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

Properties of the hemp concrete studied

- **Vapor permeability** (0-50%) : \( \delta_p = 2.5 \times 10^{-11} \text{ kg.m}^{-1} \text{ s}^{-1} \text{ Pa}^{-1} \)
- **Specific heat conductivity** : \( \lambda = 0.11 \text{ W.m}^{-1} \text{ K}^{-1} \)
- **Density of the dry material** : \( \rho_0 = 390 \text{ kg.m}^{-3} \)
- **Specific heat capacity of the dry material** : \( C_0 = 1000 \text{ J.kg}^{-1} \text{ K}^{-1} \)

Introduction

**Hemp concrete block**

**How to model the hydric behaviour of hemp concrete during its use?**
A strongly coupled system

Heat transfer
- Conduction
- Convection

Mass transfer
- Diffusion
- Convection

The model implemented in COMSOL Multiphysics

Validated from confrontation with an international benchmark HAMSTAD WP2 (multilayer, rain, air transfer test cases)
Biclimatic room able to impose real climatic conditions

Interior room / T : 18°C to 27°C / RH : 30% to 60%
Exterior room / T : -5°C to 35°C / RH : 30% to 90%

Temperature and humidity sensors

4 positions
- $x_1 = 8\text{ cm}$
- $x_2 = 12\text{ cm}$
- $x_3 = 18\text{ cm}$
- $x_4 = 22\text{ cm}$
**Simulation parameters**

- **Time simulation**: 2 weeks
- **Initial conditions**: Temperature: 23 °C  
  Relative humidity: 41.5%
- **Boundary conditions**:  
  $T_{\text{ext}}, T_{\text{int}}, RH_{\text{ext}}, RH_{\text{int}}$
  Heat transfer surface coefficient: $5 \text{ W.m}^{-2}.\text{K}^{-1}$
  Mass transfer surface coefficient: $\sim 5 \times 10^{-8} \text{ s.m}^{-1}$

**Climatic solicitations**

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Hypothesis: the sorption isotherm = the adsorption curve

Relative humidity

Temperature

Underestimation and time lag

Good agreement

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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**: \( \frac{\text{dw}}{\text{d}\phi} \)

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

**Hysteresis Effect**

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Scanning sorption curves: simplified hysteresis modelling

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

\[
w_{\text{inter}}(0.58) = w_{\text{des}}(0.43) + \alpha[w_{\text{des}}(0.58) - w_{\text{des}}(0.43)]
\]
\[
w_{\text{inter}}(0.81) = w_{\text{ads}}(0.81) + \alpha[w_{\text{des}}(0.81) - w_{\text{ads}}(0.81)]
\]

position \( x_4 = 22 \text{ cm} \)

all positions

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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