Numerical methods applied to heat and moisture transfer in porous building materials

Source: the National Geographic Photograph by Tyrone Turner

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Goal

The objective of this work is to explore the use of innovative numerical methods for solving the heat and moisture transfer in building materials, considering the nonlinearities of the problem, different geometries, different scales and multi-dimensional domains, in order to reduce the computational cost of simulations.

Methods

Heat & Moisture transfer

- Usually solved by standard techniques, such as FDM, FVM and FEM.
- The Crank-Nicolson and the implicit schemes are the most used due to a good combination of accuracy and stability.
  - ✘ Require sub-iterations to treat the nonlinearities;
  - ✘ High computational cost.

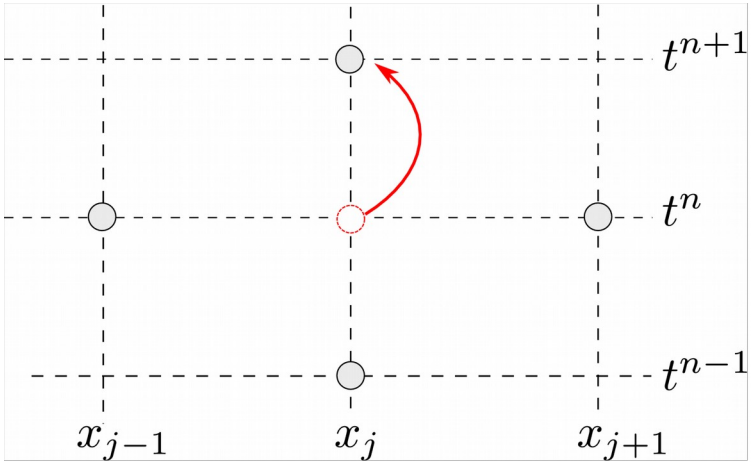
Method proposed

Heat & Moisture transfer

Solved by

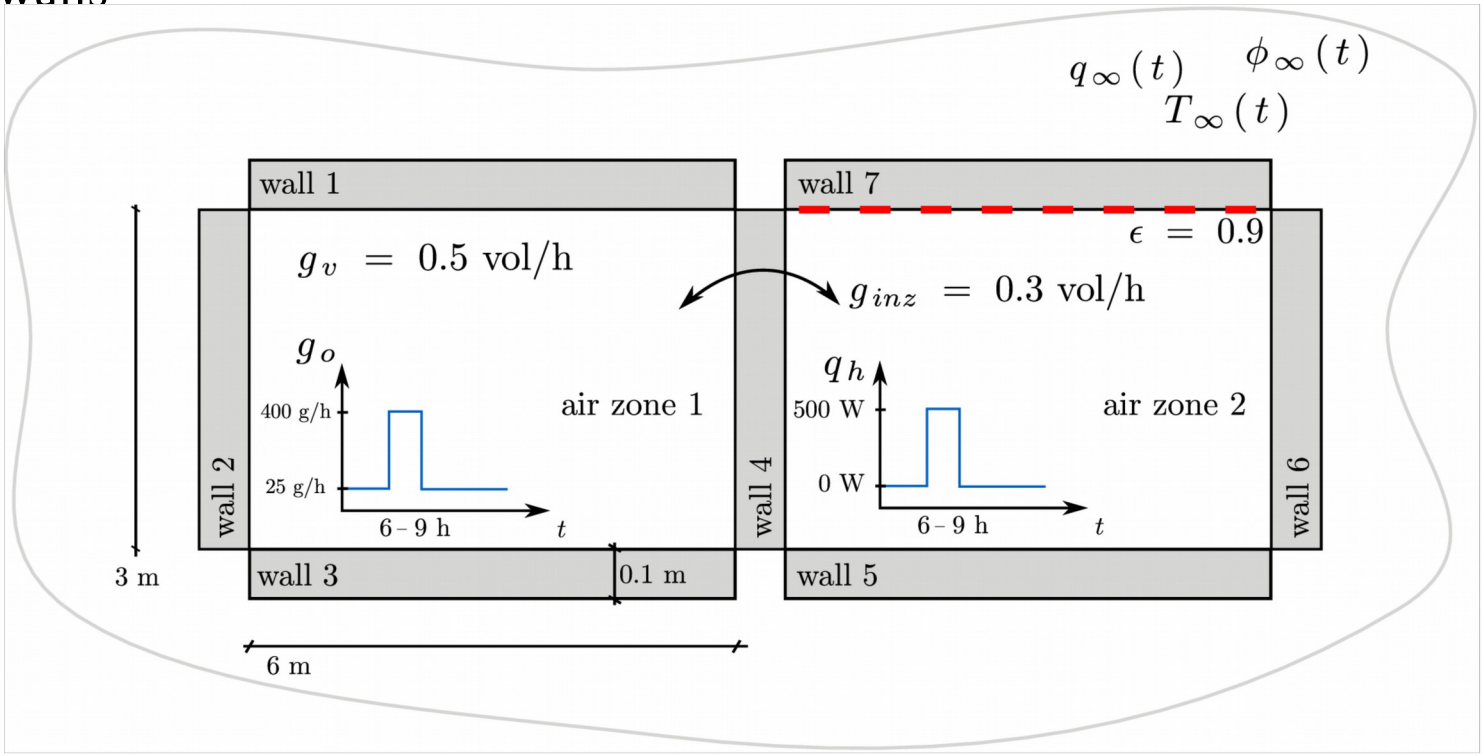
1. DUFORT-FRANKEL scheme

- ✓ Improved explicit scheme of FDM;
- ✓ No CFL condition;
- ✓ Uncondiotionably stable;
- ✓ No need of sub-iterations;



Results: Dufort-Frankel scheme

Problem: Coupling the lumped air multizone model with the transfer through porous walls



Results: Dufort-Frankel scheme

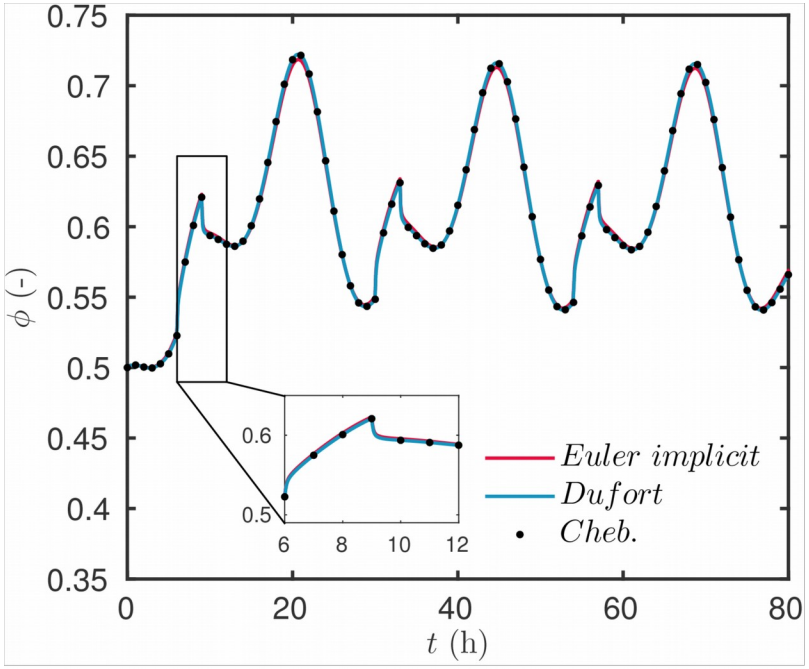


Fig.: Relative humidity for zone 1.

- ✓ Two-zone building model was analyzed.
- ✓ With a highly coupled heat and moisture transfer problem.
- ✓ Error of order of $O(10^{-4})$.
- ✓ Reduction of 95% of the CPU time of the implicit approach.
- ✓ No restriction regarding the time discretization.

Method proposed

Heat & Moisture transfer

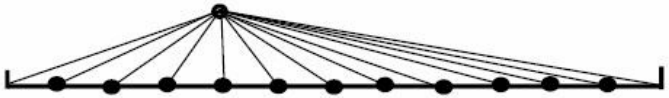
Solved by

2. SPECTRAL-METHODS

- ✓ Reduced order model;
- ✓ High-order approximation;
- ✓ Superior rate of convergence;
- ✓ Memory-minimizing;

Spectral

One high-order polynomial for WHOLE domain



Finite Difference

Multiple Overlapping Low-Order Polynomials

Challenges and Perspectives

➔ Spectral methods

Simulate 2/3D problems.

➔Whole building simulation

- Integration with a BPS tool.