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MATERIAL AND WALL SCALES INVESTIGATIONS ON THE ACOUSTICAL PROPERTIES OF LIGHT EARTH (HEMP-CLAY)

P. Glé¹, G. Massossa-Telo², E. Gourdon³, A. Hellouin de Menibus⁴, M. Degraeve-Lemeurs⁴

¹ Cerema, Univ Gustave Eiffel, IFSTTAR, UMRAE, Strasbourg, 67200, France

² Université de Lyon, ENTPE, LTDS UMR CNRS 5513, Vaulx en Velin, 69120, France

³ EcoPertica, Perche en Nocé, 61340, France

⁴ Association des Chanvriers en Circuits Courts, France

Correspondence: philippe.gle@cerema.fr

ABSTRACT

Hemp-clay is a sustainable material dedicated to the thermal and acoustical insulation of buildings. It brings a very low embodied energy (up to 20 times lower than hemp-lime materials), is renewable and can be largely available at a local scale. In the framework of Ecoterra project, special attention is given to the acoustic properties of these materials. A first study has been carried out to investigate the acoustical behavior of this mix at the material scale. In this work, more than 200 hemp-clay samples were characterized to get a global view of their acoustical performances. In addition to that, the multiscale behavior, the poroelastic dissipation, and the effect of hemp concentration in hemp-clay have also been highlighted. In order to continue these investigations, studies were then carried out at the wall scale, to test systems more representative of building envelopes, including coatings as well as timber frame effects. A new experimental campaign has been carried out with more than 20 samples (60*60 cm²) using an intensimetry approach. The results give us an interesting visibility on sound transmission loss levels and spatial homogeneity as a function of various parameters (thickness, density, manufacturing process, coatings and framing). The purpose of this presentation is to discuss the main results of these studies, and to draw the relationships existing between material and wall scales on the basis of Biot model coupled with the transfer matrix method.

1. INTRODUCTION

The use of bio-based materials for thermal insulation is a solution for reducing environmental impacts of the building sector, which represents 40% of the worldwide energy use.

Hemp concretes are materials produced by mixing hemp particles (or shiv) with a binder (lime, cement, gypsum or clay). Hemp concrete, having densities between 200 and 500 kg.m⁻³, can be used for building by shuttering techniques, spraying or casted blocks, with or without a timber frame. In this range of densities, hemp concrete might be considered as an option for insulation purposes but density has to be reduced to 200 - 400 kg.m⁻³ to reach a thermal conductivity $\lambda \leq 0.065 \text{ W.m}^{-1}\text{.K}^{-1}$. The use of clay instead of lime or cement as binder has various

advantages, but the main one is that the hardening of clay is a reversible process.

The thermal insulation provided by such materials might be recognized as a priority, but their acoustic properties remain very important to ensure a high level of quality of life for the inhabitants. For this reason, sound dissipation in porous media has been extensively studied in literature¹. Hemp based concretes present a wide spectrum of acoustical performances, so that they can be designed for specific applications. The approach must account for multiple pores scales respectively in the binder, in the aggregates and between the aggregates and it was shown that the acoustical properties are principally ruled by the interparticle pores scale². However, to our knowledge there is no literature related to the acoustical properties of light earth.

This paper provides an overview of the latest developments on the subject within the framework of Ecoterra project. The two scales of investigation are covered, from the material to the wall scales, with an attempt to position hemp-clay in the context of vegetal concretes, including hemp-lime.

2. MATERIAL SCALE INVESTIGATIONS

2.1 Materials and methods

Several hemp-clay mixes were prepared using a conventional works sector mixer³. The main parameters of formulations were assessed to understand the behavior of the material as a function of viscosity level of the mixes (water to clay ratio), hemp/binder mass ratio, compaction level and raw constituents (earth and shiv). Globally, more than 200 hemp-clay samples were characterized, with densities mainly ranging between 200 and 360 kg.m⁻³ but also up to 900 kg.m⁻³ to cover all kind of applications.

Acoustical measurements were performed in a 10 cm diameter Kundt tube, using the three microphones method without cavity in the range [50; 2000 Hz]. Characterizations of porosity, resistivity and other acoustical parameters (tortuosity, viscous and thermal characteristic lengths) were also realized to feed the modelling approach developed in this work.

2.2 Results and discussion

Main results of the material scale investigations are discussed in a dedicated paper³. An example is presented in Figure 1 with the sound absorption of three typical formulations of hemp-clay.

We observe that the agreement between the poroelastic modelling used here¹ and the data is excellent, even when

the structural resonance is pronounced. The agreement between rigid frame modelling and data is also excellent outside the resonance frequency band, but this simplified modelling cannot reproduce the mechanical resonance. The difference between the approaches is limited for light samples but can be significant for higher densities. Eventually, this analysis shows the modelling approach, initially developed for hemp-lime², is also correct for hemp-clay, which underlines the fact that the physical phenomena accounting for the sound absorption in these materials are similar.

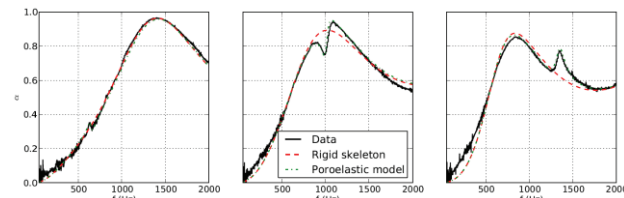


Fig. 1: Comparison between the measured and modelled sound absorption coefficients α of three hemp clay samples (densities of 219, 290 and 330 kg.m^{-3} from left to right)

3. WALL SCALE STUDY

3.1 Systems and approach

Although material scale is necessary to understand the acoustical behavior of biobased materials, it is not sufficient to predict final *in situ* performance. So, to extent our results to more complex and larger systems, more representative of building walls, other characterizations have been carried out with 60x60 cm^2 samples (small wall scale). 23 samples have been specifically prepared for these tests, involving different manufacturing process, thickness (ranging from 6 to 20 cm), framing and coatings (complete description in ⁴).

A sound intensity approach has been used in laboratory, between one reverberant room and one semi-anechoic room, following ISO 15186-2:2011, to determine the sound reduction index of these samples. Modellings have then been proposed on the basis of the transfer matrix method (TMM)¹ and the relevance of mass law predictions has been examined on the various configurations.

3.2 Outcomes and outlooks

Figure 2 compares the experimental data for 10 cm thick projected hemp-clay samples without, and with one and two 2 cm coatings, with TMM predictions and mass law computations. Many observations could be discussed here. The significant contribution of the coatings is first clearly visible, with a gain greater than 20 dB on the frequency range of interest. Besides, the behavior of the various configurations appears to be different. If the dissipation is principally ruled by thermal and visco-inertial effects for the raw materials, the elastic damping predominates as soon as there is one coating. In such conditions, mass law computation might be used in first approach for some configurations including coatings.

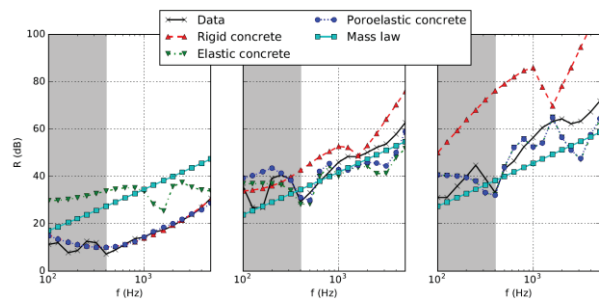


Fig. 2: Comparison between projected hemp-clay walls transmission loss data, TMM predictions and mass law computations (left: raw wall, center: wall with one coating, right: wall with two coatings)

The experimental data were finally compiled in terms of global index $Rw+C$, associated with hemp-lime values found in the literature, and compared to mass law computations to extent our first observations (Figure 3). The importance of the coating is confirmed by this synthesis. However, a strong limitation of the mass law is highlighted, particularly in the cases of raw concretes but also for coated hemp-lime walls. Further work is now in progress to confirm these observations *in situ* and to get a global view on the acoustic performance of these materials in most building configurations.

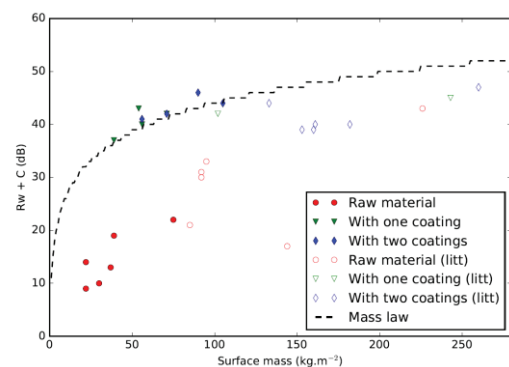


Fig. 3: Comparison between experimental measurements and mass law computations for the sound reduction of hemp concrete walls (filled markers: hemp-clay data from present study, empty markers: hemp-lime data from literature)

4. REFERENCES

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