Hygrothermal behaviour of a hemp concrete wall

Influence of sorption isotherm modelling

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Why hemp concrete ?

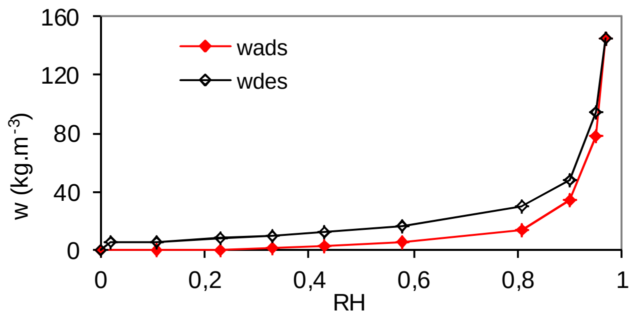
- Sustainable development context
- A porous environmentally friendly material
- Interest to evaluate energetic performance with efficient numerical tools to predict the hygrothermal behavior

Hemp concrete block

Properties of the hemp concrete studied

- ***Vapor permeability (0-50%)*** :
  $\delta_p = 2{,}5.10^{-11}\ kg.m^{-1}.s^{-1}.Pa^{-1}$
- ***Specific heat conductivity*** :
  $\lambda = 0{,}11\ W.m^{-1}.K^{-1}$
- ***Density of the dry material*** :
  $\rho_0 = 390\ kg.m^{-3}$
- ***Specific heat capacity of the dry material*** :
  $C_0 = 1000\ J.kg^{-1}.K^{-1}$

Sorption isotherm



How to model the hydric behaviour of hemp concrete during its use?

The model

A strongly coupled system

Heat transfer → T

- Conduction
- Convection

→

- Air
- Vapor water
- Liquid water
- Phase changes in pores

Mass transfer → RH

- Diffusion
- Convection

→

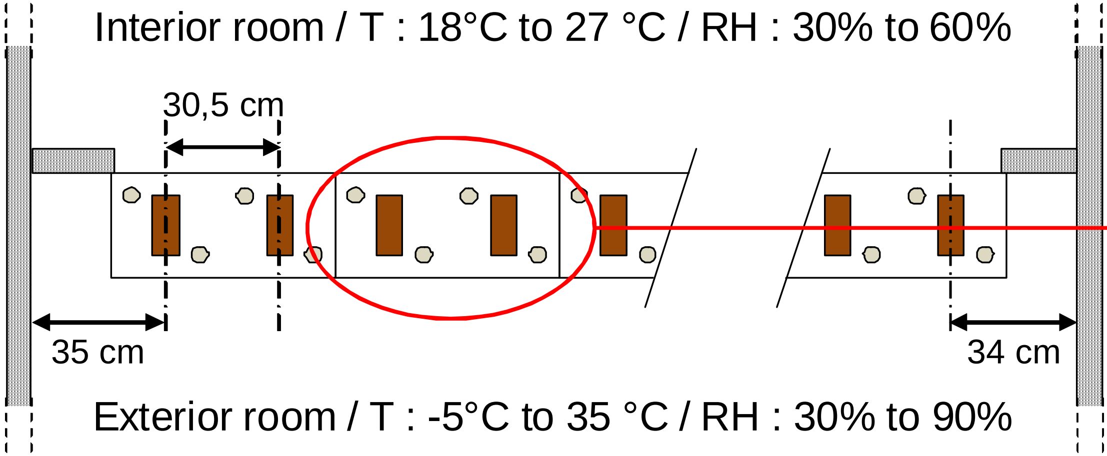
- Air
- Vapor water
- Liquid water

Model implemented in COMSOL Multiphysics

→ Validated from confrontation with an international benchmark HAMSTAD WP2 (multilayer, rain, air transfer test cases)

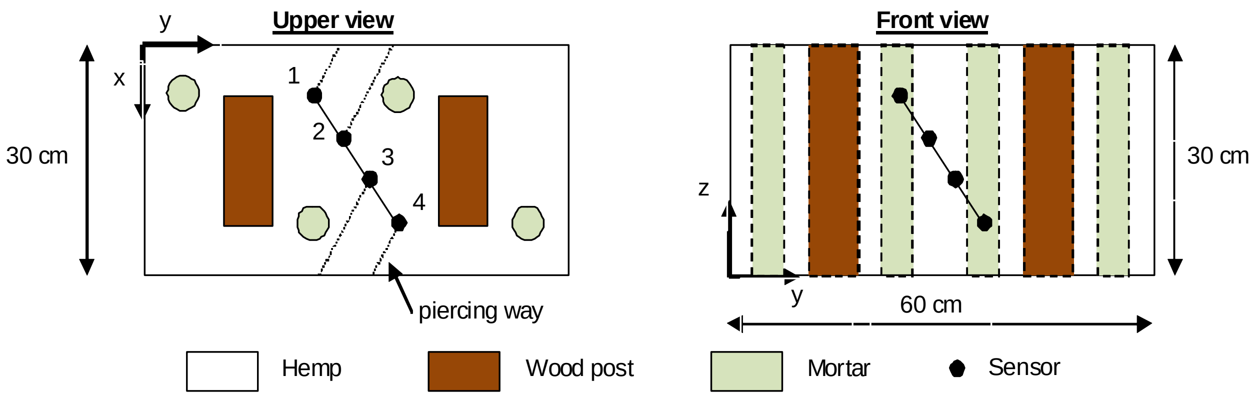
The wall and its metrology

Biclimatic room able to impose real climatic conditions



EASY Chanvre block

Temperature and humidity sensors



4 positions

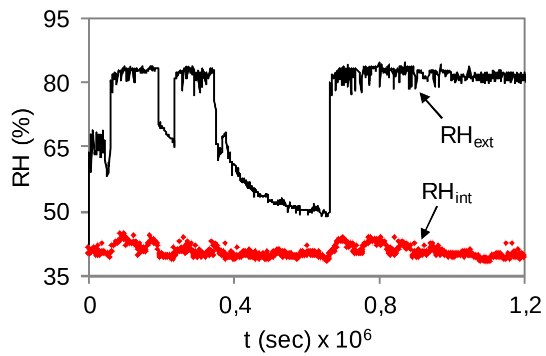
- $x_1 = 8\ cm$
- $x_2 = 12\ cm$
- $x_3 = 18\ cm$
- $x_4 = 22\ cm$

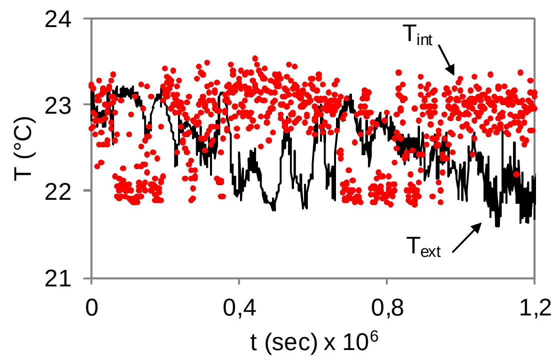
The paramaters of the study

Simulation parameters

- **Time simulation** : 2 weeks
- **Initial conditions** : Temperature : 23 °C
  Relative humidity : 41,5%
- **Boundary conditions** :
  T_{ext}, T_{int}, RH_{ext}, RH_{int}
  Heat transfer surface coefficient : $5\ W.m^{-2}.K^{-1}$
  Mass transfer surface coefficient : $\sim 5.10^{-8}\ s.m^{-1}$

Climatic solicitations

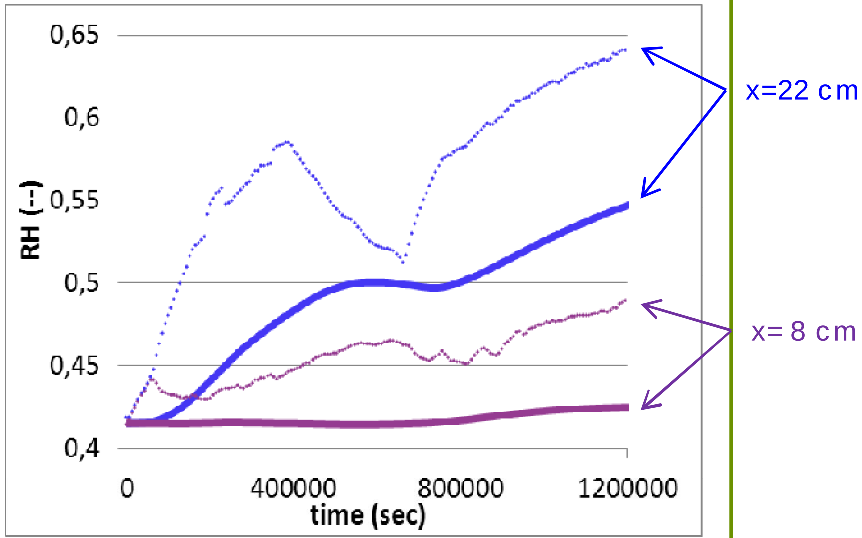




First approach

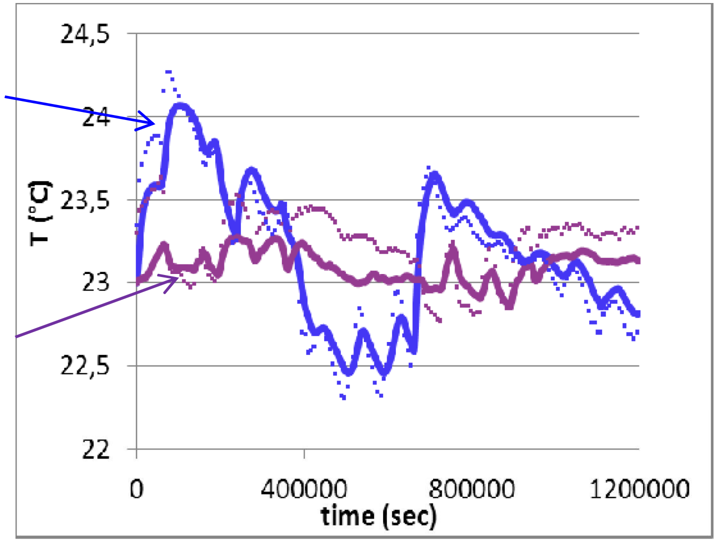
Hypothesis : the sorption isotherm = the adsorption curve

Relative humidity



Underestimation and time lag

Temperature



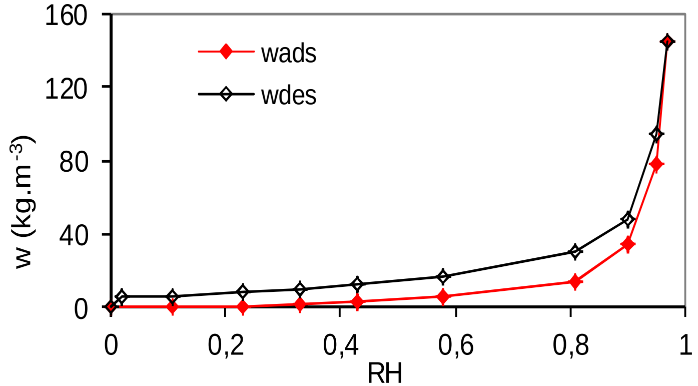
Good agreement

Influence of sorption modelling

Identification of the influent parameter(s) by a sensitivity study

- Vapor permeability
- Specific heat conductivity
- Density of the dry material
- Specific heat capacity of the dry material
- Liquid conductivity
- Sorption isotherm
- Storage capacity
- Air permeability

storage capacity : $\frac{dw}{d\varphi}$

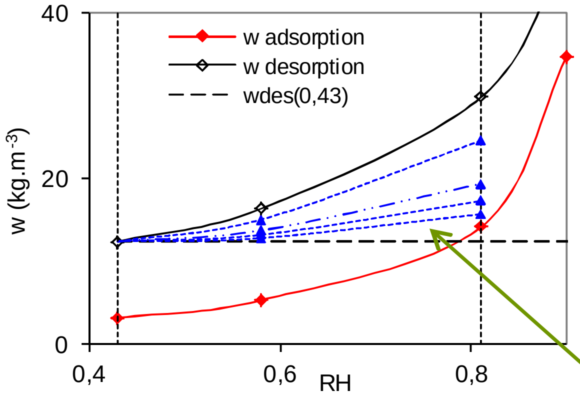


Wide overestimation of the storage capacity with main adsorption or desorption curve

HYSTERESIS EFFECT

Second approach

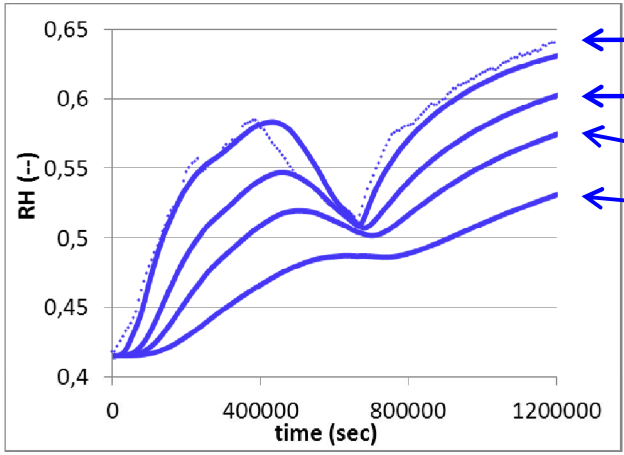
Scanning sorption curves : simplified hysteresis modelling



$$w_{inter}(0{,}58) = w_{des}(0{,}43) + \alpha[w_{des}(0{,}58) - w_{des}(0{,}43)]$$
$$w_{inter}(0{,}81) = w_{ads}(0{,}81) + \alpha[w_{des}(0{,}81) - w_{ads}(0{,}81)]$$

Physically, at a given RH, more pores are load of water when water content is closer to the desorption curve than to the adsorption one.

→ The storage capacity decreases



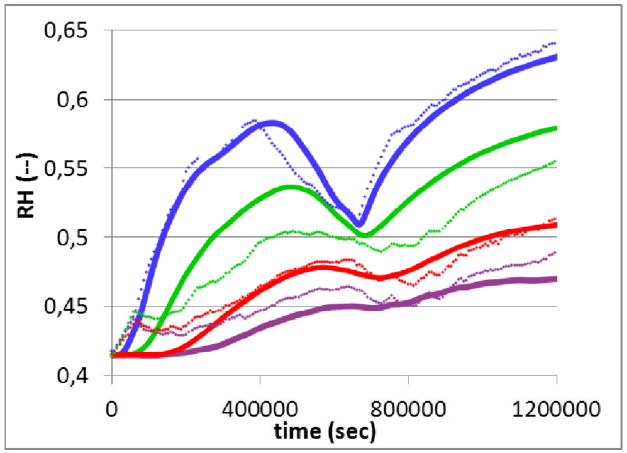
$\alpha = {}^{1}/_{10}$

$\alpha = {}^{1}/_{5}$

$\alpha = {}^{1}/_{3}$

$\alpha = {}^{2}/_{3}$

position $x_4 = 22\ cm$



all positions

Conclusion

- Sensitivity of the storage capacity
- Impact of the hysteresis phenomenon

Additional works made

- Implementation of a hysteresis model
- Intermediate sorption/desorption cycles experiments on hemp concrete

Perspectives

- Comparison to other experimental simulations (non isothermal cases)
- Taking into account the whole structure of the wall