Acoustical and thermal joint approach for the optimisation of vegetal wools used in buildings

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Context

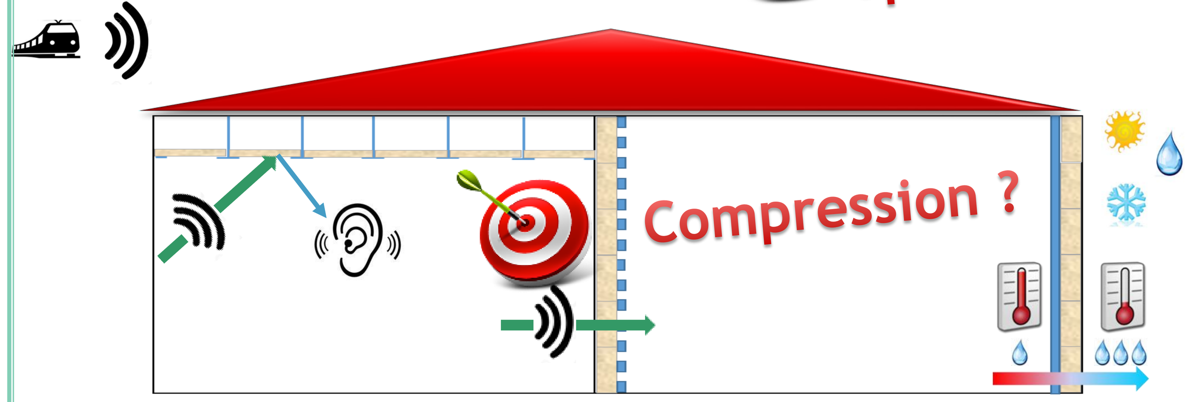
Sustainable materials[1]

- Smart management of natural ressources
- Low environmental impact

Performances[1]

Material	Thermal conductivity (W/mK)	Absorption coefficient at 500 Hz (-)
Hemp	0.04	0.6 (30cm)
Kenaf	0.044	0.74 (5cm)
Coco fiber	0.043	0.42
Wood wool	0.065	0.32

Specificities ?



Compression ?

Acoustic insulation TL or/and correction α and thermal insulation λ

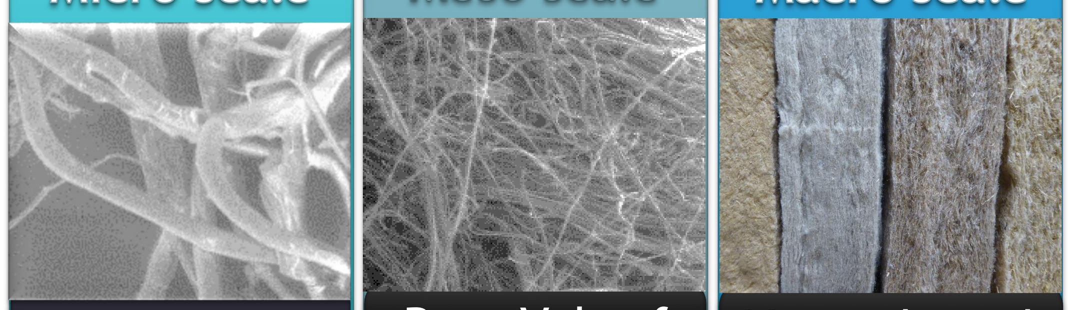
Fire treatments effects ?

Correlation ?

[1][Asdrubali *et al.* 2012] Building Acoustics

Scientific approach

Micro scale	Meso scale	Macro scale
Fibres	Rep. Vol. of fibres	Vegetal wool panel

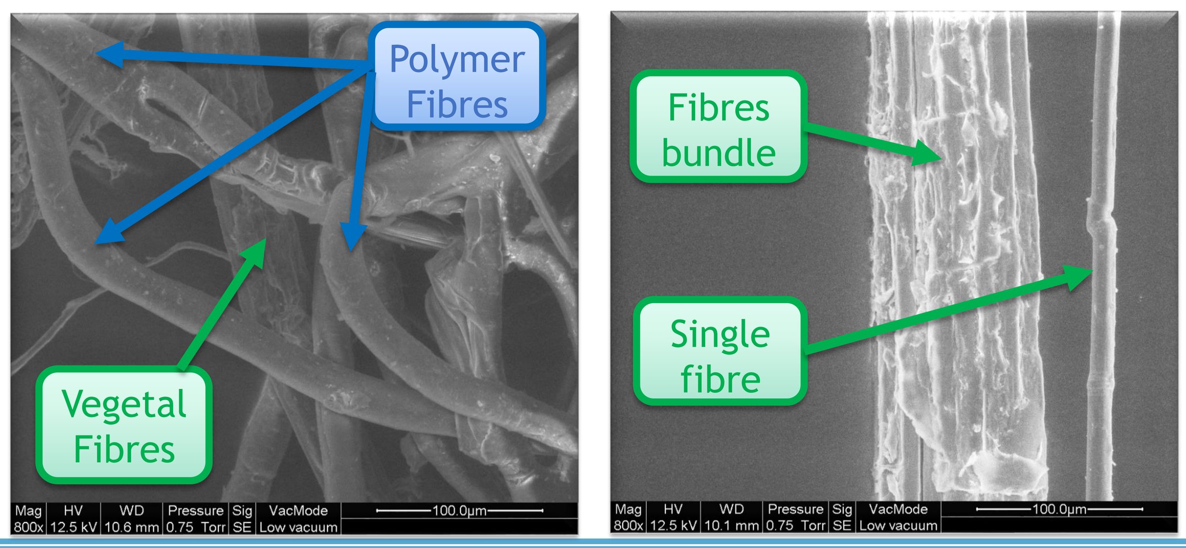


Experimental characterisation

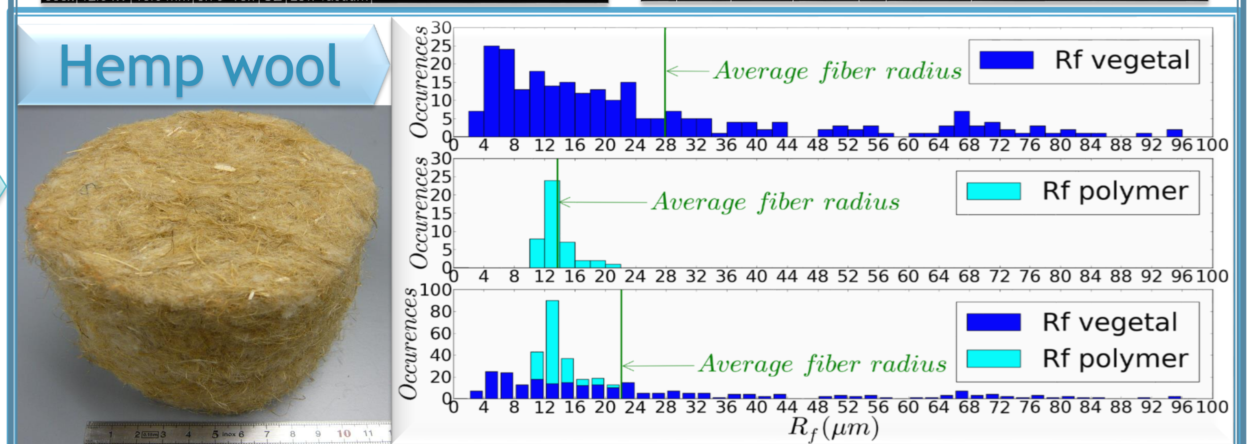
Fibres morphology	Intrinsinc parameters	Performances
Fibres radii Rf_{veg}, Rf_{pol}	Porosity Φ, Solid phase th cond λ_s, Solid phase density ρ_s, Airflow resistivity σ	Sound absorption α, Thermal conductivity λ

Homogeneisation

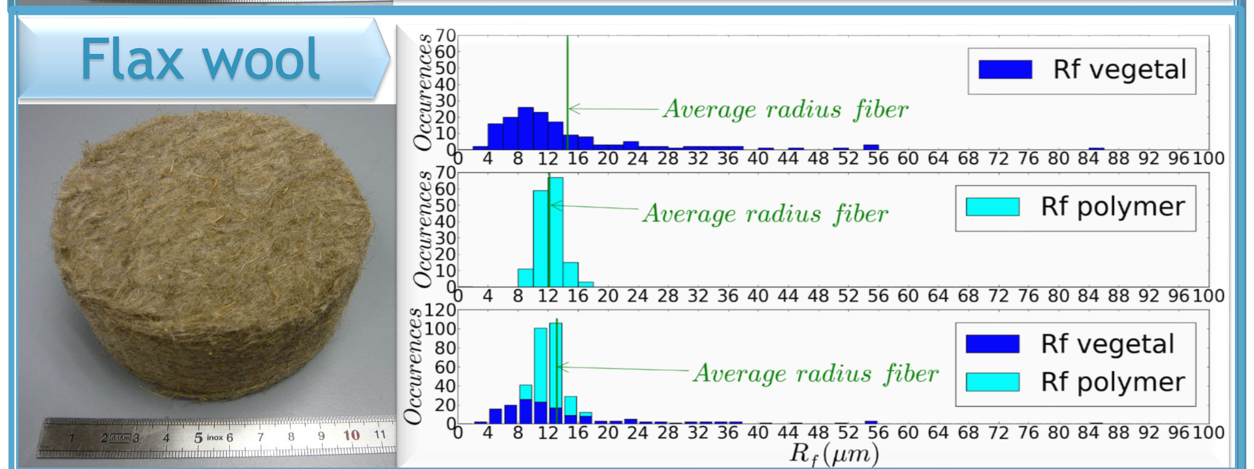
Experimental characterisation



Hemp wool



Flax wool

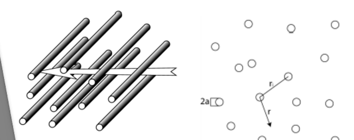


Materials	Mean Rf_{veg} (μm)	Mean Rf_{pol} (μm)	Porosity Φ(%)	Density ρ (kg.m^{-3})	Th. cond λ (W.K^{-1}.m^{-1})
Hemp	27,9	13,7	96,4	45	0,44
Flax	14,6	12,2	96,1	67	0,45

Acoustic ∩ Thermic

Modelling

Tarnow model [Tarnow 1996a] JASA



Flow ⊥ and random fibres distribution

$$\sigma_i = 4\eta \frac{(1-\phi)}{R_{f_i}^2\left[0{,}640\ ln\left(\frac{1}{(1-\phi)}\right) - 0{,}737 + (1-\phi)\right]}$$

Composite model [Gourdon & Seppi 2010] Applied Acoustics

$$K_h = \left[\frac{\tau}{K_{pol}(\omega)} + (1-\tau)\frac{F_d(\omega)}{K_{veg}(\omega)}\right]^{-1}$$

$$\Pi_h = (1-\tau)\Pi_{veg} + \tau\Pi_{pol}$$

τ : volumetric ratio of polymer fibres into the consistent medium

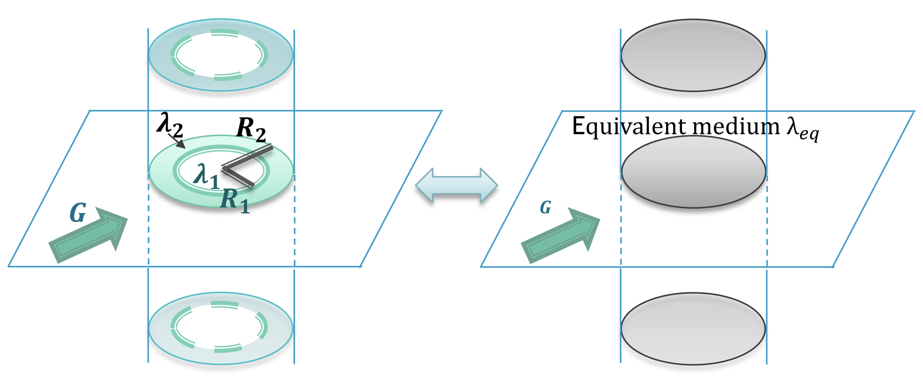
Complete coupling between fibrous medium and polymer medium $F_d(\omega) = 1$

Acoustical model for two types of fibres Rf_{veg}, Rf_{pol}, ϕ

[Piégay *et al.* 2018] Applied Acoustics 129 (2018) 36-46

Self Consistent Method (SCM)

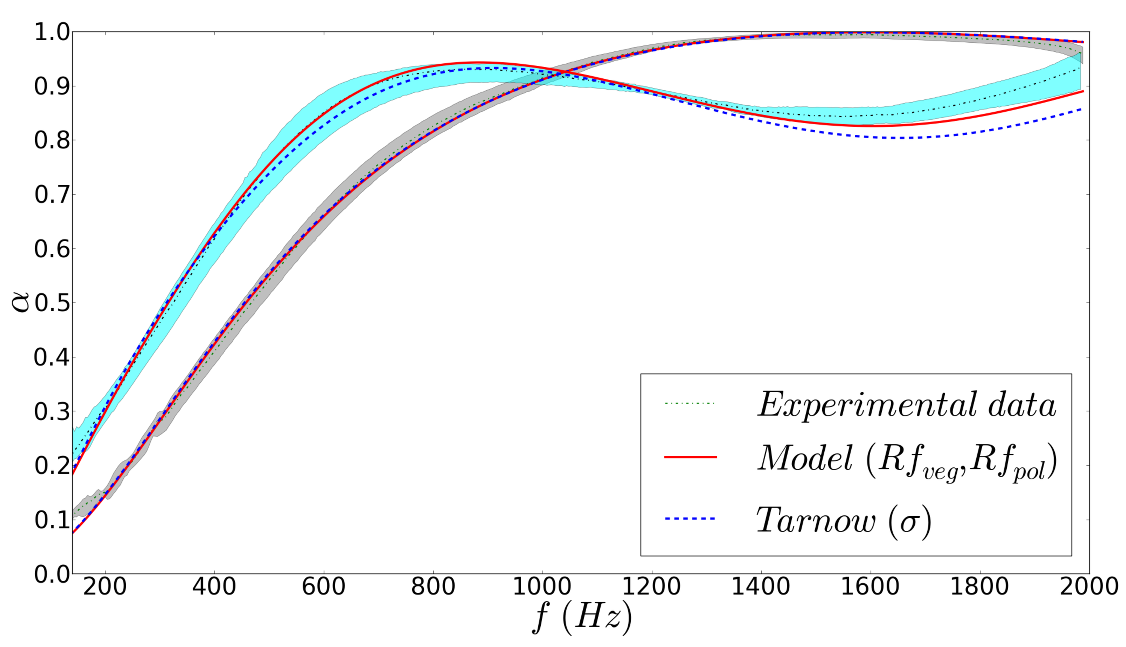
Equivalence between the cylindrical bicomposite inclusions (air into solid phase) medium and the equivalent consistent medium



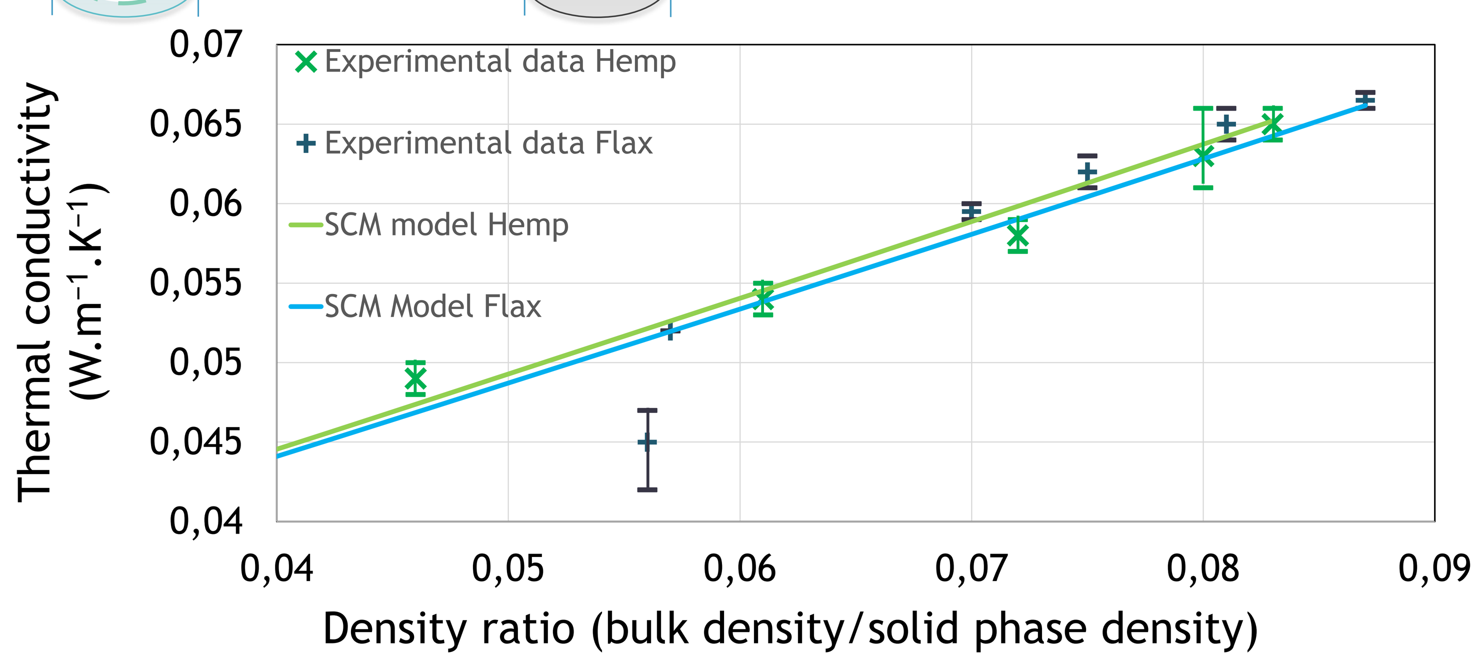
$$\phi = \left(\frac{R_1}{R_2}\right)^2$$

$$\lambda_{eq} = \lambda_2\left[1 + \frac{\phi}{\frac{(1-\phi)}{2} + \frac{1}{\lambda_1/\lambda_2 - 1}}\right]$$

Validation



Comparison of normal incidence sound absorption coefficeint for hemp and flax wools between measurements, Model (Rf_{veg}, Rf_{pol}) and Tarnow model

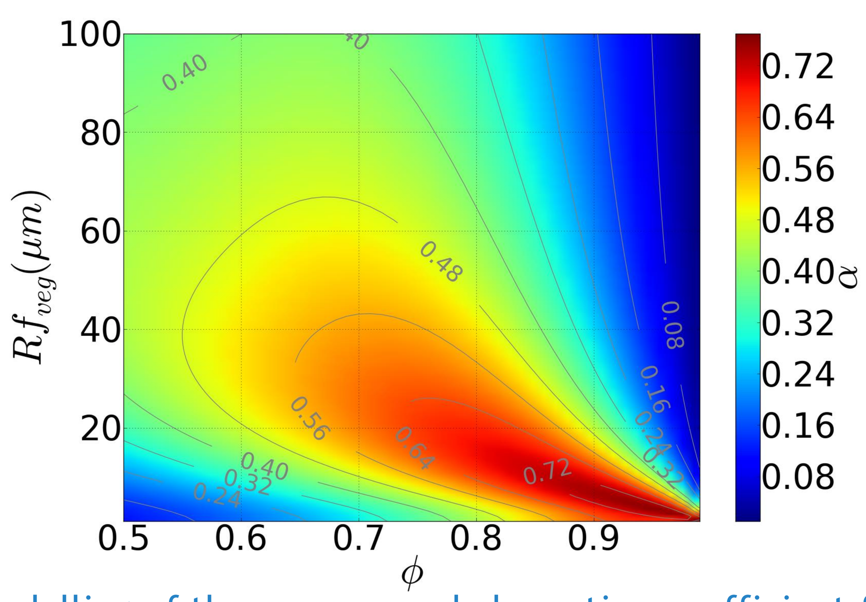


Comparison of thermal conductivity for hemp and flax wools between measurements and SCM model

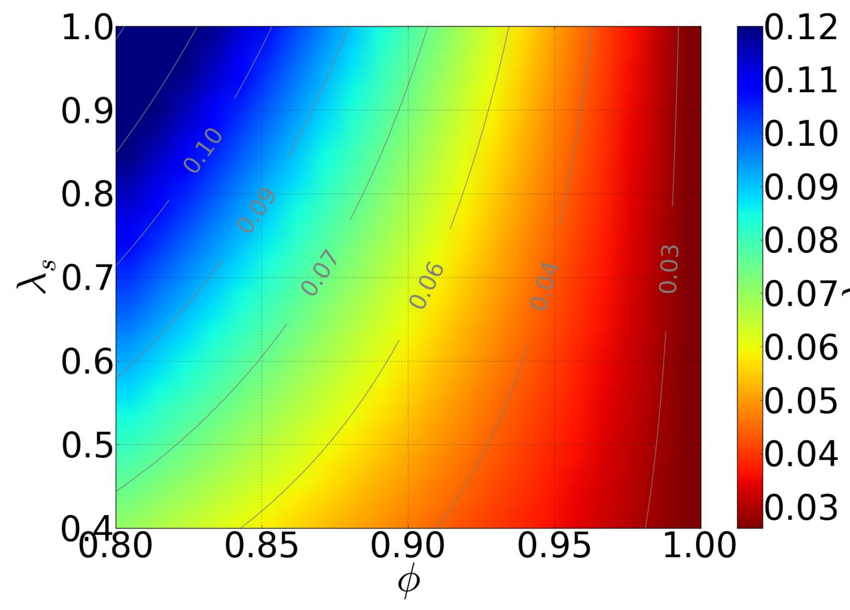
Inversion

Materials	Rf_{veg} (μm) Model	Rf_m (μm) MEB	λs_{SCM} (W.m^{-1}.K^{-1})	λs_{exp} (W.m^{-1}.K^{-1})
Hemp	26,3 ± 0,5	27,9	0,905 ± 0,093	-
Flax	13,3 ± 0,2	14,6	0,883 ± 0,091	-

Optimisation



Modelling of the mean sound absorption coefficient for a vegetal wool (e=50 mm; Rf_{pol}=13 µm) with the Model (Rf_{veg}, Rf_{pol}) for a polymer fibers proportion of $\tau = 0{,}15$.



Modelling of thermal conductivity

Perspectives

- Expansion of the range of materials

- Characterisation and modelling of compression effects
- Characterisation of ignifugation effects

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