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
  \[ y^E = E(x^E) \]

- Numerical approximation
  \[ M \approx E \]
  \[ y^M = M(x^M) \]
  \[ \|y^E - y^M\| \approx 0 \]

- **Forward vs. Inverse** mode of inverse analysis
  IM: \[ x^M = M^{INV}(y^M) \]
  FM: \[ \min F(x) = \min \|y^E - M(x^M)\| \]
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 $x_i(g) = (x_{i1}, x_{i2}, x_{i3}, ..., x_{in})$
- Population $P(g) = [x_1(g), x_2(g), ..., x_m(g)]$

- Genetic operators: cross-over, mutation, selection
Genetic operators in GRADE algorithm

- **mutation** \((x_i(g), x_{RP}, \text{mutation\_rate})\)

  \[
x_k(g+1) = (x_i(g) + MR(x_{RP} - x_i(g))
  \]

- **cross-over** \((x_q(g), x_r(g), \text{crossing\_rate})\)

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

- **selection** – to reduce number of chromosomes in the population
Laboratory experiment

Fan for optimal distribution of relative humidity in the measuring system

温度, 相对湿度

K₂SO₄

温度, 相对湿度

silica gel

DATA CAPTURE

温度, 相对湿度
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:

\[
\frac{d\rho_s}{d\varphi} \frac{\partial \varphi}{\partial t} = div\left[D_{\varphi,\rho_s} \nabla \varphi + \beta_{\varphi,\rho_s} \nabla (\varphi \rho_s) \right]
\]

Heat balance:

\[
\frac{dH}{d\varphi} \frac{\partial T}{\partial t} = div(\lambda \nabla T) + I_{\varphi} \rho_s \delta \nabla (\varphi \rho_s)
\]

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

**HEMOT**
- Computer simulation
- Generating of output file

**GRADE**
- Creation of initial population
- Generating of input file
- Fitness function assignment
  - Satisfactory fitness level?
    - YES
    - NO
      - Selection
        - Crossing-over
      - Mutation

**RESULT**
Optimization results

![Graph showing relative humidity against position over different days](image)

- **Day 1, measured**
- **Day 3, measured**
- **Day 5, measured**
- **Day 1, calculated**
- **Day 3, calculated**
- **Day 5, calculated**

Relative humidity [-]

Position [mm]
Optimization results

The water vapor exchange coefficient: $6.76 \times 10^{-9} \text{s/m}$
Conclusions

- Combined experimental and computational approach
- Water vapor permeability as a function of relative humidity
- Time and cost saving method – steady-state is not needed
- Universal method
THANK YOU FOR YOUR ATTENTION