Investigation of the hygrical-thermal suitability of vacuum insulation boards for refurbishing of Viennese “Gründerzeit”-buildings

Jürgen Dreyer, Azra Korjenic

TU Archiv

Das polytechnische Institut in Wien, erbaut 1816.

Max Theuer, um 1915 (Entstand um 1816)

University of Technology Vienna

Institute for Building Construction and Technology

Department of Building Physics and building acoustics





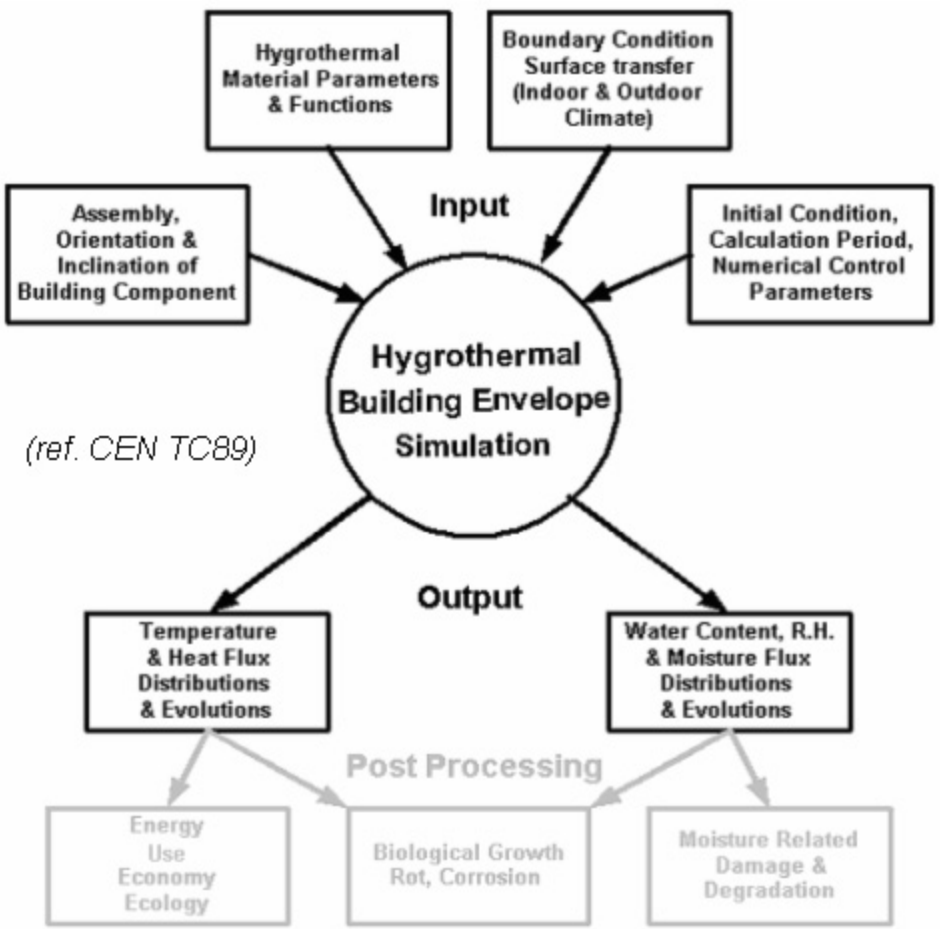




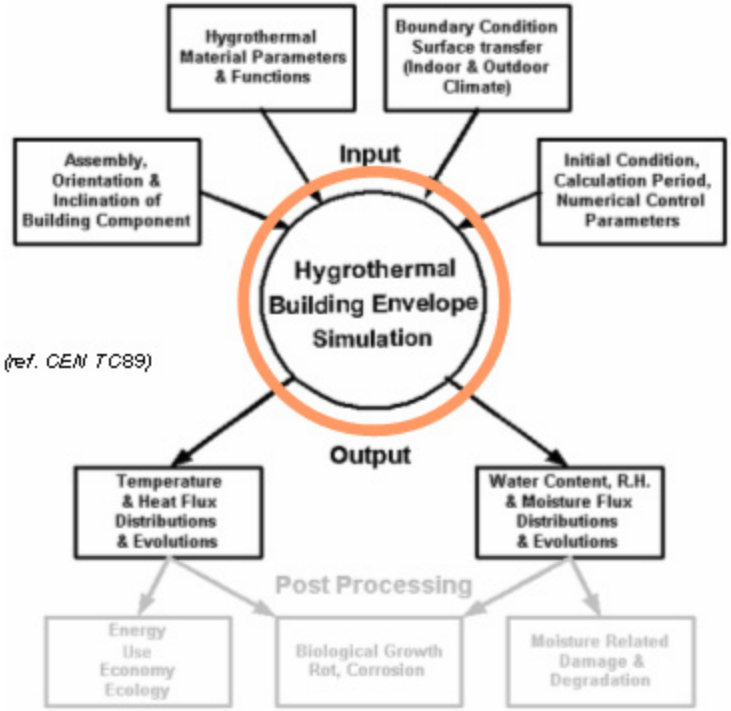


Advantages
• reducing the thickness of insulation systems to 1 ... 2 cm
• improving of the U-value smaller than 0,3 W/m²·K

For evaluation of the hygrothermal behaviour the processes must be known



For evaluation of the hygrothermal behaviour the processes must be known



Heat Transfer

Heat Storage

$$\left(c_{p,s} \cdot \rho_s + c_{p,l} \cdot w_l\right) \cdot \frac{\partial T}{\partial t} = -\frac{\partial q}{\partial x}$$

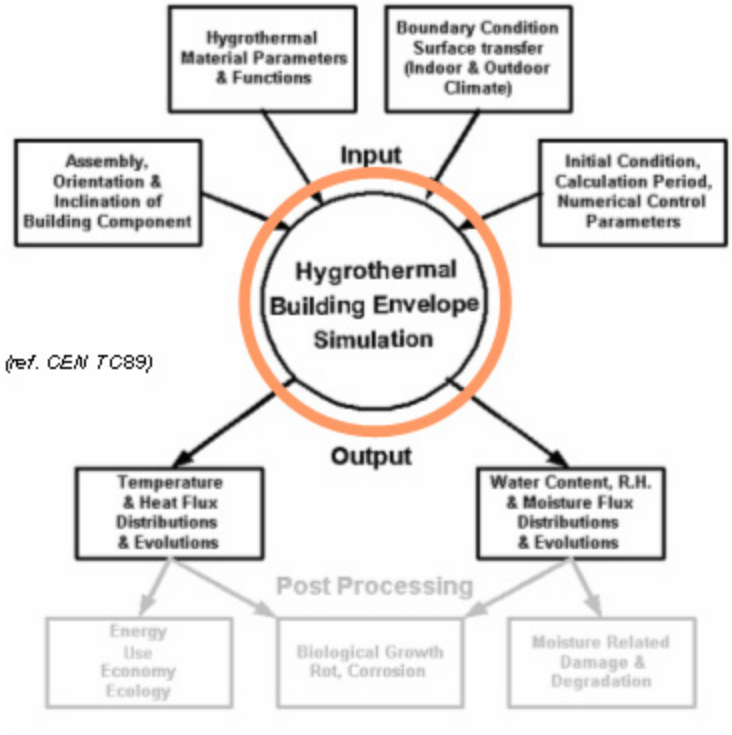
$$q = q_{cd} + q_{cv}$$

$$\left(q = q_{cond} + q_{conv} = q_{cond} + q_{conv,sensible} + q_{conv,latent}\right)$$

cd.. Heat conductivity

cv.. Heat convection

For evaluation of the hygrothermal behaviour the processes must be known



Moisture Transfer

$$\frac{\partial w}{\partial t} = -\frac{\partial g}{\partial x}$$

moisture storage function $w = w(s)$

$$g = g_v + g_l$$

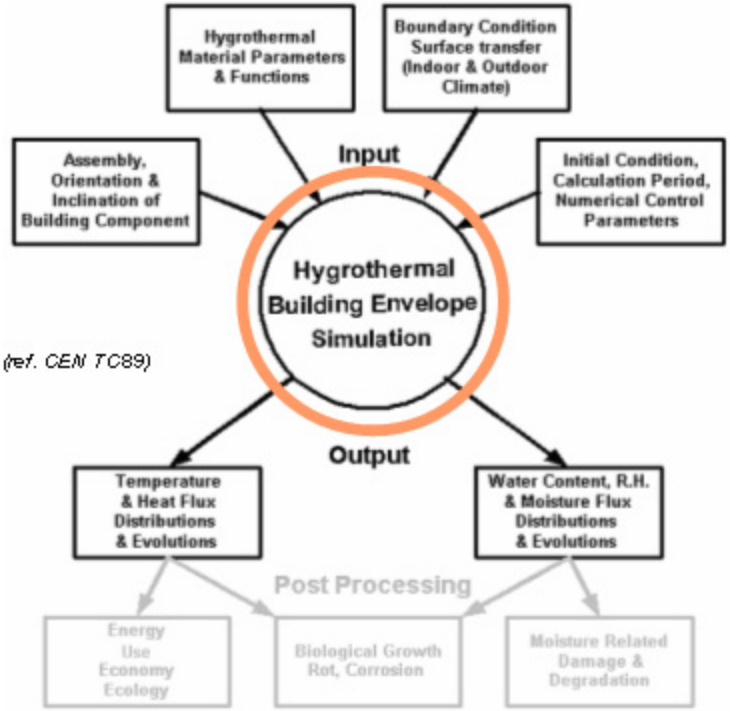
v.. diffusion

l.. Liquid water transfer

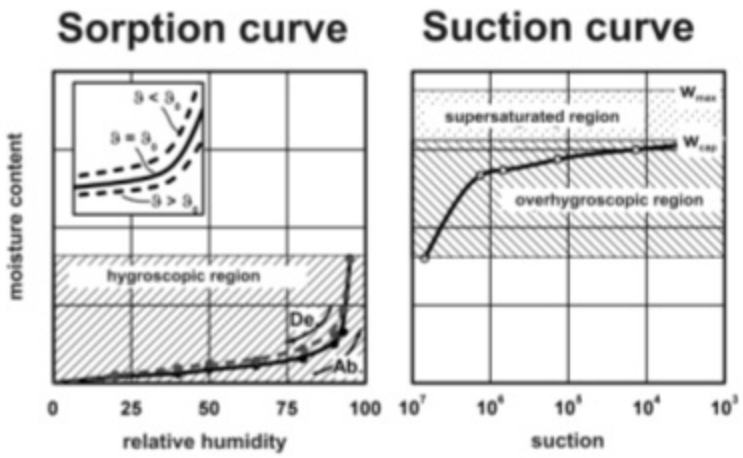
$$g_v = -\frac{1}{\mu(\varphi)} \cdot \delta_0(T) \cdot \frac{\partial p_v}{\partial x} + \frac{g_a}{\rho_a} \cdot \frac{p_v}{R_{H_2O} \cdot T}$$

$$g_l = \underbrace{\lambda_{m,l}(s) \cdot \frac{\partial s}{\partial w}}_{-D_w} \cdot \frac{\partial w}{\partial x} = -D_w \cdot \frac{\partial w}{\partial x}$$

For evaluation of the hygrothermal behaviour the processes must be known

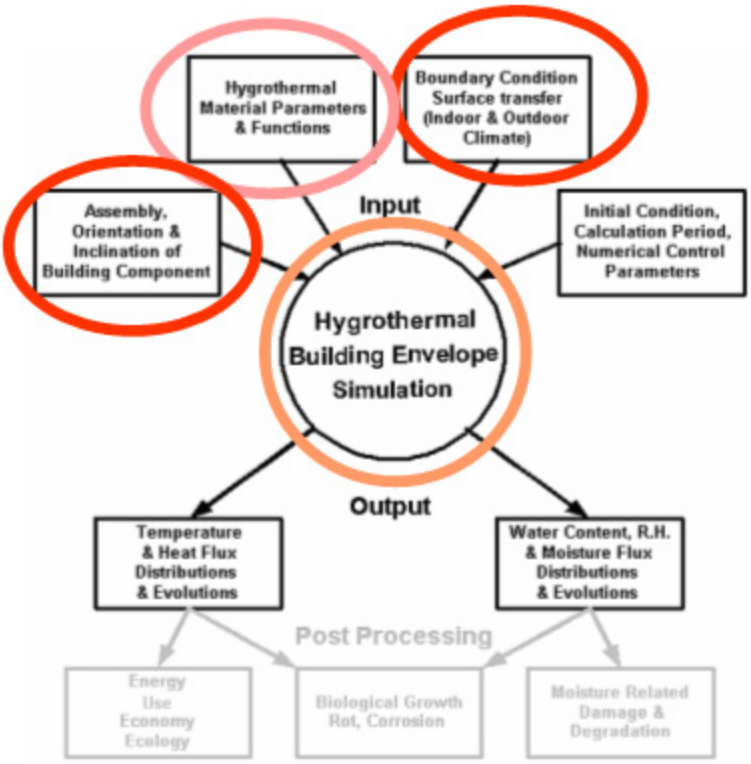


Moisture Storage



For evaluation of the hygrothermal behaviour the processes must be known

Climatic conditions



- temperature
- Water damp partial pressure
- Global radiation
- Middle temperature of the environment
- Air velocity and direction
- Air pressure and pressure difference
- Weathering (rain, snow…)

Configuration of a typical exterior wall

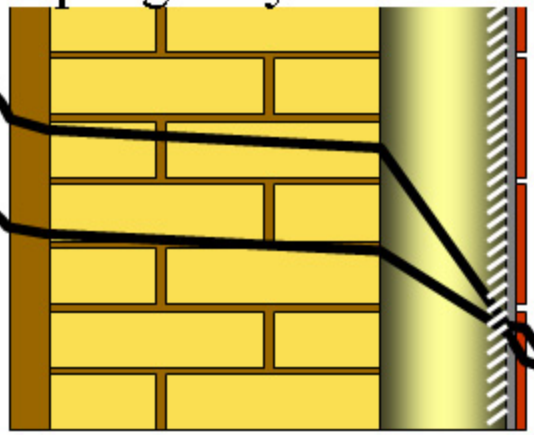
Typical for the architectural style of the period of promoterism architecture is the four or five storey house with rich decorated facades. The design follows the Neo-style of the 19th century (Neo-Gothic style, Neo-Renaissance, German Renaissance, Neo-Baroque).

A typical external wall of those buildings consist of 2cm lime cement render at the outside, 50cm brick masonry and 1,5cm interior plaster.

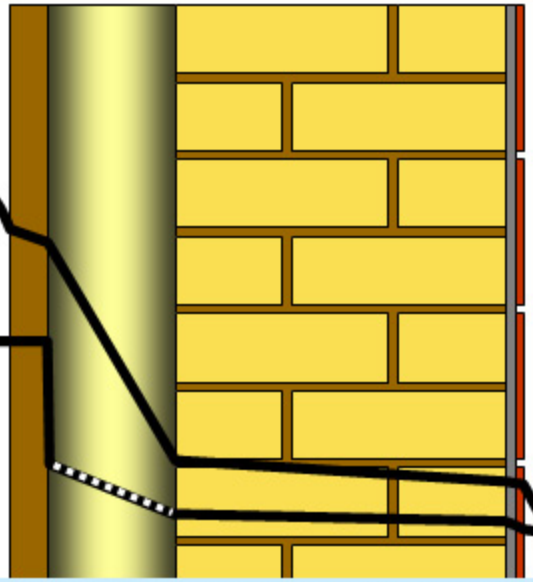
	ρ	λ	μ
	kg/m^3	W/mK	-
Lime cement render	1900	0.8	19
Bricks masonry	1800	0.6	15
plaster	850	0.2	8.3
Vacuum insulation	100	0.0045	1000000

Expectation for using a damp tight system for

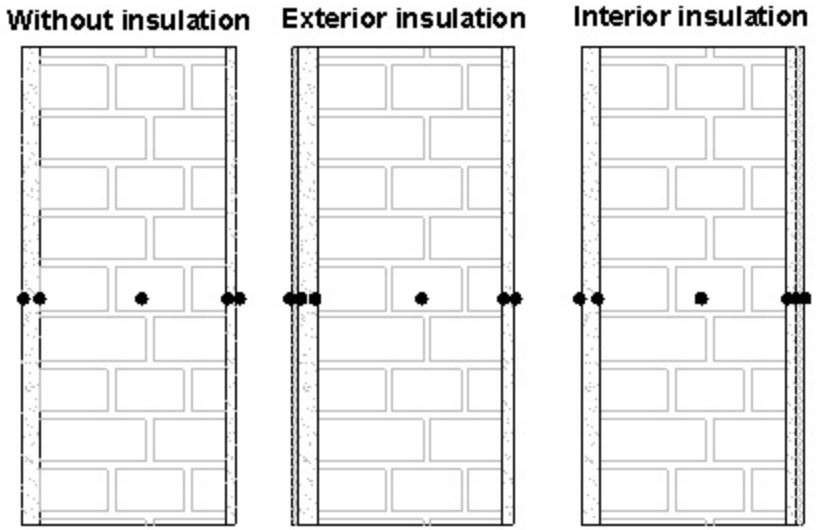
1. Exterior Insulation

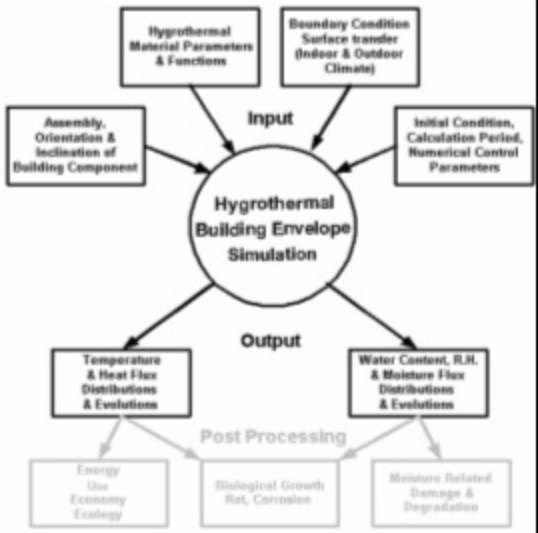


2. Interior Insulation



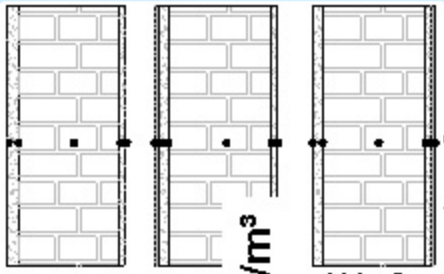
Investigation of the heat and moisture transfer in the exterior wall



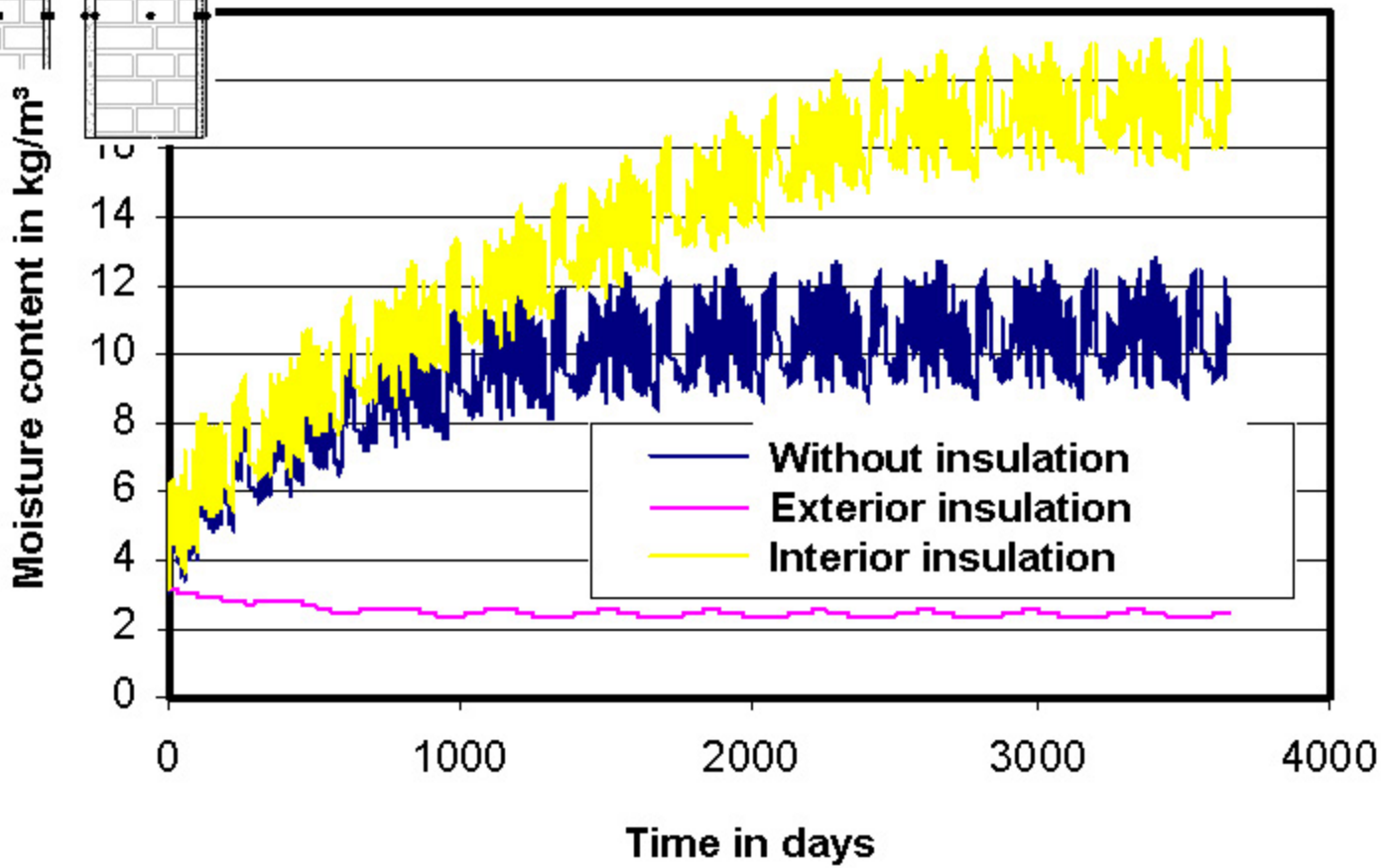


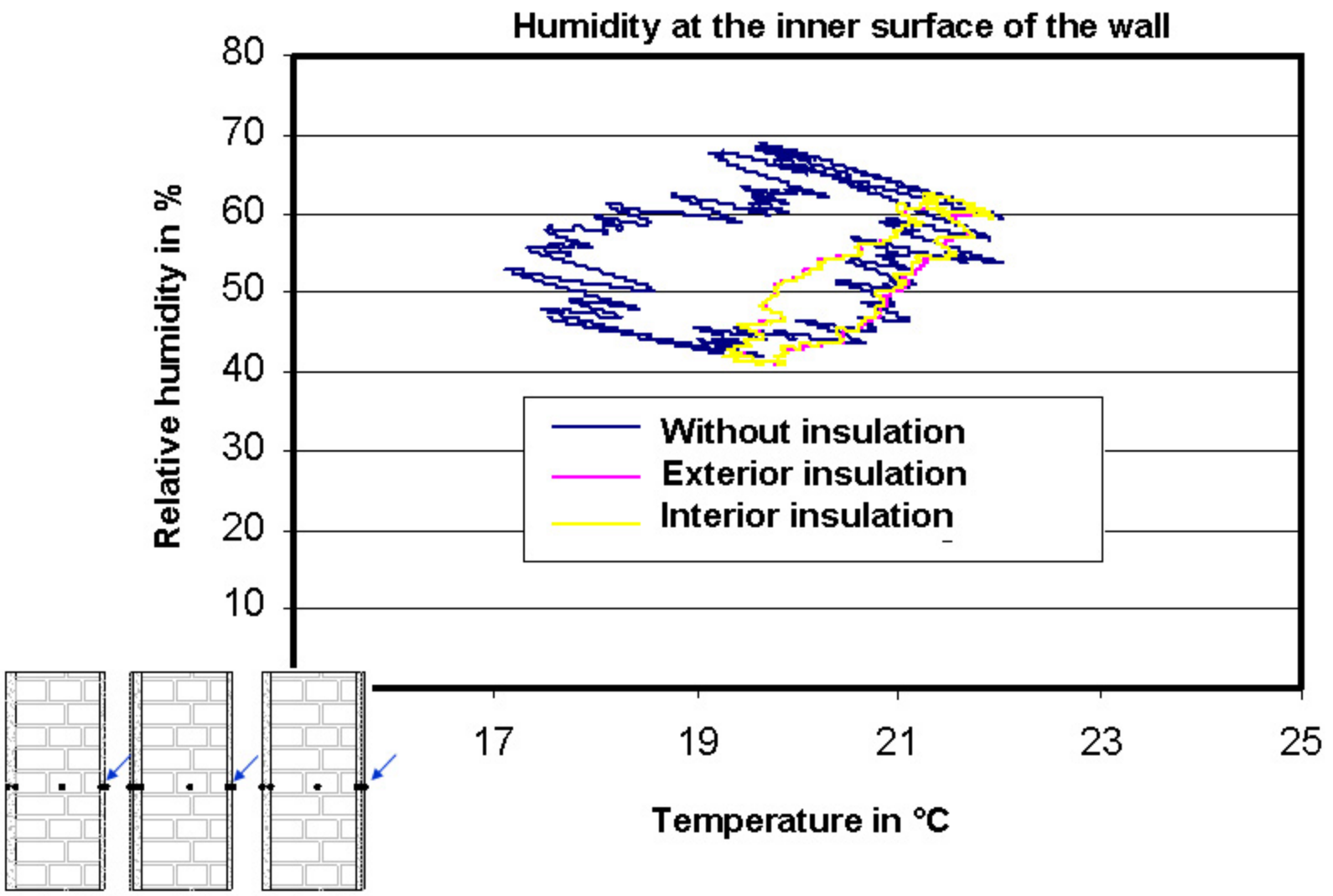
$$\frac{\partial h}{\partial \tau} = \frac{\partial}{\partial x}\lambda(w)\frac{\partial t}{\partial x} + h_{vl}\frac{\partial}{\partial x}\frac{D_{po}}{\mu(w)}\frac{\partial p}{\partial x}$$

$$\frac{\partial w}{\partial \tau} = \frac{\partial}{\partial x}K(w)\frac{\partial p_c}{\partial x} + \frac{\partial}{\partial x}\left(\frac{D_{p0}}{\mu(w)}\right)\frac{\partial p}{\partial x}$$

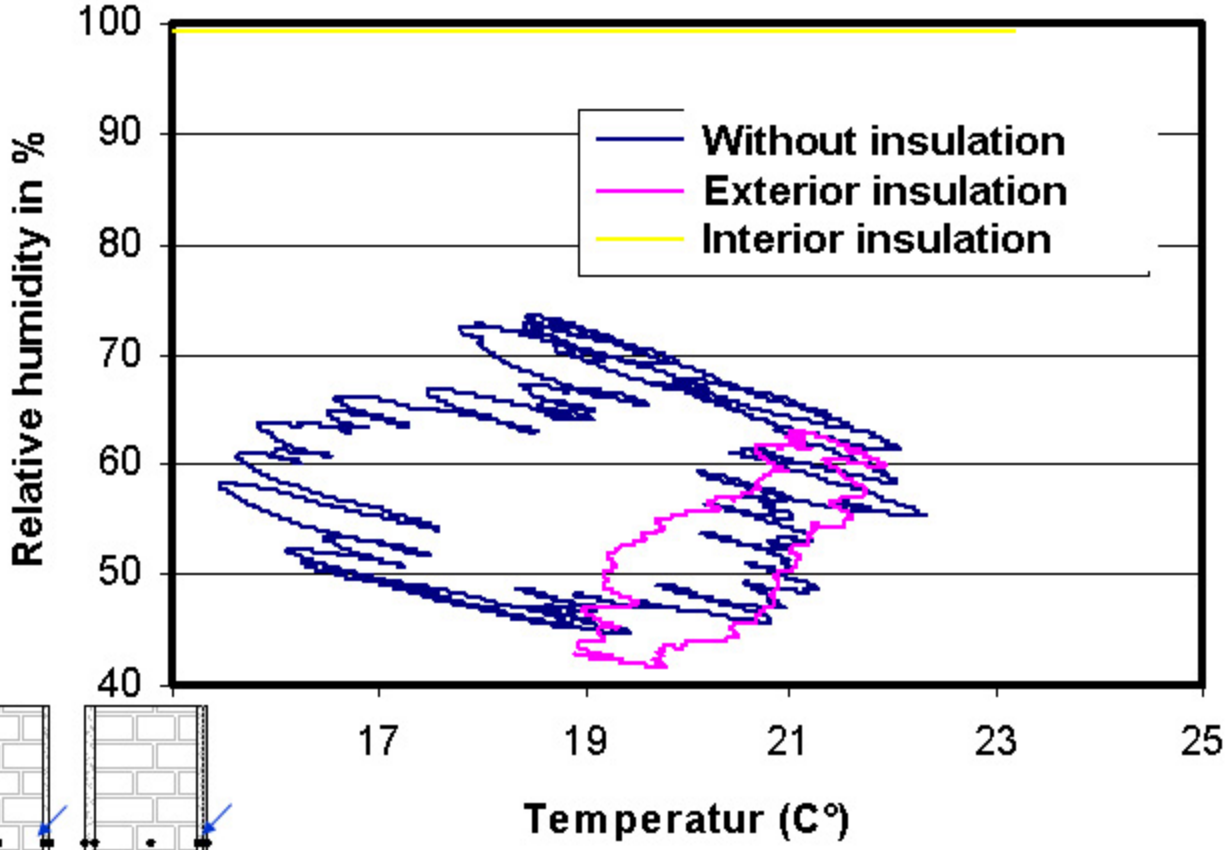


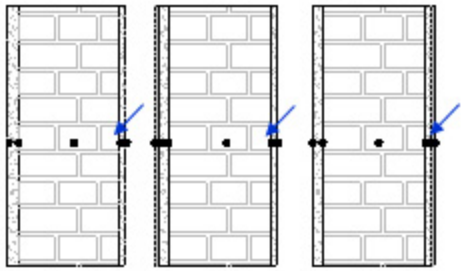
Whole moisture content of the walls

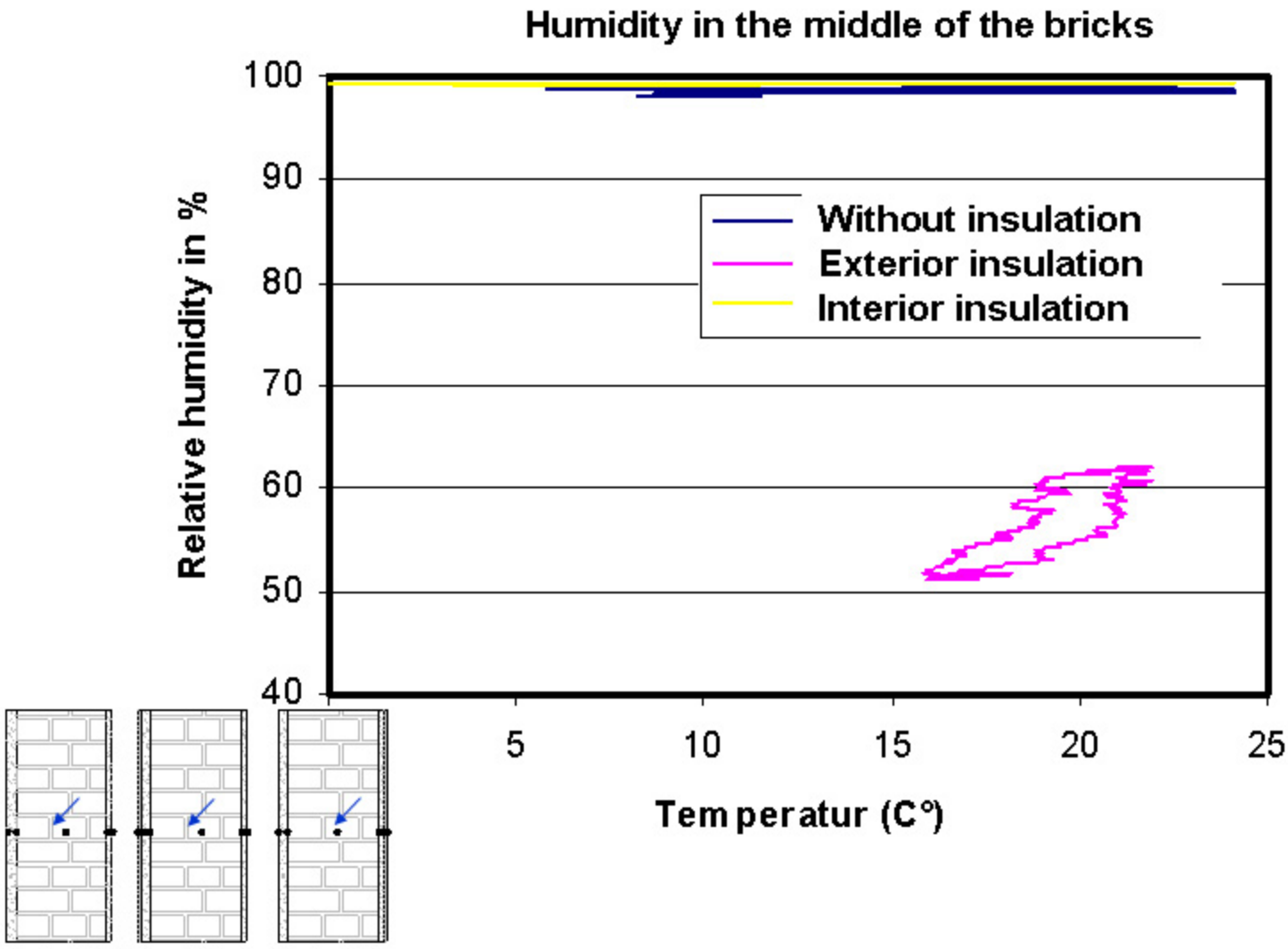



Humidity at the inner surface of the wall
Relative humidity in %
80
70
60
50
40
30
20
10
17
19
21
23
25
Temperature in °C
Without insulation
Exterior insulation
Interior insulation

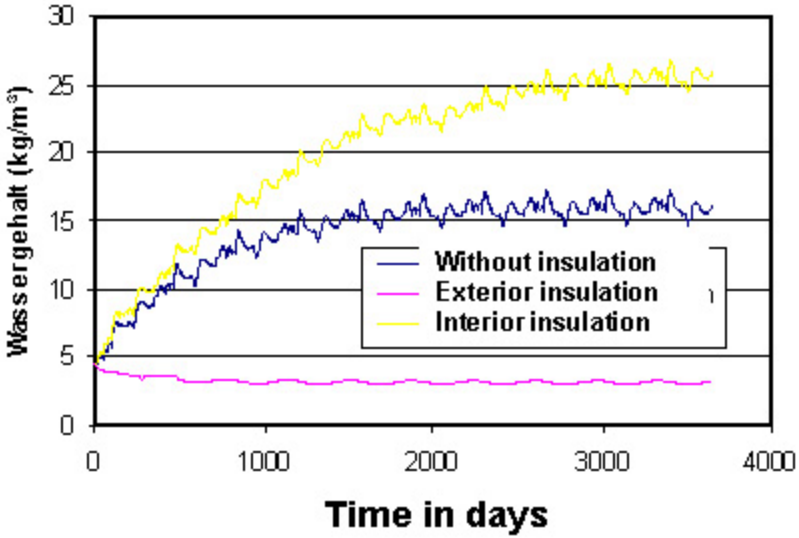
Relative humidity in the former interior plaster



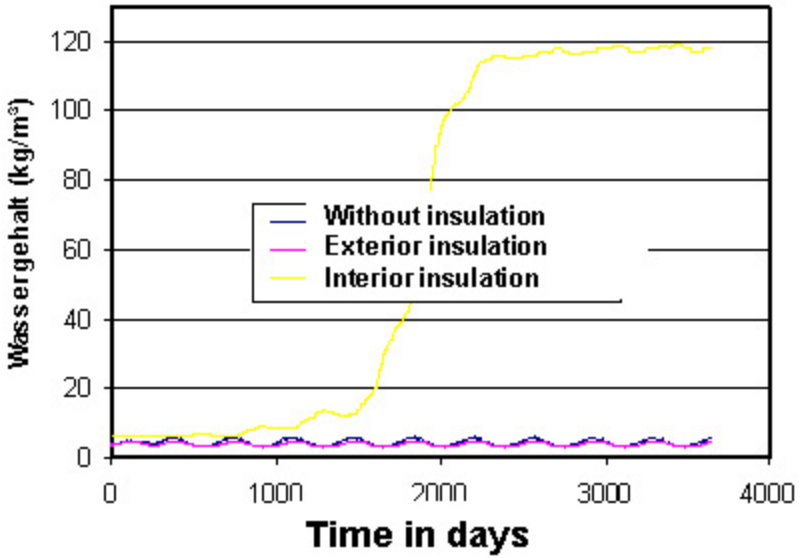


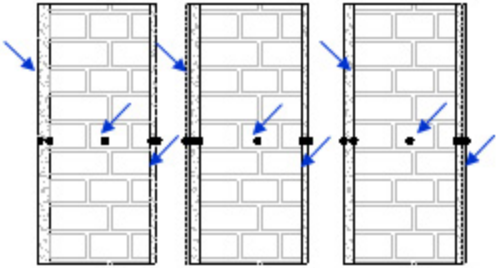

Humidity in the middle of the bricks
Relative humidity in %
100
90
80
70
60
50
40
5
10
15
20
25
Temperatur (C°)
Without insulation
Exterior insulation
Interior insulation

Water content in the bricks

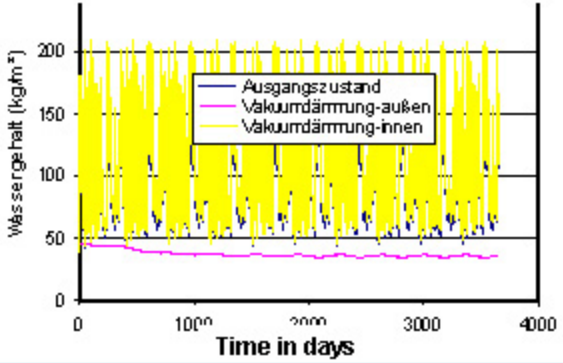


water content in the plaster

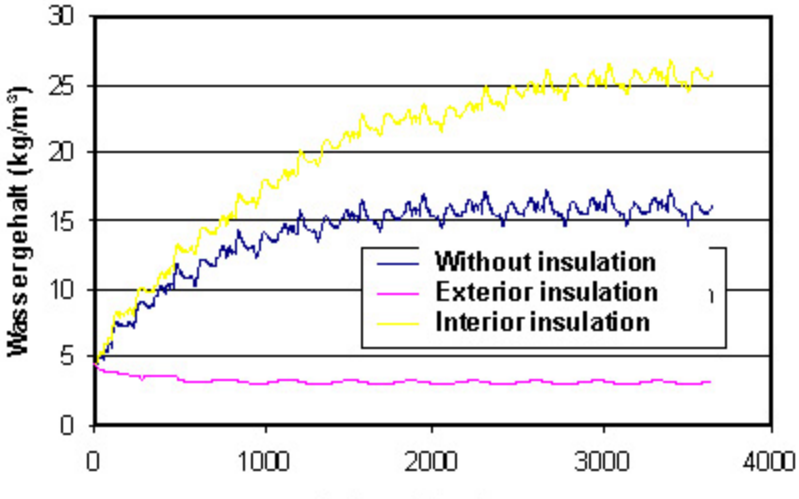




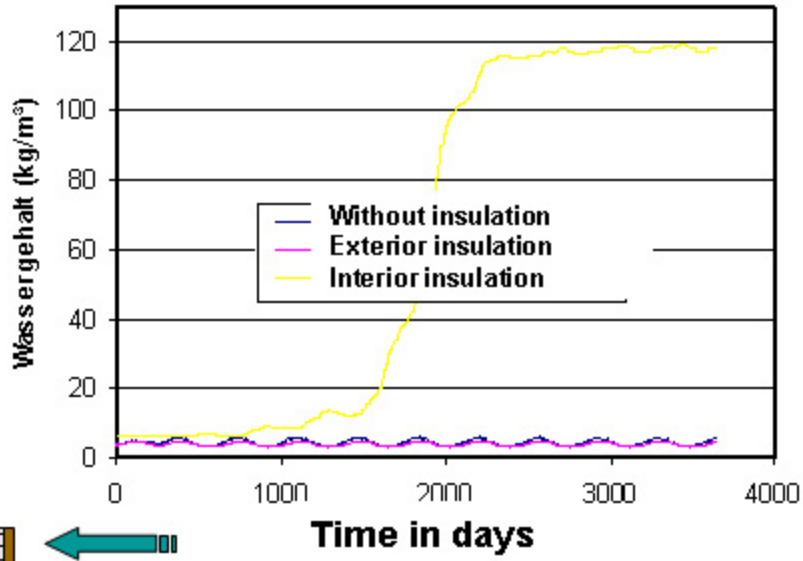
Water content in the exterior render

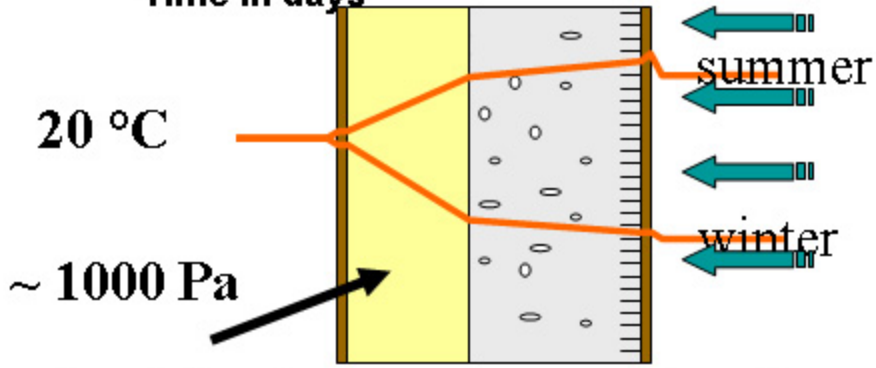


Water content in the bricks



water content in the plaster





20 °C

-5 °C Driving rain

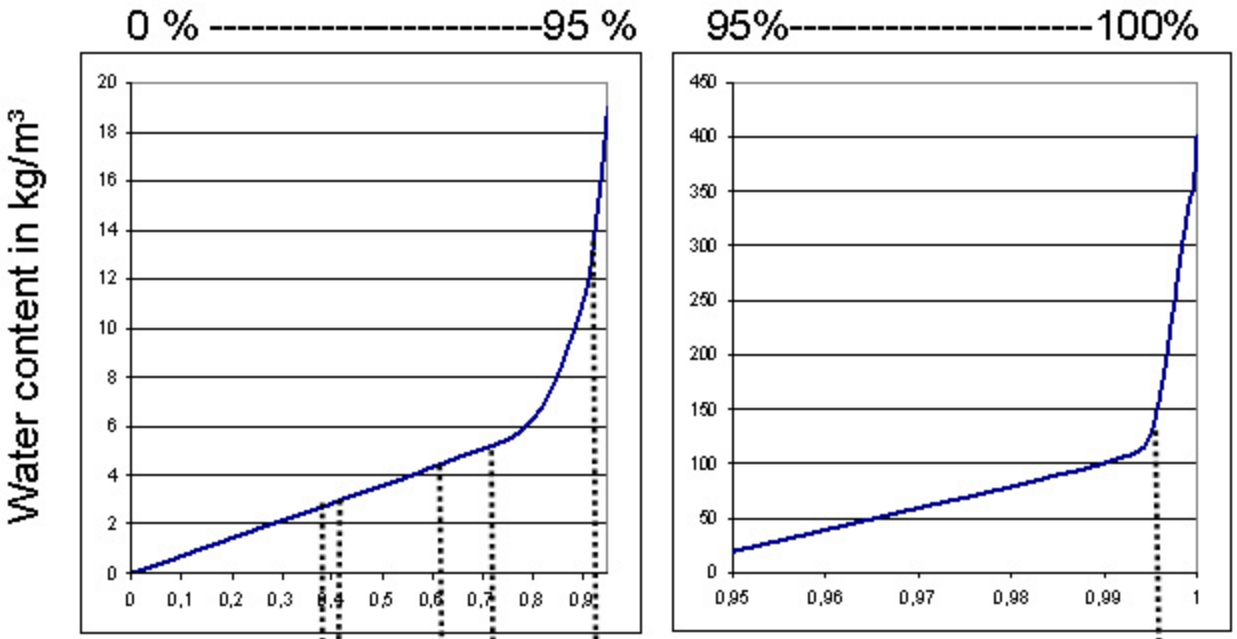
~ 1000 Pa

~ 200 Pa

Interior Insulation board

construction with interior insulation

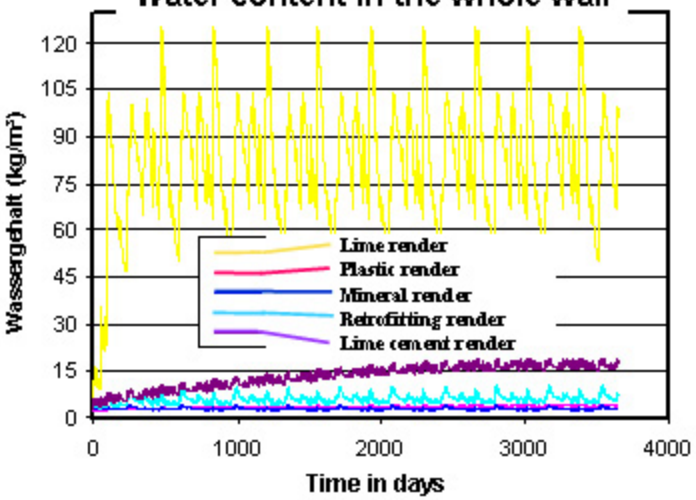
Sorption isotherm for plaster



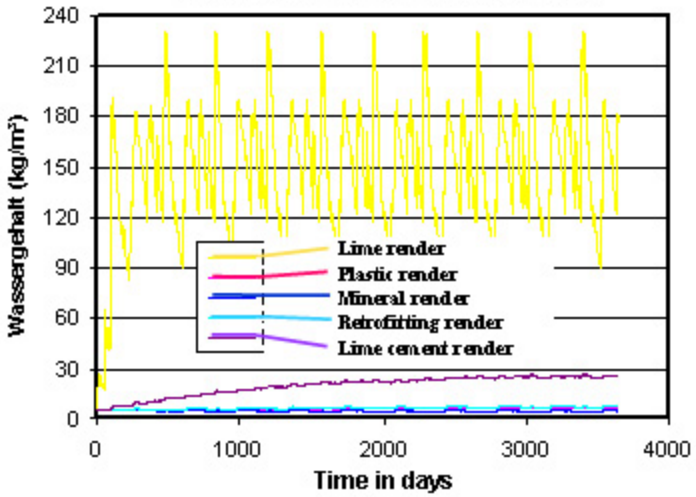
Change of the relative humidity in the former interior plaster for the cases:

Without insulation
Exterior insulation
Interior insulation

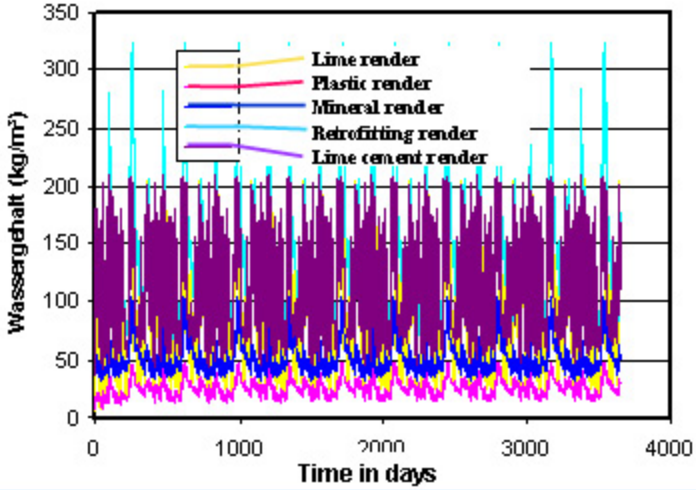
Water content in the whole wall



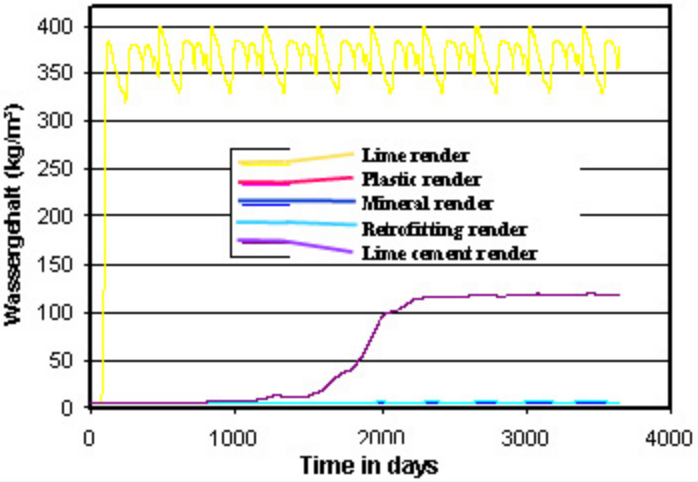
Water content in the bricks



Water content in the exterior render

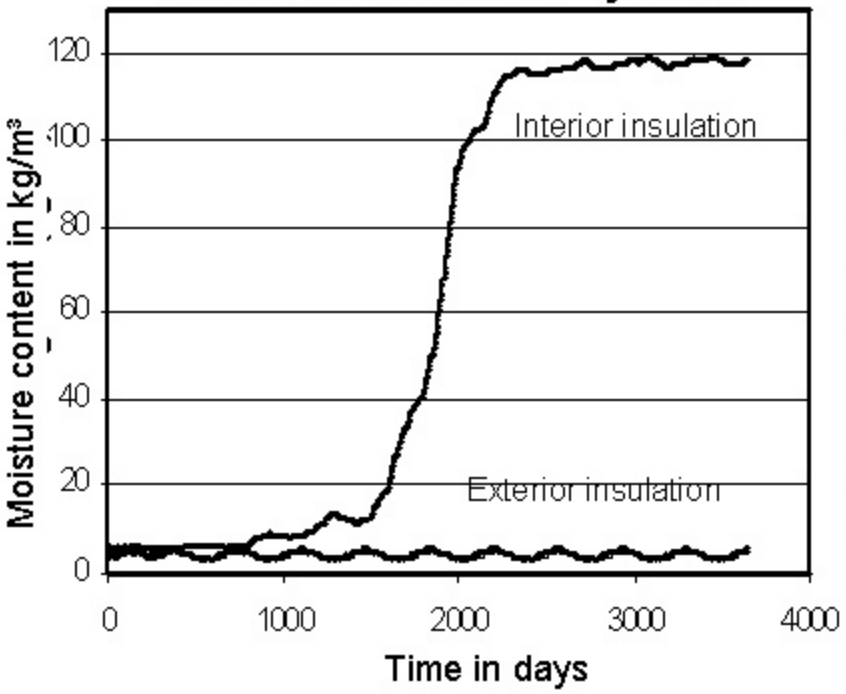


Water content in the plaster

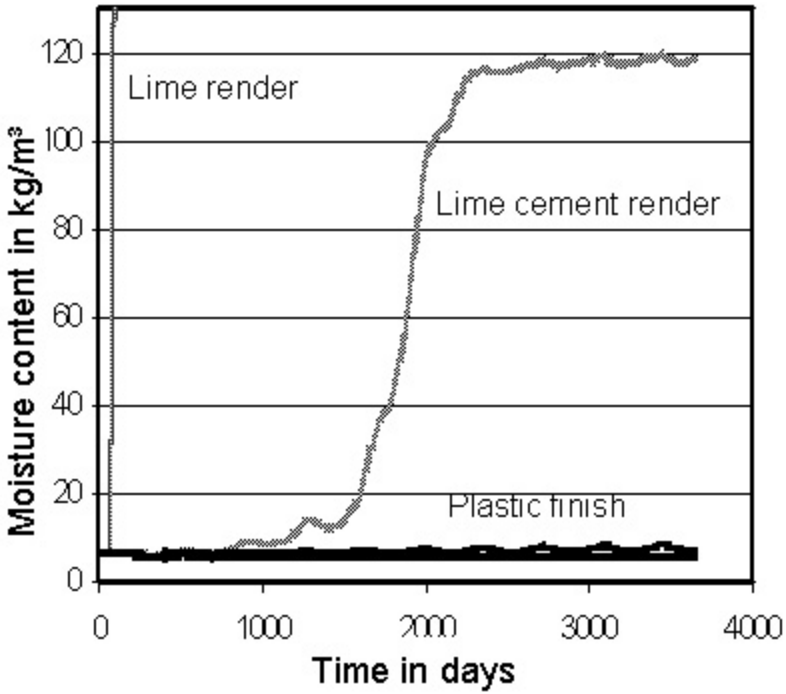


Moisture content of the former interior plaster

Influence of interior and exterior insulation with vacuum insulation systems



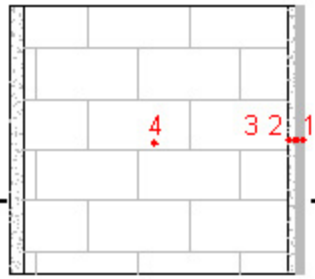
Influence of different exterior render systems



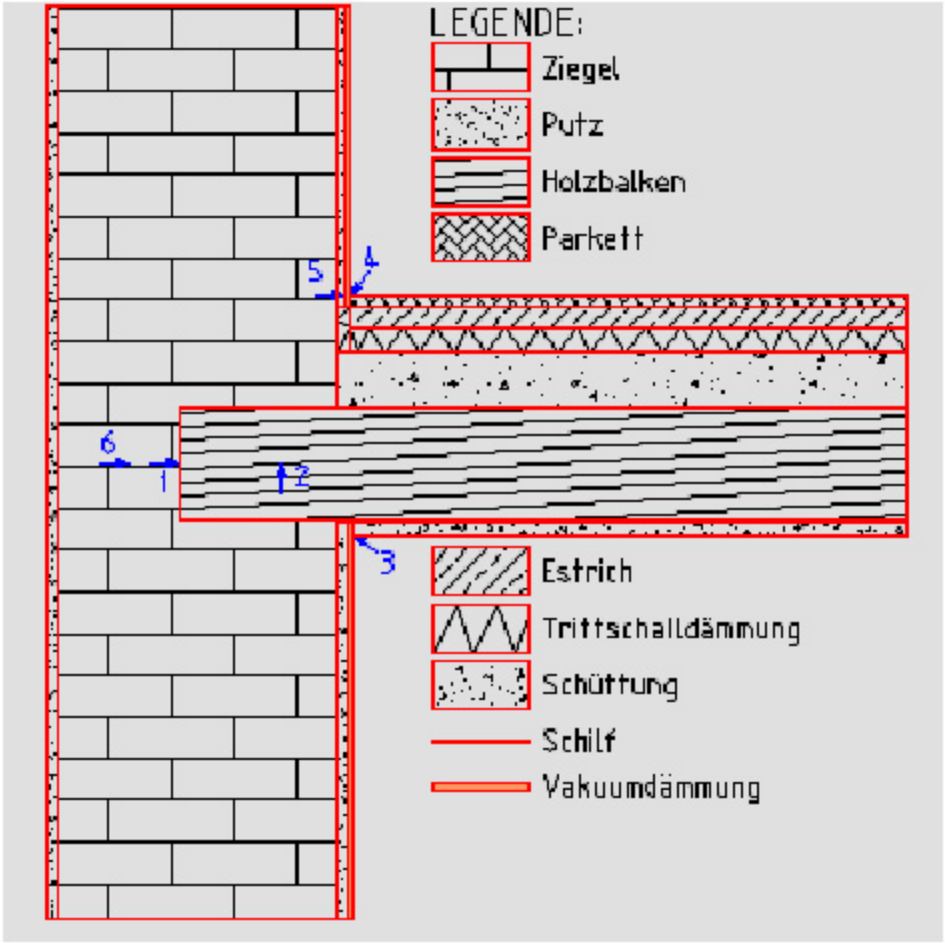
Influence of the climatic data

relative humidity at several points for an wall with interior vacuum insulation

Climate	Point	Temperature (C°)	rel. Humidity (%)	Whole moisture content (kg/m²)
Vienna	1	18,1 - 22,0	41,5 - 66,0	16,9 - 19,2
	2	9,5 - 23,0	99,1 - 99,2	
	3	9,0 - 23,0	99,1 - 99,2	
	4	2,7 - 24,3	99,1 - 99,3	
Holzkirchen (Bavaria)	1	19,1 - 21,6	41,2 - 63,1	34,7 - 40,2
	2	-2,0 - 23,8	99,7 - 99,8	
	3	-2,2 - 23,9	99,7 - 99,8	
	4	-6,2 - 25,2	99,7 - 99,8	

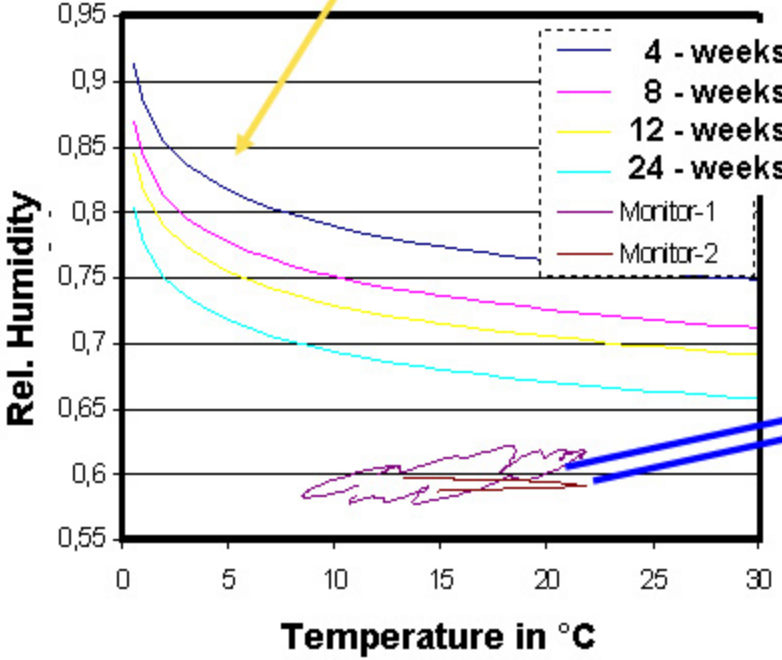


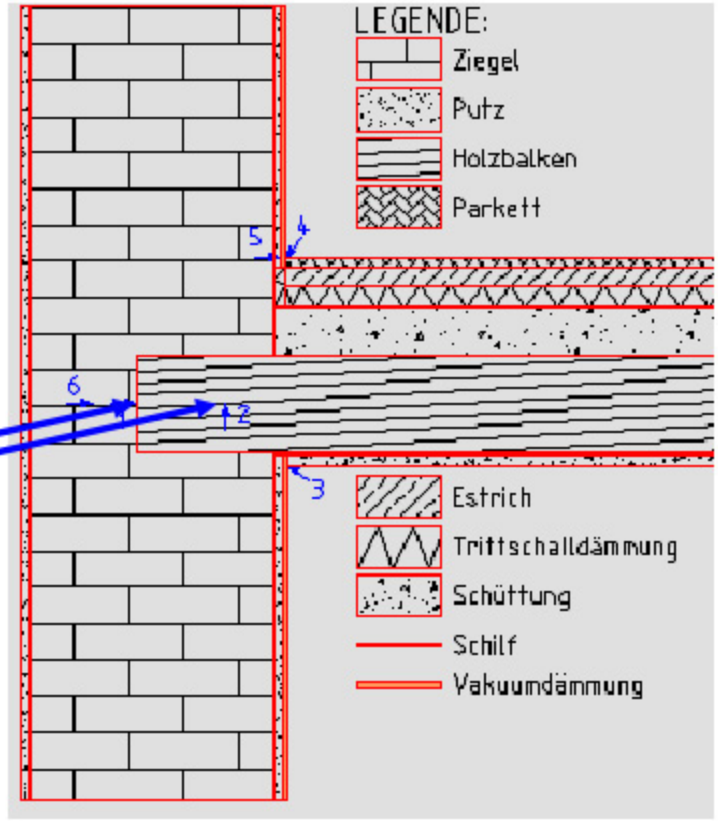
Thermal Bridge Problem "Floor Beam"



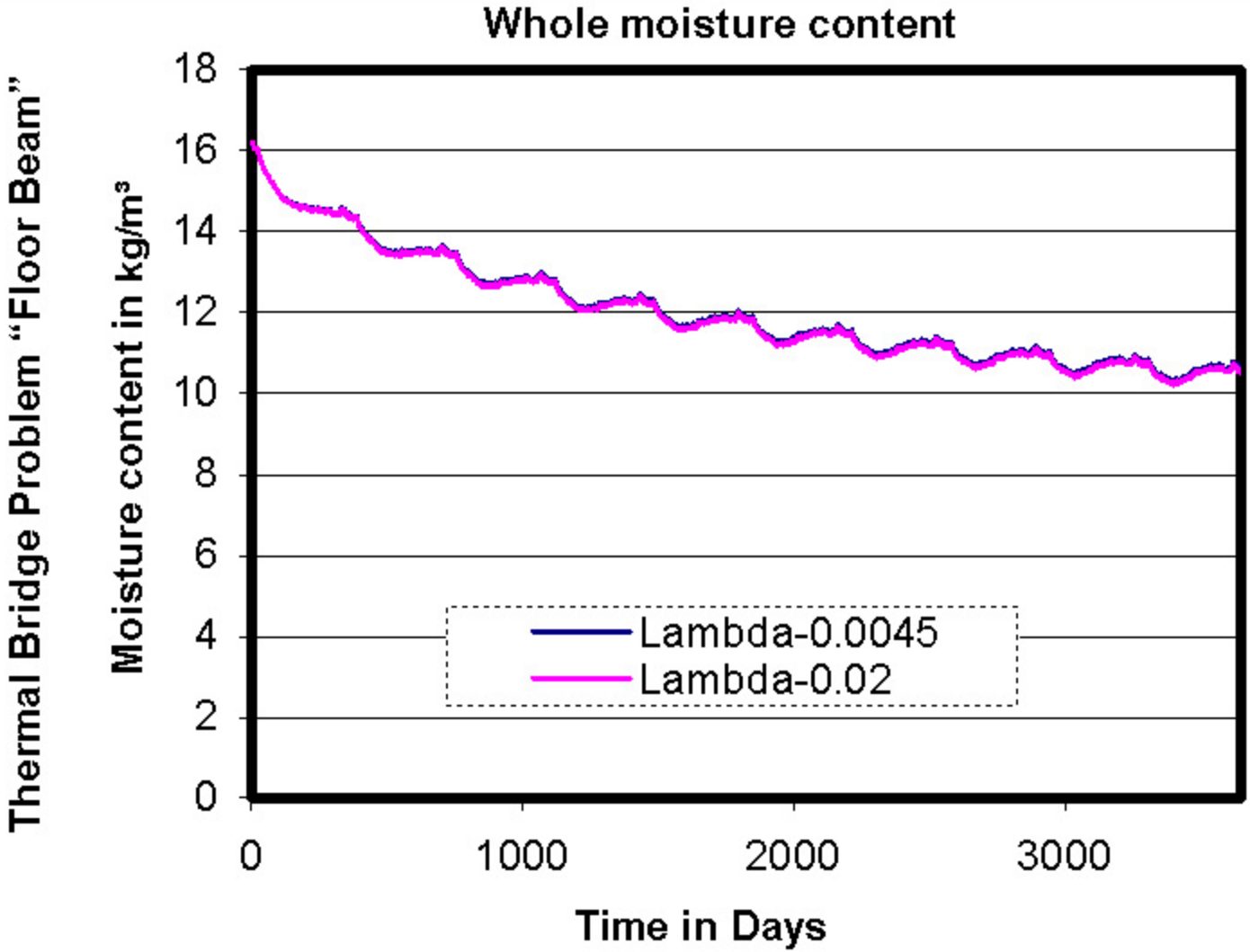
Thermal Bridge Problem "Floor Beam"

Start conditions for growth of mould and rottenness of wood



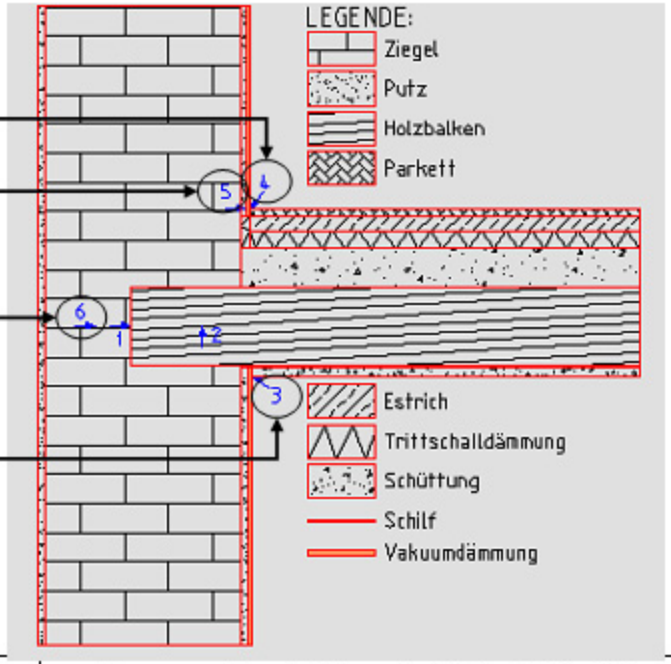


inside insulation


Whole moisture content
Thermal Bridge Problem "Floor Beam"
Moisture content in kg/m³
18
16
14
12
10
8
6
4
2
0
0
1000
2000
3000
Time in Days
Lambda-0.0045
Lambda-0.02

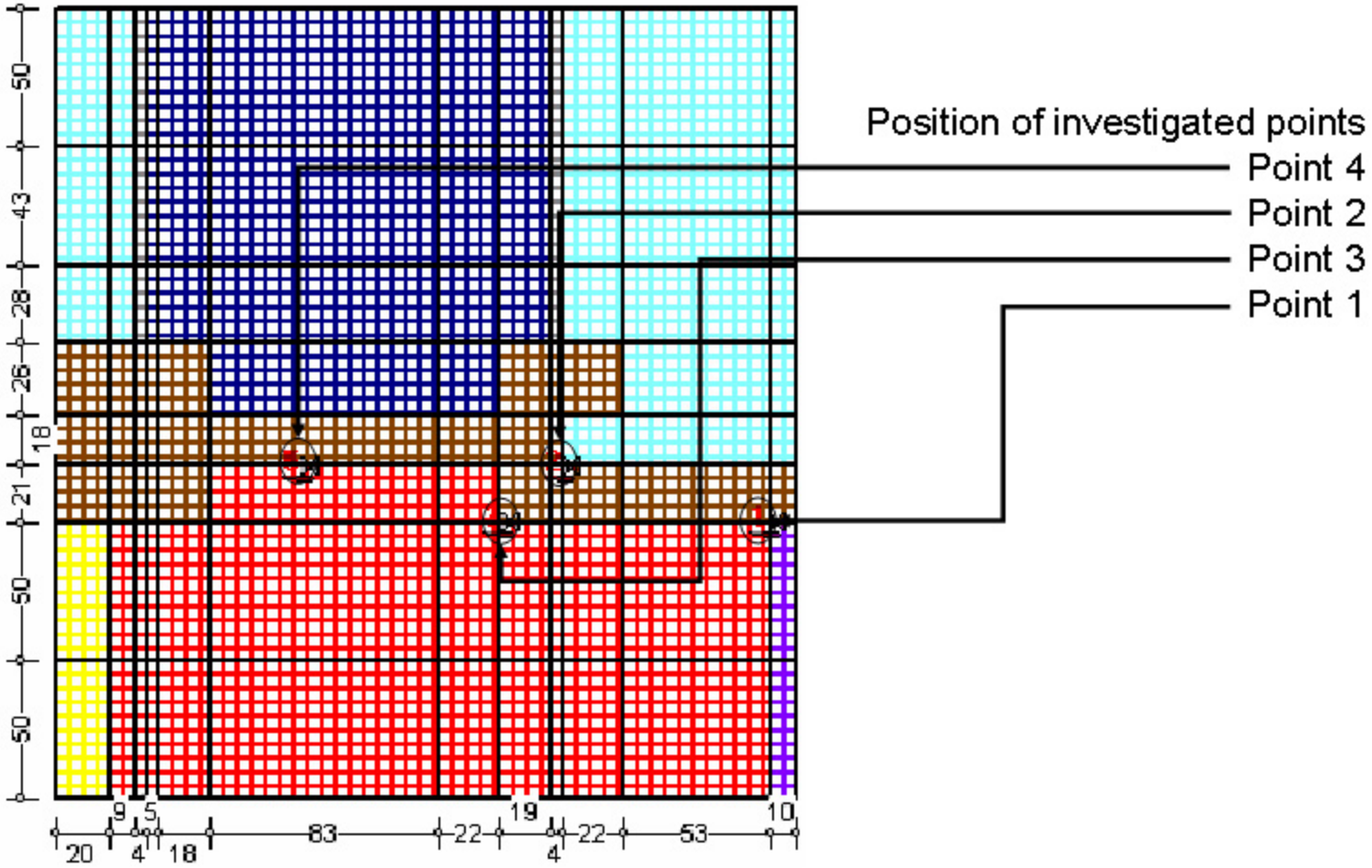
Thermal Bridge Problems

Position of investigated points
Point 4
Point 5
Point 6
Point 3

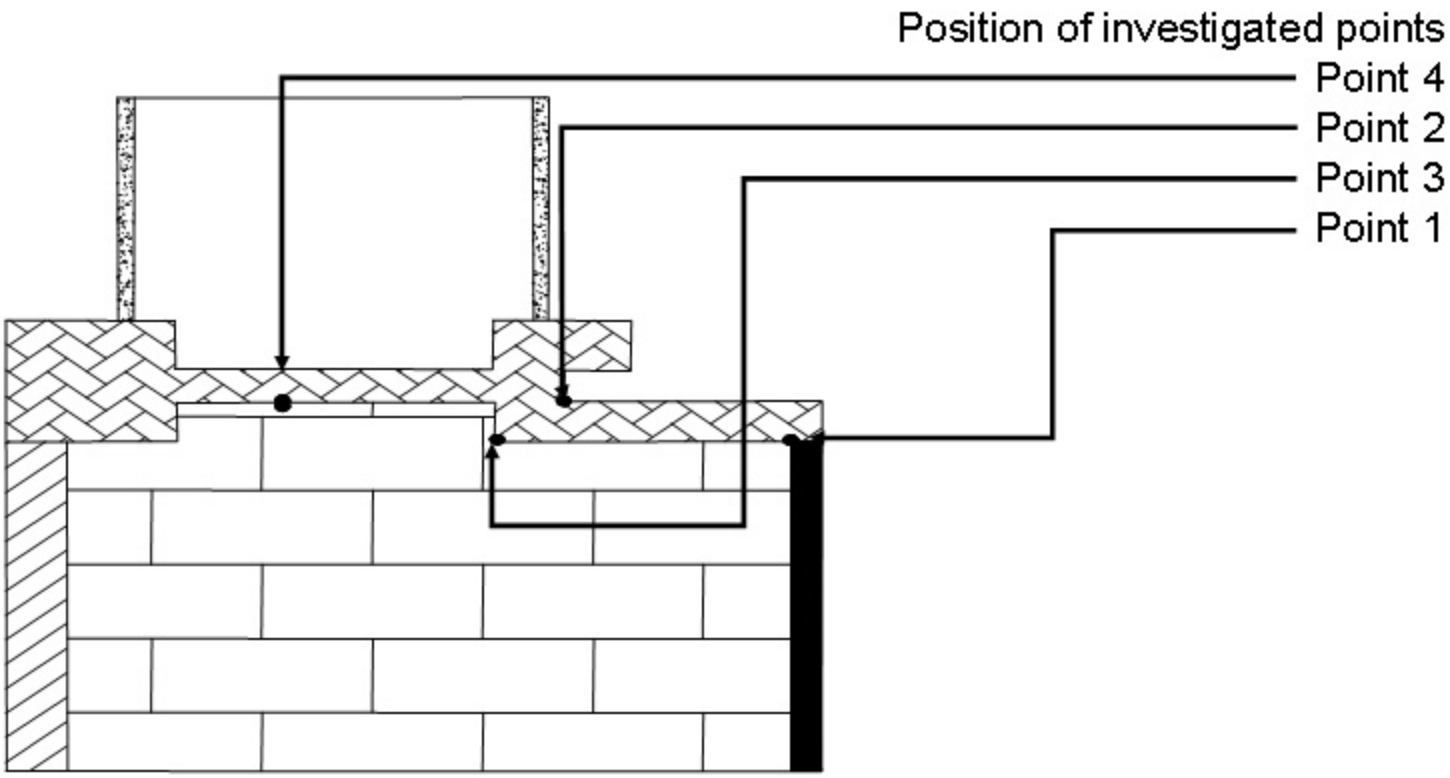


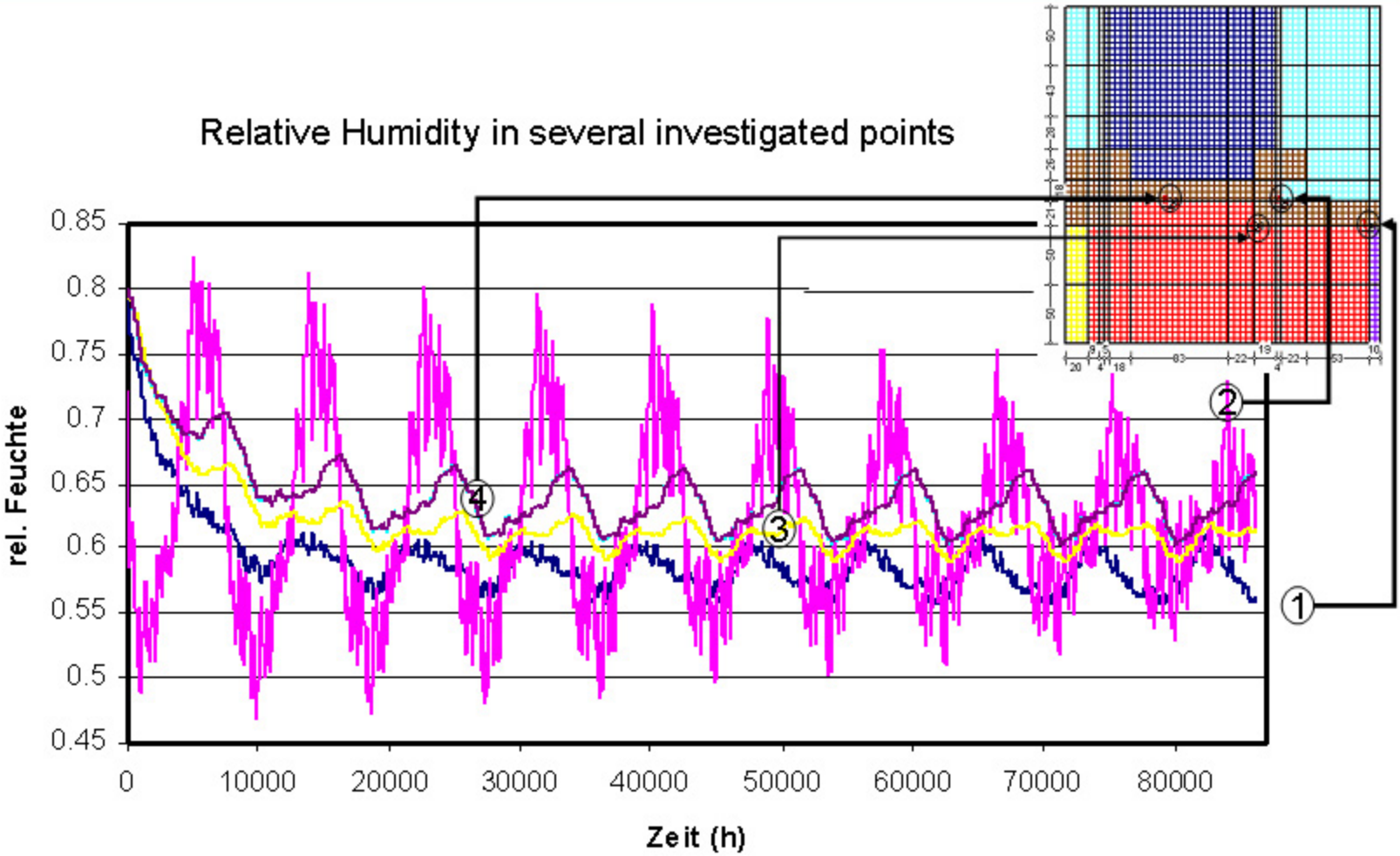
Monitor Nr.	Vacuum insulation λ=0.0045 [W/mK]		Vacuum insulation λ=0.02 [W/mK]	
	Temperature [°C]	Rel. Humidity [%]	Temperature [°C]	Rel. Humidity [%]
3	19,6-22,0	43-58	19,6-22,0	44-58
4	19,6-22,0	43-57	19,6-22,0	43-57
5	17,2-21,8	44-55	18,6-21,9	42-54
6	4,6-22,0	59-68	4,8-22,0	59-68

Thermal Bridge Problem Window Rabbet

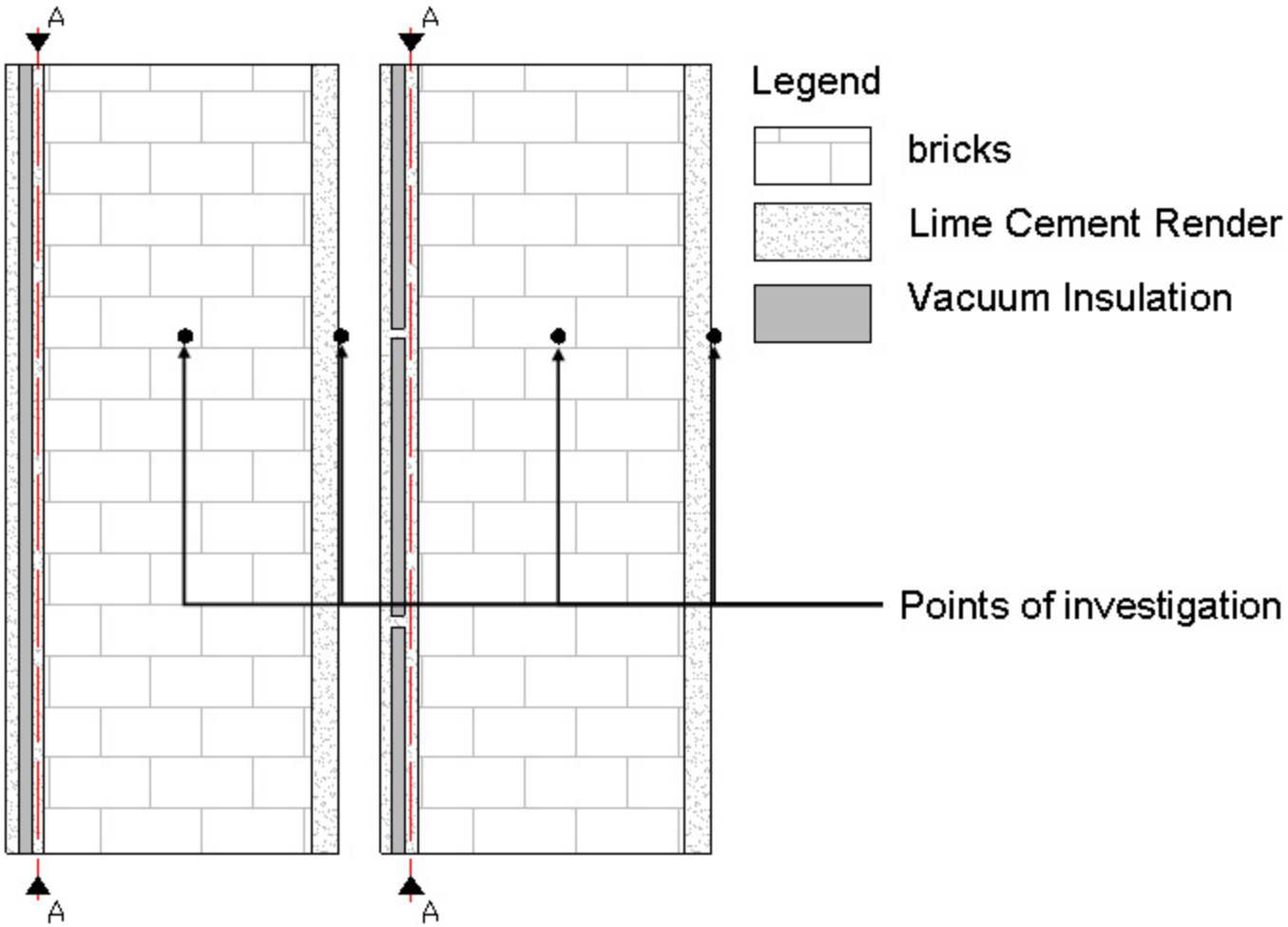


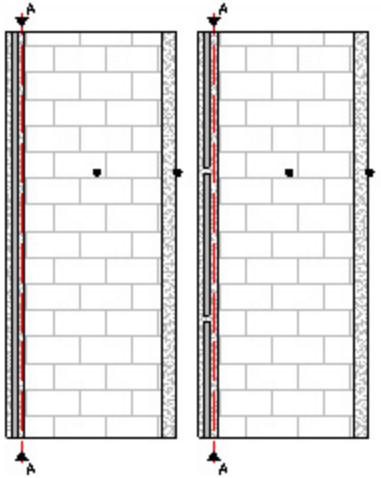
Thermal Bridge Problem Window Rabbet



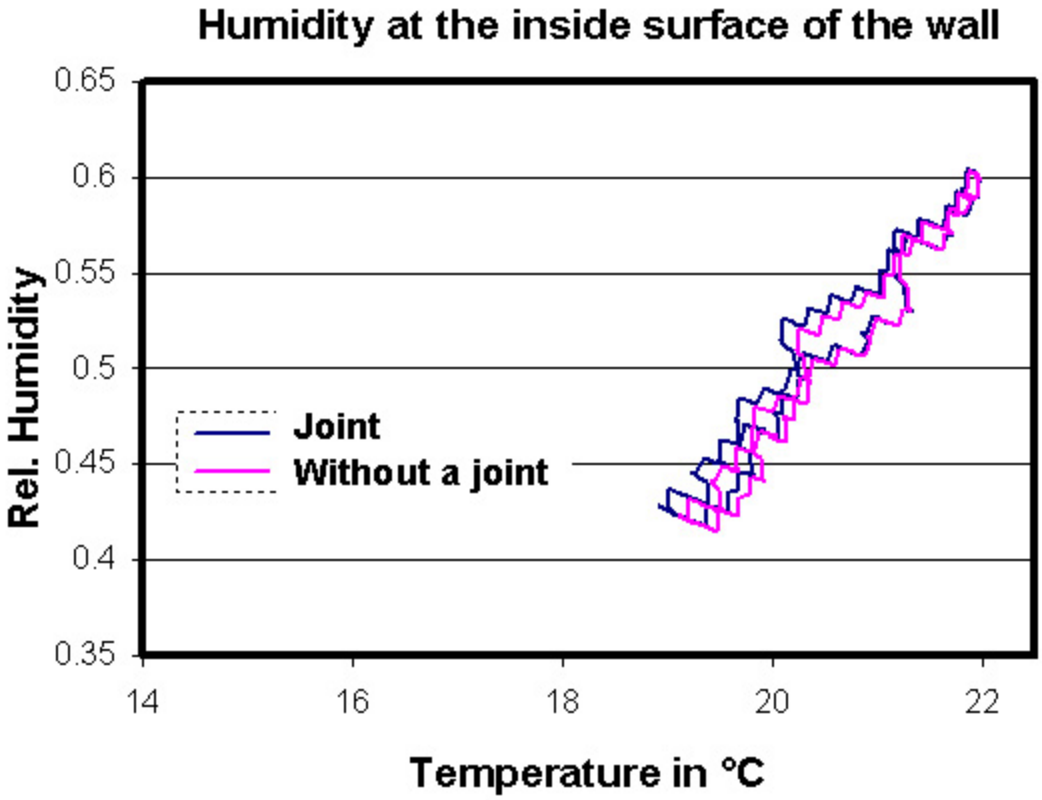

Relative Humidity in several investigated points
rel. Feuchte
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0
10000
20000
30000
40000
50000
60000
70000
80000
Zeit (h)
1
2
3
4

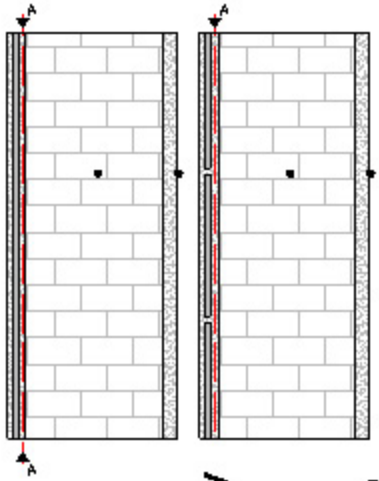
Investigation of the joint between vacuum boards





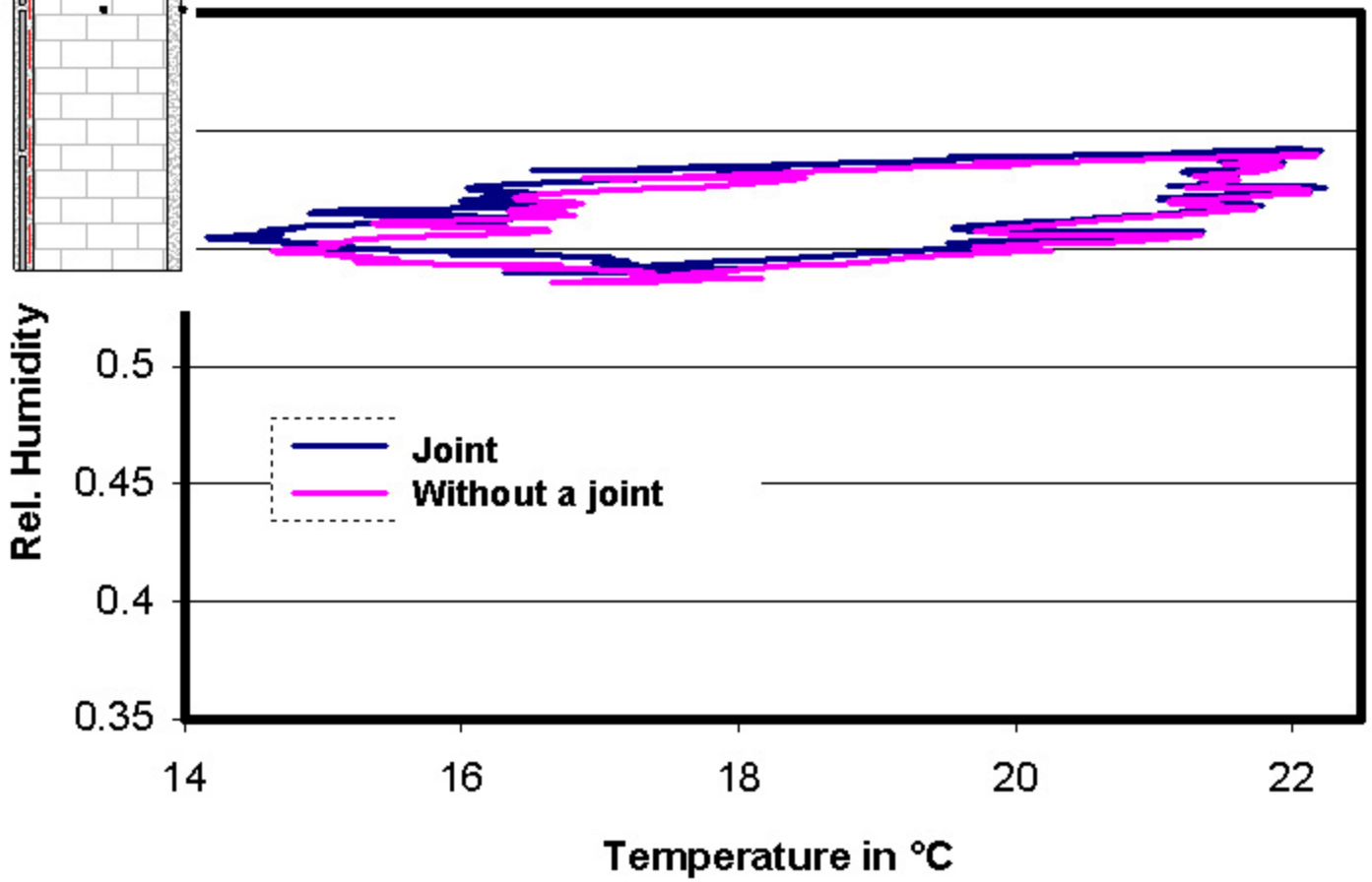
Investigation of the joint between vacuum boards

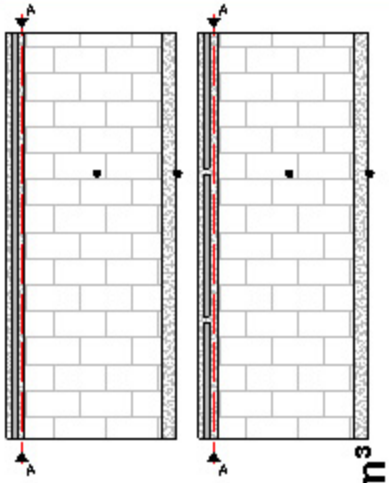




Investigation of the joint between vacuum boards

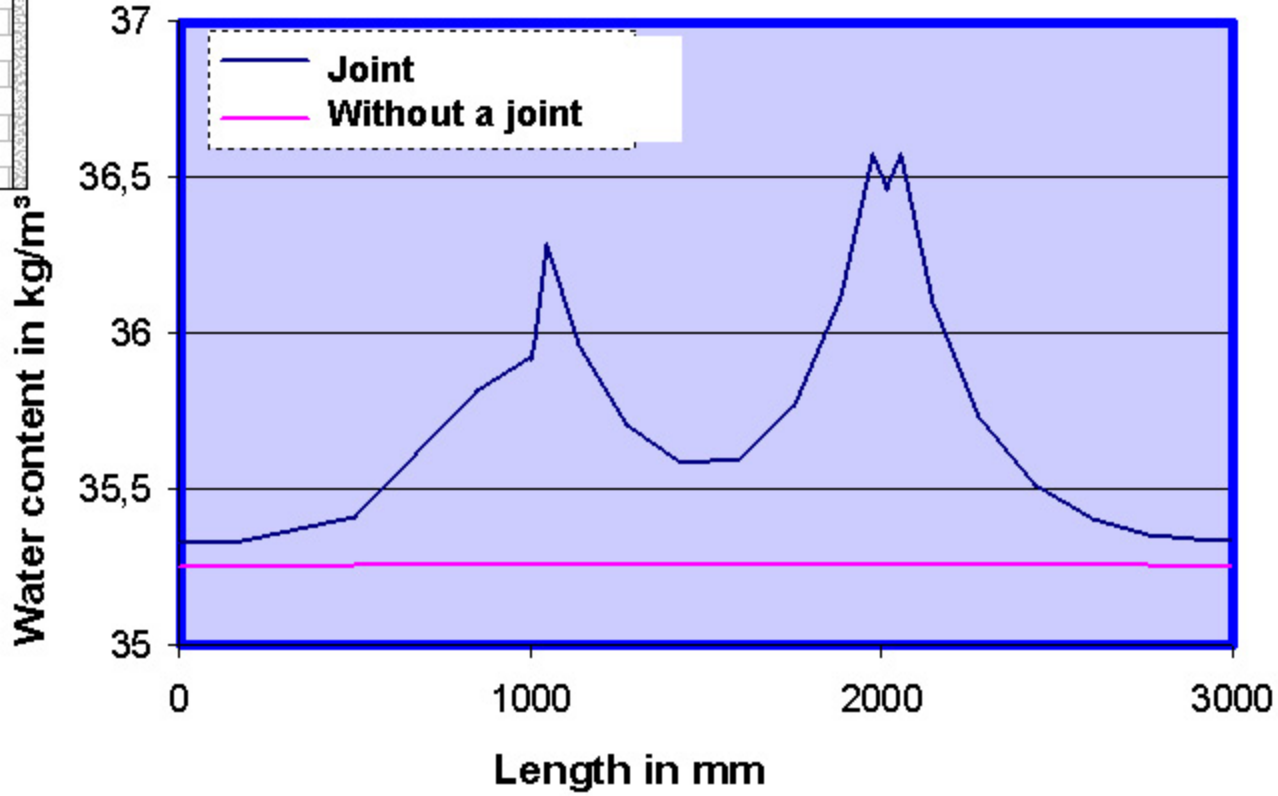
Humidity in the middle of the wall





Investigation of the joint between vacuum boards

Moisture content in the cross-section A - A



Conclusion :

- Because the Importance of an essential reduction of heating energy and CO2-emission the development of **high performance insulation systems** with an adequate effect of energy reduction, small thickness and an high durability is necessary.
- For a realistic evaluation of those materials and measures are
  modelling of heat and moisture balance of whole buildings and
  simulation of the heat and mass transfer necessary.
- Investigation of the hygrical-thermal suitability of vacuum insulation boards for refurbishing of Viennese “Gründerzeit”-buildings shows, that vacuum isolation can be used successfully for interior insulation.
- For interior insulation systems exist in the case of a driving rain load a certain risc for increasing of the moisture content. This load can be decreased by an appropriate selection of the external plaster clearly.
- The evaluation of different thermal bridges show that the thermal bridge effect is not essential.
- The influence of the external climate must be considered. The comparison of the hygrical behaviour of different locations shows substantial deviations.