3D Simulation of Heat and Moisture Diffusion in Constructions

Wooden Beam End Application

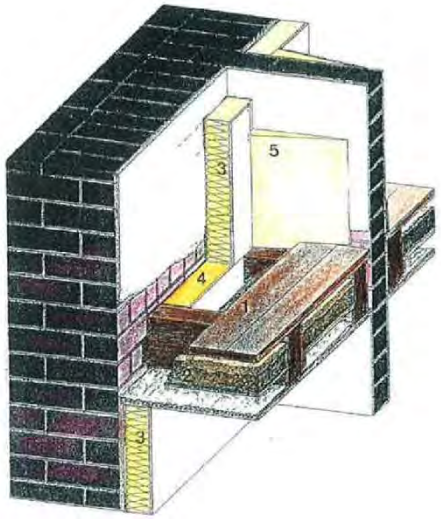
Michele Bianchi Janetti
Fabian Ochs
Wolfgang Feist

michele.janetti@uibk.ac.at

Contents

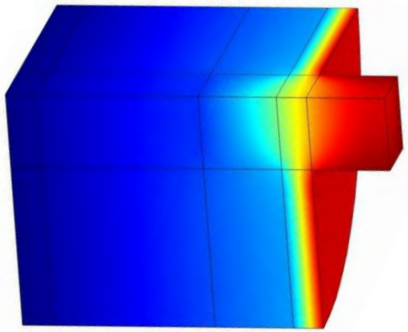
- Introduction and motivation
- State of the art and R&D demand
- Mathematical model
- Simulation results
- Outlook

Introduction and Motivation



Source: Passiv Haus Institut, Protokolband Nr.32, Architect Fingerling

temperature distribution



40% total energy consumed in buildings

↓

Retrofitting of existing buildings: **3ENCULT EU Project**

↓

Risk of damages due to water condensation

↓

Heat & moisture simulations required

State of the Art and R&D Demand

Features	Specialized Software	COMSOL Multiphysics
Geometry	limited to 2D	3D possible
CFD	no / limited	possible
Phase change (l-s)	no / limited	possible
Coupling with Matlab / Simulink	limited	possible

Mathematical Model

$$\begin{cases} \dfrac{\partial u}{\partial \varphi}\dfrac{\partial \varphi}{\partial t} + \dfrac{\partial}{\partial x}\left(-D_{m,\varphi}\dfrac{\partial \varphi}{\partial x} - D_{m,T}\dfrac{\partial T}{\partial x}\right) = 0 \\ \dfrac{\partial h}{\partial T}\dfrac{\partial T}{\partial t} + \dfrac{\partial h}{\partial \varphi}\dfrac{\partial \varphi}{\partial t} + \dfrac{\partial}{\partial x}\left(-D_{e,T}\dfrac{\partial T}{\partial x} - D_{e,\varphi}\dfrac{\partial \varphi}{\partial x}\right) = 0 \end{cases}$$

Moisture balance

Energy balance

PDE Mode coefficient form

$\varphi(t,x)$

$T(t,x)$

x	Position
t	Time
φ	Relative Humidity
T	Temperature
u	Water content
h	Enthalpy
$D_{m,\varphi}, D_{m,T}, D_{e,T}, D_{e,\varphi}$	Diffusion coefficients

Material Functions

Water storage

Energy storage

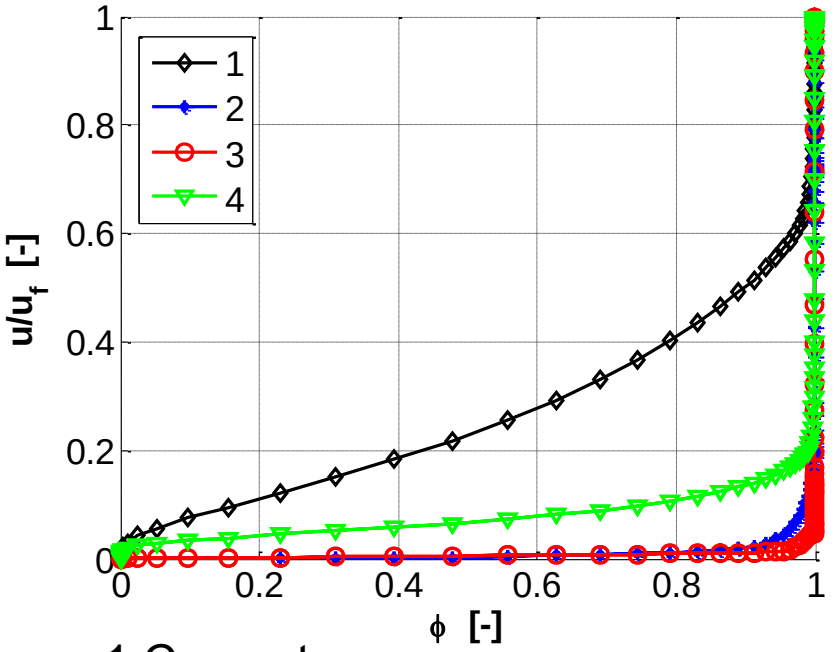
Liquid water conductivity

Vapor diffusion

Heat conductivity

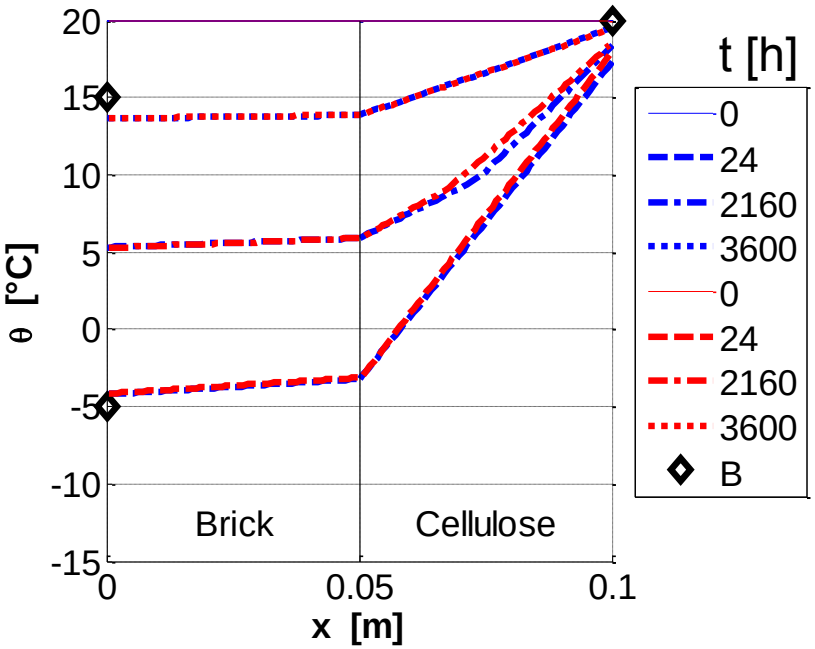
…

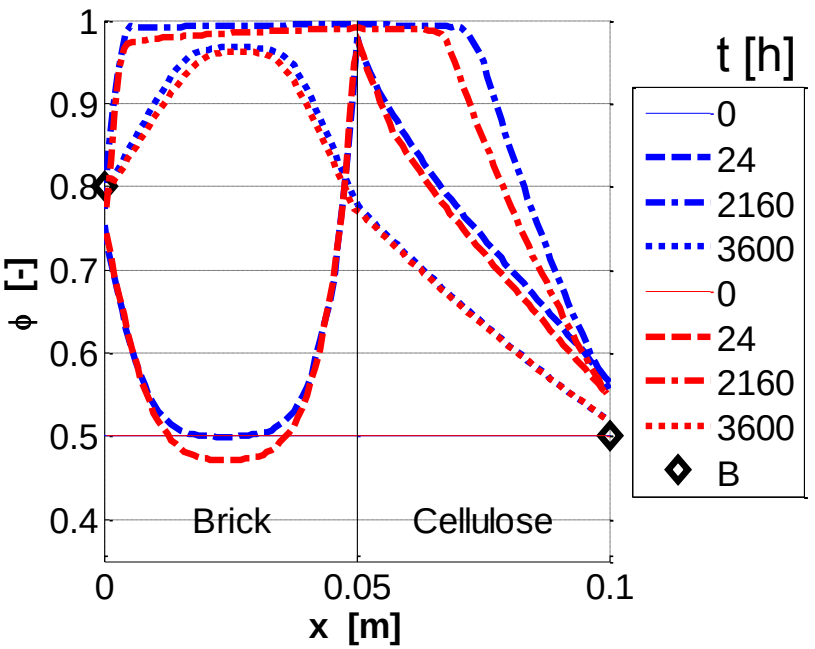
Water retention curve



1 Concrete
2 Brick
3 Cellulose
4 Spruce

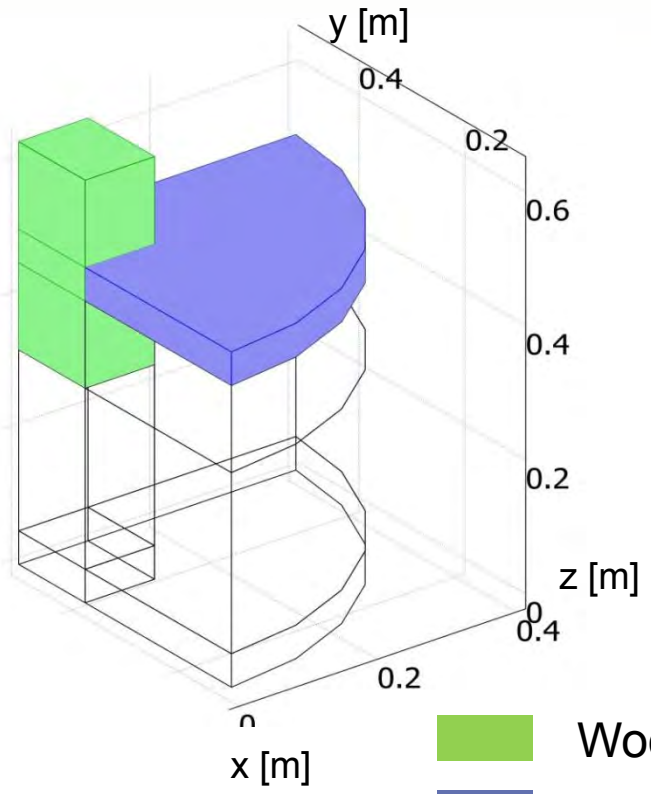
Cross Validation Comsol – Delphin
One-dimensional Wall Model

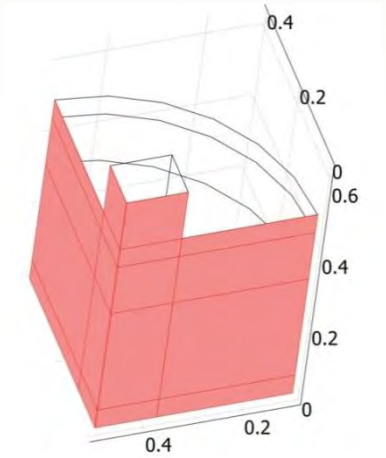




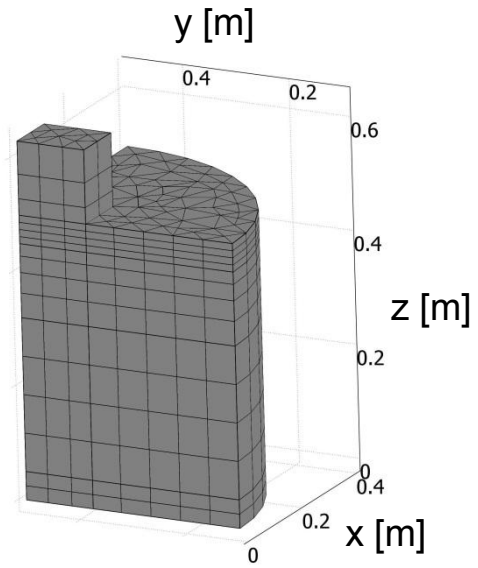
Red line: Delphin
Blue line: Comsol

Beam End 3D Simulation





Symmetry planes



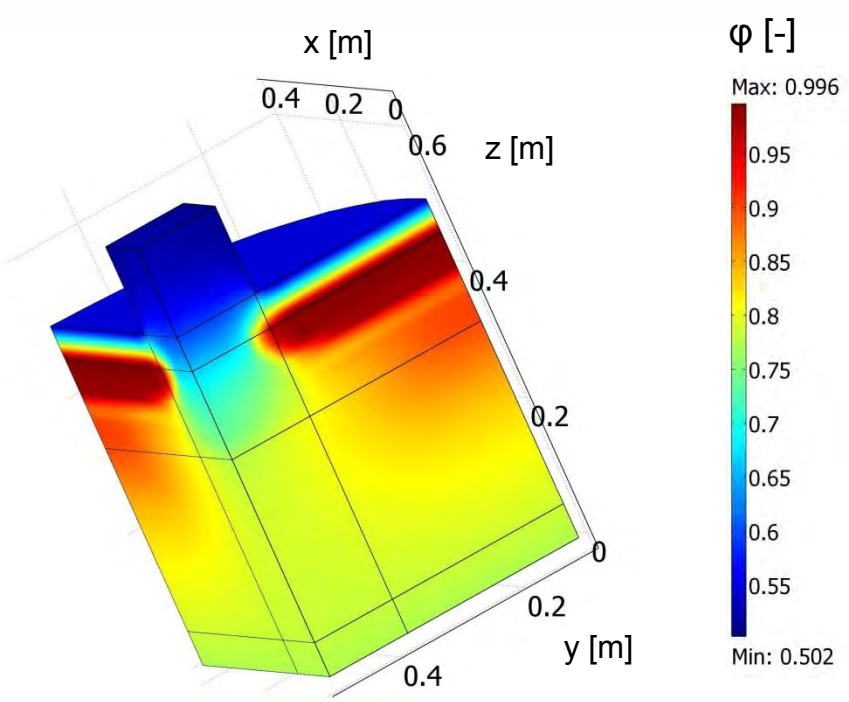
Discretization grid

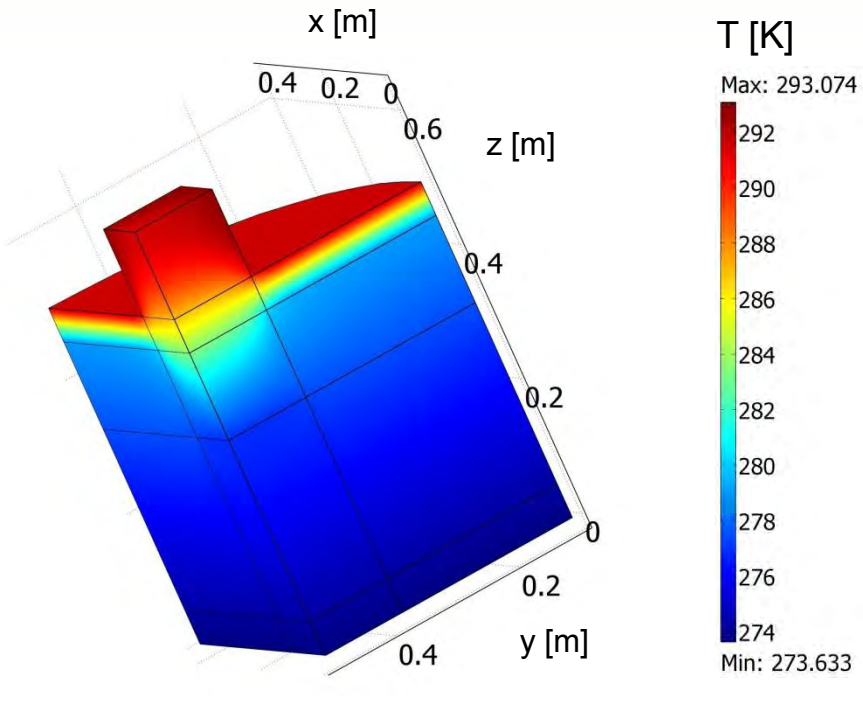
Wooden beam

Internal insulation

Brickwork

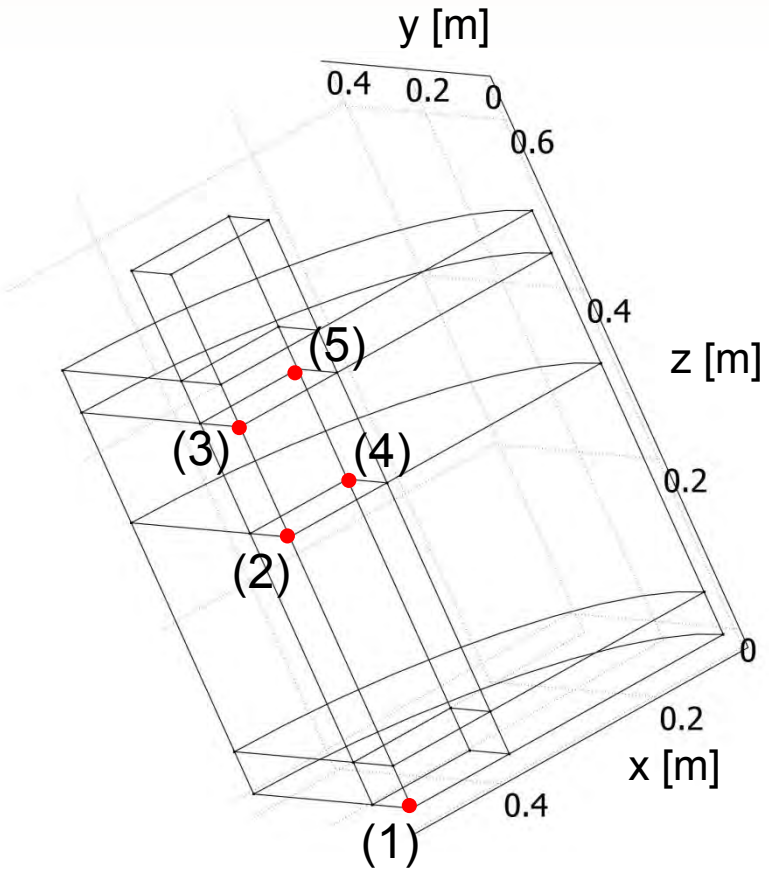
Beam End 3D Simulation

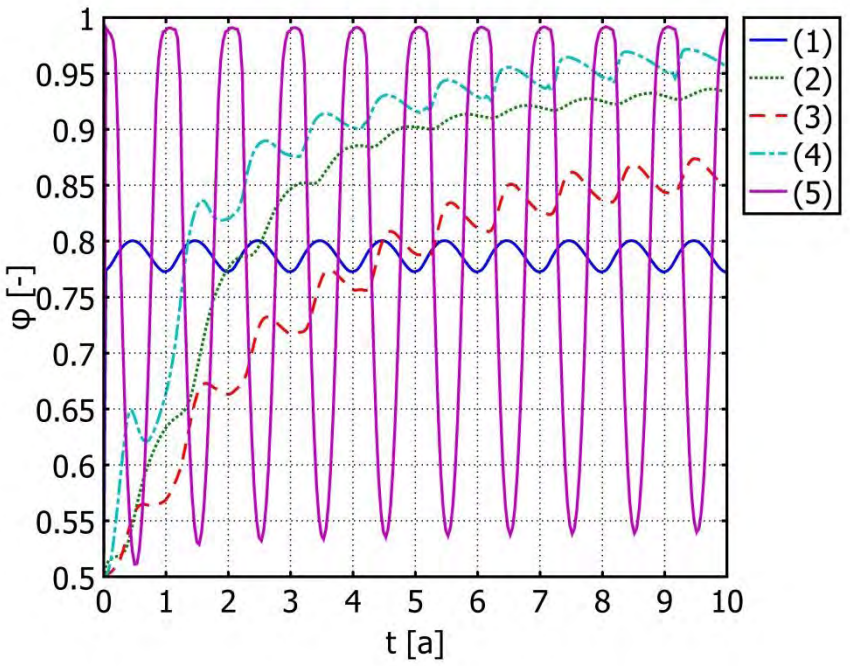




Relative Humidity and Temperature distribution
after two years

Beam End 3D Simulation





Outlook

What has already been done

- Implementation of the model in Comsol
- Cross-validation with Delphin
- 3D Simulation

Further works

- Validation against measurements
- Phase change (l - s)
- Coupling with building model
- Coupling with fluid dynamics

Thank you for your attention!

michele.janetti@uibk.ac.at