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Influence of constructive options on the vibro-acoustic behavior of a wooden lightweight structure

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Abstract :

This paper aims to present the influence of several constructive options on the vibro-acoustic behavior of a wooden lightweight structure. The experimental protocol, which was optimised and described in an preceding paper [1], allows us to quantify the influence of these constructive options in terms of acoustic level and isolation, eigenfrequencies and vibration mode shapes of the different parts of the structure. The results of this work are coherent and confirmed that the experimental test protocol is functional and repeatable.

Mots clefs : vibroacoustics / isolation / wood / lightweight structure / experimental

1 Introduction

The complexity and the huge diversity of wooden construction assemblies makes difficult the prediction of lightweight buildings vibro-acoustic properties. As a matter of fact, the acoustical behaviour of these structures can only be measured after building completion. The VIBRACOUBOIS project has been launched in 2011 to answer this problematic. It is coordinated by the innovative technology transfer center of the CRITT Bois (...pinal, France), in partnership with the LAUM (Acoustic Laboratory of the Maine University, le Mans, France) and several major industrial actors of the wooden construction sector in France. The project also benefit from a French governmental agency (ADEME) grant.

A preceding paper [1] has presented the optimisation of the experimental procedure :

- linearity of the response according to the level of excitation,
- definition of the frequency band for which the measurement are efficient,
- speed of the frequency shift in the sharp excitation,
- optimisation of the accelerometers positions to conserve a high information level,
- opening-closing of the cavities,
- position of the operator on the excited floor,

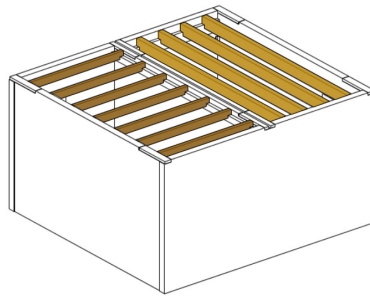


FIGURE 1 – Experimental mock up of VIBRACOUBOIS project : floors are not drawn.



FIGURE 2 – Full scale experimental mock up of VIBRACOUBOIS project.

- noise level,
- the use of an aluminium frame (in contact with the floor) or a joist (with no floor contact) to suspend the shaker,
- repeatability of the measurements in time.

The tested mockup is presented on figures 1 et 2. As described by [3] and [2], the excitation is realised by a suspended shaker figure 3, and a microphone and accelerometers are used in the cavities.

In a second section this paper gives an exhaustive review of the influence on isolation and vibration level of the floor joists orientation, the adding of plasterboard, the density of screws to claim the plasterboards, the disconnecting of the plasterboard to the walls, the loading of the structure by static load and the removing of cladding.

2 Materials and influence of constructive options

2.1 Floor type

Three types of floors are tested : two SOCOPA's joist floors (with long or short joists) (Fig. 1, 5) and a wood-concrete floor from SATOB (Fig. 4, 5).

The frequency response function measured on the microphone has a lower level with the wood-concrete floor compared to the joist-floor due to its higher mass and stiffness (Fig. 6 up). Accelerometers placed on the roof show the same behavior (Fig. 6 down). Three resonances at 18, 25 and 30 Hz are nevertheless detected and their associated accelerometer experimental mode shapes are also plotted (Fig. 7).

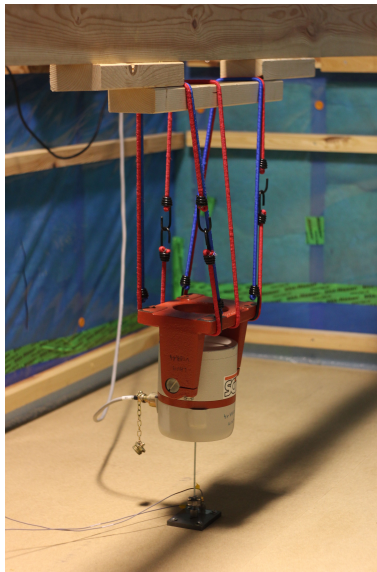


FIGURE 3 – Elastic suspension of the shaker to a wooden beam.



FIGURE 4 – SATOB's wood-concrete floor installed on the mock up.

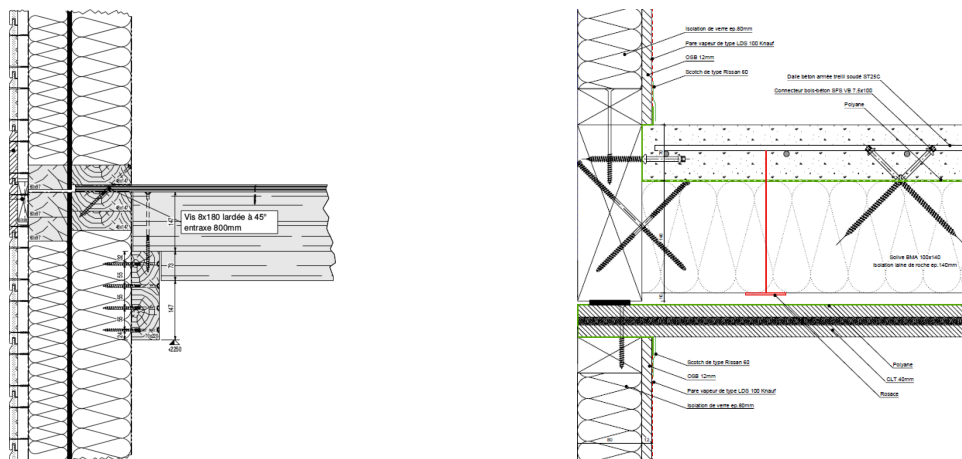


FIGURE 5 – Cut of SOCOPA floor (on the left side) and cut of SATOB floor (on the right side).

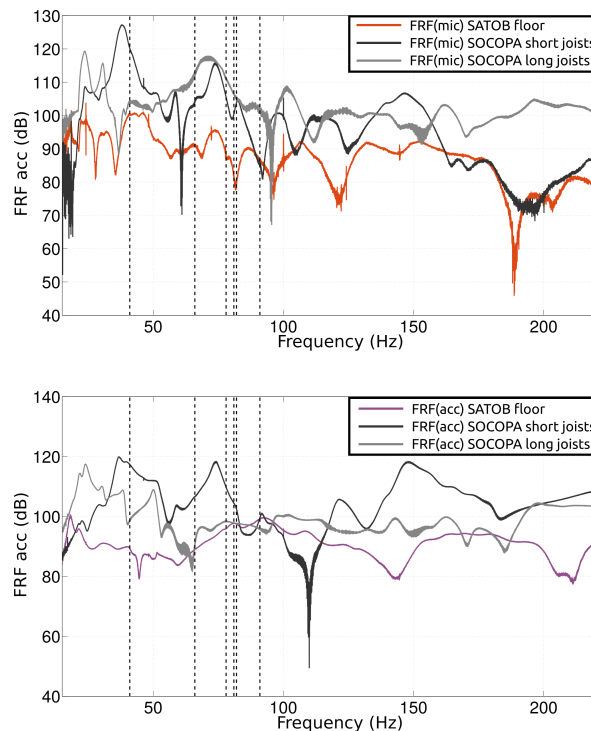


FIGURE 6 – SOCOPA AND SATOB FLOORS : Frequency response functions : microphone (orange), accelerometers (purple) in each cavities. Dashed lines corresponds to the analytical resonance frequencies of the uncoupled cavities.

Similar analysis for the joist-floors have been performed and the first resonance frequencies are near 25, 30 and 45 Hz for the floor with long joists and near 25, 40 and 52 Hz for the floor with short joists. Moreover, a higher maximum of the FRF near the first acoustic mode at 50 Hz appears for the short-joist floor which reveal a strong coupling with the cavity, the coupling with the second cavity mode near 70 Hz appears whatever the joists orientation, and the amplitude of vibration of the wall which separates the two rooms is greater for the short-joists room than for the long joist one certainly due to a direct coupling between the joists and the considered wall.

2.2 Plasterboard walls

The influence of four plasterboard layer configurations are tested :

- one layer of plasterboard,
- doubling of the screw density to connect the plasterboard to the battens,
- one layer of plasterboard disconnected from the wood structure,
- two layers of plasterboard disconnected from the wood structure,

The dimensions of the acoustic volumes are reduced when plasterboard layers are clamped to the walls, and the theoretical resonance frequencies consequently shift from 66 to 75 Hz. The figure 8 shows that the vibration intensity is less important with plasterboard and the microphone FRF confirms the increase of the frequency resonance. The doubling of the screw density to clamp the plasterboard layers to the battens or the use of two plasterboard layers has experimentally no significant effect on the room acoustics nor the vibration amplitude (Tab. 1). On the other hand when the plasterboard layers are disconnected from the structure, a small increase of the isolation between the two cavities is measured (Tab. 1).

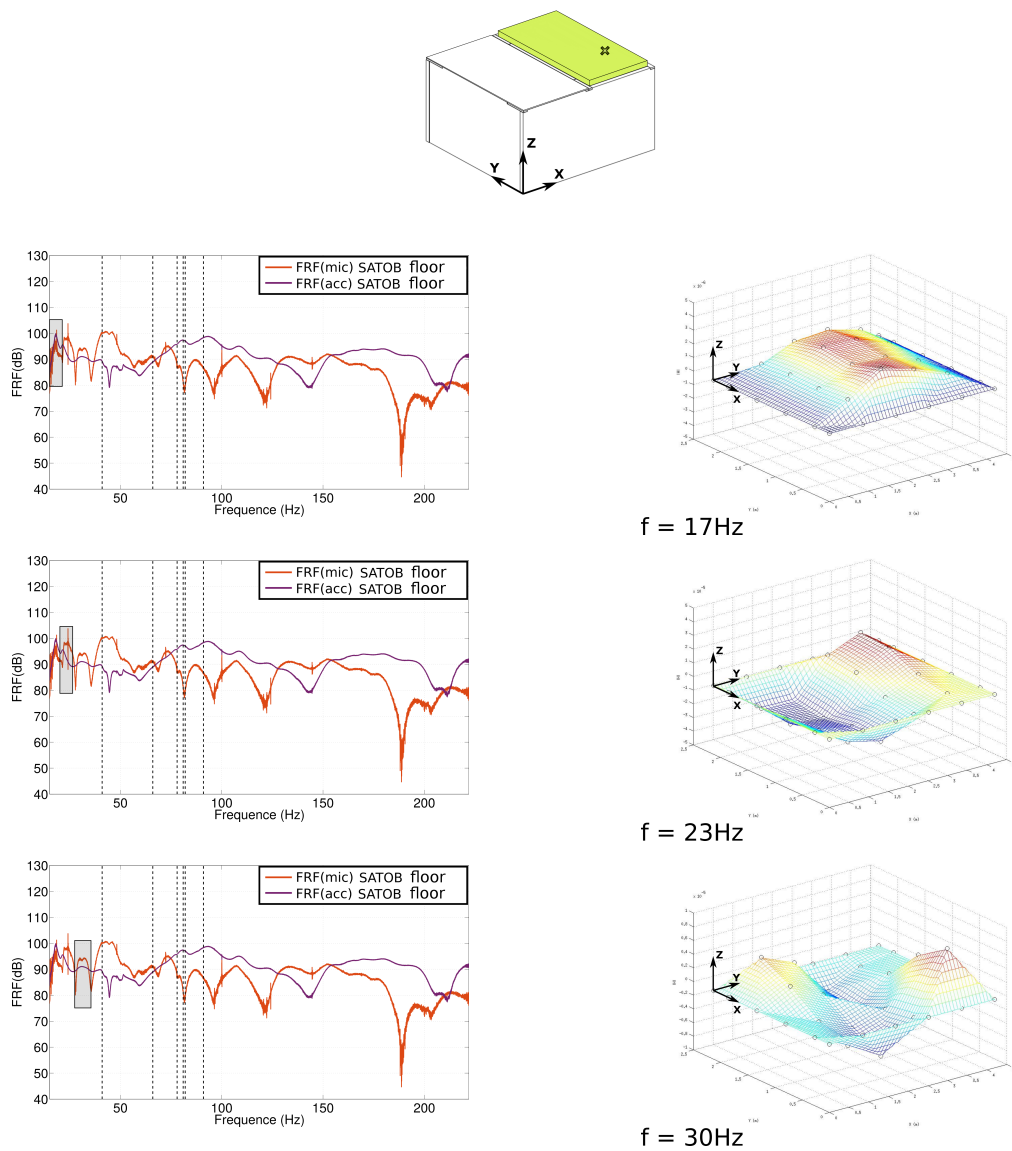


FIGURE 7 – MAQUETTE SOCOPA, PLANCHER SATOB : frequency response functions of the SATOB floor, and mode shapes at 3 resonance frequencies. The green cross represents the position of the shaker on the floor.

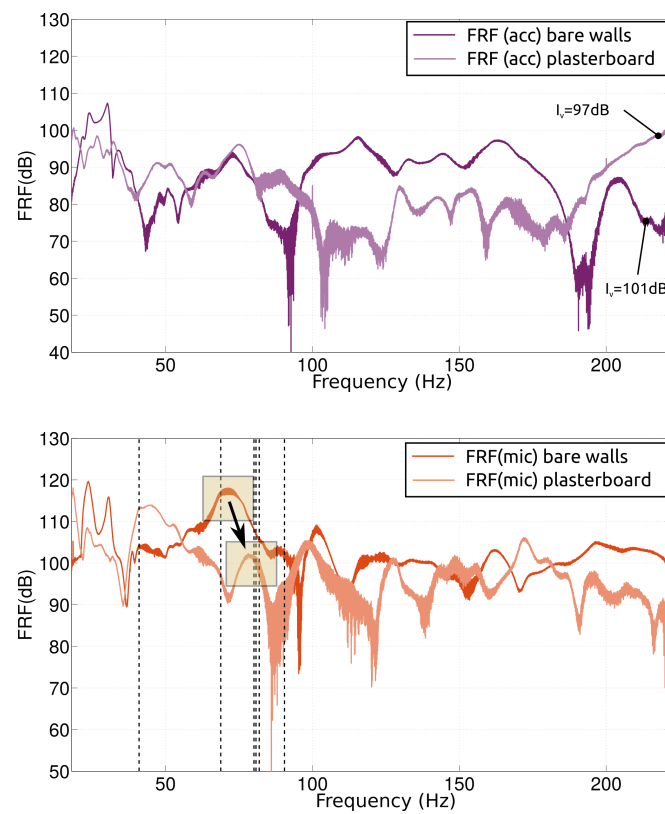


FIGURE 8 – ROOM WITH LONG JOISTS : accelerometers and microphone FRFs measured with and without one simple plasterboard layer clamped on cleats.

TABLE 1 – Acoustic isolation between the two rooms (dB) for the reference case, and deviation from this reference for each configuration.

constructive options	$D_{n,T,W}$ (dB)	T_{60} (sec)
bare structure without cleats (reference)	40 (-1 ; -4)	0.41
without cladding	+1dB	0.22
adding of floating screed	+1dB	0.29
cleats, 1 layer of plasterboard	+1dB	0.64
cleats, 1 plasterboard, screw density doubled	+0dB	0.71
cleats, 1 plasterboard, screw density doubled, static load	+1dB	0.72
1 layer of disconnected plasterboard	-1dB	0.98
2 layers of disconnected plasterboard	+2dB	1.89

2.3 Static loading of the structure

The mock up has only one level. In order to simulate a day-to-day loading on the structure, four containers of 300 liters filled with water are installed on the floor. The equivalent loading is 65 kg/m^2 . An increase of 1 dB of the acoustic isolation is measured in the cavities.

2.4 The cladding

Measurements without cladding are also performed before the dismantling of the mock up. No significant changes on isolation nor vibration level are observed.

2.5 Review of acoustic isolation in the frequency range [20 Hz-200 Hz]

The table 1 compares each configuration to a reference configuration : bare walls without cleats with the small holes between the mock up and the floor filled with glazer putty. When plasterboard layers are added, the rather small increase of the isolation is due to the multiplication by 5 of the reverberation time which has a contrary effect to those of the added mass.

3 Conclusion

The results of this work are coherent and confirmed that the experimental test protocol is functional and repeatable. The experimental data will be compared to a numerical model of the mock up currently in development in order to validate it.

Références

- [1] D. Blon, O. Dazel, J.-M. Génevaux, B. Brouard, A. Tribaleau, Experimental Investigations on the Structural-Acoustic Behaviour of a Lightweight Wooden Building : Case of a Plasterboard Wall Addition, Proceedings of Euronoise, 2015
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- [3] Jarnerö K., Brandt A. & Olsson A., In situ testing of timber floor vibration properties, Proceedings of WCTE, 2010