noise source. The values plotted are the difference between the vibration at a particular distance, v_r, and the vibration level at the point of excitation, v_o. At frequencies below 315Hz there is no significant attenuation with distance, and the reverberant sound field is dominant. This means that equation (1) can be used to compute the CLF. At frequencies above 315Hz there is significant attenuation of the vibrations with distance so that a uniform distribution of energy cannot be said to exist.

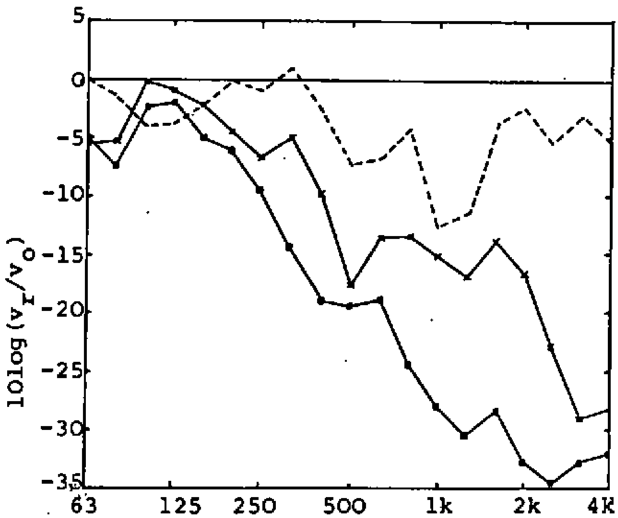

Figure 1. Attenuation of floor vibrations with distance.
– – – – – 1.5m from the source;
x——x——x 4.0m from the source;
▫——▫——▫ 6.0m from the source.

Calculations of expected attenuation with distance show that the reverberation radius, the point where the direct and reverberant sound fields are equal, is less than 500mm over the entire frequency spectrum. It is therefore clear that the non uniformity of the sound field is due to inhomogheneities of the construction.

Figure 2 shows the measured and predicted results for transmission from the floor to the column. A tapping machine was used as a noise source and measurements were made on the column and on the floor around the top of the column. At frequencies below 250 Hz there are few resonant modes and hence fluctuations in the results. However, in general there is broad agreement with the predicted results.

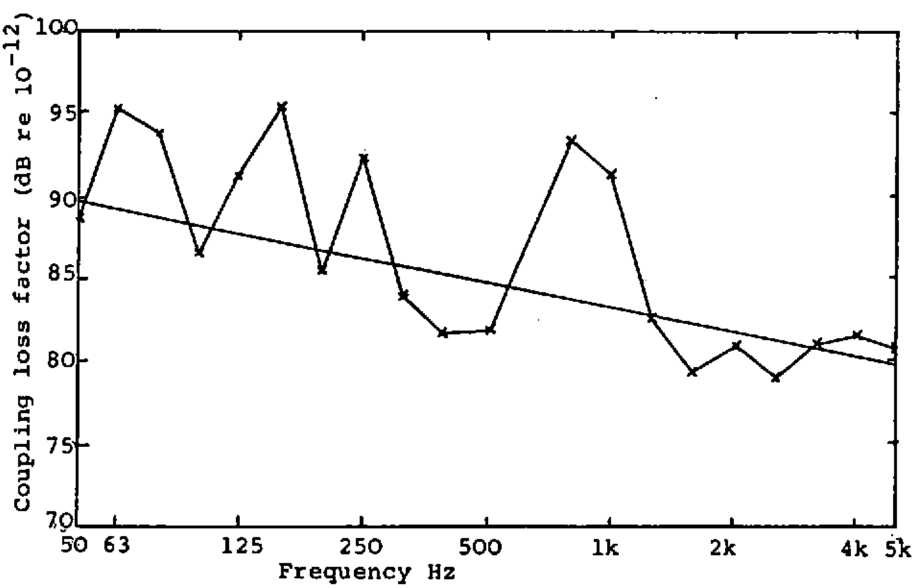

Figure 2. Coupling loss factor for sound transmission from a floor to a column.
——— predicted coupling loss factor;
x—x—x measured coupling loss factor.

Figure 3 shows the results for sound transmission from a column to a floor. At low frequencies the energy in the floor was assumed to be uniformly distributed and equation (3) was used to give a measure of the CLF. At high frequencies the direct sound field was assumed to dominate close to the column and equation (5) was used.

An impact hammer was used to excite the column and the velocities of the column and floor were recorded. For the reverberant field model measurement positions were randomly located over the entire floor. For the direct field model measurements were all inside a radius of 2m. Reasonable agreement is obtained with the predicted result.

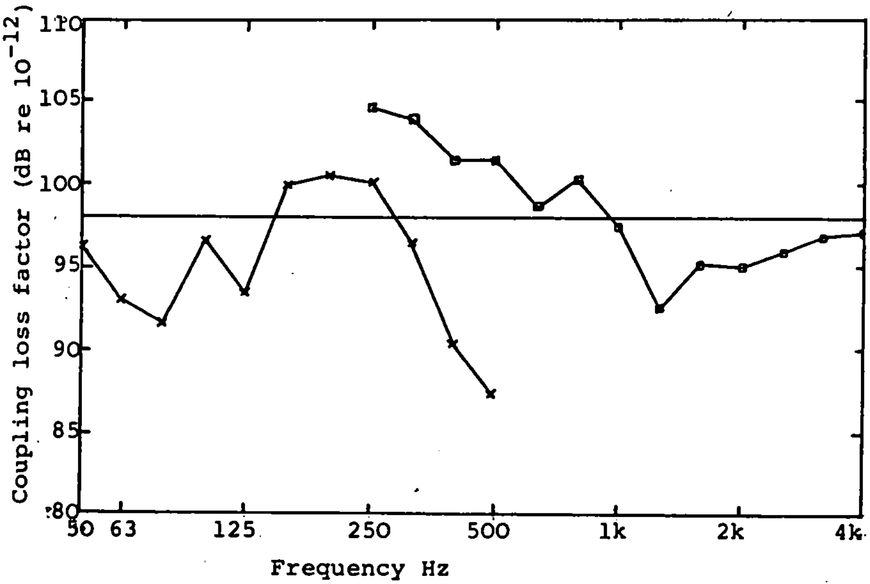

Figure 3. Coupling loss factor for sound transmission from a column to a floor.
——— predicted coupling loss factor (Eqn. (3);
x—x—x measured coupling loss factor (Eqn. (1);
□—□—□ measured coupling loss factor (Eqn. (5).

CONCLUSIONS

The results show reasonable agreement between measured and predicted results for sound transmission between a column and a floor. However, the energy in the floor is non-uniformly distributed and this leads to difficulties in predicting overall performance.

REFERENCES

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