Stiffness Properties of framed Gypsum Board Walls

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Introduction

Currently a research project is carried out at the Acoustics Laboratory about flanking transmission of sound through junctions of lightweight framed building elements. Goal of the research is to apply the direct measurement method acc. prEN ISO 10848 with structure-borne sound for the vibration reduction index K_{ij}. K_{ij} is used as input data for the prediction of sound transmission according to EN 12354. Some of the faced problems can be solved with a fundamental knowledge over the dynamics of this type of structures, their stiffness properties and the way structural changes effect them.

Measurement Techniques

Two measurement techniques have been applied and the advantages of either method is discussed in this paper.

Experimental Modal Analysis (EMA)

The frequency response functions (FRF) are measured in a equally spaced grid of 0,2 m on both leafs of the walls by single input-multiple output testing. For excitation a roving impulse hammer and as reference signals two 3d-accelerometres are used. Post analysis was done with the software ME'scopeVES of Vibrant Technology.

"Phase-Gradient-Method"

The real part of the wavenumber, hence forward only wavenumber, of a plane propagating free bending wave is given in Equation 1 by the derivative of the phase angle Φ in propagation direction [1].

$$\mathrm{Re}\{\underline{k_B}\} = \frac{\partial \Phi}{\partial r} \quad (1)$$

On real plane structures a plane propagating wave can be assumed in the direct field of a point source. If the phase difference of acceleration signals between a number of equally spaced positions on a straight line through the source and one reference point, e.g. acceleration with an impedance head at a shaker, is measured, the wavenumber can be found for each frequency from the slope of the phase change per unit distance. Unfortunately, phase difference can only be measured directly in a range from -π to π and has to be 'unwrapped' to find the absolute value for each position starting with 0° at the source. The phase gradient is found then by a linear regression analysis of the direct part of the field. The diffuse part of the sound field can be identified easily due to its rapid irregular changes of the phase with distance.

Test Specimen

Two geometrical almost identical gypsum board walls with a length of 4,2 m and height of 2,6 m were built in test chamber. One consists of a common metal frame (studs: UW/CW 75 x 0,6 mm, MS) and the other one of a wooden frame (studs: 69 mm x 45 mm, WF). Common gypsum board (2,60 m x 0,60 m x 12,5 mm) is used for the leafs. The joints of the gypsum boards are taped and filled. In case of a double layer of gypsum board the plates are only point connected due to the fixation at the studs. Lightweight mineral wool (flow resistance 5 kNs/m^4) with a thickness of 6 cm is placed in the cavities. The test walls are connected to adjacent structures using standard construction details with elastic interlayer and point connections. The lower edge of the specimens is placed on the heavy concrete floor of the test chamber. The upper edge of the test specimens is free. One vertical edge of each wall is connected to the concrete walls of the test chamber. A wooden board is used to adjust the slight inclination of the walls of the chamber. The other vertical edge is fixed at a rectangular hollow steel column that is filled with sand to increase its mass.

At the walls the phase-gradient-method was applied along different horizontal and vertical paths. The horizontal path is along the length axis of the wall. It is averaged over two measurements, when the shaker is located on the leftmost and rightmost stud. The vertical paths are along the centre line of one bay right in the middle between two studs and also along studs. Hereby, the shaker was placed in the length axis and paths above and below the shaker are averaged. No significant difference was found between the cases of a stud in the middle of a gypsum board and along a joint of boards. The proper spacing of the accelerometer positions was 5 cm for this structure in the regarded frequency range.

Also the bending stiffness of the components of the walls were measured. Gypsum boards were hanged elastically suspended at points in the laboratory and the wavenumber is measured along the two main axis [2]. Further metal channels were placed with one end in a box with sand to increase damping and were excited with a shaker at the opposite end. Again the stiffness was determined by wavenumber measurements.

Structural Changes

Following structural changes were done at the walls to investigate the influence on the bending stiffness of the wall:

S2:	Stud spacing:	0,3 m
	Leaf:	single layer gypsum board
	Screw spacing:	0,3 m
S4:	Stud spacing:	**0,6 m**
	Leaf:	single layer gypsum board
	Screw spacing:	0,3 m
S6:	Stud spacing:	0,6 m
	Leaf:	**double layer gypsum board**
	Screw spacing:	0,3 m
S8:	Stud spacing:	0,6 m
	Leafs:	single layer gypsum board
	Screw spacing:	**0,6 m**

Measurement Results

Modal Analysis

The imaginary part of the FRF of situation MS.S4 are shown in Figure 1. Below 33 Hz only modes of the complete wall have been identified. At 33 Hz the first mode of the bay between the studs was found. It agrees well with the one of a simply supported plate of the same size. The higher order modes of this plate are indicated by their order. Above 100Hz single modes cannot be identified due to the modal density and overlap. Their lower limit can be estimated by the one of a simply supported plate with dimensions of the bays between two studs.

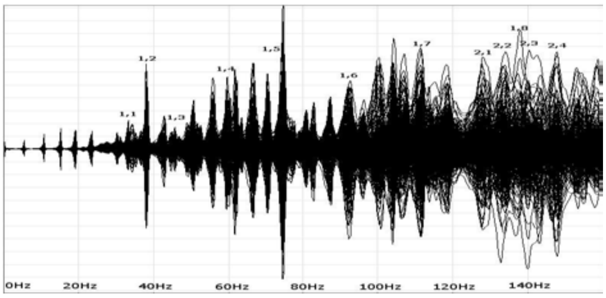

Figure 1: Imaginary part of FRFs of gypsum board wall (S4) - n,m: modes of bay agree resp. simply supported plate

"Phase-Gradient-Method"

The wavenumbers measured along the length axis of the walls fit all well to the ones measured at a simple gypsum board. Neither the material and spacing of the studs nor a doubling of the boards does increase the bending stiffness perpendicular to the studs.

The results for the measurements along the height axis in the centre of a bay are shown in Figure 2. The decrease of the wavenumbers clearly indicate the influence of the small stud spacing. Thus, if the spacing is smaller than half a bending wavelength the stiffness is dominated by the studs (below 160Hz, WF.S2), whereas it is equal to the board when it exceeds one bending wavelength (above 630Hz, WF.S2).

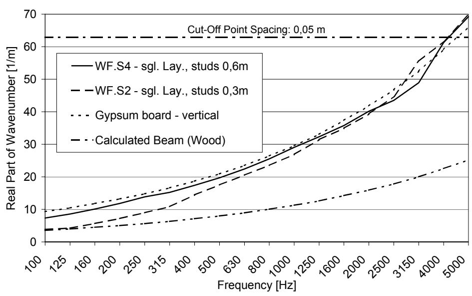

Figure 2: WF - Wavenumbers along centre of bay

A similar relationship was found in Figure 3 for the wavenumbers measured along the studs. If screw spacing is smaller than half a wavelength the beam is line connected and the stiffness equal to the one of the stud (below app. 200Hz, WF.S4). In Situation WF.S4 above 500 Hz when the bending wavelength is bigger than the screw spacing the measured wavenumbers agree well with ones of a single gypsum board. This point shifts to app. 200 Hz when the screw spacing is increased (WF.S8). In the case of a doubling of the gypsum board a decrease of the wavenumbers is also found above the upper transition frequency. Probably, it is caused by the connection of the two layers due to clamping by the fasteners along the studs.

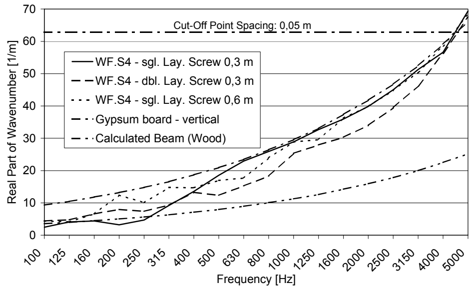

Figure 3: WF - Wavenumbers along studs

This influence is not so significant in the case of the metal stud (Figure 4). Further also the metal channel exhibits a different behaviour. Below 500 Hz it is stiffer than the gypsum board. Above 500 Hz the measured wavenumbers increase rapidly due to bending wave propagation in the flanks of the metal channel.

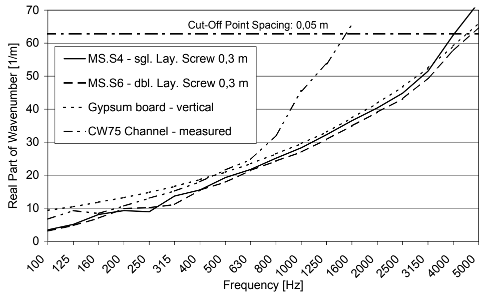

Figure 4: MS - Wavenumbers along studs

Conclusions

EMA is only useful at low frequencies below 100 Hz when the dynamics of lightweight gypsum board walls are investigated. The lower limit of the modal density and overlap of a gypsum board wall above this frequency is equal to the one of a simply-supported plate with the material properties of the leaves and the dimensions of the bays of the wall. The "Phase-Gradient-Method" can be applied in the whole frequency range of building acoustics and results can be used to model the behaviour of the structure. For framed gypsum board walls it was found that if half a bending wave length exceeds the screw as well as stud spacing the wall behaves like a orthotropic plate. If screw spacing is smaller than one bending wavelength but stud spacing is bigger it behaves like a plate with line constraints. A doubling of the leaf with point connections increases the stiffness only along the studs and above the transition frequency for the screw spacing.

Literatur

[1] Roelens, I. et al.; "In-situ measurement of the stiffness properties of building components", Applied Acoustics, **52**, 289-309 (1997)

[2] van Leth, M. et al. 'Bepaling van de verliesfactor en de buiggolflengte van gipskartonplaten', TUE, BPS (2005)