9th Nordic Symposium on Building Physics
29th May – 2nd June 2011, Tampere, Finland

Inverse analysis of water vapor transport in building materials using genetic algorithm

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Outline

- Introduction to Inverse analysis
- Genetic algorithms
- Laboratory experiment
- Computer code HEMOT
- Optimization process
- Results

Motivation and Objectives

- To find new, universal method for determination of material parameters of building materials
- To find water vapor properties of studied material

Introduction to Inverse analysis

- The aim of inverse analysis
- Physical experiment

$$\mathbf{y}^E = E(\mathbf{x}^E)$$

- Numerical approximation

$$M \approx E$$
$$\mathbf{y}^M = M(\mathbf{x}^M)$$
$$\|\mathbf{y}^E - \mathbf{y}^M\| \cong 0$$

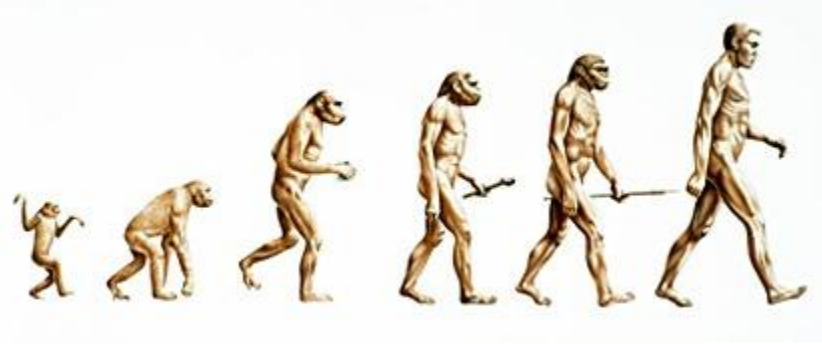
- **Forward** vs. **Inverse** mode of inverse analysis

IM: $\mathbf{x}^M = M^{INV}(\mathbf{y}^M)$

FM: $\min F(x) = min\|\mathbf{y}^E - M(\mathbf{x}^M)\|$

Genetic algorithms

- Inspired by Darwin's Theory of evolution



- The evolution starts from randomly generated population
- Fitness function
- Termination of optimization process

GRADE algorithm

- Chromosome $x_i(g) = (x_{i1}, x_{i2}, x_{i3}, \ldots, x_{in})$
- Population $P(g) = [x_1(\mathrm{g}), x_2(\mathrm{g}), \ldots, x_m(\mathrm{g})]$

- Genetic operators: *cross-over, mutation, selection*

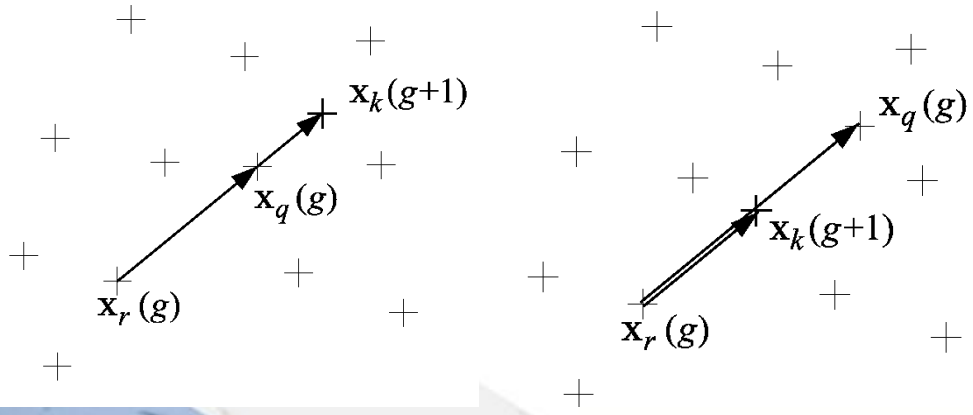
Genetic operators in GRADE algorithm

- mutation ($x_i(g)$, x_{RP}, *mutation_rate*)

$$x_k(g+1) = (x_i(g) + MR(x_{RP} - x_i(g))$$

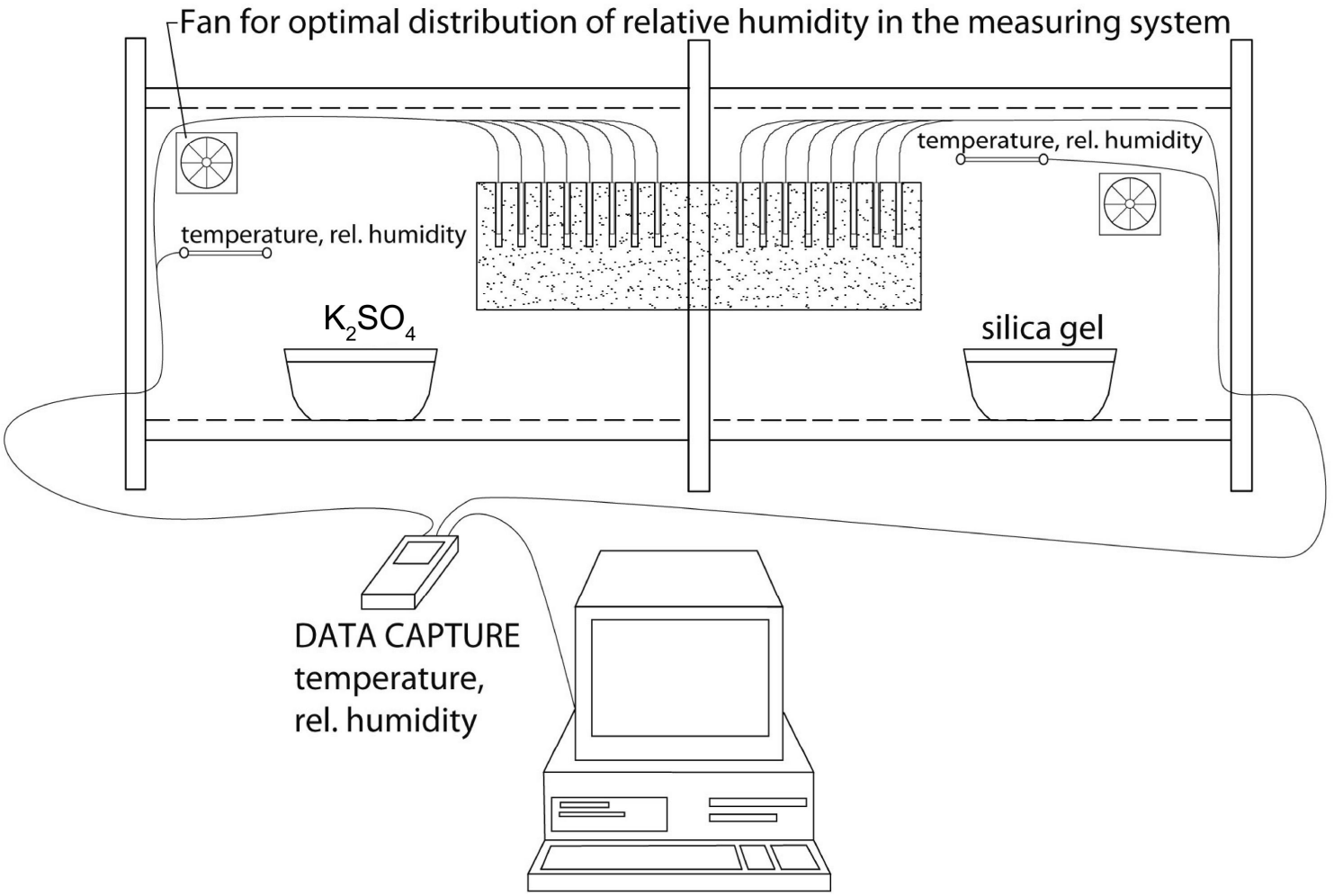
- cross-over ($x_q(g)$, $x_r(g)$, *crossing_rate*)

$$x_k(g+1) = \max(x_q(g); x_r(g)) + CR(x_q(g) - x_r(g))$$

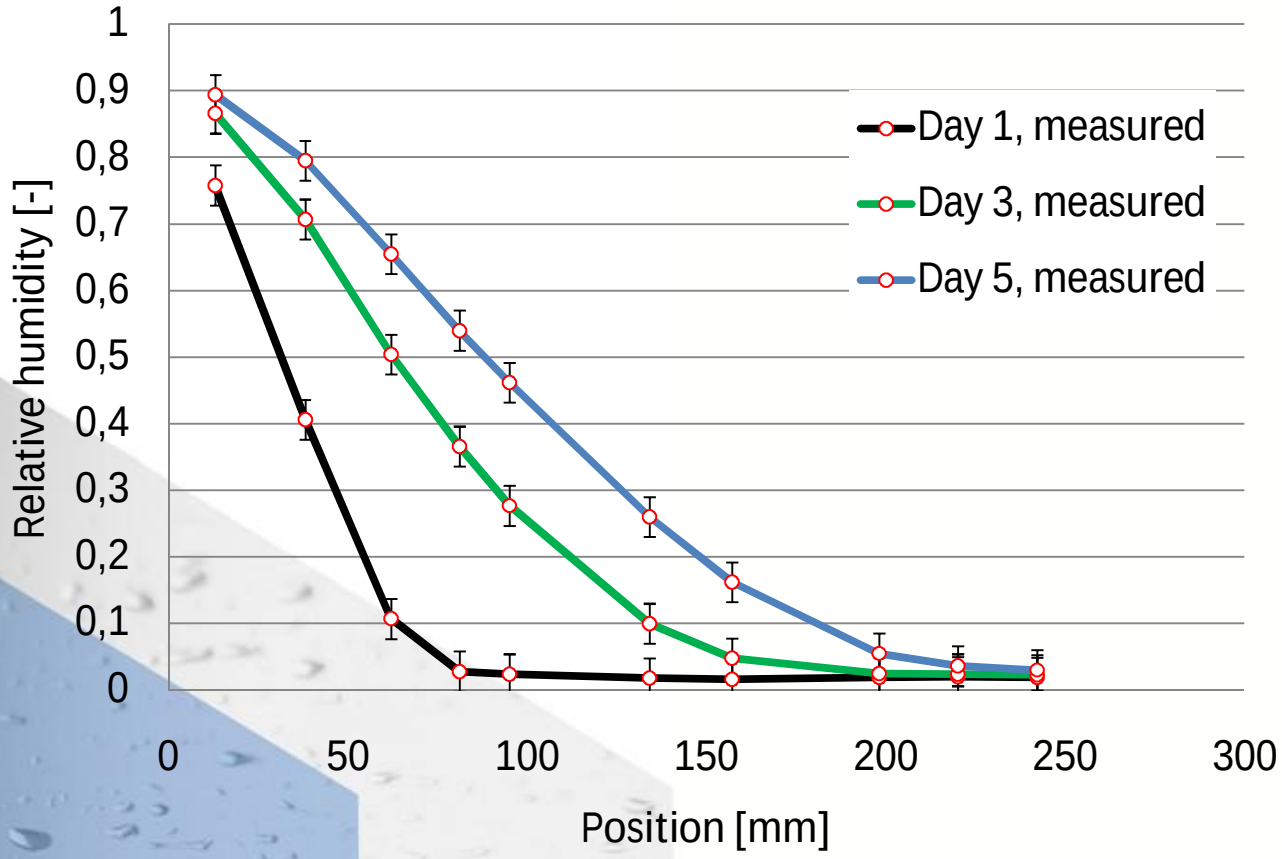


- selection – to reduce number of chromosomes in the population

Laboratory experiment



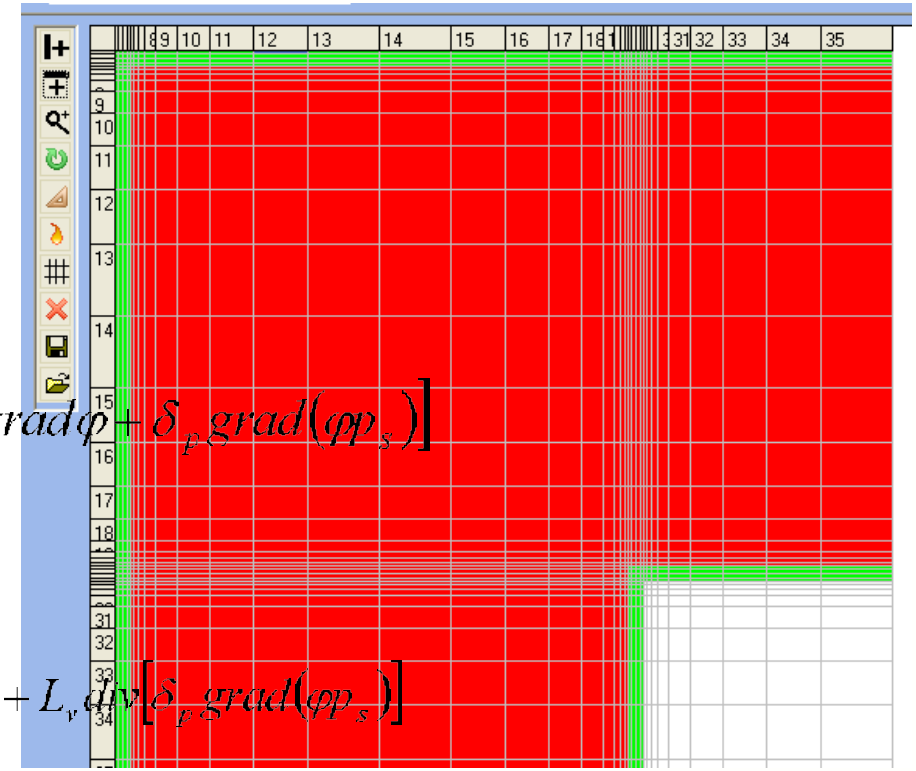
Results of laboratory experiment



Objective: To find water vapor permeability of AAC and water vapor exchange coefficient

Computer code HEMOT

- Heat and Moisture transport
- Finite element method
- Kunzel's mathematical model



Moisture balance:

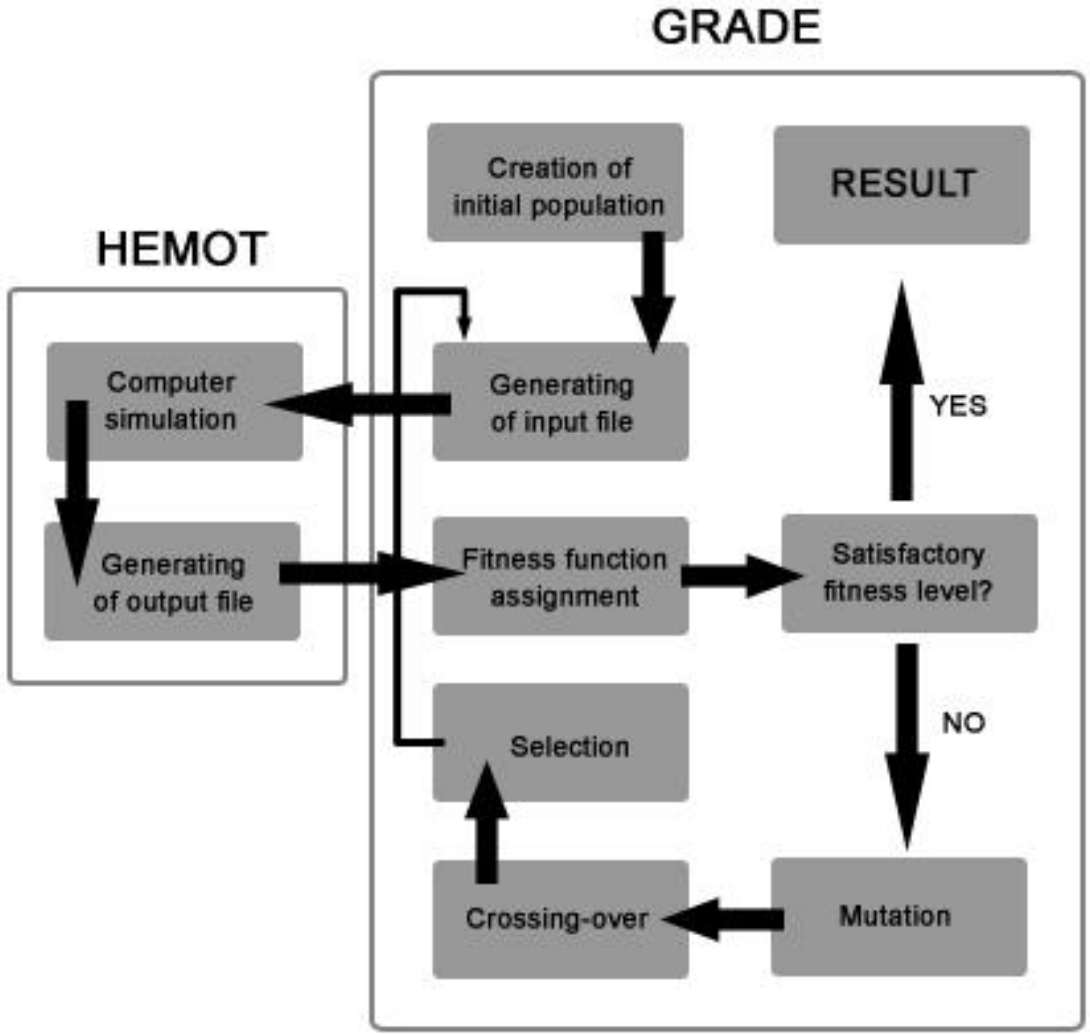
$$\frac{d\rho_v}{d\varphi}\frac{\partial\varphi}{\partial t} = div\left[D_\varphi grad\varphi + \delta_p grad(\varphi p_s)\right]$$

Heat balance:

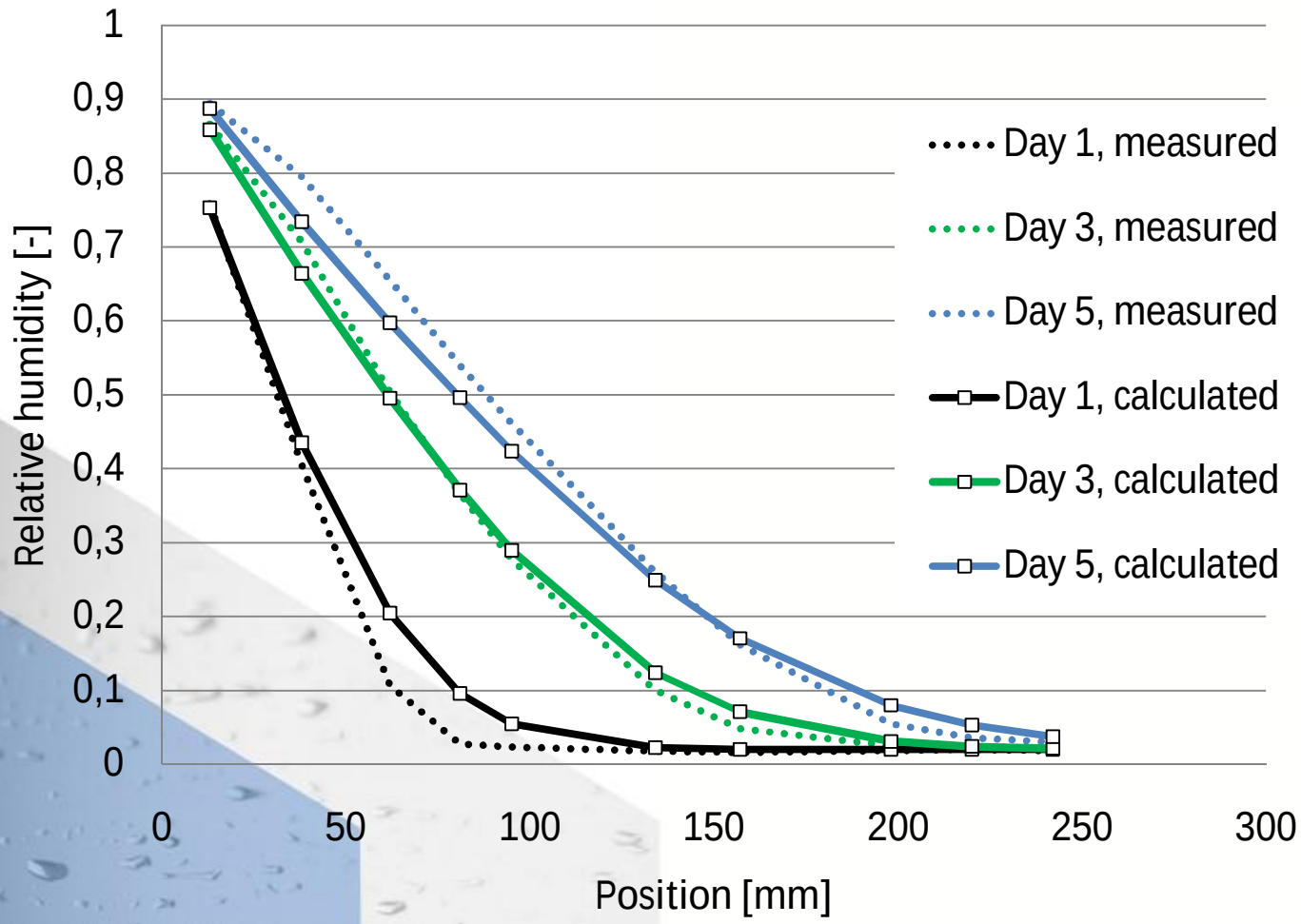
$$\frac{dH}{dT}\frac{\partial T}{\partial t} = div(\lambda gradT) + L_v div\left[\delta_p grad(\varphi p_s)\right]$$

- Water vapor permeability defined by 5 isolated points with predefined x-cordinate (5 variables of objective function)
- Water vapor exchange coefficient (constant value)

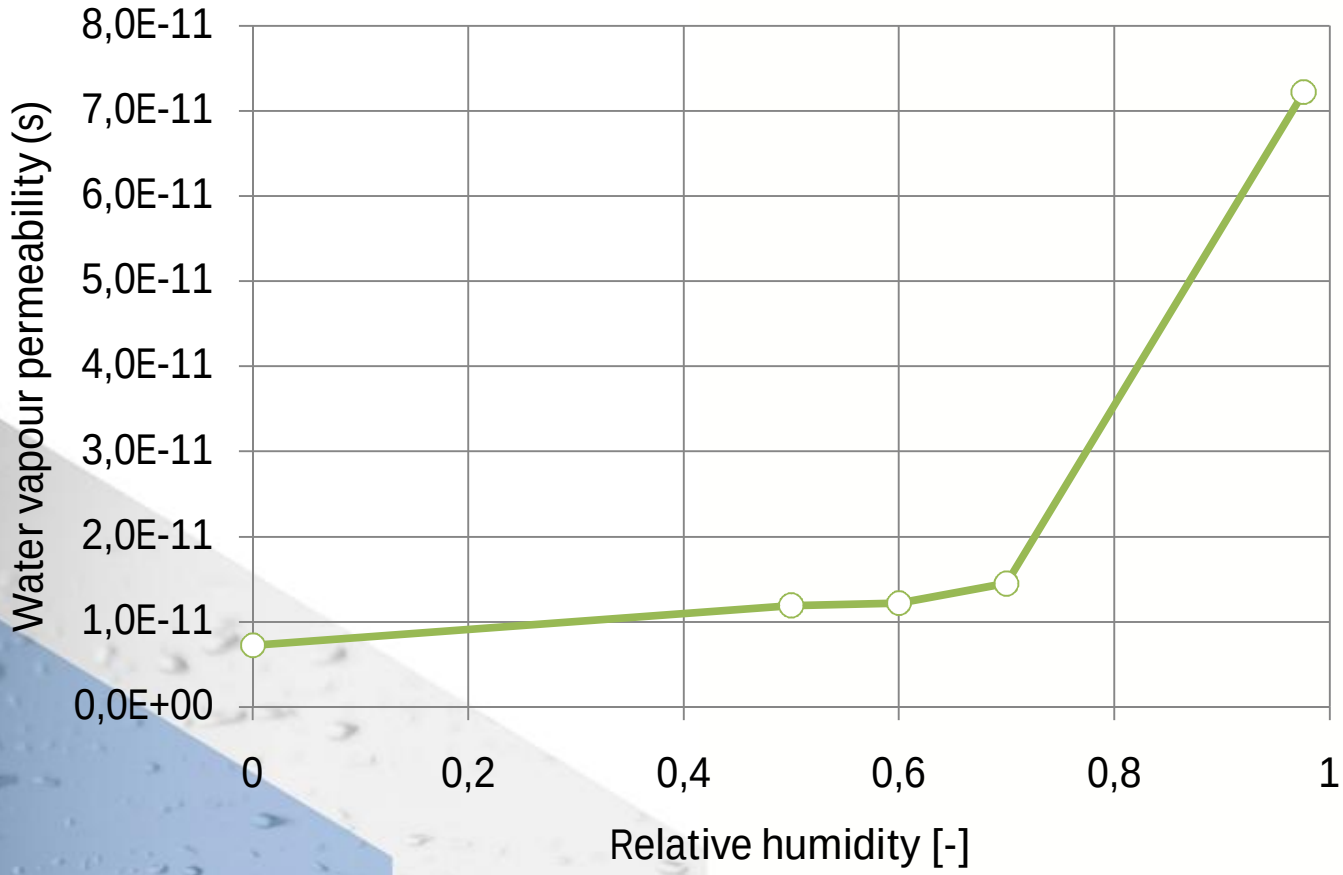
Optimization process



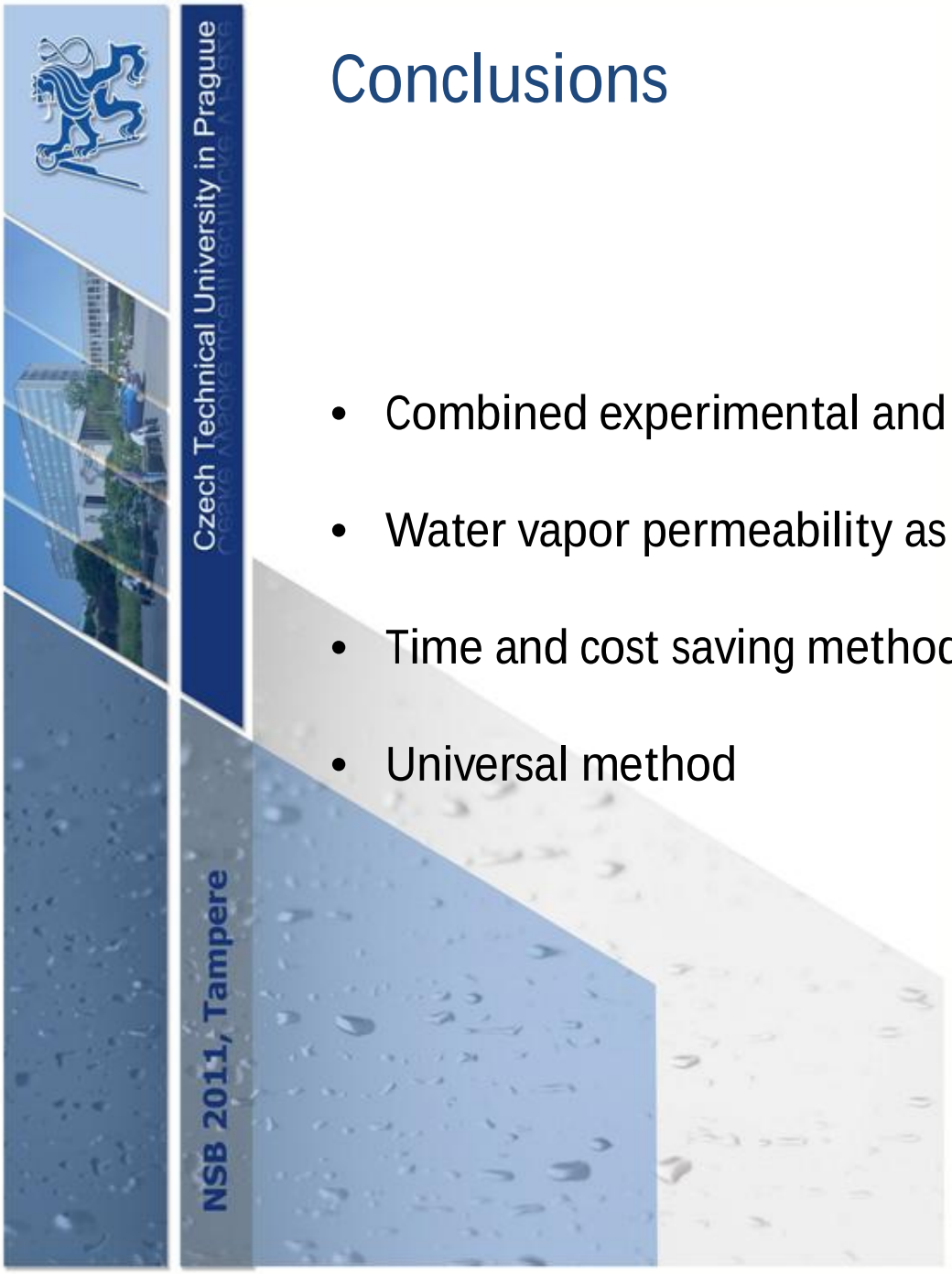
Optimization results



Optimization results



The water vapor exchange coefficient: $6{,}76 \cdot 10^{-9}$ s/m



Conclusions

- Combined experimental and computational approach
- Water vapor permeability as a function of relative humidity
- Time and cost saving method – stady-state is not needed
- Universal method

THANK YOU FOR YOUR ATTENTION