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Transmission of Sound Through Double-plate Panel Structures

Aspects of Modeling a Single-stud Double-leaf Partition using the Finite Element Method

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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

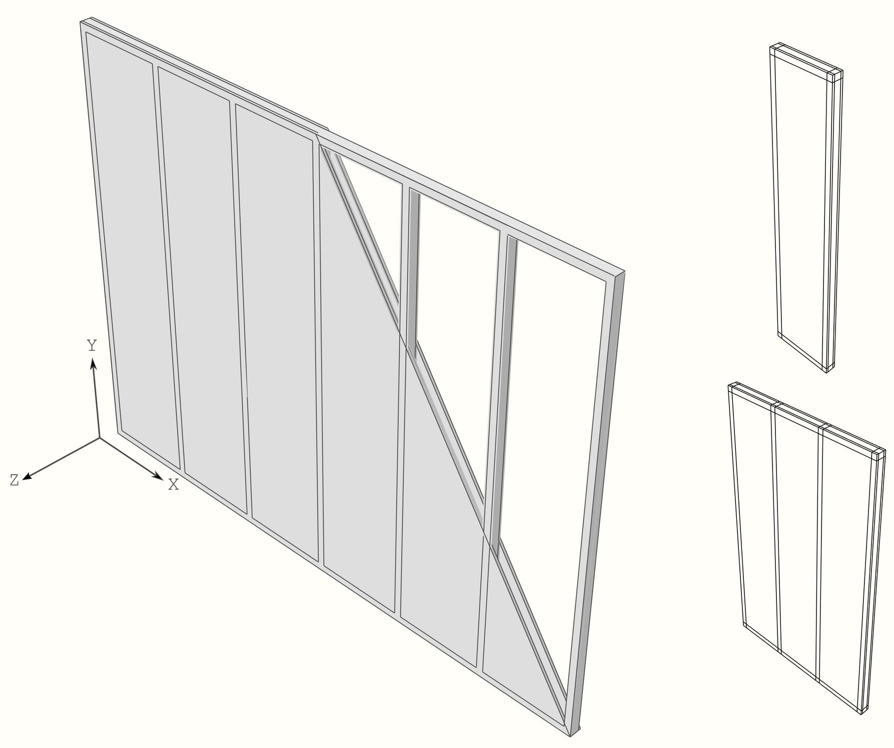
A finite-element model of a single-stud double-plate panel structure is implemented to investigate the transmission of diffuse incident sound waves through typical simple lightweight constructions. A parameter study of the effect of including the internal acoustic medium in single-stud double-leaf partitions is performed. Three scenarios are investigated:

1. A panel structure including structure-borne transmission only, i.e. without air inclusions between the plates.
2. A panel structure including an acoustic medium between the plates.
3. A simplified model where the fluid continuum elements are replaced by a simple spring connection between the two plates.

A fully coupled analysis is performed in which solid continuum finite elements are adopted for the structure, whereas the acoustic medium is discretized into fluid continuum elements. The computations are carried out in frequency domain in the range below 2 kHz and the load acts as an approximated diffuse field on one side of the panel.

Subject

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

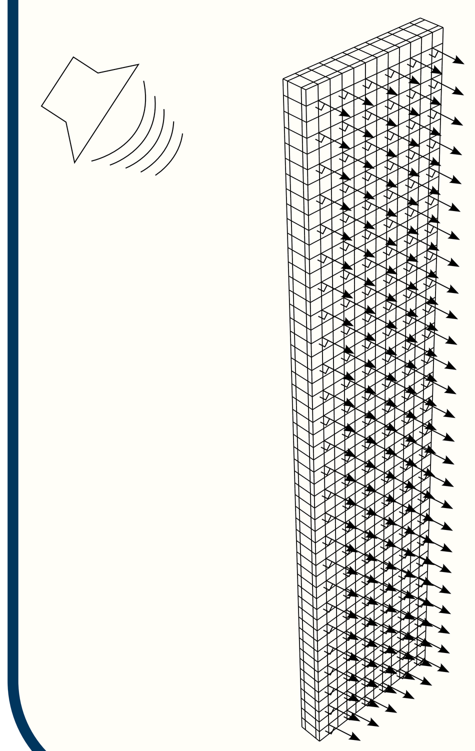


The panels are assumed to have clamped boundaries. The material parameters are:

- Timber (plates and studs): Young's modulus $E = 14$ GPa, Poisson Ratio $\nu = 0.35$, density $\rho = 500\ \mathrm{kg/m^3}$. Damping is set to 1% of the stiffness.
- Air: Bulk modulus $K_a = 141360$ Pa, density $\rho_a = 1.2\ \mathrm{kg/m^3}$.

Excitation and response

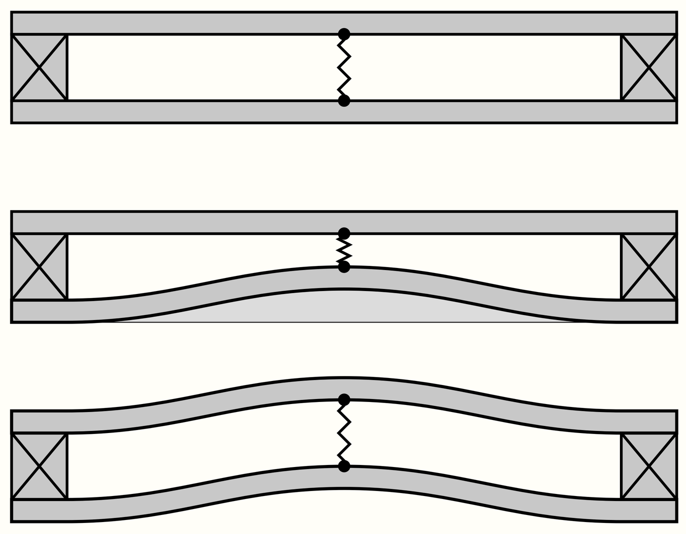
- Approximated diffuse field excitation.
- RMS surface accelleration of the receiving plate.



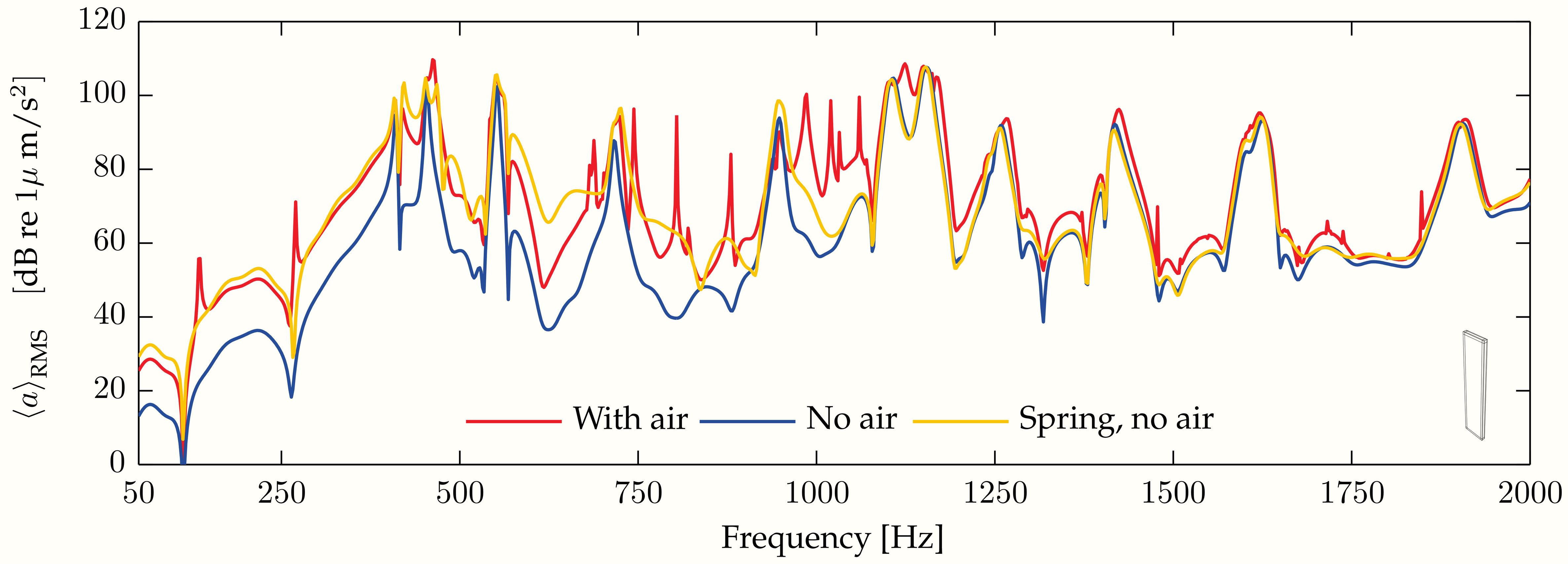
$$\langle a_z \rangle_{\mathrm{RMS}} = \sqrt{\frac{1}{N}\sum_{j=1}^{N}\left(a_z^j\right)^2}$$

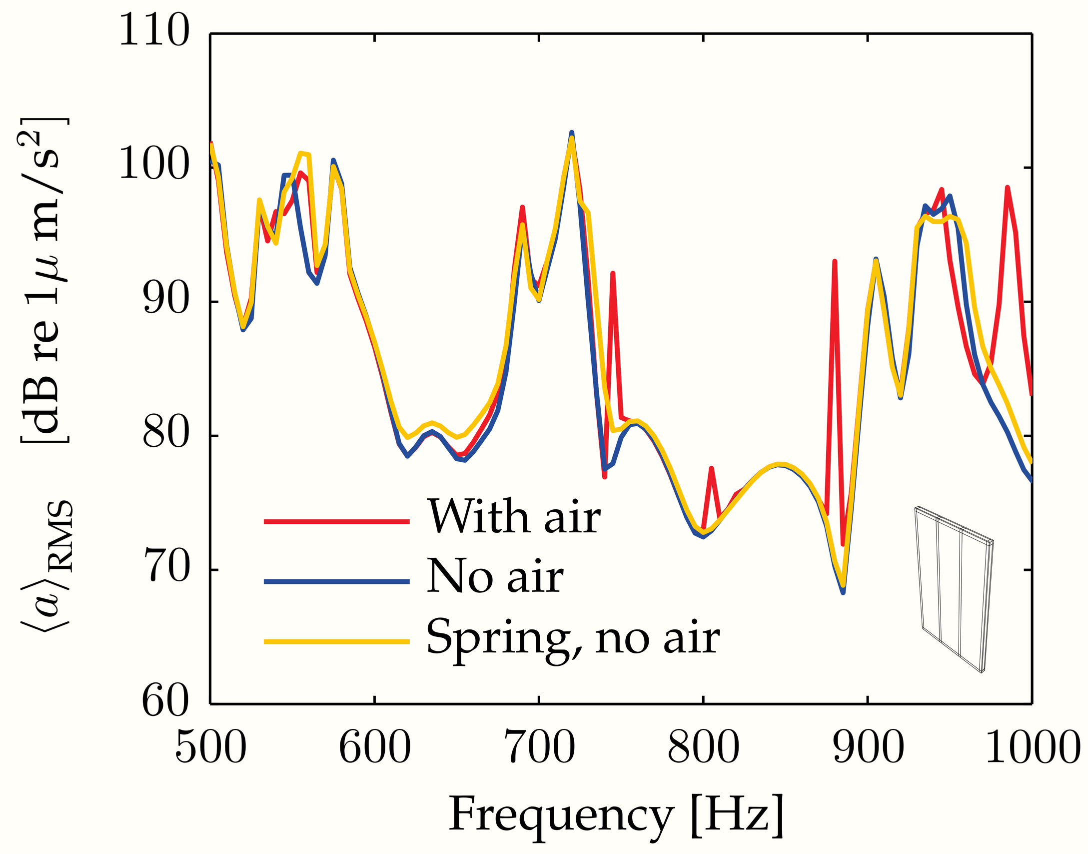
Spring model

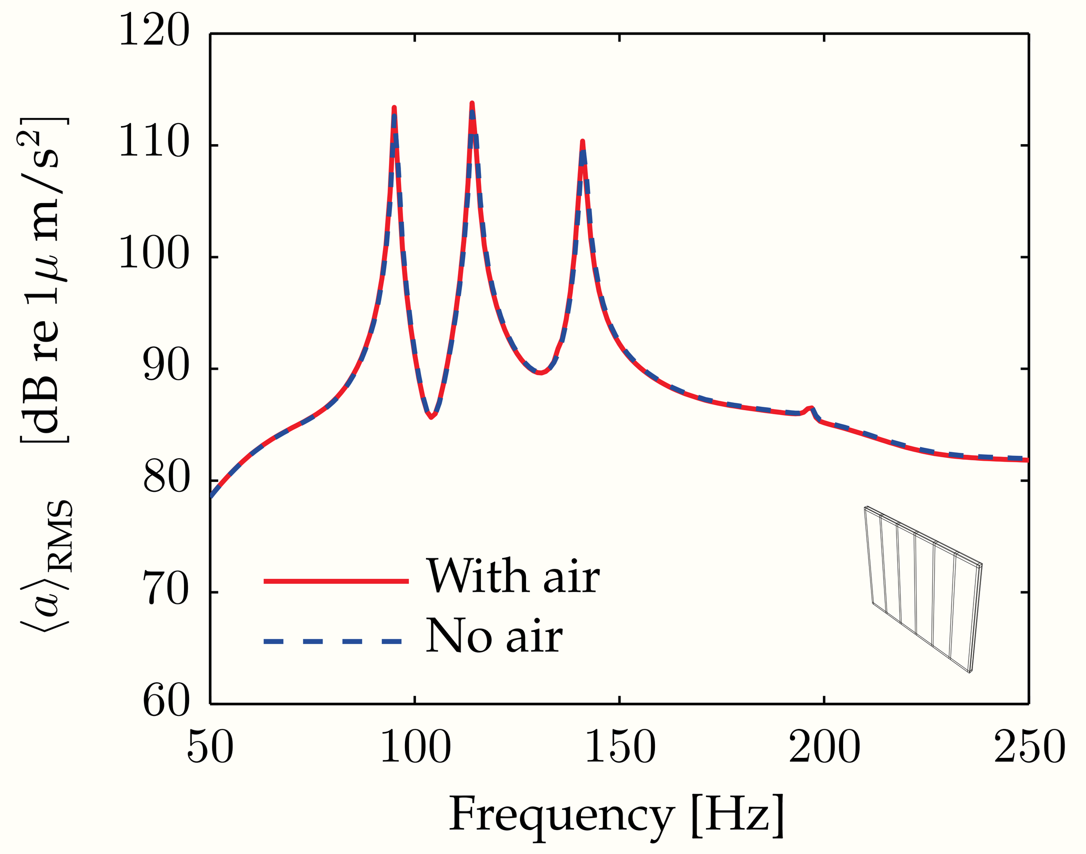
The force distribution acting on the entire surface of the source plate is concentrated at a single point.The displacement of the center point of the source plate is related to a volume change of the cavity by assuming an S-shaped deformation of the plate.



Results and discussion







A simple spring connection between the source and receiver plates provides reasonably good results at low frequencies. However, only small effects of the air inclusions are observed when considering an entire panel, i.e. the transmission is completely dominated by the structural part due to the studs being able to bend freely. In this case the differences between the cases with and without air are related to the acoustic modes of the cavities rather than to the compression/expansion of the enclosed air volume. Adding mineral wool to the cavities in the panel will cause the cavity modes to be damped and presumably their effect on the transmission will be negligible.

The simple spring connection does not perform well in the mid-frequency range. For the investigated structure that is the range 500 – 1000 Hz. At frequencies above 1000 Hz the structure-borne transmission is dominant, even for a very rigid frame, and the contributions from the air inclusions are considered negligible .

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