TECHNISCHE UNIVERSITÄT DRESDEN

INSTITUT FÜR BAUKLIMATIK

Performance Assessment of Interior Insulations by a Stochastic Method

Jianhua Zhao, Rudolf Plagge, John Grunewald

Tampere
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Institute of Building Climatology
Dresden University of Technology

Uncertainty in HAM simulation

- Material properties may be subjected to a considerable variation
  - Inhomogeneous nature of materials
  - Variation in material manufacturing
  - Variation in measurement processes
- Boundary conditions defined in the model may be also different from the real situation.
- Workmanship in the operation stage may have large influence on the performance
- Climatic conditions may be another unknown factor

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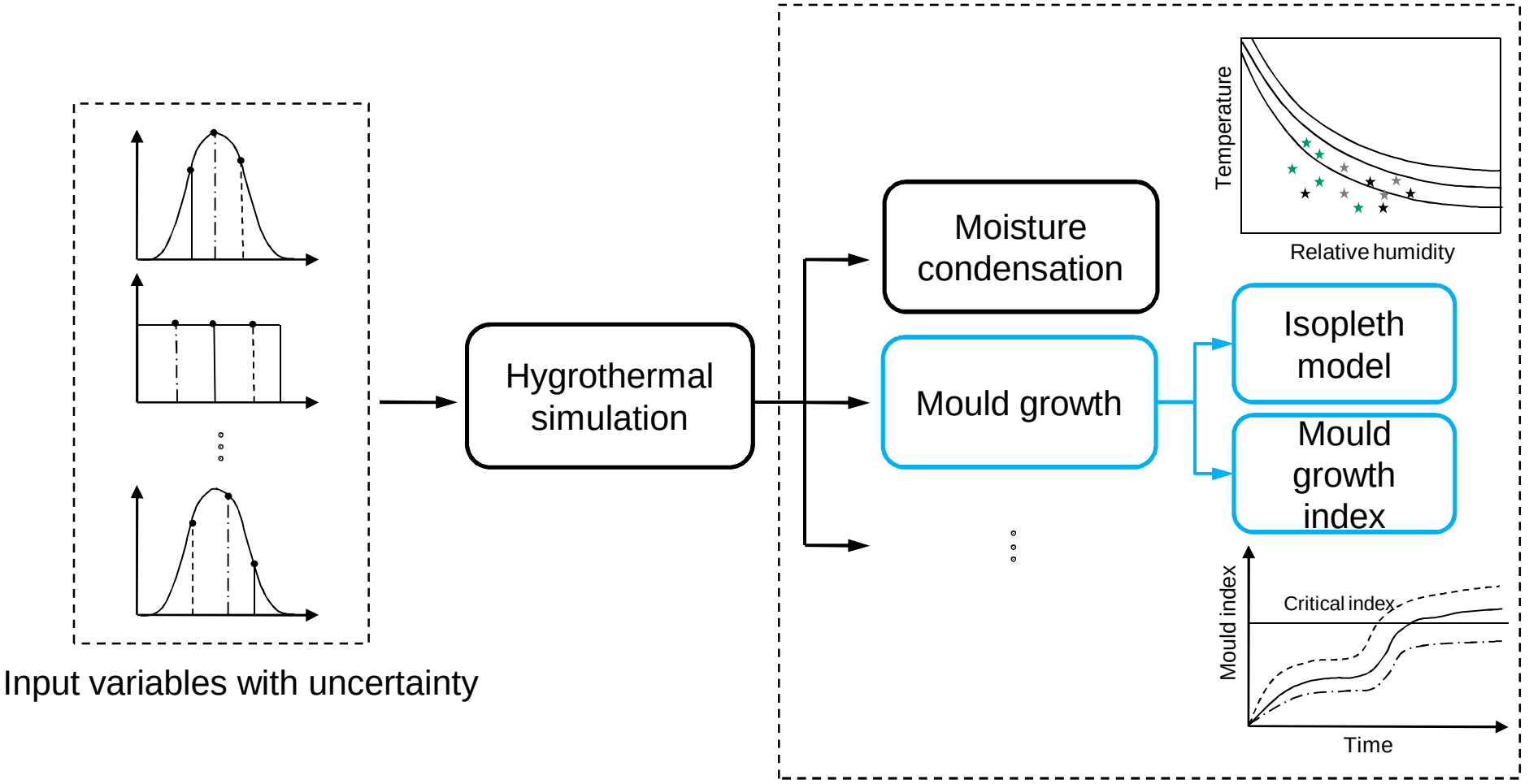
- **The outcome is not a single value but in a range of possibilities**

Risk assessment by probabilistic way

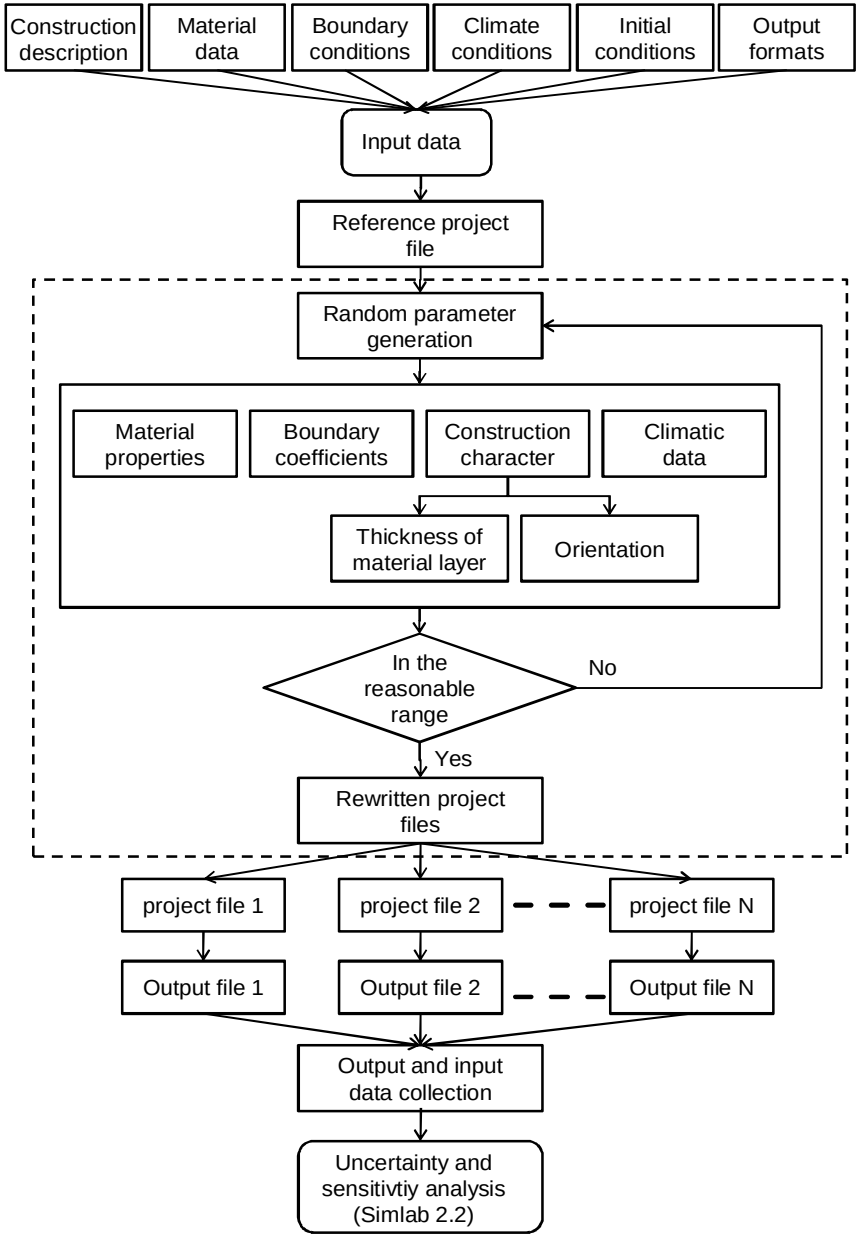
Monte Carlo Analysis (MCA): simultaneously vary several or all input variables in each simulation



Input variables with uncertainty

Performance evaluation criteria

Stochastic process



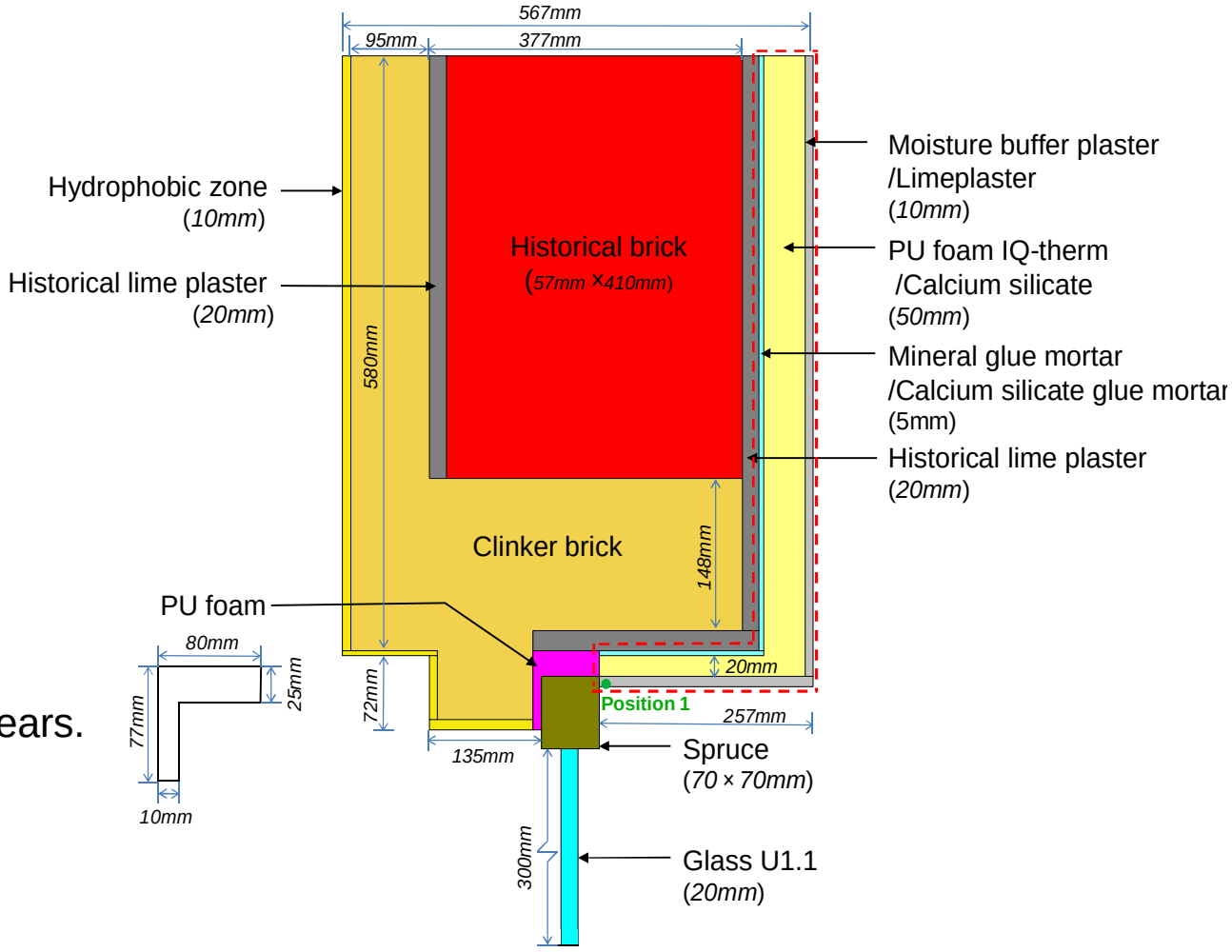
Scheme of the construction

Two interior insulations:

- *PU foam IQ-therm*
- *Calcium silicate*

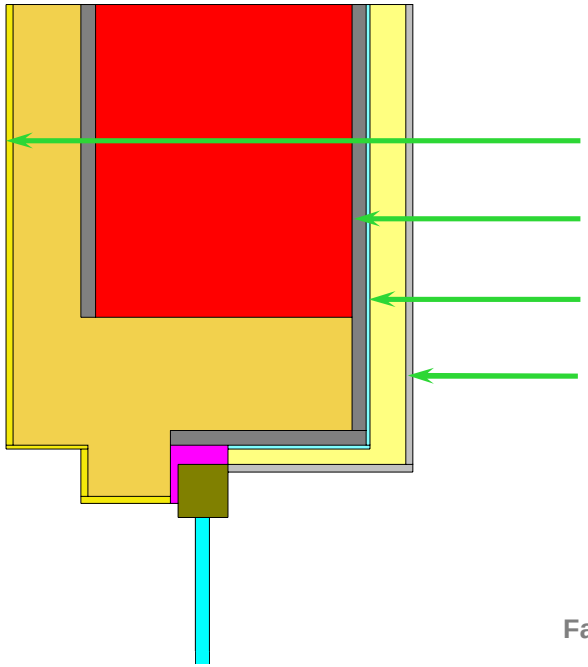
For each interior insulation 200 cases are randomly generated

The simulation starts from January 1st for a period of two years.



Uncertainties in the simulation

Uncertainty	Distribution
Material properties (basic parameters and functions)	Gaussian
Boundary coefficients	Gaussian
Orientation (North, East, West, South)	Uniform
Workmanship (thickness of the layers)	Uniform



Hydrophobic brick zone	10mm (8 , 14)
Historical lime plaster	20mm (14 ,29)
Mineral glue /calcium silicate glue mortar	5mm (4 , 7)
Moisture buffer plaster/lime plaster	10mm (8 , 14)

Material Parameters and Material Functions

Basic material parameters

Basic Parameters	**Symbols**	**Unit**
Density	ρ	kg/m^3
Specific heat capacity	c_0	J/kgk
Thermal conductivity	λ	W/mK
Open porosity	ψ_o	m^3/m^3
Effective saturation moisture content	ψ_{sat}	m^3/m^3
Capillary moisture content	ψ_{cap}	m^3/m^3
Water absorption coefficient	A	$kg/m^2s^{0.5}$
Water vapor diffusion resistance factor	μ_{dry}	-
Liquid water conductivity at saturation moisture content	K_{sat}	s

Mean value and standard deviation from measurement

Material functions and their correlated material parameters

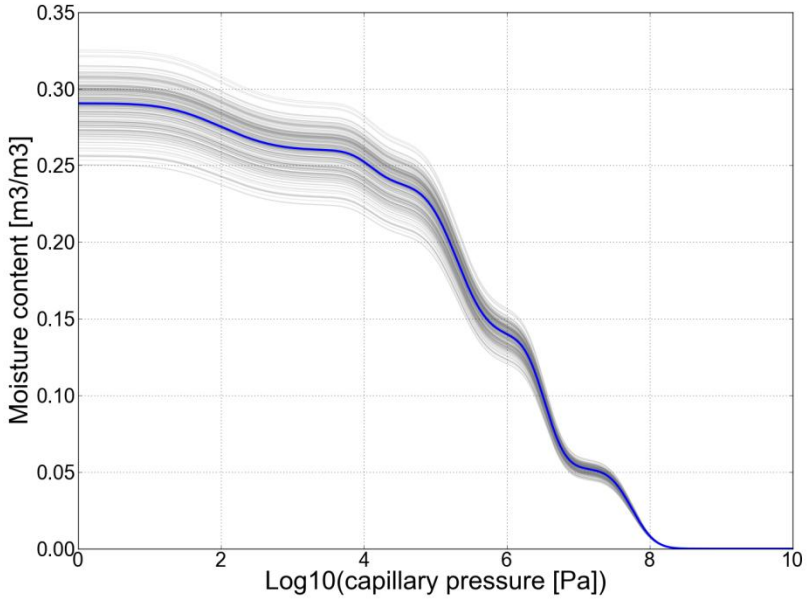
Material functions		**Parameters that affect the material functions**
Moisture retention curve (m^3/m^3)	ψ(pC)	ψ_{sat}
Water vapor permeability (s)	K_v (ψ)	ψ_o and μ_{dry}
Liquid water permeability (s)	$K_l(\psi)$	ψ_{sat} and K_{sat}
Thermal conductivity (W/mK)	$\lambda(\psi)$	ψ_{sat}

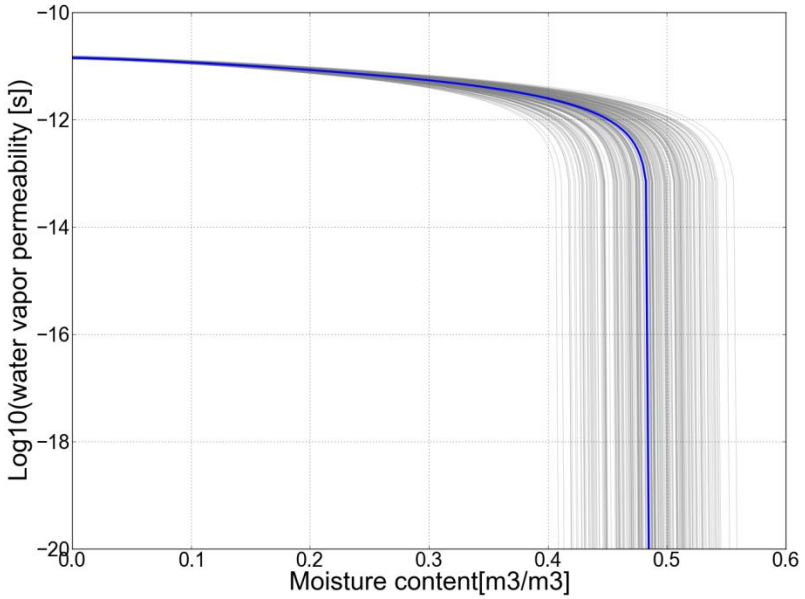
Climatic and boundary conditions

- Outdoor condition**:** Test reference year of Potsdam, Germany
- Indoor condition: T and RH vary with daily average outdoor temperature (modified DIN EN 15026)
- Boundary coefficients:

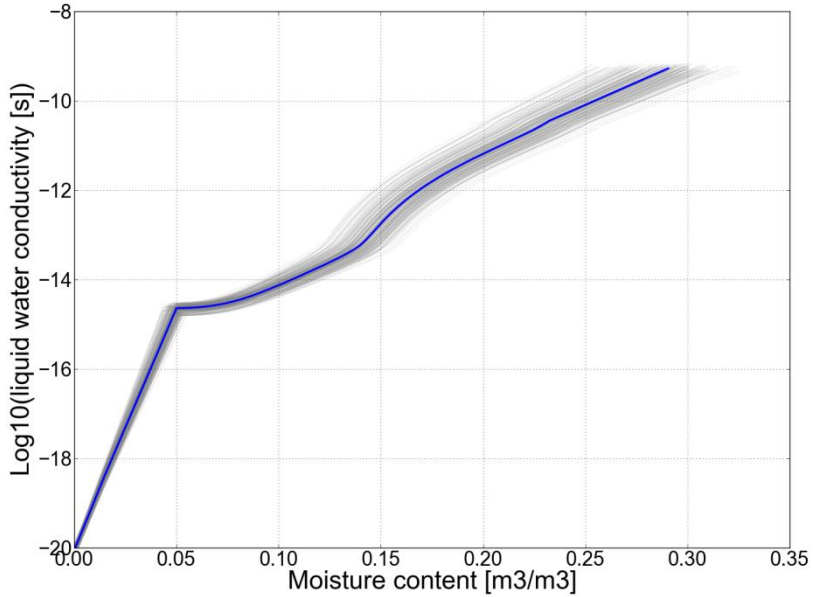
	Unit	Value
Heat transfer coefficient _ interior	W/m2K	6 (0.6)
Heat transfer coefficient _ window	W/m2K	8 (0.8)
Heat transfer coefficient _ exterior	W/m2K	25.0 (3.0)
Vapor transfer coefficient _ interior	s/m	3e-08 (3e-9)
Vapor transfer coefficient _ exterior	s/m	2e-07 (4e-8)
Absorption coefficient for short wave radiation	-	0.6 (0.06)
Emission coefficient of surrounding ground	-	0.2 (0.02)
Emission coefficient for long wave radiation	-	0.9 (0.09)
Rain exposure coefficient	-	0.5 (0.1)

Generated material functions

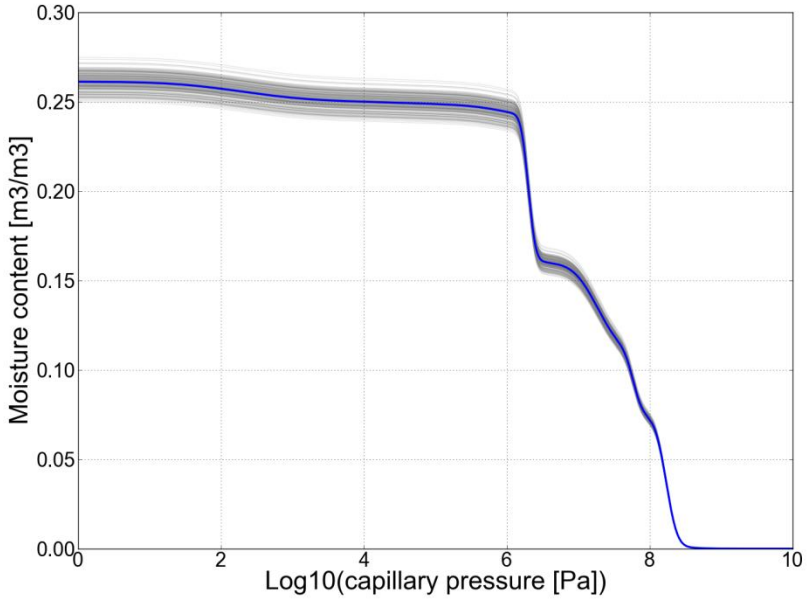


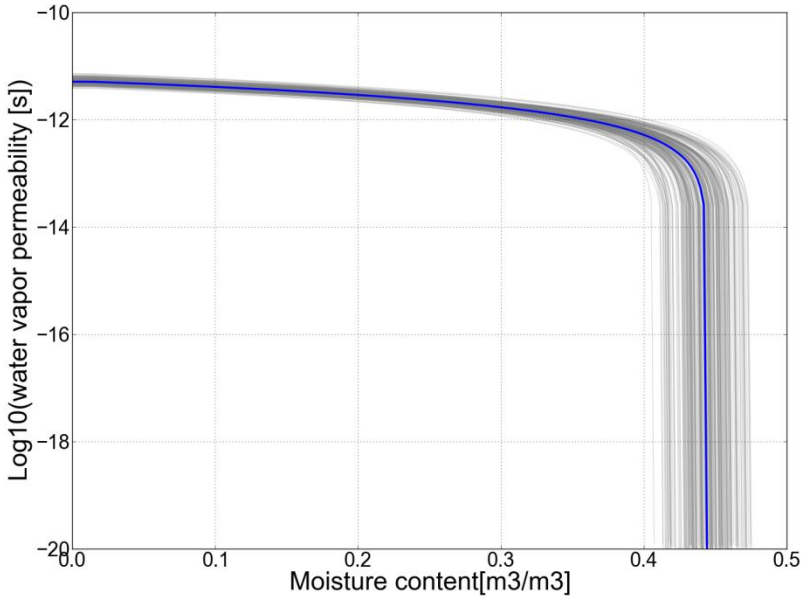


Historical lime plaster

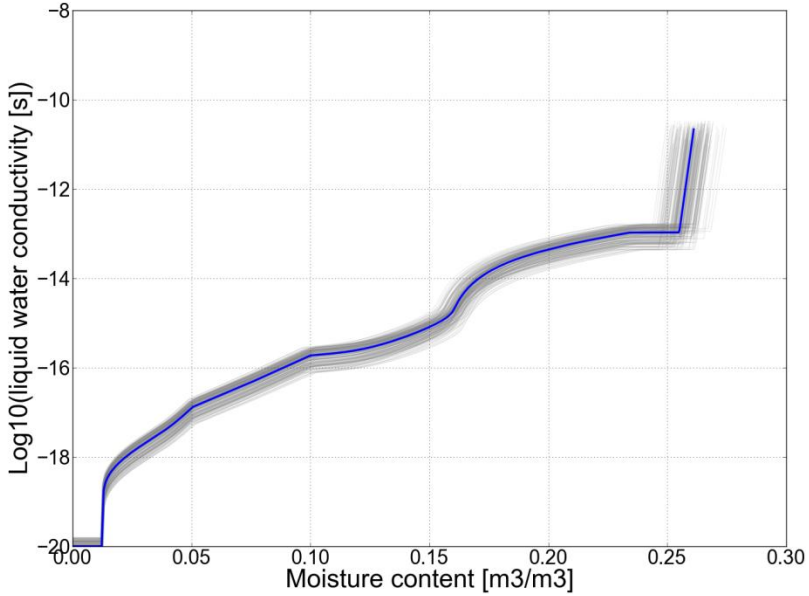


Generated material functions

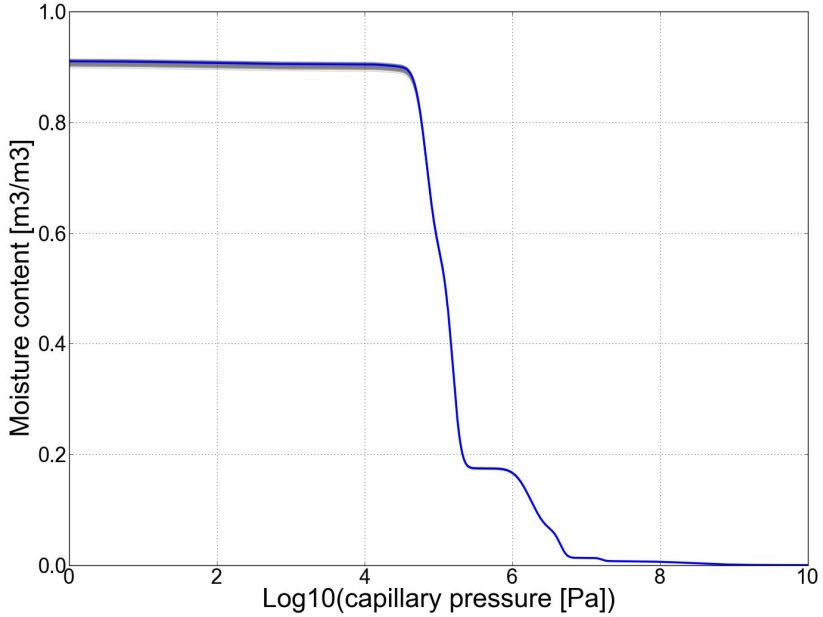


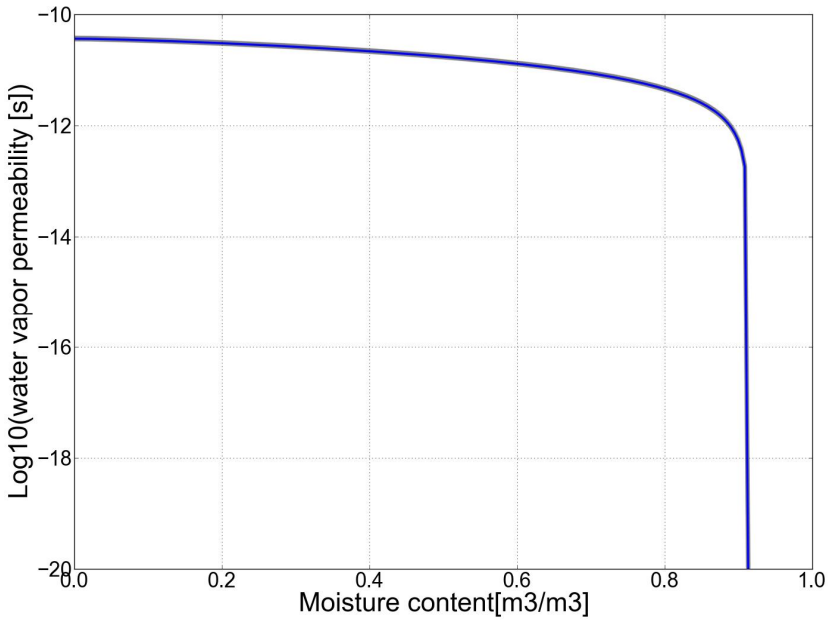


Calcium silicate glue mortar

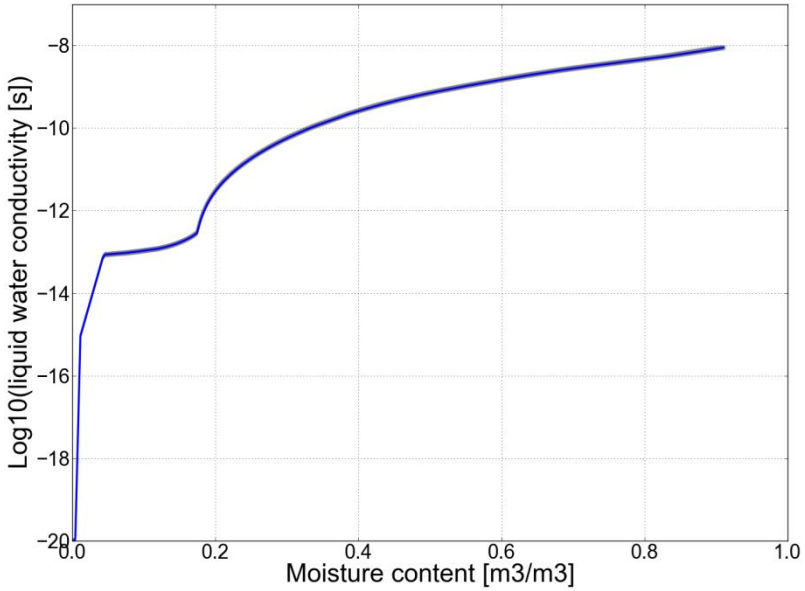


Generated material functions

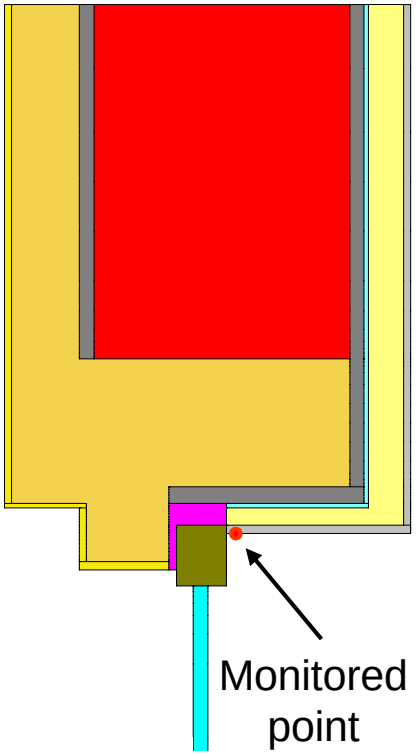


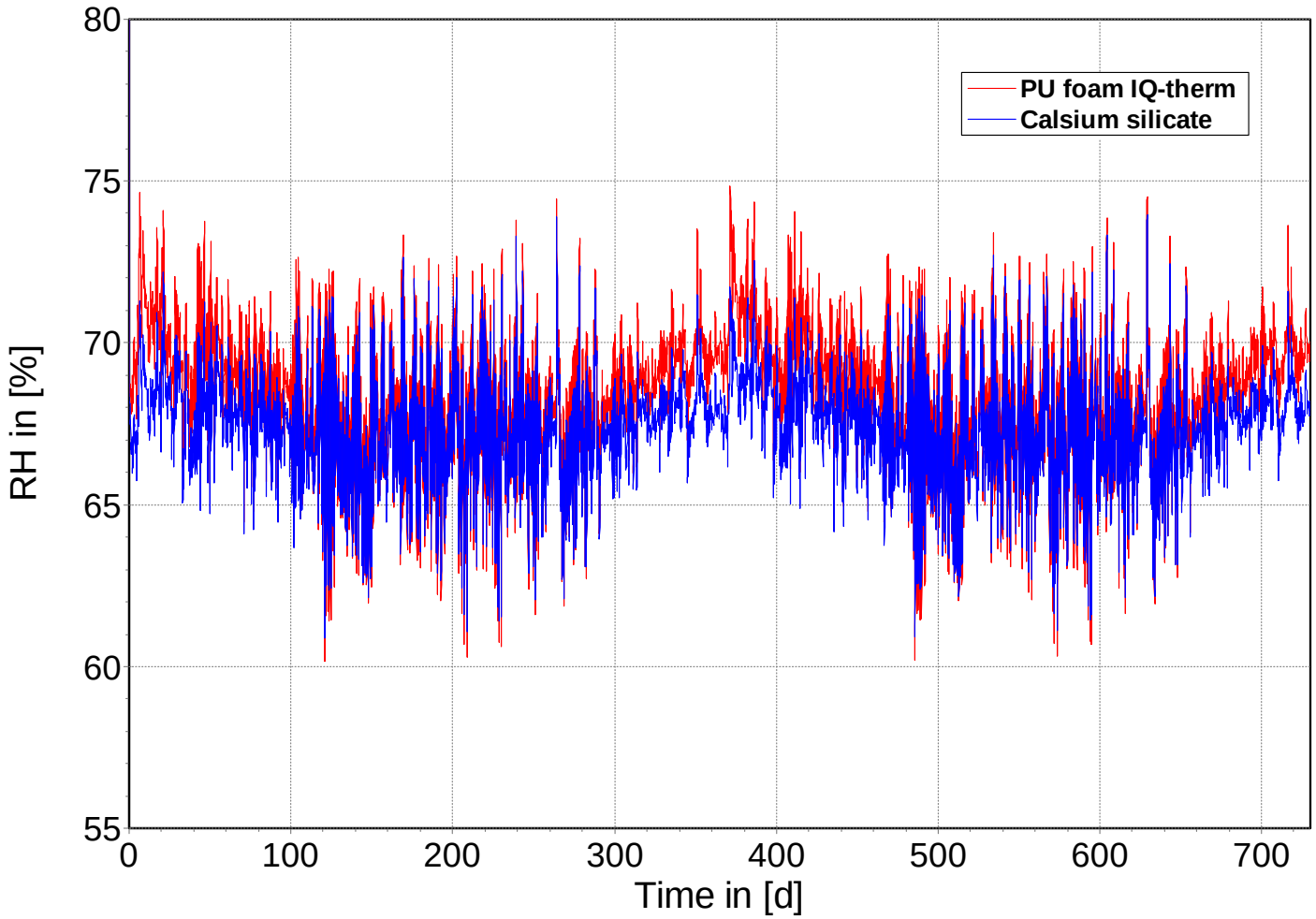


Calcium silicate

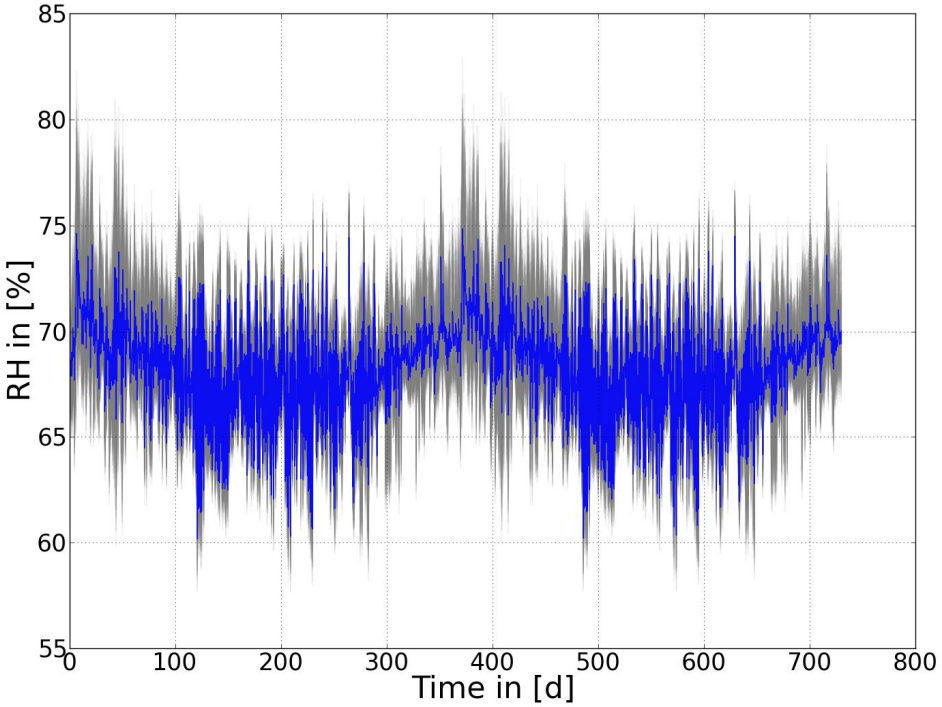


Comparison of deterministic relative humidity profiles

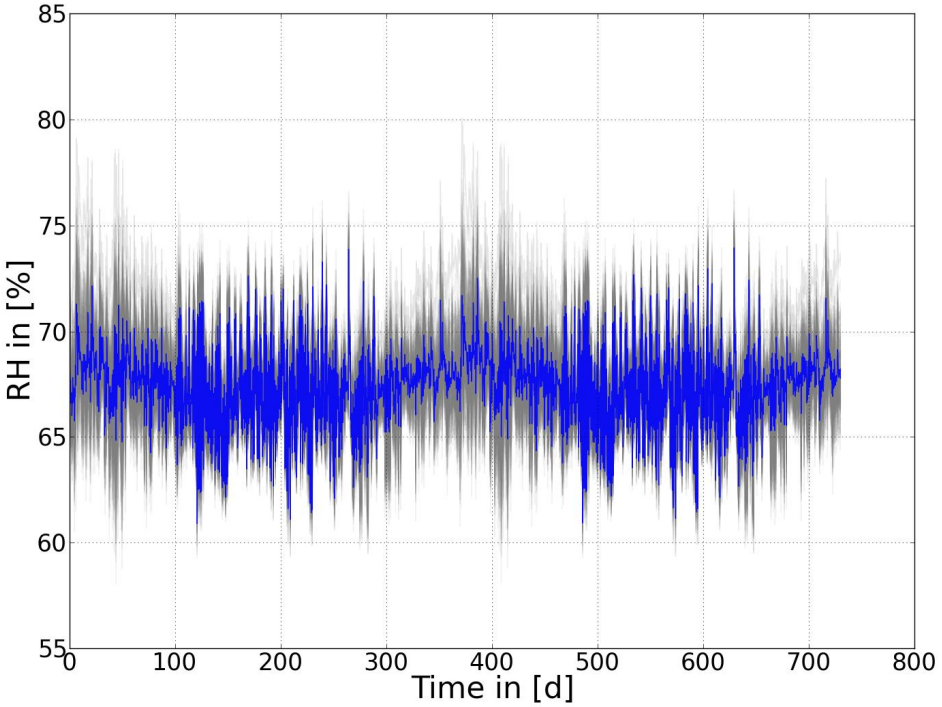




The relative humidity profiles by Monte Carlo simulation



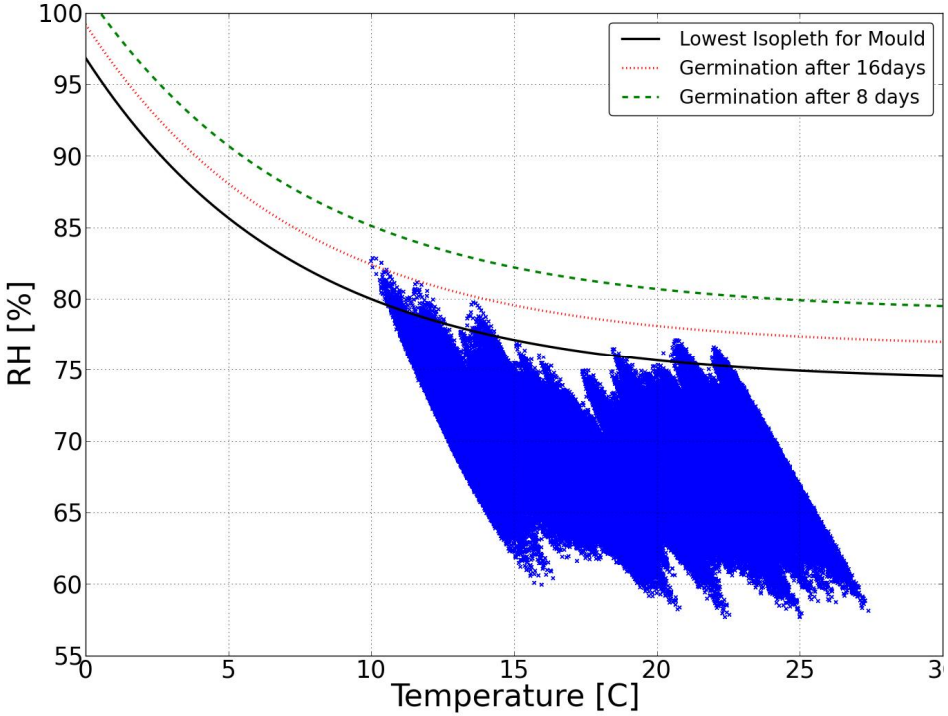
a) PU foam IQ-therm



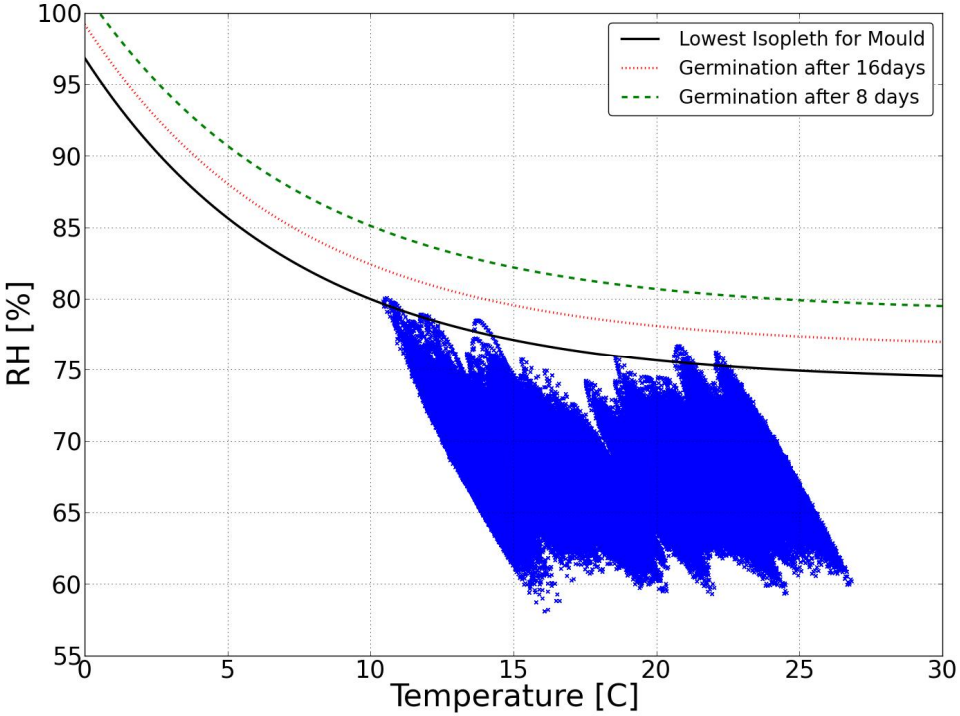
b) Calcium silicate

Isopleth system by using stochastic results

- Hourly value
- Second year data



PU foam IQ-therm



Calcium silicate

Lowest Isopleth for Mould:
0.076% from total 200 cases
spore germination after 16 days:
0.00028% from total 200 cases

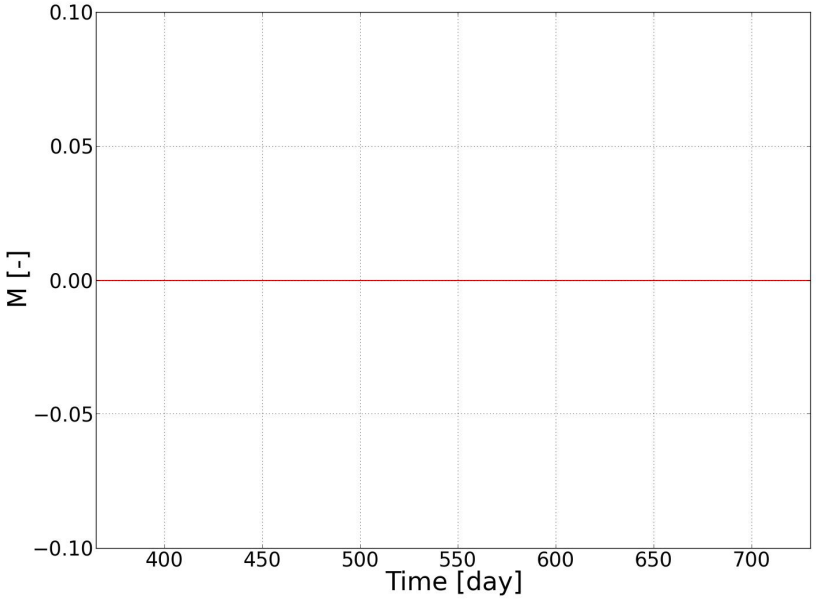
Lowest Isopleth for Mould:
0.0086% from total 200 cases
spore germination after 16 days:
no data higher than the line

The mould index

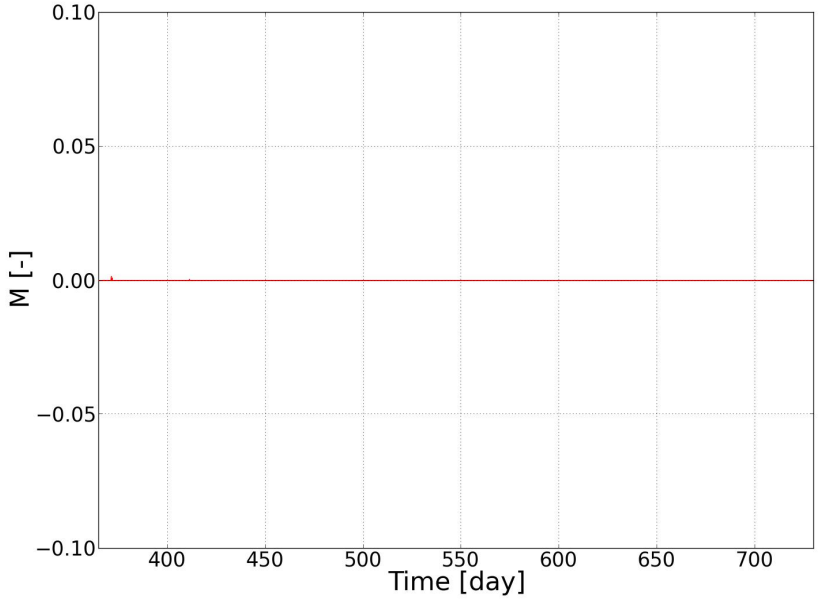
Mould index: based on visual appearance of the substrate surface.

Mould index for experiments and modeling (*Hukka and Viitanen 1999)*

Mould index	Description
0	no growth
1	some growth detected only with microscopy
2	moderate growth detected with microscopy (coverage more than 10%)
3	some growth detected visually
4	visually detected coverage more than 10%
5	visually detected coverage more than 50%
6	visually detected coverage 100%



PU foam IQ-therm



Calcium silicate

Summary

- With the uncertainty involved, the result of HAM simulation is not a deterministic value, but rather a range of possibilities.
- Stochastic method allows the user to assess moisture related risks in a probabilistic way.
- For complex simulation stochastic calculations consume a large amount of resources, e.g. require long-time calculation, high-efficient computers and huge data storage. It is useful and necessary to optimize stochastic design.
- Reliable input data are also the prerequisite for the simulation.
- Other factors, such as uncertainties in indoor and outdoor conditions, need to be further modeled.

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