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Experimental Structural Acoustic investigation of a lightweight floor structure

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ABSTRACT

A common floor construction in a lightweight building system is using chipboard plates attached to wooden beams using screws and glue. One drawback with such a system is the propagation of vibrations stemming either from harmonic (washing machines, dishwashers, HiFi-systems) especially at low frequencies and/or transient (Human walking, dropped items, slamming doors) excitations. In order to accurately predict the sound attenuation and the losses of such building systems, computationally accurate and efficient simulation techniques are needed.
The main objective of this work is to examine sandwiched floor constructs consisting of one and two layers of chipboards attached to supporting wooden beams. Of special interest are the effects of the discontinuities between adjacent boards and between the boards and beams on the loss of kinetic energy as a consequence of the evanescent wave propagation due to the acoustic attenuation process in the structure and on the phase shift of the waves as they travel past the different types of discontinuities in the floor assembly.
The measurements are performed using two-axis accelerometers distributed over the floor and recorded synchronously. The measurements are focused in the low frequency range (10-600Hz) and are also including transient loads.

1. INTRODUCTION

As lightweight constructions become increasingly popular in the building industry for the obvious reasons of the low cost and ease of construction, noise propagation is and remains an issue in light frame buildings [1]. This challenging problem finds its origin in the low weight, density and stiffness compared to traditional materials. Consequently, as more buildings are erected using these construction methods, more nuisances related to sound transmission are reported. Due to the large surface they offer, and to their primary function, floors naturally play an important role in terms of sound propagation. Therefore, it is important to understand in detail how sound and vibrations are conducted, transmitted or absorbed by floors. The properties of floors depend strongly on their structure [1] [2] [3] [4]. This study investigates the behavior of a sandwich floor made from lightweight materials. As in former studies [2] [3] , arrays of accelerometers have been used to simultaneously sense the vibrations at different points along the floor, resulting from a single point excitation. In this case, however, we use a shaker as the excitation rather than a tapping machine.

2. EXPERIMENTAL SETUP:

Floor construct

The floor construct used in this investigation is made from chipboard plates on top of spruce beams. The plates are attached to the beams using screws every 300 mm. This is a common type of floor constructs in modern lightweight building systems in Sweden. The dimensions of the plates are 1200x2400x22mm and the dimensions of the beams are 60x215x5400mm. In addition to this construct, we have also investigated the case where an additional layer of chipboards has been added on top of the first one. This type of sandwich floor constructs is common in rooms with stricter demands on durability and stiffness i.e. in bathrooms. The figure 1 represents a schematic view of the construct. Note the discontinuities between the different plates.

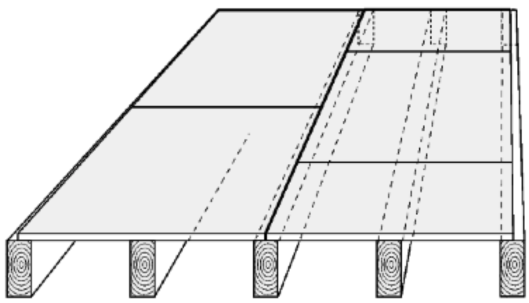

Figure 1. Schematic of the floor construct

As the second layer of chipboards is added, the plates in the second layer are shifted with respect to the first layer so that no discontinuities are directly on top on another.
The beams are placed on triangular supports one in each end of each beam and the whole construct is slightly raised above the floor in the test room enabling easy access to underneath the floor.
The measurements were performed using 27 two-axis accelerometers uniformly distributed over parts of the floor. The accelerometers were placed with 300mm spacing in the direction across the beams and with 600mm spacing along the beams. This spacing has been determined to be a good compromise between the spatial resolution and the area covered by the sensor array, given

the range of the frequencies we wanted to investigate. To get the force applied by the shaker a B&K 8200 force transducer was used placed between the shaker rod and the plate attachment. In order to get a finer grid over the floor the accelerometers are arranged in a set covering one third of the floor, this set is displaced twice and the measurement repeated accordingly at each position. This whole setup is then repeated for the second shaker position. As the measurements are performed in three different sets the synchronicity over the complete set of accelerometers is lost but is retained within a set. In order to investigate the behaviour of discontinuities, two other sets of measurements were performed, where the accelerometers were placed along the borders between different plates.

3. MEASUREMENTS

Mode excitation

The advantage of using frequency sweeps as excitation signals for the shaker is that different floor vibration modes get excited as the frequency is increased progressively. In figure 2 shows the acceleration magnitude density plot for the excitation frequencies corresponding to four modes in the case of the one-layer floor on the left and the same information for four modes but in the case of the two-layer floor.

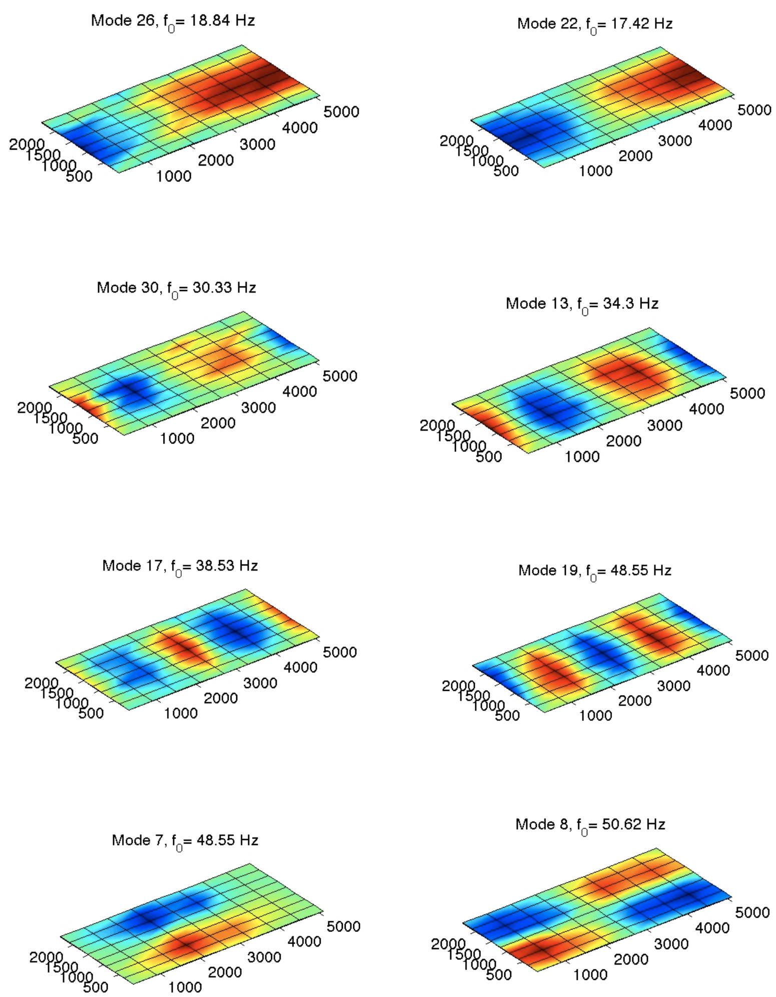

Figure 2. Eigenmodes of the floor with one layer (left) and two layers (right)

Frequency sweeps

Figure 3 represents the frequency response of 9 accelerometers around the shaker (in position 1) as the excitation frequency is increased continuously between 15Hz and 160Hz. The modes can be easily identified here as well, and since the spatial frequency is low, all channels show their minima and maxima at roughly the same frequency, at least for the lower frequencies.

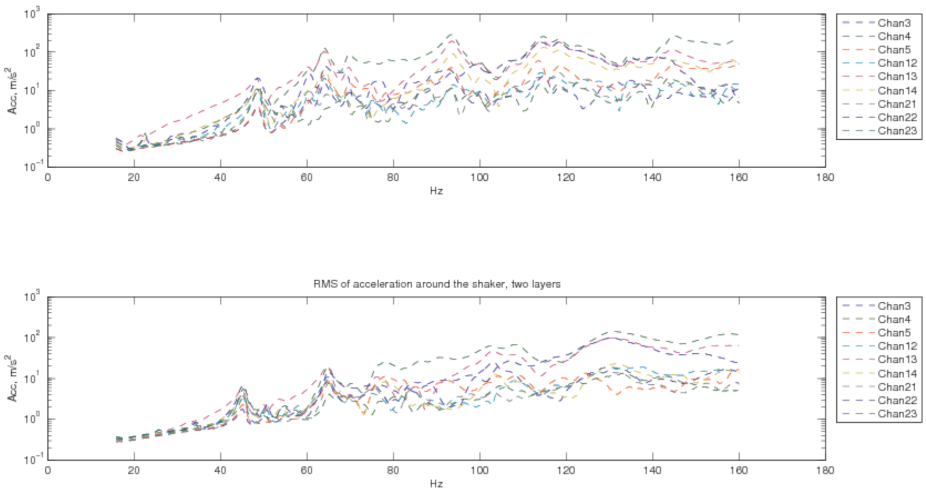

Figure 3. RMS of the acceleration around the shaker for one layer (top) and two layer (bottom)

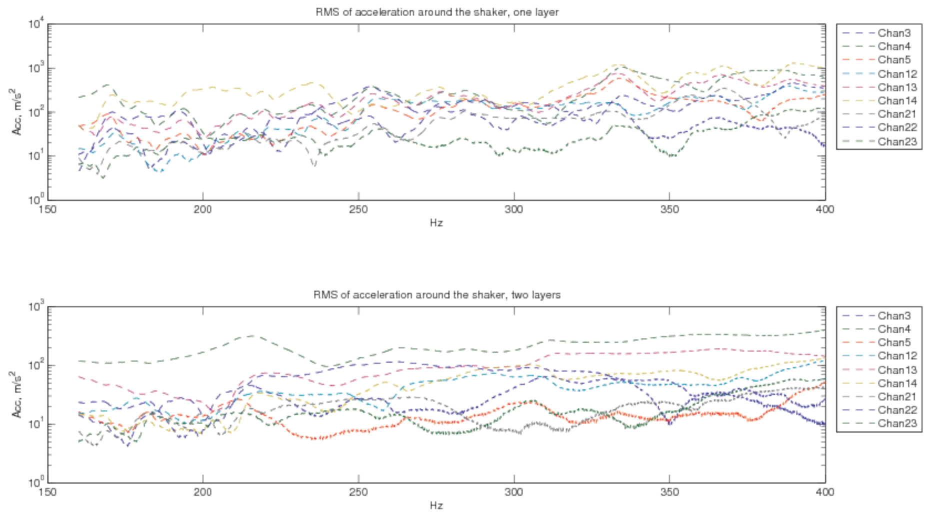

Figure 4. RMS of the acceleration around the shaker for one layer (top) and two layer (bottom)

In the figure 4, the same channels, but for a sweep frequency range of 160-400Hz is shown. Notice that the magnitude changes get out of synchronization as the frequency increases, what makes fully sense, since the spatial frequency also increases as higher order modes are excited. Therefore, small position differences count for high magnitude differences.

3.1. Floor discontinuities

Using a large number of accelerometers all over the floor plates allowed us to observe the evolution of the floors behaviour across the discontinuities as the frequency varies throug the sweep frequency range of the shaker excitation signal. In the next figures 2-dimension maps with contour plots of the acceleration magnitude over the plates are shown. For the two frequencies, the results are shown with the shaker in either of both tested positions (top versus bottom figures). Finally, and most importantly, the results with one-layer floors and two-layer floors are systematically compared (left side versus right side figures). The dimensions of the plates are outlined by white lines superimposed to the 2-D maps.

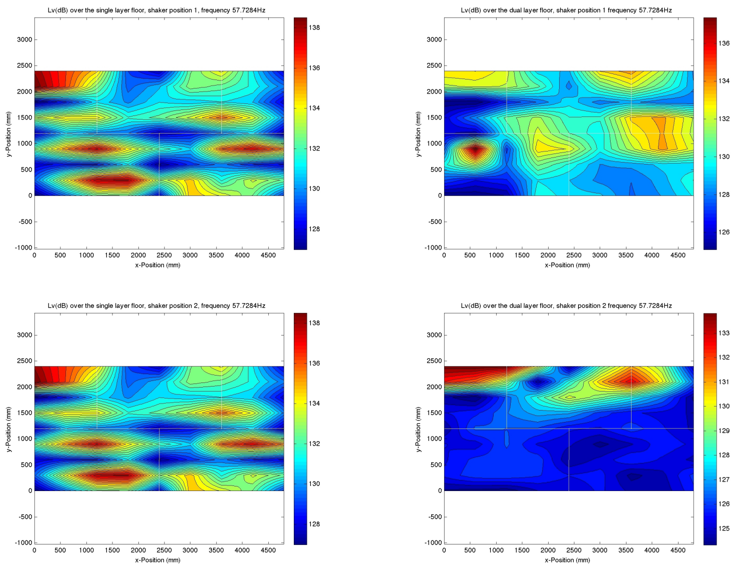

Figure 5. 2-D acceleration magnitude maps for one-layer floor structure (left) and two-layer floor structure (right), with shaker in first position (top) and second position (bottom), at a shaker excitation frequency of 57.73Hz

Figure 6 represents the measurements for the lowest available frequency of 15.87Hz. Absolutely no attenuation is to be observed across horizontal discontinuities between the plates. On the contrary, the attenuation across the vertical discontinuity is relatively significant, which is expected, since the plates are attached to the beams precisely along this line. When comparing the one-layer configuration (left) with the two-layer configuration (right), one notices that the vibrations are much more localized and propagate less far in the case of the double layer floor. In the case of the first position of the shaker (top right), one can even see that the dominant mode is of higher order compared to the one-layer case (top left).

The figure 5 corresponds to measurements done at a higher frequency of 57.73Hz. Interestingly, this frequency appears to excite modes in such a manner that the upper left extremity of the floor is subject to high vibration levels. Nevertheless, it also appears clearly that the vibration is much more localized in the case of the two-layer floor (right) compared to the one-layer floor (left).

4. CONCLUSION

An extensive study of vibration propagation in a floor over a wide range of frequencies has been done. A comparison of a one-layer structure and a two-layer structure allowed us to make some interesting observations and to draw instructive conclusions. It has first been established that the dominant mode at a given frequency is strongly affected by the type of structure used. Then, as the dependence with the frequency has been investigated over several adjacent accelerometers,

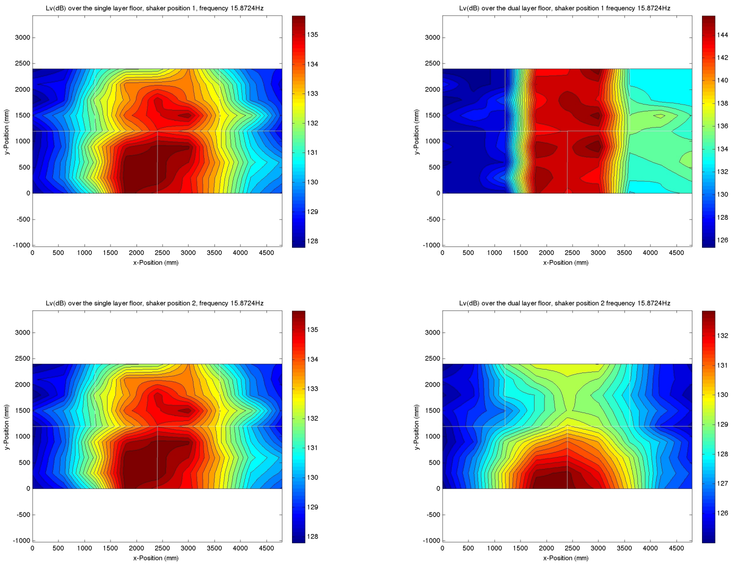

Figure 6. 2-D acceleration magnitude maps for one-layer floor structure (left) and two-layer floor structure (right), with shaker in first position (top) and second position (bottom), at a shaker excitation frequency of 15.87Hz

it has appeared obvious that the magnitude spread is drastically increased with the frequency, since the spatial frequency also increases. The most interesting part is probably the comparison of 2-dimension magnitude plots for one-layer floor structures versus two-layer floor structures. The analysis shows that the propagation of the vibrations over the floor at lower frequencies is significantly lowered by the addition of a second layer that does not exactly overlap with the first one. At higher frequencies, however, this does not seem to hold any more, the tendency even seems to reverse, the vibrations propagating further in some cases.

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