COMSOL CONFERENCE EUROPE 2012

LIMATB Laboratoire d'Ingénierie des MATériaux de Bretagne

UBS Université de Bretagne-Sud

Numerical Modelling of Heat and Mass Transfer in Porous Materials During Drying and Shrinkage

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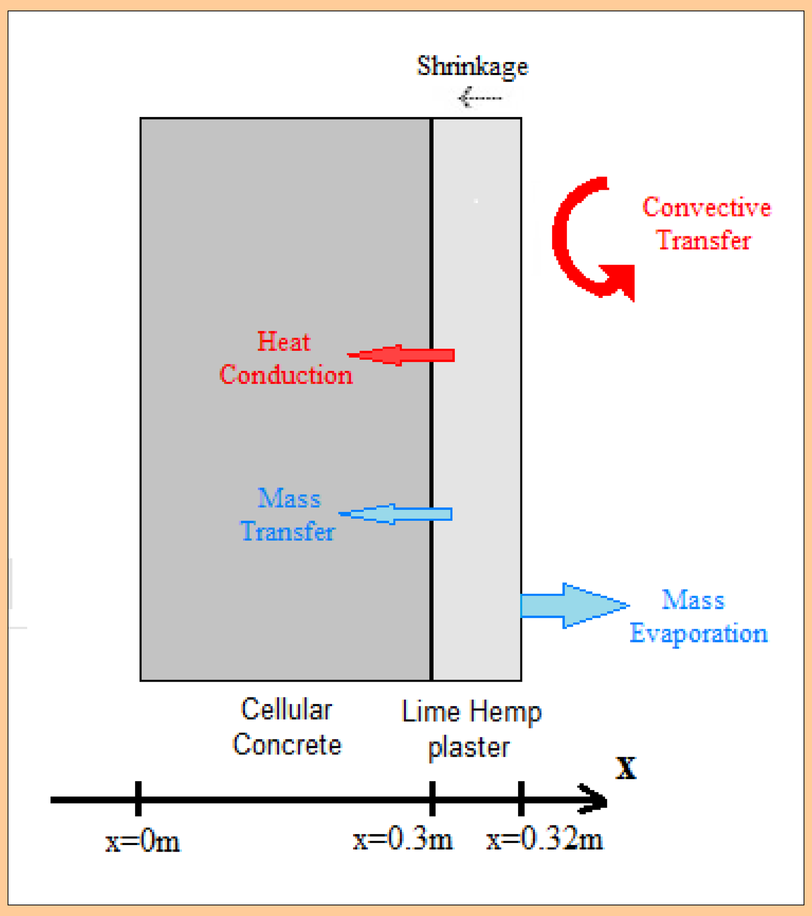
Introduction

We present a model realized on Comsol Multyphysics to simulate the drying of a wet lime hemp plaster layer on dry cellular concrete.

We will use the vapour pressure and temperature in the equations of heat and mass transfer,calculate the gas pressure through the mass balance and modelize the shrinkage of the plaster layer with the weakly compressible Navier-Stokes equation.



Computational methods

Equations

Vapour pressure equation

$$\frac{\rho_s}{P_{v,sat}}\theta\left(\frac{\partial P_v}{\partial t}+u\nabla Pv\right)+\nabla\left[\frac{\theta}{P_{v,sat}}\left(D_l^W+D_v^W\right)\nabla P_v+(D_l^T+D_v^T)\nabla T\right]=0$$

Heat equation

$$\rho C_P\left(\frac{dT}{dt}+u\nabla T\right)+D\nabla T-\nabla(\lambda\nabla T)+K(L_v+\Delta H_{ad})=0$$

Gas pressure equation

$$\frac{\partial P_g}{\partial t}+u\nabla P_g=-\frac{1}{\gamma_3}\left[\nabla(D_a^W\nabla W+D_a^T\nabla T)+\gamma_1\left(\frac{\partial T}{\partial t}\right)+\gamma_2\left(\frac{\partial W}{\partial t}\right)\right]$$

Shrinkage equation

$$\frac{\partial \rho_s^{app}}{\partial t}+\nabla\left(\rho_s^{app}u\right)=0$$

Boundaries conditions

Left side of the concrete wall (x=0m)

Temperature : T=30°C

Relative humidity : RH=0.5

Interface between concrete and plaster (x=0.3m)

Continuous temperature : $T_{concrete}=T_{plaster}$

Continuous vapour pressure : $P_{v,concrete}=P_{v,plaster}$

Interface between plaster and air (x=0.32m)

Gas pressure : $P_g=P_{atm}$

Temperature : $-\vec{n}.(\lambda\vec{\nabla}T)=h_c(T_{air}-T)$

Vapour pressure : $\vec{n}\cdot\left(D_l^W+D_v^W\right)\frac{\theta}{P_{v,sat}}\vec{\nabla}P_v=-F_m$

Results

Mono-layer simulation on plaster

A first simulation is made on the plaster only. The interface between the concrete and the plaster has an imposed temperature Tb=30°C or 35°C, and no water transfer.

Initial conditions of plaster

Temperature T=20°C

Relative humidity RH=1

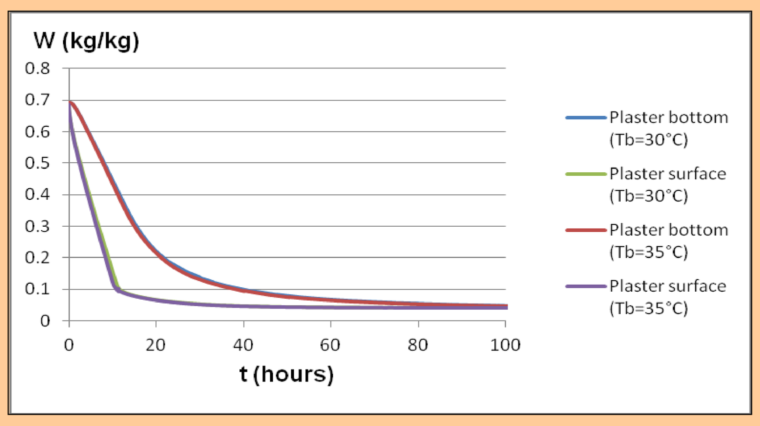
Moisture content W=0.7kg/kg

Properties of air

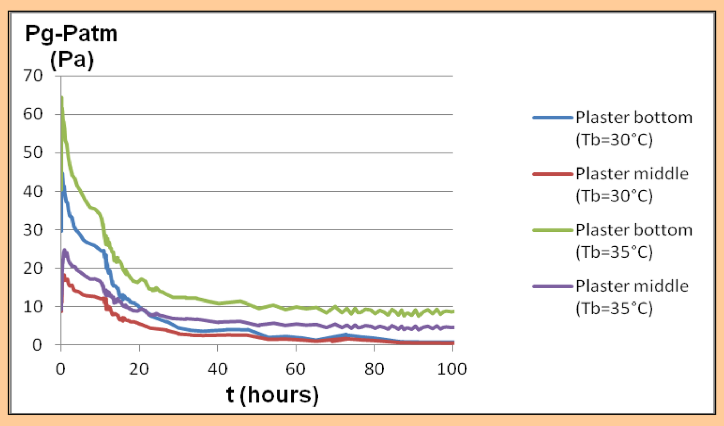
Temperature T=30°C

Relative humidity RH=0.5

Moisture content



Gas pressure



Multi-layer simulation on wall

Initial conditions of plaster

Temperature T=20°C

Relative humidity RH=1

Moisture content W=0.3kg/kg

Initial conditions of concrete

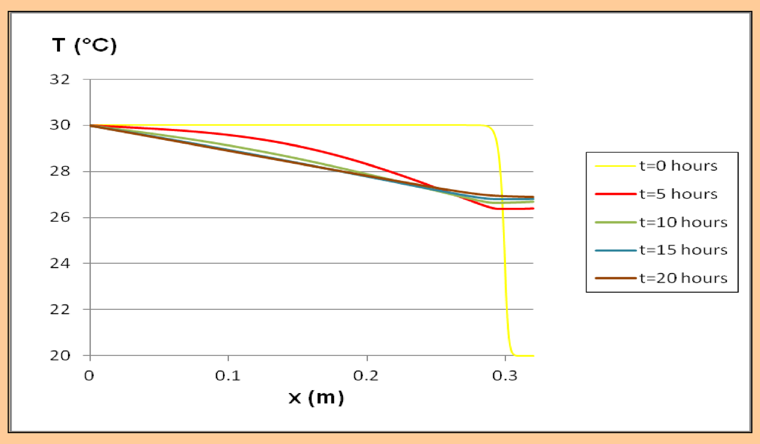
Temperature T=30°C

Relative humidity RH=0.5

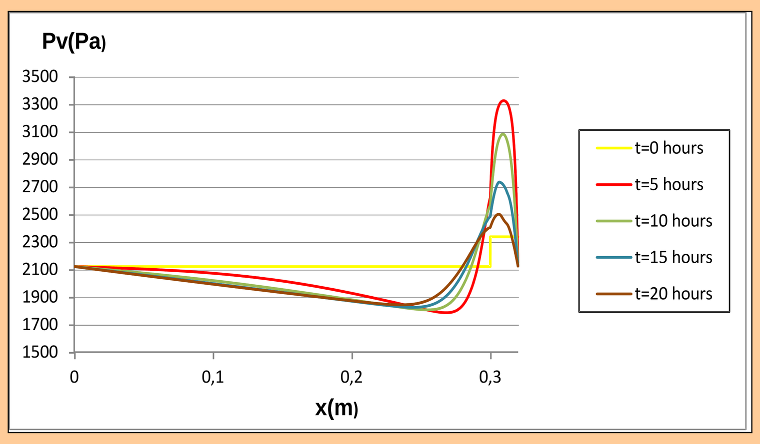
Moisture content W=0.025kg/kg

The properties of air are the same as for the mono-layer simulation.

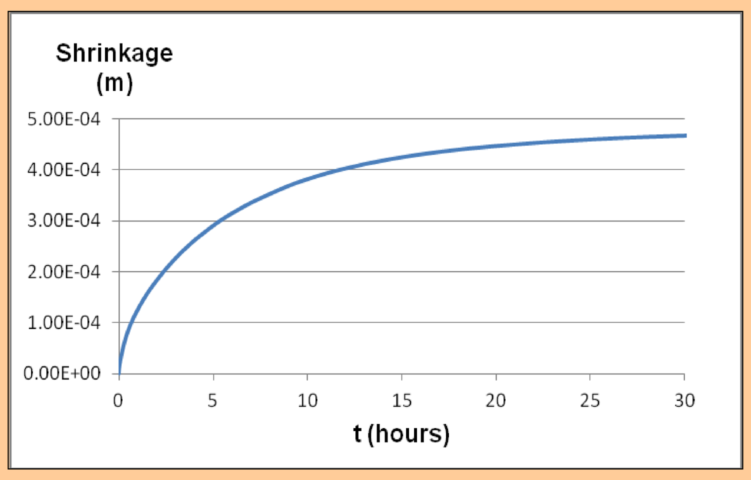
Temperature profile



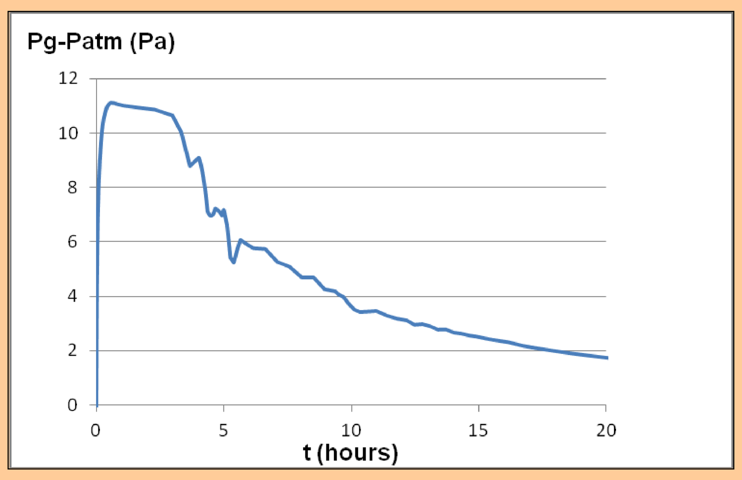
Vapour pressure profile



Shrinkage evolution



Gas pressure evolution



Conclusion

This system has been developed to modelize a multi-layer wall while solving the discontinuity issues at the interface between two materials. The COMSOL software allowed us to calculate the evolution of temperature, vapour pressure and shrinkage during the drying of wet lime hemp plaster on dry cellular concrete.

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