Characterization and modelling of the acoustical properties of hemp shiv and hemp concrete

Glé P.*, Gourdon E., Arnaud L.

DGCB FRE CNRS 3237, Ecole Nationale des Travaux Publics de l'État

Membre de l'Université de Lyon, Rue Maurice Audin, 69518 VAULX-EN-VELIN Cedex

philippe.gle@entpe.fr

Prefered presentation: Oral

Abstract

Currently, great efforts are being made to reduce the impact of buildings on our environment. In France, their energy consumption is more important than industry or transports [1]. This is mainly due to the bad thermal insulation of traditionally used materials like concrete. Besides, the manufacture of these materials usually requires a lot of energy and leads to significant emissions of carbon dioxyde. For these reasons, sustainable insulating materials are now of major interest and are extensively used for new constructions. It is important to know the acoustical properties of these new materials to ensure comfort to the inhabitants.

Asdrubali [2] presented differents results concerning these sustainable materials and seperates them into two categories, the natural materials like wood wool, sheap wool and clay and the recycled materials like recycled rubber [3] or recycled carpet [4]. The subject of the present study is hemp concrete, a natural material consisting in hemp particles mixed with a binder. In Figure 1, one can see the particles that come from the woody part of hemp. Its life cycle analysis reported that 1 m^2 of hemp concrete having a thickness of 26 cm with a timber frame stores 35 kg of carbon dioxyde on a reference period of 100 years [5]. It is a multifunctional material since it combines interesting properties in mechanics (light material having an important ductility), in thermics (its thermal conductivity is about 0.08 W/mK) and in acoustics [6].

The acoustical properties of hemp concretes have been explored in several studies [6, 7]. These studies showed interesting sound absorptions for hemp concrete, which can be controlled using the different fabrication parameters of this material, the choice of its constituants and of its fabrication process. Concerning its transmission loss, only one study provided results [8] and discussed the effect on coatings facing the concrete.

The modelling of hemp concretes faces several difficulties. First, the shape of the particles of hemp is far from spherical. It can be approximated by a parallelepidepal shape having a 3D particle size distribution. These properties affects the acoustical parameters, like the tortuosity of the material [9], so that the classical porous models [10, 11] for granular media do not give consistent predictions. Moreover, hemp concrete is characterized by several scales of porosity, with interparticle pores ($\approx 1mm$) between the particles, intraparticle pores ($\approx 10\mu m$) into the particles and intrabinder pores ($\approx 1\mu m$) into the binder. It is very hard to distinguish the effect of the different scales on the macroscopic acoustical properties.

The aim of this study is to outline the acoustical properties of hemp concretes. First, the experimental results for the sound absorption and transmission loss of these materials are reviewed and discussed, these data are then confronted to new measurements in normal incidence. In a second part, a physical analysis of the experimental results enables to predict the acoustical behaviour of hemp concrete using a multiple porosity approach.

Several configurations of hemp concretes have been tested to explore their acoustical properties. In a first time, hemp particles in bulk (hemp shiv) have been examined using particles of different origins, different particles size distributions, under different packings. Secondly, hemp concretes have been fabricated with different binders, different binder/shiv proportions and different densities. These materials have been tested in the frequency range 150-2000 Hz in normal incidence using a B&K Type 4106 impedance tube. The dynamic densities, bulk modulus and sound absorption have been measured using a three microphone technique with a riging backing behind the samples [12]. The transmission loss has been evaluated using a four microphone technique and an anechoic end [13]. The thickness of the samples is 5 cm.

The comparison of the real part of the bulk modulus with the measured open porosity of the different configurations revealed a multiple porosity behaviour as described by Olny and Boutin [14]. In the case of high contrast of permeability between micropores and mesopores in a same material, if the frequency is above a characteristic diffusion frequency, only the mesopores take part into the acoustical dissipation, so that the dynamic density and bulk modulus of the material can be approximated by the properties of the mesopores.

To compute the intrinsic properties of the mesopores, Johnson model [15] can be used for the dynamic density and Zwikker and Kosten model [16] can be used for the bulk modulus [7]. An example is given Figure 1 for the modelling of hemp shiv. In this figure, measured sound absorption α, normalised dynamic density ρ/ρ_0, normalised bulk modulus K/P_0 and transmission loss TL are confronted to the modelling using the double porosity model.

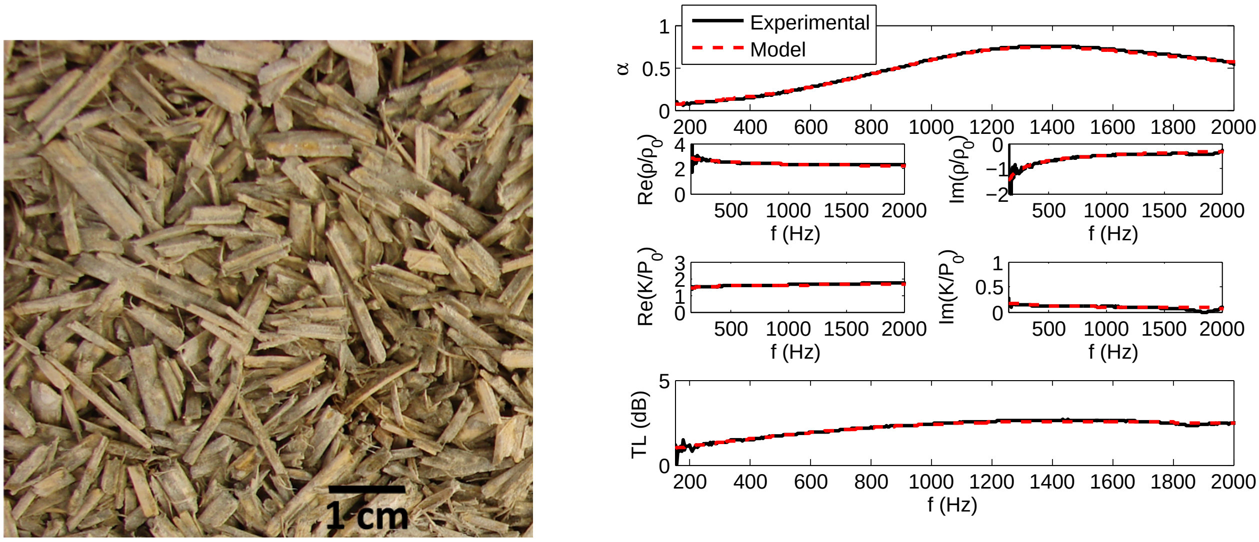

Figure 1: Hemp concrete ($left$) and modelling of hemp shiv having a density $\rho = 120kg/m^3$ ($right$)

References

[1] Commissariat général au développement durable. *Bilan énergétique de la France pour 2009*. 2010.

[2] F. Asdrubali. Survey on the acoustical properties of new sustainable materials for noise control. In *Euronoise, Tampere, Finland*, 2006.

[3] M-J. Swift, P. Bris, and K-V. Horoshenkov. Acoustic absorption in re-cycled rubber granulate. *Applied Acoustics*, 57:203–212, 1993.

[4] I-M. Rushforth, K-V. Horoshenkov, M. Miraftab, and M-J. Swift. Impact sound insulation and viscoelastic properties of underlay manufactured from recycled carpet waste. *Applied Acoustics*, 66:731–749, 2005.

[5] M-P. Boutin, C. Flamin, S. Quinton, and G. Gosse. Analyse du cycle de vie : Compounds thermoplastiques chargés fibres de chanvre et Mur en béton de chanvre banché sur ossature bois. *Rapport d'Étude INRA Lille, Réf. MAP 04 B1 0501.*, page 32, 2005.

[6] V. Cerezo. *Propriétés mécaniques, thermiques et acoustiques d'un matériau à base de particules végétales: approche expérimentale et modélisation théorique.* PhD thesis, Ecole doctorale MEGA, Lyon, 2005.

[7] P. Glé, E. Gourdon, and L. Arnaud. Acoustical properties of materials made of vegetable particles with several scales of porosity. *Applied Acoustics*, 72:249–259, 2011.

[8] P-Y. Butschi, C. Deschenaux, B. Miao, and N-K. Srivastava. Caractérisation d'une maçonnerie composée d'éléments en aggloméré de chanvre. *Revue canadienne de génie civil*, 31 (3):526–529, 2004.

[9] J. Comiti and M. Renaud. A new model for determining mean structure parameters of fixed beds from pressure drop measurements: Application to beds packed with parallelepipedal particles. *Chemical Engineering Science*, 44(7):1539–1545, 1988.

[10] C. Boutin and C. Geindreau. Estimates and bounds of dynamic permeability of granular media. *Journal of the Acoustical Society of America*, 124(6):3576–3593, 2008.

[11] O. Umnova, K. Attenborough, and K-M. Li. Cell model calculations of dynamic drag parameters in packings of spheres. *The Journal of the Acoustical Society of America*, 107(6):3113–3119, 2000.

[12] T. Iwase, Y. Izumi, and R. Kawabata. A new measuring method for sound propagation constant by using sound tube without any air spaces back of a test material. *Internoise 98, Christchurch, New Zealand*, page 4, 1998.

[13] B-H. Song and J-S. Bolton. A transfer-matrix approach for estimating the characteristic impedance and wave numbers of limp and rigid porous materials. *Journal of the Acoustical Society of America*, 107(3):1131–1152, 2000.

[14] X. Olny and C. Boutin. Acoustic wave propagation in double porosity media. *Journal of the Acoustical Society of America*, 114(1):73–89, 2003.

[15] D-L. Johnson, J. Koplik, and R. Dashen. Theory of dynamic permeability and tortuosity in fluid-saturated porous media. *Fluid Mechanics*, 176:379–402, 1987.

[16] C. Zwikker and C-W. Kosten. Sound absorbing materials. *Elsevier, New-York*, page 174, 1949.