



A joint modelling approach for the acoustic and thermal properties of fibrous materials: application to building's vegetal wools

Clément Piegay, Emmanuel Gourdon, Etienne Gourlay, Sandrine Marceau

► To cite this version:

Clément Piegay, Emmanuel Gourdon, Etienne Gourlay, Sandrine Marceau. A joint modelling approach for the acoustic and thermal properties of fibrous materials: application to building's vegetal wools. Forum Acusticum, Dec 2020, Lyon, France. pp.2889-2890, 10.48465/fa.2020.0437 . hal-03235446

HAL Id: hal-03235446

<https://hal.science/hal-03235446>

Submitted on 27 May 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

A JOINT MODELLING APPROACH FOR THE ACOUSTIC AND THERMAL PROPERTIES OF FIBROUS MATERIALS: APPLICATION TO BUILDING'S VEGETAL WOOLS

Clément Piégay¹

Etienne Gourlay³

Philippe Glé¹

Sandrine Marceau⁴

Emmanuel Gourdon²

¹ Cerema, Université Gustave Eiffel, UMRAE - Laboratoire de Strasbourg

11 rue Jean Mentelin 67035 Strasbourg, France

² Université de Lyon, ENTP, LTDS UMR CNRS 5513

3 rue Maurice Audin 69518 Vaulx-en-Velin Cedex, France

³ Cerema, BPE Team - Laboratoire de Strasbourg

11 rue Jean Mentelin 67035 Strasbourg, France

⁴ Université Gustave Eiffel, MAST/CPDM, 77454 Marne-La-Vallée Cedex 2, France

clement.piegay@cerema.fr

ABSTRACT

In order to jointly predict the acoustic and thermal properties of fibrous materials, a joint modelling approach relating their microstructural parameters to their macroscopic properties is developed. This original approach can be applied for vegetal wools increasingly used in green buildings field.

1. EXTENDED ABSTRACT

Biobased fibrous insulation materials, such as vegetal wools, that belong to the green carbon sector, more specifically in green building fields, provide an effective response in a sustainable way. Indeed, they are able to store atmospheric carbon dioxide [1] and contribute to limiting the impact on biodiversity. Moreover, they have a number of multifunctional properties [2].

This potential is represented more particularly by acoustic and thermal high level performances due to their specific microstructure [3, 4].

In this context, an innovative acoustic and thermal joint modelling approach has been developed as shown in Figure 1.

This approach is based on a micro-macro homogenisation method. Only two input parameters are necessary to obtain fibrous material properties: the fibrous material open porosity ϕ and an equivalent fibre radius value R_{eq} .

For the acoustic and the thermal conduction transfer modelling, the macroscopic behaviour laws are established by using the homogenisation of periodic media (HPM) [5].

However, HPM is used regardless of the chosen periodic representative elementary volume (PREV). Therefore, numerical computations must be carried out to solve the equations and to obtain solutions. So, in order to find analytical solutions, it is possible to use a Self-Consistent Method (SCM) based on a simplification of the PREV [6]. In the fibrous material case based on a cylindrical geom-

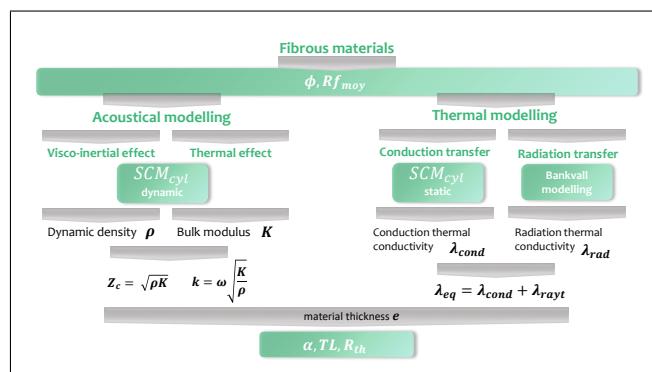


Figure 1. The joint acoustic and thermal modelling approach for fibrous materials

etry representative of the fibres morphology, it is called SCM_{cyl}.

To do this, at microscopic scale, we considered a generic cylindrical inclusion described by a cylinder of radius (R) and surface (∂R) as shown in Figure 2. The solid phase is represented by a fibre of volume (Ω_s) and a radius (βR). This radius is considered constant along its entire length and, in first approximation, large in comparison with the cylinder cross-section. This solid phase is included in the fluid phase represented by an air cylinder hollowed out in its center, with an external radius R and an internal radius βR .

Moreover, the SCM is based on the energy equivalence between the cylindrical generic inclusion, representative of the fibrous material physical and geometrical properties at microscopic scale, and the equivalent homogeneous medium at the macroscopic scale.

For the acoustic properties modelling, SCM_{cyl} is developed in a dynamic approach (function of frequency) [7]. As shown in the Figure 1, it leads to the determination of both parameters, the dynamic densities ρ and the bulk modulus K . Then, it is possible to obtain the intrinsic pa-

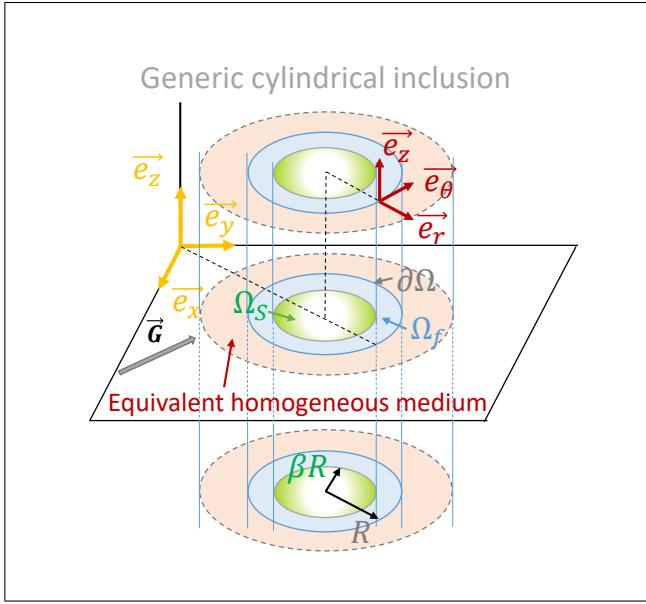


Figure 2. Schematic representation of a fibrous medium at macroscopic and microscopic scales by the periodic cell Ω . Ω_s and Ω_f correspond to volumes of the solid and fluid phases. Γ is the solid-fluid interface.

parameters of the materials, i.e. the characteristic impedance Z_c and the wave number k .

For the thermal properties modelling heat transfer contributions are represented by a specific thermal conductivity: λ_{cond} for conduction and λ_{rad} for radiation. SCM_{cyl} is developed in a static approach for the conduction transfer modelling [4]. In order to take the significant impact of radiation transfer for materials with densities below 30 kg.m^{-3} into account, the Bankvall empirical modelling approach is used [8]. It is also based on the both parameters ϕ and $R_{f_{eq}}$.

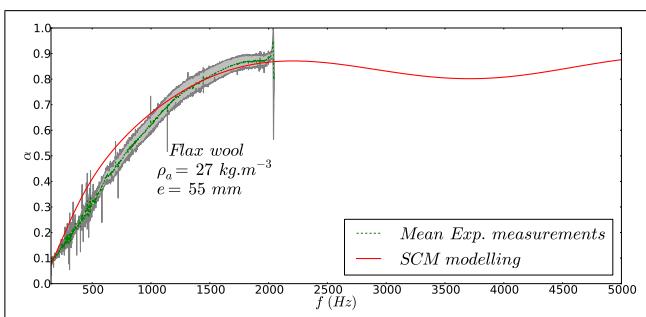


Figure 3. SCM_{cyl} modelling of acoustic absorption coefficient for a flax wool

Finally, validation of this acoustic and thermal joint modelling approach is carried out by comparing results with vegetal wools experimental data, as shown in Figures 3 and 4 for a flax wool.

2. REFERENCES

- [1] F. Pittau, F. Krause, G. Lumia, and G. Habert, “Fast-growing bio-based materials as an opportunity for stor-

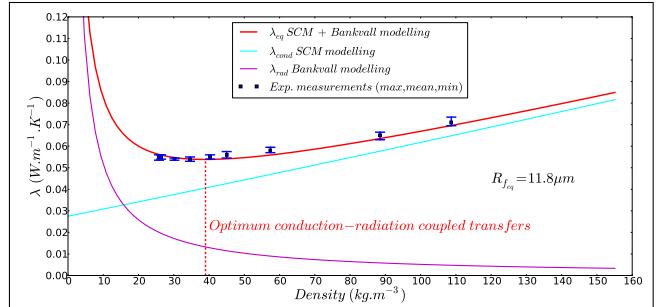


Figure 4. Modelling of thermal conductivity for a flax wool

ing carbon in exterior walls,” *Building and Environment*, vol. 129, pp. 117–129, Feb. 2018.

- [2] J. Arenas and F. Asdrubali, “Eco-Materials with Noise Reduction Properties,” in *Handbook of Ecomaterials* (L. M. T. Martz, O. V. Kharissova, and B. I. Kharisov, eds.), pp. 1–26, Cham: Springer International Publishing, 2018.
- [3] C. Piégay, P. Glé, E. Gourdon, E. Gourlay, and S. Marceau, “Acoustical model of vegetal wools including two types of fibers,” *Applied Acoustics*, vol. 129, pp. 36–46, Jan. 2018.
- [4] C. Piégay, P. Glé, E. Gourdon, and E. Gourlay, “A cylindrical self-consistent modelling of vegetal wools thermal conductivity,” *Construction and Building Materials*, vol. 232, p. 117123, Jan. 2020.
- [5] J.-L. Auriault, “Dynamic behaviour of a porous medium saturated by a newtonien fluid,” *International Journal of Engineering Science*, vol. 18, no. 6, pp. 775–785, 1980.
- [6] C. Boutin and C. Geindreau, “Estimates and bounds of dynamic permeability of granular media,” *The Journal of the Acoustical Society of America*, vol. 124, pp. 3576–3593, Dec. 2008.
- [7] C. Piégay, P. Glé, E. Gourdon, and E. Gourlay, “A Self-Consistent Approach for the Acoustical Modeling of Vegetal Wools,” *Institute of Noise Control Engineering*, vol. InterNoise 18, Chicago, IL, pp. 1708–1715, Aug. 2018.
- [8] C. Bankvall, “Heat Transfer in Fibrous Materials,” *Journal of Testing and Evaluation*, vol. 1, no. 3, pp. 235–243, 1973.