The effect of timber stud decoupling approaches on the transmission loss of double walls; a numerical study

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Summary
A novel design is proposed in which timber studs are modified in order to decouple the two panels of double walls. The effect of a number of decoupling slit configurations were investigated numerically, using the finite element method. The transmission losses of the double wall configurations with slit modified timber studs were compared with the transmission loss of a double wall with non-modified, solid timber studs. Conclusions with respect to the effectiveness of the slit configurations are presented.

1. Introduction

Double walls are a very common construction method especially for, but not limited to, prefab buildings. They are easy to build and usually consist of a gypsum board on either side of the wall. In between there are timber studs for stability and some isolating material like rockwool. Obviously, the timber studs are a stiff connection between the two sides of the wall, since that's their main purpose, but that also means they provide a good way for noise to travel through the wall.
In this paper we examine four wall types with different configurations of slits in the timber studs as shown in figures 1-4.

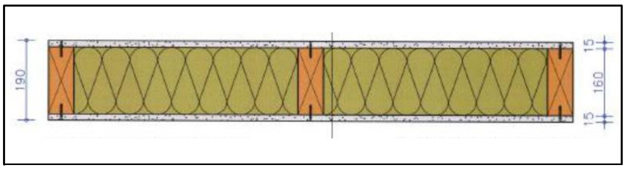

Figure 1: Top view of panel R.1 with solid studs

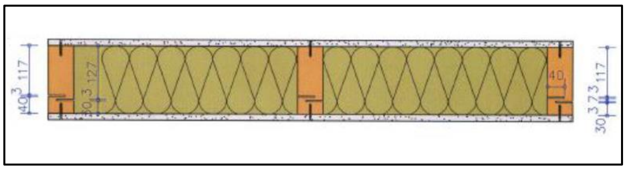

Figure 2: Top view of panel R.3.1 with asynchronous slits

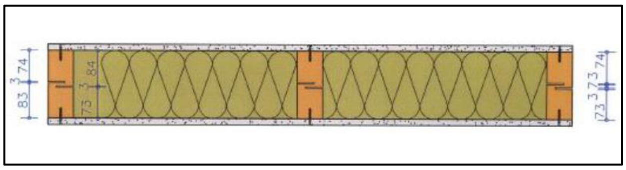

Figure 3: Top view of panel R.3.2 with slits in the middle

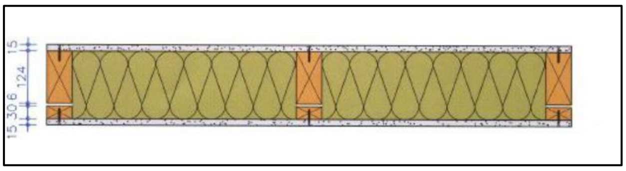

Figure 4: Top view of panel R.5.1 with complete cuts through the studs

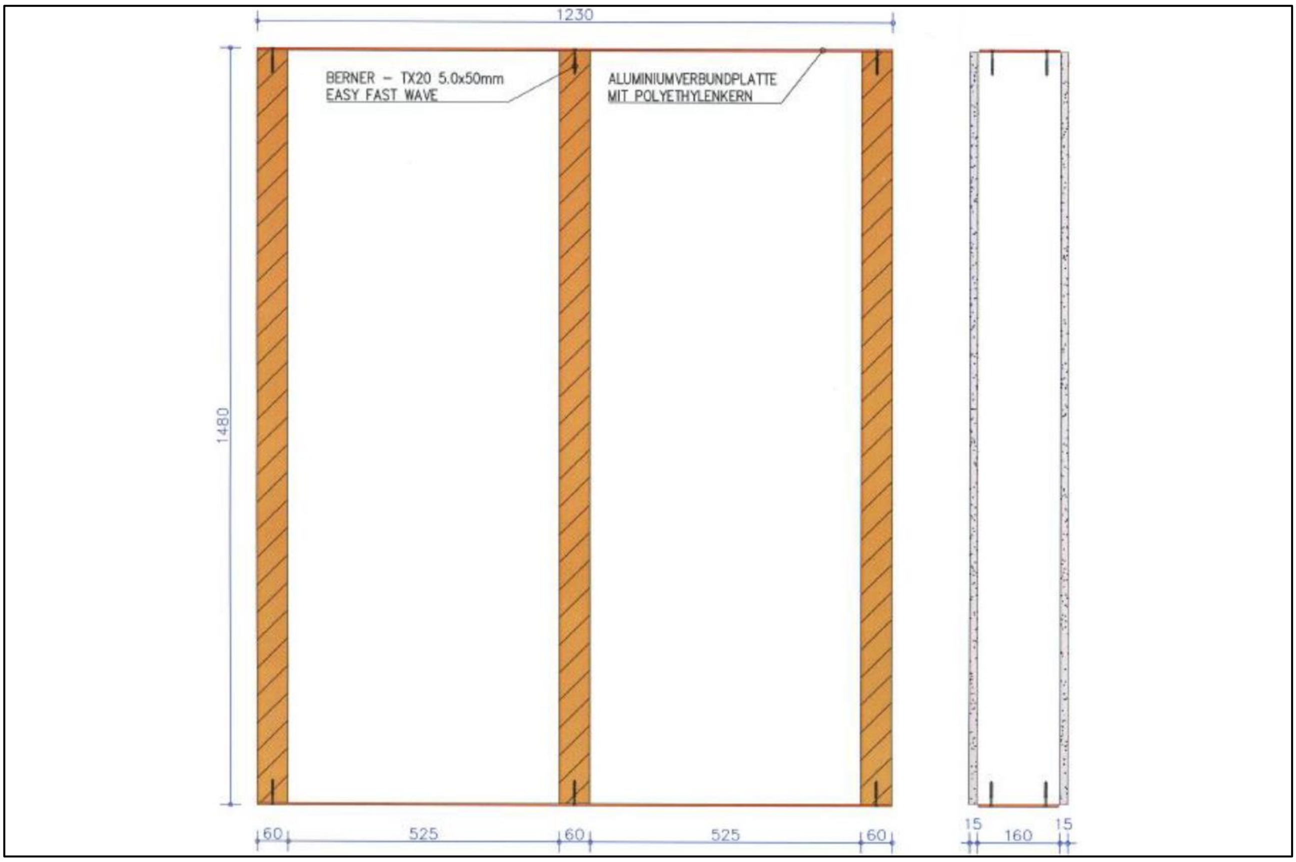

Figure 5: Front and side view of the panels

Figure 5 shows the front and side of the panels that were calculated in this study.

All samples are 123 cm wide, 148 cm tall and 19 cm think. They consist of two gypsum boards, each 1.5 cm thick, on the front and back of the panel and three timber studs (one on each side and one in the middle of the wall panel). The timber studs are 6 cm wide and 16 cm thick. The remaining room between the timber studs is filled with rockwool.

The simplest panel is R.1, it consists of solid timber studs. This is the configuration in which these double walls are currently usually built.

In panels R.3.1 and R.3.2 the timber studs have slits on both sides that act like springs. In panel R.3.1 the slits are moved to one side to avoid symmetry in the panel; in panel R.3.2 they are in the middle of the stud.

Panel R.5.1 is completely decoupled.

2. Hardware and software setup

Some early tries for the simulation were performed on a laptop computer with only 4 GB of memory, which did not work out very well.

Therefore, all calculations for this paper were performed on a more powerful machine:

- Processor: AMD FX-4350 @ 4.2 GHz
- Memory: 16 GB
- Operating System: Windows 10 Pro

The panels were all modelled as 3D-structures in Comsol Multiphysics 5.0, the results exported as csv files and then imported into Matlab R2018a to calculate the transmission loss for a random incidence, diffuse acoustic field.

3. Numerical model and material properties

In Comsol all parts (i.e. the timber studs, the rockwool and the gypsum boards) were modelled as 3D solids and we let Comsol choose the mesh itself. We set it to “physics-controlled mesh” and mesh size “normal”.

For each of the panels we ran two models: One with a fixed constraint, where the edges of the gypsum boards were rigidly fixed with a boundary condition of a displacement of zero. For the second version we “mounted” the same edges in a spring foundation with a spring constant per unit area of 4.25e9 N/(m m²). This value was found via trial and error to match the first eigenfrequency in the numerical model with the real eigenfrequency (measured via laser doppler vibrometry). We also

Table I: Material properties used in the model

	Density (ρ)	*Poisson's ratio (ν)*	*Young's modulus (E)*
Gypsum board	1150 kg/m³	0.3	3.8e9 Pa
Timber studs	430 kg/m³	0.3	11e9 Pa
Rockwool	130 kg/m³	0	4.4e6 Pa

added some damping in the materials by adding 0.05i to the Young's moduli of the materials.
For all eight models (4 panel types, each in two versions as described above) we calculated the eigenfrequencies of the panels. The results of these studies were then used for the modal analysis in the frequency-domain: we split the front gypsum board in 100 subpanels in a 10-by-10 grid and excited each of these subpanels individually with a diffuse field of 1 Pa. This modal analysis was performed between the frequencies of 20 Hz and 300 Hz. The results were obtained from the patch mobilities of the structure, following a procedure as proposed in [1]. To save on calculation time, we calculated these studies only for the 25 subpanels in the lower left quadrant, as indicated in , and obtained the remaining 75 studies by symmetry.

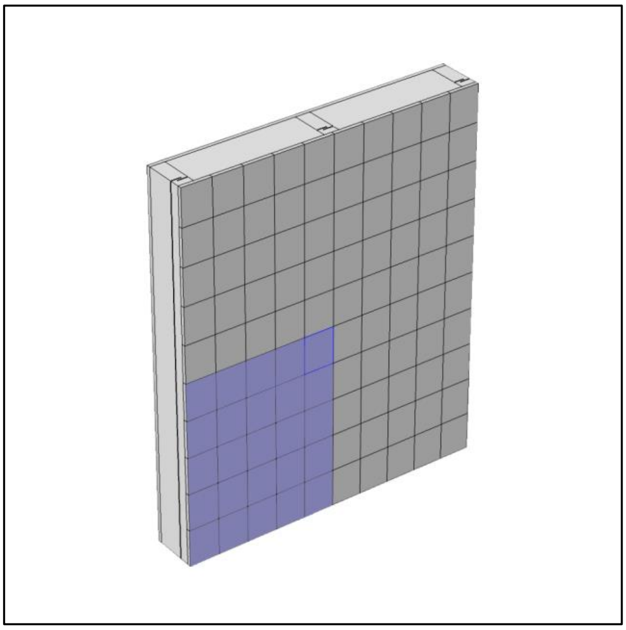

Figure 6: Panel R.3.1 with the subpanels that were actually calculated indicated in blue

To perform the calculation in Comsol we also needed the following physical properties of the materials: density (ρ), Poisson's ration (ν) and Young's modulus (E). All the properties used in our calculations are listed in Table I. The properties for the rockwool were taken from [2], those for the gypsum boards were taken from the manufacturer's website [3] and the density of the studs was measured at the TGM in Vienna. For the model variants including damping we added 0.05i to all the Young's moduli.

4. Results

For each of the panels we now give the results in the form of Matlab plots of the transmission loss for a random incidence, diffuse acoustic field. In all figures the dashed lines denote the transmission loss for the variant without damping and the solid lines represent the transmission loss for those with damping.

4.1 Panel R.1

Unfortunately, for this panel the calculation for the panel without damping always gave an error, so that result is missing. The first three eigenfrequencies for the model with damping are 79.6 Hz, 104.7 Hz and 113.91 Hz.

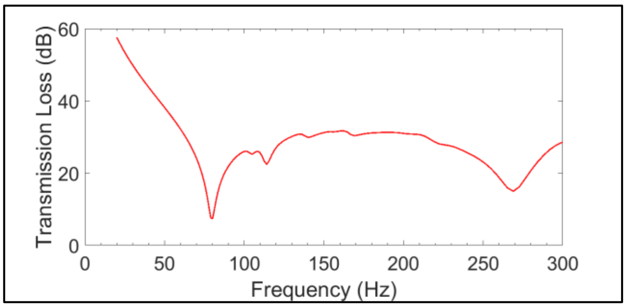

Figure 7: Transmission loss for panel R.1 with damping

4.2 Panel R.3.1

The first three eigenfrequencies for the model with damping are 77.7 Hz, 103.23 Hz and 112.46 Hz. Those for the model without damping are 96.7 Hz, 105.9 Hz and 121.14 Hz.

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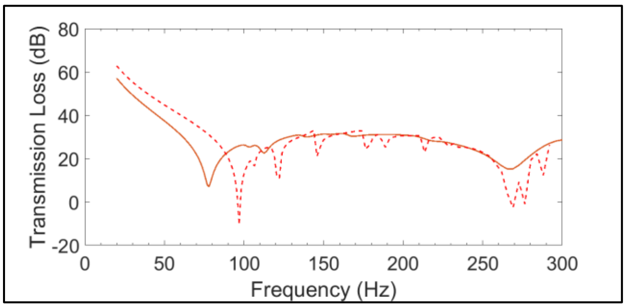

Figure 8: Transmission loss for panel R.3.1. The solid line is for the model with damping and the dashed line without.

4.3 Panel R.3.2

The first three eigenfrequencies for the model with damping are 78 Hz, 104.7 Hz and 112.9 Hz. Those for the model without damping are 96.7 Hz, 105.94 Hz and 121.14 Hz.

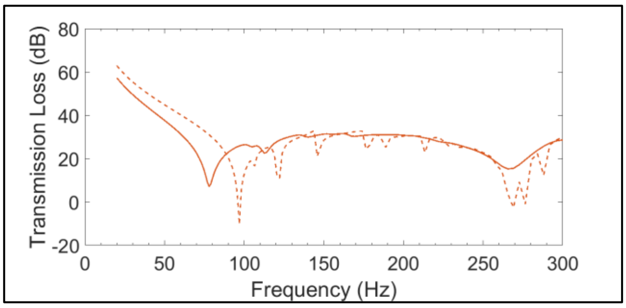

Figure 9: Transmission loss for panel R.3.2. The solid line is for the model with damping and the dashed line without.

4.3 Panel R.5.1

The first three eigenfrequencies for the model with damping are 65 Hz, 95.4 Hz and 105.9 Hz. Those for the model without damping are 79.6 Hz, 101.6 Hz and 116 Hz.

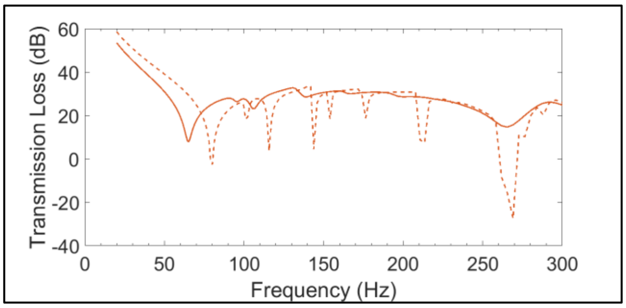

Figure 10: Transmission loss for panel R.5.1. The solid line is for the model with damping and the dashed line without.

4.5 Comparison of the panels

As can be seen in Figure 11, the panel with the highest eigenfrequency is the one with the solid timber studs (R.1). The eigenfrequencies for the ones with the slits (R.3.1 and R.3.2) are (just slightly) but noticeably lower. Of those two the panel with the asynchronous slits (R.3.1) has a slightly lower eigenfrequency, but the difference is miniscule (77.7 Hz vs 78 Hz). The completely decoupled panel R.5.1 has by far the lowest eigenfrequency.
Comparing the transmission loss of the various panels, it must be said that the dips are quite

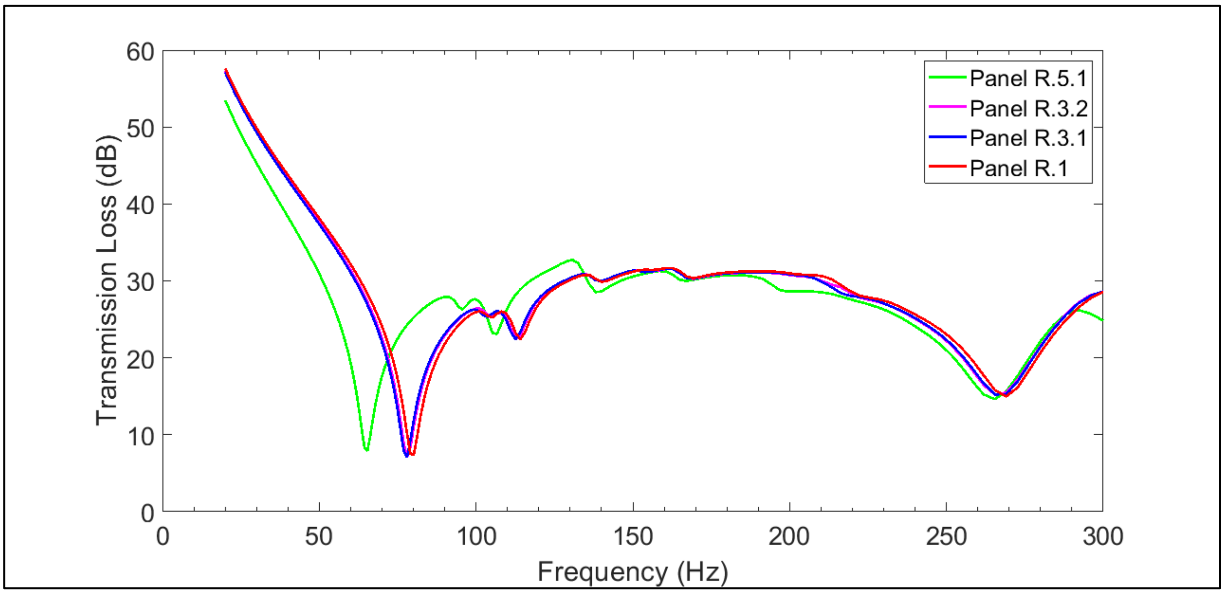

Figure 11: Comparison of the Transmission Losses of all the panels with damping

similar, although at different frequencies. Especially the differences between R.3.1 and R.3.2 are barely noticeable.

Acknowledgements

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