University of Latvia, Faculty of Physics and Mathematics
Laboratory for Mathematical Modelling of Environmental and Technological Processes

RESEARCH OF COMPOSITE CONSTRUCTIONS' IMPACT ON THE ENERGY EFFICIENCY OF BUILDINGS

Authors: Toms Dzenis, Staņislavs Gendelis and Andris Jakovičs

Advanced Constructions, Kaunas, 2012 October 19

Contents

VTPMML

Introduction

- High operation costs for heaters and conditioners
- Composite materials in building construction, advantages
- 2D and 3D heat exchange simulations
- Result physical interpretation and validation

Equations used in mathematical modelling

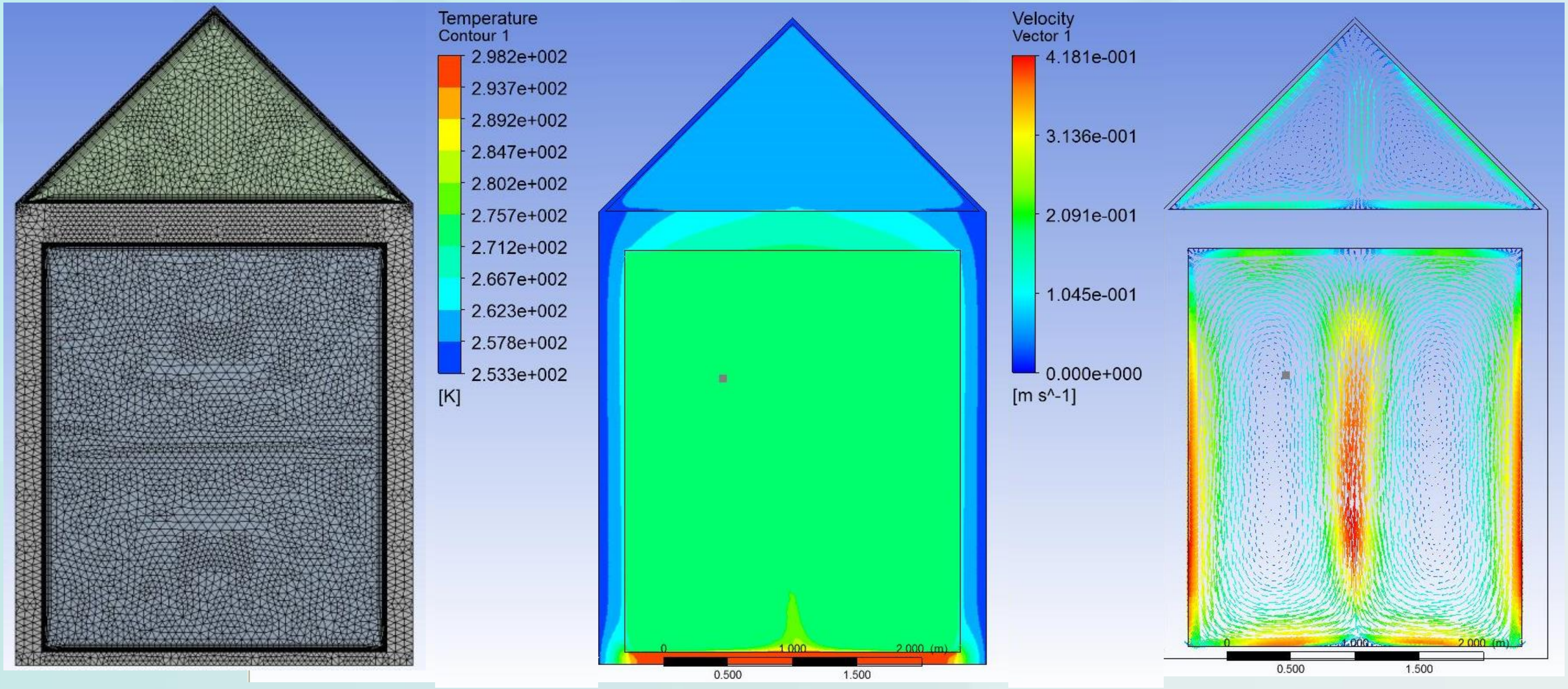
- Heat conduction $$q_{cond.} = -\lambda \cdot gradT$$
- Heat diffusion $$\int_V \gamma c_p \frac{\partial T}{\partial t} dV = \oint_S \lambda \cdot \mathrm{grad} T \cdot d\mathbf{S} + \int_V q_{vol} dV$$
- The continuity equation $$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \cdot U) = 0$$
- Navier–Stokes equations in non-dimensional form $$\frac{\partial \mathrm{v}}{\partial t} + (\mathrm{v} \cdot \nabla)\mathrm{v} = -\nabla p + \frac{1}{Re} \Delta \mathrm{v} + \frac{1}{Fr} \mathbf{f}^{ext}$$
- Momentum equation $$\frac{\partial (\rho V)}{\partial t} + \nabla \cdot (\rho V \otimes V) = -\nabla p + \nabla \cdot \tau + S_M$$
- Energy equation $$\frac{\partial (\rho h)}{\partial t} + \nabla \cdot (\rho V h) = \nabla \cdot (\lambda \nabla T) + \tau : \nabla V + S_E$$
- $k - \omega\ Shear\ Stress\ Transport$ two parameter flow turbulence model

Boundary conditions

- Adiabatic boundary condition $q_W = 0$
- The temperature distribution at the surface $T = T_{surf.}$
- The distribution of thermal flux $q_W = q_{spec}$
- The convective cooling $q_W = \alpha(T_b - T_{nw}),$

VTPMML

Two dimensional model



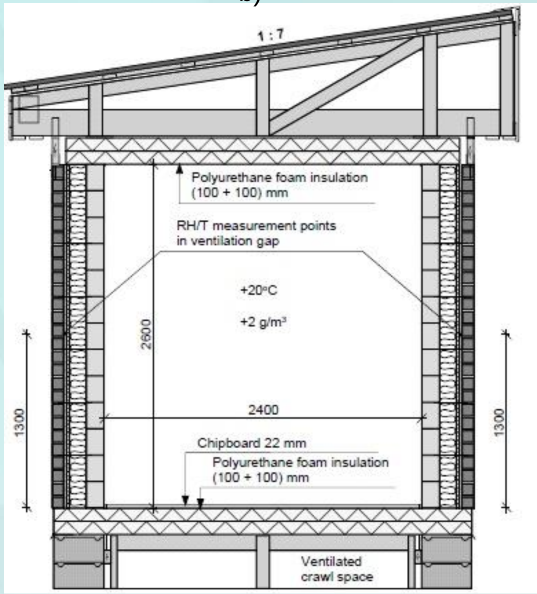
- Mesh, temperature field and air velocity examples
- 20 000 mesh elements, geometry dimensions 3 m x 5 m
- Temperatures: -20^{o}C outside and 25^{o}C constant floor heating

VTPMML

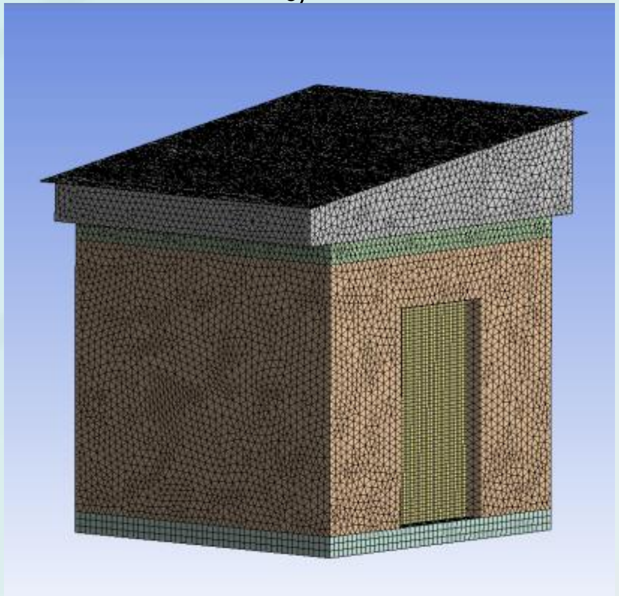
Test building from TUT

a)

b)



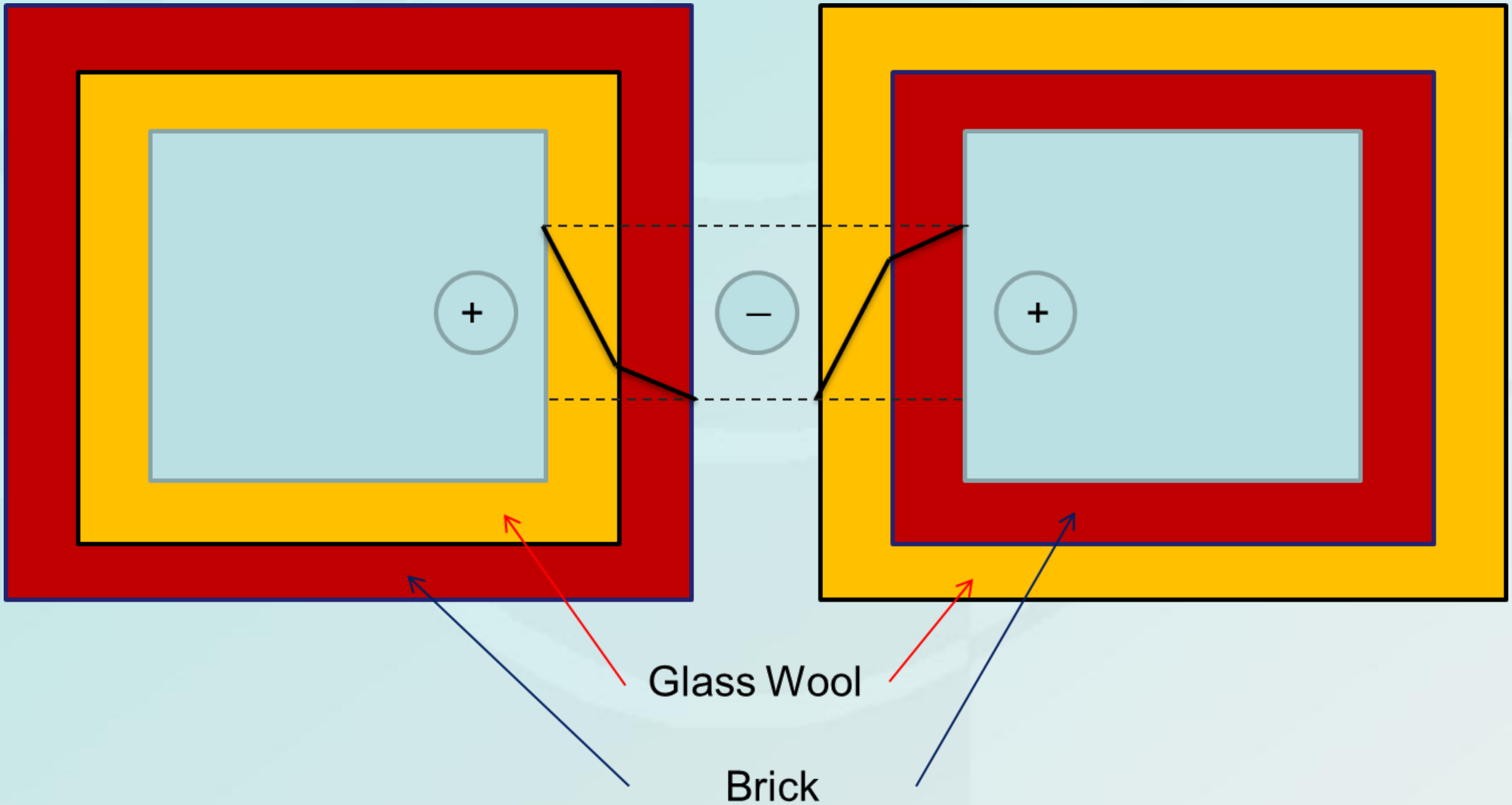
c)



- Simplified monolithic one material constructions
- Constant floor heating +25°C and outside temperature -20 °C
- Several steady state simulations and first transient simulations

VTPMML

Two modelling variants to compare



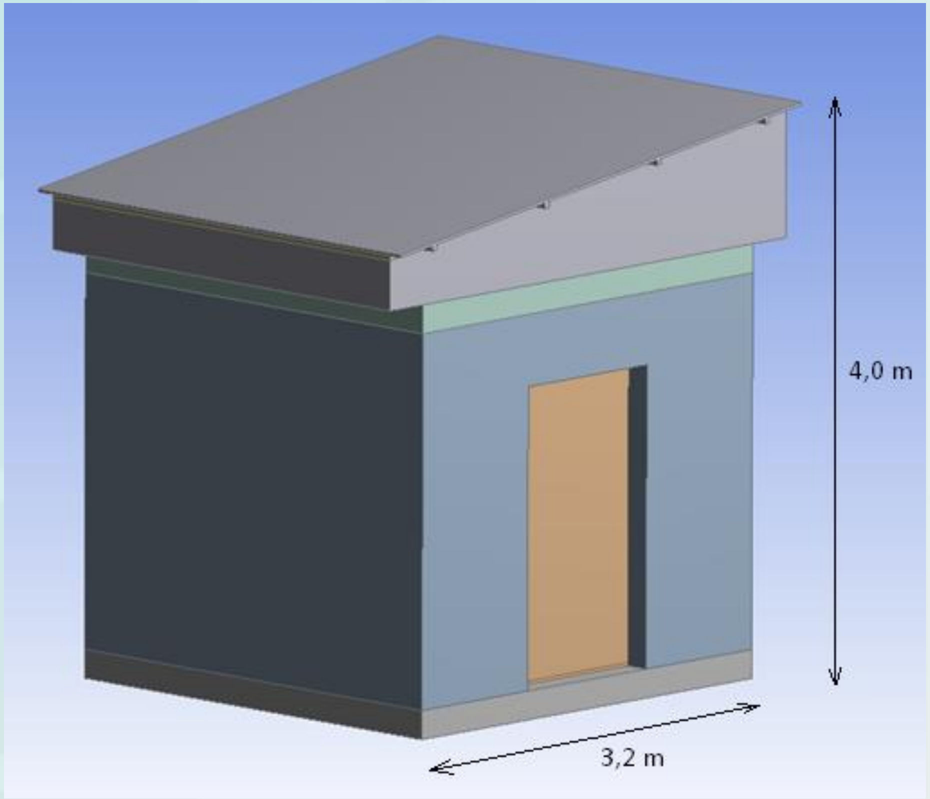
- Upper view with expected steady state temperature distribution in constructions (scale is not observed)
- Two material composite construction

VTPMML

Model properties

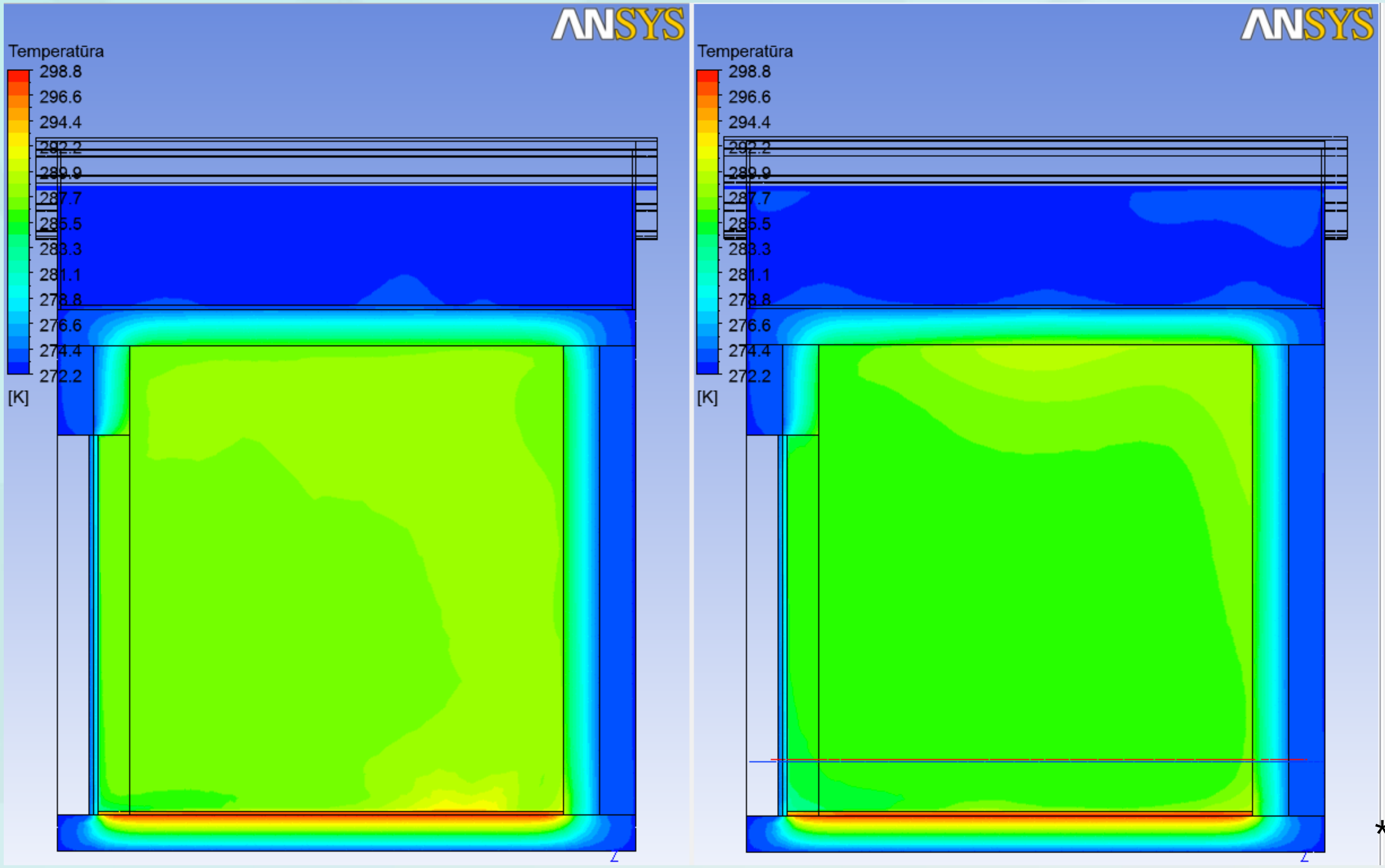
- No air inflows in the room; ventilated attics
- Materials: glass wool, brick, hard wood
- >1e+6 mesh elements;

  2cm thin close to wall layers
- Incompressible fluid; Bussinesk's approximation
- Re>3000; flow turbulence model SST
- Thermal radiation wasn't taken in to account



VTPMML

Construction with glass wool inside, brick outside



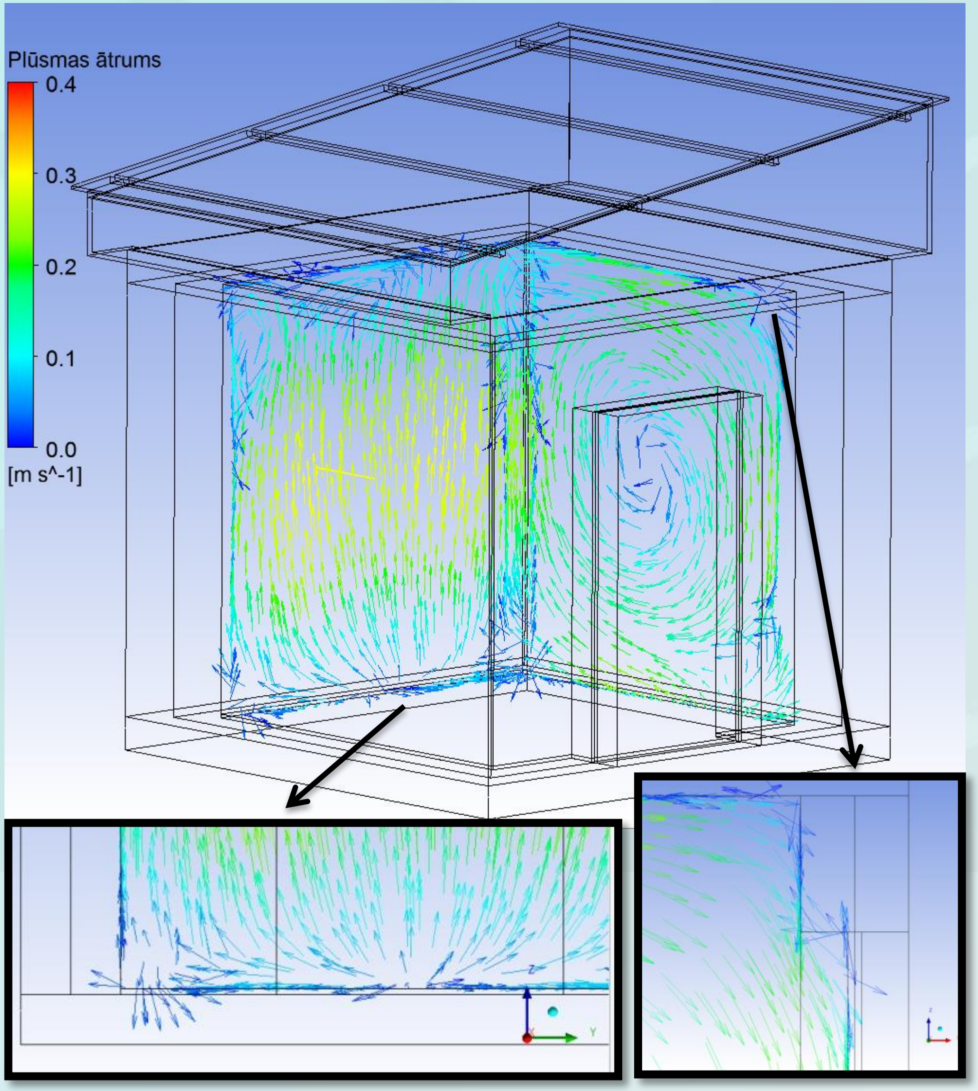
ΔT=0,5 °C

Temperature distribution, transient calculation for 34 hours

Temperature distribution, steady state calculation

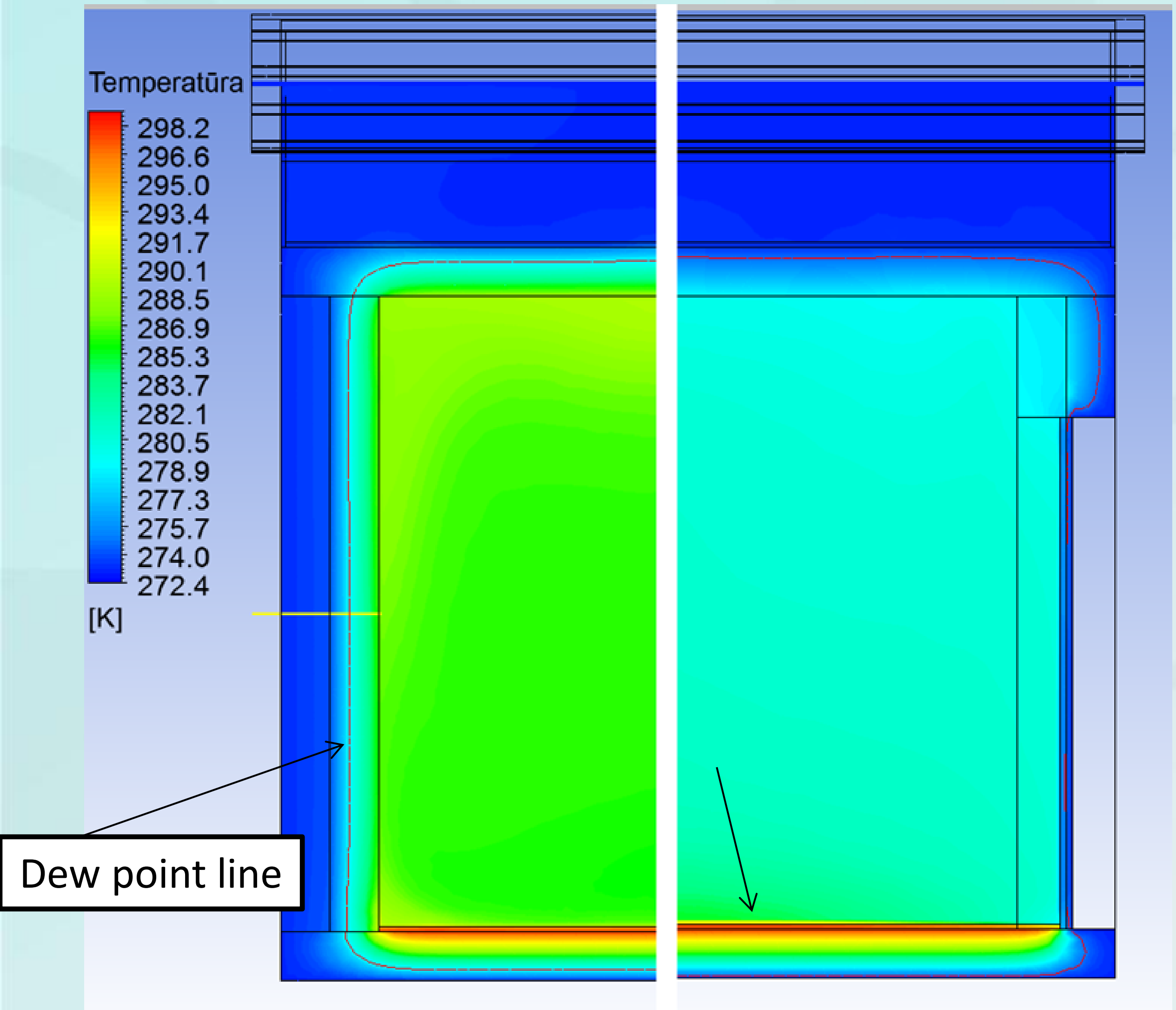
VTPMML

Construction with glass wool inside, brick outside



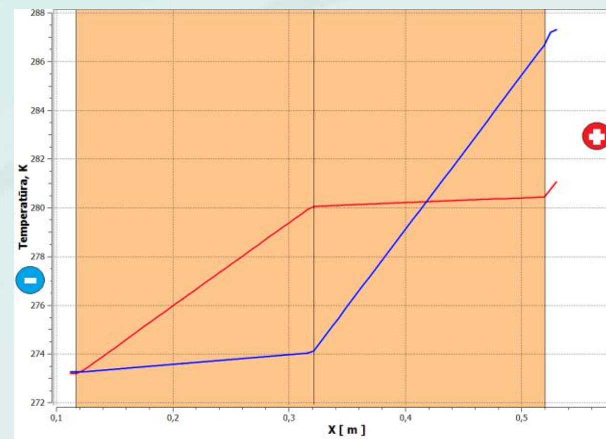
- Air velocity in the room
- Velocity vector field plotted on two perpendicular planes close to the wall (in figure vectors are with same size, but color represents the value)
- Axial symmetry because of door effect
- Additional or secondary vortexes

Steady state simulations



***(On the left glass wool is inside, on the right brick material is inside)**

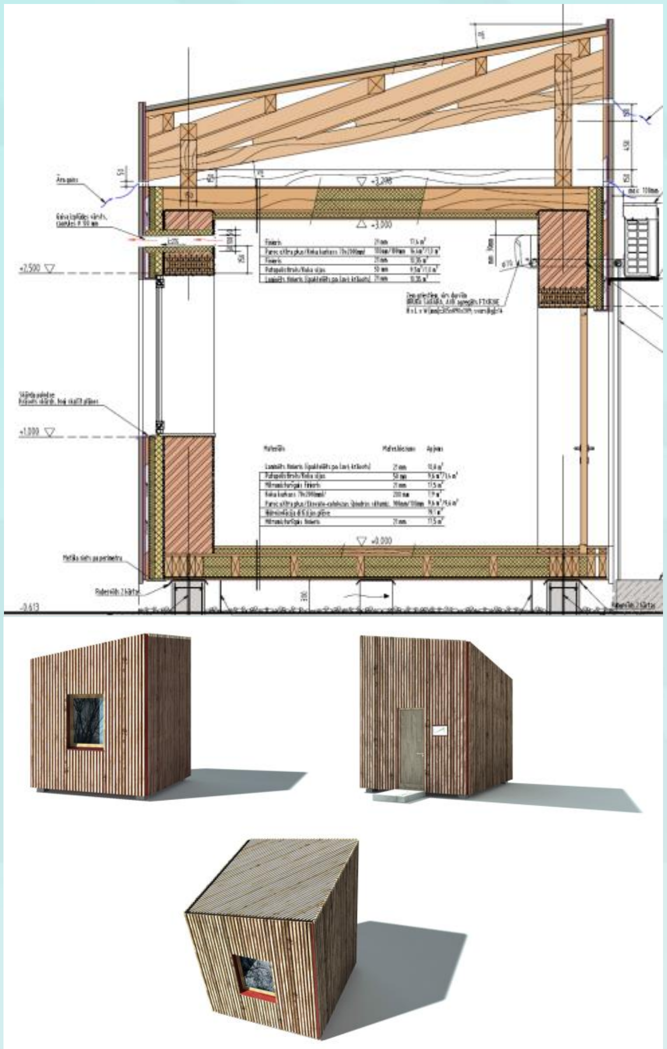
- Temperature field distribution for both simulation models
- Preview for 3D model cut with plane
- Dew point in constructions, 60% characteristic air humidity



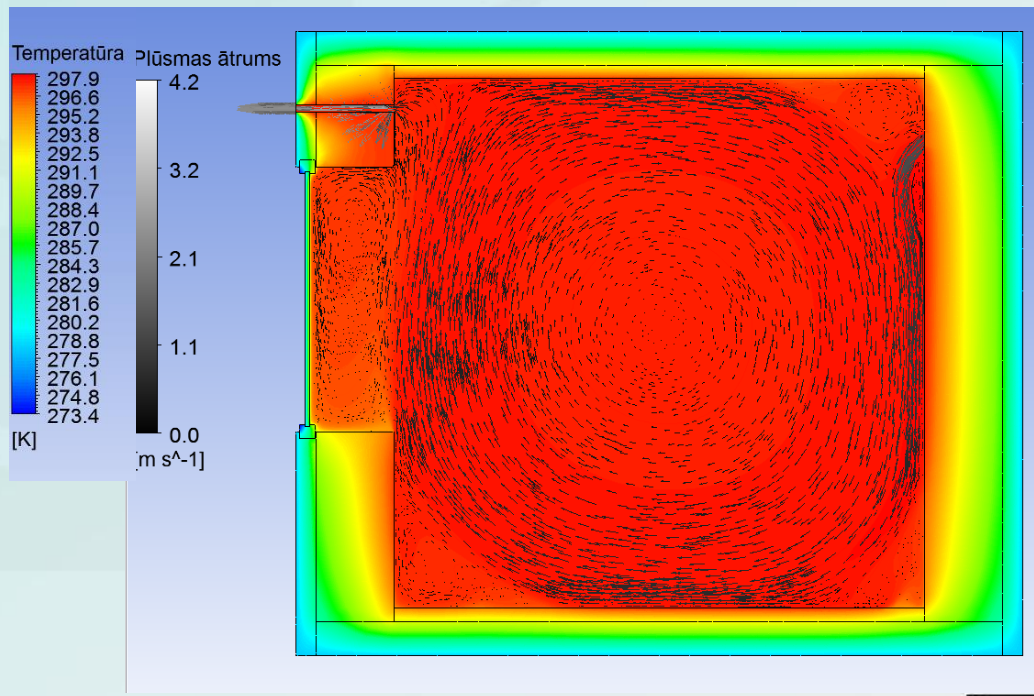
- Temperature distribution in wall

VTPMML

Test building construction in the Botanical garden of LU



- Five different test buildings
- Same heat transfer coefficient U=0,16 $\left[\frac{W}{m^2 \cdot K}\right]$
- Air conditioner with heat pump
- 3D steady state and 2D transient



Conclusions

- Important to reduce impact of buildings’ covering, grounds, doors and windows
- Large data amount in calculations and huge computational power needed that’s why next studies are reduced to two dimensions in transient calculation mode
- Material arrangement in composite construction impact can be seen already in very simple simulations
- This research direction need to be analyzed and studied in more details for more valuable results because of dynamical effect

VTPMML

LATVIJAS UNIVERSITĀTE
ANNO 1919
UNIVERSITY OF LATVIA

Thank you for your attention!

ERAF
EIROPAS REĢIONĀLĀS ATTĪSTĪBAS FONDS

EIROPAS SAVIENĪBA

IEGULDĪJUMS TAVĀ NĀKOTNĒ

Acknowledgement: This work was supported by the European Regional Development Fund project Nr. 2011/0003/2DP/2.1.1.1.0/10/APIA/VIAA/041

VTPMML