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VIBRATION TRANSMISSION AT FLOOR/JOIST CONNECTIONS IN WOOD FRAME BUILDINGS

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INTRODUCTION

Floors in wood frame buildings usually consist of a number of Oriented Strand Board (OSB) sheets supported by a series of parallel wood joists. The OSB subfloor is connected to the joists by a number of equally spaced screws. When predicting flanking transmission in wood frame buildings using statistical energy analysis (SEA), two issues need to be addressed. Firstly, one needs to determine whether the joist should be treated as a beam or as a plate strip. Secondly, the frequency dependent behaviour of the joist/floor connection should be characterized. Both topics will be discussed in the following paragraphs, which deal with structure-borne sound transmission in the direction normal to the joists.

MODELLING THE JOISTS

In SEA, beams at plate/beam junctions are often considered as undamped coupling elements and not as subsystems [1-2]. The influence of a beam is taken into account when calculating the coupling loss factor, since the presence of the beam changes the impedance of the junction and therefore also the energy flow between the coupled plates. As cross-section deformation is typically not included, this approach is particularly suited for beams having a rectangular cross-section and an aspect ratio close to 1.

However, since the aspect ratio of a joist cross-section is usually larger than 6, some deformation is likely to occur at relatively low frequencies. As a result, the impedance at the junction is considerably overestimated when the cross-section is modelled as infinitely rigid. In fact, it is more appropriate to model the joist as an undamped plate strip [3]. Also in this case, the joist is not included as a subsystem in the SEA model. Figure 1 illustrates that a plate strip model allows the joist to bend in the plane of its cross-section, whereas, in the traditional plate/beam model, the cross-section behaves as a rigid body.

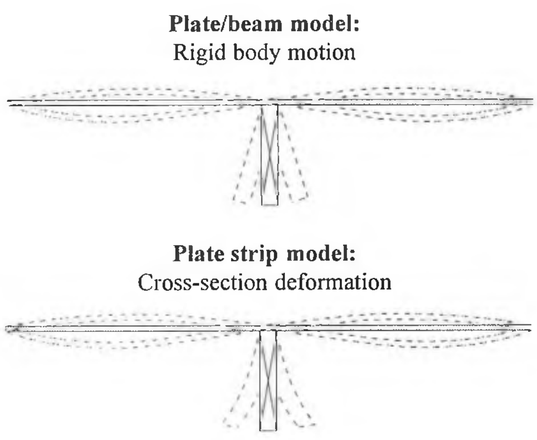

Figure 1: Plate/beam model versus plate strip model. (View: cross-section normal to the joist.)

Modelling the joist as an undamped plate strip is justified as long as the energy dissipation in the joist is negligible compared to the damping of the OSB plates. This implies that the plate strip model should be applied in a frequency range where the joists support only few modes. At high frequencies, the dissipation cannot be ignored and the joists should be modelled as plate subsystems in order to obtain the correct energy distribution in the floor. In this case, coupling loss factors are calculated by modelling the floor/joist junction as a T-joint.

The three models were applied to a subfloor/joist junction and compared to experimental data obtained in laboratory. One OSB sheet (2.4 x 1.2 x 0.0148 m) was connected to a wood joist (1.2 x 0.235 x 0.038 m) by a combination of glue and 17 equally spaced screws. The joist divided the OSB sheets into two identical plates measuring 1.2 x 1.2 m. The calculations were carried out using thin plate theory for homogeneous and isotropic plates and by assuming a line connection between the plate and the stiffener. In view of the anisotropic nature of OSB and the wood joist, the presented comparison is not entirely justified, but tendencies can still be compared.

Figure 2 shows the theoretically and experimentally obtained velocity level difference between both plates as a function of frequency. At low frequencies, the predictions of the plate/beam model and plate strip approach are essentially the same. However, the results of both models deviate at mid and high frequencies, where the plate/beam model clearly overestimates the velocity level difference. The plate strip prediction shows a pronounced maximum near 1250 Hz. A similar feature can be observed for the measured data at 1600 Hz. The T-joint model works well at high frequencies, but underestimates the transmission considerably at low and mid frequencies. In general, there is a reasonable agreement between the trends of the plate strip calculations and the measurements.

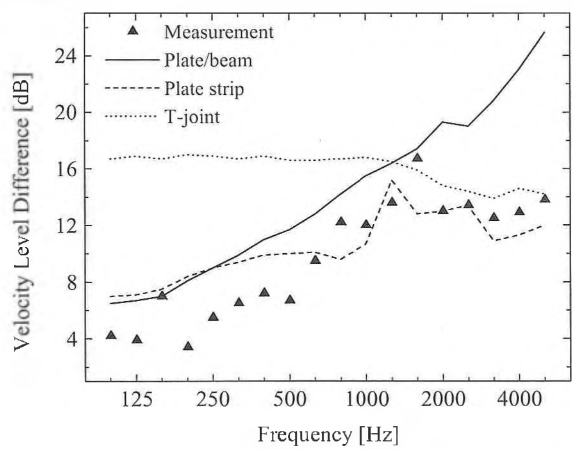

Figure 2: Predicted and measured velocity level difference for a subfloor-joist connection.

MODELLING THE JOIST/FLOOR CONNECTION

Characterizing structural connections using nails or screws represents a major difficulty of modelling flanking transmission in wood frame buildings. In the context of lightweight walls, it has been suggested to treat the joint between a gypsum board sheet and a wood stud as a line connection at low frequencies and a point connection at high frequencies [4]. The transition between both regimes was found to be the frequency at which the spacing between the nails matched half the bending wavelength in the gypsum board. This simplified approach assumes an infinitely small contact area between the plate and the beam element. In addition, it treats the plate as one entire subsystem and therefore neglects the vibration attenuation across the stud. Consequently, the simplified theory is not suited for the purposes of this paper.

The influence of the screw spacing on structure-borne sound transmission at a floor/joist connection is investigated experimentally by two series of measurements on the same floor section as considered in the previous section. In the first series, the OSB sheet was attached to the joist by 5, 9 and 17 equally spaced screws, corresponding to a screw spacing of 0.3, 0.15 and 0.075 m. In the second series of tests, the same number of screws was considered, but a thin aluminum plate (0.038 x 0.038m) was positioned between the joist and the OSB sheet at each of the fasteners. The aluminum spacers were applied to create a well defined contact area at the joint. The results of the two series are shown in Figures 3 and 4. All results were compared to a line junction, which corresponds to a combination of glue and 17 screws.

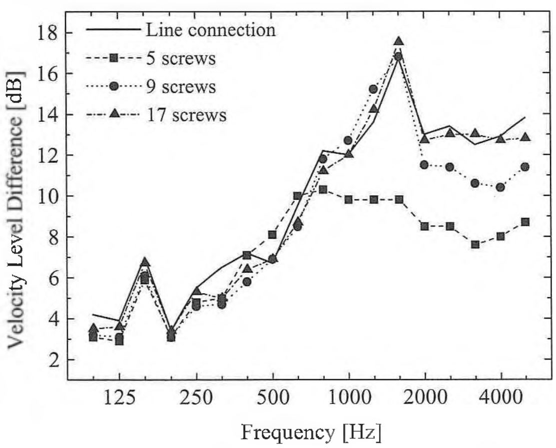

Figure 3: Measured velocity level difference between the OSB plates for the connection using screws only.

Figure 3 shows that the 17 screw connection behaves as a line junction over the entire frequency range. The case with 9 fasteners approximates a line connection up to 2 kHz, whereas the case with 5 screws does the same up to 800 Hz. Above these cut-off frequencies, the velocity level difference drops, indicating a weakened coupling between the joist and the plate. By comparing Figures 3 and 4, it can be observed that the connections with spacers are characterized by a considerably lower cut-off frequency. This leads to the conclusion that the transition from line to 'local' connection is not determined exclusively by the spacing between the fasteners. Moreover, the results indicate that the effective contact area between the joist and the plate is considerably greater that the thickness of the fastener.

As a first step toward modelling the effective contact area, the measured data for the junctions with spacers are compared to calculated results based on the theory presented in [5]. The agreement between measured and predicted data in Figure 5 for the cases with 17 and 5 fasteners is reasonable, but large discrepancies can be observed for the remaining case. However, further research is required to determine the influence of the anisotropy of the materials.

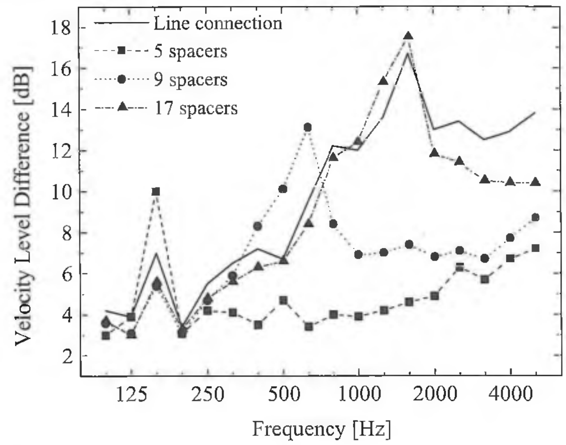

Figure 4: Measured velocity level difference between the OSB plates for the connection using screws and spacers.

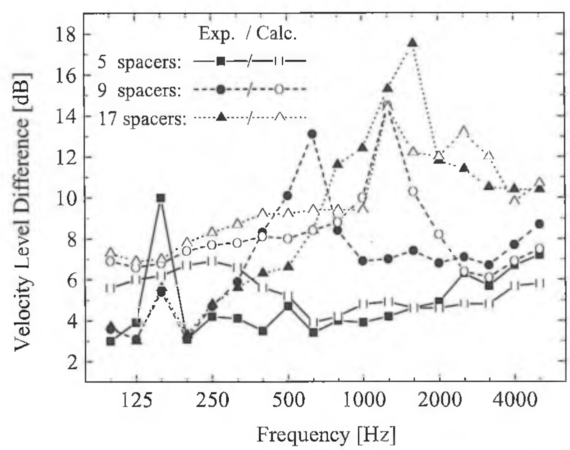

Figure 5: Measured and predicted velocity level difference for the three cases with spacers.

CONCLUSIONS

Structure-borne sound transmission at a floor/joist connection was studied theoretically and experimentally. It was shown that the joist should be treated as a plate strip rather than as a beam. It was further demonstrated that the transition from line to local connection is not only determined by the fastener spacing but also by an effective contact area between the plate and the joist. However, a more complete analysis is required to include anisotropic characteristics of the subfloor and joist material.

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