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The Use of COMSOL in Teaching Heat and Moisture Transport Modeling in Building Constructions

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Introduction

- Building envelope as a separation between the outdoor and indoor climate:
  - sunshine,
  - rain,
  - wind and
  - air temperatures
- Comfort in the rooms of a building:
  - energy
  - air quality and air humidity
  - durability, maintenance, use of materials and recyclability

Introduction

- **Past:**
  - **design of these structures was lead by experience**
- **Nowadays:**
  - **more rigid requirements on performance**
  - **enormous increase of new building techniques,**
  - **new materials and**
  - **new building shapes;**
  - **reliance on experience is often not applicable any more**

Introduction

- The result may be
  - building damage,
  - a bad indoor climate and
  - an unnecessary high energy consumption.
- Knowledge of heat and moisture transport through building structures and joints is increasingly important for building design.
- The knowledge, insight and prediction models of building physics are indispensable for the realization of high quality buildings that satisfy the required performances.

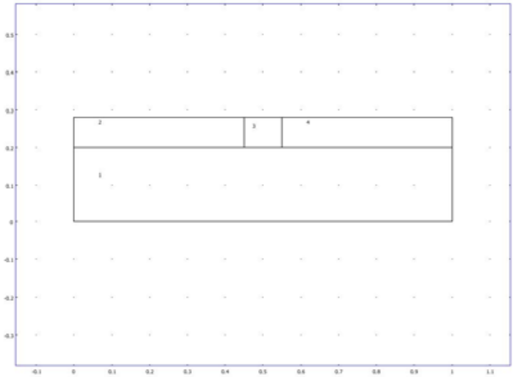
Steady state heat transport

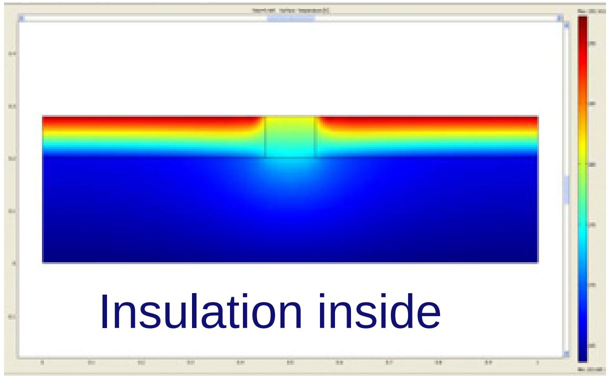
The students learn:

1. **The relation with their current knowledge on heat transport, the corresponding PDE and boundary conditions.**
2. **What the effect is of adding (inside/outside) insulation material.**
3. **To recognize different types of thermal bridges.**
4. **To evaluate thermal constructions using the appropriate performance indicators.**

Steady state heat transport

Thermal bridges by using different materials

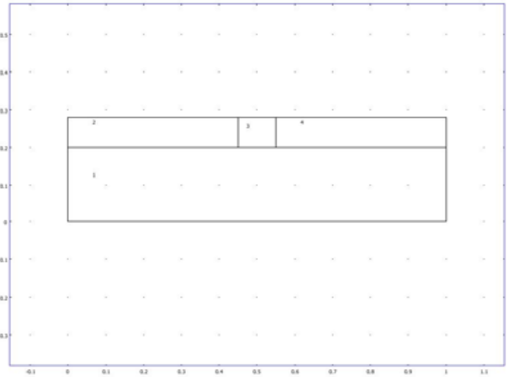


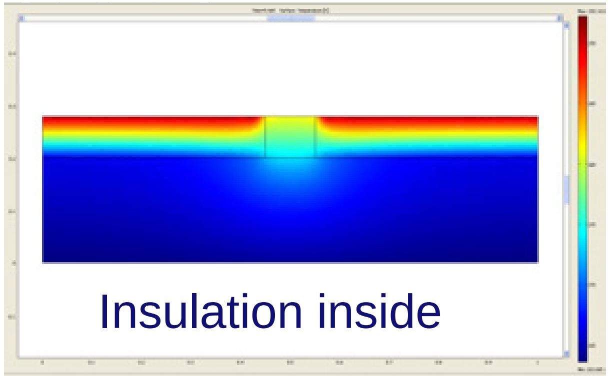


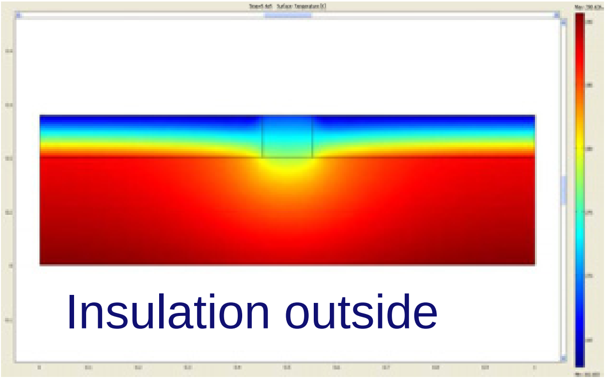
Geometrical thermal bridges

Steady state heat transport

Thermal bridges by using different materials



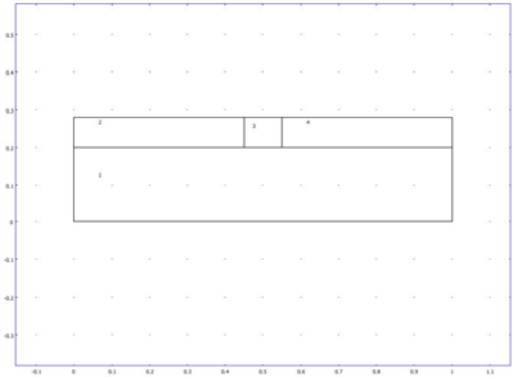


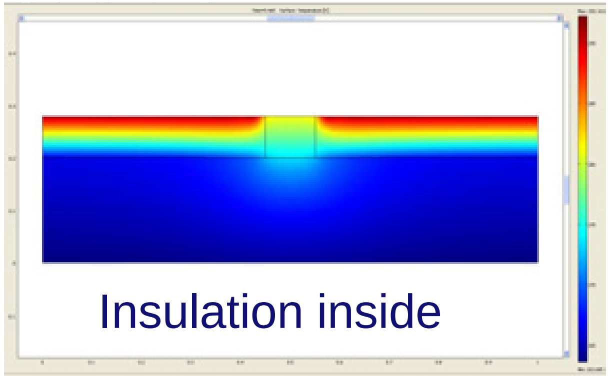


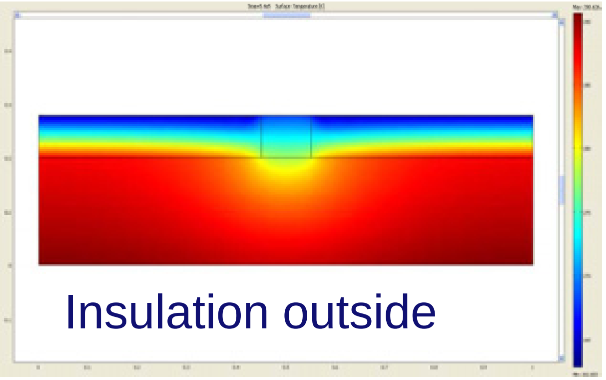
Geometrical thermal bridges

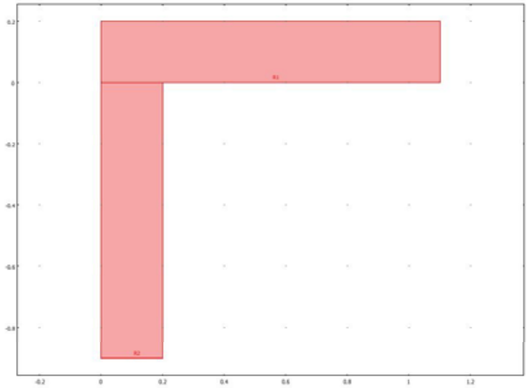
Steady state heat transport

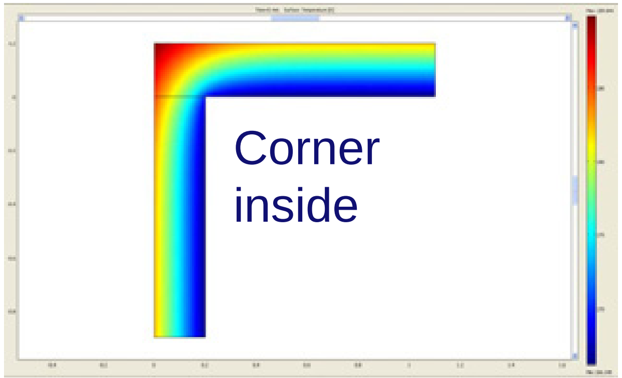
Thermal bridges by using different materials







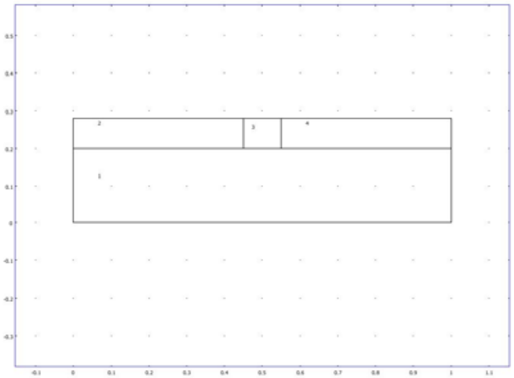


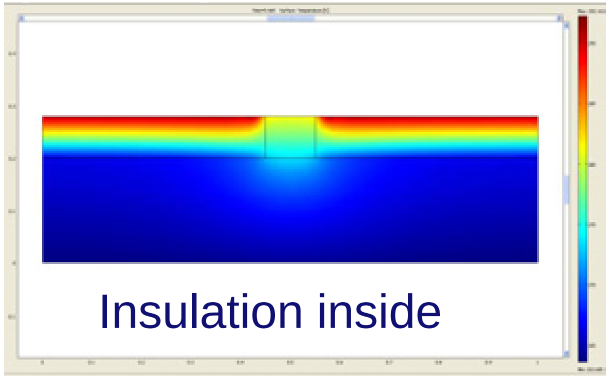


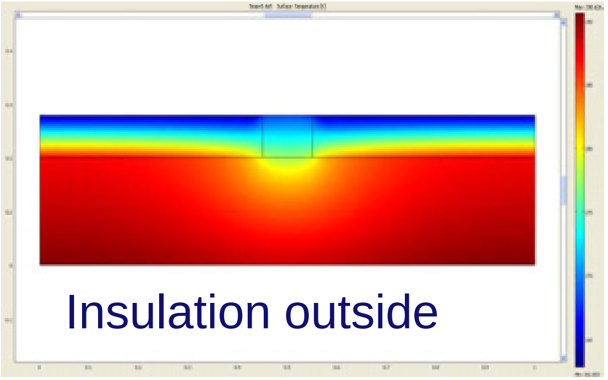
Geometrical thermal bridges

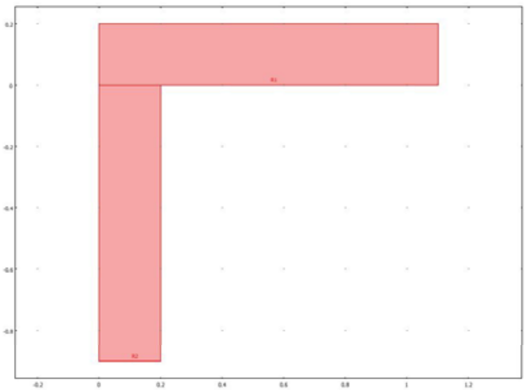
Steady state heat transport

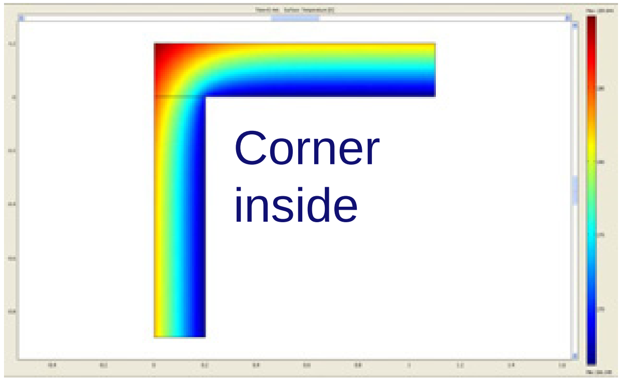
Thermal bridges by using different materials

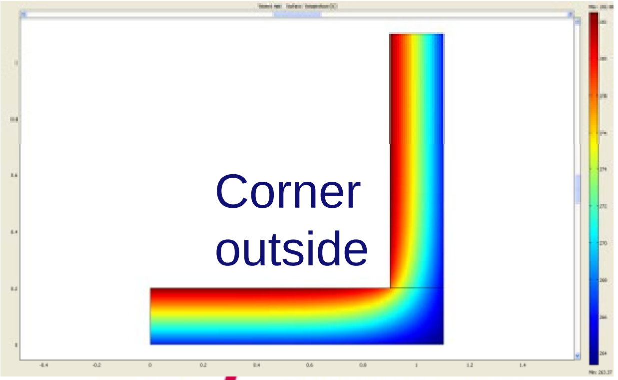












Geometrical thermal bridges

Transient heat transport

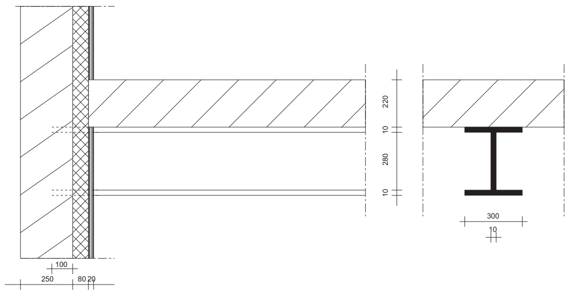
The students learn:

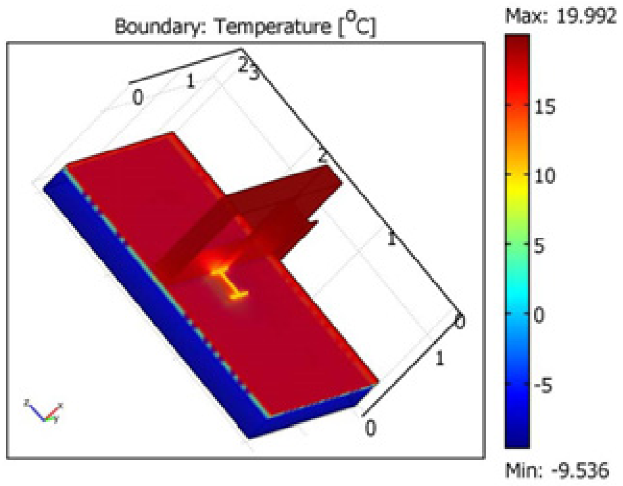
1. **What the effect is of entering dynamics into the equation.**
2. **What the effect is of daily and yearly fluctuations and using real climate data.**
3. **To evaluate dynamic thermal results using performance indicators.**

Case study: A steel beam penetrating inside insulation 3D

The students learn:

1. To implement a 3D application from a real case from the practice
2. To evaluate dynamic 3D thermal results using the related performance indicators





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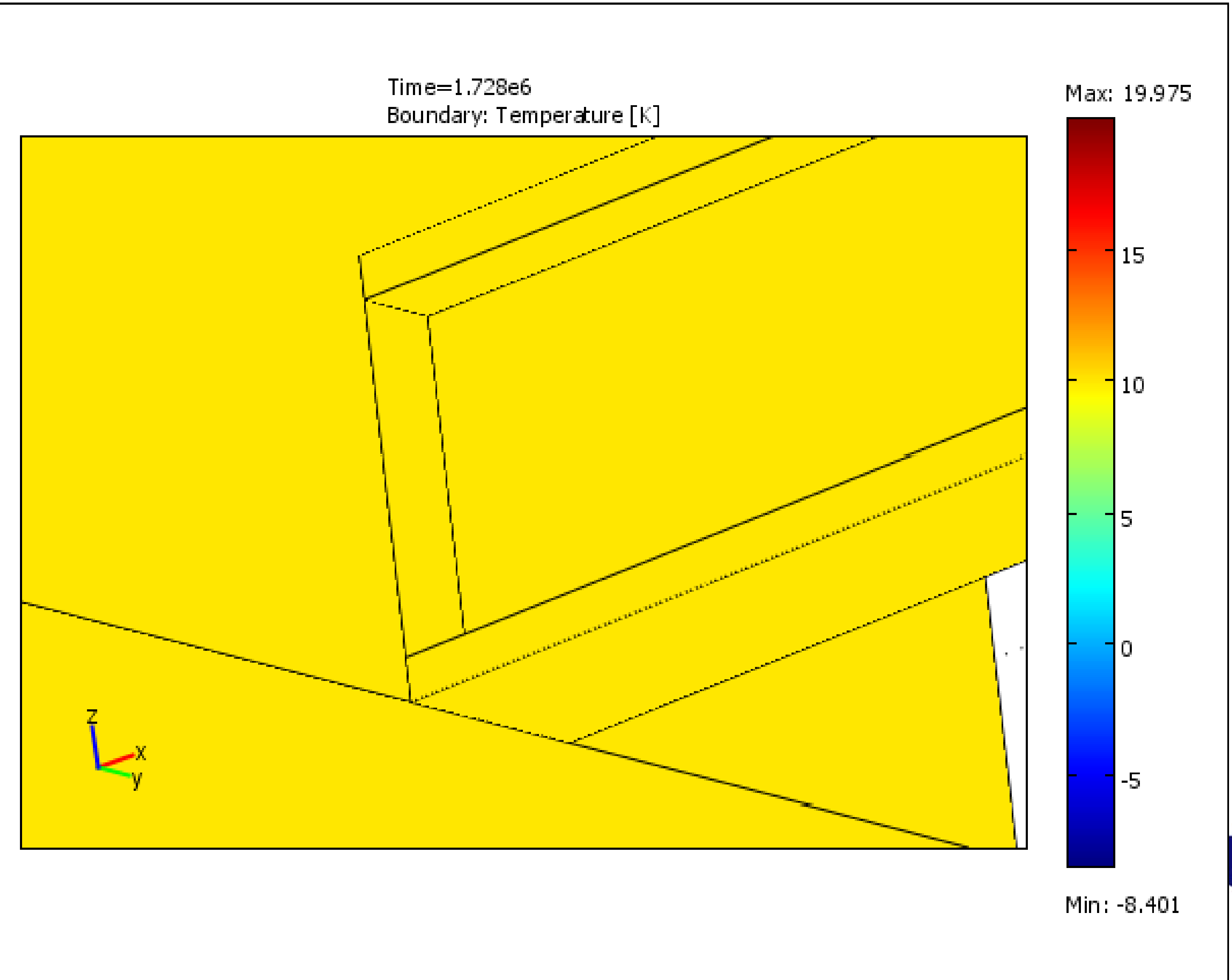
Transient steel temperature



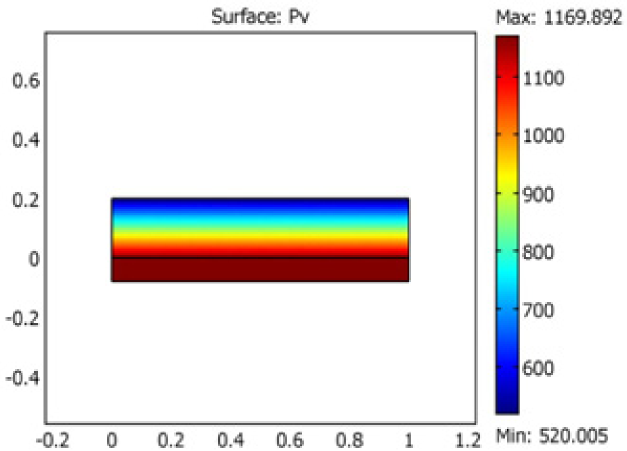
Steady state moisture (vapour) transport

The students learn:

1. **The relation with their current knowledge on vapour transport, the corresponding PDE and boundary conditions.**
2. **To implement and simulate vapour transport.**
3. **To evaluate hygric constructions using the important performance indicators.**
4. **To make use of vapor resistant barriers to improve the situation.**

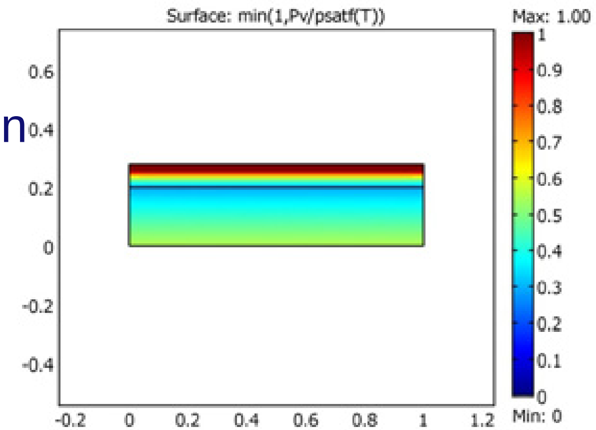
Steady state moisture (vapour) transport

vapour distribution

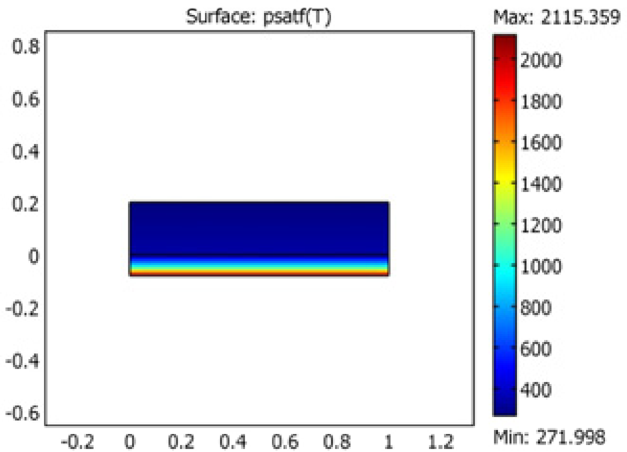


condensation risk:

outside insulation

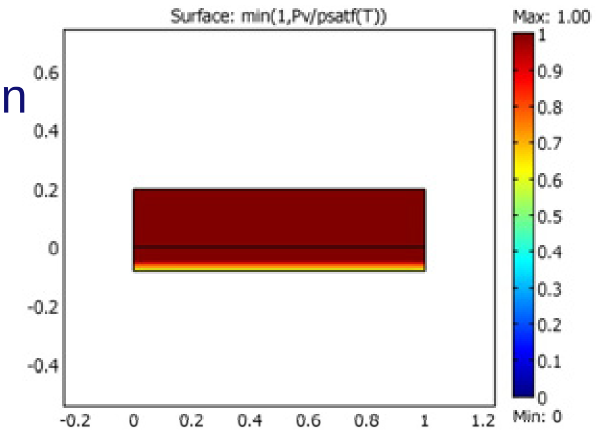


saturation vapour distribution



condensation risk:

inside insulation



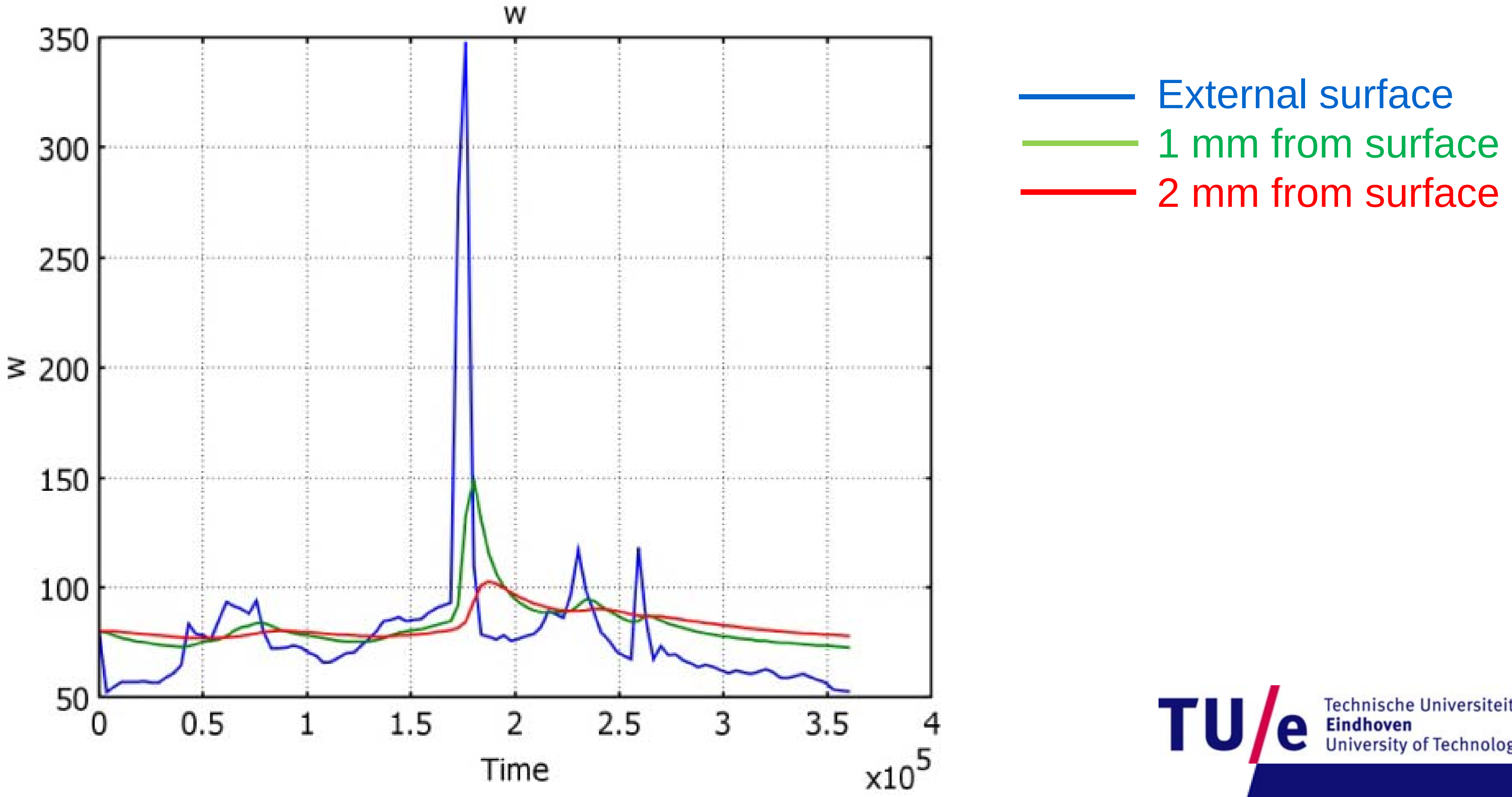
Transient moisture (Liquid) transport

The students learn:

1. **The relation with their current knowledge on liquid transport, the corresponding PDE and boundary conditions.**
2. **To implement and simulate liquid transport, including realistic material properties**
3. **To evaluate the performance of building materials during drying and wetting**

Transient moisture (Liquid) transport

Moisture content in concrete



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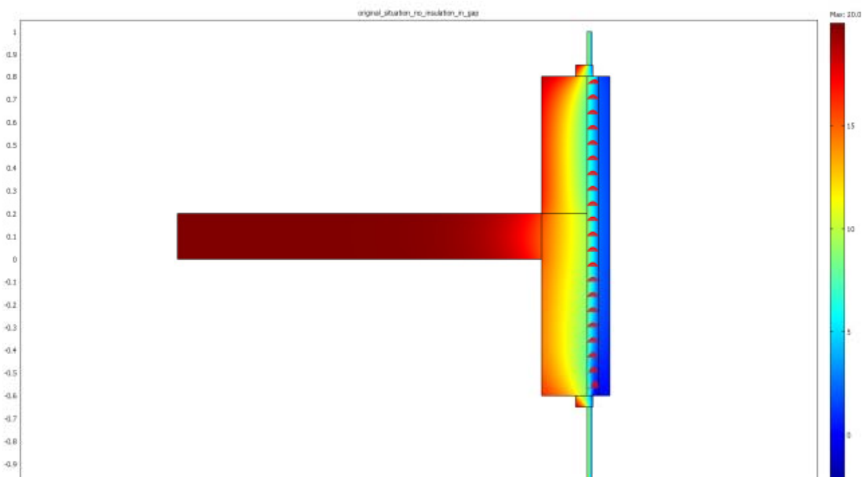
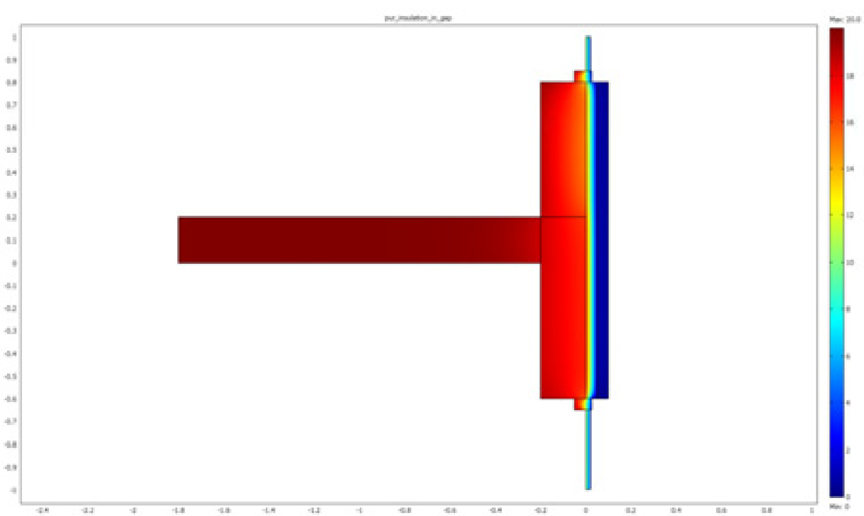
Case study: Hygro thermal design of building facade (2D)

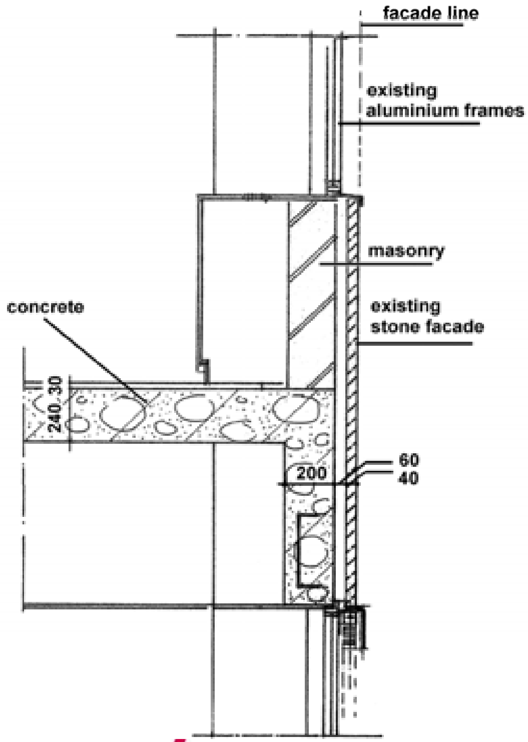
The students learn to apply the gained heat and moisture modeling skills for a real case



uninsulated



insulated



Conclusions

- COMSOL Multiphysics is very useful for teaching heat and moisture transport modeling in the research area of building physics.
- The main advantages are:
  - Abstraction level. The theory based on PDEs can be relatively easily implemented in the models.
  - Solving capabilities. Most of the time the quality of the solution of the PDE problem is acceptable using the default settings.
  - User interface. The students appreciated the presence of an intuitive user interface, especially when modeling 3D problems

Conclusions

- **Graphical output. The visualization tools provide a good opportunity to critically evaluate the simulation results.**
- **All together it is possible to make complicated models and produce simulations results within a short time also for non experienced software users.**