Experimental investigation of the damping coefficient in light-weight constructions

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Introduction

Light-weight timber construction has many advantages, but the main challenge in the acoustic design process is to improve the relatively poor sound insulation through different junctions, especially in the low frequency range. Increasing the total mass can eliminate the sound transmission rate, but is of course against the basic aim of light-weight construction. One alternative is to put a sandwich construction that contains a number of EPDM rubber layers and a thin piece of synthetic material layer in between. The aim of the research project is to improve the sound insulation ,using rubber layer, prediction by numerical methods for light-weight building systems. The approach is to combine a numerical method (FEM) and laboratory measurements to investigate the complex physical phenomena that occur in the structure.

Floor structure

The floor structure, partly represented by figure 1, is constituted by a regular succession of 11 beams of length 4.8m, which are placed parallel to each other. They support particle boards of dimensions 2.4 by 1.2m and 1.2 by 1.2m. The total dimension of the floor structure was 6 by 4.8m. We have in consequence an alignment of 5 plates in one direction, and 2 or 3 plates in the other direction, according to the pattern illustrated in the figure.

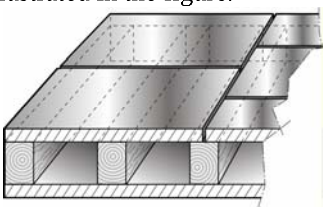

Figure 1: Floor structure.

Scale model

The first structure (left in figure 2) is constituted by a plate of dimensions 1m by 1m, placed on a spruce wood beam which is 6cm wide and 22cm high. Fixation is done using screws placed at 20 cm from each other. The second (on the center) is similar to the first one, except that the beam is now fixed at the middle of the plate. Finally, for the last structure (right), the plate is divided into two parts, each of which is fixed onto one beam using screws.

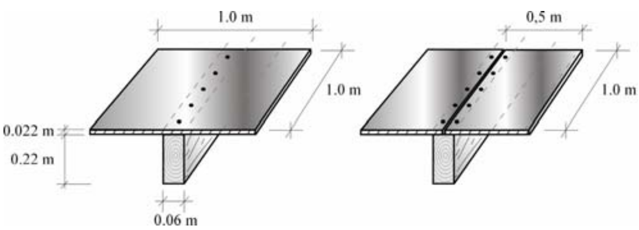

Figure 2: The two models of a beam-plate assembly

Measurements

The aim of the measurements is to validate the Finite Elements Model of the structure. For this purpose, a scale model of this latter has been built using wood plates and beams. The structure has been excited using a mechanical hammer. The excitation type is known as sound impact. Triaxial accelerometers have been fixed on the structure in order to record the vibrations. Accelerometer has been placed at several positions across the structure, and different structure configurations have been tested. A FFT of the acceleration has been done in order to obtain frequency domain information instead of the time domain. By analyzing the Frequency repartition of the acceleration on all three axes, several peaks could be found, corresponding to frequencies at which the most of the oscillations took place. Those peak positions have been correlated with the frequencies obtained by simulation at the same position on the same structure, using nodal analysis and FEM techniques. The figure 3 illustrates the measurement setup.

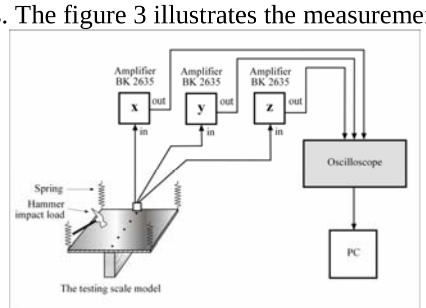

Figure 3: Measurements set up.

Finite Elements

The investigation of the dynamic properties of the floor structure was performed by the three dimensional Finite Element method. The objective of the calculations is to investigate the the response of the floor structure when an time dependent impact load exerts on the floor structure.

In order to find out the main characters of the structure acoustic excitation, the eigenfrequency calculations have carried out. To be able to calculate the transmission rate, reflection rate and the mode conversion rate, the modal frequency response and the modal transient response with coupled mass have been carried out for both the scale models and for the whole floor structure.

Validation of the model

In this section, the results from the simulation of finite element models are compared with the experimental measurements.The differences between the experimental measurement results and the computational results in all three dimensions are outlined in figures 4, 5 for both models.

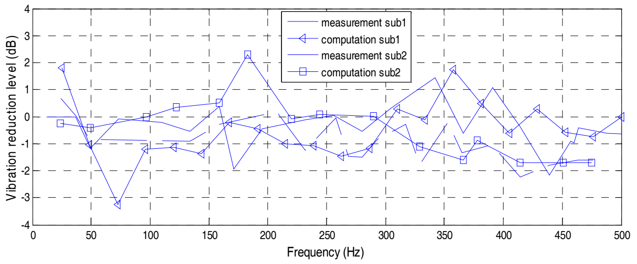

Figure 4: Vibration level in the propagation direction.

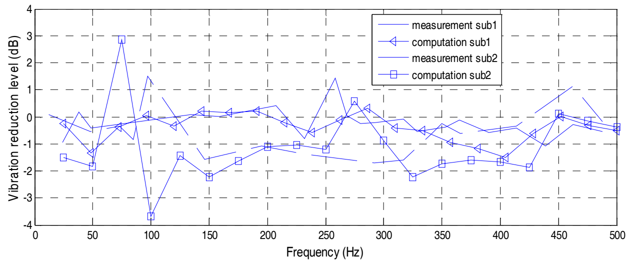

Figure 5: Vibration level in the vertical direction.

Since there is a discontinuity between two plates in the first model, noticeable kinetic energy dissipates as the wave propagates through that junction. The transmission rate is higher for the second model. The agreement between the computational results and the experimental measurement calibrations for both sub-models are relatively close; all this figure confirm that the numerical prediction models do follow the same trend as the experimental measurements and can be regarded as a reliable calculation method.

Floor Without rubber

During the simulation of the whole floor, the frequency spectrum of the impact considered was between 15 Hz to 500 Hz. The excitation was on the upper bay side. The distance between the excitation and the observation location was 1.45m in the propagation direction. Results from eight nodes in the vicinity of the response positions, also on the upper bay-side, yielded a mean response function. The computational results were compared with the experimental measurements reported previously [1]. Figure 6 shows the average attenuation rates, in third octave bands, in the low frequency range.

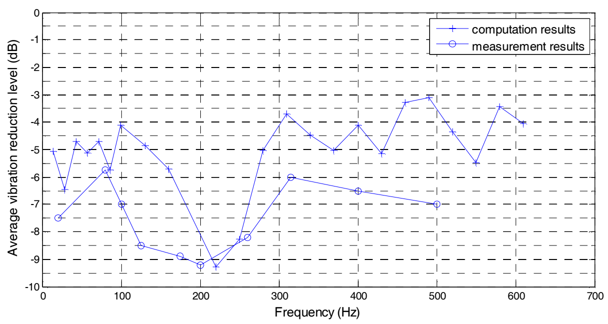

Figure 6: Average vibration reduction level per unit length of floor.

Floor element with a rubber layer

A thin EPDM rubber layer is added at one edge of all chipboards to investigate how this factor can affect the transmission rate. During the calculation, the rubber layer has been modelled with shell element, the thickness of the rubber layer is 3 mm. To be able to find out if a rubber layer can improve the structural vibration isolation for an impact load. The transient response calculation of a floor element contains only one junction. The time dependent excitation load for this simulation was also generated with the random number generator in Matlab. The direction of the excitation force is set in the vertical direction also. The excitation duration was set to be 0.04 second. The fourier transform of the transient response for the subpart with only one junction calculation at two time intervals gives the transmission rate, the reflection rate and the corresponding wave conversion rate of a floor element with a rubber layer. The first time interval captures the wave propagation from the moment the excitation started until the first wave reaches the junction and the second time interval has the same time duration and started when the structural wave starts to propagate through the junction.

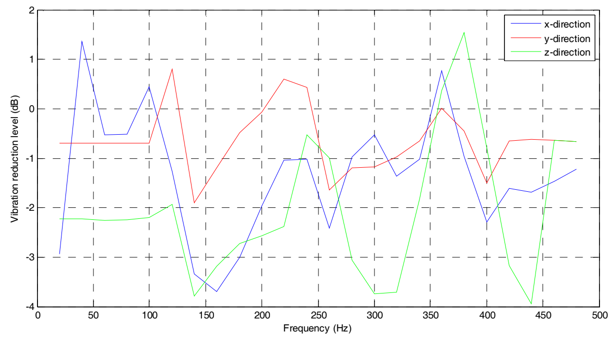

Figure 7: Vibration reduction level in three directions for a rubber layer junction.

Compare with the vibration reduction level of the floor element without a rubber layer at one edge, the transmission rate of the floor structure that has a rubber layer is lower. The acoustic wave scattering pattern has also altered, this may depends on the different mode conversion mechanism of the rubber as materia

Conclusion

The material characteristics of chipboard and timber beams influences a number of different acoustic wave propagation characters, a further investigation of the three dimensional damping characters of the chipboard could provide an more realistic input file for the finite element calculations. To be able to capture the critical motions of the flexure wave propagation, a larger scale model is needed, where the length of the structure in one direction is the same size as the real floor.

References:

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