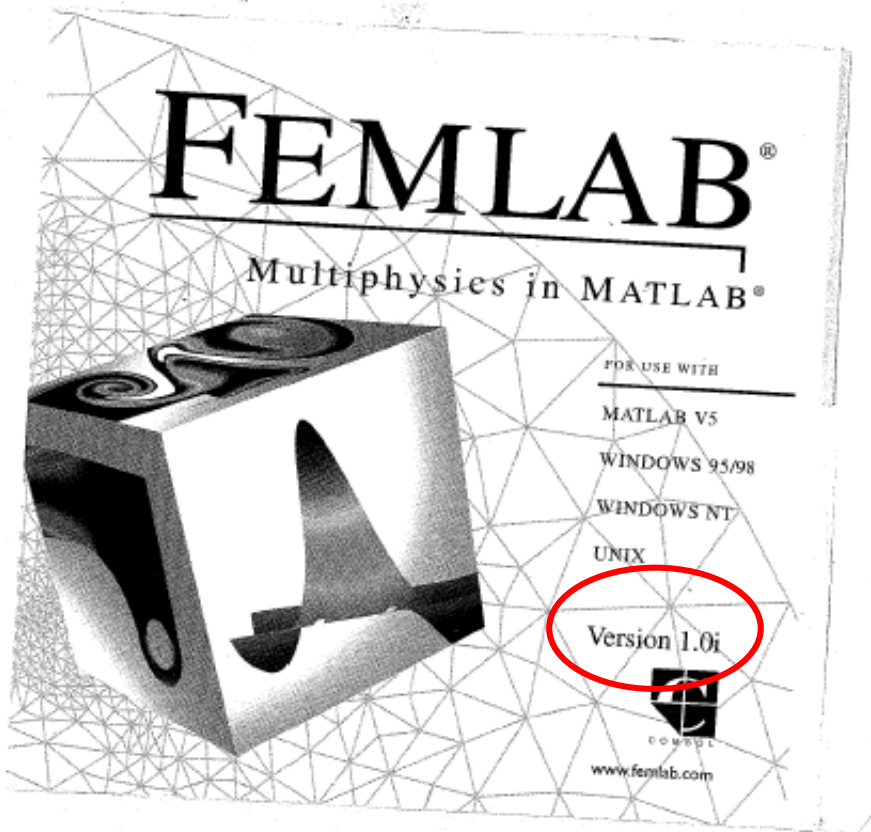


HAMSTAD Benchmarks using Comsol revisited

Jos van Schijndel (presenter)
Henk Schellen
Sander Goesten

@TU/e: Asst. professor

User since 1998 (Femlab 1.0i)



@CompuToolAble: Entrepreneur

SME since 2015

SERVICES

What we do, how and why.

Free Advice and Tips on Modeling and Simulation
If you contact us about your modeling and simulation challenge, we will provide free advice and tips on how to proceed with your modeling request.

CompuToolAble's Deliverables (What)
CompuToolAble delivers products and services. For a client with software license(s) there are two possibilities: (1) If the client only wants the tool itself, we deliver software files as product. (2) If the client also wants tool development knowledge and skills, we deliver a service, i.e. modeling expertise. For a client without software license(s), we deliver a report including description of the models as product. See also the table below.

Deliverables	Client with Software	Client without Software
Client does not want to be involved with the modeling process.	SOFTWARE DEVELOPMENT CompuToolAble delivers a product: Software Files	CONSULTANT CompuToolAble delivers a product: Report
Client wants to be (more closely) involved with the modeling process.	MODEL DEVELOPMENT CompuToolAble delivers a service: Co-development of models	SOFTWARE COURSE CompuToolAble delivers a service: Modeling Course

Innovative Design begins with Simulation Software

Contact
Email: jos@computoolable.nl

[in](#)

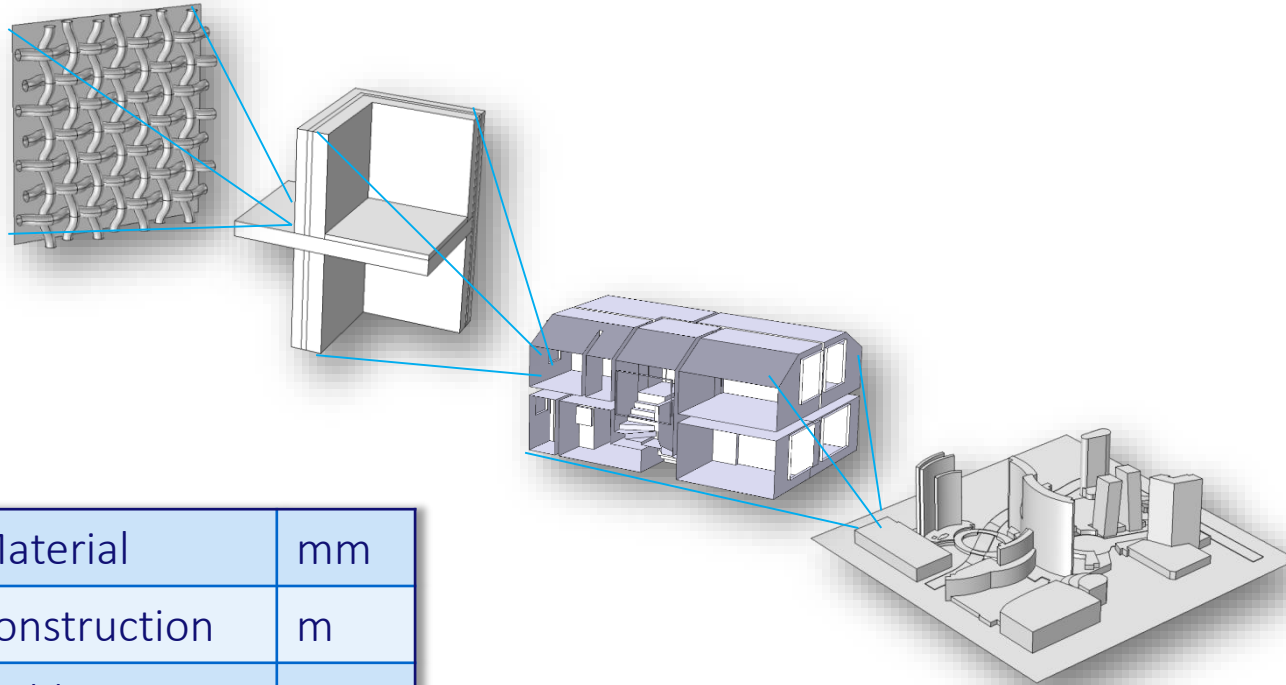
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 - **Physics of the built environment and scale levels**
 - **Examples**
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The built environment is **Multiscale** in space and time



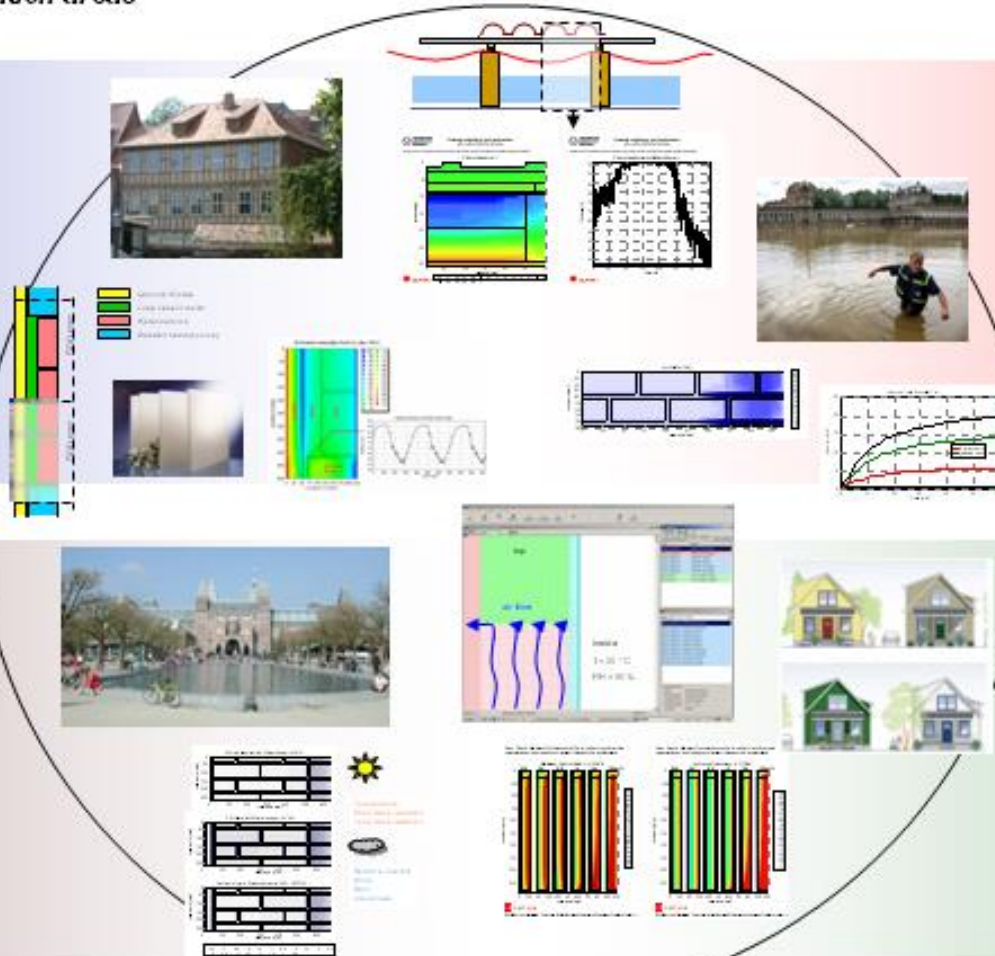
Material	mm
Construction	m
Building	10 m
Urban Area	1 km

The laws of nature of the built environment are **Multiphysics**

CHAMPS-BES Application areas

Building Climatology

- Preservation of historical buildings and cultural heritage
- Interaction Building – Climate – Inhabitants



Mechanical & Energy Engineering

- Energy efficiency, sustainable development of built environment
- Mechanical properties, durability, damaging processes

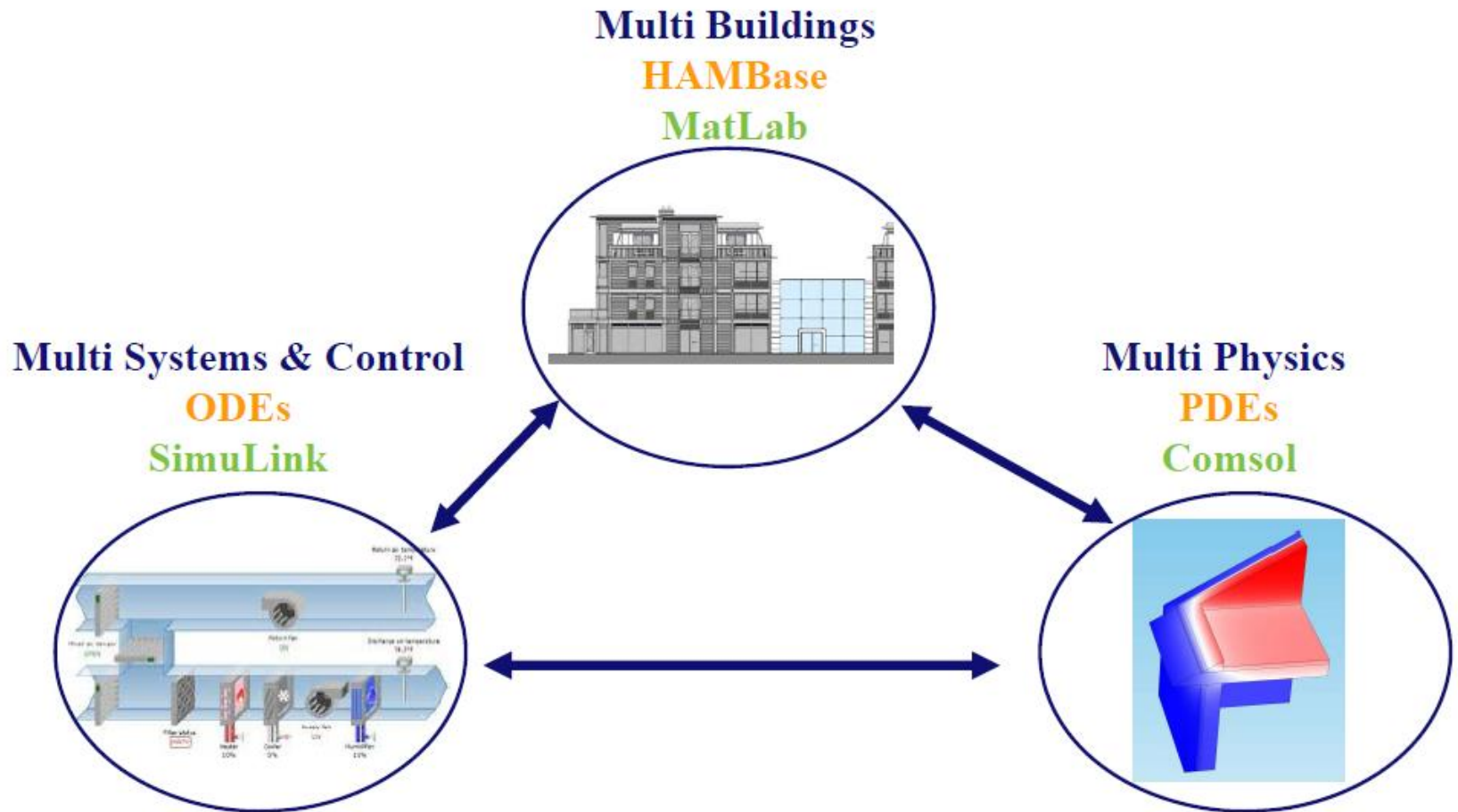
Building Physics & Soil Science

- New materials and processes
- Hygrothermal and hydraulic material properties

Environmental & Architectural Engineering

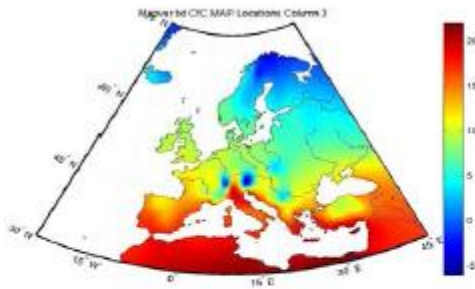
- Material emissions and IAQ
- Outdoor to indoor pollutant transport
- Moisture buffering, dampness and mold control

Computational Tools are needed to understand, predict and control



Physics of the Built Environment

Scale levels



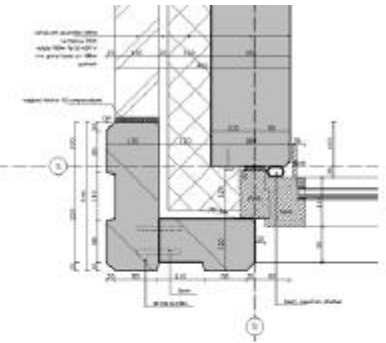
~Mm



~km



~m

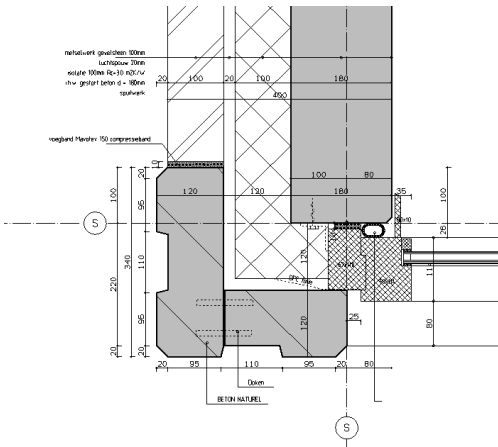


~mm

Scale levels, from left to right: EU; Urban area; Building; Material;

Physics of the Built Environment

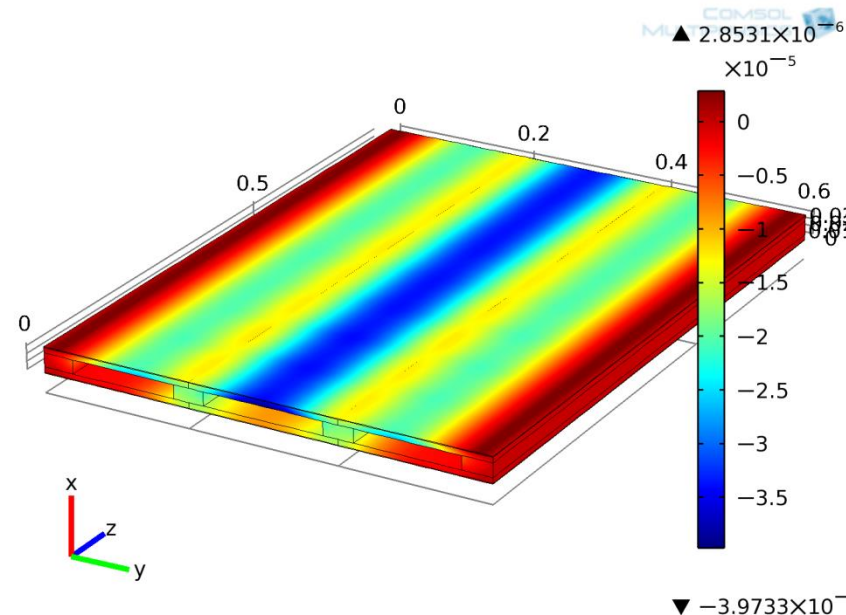
Scale level [mm]



Material ~ mm

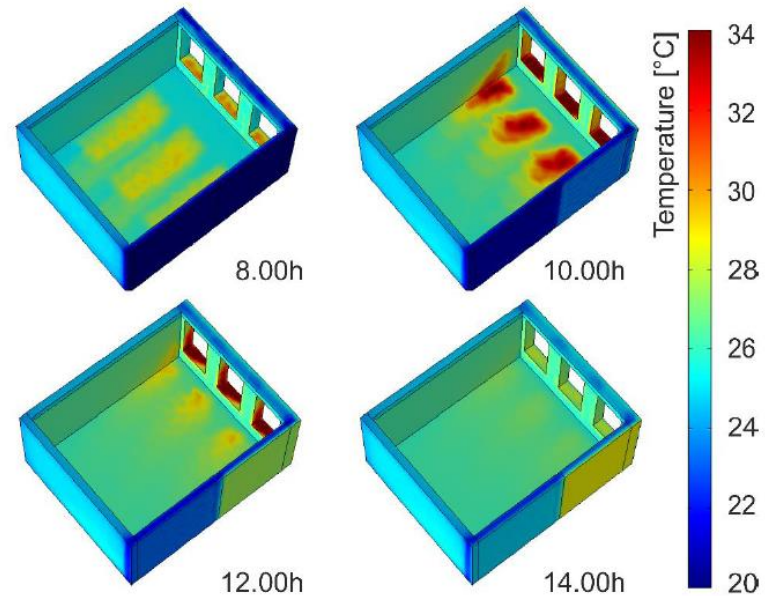
Material Physics

- Durability
- Energy



Physics of the Built Environment

Scale level [m]



Building ~ m

Building Physics

- Indoor Climate
- Building systems
- Energy
- Health

Physics of the Built Environment

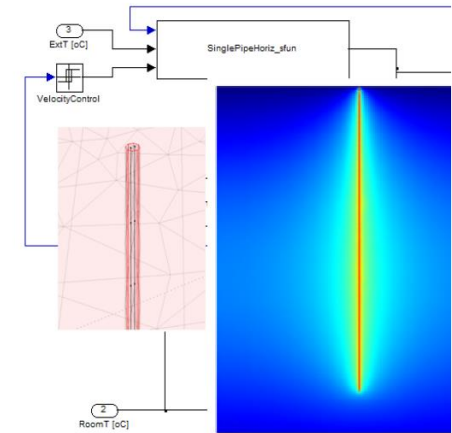
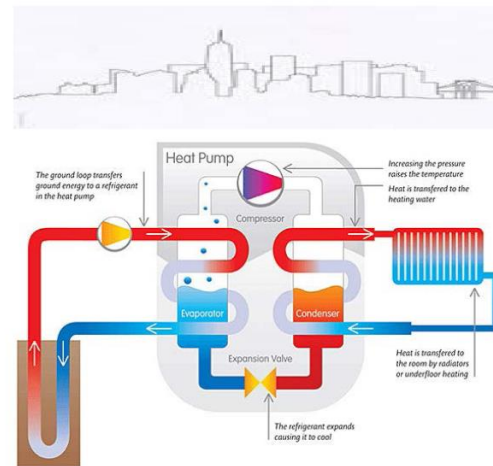
Scale level [km]



Urban Area ~ km

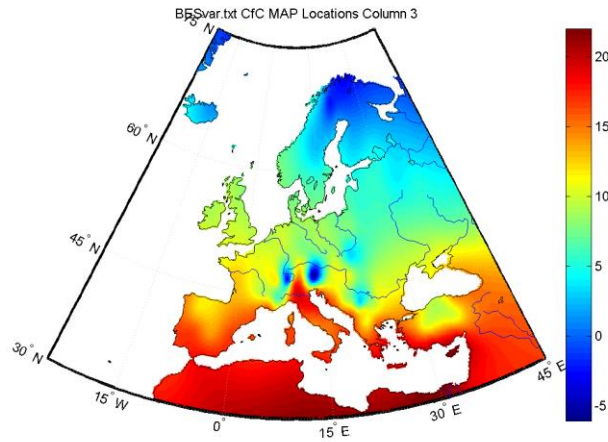
Urban Physics

- Urban Climate
- Urban district systems
- Energy



Physics of the Built Environment

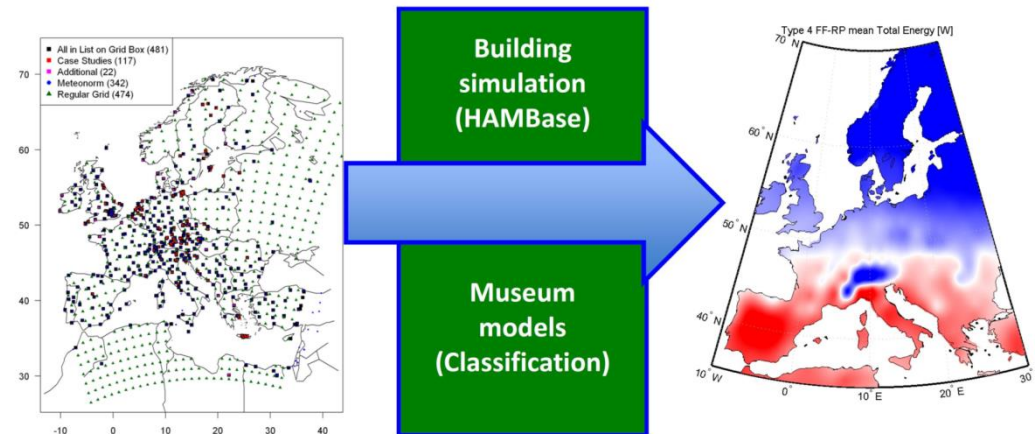
Scale level [Mm]



EU ~ Mm

Global Climate Physics

- (Future) Climate
- Mapping
- Energy

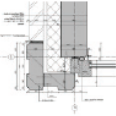


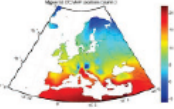


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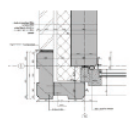


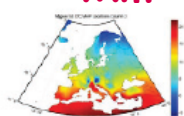
Physics of the Built Environment

Multiphysics and Scales

Topic Scale	Heat	Moisture	Air	Stress
~ mm 				
~ m 				
~ km 				
~ Mm 				

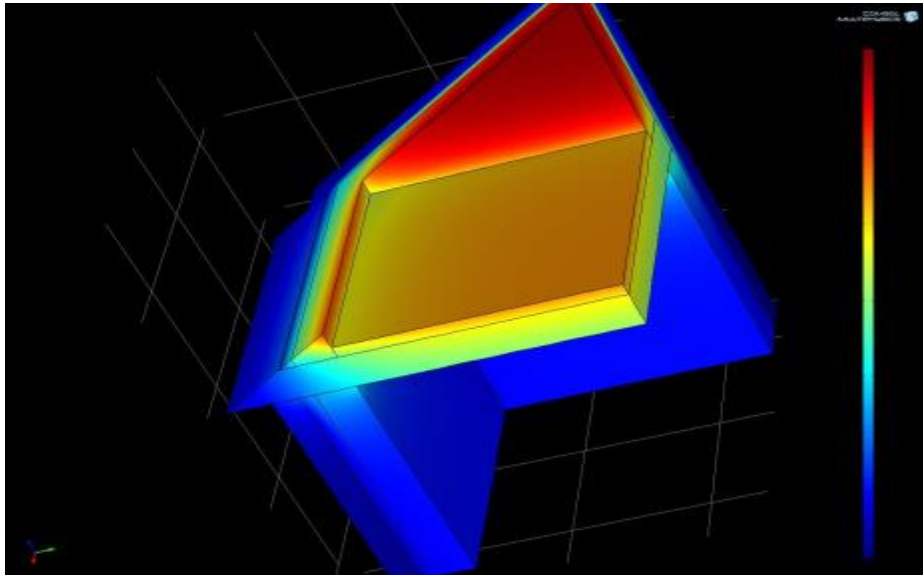
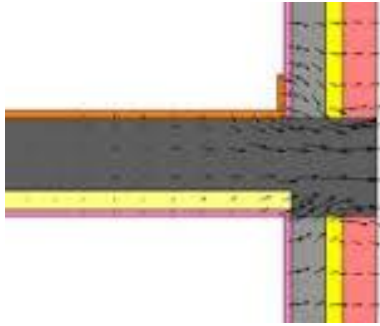
Example

Heat ~mm

Topic \ Scale	Heat	Moisture	Air	Stress
~ mm 				
~ m 				
~ km 				
~ Mm 				

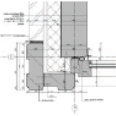


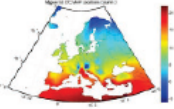
Example Thermal Bridges

Heat ~mm



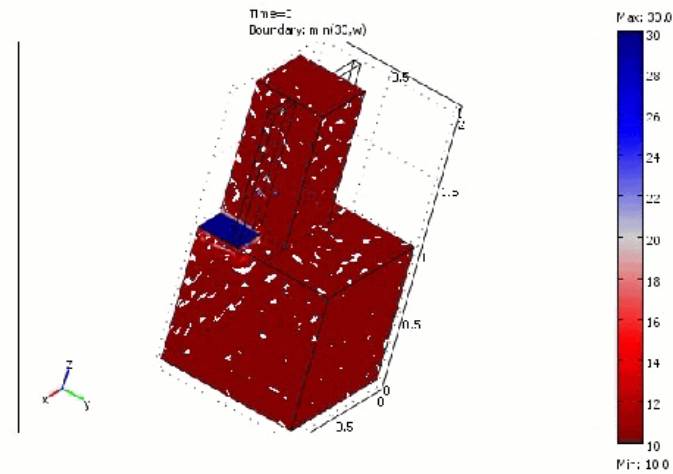
Example

Moisture ~mm

Topic Scale	Heat	Moisture	Air	Stress
~ mm 				
~ m 				
~ km 				
~ Mm 				

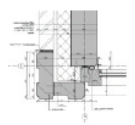


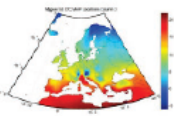
Example Water Leakages

Moisture ~mm



HAMSTAD

Heat & Moisture ~mm

Topic \ Scale	Heat	Moisture	Air	Stress
~ mm 				
~ m 				
~ km 				
~ Mm 				

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PDEs based on T & LPc

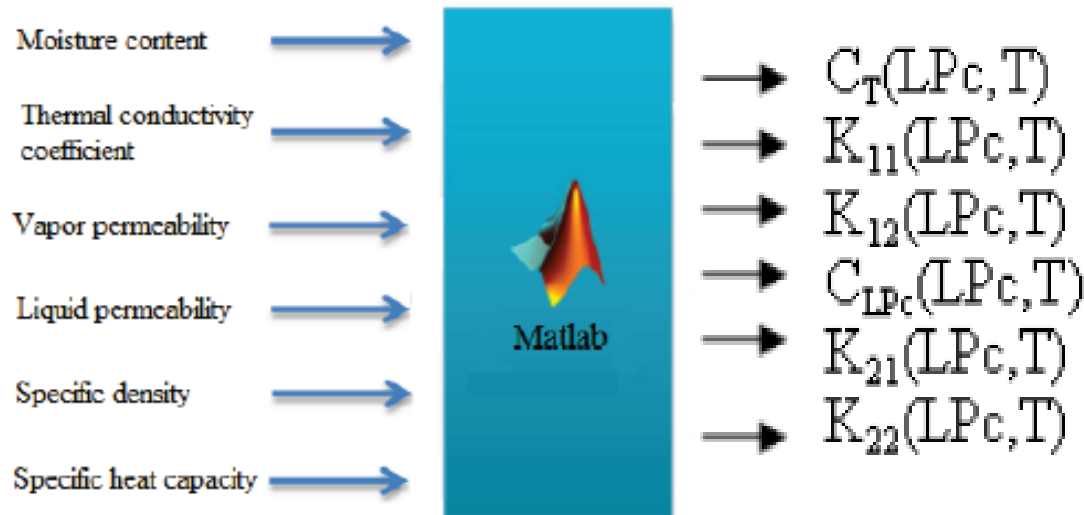
$$C_T \frac{\partial T}{\partial t} = \nabla \cdot (K_{11} \nabla T + K_{12} \nabla LPc)$$

$$C_{LPc} \frac{\partial LPc}{\partial t} = \nabla \cdot (K_{21} \nabla T + K_{22} \nabla LPc)$$

Calculating PDE Coefficients Using Material Properties

$$C_T \frac{\partial T}{\partial t} = \nabla \cdot (K_{11} \nabla T + K_{12} \nabla LPc)$$

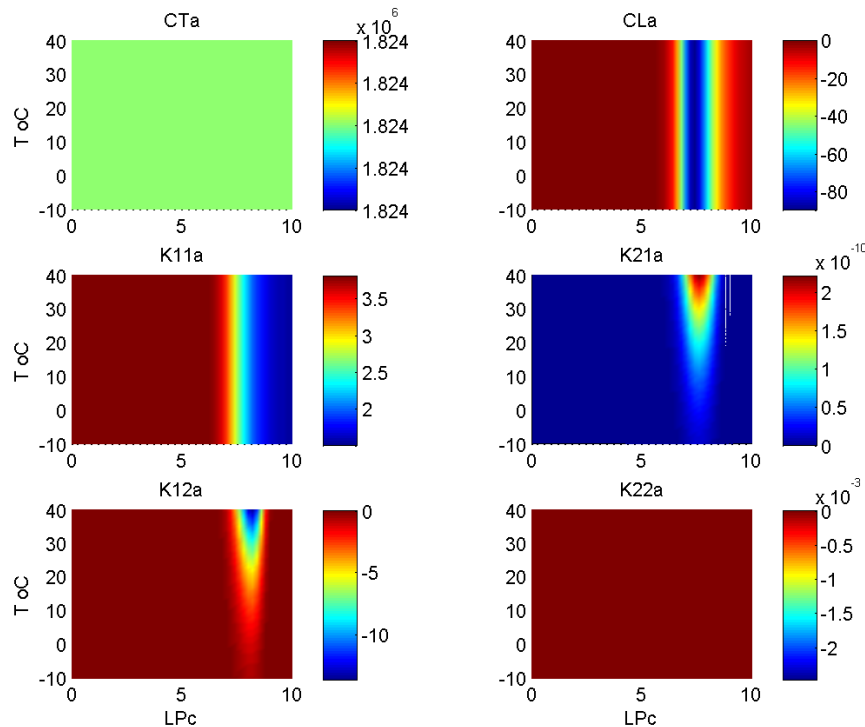
$$C_{LPc} \frac{\partial LPc}{\partial t} = \nabla \cdot (K_{21} \nabla T + K_{22} \nabla LPc)$$



Calculating PDE Coefficients Using Material Properties

$$C_T \frac{\partial T}{\partial t} = \nabla \cdot (K_{11} \nabla T + K_{12} \nabla LPc)$$

$$C_{LPc} \frac{\partial LPc}{\partial t} = \nabla \cdot (K_{21} \nabla T + K_{22} \nabla LPc)$$



Contents

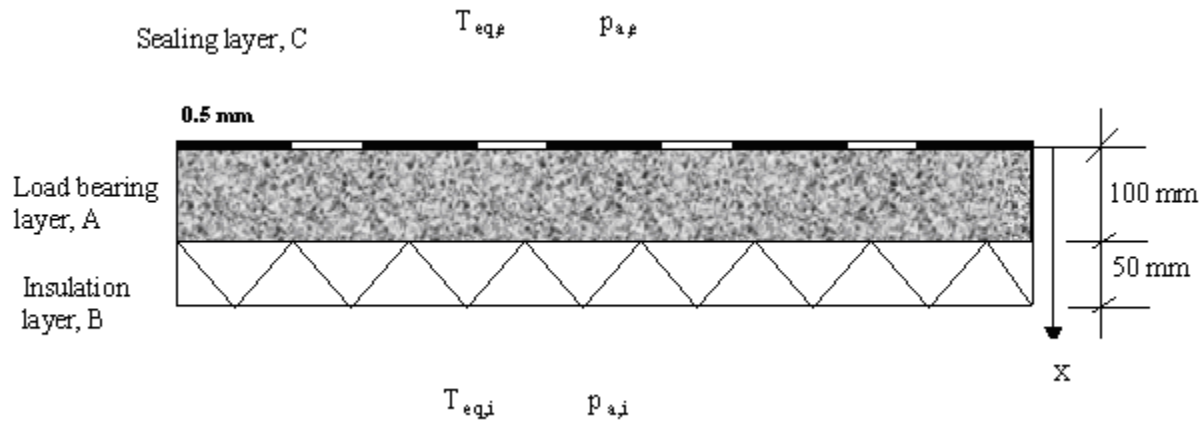
- Introduction
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HAMSTAD Benchmark no 1

Roof with condensation

$$q = h_e \cdot (T_e - T)$$

$$g = 0$$

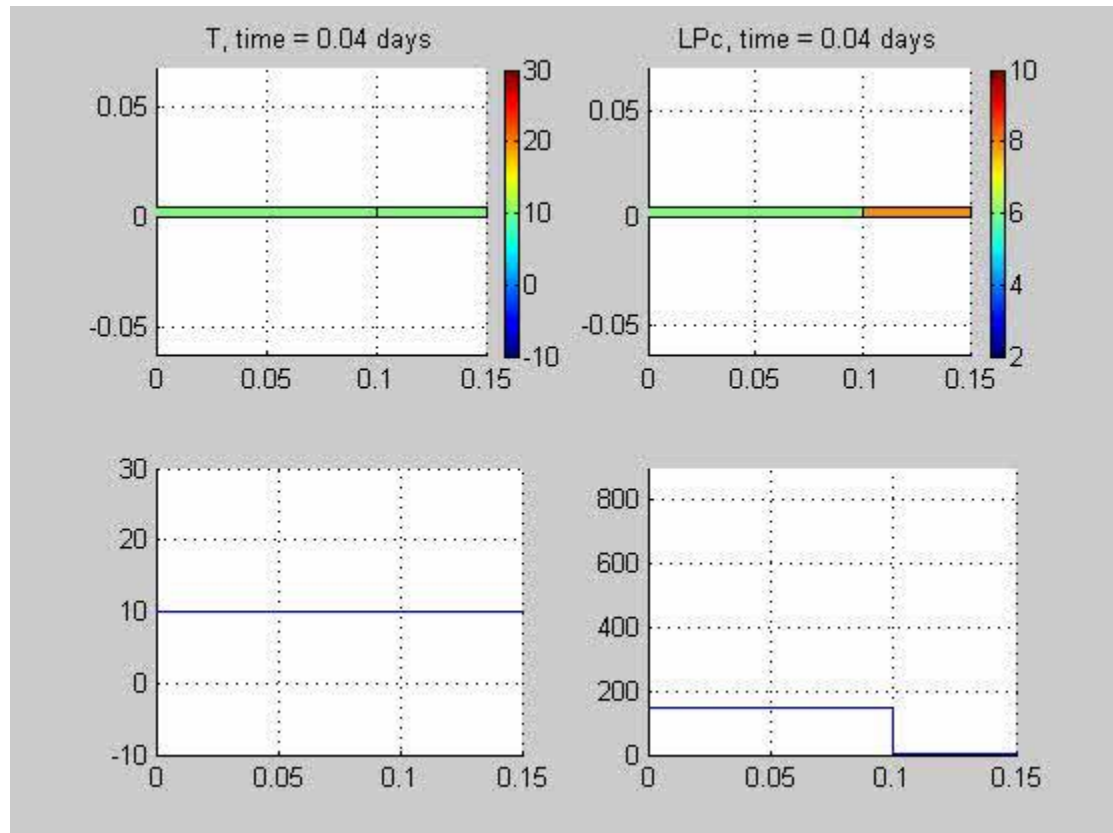


$$q = h_i \cdot (T_i - T) + l_{lv} \cdot \beta \cdot (p_i - p)$$

$$g = \beta \cdot (p_i - p)$$

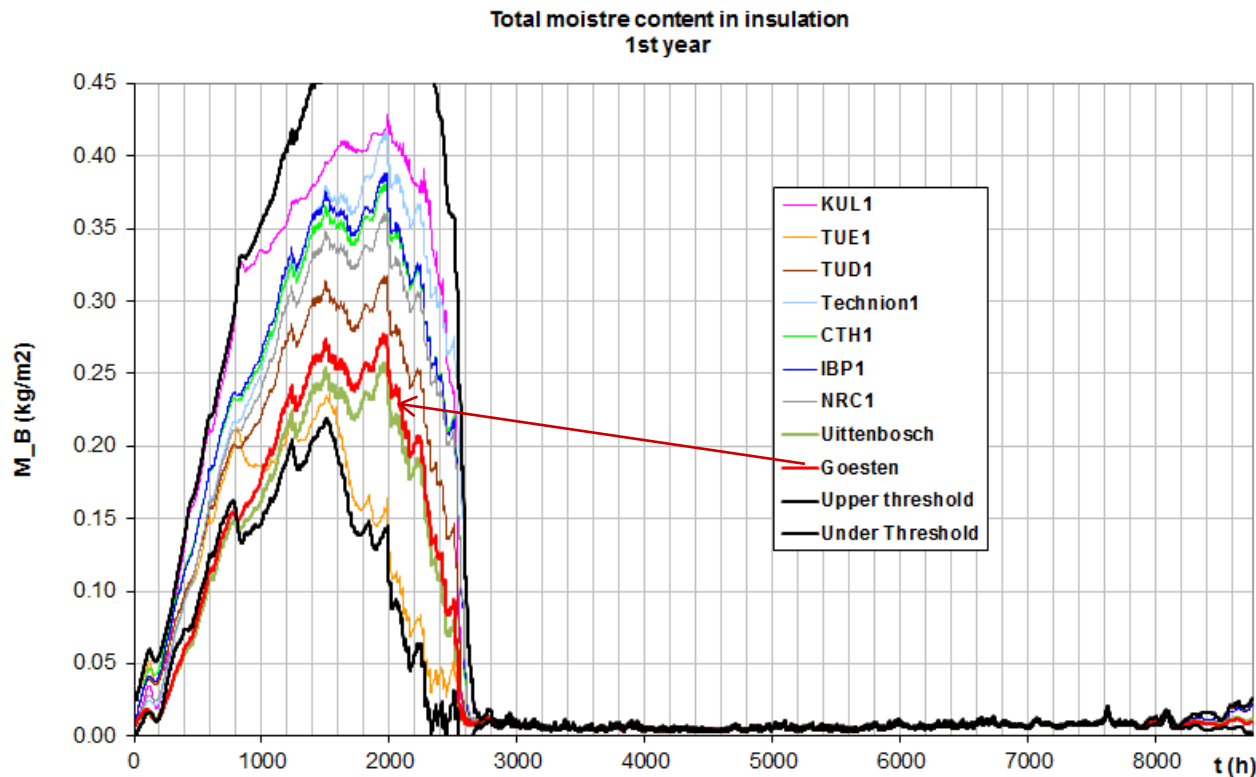
HAMSTAD Benchmark no 1

Roof with condensation



HAMSTAD Benchmark no 1

Roof with condensation

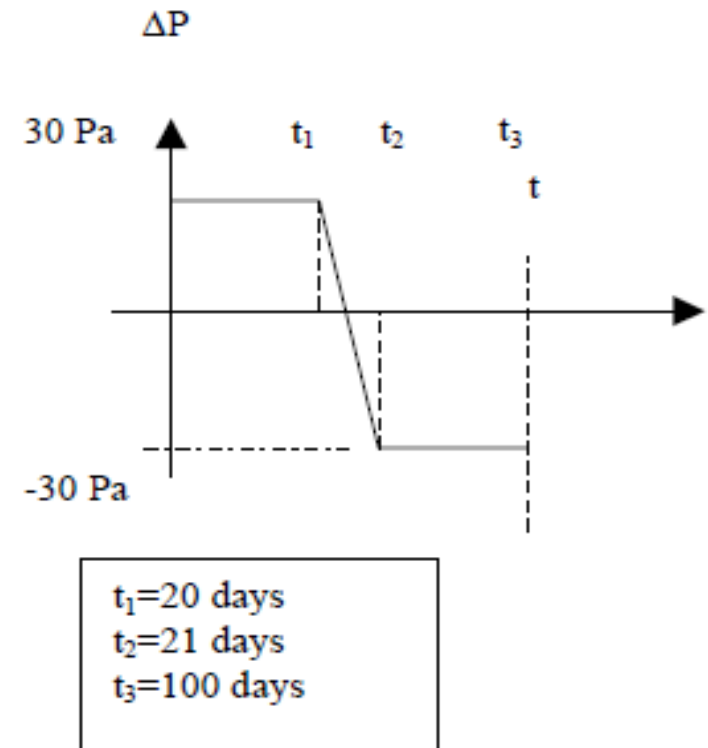
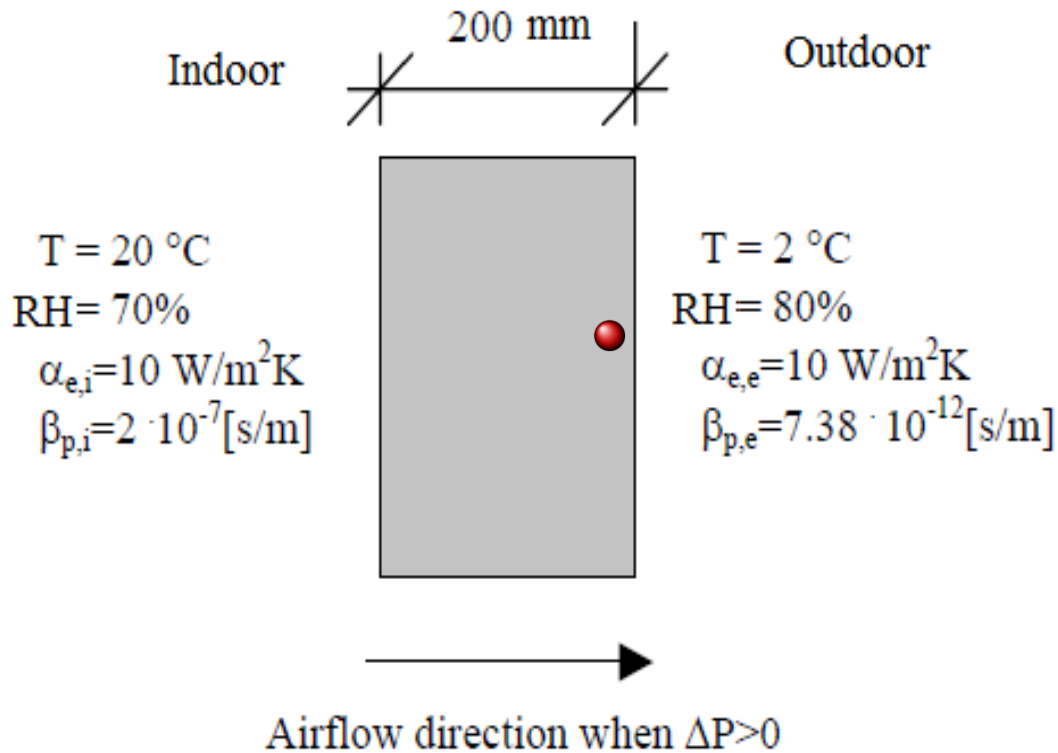


Ref: MSc Thesis Sander Goesten TUE (2016)

HAMSTAD-Benchmark 3

Insulation with airflow

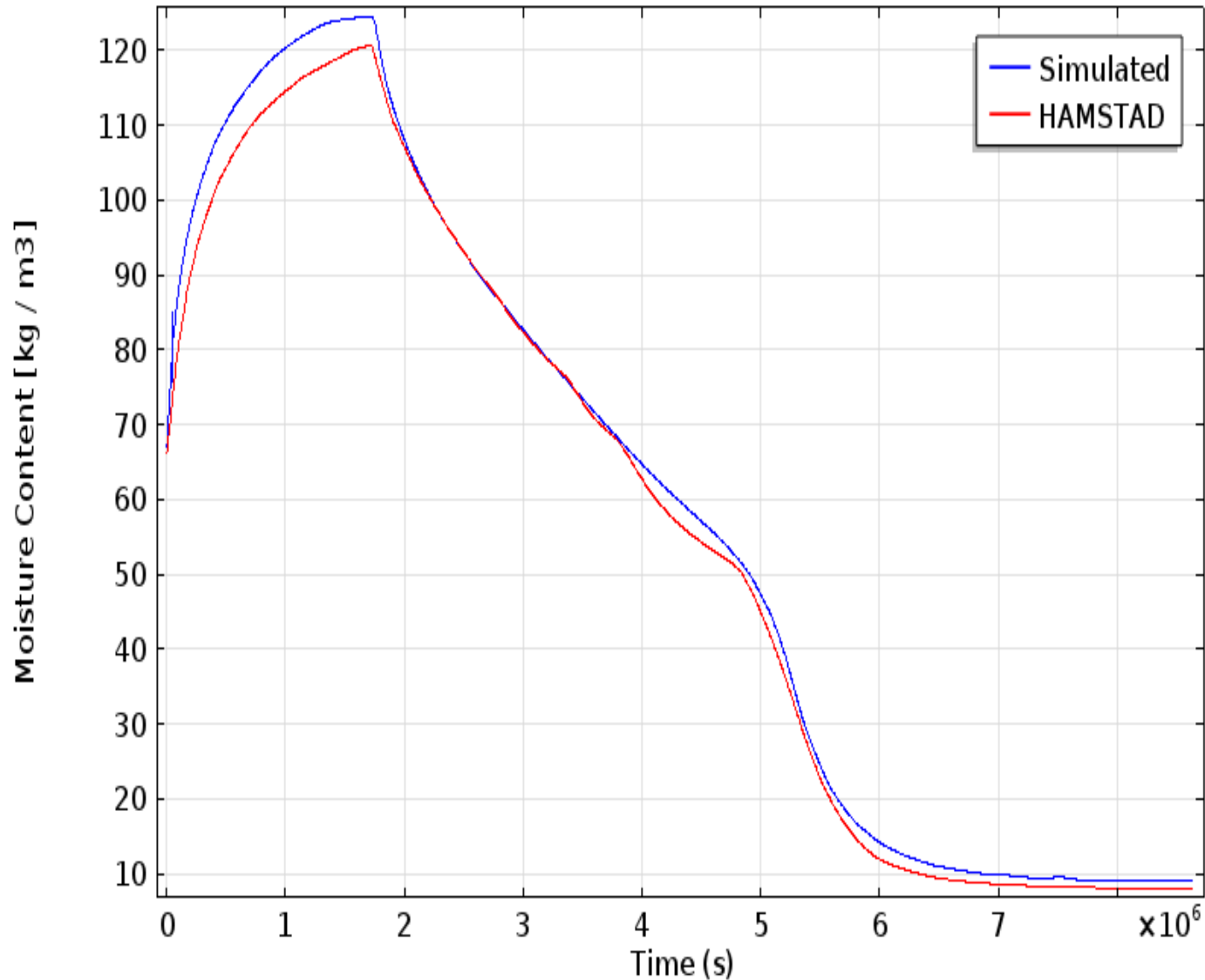
Benchmark 3



At point 190 mm

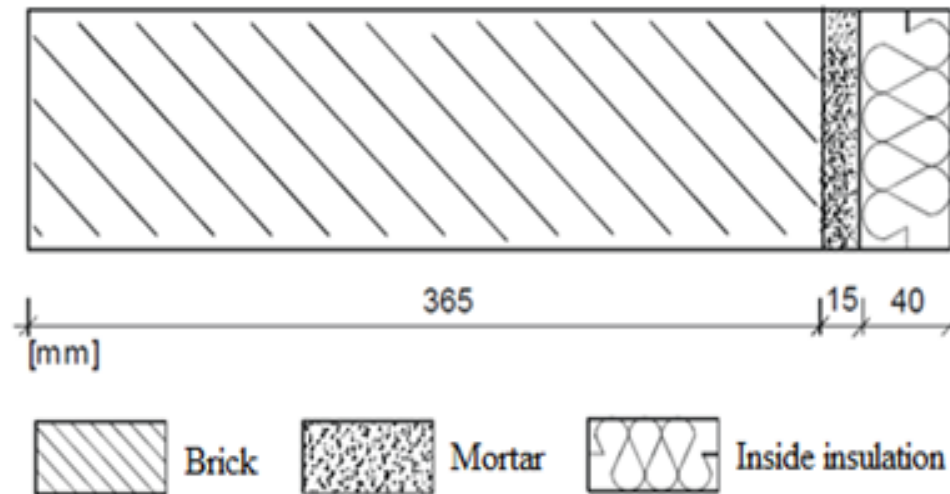
HAMSTAD-Benchmark 3

Insulation with airflow

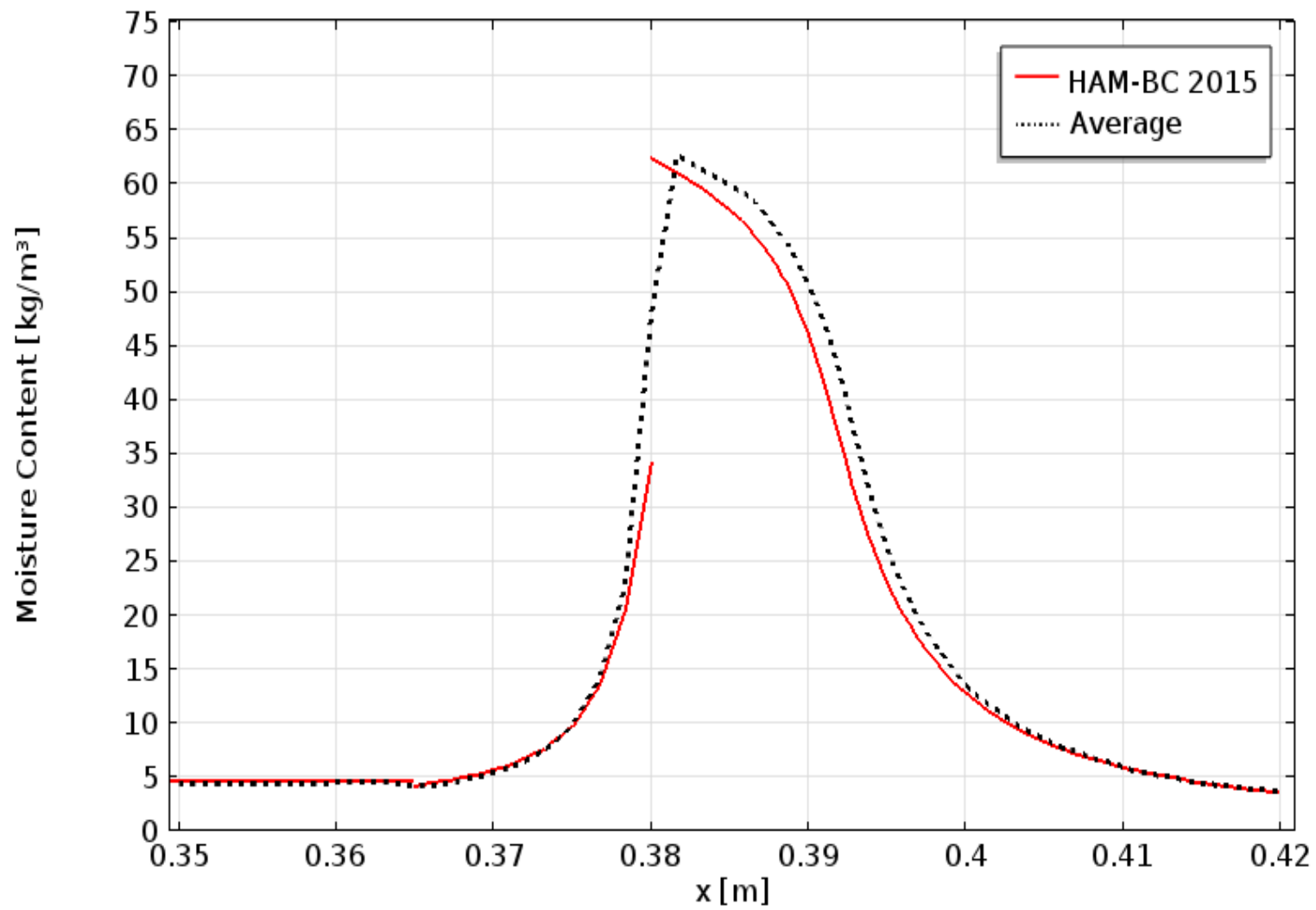


HAMSTAD-Benchmark5 discontinuous Interface

Benchmark 5



At day 60



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Conclusions

- **HAMSTAD benchmark in Comsol 5.2a**
 - **Modeling approach valid**
 - **Results are satisfactory for all 5 benchmarks**

- **Thank you**