A Parameter Study of Coupling Properties in Finite Element Models of Single-Stud Double-Plate Panels

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A Parameter Study of Coupling Properties in Finite Element Models of Single-stud Double-plate Panels

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Motivation

While the current trend towards lightweight constructions may be of both economical and environmental benefit, the tradeoff between reduction of structural weight and reduction of the level of sound and vibration is an important issue that must be dealt with by optimizing the designs.

Abstract

The present work utilizes a finite element model of a single-stud double-plate panel structure to investigate how different couplings between the plates and the frame structure affect the direct sound transmission. Four different coupling configurations are considered:

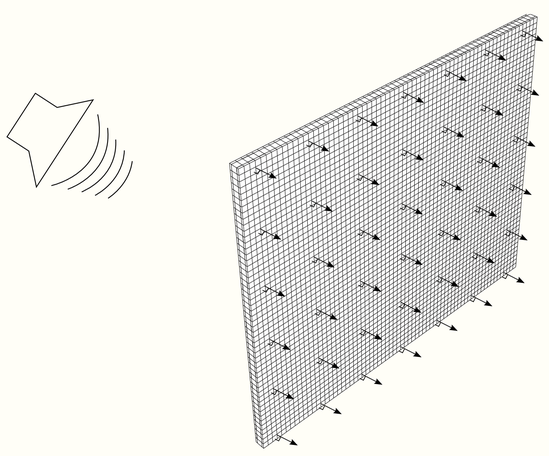
1. All structural contact points are completely tied;
2. only nodes on the centre lines of the structure are tied;
3. a narrow strip of tied elements connect the frame to the plates;
4. evenly spaced discrete elements are tied. In all cases the interaction between non-tied elements is neglected.

The investigations are performed as parameter studies focusing on the effect of change in the model.

Computational model

The finite element model is using solid continuum elements for the entire structure. The computations are carried out in frequency domain in the range below 500 Hz and the load acts as a diffuse field on one side of the panel.

- Approximated diffuse field excitation.
- RMS surface acceleration of the receiving plate.

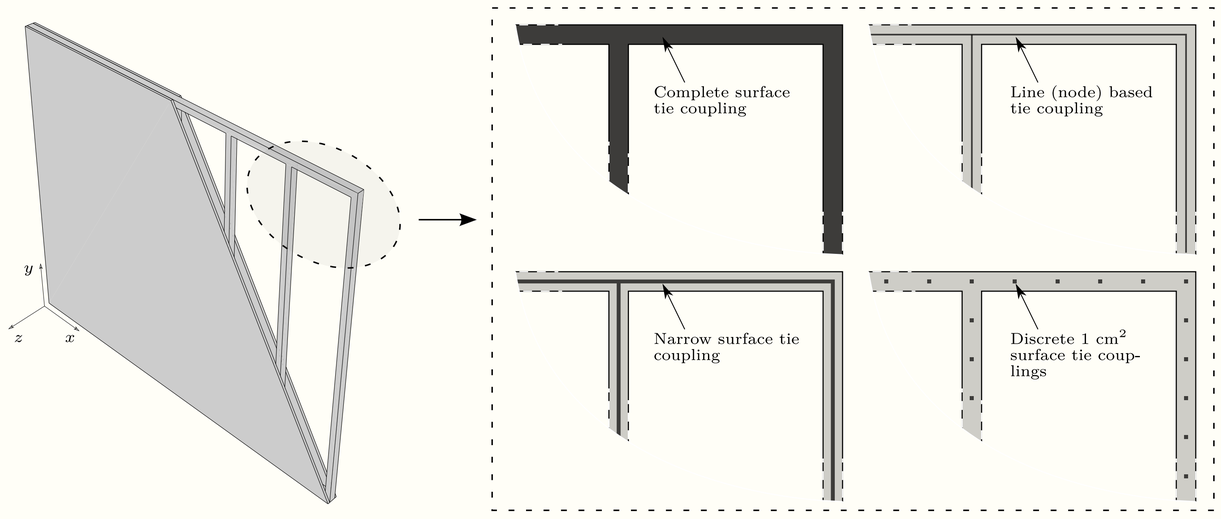


$$\langle a_z \rangle_{\mathrm{RMS}} = \sqrt{\frac{1}{N}\sum_{j=1}^{N}\left(a_z^j\right)^2}$$

Materials (timber):
Young's modulus $E = 14$ GPa, Poisson Ratio $\nu = 0.35$, density $\rho = 500$ kg/m^3. Damping is set to 1% of the stiffness. This simulates the effects of friction in the timber.

Model configurations

A single-stud double-plate panel is investigated in different configurations:



The panels are assumed to have clamped boundaries.

Results and discussion

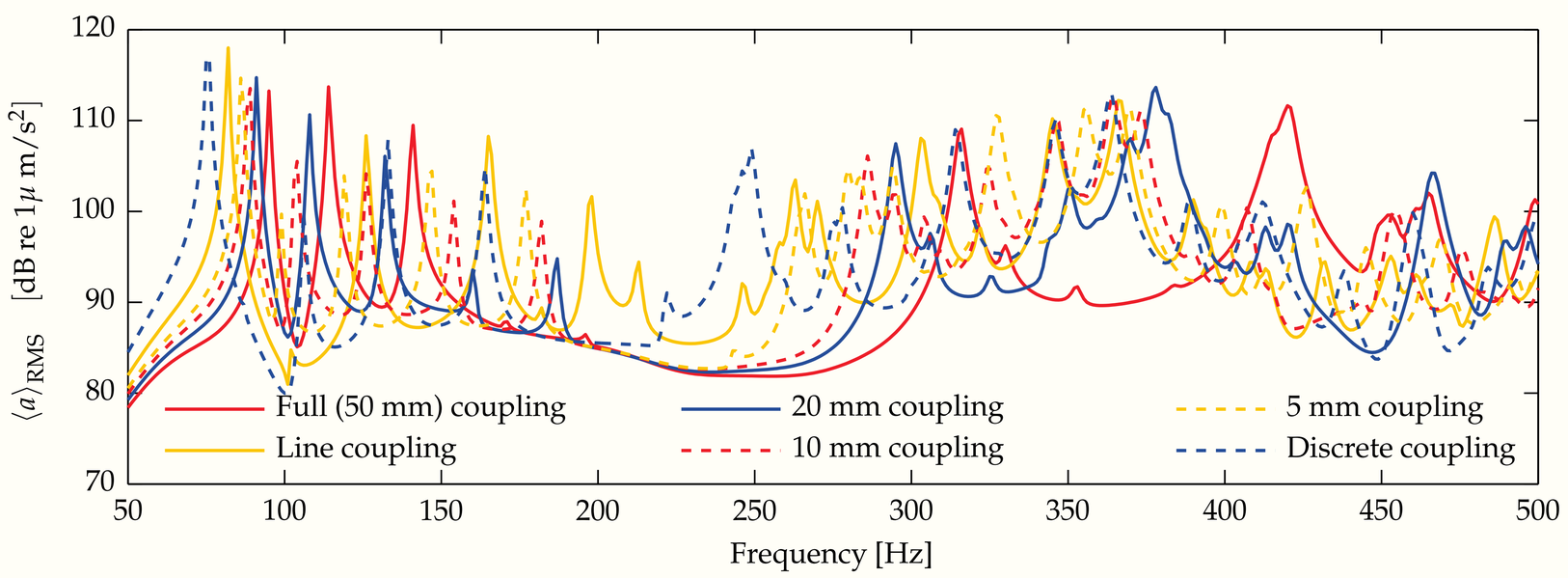
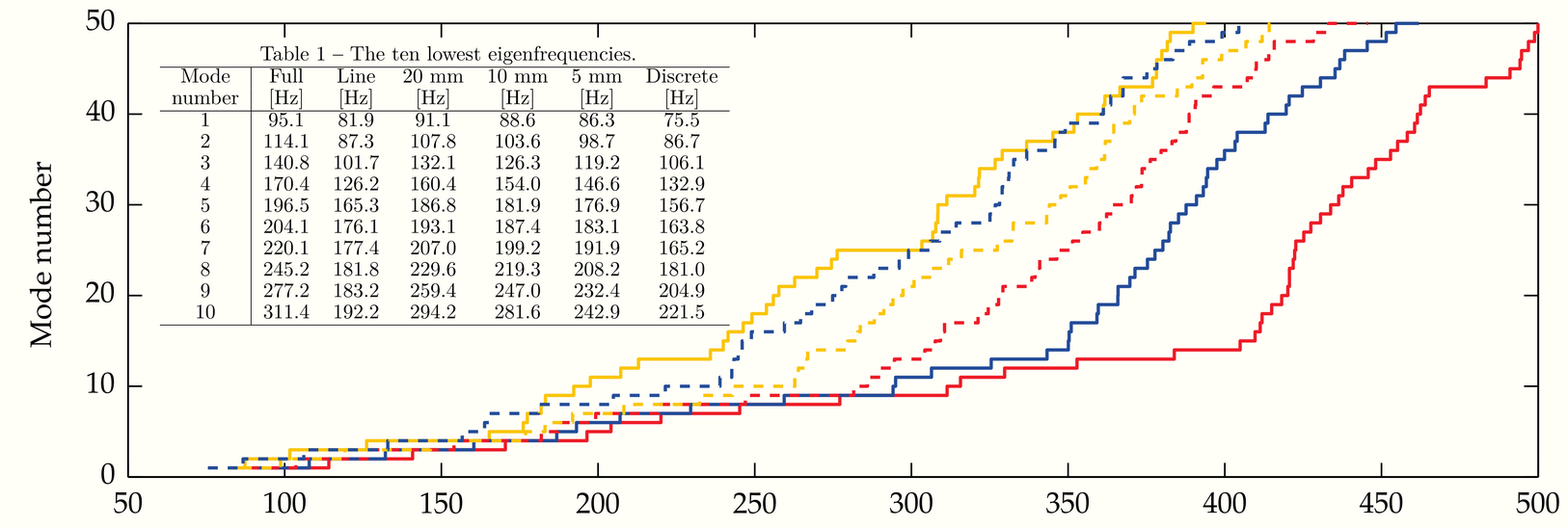


Table 1 – The ten lowest eigenfrequencies.

Mode number	Full [Hz]	Line [Hz]	20 mm [Hz]	10 mm [Hz]	5 mm [Hz]	Discrete [Hz]
1	95.1	81.9	91.1	88.6	86.3	75.5
2	114.1	87.3	107.8	103.6	98.7	86.7
3	140.8	101.7	132.1	126.3	119.2	106.1
4	170.4	126.2	160.4	154.0	146.6	132.9
5	196.5	165.3	186.8	181.9	176.9	156.7
6	204.1	176.1	193.1	187.4	183.1	163.8
7	220.1	177.4	207.0	199.2	191.9	165.2
8	245.2	181.8	229.6	219.3	208.2	181.0
9	277.2	183.2	259.4	247.0	232.4	204.9
10	311.4	192.2	294.2	281.6	242.9	221.5



The top figure above shows the sound transmission through the panel, expressed as RMS surface acceleration of the receiving plate. The results indicate that the choice of connection has significant effect on the outcome of the model. From this, two conclusions can be drawn:

- To accurately predict the low frequency sound transmission, the actual behavior of commonly used building elements should be investigated and compared with different modeling approaches;
- In the design of lightweight elements, the coupling between the plates and the frame structure may be an important parameter that can be tweaked to optimize the acoustic performance.

Furthermore, is is seen that a looser coupling does not necessarily transmit less sound, which is thought to be caused by the fact that looser couplings allow the plates to bend easier compared with stiff frame–plate couplings. Furthermore, the loose couplings have a higher mode count in the investigated frequency range.

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