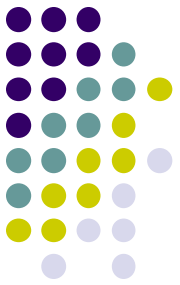# 4D SIMULATION

Implementation of a periodic
thermal conduction model in a
4D simulation program
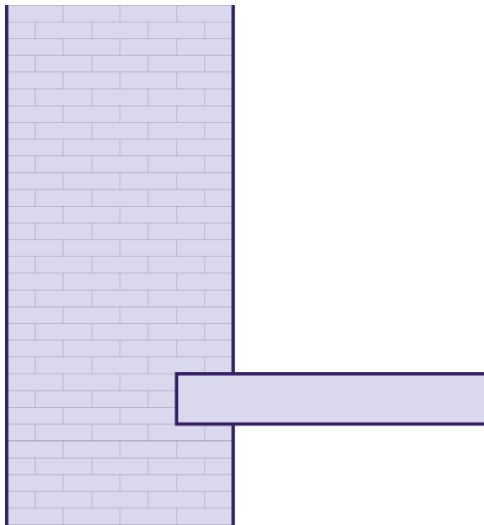
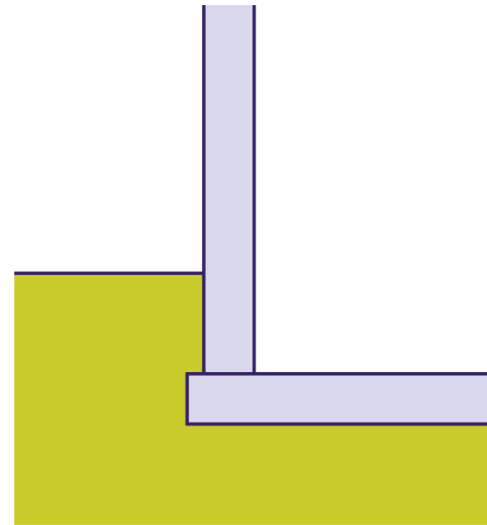Tomasz Kornicki, Joachim Nackler, Klaus Kreč

Introduction

- thermal bridge calculations usually treated time-independent
  - heat storage not taken into consideration
  - useful results just for constructions with neglectable heat storage
- what about systems with higher heat-storage-capacity?
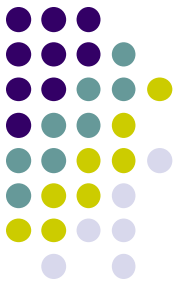 - 3D transient calculation is necessary

massive masonry   earth-bound systems

Periodic Calculation Approach

- theoretical basis is known for some time

- allows capturing heat conduction and heat storage effects in 3D
- heat conduction equation can be solved for each harmonic in case of periodic set boundary conditions (without time discretization)
- problem of unknown starting conditions does not arise

- at given conductances and weighting-factors, thermal conduction + heat storage processes can be described 3D (any shape and composition)
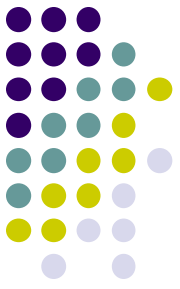
heat-loss

$$\hat{\Phi}_i = -\sum_j \tilde{L}_{i,j} \cdot \hat{\Theta}_j$$

temperature

$$\hat{\Theta}(x, y, z) = \sum_j \tilde{g}_j(x, y, z) \cdot \hat{\Theta}_j$$

Periodic Calculation Approach

Following procedure for calculating temperature profile or heat flows:

- calculate mean values and complex amplitudes. Amount of harmonics depending on question to be answered and accuracy requirements.

- complex amplitudes of the variable to be found and its mean values are calculated. Thermal conductances and temperature weighting factors have to be determined beforehand using periodic thermal bridge calculation.

- final Fourier synthesis leads to parameter varying in time.
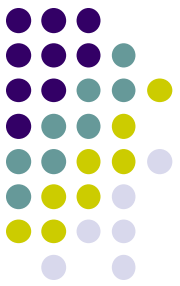
Visualization of Results

- 3D visualization even in steady state case sophisticated

- special challenge to visualize 4D

three spacial coordinates + time

- highly depending on question to be answered…

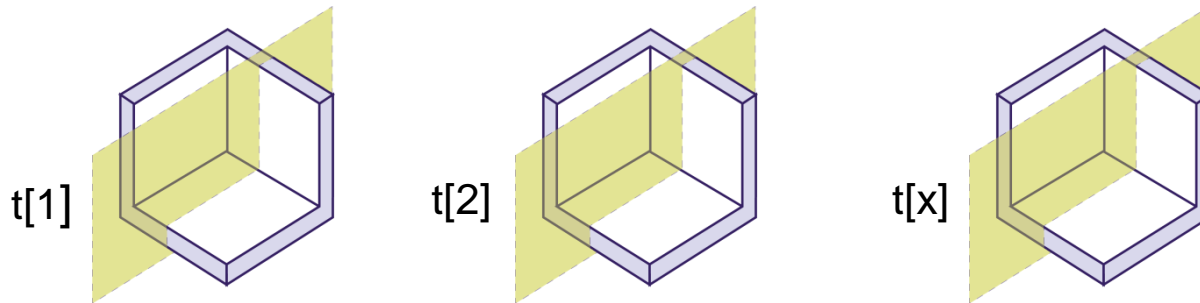- reducing dimensions leads to more practical information
 - sections through construction

?

2D

Visualization of Results

- temperature distribution on section planes in manner of slide show

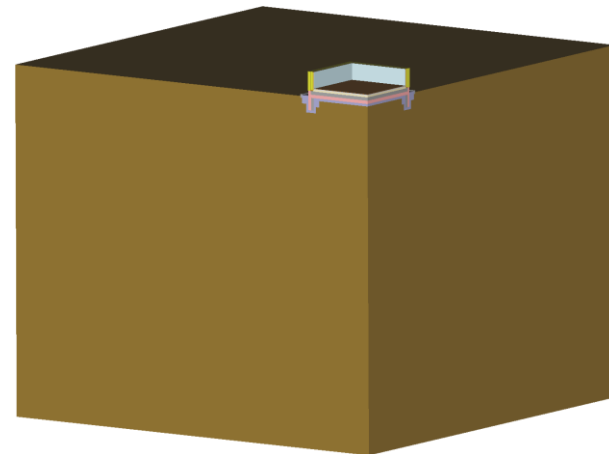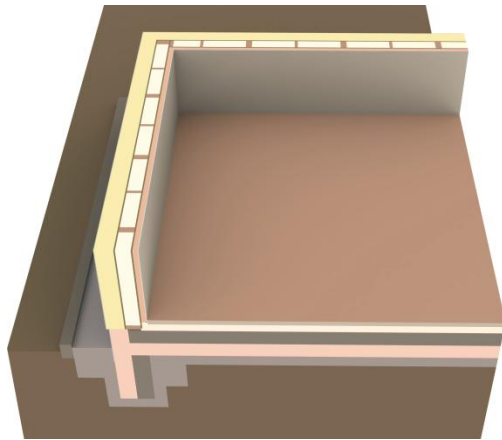t[1]   t[2]   t[x]

- often useful to focus on specific points
  - point of minimal surface temperature (EN ISO 10211)

- heat loss from one room to another: in diagrams

- totality of points of same temperature
  - isocurves on cutting planes (frostline)
  - Isosurfaces
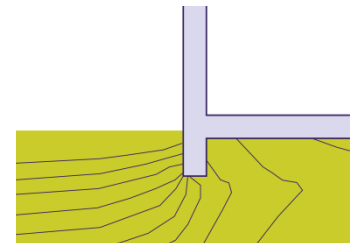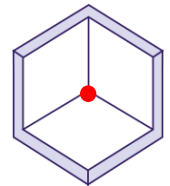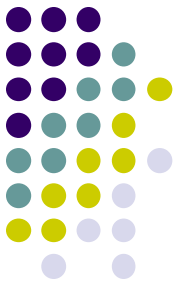
Example of Application

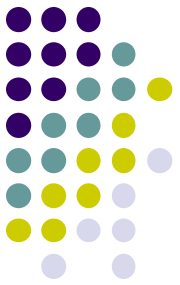cut-out of foundation slab, passive house standard, incl. 1m ext. wall

- 1D approach not suitable
- 2D no useful results
  - Influence of corners

3D

- Wide areas of the surrounding ground affected by heat-flow

transient
(periodically in time)

Example of Application

- 3D periodic calculation implemented in thermal bridge program AnTherm[1]

- AnTherm provides thermal conductance between inside and outside + matrices of harmonic thermal conductance of considered 6 harmonics

- heat loss during course of year calculated by 3D periodic based thermal building software Thesim[2]
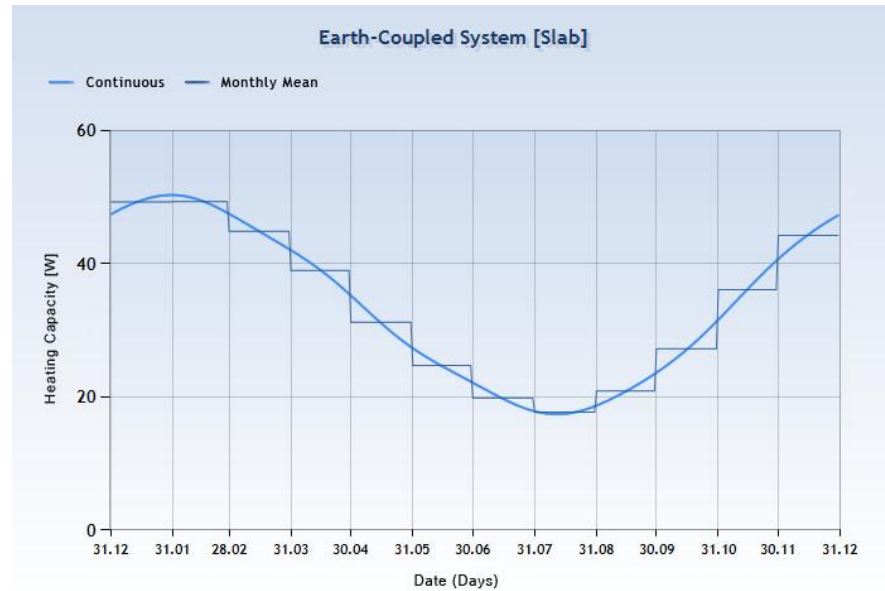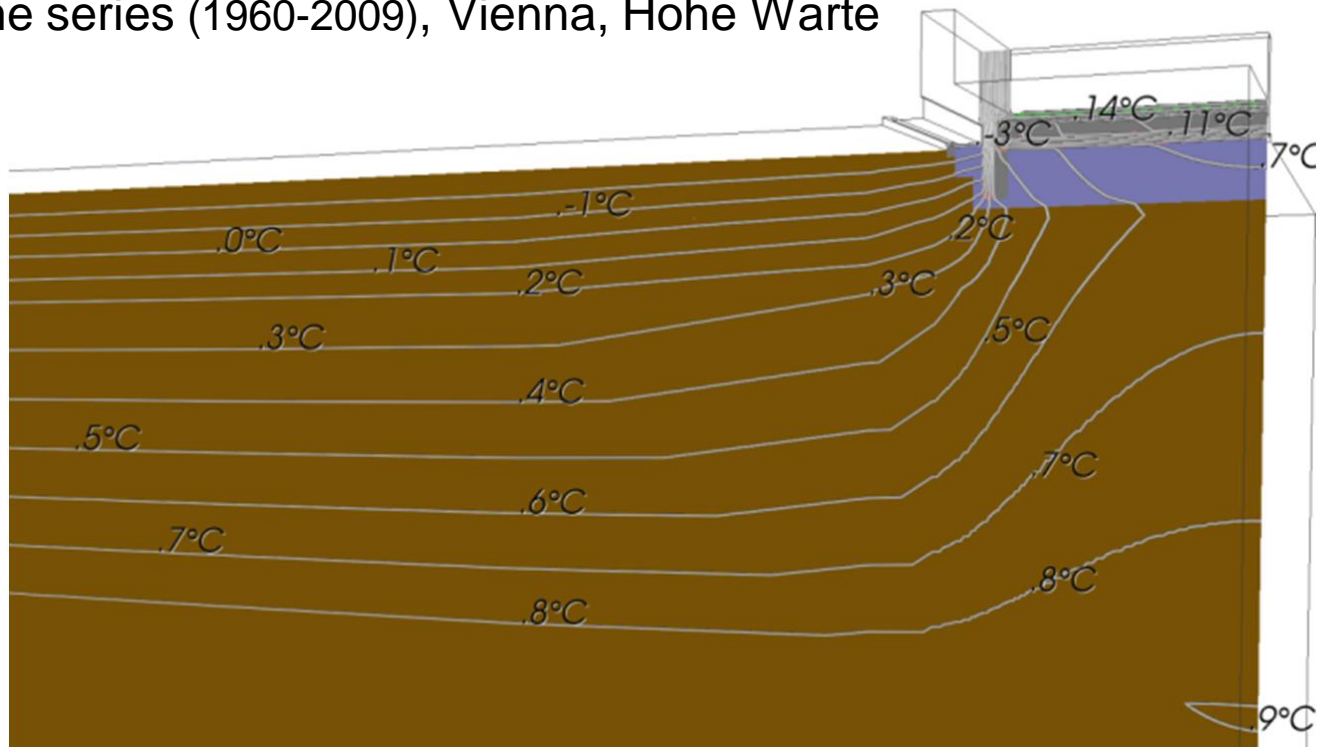

[1] www.antherm.eu

[2] www.thesim.at
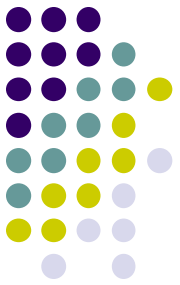
thesim visualization of annual heat-loss
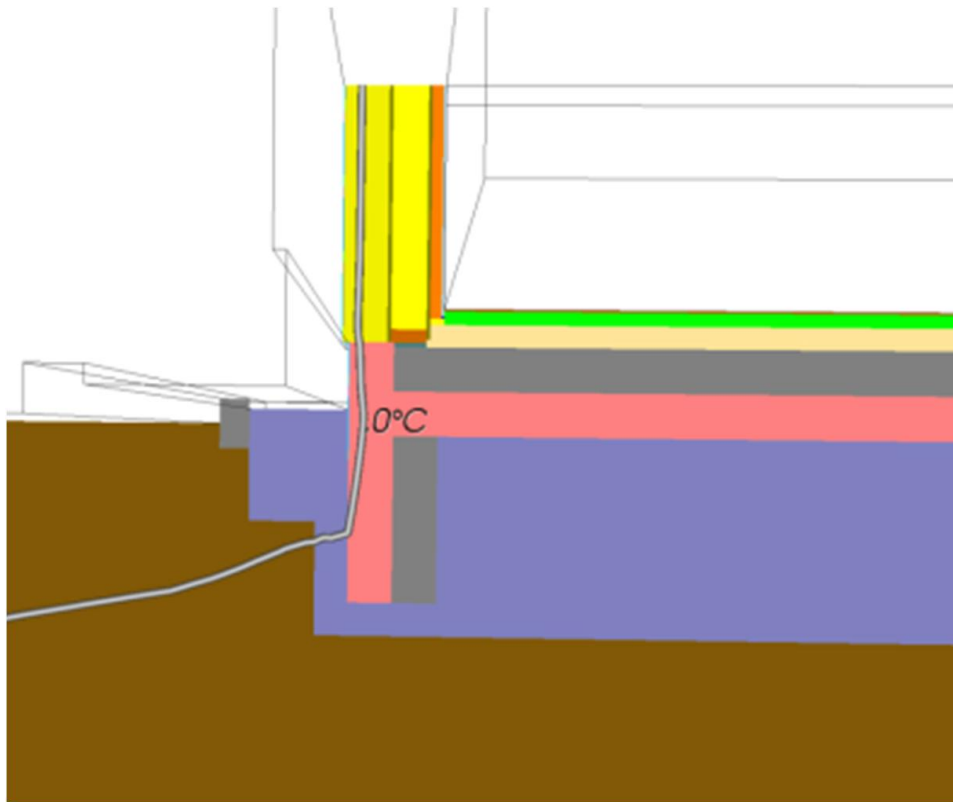
Example of Application

- frost line in ground plays important role
  - calculation based on long-term mean values cannot be used
  - extreme winter conditions - most extreme winter temperatures of 50-year time series (1960-2009), Vienna, Hohe Warte

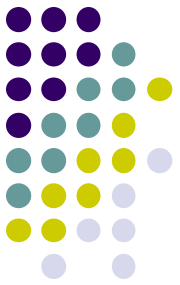AnTherm visualization of isothermes on Feb. 8th, 08:00
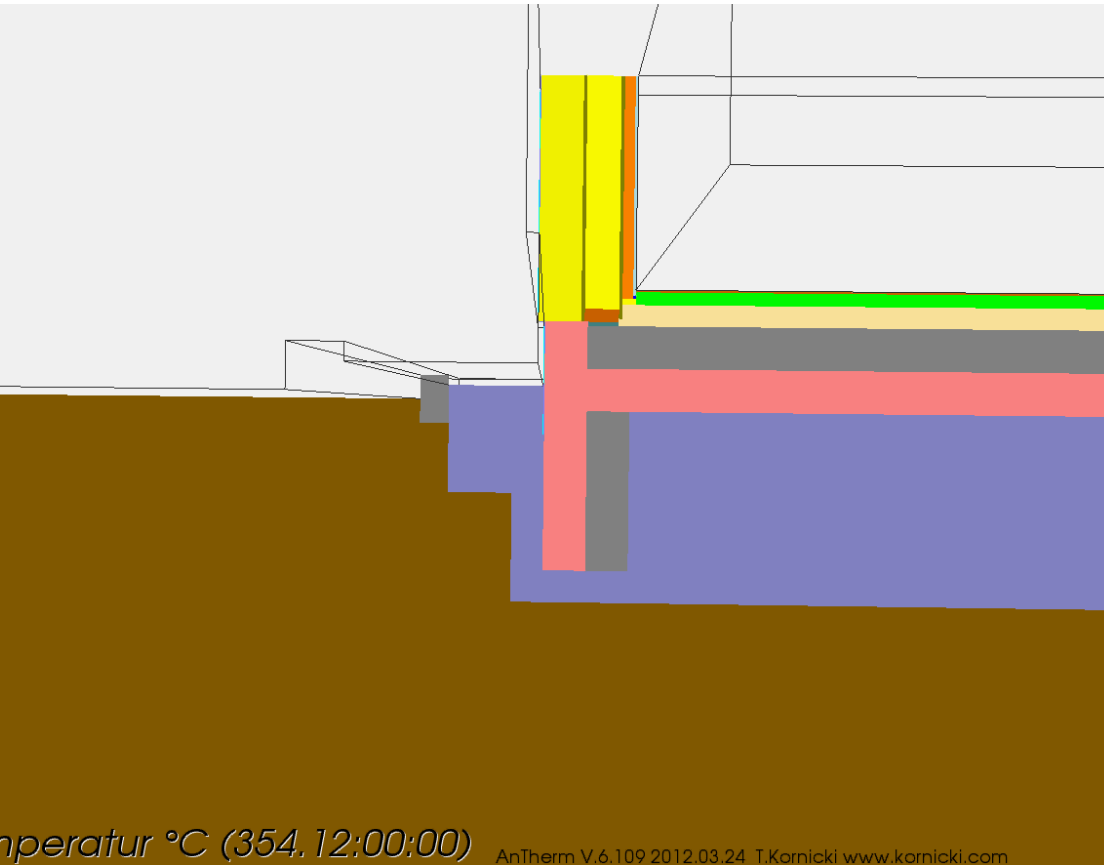
Example of Application

0°C

AnTherm visualization of zero degree isotherm

- Strip foundation remains frost free
- What about area of edge?

Example of Application

mperatur °C (354.12:00:00) AnTherm V.6.109 2012.03.24 T.Kornicki www.kornicki.com

AnTherm visualization of zero degree isotherm

- Strip foundation remains frost free
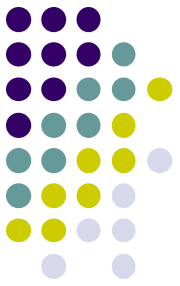- What about area of edge?
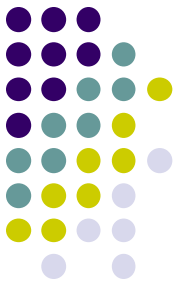
Example of Application

- isosurface of 0°C
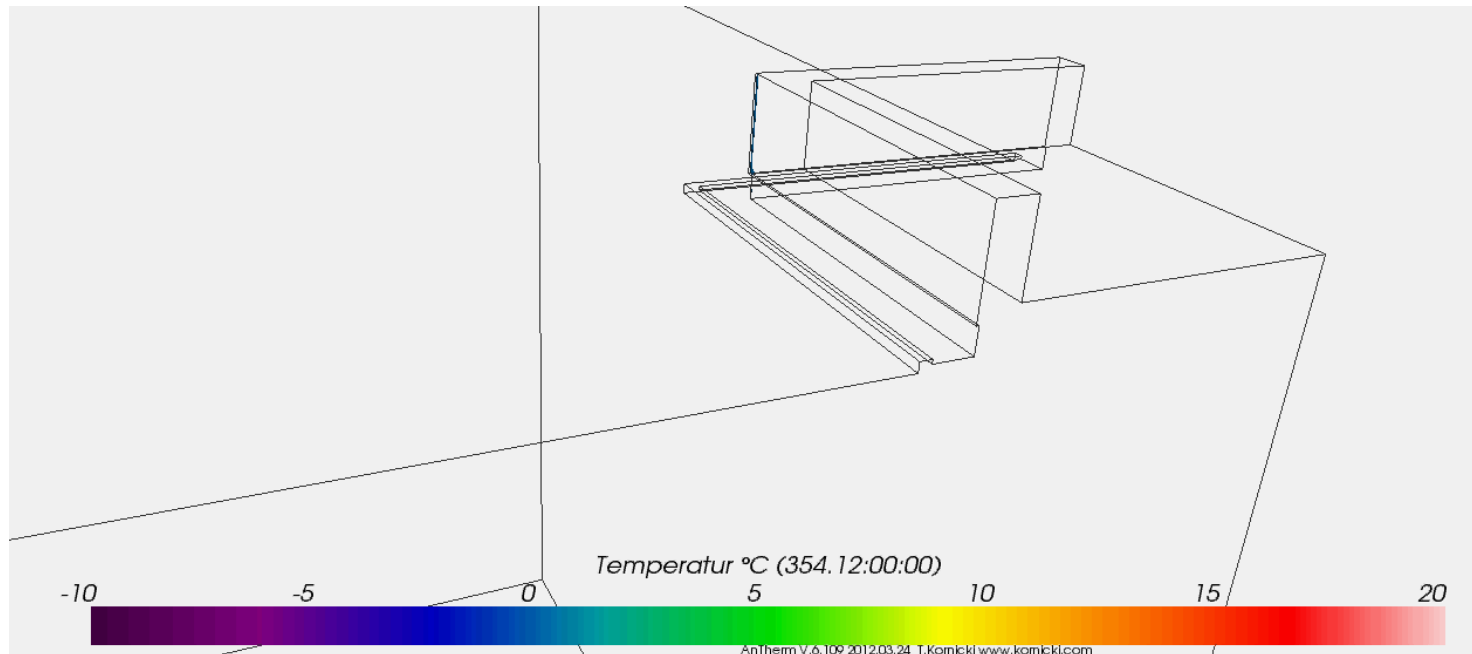- foundation keeps frost free for this location
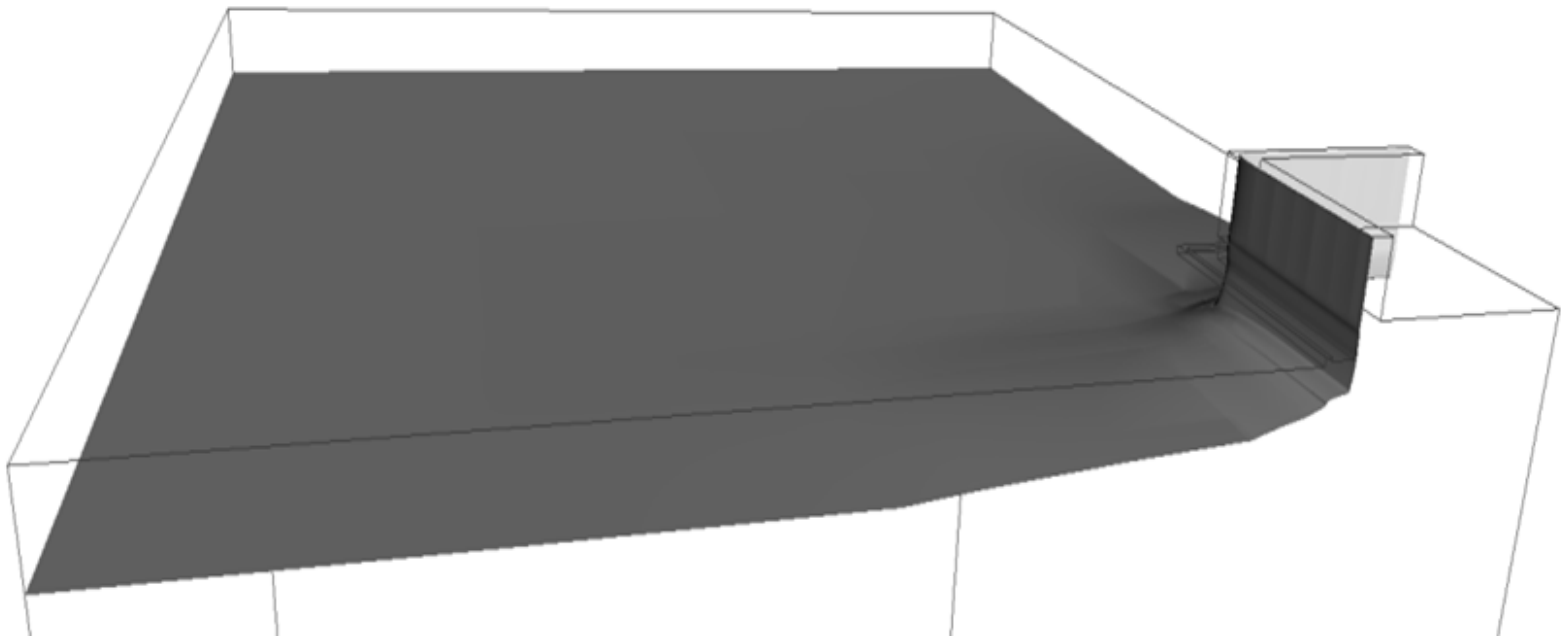
AnTherm visualization of zero grade isosurface

Example of Application

- isosurface of 0°C

- foundation keeps frost free for this location

AnTherm visualization of zero grade isosurface

Questions?

Tomasz Kornicki, Joachim Nackler, Klaus Kreč