D 6.2 Documentation of each study case

CS6 Wilhelminian Villa, Dresden (Germany)

Delivered at M42

EUROPEAN COMMISSION

DG Research and Innovation

Seventh Framework Programme

Theme [EeB.ENV.2010.3.2.4-1]

[Compatible solutions for improving the energy efficiency of historic buildings in urban areas]

Collaborative Project – GRANT AGREEMENT No. 260162

Technical References

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2 Template for Case study presentation

2.1 Brief description of the building

This table is to be considered as an identity card with brief descriptions of the building so that it is possible to compare the different case studies.

Object Name: Wilhelminian Villa in Dresden	
Location	
Country	Germany
City	Dresden
Altitude	154 m
Heating days	265
Heating degree days	2467 Kd/a
Previous locality names	Gründerzeitvilla, Loschwitzerstr. 17
Building contractor	Dr. F. Zinsser, D-01589 Riesa, Meissener Straße 29
Heritage administration	Landesamt für Denkmalpflege Sachsen, D-01067 Dresder Schlossplatz 1
Responsible Planner/ Architect	Architektur- und Planungsbüro ATEA GmbH, D-0158 Riesa Poppitz, Moritzer Str. 17
Local case study team	Institute of Building Climatology, Dresden University c Technology, Rudolf Plagge, Frank Meissner, Ayma Bishara, Magdy Kahlil, Remmers Baustofftechnik GmbH, Remmers Fachplanun GmbH, 49624 Löningen, Bernhard-Remmers-Str. 13, Jen Engel, Dirk Meier
Name and company of surveyor	Institute of Building Climatology, Dresden University c Technology, Rudolf Plagge, Philip Heinze
Previous locality names	Gründerzeitvilla, Loschwitzerstr. 17
History	
Date of construction	• Main structure was built in 1870 • In 1912 reconstructed. • 2010 completion of the renovation

Construction Type (according to its age)	Wall: masonry construction, sandstone cellar and brick konstruction, trass cement - lime plaster, wooden beam Roof: hip roof having complex shape, structure in wood, roof with tiles
Original use and functional	Residential house (villa for one Family)
Current use	Residential house (each floor has one apartment)
Expected use in future	Residential house for more Families
General description	
Status quo	already inhabited
Architectural style	The villa is based on the neo-Renaissance style
Construction materials	External walls: Masonry in natural stone (gneiss), plaster Ceilings: wooden beam ceiling Roof: Roof structure in wood, roof with tiles
Overall conservation status	Original state with a few changes
Urban Context	
Quarter/town	Blasewitz, Dresden, Saxony
Development plans	Blasewitz was originally a Slavic fishing village. from about 1860 built the first country houses and villas. Blasewitz is today one of the most senior districts of Dresden
Key figures as e.g. % of historic buildings, renovation rate	20-30 %
Cultural Value (Specific valuable aspects)	
Historical Values	One of the oldest houses in this area
Design Value	Unique buildings with special architectural style of the rest of the district
Constraint condition	-
Building Problems (cracks, deterioration, moulds and fungi..etc)	
1	Old windows were only fragments exist
2	The ceiling of the basement ceiling (was built of wooden beam ceiling and a brick arch above the original boiler room) was broken

3	broken window
4	drop pipes ended in nothing, and flooded the facade
5	Roof was defective
6	mould growth at thermal bridges, bath rooms, kitchen
7	rotten wooden beam ends in the main floor (all), 2 wooden beam ends in the 1st floor, 1 wooden beam ends 2nd floor
8	flaking of the inner and outer plaster
Planned/Proposed/Possible activities	
Diagnosis	• Thermography to detect weak areas in the construction • Analysis of material samples: plaster, brick, sandstone from exterior wall (hygrothermal material properties, numerical simulation) • Opening of all wooden ceiling beam ends in the whole building: visual diagnosis on position and state of beam ends • Long term monitoring of indoor and outdoor climate (see monitoring system)
Planned solutions	• Enhancement of the energy efficiency of building in order to achieve the demands of actual standard of non listed buildings. • Implementation of the new Remmers interior insulation system products iQ-Therm: consist of iQ-Fix, iQ-Top, iQ-Tex, etc. • Workshops on the planning and application of the interior insulation systems • During the project runtime the refurbishment of the building was planned by IBK: • Hygrothermal simulation and calculation of several refurbishment solutions regarding energy efficiency (Critical construction parts and critical connections, like incorporated walls or ceiling beam bearings, were evaluated by simulation.) • Concept of insulation. Upgrade of ceilings to ensure the required F30 fire resistance, was done by suspended ceiling. This also enabled to install cable and wiring under the storey ceiling, allows the incorporation of fire protection bulkheads and improves the acoustic

	protection. Since iQ-Therm consist of PU-foam, fire protection class B2, it cannot be applied along the storey ceiling. In this area calcium silicate boards were used. The different systems use the same glue mortar and interior plaster. (This was analyzed an evaluated in the lab.) • Use of geothermal energy by 5 energy sunk tubes, placed down to 100 and 120m depth and heat pump techniques. • Warm water-preparation: heat pump is used for preheating and a gas condensing boiler provides a water temperature level of 60°C, assure redundancy of the heating system. • Summerly heat protection: the heat pump in conjunction with the surface heating is employed for cooling, use of awnings on the south facade windows, (panels reconstructed according to historical indication) • The construction work was accompanied in the design process by: - application of software tools regarding building element simulation, energy efficiency of the thermal envelope - advanced training of construction workers and architects
Monitoring system	Monitoring Concept: support the evaluation of interior insulation system, which is a main task of TUD • Indoor climate - temperature and relative humidity of different rooms (bath, living room) - surface temperatures of critical points in the construction (wall, corner, reveal, dogging of a floor and inside wall, constructive details) • Outdoor climate - temperature and relative humidity outer Climate (north-east position close to the building fassade) - surface temperature at different oriented positions of the wall construction • Weather station - temperature and relative humidity of outer climate - Solar radiation, short- and long wave radiation - Wind direction, velocity - Precipitation • Within the Construction - temperature and combined temperature/relative humidity at different positions (wooden beam heads, in the wall between insulation and old

	construction, critical positions at thermal bridges, wall heating system - heat-flux of different wall constructions and wall heating system to evaluate the energy flux through insulated walls and effected by the wall heating system Approach: Continuous monitoring: - Installation of Monitoring during reconstruction of the building - Continuous monitoring of all selected wall constructions and rooms during the construction phase • Monitoring during interventions - Selected wall constructions and rooms are measured during the installation and testing of the wall heating system, evaluation of heating performance • Monitoring after interventions and refurbishment - Selected wall constructions and rooms are continuously measured during the first 3 years, evaluation of the interior insulation system and construction details in respect to damage free usage, and performance measures
Simulation	Building physical assessment and analysis of selected construction details in combination with the interior insulation iQ-Therm: • Simulation PHPP and Delphin: As-is-state • Simulation PHPP and Delphin: Solutions All simulations were evaluated for the minimum thermal insulation (according to German building regulation DIN 4108-3) and on the other hand for the real climate. The selected 2D- real climate details cases were calculated using DIN climate and TestReferenceYear. The likelihood of mould growth, the temperature gradients within the structure and the profiles of the relative humidity and moisture in the structure were considered.
Transfer to urban scale concept	There are many similar villas in Blaswitz with neo-Renaissance style. The Gründerzeit villa should serve as an Example, so that the other building in the environment can be also preserved and kept its historical value by reasonable energetic renovation with use of interior insulation system.
Others	Knowledge transfer: further education and qualification in the frame of the *Remmers Infotage 2014* at 16 locations in Germany: - 14.01.2014 in Dresden - 15.01.2014 in Leipzig - 16.01.2014 in Eisenach - 21.01.2014 in Dortmund - 22.01.2014 in Köln

	- 23.01.2014 in Frankfurt a.M. - 28.01.2014 in Berlin - 29.01.2014 in Krakow a. See (Linstow) - 04.02.2014 in Karlsruhe - 05.02.2014 in Nürnberg - 06.02.2014 in München - 18.02.2014 in Oldenburg - 19.02.2014 in Münster - 25.02.2014 in Hannover - 26.02.2014 in Hamburg - 27.02.2014 in Neumünster Monitoring of interior insulation systems • recommended practices • influence of user behavior • quality of living space • solutions for building construction details
Documentation	
Existing documentation	plans, sections and facades Plagge, R., P. Heinze & F. Meißner 2009: Baupysikalische Bewertung und Analyse ausgewählter konstruktiver Details mit dem Innendämmsystem iQ-Therm von Remmers, Report 250-402-6255, 151 pp. Plagge, R. & F. Meißner 2010: Beschreibung Testhaus Loschwitzer Str in Dresden, Report 250-402-6247. 8 pp.
Scanned/photocopied materials	-
Digital materials	Site measuring and photos
Inside surface	Photos
Outside Surface	Photos

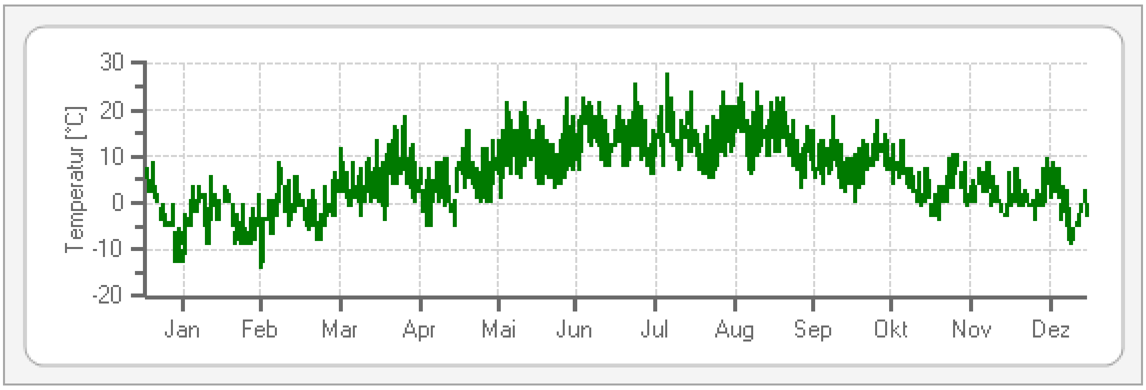
2.2 Detailed description

2.2.1 Local climate data

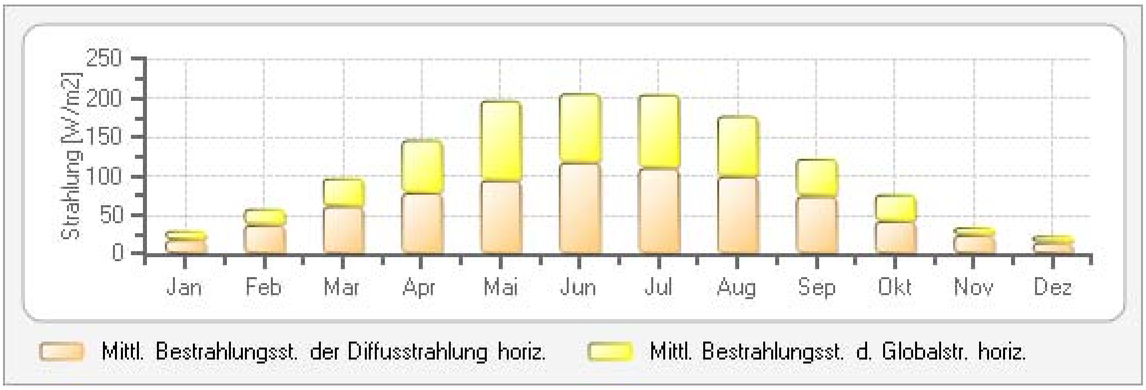
Local climate date[1] (rif. Central city:)	
	Climate zone: III, 3
	Climate area: humid continental climate
	Degree days: 2467 kd/a
	Altitude: 154 m
	Coordinates: 50° 55′ N, 13° 21′ O
	Average wind speed: January 4,4 m/s August 3,4 m/s
	Prevailing wind direction: #
Winter climate data	**Summer climate data**
Winter design temperature: - 5°C	Temperature: dry: 20 °C
HR max:	HR
Heating days per year: 183 (15 Oct.- 15 Apr.)	-

[1] Example of data

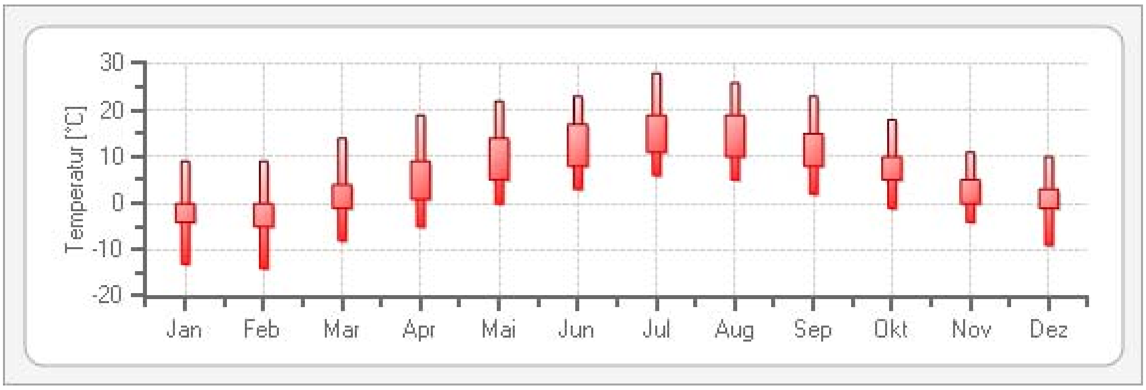
Daily temperature range:



Monthly radiation directly/diffuse:



Monthly temperature:



2.2.2 Report on history of the building

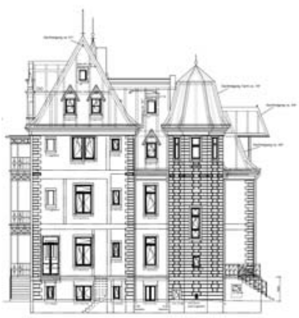
The building was most likely build in the years of 1870 and was altered in 1912. That is what we reason due to copies of old layout plans.

Even the younger history of the property is very moving. The current owner is the third private owner since the political "turnaround" in 1989. Via a record in the cadastre we received notice of an owner in Switzerland.

He, respectively his grandson, was in contact with the last and long-lasting owners in the GDR, who kindly provided us a copy of old plans, out of which a modernisation around 1912 can be deduced. At that point the house seams to have been converted for the first time to suite 2 families. In the 80's the first floor and the first and second attic floor were inhabited as well as the basement partially. The rooms of the "Pentacon" were to be found in the upper floor. Originally, according to the room arrangement, the house was designed for one family with only three lordly above stairs in the upper floor, economic areas in the basement and chambers in the attic floor. Traces of this first version were found during the reconstruction work. In the first floor the three rooms looking onto the road were originally linked with a typical enfilade of doors.

Unfortunately only now, with the reconstruction work being done, we were fortunately able to get into contact with a former tenant who spent her childhood in this building and who was able to provide some old interesting photographs regarding the 1940'.

Historical summary table

History of the building			
	First phase of construction:	1870	-
	Second phase of construction (first extension):	1912	-
	Major renovations	2008 - 2010	renovation
	Constraint condition:	-	-

2.2.3 Building consistency

Building consistency		
	Building structure	Old masonry with wooden beam ceiling
	Internal partition	See plans
	External finishing	Historical renovation plaster
	Number of floors above ground	3
	Number of basement floors	1
	Covered area	140 m²
	Numbers of rooms	21
	Gross area	3
	Net area	120 m²
	Heated surface	480 m²
	Surface cooled	480 m²
	Heated volume	1080 m³

2.2.4 Building Energy consumption

Building Energy consumption			
Electricity	**Years**	**Consumption (kWh)**	**Cost (€) (average cost €/kWh)**
	#		
Diesel	**Year**	**Consumption (l)**	**Cost (€) (average cost €/l)**
Gas	**Years**	**Consumption (mc)**	**Cost (€) (average cost €/mc)**
Gecam	**Years**	**Consumption (l/mc)**	**Cost (€) (average cost €/mc)**

2.3 Constraint condition and protection

Building general:

- No damages to timber
- Internal insulation can be installed on walls with only a relatively small thickness, because room size is too small.
- Insulation of floor and ceiling is not possible, because the ceiling height is low. Additionally the historic construction would be damaged.
- Heating can only be electrically. Oven heating cannot be used.
- No refurbishment of windows is possible, because it’s not enough time.
- Bad roof cladding.
- Regular flooding of the façade caused by broken downspouts

Room 0.2:

- No damages at the historical timber.
- Internal insulation must be installed behind the historical timber.

2.4 Selected area of intervention

If building as a whole is composed of different building blocks, you can break down the analysis for different functional area.

2.4.1 Functional area: Area 1 (name or function)

Functional area consistency		
Functional area 1:	Height interpolated average net (m):	3,0 m
(Plans and Photos of the rooms)	Surface area (Gross/Net) heated (mq):	120 m^2
	Volume (gross/net) heated (mc):	360 m^3
	Opening to the public (from/to; hours /day; temperature set-up):	-
	Hours of working (from/to, hours/ day; temperature set-up):	-

	Hours of air conditioning (from/to; hours/day; temperature set-up)	-

2.4.2 Functional area: Area 2 (name or function)

Functional area consistency		
Functional area 2:	Height interpolated average net (m):	#
(Plans and Photos of the rooms)	Surface area (Gross/Net) heated (mq):	#
	Volume (gross/net) heated (mc):	#
	Opening to the public (from/to; hours /day; temperature set-up):	#
	Hours of working (from/to, hours/ day; temperature set-up):	#
	Hours of air conditioning (from/to; hours/day; temperature set-up)	#

3 Report on status pre-intervention

3.1 Analysis and monitoring results

In this property the IQTherm® system of the Remmers Company is used (internal insulation system). Capturing the functionality of the insulations system in terms of temperature and humidity profile, three different measuring points with different sensors were installed during the construction phase.

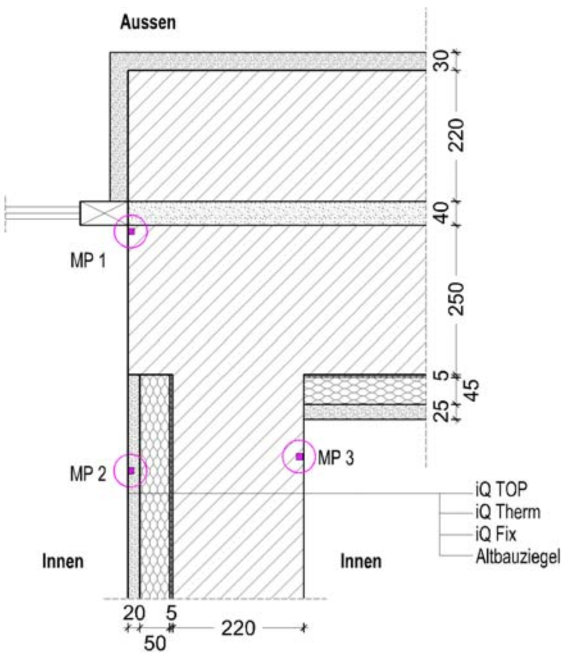
Only sensor technology and data logger by Ahlborn Company were used in the case study house Loschwitzer Straße. The sensor connections of the measuring points 1 and 2 in the ground floor, room 3 were summarized in a distribution board above the suspended ceiling construction and were brought to the supply duct in the ground floor, room 7 in a separated cable route. Together with the sensor connections of the measuring point 3 (from another distribution board above the suspended ceiling construction) the connection with two data loggers takes place within another distribution board located in the boiler room. The sensors of the measuring points 1 and 2 are connected to the data logger 0 and the measuring point 3 is connected to the data logger 1.

3.1.1 Structural analysis and assessment of moisture

Simulation of critical details

3.1.1.1 **<u>Construction 5a / 2D: „Ground floor bathroom with insulation Det. H“</u>**

Construction layout



The structure is calculated without the sandstone to save simulation time, the sandstone has a higher thermal conductivity than the brick.

3.1.1.2 Calculation under steady conditions

climate according to DIN 4108-2. Proof of the minimum thermal protection according to DIN 4108

The proof of the minimum thermal protection is conducted in accordance to DIN 4108-2 Section 6.2 for avoidance of mold growth.

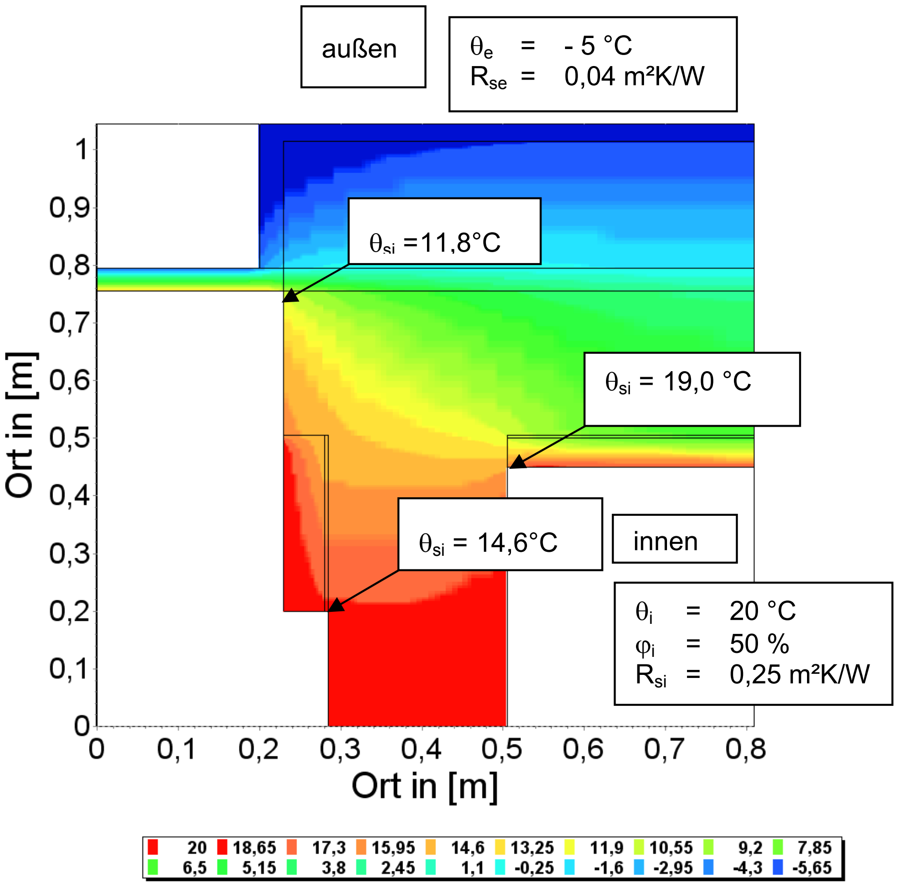


Figure 3.1.1: Temperature distribution of the structure 5a / 2D steady state surface temperature in [°C], boundary conditions according to DIN 4180 part 2.

$\theta_{si,\ Innenecke,\ oben}$ = 11,83 °C > $\theta_{si,\ zulässig}$ = 12,6 °C

The proof according to DIN 4108 – 2, section 6.2 is not complied for MP_1.

With the sandstone share in the construction, the surface temperature would be even lower, and the proof would also not be complied.

MP_2 and MP_3 can achieve the minimum temperature of 12,6 °C.

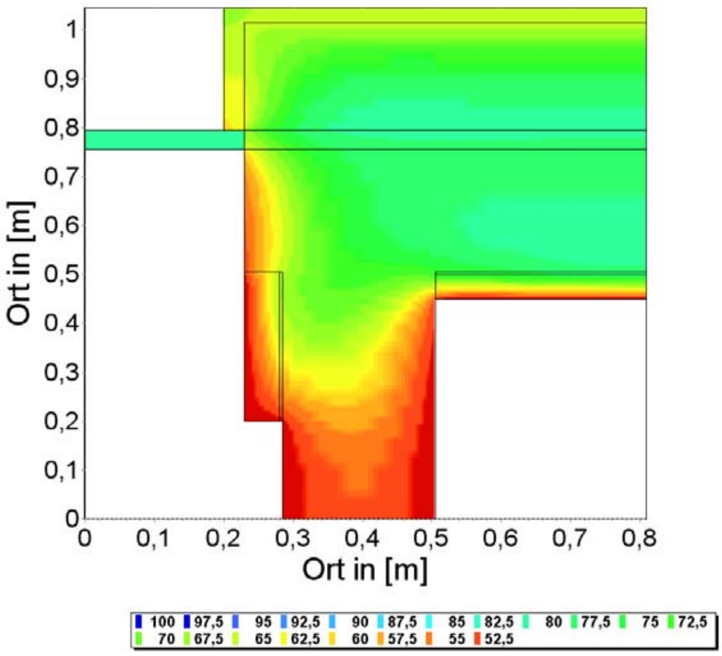


Figure 3.1.2: Humidity distribution of the construction 5a / 2D in the steady state.

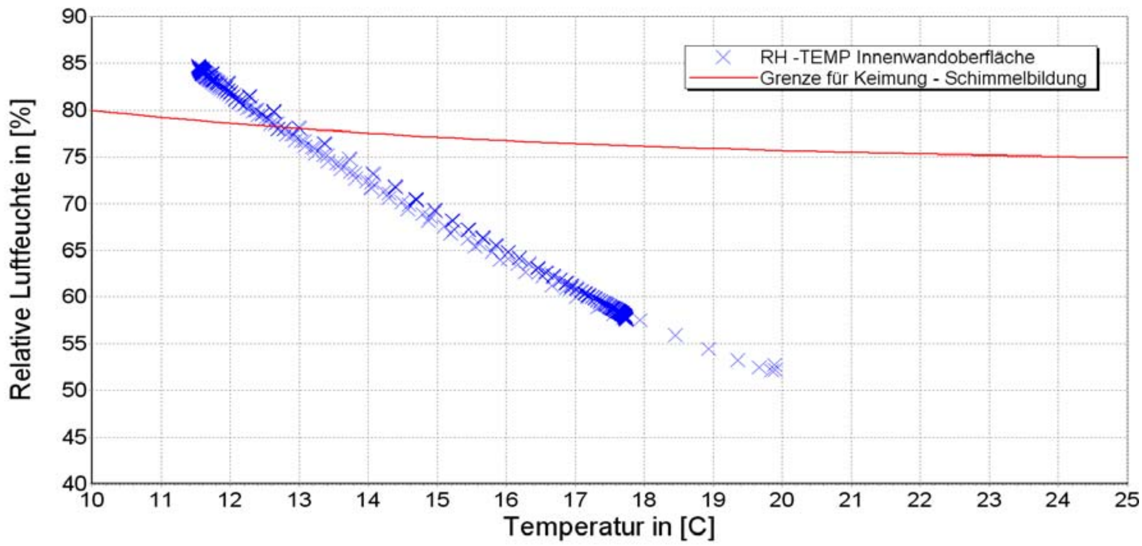


Figure 3.1.3: Graphic on the likelihood of mold formation of the construction 5a / 2D in the steady state. A mold formation with DIN required climate conditions cannot be excluded.

3.1.1.3 Climatic boundary conditions at Real Climate:

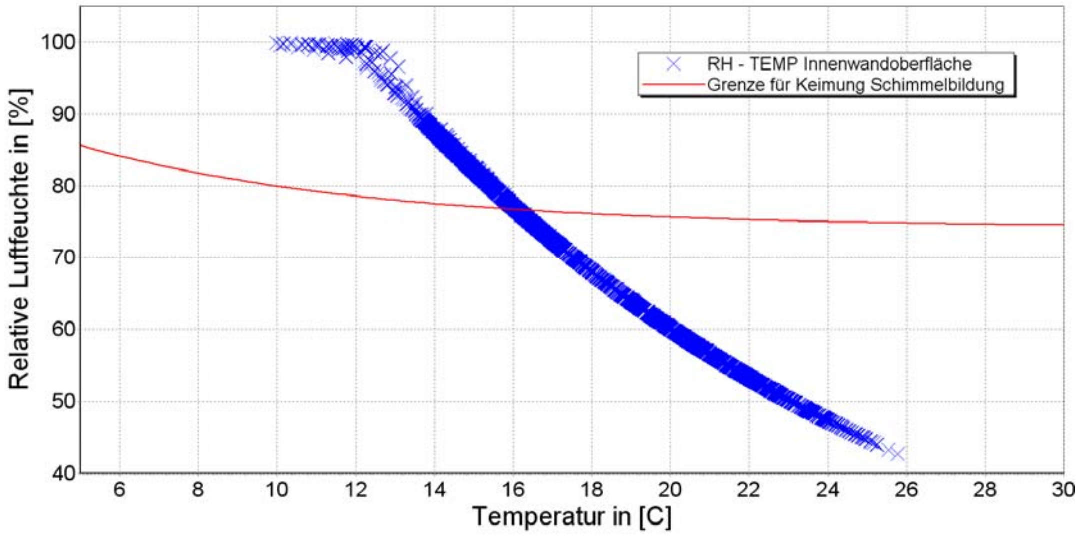


Figure 3.1.4 : Graphic on the likelihood of mold formation of the construction 5a / 2D for the reference year. A mold formation cannot be excluded.

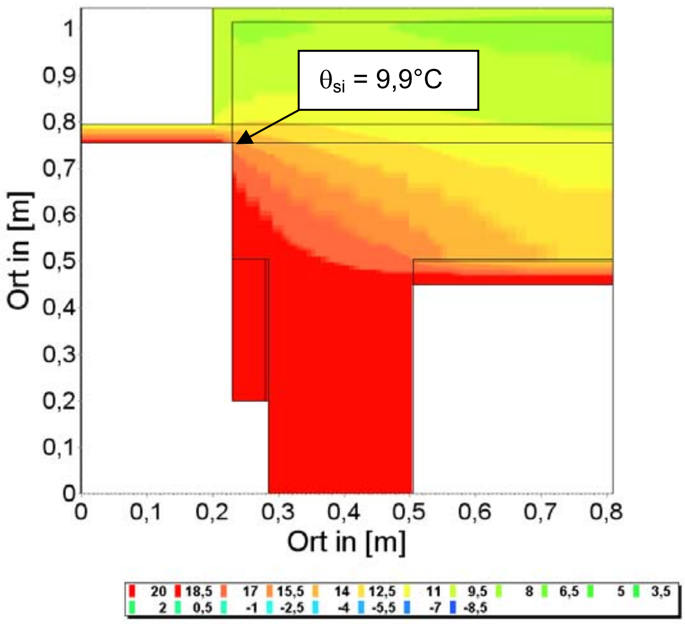


Figure 3.1.5: Temperature distribution of the construction 5a / 2D at 3rd February of the reference year.

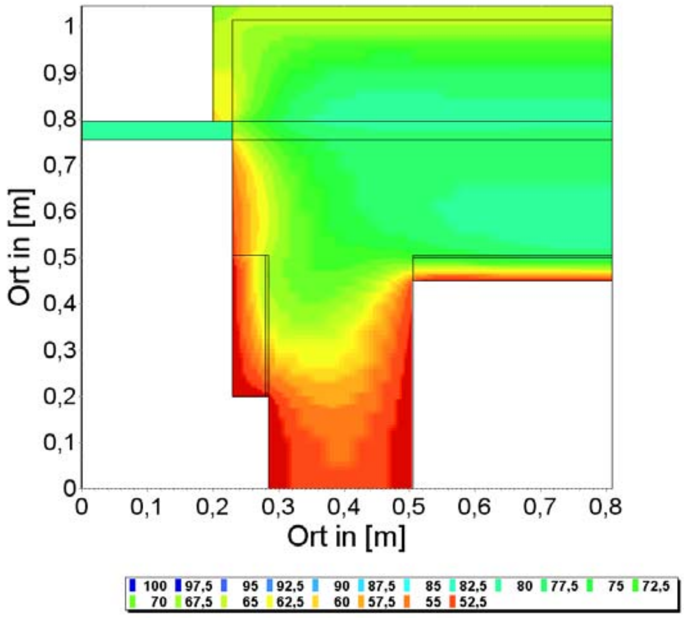


Figure 3.1.6: Humidity distribution of the construction 5a / 2D at 3rd February of the reference year.

3.1.1.4 Evaluation of the results for the Real Climate

There will be damaging effects of a thermal bridge. There is mold formation at the critical measuring point. The minimum temperature in the reference - year is 9,89°C. An embrasure insulation is necessary in the area of the window. Further simulations have shown, these included the sandstone, that a wedge insulation with a thickness of 25mm is already sufficient to meet the requirements of DIN and can prevent mold growth in the TRY. Possibly a technical solution (temperature control) is to pursue in this area.

3.2 Results derived from the application of PHPP

Virtually all of the calculated construction and construction details can be executed without damage according to the available plans. In many areas insulation wedges on the incorporating interior walls may not be necessary. Calculating precept was a room temperature of 20 °C (according to DIN 4108). For larger deviations from this precept a drop below the required DIN limits can occur.

The present plans correspond with the generally recognised codes of practice. In designing adequate guarantees were planned to minimize the residual risk, taking the economy into account.

The material functions used in the simulation essentially determine the hygrothermal behaviour of the structures. The material functions of the existing building materials have been adjusted using the test reports and were used in the simulation program. The material functions of the interior insulation system are taken from the material data of the company Remmers. If building materials that differ greatly from the used material functions exist or other materials than the ones being assumed in the simulation are implemented, then it can lead to a different behaviour. The statements and recommendations for the construction made in this statement then apply only limited. At the outer facade it is assumed that a driving rain-safe and diffusion-open structure is present. An intact sufficiently waterproof, diffusion-open exterior plaster and paint is to be understood by that. If this external plaster as such cannot be warranted, a hydrophobicity of the external plaster as a further measure is recommended. The paint should also be sufficiently waterproofed and diffusion-open, it also must be compatible with the possibly hydrophobic external plaster.

3.3 Overall rating

The house was permanently used as a residence building. Since the building is more than 150 years old, many construction parts have to be rebuild and retrofitted. Installation of plumber, heating, electricity, practically any technical part had to be reconstructed according to nowadays building regulations.

Each floor consists of one large apartment and a large staircase. Within an apartment 4 to 5 rooms and a large usable floor area (~120 and 140 m2) provide comfortable living. Due to heritage requirements the structure of the retrofitted building should be retained, leading to rooms of similar size facing the facade front, plenty interior doors and a large hallway. The structure of the house allows an open interior design simply in the areas of the roof. Fortunately, the basement was not supposed to be used as living space except one room for a housekeeper. It is planned to use the rooms as stockrooms.

Energetic redevelopment. The beside the monument conservation the client is looking for sustainable building concepts. To create affordable living space over a long-term basis at low expenses, the energetic redevelopment becomes an important part in the reconstruction.

Design and Building construction. The client pays large attention to cultural heritage requirements and set great value upon emphasising typical aspects of the building, factoring encountered details in – even if only small references remained - and underlining them during the reconstruction. Old substance should preferably be preserved and new material should be evaluated especially for each individual place of installation.

Summarizing:

The construction is characterized by a large energy demand. Responsibility for these losses are:

- high transmission heat losses through opaque parts of the thermal envelope and through windows
- high infiltrations respectively uncontrolled ventilation heat losses mainly caused by not tight/leaking windows
- high relative humidity in basement floors (caused by capillary water uptake though the Sandstone cellar, no functioning liner or sealing, salt efflorescense, mould grow risk)
- condensation and mould grow risk in window reveals and weak points of the thermal envelope (putty, window throat)

The building construction is in a bad shape and needs retrofitting.

4 Description of intervention needs

4.1 Intervention needs

The analysis and evaluation on the pre-intervention make clear, that the application of the capillary active interior insulation in combination with the energetic redevelopment of the building is required. Since TUD has an emphasis on interior insulation systems the focus is laying on the evaluation of applicability of iQ-Therm.

4.2 Simulation

The computer code DELPHIN was used to analyse the functionality of build solution. For the design of construction details, the hygrothermal simulation is a quality control. Hygrothermal dynamic simulation tools can assure damage-safe design of energy refurbishment.

4.3 Planned solution Intervention Hypothesis

Energetic redevelopment. The energetic redevelopment has been implemented in the interaction of the service plant and construction. The heat production takes place via geothermal 5 energy sunk tubes, placed down to 100 and 120m depth. A special heat pump provides an efficiently energy use, even at low flow temperatures. For the Warm water-preparation, the heat pump is used to preheat the water. The heating of water to the level of 60°C, a gas condensing boiler is used, warrant the redundancy of the heating system.

Constructive measures for the energetic building restoration. Since old windows were only fragmentarily existing, new reconstructed wooden type windows were developed for the building. Due to the large window openings, it was possible to draw standard profiles, whose cross-section and profiling was adjusted to the original model. A 2-pane insulating glazing was chosen.

The wooden beams and the wooden ceiling of the basement showed remarkable damages and had to be renewed completely. Since the old parquet in the ground-floor had to be abandoned and protected against the cellar climate, a more parquet save solution was applied. Reinforced concrete ceiling was used in some parts of the ceiling. Old joist end bearings were preferably used to manufacture thermally insulated bearing pockets of the ceiling. The bottom side of the ceiling was insulated in the area of the vaulted cellar with lightweight concrete with certified insulating properties. The floor of the ground floor was then constructed with a conventional heating screed. The flooring was carried out with solid oak parquet and tiles according to the historic ideal.

The roof cladding was completely removed and roof timbering was upgraded. The roof decking is a 32 mm thick wooden fibre board. Between the rafters cellulose was used for insulation, with a minimum thickness of 20 cm, which usually was often exceeded because of the height adjustment.

Interior insulation. The challenge is to insulate the designed facade. An exterior insulation was thereby excluded. Thus it was necessary to find a capillary active and diffusion permeable interior insulation. Since the building material company Remmers, one industrial partner of the 3ENCULT project, developed such insulation called iQ-Therm, this relatively new insulation material was applied. This panel consisting of PU- foam and has throughout tubes filled by mineral mortar components. They ensure moisture transport in the liquid phase to dry the wall by capillary action. To prevent damages the interior insulation was evaluated in the planning phase using hygrothermal simulation. Critical construction parts and critical connections, like incorporated walls or ceiling beam bearings, were evaluated by simulation.

Additionally, the behaviour of the wall in terms of the heat and moisture transfer was continued observed by means of sensor measurements in a period of more than 5 years thanks to the commitment of the manufacturer REMMERS. To heat the apartment rooms a surface heating system was realized. An underfloor heating with cement screed was build in the ground and attic floors. In some attic floors an underfloor heating was installed using dry screed. In the upper floor the old slab parquet could be retained. In some rooms, e.g. bath rooms, a wall heating system was installed, increasing the amount of construction variants to be tested. Wall heating surfaces are available in all apartments in the bathrooms in combination with an underfloor heating.

The summerly heat protection is assisted by awnings on the south facade windows. The panels are reconstructed according to historical indication. In the attic floors, the heat pump in conjunction with the surface heating is employed for a passive cooling. The exposed DFF is equipped with opacity. Additionally, the proper insulation material was chosen, that the temperature peak is compensated by the temperature phase shift and reasonable ventilation. A ventilating system was omitted for various reasons. But still the windows are provided by control-air ventilation elements, providing adequate ventilation behaviour is expected.

Old chimney flues were opened and cleaned or removed and replaced by walled up supply wells. One chimney has been restored, allowing the tenants the installation of a solid fuel burning cook stove as an auxiliary heating.

Design and Building construction. Guidelines for the reconstruction of the building have always been the preservation of the original building substance and the respect of its constructive demands. The stonework in the basement/lower floor consists of sandstone blocks. In contrary to the original design, these stones have been left unrendered. In the former more high-grade used rooms, like for example the serving cabinets, the wood covering was reconditioned and kept in the basement. In front of these rooms an air duct was preceded incurring the function of a vertical barrier. This was repaired and completed for the following rooms that formerly subordinate were used (heating and coal cellar, laundry room) and did not posses this “vertical barrier”. In the ground floor, as already stated, the old floor had to be abandoned. On the sandstone balcony on the southern side the railing and the corbels were able to be worked off, and in the upper floor the parquet. The balcony on the southern side was completely reconstructed including the corbels. Doors were worked off in the entire house; the frames on the ground floor had to be recreated due to damage of the wood. The loggia on the eastern side was overhauled with a lot of effort to obtain as many components as possible. This enabled the old substance to be obtained and a replica could be prevented. But it was not possible to redo the same with the wooden balcony in the first attic floor. Here, the substance was so bad, that a replica was build according to the original model and old historical joints. The decorated dormer windows were removed, all components were preferably obtained and overhauled and only in exceptional cases replaced. The mullions were partially in surprisingly good condition. The attic floor was gutted to the supporting structure and a composite space was created in a pointed arch.

Out of this one can find its way onto a rooftop terrace, which has been embedded as a trough, suspended in the old construction. Old gable anchors and lightning protection flags have been overhauled and continue to fulfil their original function. Sandstone elements and finials were obtained in principal and supplemented with crossings. This applies equally to the facade elements and sandstone, that all had to be anchored to the ceiling joints. The facade plaster has been preserved in large parts. The plaster had a remarkably firm consistency compared to the basic “soft stonework”. A removal of the plaster would have led to significant damage to the subsurface. According to examinations by a conservator the colour of the facade was set in accordance with historical model. Old and new plaster surfaces were painted by one-component silicate paint.

Fire protection and soundproofing. The ceilings had to be upgraded for fire protection. Since no original plaster or any other ceiling design revealed, this was done with a suspended ceiling. This also enables to put cable and wiring under the storey ceiling with incorporation of numerous fire protecting bulkheads. In the connection range to the outer walls to the suspended ceiling a calcium silicate panel replaced the PU foam insulation to ensure the required F30 fire resistance. Local smoke detectors were placed in context of establishing the alarm system in the living areas. The suspended ceilings were also used to improve the acoustic protection. For each room soundproofing measures for the ceilings and floors were set due to their room specifics and with the maximum utilization of the ceiling beams in mind. Here, mainly in the section of the wood-beamed ceilings, was carried out with bulks, insertions and dry screed systems out of brick panels. The exposed windows were executed in adequate acoustic protection class.

Staircase. The oak wood stairs in the relatively small and modestly designed staircase are used. The apartment entry doors were renewed. The design of the wall surfaces could have been detected and reconstructed. The last flight of stairs had to be renewed for reasons of the fire safety. Modestly designed lead glass windows were designed and thermally upgraded while reintegrate old slices.

Measuring system, inserted sensor technology. Only sensor technology and data loggers from the Ahlborn Company were used in the case study building Loschwitzer Straße. The sensor connections of the measuring points 1 and 2 in the ground floor, room 3 were summarized in a distribution board above the suspended ceiling construction and were brought to the supply duct in the ground floor, room 7 in a separated cable route. Together with the sensor connections of the measuring point 3 (from another distribution board above the suspended ceiling construction) the connection with two data loggers takes place within another distribution board located in the boiler room. The sensors of the measuring points 1 and 2 are connected to the data logger 0 and the measuring point 3 is connected to the data logger 1. Based on the results of diagnoses, monitoring and simulation, the problem should be determined in order to find the probabilistic solutions. Also the planned solution should be explained using drawing detail, photos etc. Such as Internal insulation, refurbishment windows, technical system etc.

4.4 Transfer to urban scale concept

The case study deliver the acknowledgement, that interior insulation using the system iQ-Therm from Remmers can be use for thermal upgrade of historical constructions. Also the expected performance of the insulation product can convince possible users to follow the iQ-Therm solution. To make this public to a number of architects, engineers, builder and clients, further education and qualification seminars are planned. A profound knowledge transfer will be communicated in the frame of the "*Remmers Infotage 2014"* at 16 locations in Germany. Up to 1500 relevant persons are teach and informed in this seminar. In this manner the transfer to historic city centre up to a urban scale is conducted.

4.5 Information for on-site retrofit works

Description of nearby areas for organizing the on-site retrofit works	A large parking and garden is available, space is not a question.
How is the building/building part used during the retrofit works?	unused

5 Implementation

Figure 5.1: Removal of unstable interior plaster consist of a lime-gypsum plaster in the ground floor, analysis of all wooden beam heads, surveying and mapping of different materials (left). Natural sandstone from Reinhardsdorf in the cellar shows the right picture.

Figure 5.2: iQ-Term interior insulation system in assembly and handling (left). Trim to fit the insulation board by an electric saw with exhaustion (right). A continuous deck of the insulation board by glue mortar is required.

Figure 5.3: Staggered iQ-Term boards at the reveal. The bare brick wall is covered by a compensating plaster (left), The complete wall is covered by iQ-Therm. The collision corners are protected. In the connection range, outer walls to the suspended ceiling, a calcium silicate panel replaced the PU foam insulation to ensure the required F30 fire resistance. Local smoke detectors were placed in context of establishing the alarm system in the living areas. The suspended ceilings were also used to improve the acoustic protection.

Figure 5.4: The iQ-Term boards are adjusted at the reveal, providing arcuated forms (left). In the connection range, outer walls to the suspended ceiling, a calcium silicate panel replaced the PU foam insulation and ensure F30 fire resistance. When iQ.Therm and calcium silicate boards are covered by the rendering, no material alternation can be seen. All system components can be used for iQ.Therm and calcium silicate as well (right).

Figure 5.5: Precise preparation of iQ-Term boards at the reveal with collision corners (left). Complete insulation of the outer wall in the range of the suspended ceiling, using calcium silicate (right).

Figure 5.6: To prevent damages when installing electric terminal boxes, the rear part is additionally insulated. In this manner thermal bridges can be suppressed (left). Outer wall with bare brickwork and laying of electrical cables (right). The wall is ready to be covered by a compensating plaster.

Figure 5.7: Workmanship of the iQ-Top render. After combing a first 6mm thin layer of the moisture regulating iQ-Top plaster upon the insulation, a mesh (iQ-Tex) is placed on the fresh surface. Later a second layer of plaster is used to cover the wall, providing the surface finish (left). The finished surface is shown on the right hand side. The drying potential of calcium silicate can be recognized by the almost dry plaster close the ceiling (right).

Figure 5.8: The finished laying of the wall heating system is given above. The tubes are covering the whole wall up to the suspended ceiling (left). The insulation system is placed around the wooden beam. To prevent convection processes expandable band is used and recognized by the red foil covers.

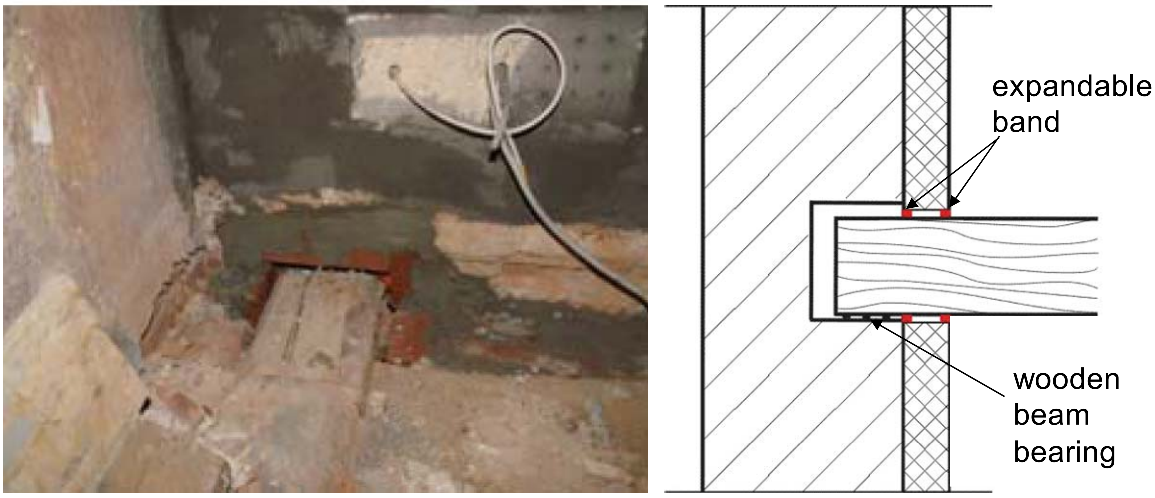


Figure 5.9: The air bathed connection of the wooden beam head in the wall construction is shown, where the compensating plaster already equals the wall surface (left). The sketch visualize the wooden beam bearing, preventing capillary moistening of the beam, and the usage of the expandable bands, preventing convective air flow around the wooden beam head (right).

Figure 5.10: Teaching and training of application technique for interior insulation for Remmers technician and engineers after successful installation if iQ-Therm insulation system.

6 Annex 1 - PHPP calculation for status pre-intervention

6.1 Results derived from the application of PHPP before refurbishment

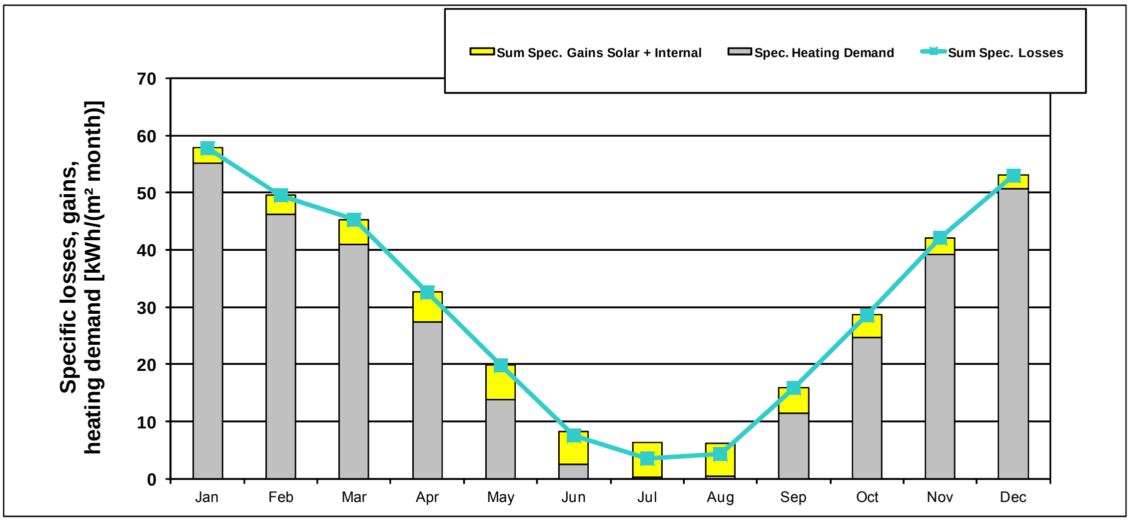
The PHPP calculations describe the heating demand before retrofitting and deliver the pre intervention status of the building. Since it is difficult to evaluate e.g. ventilation rate, bad moulding and others, the quantitative result can only deliver a rough estimate. But the dimensions give a bearing.

Passive House verification

SPECIFIC ANNUAL HEAT DEMAND
MONTHLY METHOD

Climate:	Dresden	Interior Temperature:	20 °C
Building:	Gründerzeitvilla	Building Type/Use:	Residential
		Treated Floor Area A_{TFA}:	637 m²

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
Heating Degree Hours - E	15.4	13.2	12.0	8.6	5.1	2.5	1.5	1.7	4.2	7.6	11.2	14.1	97	kKh
Heating Degree Hours - G	2.3	2.1	2.2	1.8	1.4	-1.8	-2.1	-2.2	0.9	1.3	1.6	2.0	9	kKh
Losses - Exterior	35559	30411	27657	19783	11853	5818	3436	3951	9642	17522	25934	32639	224204	kWh
Losses - Ground	1247	1145	1176	963	775	-1007	-1169	-1190	499	696	887	1118	5141	kWh
Sum Spec. Losses	57.8	49.5	45.3	32.6	19.8	7.6	3.6	4.3	15.9	28.6	42.1	53.0	360.0	kWh/m²
Solar Gains - North	66	109	195	298	399	421	439	343	230	136	70	43	2750	kWh
Solar Gains - East	146	257	404	605	769	707	753	688	472	326	177	89	5394	kWh
Solar Gains - South	454	732	927	1128	1263	1091	1201	1230	1001	862	541	294	10724	kWh
Solar Gains - West	74	129	225	350	456	440	475	404	254	168	80	40	3094	kWh
Solar Gains - Horiz.	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Solar Gains - Opaque	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Internal Heat Gains	995	899	995	963	995	963	995	995	963	995	963	995	11720	kWh
Sum Spec. Gains Solar +	2.7	3.3	4.3	5.2	6.1	5.7	6.1	5.7	4.6	3.9	2.9	2.3	52.9	kWh/m²
Utilisation Factor	100%	100%	100%	100%	99%	89%	55%	67%	99%	100%	100%	100%	90%	
Annual Heating Demand	35070	29431	26087	17404	8773	1591	130	308	7239	15731	24989	32296	199050	kWh
Spec. Heating Demand	**55.0**	**46.2**	**40.9**	**27.3**	**13.8**	**2.5**	**0.2**	**0.5**	**11.4**	**24.7**	**39.2**	**50.7**	**312.4**	kWh/m²



Annual Heating Demand: Comparison

EN 13790 Monthly Method	**199050**	**kWh/a**	**312.4**	**kWh/(m²a) Reference to habitable area**
PHPP, Heating Period Method	**185524**	**kWh/a**	**291.2**	**kWh/(m²a) Reference to habitable area**

6.2 Results derived from the application of PHPP after refurbishment

The PHPP calculations describe the heating demand after retrofitting and deliver the post intervention status of the building.

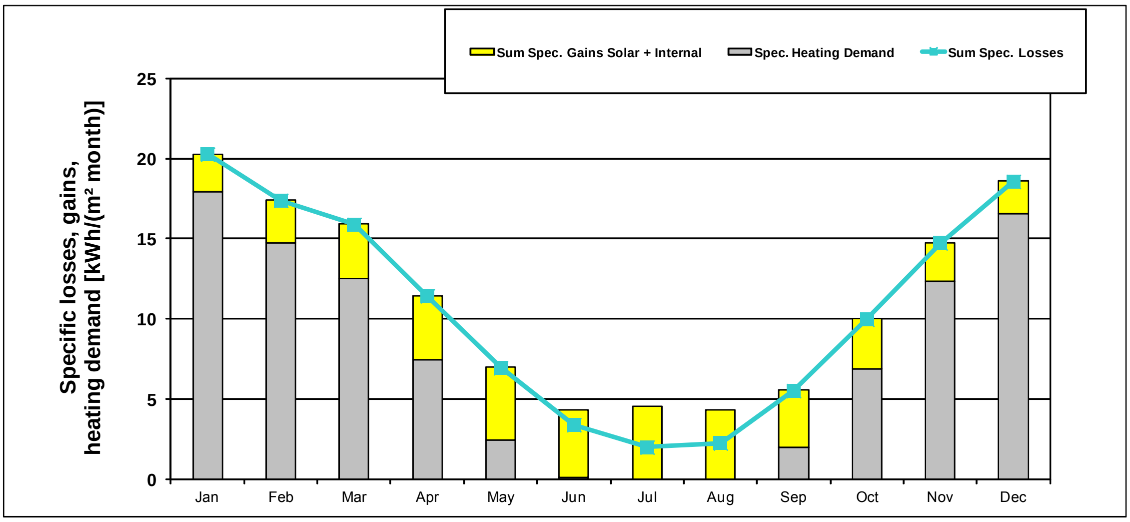
Passive House verification

SPECIFIC ANNUAL HEAT DEMAND
MONTHLY METHOD

Climate: Dresden
Building: Gründerzeitvilla

Interior Temperature: 20 °C
Building Type/Use: Residential
Treated Floor Area A_{TFA}: 569 m²

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
Heating Degree Hours - E	15.4	13.2	12.0	8.6	5.1	2.5	1.5	1.7	4.2	7.6	11.2	14.1	97	kKh
Heating Degree Hours - (	6.9	6.7	7.2	6.1	5.0	2.2	1.2	0.7	2.3	3.2	4.4	5.9	52	kKh
Losses - Exterior	11255	9625	8754	6261	3752	1842	1087	1251	3052	5546	8208	10330	70962	kWh
Losses - Ground	281	271	291	247	203	89	49	30	91	130	177	238	2097	kWh
Sum Spec. Losses	20.3	17.4	15.9	11.4	6.9	3.4	2.0	2.2	5.5	10.0	14.7	18.6	128.4	kWh/m²
Solar Gains - North	35	57	103	157	212	224	234	182	121	71	37	22	1455	kWh
Solar Gains - East	82	144	227	340	432	397	423	387	265	183	100	50	3031	kWh
Solar Gains - South	277	446	566	689	772	667	734	751	611	526	330	179	6546	kWh
Solar Gains - West	47	81	141	219	286	276	298	253	159	106	50	25	1940	kWh
Solar Gains - Horiz.	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Solar Gains - Opaque	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Internal Heat Gains	889	803	889	861	889	861	889	889	861	889	861	889	10470	kWh
Sum Spec. Gains Solar +	2.3	2.7	3.4	4.0	4.6	4.3	4.5	4.3	3.5	3.1	2.4	2.0	41.2	kWh/m²
Utilisation Factor	100%	100%	100%	100%	100%	78%	44%	52%	100%	100%	100%	100%	86%	
Annual Heating Demand	10206	8365	7119	4242	1373	40	0	1	1134	3901	7008	9402	52791	kWh
Spec. Heating Demand	**17.9**	**14.7**	**12.5**	**7.5**	**2.4**	**0.1**	**0.0**	**0.0**	**2.0**	**6.9**	**12.3**	**16.5**	**92.8**	kWh/m²



Annual Heating Demand: Comparison

EN 13790 Monthly Method	52791	kWh/a	92.8	kWh/(m²a) Reference to habitable area
PHPP, Heating Period Method	51452	kWh/a	90.4	kWh/(m²a) Reference to habitable area

7 Annex 2 - Description of the monitoring system

7.1 Hygrothermal and environmental monitoring

Measuring system and inserted sensor technology

Only sensor technologies and data logger systems from Ahlborn Company were used in the CS "Gründerzeit Villa in Dresden". The sensor connections of the measuring points 1 and 2 in the ground floor, room 3 were summarized in a distribution board above the suspended ceiling construction and were brought to the supply duct in the ground floor, room 7 in a separated cable route. Together with the sensor connections of the measuring point 3 (from another distribution board above the suspended ceiling construction) the connection with two data loggers takes place within another distribution board located in the boiler room. The sensors of the measuring points 1 and 2 are connected to the data logger 0 and the measuring point 3 is connected to the data logger 1.

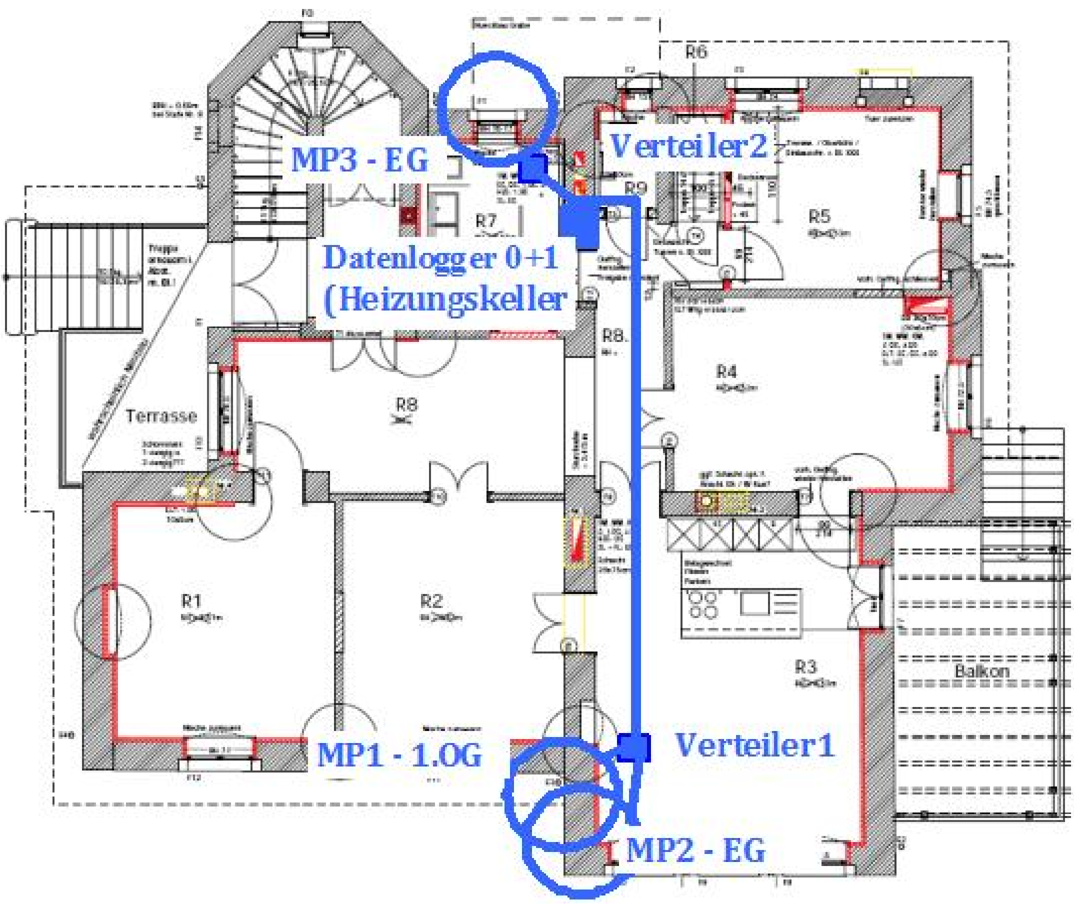


Figure 7.1.1: Measurement system (Planning Document), location of the different points of measurement in the cellar, the basement and the 1st floor and the location of the cable distribution in the suspended ceiling.

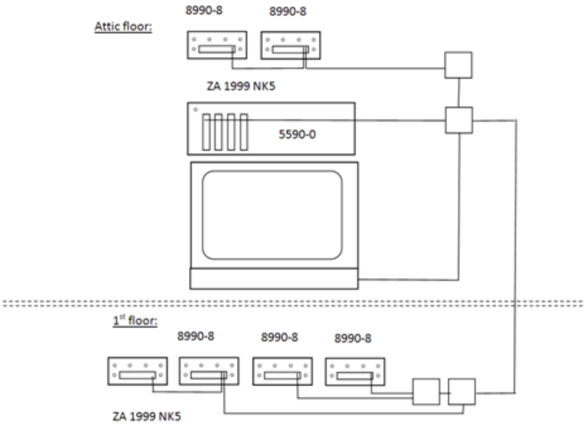


Figure 7.1.2: Place of the data logging units in the cellar (left). Ahlborn – network arrangement (right).

Measuring position 1 (1. Upper floor, room R2 – southern side)

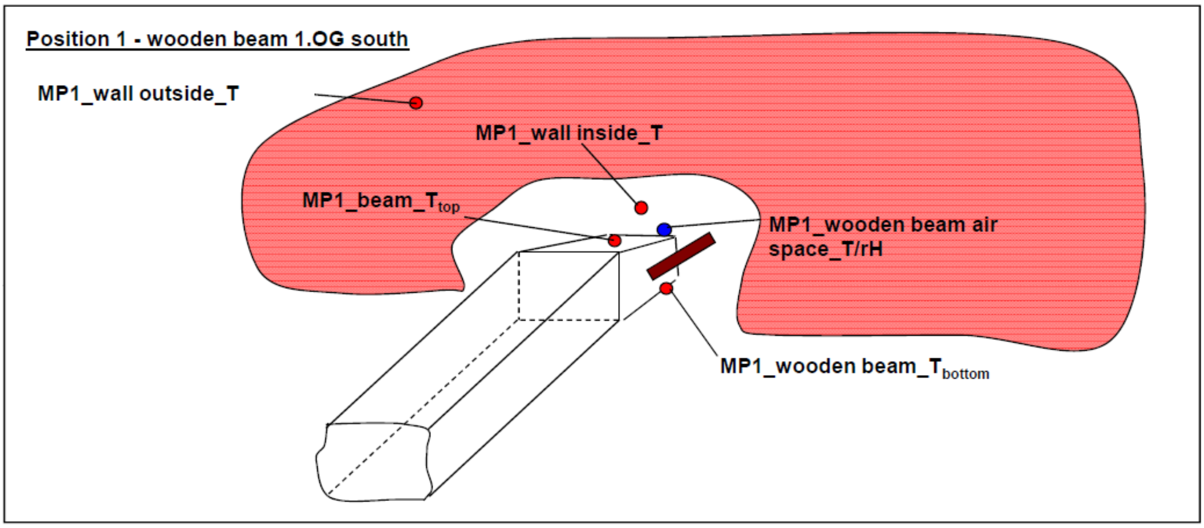


Figure 7.1.3: Measuring point at position 1- wooden beam 1OG south.

The measuring point 1 is located directly at the integration of a ceiling beam in the exterior wall. With this measuring point the thermal and hygric behaviour of the wooden beam in combination with the interior insulation system on an exterior wall can be evaluated.

Inserted sensors:

- temperature exterior wall (Ntc-temp.sensor)

- temperature interior wall beam airspace (Ntc-temp.sensor)

- temperature beam upper side (Ntc-temp.sensor)

- temperature beam bottom side (Ntc-temp.sensor)

- temperature and relative humidity wooden beam airspace (digital temp./humidity sensor)

Measuring position 2 (Ground floor, room R3 – southern side)

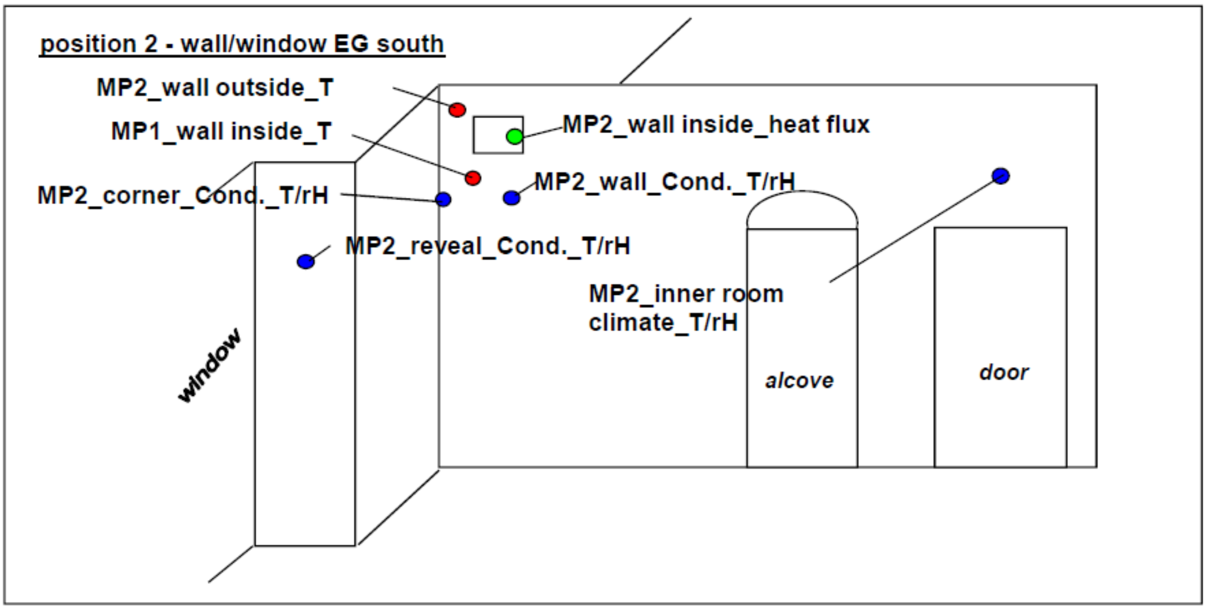


Figure 7.1.4: Measuring point at position 2- room R3 EG, wall/window in ground floor- south.

The measuring point 2 is located in the same aligned exterior wall as measuring point 1, but on the ground floor. Arising condensate (wall, corner, embrasure), heat flow through the insulation system, as well as indoor climate shall be gathered.

Inserted sensors:

- temperature exterior wall (Ntc-temp.sensor)

- Temperature interior wall (Ntc-temp.sensor)

- temperature and relative humidity cond.zone wall (digital temp./humidity sensor)

- temperature and relative humidity cond.zone corner (digital temp./humidity sensor)

- temperature and relative humidity cond.zone reveal (digital temp./humidity sensor)

- temperature and relative humidity inner room (digital temp./humidity sensor)

- Heat flux plate wall inside under plaster (WFP 250mm x 250mm)

Measuring section 3 (Ground floor, room R7 – northern side)

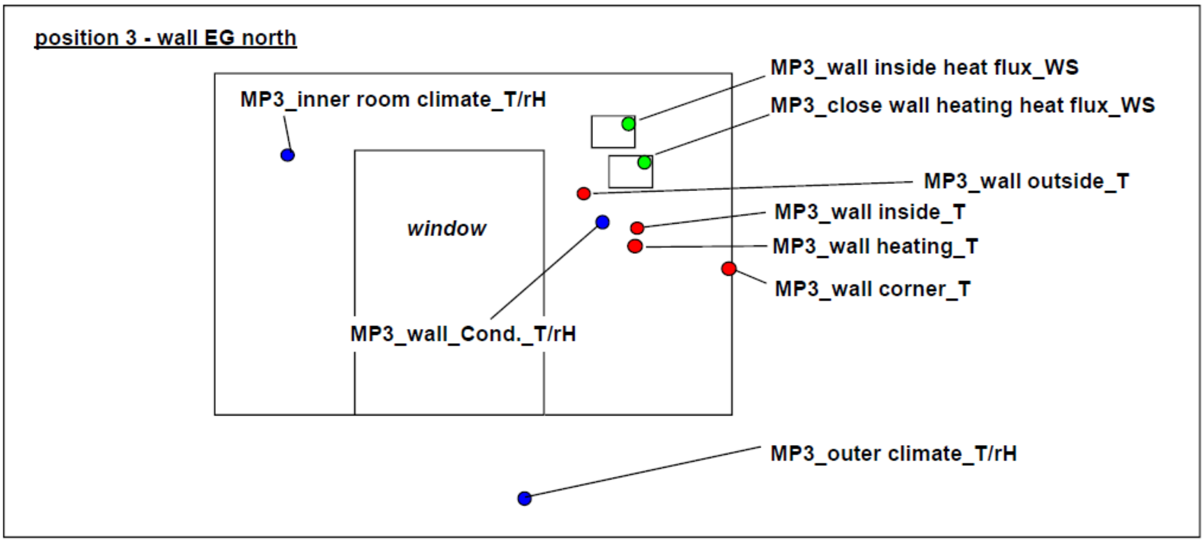


Figure 7.1.5: Measuring point at position 3 - Wall in ground floor, north.

The measuring point 3 is located in the north-side orientated exterior wall of the room R7 on the ground floor. Since this is a wet room, there is a particular susceptibility towards condensate. Like at measuring point 2, the temperature and humidity in the condensate layer as well as the indoor climate is gathered. The heat flows of the outer layer and inner layer can be measured separately via two heat flow panels (adhesive layer behind the wall heating and in the interior plaster). At this measuring point there is an additional temperature/humidity sensor for the outdoor climate conditions.

Inserted sensors:

- temperature exterior wall (Ntc-temp.sensor)
- temperature interior wall (Ntc-temp.sensor)
- temperature interior wall - corner (Ntc-temp.sensor)
- temperature wall heating pipe (Ntc-temp.sensor)
- temperature and relative humidity cond.zone wall (digital temp./humidity sensor)
- temperature and relative humidity outdoor climate (digital temp./humidity sensor)
- temperature and relative humidity interior climate (digital temp./humidity sensor)
- Heat flux plate cond. zone (WFP 250mm x 250mm)
- Heat flux plate interior plasters (WFP 250mm x 250mm)

7.2 Measured data from the post-intervention status

The data of all Measuring positions are presented in the following chapter.

Measuring position 1 (1. Upper floor, room R2 – southern side)

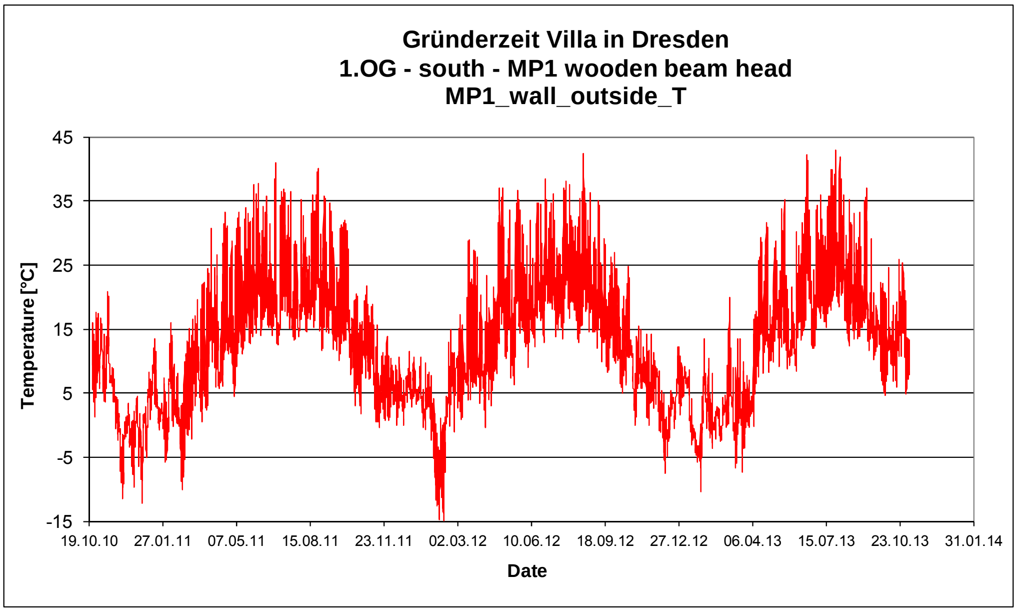


Figure 7.2.1: Temperature at the outside wall during the building phase, measuring point at position 1- wooden beam 1OG south.

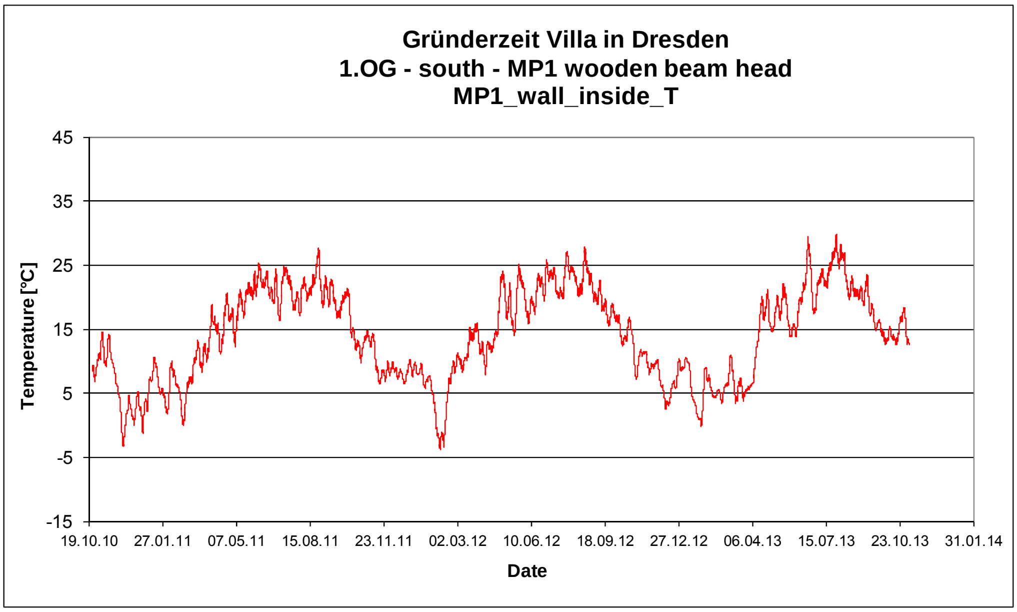


Figure 7.2.2: Temperature at the inside wall during the building phase, measuring point at position 1-wooden beam 1OG south.

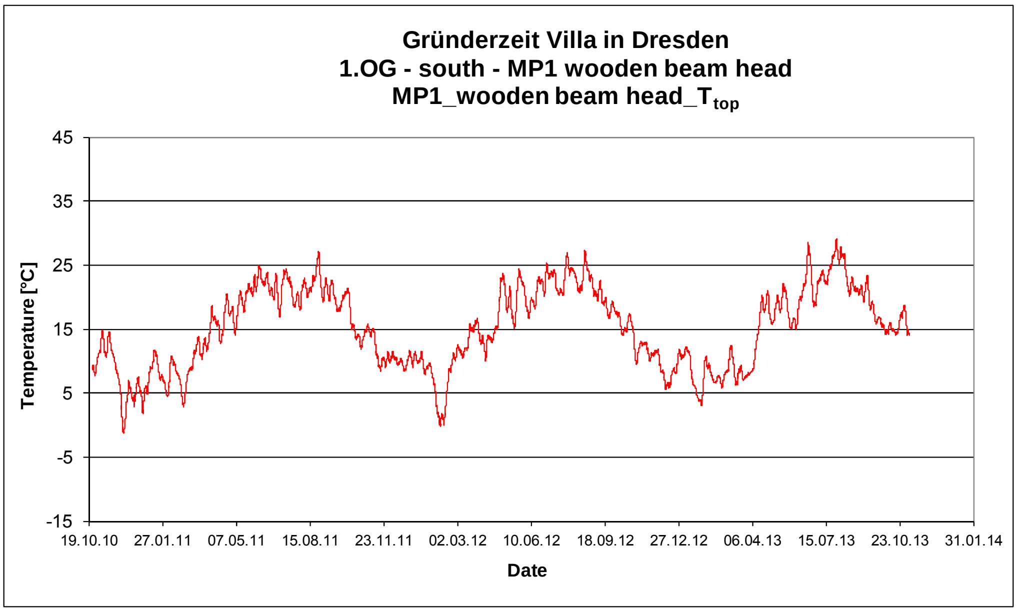


Figure 7.2.3: Temperature on top of the wooden beam head during the building phase, measuring point at position 1- wooden beam 1OG south.

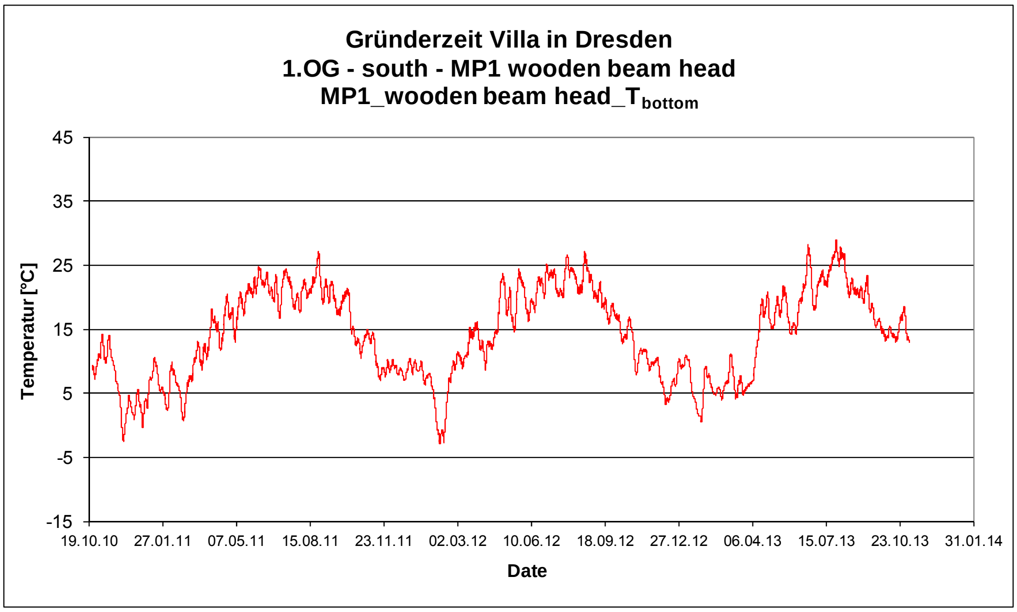


Figure 7.2.4: Temperature on the bottom of the wooden beam head during the building phase, measuring point at position 1- wooden beam 1OG south.

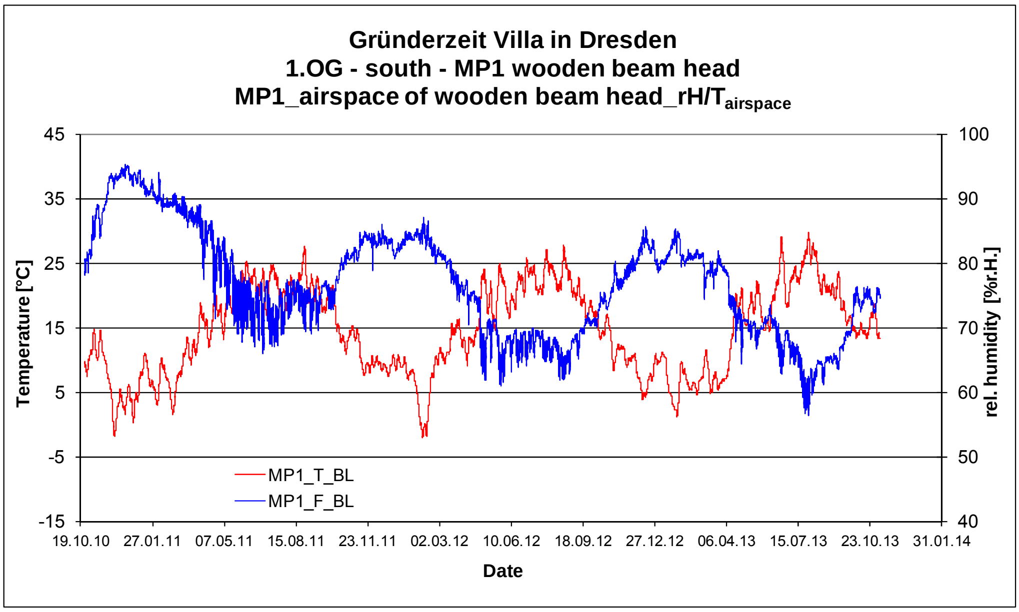


Figure 7.2.5: Temperature and relative humidity in the airspace between wall and wooden beam head during the building phase, measuring point at position 1- wooden beam 1OG south.

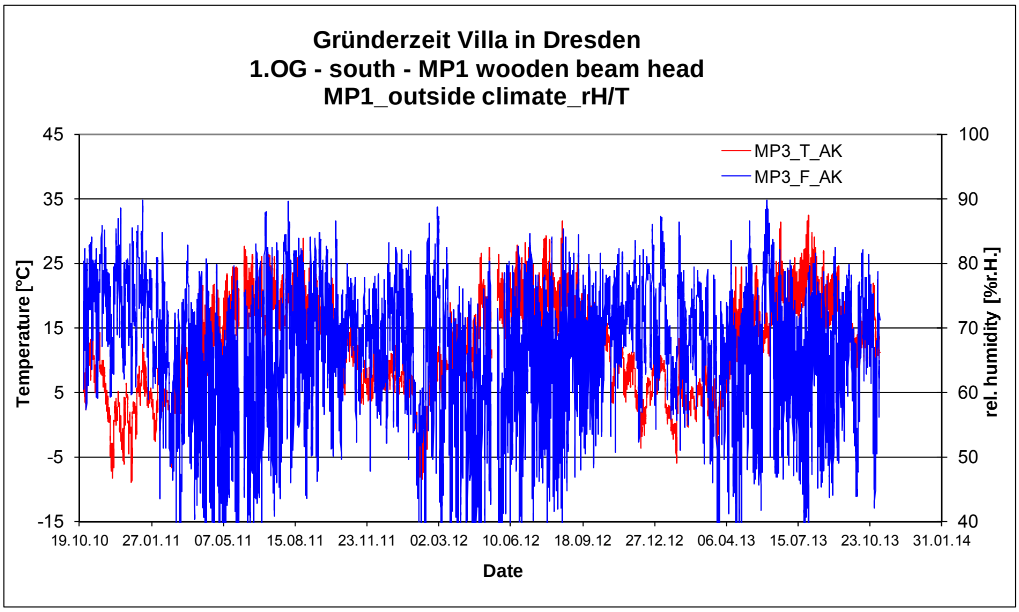


Figure 7.2.6: Temperature and relative humidity of the outer climate during the building phase, measuring point at position 1- wooden beam 1OG south.

Measuring position 2 (Ground floor, room R3 – southern side)

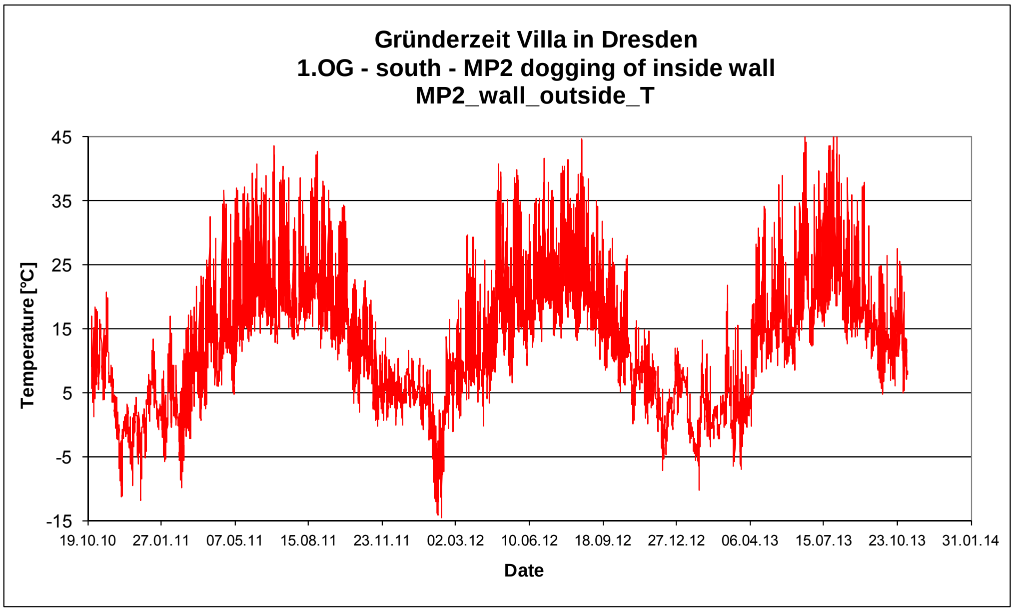


Figure 7.2.7: Temperature at the outside wall during inhabitation, measuring point at position 2 - dogging of inside wall 1OG south.

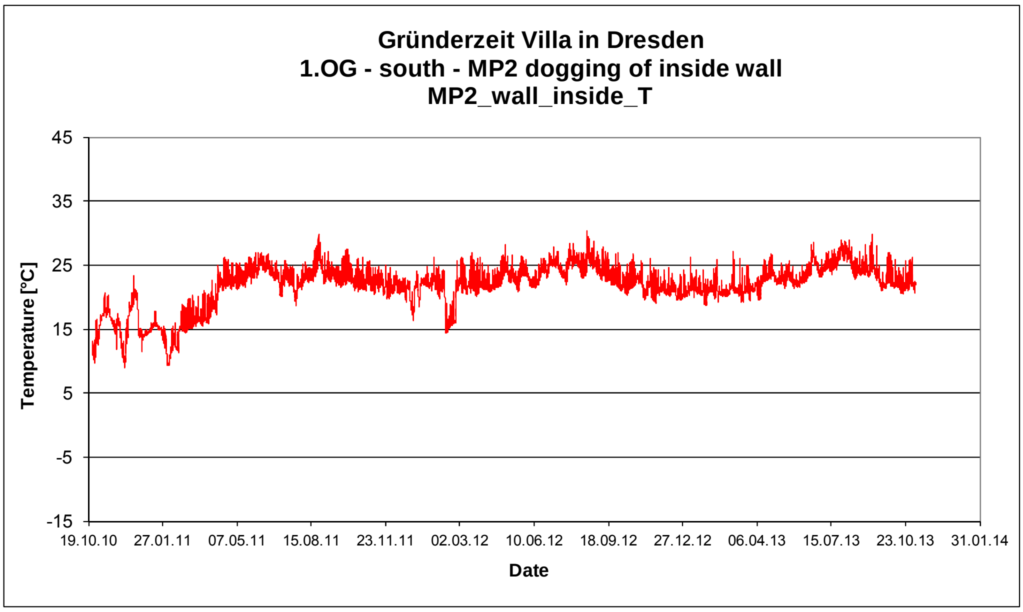


Figure 7.2.8: Temperature at the inside wall during inhabitation, measuring point at position 2 - dogging of inside wall 1OG south.

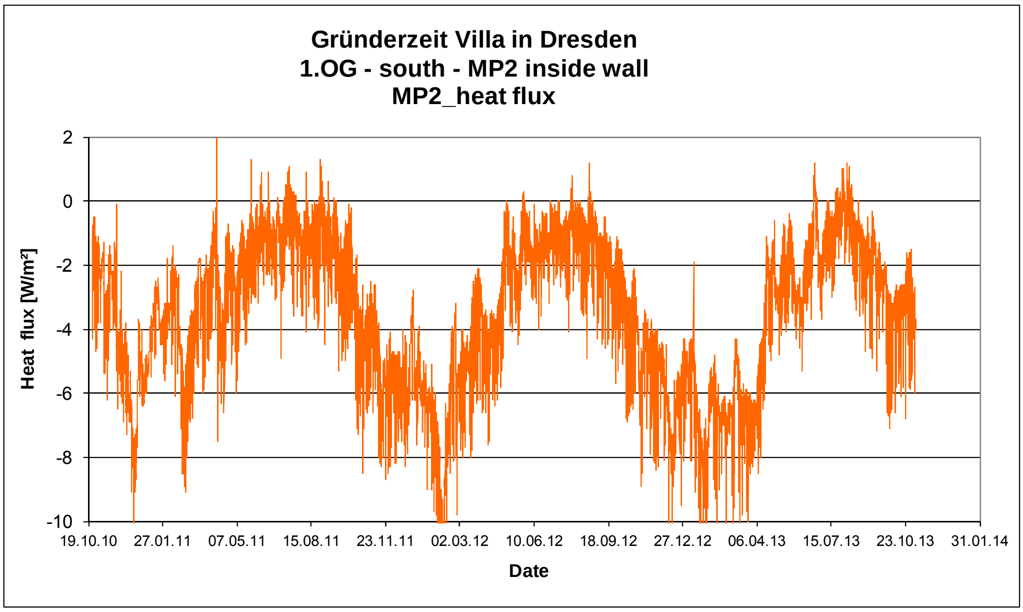


Figure 7.2.9: Heat flux at the inside wall during inhabitation, measuring point at position 2 - dogging of inside wall 1OG south.

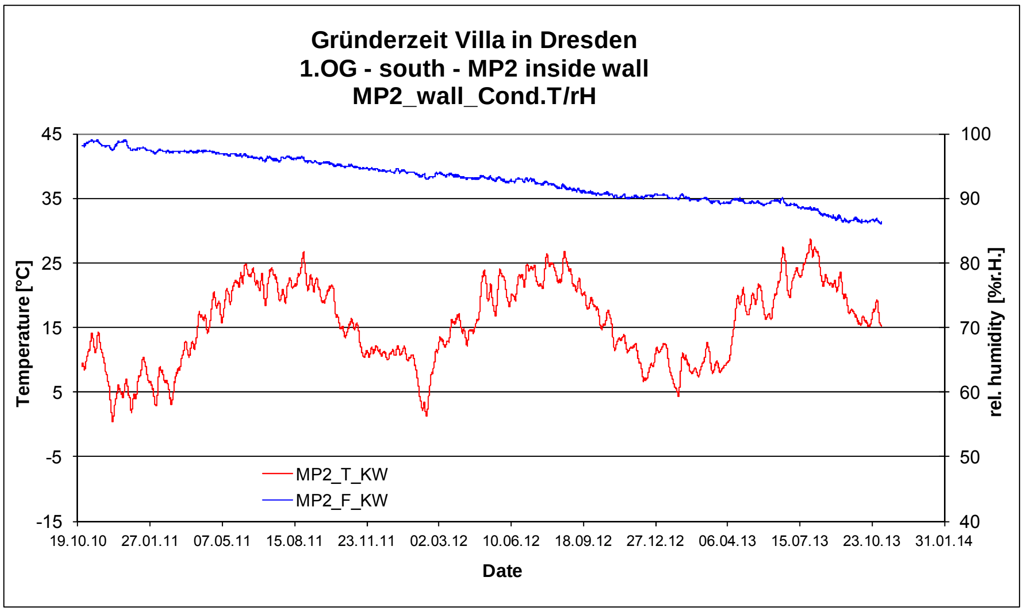


Figure 7.2.10: Temperature and relative humidity in the condensation zone between insulation an masonry wall during inhabitation, measuring point at position 2 - dogging of inside wall 1OG south.

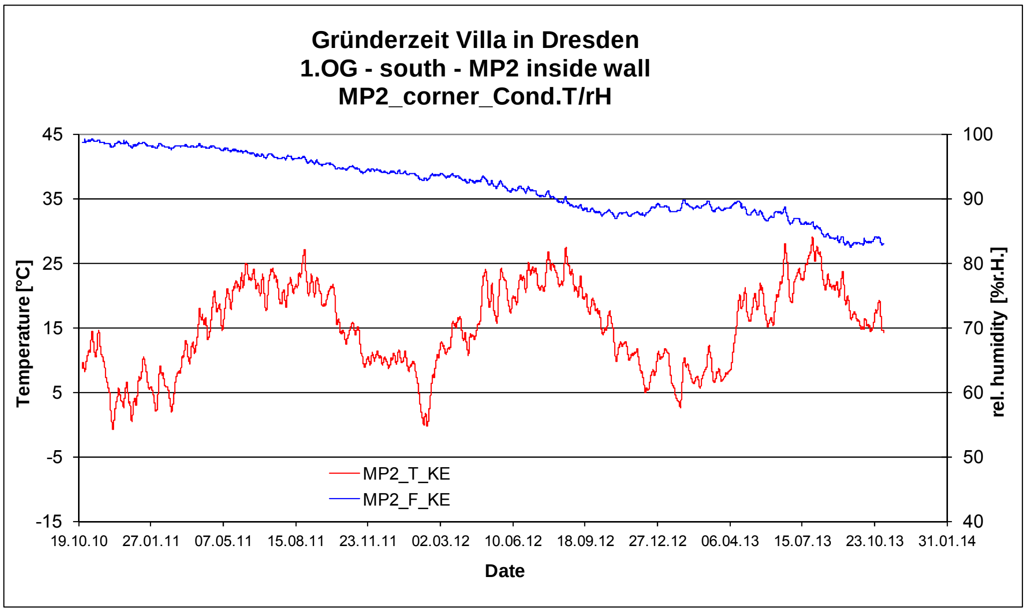


Figure 7.2.11: Temperature and relative humidity in the condensation zone between insulation an masonry wall during inhabitation, measuring point at position 2 – corner of the wall 1OG south.

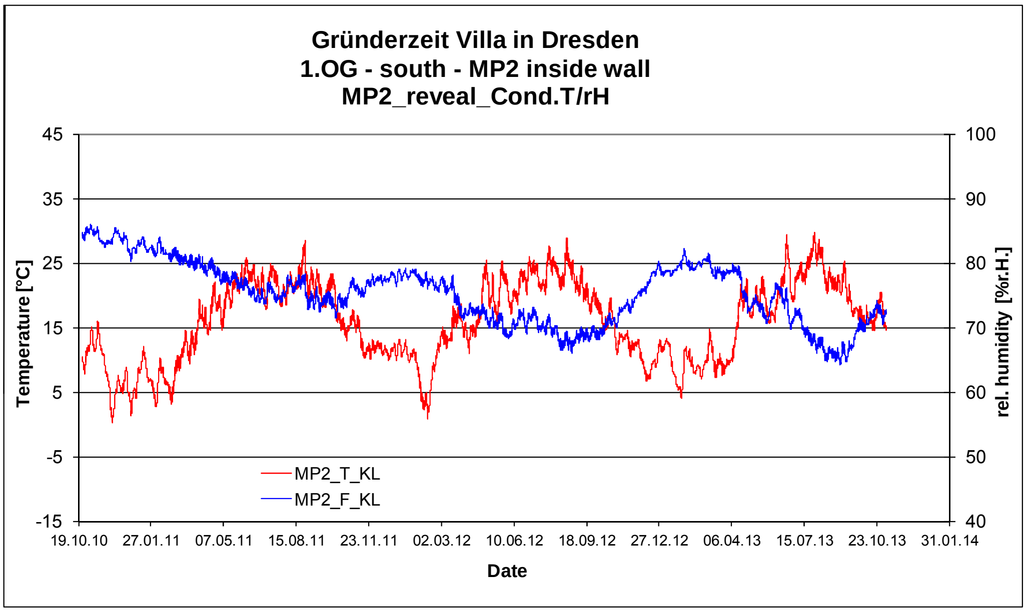


Figure 7.2.12: Temperature and relative humidity in the condensation zone between insulation an masonry wall during inhabitation, measuring point at position 2 – reveal of the window 1OG south.

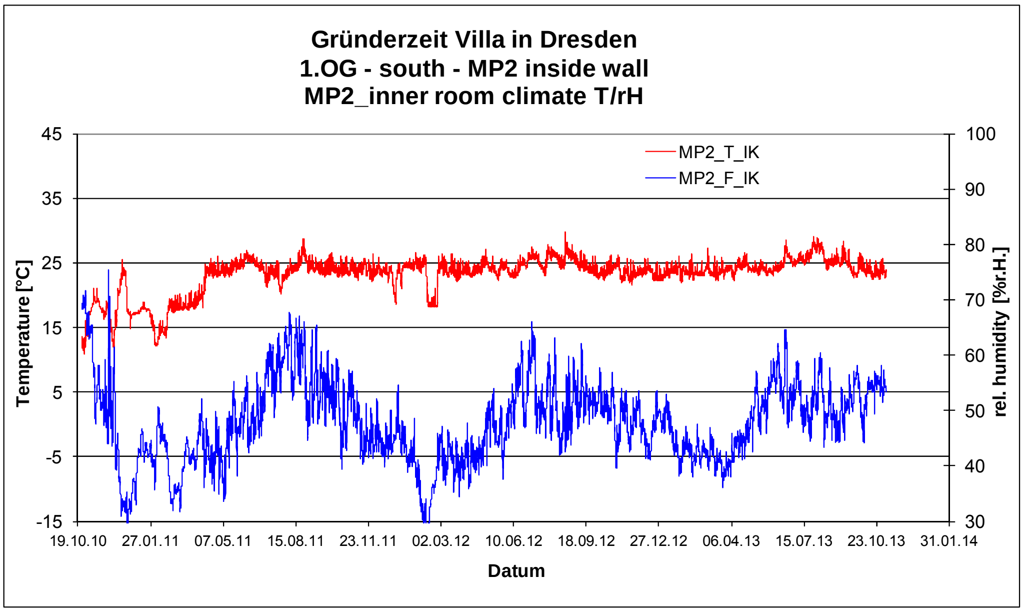


Figure 7.2.12: Temperature and relative humidity of the inner room climate, measuring point at position 2 – inside wall 1OG south.

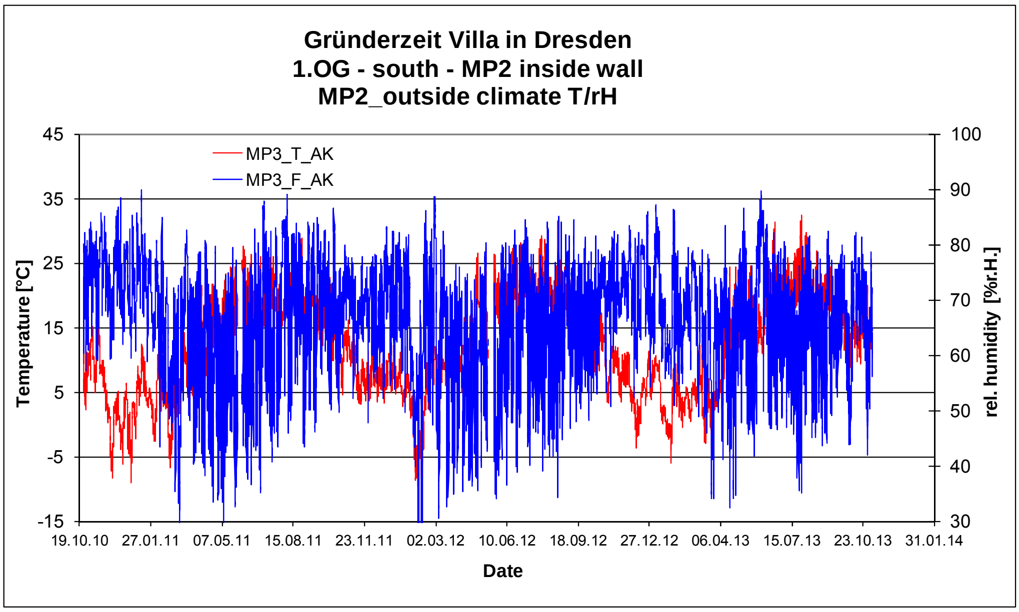


Figure 7.2.13: Temperature and relative humidity of the outside climate, measuring point at position 2 – outside wall 1OG south.

Measuring section 3 (Ground floor, room R7 – northern side)

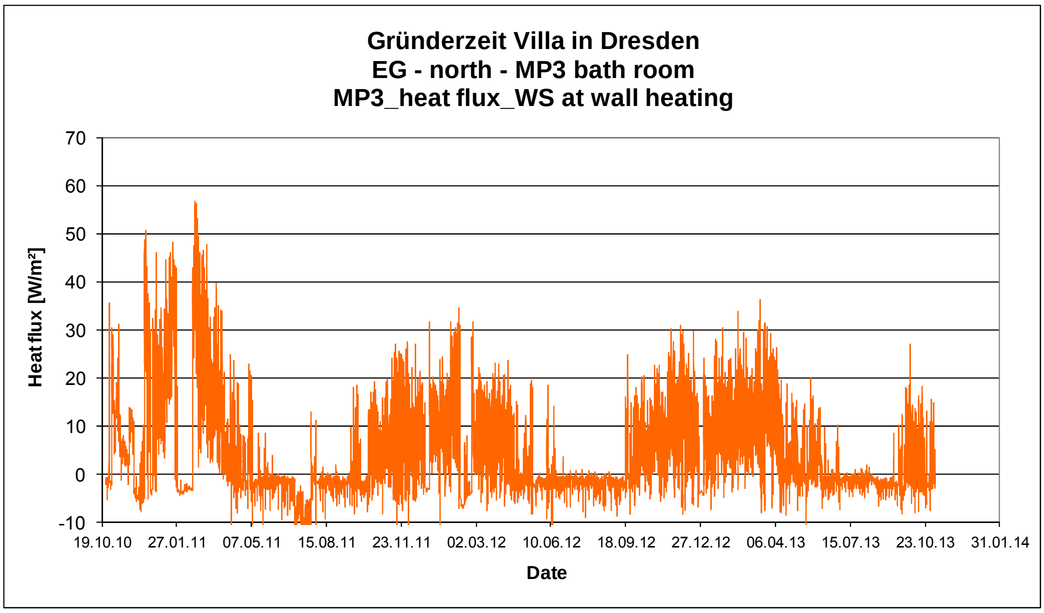


Figure 7.2.14: Heat flux in the plain of the wall heating system during inhabitation, measuring point at position 3 – bath room EG north.

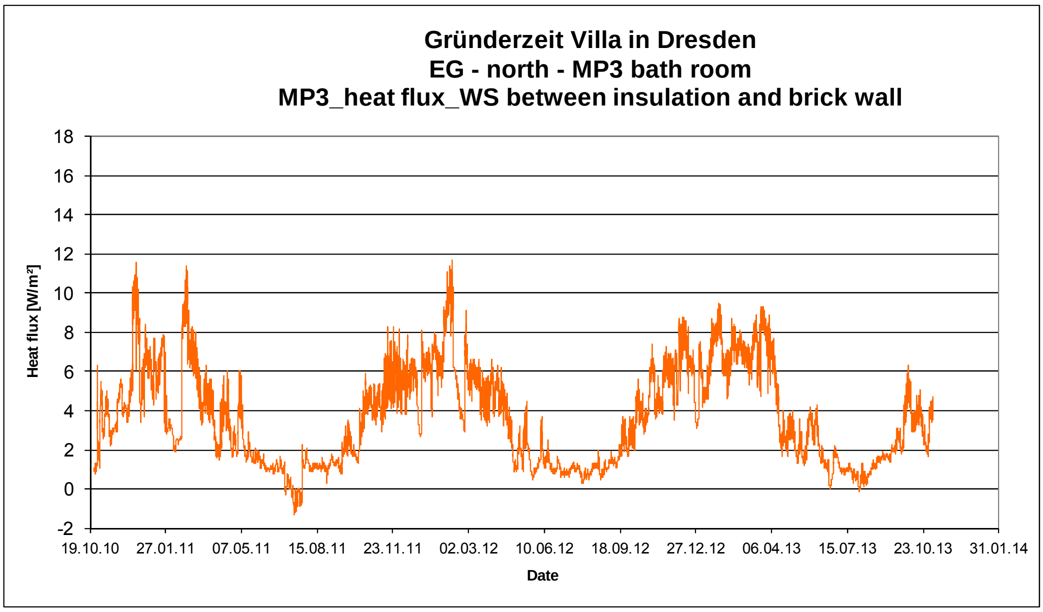


Figure 7.2.15: Heat flux at the inner wall surface during inhabitation, measuring point at position 3 – bath room EG north.

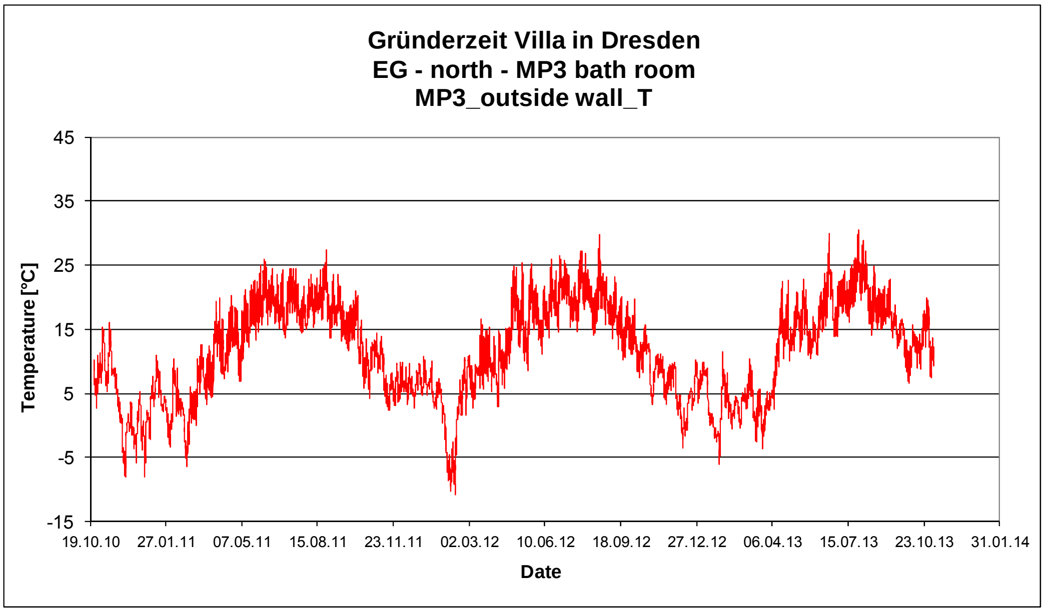


Figure 7.2.16: Temperature at the outside wall during inhabitation, measuring point at position 3 – bath room EG north.

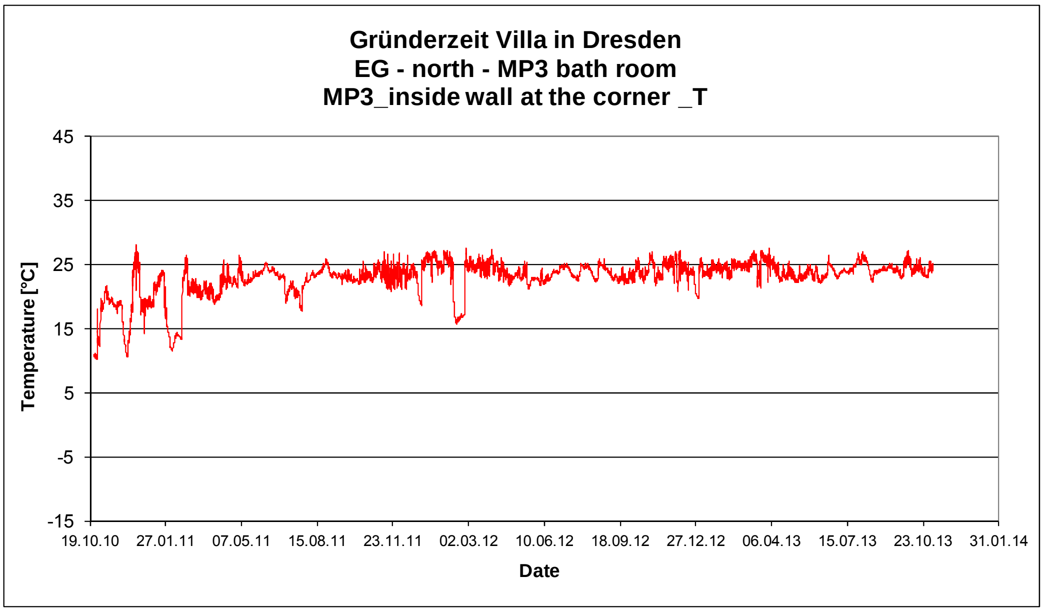


Figure 7.2.17: Temperature at the inside wall in the inner corner close the dogging of the inside wall during inhabitation, measuring point at position 3 – bath room EG north.

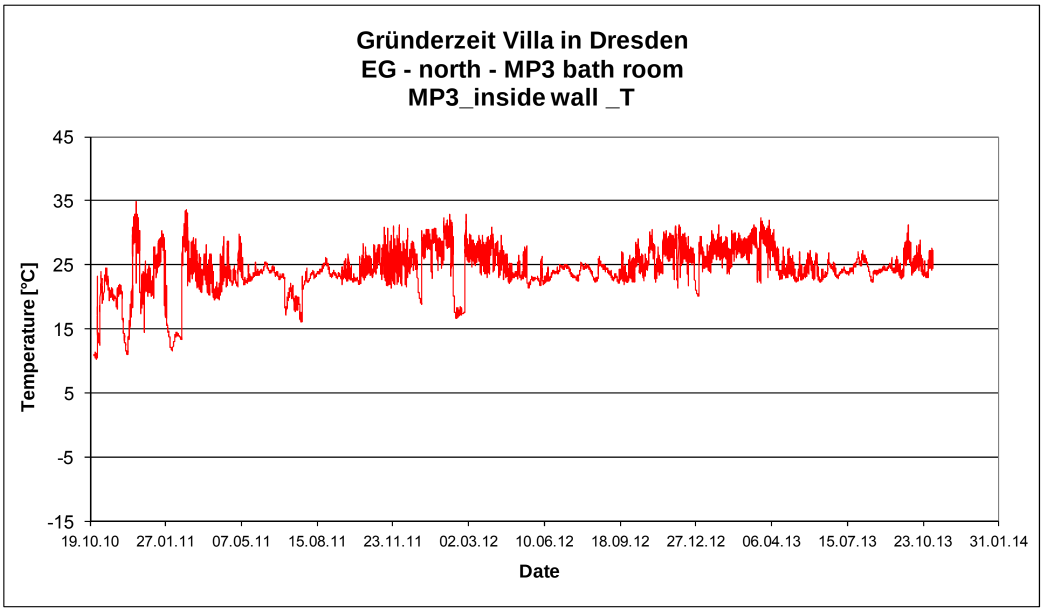


Figure 7.2.18: Temperature at the inside wall in the inner corner close the dogging of the inside wall during inhabitation, measuring point at position 3 – bath room EG north.

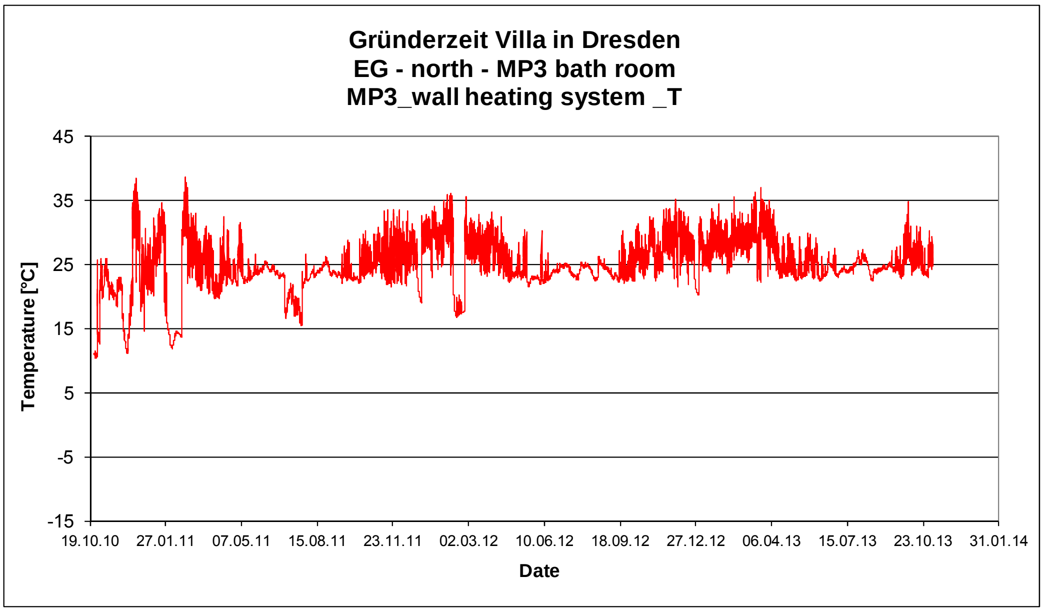


Figure 7.2.19: Temperature in the plain of the wall heating system during inhabitation, measuring point at position 3 – bath room EG north.

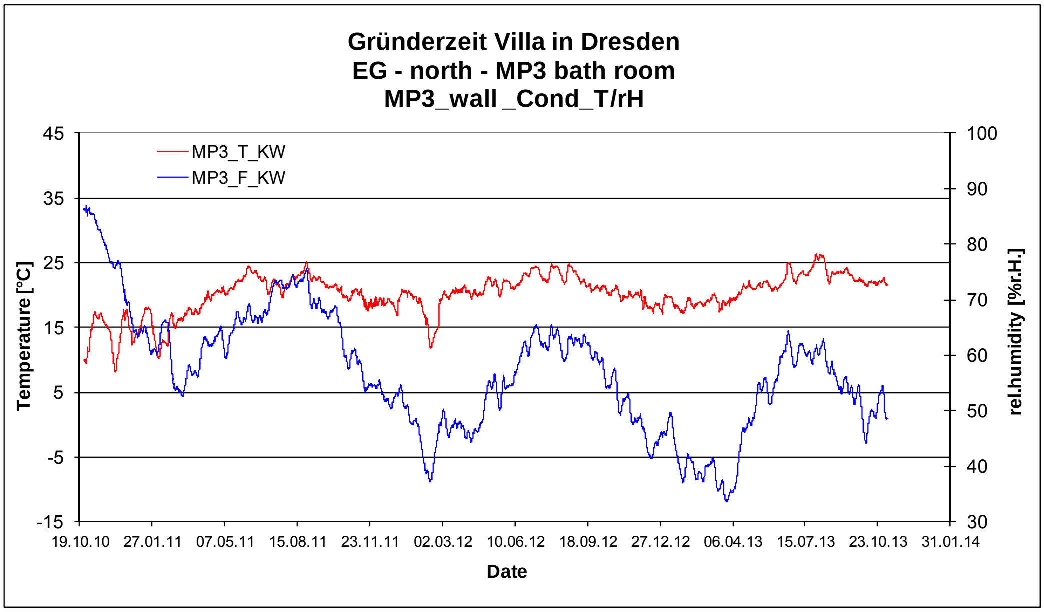


Figure 7.2.20: Temperature and relative humidity in the condensation zone between insulation an masonry wall during inhabitation, measuring point at position 3 – bath room EG north.

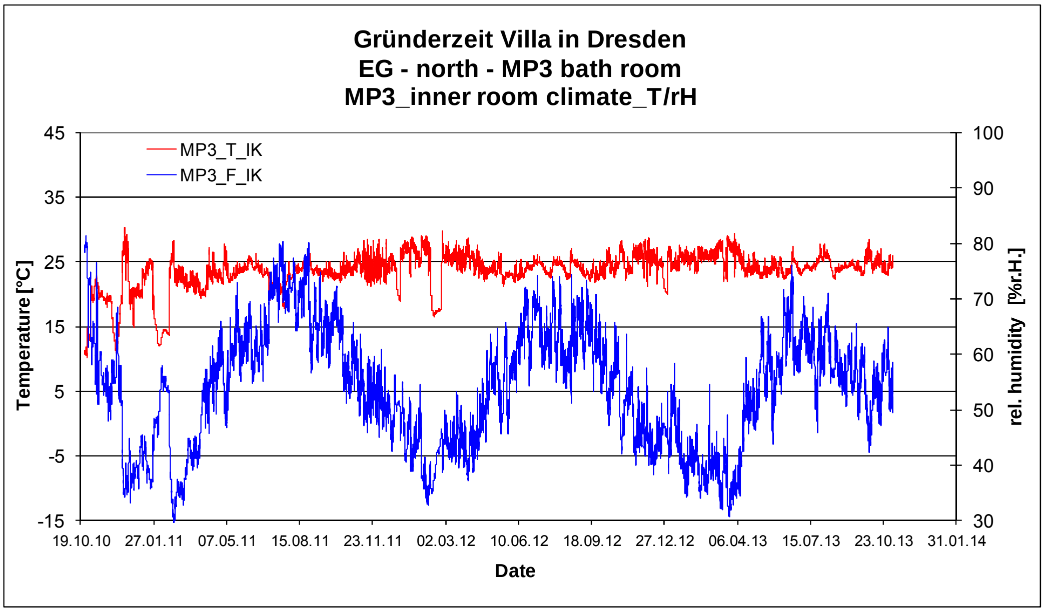


Figure 7.2.21: Temperature and relative humidity inner room climate during inhabitation, measuring point at position 3 – bath room EG north.

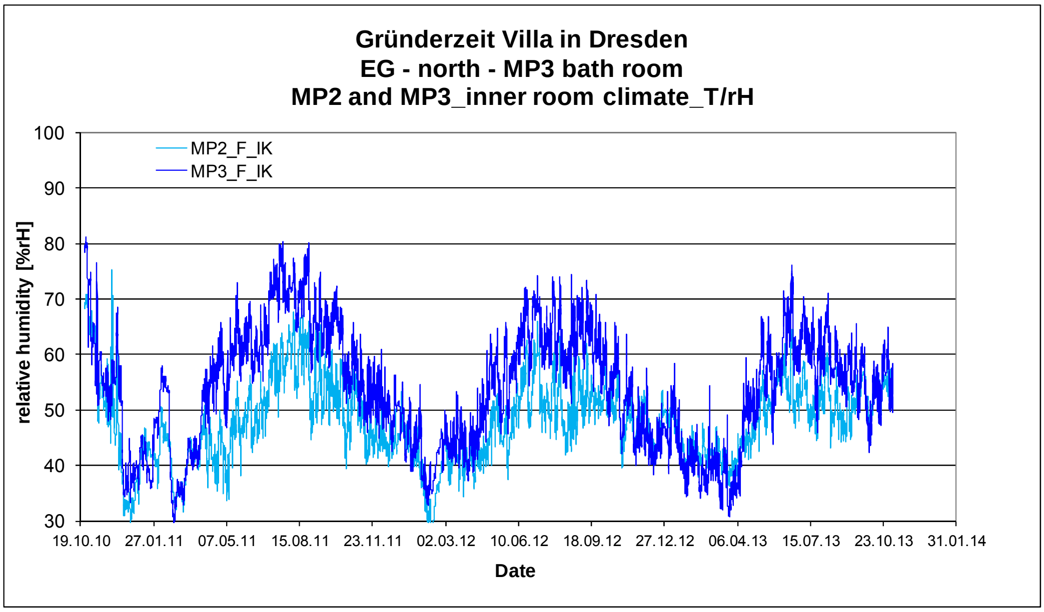


Figure 7.2.22: Comparison of relative humidity measured in the bath room MP3 and the living room MP2 during inhabitation, measuring point at position 2 – inside wall 1OG south and at position 3 – bath room EG north.

D 6.2 Documentation of each study case
CS6 Wilhelminian Villa, Dresden (Germany)
Building physical assessment and analysis of selected structural details with the interior insulation
Delivered at M42

EUROPEAN COMMISSION

DG Research and Innovation

Seventh Framework Programme

Theme [EeB.ENV.2010.3.2.4-1]

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Table of Content

Building physical assessment and analysis of selected structural details with the interior insulation iQ-Therm by Remmers

1 Structural analysis and assessment of moisture

1.1.1 Simulation description

The following documents the evaluation for one-dimensional and two-dimensional wall structures. The evaluation of the simulation calculation is carried out with the numerical simulation program DELPHIN. All simulation calculations were calculated on the one hand for the minimum thermal insulation according to DIN 4108-3 and on the other hand for the real climate.

In selected cases 2D-details were calculated with DIN climate and real climate (TestReferenceYear). The likelihood of mould growth, the temperature gradients within the structure and the curves of the relative humidity in the structure were considered. The simulations for the minimum energy performance were carried until it reached the quasi-steady state, meaning until the observed measurement point results in the construction don't change no more from year to year. The temperature and humidity gradients are outputted for the construction as fields.

1.1.2 Software planning tools COND, CHAMPS, DELPHIN

The computational analysis of building structures is based on an unsteady calculation model. The hygrothermal performance of a building component is calculated by the means of given climate gradients (e.g. indoor and outdoor air). Different questions can be processed depending on the simulation too. The following describes exemplarily the simulation program DELPHIN.

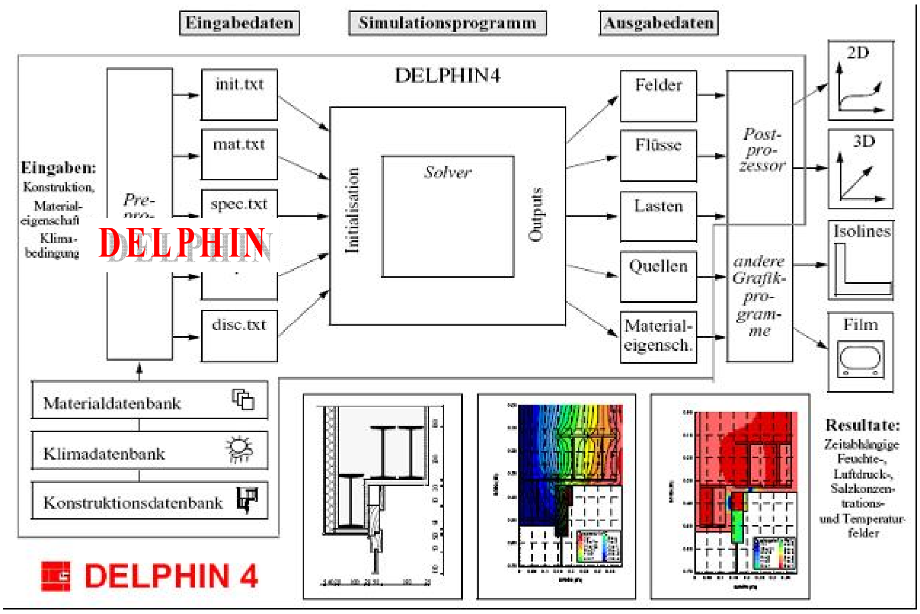


Figure 1.1: Overview over the DELPHIN 5 program components

The numerical heat, moisture, air and sea transportation program DELPHIN 5 underlying theory is derived from thermodynamic principles that describe the transport processes and the transitions between solid, liquid and gaseous phases. The simulation of the behaviour of porous materials is based on the theory of transport processes in multiphase systems. These transport coefficients are described as material properties dependent on the system state and provided to the simulation program.

A schematic overview of the program structure is given in Figure a). The simulation program is divided into a numeric part and a package for pre- and post processing. The pre-processor serves the graphic generation and cross-linking of the geometric model of the construction, as well as the specification and classification of the boundary conditions and material properties. A database for building materials is attached, which material properties in terms of humidity and temperature-dependent material functions suffice the high demands of the modelling. A climate database contains the characteristic weather sequences of the major German climate regions.

The numerical solver processes the input data according to the standard coupled model to describe the material and energy transport and it delivers state fields, flows, sources, sinks and material properties as output files. With the post-processing the output data can be visualized, while different graphical display options for also complex 2-dimensional geometric details exist.

1.1.3 Climatic boundary conditions

The construction climate basic requirements consist in weather protection, the creation of a user-desired indoor climate and the damage freedom of the buildings themselves. The climate that is established in the building is thereby the result of the interaction between:

- Outdoor climate (temperature, humidity, radiation exposure, wind and precipitation)
- Function side effects (internal sources, such as people, equipment, lighting ...)
- behavior of the structure, or of the individual components (heat transfer resistance, thermal storage, moisture buffering, ...)
- Air flow rate (normal rooms min. 20 m^3/m^2 h)
- building technical facilities (heating and air conditioning systems)

Outdoor climate and function side effects interfere with the thermal balance of the building. The building counters this load with its transportation and storage resistance and attenuates the load peaks. These properties, in conjunction with the ventilation, the building itself can withstand the indoor climate within limits for a large part of the year. If these properties do not suffice, heating and air conditioning systems need to be cut in.

On the other hand it gets clear that for example the installation of new dense windows not only effects the energetic upgrading but also the influence of the building ventilation, whereby the load limits shift (keyword: mould problems). Similarly, an inner insulation measure also leads to massive construction climate changes of the building. Simplified assumptions on the climate (see Table 1), applicable to non-air-conditioned living and office spaces as well as in buildings of similar use, in accordance with DIN 4108-3 can be taken as a base to evaluate a planned measure.

In the current simulations, real reference climate conditions are used. The records of test reference years (TRY) from the German Weather Service for Region 4 Potsdam climate with little harder driving rain and freezing conditions, which is similar to the Dresden air, come to use depending on the building design. More climate data apart from the climate conditions of temperature and relative humidity is considered for the simulations calculation:

- Precipitation parameters: precipitation, wind speed and wind direction
- Radiation parameters: short-wave and long-wave radiation
- Short-wave radiation, perpendicular to the surface of the structural component
- Direct sunlight on a horizontal surface
- Diffuse radiation on a horizontal surface
- Long-wave radiation, perpendicular to the surface of the component
- Long-wave radiation reflected from clouds and particles in the atmosphere
- Sky coverage

The indoor climate conditions being used in the calculations result from the DIN 4108 and are shown in the table below.

Tab. 1: Simplified climate conditions according to DIN 4108

Zeile	Klima	Temperatur θ °C	Relative Luftfeuchte ϕ %	Dauer h	Dauer d
1	Tauperiode				
1.1	Außenklima [a]	− 10 // -5	80	1 440 2160	60 90
1.2	Innenklima	20	50		
2	Verdunstungsperiode				
2.1	Wandbauteile und Decken unter nicht ausgebauten Dachräumen				
2.1.1	Außenklima	12	70	2 160	90
2.1.2	Innenklima				
2.1.3	Klima im Tauwasserbereich		100		
2.2	Dächer, die Aufenthaltsräume gegen die Außenluft abschließen [b]				
2.2.1	Außenklima	12	70	2 160	90
2.2.2	Temperatur der Dachoberfläche	20	—		
2.2.3	Innenklima	12	70		

[a] Gilt auch für nicht beheizte, belüftete Nebenräume, z. B. belüftete Dachräume, Garagen.

[b] Vereinfachend können bei diesen Dächern auch die Klimabedingungen für Bauteile der Zeile 2.1 zu Grunde gelegt werden.

The simulations are carried out until reaching the quasi-stationary state. This means that, after a settling time, which can last several years, the temperature and the moisture content at each point of the construction is virtually indistinguishable from year to year. Meaning that the construction behaves hygrothermal stabile.

With the intention of testing the design conservatively, the calculations are performed with Western orientation. Thereby the building is loaded with driving rain, whereas the studies represent a tough test. The occurring moisture load thus represents only the condensate but also the driving rain entry.

2 Application of numerical simulation

As possibilities of a comparative visualization of the results, the following states are mapped:

- the likelihood of mould,
- the relative humidity in the structure at the 3rd February after a year-long settling time,
- the temperature in the construction in the 3rd February after a year-long settling time,
- the arising condensate.

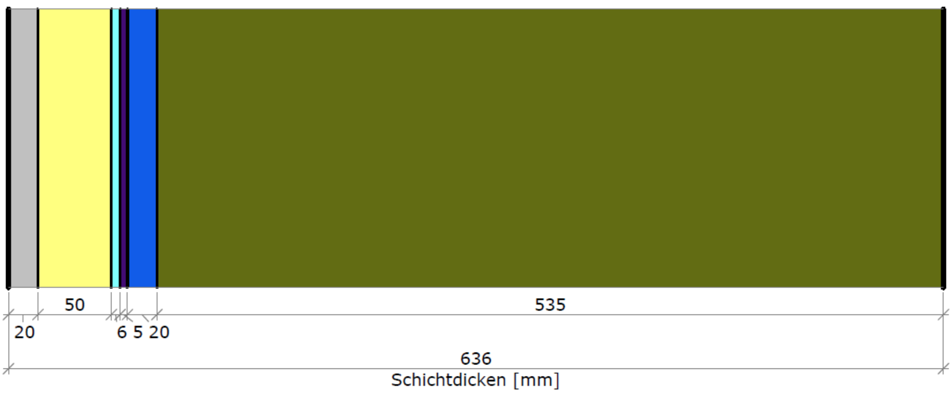
3 1D Constructions

3.1 Construction 1: „upper floor with insulation“

3.1.1 COND-result for a one-dimensional wall construction

Construction sketch

warm



cold

Construction layout and material parameter

	Material	d [mm]	λ [W/mK]	μ [---]	w_{80} [m³/m³]	w_{sat} [m³/m³]	A_w [kg/m²s½]
1	Antischimmelputz IQ-Top	20	0,111	12,0	0,015	0,149	0,014
2	Klimaplatte IQ-Therm	50	0,031	27,2	0,003	0,980	0,013
3	Kleber IQ-Fix	6	0,497	17,0	0,033	0,350	0,005
4	Bitumen	5	0,145	1,5E04	0,000	0,003	0,000
5	LO_Putz	20	0,850	11,0	0,025	0,250	0,176
6	Sandstein	535	1,150	11,5	0,002	0,243	0,026

d = Schichtdicke; λ = Wärmeleitfähigkeit; μ = Wasserdampfdiffusionswiderstandszahl; w_{80}/w_{sat} = Feuchtegehalt bei 80% rel. Luftfeuchte bzw. bei Sättigung; A_w - Wasseraufnahmekoeffizient

Summary of the calculation results

Wärmedurchgangskoeffizient der Konstruktion (feuchteabhängig)	U =	0,409	W/(m²K)
Wärmedurchgangskoeffizient der Konstruktion (trocken)	U =	0,400	W/(m²K)
Wärmedurchlasswiderstand der Konstruktion	R =	2,328	m²K/W
Kondensatmasse am Ende der Kondensationsperiode (nach COND)	M_c =	0,376	kg/m²
Trocknungszeit	t_{ev} =	87,71	d
DIN 4108-2 Tab. 3,1+11 (Wärmedurchlasswiderstand) R >= 1,2 m²K/W		**Anforderung erfüllt**	
DIN 4108-3 4.2.1.d (nicht wasseraufnahmefähig) M_c <= 0,5 kg/m²		**Anforderung erfüllt**	
Trocknungsdauer im Sommer t_{ev} < 90d		**Anforderung erfüllt**	

3.1.2 Delphin-results for a one-dimensional wall construction

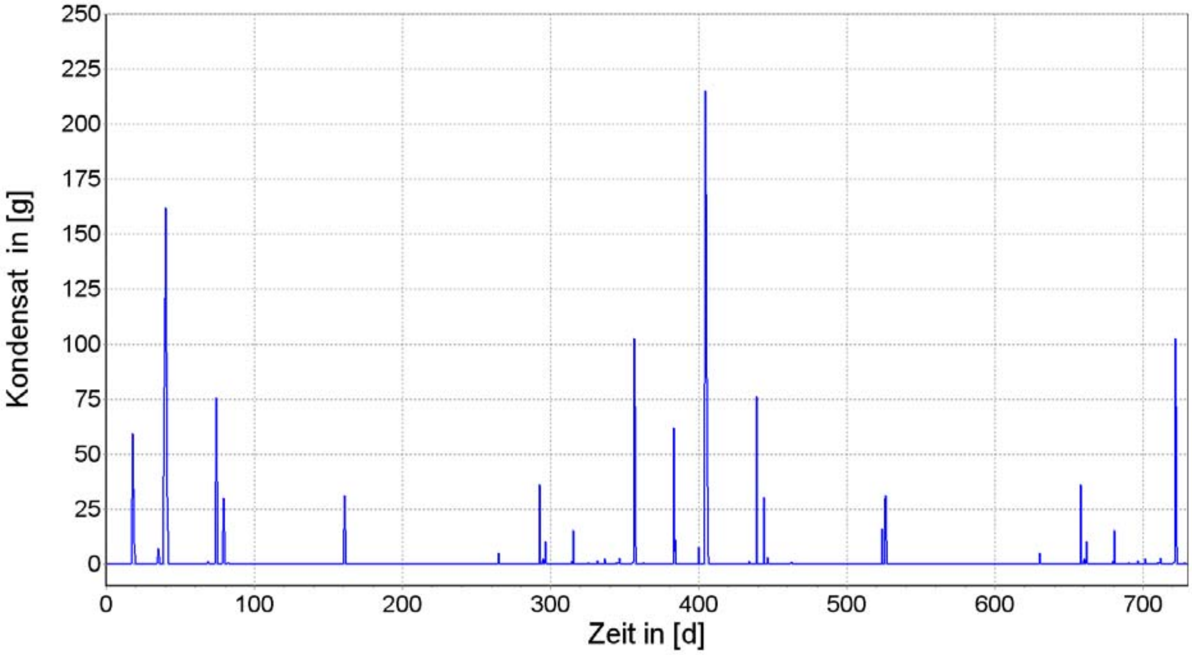


Figure 3.1.1: Course of the inner condensate in steady state in wall construction K1-brickwork (TRY Potsdam).

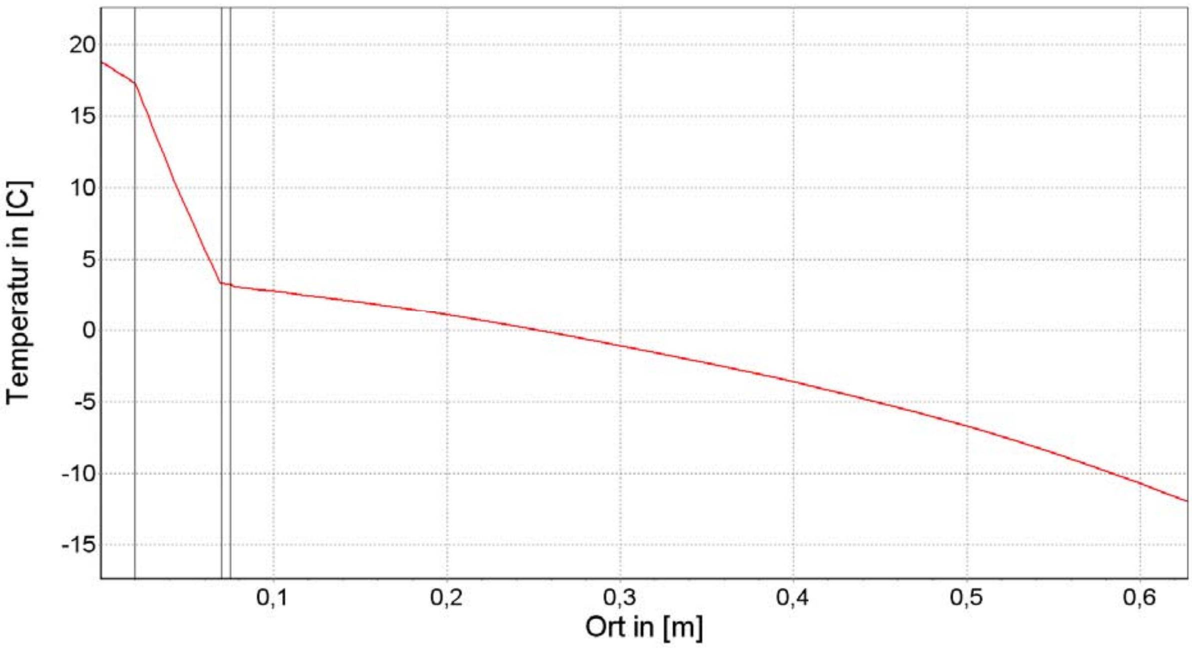


Figure 3.1.2: Characteristic temperature profile on 3rd February in wall construction K1 (TRY Potsdam)

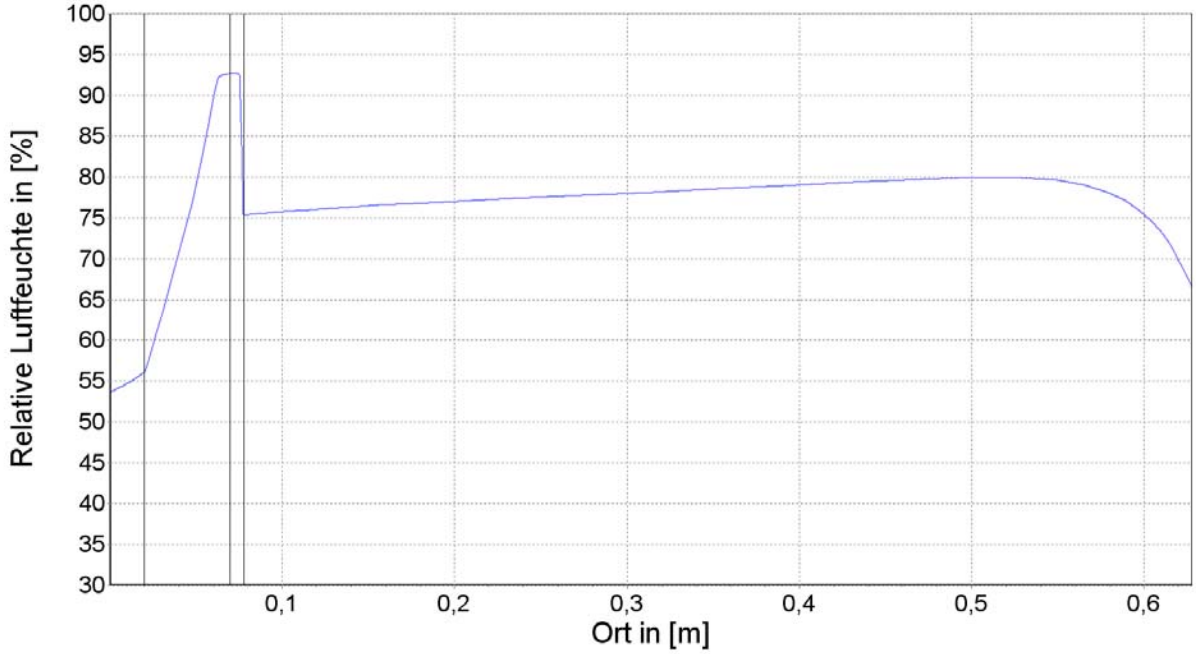


Figure 3.1.3: Characteristic air-humidity profile on 3rd February in wall construction K1 (TRY Potsdam)

3.1.3 Assessment of the one-dimensional calculations and simulations

All boundary values regarding minimum thermal insulation (R> 1.2 m² · K / W), amount of condensate ($m_{W,T} \leq 0{,}5/1{,}0$ kg/m²) and dehydration ($m_{W,V} \geq m_{W,T}$) are adhered in the COND calculations with stationary climate conditions.

The conditions of DIN4108-3 regarding condensate and dehydration are also observed in the simulations:

$m_{W,T,max}$ = 0,216 kg/m² $\leq$ $m_{W,T,DIN4108-3}$ = 1,0 kg/m²

$m_{W,V}$ $\geq$ $m_{W,T,max}$

with $m_{W,T,max}$: the maximum amount of condensate of the inner layers, (that means without external brick and mortar layer.)

with $m_{W,T,max}$: allowed maximum amount of condensate according to DIN 4108-3, section 4.2.1

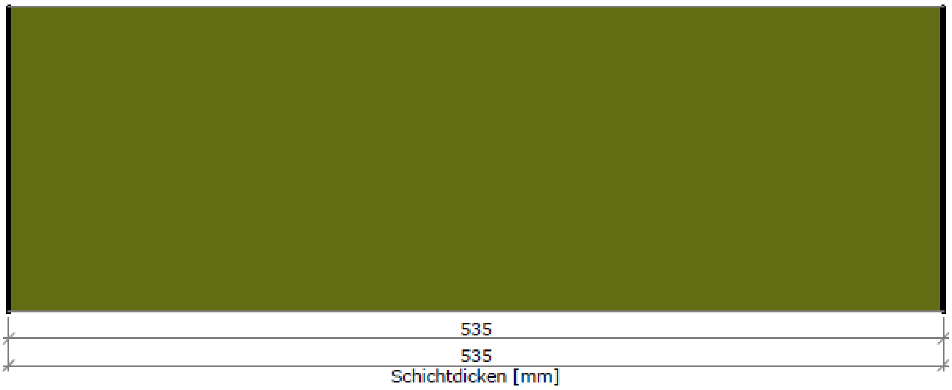
with $m_{W,V}$: Summer evaporation rate

3.2 Construction 2: „basement without insulation“

3.2.1 COND-results for a one-dimensional wall construction

Construction sketch

warm



cold

Construction layout and material parameter

	Material	d [mm]	λ [W/mK]	μ [---]	w_{80} [m^3/m^3]	w_{sat} [m^3/m^3]	A_w [$kg/m^2s^{½}$]
1	Sandstein	535	1,150	11,5	0,002	0,243	0,026

d = Schichtdicke; λ = Wärmeleitfähigkeit; μ = Wasserdampfdiffusionswiderstandszahl; w_{80}/w_{sat} = Feuchtegehalt bei 80% rel. Luftfeuchte bzw. bei Sättigung; A_w - Wasseraufnahmekoeffizient

Summary of the calculation results

Wärmedurchgangskoeffizient der Konstruktion (trocken)	U =	1,574	W/(m²K)
Wärmedurchlasswiderstand der Konstruktion	R =	0,465	m²K/W
DIN 4108-2 Tab. 3,1+11 (Wärmedurchlasswiderstand) R >= 1,2 m²K/W		**Anforderung nicht erfüllt**	

Kein Kondensat in der Konstruktion!

3.2.2 Delphin-results for a one-dimensional wall construction

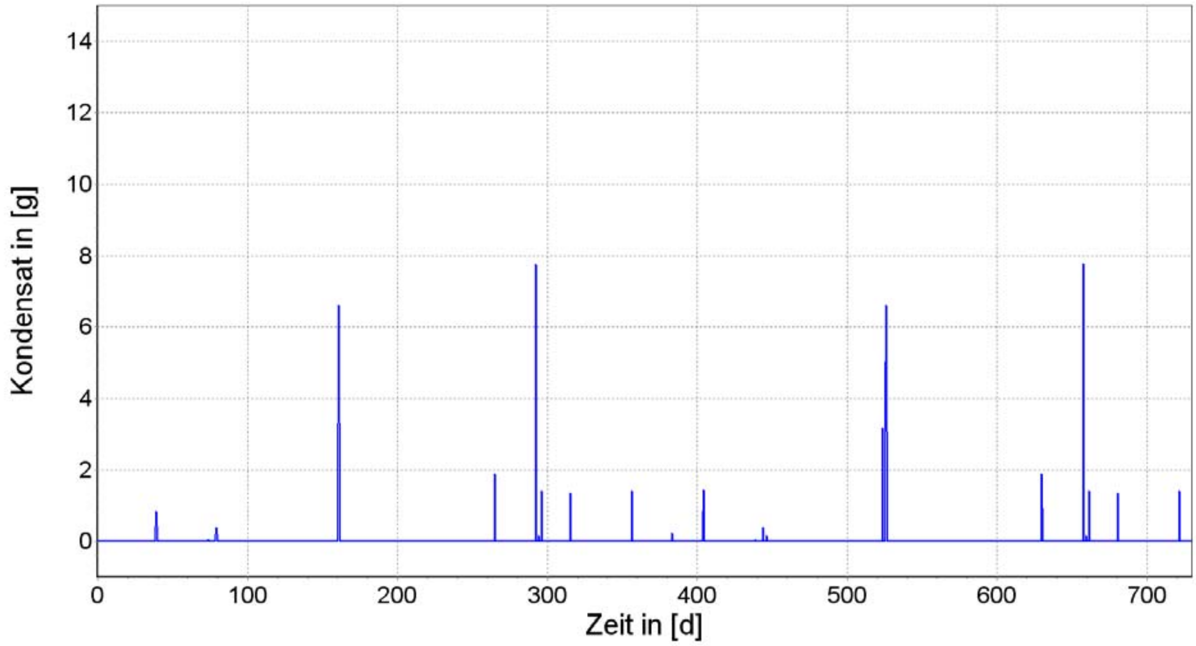


Figure 3.2.1: Course of the inner condensate in steady state in wall construction K2-brickwork (TRY Potsdam)

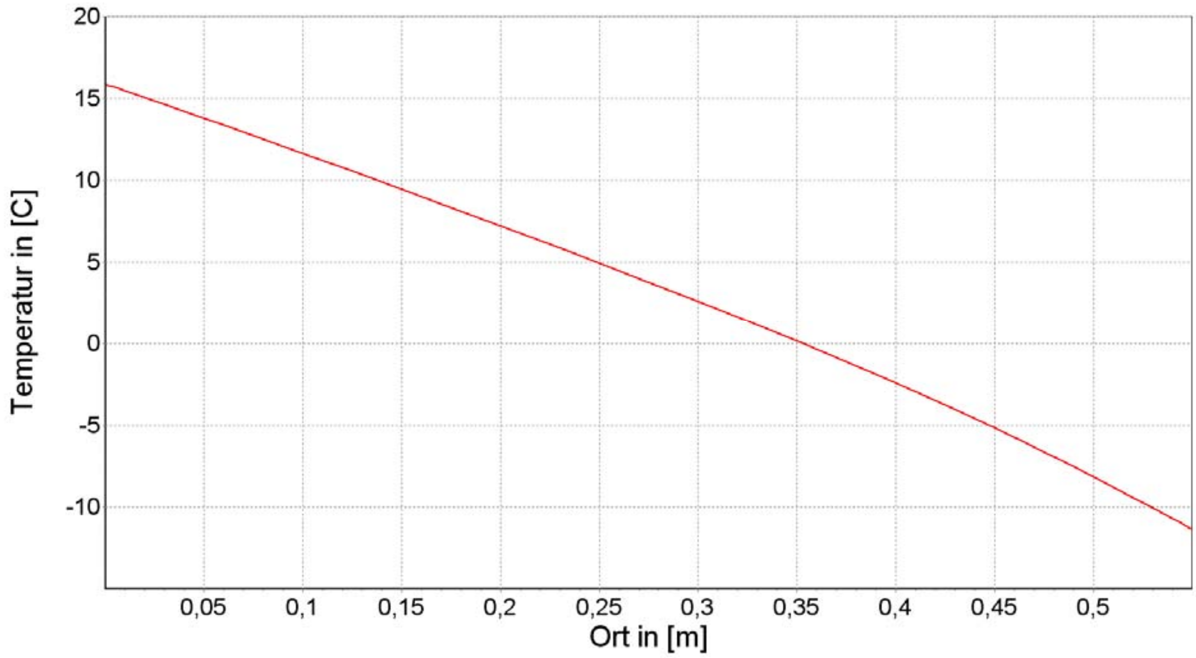


Figure 3.2.2: Characteristic temperature profile on 3rd February in wall construction K2 (TRY Potsdam)

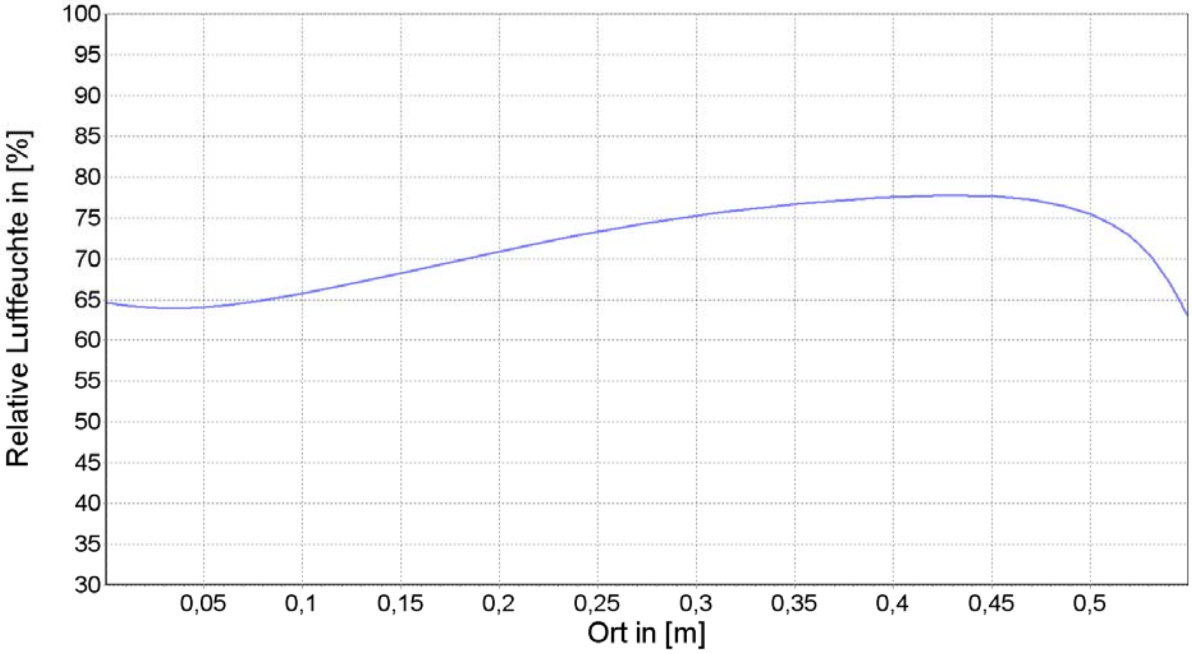


Figure 3.2.3: Characteristic air-humidity profile on 3rd February in wall construction K2 (TRY Potsdam)

3.2.3 Assessment of the one-dimensional calculations and simulations

The limits regarding the minimum energy performance are taken from the DIN 4108-02 Section 6.2 for the basement area. An annual internal temperature of 10 ° C can be assumed in unoccupied rooms. A f_{rsi}-value of 0,7 is stipulated here. The minimum surface temperature for the cold period according to DIN is 6.93 ° C in the basement area so that a f_{rsi}-value of 0.82> 0.7 is calculated. In the case of the minimum thermal insulation the COND calculation is considered to be irrelevant. The amount of condensate ($m_{W,T} \leq$ 0,5/1,0 kg/m²) and dehydration ($m_{W,V} \geq m_{W,T}$) are adhered in the COND-calculations with the stationary climate conditions.

The conditions of DIN 4108-3 regarding amount of condensate and dehydration are also adhered in the simulations:

mW,T,max = 0,007 kg/m² < mW,T,DIN4108-3 = 1,0 kg/m²

mW,V > mW,T,max

with mW,T,max : the maximum amount of condensate of the inner layers, (that means without external brick and mortar layer.)

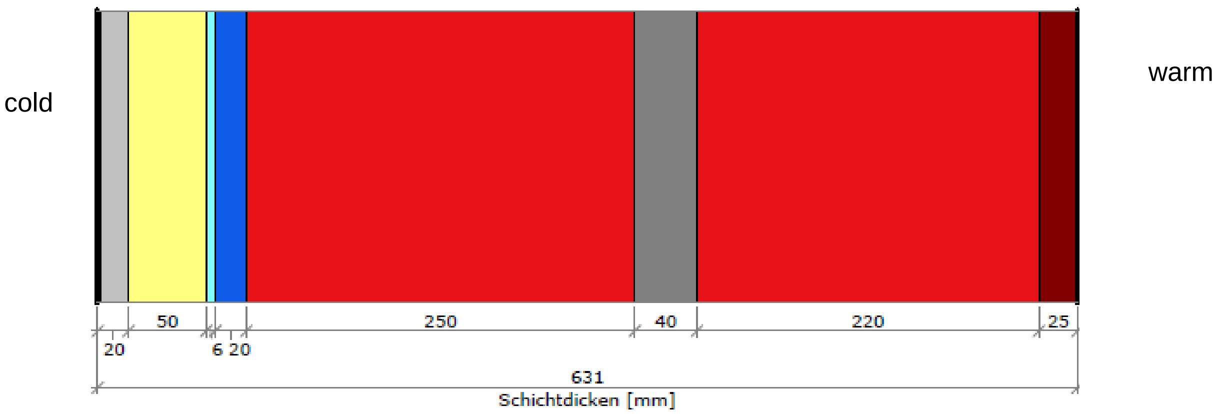
with mW,T,max : allowed maximum amount of condensate according to DIN 4108-3, section 4.2.1

with mW,V : Summer evaporation rate

3.3 Construction 3a: „ground floor with insulation“

3.3.1 COND-results for the one-dimensional wall construction

Construction sketch



Construction layout and material parameter

	Material	d [mm]	λ [W/mK]	μ [---]	w_{80} [m³/m³]	w_{sat} [m³/m³]	A_w [kg/m²s½]
1	Antischimmelputz IQ-Top	20	0,111	12,0	0,015	0,149	0,014
2	Klimaplatte IQ-Therm	50	0,031	27,2	0,003	0,980	0,013
3	Kleber IQ-Fix	6	0,497	17,0	0,033	0,350	0,005
4	LO_Putz	20	0,850	11,0	0,025	0,250	0,176
5	LO-ziegel	250	0,750	8,1	0,005	0,319	0,331
6	LO_Mörtel	40	0,700	11,0	0,030	0,320	0,173
7	LO-ziegel	220	0,750	8,1	0,005	0,319	0,331
8	LO_putz	25	0,850	11,0	0,025	0,250	0,176

d = Schichtdicke; λ = Wärmeleitfähigkeit; μ = Wasserdampfdiffusionswiderstandszahl; w_{80}/w_{sat} = Feuchtegehalt bei 80% rel. Luftfeuchte bzw. bei Sättigung; A_w - Wasseraufnahmekoeffizient

Summary of the calculation results

Wärmedurchgangskoeffizient der Konstruktion (feuchteabhängig)	U =	0,370	W/(m²K)
Wärmedurchgangskoeffizient der Konstruktion (trocken)	U =	0,369	W/(m²K)
Wärmedurchlasswiderstand der Konstruktion	R =	2,542	m²K/W
Kondensatmasse am Ende der Kondensationsperiode (nach COND)	M_c =	0,016	kg/m²
Trocknungszeit	t_{ev} =	2,87	d
DIN 4108-2 Tab. 3,1+11 (Wärmedurchlasswiderstand) R >= 1,2 m²K/W		**Anforderung erfüllt**	
DIN 4108-3 4.2.1.c (wasseraufnahmefähig) M_c <= 1,0 kg/m²		**Anforderung erfüllt**	
Trocknungsdauer im Sommer t_{ev} < 90d		**Anforderung erfüllt**	

3.3.2 Delphin-results for the one-dimensional wall construction

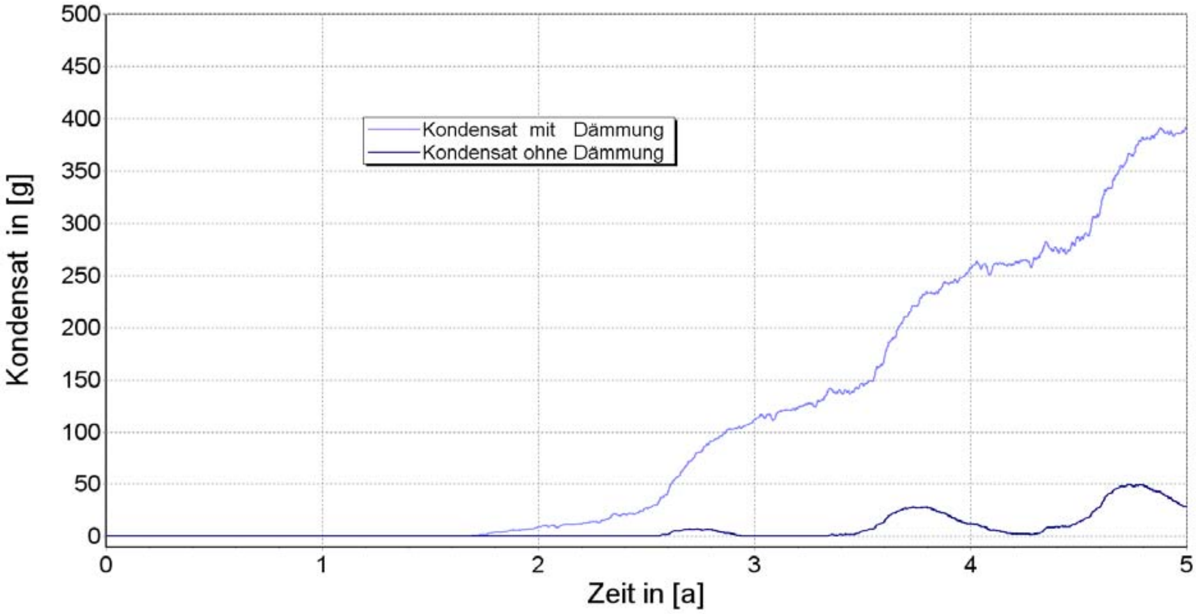


Figure 3.3.1: Course of the condensate in comparison for the construction before the reconstruction measure (without insulation) and after the reconstruction measure (with insulation). Wall construction K3 – brickwork (TRY Potsdam). There is an increase of the inner condensate to be noticed, which is levelled out after 12 years with smaller than 1000g.

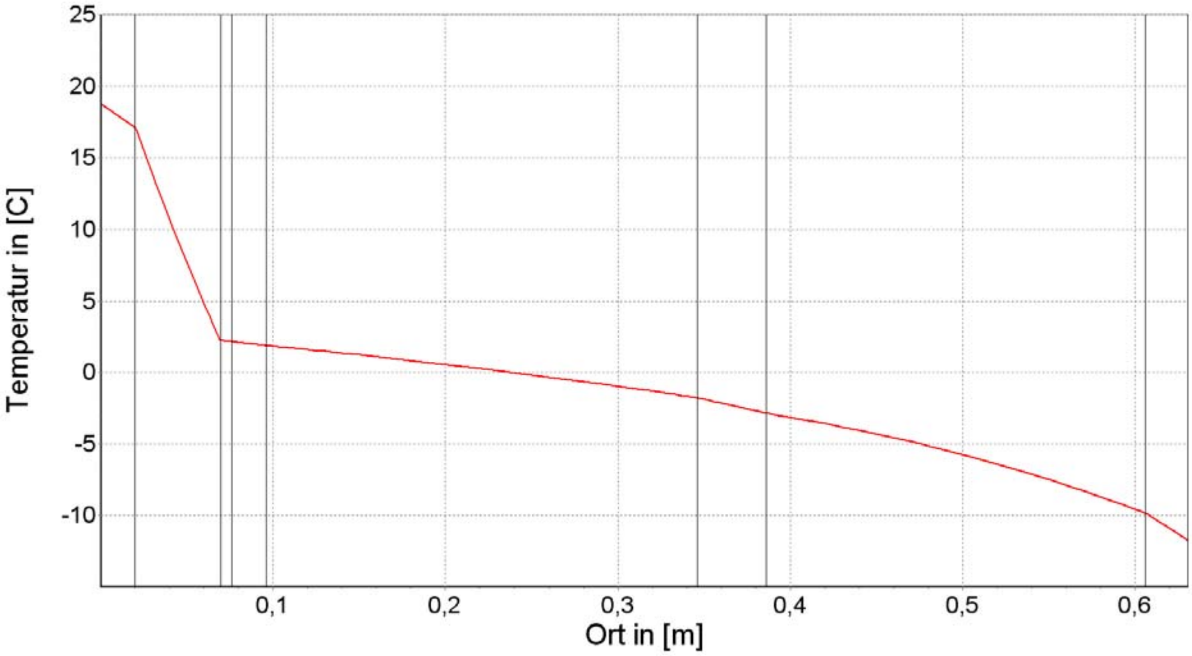


Figure 3.3.2: Characteristic temperature profile on the 3rd February in wall construction K3 (TRY Potsdam)

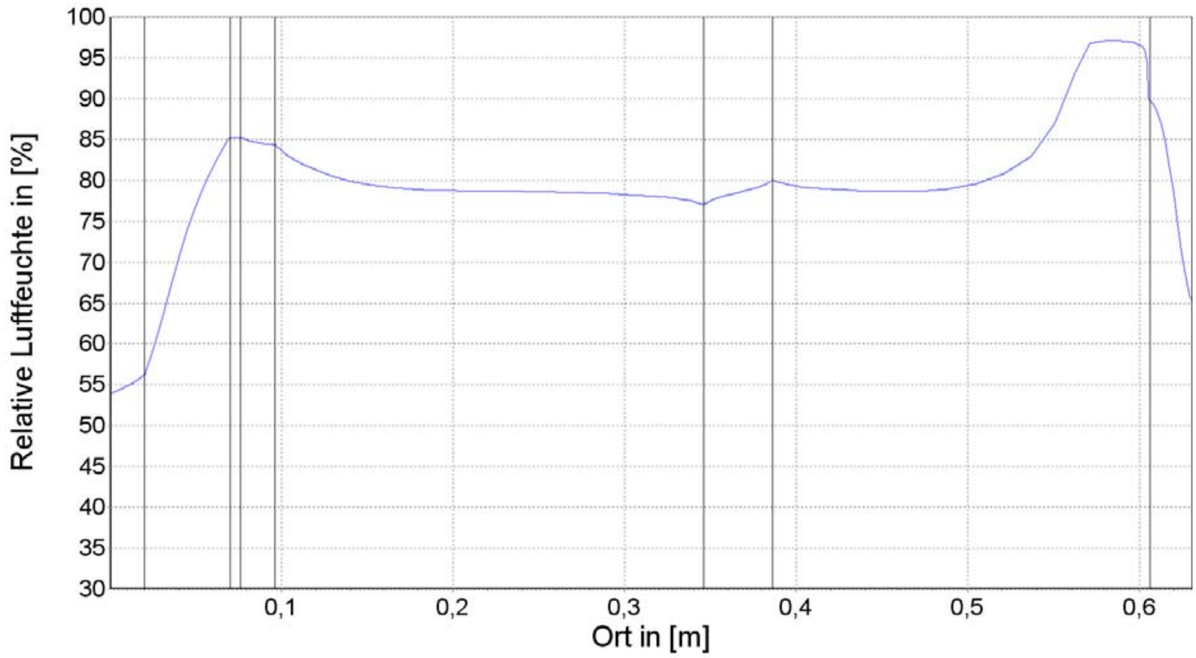


Figure 3.3.3: Characteristic air-humidity profile on 3rd February in wall construction K3 (TRY Potsdam)

3.3.3 Assessment of the one-dimensional calculations and simulations

All boundary values regarding minimum thermal insulation (R> 1.2 m² · K / W), amount of condensate (mW,T < 0,5/1,0 kg/m²) and dehydration (mW,V > mW,T) are adhered in the COND calculations with stationary climate conditions.

The conditions of DIN4108-3 regarding condensate and dehydration are also observed in the simulations:

mW,T,max <1 kg/m² < mW,T,DIN4108-3 = 1,0 kg/m²

mW,V > mW,T,max

with mW,T,max : the maximum amount of condensate of the inner layers,

(that means without external brick and mortar layer.)

with mW,T,max : allowed maximum amount of condensate according to DIN 4108-3, section 4.2.1

with mW,V : Summer evaporation rate

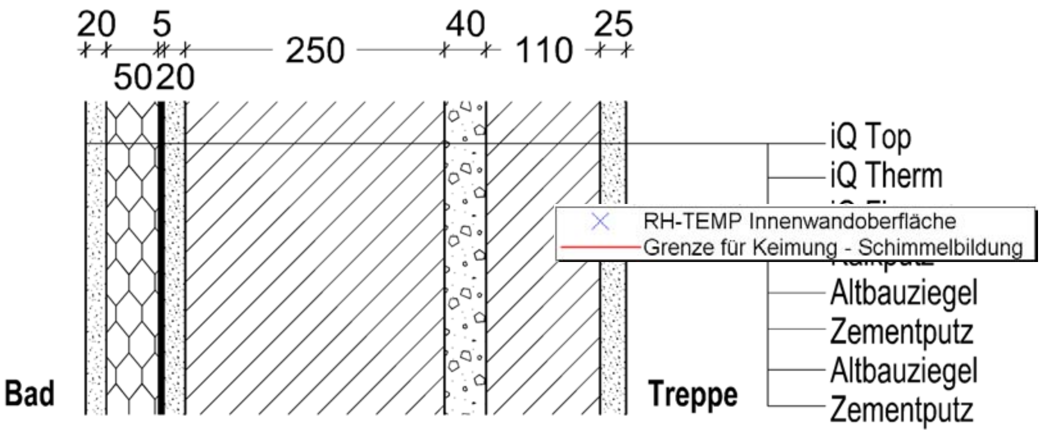
3.4 Construction 3b: "Bathroom – Staircase"

Due to the special boundary conditions no COND-calculation is being made solely a Delphin simulation is being customized.

3.4.1 Delphin-results for a one-dimensional wall construction

- Indoor climate bathroom:
    - 20°C / 50% relative humidity, duration: until constant levelled out condition is reached,
    - Thermal contact resistance: 0,13 m²·K/W
- Climate staircase:
    - 10°C / 35% relative humidity, duration: until constant levelled out condition is reached,
    - Thermal contact resistance: 0,13 m²·K/W

Construction layout for construction 3b:



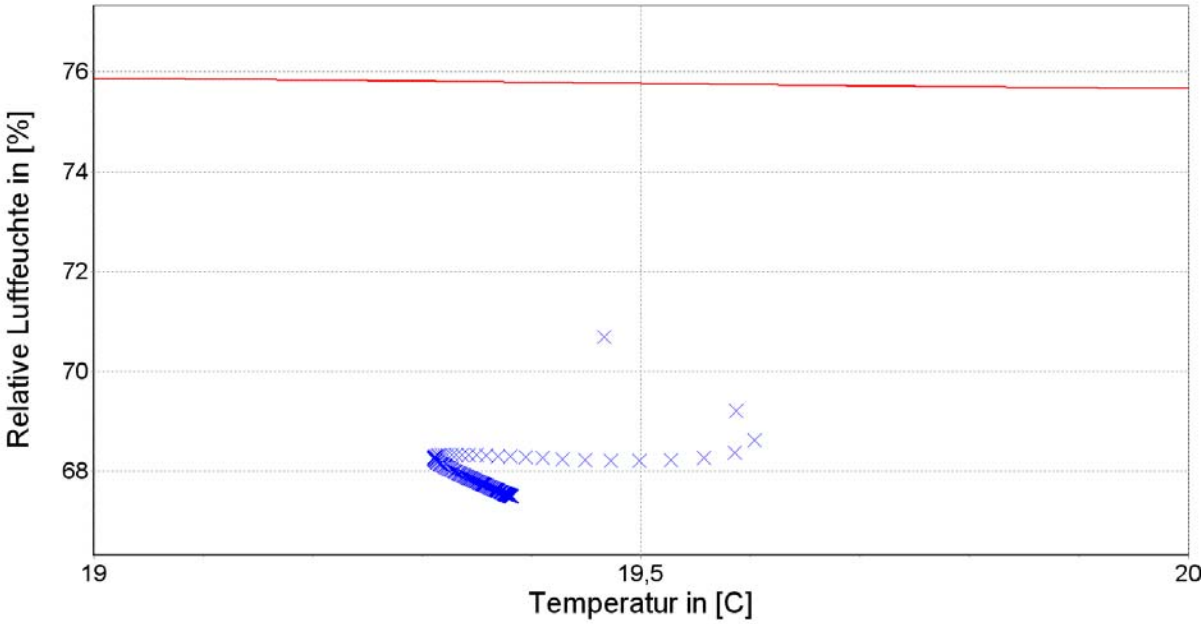


Figure 3.4.1: Likelihood of mould growth. Mould formation can be excluded in the construction K3b.

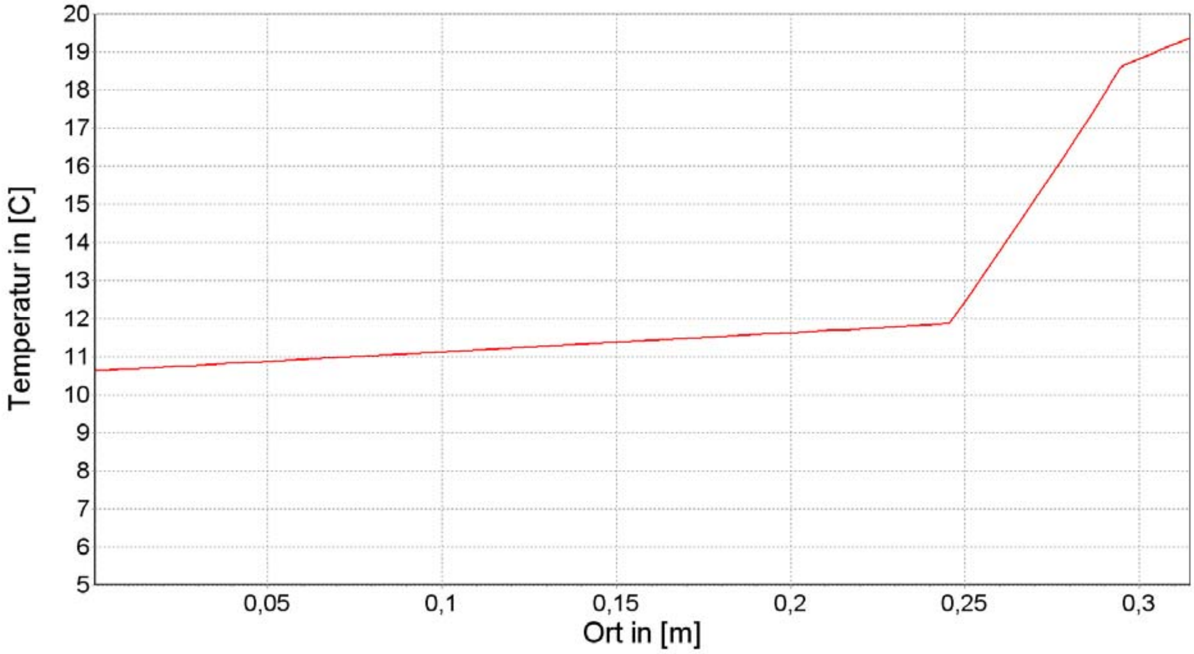


Figure 3.4.2: Characteristic temperature-profile in wall construction K3b under steady condition

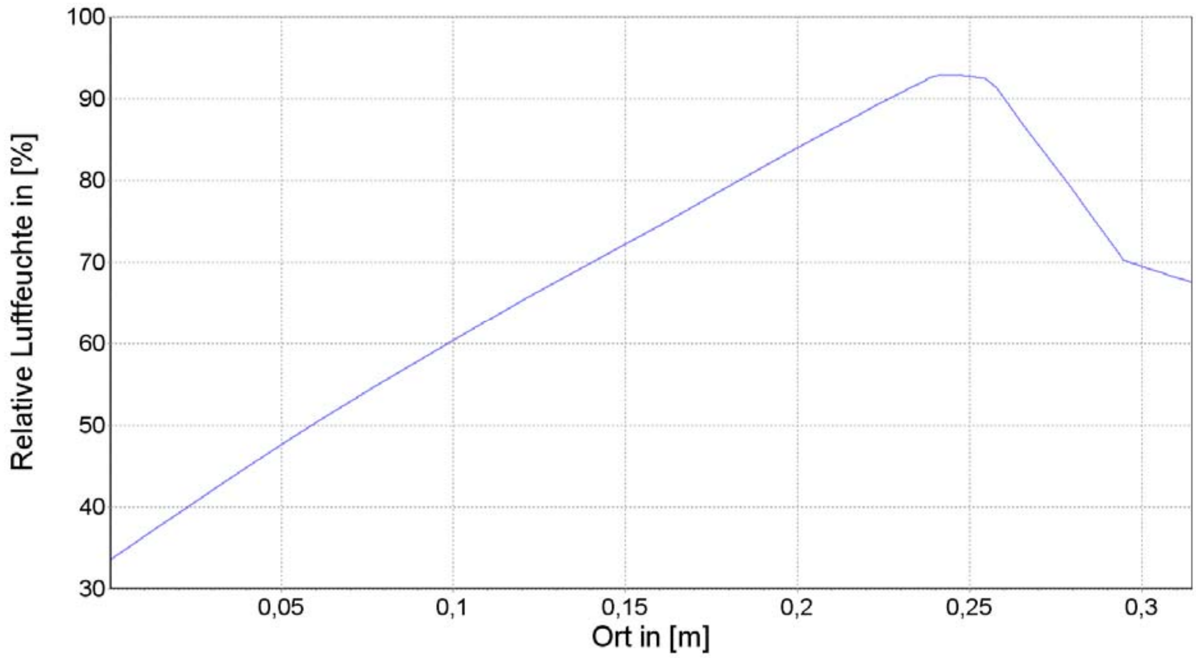


Figure 3.4.3: Characteristic air-humidity-profile in wall construction K3b under steady condition

3.4.2 Evaluation of the one-dimensional calculation

All boundary values regarding minimum thermal insulation (R> 1.2 m² · K / W), amount of condensate (mW,T < 0,5/1,0 kg/m²) and dehydration (mW,V > mW,T) are adhered in the COND calculations with stationary climate conditions.

The conditions of DIN4108-3 regarding condensate and dehydration are also observed in the simulations:

mW,T,max = 0 kg/m² < mW,T,DIN4108-3 = 1,0 kg/m²

mW,V > mW,T,max

with mW,T,max : the maximum amount of condensate of the inner layers, (that means without external brick and mortar layer.)

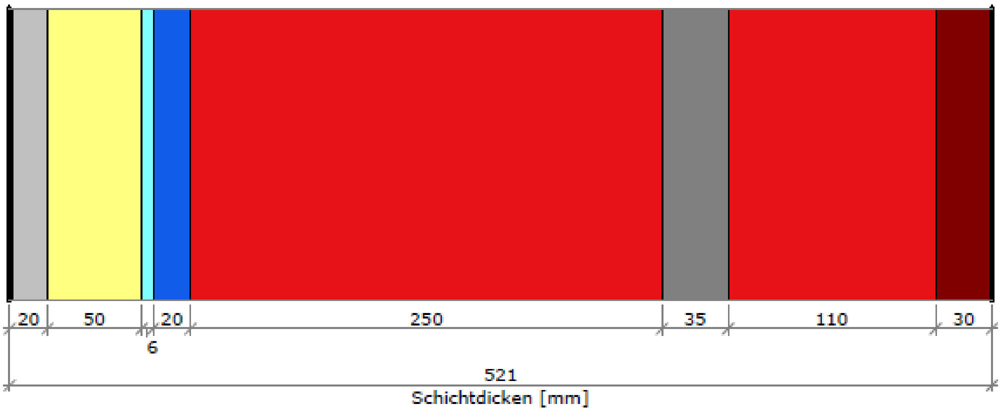
with mW,T,max : allowed maximum amount of condensate according to DIN 4108-3, section 4.2.1

There isn't point in the construction 3b where condensate may emerge.

3.5 Construction 8: „upper floor with insulation“

3.5.1 COND-results for a one-dimensional wall construction

Construction sketch



Construction layout and material parameter

	Material	d [mm]	λ [W/mK]	μ [---]	w_{80} [m³/m³]	w_{sat} [m³/m³]	A_w [kg/m²s½]
1	Antischimmelputz IQ-Top	20	0,111	12,0	0,015	0,149	0,014
2	Klimaplatte IQ-Therm	50	0,031	27,2	0,003	0,980	0,013
3	Kleber IQ-Fix	6	0,497	17,0	0,033	0,350	0,005
4	LO_Putz	20	0,850	11,0	0,025	0,250	0,176
5	LO-ziegel	250	0,750	8,1	0,005	0,319	0,331
6	LO_Mörtel	35	0,700	11,0	0,030	0,320	0,173
7	LO-ziegel	110	0,750	8,1	0,005	0,319	0,331
8	LO_putz	30	0,850	11,0	0,025	0,250	0,176

d = Schichtdicke; λ = Wärmeleitfähigkeit; μ = Wasserdampfdiffusionswiderstandszahl; w_{80}/w_{sat} = Feuchtegehalt bei 80% rel. Luftfeuchte bzw. bei Sättigung; A_w - Wasseraufnahmekoeffizient

Summary of the calculation results

Wärmedurchgangskoeffizient der Konstruktion (feuchteabhängig)	U =	0,391	W/(m²K)
Wärmedurchgangskoeffizient der Konstruktion (trocken)	U =	0,390	W/(m²K)
Wärmedurchlasswiderstand der Konstruktion	R =	2,394	m²K/W
Kondensatmasse am Ende der Kondensationsperiode (nach COND)	M_c =	0,095	kg/m²
Trocknungszeit	t_{ev} =	16,13	d
DIN 4108-2 Tab. 3,1+11 (Wärmedurchlasswiderstand) R >= 1,2 m²K/W		**Anforderung erfüllt**	
DIN 4108-3 4.2.1.c (wasseraufnahmefähig) M_c <= 1,0 kg/m²		**Anforderung erfüllt**	
Trocknungsdauer im Sommer t_{ev} < 90d		**Anforderung erfüllt**	

3.5.2 Delphin-results for a one-dimensional wall construction

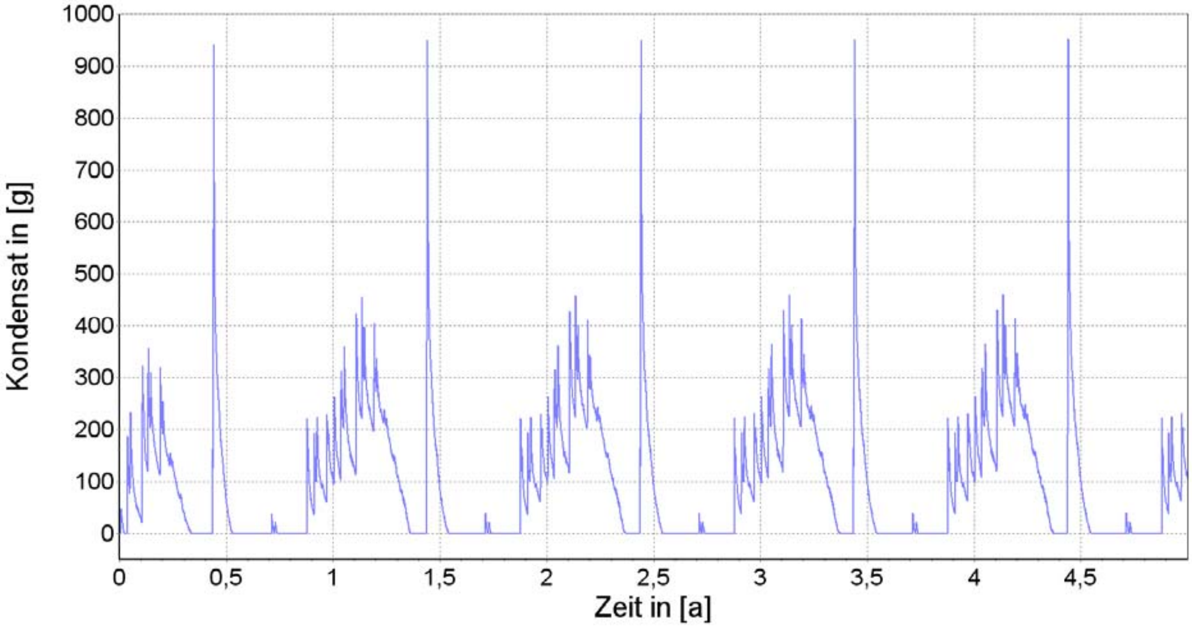


Figure 3.5.1: Course of the onner condensate at the levelled out condition in wall construction K8 – brickwork (TRY Potsdam)

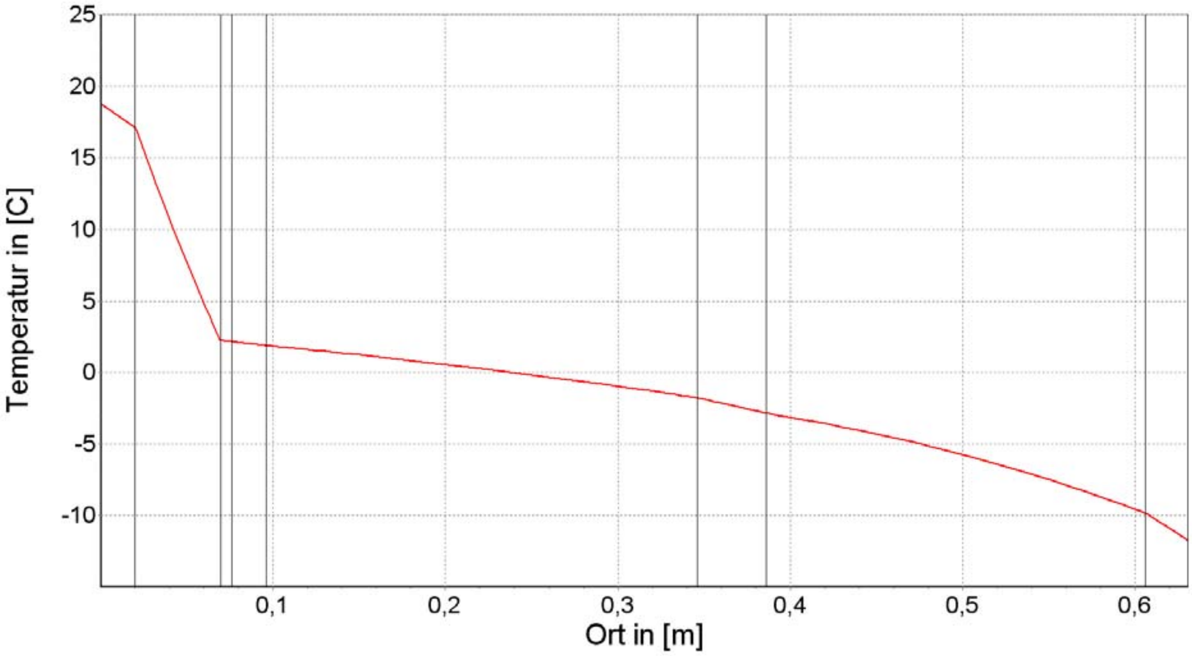


Figure 3.5.2: Characteristic temperature-profile at the 3rd February in wall construction K8 (TRY Potsdam)

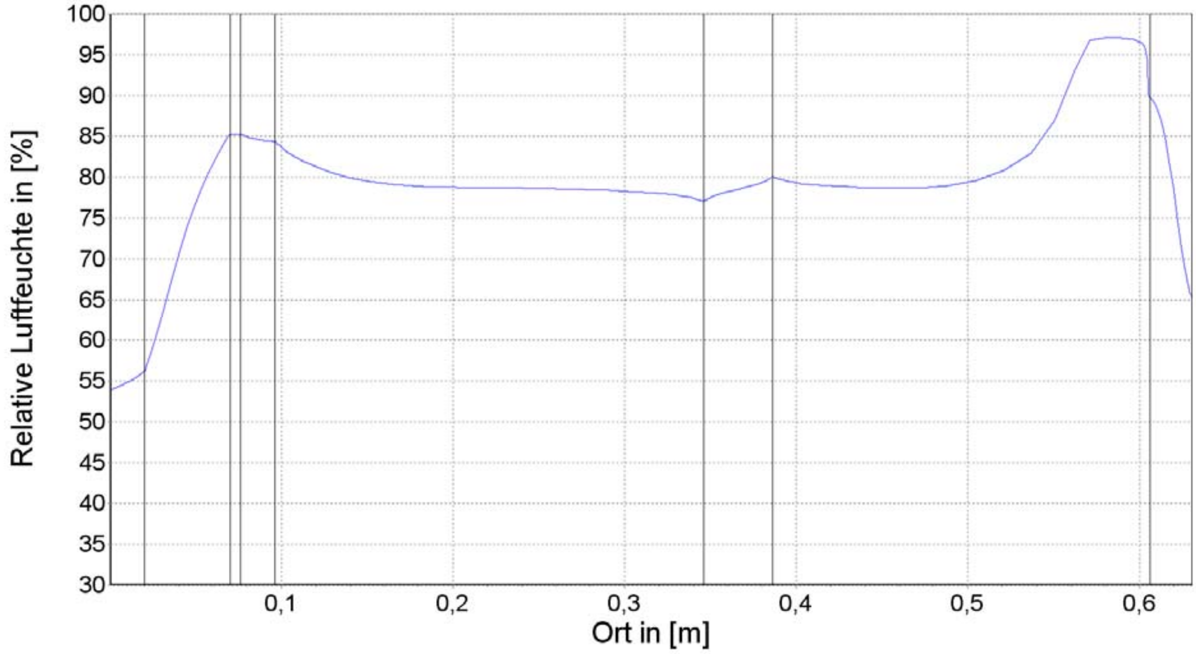


Figure 3.5.3: Characteristic air-humidity-profile at the 3rd February in wall construction K8 (TRY Potsdam)

3.5.3 Evaluation of the one-dimensional calculation and simulation

All boundary values regarding minimum thermal insulation (R> 1.2 m² · K / W), amount of condensate (mW,T < 0,5/1,0 kg/m²) and dehydration (mW,V > mW,T) are adhered in the COND calculations with stationary climate conditions.

The conditions of DIN4108-3 regarding condensate and dehydration are also observed in the simulations:

mW,T,max = 0,92 kg/m²	<	mW,T,DIN4108-3 = 1,0 kg/m²
mW,V	>	mW,T,max

with mW,T,max : the maximum amount of condensate of the inner layers, (that means without external brick and mortar layer.)

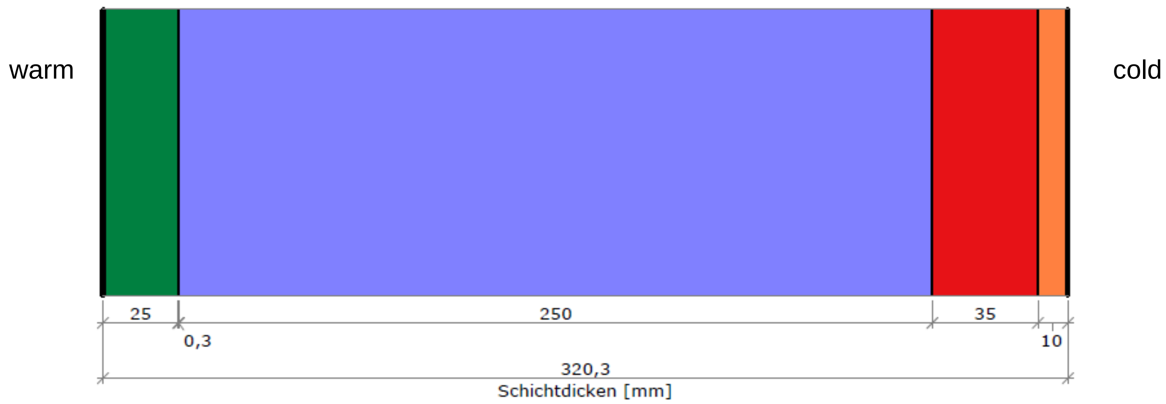
with mW,T,max : allowed maximum amount of condensate according to DIN 4108-3, section 4.2.1

with mW,V : Summer evaporation rate

3.6 Construction 11a: „2nd attic floor with insulation mit Dämmung“

3.6.1 COND-results for a one-dimensional wall construction

Construction sketch



Construction layout and material parameter

	Material	d [mm]	λ [W/mK]	μ [---]	w_{80} [m³/m³]	w_{sat} [m³/m³]	A_w [kg/m²s½]
1	Gipskartonplatte	25	0,200	10,0	0,007	0,551	0,277
2	Dampfbremse	0,3	0,150	1533	0,001	0,009	0,000
3	Zellulosedämmung	250	0,040	2,1	0,007	0,700	0,563
4	Holzfaserplatte	35	0,110	30,0	0,102	0,457	0,033
5	Dachziegel	10	0,900	31,0	0,003	0,187	0,091

d = Schichtdicke; λ = Wärmeleitfähigkeit; μ = Wasserdampfdiffusionswiderstandszahl; w_{80}/w_{sat} = Feuchtegehalt bei 80% rel. Luftfeuchte bzw. bei Sättigung; A_w - Wasseraufnahmekoeffizient

Summary of the calculation results

Wärmedurchgangskoeffizient der Konstruktion (feuchteabhängig)	U =	0,150	W/(m²K)
Wärmedurchgangskoeffizient der Konstruktion (trocken)	U =	0,145	W/(m²K)
Wärmedurchlasswiderstand der Konstruktion	R =	6,706	m²K/W
Kondensatmasse am Ende der Kondensationsperiode (nach COND)	M_c =	0,482	kg/m²
Trocknungszeit	t_{ev} =	46,27	d
DIN 4108-2 Tab. 3,1+11 (Wärmedurchlasswiderstand) R >= 1,2 m²K/W		**Anforderung erfüllt**	
DIN 4108-3 4.2.1.c (wasseraufnahmefähig) M_c <= 1,0 kg/m²		**Anforderung erfüllt**	
DIN 4108-3 4.2.1.e Holzwerkstoff: Δu_m < 3%		**Anforderung erfüllt**	
Trocknungsdauer im Sommer t_{ev} < 90d		**Anforderung erfüllt**	

3.6.2 Delphin-results for a one dimensional wall construction

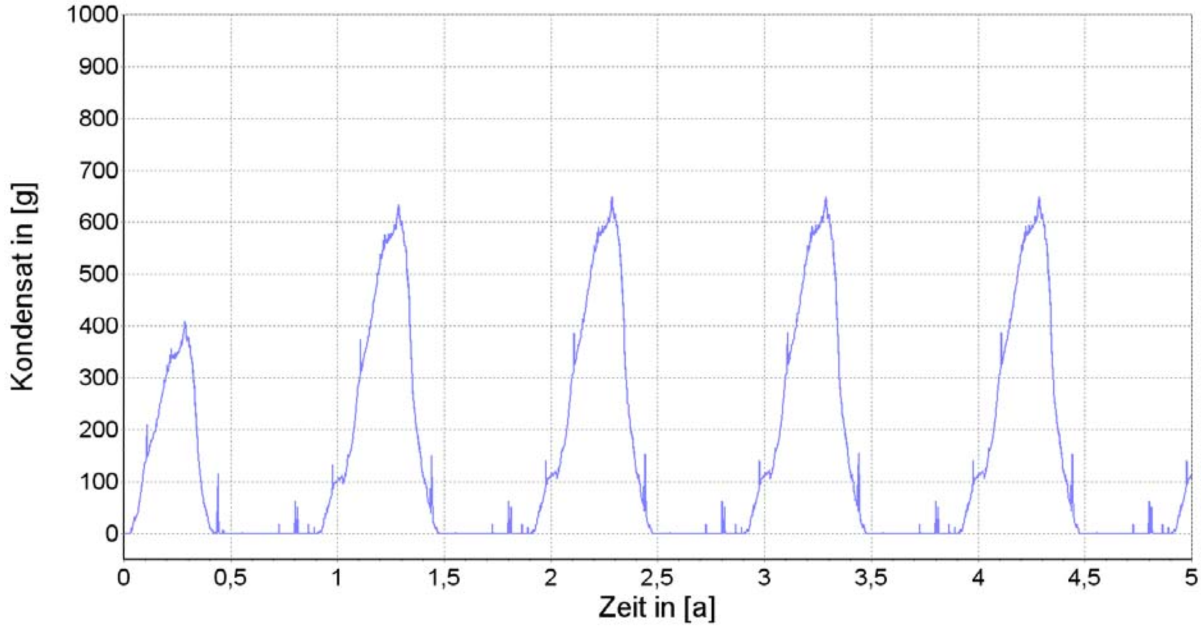


Figure 3.6.1: Course of the inner condensate at the levelled out condition in wall construction K11a – (TRY Potsdam)

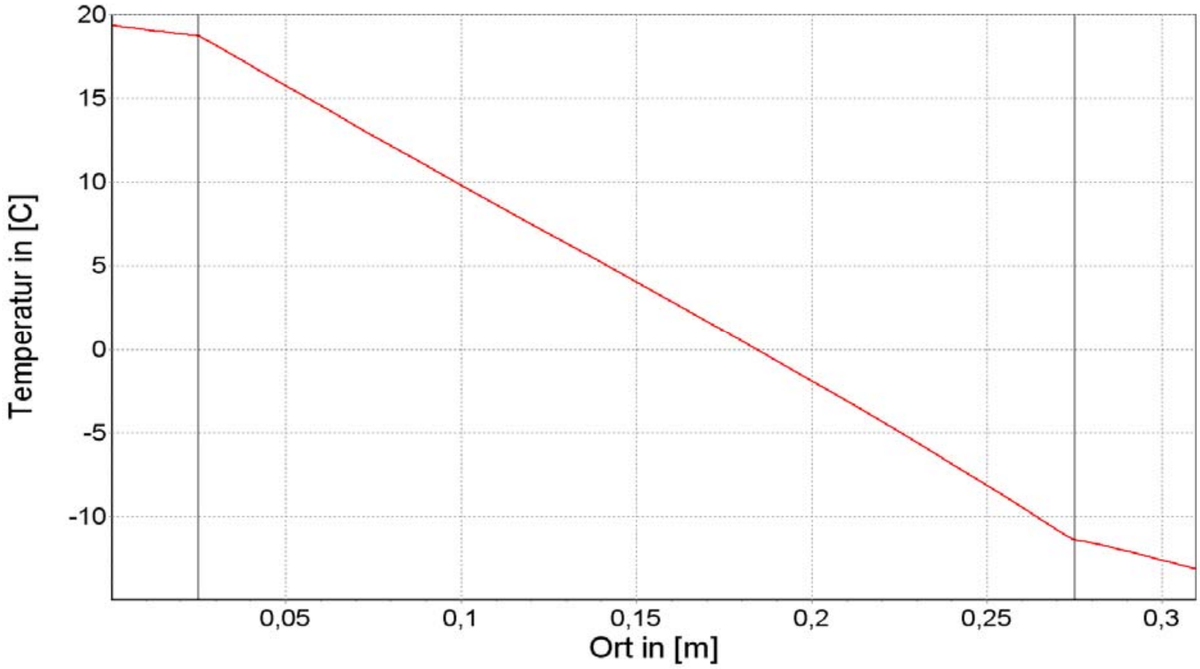


Figure 3.6.2: Characteristic temperature profile at the 3rd February in wall construction K11a (TRY Potsdam)

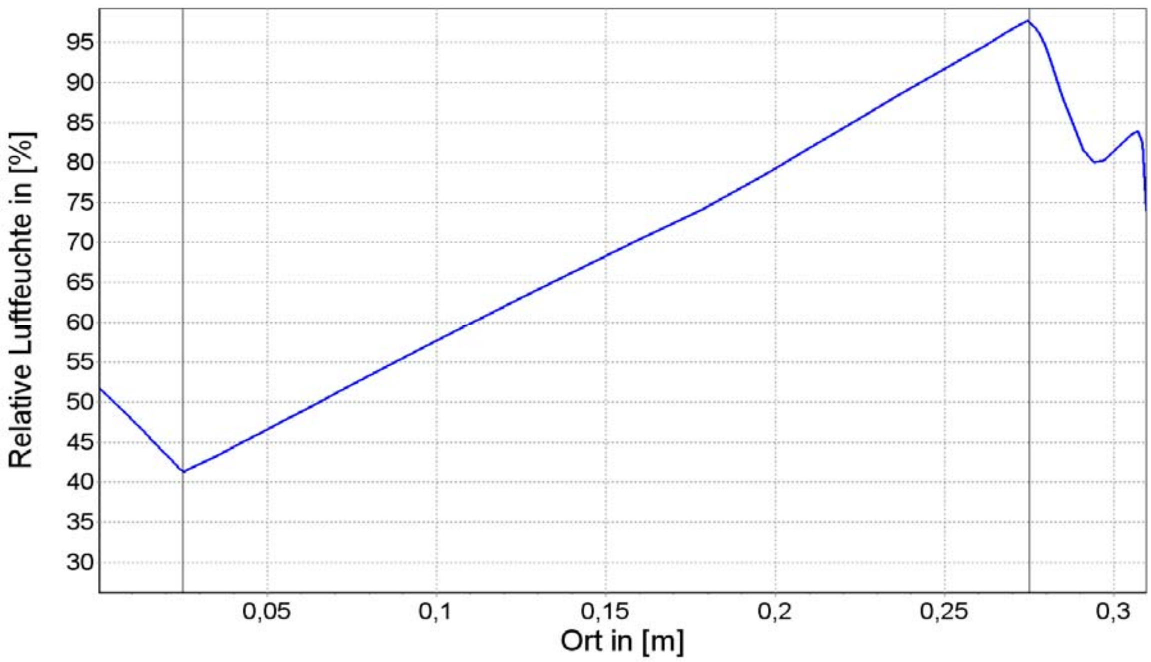


Figure 3.6.3: Characteristic air-humidity-profile at the 3rd February in wall construction K11a (TRY Potsdam)

3.6.3 Evaluation of the one-dimensional calculation and simulation

All boundary values regarding minimum thermal insulation (R> 1.2 m² · K / W), amount of condensate (mW,T < 0,5/1,0 kg/m²) and dehydration (mW,V > mW,T) are adhered in the COND calculations with stationary climate conditions.

The conditions of DIN4108-3 regarding condensate and dehydration are also observed in the simulations:

mW,T,max = 0,648 kg/m² < mW,T,DIN4108-3 = 1,0 kg/m²

mW,V > mW,T,max

with mW,T,max : the maximum amount of condensate of the inner layers,

(that means without external brick and mortar layer.)

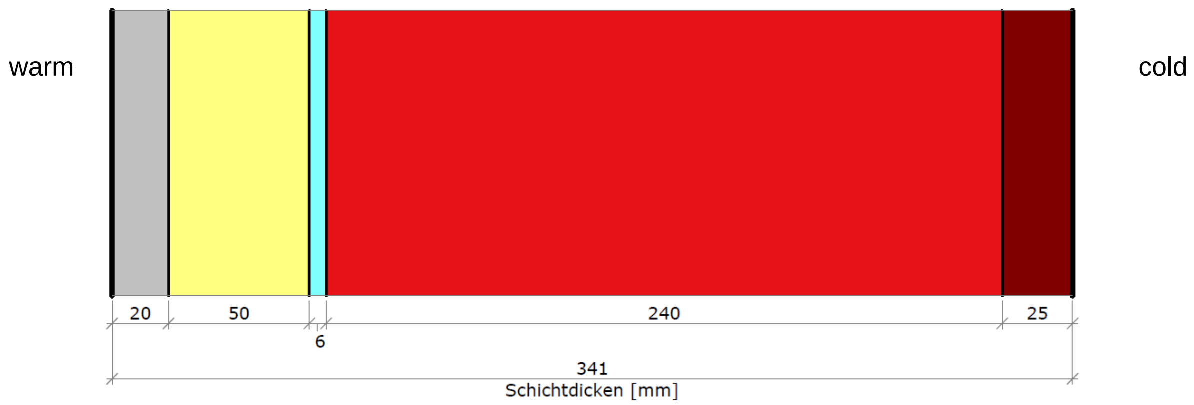
with mW,T,max : allowed maximum amount of condensate according to DIN 4108-3, section 4.2.1

with mW,V : Summer evaporation rate

3.7 Construction 11b: „2. attic floor with insulation“

3.7.1 COND-results for a one-dimensional wall construction

Construction sketch



Construction layout and material parameter

	Material	d [mm]	λ [W/mK]	μ [---]	w_{80} [m³/m³]	w_{sat} [m³/m³]	A_w [kg/m²s½]
1	Antischimmelputz IQ-Top	20	0,111	12,0	0,015	0,149	0,014
2	Klimaplatte IQ-Therm	50	0,031	27,2	0,003	0,980	0,013
3	Kleber IQ-Fix	6	0,497	17,0	0,033	0,350	0,005
4	LO-ziegel	240	0,750	8,1	0,005	0,319	0,331
5	LO_putz	25	0,850	11,0	0,025	0,250	0,176

d = Schichtdicke; λ = Wärmeleitfähigkeit; μ = Wasserdampfdiffusionswiderstandszahl; w_{80}/w_{sat} = Feuchtegehalt bei 80% rel. Luftfeuchte bzw. bei Sättigung; A_w - Wasseraufnahmekoeffizient

Summary of the calculation results

Wärmedurchgangskoeffizient der Konstruktion (feuchteabhängig)	U =	0,432	W/(m²K)
Wärmedurchgangskoeffizient der Konstruktion (trocken)	U =	0,430	W/(m²K)
Wärmedurchlasswiderstand der Konstruktion	R =	2,155	m²K/W
Kondensatmasse am Ende der Kondensationsperiode (nach COND)	M_c =	0,155	kg/m²
Trocknungszeit	t_{ev} =	21,74	d
DIN 4108-2 Tab. 3,1+11 (Wärmedurchlasswiderstand) R >= 1,2 m²K/W		**Anforderung erfüllt**	
DIN 4108-3 4.2.1.c (wasseraufnahmefähig) M_c <= 1,0 kg/m²		**Anforderung erfüllt**	
Trocknungsdauer im Sommer t_{ev} < 90d		**Anforderung erfüllt**	

3.7.2 Delphin-results for a one-dimensional wall construction

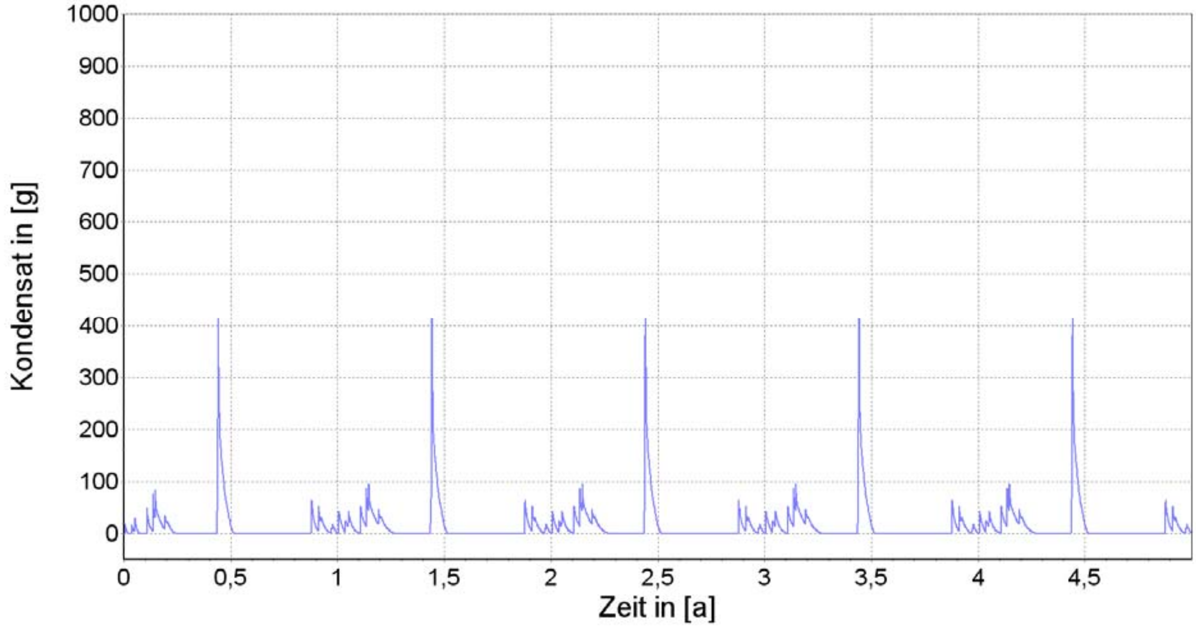


Figure 3.7.1: Course of the inner condensate at the levelled out condition in wall construction K11b – (TRY Potsdam)

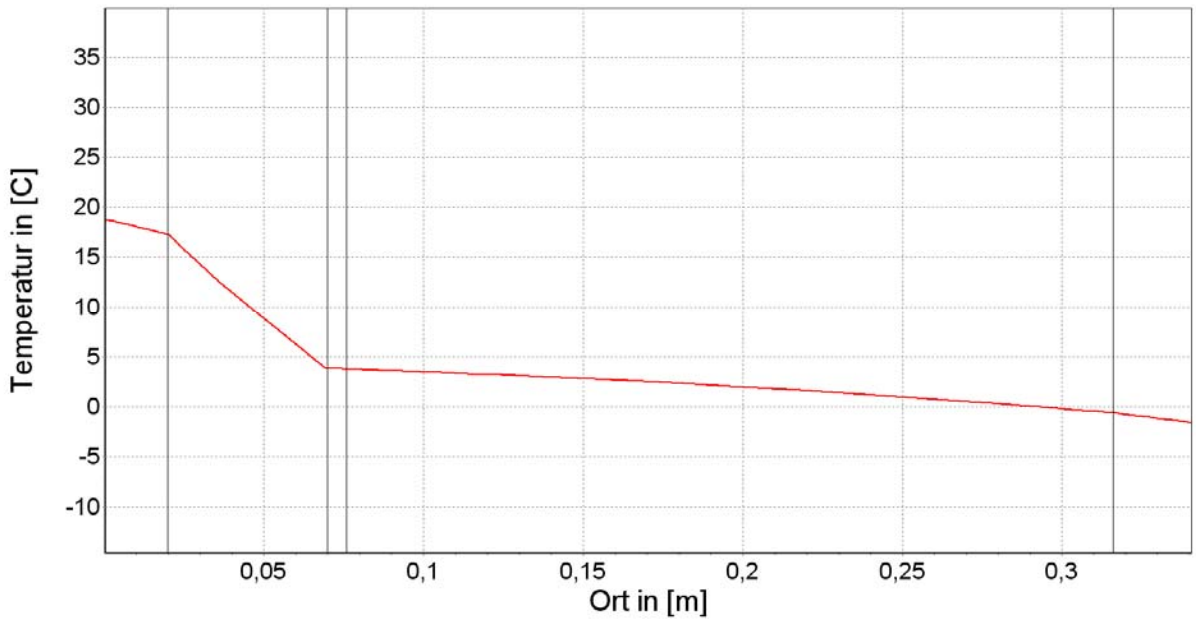


Figure 3.7.2: Characteristic temperature-profile at the 3rd February in wall construction K11b (TRY Potsdam)

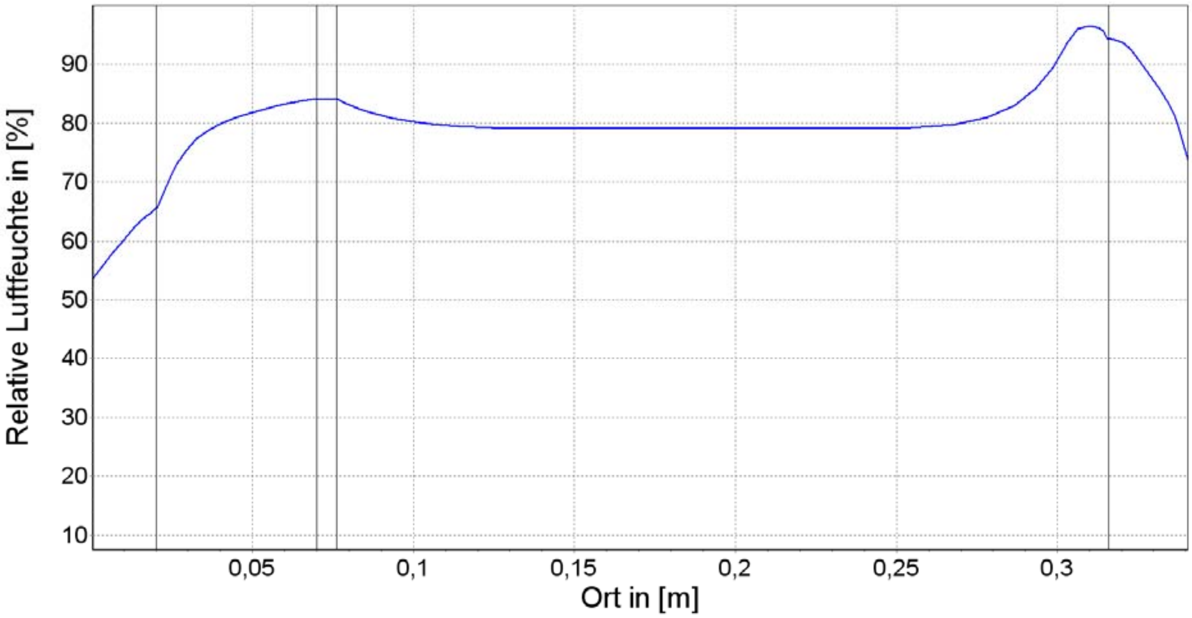


Figure 3.7.3: Characteristic air-humidity-profile at the 3rd February in wall construction K11b (TRY Potsdam)

3.7.3 Evaluation of the one-dimensional calculation and simulation

All boundary values regarding minimum thermal insulation (R> 1.2 m² · K / W), amount of condensate (mW,T < 0,5/1,0 kg/m²) and dehydration (mW,V > mW,T) are adhered in the COND calculations with stationary climate conditions.

The conditions of DIN4108-3 regarding condensate and dehydration are also observed in the simulations:

mW,T,max = 0,41 kg/m²	<	mW,T,DIN4108-3 = 1,0 kg/m²
mW,V	>	mW,T,max

with mW,T,max : the maximum amount of condensate of the inner layers, (that means without external brick and mortar layer.)

with mW,T,max : allowed maximum amount of condensate according to DIN 4108-3, section 4.2.1

with mW,V : Summer evaporation rate

4 2D – Simulation calculation

4.1 Climatic boundary conditions for the minimum requirements in the field of thermal bridges:

The climatic conditions in the steady calculation correspond to the data in the DIN 4180-2:

- Indoor climate: 20°C / 50% relative air-humidity
- Thermal transfer resistance: 0,13 m²·K/W
- Outdoor climate: -5°C / 80% relative air-humidity
- Thermal transfer resistance: 0,04 m²·K/W

Merely the minimum thermal protection was reviewed for the following listed details. The adherence to the minimum thermal protection is no confirmation that the proof of the Energy Saving Regulation is met or that a required U-value of 0.4 W/m²K is adhered.

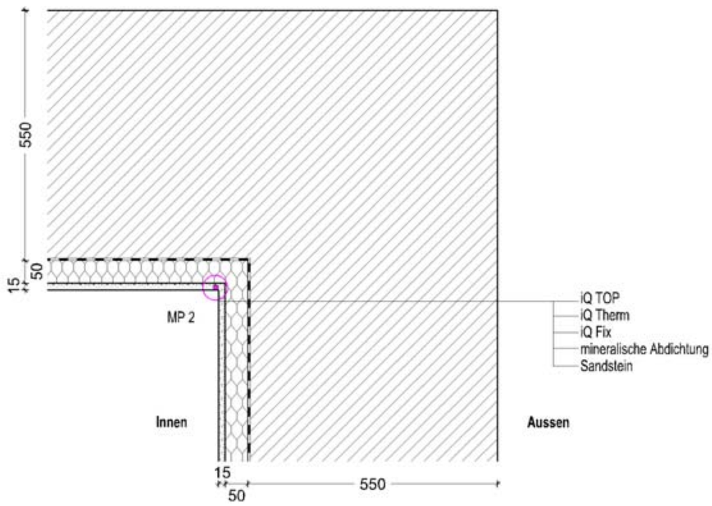
4.2 Climatic boundary conditions for the discussion of possible thermal bridges at Real Climate:

The proof of the minimum thermal insulation is kept in accordance with DIN 4108-2 Section 6.2 in order to avoid mould growth.

- Indoor climate: 20°C / 50% relative air-humidity
- Thermal transfer resistance: 0,13 m²·K/W
- Outdoor climate: Test Reference Year for Potsdam obtained from the DELPHIN data base
- Thermal transfer resistance: 0,04 m²·K/W

4.3 Construction 1 / 2D: „Upper floor corner with insulation“

Construction layout



4.3.1 Calculation under steady conditions – climate according to DIN 4108-2, Proof of the minimum thermal protection according to DIN 4108

The proof of the minimum thermal protection is conducted in accordance to DIN 4108-2 Section 6.2 for avoidance of mould growth.

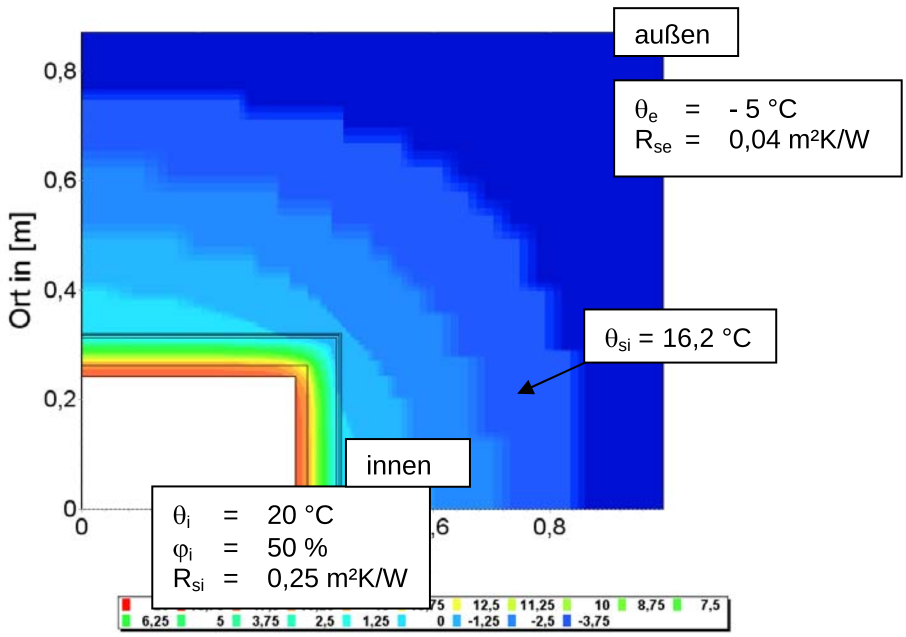


Figure 4.3.1: Temperature distribution of the structure 1 / 2D steady state surface temperature in [°C], boundary conditions according to DIN 4180 part 2.

$\theta_{si,\ Inside\ corner,\ top}$ = 16,2 °C > $\theta_{si,\ acceptable}$ = 12,6 °C

The proof according to DIN 4108 – 2, section 6.2 is complied.

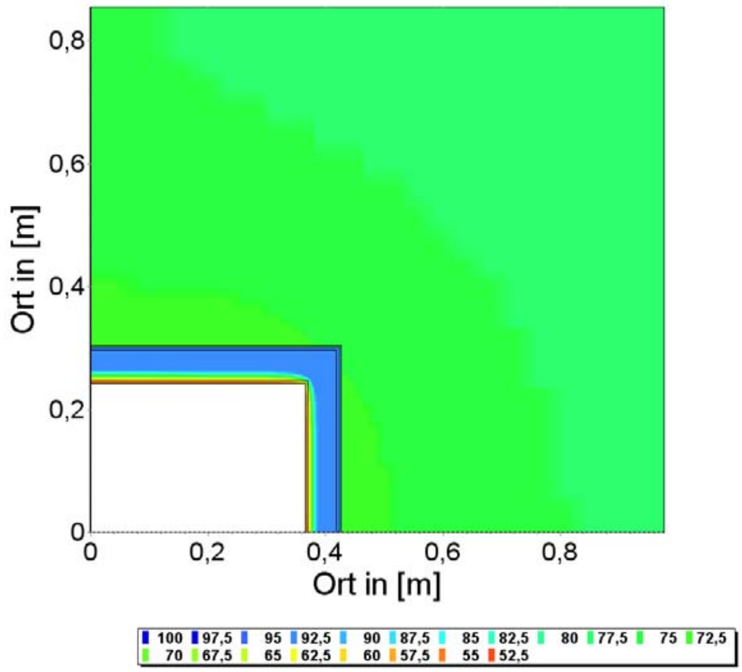


Figure 4.3.2: Humidity distribution of the construction 1 / 2D in the steady state

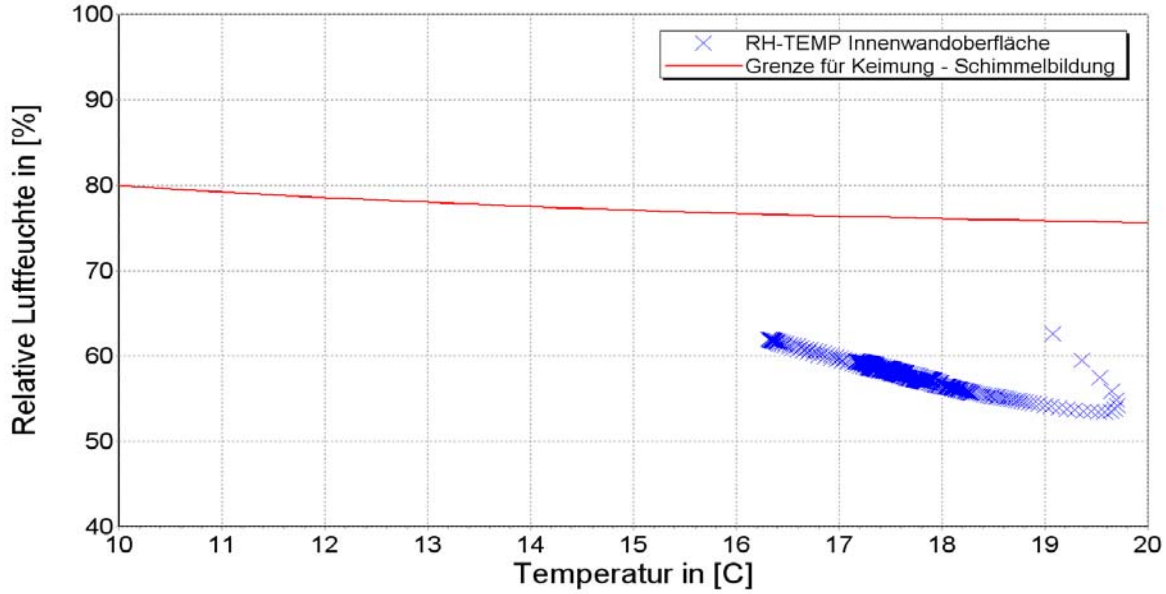


Figure 4.3.3: Graphic on the likelihood of mould formation of the construction 1 / 2D in the steady state. A mould formation with DIN required climate conditions can be excluded.

4.3.2 Climatic boundary conditions for the discussion of possible thermal bridges at Real Climate:

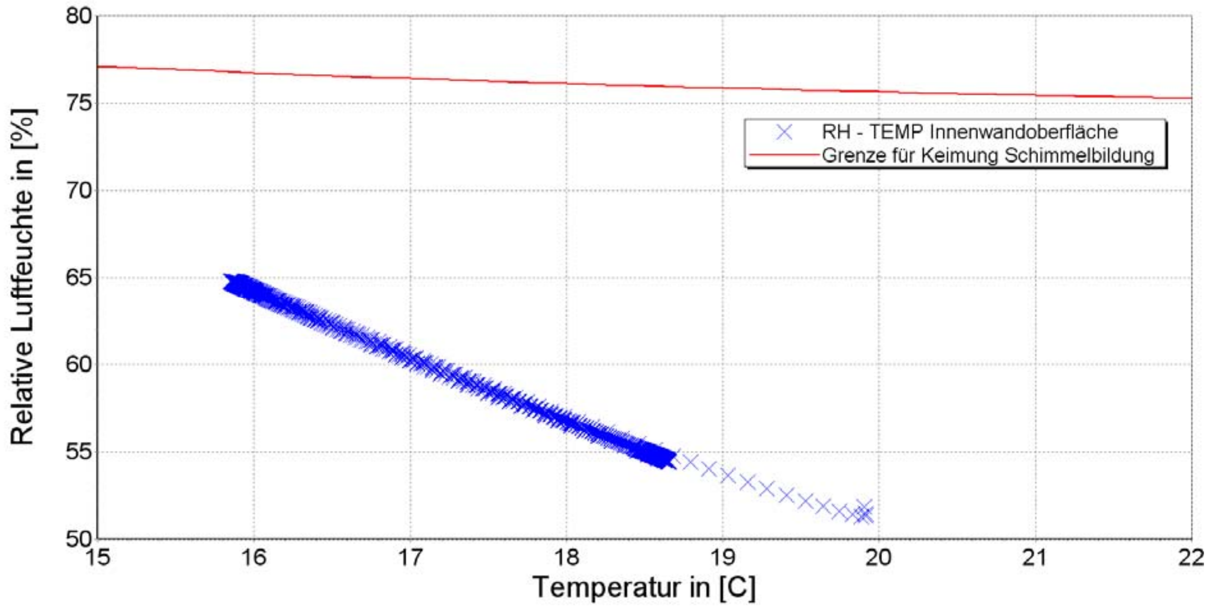


Figure 4.3.4: Graphic on the likelihood of mould formation of the construction 1 / 2D for the reference year. A mould formation can be excluded.

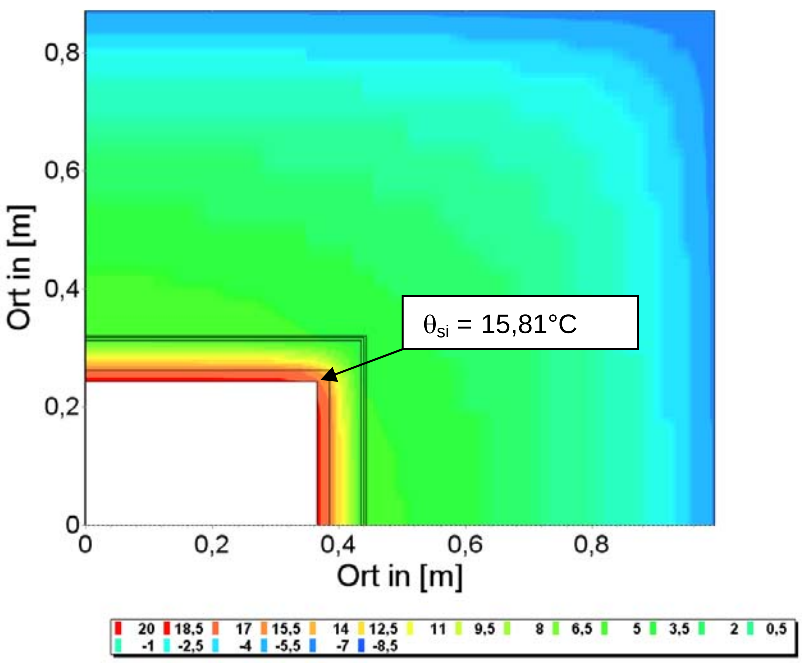


Figure 4.3.5: Temperature distribution of the construction 1 / 2D at 3rd February of the reference year.

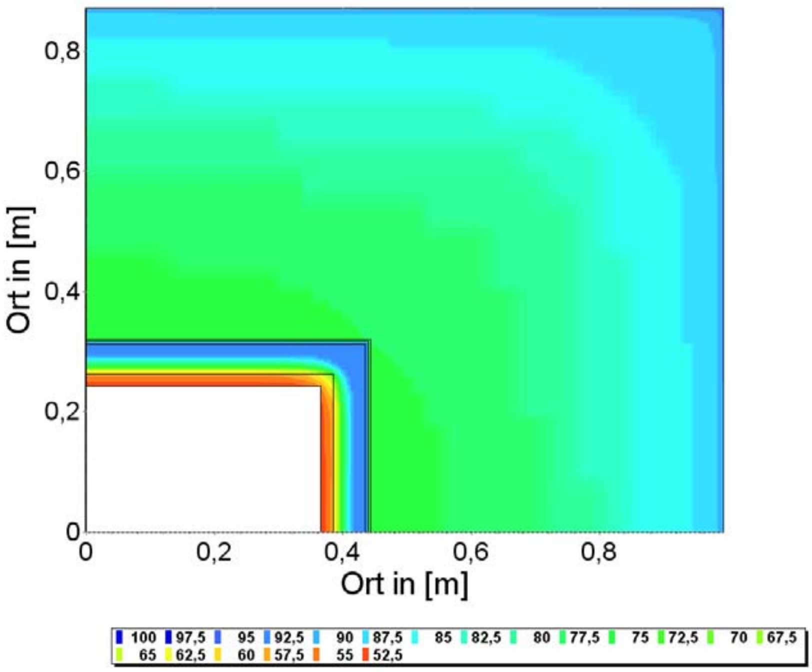


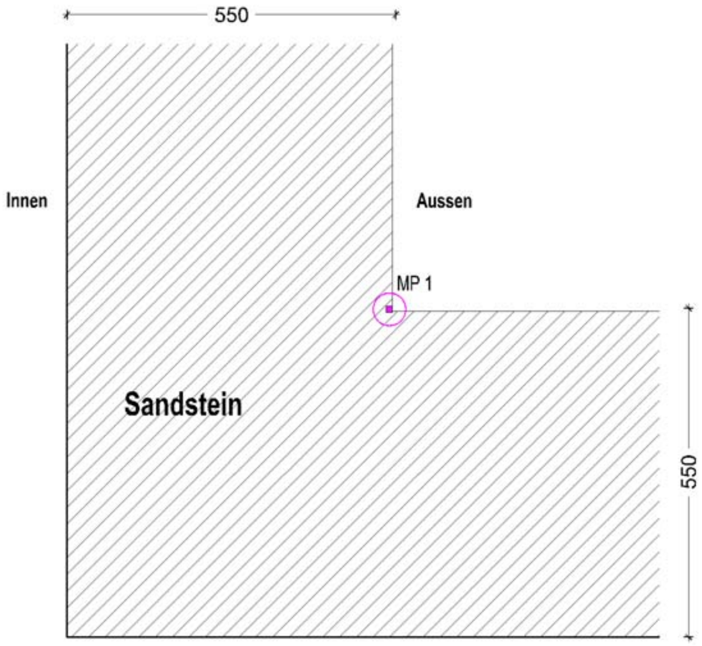
Figure 4.3.6: Humidity distribution of the construction 1 / 2D at 3rd February of the reference year.

4.3.3 Evaluation of the results for the Real Climate

There will be no damaging effects of a thermal bridge. There is no mould formation at the critical measuring point. The minimum temperature in the reference - year is 15.81 °C.

4.4 Construction 2 / 2D: „Upper floor corner without insulation“

Construction layout



The limit values regarding the minimum thermal protection are taken from the DIN 4108-02 Section 6.2 for the basement area. A frsi-value von 0,7 is required consequently. The minimum surface temperature for the cold period according to DIN in the basement area is 4.03 ° C, this calculates a frsi-Wert von 0,71 > 0,7.

The conditions of the DIN4108-3 regarding amount of condensate and dehydration are adhered in the 1D simulations. Only the calculations to the reference year follow.

4.4.1 Calculation under steady conditions – climate according to DIN 4108-2 proof of the minimum thermal protection according to DIN

The proof of the minimum thermal protection is conducted according to DIN 4108 part 2 Section 6.2 for the avoidance of mould formation.

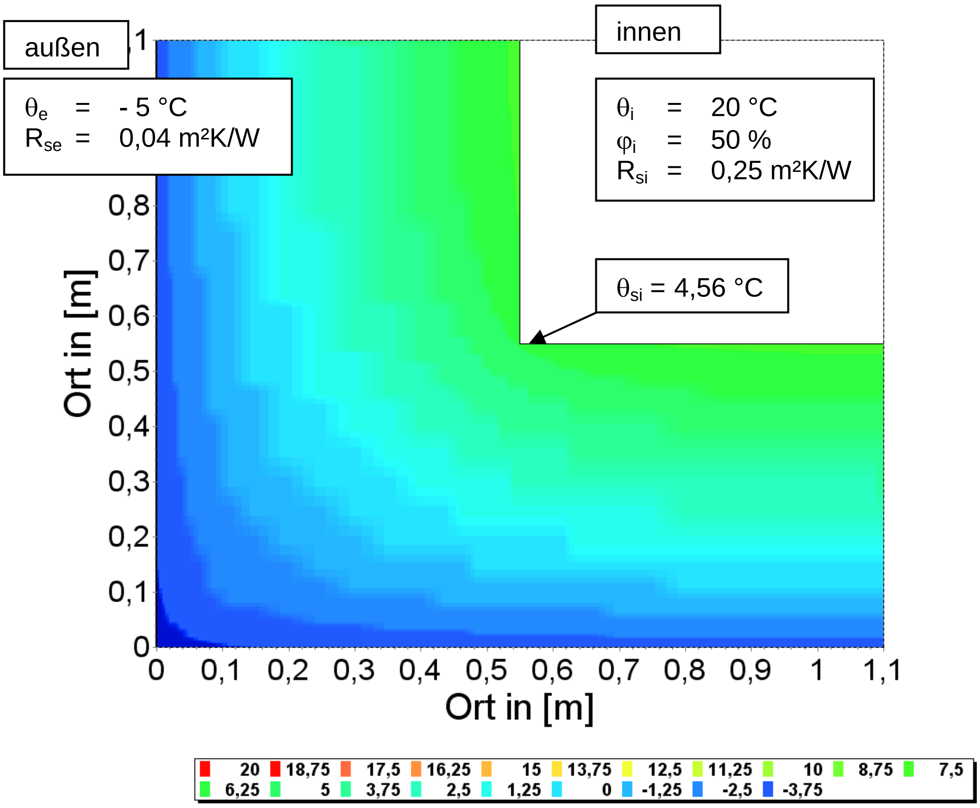


Figure 4.4.1: Temperature distribution of the construction 2 / 2D in a steady state, surface temperature in [°C], boundary conditions according to DIN 4108 part 2.

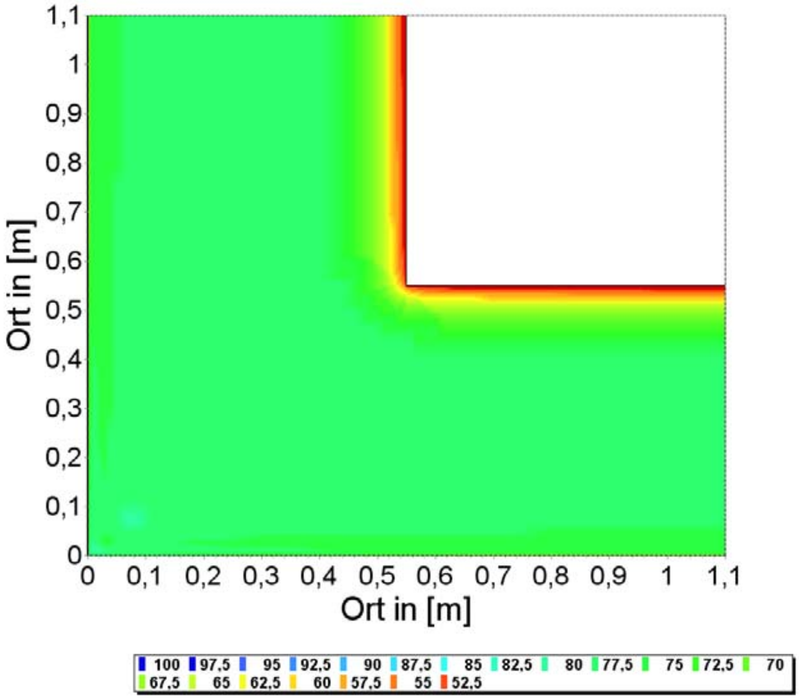


Figure 4.4.2: Humidity distribution of the construction 2 / 2D in a steady state

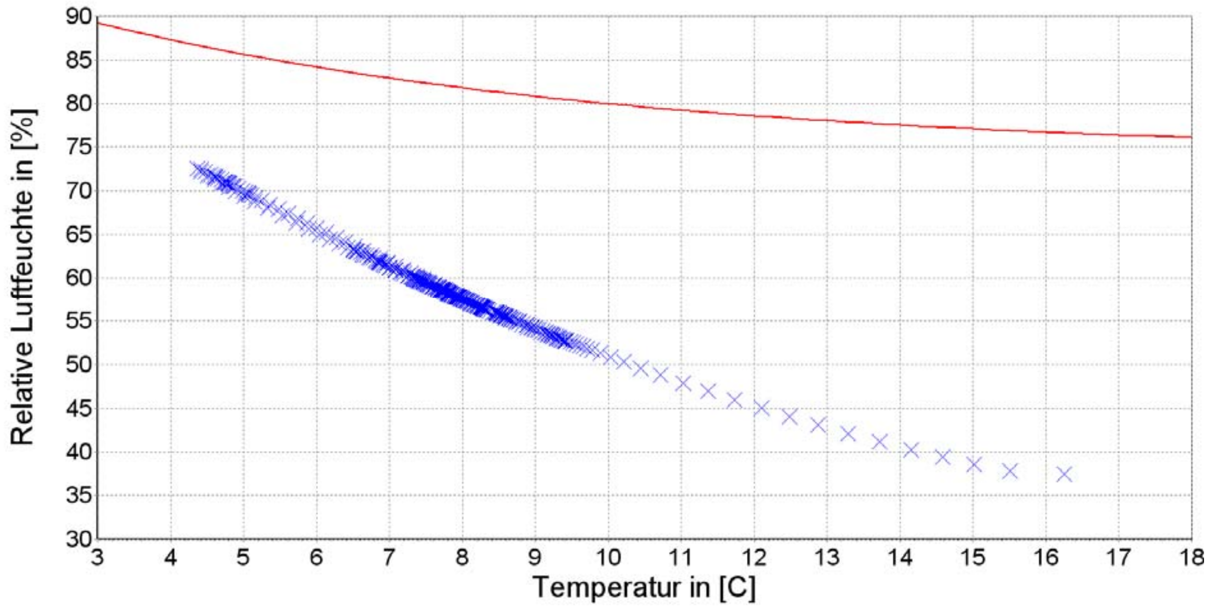


Figure 4.4.3: Graphic on the likelihood of mould formation of the construction 2 / 2D in the steady state. A mould formation with DIN required climate conditions can be excluded.

4.4.2 Climatic boundary conditions for the discussion of possible thermal bridges with Real climate:

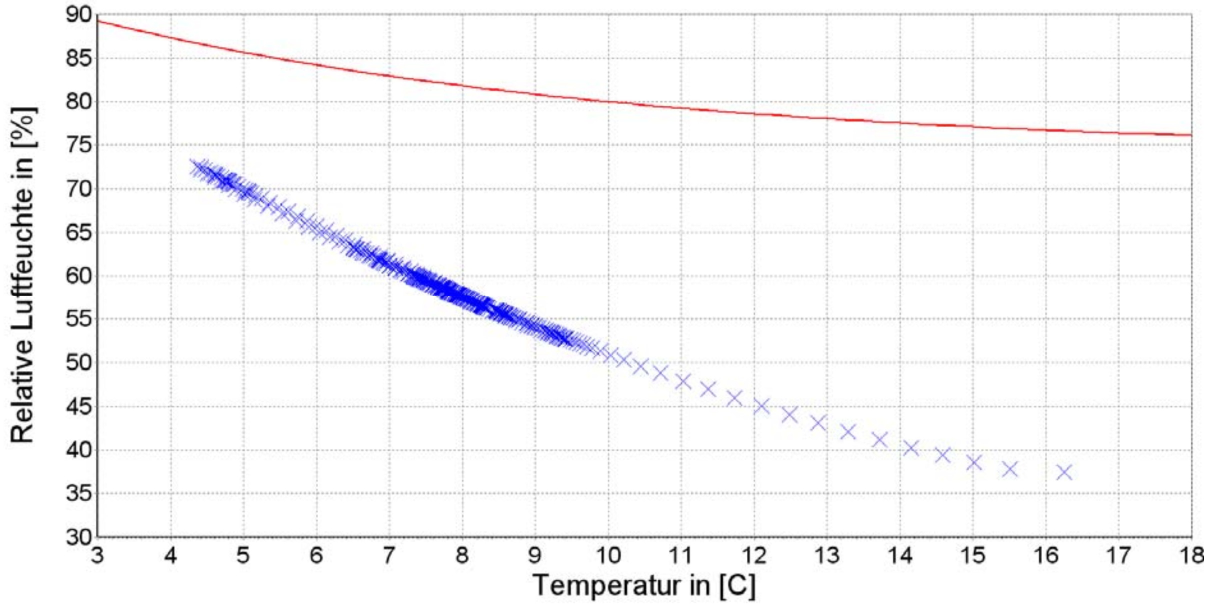


Figure 4.4.4: Graphic on the likelihood of mould formation of the construction 2 / 2D for the reference year.   A mould formation can be excluded.

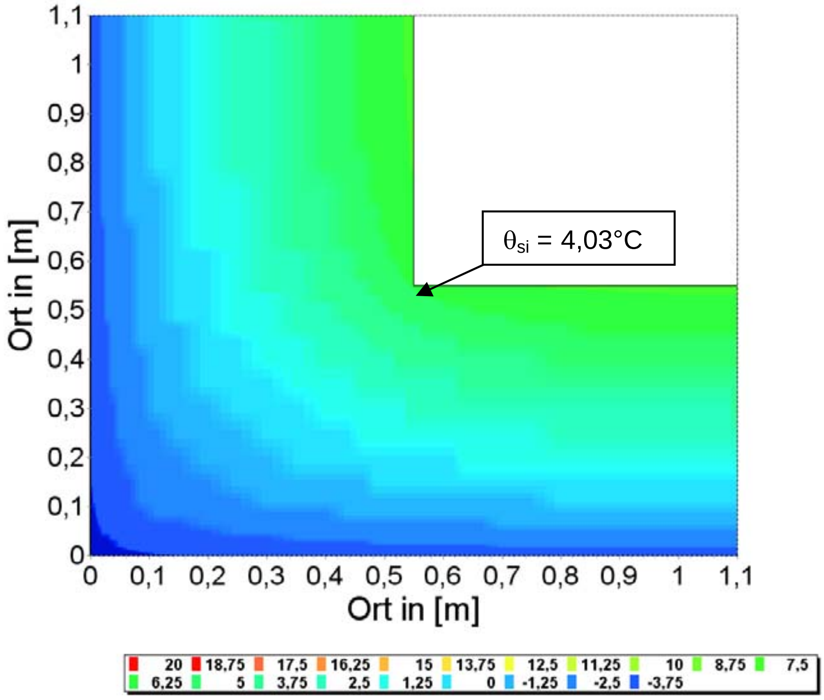


Figure 4.4.5: Temperature distribution of the construction 2 / 2D at the 3rd February of the reference year.

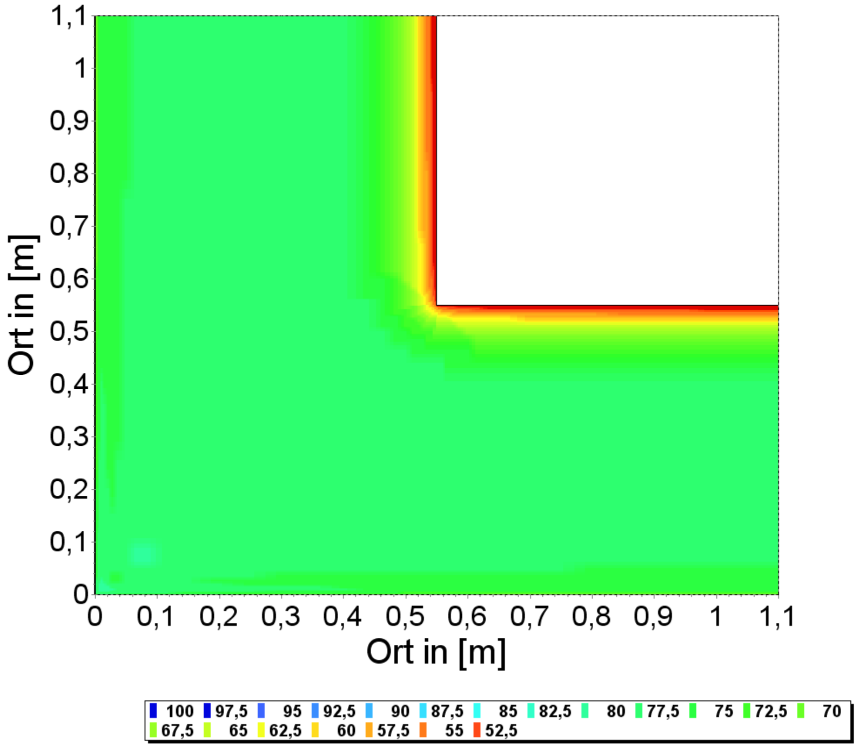


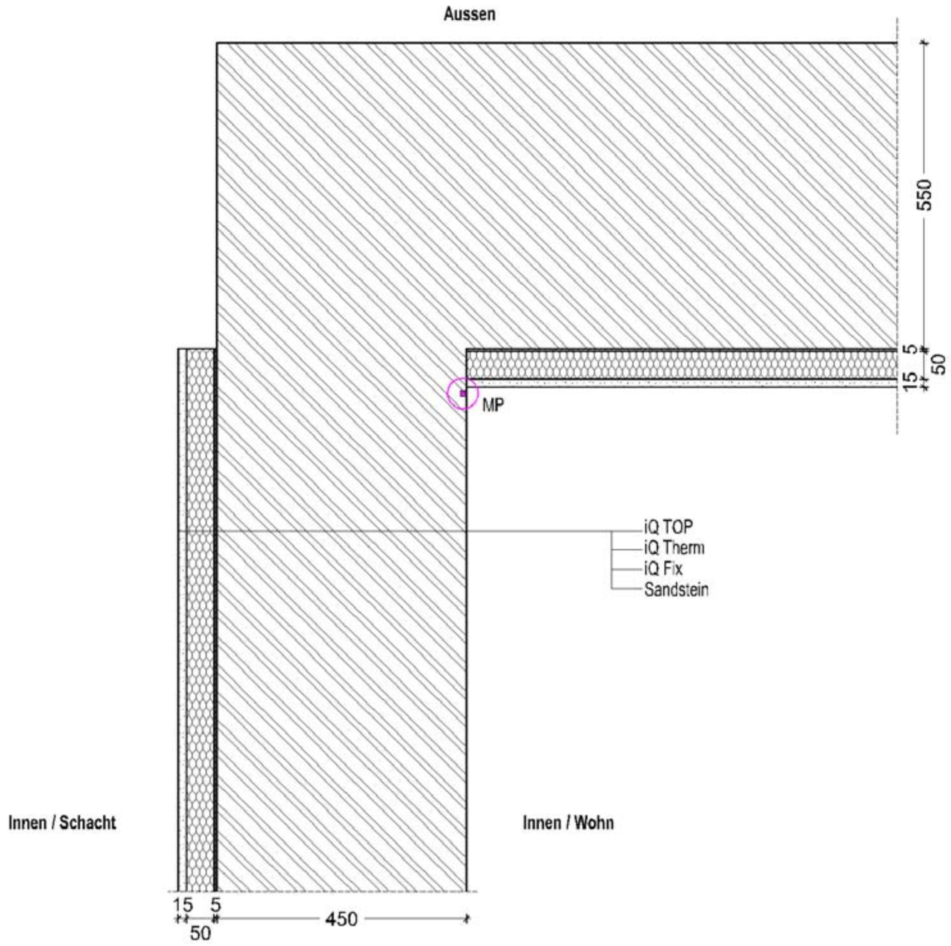
Figure 4.4.6: Humidity distribution of the construction 2 / 2D at the 3rd February of the reference year.

4.4.3 Evaluation of the results

No damaging effect of a thermal bridge occurs under the assumed climate conditions. There is no mould growth at the critical measuring point. The minimum temperature in the reference - year is 4.03°C. The frsi-value of > 0,7 can be only barely maintained for both simulations. Drought was assumed for the sandstone. This drought can be expected in the trench. Sandstone part, which are not sufficiently protected against moisture and rain are constituted problematic, since an increased thermal conductivity must be assumes for these parts. For these components, the required frsi-value of > 0.7 cannot be guaranteed. The exterior plaster being applied to the sandstone should preferably be waterproofed and diffusible in order to eliminate this moisture exposure.

4.5 Construction 3 / 2D: „Upper floor living room-well Det. H“

Construction layout



4.5.1 Calculation under steady conditions – climate according to DIN 4108-2, proof of the minimum thermal protection according to DIN 4108

The proof of the minimum thermal protection will be conducted according to DIN 4108 Part 2 Section 6.2 to avoid mould growth.

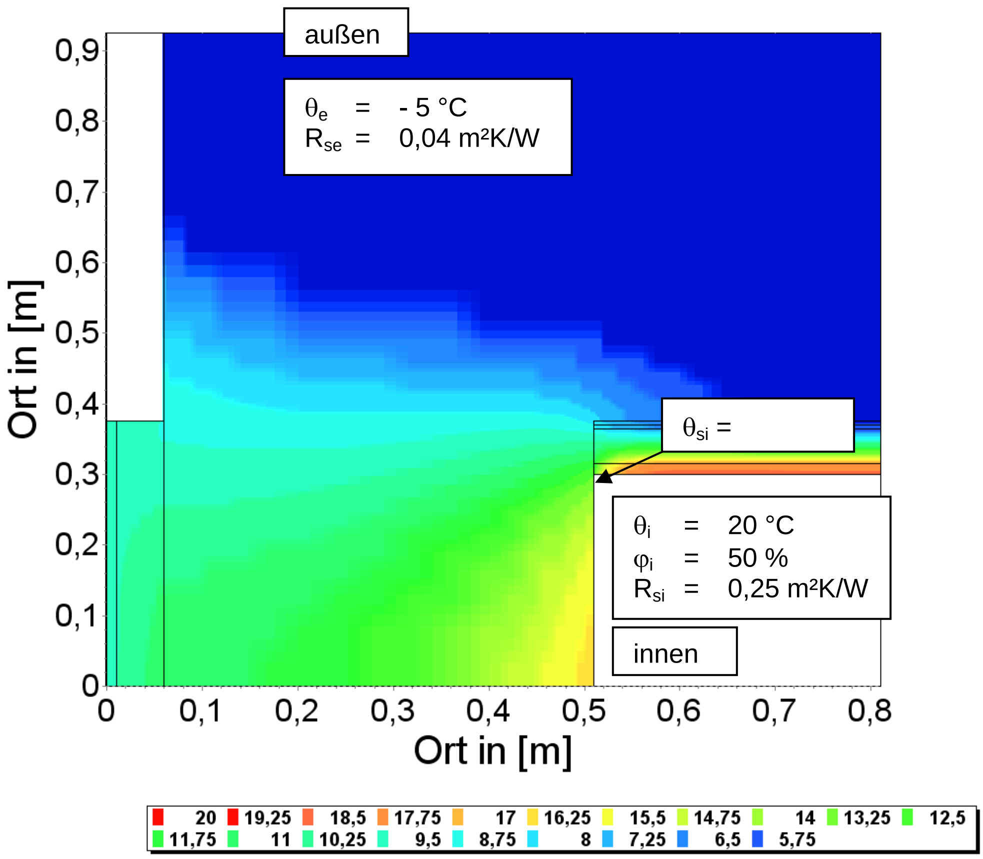


Figure 4.5.1: Temperature distribution of construction 3 / 2d in the steady state, surface temperature in [°C], boundary conditions according to DIN 4108 part 2.

$\theta_{si,\ inside\ corner,\ top}$ = 16,25 °C > $\theta_{si,\ acceptable}$ = 12,6 °C

The proof according to DIN 4108 -, sec. 6.2 is complied.

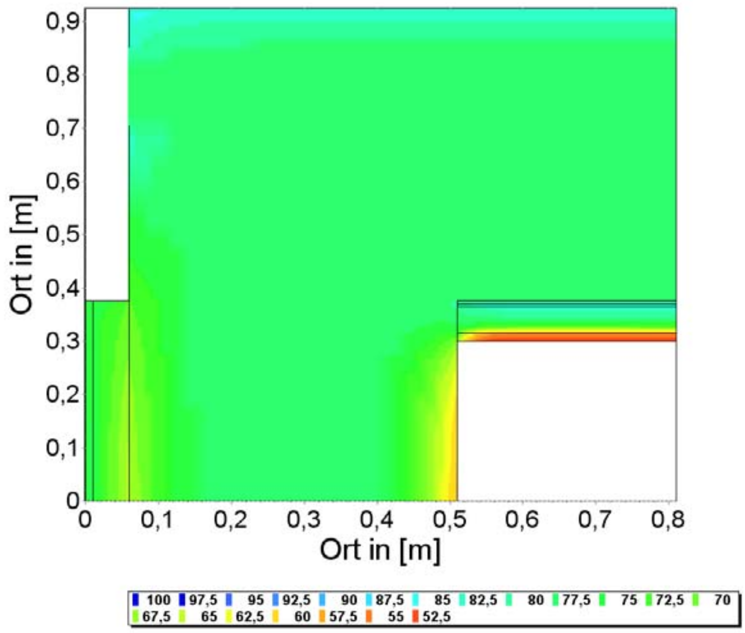


Figure 4.5.2: Humidity distribution of the construction 3 / 2D in a steady state

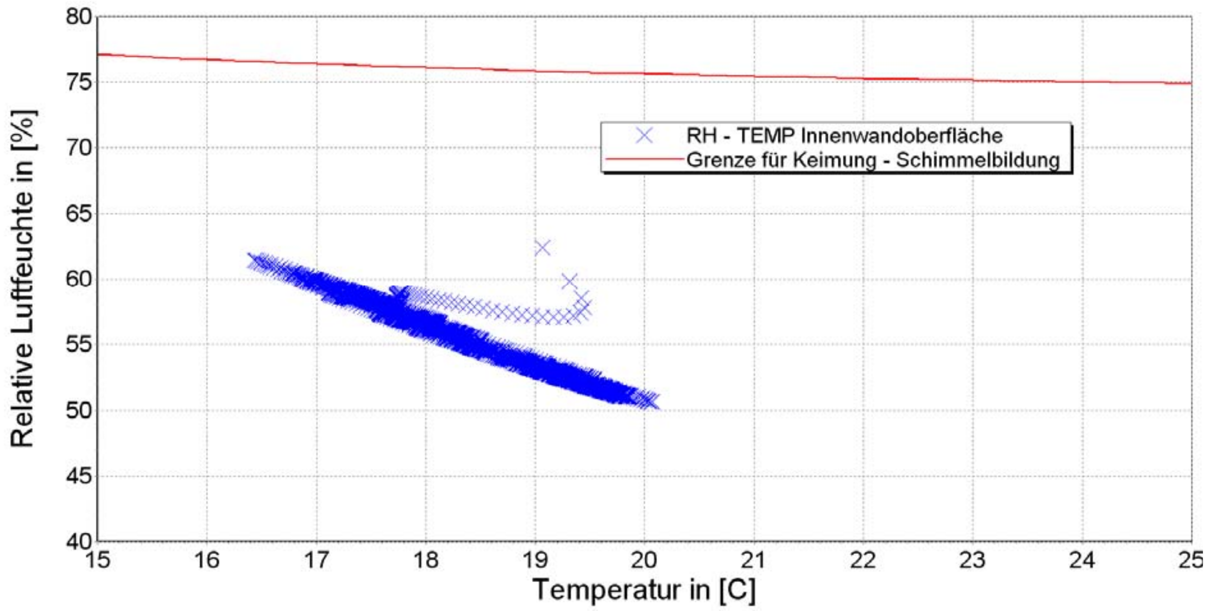


Figure 4.5.3: Graphic on the likelihood of mould formation of the construction 3 / 2D in the steady state. A mould formation with DIN required climate conditions can be excluded.

4.5.2 Climatic boundary conditions for the discussion of possible thermal bridges with Real climate:

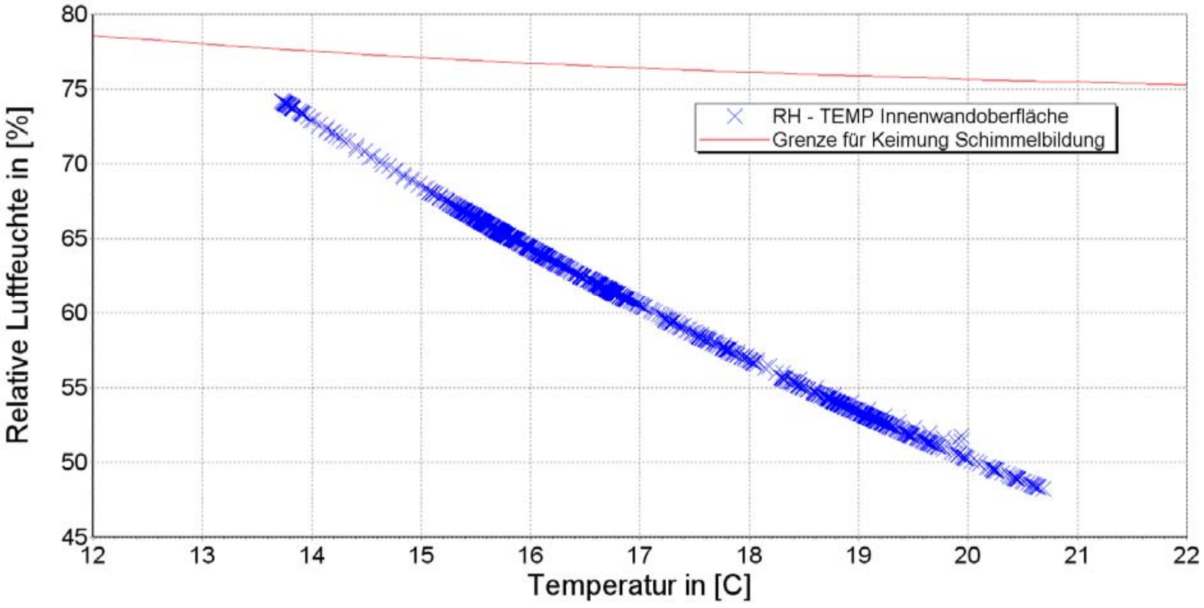


Figure 4.5.4: Graphic on the likelihood of mould formation of the construction 3 / 2D for the reference year. A mould formation with the in the DIN required climate constitutions can be excluded.

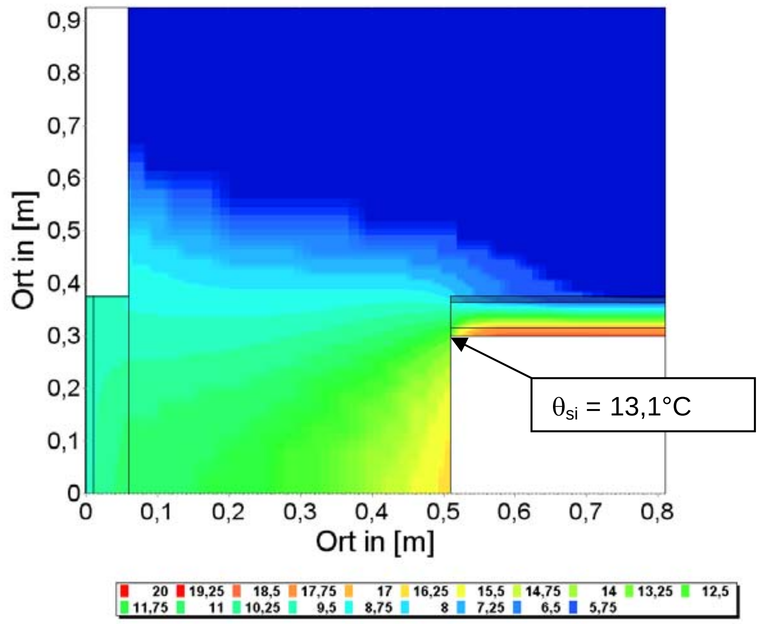


Figure 4.5.5: Temperature distribution of the construction 3 / 2D at the 3rd February of the reference year.

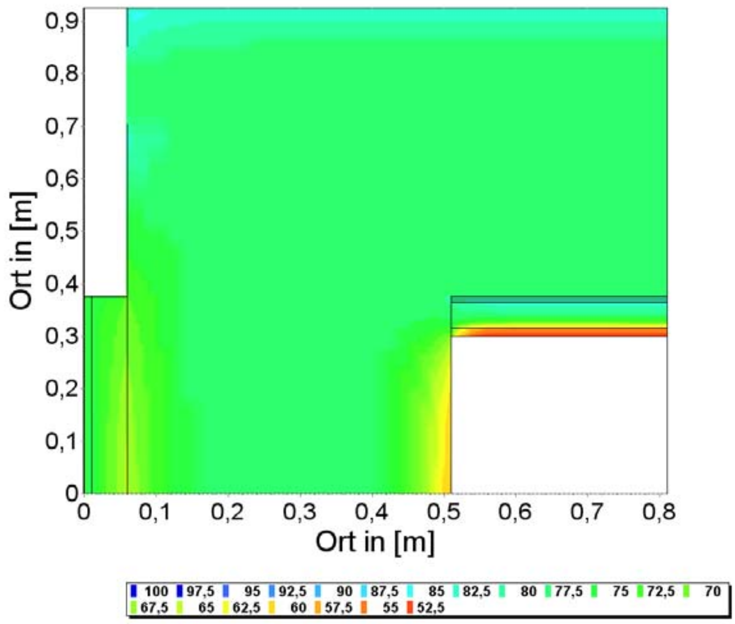


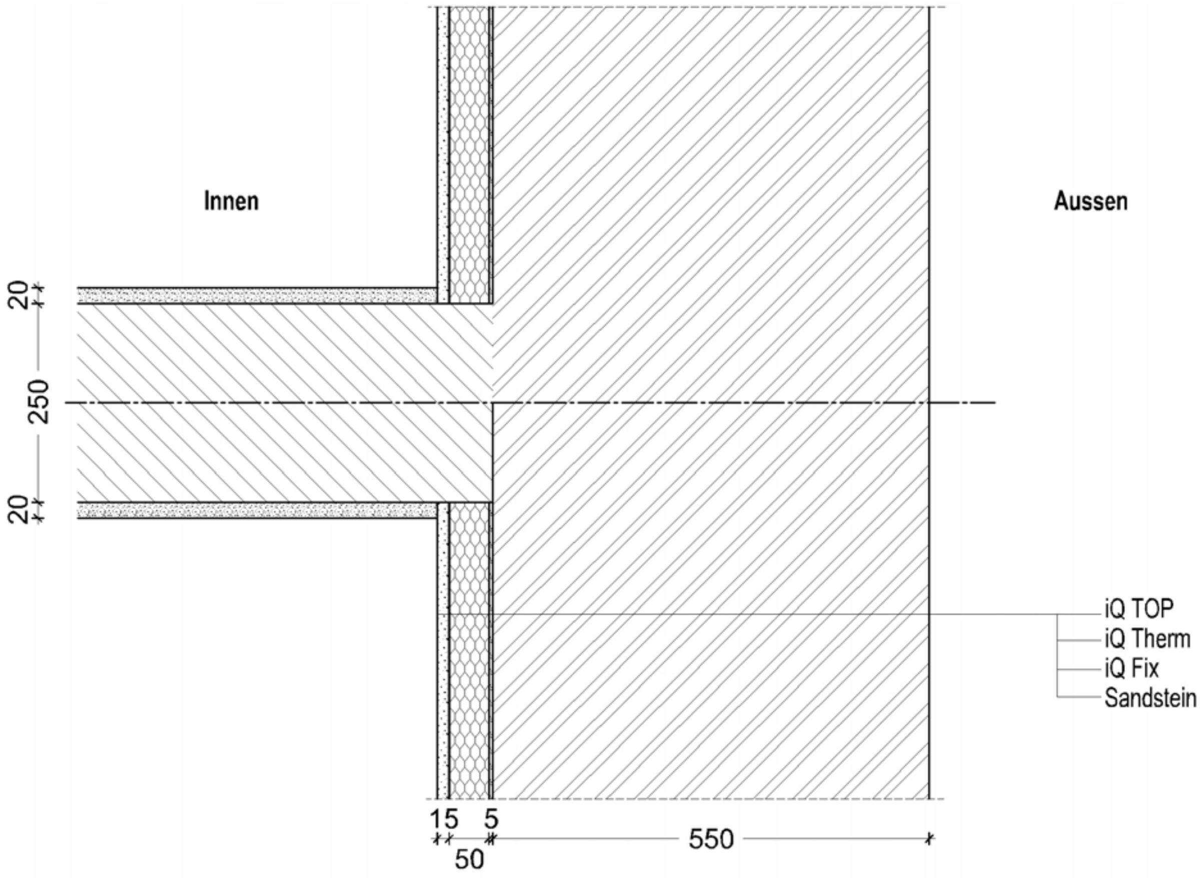
Figure 4.5.6: Humidity distribution of the construction 3 / 2D at the 3rd February of the reference year.

4.5.3 Evaluation of the results for the Real climate

There will be no damaging effect of a thermal bridge. There is no mould growth at the critical measuring point. The minimum temperature in the reference - year is 13.05°C. Due to the low temperature (near 12°C) in the corner and possible poorer ventilation through the stairs, this area is not uncritical. In extreme cold years, a surface condensation and mould damage cannot be ruled out. Therefore the embrasure should be executed with an insulation wedge of 25 cm.

4.6 Construction 4 / 2D: „Upper floor incorporating I-wall Det. I“

Construction layout



4.6.1 Calculation under steady conditions – climate according to DIN 4108-2, proof of the minimum thermal protection according to DIN 4108

The proof of the minimum thermal protection is conducted in accordance to DIN 4108-2 Section 6.2 for avoidance of mould growth.

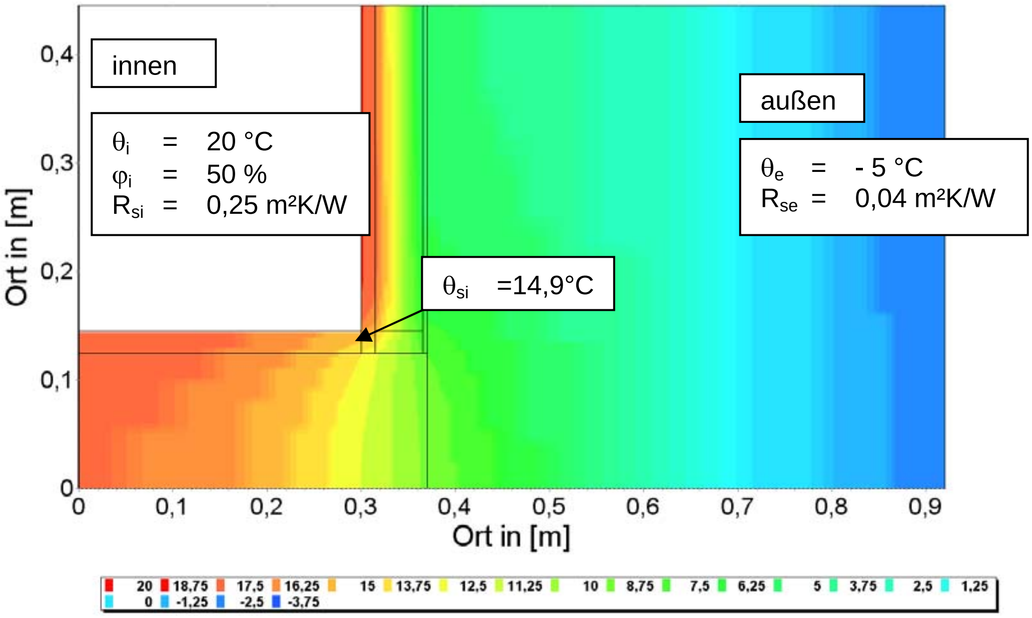


Figure 4.6.1: Temperature distribution of the structure 4 / 2D steady state surface temperature in [°C], boundary conditions according to DIN 4180 part 2.

$\theta_{si,\ inside\ corner,\ top}$ = 14,89 °C > $\theta_{si,\ acceptable}$ = 12,6 °C

The proof according to DIN 4108 – 2, section 6.2 is complied.

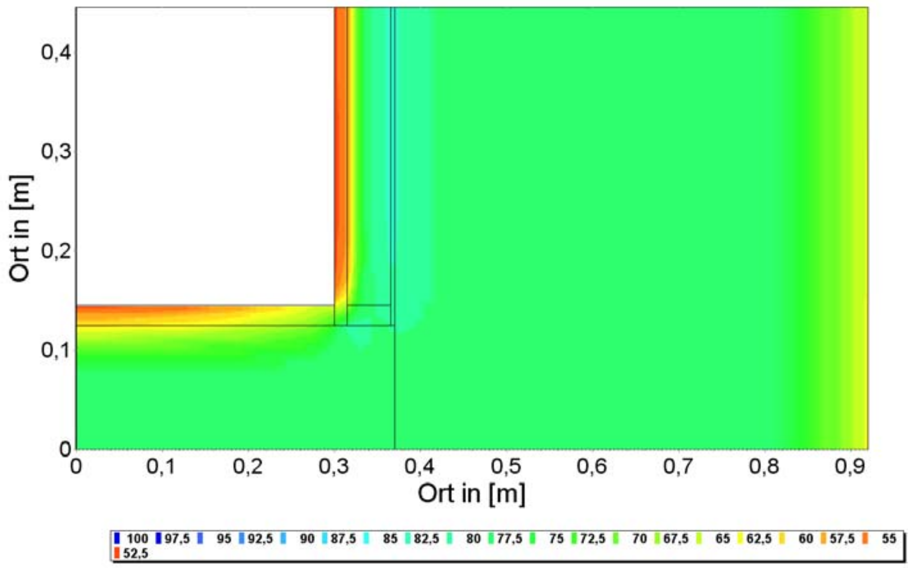


Figure 4.6.2: Humidity distribution of the construction 4 / 2D in the steady state

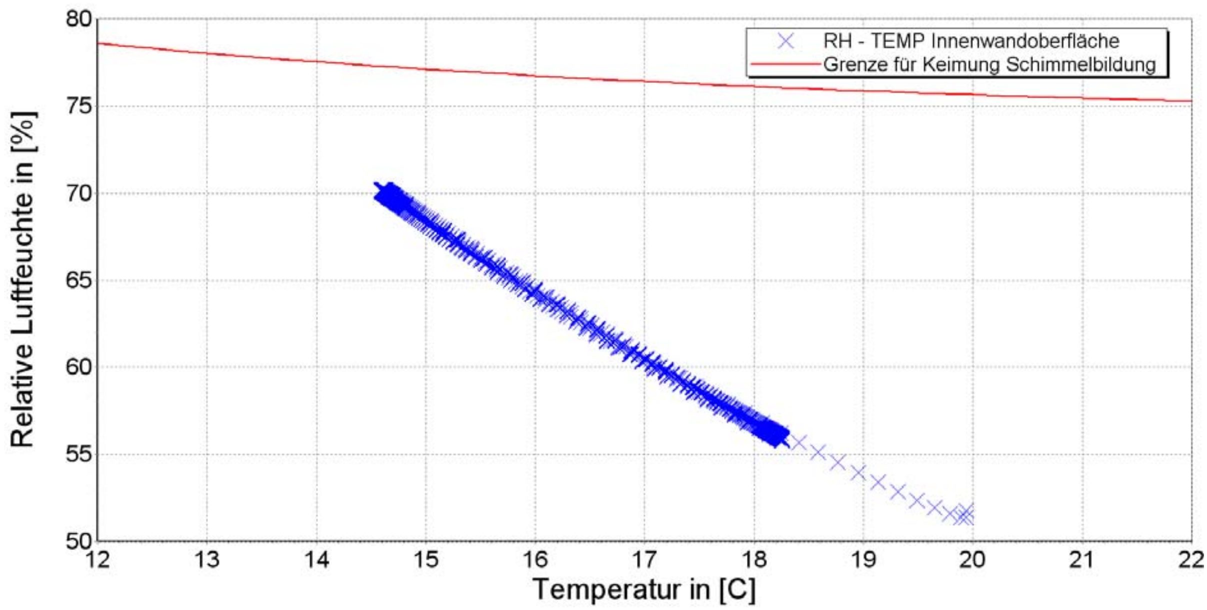


Figure 4.6.3: Graphic on the likelihood of mould formation of the construction 4 / 2D in the steady state. A mould formation with DIN required climate conditions can be excluded.

4.6.2 Climatic boundary conditions for the discussion of possible thermal bridges at Real Climate:

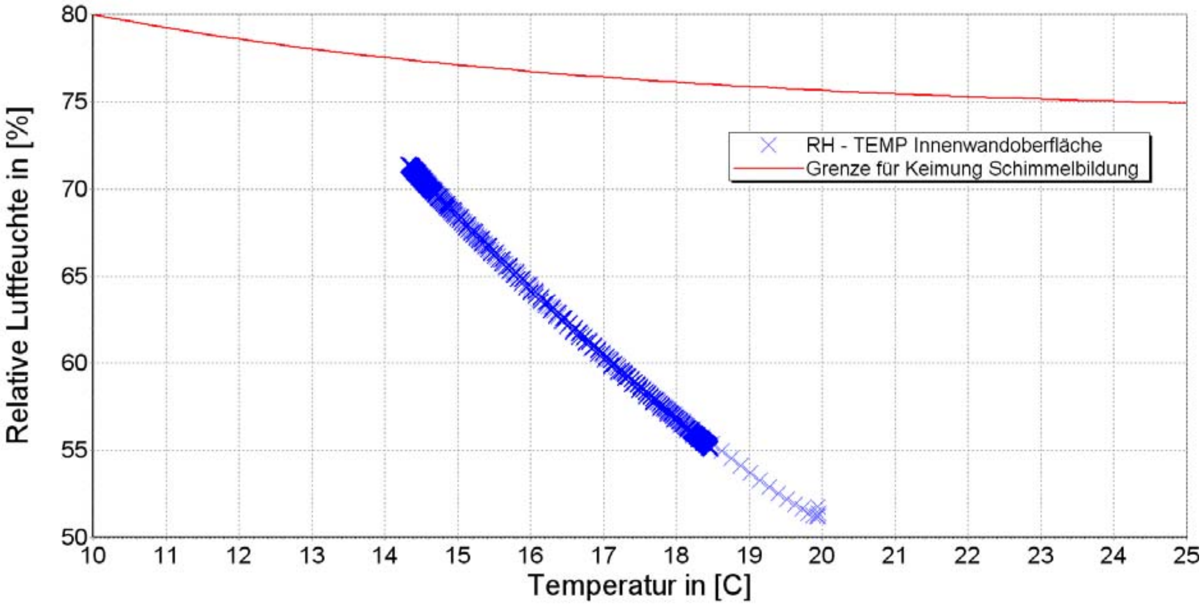


Figure 4.6.4: Graphic on the likelihood of mould formation of the construction 4 / 2D for the reference year. A mould formation can be excluded.

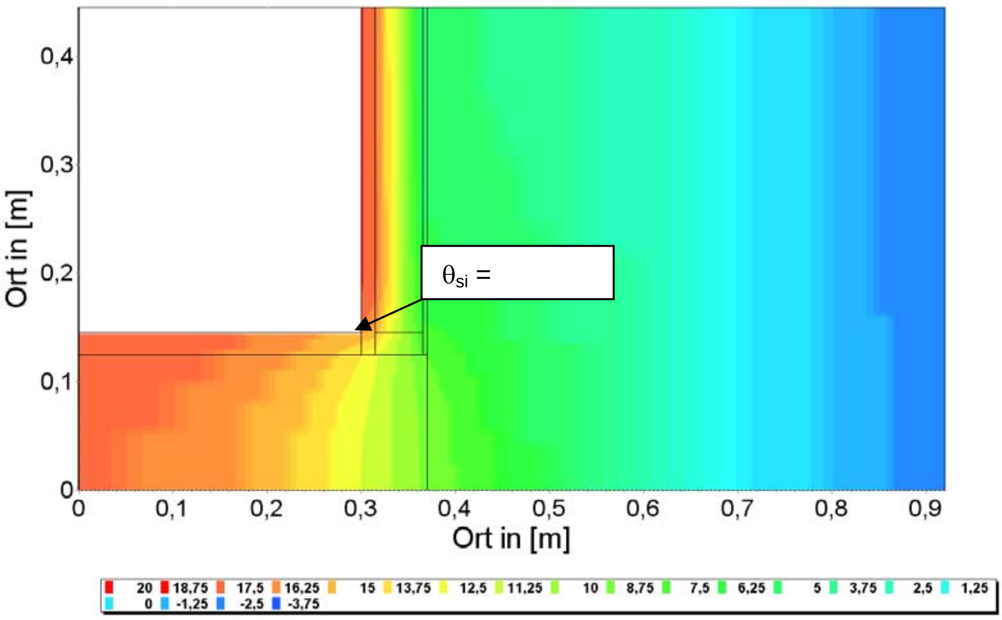


Figure 4.6.5: Temperature distribution of the construction 4 / 2D at 3rd February of the reference year.

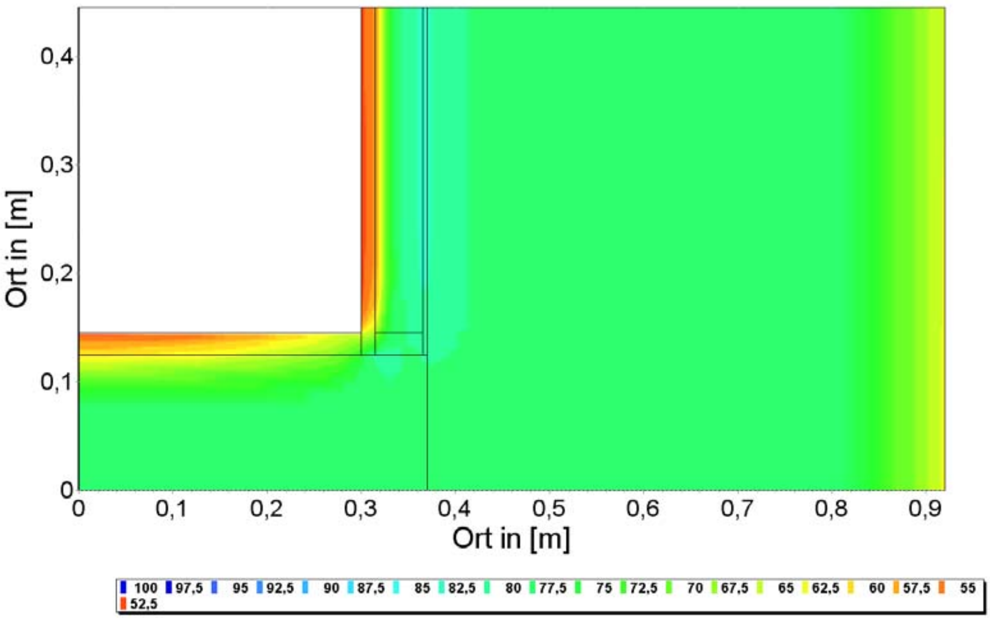


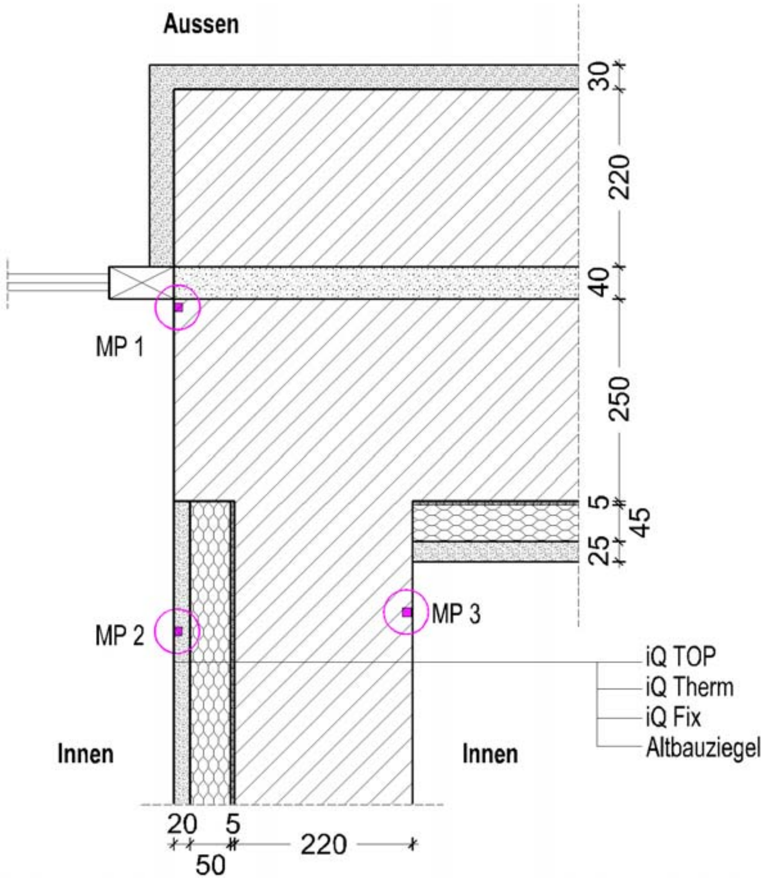
Figure 4.6.6: Humidity distribution of the construction 4 / 2D at 3rd February of the reference year.

4.6.3 Evaluation of the results for the Real Climate

There will be no damaging effects of a thermal bridge. There is no mould formation at the critical measuring point. The minimum temperature in the reference - year is 14,23°C.

4.7 Construction 5a / 2D: „Ground floor bathroom with insulation Det. H“

Construction layout



The structure is calculated without the sandstone to save simulation time, the sandstone has a higher thermal conductivity than the brick.

4.7.1 Calculation under steady conditions – climate according to DIN 4108-2, proof of the minimum thermal protection according to DIN 4108

The proof of the minimum thermal protection is conducted in accordance to DIN 4108-2 Section 6.2 for avoidance of mould growth.

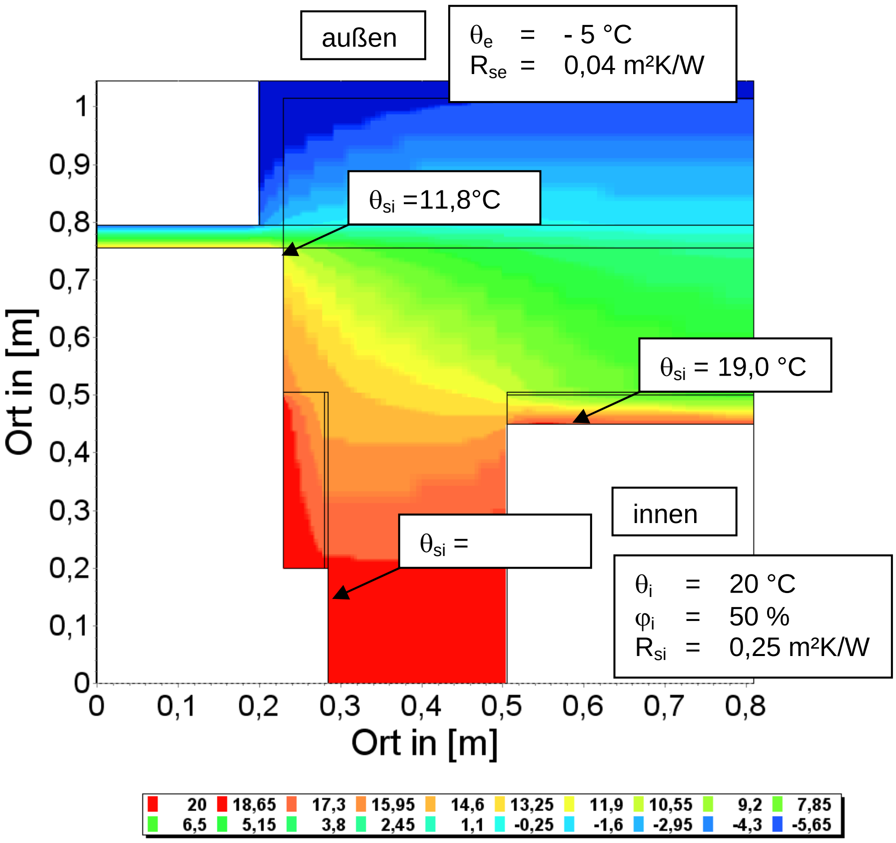


Figure 4.7.1: Temperature distribution of the structure 5a / 2D steady state surface temperature in [°C], boundary conditions according to DIN 4180 part 2.

$\theta_{si,\ Innenecke,\ oben}$ = 11,83 °C > $\theta_{si,\ zulässig}$ = 12,6 °C

The proof according to DIN 4108 – 2, section 6.2 is not complied for MP_1.
With the sandstone share in the construction, the surface temperature would be even lower, and the proof would also not be complied.

MP_2 and MP_3 can achieve the minimum temperature of 12,6 °C.

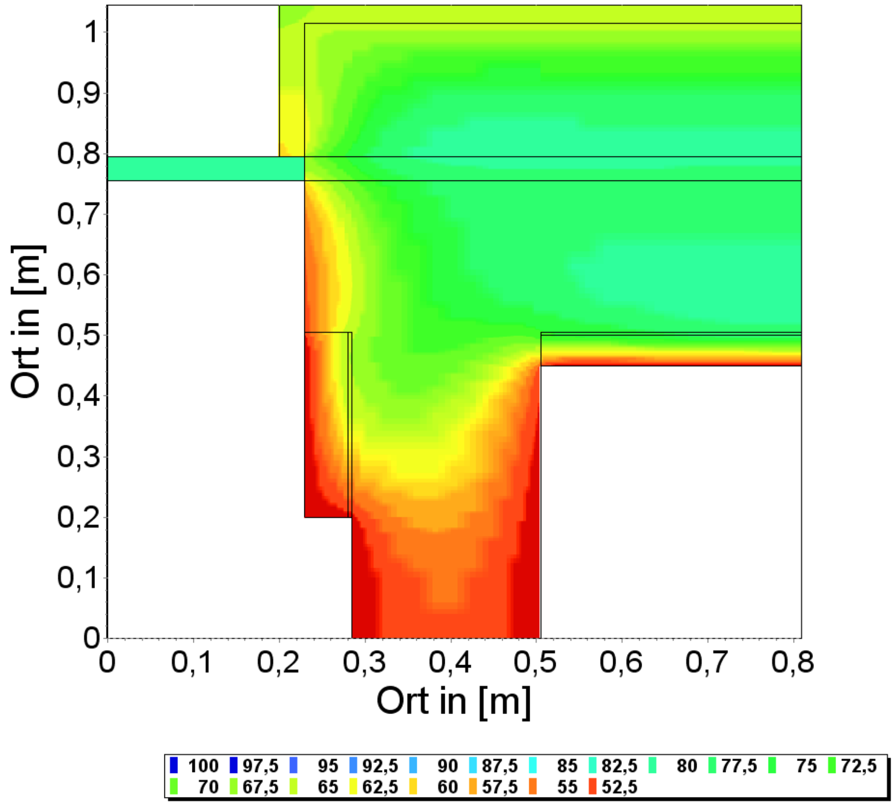


Figure 4.7.2: Humidity distribution of the construction 5a / 2D in the steady state

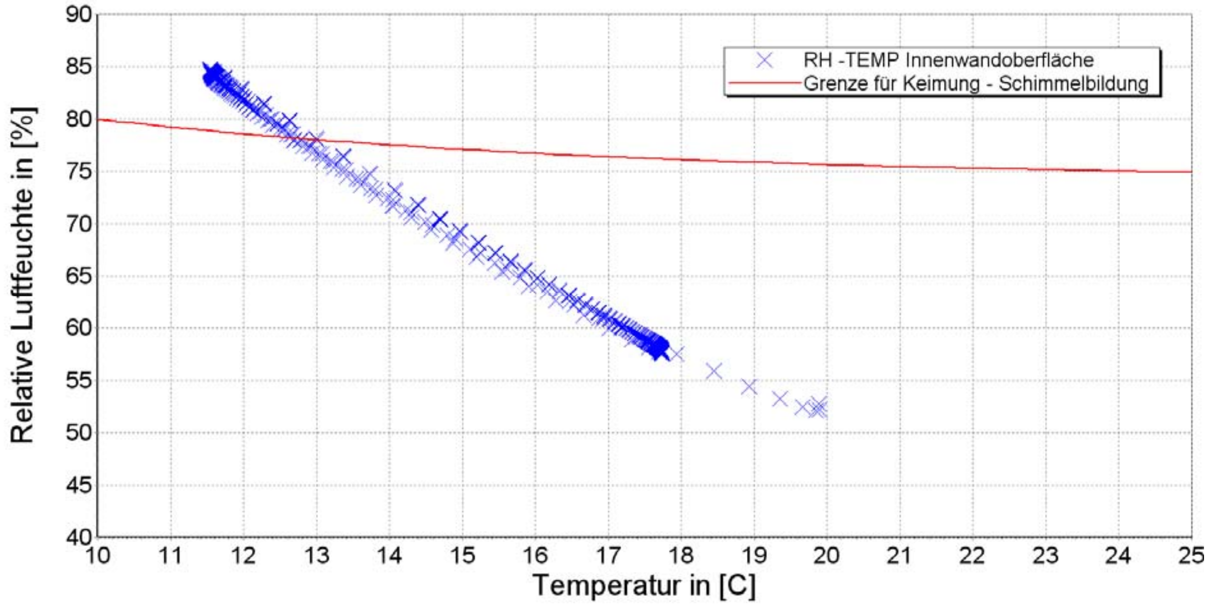


Figure 4.7.3: Graphic on the likelihood of mould formation of the construction 5a / 2D in the steady state. A mould formation with DIN required climate conditions cannot be excluded.

4.7.2 Climatic boundary conditions for the discussion of possible thermal bridges at Real Climate:

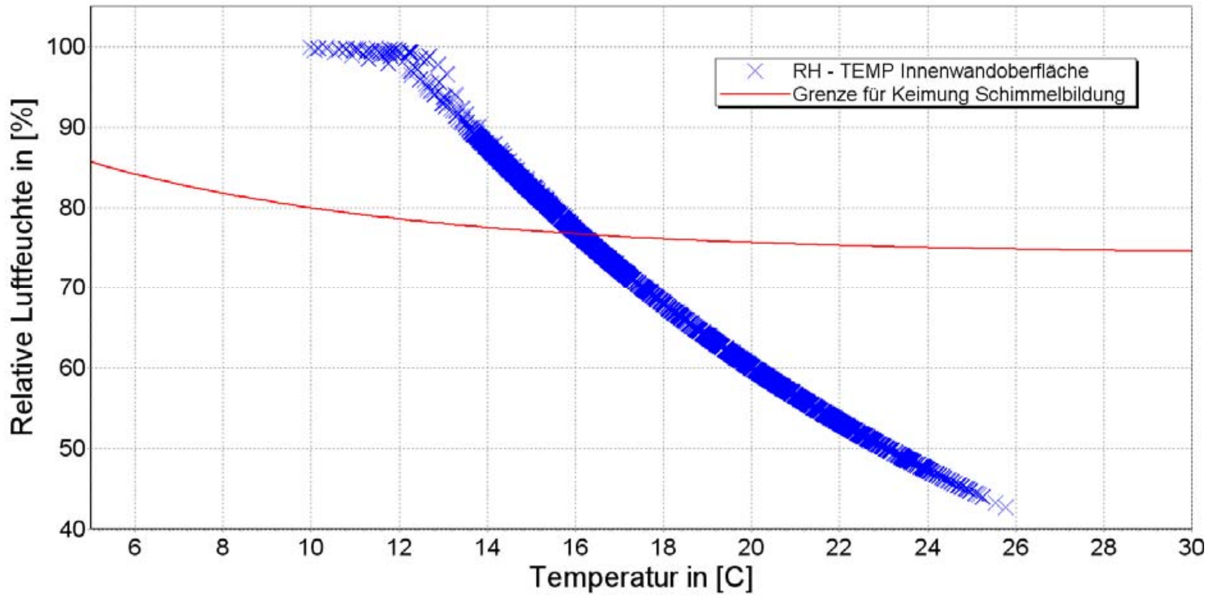


Figure 4.7.4: Graphic on the likelihood of mould formation of the construction 5a / 2D for the reference year. A mould formation cannot be excluded.

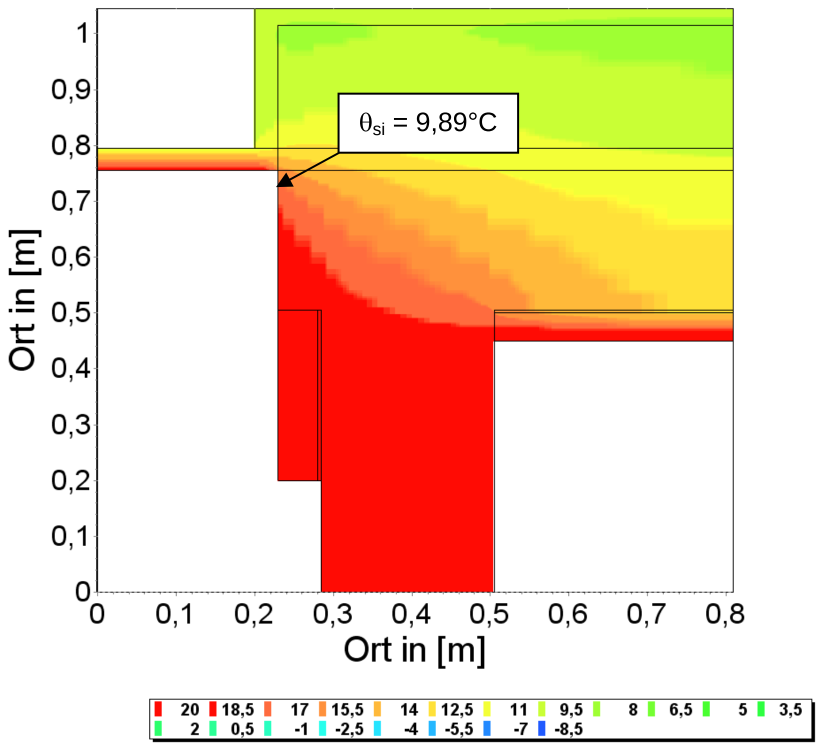


Figure 4.7.5: Temperature distribution of the construction 5a / 2D at 3rd February of the reference year.

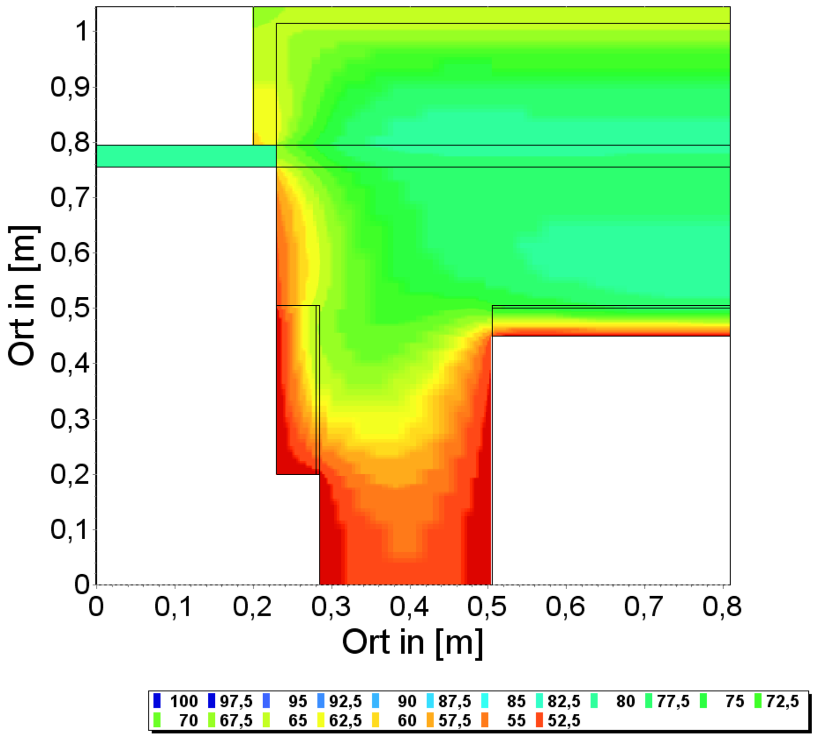


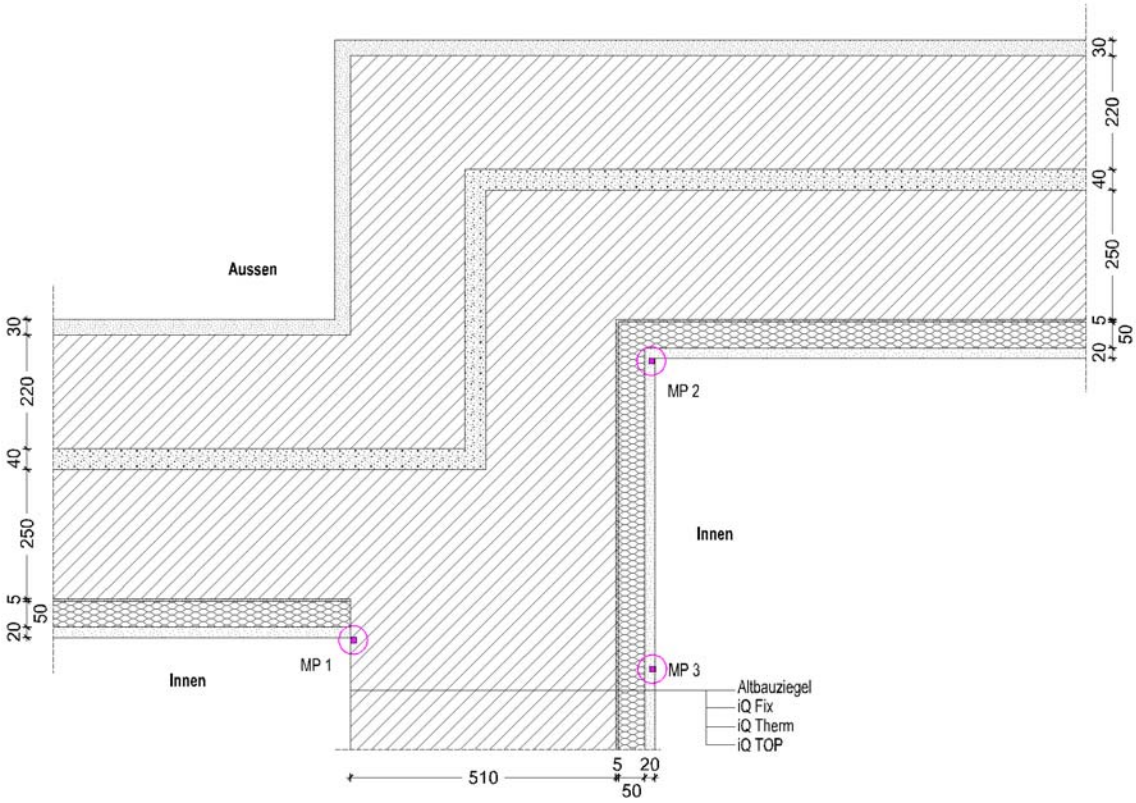
Figure 4.7.6: Humidity distribution of the construction 5a / 2D at 3rd February of the reference year.

4.7.3 Evaluation of the results for the Real Climate

There will be damaging effects of a thermal bridge. There is mould formation at the critical measuring point. The minimum temperature in the reference - year is 9,89°C. An embrasure insulation is necessary in the area of the window. Further simulations have shown, these included the sandstone, that a wedge insulation with a thickness of 25mm is already sufficient to meet the requirements of DIN and can prevent mould growth in the TRY. Possibly a technical solution (temperature control) is to pursue in this area.

4.8 Construction 5b / 2D: „ Ground floor bathroom with insulation Det. A“

Construction layout



4.8.1 Calculation under steady conditions – climate according to DIN 4108-2, proof of the minimum thermal protection according to DIN 4108

The proof of the minimum thermal protection is conducted in accordance to DIN 4108-2 Section 6.2 for avoidance of mould growth.

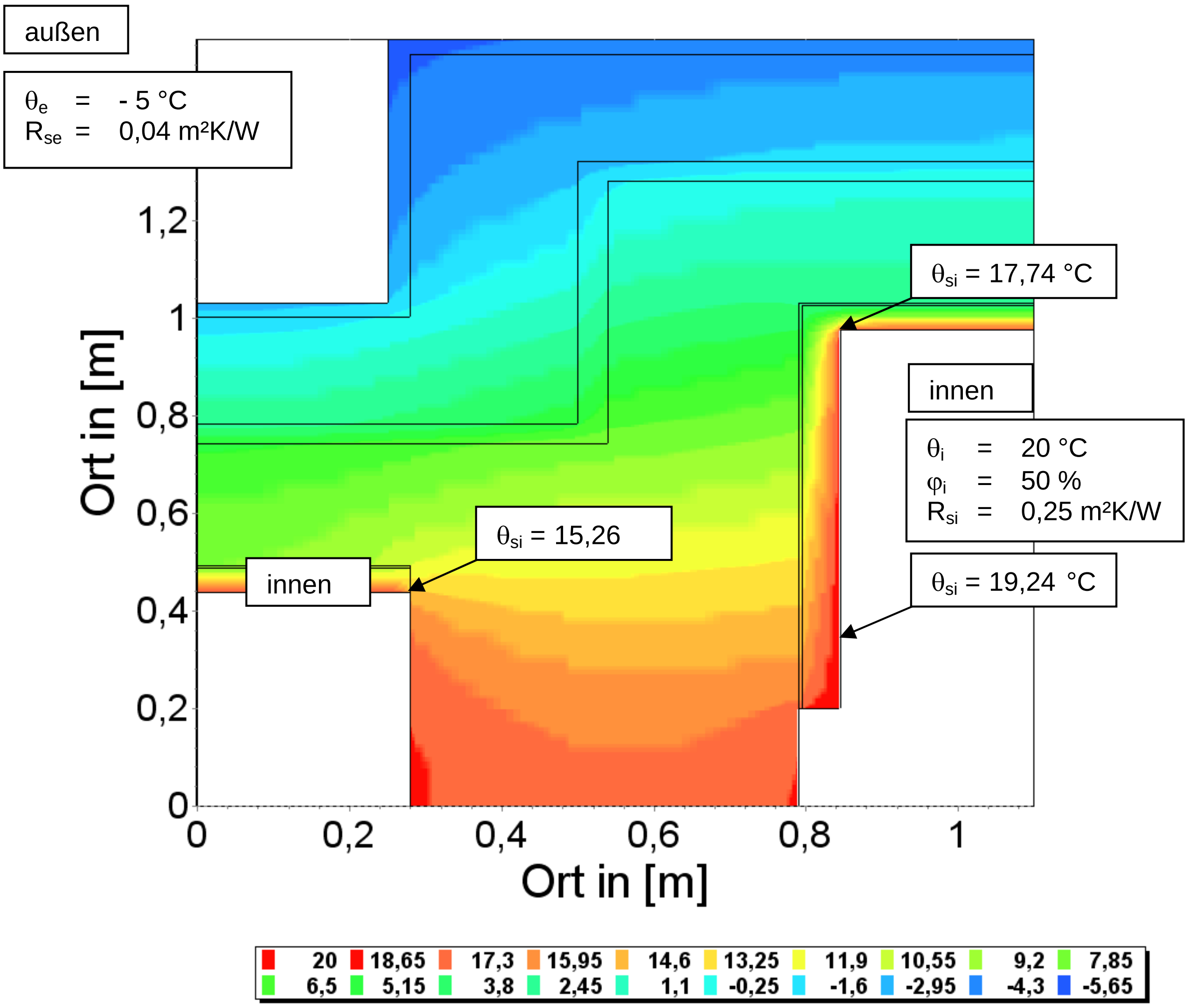


Figure 4.8.1: Temperature distribution of the structure 5b / 2D steady state surface temperature in [°C], boundary conditions according to DIN 4180 part 2.

$\theta_{si,\ inside\ corner,\ mp1}$ = 15,26 °C > $\theta_{si,\ acceptable}$ = 12,6 °C

The proof according to DIN 4108 – 2, section 6.2 is complied for MP_1 untill MP_3.

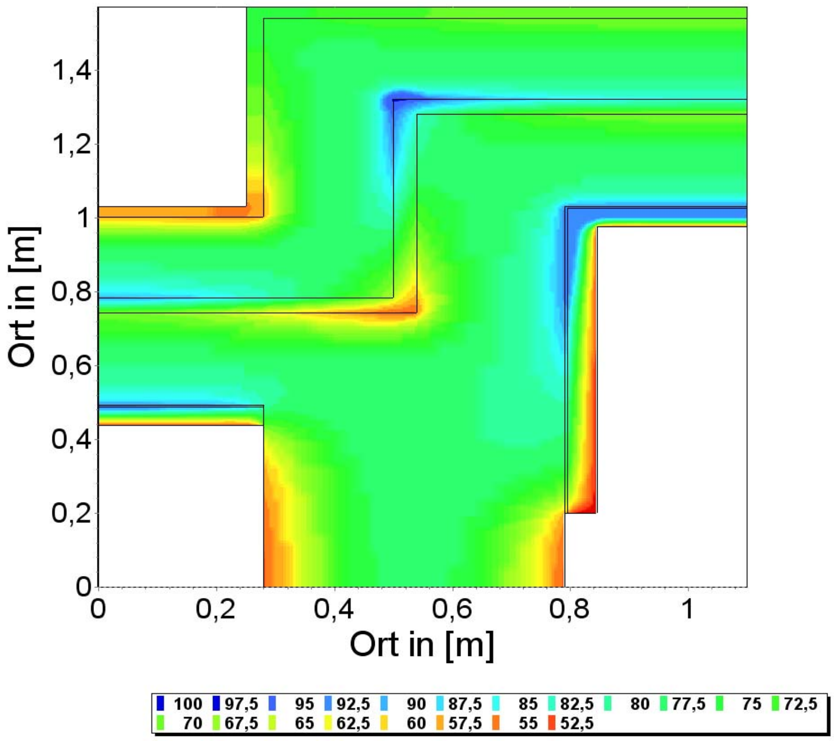


Figure 4.8.2: Humidity distribution of the construction 5b / 2D in the steady state

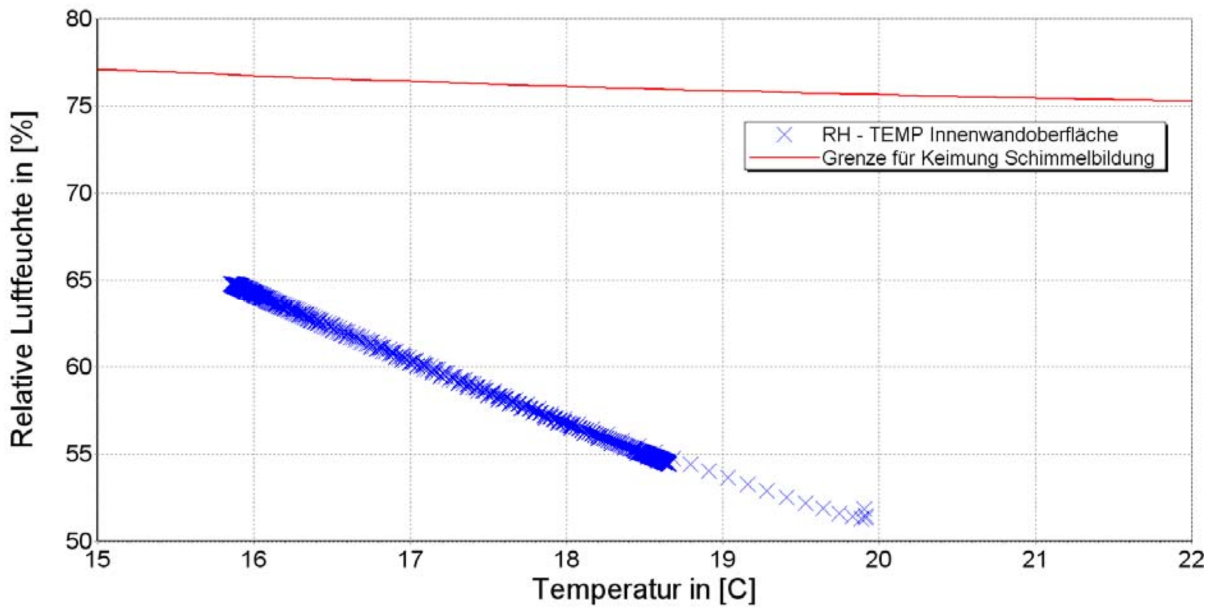


Figure 4.8.3: Graphic on the likelihood of mould formation of the construction 5b / 2D in the steady state. A mould formation with DIN required climate conditions can be excluded.

4.8.2 Climatic boundary conditions for the discussion of possible thermal bridges at Real Climate:

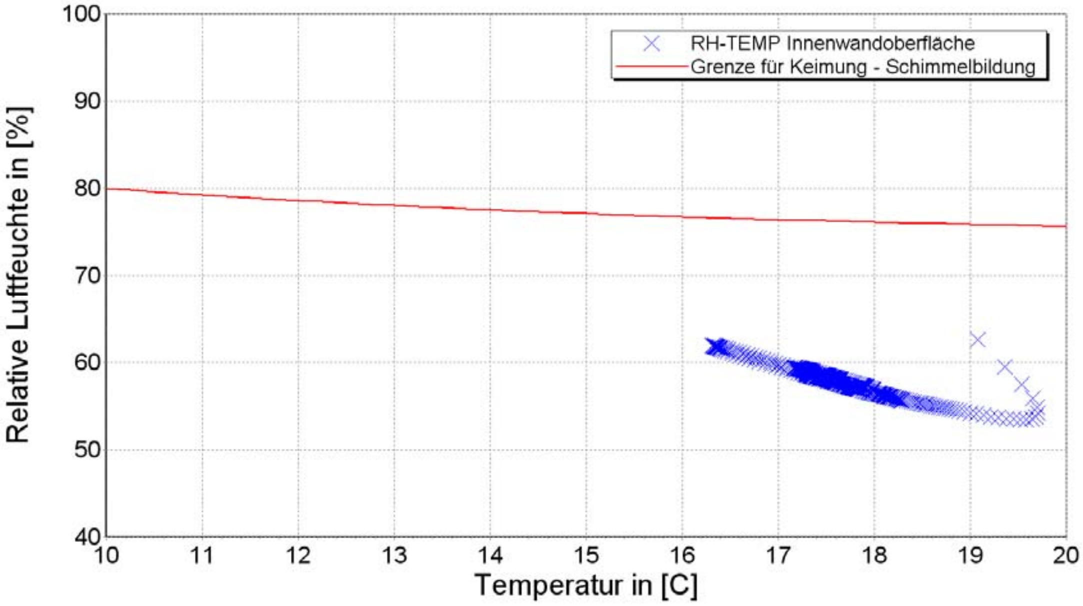


Figure 4.8.4: Graphic on the likelihood of mould formation of the construction 5b / 2D for the reference year. A mould formation with DIN required climate conditions can be excluded.

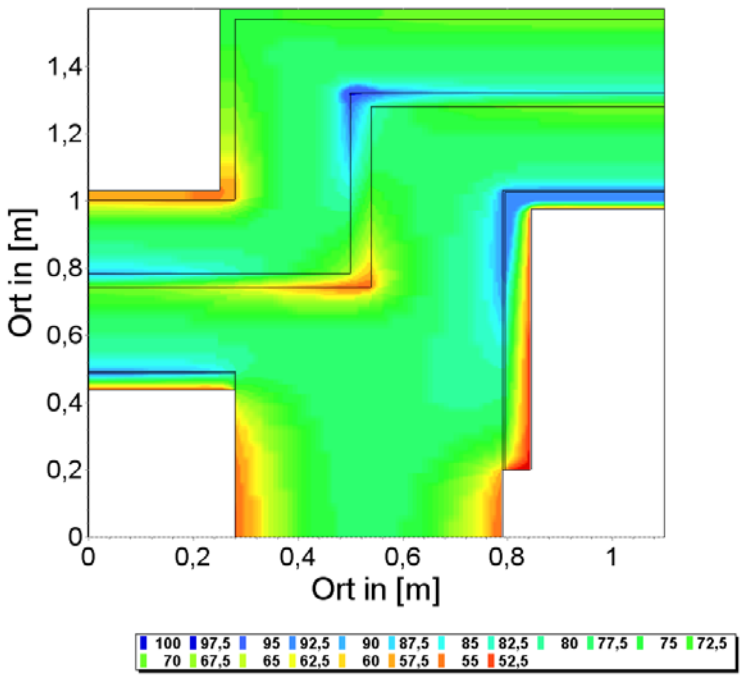


Figure 4.8.5: Temperature distribution of the construction 5b / 2D at the 3rd February of the reference year.

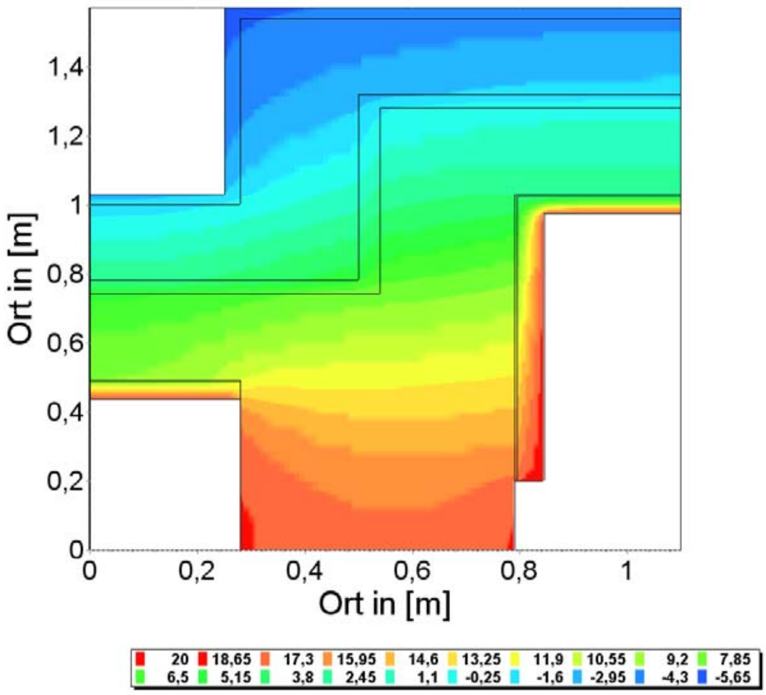


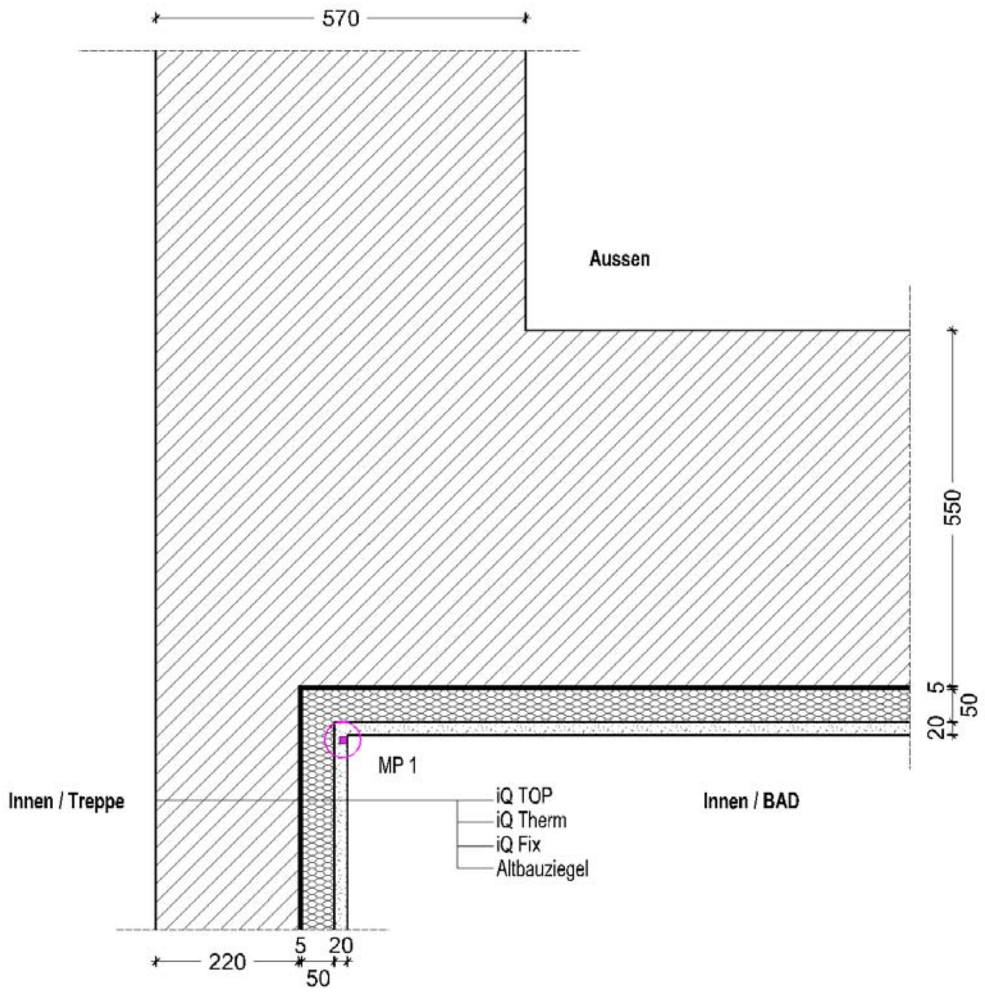
Figure 4.8.6: Humidity distribution of the construction 5b / 2D at the 3rd February of the reference year.

4.8.3 Evaluation of the results for the Real Climate

There will be no damaging effects of a thermal bridge. There is no mould formation at the critical measuring point. The minimum temperature in the reference - year is 16,54°C at measuring point 1.

4.9 Construction 6 / 2D: „Ground floor bathroom-staircase“

Construction layout



The plaster layer in the 550mm thick external wall has been omitted for simplifying reasons. Brick and plaster have similar building climatical properties.

4.9.1 Calculation under steady conditions – climate according to DIN 4108-2, proof of the minimum thermal protection according to DIN

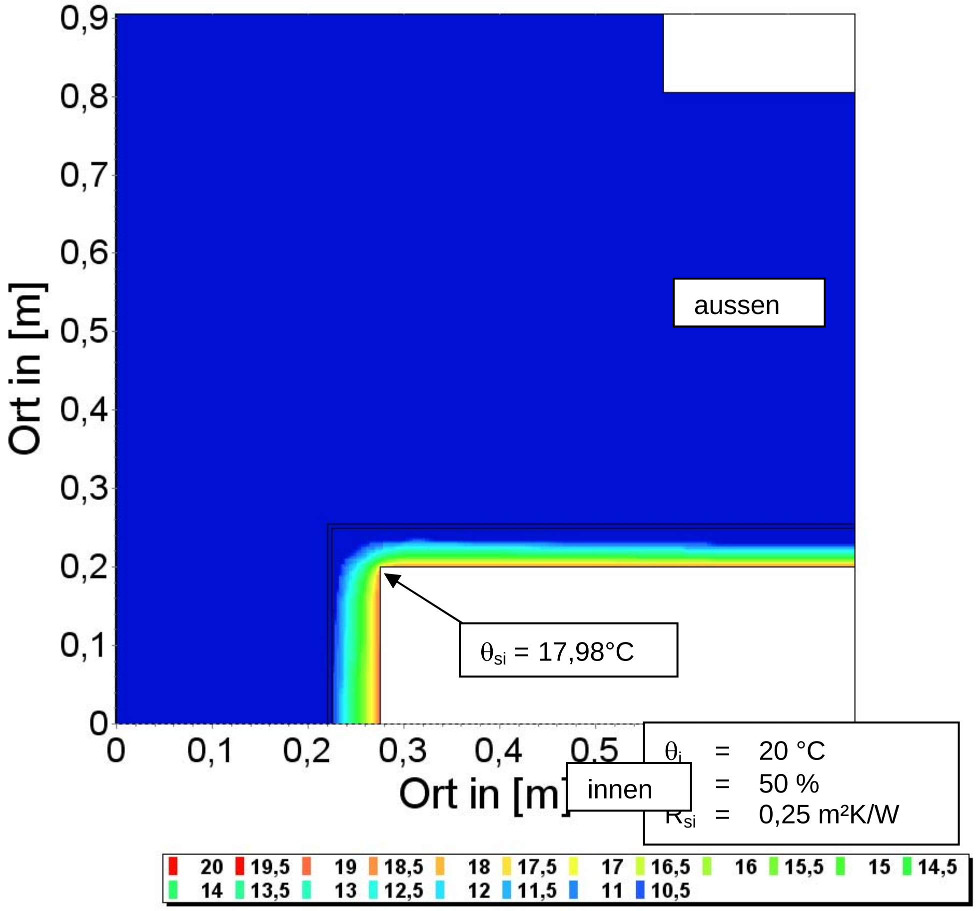


Figure 4.8.1: Temperature distribution of the construction 6 / 2D in a steady state, surface temperature in [°C], boundary conditions according to DIN 4108 part 2.

$\theta_{si,\ inside\ corner,\ top}$ = 17,98 °C > $\theta_{si,\ acceptable}$ = 12,6 °C

The proof according to DIN 4108 – 2, section 6.2 is complied.

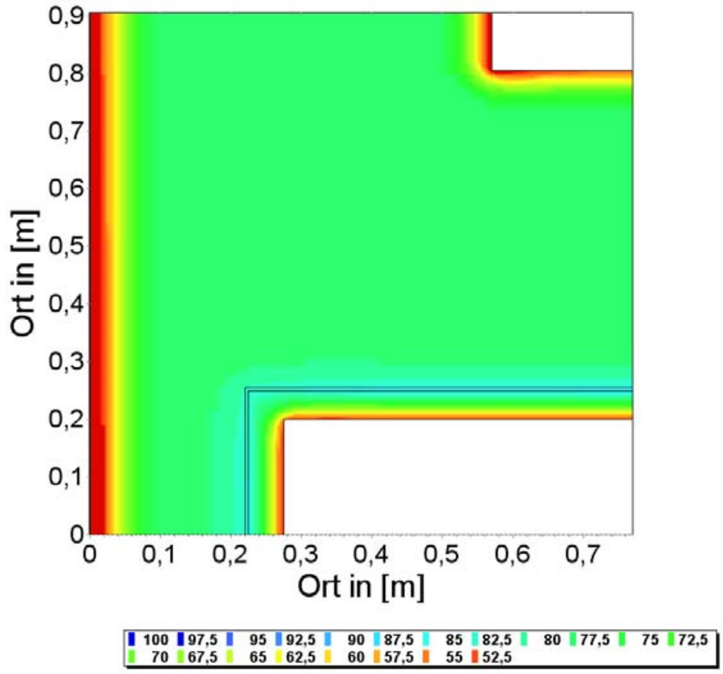


Figure 4.8.2: Humidity distribution of the construction 6 / 2D in the steady state

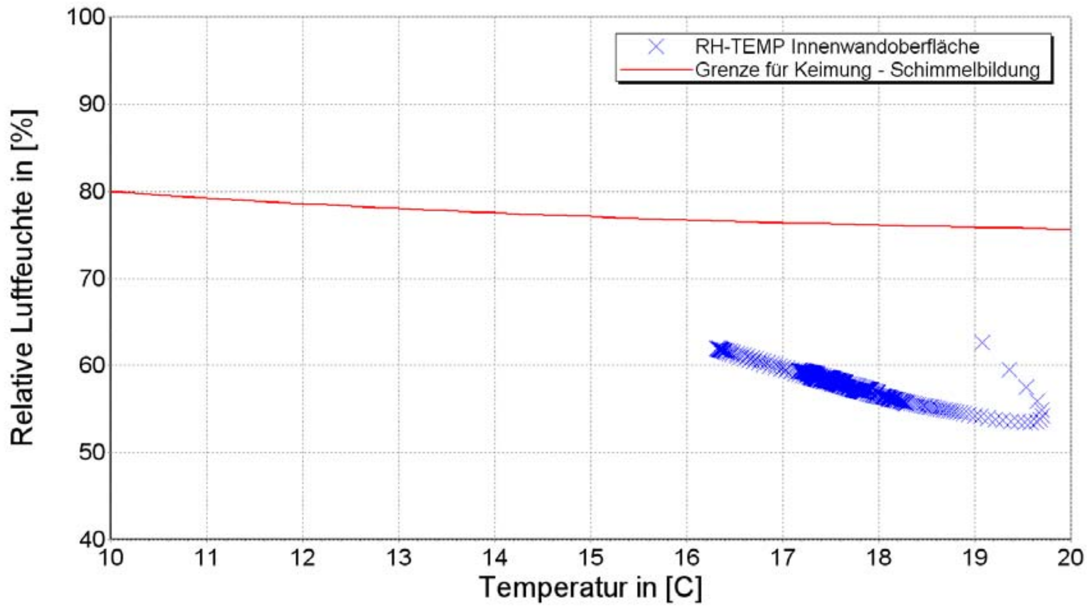


Figure 4.8.3: Graphic on the likelihood of mould formation of the construction 6 / 2D in the steady state. A mould formation can be excluded.

4.9.2 Climatic boundary conditions for the discussion of possible thermal bridges at Real Climate:

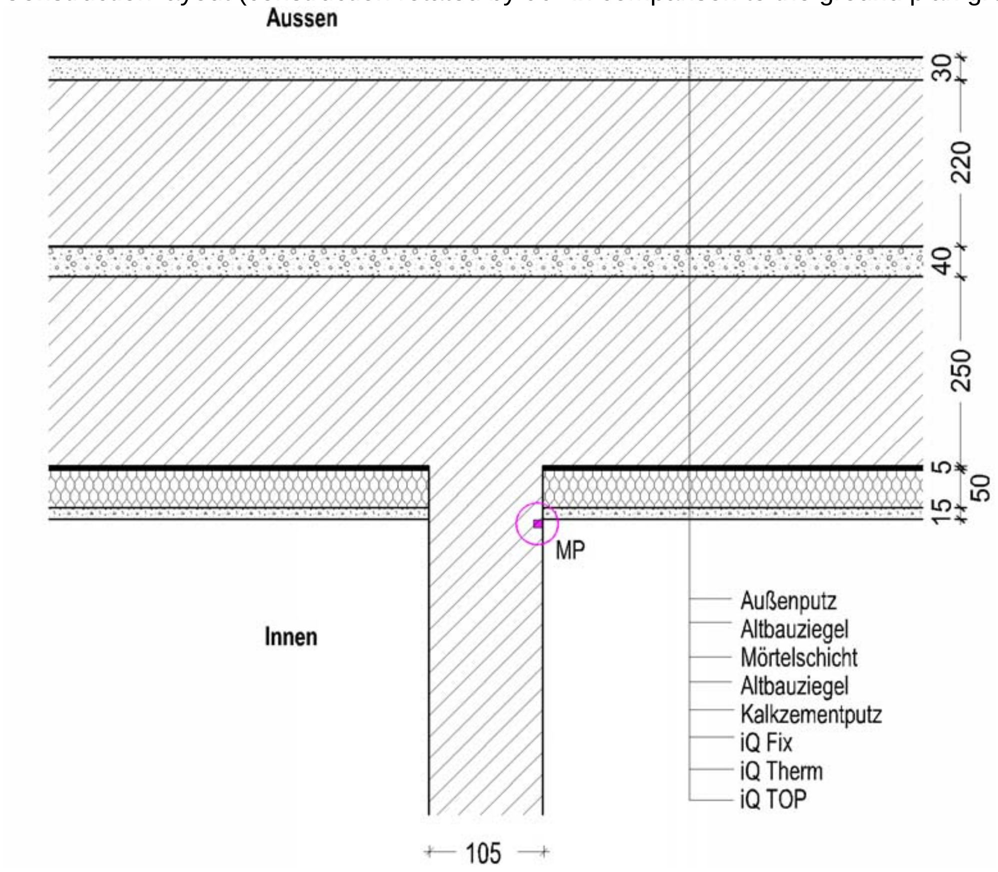
A calculation for the real climate is not performed. A damaging thermal bridge can be excluded using the previous design calculations. Likewise there is no mould growth.

4.9.3 Evaluation of the results for the Real Climate

In the simulation it was assumed that the in the stairwell stated climate conditions with a temperature of 10 °C and a relative humidity of 35% prevail. Under this premise, a damaging thermal bridge can be excluded. In freezing conditions or in the wintertime, the window should not remain open for a long time under any circumstances since such a compliance with the adopted boundary condition is not guaranteed.

4.10 Construction 7 / 2D: „Ground floor incorporating I-wall Det. B“

Construction layout (construction rotated by 90° in comparison to the ground plan ground floor)



4.10.1 Calculation under steady conditions – climate according to DIN 4108-2, proof of the minimum thermal protection according to DIN 4108

The proof of the minimum thermal protection is conducted in accordance to DIN 4108-2 Section 6.2 for avoidance of mould growth.

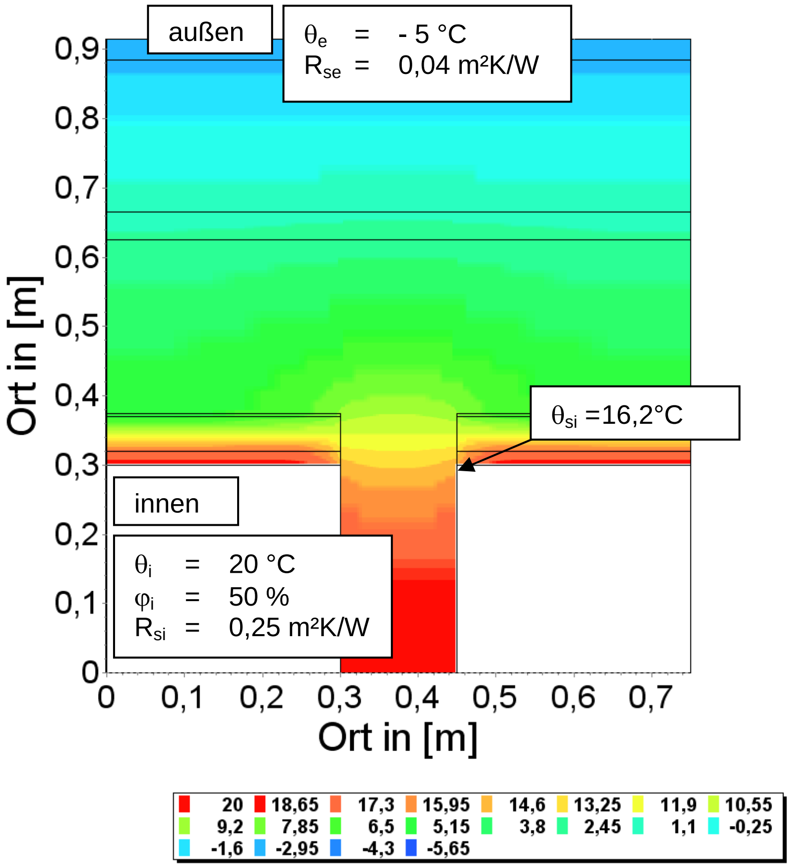


Figure 4.10.1: Temperature distribution of the structure 7 / 2D steady state surface temperature in [°C], boundary conditions according to DIN 4180 part 2.

$\theta_{si,\ inside\ corner,\ top}$ = 16,2°C > $\theta_{si,\ acceptable}$ = 12,6 °C

The proof according to DIN 4108 – 2, section 6.2 is complied.

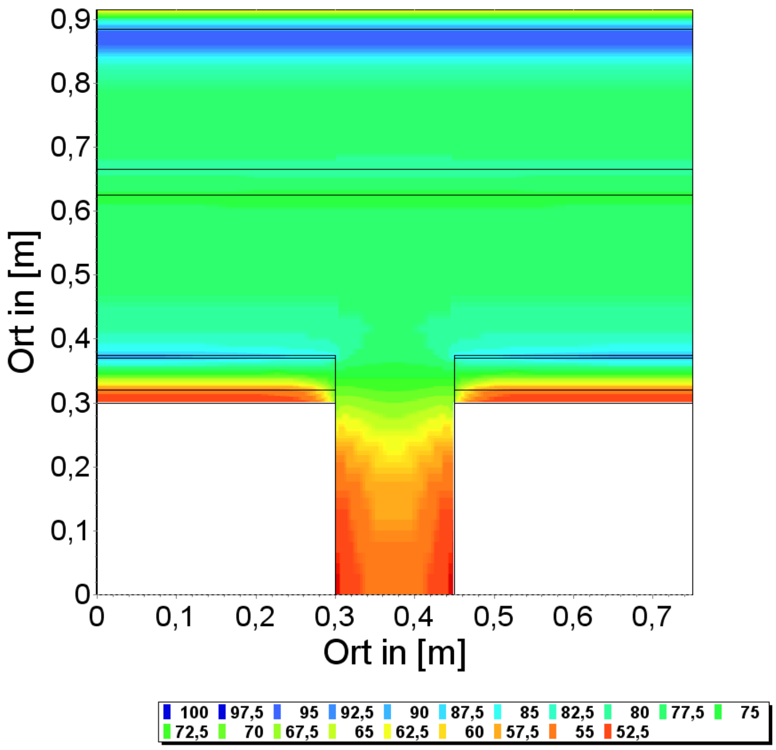


Figure 4.10.2: Humidity distribution of the construction 7 / 2D in the steady state

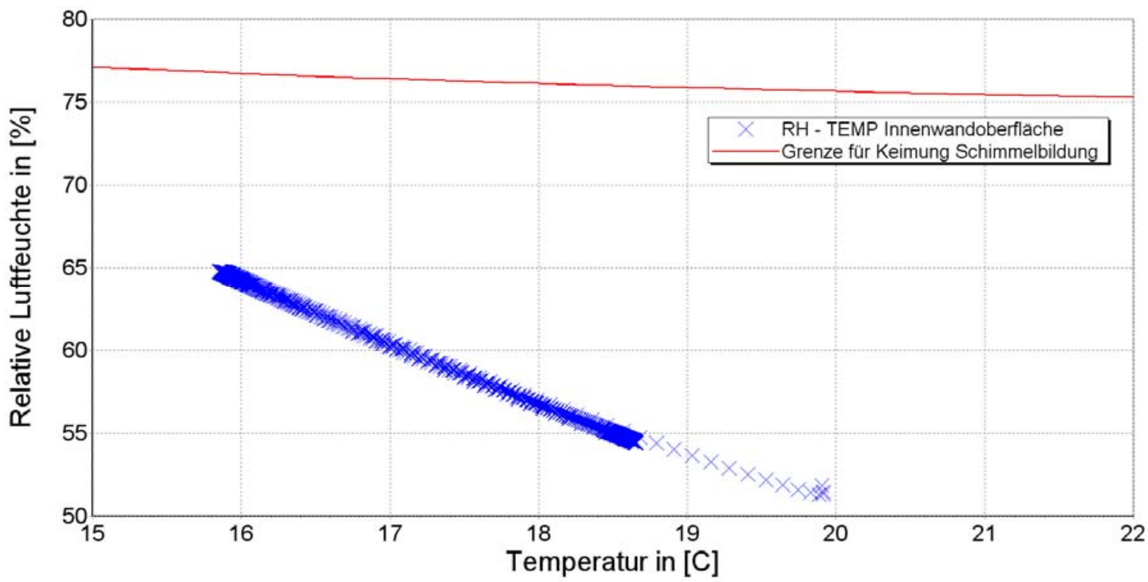


Figure 4.10.3: Graphic on the likelihood of mould formation of the construction 7 / 2D in the steady state. A mould formation with DIN required climate conditions can be excluded.

4.10.2 Climatic boundary conditions for the discussion of possible thermal bridges at Real Climate:

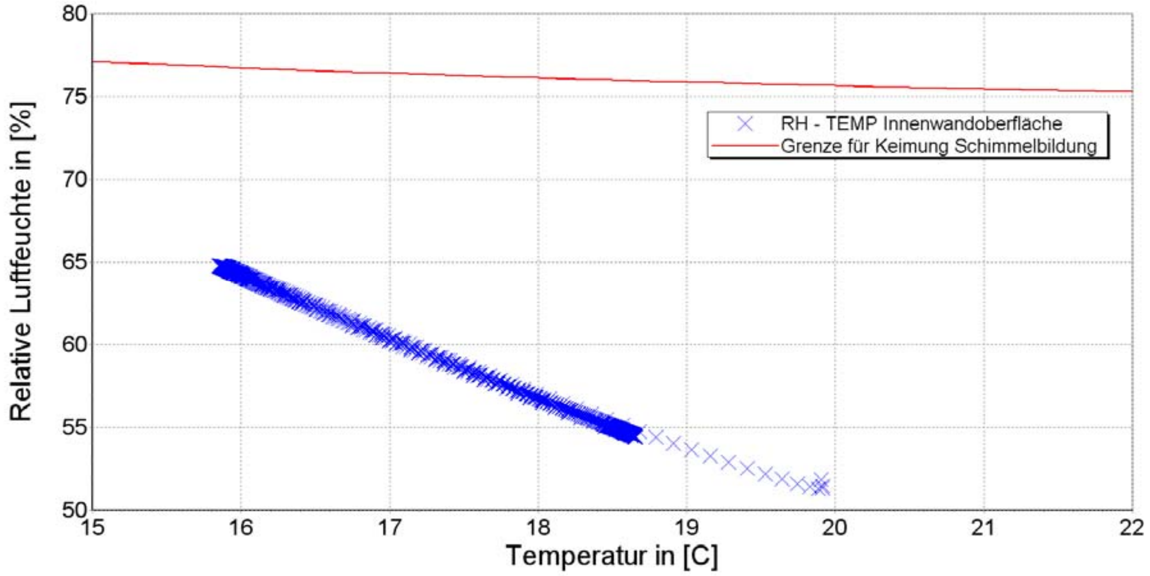


Figure 4.10.4: Graphic on the likelihood of mould formation of the construction 7 / 2D for the reference year. A mould formation can be excluded.

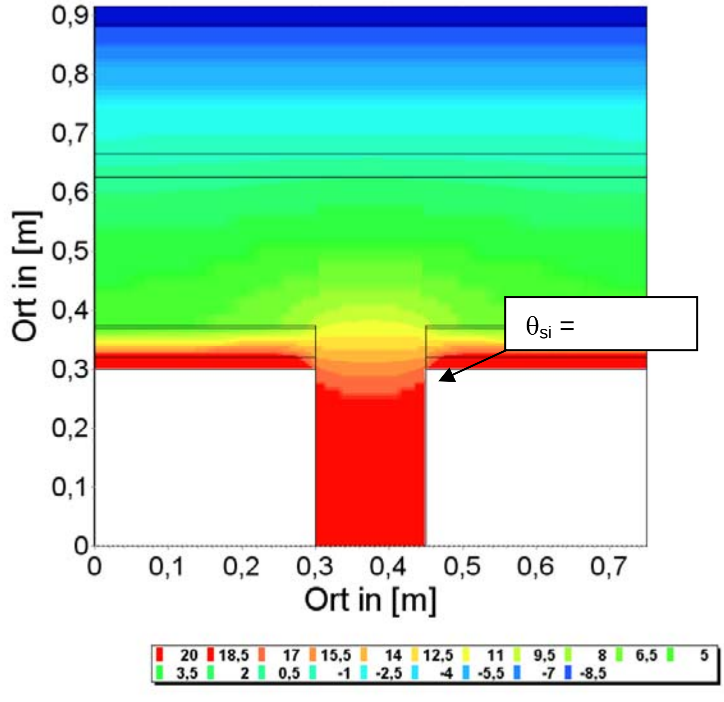


Figure 4.10.5: Temperature distribution of the construction 7 / 2D at 3rd February of the reference year.

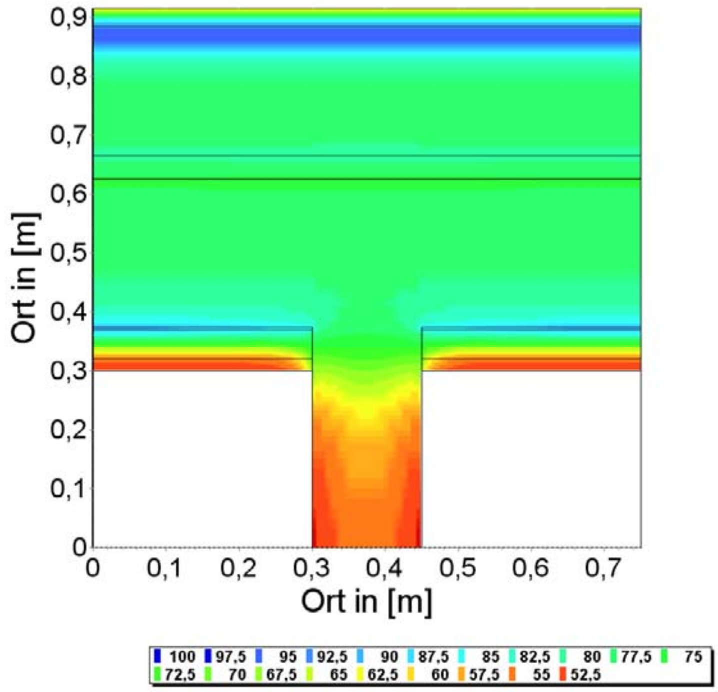


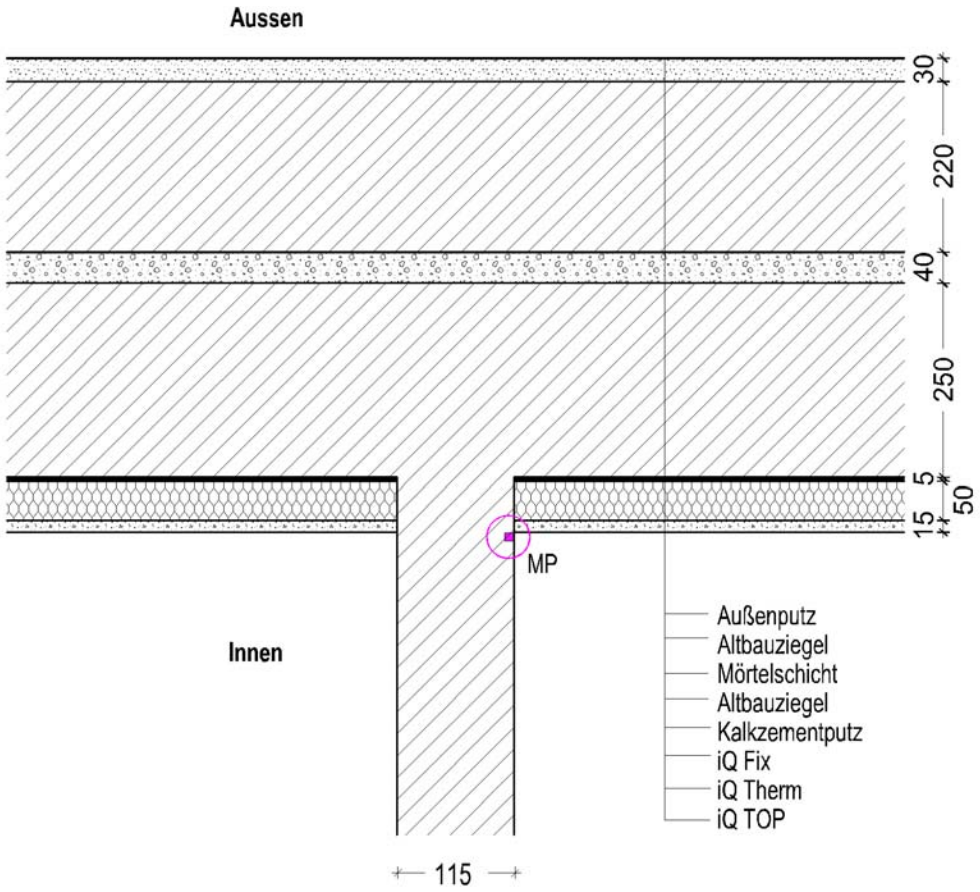
Figure 4.10.6: Humidity distribution of the construction 7 / 2D at 3rd February of the reference year.

4.10.3 Evaluation of the results for the Real Climate

There will be no damaging effects of a thermal bridge. There is no mould formation at the critical measuring point. The minimum temperature in the reference - year is 15,56°C.

4.11 Construction 8 / 2D: „Ground floor incorporated I-wall Det. F“

Construction layout (construction rotated by 180° in comparison to the ground plan ground floor)



4.11.1 Calculation under steady conditions – climate according to DIN 4108-2, proof of the minimum thermal protection according to DIN 4108

The proof of the minimum thermal protection is conducted in accordance to DIN 4108-2 Section 6.2 for avoidance of mould growth.

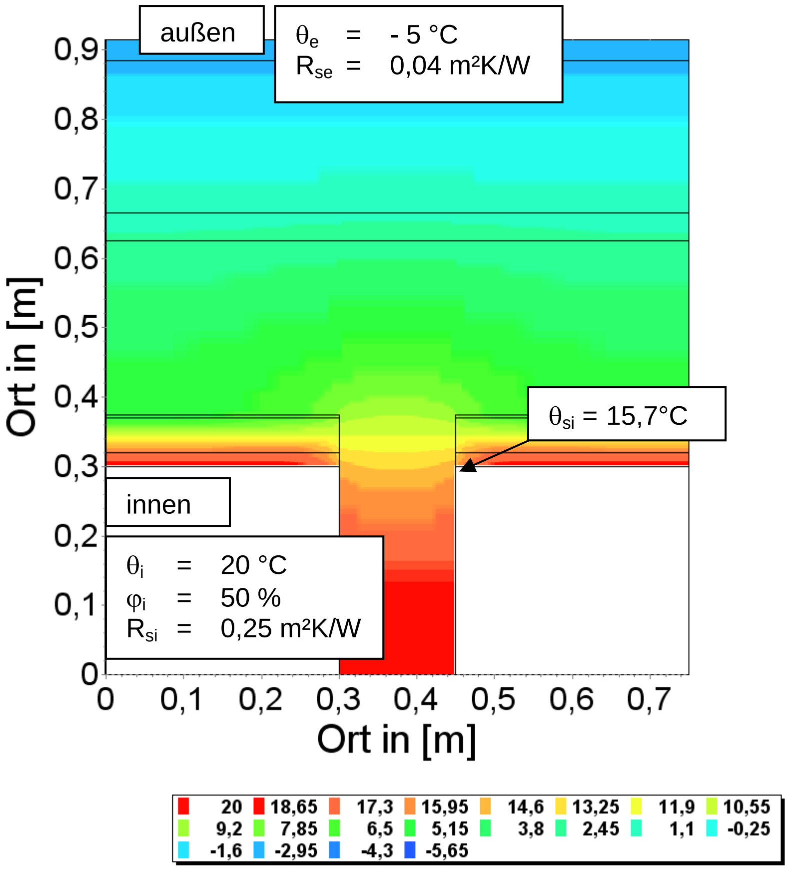


Figure 4.11.1: Temperature distribution of the structure 8 / 2D steady state surface temperature in [°C], boundary conditions according to DIN 4180 part 2.

$\theta_{si,\text{ inside corner, top}} = 15{,}7\ °C > \theta_{si,\text{ zulässig}} = 12{,}6\ °C$

The proof according to DIN 4108 – 2, section 6.2 is complied.

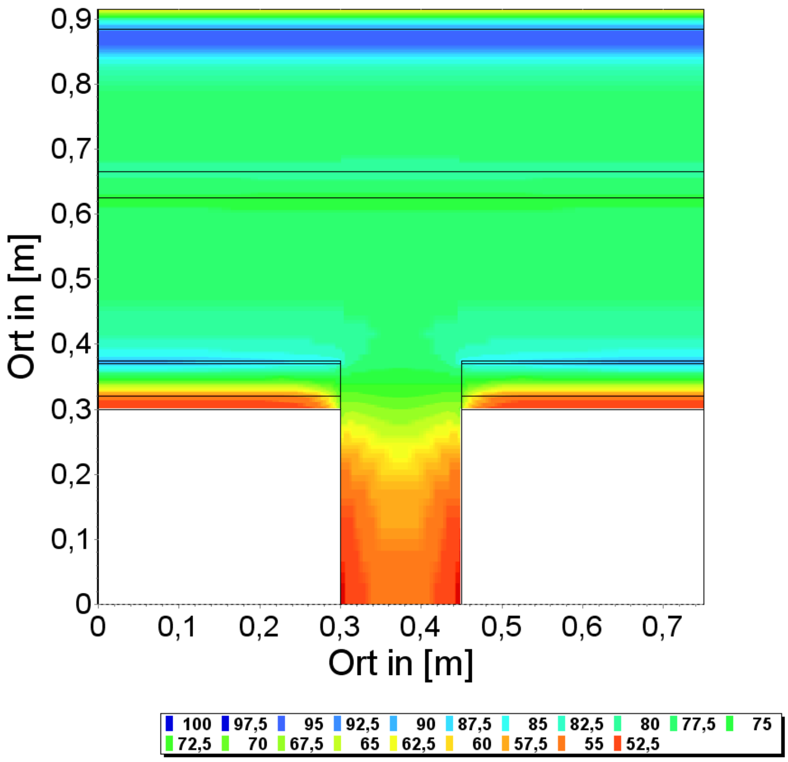


Figure 4.11.2: Humidity distribution of the construction 8 / 2D in the steady state

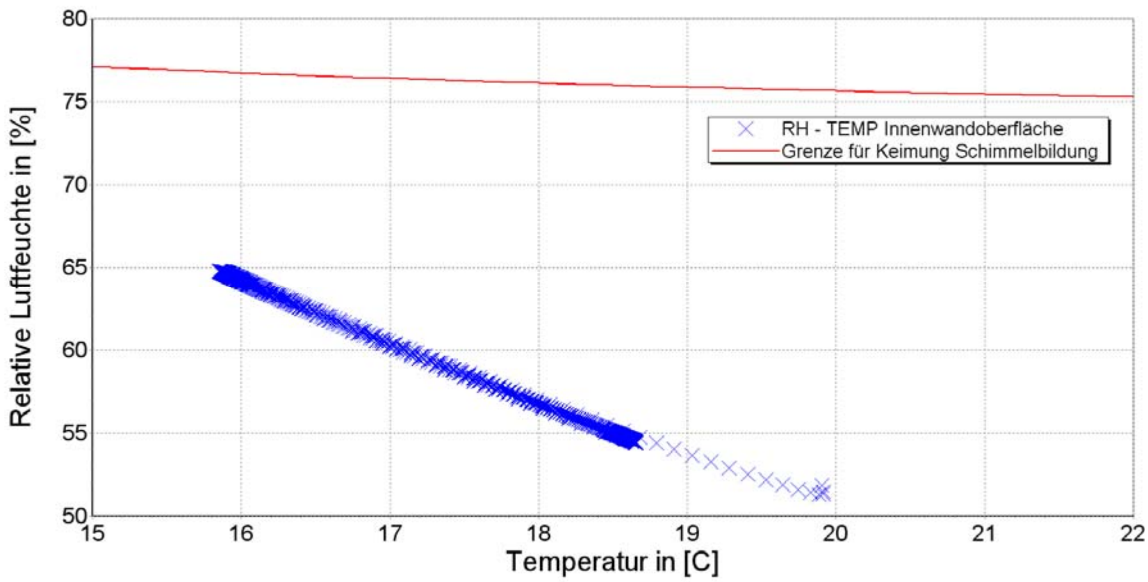


Figure 4.11.3: Graphic on the likelihood of mould formation of the construction 8 / 2D in the steady state. A mould formation with DIN required climate conditions can be excluded.

4.11.2 Climatic boundary conditions for the discussion of possible thermal bridges at Real Climate:

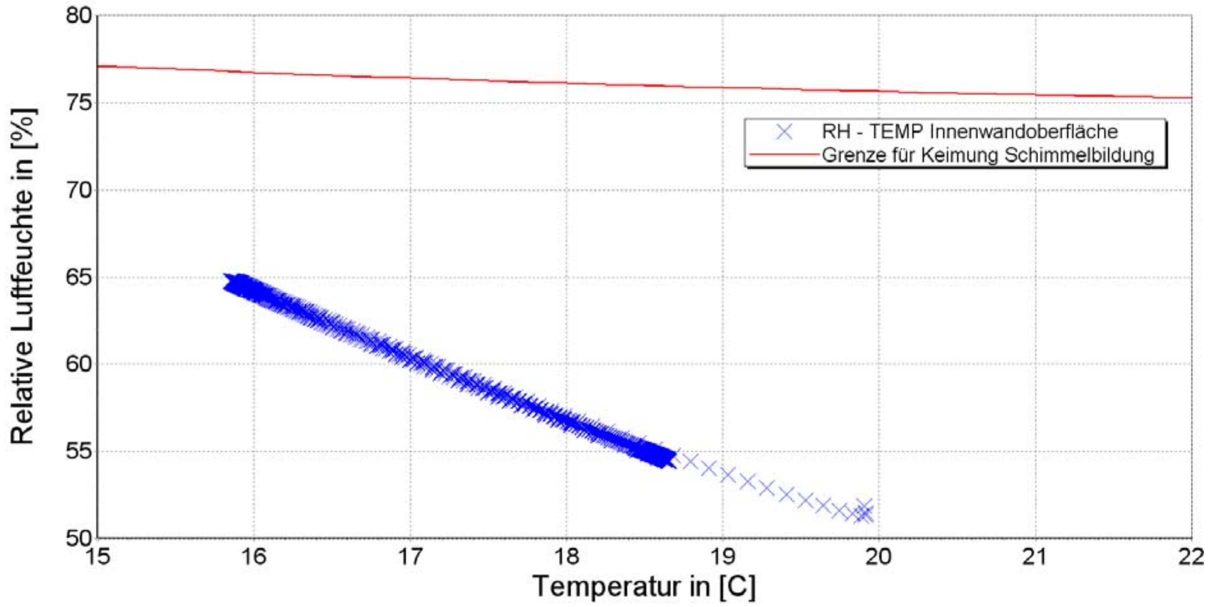


Figure 4.11.4: Graphic on the likelihood of mould formation of the construction 8 / 2D for the reference year. A mould formation can be excluded.

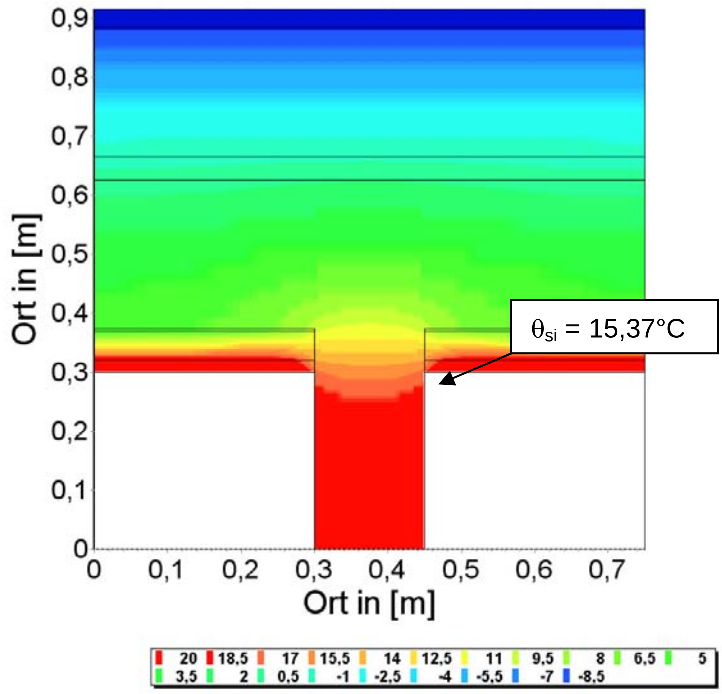


Figure 4.11.5: Temperature distribution of the construction 8 / 2D at 3rd February of the reference year.

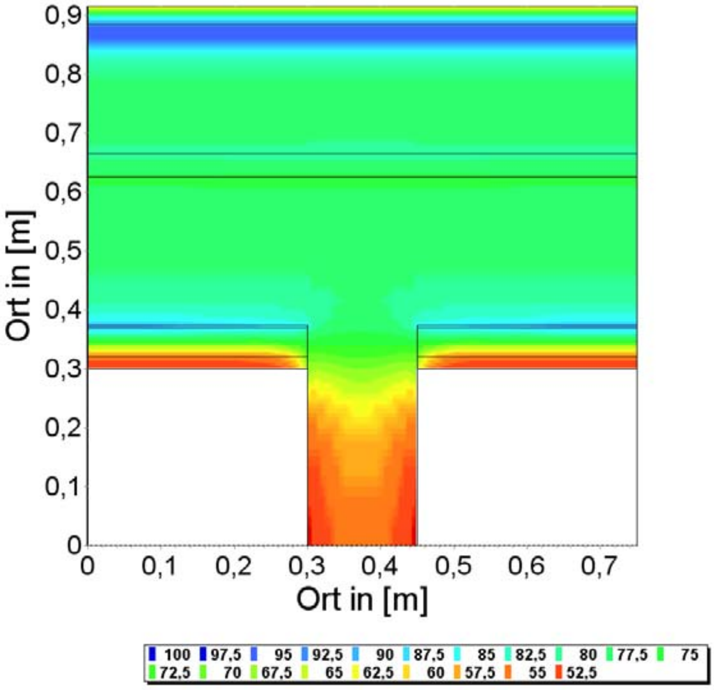


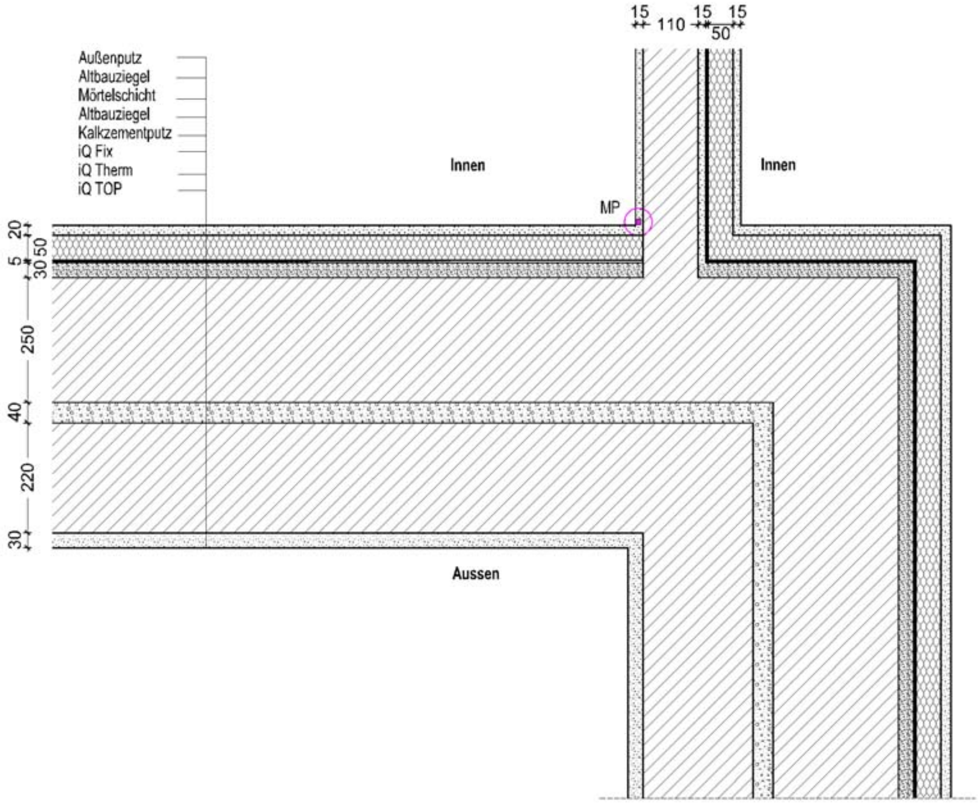
Figure 4.11.6: Humidity distribution of the construction 8 / 2D at 3rd February of the reference year.

4.11.3 Evaluation of the results for the Real Climate

There will be no damaging effects of a thermal bridge. There is no mould formation at the critical measuring point. The minimum temperature in the reference - year is 15,37°C.

4.12 Construction 9 / 2D:„Ground floor incorporating I-wall Det. I“

Construction layout



4.12.1 Calculation under steady conditions – climate according to DIN 4108-2, proof of the minimum thermal protection according to DIN 4108

The proof of the minimum thermal protection is conducted in accordance to DIN 4108-2 Section 6.2 for avoidance of mould growth.

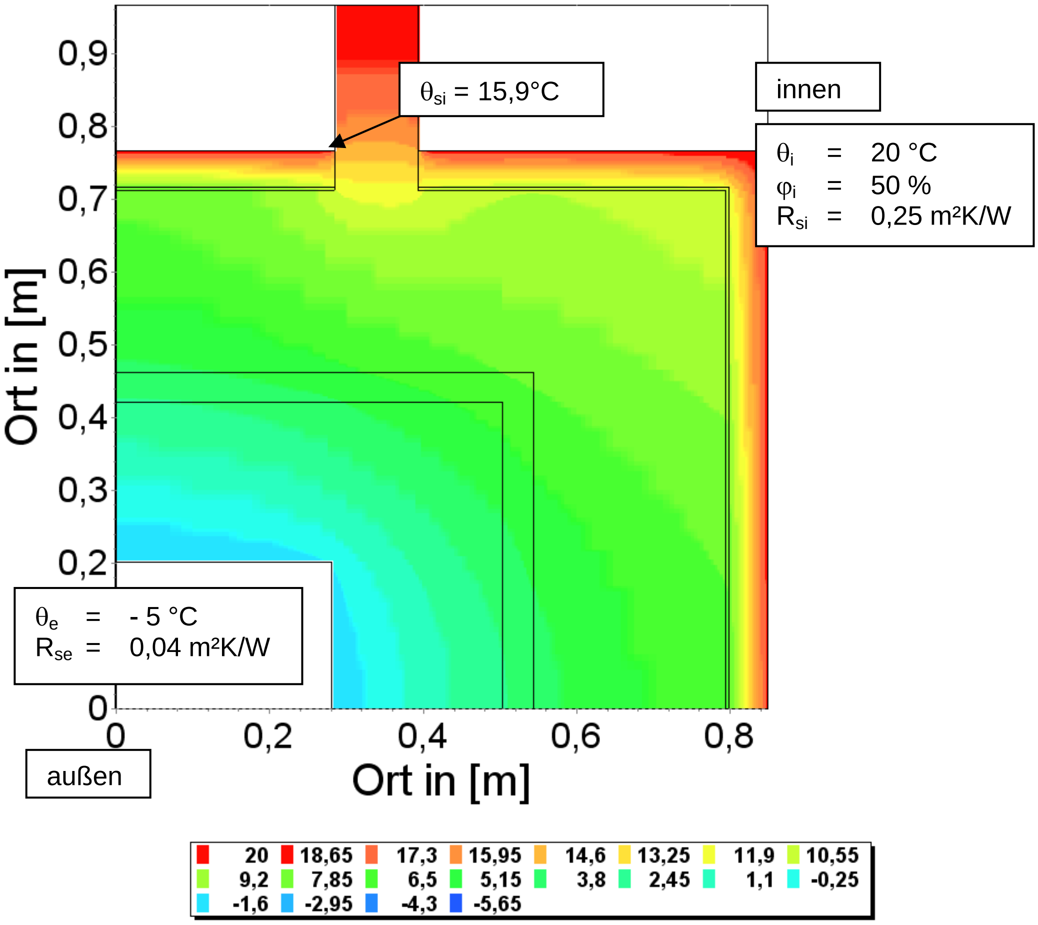


Figure 4.12.1: Temperature distribution of the structure 9 / 2D steady state surface temperature in [°C], boundary conditions according to DIN 4180 part 2.

$\theta_{si,\ inside\ corner,\ top}$ = 15,85°C > $\theta_{si,\ acceptable}$ = 12,6 °C

The proof according to DIN 4108 – 2, section 6.2 is complied.

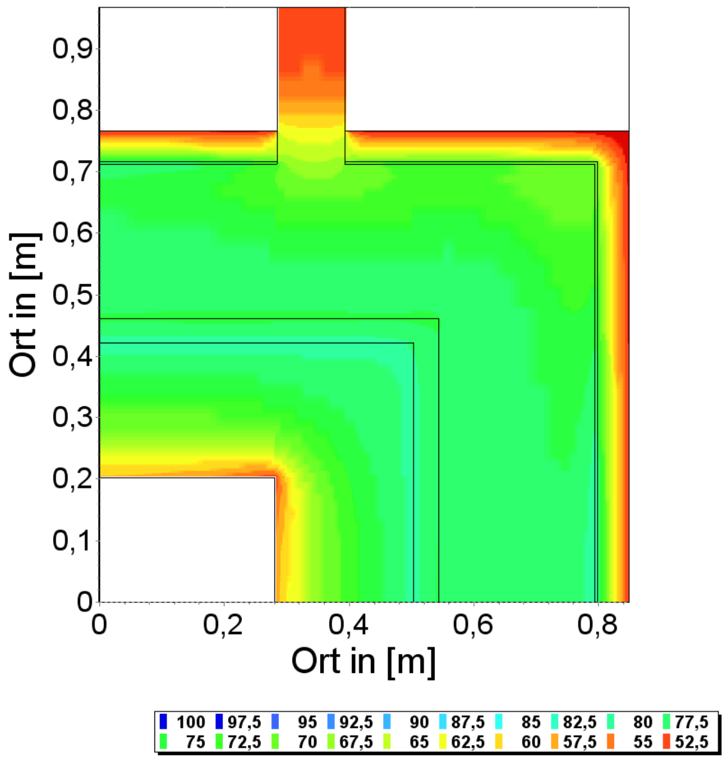


Figure 4.12.2: Humidity distribution of the construction 9 / 2D in the steady state

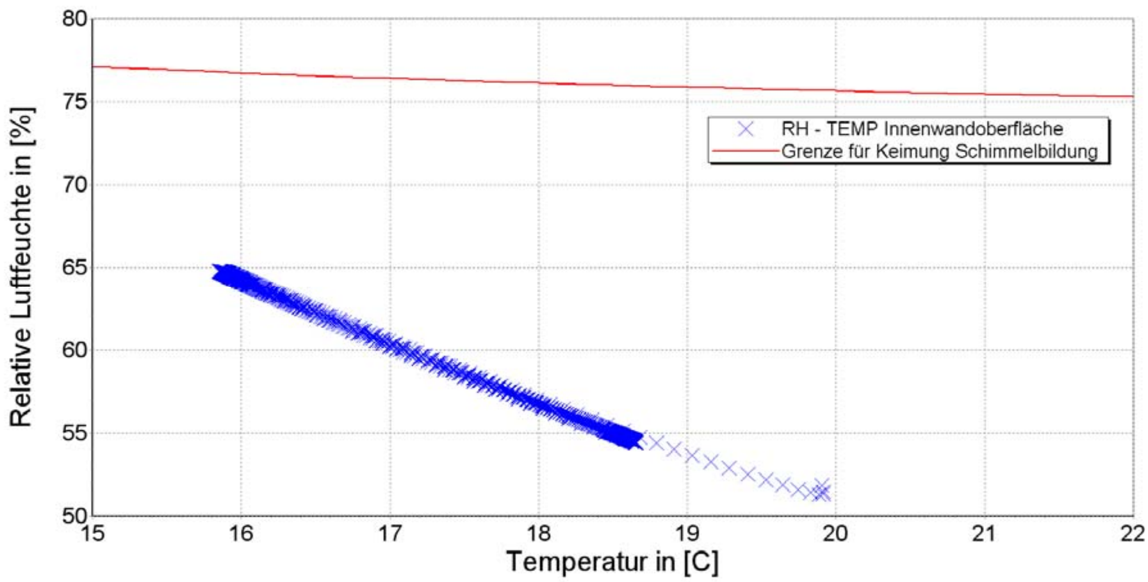


Figure 4.12.3: Graphic on the likelihood of mould formation of the construction 9 / 2D in the steady state. A mould formation with DIN required climate conditions can be excluded.

4.12.2 Climatic boundary conditions for the discussion of possible thermal bridges at Real Climate:

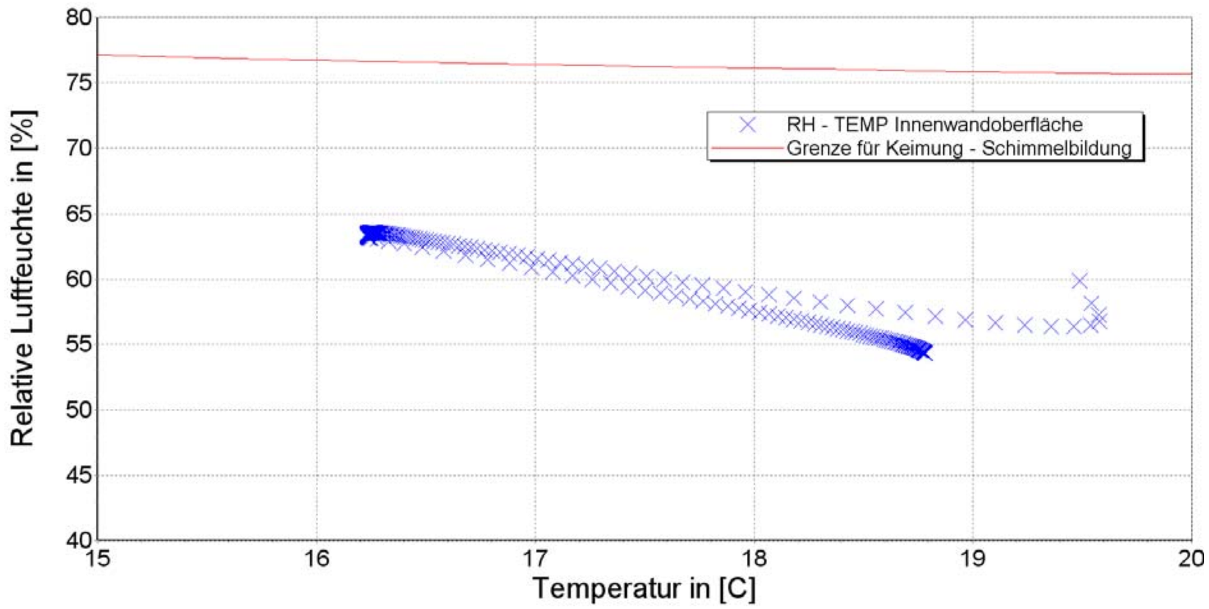


Figure 4.12.4: Graphic on the likelihood of mould formation of the construction 9 / 2D for the reference year. A mould formation can be excluded.

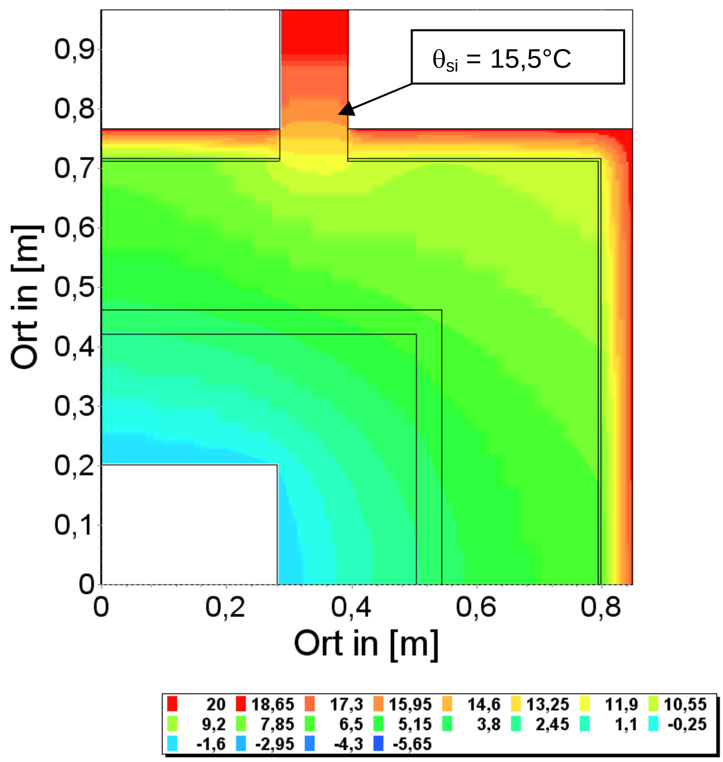


Figure 4.12.5: Temperature distribution of the construction 9 / 2D at 3rd February of the reference year.

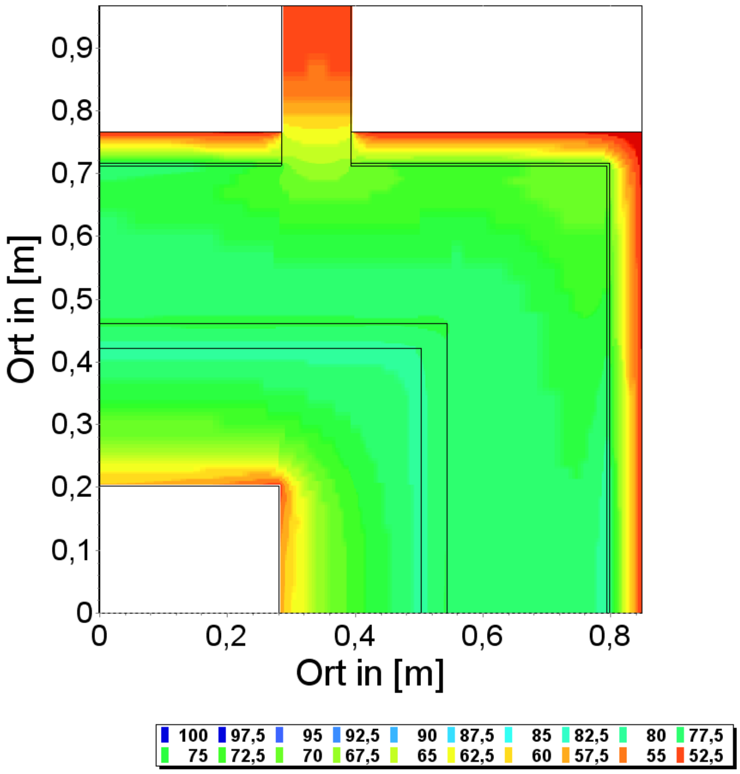


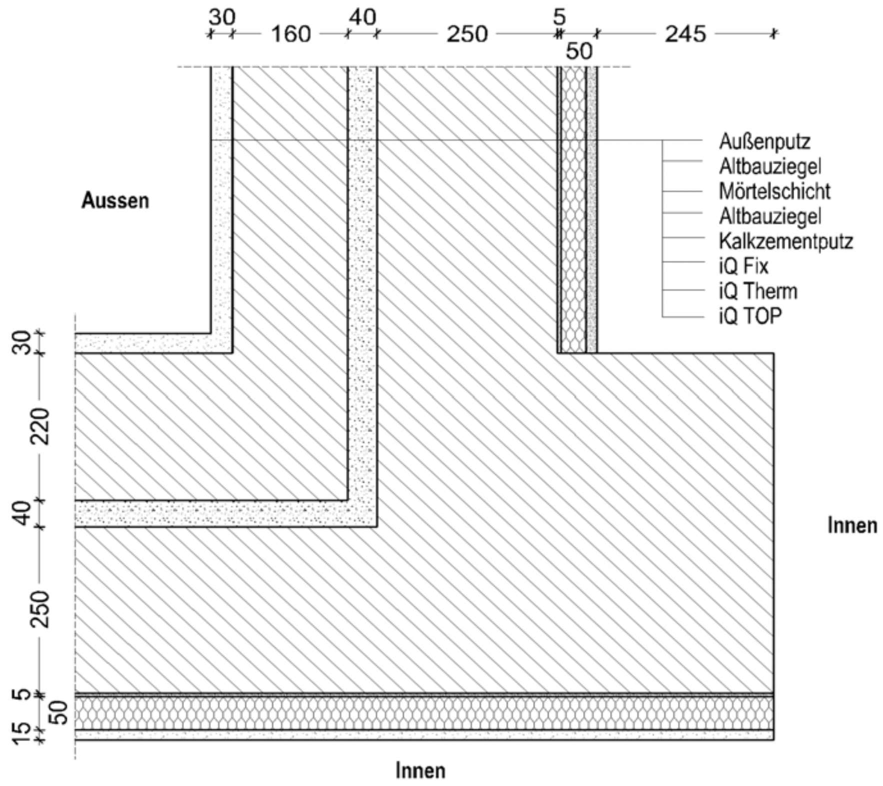
Figure 4.12.6: Humidity distribution of the construction 9 / 2D at 3rd February of the reference year.

4.12.3 Evaluation of the results for the Real Climate

There will be no damaging effects of a thermal bridge. There is no mould formation at the critical measuring point. The minimum temperature in the reference - year is 15,5°C.

4.13 Construction 10/ 2D:„Ground floor corner West Det. E“

Construction layout



4.13.1 Calculation under steady conditions – climate according to DIN 4108-2, proof of the minimum thermal protection according to DIN 4108

The proof of the minimum thermal protection is conducted in accordance to DIN 4108-2 Section 6.2 for avoidance of mould growth.

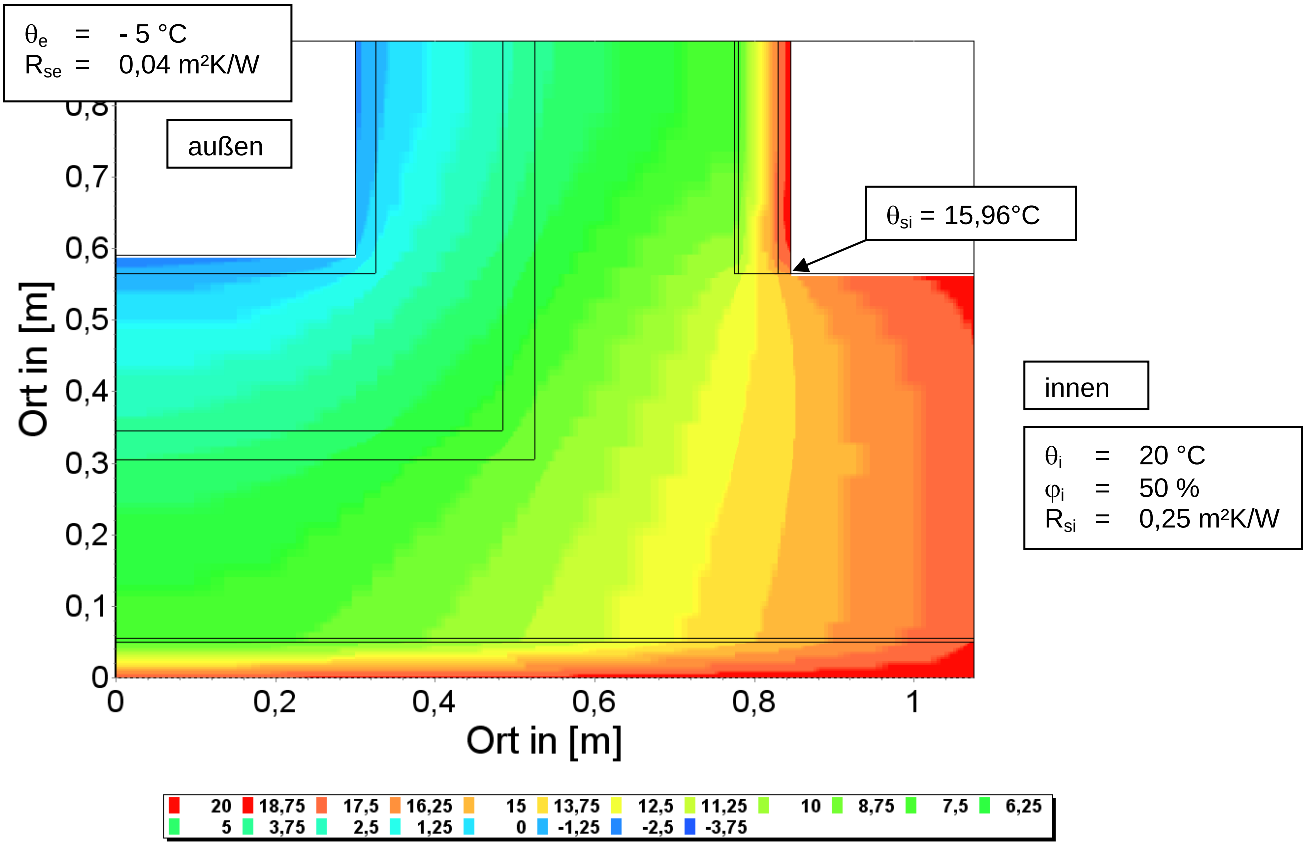


Figure 4.13.1: Temperature distribution of the structure 10 / 2D steady state surface temperature in [°C], boundary conditions according to DIN 4180 part 2.

$\theta_{si,\ inside\ corner,\ top}$ = 15,96°C > $\theta_{si,\ zulässig}$ = 12,6 °C

The proof according to DIN 4108 – 2, section 6.2 is complied.

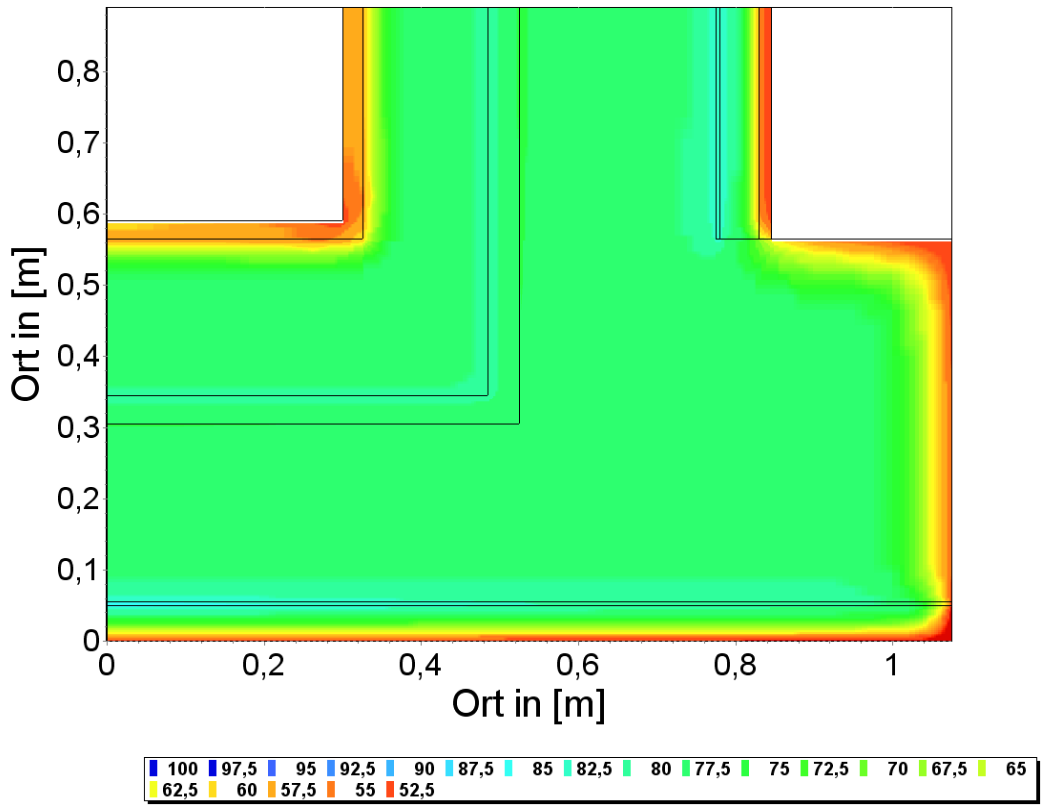


Figure 4.13.2: Humidity distribution of the construction 10 / 2D in the steady state

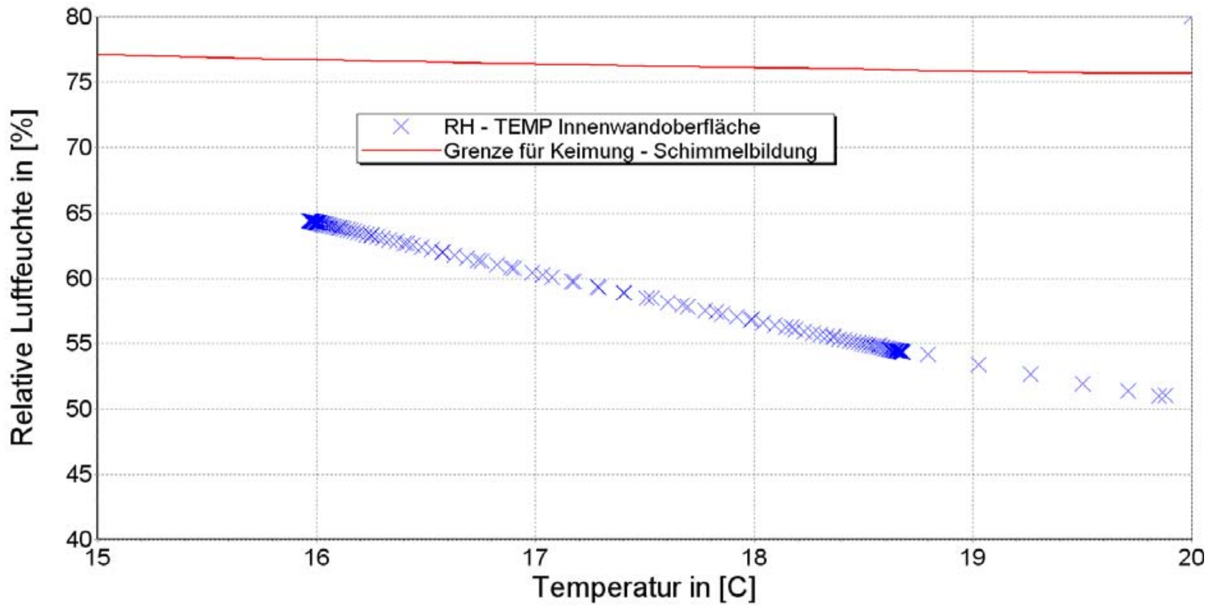


Figure 4.13.3: Graphic on the likelihood of mould formation of the construction 10 / 2D in the steady state. A mould formation with DIN required climate conditions can be excluded.

4.13.2 Climatic boundary conditions for the discussion of possible thermal bridges at Real Climate:

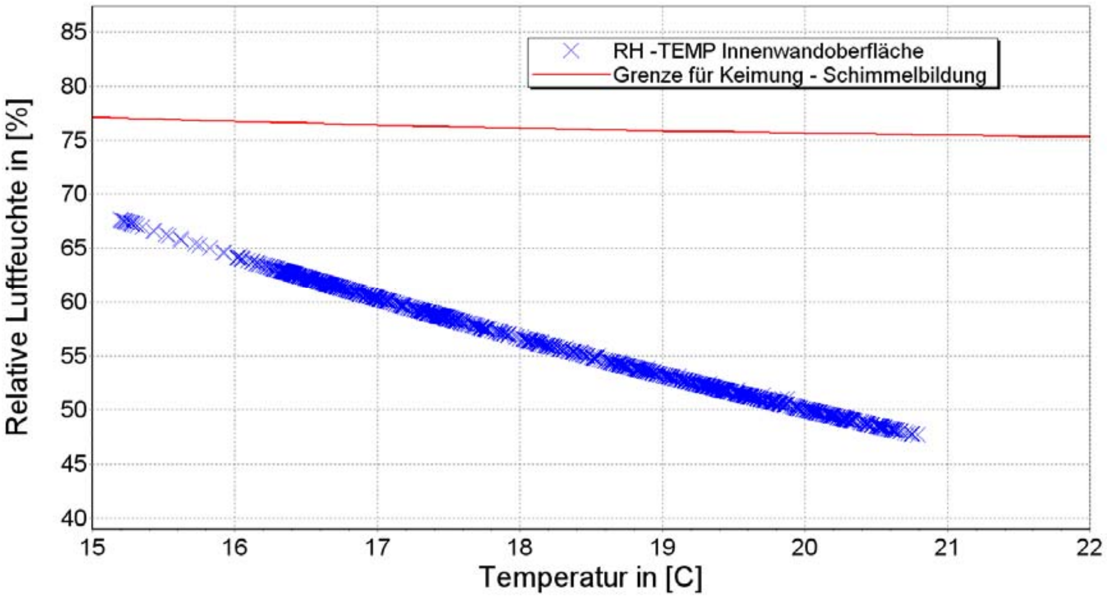


Figure 4.13.4: Graphic on the likelihood of mould formation of the construction 10 / 2D for the reference year. A mould formation can be excluded.

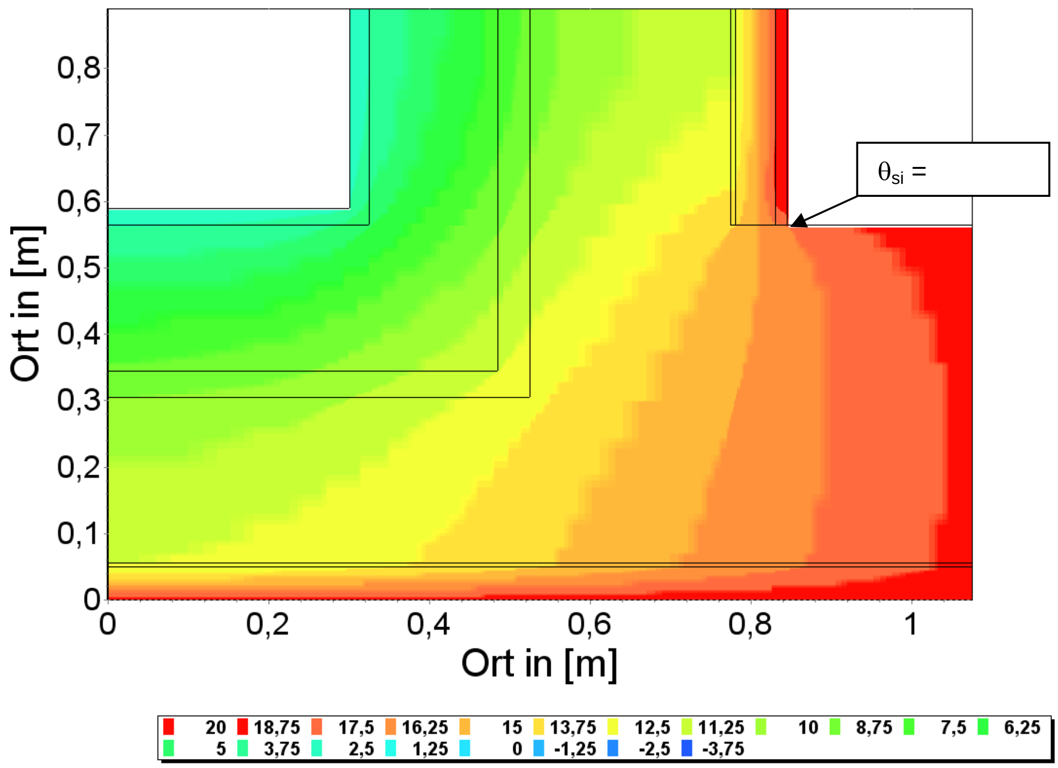


Figure 4.13.5: Temperature distribution of the construction 10 / 2D at 3rd February of the reference year.

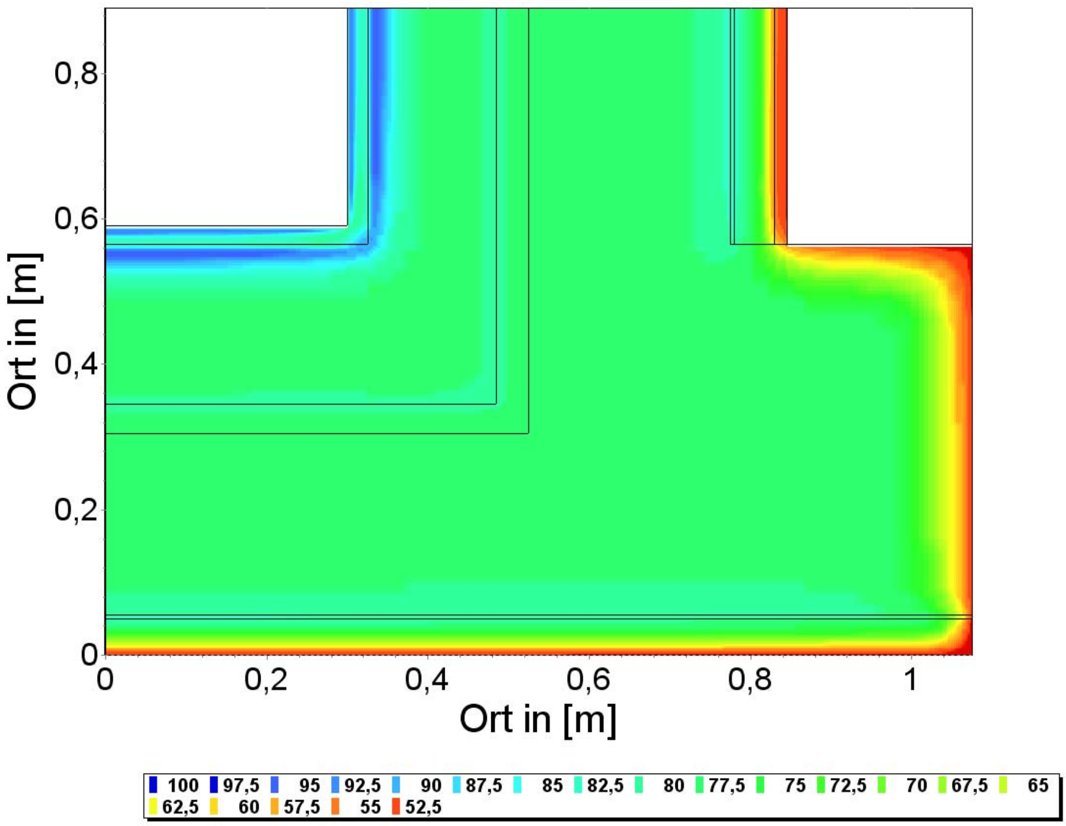


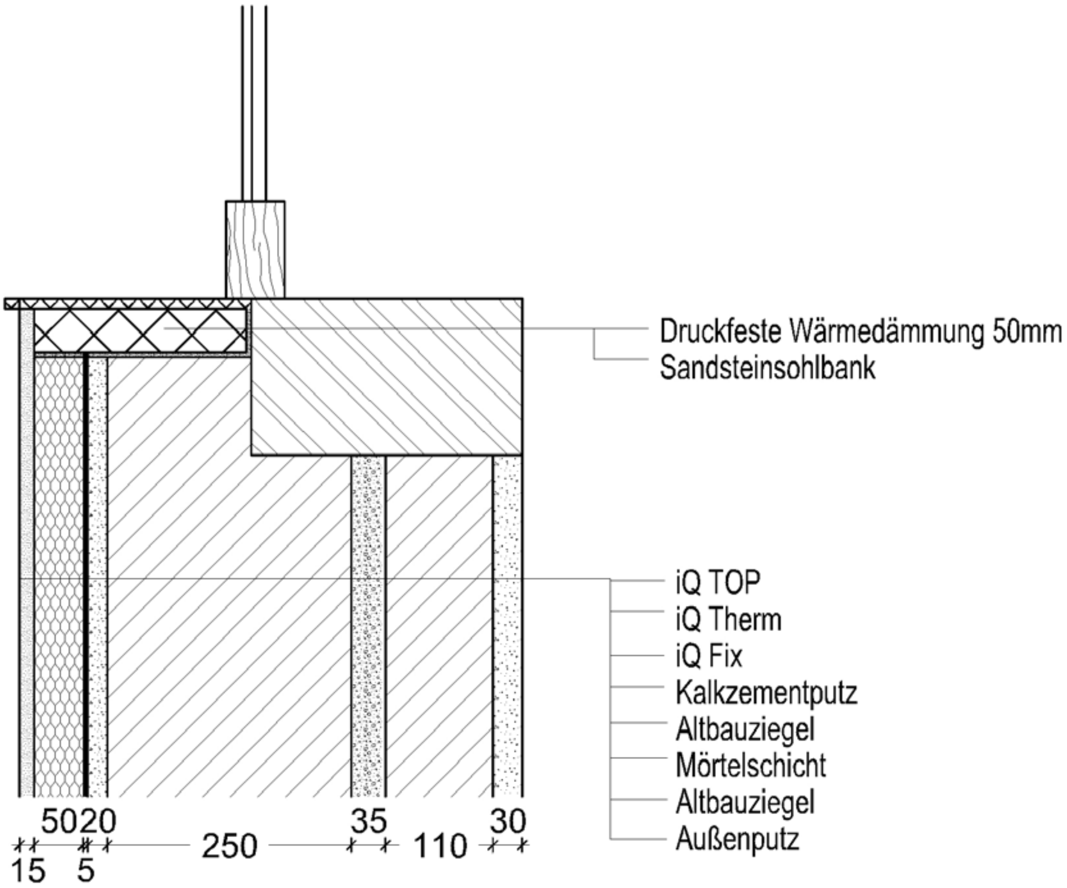
Figure 4.13.6: Humidity distribution of the construction 10 / 2D at 3rd February of the reference year.

4.13.3 Evaluation of the results for the Real Climate

There will be no damaging effects of a thermal bridge. There is no mould formation at the critical measuring point. The minimum temperature in the reference - year is 15,19°C.

4.14 Construction 11/ 2D:„Ground floor window“

Construction layout



4.14.1 Calculation under steady conditions – climate according to DIN 4108-2, proof of the minimum thermal protection according to DIN 4108

The proof of the minimum thermal protection is conducted in accordance to DIN 4108-2 Section 6.2 for avoidance of mould growth.

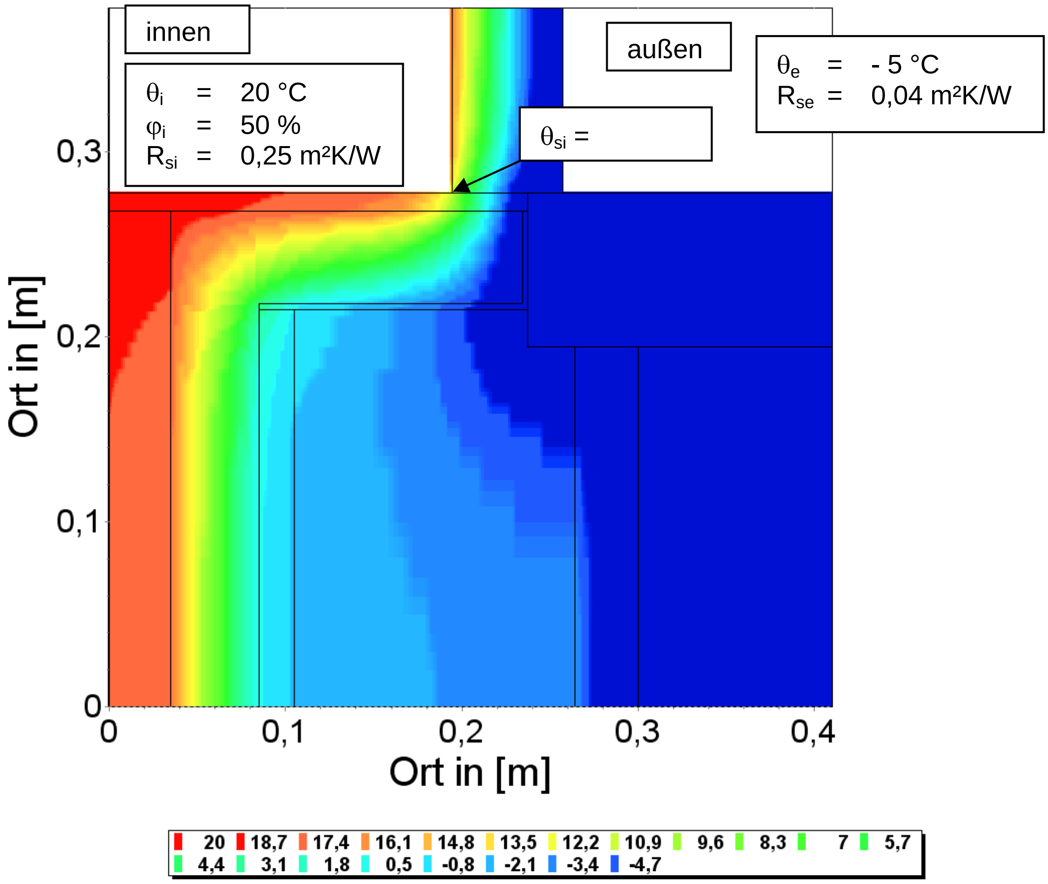


Figure 4.14.1: Temperature distribution of the structure 11 / 2D steady state surface temperature in [°C], boundary conditions according to DIN 4180 part 2.

$\theta_{si,\ inside\ corner,\ top}$ = 16,3 °C > $\theta_{si,\ zulässig}$ = 12,6 °C

The proof according to DIN 4108 – 2, section 6.2 is complied.

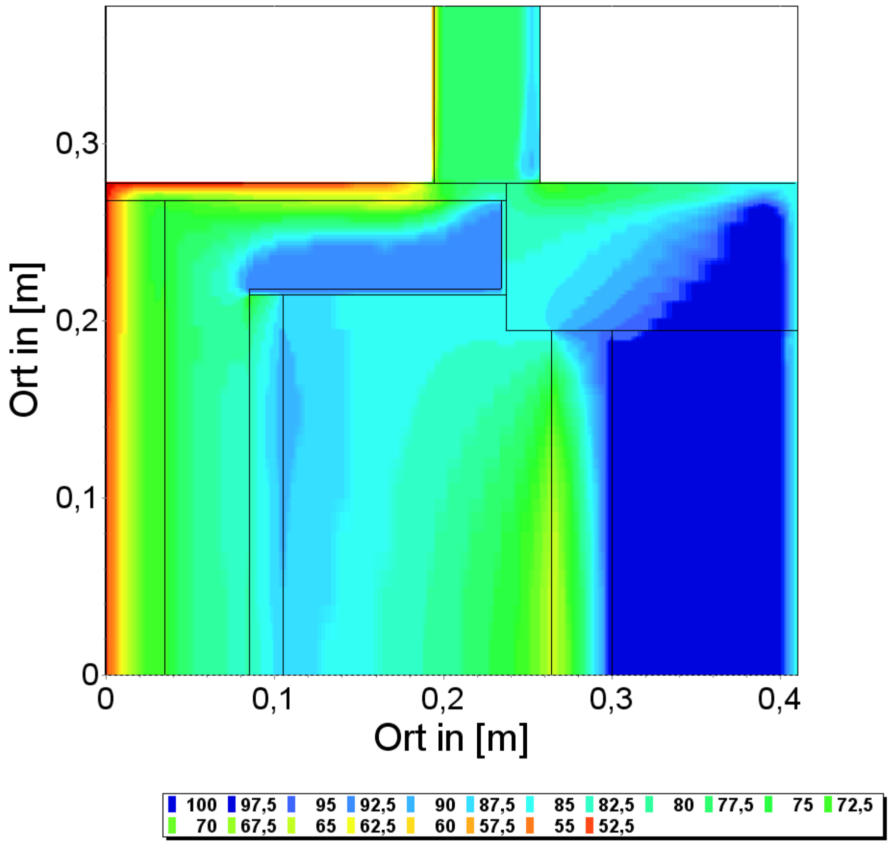


Figure 4.14.2: Humidity distribution of the construction 11 / 2D in the steady state

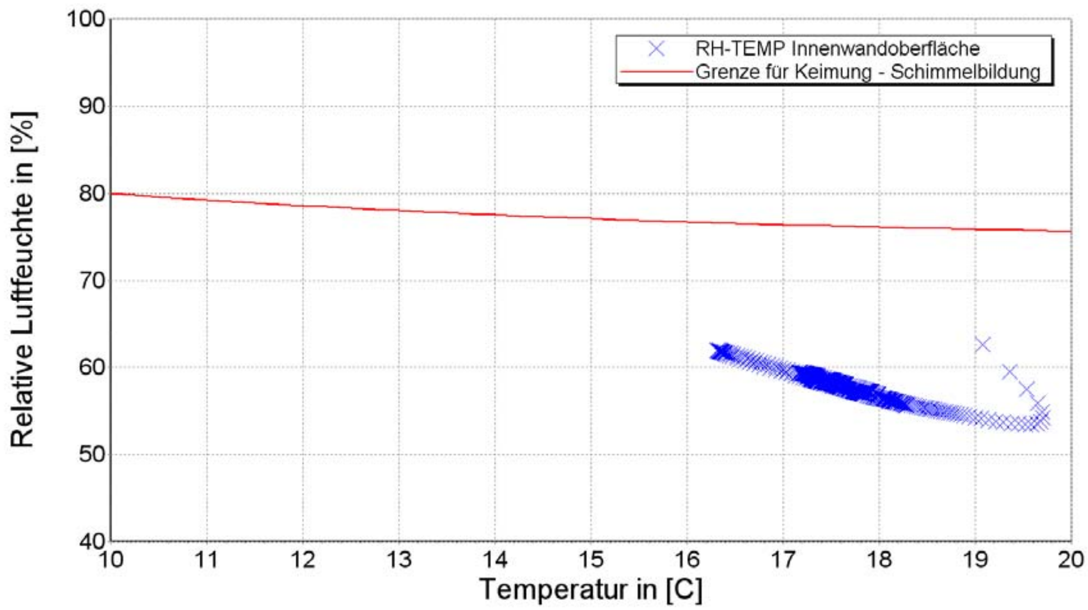


Figure 4.14.3: Graphic on the likelihood of mould formation of the construction 11 / 2D in the steady state. A mould formation with DIN required climate conditions can be excluded.

4.14.2 Climatic boundary conditions for the discussion of possible thermal bridges at Real Climate:

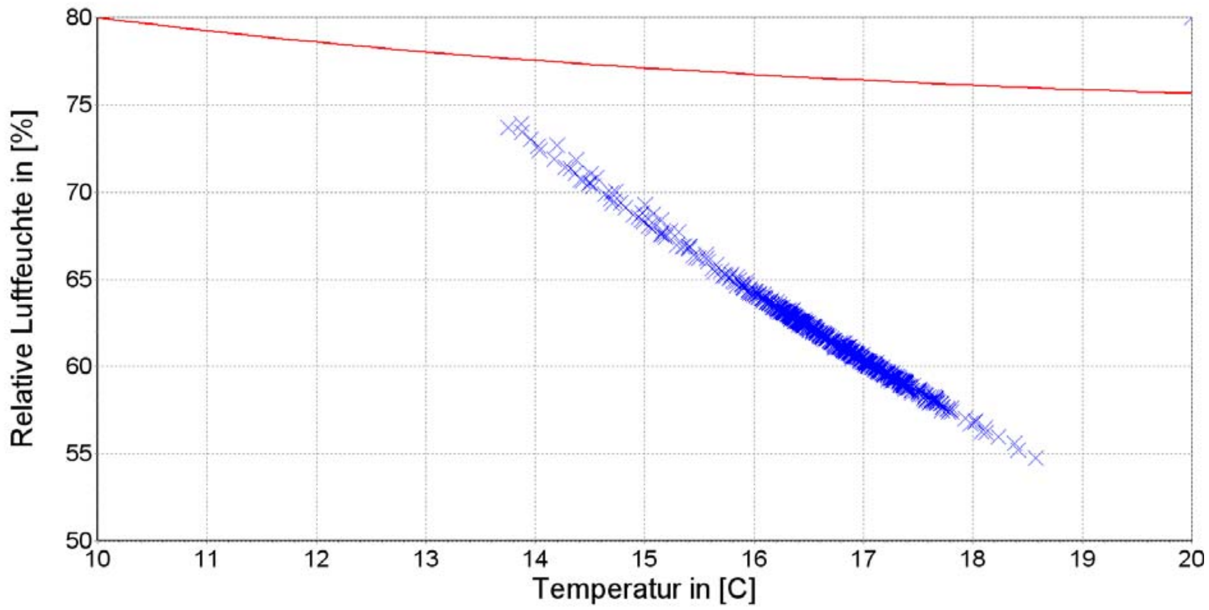


Figure 4.14.4: Graphic on the likelihood of mould formation of the construction 11 / 2D for the reference year. A mould formation can be excluded.

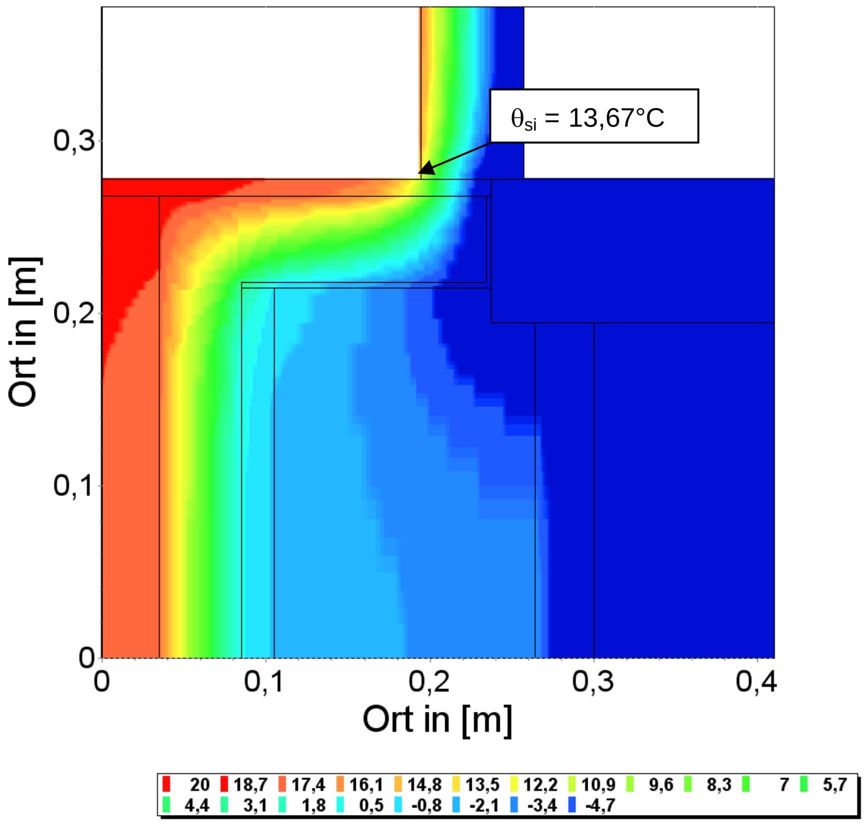


Figure 4.14.5: Temperature distribution of the construction 11 / 2D at 3rd February of the reference year.

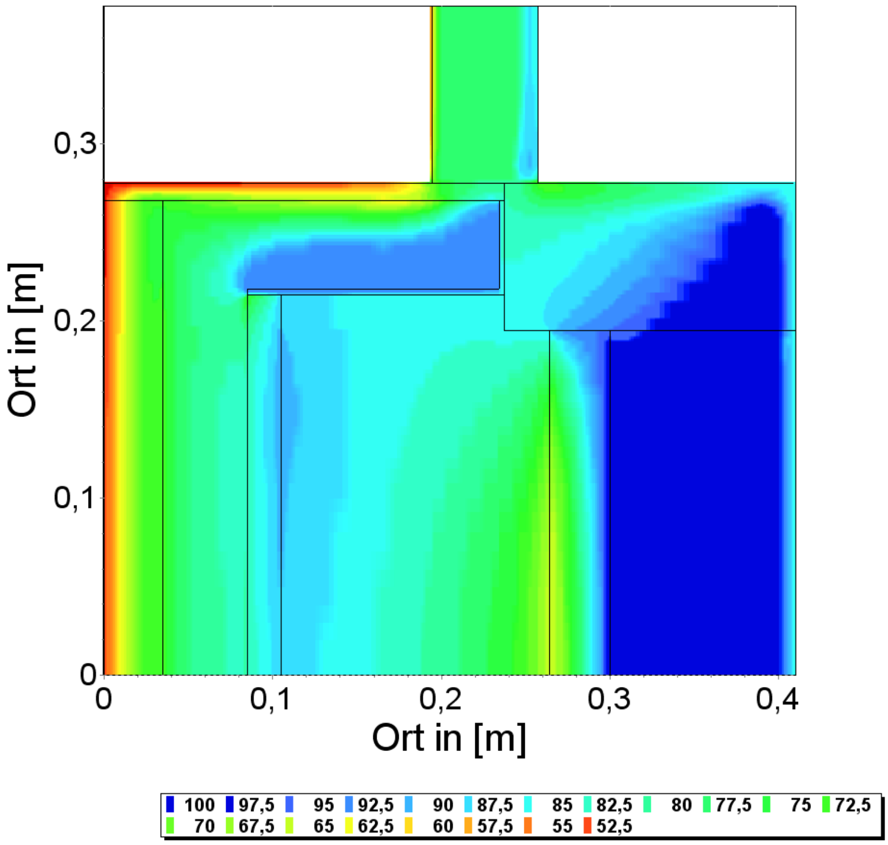


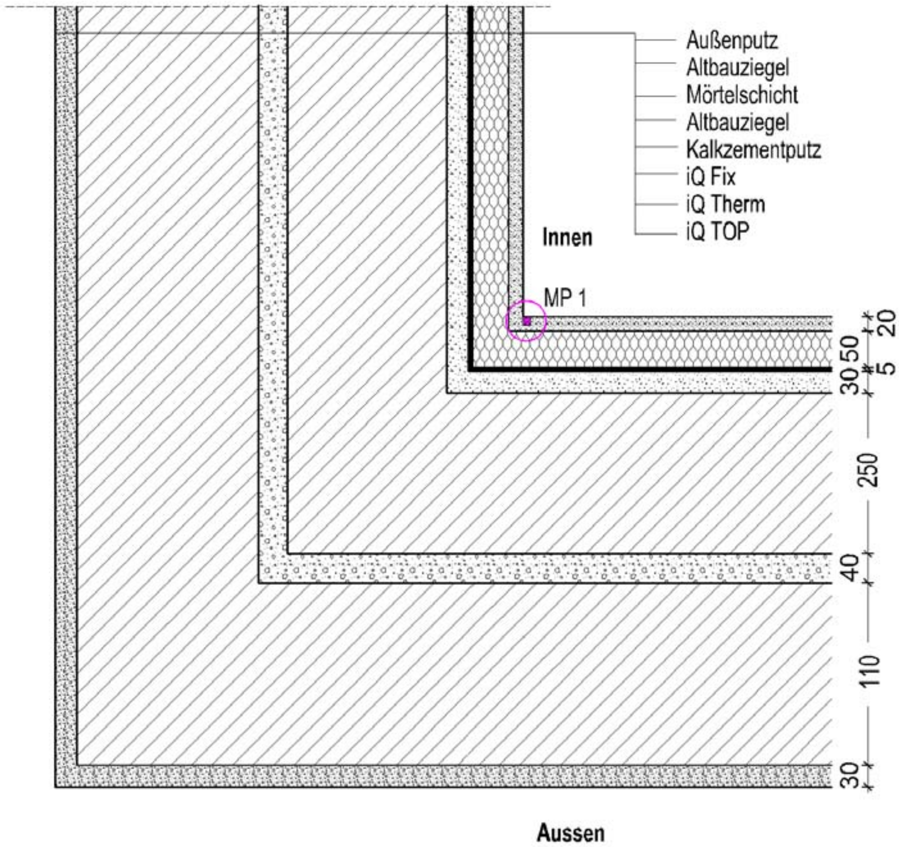
Figure 4.14.6: Humidity distribution of the construction 11 / 2D at 3rd February of the reference year.

4.14.3 Evaluation of the results for the Real Climate

There will be no damaging effects of a thermal bridge. There is no mould formation at the critical measuring point. The minimum temperature in the reference - year is 13,67°C.

4.15 Construction 12/ 2D:„Upper floor corner South-West"

Construction layout



4.15.1 Calculation under steady conditions – climate according to DIN 4108-2, proof of the minimum thermal protection according to DIN 4108

The proof of the minimum thermal protection is conducted in accordance to DIN 4108-2 Section 6.2 for avoidance of mould growth.

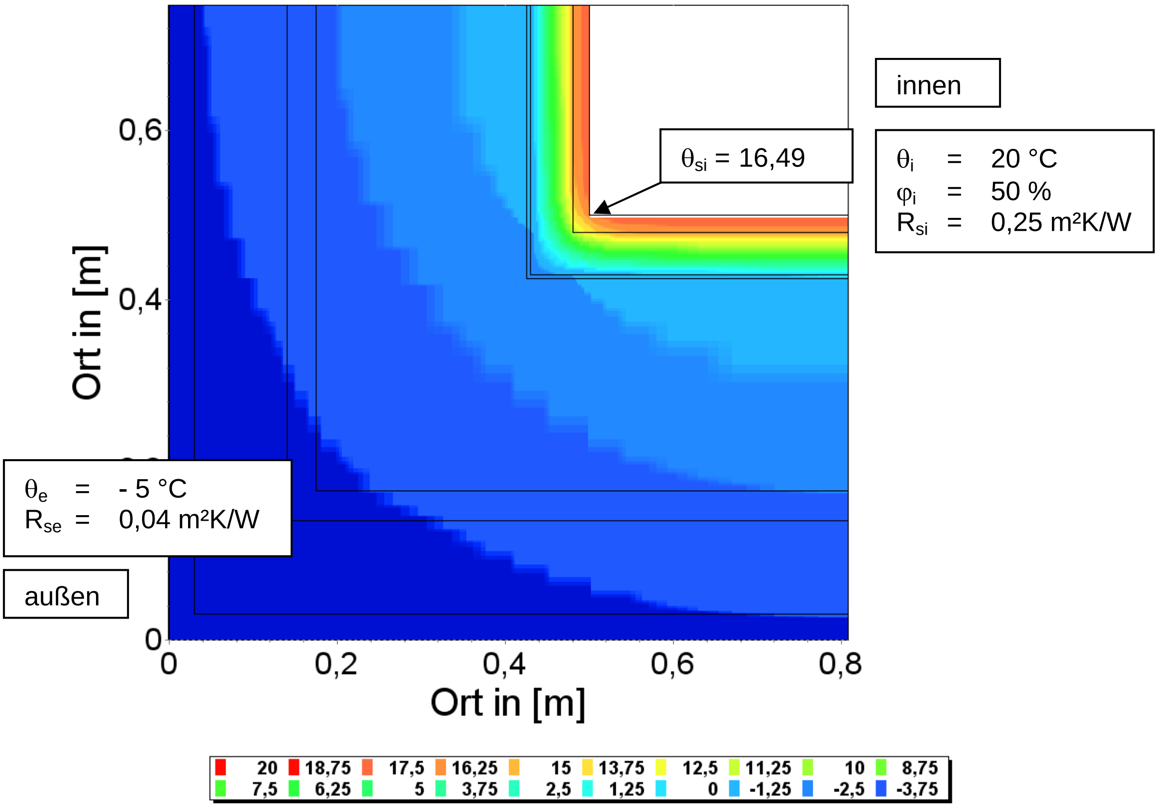


Figure 4.15.1: Temperature distribution of the structure 12 / 2D steady state surface temperature in [°C], boundary conditions according to DIN 4180 part 2.

$\theta_{si,\ inside\ corner,\ top}$ = 16,49°C > $\theta_{si,\ acceptable}$ = 12,6 °C

The proof according to DIN 4108 – 2, section 6.2 is complied.

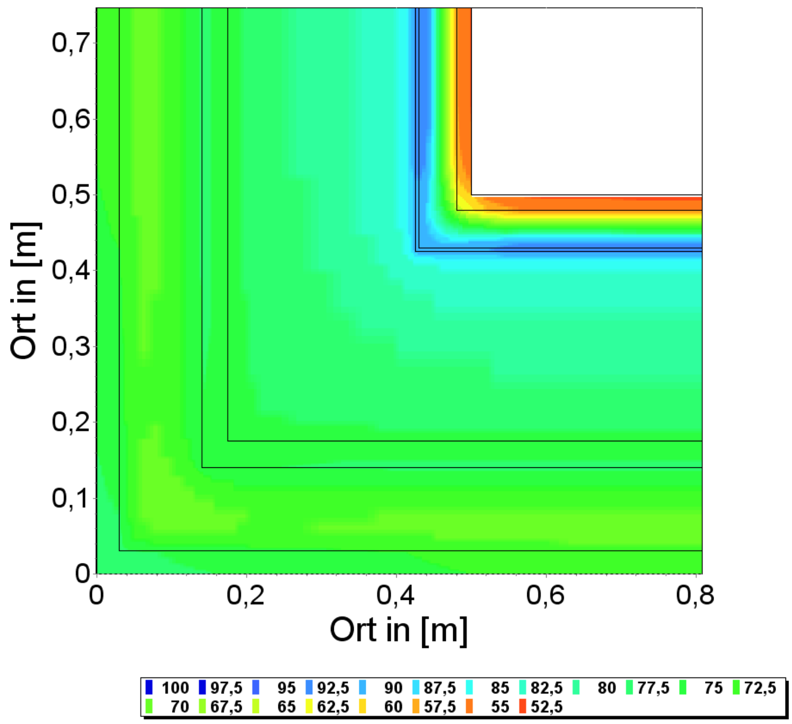


Figure 4.15.2: Humidity distribution of the construction 12 / 2D in the steady state

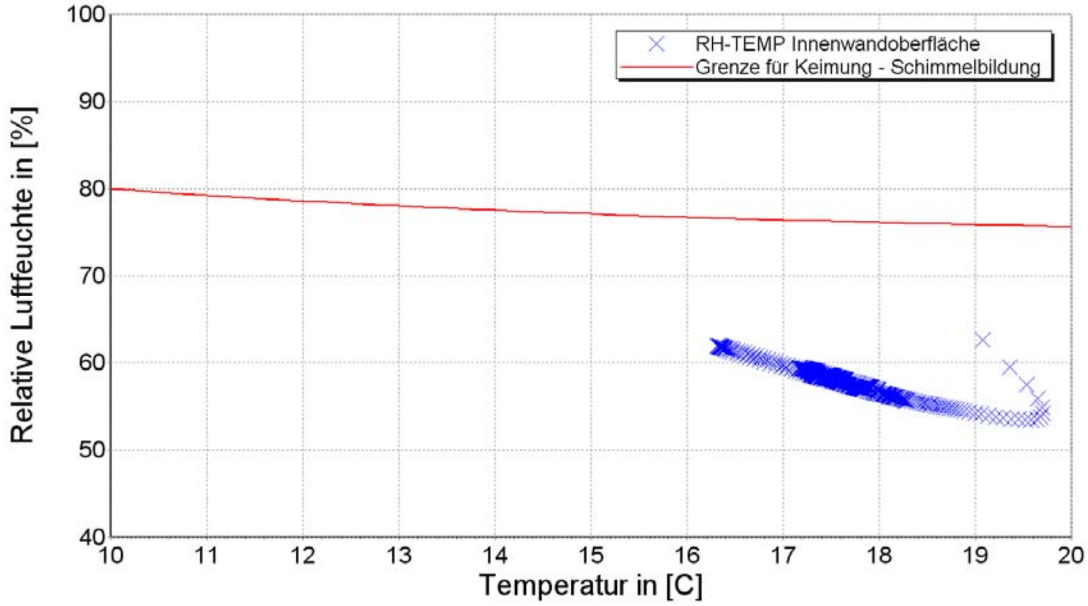


Figure 4.15.3: Graphic on the likelihood of mould formation of the construction 12 / 2D in the steady state. A mould formation with DIN required climate conditions can be excluded.

4.15.2 Climatic boundary conditions for the discussion of possible thermal bridges at Real Climate:

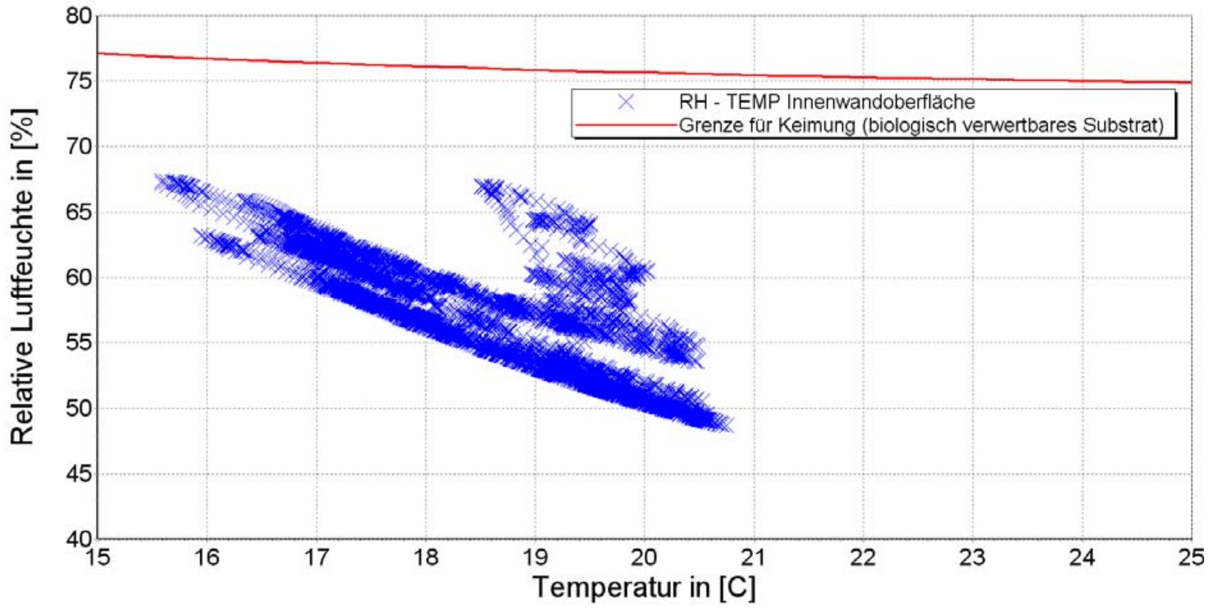


Figure 4.15.4: Graphic on the likelihood of mould formation of the construction 12 / 2D for the reference year. A mould formation can be excluded.

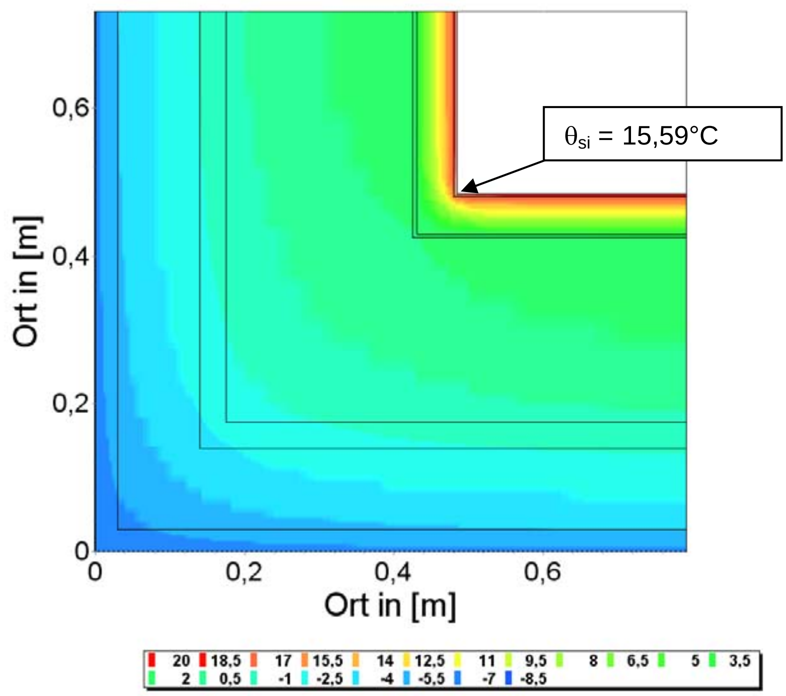


Figure 4.15.5: Temperature distribution of the construction 12 / 2D at 3rd February of the reference year.

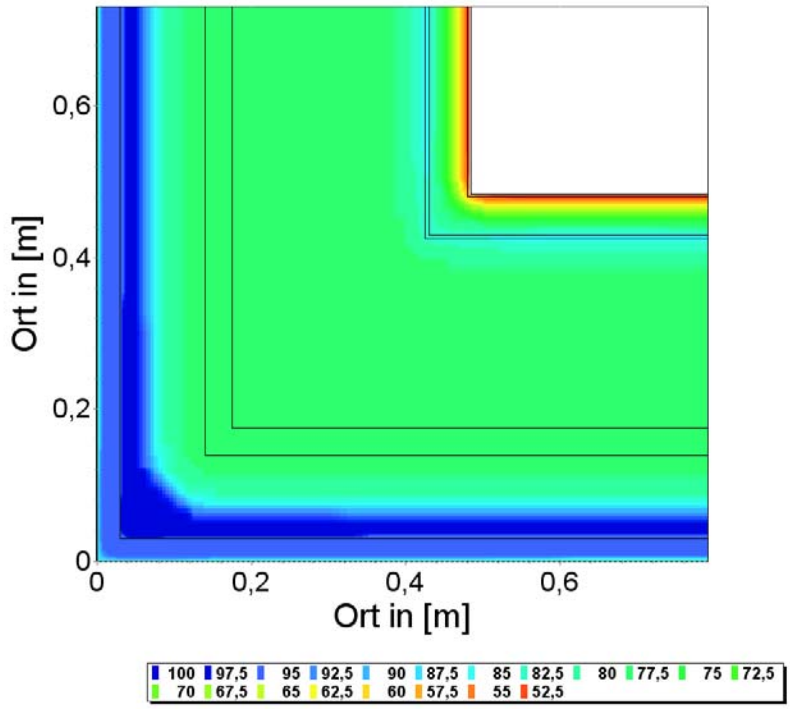


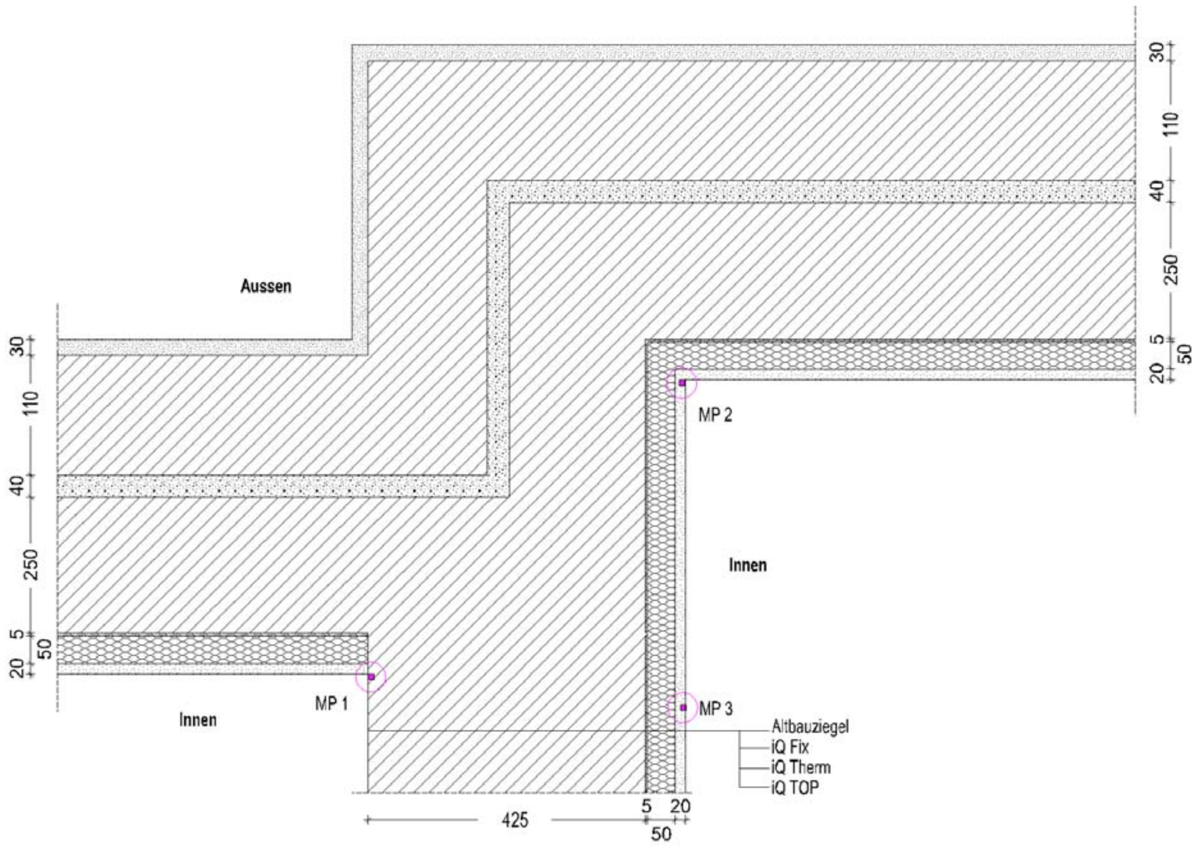
Figure 4.15.6: Humidity distribution of the construction 12 / 2D at 3rd February of the reference year.

4.15.3 Evaluation of the results for the Real Climate

There will be no damaging effects of a thermal bridge. There is no mould formation at the critical measuring point. The minimum temperature in the reference - year is 15,59°C.

4.16 Construction 14/ 2D:„Upper floor incorporating I-wall Det. A“

Construction layout



4.16.1 Calculation under steady conditions – climate according to DIN 4108-2, proof of the minimum thermal protection according to DIN 4108

The proof of the minimum thermal protection is conducted in accordance to DIN 4108-2 Section 6.2 for avoidance of mould growth.

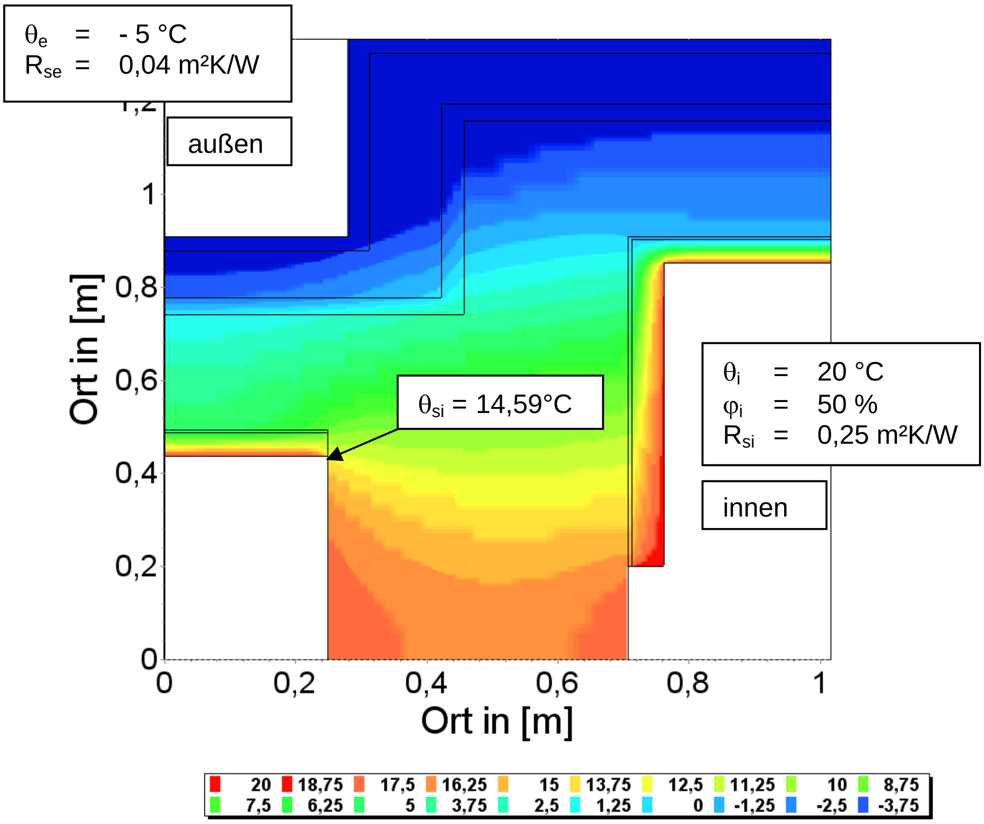


Figure 4.16.1: Temperature distribution of the structure 14 / 2D steady state surface temperature in [°C], boundary conditions according to DIN 4180 part 2.

$\theta_{si,\text{ inside corner, top}} = 14{,}59°C > \theta_{si,\text{ acceptable}} = 12{,}6\ °C$

The proof according to DIN 4108 – 2, section 6.2 is complied.

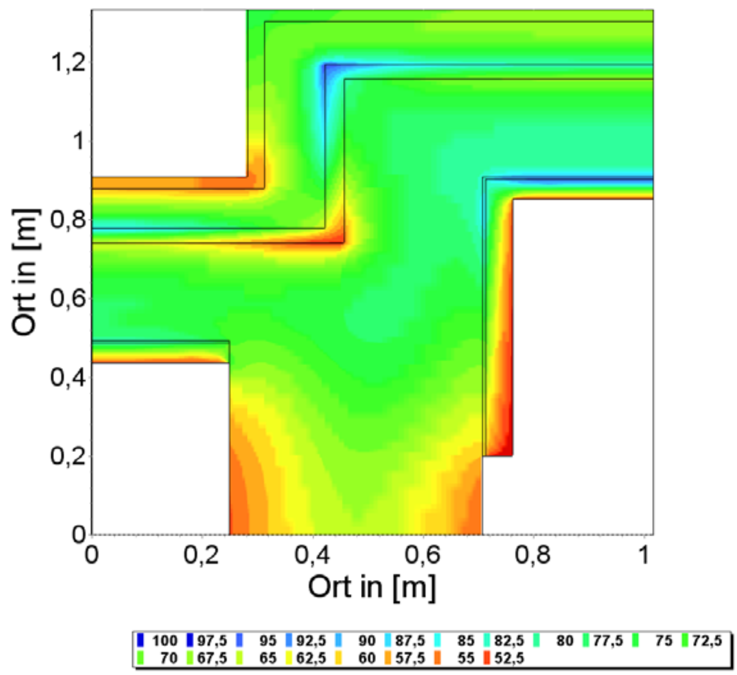


Figure 4.16.2: Humidity distribution of the construction 14 / 2D in the steady state

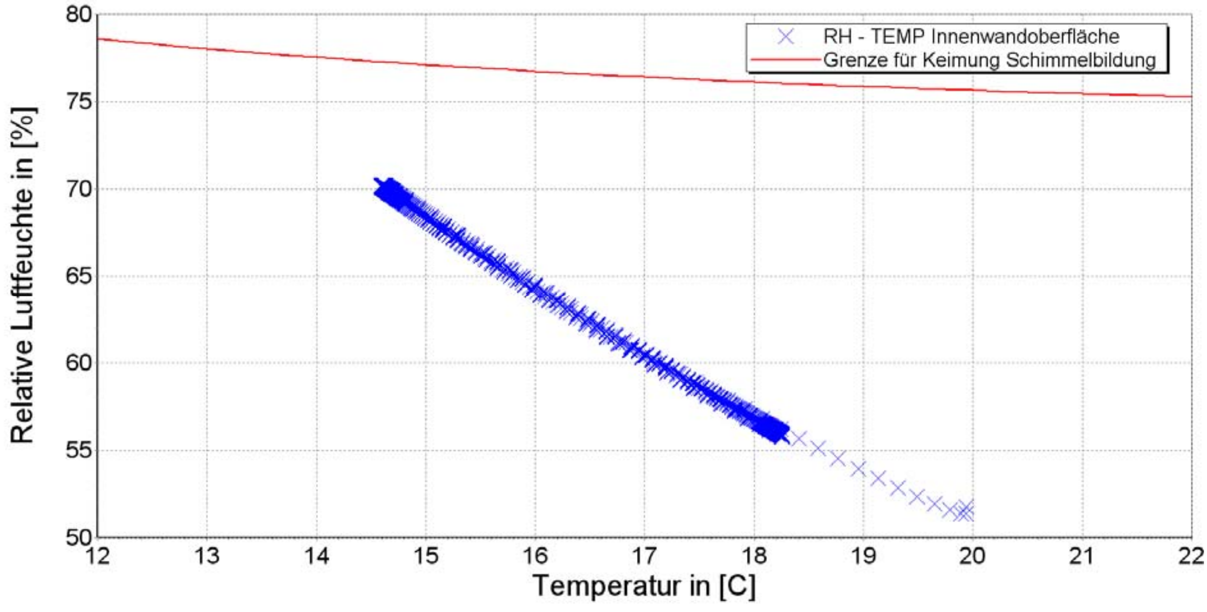


Figure 4.16.3: Graphic on the likelihood of mould formation of the construction 14 / 2D in the steady state. A mould formation with DIN required climate conditions can be excluded.

4.16.2 Climatic boundary conditions for the discussion of possible thermal bridges at Real Climate:

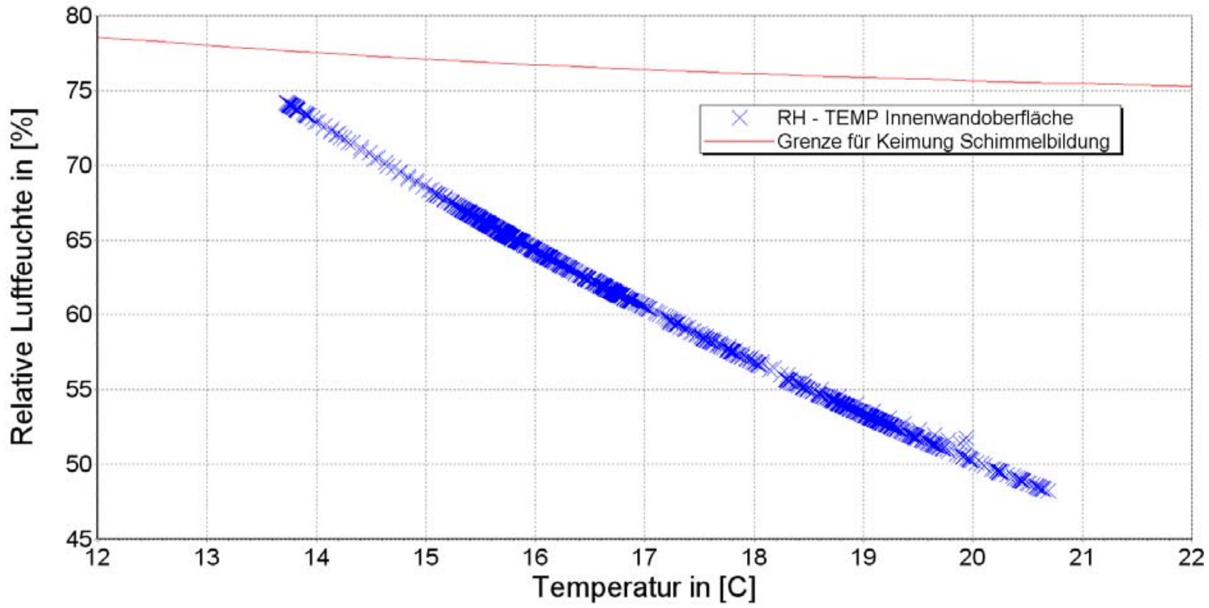


Figure 4.16.4: Graphic on the likelihood of mould formation of the construction 14 / 2D for the reference year. A mould formation can be excluded.

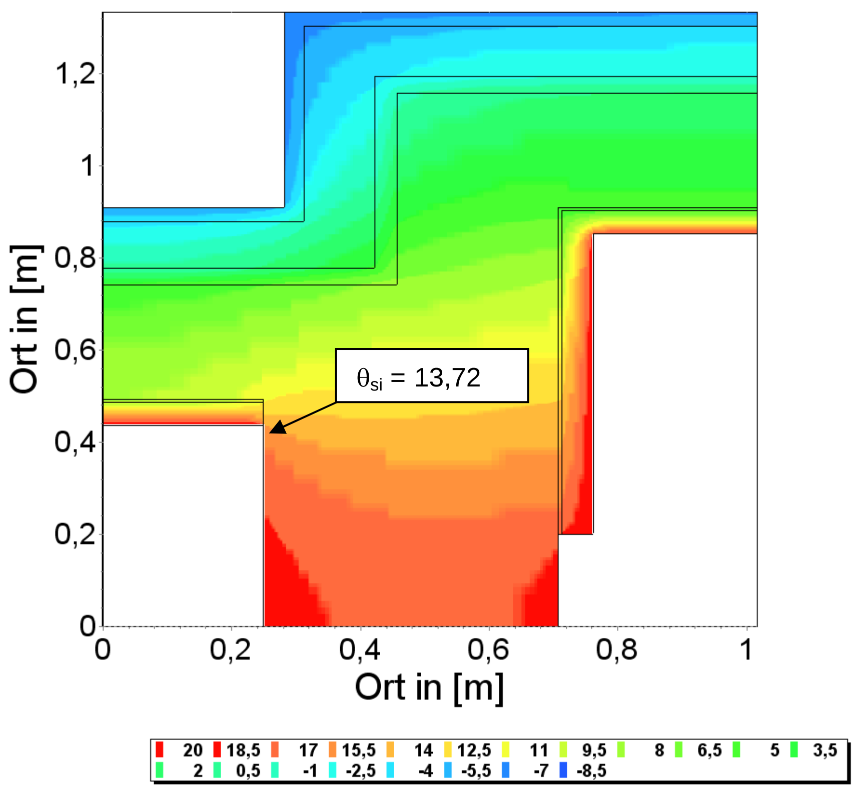


Figure 4.16.5: Temperature distribution of the construction 14 / 2D at 3rd February of the reference year.

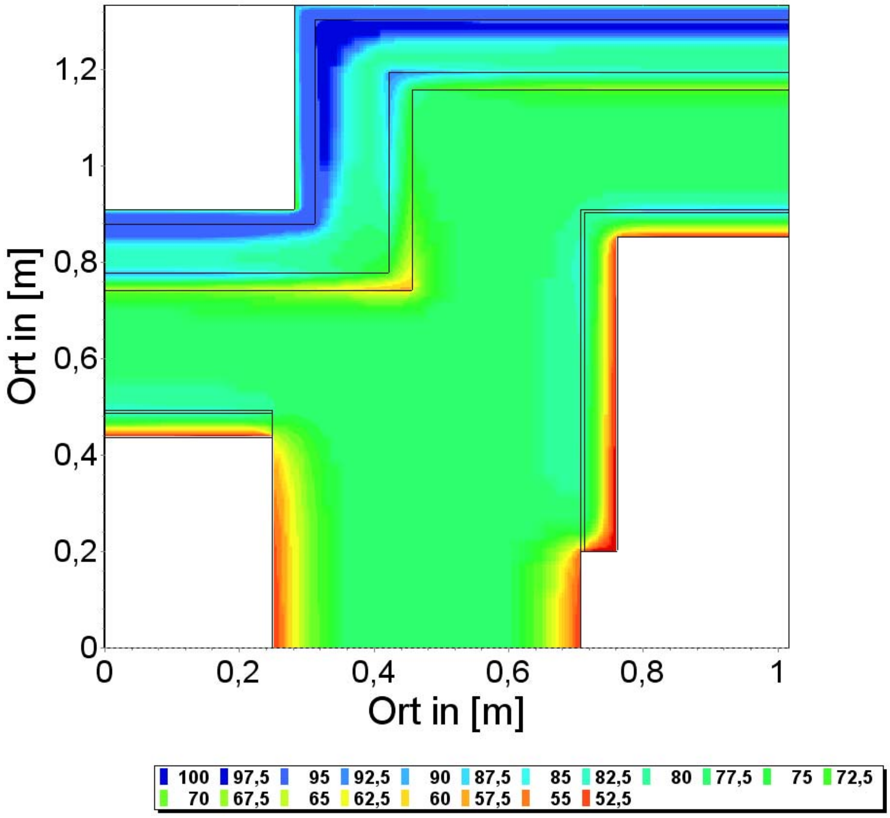


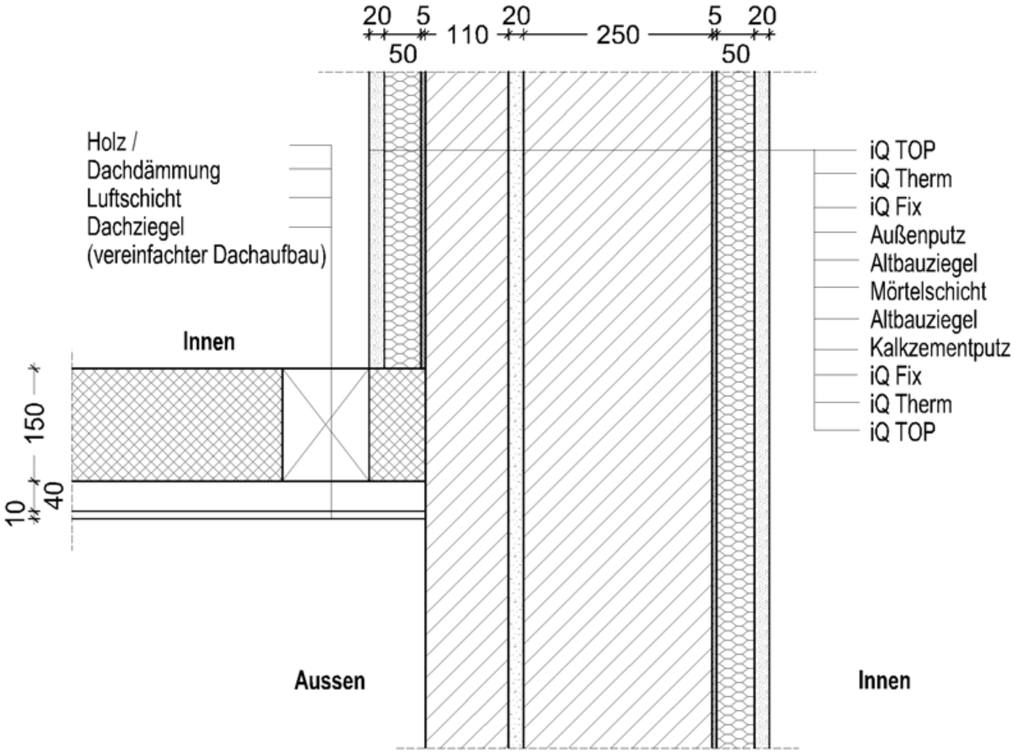
Figure 4.16.6: Humidity distribution of the construction 14 / 2D at 3rd February of the reference year.

4.16.3 Evaluation of the results for the Real Climate

There will be no damaging effects of a thermal bridge. There is no mould formation at the critical measuring point. The minimum temperature in the reference - year is 13,72°C. Due to the low temperature (near 12°C) in the corner, this area is not uncritical. In extreme cold years, a surface condensation and mould damage cannot be ruled out. Therefore the embrasure should be executed with an insulation wedge of 20 cm.

4.17 Construction 17/ 2D:„Attic floor wall-roof connection Det. E“

Construction layout



4.17.1 Calculation under steady conditions – climate according to DIN 4108-2, proof of the minimum thermal protection according to DIN 4108

The proof of the minimum thermal protection is conducted in accordance to DIN 4108-2 Section 6.2 for avoidance of mould growth.

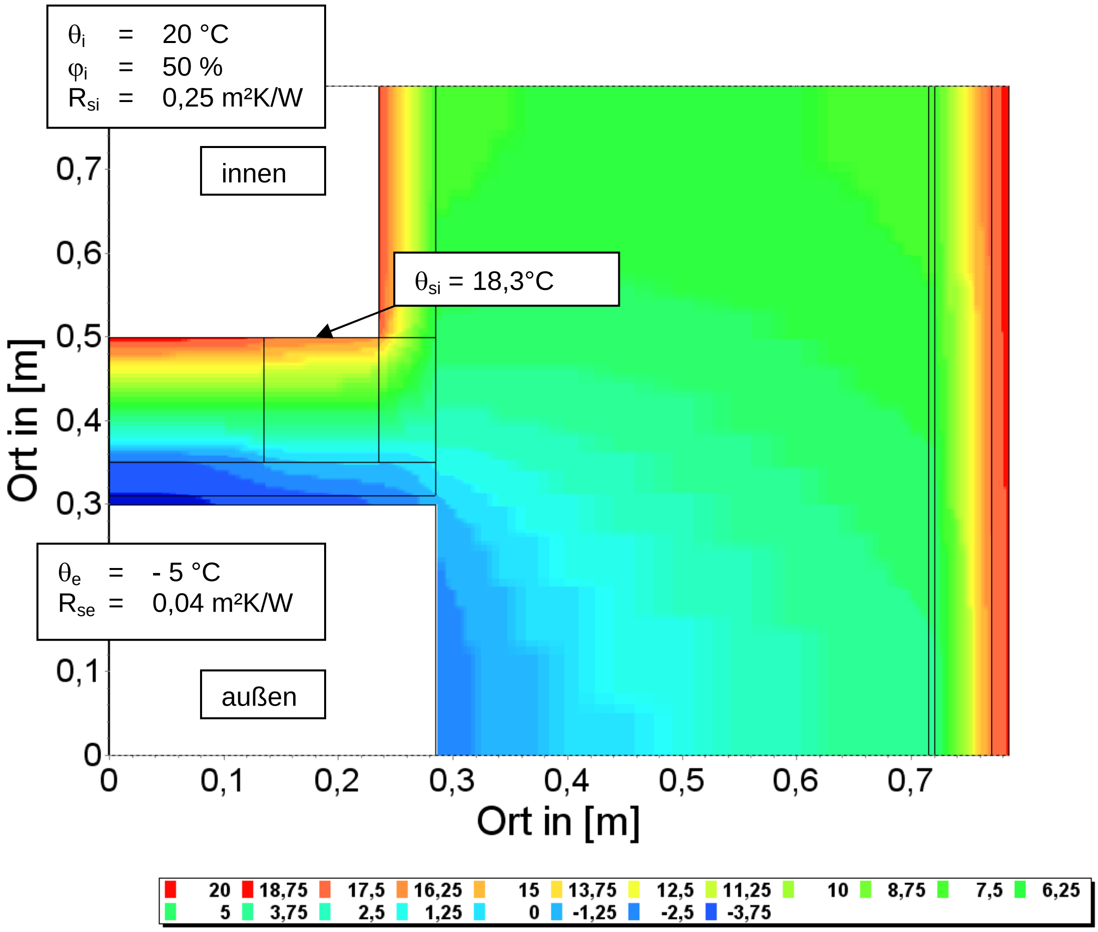


Figure 4.17.1: Temperature distribution of the structure 17 / 2D steady state surface temperature in [°C], boundary conditions according to DIN 4180 part 2.

$\theta_{si,\ inside\ corner,\ top}$ = 18,26°C > $\theta_{si,\ acceptable}$ = 12,6 °C

The proof according to DIN 4108 – 2, section 6.2 is complied.

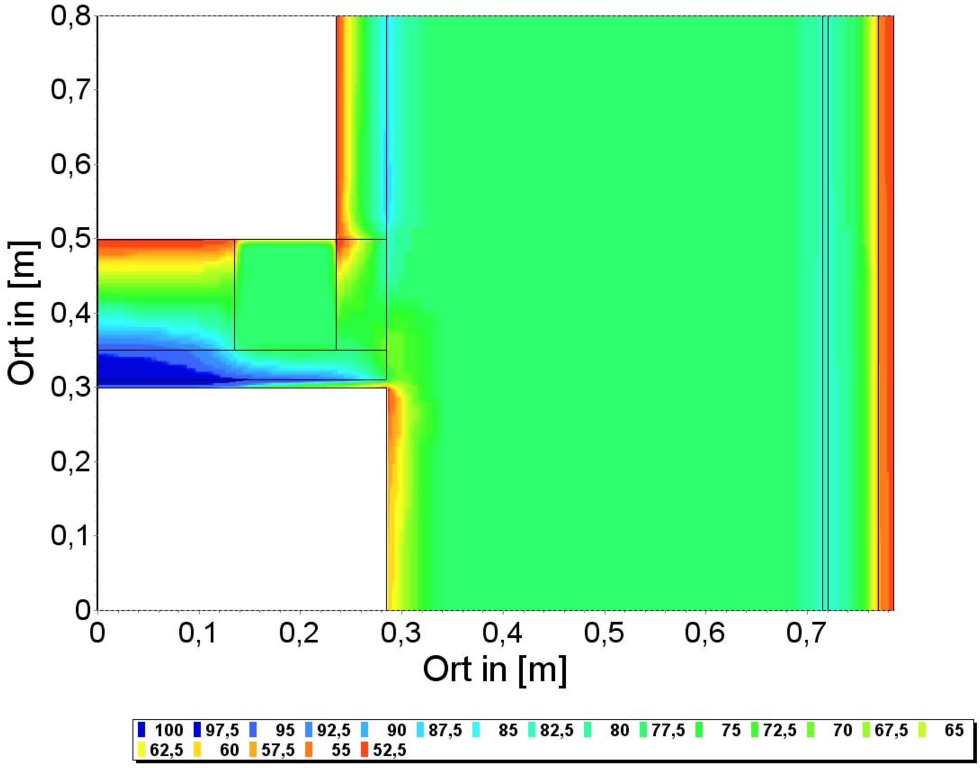


Figure 4.17.2: Humidity distribution of the construction 17 / 2D in the steady state

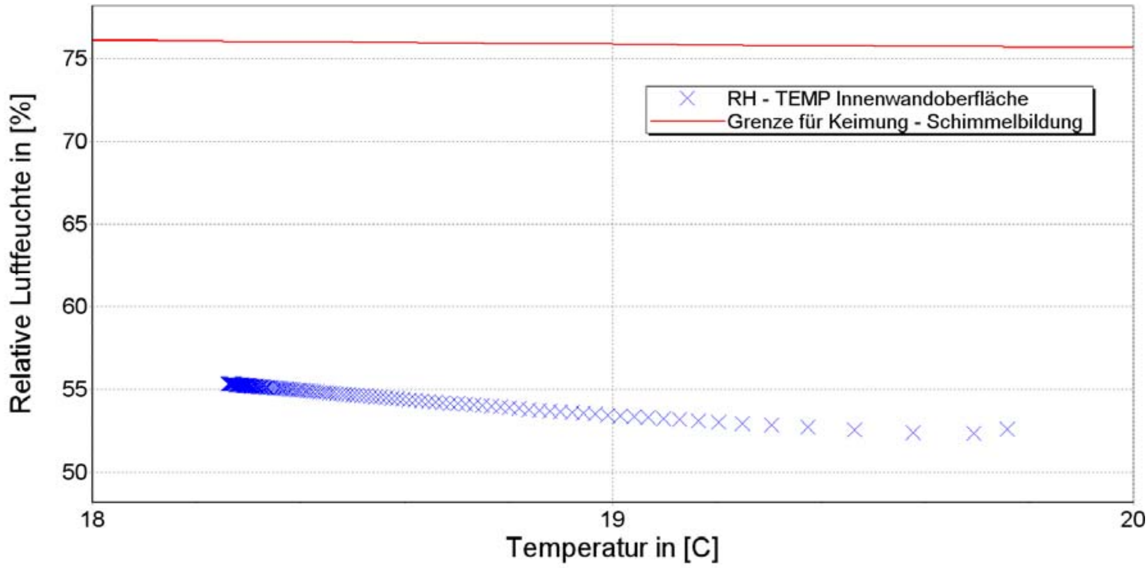


Figure 4.17.3: Graphic on the likelihood of mould formation of the construction 17 / 2D in the steady state. A mould formation with DIN required climate conditions can be excluded.

4.17.2 Climatic boundary conditions for the discussion of possible thermal bridges at Real Climate:

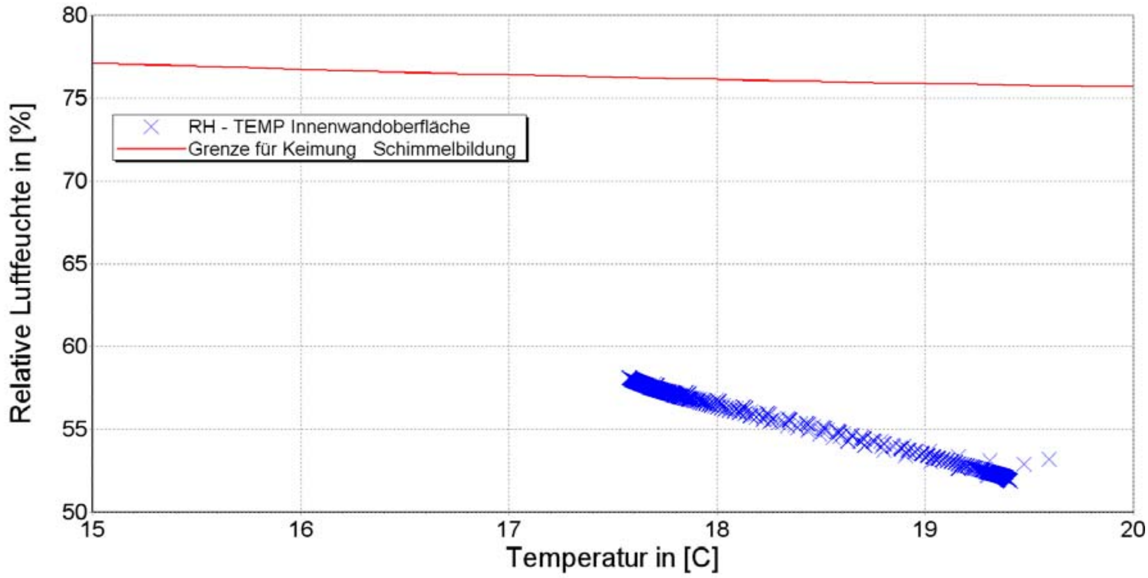


Figure 4.17.4: Graphic on the likelihood of mould formation of the construction 17 / 2D for the reference year. A mould formation can be excluded.

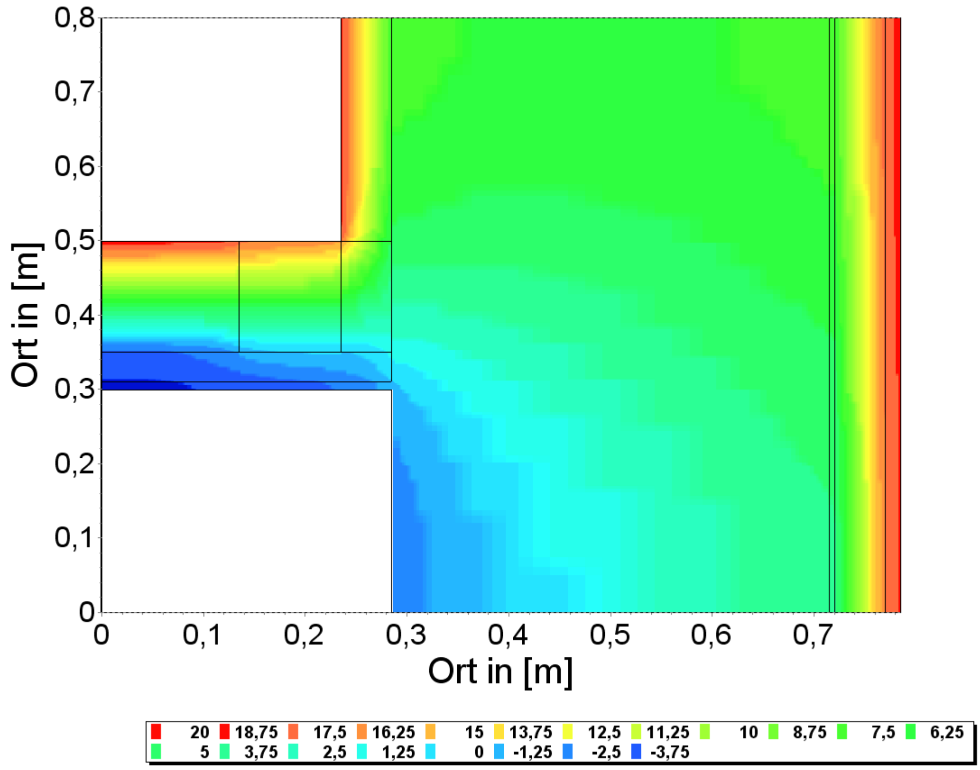


Figure 4.17.5: Temperature distribution of the construction 17 / 2D at 3rd February of the reference year.

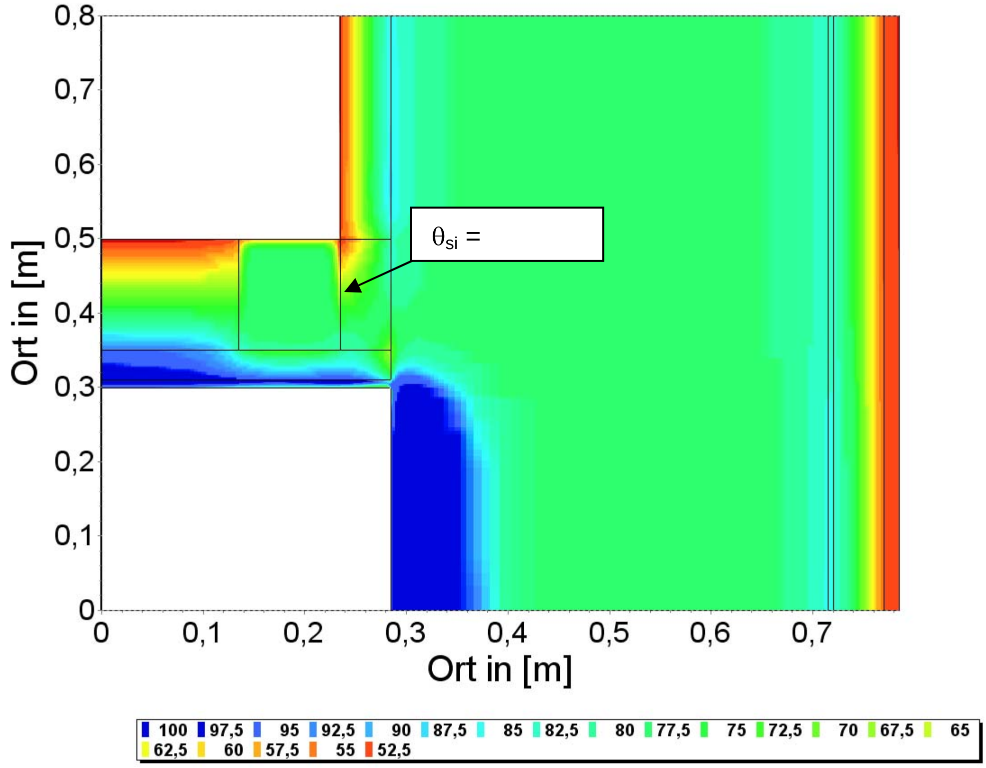


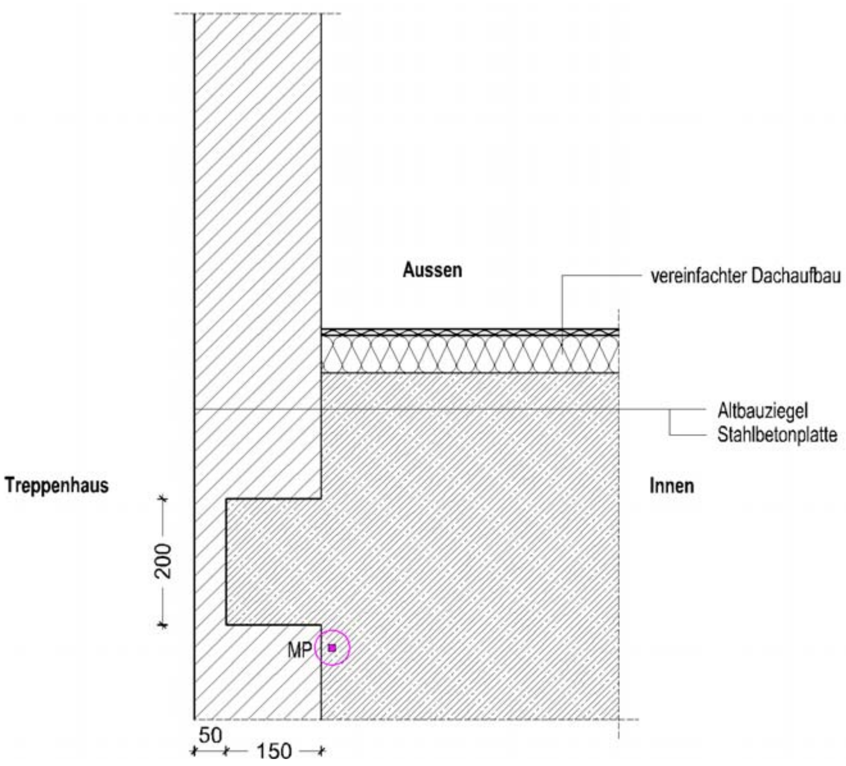
Figure 4.17.6: Humidity distribution of the construction 17 / 2D at 3rd February of the reference year.

4.17.3 Evaluation of the results for the Real Climate

There will be no damaging effects of a thermal bridge. There is no mould formation at the critical measuring point. The minimum temperature in the reference - year is 17,65°C. To avoid thermal bridges the construction is in need of thermal insulation on both sides of the incorporating wall.

4.18 Construction 19/ 2D:„Attic floor 1 reinforced concrete ceiling“

Construction layout



4.18.1 Calculation under steady conditions – climate according to DIN 4108-2, proof of the minimum thermal protection according to DIN 4108

The proof of the minimum thermal protection is conducted in accordance to DIN 4108-2 Section 6.2 for avoidance of mould growth.

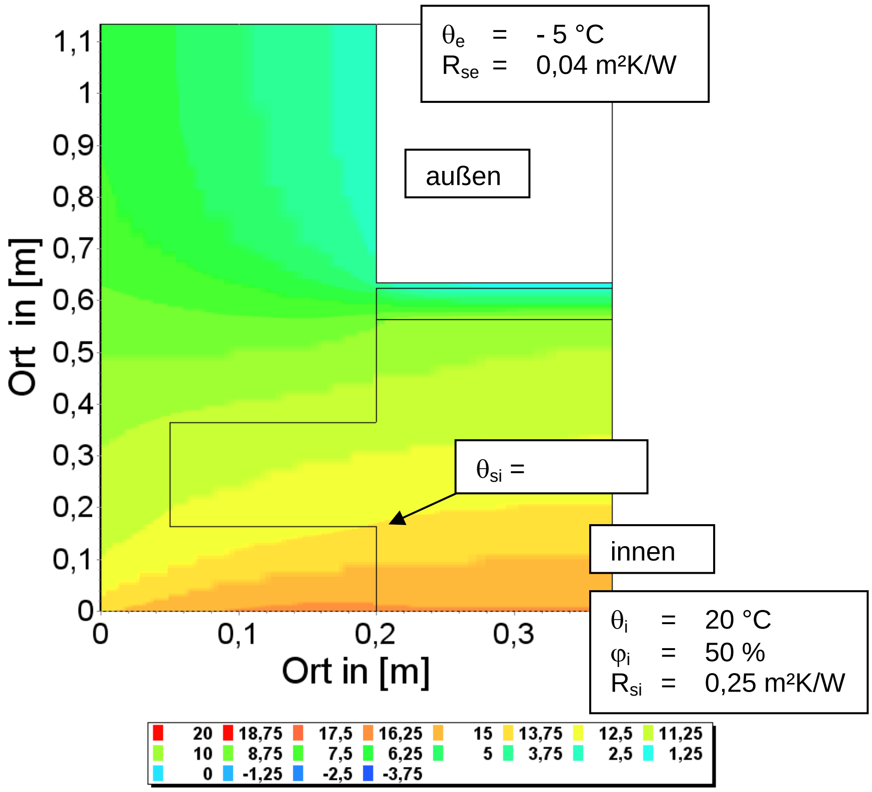


Figure 4.18.1: Temperature distribution of the structure 19 / 2D steady state surface temperature in [°C], boundary conditions according to DIN 4180 part 2.

$\theta_{si,\ inside\ corner,\ top}$ = 16,11°C > $\theta_{si,\ acceptable}$ = 12,6 °C

The proof according to DIN 4108 – 2, section 6.2 is complied.

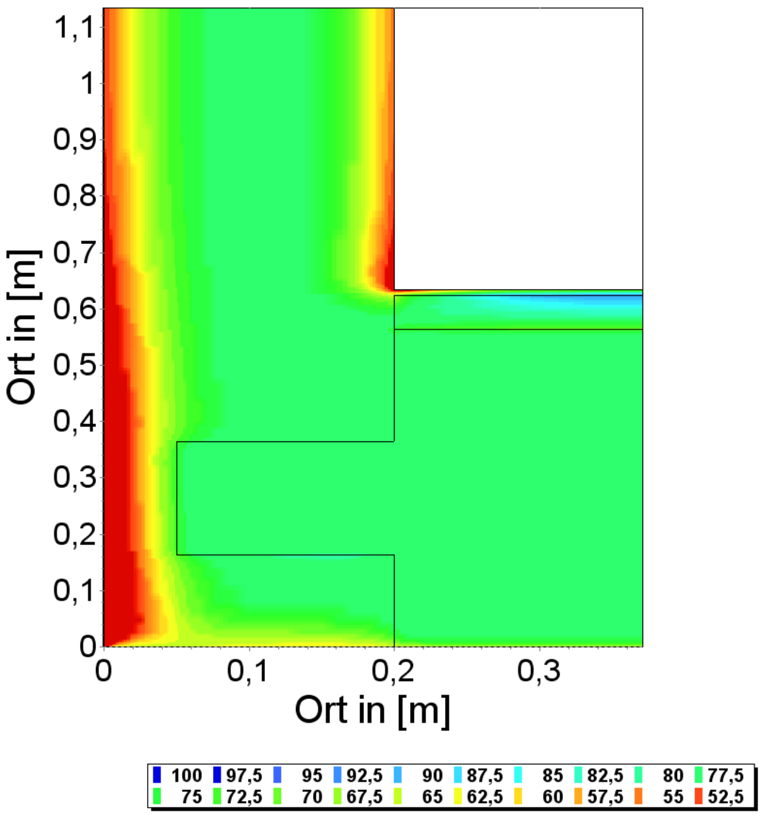


Figure 4.18.2: Humidity distribution of the construction 19 / 2D in the steady state

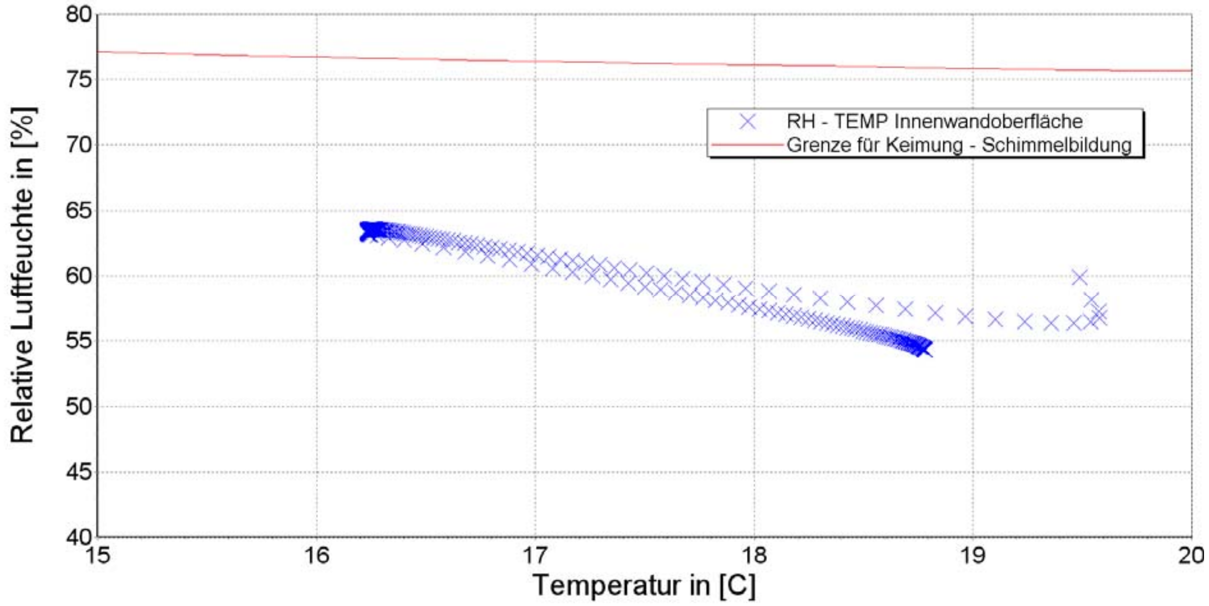


Figure 4.18.3: Graphic on the likelihood of mould formation of the construction 19 / 2D in the steady state. A mould formation with DIN required climate conditions can be excluded.

4.18.2 Climatic boundary conditions for the discussion of possible thermal bridges at Real Climate:

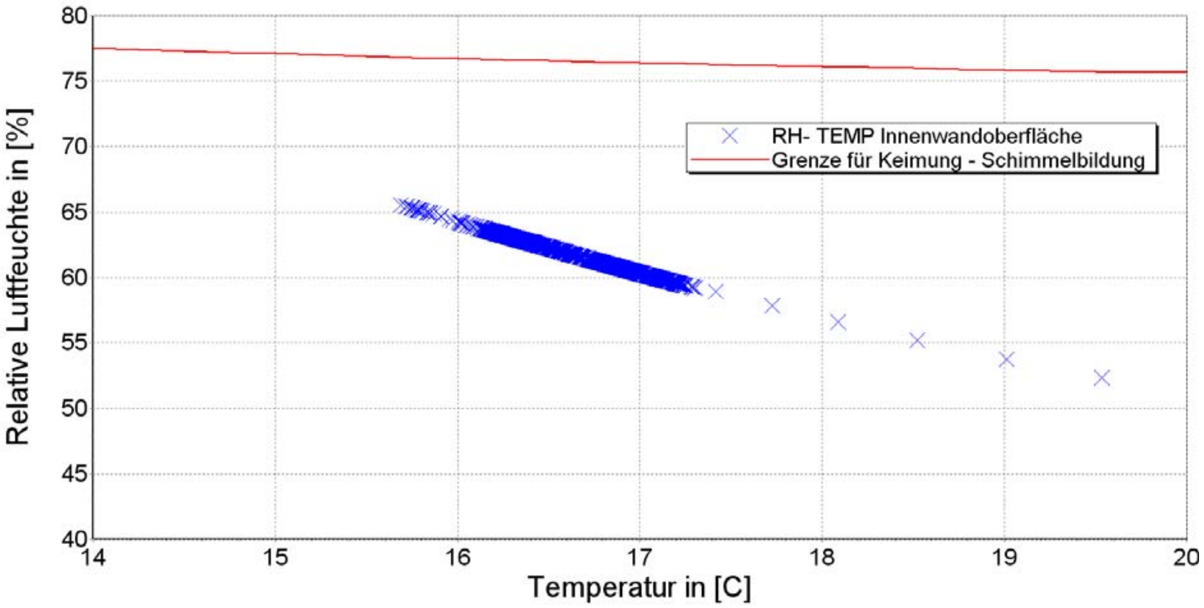


Figure 4.18.4: Graphic on the likelihood of mould formation of the construction 19 / 2D for the reference year. A mould formation can be excluded.

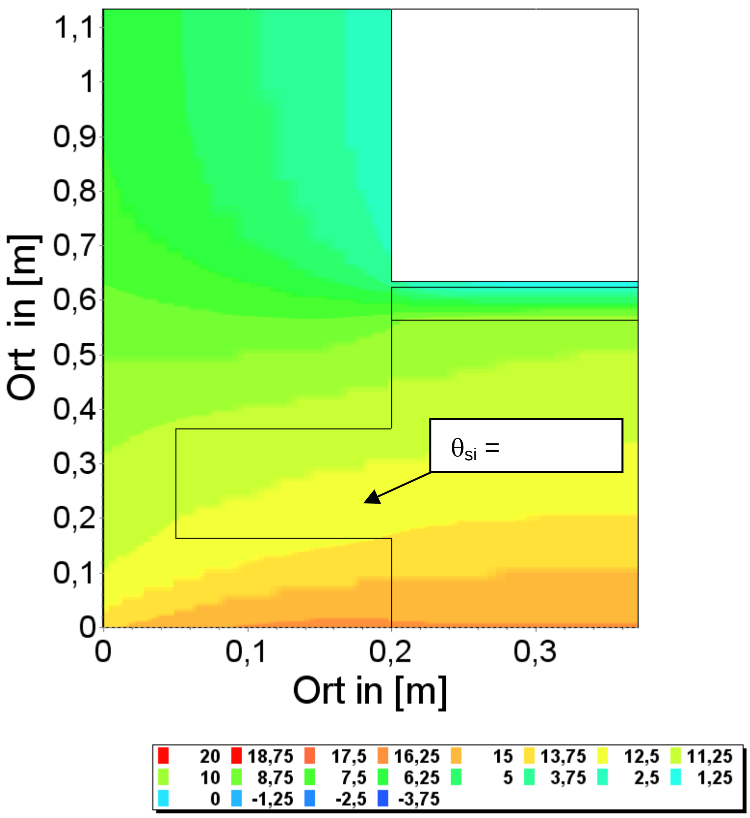


Figure 4.18.5: Temperature distribution of the construction 19 / 2D at 3rd February of the reference year.

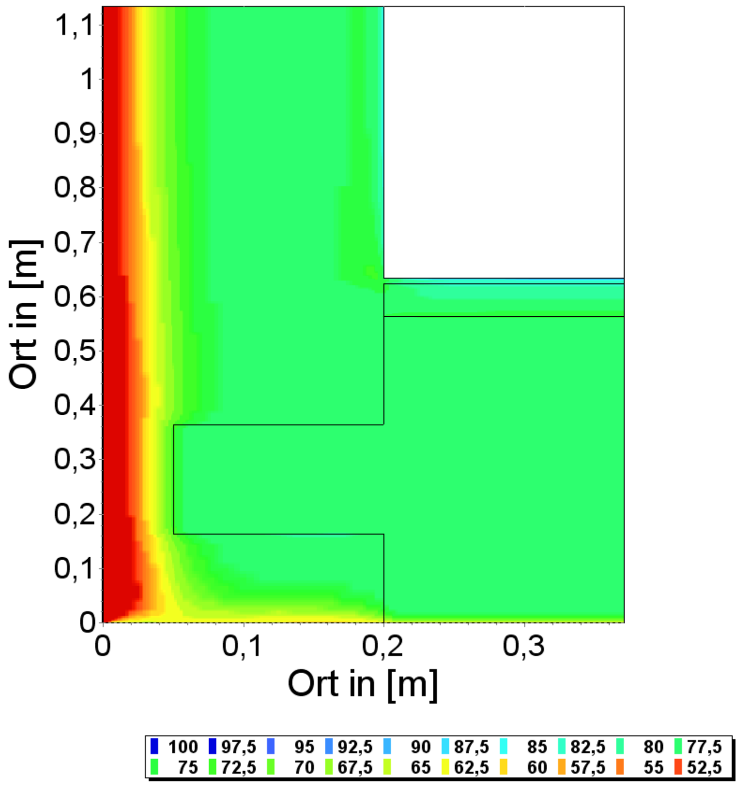


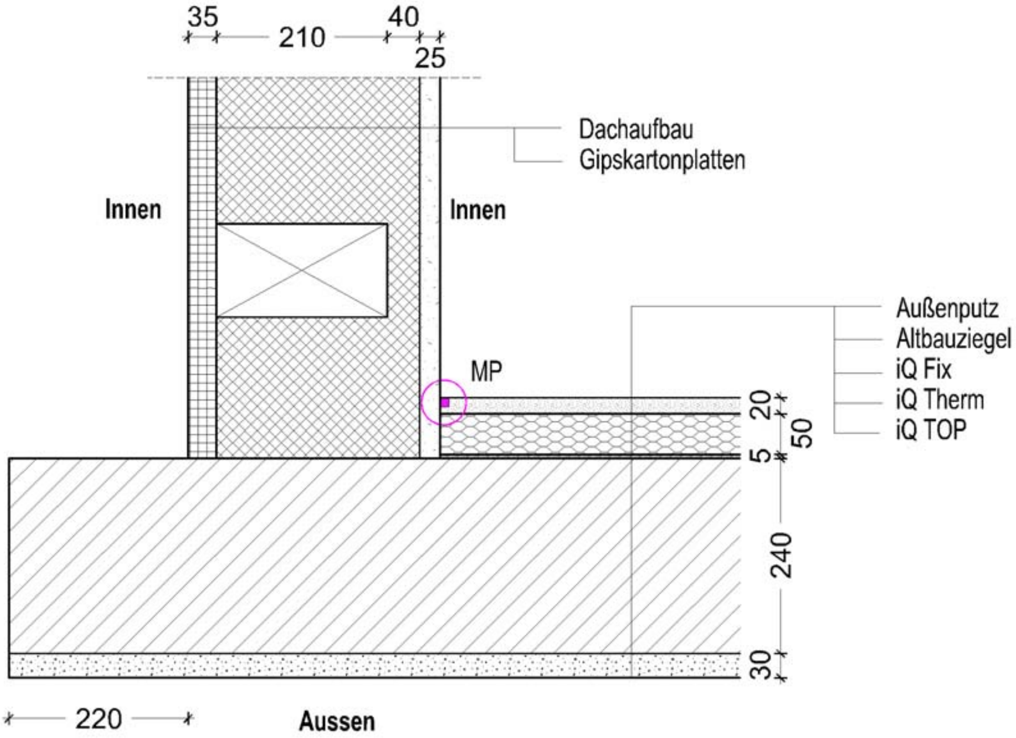
Figure 4.18.6: Humidity distribution of the construction 19 / 2D at 3rd February of the reference year.

4.18.3 Evaluation of the results for the Real Climate

There will be no damaging effects of a thermal bridge. There is no mould formation at the critical measuring point. The minimum temperature in the reference - year is 15,69°C.

4.19 Construction 20/ 2D: „DG 2 Wand-Dachanschluss Det. G“

Construction layout



4.19.1 Calculation under steady conditions – climate according to DIN 4108-2, proof of the minimum thermal protection according to DIN 4108

The proof of the minimum thermal protection is conducted in accordance to DIN 4108-2 Section 6.2 for avoidance of mould growth.

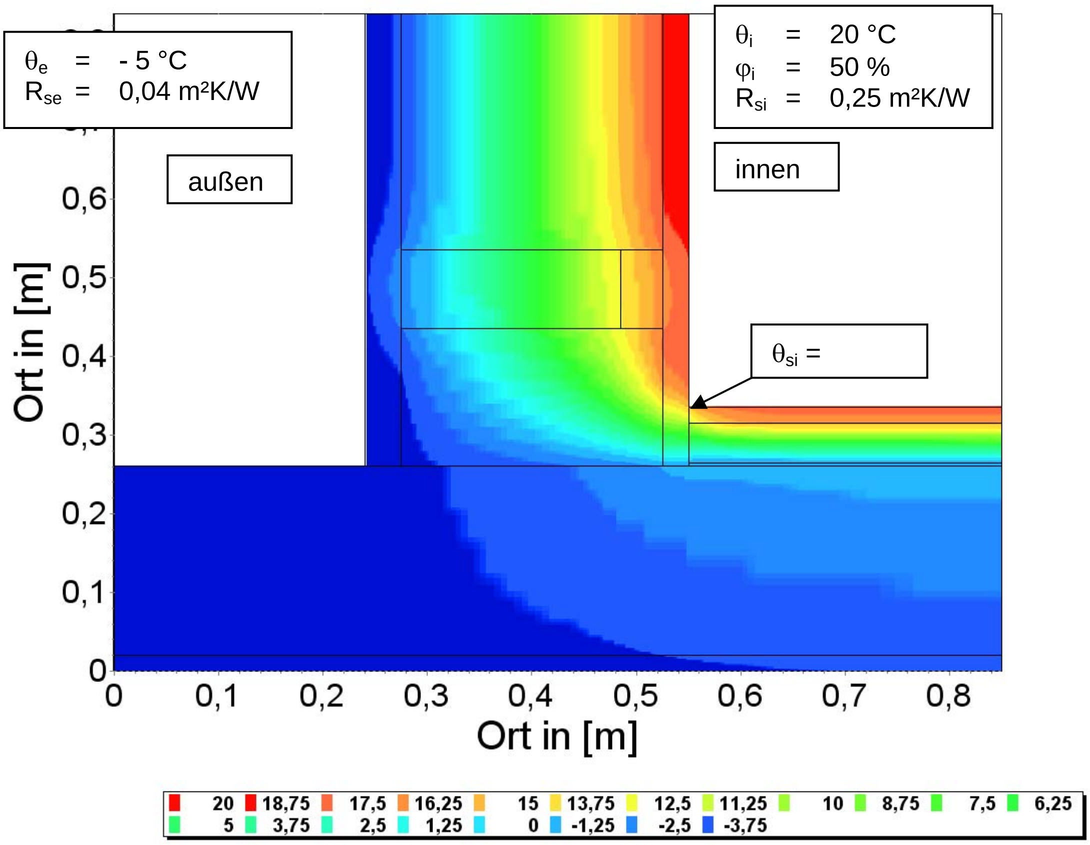


Figure 4.19.1: Temperature distribution of the structure 20 / 2D steady state surface temperature in [°C], boundary conditions according to DIN 4180 part 2.

$\theta_{si,\text{ inside corner, top}}$ = 15,1°C > $\theta_{si,\text{ zulässig}}$ = 12,6 °C

The proof according to DIN 4108 – 2, section 6.2 is complied.

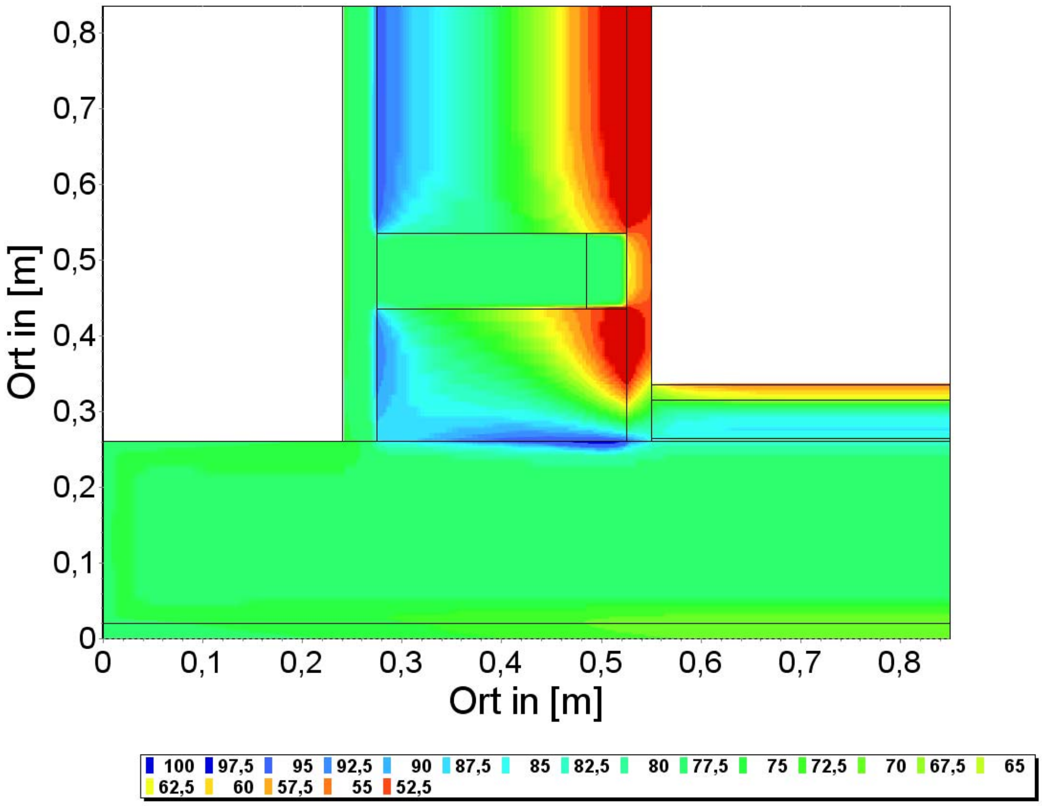


Figure 4.19.2: Humidity distribution of the construction 20 / 2D in the steady state

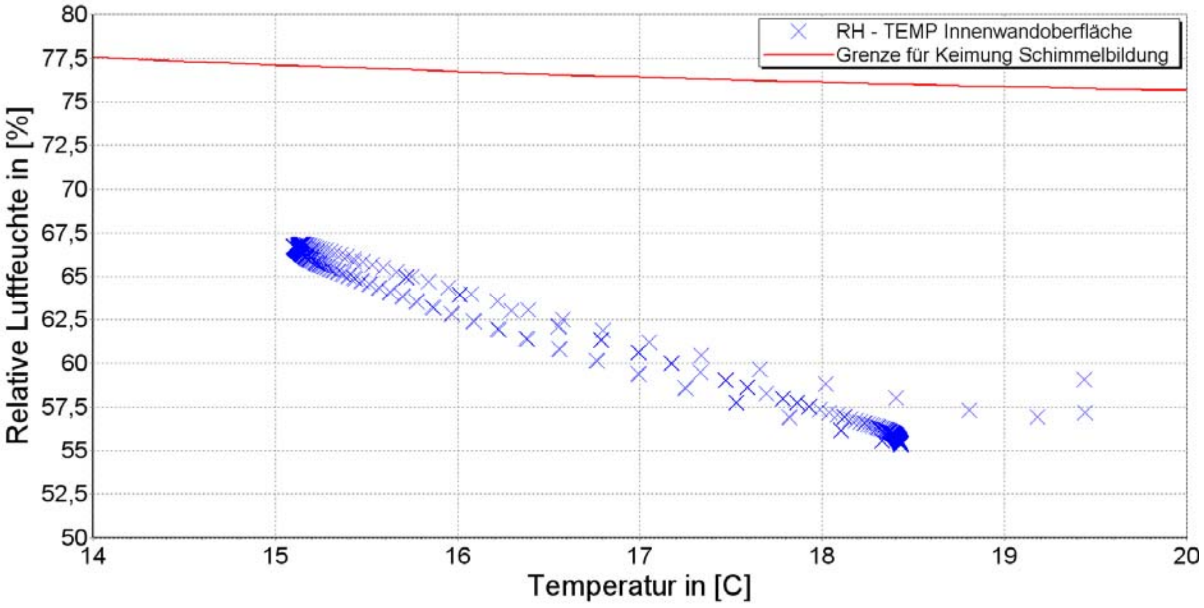


Figure 4.19.3: Graphic on the likelihood of mould formation of the construction 20 / 2D in the steady state. A mould formation with DIN required climate conditions can be excluded.

4.19.2 Climatic boundary conditions for the discussion of possible thermal bridges at Real Climate:

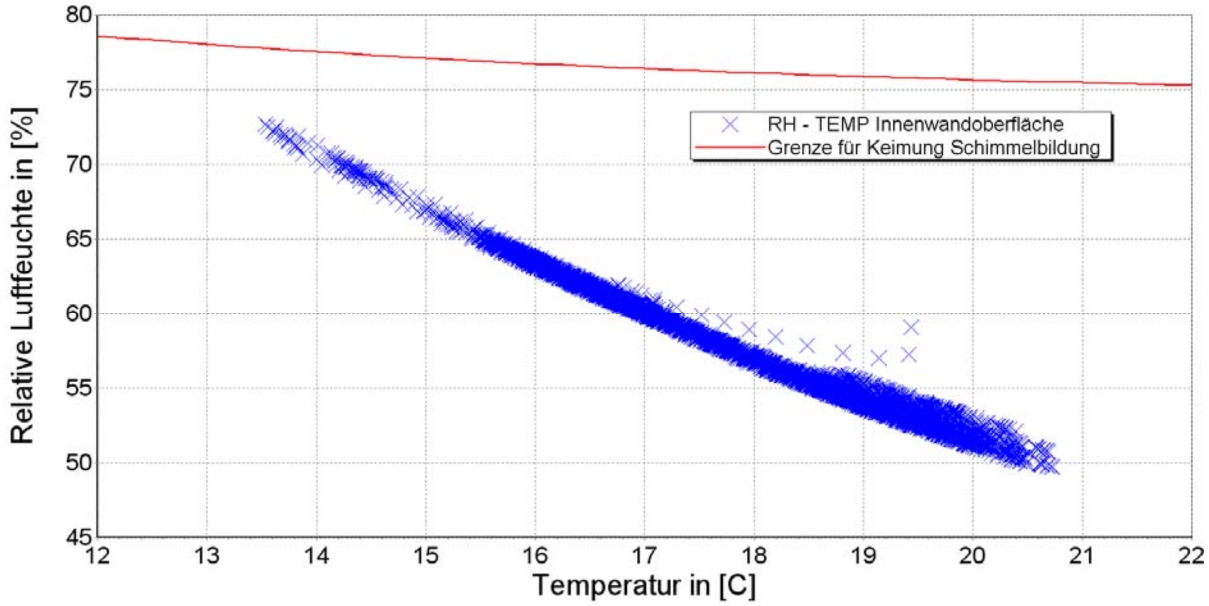


Figure 4.19.4: Graphic on the likelihood of mould formation of the construction 20 / 2D for the reference year. A mould formation can be excluded.

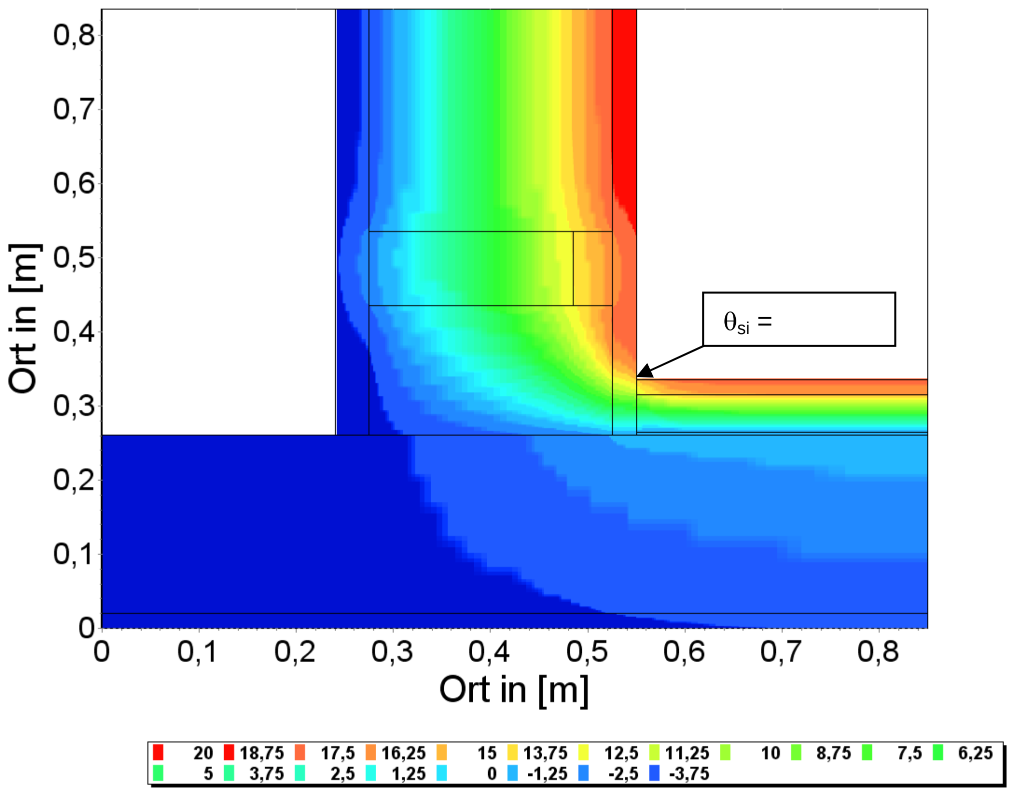


Figure 4.19.5: Temperature distribution of the construction 20 / 2D at 3rd February of the reference year.

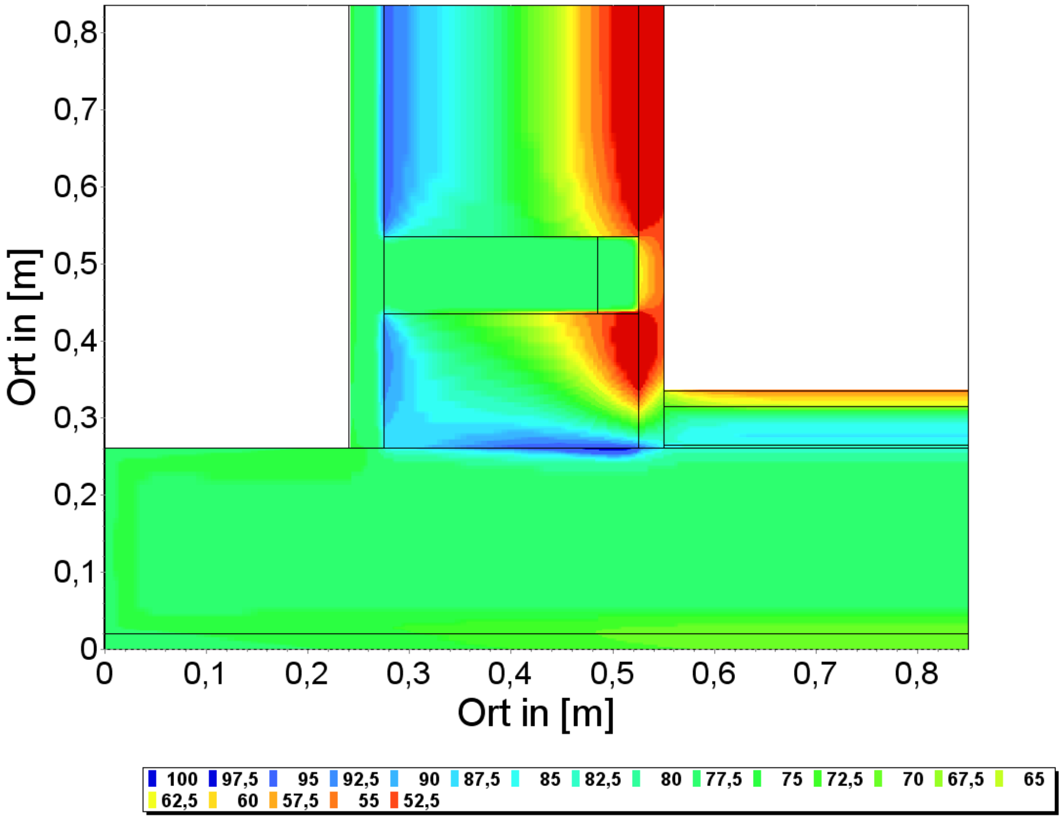


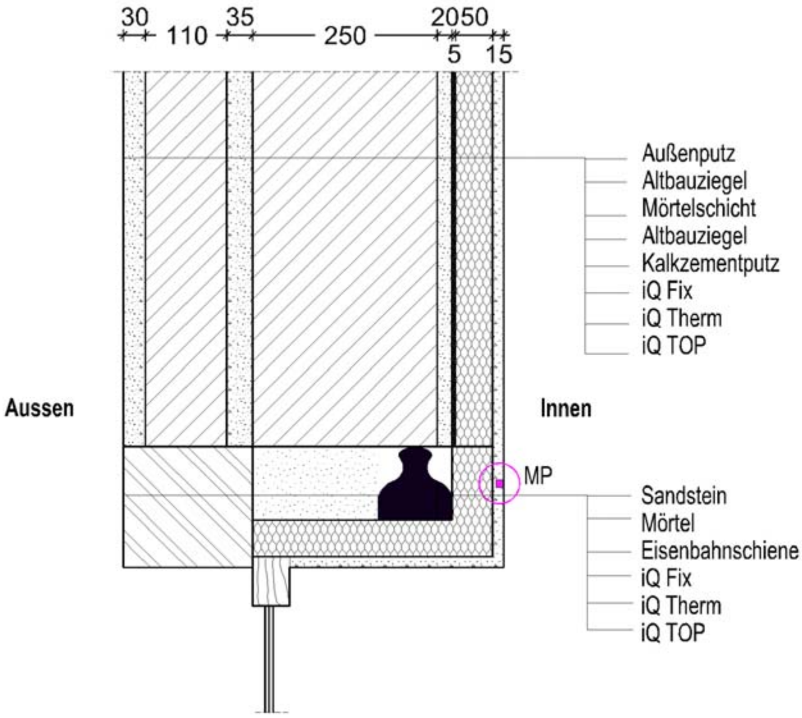
Figure 4.19.6: Humidity distribution of the construction 20 / 2D at 3rd February of the reference year.

4.19.3 Evaluation of the results for the Real Climate

There will be no damaging effects of a thermal bridge. There is no mould formation at the critical measuring point. The minimum temperature in the reference - year is 13,53°C.

4.20 Construction 21/ 2D:„1.Attic floor window railway track“

Construction layout



4.20.1 4.24.2 Calculation under steady conditions – climate according to DIN 4108-2 Proof of the minimum thermal protection according to DIN 4108

The proof of the minimum thermal protection is conducted in accordance to DIN 4108-2 Section 6.2 for avoidance of mould growth.

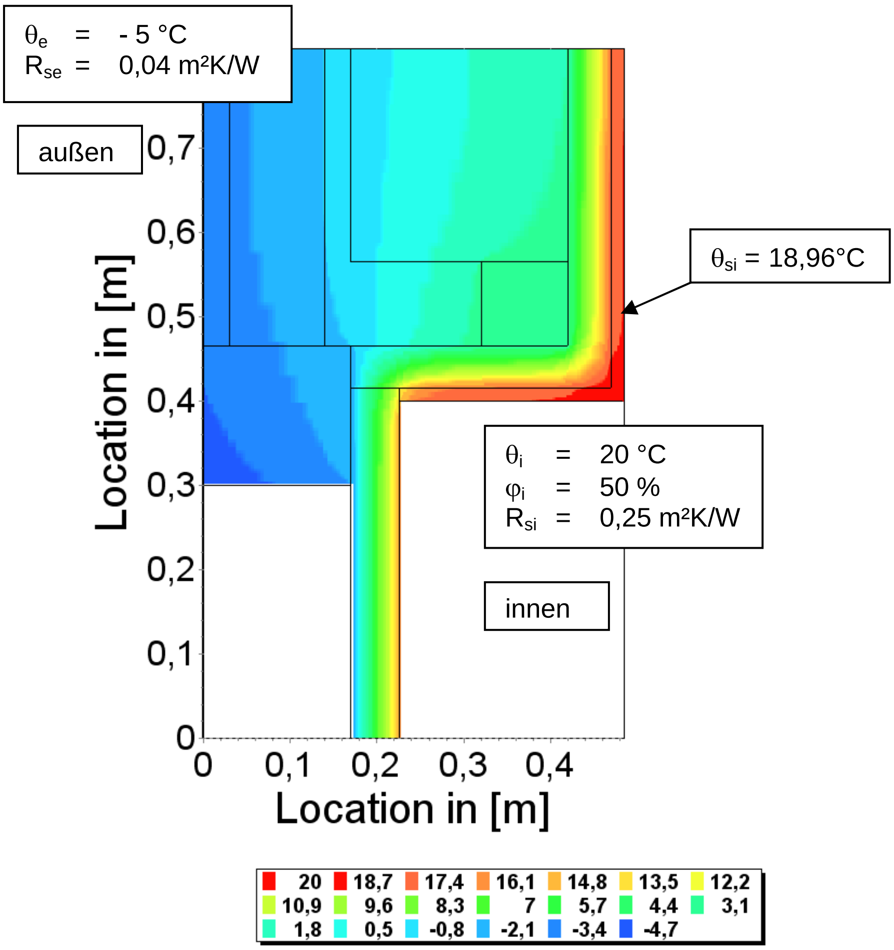


Figure 4.20.1: Temperature distribution of the structure 21 / 2D steady state surface temperature in [°C], boundary conditions according to DIN 4180 part 2.

$\theta_{si,\ inside\ corner,\ top}$ = 18,96,1°C > $\theta_{si,\ acceptable}$ = 12,6 °C

The proof according to DIN 4108 – 2, section 6.2 is complied.

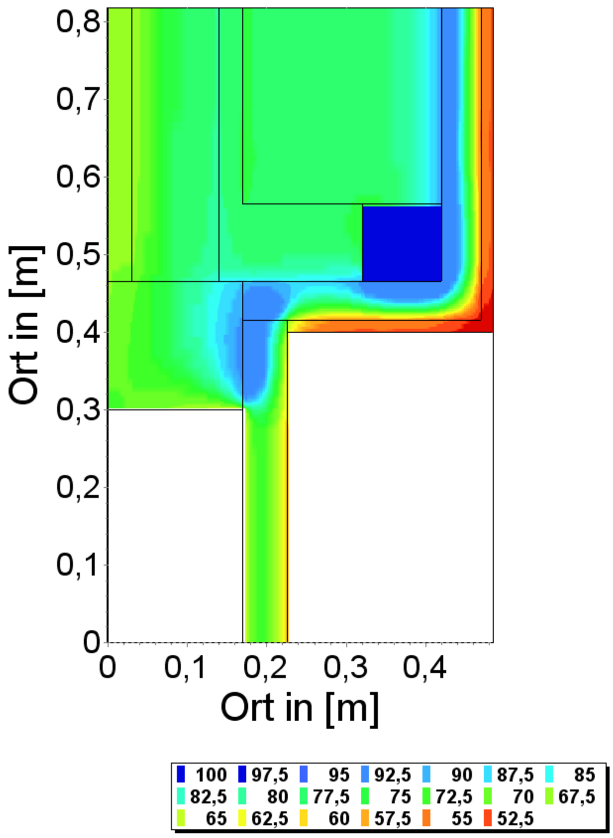


Figure 4.20.2: Humidity distribution of the construction 21 / 2D in the steady state

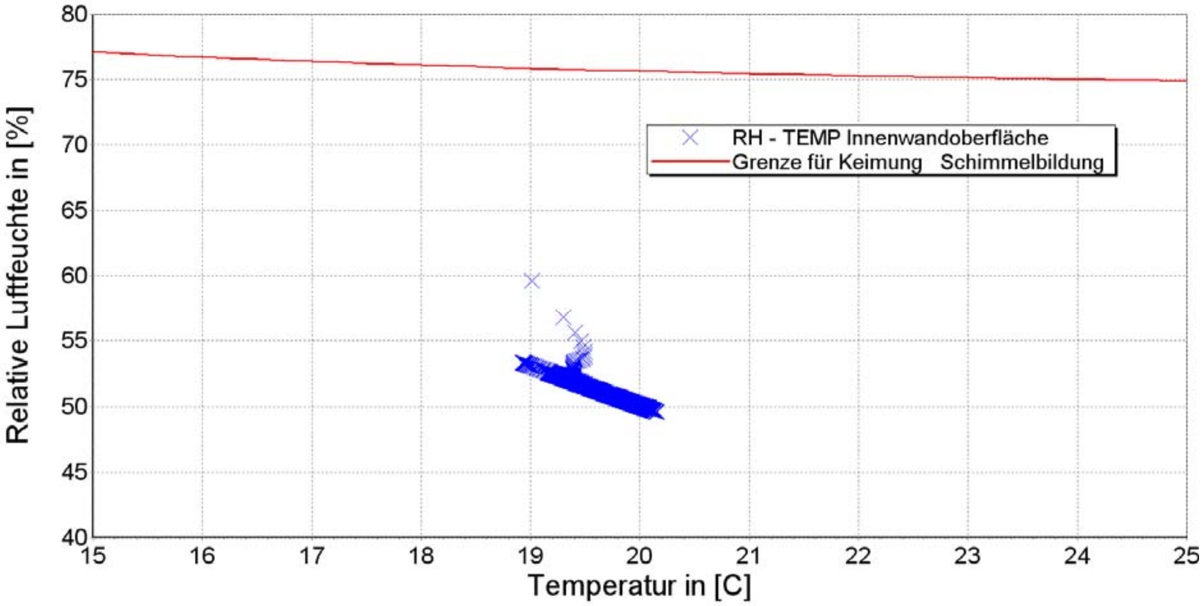


Figure 4.20.3: Graphic on the likelihood of mould formation of the construction 21 / 2D in the steady state. A mould formation with DIN required climate conditions can be excluded.

4.20.2 4.24.3 Climatic boundary conditions for the discussion of possible thermal bridges at Real Climate:

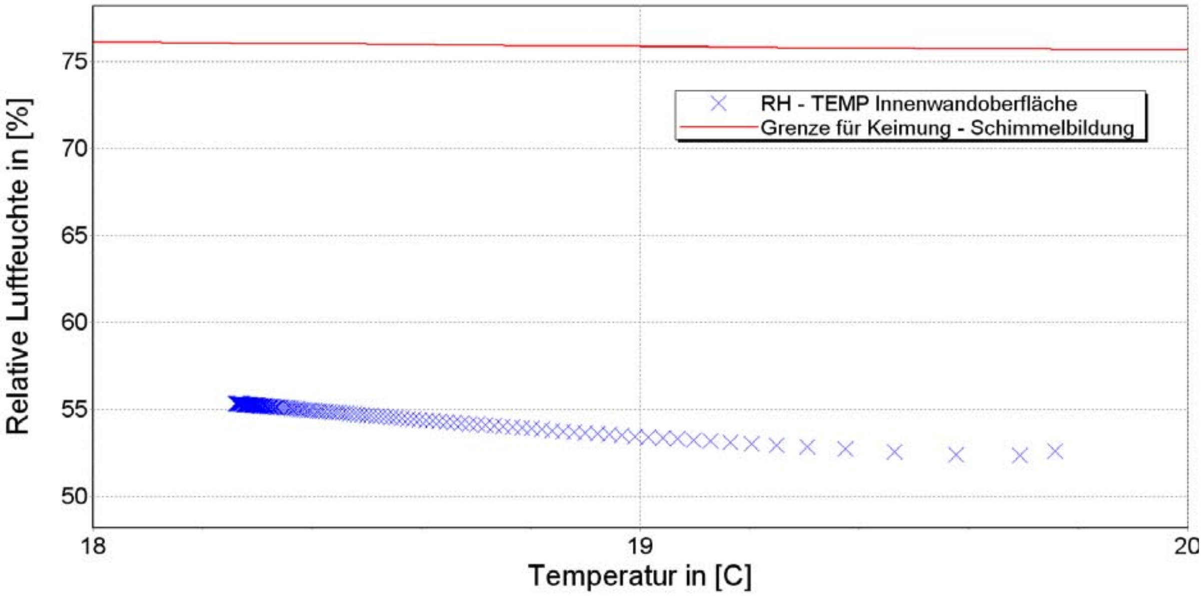


Figure 4.20.4: Graphic on the likelihood of mould formation of the construction 21 / 2D for the reference year. A mould formation can be excluded.

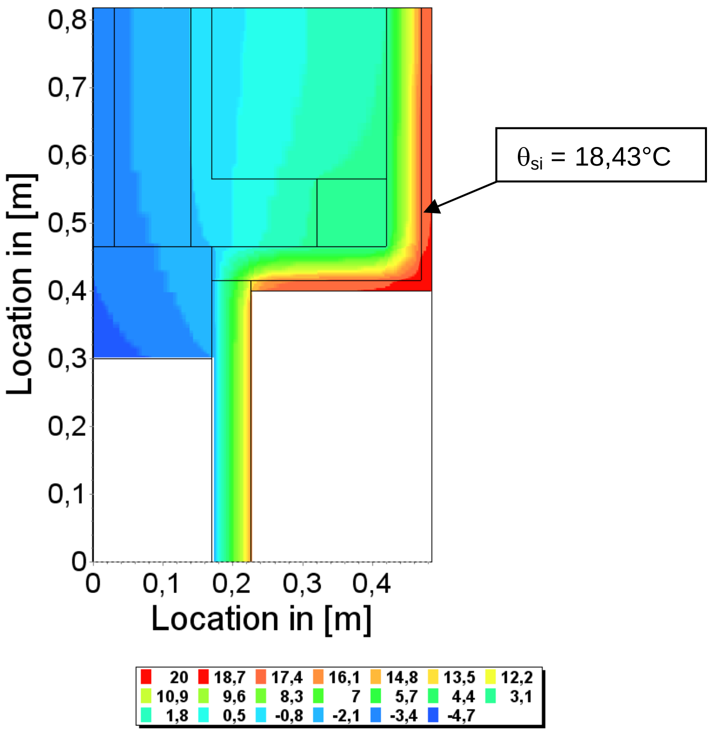


Figure 4.20.5: Temperature distribution of the construction 21 / 2D at 3rd February of the reference year.

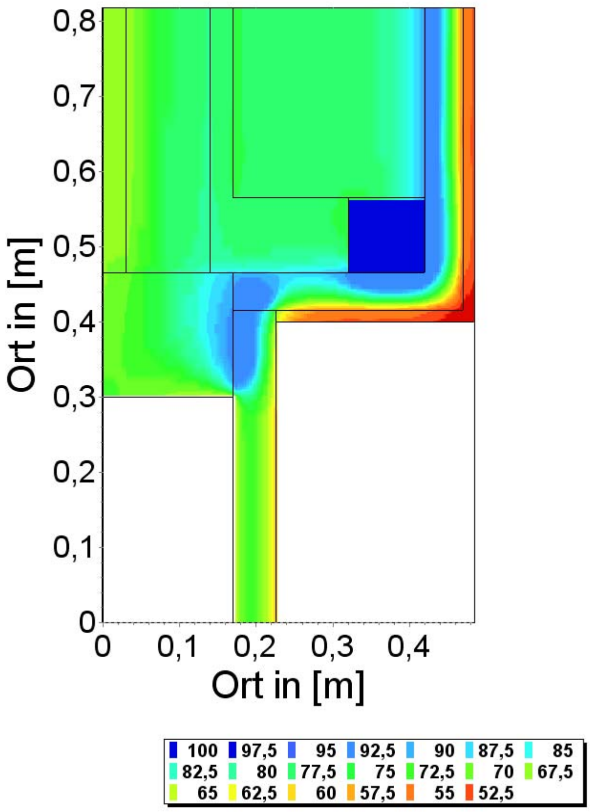


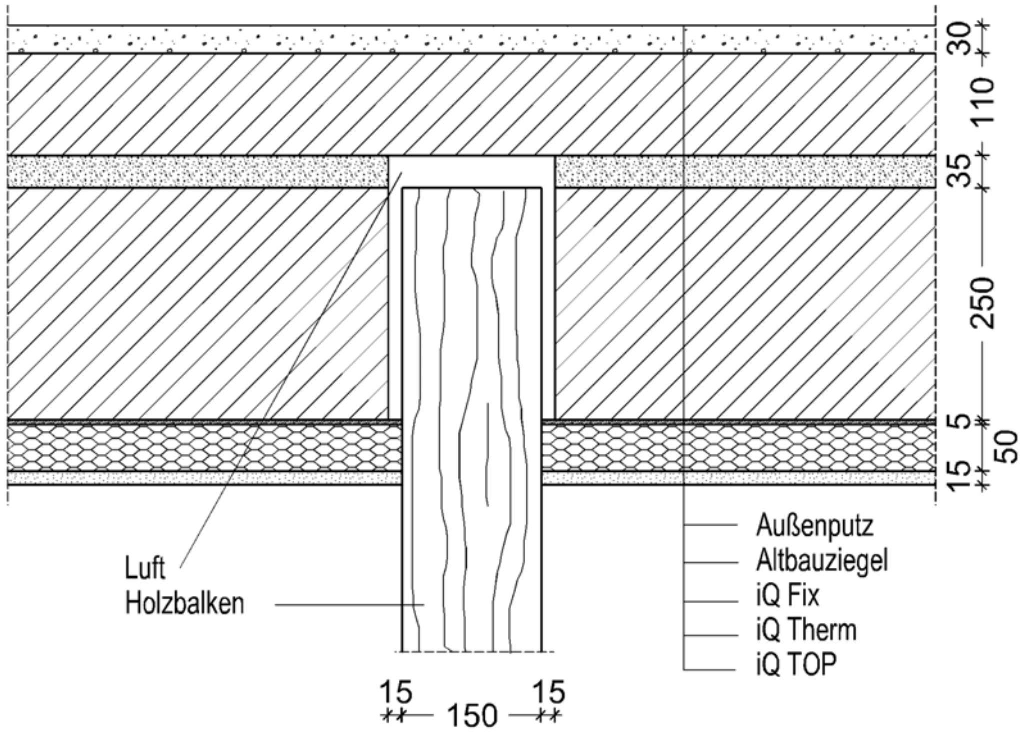
Figure 4.20.6: Humidity distribution of the construction 21 / 2D at 3rd February of the reference year.

4.20.3 Evaluation of the results for the Real Climate

There will be no damaging effects of a thermal bridge. There is no mould formation at the critical measuring point. The minimum temperature in the reference - year is 18,43°C.

4.21 Construction 23/ 2D:„Wooden beam“

Construction layout



4.21.1 Proof of the permissible wood moisture according to DIN 68800-3

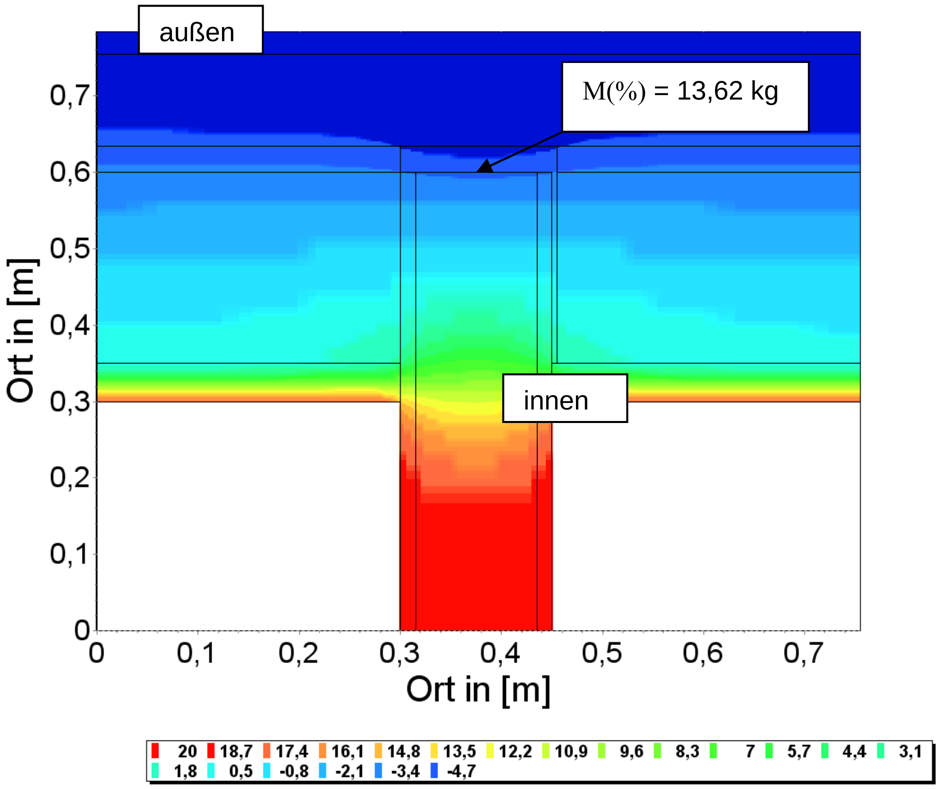


Figure 4.21.1: Temperature distribution of the construction 23 / 2D at the point of time 3rd February after one year settling time.

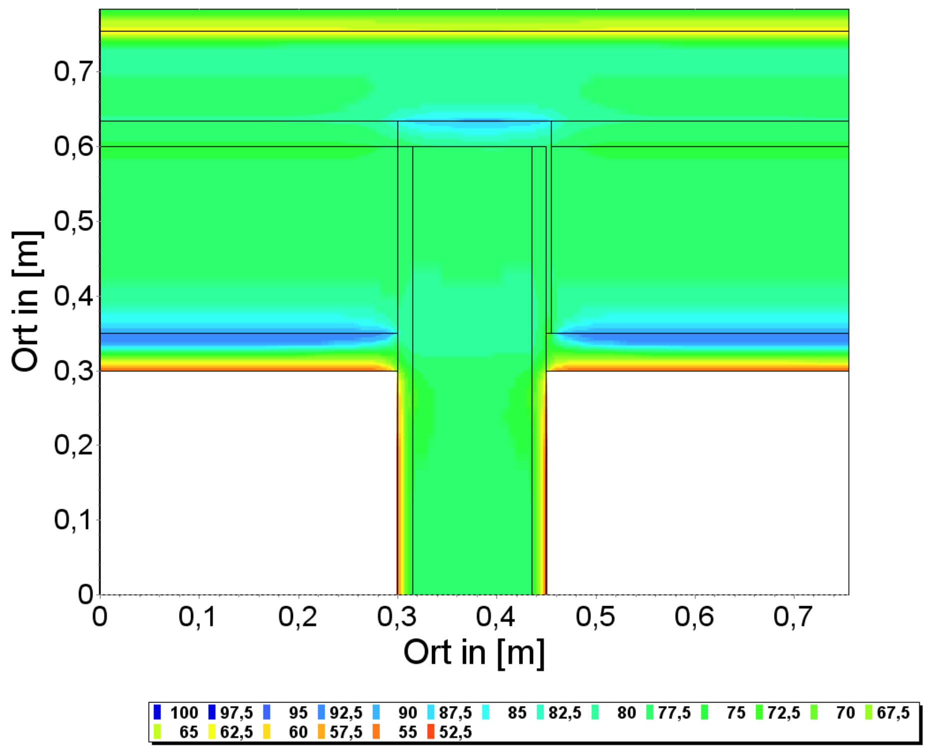


Figure 4.21.2: Humidity distribution of the construction 23 / 2D at the point of time 3rd February after one year settling time.

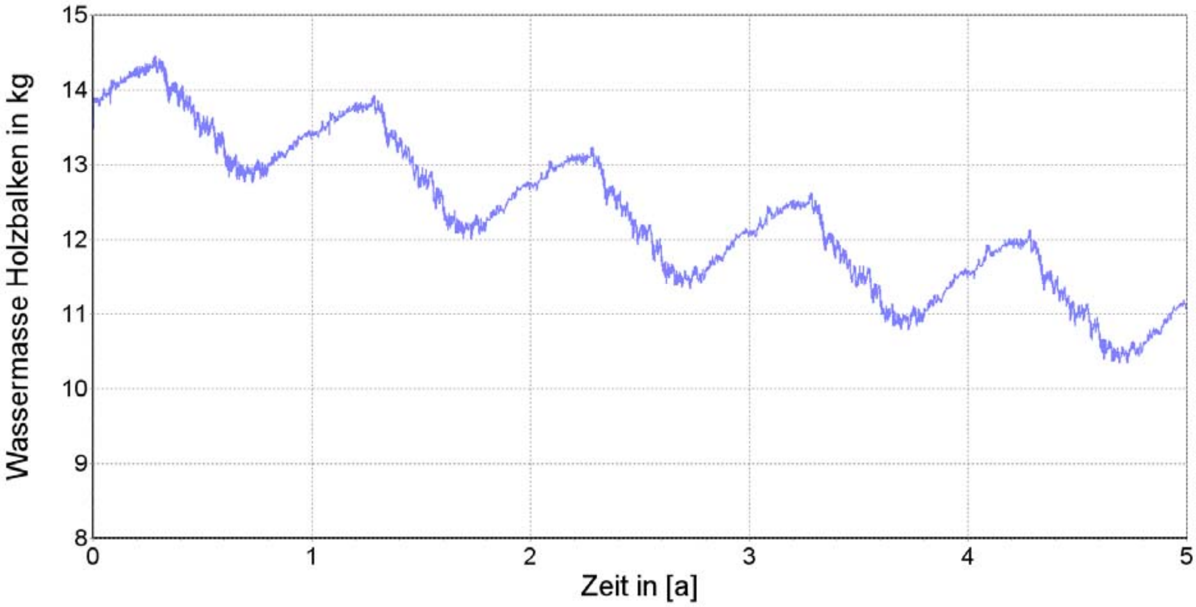


Figure 4.21.3: Graphic to the course of the percentage amount of water at the critical point of the wooden beam head in dependence on time.

$M_{, Holz}$ = 13,62 kg > $M_{Holz, zulässig}$ = 20 kg (Measurement after one year settling time.)

The proof of the permissible wood moisture according to DIN 68800-3 is complied.

4.21.2 Evaluation of the results for the Real Climate

The simulation calculations of the wooden beam heads were calculated for the real climate. Under the premise that the exterior plaster and paint forms a driving rain safe and diffusion-open system, a threat to the wooden beam heads can be excluded. The allowable 20 mass-% of water in the wood beam are not exceeded at any time. Over the years a decrease in moisture content sets in.

5 Overall evaluation and information on residual risks

Virtually all of the calculated construction and construction details can be executed without damage according to the available plans. In many areas insulation wedges on the incorporating interior walls may not be necessary. Calculating precept was a room temperature of 20 °C (according to DIN 4108). For larger deviations from this precept a drop below the required DIN limits can occur.

The present plans correspond with the generally recognised codes of practice. In designing adequate guarantees were planned to minimize the residual risk, taking the economy into account.

The material functions used in the simulation essentially determine the hygrothermal behaviour of the structures. The material functions of the existing building materials have been adjusted using the test reports and were used in the simulation program. The material functions of the interior insulation system are taken from the material data of the company Remmers. If building materials that differ greatly from the used material functions exist or other materials than the ones being assumed in the simulation are implemented, then it can lead to a different behaviour. The statements and recommendations for the construction made in this statement then apply only limited. At the outer facade it is assumed that a driving rain-safe and diffusion-open structure is present. An intact sufficiently waterproof, diffusion-open exterior plaster and paint is to be understood by that. If this external plaster as such cannot be warranted, a hydrophobicity of the external plaster as a further measure is recommended. The paint should also be sufficiently waterproofed and diffusion-open, it also must be compatible with the possibly hydrophobic external plaster.

D 6.2 Documentation of each study case
CS6 Baroque building, Görlitz (Germany)
Delivered at M42

EUROPEAN COMMISSION

DG Research and Innovation

Seventh Framework Programme

Theme [EeB.ENV.2010.3.2.4-1]

[Compatible solutions for improving the energy efficiency of historic buildings in urban areas]

Collaborative Project – GRANT AGREEMENT No. 260162

Technical References

Project Acronym	3ENCULT
Project Title	Efficient ENergy for EU Cultural Heritage
Project Coordinator	Alexandra Troi EURAC research, Viale Druso 1, 39100 Bolzano/Italy Alexandra.troi@eurac.edu
Project Duration	1 October 2010 – 31 March 2014 (42 Months)

Deliverable No.	D6.2
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Contributing beneficiary(ies)	P10 COBO
Author(s)	Rudolf Plagge
Co-author(s)	Ayman Bishara, Frank Meissner
Date	31 March 2014
File Name	WP6_D6.2_20140331_ Documentation of Case Study 6

Table of Content

2 Template for Case study presentation

2.1 Brief description of the building

This table is to be considered as an identity card with brief descriptions of the building so that it is possible to compare the different case studies.

Object Name: Baroque building in Görlitz	
Location	
Country	Germany
City	Görlitz
Altitude	199 m
Heating days	$\mathbf{T_{15}}$ = 274 d, $\mathbf{T_{10}}$ = 197 d
Heating degree days	Daily temperature figure**:** $\mathbf{G_{20/10}}$ = 3419 K*d, $\mathbf{G_{20/15}}$ = 4000 K*d Heating degree days: $\mathbf{G_{10}}$ = 1450 K*d, $\mathbf{G_{15}}$ = 2628 K*d [Heating degree days]
History	
Date of construction	• Main structure was built in 1250 • In 1726 the building burned out completely • In 2004 renovation began. • 2011 completion of the renovation
Construction Type (according to its age)	middle Ages
Original use and functional	Residential house
Current use	Residential house with two apartments
Expected use in future	Residential house with two apartments
General description	
Status quo	renovated
Architectural style	baroque
Construction materials	External walls: Masonry in natural stone, plaster Ceilings: wooden beam ceiling Roof: Roof structure in wood, roof with tiles
Overall conservation status	endangered before renovation

Urban Context	
Quarter/town	Old town: The listed house is part of the oldest Settlement area of Görlitz in Saxony.
Development plans	building is a representative example of the building stock of the middle age in the historic city Center of Freiberg
Key figures as e.g. % of historic buildings, renovation rate	about 50%
Cultural Value (Specific valuable aspects)	
Historical Values	major resource of identification for the citizens and important touristic attraction
Design Value	building is a representative example of the building stock of the middle age in the historic city Center of Görlitz
Constraint condition	Vault from the 16th century, wood beam ceiling of 1726
Building Problems (cracks, deterioration, moulds and fungi..etc)	
1	Indoor humidity and temperature
2	Salt rising in masonry walls
3	Roof structure and ceilings with real dry rot
Planned/Proposed/Possible activities	
Diagnosis	• Visual inspection • Geometrical survey (plan view, section, volumes, …) • Window frames survey • Measurements of Air T and RH in rooms; measurements of superficial temperature on walls • Mapping of air T and RH • U-value measurements • Survey of openings in ceilings/floors • Carrier gas measurement • Software simulation (Energieberater – Hottgenroth, Therm, Delphin)
Planned solutions	• Outer wall (facing the street) with capillary interior insulation that is open to diffusion and made of calcium silicate • Outer wall (facing courtyard) exterior insulation finishing system (EIFS) that matches the building's appearance ground floor as a buffer zone

	• Wooden box-type windows with double glazed insulating solar glass, Wooden windows with triple-glazed insulating solar glass • Reduction of thermal bridges • Roof with hemp insulation between the rafters and clay-plate insulation under the rafters • Air tightness • Mechanical ventilation with heat recovery • Solar thermal energy • Computer-aided control • Long-term monitoring of critical components
Monitoring system	Data logger from Ahlborn for: • metrological screening reaches for the capture of meteorological data at the old town quarter (urban) • the thermal and humidity performance of the building (air temperature and humidity of rooms, surface temperature, material humidity, and temperature profile inside the materials) freely programmable universal controls UVR 1611 use for facility management • furthermore the consumption of primary energy carrier • solar heat production by solar collectors • the volume flow of supply and used air
Simulation	Energieberater, Delphin, PHPP, Therm, Designbuilder
Transfer to urban scale concept	The apartment house City Görlitz is a place where the habitants can live and work in reconstructed on newest technological energy standards (heating and cooling) based on renewable energy. It should be also a place for optimisation, demonstration and teaching of technology and using in the subject of renewable energies and building.
Others	The test building is to be used for continuing education for architects and engineers.
Documentation	
Existing documentation	Conrad, C., J. Grunewald & J. Bolsius: "Energetisch und bauphysikalisch optimierte Sanierung eines Baudenkmals in Görlitz“ - „Bauklimatische, messtechnisch validierte Gebäude-simulation und Ausarbeitung eines Regelwerkes zur energetisch und umwelttechnisch optimierten Sanierung eines Baudenkmals in Görlitz“ DBU AZ 21216, Selbstverlag, Dresden, 2010

Scanned/photocopied materials	-
Digital materials	Site measuring and photos
Inside surface	Photos
Outside Surface	Photos

2.2 Detailed description

2.2.1 Local climate data

Local climate date[1] (rif. Central city:)	
(building plan showing the north)	Climate zone: #
	Climate area: #
	Degree days: #
	Altitude: 199 m
	Coordinates: 51° 16′ N, 14° 99′ O
	Average wind speed: #
	Prevailing wind direction: #
Winter climate data	#
Winter design temperature: - 5°C	Temperature: -16 °C
HR max: 95% (Nov.- Dec.)	#
Heating days per year: 183 (15 Oct.- 15 Apr.)	#
Other	#

[1] Example of data

2.2.2 Report on history of the building

Historical summary table

History of the building			
(drawing)	First phase of construction:	1250	Area first time covered with buildings
		1726	Reconstruction of the building - Barrel vault, Foundation wall from preliminary Building
	Second phase of construction (first extension):	1856	Using extension - Increase at one storey - Adjustment of the old Roof Structure
		1976	Renovation – broad Modification - Change of floor plan, reinforced stell staircase, Indoor bathrooms - Reparation roof structure, new Roofing - Integration of a Heating system covering one floor - new Windows and doors
	Major renovations	2003 - 2011	renovation
		2003	Begin of renovation
		2004	Completion 2nd floor
	Constraint condition:	#	#

History and Monumental Significance

City Development

In the case of this object it is about a four-storey residential building, which like all houses in the street “Handwerk“, stands in closed construction.

The nucleus of the prospective town of Görlitz was the castle Yzhorelik at the Neiße crossing, which was newly embattled in 1130 according to instructions of the duke of Bohemia Sobieslaus. In 1268 a court as well as a merchants settlement with the church of St. Nicholas followed. Next to it a slavic village existed already for quite some time indeed. From beginning of the 13th century the later Untermarkt expanded, with related streets, to the Obermarkt in 1250, because of the building activity of the merchants and the come along craftsmen in the southwest of the castle hill. Both urban cores, so first that one around the Untermarkt and later the expanded one with the Obermarkt, were enclosed by town walls early on.

The street „Handwerk" is located in the oldest part of the city with centre (Fig. #).

Figure 2.1: Townscape of 1714

The surrounding quarter is called Neißeviertel, whereas there are three more quarters, which are named after the high middle ages town gates.

The Handwerk runs from the Weberstraße, which is in alignment with the Petersstraße. This axis is the connection between court, Untermarkt and the southern end of the town. For the name of Handwerk Richard Jecht [2] writes following: „Handwerk is named after the site of the crafts, i.e. the cloth-maker. According to the historical development of this description it is not surprising, that the name of the lane Handwerk can be found only occasional in oldest time, first 1392, 1449 and 1458. All the more you read Federmarkt. The fires of 1525 and 1726 rampaged badly in this quarter; mostly the houses were owned by minor craftsmen, in particular cloth-maker. "However the today’s plot Handwerk 15 was called for centuries, already since the time of the origin of the town it has been developed.

History of the building Handwerk 15

The appearence of the today’s building Handwerk 15 presents itself simply. The house has a plain plaster façade, a regular window grid with three axes to the front and the back. The entrance with segmental arch is aligns itself to the right, while in the ground floor there is only one window to its left. The building has a depth of 17.0 m, like the other ones in the street, but it counts to the narrowest (Fig. 2.1).

With the perimeter of the time of construction apriori we can rely on facts. So it is known, that in 1726 a fire put down broad parts of the Neißeviertel with the Handwerk. Undoubtedly the fire spread to Handwerk 15. Besides we have results of a dendrochronological screening of different lumbers. Cutting dates in the years 1727 (beam ceiling, 1st floor), 1714 (roof truss, top plate) and 1728 (brace of the roof truss) have been determined. So a time construction after 1728 results, so it's sure, the building had been rebuilt after the fire of 1726.

Townscapes and sources prove, that during fires usually the walls, chimneys and vaults of the buildings persist, merging into the newly constructed building. That is the case also with Handwerk 15. Definitely not only from the time after 1728 the ground floor arch descends, which consists of a single barrel vault, reaching half the depth of the building (Fig. *2.9*). It belongs to the, in 1726, burnt down construction, its appearence differed from the today's one.

Explanation. Still on the city plan of Görlitz from 1714 we find a townscape, almost solely showing gable houses, lining the streets of the medieval towns, seamlessly stringing together. Also at the place of Handwerk 15 we see such a gable house, which has the same cubature like the today existing construction, proved by the older barrel vault. So the straight house had not been merged with other ones, as common in the early modern period. The process of turning the roof, from gable to eave because of a better fire prevention, confined itself only to the building Handwerk 15, whereas the fire of 1726 required extensive building work anyway.

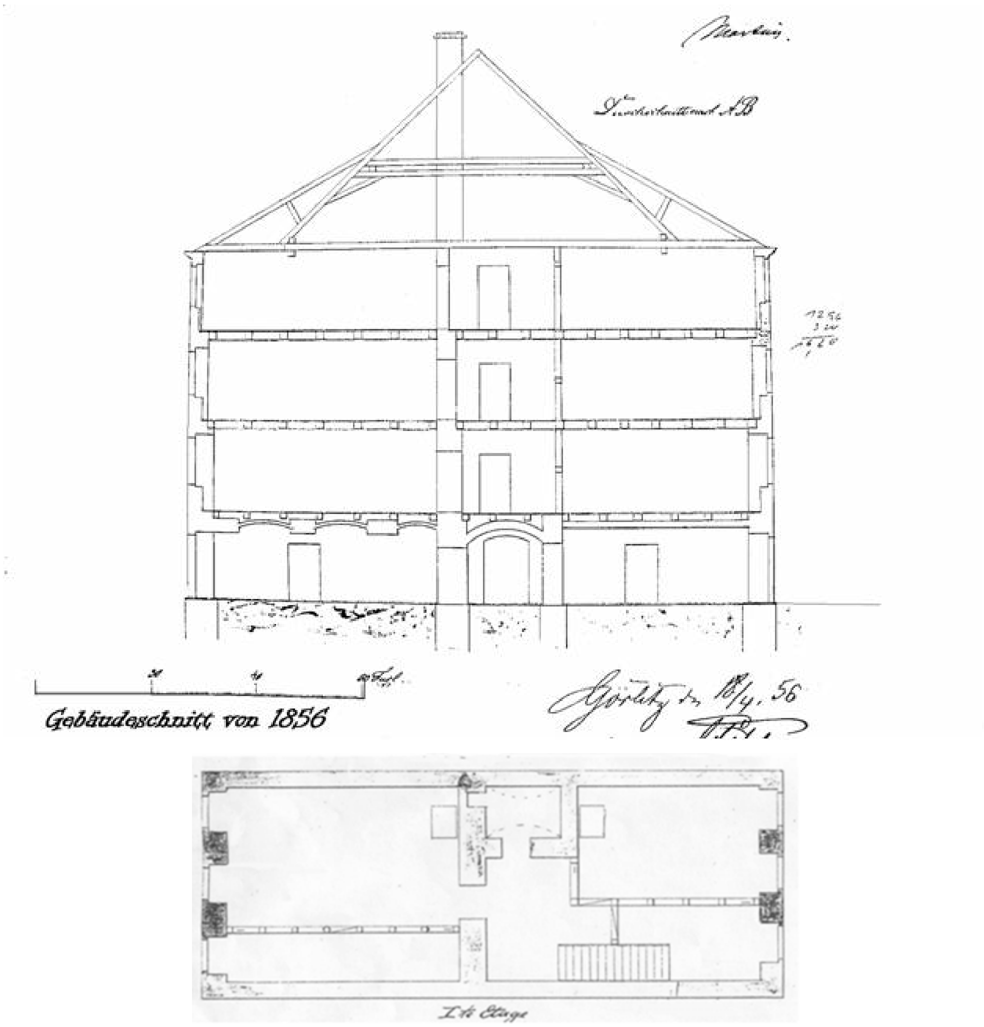


Figure 2.2: section and floor plan from 1856.

At Handwerk 15 the whole substance of the predecessors building's ground floor is preserved. Beside the mentioned vault also the rear room belongs to this. Potentially the exterior and interior walls of the lower three floors are not only from 1728. Perceptions refer to this have to be abandoned to a detailed building research. The ground floor vault without doubt dates from the time around 1600. The predecessors building, the gable house, can be dated back to the Renaissance.

Utilization Adaption

Despite preserved predecessor buildings, and also if they would not have been survived, the today's construction has a building historical value. In its outer appearence it is characterized by baroque, whereas the rooms looking to the street, obtained unaltered in their structure. A conversion in 1856 implicated modifications.At this time the façade had been newly troweled and a forth storey had been added. The collar beam roof from 1728 did not disappear. But it got a new appearence employing oversized firrings (**Fehler! Verweisquelle konnte nicht gefunden werden.**Fig.#). Because of the insufficient roof pitch blowing snow could get into the attic. This stress of humditiy particularly led to moisture damages in the eave areas and to attacks of dry rot at the roof and the third floor. For that reason the roof truss had been rebuilt in 2003 employing all usable parts of the construction.

Idependently from the results of a detailed building reearch, the visible, extensive structural substance of the 16th century at the ground and the first floor has to be pointed out. [Auf den im südlichen Hausteil befindlichen Keller mit Tonnengewölbe (teilweise sind Spuren der Schalungsbretter zu erkennen) sind möglicherweise noch älter.]

The inclusion of the street wall to the barrel vault in the ground floor indicates that this wall is younger and indeed from the reconstruction after the fire in 1726. Also the simple plank ceilings in two of the rooms in the first floor deserve attention (Chapter 3.3).

Major interventions happened in the 1970s. These especially concerned the rear rooms and the old staircase. The latter, originally in the middle of the building at the right fire wall, made way for a reinforced concrete staircase at the courtyard side. Several reinforced concrete ceilings had been installed. In the area of the front rooms a chimney with five tracks was installed. Most of the interior walls were newly built and troweled. Due to the installation of the gravitational heating system, with its feed lines and the heavy cast-iron radiators, and the electric wires, the old plasters were eliminated almost completely. In the apartments the old planking was destroyed by the screwing of chipboards.

Evaluation of the Characteristics of being a Monument

The property of Handwerk 15 is capable of being a monument. This results from its historical and town planning importance, which stand in an inseparable context with the town history of Görlitz.

The property has a town planning importance. On this "…it is about the preservation of defining buildings for the appearence of a street, a square or a whole town" [4]. Doubtlessly Handwerk 15 is a defining building for the appearance of whole the proximity. It is part of the closed structure of the lane Handwerk, which defines the townscape of Görlitz and which is typical for this. The public street space of the Handwerk is simple, but in this simplicity agelessly historic and but not historical or even modern.

The Handwerk 15 is significant for the urban planning history, the building history and the appearence of Görlitz. Also after the renovation the old buidling will have a monumental protection value, i.e. there is a public conservation interest. This stomach for the preservation of the property Handwerk 15 is based especially on its scientifical-documentary value. The building exhibits substance of various centuries – from Renaissance to baroque to the 19th century. It is a veritable lesson in the matter of urban and building history. The base is the strait renaissance building, its roof is „rotated" and which after a fire sustains in parts in a baroque buidling. This one again was renewed and renovated in the 19th century before the time of historism refering to clichés. The windows are baroque in shape and assembly. Thereon nothing changed since 1728, as plans prove (except the addition of the third floor) (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Deforming modification confine itself to the interior of the upper floors looking to the backyard. Whole the exterior surface, the structure of the rooms looking to the street and the roof, in its modification of 1856, are unaltered. So the condition of 1728 dominates.

The building is part of the block perimeter structure of the lane Handwerk, its conservatorial value bases on character of coherence and originality. Not only the historical stock of buildings but also the pavements consisting of big granite panels contribute to this. While evaluating a single monument like Handwerk 15 also the affiliation to the street, which is of extrodinary conservatorial value in this case, is to be considered in an overall context. Insofar the building has an importance for the surrounding and the appearance of the town. It is not possible to imagine the old town of Görlitz without this component of the townscape [fig. 2.1].

2.2.3 Building consistency

Building consistency		
(photos)	Building structure	#
	Internal partition	#
	External finishing	#
	Number of floors above ground	3
	Number of basement floors	1
	Covered area	#
	Numbers of rooms	#
	Gross area	#
	Net area	#
	Heated surface	#
	Surface cooled	#
	Heated volume	#

2.2.4 Building Energy consumption

Building Energy consumption			
Electricity	**Years**	**Consumption (kWh)**	**Cost (€) (average cost €/kWh)**
	#		
Diesel	**Year**	**Consumption (l)**	**Cost (€) (average cost €/l)**
Gas	**Years**	**Consumption (mc)**	**Cost (€) (average cost €/mc)**
Gecam	**Years**	**Consumption (l/mc)**	**Cost (€) (average cost €/mc)**

2.3 Constraint condition and protection

2.4 Selected area of intervention

If building as a whole is composed of different building blocks, you can break down the analysis for different functional area.

2.4.1 Functional area: Area 1 (name or function)

Functional area consistency		
Functional area 1:	Height interpolated average net (m):	#
(Plans and Photos of the rooms)	Surface area (Gross/Net) heated (mq):	#
	Volume (gross/net) heated (mc):	#
	Opening to the public (from/to; hours /day; temperature set-up):	#
	Hours of working (from/to, hours/ day; temperature set-up):	#
	Hours of air conditioning (from/to; hours/day; temperature set-up)	#

2.4.2 Functional area: Area 2 (name or function)

Functional area consistency		
Functional area 2:	Height interpolated average net (m):	#
(Plans and Photos of the rooms)	Surface area (Gross/Net) heated (mq):	#
	Volume (gross/net) heated (mc):	#
	Opening to the public (from/to; hours /day; temperature set-up):	#
	Hours of working (from/to, hours/ day; temperature set-up):	#
	Hours of air conditioning (from/to; hours/day; temperature set-up)	#

3 Report on status pre-intervention

3.1 Analysis and monitoring results

3.1.1 Structural analysis and assessment of moisture

Outdoor and indoor climate

The thermal and hygrothermal behavior of construction and the entire building will be affected by the following parameters: air temperature, relative humidity or partial pressure of water vapor, direct and indirect radiation, diffuse sky radiation, driving rain and air pressure.

For a building's physical components and building design a quantification of these external climatic parameters required. To record the outdoor climate directly in the urban area a meteorological station was installed on the roof of the building (see Fig. 3.1).

The indoor climate is measured in every room by a temperature / humidity sensor.

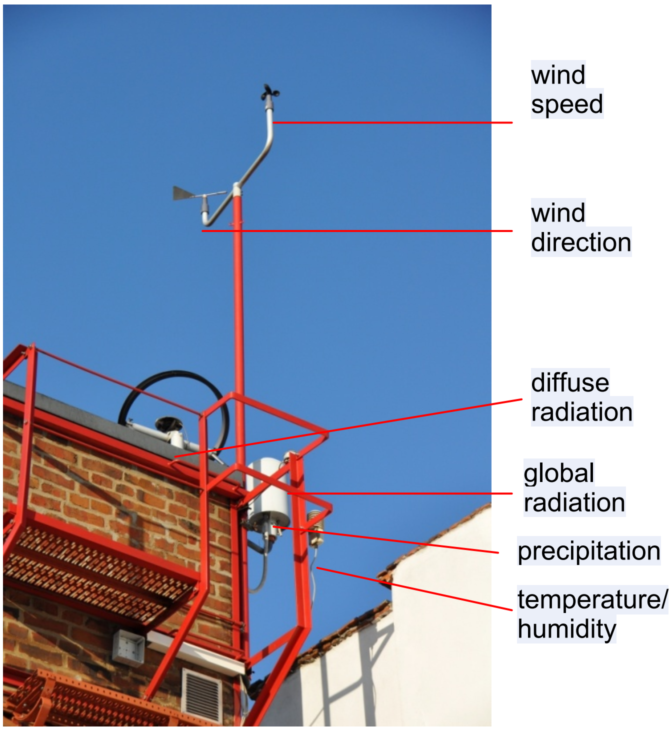


Figure 3.1: Meteorology station.

We also compare the data from the weather station of the German Weather Service of the stadium with the data of Görlitz weather station on the roof of the building “Handwerk 15”.

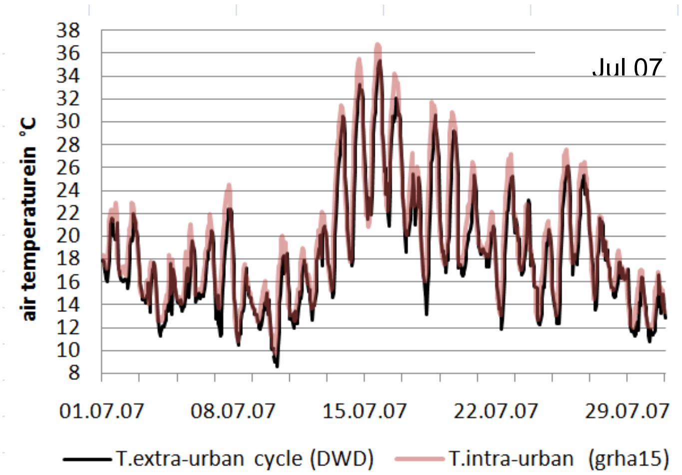


Figure 3.2: Air temperature “Handwerk 15” (intra-urban) and Station DWD Görlitz (extra-urban cycle) in July 2007 in °C.

Fig. 3.2 and Fig. 3.3 show examples of the progress of the air temperature at the “Handwerk 15” (intra-urban) and the outside air temperature of the station DWD Görlitz (extra-urban cycle) for July 2007 and January 2008. The maximum and minimum temperature are around 1 K higher in the urban range. Concerning the building itself, there are additional temperature differences between the storeys and the north and south facades.

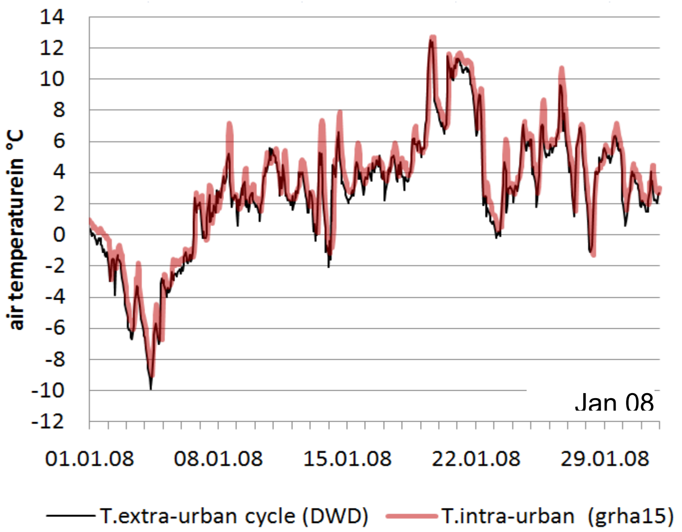


Figure 3.2: Air temperature “Handwerk 15” (intra-urban) and Station DWD Görlitz (extra-urban cycle) in January 2008 in °C.

Measuring sections in the building construction

In the building installed over 10 measuring sections in the construction.

As an example, the measuring path in mixed masonry with interior insulation, exterior view presented 2nd floor North is shown (see Fig. 4).

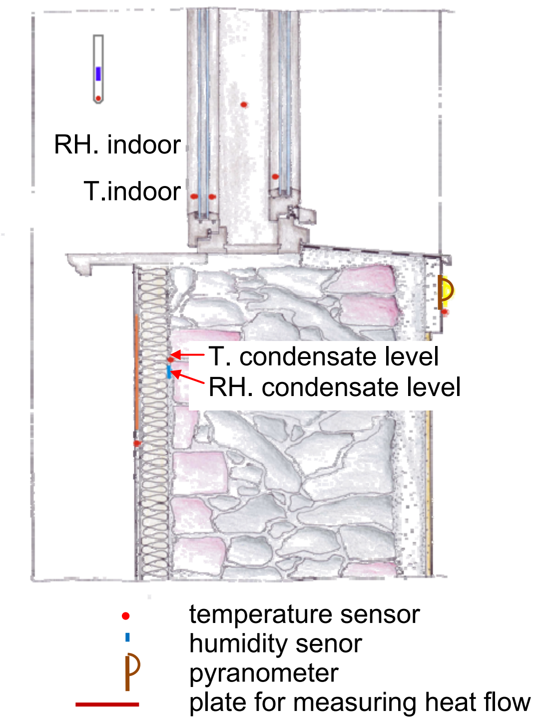


Figure 3.4: External wall insulation, walls were improved with interior insulation (5 cm of calcium silicate) and 3 cm of outdoor insulation plaster. To monitor humidity and temperature conditions in the wall, miniature sensors (humidity, temperature, heat conductivity) were installed.

The relative humidity on the cold side of the insulation was in January 2008 on its maximum of 85%. Although the outside temperature fluctuates greatly (see Fig 3.5), is the temperature on the cold side of insulation almost constant (see Fig 3.6).

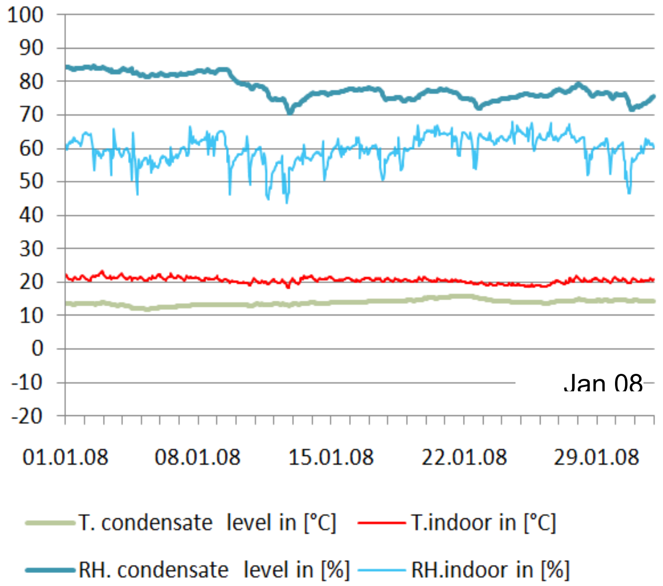


Figure 3.5: Kitchen on the 2nd floor, temperature and humidity of the indoor climate and humidity and temperature conditions in the wall, January 08.

Apparently the higher relative humidity at the cold side of the interior insulation passes through the permeable structure to the level of relative humidity of the interior in July 2007 back (see Fig 3.6). At the extreme heat wave between July 15th and 20th is the temperature at the cold side of insulation is lower than the room temperature. This means that even in the niche with a smaller wall thickness the mass of the building still accounts for buffering the indoor temperature.

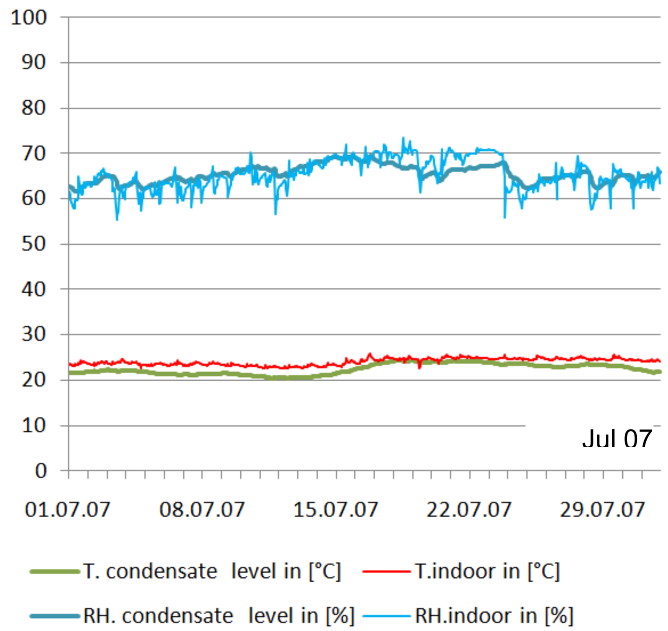


Figure 3.6: Kitchen on the 2nd floor, temperature and humidity of the indoor climate and humidity and temperature conditions in the wall, July 2007.

Analog is the brick wall with thermal insulation systems built, exterior 1nd floor south and compound wall with EIFS, exterior wall 1st floor south. This experiment points to the effectiveness of EIFS. The mass of the building used for the energy storage is improved through the application of EIFS (see Fig.12). In the 2nd floor are 4 test sections with different insulations as a rafter insulation (hemp, cork and clay-plate insulation) installed. Here, the impact on the indoor climate is investigated particularly in summer.

Fig. 7 shows an example of the progress of the air temperature, surface temperature and the temperature in the box-type windows (see Fig. 7). The temperature in the box-type windows is over 50 °C and the surface temperature is higher than the indoor temperature.

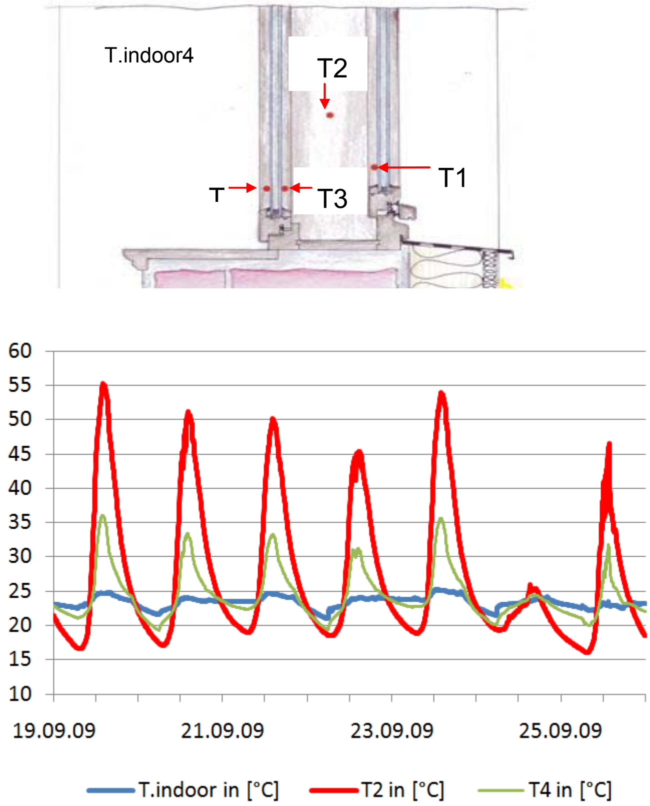


Figure 3.7: 1st floor south, box-type windows, temperature of the indoor climate conditions in and on the box-type windows.

3.1.2 Analysis of architectural elements

Renovation and repairs

The energy measures and maintenance activities contribute to sustainable reconstruction of the cultural heritage as well as the restoration. They are a prerequisite for continuing (re-) use of these historic buildings while they meet the current requirements. The cubature of the previous baroque building had been completely intact. The building “Handwerk 15” is urban history, architectural history and urban momentous. The historic building could be saved from decay. The appearance after the energetic reconstruction is geared to the construction period.

Figure 3.8: Building at “Handwerk 15” before renovation.

Figure 3.9: Building at “Handwerk 15” after renovation.

This unique opportunity was used: with the recontruction the building was aesthetically upgrated (see Fig. 3.8 and Fig. 3.9). The restorer praised the plan as follows: "In view of the recent heavy interventions the house gets back a face, as in this or a similar type has been created at build time.“ In the northern area of the 1st floor was the representative room of the building. The restoration of this wood beam ceiling from the 17th Century represents a responsible approach to the cultural heritage (see Fig. 3.10). By a special dating procedure the year cut of the ceiling could be determined to 1727.

Figure 3.10: Restoration a wood beam ceiling from the 17th Century.

The building was in an uninhabitable condition. The long vacancy and the leak of roof construction have led to numerous damages. The roof had a real dry rot (Fig. 3.10). Many building parts were not stable. For this reason, all work had to be carried out without the use of machinery. On the south side was in the basement area of an approximately 2 m deep wall built at a distance of 1 m. The existing exterior wall was permanently ventilated (see Fig. 3.11, r + i).

The heavily damaged ceilings of the second floor had to be removed and replaced by brick ceilings. The old roof structure was also not stable enough. It had to be pull down and the wood from the old roof was used for the new roof structure.

Figure 3.11: Roof structure and ceilings with real dry rot.

Overview of energy measures

Necessary building repairs were combined with the thermal protection. In this way, an economic energy restoration was led. The energy conservation measures are highlighted in the cross-section view shown in Fig. 12, and listed in the table below:

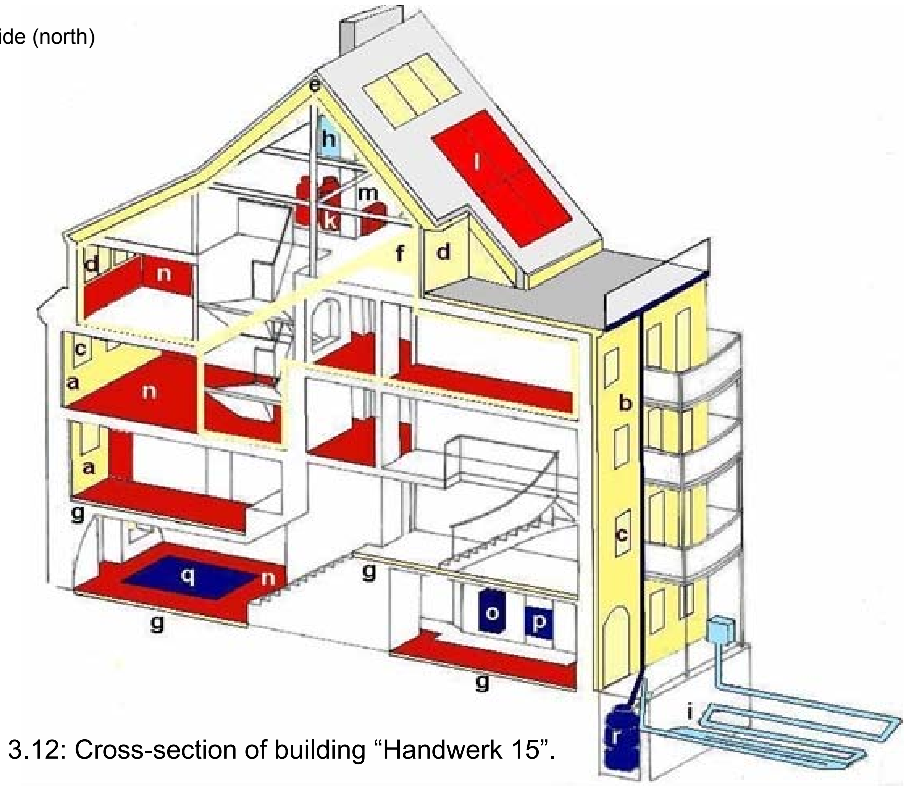


Figure 3.12: Cross-section of building “Handwerk 15”.

Table 3.1: Overview of insulation measures

Insulation measures		U [W/m²*K]
a	Outer wall (facing the street) with capillary interior insulation that is open to diffusion and made of calcium silicate:	0,40 – 0,60
b	Outer wall (facing courtyard) exterior insulation finishing system (EIFS) that matches the building's appearance:	0,20 – 0,25
c	Wooden box-type windows with double glazed insulating solar glass:	0,75
d	Wooden windows with triple-glazed insulating solar glass:	1,10
e	Roof with hemp insulation between the rafters and clay-plate insulation under the rafters:	0,15
f	Manufacture of fire-resistant walls and insulation to adjacent buildings with calcium silicate:	0,4 – 0,70
g	Downstream tempered zone with two insulated ceiling layers:	0,30 – 0,50

Outer wall with capillary active insulation (facing the street)

Currently the multilayered external insulation are not accepted on such high quality heritage buildings, so capillary active indoor insulation, which is open to diffusion and made of calcium silicate, was combined with conventional insulating plaster on the two floors above the ground (see Fig. 3.11). The use of insulation plaster reduces the risk of condensation at the cold side of the interior insulation.

On the first top floor and second top floor, indoor insulation made of calcium silicate was widely-used for the fire-proof walls as well as for insulation of the adjacent buildings (see Fig. 12, f).

Exterior insulation finishing system (EIFS) (facing courtyard)

For the first time in the Free State of Saxony, a permit was issued for the use of exterior insulation finishing system. The insulation consists of a layer of mineral wool and a lightweight mineral plaster on top of a high quality heritage site situated on the facade facing the courtyard. This multilayered insulation retained the overall appearance of the facade by means of a finished plaster with felt board and decorative relief lines. The adaptation of external multilayer insulation suits the needs of heritage sites and is exemplary in this case and deserves to be better known.

Wooden box-type windows

The use of triple glazing for relatively small windows and the required multi-pane window design made the French casement windows unacceptably wide from the viewpoint of heritage conservation and aesthetics. The highly insulating box-type windows produced by project members have a low U-value of 0.75 W/(m²K) thanks to the use of double glazed solar insulating glass (U =1.3 W/(m²K), g =0.76). These windows have a very good sound insulation and an adequate air-tightness. The profiles were designed to look like windows from the 19th century (see Fig. 13 and Fig. 12, c).

Inside *outside*

Figure 3.13: box-type windows, double glazed solar insulating glass.

Wooden windows with triple-glazed

In the dormer of a roof, the more favorable 2-part wooden windows with a 3-pane glazing (see Fig. 12, d) were used. The production of a sufficient air-tightness in lock facing is more difficult.

The noise is in direct comparison to the box windows considerably worse.

Window in the roof

The window in the roof was replaced another consisting of thermally excellent triple glazing.

Figure 3.14: Roof window as second emergency exit, thermally excellent triple glazing, condensation and frost on the exterior, prevention of condensation and frost with external coating Condensation on 2/20/2006.

When the sky is clear, heat losses at night cause condensation and frost to build up on the outer pane. A coating was added to this outer pane to minimize these effects and further improve the window's energy performance (see Fig. 3.14).

Roof

The roof was insulated with hemp between the rafters. To improve protection from summer heat, insulating clay plates were used as insulation under the rafters.

3.1.3 Analysis of technical systems

Overview of technical systems

Court side (south)

Street side (north)

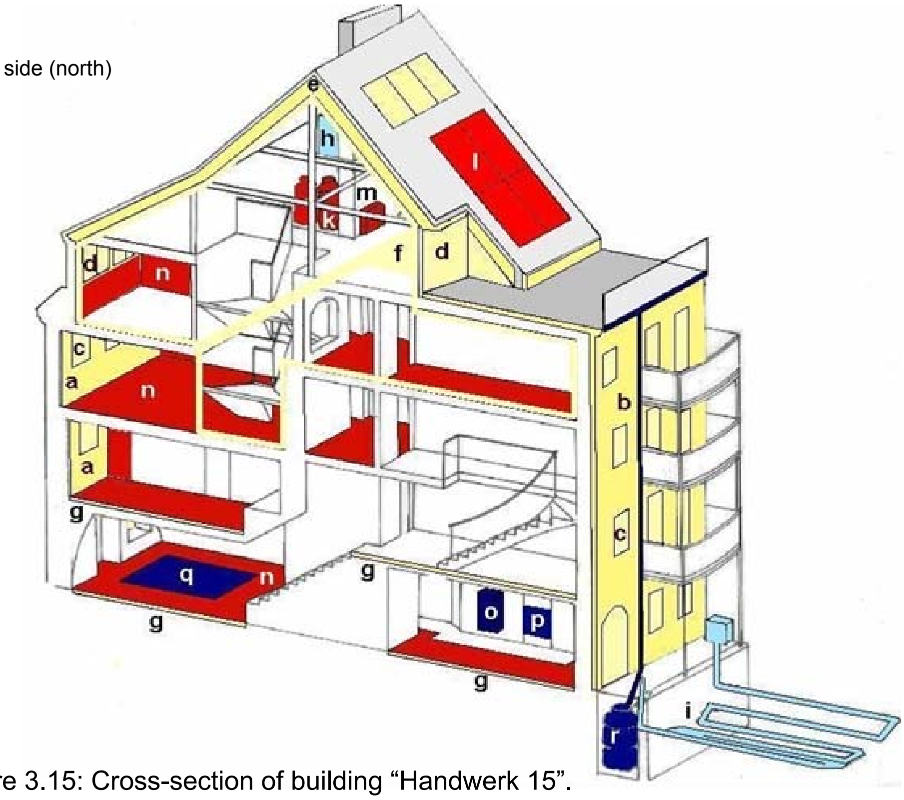


Figure 3.15: Cross-section of building “Handwerk 15”.

Table 3.2: Overview Building service equipment (see Fig.3.15)

Air exchange system with heat recovery		
e	Synthetic counter-current channel heat exchanger, heat recovery rate:	85 to 95 %
f	Geothermal heat exchanger with 35 m of synthetic tubes to preheat air	
Heating equipment		
k	Heater consisting of an 800 L layered storage tank, an 800 L buffer tank, and an instantaneous drinking water heater with stainless steel corrugated piping	
l	Solar collector with 12.16 m2 of vacuum tube collectors	
m	Solid fuel boiler - modem fireplace, hot water output / space heating [kW]:	11,5 /3,4
n	Combination of self-regulating wall and floor heaters	
Drinking water and wastewater		
o	Gray water recovery system with an output of 300 l/d	
p	Wastewater heat recovery with gray water floor heater	
q	Wastewater heat recovery with wastewater floor heater	
r	Rainwater collector system	

Air exchange system with heat recovery

Reducing consumption of primary energy even further would not necessarily pay for itself in terms of transmission heat losses because the heat losses from ventilation would increase at the moment, ventilation is performed up to three times a day manually by opening the windows.

The humidity (without a ventilation system) is too high at 70 %. The temporarily certain CO_2-pollution in the sleeping rooms with over 2000 ppm were too high as well. Therefore the decision was taken to install a ventilation system that exchanges indoor and outdoor air with heat recovery, and this system was installed in the winter of 09/10. Special attention was paid to keeping operating costs down (low power consumption and long service life for filters) when the ventilation system was designed.

Heating equipment

The buffer tank and the layered storage tank are at the centre of the heating system. The volume of domestic hot water was kept at 55 litres. The domestic hot water is heated in flow. A thermal disinfection of to combat legionella is not required. It is saved a lot of energy for water heating.

Figure 3.16: Solar collectors on the roof, side facing the court, south.

The solar collectors placed on the side facing the courtyard side (see Fig. 16, Fig. 18 and Fig. 15, l). The vacuum tubes used have an integrated heat pipe to ensure a high level of efficiency at low temperatures and low solar radiation. In the summer, excess solar heat at tank temperatures exceeding 60 to 70 °C is used to temper the ground floor, reducing summer condensation on that floor. The solar collectors cover more than 50 % of the building's heating demand.

A fireplace with a boiler provides the rest of the heat required (see Fig. 15, k). As the adjacent buildings were expected to remain empty, relatively large heating systems were used (acombination of floor and wall heaters with radiators facing interior walls) (see Fig. 15, n).

3.2 Drinking water and wastewater

In the centre of town, rainwater alone does not suffice to provide the water needed for toilets and laundry in a building with several stories. To a large extent, however, both consumption of drinking water and wastewater production can be greatly reduced if rainwater is combined with a gray water treatment system.

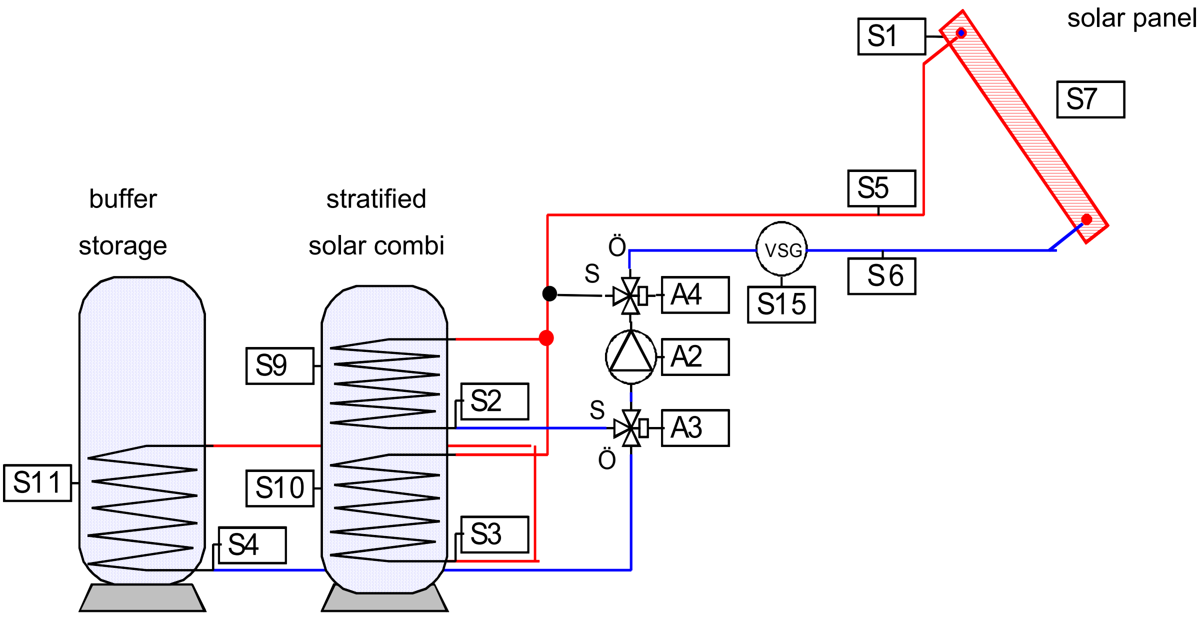
The fully organic gray water system treats the water used in the building for baths and showers so that the water can be reused to clean laundry, clean the building and to flush toilets (see Fig. 17). As the building's energy efficiency continues to increase, the share of domestic hot water in the overall energy consumption also increases. Currently, investigations are being conducted to see how this energy consumption item can be reduced by a heat recovery system using the wastewater in the building's thermal envelope.

Figure 3.17: Gray water recovery system with an output of 300 l/d x:

Solar system control

The uses of freely programmable universal controls facilitate us to program and log many of the control processes for the research project in this building without limitations. These controls enable an exemplary building management (e.g.: the optimization of the operation hours of the pumps, air exchange system etc.) in terms of energy efficiency and costs. This system has proved and tested over 5 years. With this technology many disturbances of the building service can be removed, which would otherwise remain unnoticed in other buildings. The malfunction could be remedied by changing the programming.

Through the network, each regulator accesses over 100 sensors (temperature, flow, radiation can sensor, digital inputs, humidity), the states of the initial functions and outputs and as well to the 3 freely programmable universal controllers UVR 1611. The readouis takes places over 5 data logger. For practical purposes, the programming will be further optimized to give comparable buildings only 1 or 2-controllers.



S1 - S6, S9 - S11	Temperature sensors
S7	Radiation sensor
S15	Airflow sensor
A2	Speed-controlled pump
A3, A4	3-way valves

Figure 3.18: Simplified system diagram of the solar system for the programming and measurement set.

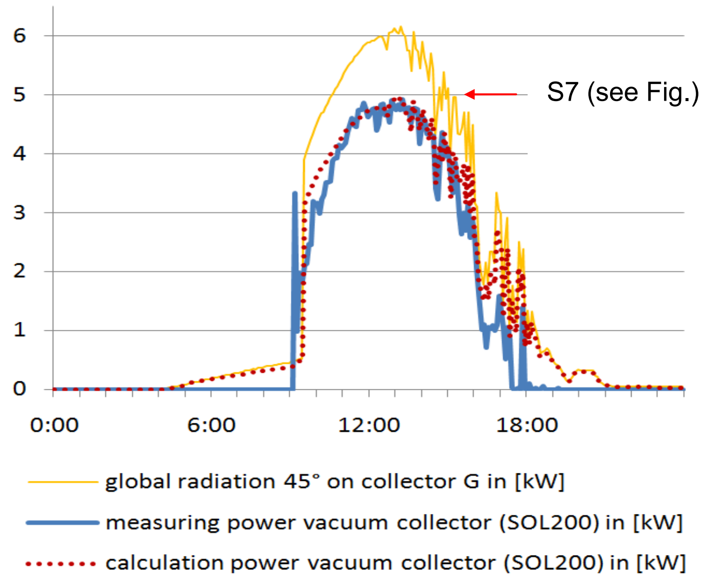


Figure 3.19: Comparison measured and measured performance of the collector.

The Fig. 3.19 shows a good correlation of the measured performance of the vacuum collectors and the calculated power with the parameters of the collector (by manufacturer). With the building simulation the manufacturer dates of the installation engineering components were tested. These formulas were used: (table 3.3)

Table 3.3: Formulas.

$$\dot{Q}_{Solar,cal} = (\eta_0 \cdot G - a_1 \cdot \Delta T - a_2 \cdot \Delta T^2) \cdot A_C \quad (1)$$

η_0	zero loss efficiency	[-]
a_1	heat loss coefficient	W/(m²K)
a_2	temperature dependence of the heat loss coefficient	W/(m²K²)
G	hemispherical solar / global irradiance	W/m²
A_C	Aperture surface area	m

$$T_{panel} = \frac{(T_e - T_{in})}{2} \quad (2)$$

T_{panel} absorber temperature °C

T_e	fluid outlet temperature, sensor S 5 Fig. 17	°C
T_{in}	fluid inlet temperature, sensor S 6 Fig. 17	°C

$$\Delta T = T_{panel} - T_a \quad (3)$$

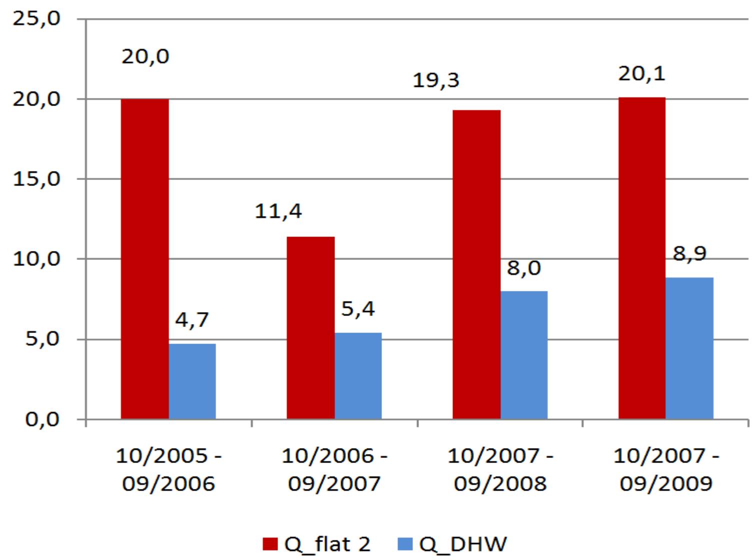
T_a	ambient temperature	°C

$$\dot{Q}_{Solar,mea} = c \cdot \rho \cdot \dot{V}_{VSG} \cdot (T_e - T_{in}) \quad (4)$$

c_{eff}	effective heat capacity	J/(m²K)
ρ	density of heat transfer fluid	kg/m³
$\dot{V}_{VSG}$	volume flow, sensor S 15 Fig. 3.17	l/h

Gross energy consumption

Renewable energy can be used for energy provision. Only for auxiliary power was consumed conventional energy. Consumption for the heating of the building and domestic hot water (DHW) (initially without a ventilation system, gray water system, and the wastewater floor heater) amounted to around 25 kWh/(m²a) in the heating season of 2005/2006 and around 20 kWh/(m²a) in the heating season of 2007/2008 for floor space AN, which brought the building close to the passive house standard.



**10/07 - 09/09 DHW (with the second apartment)*

Figure 3.20: Consumption of energy for heating and domestic hot water (DHW) of the apartment 2 * of the building “Handwerk 15” in Görlitz in the period from 01 October 2005 until 30. September 2009 per heating season in [kWh/m²a].

The large differences in the heating energy consumption are essentially on the temporary vacancy in the neighbouring buildings and only partly due to the outdoor climate (see Fig 3.20).

Given the right partners and enough commitment, it is easily possible to fulfil the low emission standard even with moderate insulation, while keeping a heritage building's appearance in line with historic, protected facades. The approach and the steps taken are exemplary for similar projects. This renovation project managed to successfully combine the requirements of heritage protection and the need for environmental and climate protection.

5 Annex 1 - PHPP calculation for status pre-intervention

The PHPP calculations describe the heating demand before retrofitting and deliver the pre intervention status of the building.

EnerPHit verification


Building:	Apartment building Handwerk 15
Street:	Handwerk 15
Postcode / City:	02826 Görlitzz
Country:	Germany
Building type:	Apartment building
Climate:	Goerlitz_2012 — Altitude of building site (in [m] above sea level): -
Home owner / Client:	Janet Conrad
Street:	Handwerk 15
Postcode/City:	02826 Görlitzz
Architecture:	Dipl.-Ing Janet Conrad, Dipl.-Ing Christian Conrad
Street:	Handwerk 15
Postcode / City:	02826 Görlitzz
Mechanical system:	Dipl.-Ing Christian Conrad
Street:	Handwerk 15
Postcode / City:	02826 Görlitzz

Year of construction:	5th century	Interior temperature winter:	20.0	°C	Enclosed volume V_e m³:	868.6
No. of dwelling units:	3	Interior temperature summer:	25.0	°C	Mechanical cooling:	
No. of occupants:	6.6	Internal heat sources winter:	2.1	W/m²		
Spec. capacity:	108 Wh/K per m² TFA	Ditto summer:	2.7	W/m²		

Specific building demands with reference to the treated floor area

		Value	Unit	Requirements	Fulfilled?*
	Treated floor area	230.0	m²		
Space heating	Heating demand	173	kWh/(m²a)	25 kWh/(m²a)	no
	Heating load	67	W/m²	-	-
Space cooling	Overall specif. space cooling demand		kWh/(m²a)	-	-
	Cooling load		W/m²	-	-
	Frequency of overheating (> 25 °C)	1.7	%	-	-
Primary energy	Heating, cooling, dehumidification, DHW, auxiliary electricity, lighting, electrical appliances	101	kWh/(m²a)	310 kWh/(m²a)	yes
	DHW, space heating and auxiliary electricity	72	kWh/(m²a)	-	-
	Specific primary energy reduction through solar electricity		kWh/(m²a)	-	-
Airtightness	Pressurization test result n_{50}	0.6	1/h	1 1/h	yes

* empty field: data missing; '-': no requirement

EnerPHit building retrofit (according to heating demand)?	no

The PHPP calculations describe the heating demand after retrofitting and deliver the post intervention status of the building.

EnerPHit verification

Building:	Apartment building Handwerk 15
Street:	Handwerk 15
Postcode / City:	02826 Görlitzz
Country:	Germany
Building type:	Apartment building
Climate:	Goerlitz_2005 — Altitude of building site (in [m] above sea level): -
Home owner / Client:	Janet Conrad
Street:	Handwerk 15
Postcode/City:	02826 Görlitzz
Architecture:	Dipl.-Ing Janet Conrad, Dipl.-Ing Christian Conrad
Street:	Handwerk 15
Postcode / City:	02826 Görlitzz
Mechanical system:	Dipl.-Ing Christian Conrad
Street:	Handwerk 15
Postcode / City:	02826 Görlitzz

Year of construction:	5th century		Interior temperature winter:	20.0	°C	Enclosed volume V_e m³:	1245.0
No. of dwelling units:	3		Interior temperature summer:	25.0	°C	Mechanical cooling:	
No. of occupants:	8.3		Internal heat sources winter:	2.1	W/m²		
Spec. capacity:	108	Wh/K per m² TFA	Ditto summer:	2.7	W/m²		

Specific building demands with reference to the treated floor area

				Requirements	Fulfilled?*
	Treated floor area	290.1	m²		
Space heating	Heating demand	**28**	**kWh/(m²a)**	25 kWh/(m²a)	**no**
	Heating load	**20**	**W/m²**	-	**-**
Space cooling	Overall specif. space cooling demand		**kWh/(m²a)**	-	**-**
	Cooling load		**W/m²**	-	**-**
	Frequency of overheating (> 25 °C)	5.7	%	-	-
Primary energy	Heating, cooling, dehumidification, DHW, auxiliary electricity, lighting, electrical appliances	**66**	**kWh/(m²a)**	136 kWh/(m²a)	**yes**
	DHW, space heating and auxiliary electricity	19	kWh/(m²a)	-	-
	Specific primary energy reduction through solar electricity		kWh/(m²a)	-	-
Airtightness	Pressurization test result n_{50}	**0.6**	**1/h**	1 1/h	**yes**

* empty field: data missing; '-': no requirement

EnerPHit building retrofit (according to heating demand)?	**no**

6 Annex 2 - Description of the monitoring system

The metrological screening reaches for the capture of meteorological data at the old town quarter (urban) and the thermal and humidity performance of the building (air temperature and humidity of rooms, surface temperature, material humidity, and temperature profile inside the materials). Furthermore the consumption of primary energy carrier, solar heat production by solar collectors and also the volume flow of supply and used air are recorded.

For the metrological screening at the building two independent systems had been installed. The building control system can also be used for the metrological screening

		Windspeed	Winddirection	Precipitation	Radiation	Rel. humidity sensor	Temperature sensor	Barometric pressure sensor	Heat flow meter	window A-contact	Volume Flow	Heat quantity counter	Electric meter (Ahlborn)	Output variables	**Sum**
Ahlborn	Weather station	1	1	1	2	2	2	1							10
	Indoor climate					20	20								40
	User conduct									27				19	46
	Measuring sections														
	1. external wall 3rd floor north				1	1	8		1						11
	2. external wall 4rd floor south				1		6		1						8
	2. external wall 2nd floor south						3		1						4
	4. external wall 1st floor north						6								6
	5. internal wall 1st floor north						4								4
	6. roof attic floor north					2	4		1						7
	7. roof attic floor north					2	4		1						7
	8. roof attic floor north					2	4		1						7
	9. roof attic floor south						4		1						5
	10. window 3rd floor north						5								5
	11. window 4rd floor south						4								4
	12. window attic floor north						4								4
	Building connections										1		1		2
	Measurement instrumentation												1		1
Controller	Solar heating system				1		14				1	1	1	4	22
	Circuit of hot water						2				1	1	1	1	6
	Solid fuel boiler						7				1	1	1	4	14
	Heater loops						8				3	3	1	14	29
	Air exchange system					6	8						1	6	21
	Domestic hot water						3				1	1			5
	Gray water recovery system						6				3	3	1	1	14
	Wastewater heat recovery with wastewater floor heater						3		1		1	1	1	2	9
	Sum	1	1	1	5	35	129	1	8	27	12	11	9	51	291

Figure 6.1: Overview measuring points

2. Measuring capture for inner and outer climate and structural design

For the inner and outer climate, the user behavior and the 12 sections of measurement it has been reverted to a pure measurement capturing system.

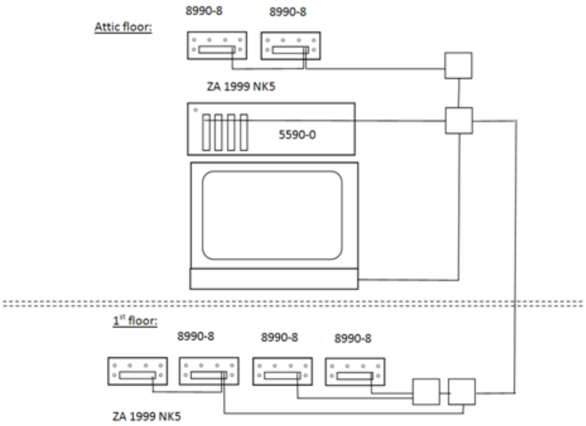


Figure 6.1: Ahlborn – network arrangement

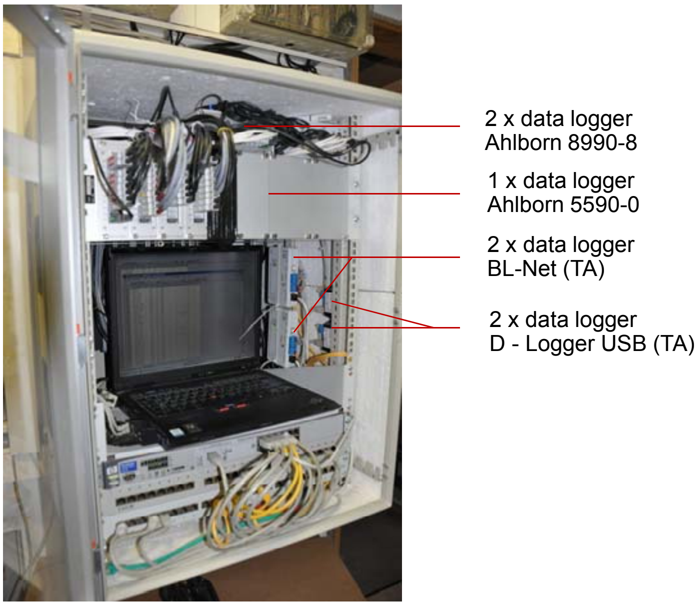


Figure 6.2: Attic floor, server-side data collection.

2.1 Climate measurements

The thermal and hygroscopic behavior of the materials and the whole building is influenced by the following outer climate parameters:

1. Air temperature
2. Relative humidity resp. partial pressure of steam
3. Direct and indirect radiation
4. Long wave emission
5. Driving rain (element out of wind and precipitation)
6. Air pressure

Climate measuring station

For a building and material measurement in the way of building physics a quantification of these outer climate parameters is required.

2.2 Measurement of inner climate

Sensors

The inner climate is captures by the building management system via the UVR Controller with the temperature/humidity sensors RFS-DL and the control panel CAN Monitor with integrated temperature/humidity sensor. For the building simulation the inner climate management is supplemented by the very exact capacitive humidity sensors Type FHA646 of the firm Ahlborn.

Temperature/humidity sensors RFS-DL | CAN Monitor with integrated temperature/humidity sensor | very exact capacitive humidity sensors Typ FHA646

Figure 6.3: Sensors for inner climate

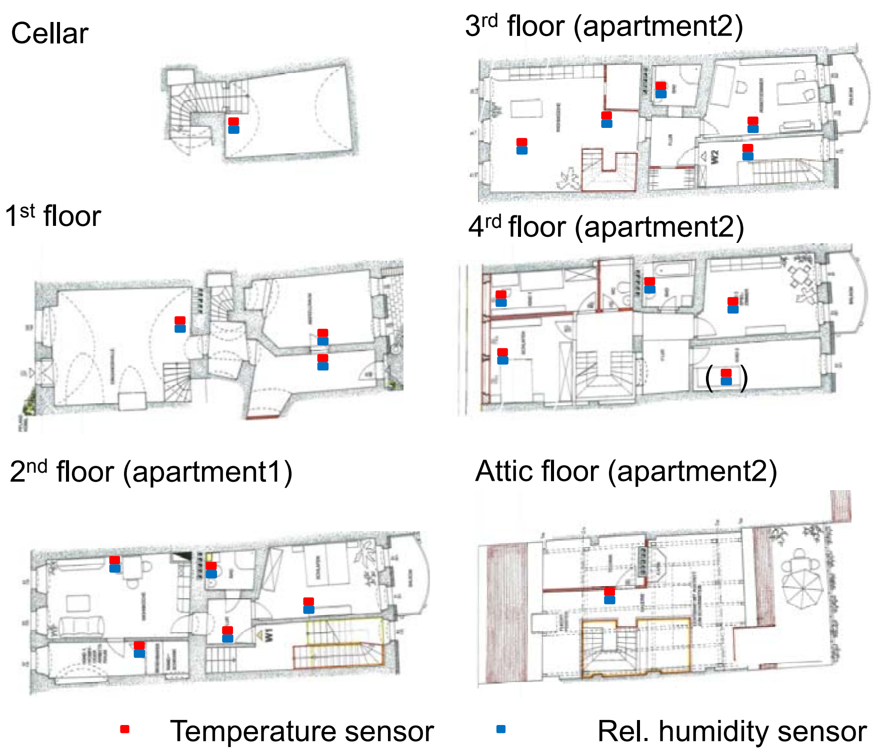


Figure 6.4: Positions of the Sensors for inner climate.

2.3 Measuring sections 1-3 installed into external wall constructions

The illustration of the measurement data employing project pictures and diagrams, helps to discern the coherence and potential disfunctions in capturing measurement data more easily.

Diagrams - Illustration

For the sections of measurement and the recording of the outer and inner climate the project diagrams can be produced with the program AMR WinControl (Figure 6.5).

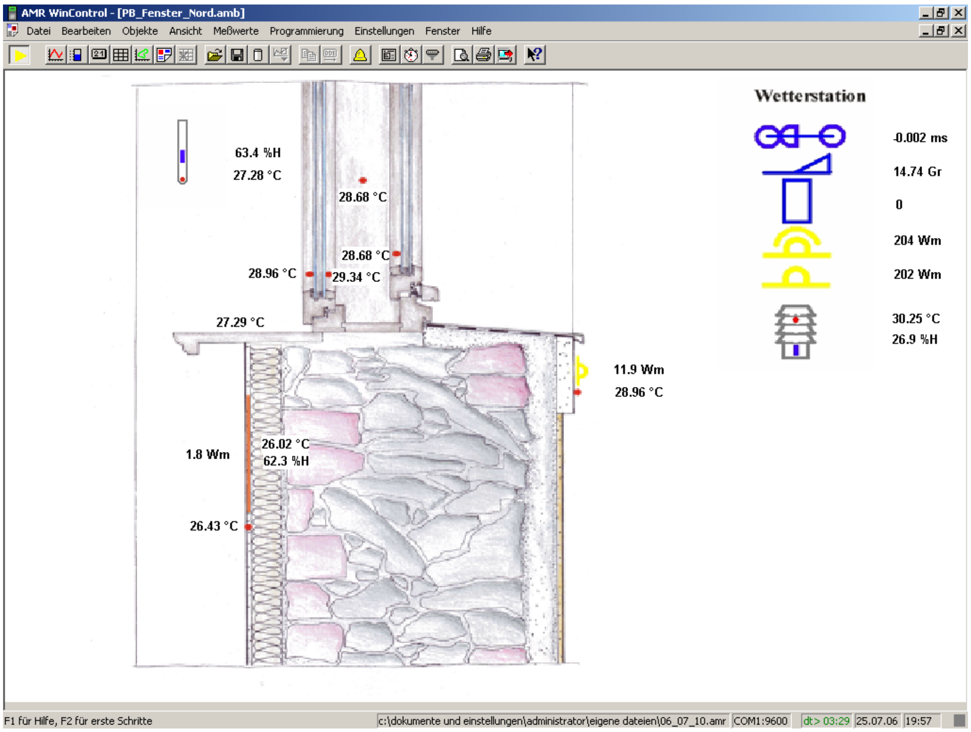


Figure 6.5: Project image, External wall insulation, walls were improved with interior insulation (5 cm of calcium silicate) and 3 cm of outdoor insulation plaster. To monitor humidity and temperature conditions in the wall, miniature sensors (humidity, temperature, heat conductivity) were installed.

Location sections of measurement exterior wall

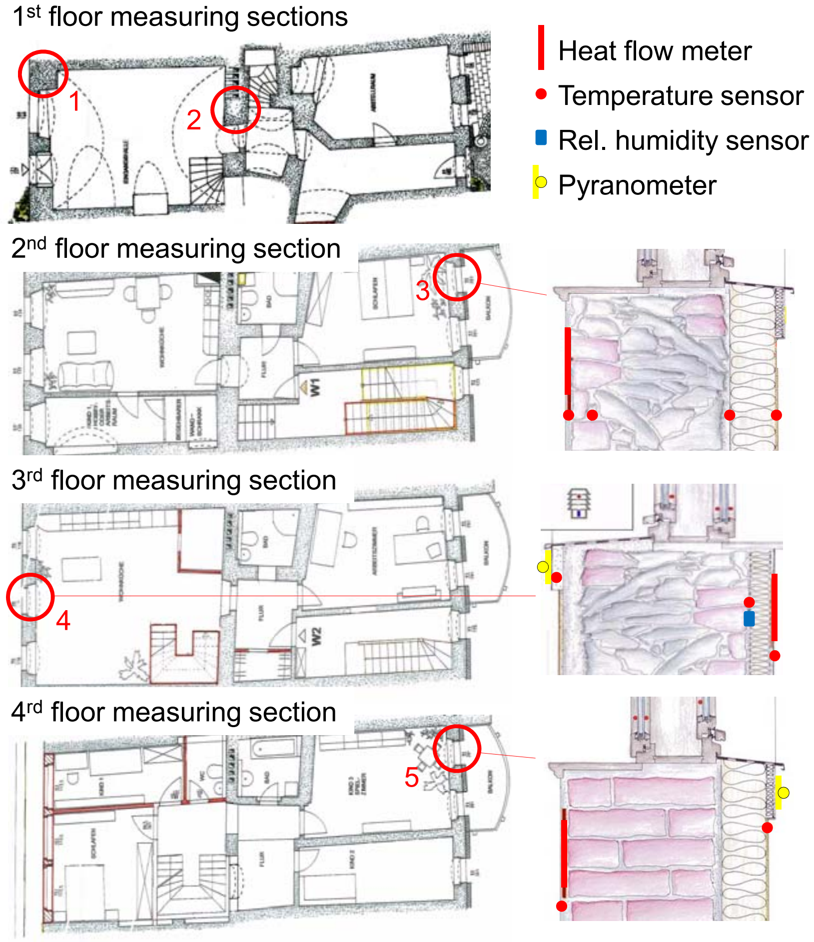
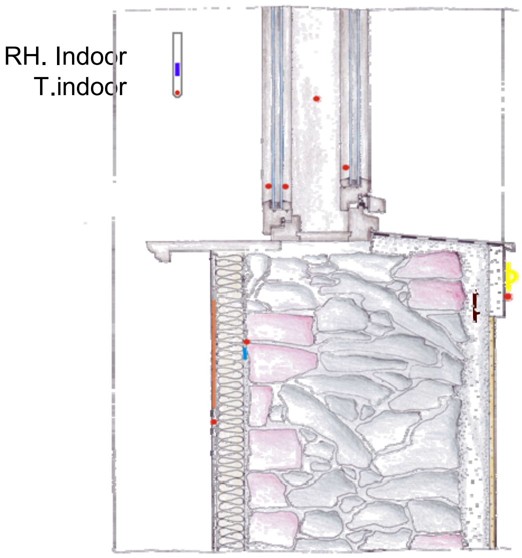


Figure 6.6: Overview measuring sections of the exterior walls

Example exterior wall: Mixed brickwork with internal insulation, exterior wall 2th floor north



- Temperature sensor
- Humidity senor
- Pyranometer
- plate for measuring heat flow

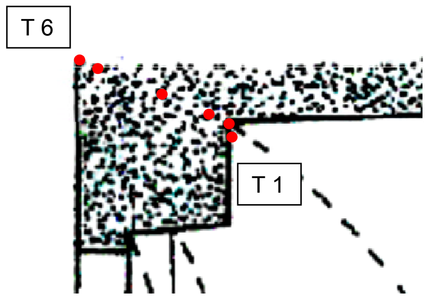
Figure 6.7: External wall insulation, walls were improved with interior insulation (5 cm of calcium silicate) and 3 cm of outdoor insulation plaster. To monitor humidity and temperature conditions in the wall, miniature sensors (humidity, temperature, heat conductivity) were installed.

Measuring sections 4-5 installed into internal wall constructions

The sections of measurement Mixed brickwork with internal insulation, exterior wall basement north and Mixed brickwork, interior wall basement are located in the foyer with the barrel vault. The foyer at the basement serves as tempered zone for the dwellings.

These sections of measurement consist each of surface temperature sensors and temperature sensors into the wall. With them the energetic evaluation of the super-heavy basement is supposed to happen.

The surface temperature sensor is located directly under the thin-layer plaster. In depth of 3 cm, 10 cm and at the core of the wall there is one sensor for the evaluation of the inner and outer climate each (Figure 6.8).



T1 ... surface temperature, wall (interior)
T2 ... temperature, 3 cm deep, wall (interior)
T3 ... temperature, 10 cm deep, wall (interior)
T4 ... temperature in the middle, wall
T5 ... temperature 10 cm deep, wall (exterior)
T6 ... surface temperature, wall (exterior)

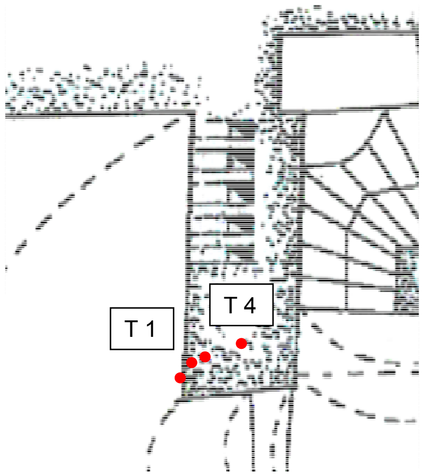


Figure 6.8: Measuring sections 4-5 installed into internal wall constructions.

Measuring sections 6-9 installed into the roof construction

There had been installed standard measurement sections, analogously to the internal insulation at the second floor for the evaluation of the thermal/hygrothermal behavior of the under rafter insulation, especially for the improvement of the summerly thermal protection

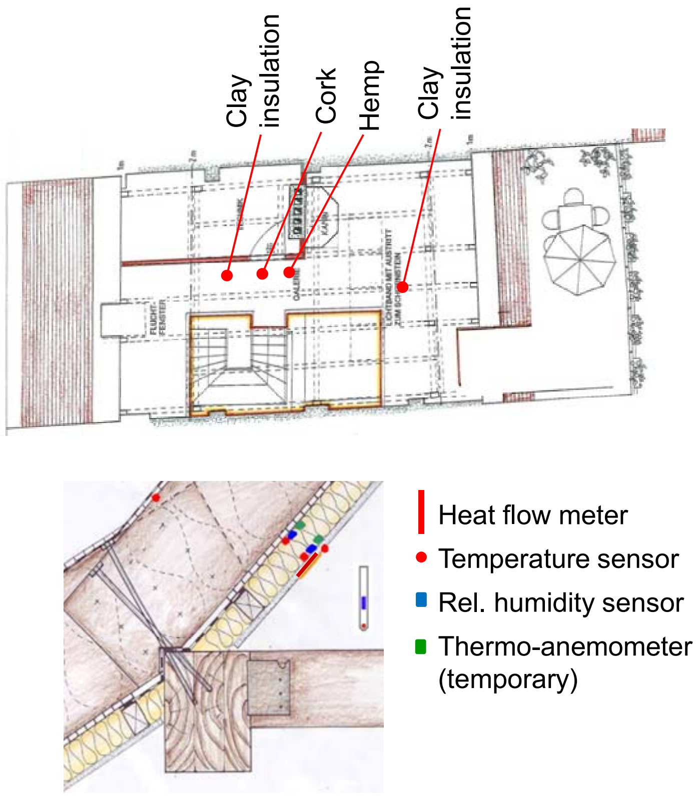


Figure 6.9: Measuring sections 6-9 installed into the roof construction.

At the attic there are measurement sections monitoring the under rafter insulation with clay heat insulation panels (WDP, 6th measurement section), cork tile (EKP, 7th measurement section) and hemp (8th measurement section) located at the north side.

At the south side of the roof the 9th measurement section is equipped without temperature/humidity sensors.

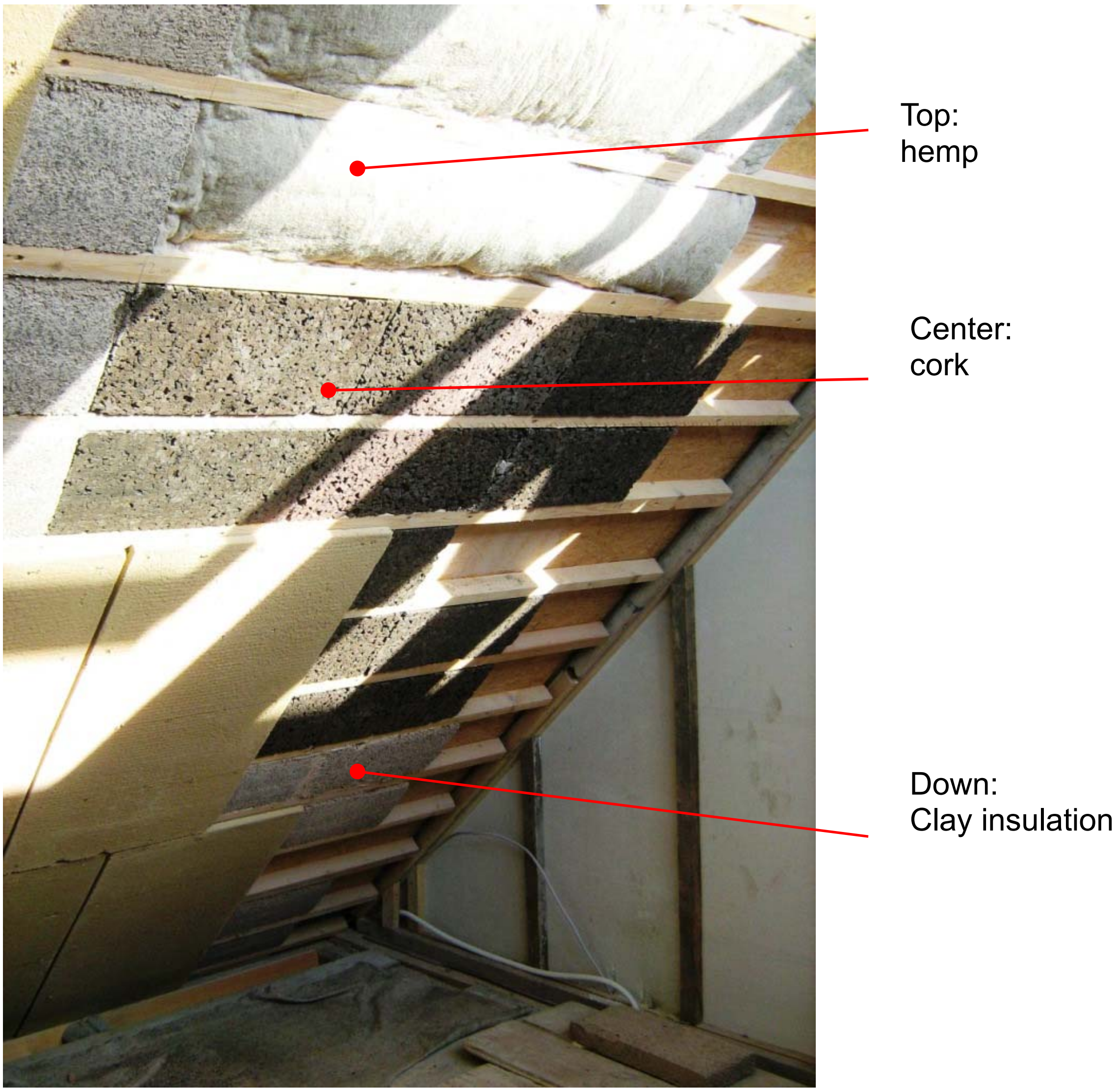


Figure 6.10: Measuring sections 6-8 installed into the roof construction.

Figure 6.11: Measuring sections 6-8 installed into the roof construction.

Measuring sections 10-12 installed at the windows - Example measurement section box-window: Location and structure of the measurement section box-window, 2th floor

At the windows of the north and south side there is one measurement section each.

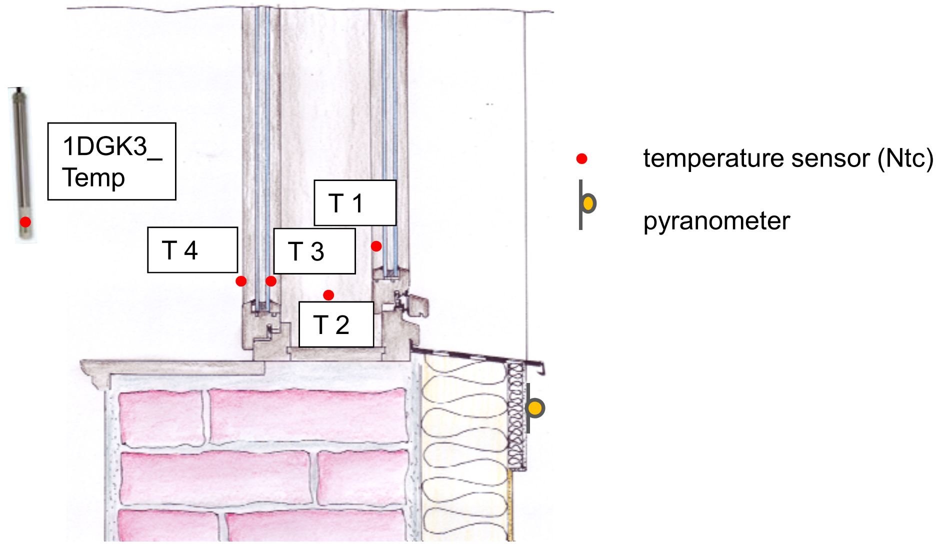


Figure 6.12: 1st floor south, box-type windows, temperature of the indoor climate conditions in and on the box-type windows.

The windowpane surface temperature and the temperature between the two windows are recorded online. This data are completed by outer and inner climate.

For the capturing of the surface temperatures the Negative Temperature Coefficient (NTC) Thermistors had been glued to the glass with special clear silicone.

Installation of modern control

The freely programmable universal control UVR 1611 of the firm „Technische Alternative - elektronische Steuerungsgerätegesellschaft mbH" can be calibrated for every hardware configuration. Eight UVR 1611 and three CAN-Monitors had been installed in the network. By way of the network every control panel is able to access the sensors (temperature, humidity, volume flow, radiation, digital inputs), the initial states of the functions and outputs as well as the three control panels. The readout works via data logger.

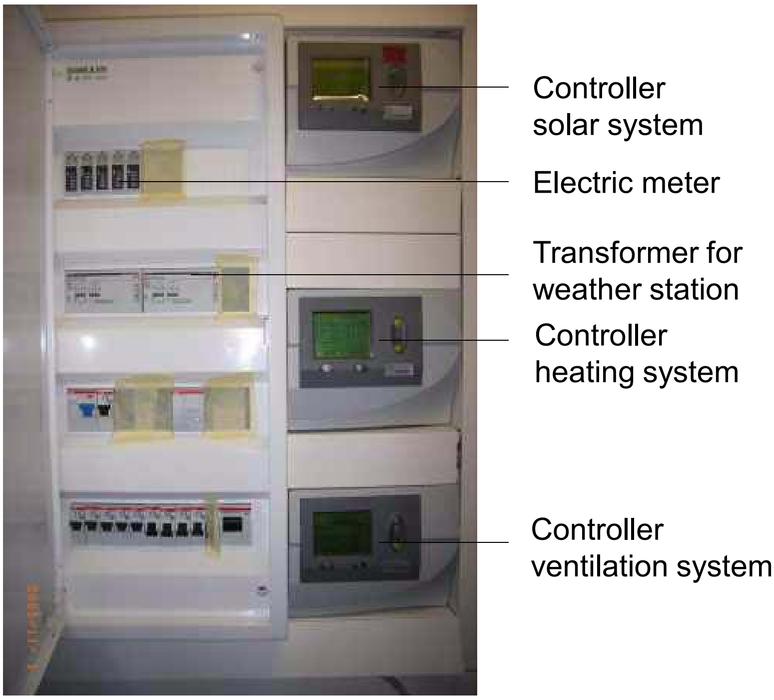


Figure 6.13: Attic floor, the freely programmable universal control UVR 1611

Programming

With these controllers it is possible to program all necessary control processes in the building without limitation for the research project on your own employing the programming software TAPPS (Figure 33).

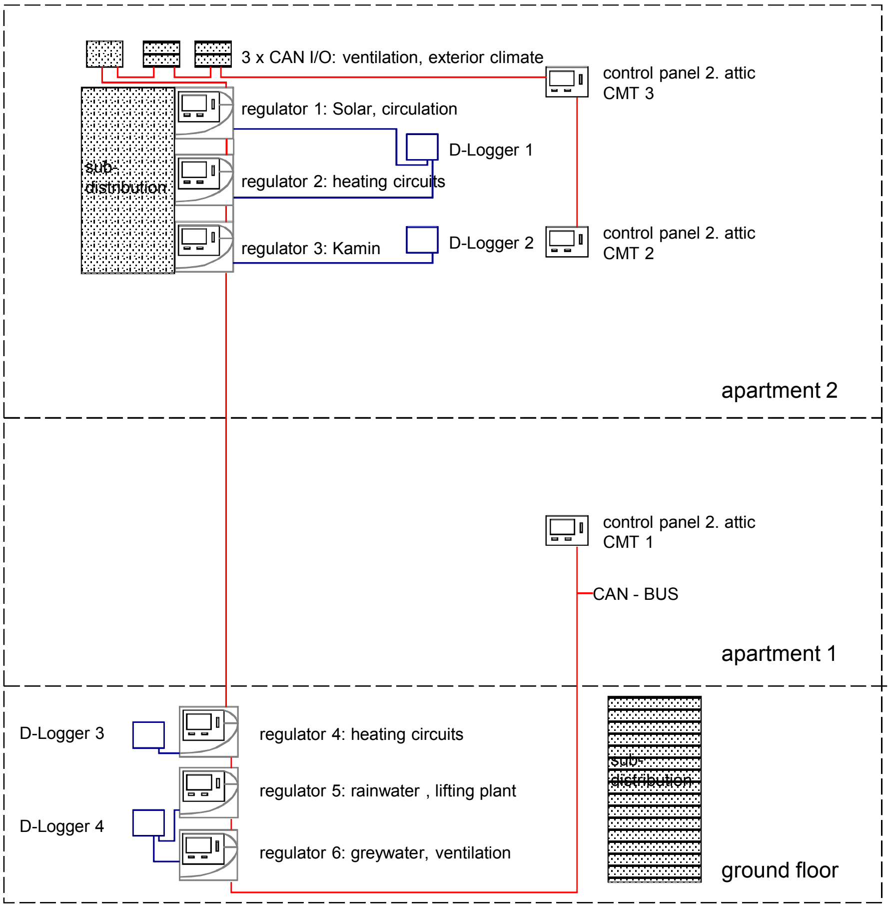


Figure 6.14: Network arrangement of the freely programmable universal control UVR 1611.

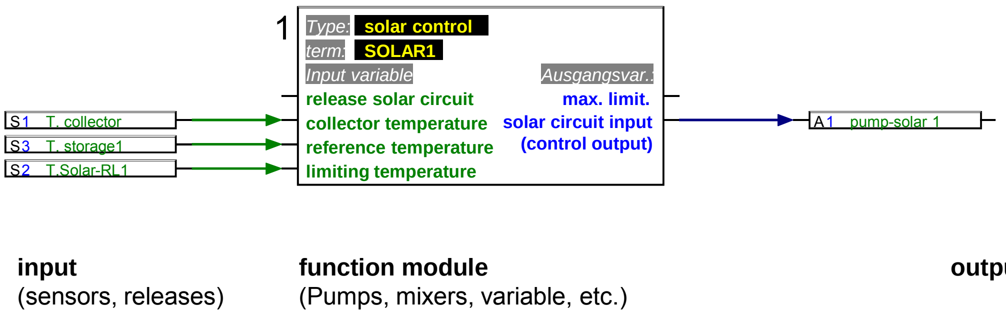
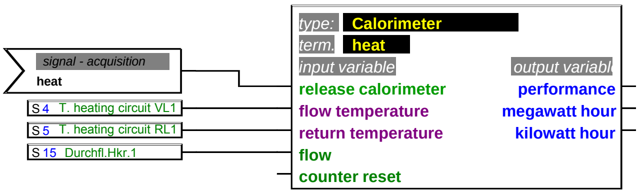


Figure 6.15: Basic schematic of the programming software TAPPS.

Principle capture of energy

With the function heat meter two temperature sensors (Pt 1000) and a volume flow sensor (VSG) are combined to a heat meter with a high resolution of the instantaneous power and an ongoing metering of the amount of energy. Among others the calibrating program of the UVR 1611 control is remarkable.

calorimeter heating



calorimeter cooling

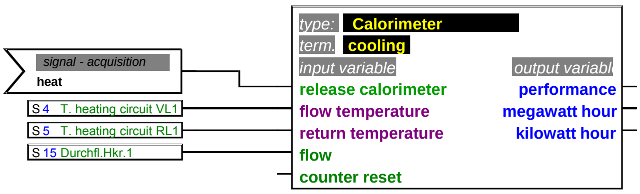


Figure 6.16: TAPPS, basic schematic of the heat quantity counter.

Via a bootloader the control system of the UVR 1611 is connected to a LAN network for remote controlling and visualization. The illustration of the facility scheme as a base for the programming is also used as online scheme for displaying it in browsers.

Function control

With the help of the program WINSOL the progress of all important input and output conditions are analysed daily.

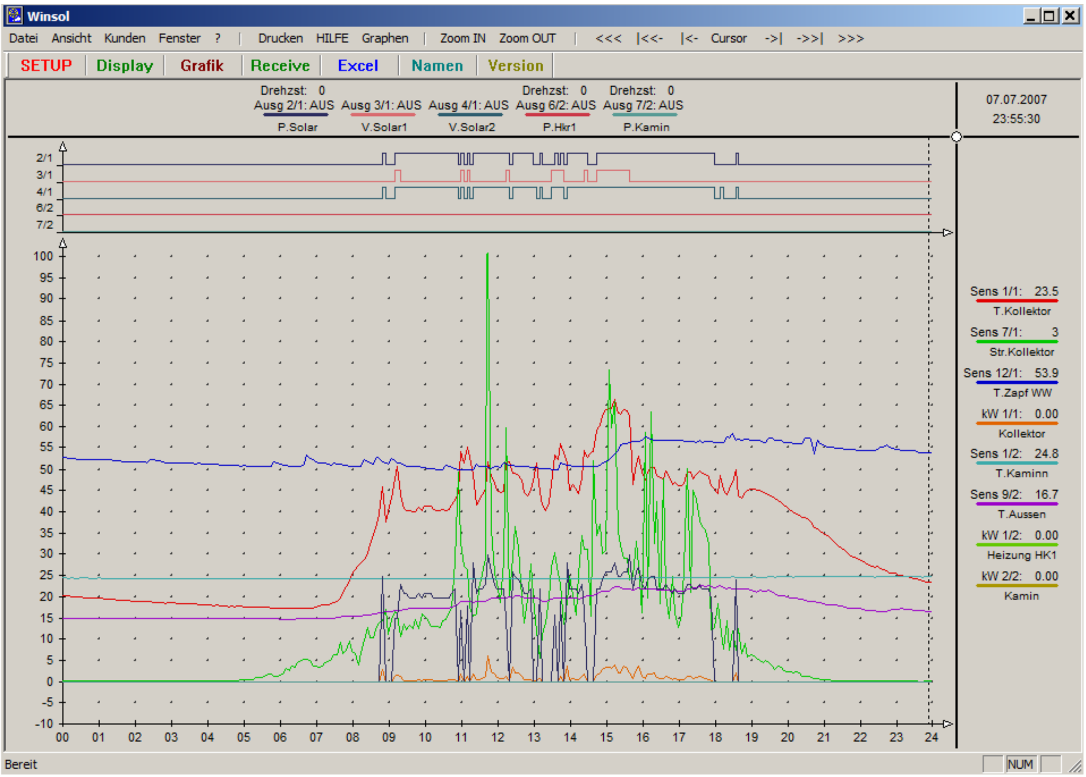
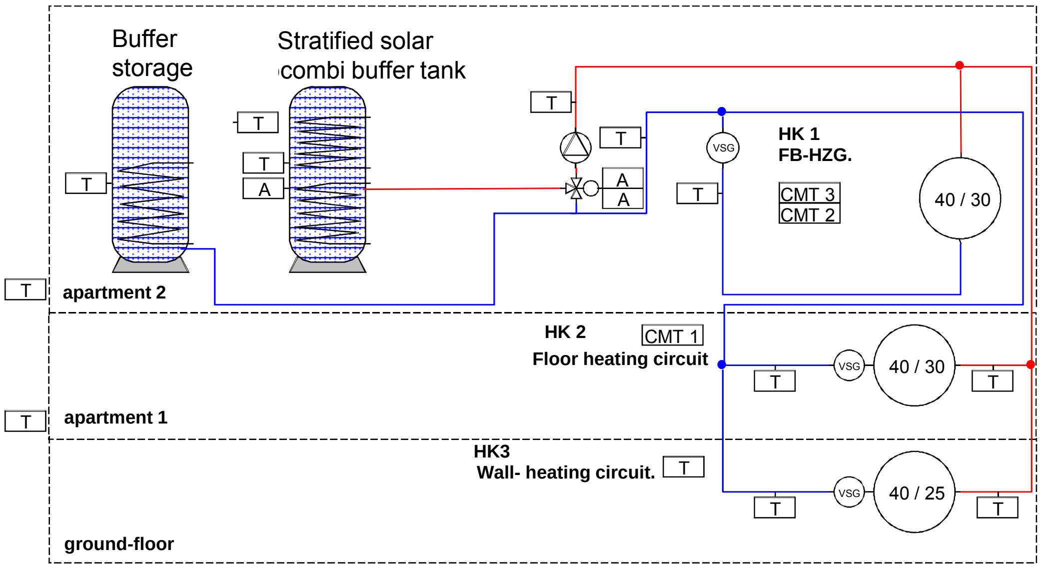


Figure 6.17: Visualization of plant technology with the program Winsol.

Example system component: Heating circuits and heating surfaces

The thermal behavior of the particular building components differs from each other. In the basement heating energy is required to avoid summer condensation. Dwelling 1 in the 1st floor behaves like a very heavy building. The thermal behavior of dwelling 2 reaches from a light to a heavy building.



A … Speed-controlled pump, cartridge heater)
T …. Temperature sensors
VR … Volume Flow

Figure 6.18: Basic schematic of the heating circuits and heating surfaces.

In dwelling 1 there is one (CMT1) and in dwelling two there are two (CMT2, CMT3) control panels with room temperature sensors. In the building there are three different heating circuits. To be able to run the heating circuits with a pump and a mixer, the UVR control calculates the supply temperature and adjusts the maximum one, dependent on the outer temperature and the room temperature (CMT1-3), for every heat circuit. The speed-controlled pump controls the return temperature of the sensor employing the differential control.

The return temperature results of the calculated supply temperature minus the required temperature difference (Fig. 3.12). The heating circuit 3 is used to temper the basement with the surplus solar heat to avoid summer condensation. With increasing the room temperature the relative humidity decreases. The heating circuit is plugged if the relative humidity reaches a harmful level for the building components (Fig. 3.12).

The room controller adjusts the outlets of the floor- and wall-heating system in the dwellings. In dwelling 2 there are three user groups (kitchen-living-room/shower/office, child's and sleeping room, gallery) which are controlled by a schedule. The self regulating panel heating is turned off during the operating mode lowering. At heating circuit 3 the actuators are adjusted directly via the control panels. The conditions of the outlets are recorded for the building simulation.

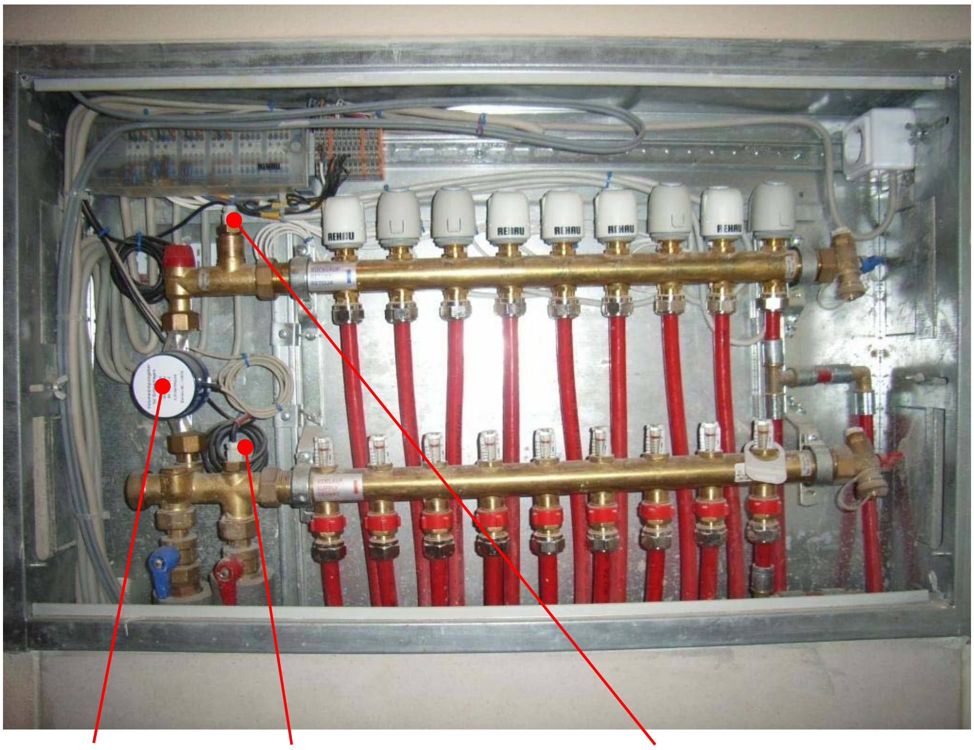


Figure 6.19: 2nd floor, basic schematic of the heat quantity counter.

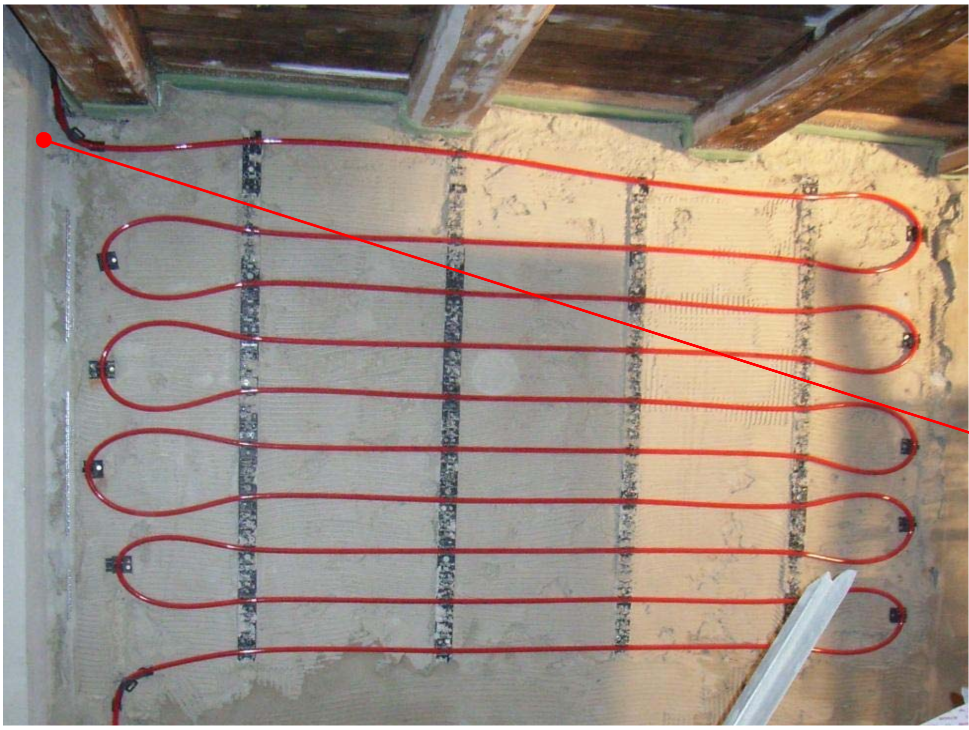


Figure 6.20: 2nd floor Wall heating.

To ensure a not harmful moisture content at the area of the trimmed joist, at the exterior wall with internal insulation looking at the street, there has been laid a heating pipe under the plaster.

To avoid damage at the historical wooden beam ceilings, a continuous thermal output with a high amount of radiation and minor variation in temperature is chosen.

The measurements demonstrate, that the floor- and wall-heating systems are quite inert. After a rush airing it takes a long time to reheat the room. While operating the ventilation system a rush airing is not necessary.

With vacancy of the dwelling 1 (holiday apartment) it is investigated, if an additional tempering resp. operating mode lowering is necessary to ensure a not harmful relative humidity for the historical wooden beam ceilings. In so doing conclusions can be drawn for the increasing temporary and enduring vacancy. The bilateral influence of the heating system and the air ventilation system is supposed to be worked out

3encult
EFFICIENT ENERGY FOR EU CULTURAL HERITAGE

D 6.2 Documentation of each study case
CS6 Warehouse City, Potsdam (Germany)
Delivered at M42

EUROPEAN COMMISSION
DG Research and Innovation

Seventh Framework Programme

Theme [EeB.ENV.2010.3.2.4-1]

[Compatible solutions for improving the energy efficiency of historic buildings in urban areas]

Collaborative Project – GRANT AGREEMENT No. 260162

Technical References

Project Acronym	3ENCULT
Project Title	Efficient ENergy for EU Cultural Heritage
Project Coordinator	Alexandra Troi EURAC research, Viale Druso 1, 39100 Bolzano/Italy Alexandra.troi@eurac.edu
Project Duration	1 October 2010 – 31 March 2014 (42 Months)

Deliverable No.	D6.2
Dissemination Level	PU
Work Package	WP 6 “Case studies & Transferability”
Lead beneficiary	P09 TUD
Contributing beneficiary(ies)	P10 COBO
Author(s)	Rudolf Plagge
Co-author(s)	Ayman Bishara, Frank Meissner
Date	31 March 2014
File Name	WP6_D6.2_20140331_ Documentation of Case Study 6

Table of Content

2 Template for Case study presentation

2.1 Brief description of the building

This table is to be considered as an identity card with brief descriptions of the building so that it is possible to compare the different case studies.

Object Name: Warehouse City Potsdam	
Location	
Country	Germany
City	Warehouse City, Potsdam
Altitude	35 m
heating days	268 d (heating lower than 15°C)
Heating degree days	2483 Kd / a
Surrounded Area	
• Mountainous Area	
• Plan Area	
Other comments	
History	
Date of construction	1688 (Persiusspeicher), 1834-36 (Schinkelspeicher)
Construction Type (according to its age)	Old Masonry
Original Objective	Since 1688 when the first building was finished until 1994 the Warehouse City was used for the supply of the habitants with corns and other food.
Current use	Residential, offices, exhibition & art use
Expected use in future	There will be build 137 apartments and 15 business units with about 18.500 m² rentable area.
Other comments	
General description	
Status quo	

Architect style	
Construction materials	
General condition	
Urban Context	
Quarter/town	Potsdam is the capital of the german state Brandenburg with about 150.000 habitants. The Warehouse City is located in the centre of Potsdam, close to the main station.
Development plans	Development of inner-city quarters based on the principle sustainability at a location with historic and valuable buildings in combination with new buildings. Integration of the quarter into the surrounding city, scenic and traffic space, its connections to the surrounding region and its rural areas. Optimization of the energy demand by suitable city planning structures, modern thermo technical designs of the buildings, using the fuel-celltechnology and its complete supply with renewable energy. Urban context
Key figures as e.g. % of historic buildings, renovation rate	
Cultural Value (Specific valuable aspects)	
Historical Values	The remaining historical buildings are the formative feature of the warehouse city. It creates the genius loci, the best places at the bank, with prestigious addresses and tradition. This ensemble of the original "Königliche Preußischen Heeresproviantamt" will be completed in its former formation by corresponding additional buildings.
Design Value	It is existing from 1688. It is the oldest building in Potsdam, which is almost completely conserved in their original building state.
Building Problems (cracks, deterioration, moulds and fungi..etc)	
1	Indoor humidity and temperature
2	Salt rising in masonry walls
Planned/Proposed/Possible activities	
Diagnosis	• Visual inspection • Geometrical survey (plan view, section, volumes, …) • Window frames survey

	• Measurements of Air T and RH in rooms; measurements of superficial temperature on walls • Mapping of air T and RH • IR thermograph investigations for energetic purposes, • U-value measurements; • Survey of openings in ceilings/floors • PHPP calculations
Planned solutions	The re-building and restoration of the building (Schinkelspeicher) is already completed. In November 2009 the first inhabitants move in and the monitoring of the energy requirement and use can start. Interventions: internal insulation, windows, energy production (biomass CHP)
Monitoring system	**Monitoring Concept:** **Indoor climate** Air temperature, air humidity. Surface temperatures on constructional critical points of the thermal envelope. **Approach:** • **Monitoring As-is-state:** - Selected rooms will be monitored to detect temperature and relative humidity? • **Interventions:** - Selected rooms will be monitored to detect wall temperature and relative humidity. - Selected rooms will be monitored to detect temperature, relative humidity to interact with the building management system in order to increase the energy efficiency of the building.
Simulation	In a previous project, the IBK laboratory held a sries of simulation processes on the building. On the basis of measurement to transient 2D simulations of six design details with the program DELPHIN4 be performed. The aim of the study was the analysis of interior insulation focusing on possible condensation and critical moisture contents in wood construction and the risk of mold growth.
Transfer to urban scale concept	After completion the Warehouse City should be a place where the habitants can live and work in reconstructed and new buildings on newest technological energy standards (heating and cooling) based on renewable energy. It should be also a place for optimisation, demonstration and teaching

	of technology and using in the subject of renewable energies and building.
others	The saving of energy use will be about 40% under the lawful rules - with exclusive using of renewable energies. The fuel cell will be sponsored by the NOW GmbH (national organisation for hydrogen and fuel cell) in the NIP (national innovation program hydrogen and fuel cell), which is applied by the German federal government.
Documentation	
Existing documentation	
Scanned/photocopied materials	-
Digital materials	Site measuring and photos
Inside surface	Photos
Outside Surface	Photos
Climate	
solar radiation	Januar 25 Februar 51 März 98 April 153 Mai 204 Juni 221 Juli 212 August 181 September 125 Oktober 70 November 29 Dezember 18
monthly mean temperatures	Januar 0,3 Februar 1,3 März 3,8 April 8,8 Mai 13,7 Juni 16,5 Juli 18,4 August 18,2 September 14,4 Oktober 9,4 November 4,3 Dezember 0,9
Monthly mean Humidity	Januar 88 Februar 84 März 79 April 70 Mai 68 Juni 67

	Juli 68 August 69 September 75 Oktober 83 November 90 Dezember 90
Topography	Potsdam has got a high percentage of water area (rivers and lakes)

3 Monitoring scheme

3.1 Laboratory Work

Sponsor: Warehouse District Potsdam GmbH
Allee Strasse 9, 14469 Potsdam

Materials: old clinker brick buildings 3, 5 and 7
Material Name: PoZ_3, and PoZ_5 PoZ_7
Date: 04.05.2006

Subject: Determination of water absorption coefficient and water vapor diffusion resistance of the clinker brick warehouse district of Potsdam

Commissioning

Commissioning with the date of 04.05.2006, the research and development laboratory of the Institute for Building Climatology at the Technical University of Dresden, was entrusted to sample three different old clinker brick of buildings 3, 5 and 7 of the warehouse district of Potsdam and its hygric parameters to study water absorption and water vapor diffusion resistance and evaluate them. On the basis of measurement to transient 2D simulations of six design details with the program DELPHIN4 be performed.

The aim of the study is to analyze the internal insulation planned with a focus on possible condensation and critical moisture contents in wood construction and the risk of mould growth.

Work Programme

Sampling.

Measurement of material samples.

Determination of characteristic material functions.

Application of hygric material functions in the simulation.

General Requirements

Building materials and systems are then classified for suitability and adaptability in site. A range of material properties are measured:

1. moisture storage properties:
2. water retention
3. hygroscopic moisture storage
4. water absorption coefficient
5. water vapour diffusion (according EN ISO 12572) resistance

General hygrothermal characterization of brick and mortar samples data base:

In the IBK Laboratory the Dry bulk density and porosity of the old clinker bricks, lime mortar, and joint covering samples was examined.

Determining the relevant hygrothermal characteristic of old building clinker and the mortar samples

1. Characterization of hygric moisture storage
2. Moisture transport properties
3. Water absorption coefficient and capillary saturation
4. Determination of the permeability (water vapor diffusion resistance)

3.2 Measurements In-site

A 1-wire based monitoring concept for phase 1 was installed. The table below shows some details.

Case Study	Sensorart	Number of sensors	Position of sensors	Start of measurement
CS 6 - Warehouse	Surface temperature	6	Wall, bottom, ceiling, window	27.04 .2009
	Room climate	2	Room	
	Near field climate	2	Wall	
	Velocity	0	Window	

All this data will be measured and achieved every minute.

Measuring Sections

- Tray 1: two measurement sections, each with an indoor air measurements,
- Tray 3: two measurement sections, each with an indoor air measurements,
- Tray 5: a measurement section with one interior climate measurement and
- Tray 7: provided a measured distance, each with an internal air measurement

In each measurement section are measured the indoor climate (temperature, relative humidity), the surface temperatures (inside and outside), the heat flux (inside) and measured on the cold side of the internal insulation, the temperature and relative humidity.

Site: There is a flush-mounted box recommended in the stairwell. Per test section will require a connection to the network of the warehouse district, a 230V outlet, and conduits of the flush-mounted box for measuring distance and indoor air sensor. For remote access from one server to the -outside is necessary where several measuring sections summarized the existing network, data can be recorded and stored online. To characterize the outdoor climate (temperature, relative -humidity, wind speed, wind direction, precipitation, rain, direct and indirect radiation) there should possibly be made an access to of the weather station about 500 meters away.

Location: 1st Measuring range: Exterior wall 2 2nd floor corner OG South / West
2nd Measuring range: Exterior wall 2 OG West facade

The following figures show, as an example for the monitoring systems, the current sensor plans from CS 6 - Warehouse.

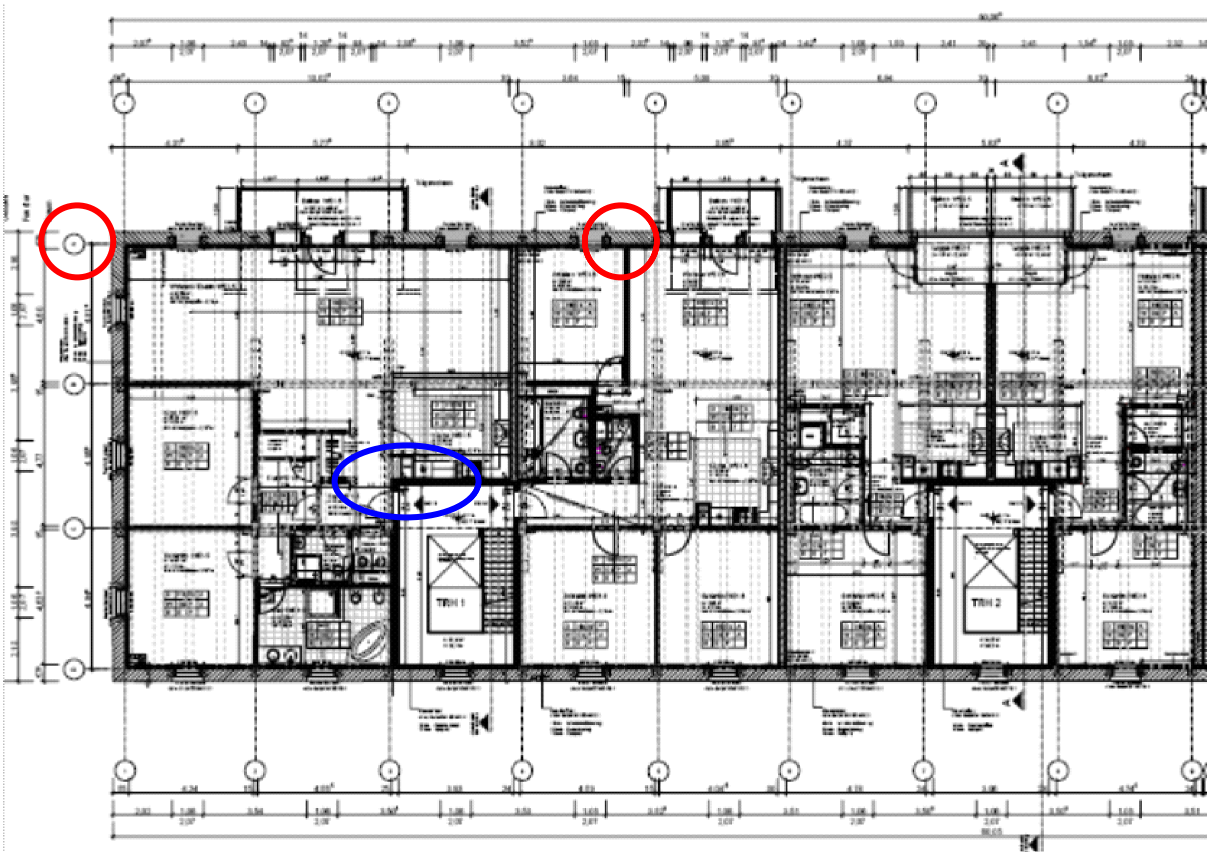


Figure 3.1: Tray 3, 2 OG, location of the test sections and the data logger.

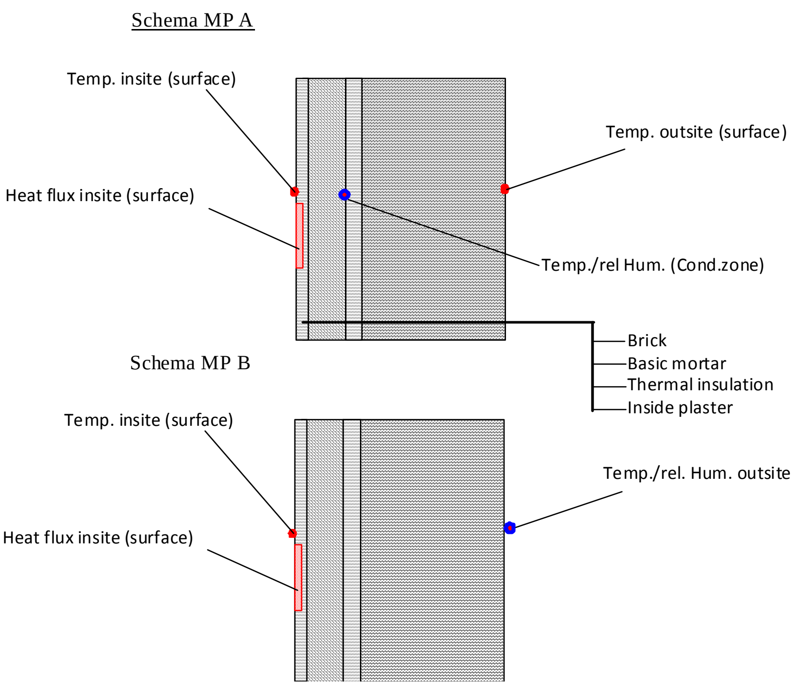


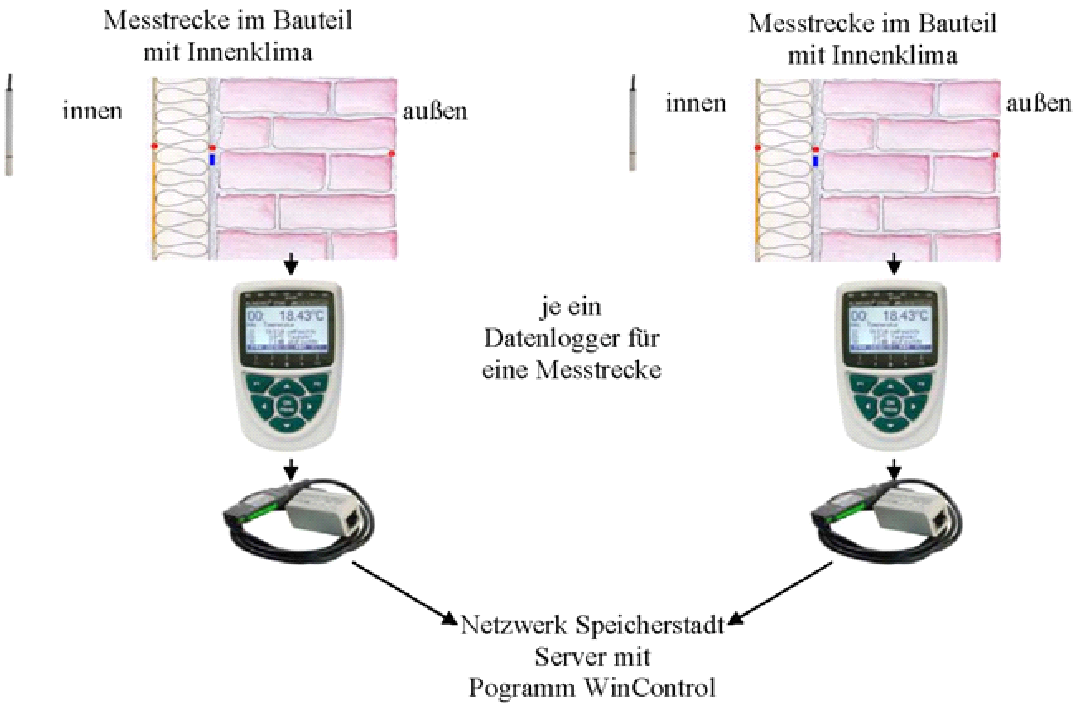
Figure 3.2: measurement points MP A and MP B, in the second floor on the south and west side.

Figure 3.3: measurement points MP A and MP B, in the second floor on the south and west side (from inside)

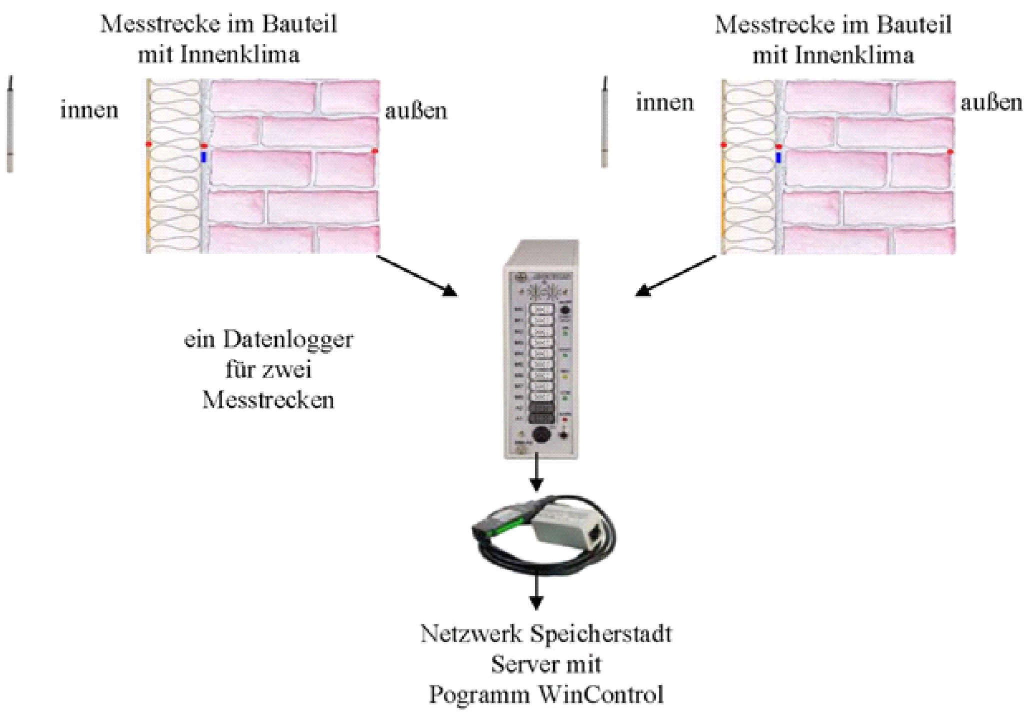
Figure 3.4: measurement Points MP A and MP B, in the second floor on the south and west side (from outside).

The sensors can be removed from the data logger installed with special extension cables up to 100 meters. The cables can be pulled into conduits. Depending on the location of the data logger results in two solutions:

Option 1: One data logger for each test section of measurement for measuring indoor climate



Option 2: One data logger for two test sections, each with an indoor climate measurement



3.3 Simulation

This report was sent to the Warehouse district of Potsdam GmbH, which served as the basis for the selection of interior insulation.

In addition to evaluating energy efficiency of building also some typical construction details were examined in terms of their impact on the planned hygric internal insulation.

For direct use in simulation models, material parameters (examined in Lab) and real climate conditions (measured by installed monitoring systems) were prepared.

Numerical simulations of critical points of detail

3.3.1 Ceiling fourth Floor – Tower roof - Roof construction - Loggia ceiling connection - Foot tower terrace detail – Tower terrace

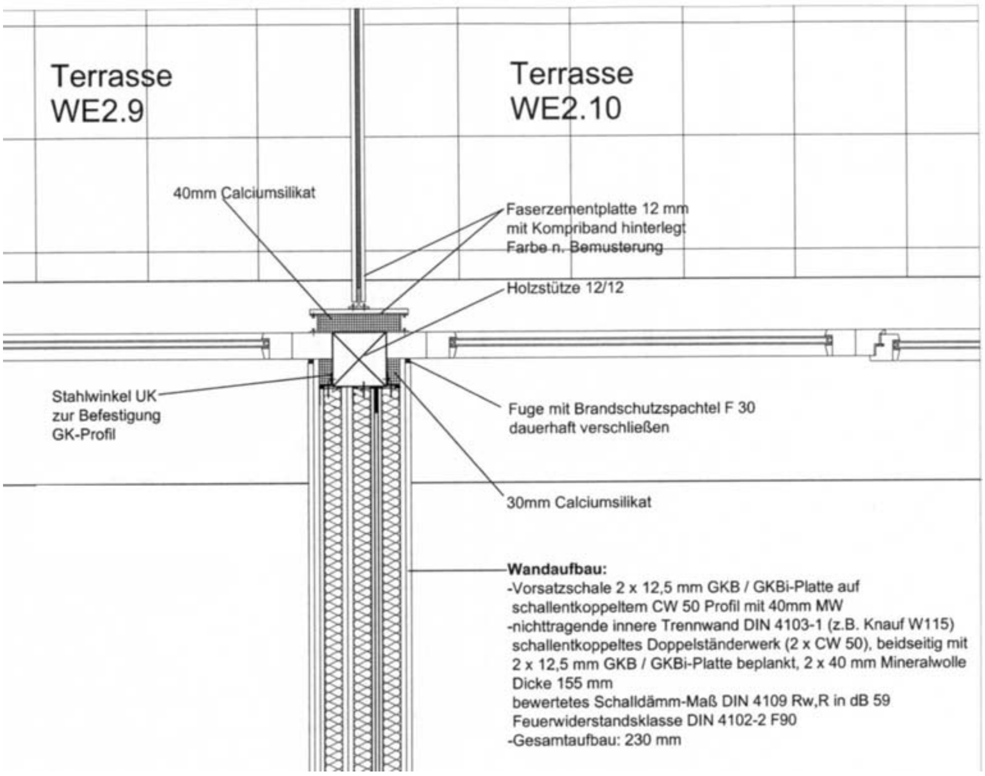


Figure 3.5: Detailed plan vertical section WE- wall separating (partition wall) 4th floor .

Calculation under stationary conditions - climate according to DIN 4108-2, Proof of minimum thermal insulation (DIN 4108).

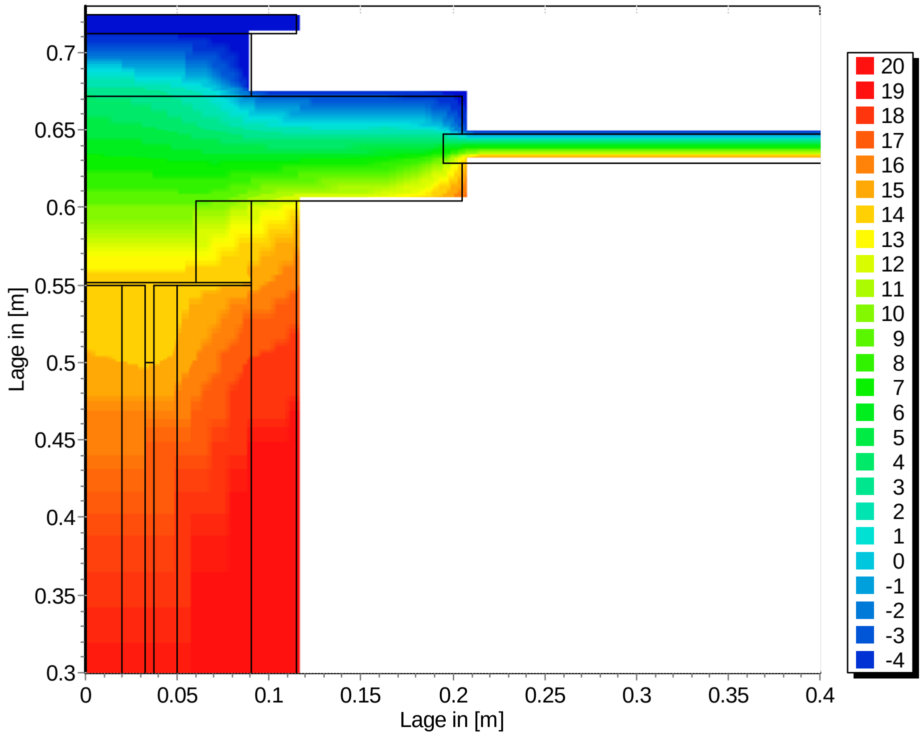


Figure 3.6: Temperature field, Surface temperature in [°C], mineral wool instead of the outside Calcium silicate (version 1), boundary conditions according to DIN 4108-2.

Calculation under unsteady state conditions according to DIN 68800 – Outer climate Potsdam (test reference year TRY04)

The area around the insulation in the angle timber stud/window frame is to be seen critical, since apart from the window frame, the static load-bearing timber stud is affected. Therefore the moisture content is examined more closely at this point.

The simulation for this construction detail was realized with real climate conditions over a period of 3 years until the quasi-steady condition was reached.

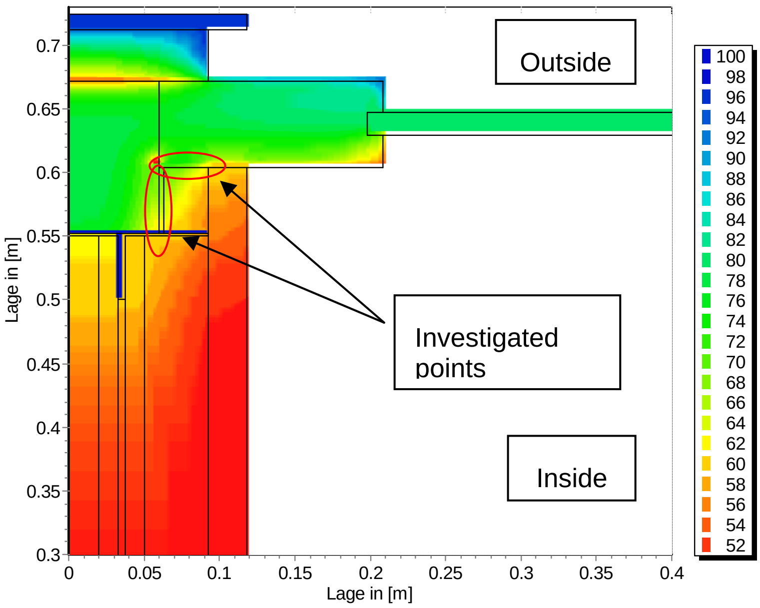


Figure 3.7: Distribution of the rel. Humidity at 09. Febr., boundary conditions with outdoor air -. Potsdam (TRY 04, closely examined sites are marked).

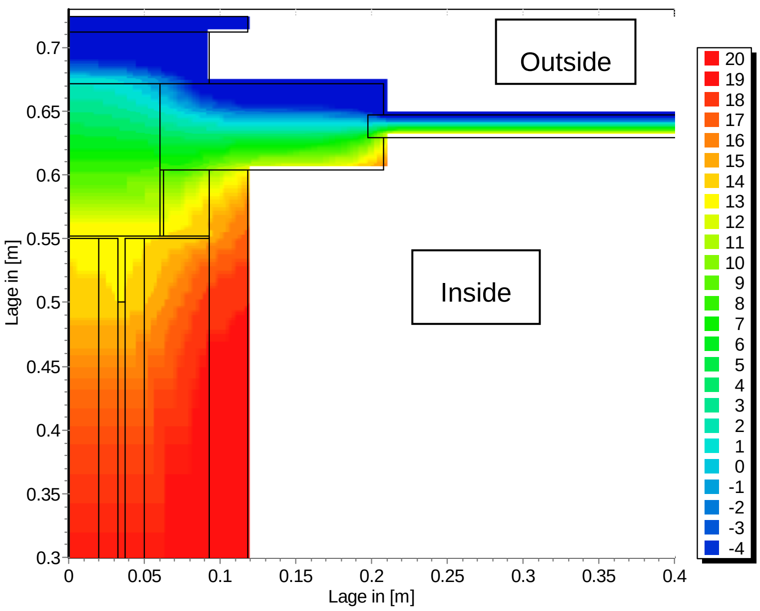


Figure 3.8: Distribution of t he Temperature at 01.Febr.., boundary condition with outdoor climate, Potsdam (TRY 04).

Interior condensate, i.e. condensate on the internal insulation or condensate that could be referred to the internal insulation does not emerge in Potsdam.

Regarding the timber stud it was examined, whether the hygrothermal conditions are sufficient for the potential attack by biological pests. The best-known and most dangerous wood pest is the real dry rot (Serpula lacrymans), as it is relatively undemanding. The lower limit value for the growth and overgrowth with the real dry rot lies at 21 mass percent (M%) according to recent perceptions, which at a density of 530kg/m^3 corresponds with approximately 11 volume percent (Vol%). Though the ultimate degradation of the wood substance can only begin above the fibrous-saturation point of the dry rot. The average moisture content for the fibrous-saturation point of spruce is indicated within a range from 25 to 30M% (11.25 to 13.5Vol%) depending on the source literature. In the DIN 68800-3 it's required that the moisture content of wood does not exceed 20M% (equivalent to approx. 10 Vol%) on a long-term basis.

Thus a line is drawn at 10Vol% in the following figure that symbolizes the limit value.

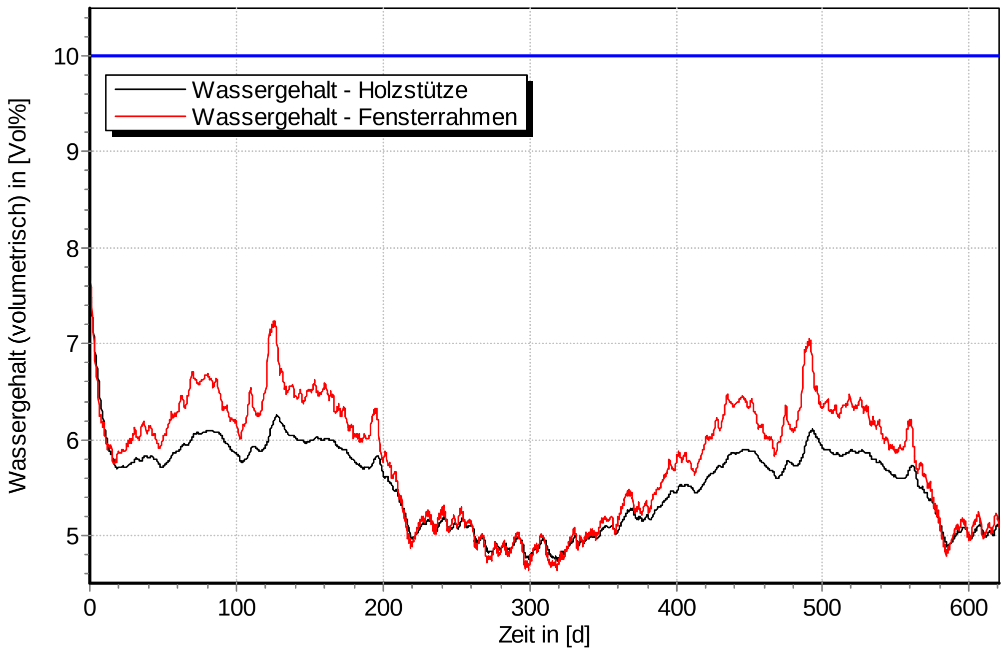


Figure 3.9: The year trend of the water content, outside (insulation 1) mineral wool insulation, inside calcium silicate insulation, the positions are taken from figure 1, boundary conditions with outdoor air Potsdam.

As shown in the figure above, the moisture content proceeds on the most critical points in window frames and timber stud (see fig. 3.4) far below the limit value of 10Vol%.

If instead of calcium silicate mineral wool is applied in the angle of pillar and window frame, only an insignificant difference in the progress of the moisture content is to be noticed.

Evaluation. Hygrothermal simulations show that the use of the calcium silicate (usual interior insulation) is unnecessary between fibre cement panels and timber studs ("insulation 1"). At this point an alternative insulation material is recommended, e.g. mineral wool (WLG 040 or better 035). This has the added advantage of improved thermal insulation features.

If the use of calcium silicate in the angle timber stud/window frame is not prescribed for fire safety reasons (“insulation 2”), the application of calcium silicate can be omitted while falling back on mineral wool. A capillary-inactive construction material like mineral wool due to the small geometrical extends of this area does not violate the protection against moisture. The temperatures on the inner surface practically don’t change. The fugues connections in this area must satisfy the requirements of fire protection and air tightness.

Assessment. Hygrothermal simulations showed that the use of calcium silicate (usual interior insulation) between fiber cement board and wood support is not necessary ("insulation 1"). Here is an alternative recommended insulation such as mineral wool (WLG 040 or better 035). This has the added advantage of better thermal insulation properties. Unless prescribed fire safety reasons the use of calcium silicate in the wood support angle / window frame ("insulation 2"), may also be waived on the Application of calcium silicate and are instead falling back to mineral wool. Due to the small geometric expansion of the range of moisture protection is not violated by a capillary inactive construction materials such as mineral wool, the temperature change on the inner surface is not practical. The joint connections in this area must meet the requirements of fire protection and air tightness.

3.3.2 Ceiling 4th Floor, steeple roof - magazine 3

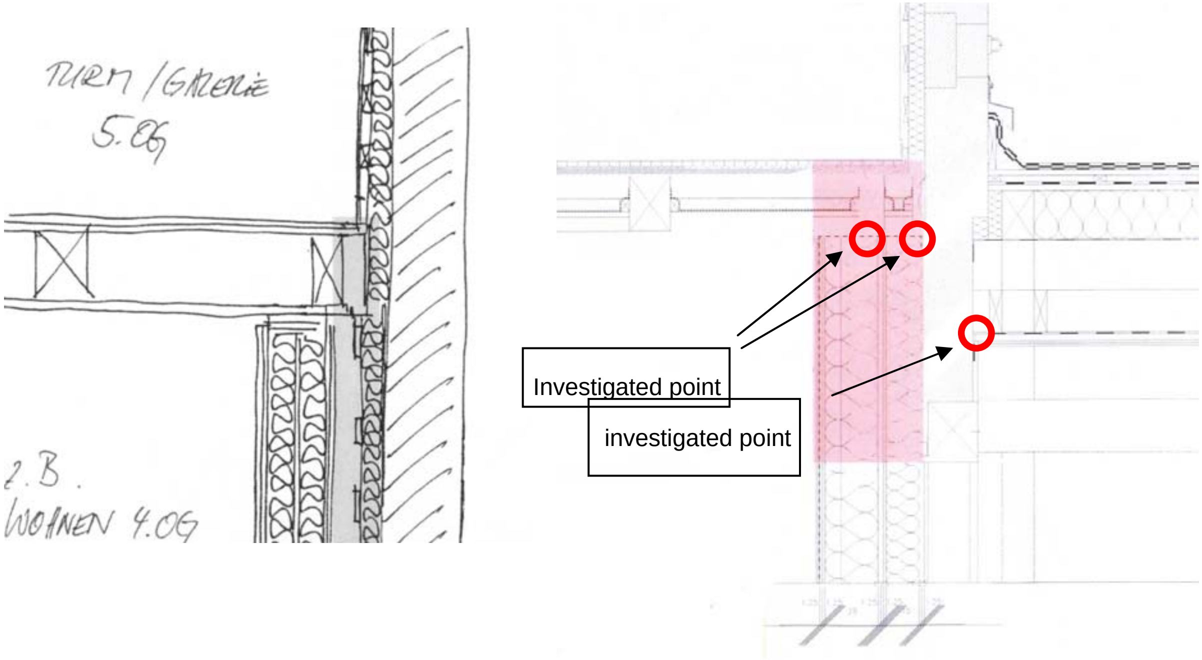


Figure 3.10: *Above:* Magazine 3 - sketch Gable / ceiling connection 4 OG: thermal insulation clay is carried out up to the 4th floor (AKM architect Community from 29/01/09) continued, *Below:* Magazine 3 - Detail timber terminal (Plan-Nr. 362, AKM architect community of 25.08.2008)

For the connection of the ceiling 4th floor in the steeple floor it was originally planned to lead the mineral wool insulation on the, that was attached directly on the house wall, right up to the ceiling. The problem with that is that up to the ridge area, the wall on the 4th floor is partially exposed to outside climate. In this context it was to be clarified whether it would be more appropriate to lengthen the heat insulation clay insulation from the 5th upper floor to the level of the eave area in the 4th upper floor. For the vapour retarder, which is applied on the 4th upper floor between plasterboard and mineral wool, two different s_d-values were tested: a high vapour diffusion resistance of s_d= 50m and a lower resistance of s_d= 1m.

The details were processed computationally based on the dimensions in figure 3.5 (below).

Calculation under steady conditions –climate according to DIN 4108-2, proof of the minimum thermal protection according to DIN 4108

The proof of the minimum thermal protection is performed according to DIN 4108 Part 2 Section 6.2 to prevent mold growth. Even here no problems are to be expected on the room side surfaces in terms of internal insulation. Therefore, only the temperature field of the consistent with thermal insulation clay insulated version is shown and the more critical upper angle is documented.

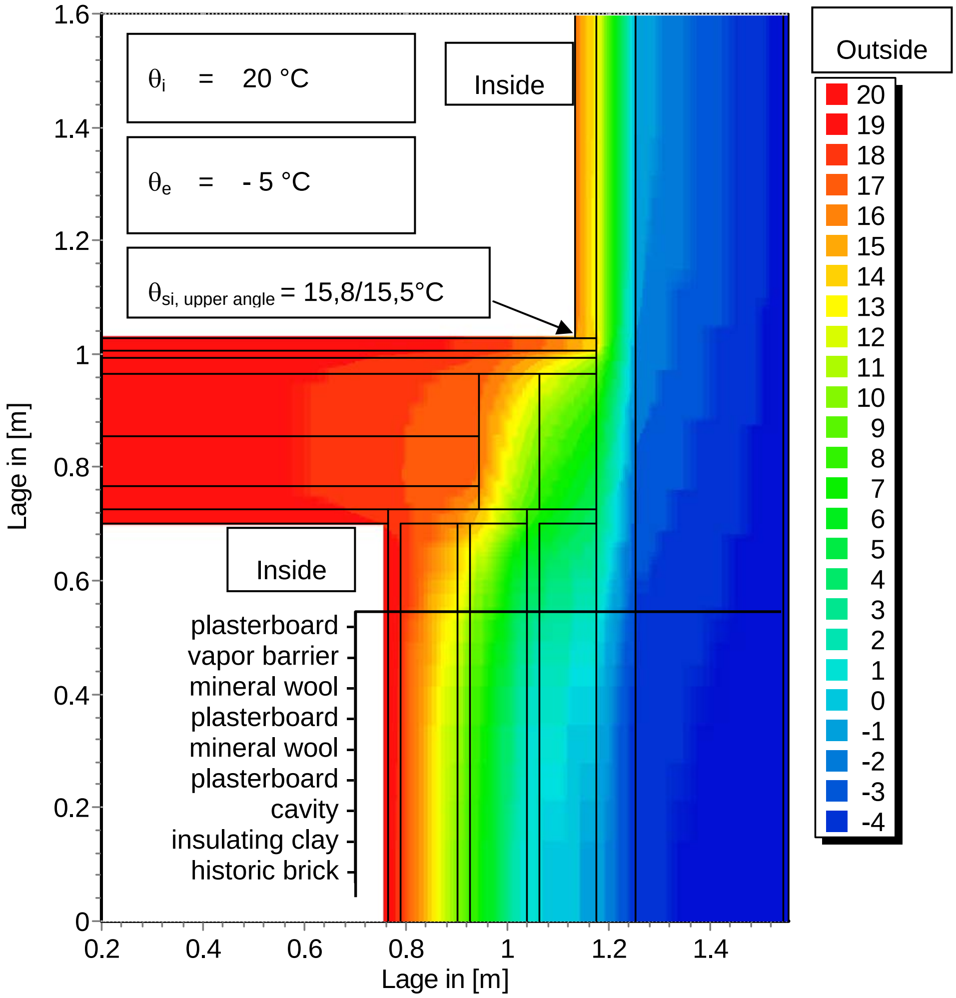


Figure 3.11: Temperature field, surface temperature in [° C], outer wall throughout with thermal insulation clay, boundary conditions according to DIN 4108-2

$\theta_{si,\ Oberer\ Winkel,\ WDL}$ =15,8 °C > $\theta_{si,\ acceptable}$ = 12,6 °C

$\theta_{si,\ Oberer\ Winkel,\ MiWo}$ =15,5 °C > $\theta_{si,\ acceptable}$ = 12,6 °C

The proof according to DIN 4108-2 for the gable wall at the height of the ceiling of the 4th upper floor is fulfilled for both insulation versions.

Calculation under steady conditions, climate according to DIN 4108 proof of the condensation according to DIN 4108-3

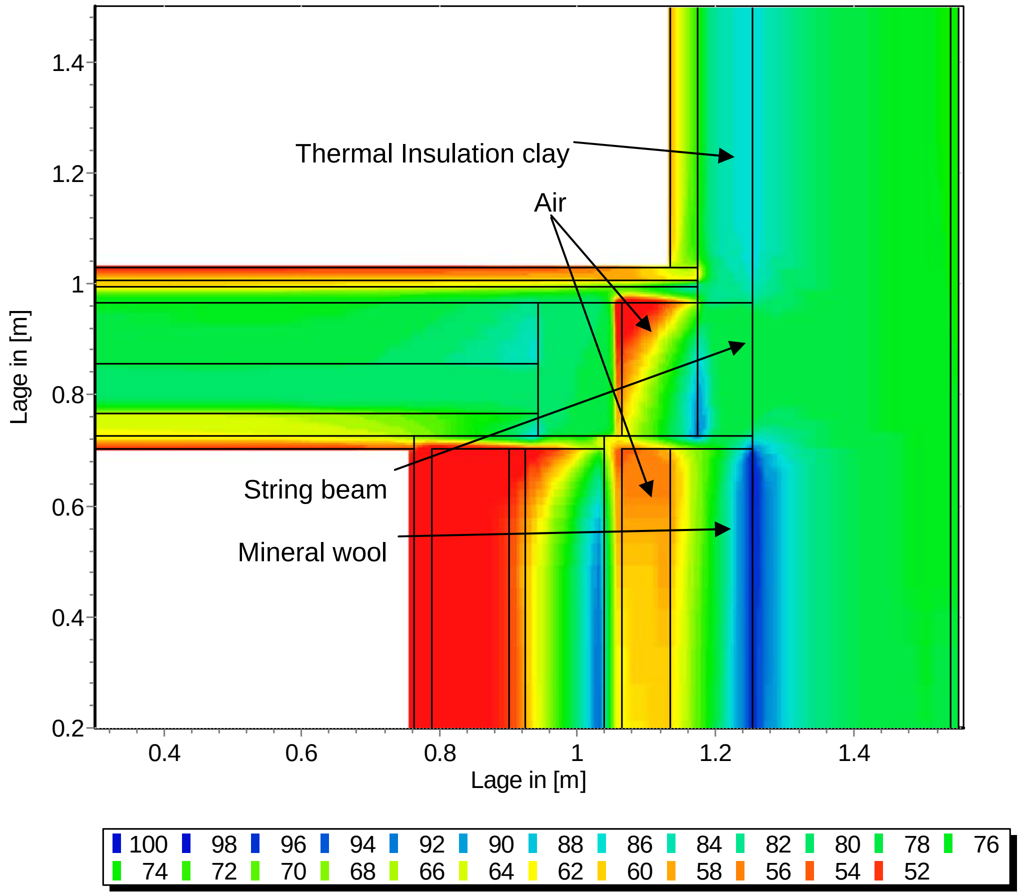


Figure 3.12: Distribution of humidity after 60 days winter climate, humidity in [%], all layers of insulation in the underlying floor with mineral wool.

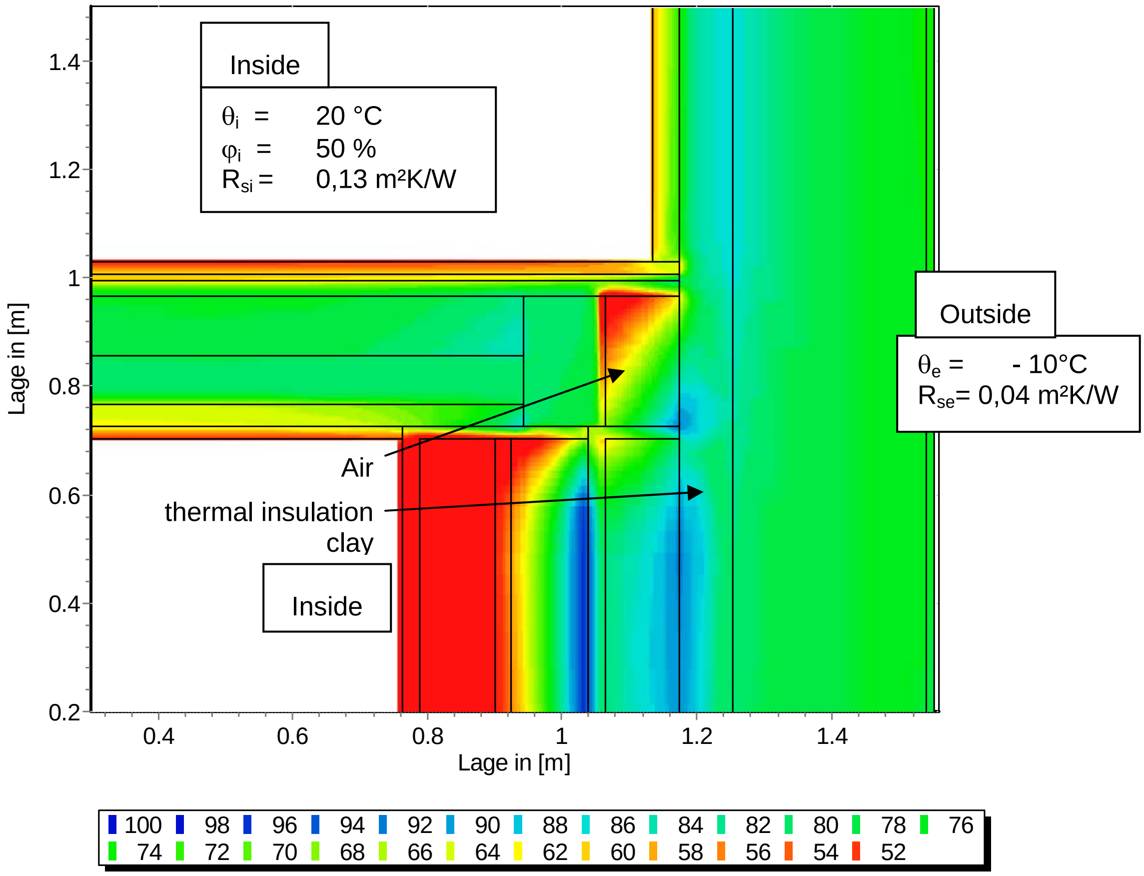


Figure 3.13: Distribution of humidity after 60 days winter climate, humidity in [%], with thermal insulation clay.

If the external wall is consistently insulated with thermal insulation clay, there will be virtually no condensation or below 0.073kg/m within the construction with mineral wool and plasterboard of the 4th upper floor (fig. 3.9). The moisture content at the outer corners of the wooden beam decreases from approx. 15M% t below 12M% at the end of the period of thaw (here at a time not shown).

A condensate amount of 0.568kg/m will emerge in the entire construction detail if mineral wool is continuously applied in the 4th upper floor. The condensation is focused on the contact surface mineral wool/existing brickwork as can be seen from figure 3.7. The applied method with constant boundary conditions, however, clearly refers to a one-dimensional wall cross-section of a one square meter area. Therefore the limit value of the DIN (0.5 or 1.0kg/m^2) cannot be applied for this detail. Nevertheless, the impression is created that the limit value would not be exhausted at a level of the detail of approx. 1.70 m.

However, if the one-dimensional structure of the basement is admitted with the steady climate boundary conditions of the DIN 4108-3, the resulting condensate totalizes to 0.55 kg/m². This would mean that the condensation water amount would lie just above the limit value of 0.5kg/m according to DIN 4108-3, Section 4.2.1d.

Remark: The limit value of 0.5 kg/m applies to a condensate area, which is formed on capillary non-absorptive materials such as mineral wool.

Applying a vapour retarder with an s_d-value of 10 m to this one-dimensional wall structure would reduce the condensation water amount to 0.410 kg/m². In an identical one-dimensional wall structure in the 4th upper floor with thermal insulation clay only a condensate mass of 0.070 kg/m² would turn out.

The amount of condensate of each of the presented calculations dried again in the evaporation period.

The water content in the ceiling beams proceeds similarly to the construction with thermal insulation clay, though the water content in the trimmer beam (that will be obtained within this redevelopment version according to the sketch) increases from 15M% to just under 18 M%.

With the results of the steady calculations no clear statement can be made, because it is a two-dimensional detail. On the basis of the results of the one-dimensional calculations the version with the thermal insulation clay should be applied in both floors to ensure a sustainable avoidance of structural damage due to moisture.

Calculation under unsteady conditions for the proof according to DIN 68800 – outer climate Potsdam (test reference year TRY04)

The fields of the relative humidity show in the 5th upper floor virtually no difference, as expected. In the Basement qualitative differences are apparent.

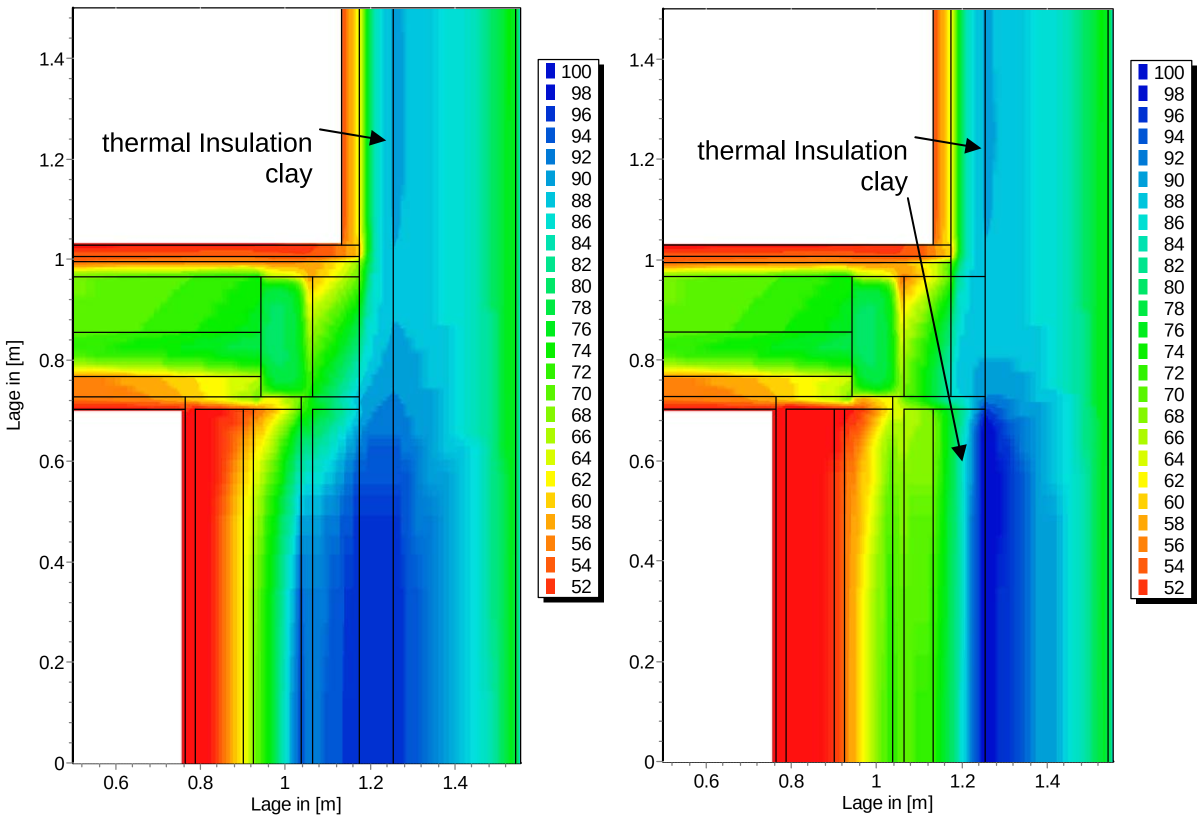


Figure 3.14: Fields of relative humidity on 1 April: Left: the 4th and 5 OG thermal insulating clay on the outer wall, right: in the fourth OG with mineral wool on the outside wall, boundary conditions with outdoor air Potsdam (north direction).

Based on the fields of relative humidity the version with thermal insulation clay (figure 2.2.3 left of the illustration) appears slightly more critical in the basement, because of the blue colour that is representative for high humidity and which is more dominate. However, this impression is misleading, as the following illustration of the course of the condensate (figure 2.2.5) shows: although the humidity with thermal insulation clay is distributed over a larger area, it hardly forms condensate.

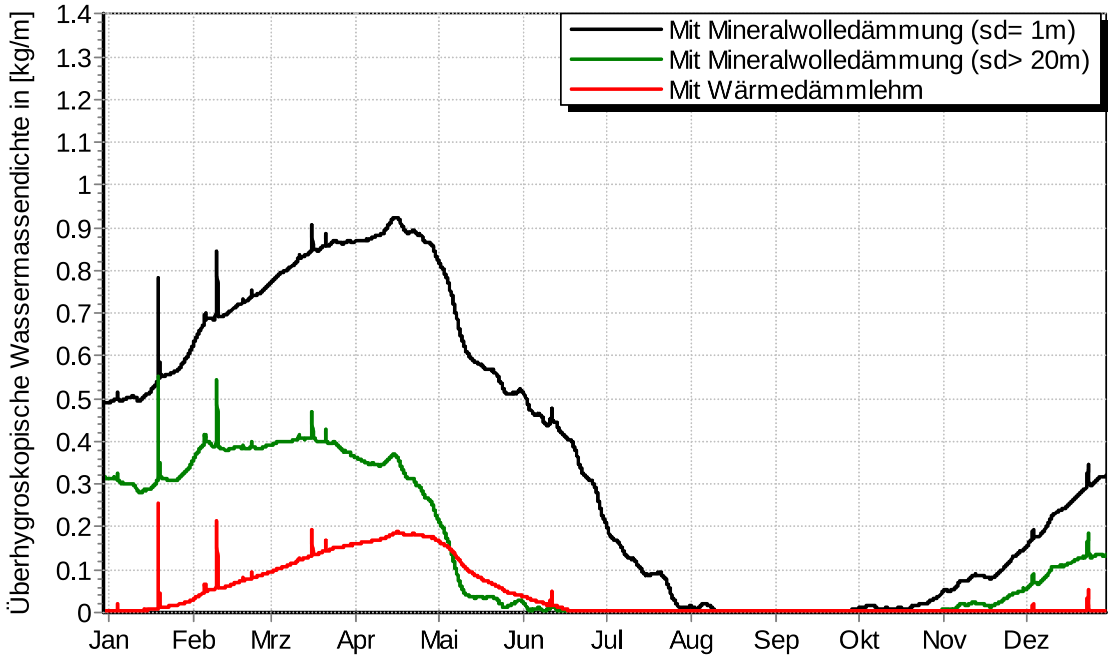


Figure 3.15: Trend of the condensate in full detail, with exterior air conditions Potsdam (north direction).

Figure 3.10 documents the course of the condensate within the 1.7m high detail in total in the period of one year. Less that 0,2kg/m condensate water occur in the third year in the construction being continuously provided with thermal insulation clay. The short-term peaks are caused by penetrating driving rain after heavy rainfall, which will dry out quickly and therefore will not be rated. Within the construction, being insulated on the 4th upper floor with mineral wool only, 0.920kg/m² with an inner s_d-value of 1 m and approximately 0,420kg/m² with an inner s_d-value is reached. A vapour retarder with a higher s_d-value (s_d= 50m) the amount of condensate water remains below the limit value for one-dimensional structures of 0,5kg/m².

In one-dimensional simulations the field in which the s_d-value should be located was determined. An upper limit value of the s_d-value is necessary so that the drying potential of the interior is not completely suppressed. An s_d-value between 10 and 200 m is recommended.

Hardly any differences were observed in the comparison of the process of water content within the beam. The outer, lower corner of the ceiling beam was considered more carefully for this comparison.

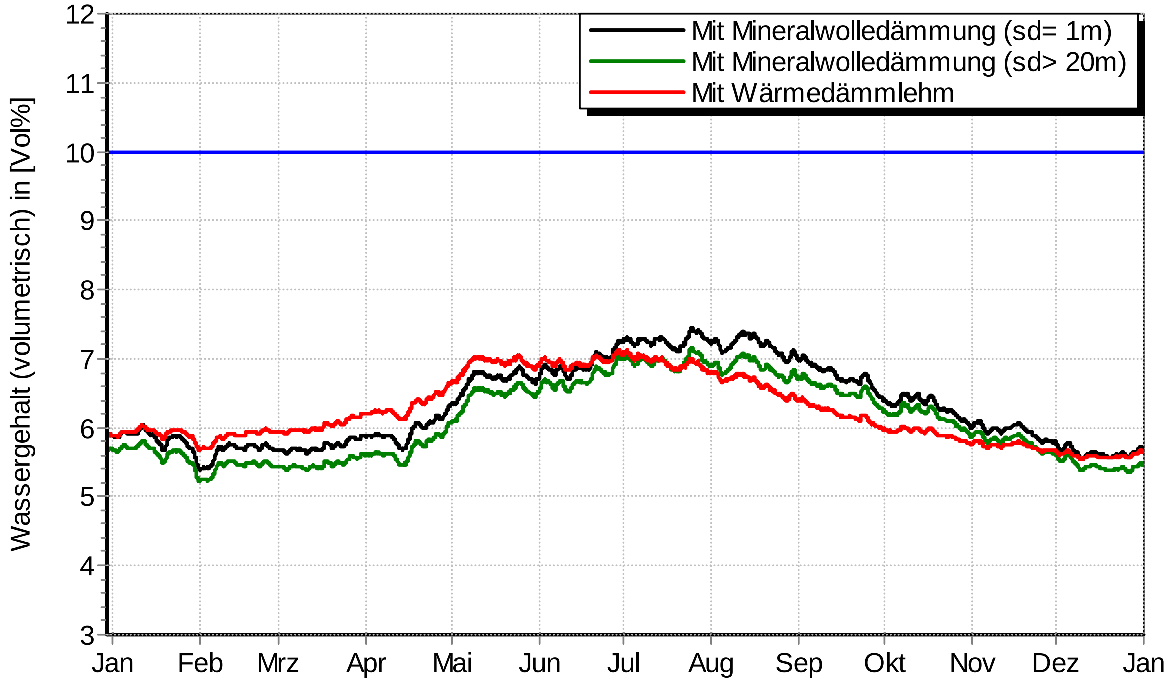


Figure 3.16: Trend of the water content in the lower outer corner of the ceiling timber with a mineral wool insulation (two different vapor barriers) and with thermal insulation clay in the 4th OG (north direction).

The process of the water content at the ceiling beam (figure 2.2.6) is uncritical for all alternatives. The water content lies below the limit of 10% (DIN 68800-3) all-year in all wall structures.

The results of the simulation with southern exposure ware qualitatively the same, or slightly positive, because the building construction will be warmed up by solar radiation and therefore additional drying processes occur. Although the accruing amount of driving rain is larger, the hydrophobicity prevents the penetration through this moisture exposure. Thus the results of structures with a southern exposure are not shown because they do not lead to new insights.

Evaluation

The mineral wool insulation system being installed in the 4th upper floor provide excellent hygrothermal conditions on the inner wall surface and a very low loss of heat energy through these areas on the one hand but on the other hand it unfortunately also favours the formation of condensate. The very thick inner mineral wool insulation cools down the existing brickwork very strongly, but hardly reduces the vapour transport form the inside out. Water vapour, which flows from the outside in summer and from the inside in winter into the brickwork, condenses at that point as condensate. The amounts of condensate are significantly lower when the area being exposed to the outer climate is insulated with thermal insulation clay.

It was also tested whether a higher vapour diffusion resistance of the construction leads to lower amounts of condensate. For this, a vapour retarder with an sd-value of 50 m between plasterboard lining and the mineral wool of the 4th upper floor had been mounted. This measure halves approximately the amount of condensate, which then lay below the limit value of 0.5 kg/m² according to DIN 4108-3. However, the vapour retarder should not be a vapour barrier, because otherwise the drying potential towards the interior would be completely prevented. By the means of a one-dimensional simulation the optimal range for the s_d-value of the vapour retarder can be narrowed down to the range of 10 to 200 m.

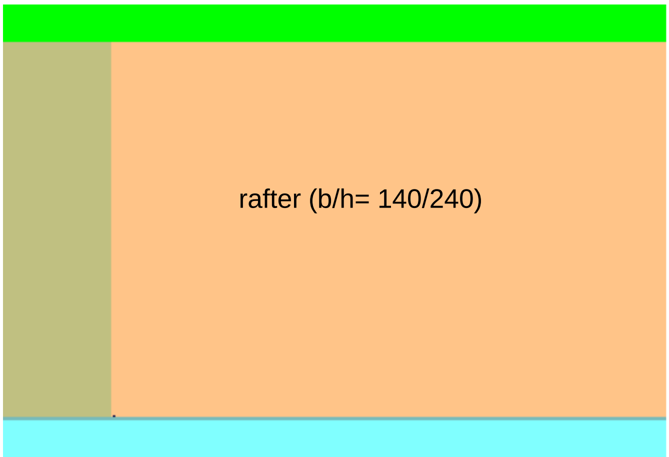
No wood moisture over 10Vol% could be determined within the ceiling beams.

Increased water content with small amounts of condensate in the outer wall is so far tolerable as no ceiling beams were involved in the tested wall structure and the affected areas between ridge and eaves are relatively small.

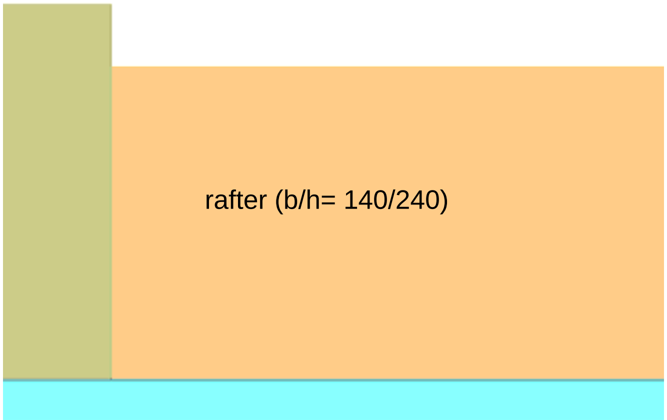
Thus, the thermal insulation clay does not need to be extended up the eaves high in the 4th upper floor and pure mineral wool insulation can be used in the 4th upper floor. A requirement for this is the vapour retarder in the 4th upper floor that needs to feature an s_d-value between 10 and 200 m.

3.3.3 Detail roof construction

Original and new construction



Roof construction (old):
- 25 mm OSB-board
- 240 mm cellulose
- vapor barrier (s_d= 0.7m)
- 2*12.5 mm plasterboard



Roof construction (new):
(- 40 mm air layer)
- 200 mm cellulose
- vapor barrier (s_d= 0.7m)
- 2*12.5 mm plasterboard

Figure 3.17: Investigated roof structure according to the sketches of the AKM Architect Community - Top: new design (drawing from 17.02.), below: old construction.

The sketchy in figure 3.12 illustrate the examined roof structures. Above the originally planned construction with a high diffusion resistance of the oriented strand board (μ= 550/700), below the revised construction with a 40 mm thick, air-washed layer and a 40 mm reduced in thickness insulation layer.

In the simulation the construction ends outside at the air-encircling layer. According to DIN 4108-3 part 3 the outer climate in the form of the temperature and air humidity is positioned with an increased transfer resistance of 0,08 W/m²·K at this point. Hence the construction ends with the oriented strand board (OSB) respectively with the cellulose insulation/rafter. Due to the symmetry of the construction through the centre of the field or the centre of the rafter only one half of the rafter and the insulation area has to be considered.

Calculation under steady conditions–climate according to DIN 4108-2, proof of minimum thermal protection according to DIN 4108

Both examined structures are completely uncritical in terms of the minimal thermal protection, so at this point only the temperature field of the "new" structure is shown:

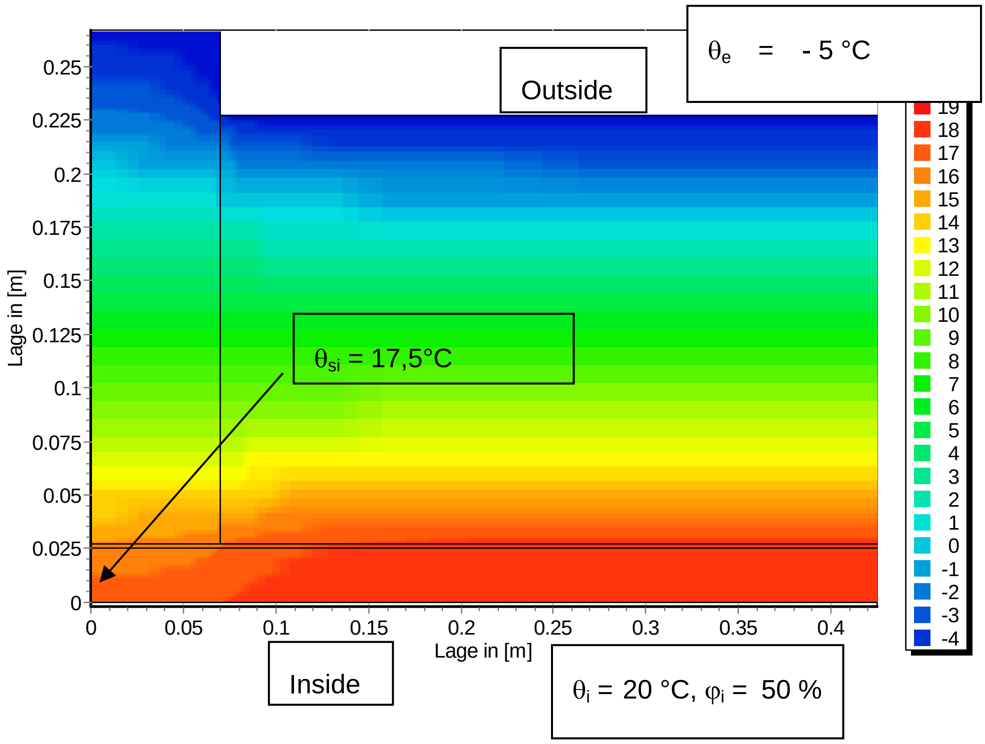


Figure 3.18: Temperature field of the new construction, surface temperature in [° C], Conditions according to DIN 4108 Part 2

$\theta_{si,\ new\ construction}$ = 17,5 °C ≥ $\theta_{si,\ acceptable}$ = 12,6 °C

$\theta_{si,\ old\ construction}$ = 17,8 °C ≥ $\theta_{si,\ acceptable}$ = 12,6 °C

The proof according to DIN 4108-2, section 6.2 for both different roof constructions with the chosen structure is complied.

Calculation under steady conditions–climate according to DIN 4108-3, proof of the condensation water dropping out according to DIN 4108-3

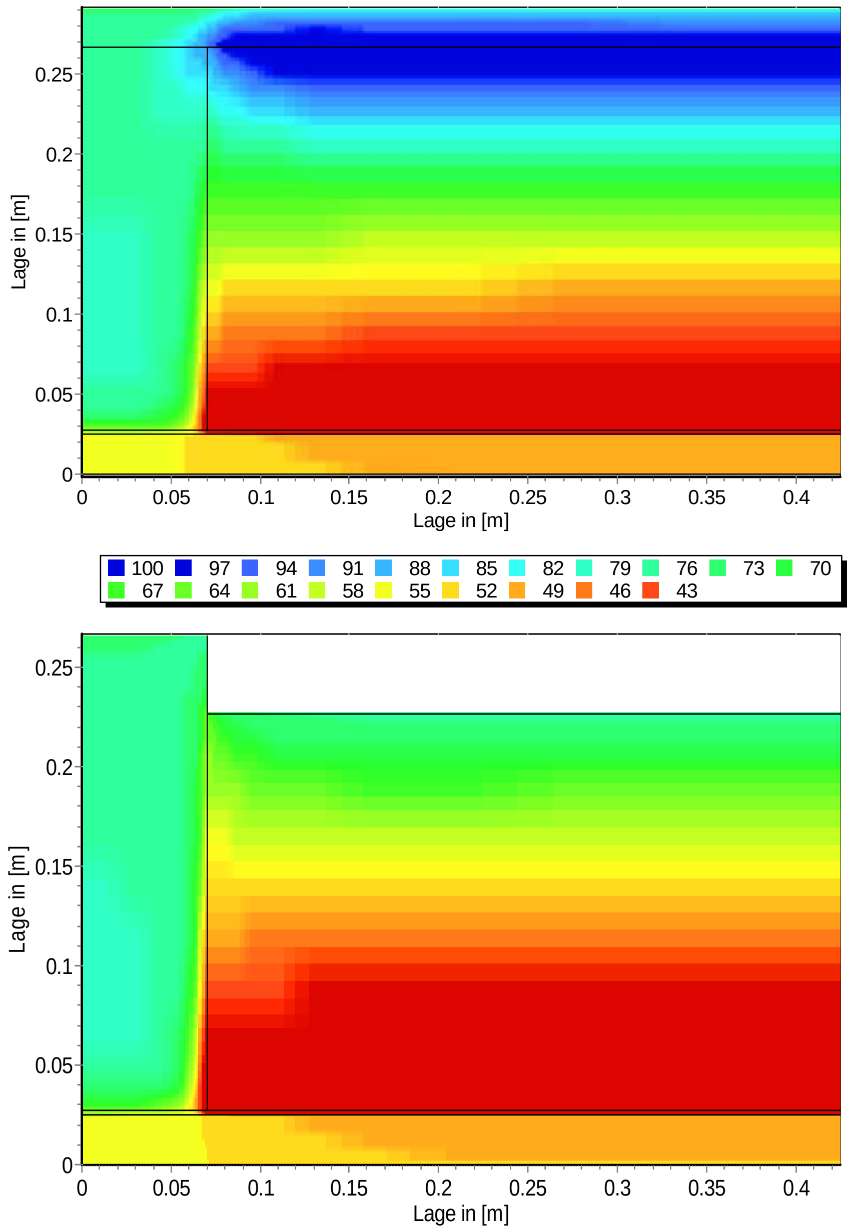


Figure 3.19: Distribution of humidity after 60 days winter climate, humidity in [%], Top: original design, Bottom: a new design with an air space.

As seen quite clear in figure 3.19, the condensation water forms in the original construction exclusively the field area and not in the rafters.

No condensate accrues within the new roof construction.

According to DIN 4108-3 the mass-related water content within a one-dimensional construction is allowed to increase in constructional timber by 5 mass percent at most, in wood-based material panels by 3 mass percent at most.

Here this limit value is also applied to the two-dimensional roof construction. By a conversion factor (1/width of the detail with 0.425 m) the gained amount of condensate from the simulation can be converted into the required unit kg/m².

The allowed amount of condensate is obtained as follows:

$$630\ kg/m^3 \cdot 0.025\ m \cdot 0.03\ M\%/M\% = \underline{0.473\ kg/m^2}$$

In the calculation of the originally planned construction an amount of condensate of 0,411 kg/m² is obtained for the two-dimensional construction. If the rafter is neglected and so a one-dimensional simulation of the field is implemented, the condensate totalizes to 0.477 kg/m².

$m_{W,T,\ new\ construction} = 0.0\ kg/m^2 \quad \leq \quad m_{W,T,\ acceptable} = 0.473\ kg/m^2$

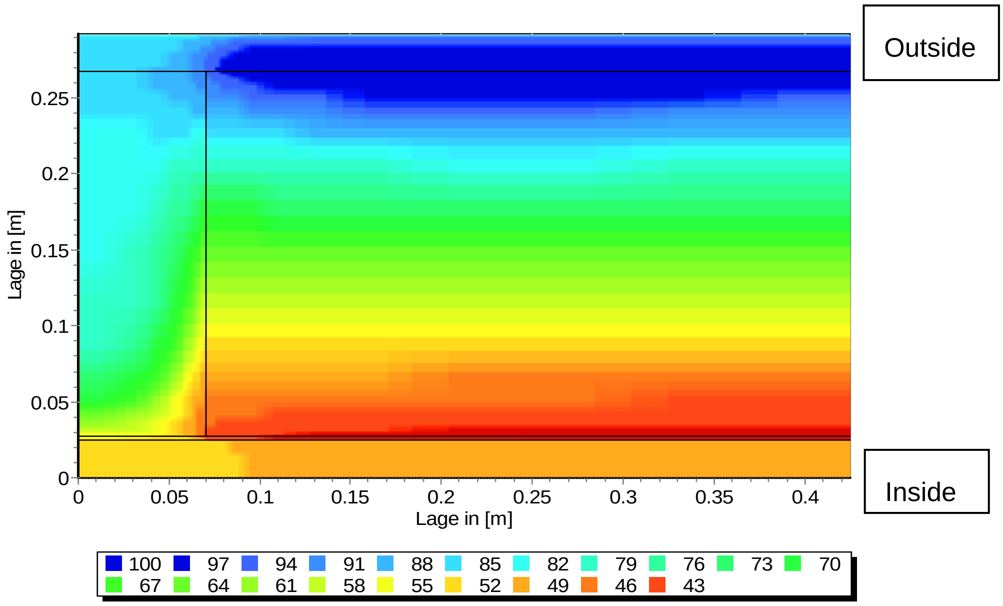
$m_{W,T,\ old\ construction,\ 2D} = 0.411\ kg/m^2 \quad \leq \quad m_{W,T,\ acceptable} = 0.473\ kg/m^2$

($m_{W,T,\ old\ construction,\ 1D} = 0.597\ kg/m^2 \quad > \quad m_{W,T,\ acceptable} = 0.473\ kg/m^2$ → requirements are not fulfilled!)

Out of this it can be seen that the results of the roof construction lie within the limits prescribed by the DIN, however, are fraught with problems.

At the end of this section the evaluation will be discussed.

Calculation under unsteady conditions - Outer climate Potsdam (test-reference year TRY04)



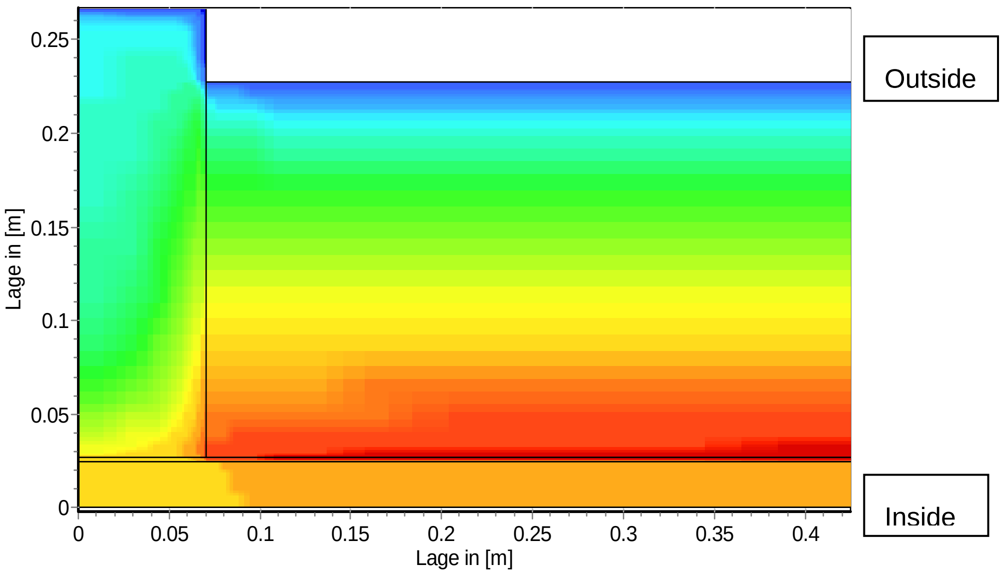


Figure 3.20: Relative humidity in [%], boundary conditions as TRY04 Potsdam, Top: Original roof structure, distribution of humidity at 28.March, Bottom: new roof structure, distribution of humidity on 19.Oct.

As can be see in the steady procedure already, the condensate concentrates in the original construction with the OSB-panels on the underside of the stiffening OSB-panel. But even with the new construction high air humidities can be recorded on the outside of the insulation and the rafters, as eventually the outside air, especially during rain events, increased air humidity is exhibited. In the simulation with test reference climate an amount of 0.562kg/m² condensate emerges, which is above the limit value of the previous section (0.471kg/m²). Nevertheless the limit value only applies to the amount of condensate being calculated by the climatic boundary conditions of the steady procedure.

At the new modified construction with real climate only a vanishing small amount of condensation water with 0.03kg/m² at most is generated.

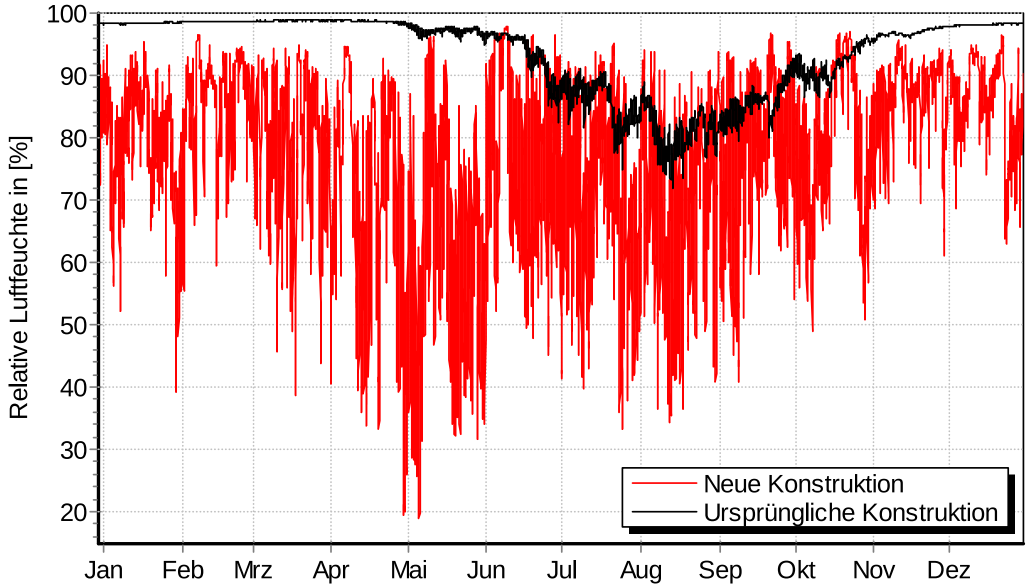


Figure 3.21: Trend of the relative humidity in the field area at the outer side of the cellulose insulation, boundary conditions according TRY04 Potsdam.

The course of the relative air humidity in the previous figure demonstrates the difference between both construction variants. With the OSB panel the humidity bottles up on the underside, so that the air humidity is constantly at a very high level with the exception of the summer and early fall. Without the OSB panels the air humidity depicts the path of the outer air humidity on the same position.

Evatuation. The limit values regarding condensate are barely adhered with the originally planned roof construction with OSB panels, however the use of this application must be urgently discouraged.

A remark in DIN 4108-3 section 4.3.3.2 indicates that in "non-ventilated roofs with ventilated or not ventilated roofing and external diffusion-inhibiting layers with $s_{d,e} \geq 2$ m an increased construction moisture or an invading moisture being the product of a later leakiness can only poorly or not at all dry out", which would apply to the original construction. Furthermore this would violate the well-known "rule of thumb" in finding that the diffusion resistance of the outer layer (here OSB: s_d = 17.5 m) should unconditionally be smaller the resistance of the inner layer (here plasterboard and vapour retarder: s_d = 0.95 m).

Other important reasons that can never be ruled out are the minor damage of the vapour-sealing layer by the future user or improper installation of the vapour retarder in construction (keywords: adhesion of the retarder layers to each other and connecting joints).

The proposed alternatives from our side, to replace the OSB panel by diffusion-open DWD panels in combination with wind bands, were rejected by the planner because of the high expenditure. The planners' alternative and here calculated construction with the additional air layer is also a viable option.

One of the following two alternatives, which can be optionally carried out with **less expenditure of human labour and less expenditure of time**, is also possible:

1. Removing the plasterboard panels and vapour retarder (inside). Applying a vapour retarder with an s_d-value > 20 m as well as two layers of plasterboard panels.
2. Appling a vapour retarder **or** a paint with an s_d-value > 20 m on the inside of the existing constructi3on and protecting this layer mechanically with an additional layer of plasterboard (d= 12.5 mm). Future users should be absolutely prohibited to perforate the roof slope (dwel holes, etc.). By this measure some lettable space gets lost.

Additionally to that, another hole in the outer OSB panel should also be drilled to approximately the middle of the rafter length, as already being down in at the ridge and into the eaves.

3.3.4 Detail roof connection loggia (detail 3136 SK)

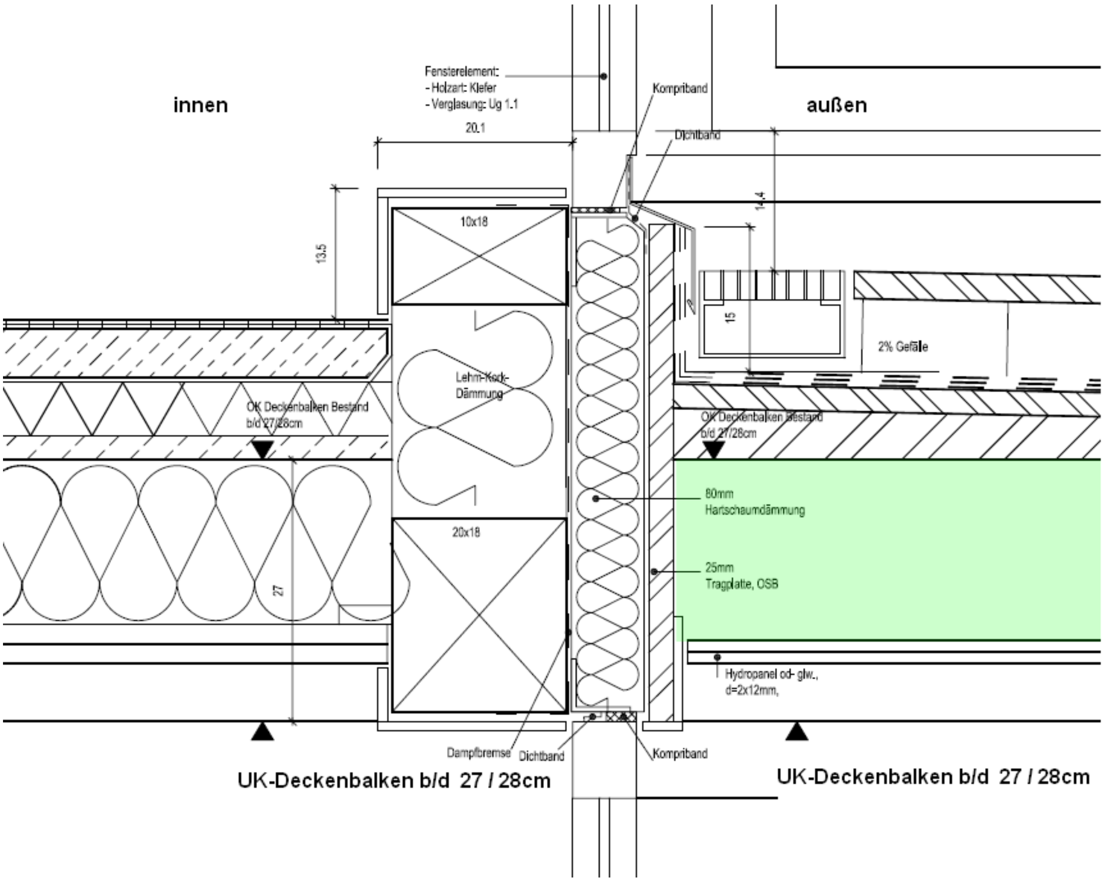


Figure 3.22: Section of detailed sketch of AKM Architects Community Plan No.:. SK 3136 from 16.02.2009 deduction.

The construction is recommended as shown in the detail plan plan-no.: 3136 SK of 16.02.2009 (subtraction). Thereby it is important to make sure that the continues ceiling beams corresponding to the inside or the outside are connected, the same way as the sealing bands and the compriband between the window and angular rigid foam insulation. The working and expansion joints between wall and continuous ceiling beams must be filled out completely with insulation. Considering the above-guidance information, the minimum thermal insulation according to DIN 4108-2 is maintained under steady conditions. Thus there is no risk of mould formation in the areas of the inner corner.

Calculation under steady conditions–climate according to DIN 4108-2, proof of the minimum thermal protection according to DIN 4108

For the calculation of the minimum thermal insulation according to DIN 4108-2 on the room sided wall corner steel beam / window frame it is assumed that the connection between the continuous existing wooden beam and the wall is being carried out with the use of a vapour retarder room sided and on the outside driving rain consistent, like for example with the use of a compriband. For the calculation the working and expansion joints between the existing wooden beams and the wall had been filled with insulation.

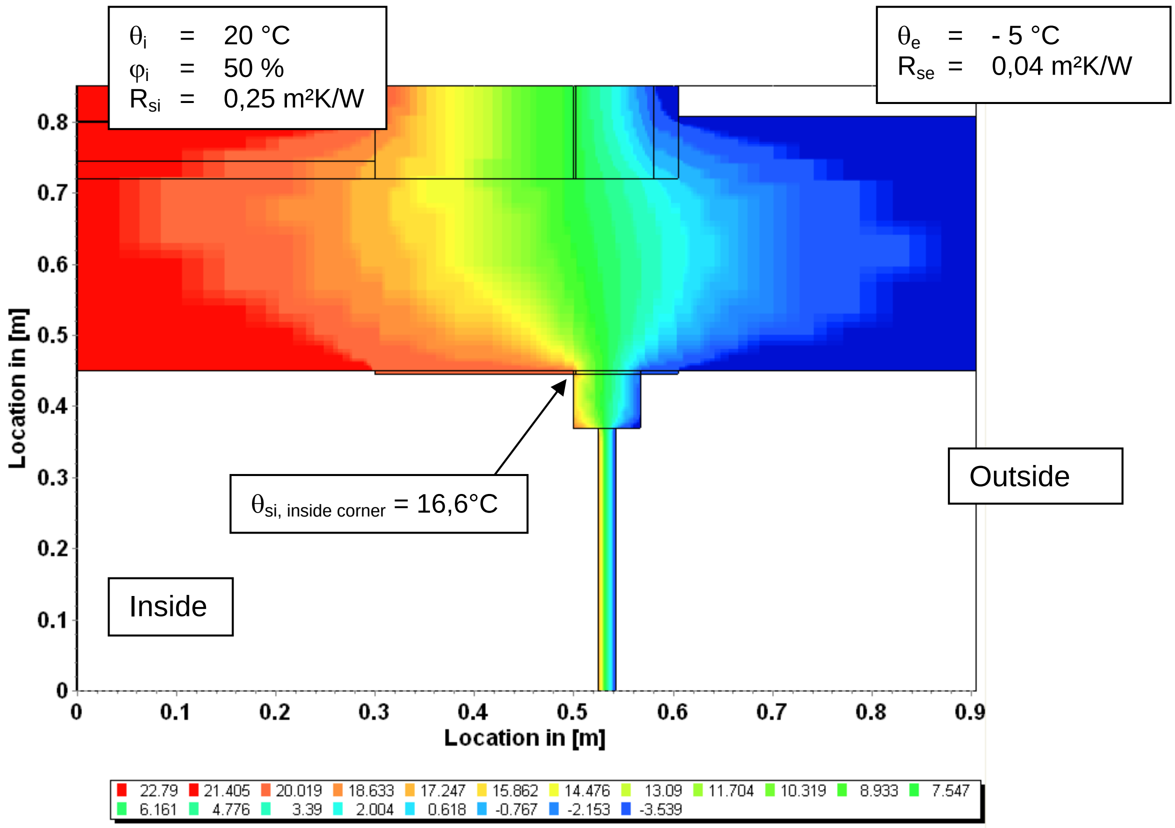


Figure 3.23: Field of temperature, surface temperature in [°C], boundary condition according to DIN 4108 part 2.

$\theta_{si,\ inside\ corner}$ =16,6 °C > $\theta_{si,\ acceptable}$ = 12,6 °C

The proof according to DIN 4108-2, section 6.2 is complied in the realm of the window connection with the chosen construction.

Calculation under unsteady conditions Outer climate Potsdam (test reference year TRY04)

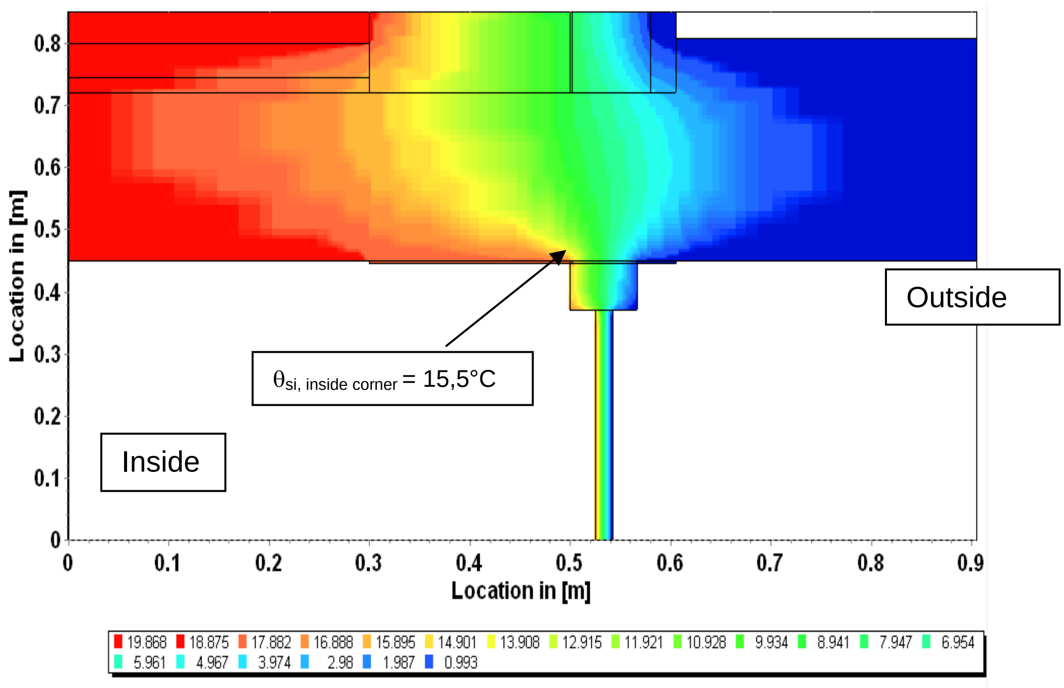


Figure 3.24: Field of the temperature, surface temperature in [°C], boundary condition according to TRY04 Potsdam.

$\theta_{si,\ inside\ corner}$ =15,5 °C < $\theta_{si,\ acceptable}$ = 12,6 °C

The proof referring to DIN 4108-2 is complied with the usage of the test reference year Potsdam (TRY04).

3.3.5 Detail foot tower terrace (detail SK 3118a)

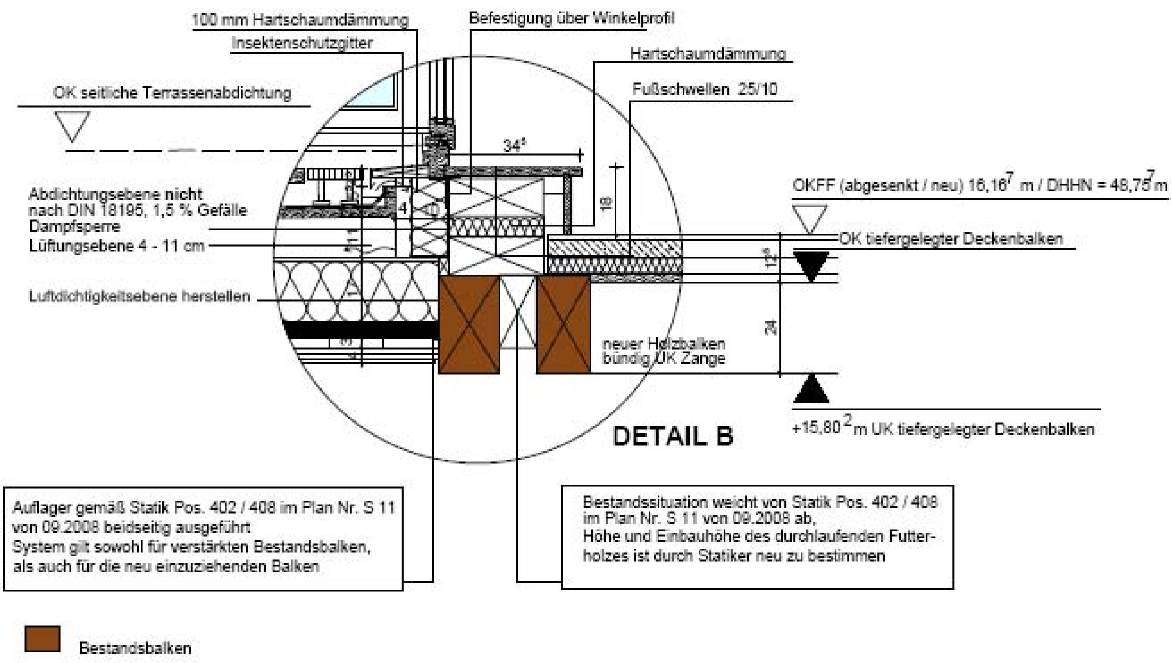


Figure 3.25: Detail B foot point- tower terrace AKM architect Community (Plan No. SK 3118a) from 12.01.2009.

Calculation under steady conditions-climate according to DIN 4108-2
Proof of the minimum thermal protection according to DIN 4108

The proof of the minimum thermal protection according to DIN 4180 part 2 section 2.6 was performed for this detail to prevent mould growth.

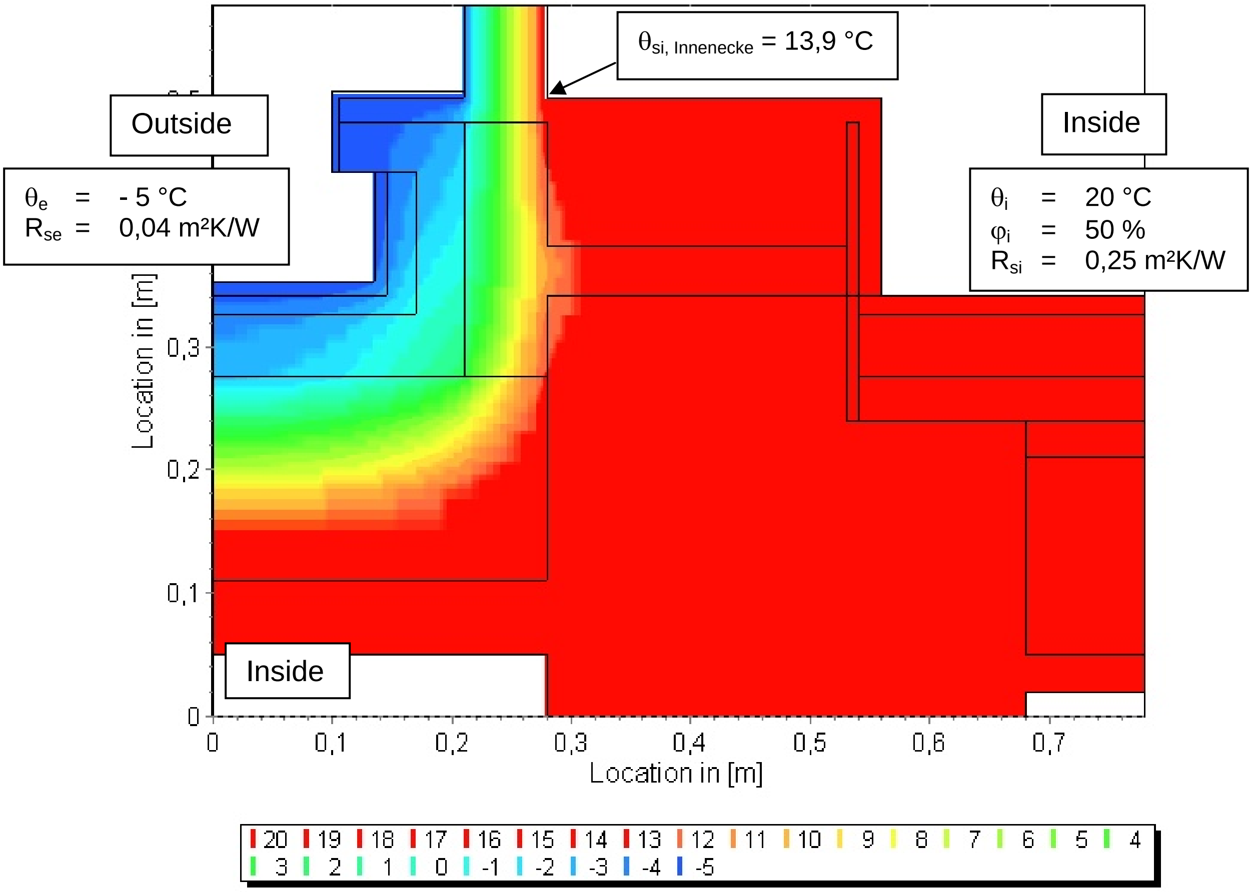


Figure 3.26: Temperature field, surface temperature in [° C], Conditions according to DIN 4108 Part 2.

$\theta_{si,\ Innenecke}$ =13,9 °C > $\theta_{si,\ zulässig}$ = 12,6 °C

The proof according to DIN 4108 – 2, section 6.2 is complied in the realm of the lower terrace door connection.

The minimum thermal protection is guaranteed for the detail of the lower connection. Hardwearing hard foam is used as insulation under the inner step. It is important to be mindful of technically correct connection of the air sealing layer at the window.

3.3.6 Detail point of eave tower terrace (detail SK 3117a)

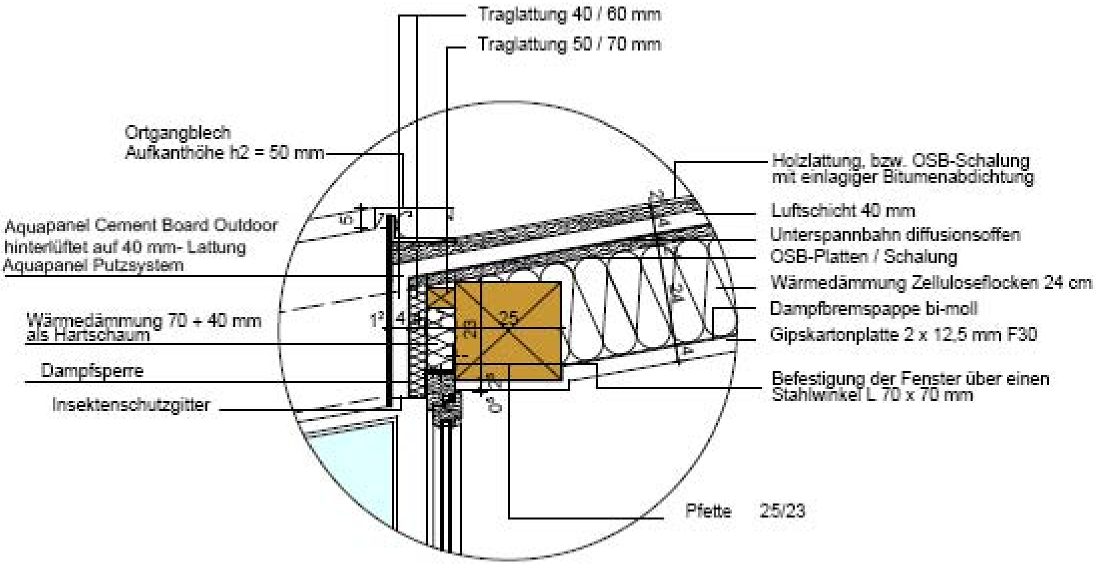


Figure 3.27: Detail A, eaves point- tower terrace AKM Architects community (Plan No. SK 3117a) from 27.01.2009.

A dimensioning was already made for this detail, which is not shown here. Thereby the minimum thermal protection was not complied. The IBK of the Technical University of Dresden suggested moving the window tier to the inside.

With the alternations of 27th January 2009 an additional externally placed insulating layer supplements the point of eave, the fixing of the windows should now take place by the means of T-squares.

According to the statement of the architect the proposed moving of the window tier to the inside is not possible.

Calculation under steady conditions-climate according to DIN 4108-2, proof of minimum thermal protection according to DIN 4108

The proof of the minimum thermal insulation according to DIN 4108 part 2, section 2.6 was performed for this detail to prevent mould growth.

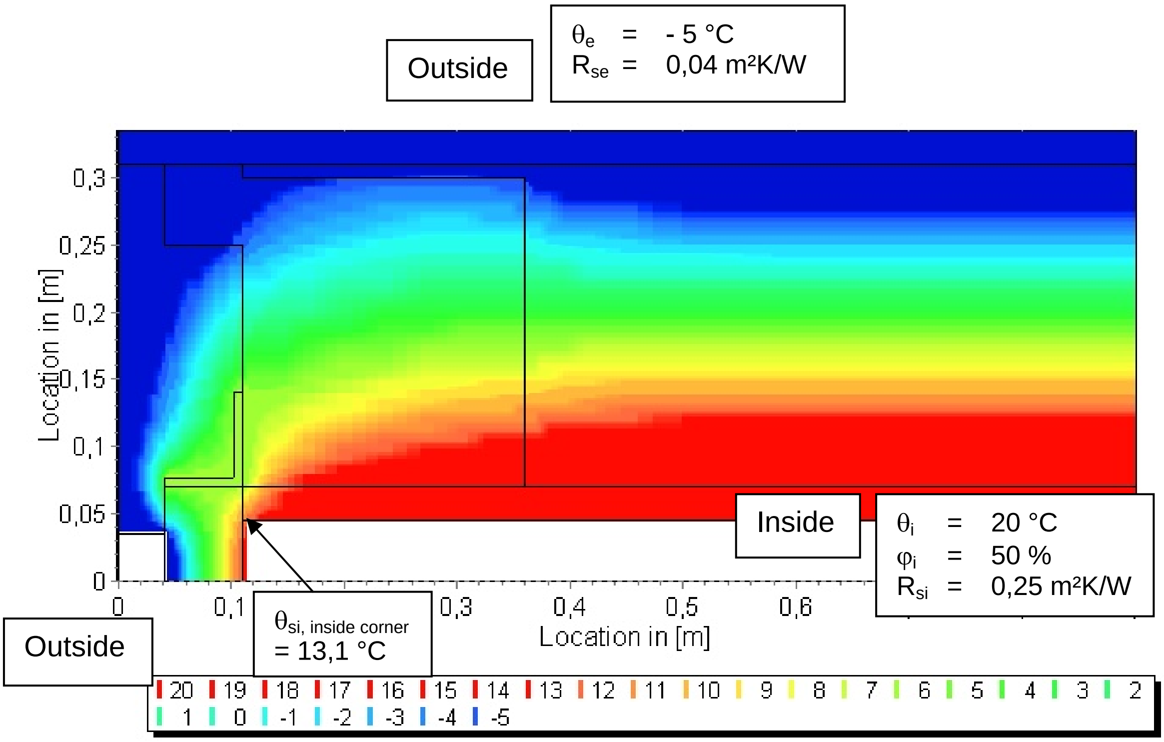


Figure 3.28: Temperature field, surface temperature in [° C], Conditions according to DIN 4108 Part 2.

$\theta_{si,\ Innenecke}$ =13,1 °C > $\theta_{si,\ zulässig}$ = 12,6 °C

The proof according to DIN 4108 – 2, section 6.2 is complied in the realm of the lower terrace door connection with the additional insulating layer.

Calculation under steady conditions-climate according to DIN 4108, proof of the condensation according to DIN 4108-3

80 % relative humidity and 10°C were chosen as initial conditions. The proof took place based on the stepping-climate according to DIN 4108-3 part 3 with 4 periods of thaw and 3 periods of evaporation.

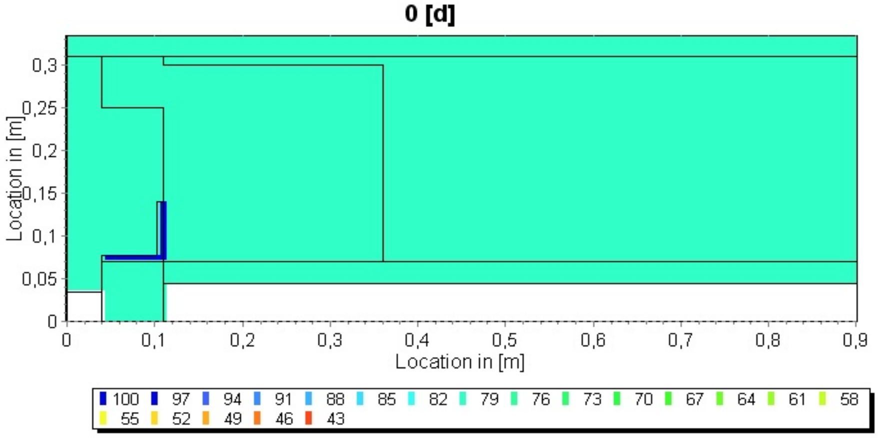


Figure 3.29: Moisture field of relative humidity in [%] with initial conditions.

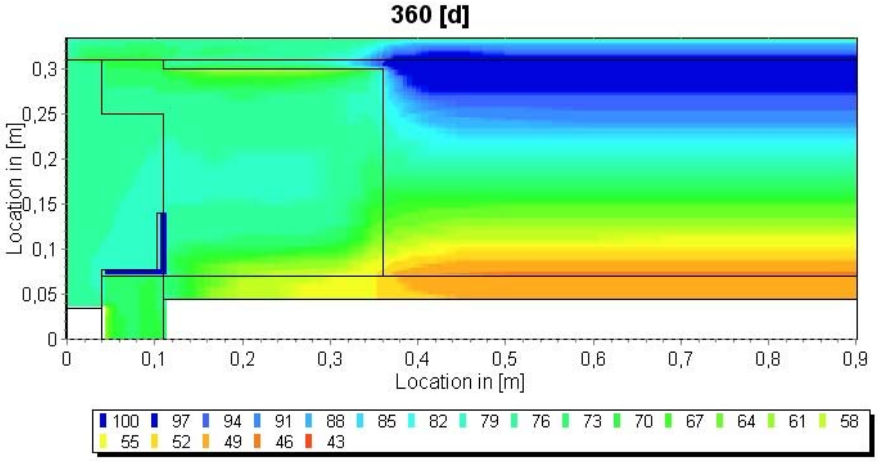


Figure 3.30: Moisture field of relative humidity in [%] after the 3rd dew period.

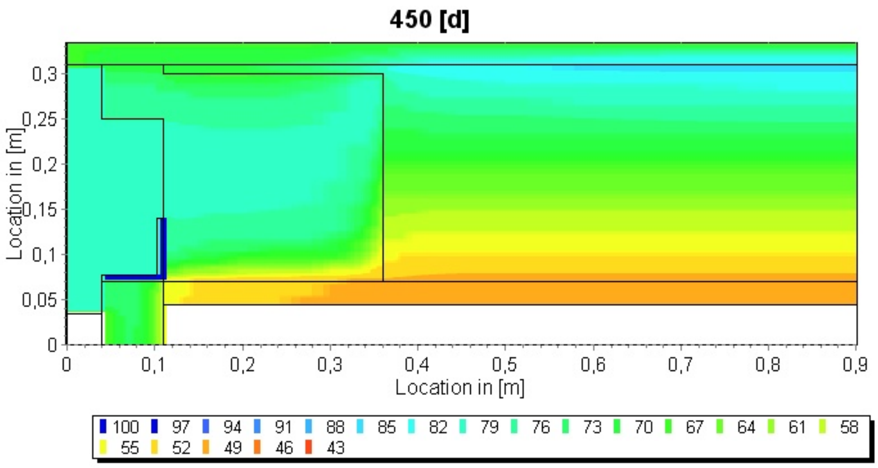


Figure 3.31: Moisture field of relative humidity in [%] after the 3rd evaporation period.

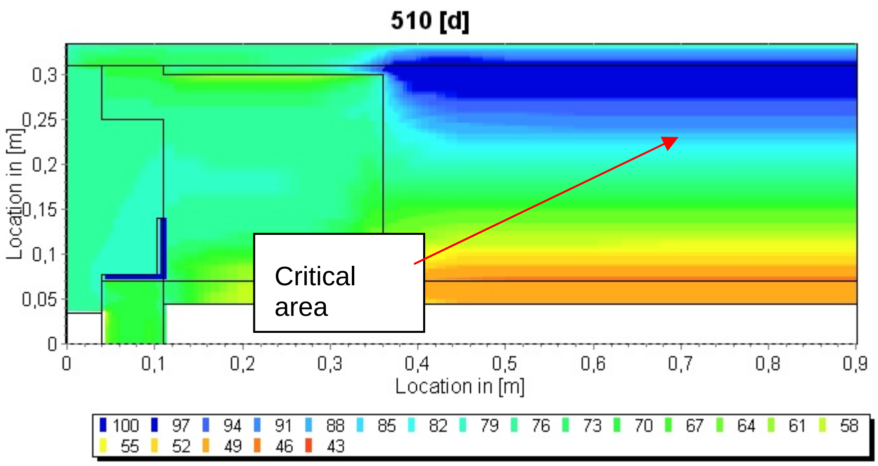


Figure 3.32: Moisture field of relative humidity in [%] after the 4th dew period.

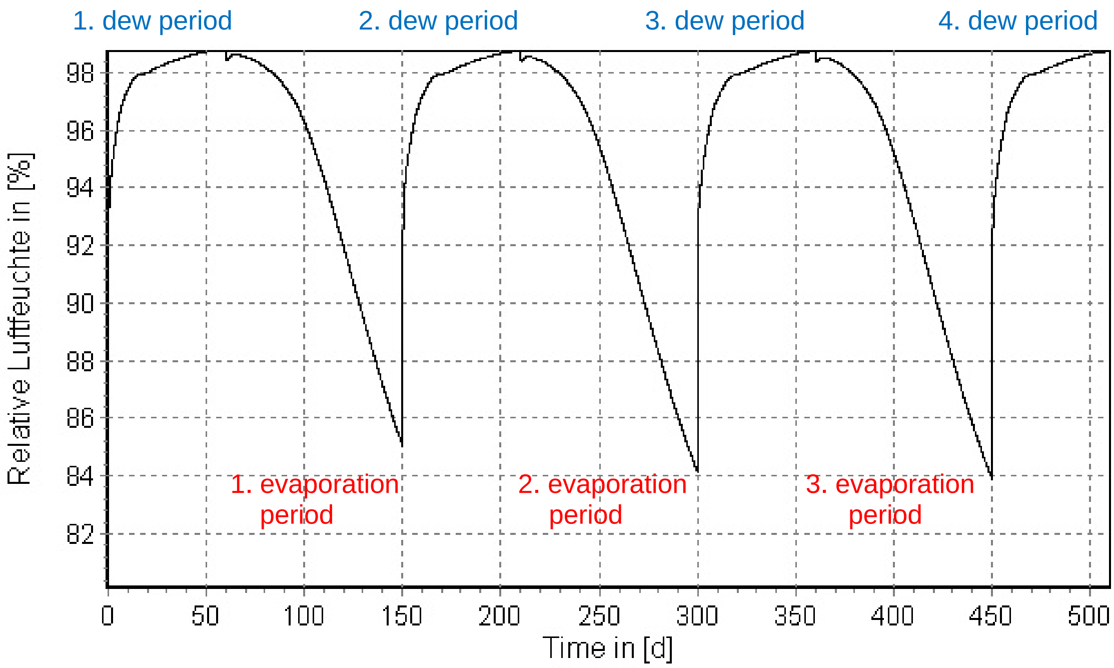


Figure 3.33: Trend of the rel. Humidity in [%] in the critical area of the transition OSB plate- insulation, 4 dew periods and 3 evaporation periods.

After the 2nd evaporation period a steady state is being reached. With a max. humidity of 98% during the period of thaw condensate occurs in the illustrated critical realm. The high air humidity in the period of thaw appears very quickly. Even with a detailed calculation with real climate a development of condensate is to be expected.

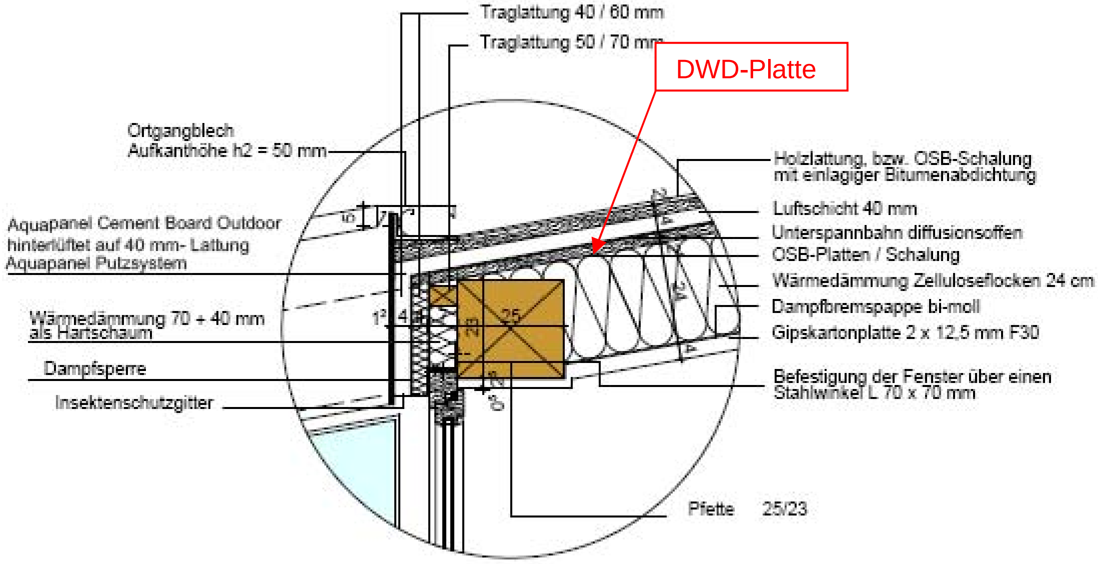
The insulation can sag as a result of the condensate. The insulating effect gets lost. The insulation material must be mold resistant.

The OSB panel is too close to the outside of the roof insulation.

For the diffusion-open construction a DWD-panel should be attached to the outside. The ratio of the s_D-value between inside and outside should add up to 10:1. The production of the air-tightness layer has to be effected by the means of the RAL-assembly guidelines.

For the insertion of the planned loose-fill insulation an OSB panel should be attached to the inner surface. An additional vapour retarder is not necessary in case of an appropriate adhesion of the splices of the OSB panel on the inner surface.

For the following calculation under the same conditions the OSB panel on the outside of the insulation was replaced by a DWD-panel.



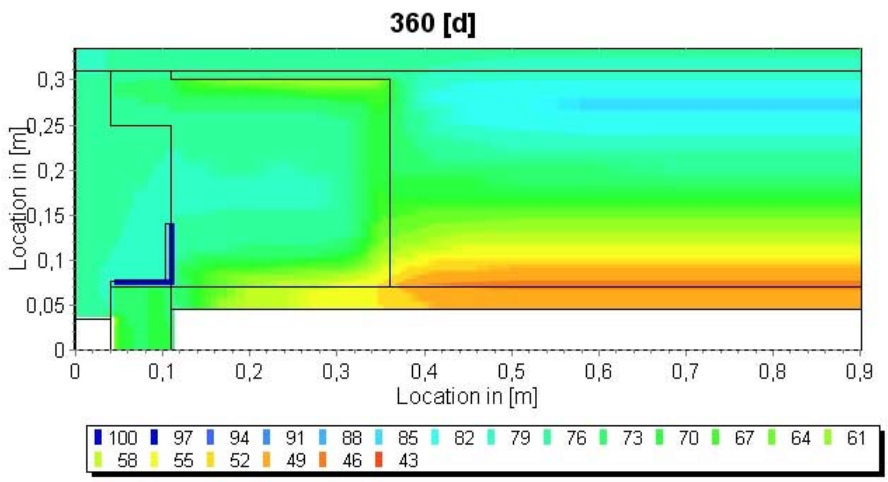


Figure 3.34: Moisture field of relative humidity in [%] after the 3rd Thaw period (outside DWD).

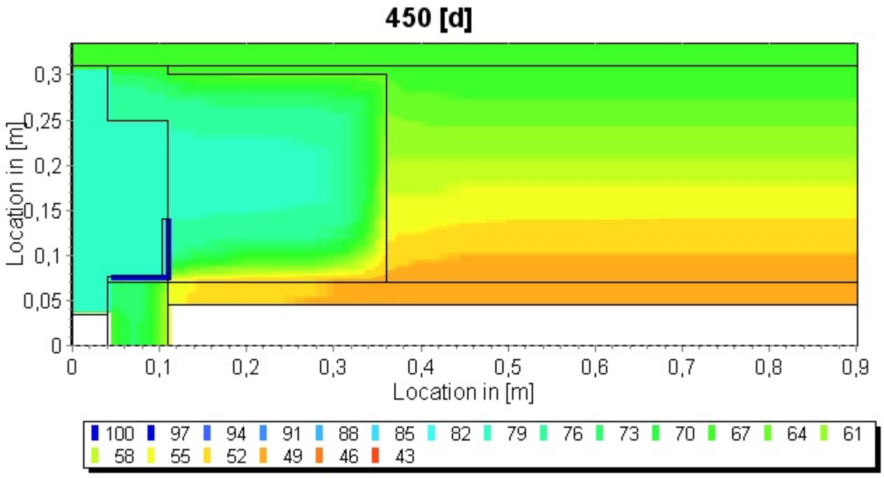


Figure 3.35: Moisture field of relative humidity in [%] after the 3rd Evaporation period (outside DWD).

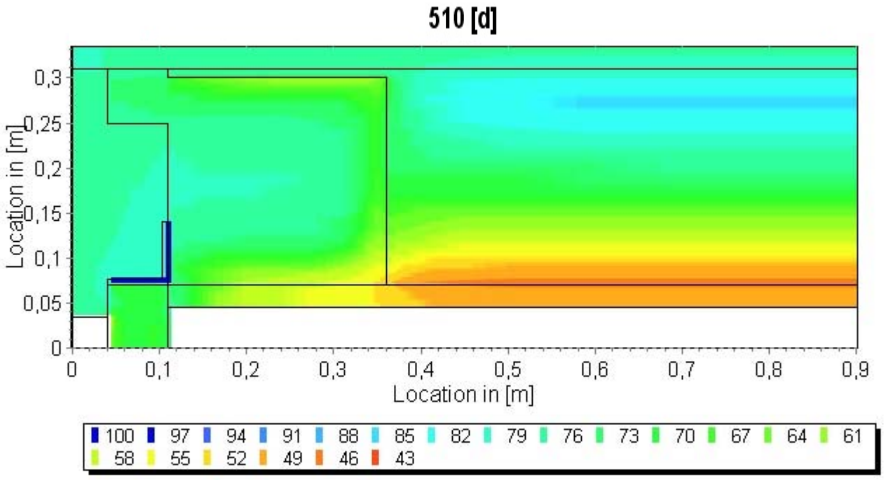


Figure 3.36: Moisture field of relative humidity in [%] after the 4th Thaw period (outside DWD).

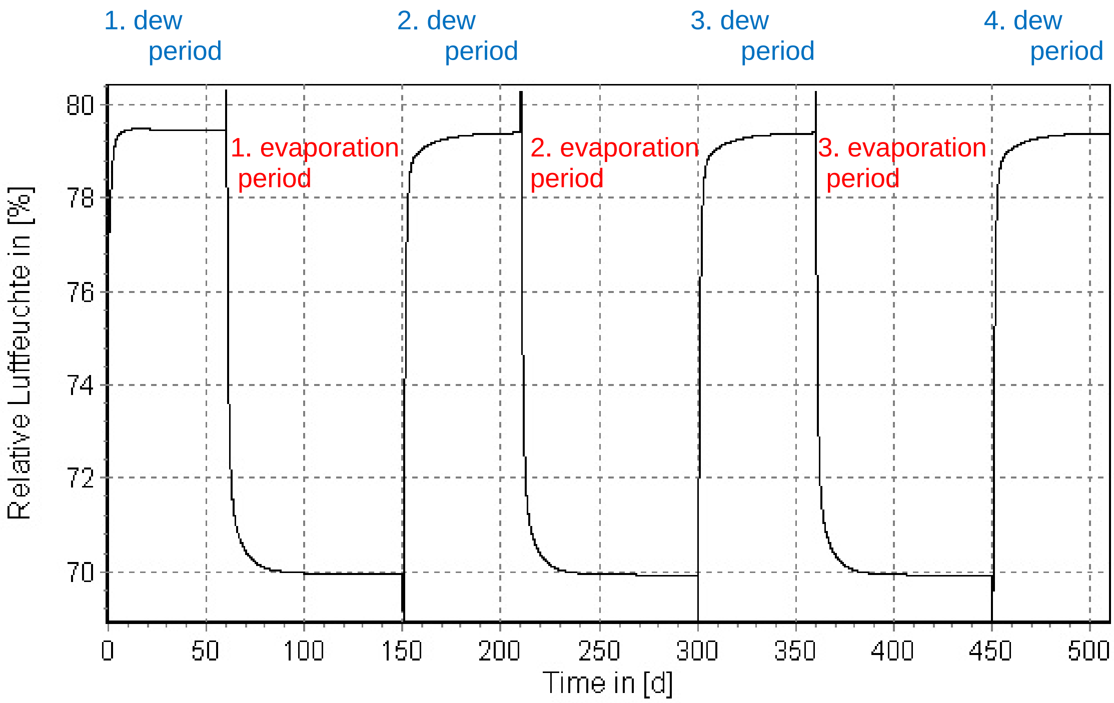


Figure 3.37: Trend of the rel. Humidity in [%] in the transition DWD board - insulation, 4 dew period and 3 evaporation period.

After the 1st evaporation period a steady state is being reached. The diffusion-open construction displays a sufficient drying potential. There will be no condensation in the construction.

4 Drawings and Images

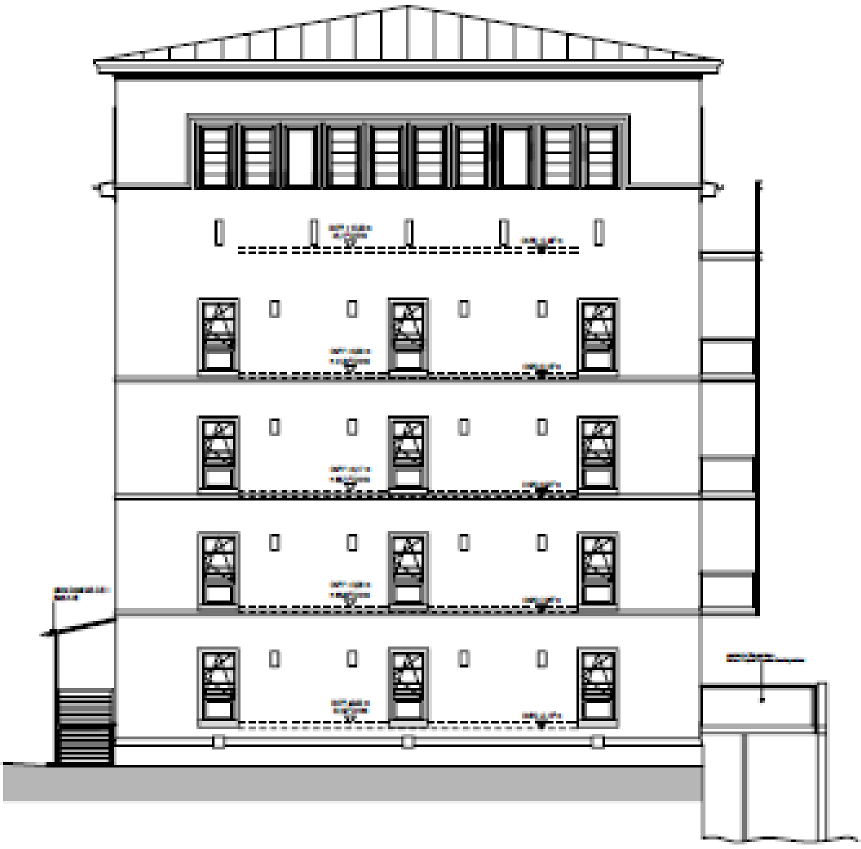


Figure 3.38: Elevation North façade.

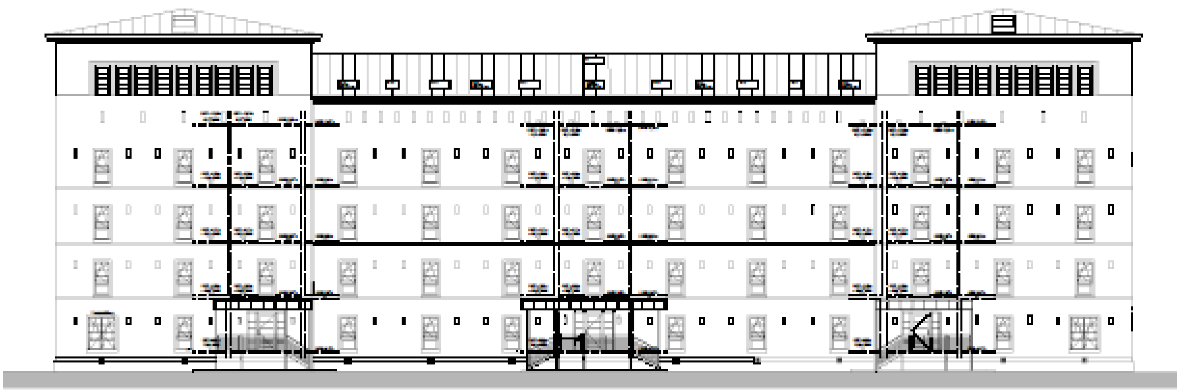


Figure 3.39: Elevation West façade (view from the river).

Figure 3.40: North and West façade facing the river Havel.

Figure 3.41: Attic floor for grain storage (grain scale is well preserved on the pillars).

Figure 3.42: East façade under construction.

Figure 3.43: Interior details.

D 6.2 Documentation of each study case

CS6 Renaissance Building, Freiberg (Germany)

Delivered at M42

EUROPEAN COMMISSION

DG Research and Innovation

Seventh Framework Programme

Theme [EeB.ENV.2010.3.2.4-1]

[Compatible solutions for improving the energy efficiency of historic buildings in urban areas]

Collaborative Project – GRANT AGREEMENT No. 260162

Technical References

Project Acronym	3ENCULT
Project Title	Efficient ENergy for EU Cultural Heritage
Project Coordinator	Alexandra Troi EURAC research, Viale Druso 1, 39100 Bolzano/Italy Alexandra.troi@eurac.edu
Project Duration	1 October 2010 – 31 March 2014 (42 Months)

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Work Package	WP 6 “Case studies & Transferability”
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Contributing beneficiary(ies)	P10 COBO
Author(s)	Rudolf Plagge
Co-author(s)	Ayman Bishara, Frank Meissner
Date	31 March 2014
File Name	WP6_D6.2_20140331_ Documentation of Case Study 6

Table of Content

2 Template for Case study presentation

2.1 Brief description of the building

This table is to be considered as an identity card with brief descriptions of the building so that it is possible to compare the different case studies.

Object Name: Renaissance Building Freiberg	
Location	
Country	Germany
City	Freiberg
Altitude	400 m
Heating days	$\mathbf{T_{15}}$ = 201 d, $\mathbf{T_{10}}$ = 197 d (PLZ D-09599)
Heating degree days	daily temperature figure**:** $\mathbf{G_{20/10}}$ = 3473 K*d, $\mathbf{G_{20/15}}$ = 4090 K*d [Gradtagszahl] Heating degree days: $\mathbf{G_{10}}$ = 1461 K*d, $\mathbf{G_{15}}$ = 2673 K*d [Heizgradtage]
History	
Date of construction	• Main structure was built in 1518 • Renovated in the 19^{th} century • In 2009 intervention began • 2011 completion of the intervention
Construction Type (according to its age)	The building has different types of construction according to the time of creation of its parts. The basement dates to the Middle Ages while the ground floor was built during the Renaissance. First floor and the roof are of younger times.
Original objective	Residential house
Current use	Residential house with two apartments
Expected use in future	Residential house with two (optional three) apartments
General description	
Status quo	Renovated
Architectural style	The street façade and a small part oft he back yard

	façade have a Renaissance appearence. Both the interior and most of the back yard façade are equivalent to a contemporary style.
Construction materials	External walls: Masonry in natural stone (gneiss), plaster Ceilings: wooden beam ceiling Roof: Roof structure in wood, roof with solar panels
Overall conservation status (General condition)	Endangered before renovation
Urban Context	
Quarter/town	Old town: The listed house is part of the oldest Settlement area (Sächsstadt) of Freiberg in Saxony.
Development plans	building is a representative example of the building stock of the middle age in the historic city Center of Freiberg
Key figures as e.g. % of historic buildings, renovation rate	about 50%
Cultural Value (Specific valuable aspects)	
Historical Values	major resource of identification for the citizens and important touristic attraction
Design Value	building is a representative example of the building stock of the middle age in the historic city Center of Freiberg
Constraint condition (Others)	-
Building Problems (cracks, deterioration, moulds and fungi..etc)	
1	Indoor humidity and temperature
2	Salt rising in masonry walls
Planned/Proposed/Possible activities	
Diagnosis	• Visual inspection • Geometrical survey (plan view, section, volumes, …) • Window frames survey • Measurements of Air T and RH in rooms; measurements of superficial temperature on walls • Mapping of air T and RH

	• U-value measurements • Survey of openings in ceilings/floors • Carrier gas measurement • Software simulation (Energieberater – Hottgenroth, Therm, Delphin) • Blower door test
Planned solutions	• Atrium as a buffer zone • Insulation and Windows (two to triple glazing) • Reduction of thermal bridges • Air tightness • Mechanical ventilation with heat recovery • Solar thermal energy and Seasonal storage • Photovoltaic system • Computer-aided control • Long-term monitoring of critical components
Monitoring system	• freely programmable universal controls UVR 1611 use for: • facility management • measuring sections
Simulation	Energieberater, Delphin, PHPP, Therm, Designbuilder
Transfer to urban scale concept	The apartment house City Freiberg is a place where the habitants can live and work in reconstructed on newest technological energy standards (heating and cooling) based on renewable energy. It should be also a place for optimisation, demonstration and teaching of technology and using in the subject of renewable energies and building.
Others	The test building is to be used for continuing education for architects and engineers.
Documentation	
Existing documentation	-
Scanned/photocopied materials	-
Digital materials	Site measuring and photos
Inside surface	Photos
Outside Surface	Photos

2.2 Detailed description

2.2.1 Local climate data

Local climate date[1] (rif. Central city:)	
(building plan showing the north)	Climate zone: #
	Climate area: #
	Degree days: #
	Altitude: 400 m
	Coordinates: 50° 55′ N, 13° 21′ O
	Average wind speed: #
	Prevailing wind direction: #
Winter climate data	#
Winter design temperature: - 5°C	Temperature: #
HR max: 95% (Nov.- Dec.)	#
Heating days per year: 183 (15 Oct.- 15 Apr.)	#
Other	#

[1] Example of data

2.2.2 Report on history of the building

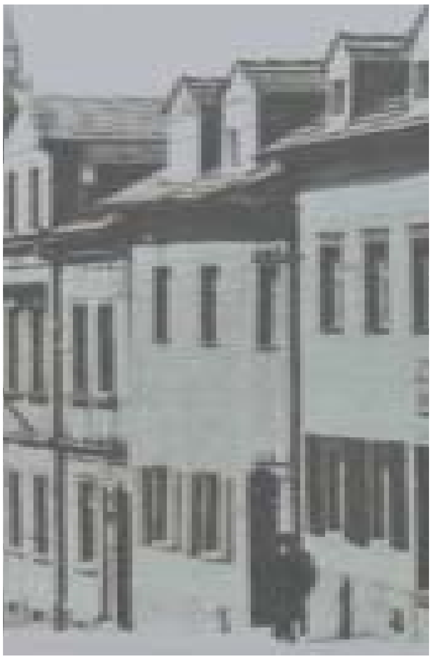
Historical summary table

History of the building			
(drawing)	First phase of construction:	1168	First silver discovery in the region. Founding of the Bergläutesiedlung Sächsstädt (later Jakobiviertel)
		1516	Construction of the building (dentrological determination of the ceiling beams).
		1554	Owner can be retraced gapless to this point of time.
	Second phase of construction (first extension):	1845	Nursery man Hanisch. The building burns out completely. In the Freiberger news is written „the fire takes all goods and chattles from the family
		1882	A carpenter family lives in the house about four generations
	Major renovations	2009 - 2011	renovation
	Constraint condition:	#	#

facing to the street (2007)

facing to the backyard (2007)

Figure 2.1: Picture of the Renaissance Building Freiberg



Donatsgasse 21 of 1933

Donatsgasse 21 of 2007

Figure 2.2: Picture of the Renaissance Building Freiberg

2.2.3 Building consistency

Building consistency		
(photos)	Building structure	#
	Internal partition	#
	External finishing	#
	Number of floors above ground	3
	Number of basement floors	1
	Covered area	#
	Numbers of rooms	#
	Gross area	#
	Net area	#

	Heated surface	#
	Surface cooled	#
	Heated volume	#

2.2.4 Building Energy consumption

Building Energy consumption			
Electricity	**Years**	**Consumption (kWh)**	**Cost (€) (average cost €/kWh)**
	#		
Diesel	**Year**	**Consumption (l)**	**Cost (€) (average cost €/l)**
Gas	**Years**	**Consumption (mc)**	**Cost (€) (average cost €/mc)**
Gecam	**Years**	**Consumption (l/mc)**	**Cost (€) (average cost €/mc)**

2.3 Constraint condition and protection

2.4 Selected area of intervention

If building as a whole is composed of different building blocks, you can break down the analysis for different functional area.

2.4.1 Functional area: Area 1 (name or function)

Functional area consistency		
Functional area 1:	Height interpolated average net (m):	#
(Plans and Photos of the rooms)	Surface area (Gross/Net) heated (mq):	#
	Volume (gross/net) heated (mc):	#
	Opening to the public (from/to; hours /day; temperature set-up):	#
	Hours of working (from/to, hours/ day; temperature set-up):	#
	Hours of air conditioning (from/to; hours/day; temperature set-up)	#

2.4.2 Functional area: Area 2 (name or function)

Functional area consistency		
Functional area 2:	Height interpolated average net (m):	#
(Plans and Photos of the rooms)	Surface area (Gross/Net) heated (mq):	#
	Volume (gross/net) heated (mc):	#

	Opening to the public (from/to; hours /day; temperature set-up):	#
	Hours of working (from/to, hours/ day; temperature set-up):	#
	Hours of air conditioning (from/to; hours/day; temperature set-up)	#

3 Report on status pre-intervention

3.1 Analysis and monitoring results

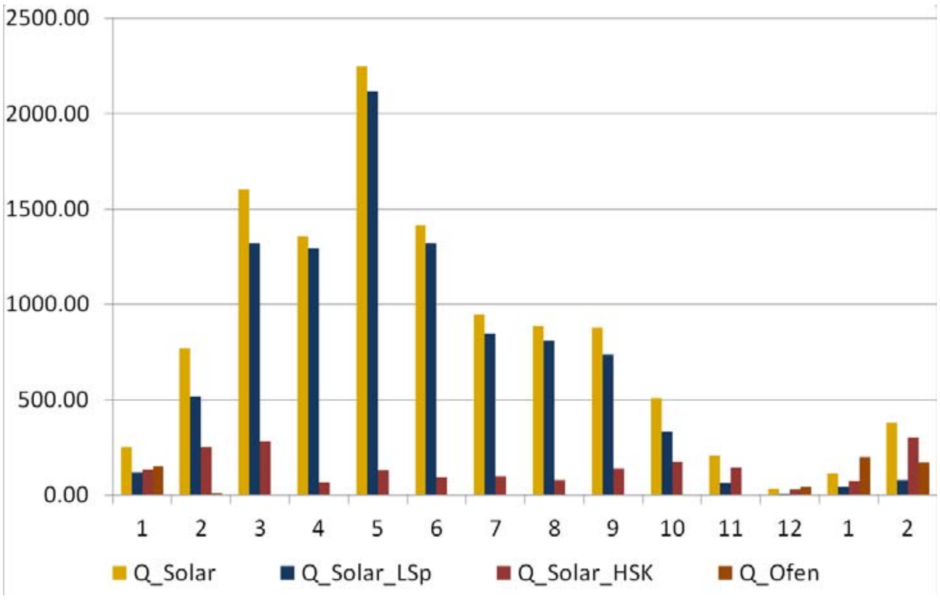


Figure 3.1: Energy generated, 01.01.2010 to 02.29.2012 in [kWh].

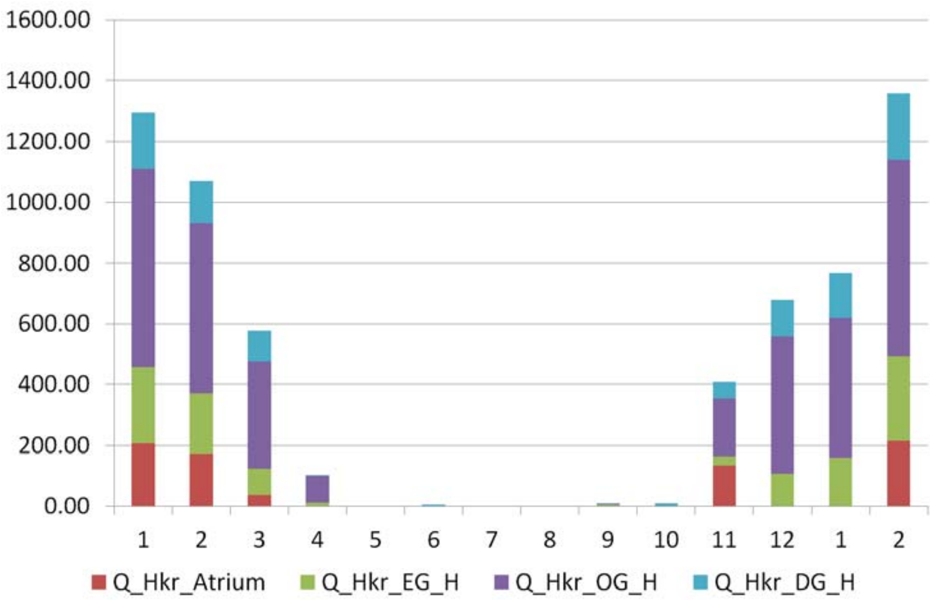


Figure 3.2: Heating energy consumption, 01.01.2010 to 02.29.2012 in [kWh].

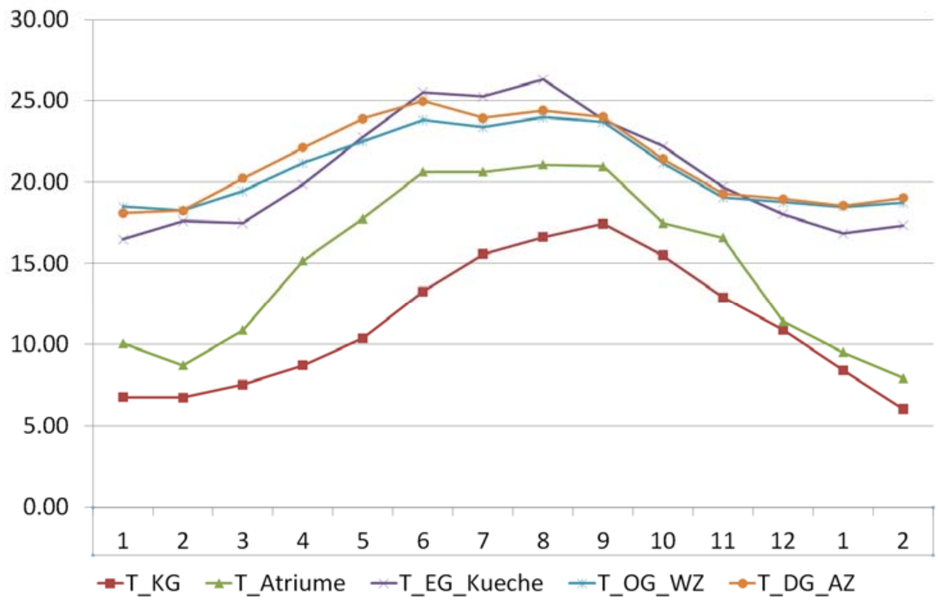


Figure 3.3: Indoor temperatures, 01.01.2010 to 02.29.2012 in [° C].

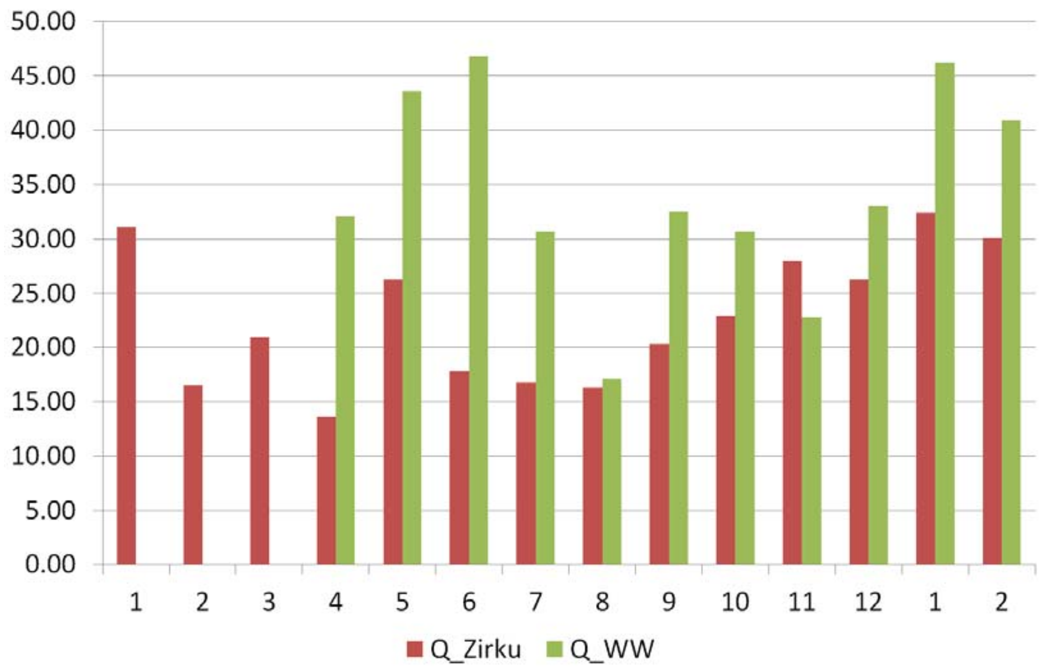


Figure 3.4: Circulation and WW, 01.01.2010 to 02.29.2012 in [kWh].

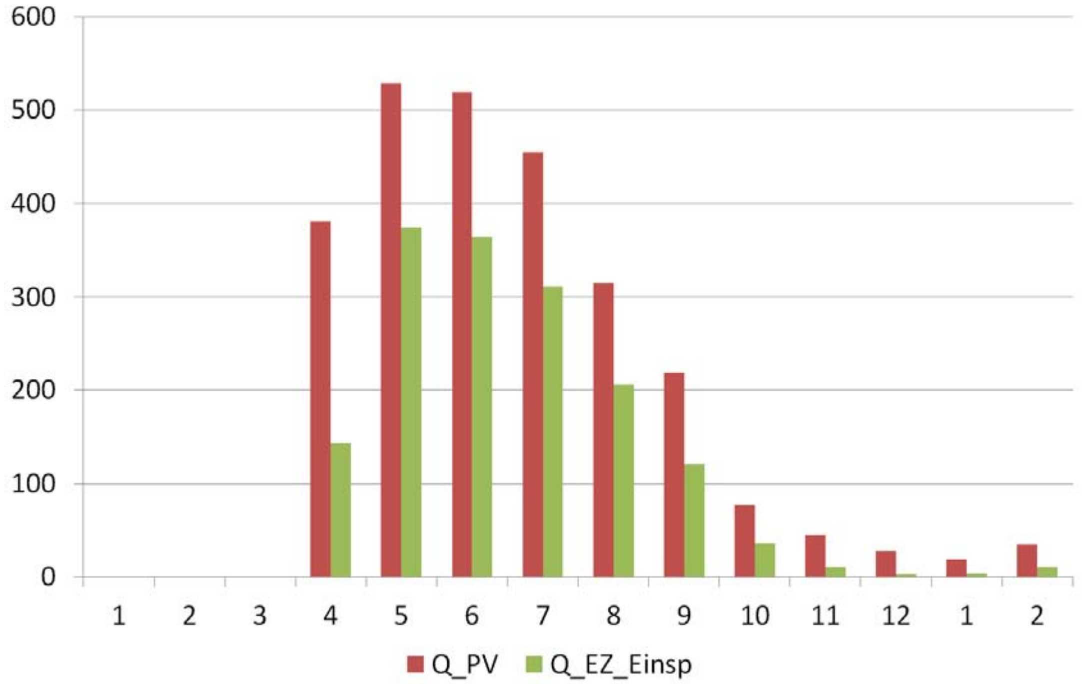


Figure 3.5: Photovoltaic system, from 01.04.2010 to 29.02.2012 in [kWh].

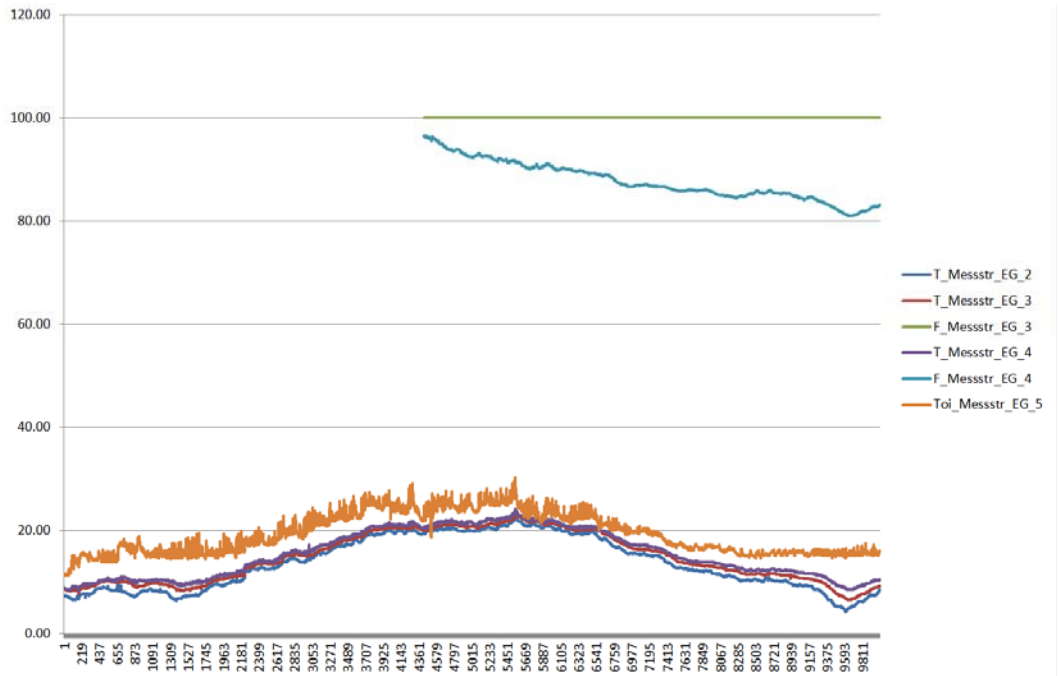


Figure 3.6: Measurement section 1, raw data, 01.01.2010 to 02.29.2012 in [° C,%].

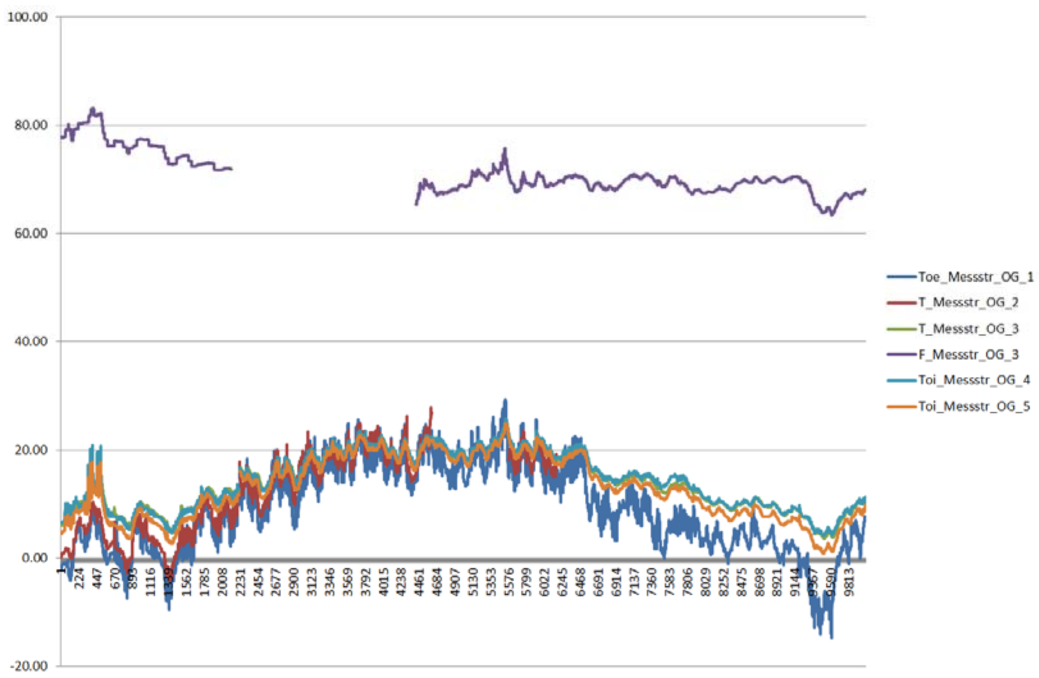


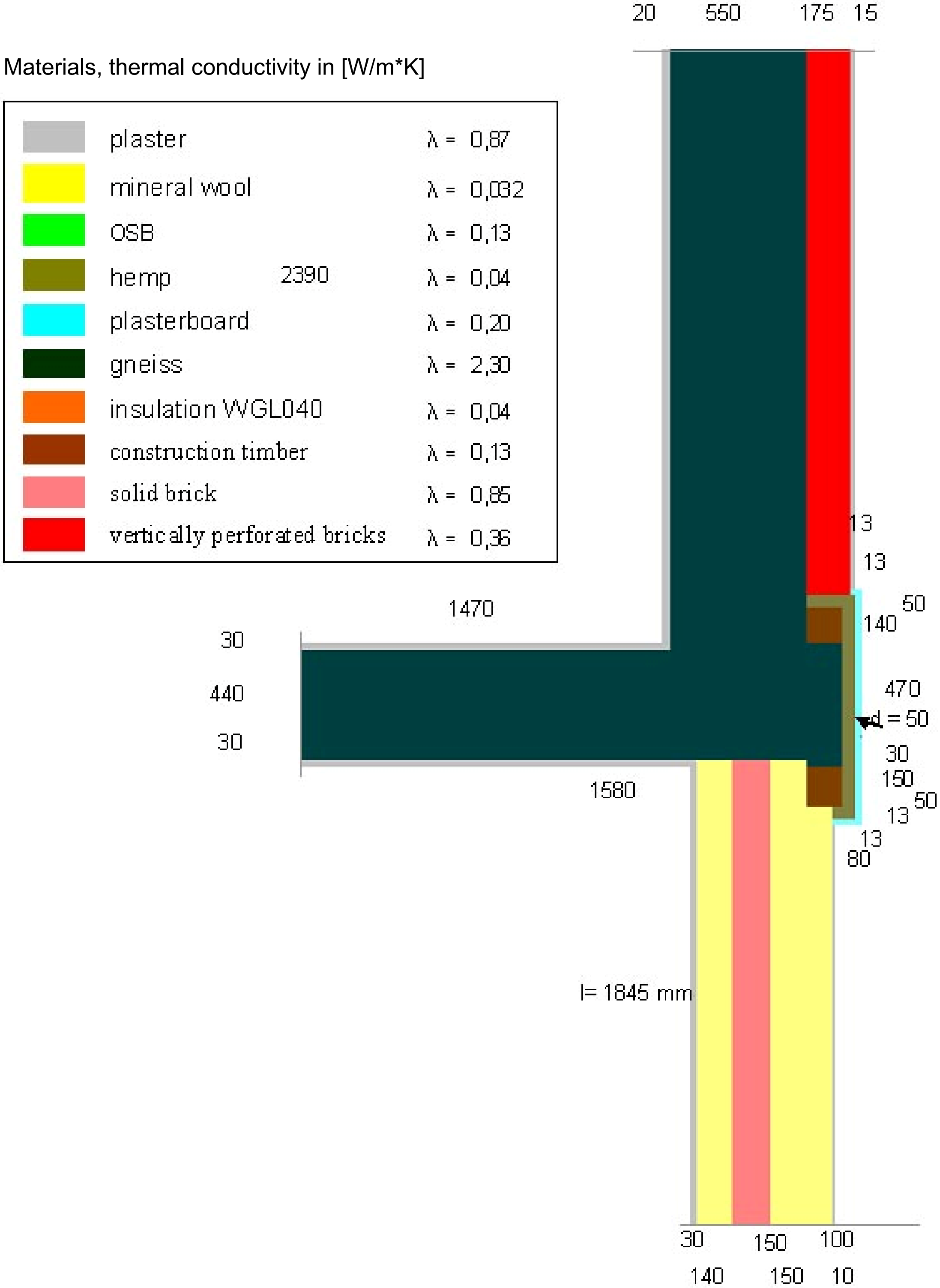
Figure 3.7: Measuring section 2, raw data, 01.01.2010 to 02.29.2012 in [° C,%].

3.1.1 Structural analysis and assessment of moisture

Simulation of critical thermal bridges

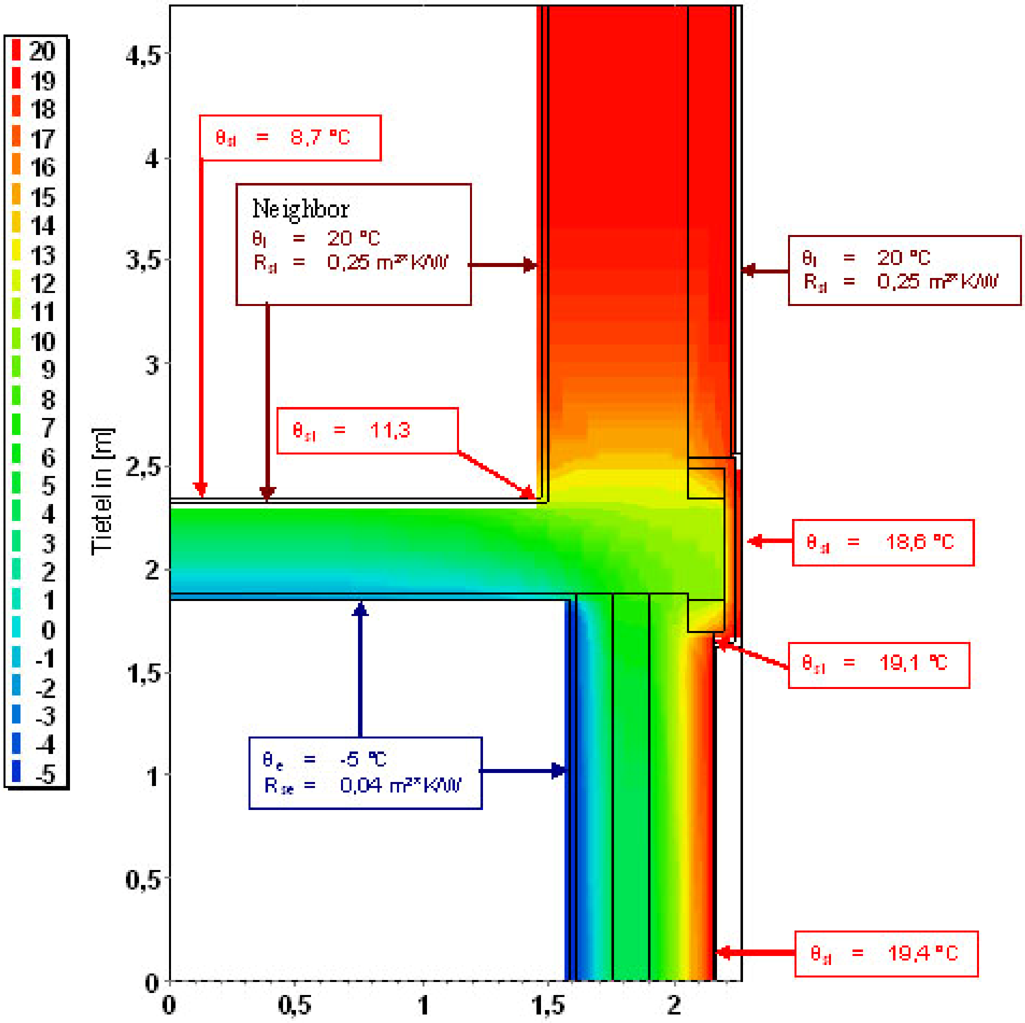
As proof of the minimum thermal insulation to prevent mold growth and condensation water on the surface of the component single critical thermal bridges are calculated with the software Delphin.

Example: WB 07 – Exterior wall / inner wall AW 13 wall first floor east and inner wall



Discretisation grid in [mm],

b) Proof of minimum thermal protection for DIN 4108



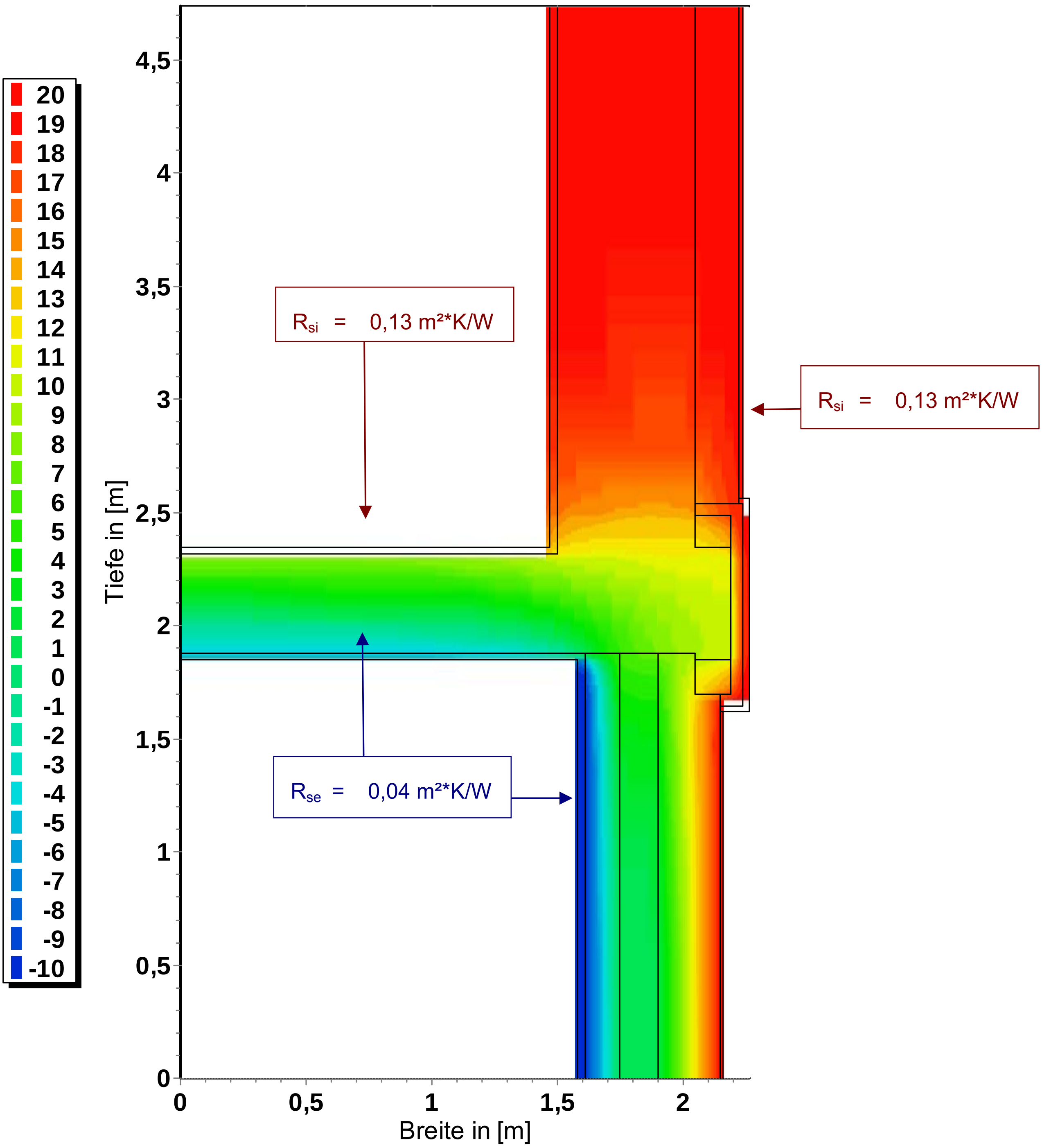
Temperature field in [° C], surface temperature in [° C], boundary conditions according to DIN 4108 part 2

Detailed point	surface temperature		Temperature factor on the inner surface		
Wall:	θ_{si}=	18,6 °C ≥ 12,6 °C	f_{Rsi} =	0,94 > 0,7	Proof fulfilled!

Results of the calculation:

The proof of the minimum thermal insulation to prevent mold growth and condensation water on the surface of the component according to DIN 4108 part 2 is satisfied.

c) **Calculation of the reference value for Ψ according to DIN EN ISO 10 211 and demonstration of equivalence according to DIN 4108 Supplement 2, Section 3.5, c) and d)**



Temperature field in [° C], boundary conditions for DIN EN ISO 10 211

Results of the calculation:

	l	$\theta i - \theta e$	Φ_{2D}	L_{2D}	Φ_{1D}	U_{1D}	Ψ
	[m]	[K]	[W/m]	[W/(m*K)]	[W/m²]	[W/(m²*K)]	[W/(m*K)]
				$\Phi_{2D}/(\theta_i - \theta_e)$		$\Phi_{1D}/(\theta_i - \theta_e)$	$L_{2D} - U_{1D,i} * l_i$
support area							
wall	1,845	30	12,95	0,432	2,,524	0,84	0,276
						linear thermal transmittance:	**0,28**

The linear heat transfer coefficient is 0,28 W/(m*K). The energetic effects of the thermal bridge are less than the numerical values representing, as the outer dimension 1.845 m for the EnEV - calculation is used. The thermal bridge effect is sufficient to wait until the new guise of building partition (see temperature field).

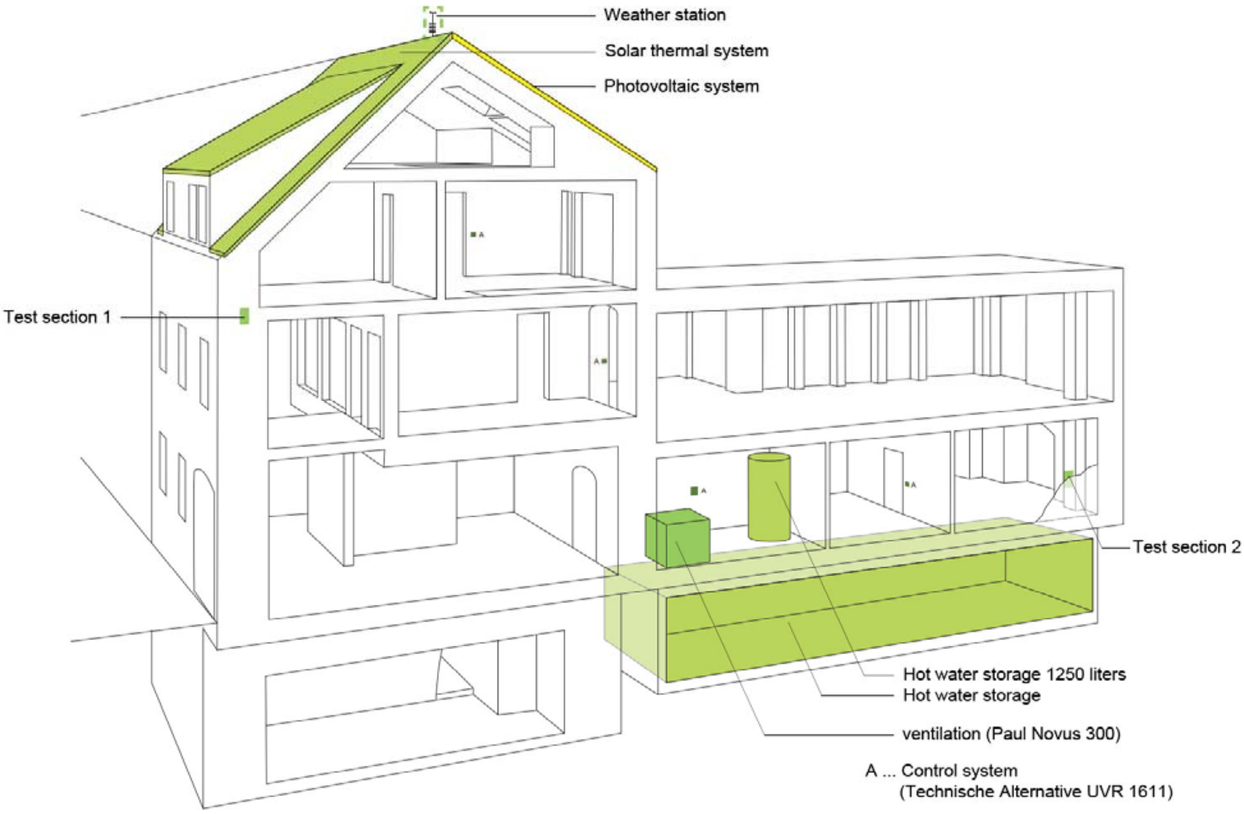
3.1.2 Analysis of architectural elements

Street side (south)

Court side (north)

3-D section of the renovated building

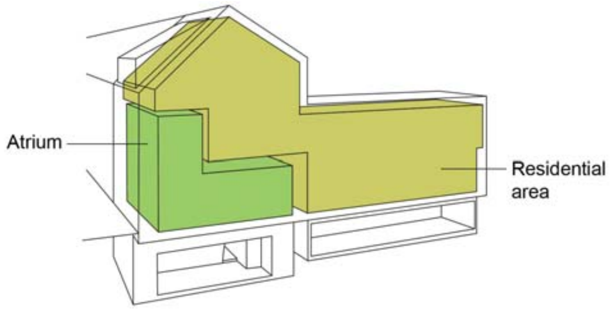
3.1.3 Analysis of technical systems



Street side (south) Court side (north)

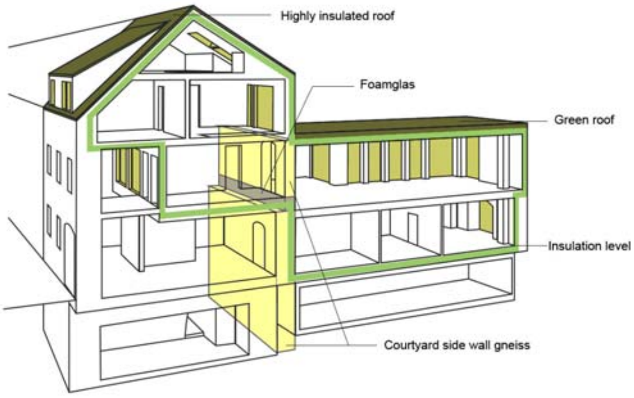
Overview of the technical measures

Atrium as a buffer zone



The insulation of the listed gneiss wall jambs with Renaissance paintings and would be of historic preservation considerations have been unthinkable. We have therefore decided to keep the facade of the arrangement a "buffer zone" to be unchanged. This is used as the entrance and stairwell. This was the historic facade be preserved in their original form. The buffer zone also reduces the heating losses of the house.

Insulation and Windows



The insulation of exterior walls at U <0.1 W/m²K was consistently implemented. This was partially possible only as a capillary interior insulation with calcium silicate boards and perlite stones. If possible, an outer insulation by means of (i) composite heat insulation system or (ii) mineral wool, U*Psi-girder reacted (to reduce thermal bridges), and wood paneling. Throughout the building passive house window came with triple glazing with Uw < 0.7 W/m²K is used, the shape of the historic windows have been adjusted. The roof structure was obtained, in addition to insulation between rafters, an upper rafters run.

Reduction of thermal bridges

Cutting of the masonry

Thermal insulation by foam glass

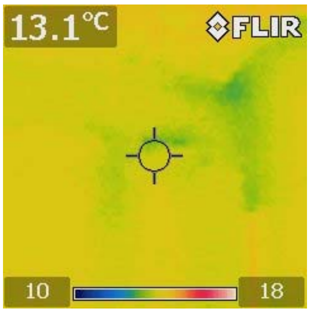
The elimination of thermal bridges was consistently in the old building. For this purpose have been partially gneiss walls cut horizontally and with foam glass lined, to ensure the static despite thermal separation. The hygrothermal simulations were performed using the software Delphin.

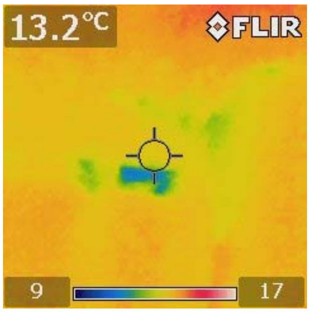
Air tightness and Mechanical ventilation with heat recovery

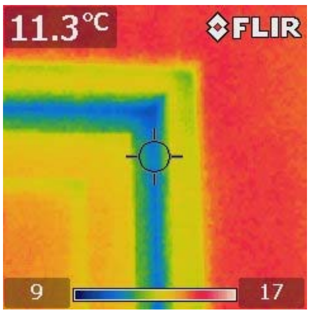
Differential pressure measurement techniques - Blower door test

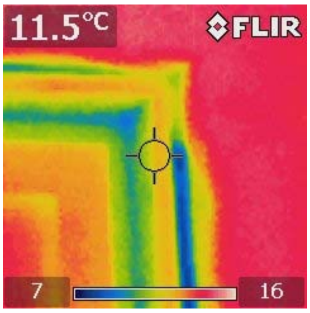
Ventilation system with heat recovery

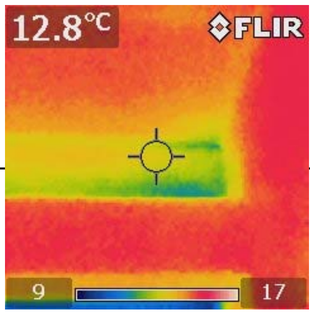
In order to avoid loss of heat energy through uncontrolled ventilation, were consistent with the redevelopment eliminates leaks. The review of activities carried out regularly by blower door measurements. Through a ventilation system with heat recovery heat energy losses are further reduced and made a high air quality and mold in the old building safely avoided.

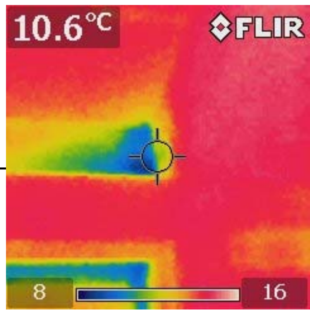




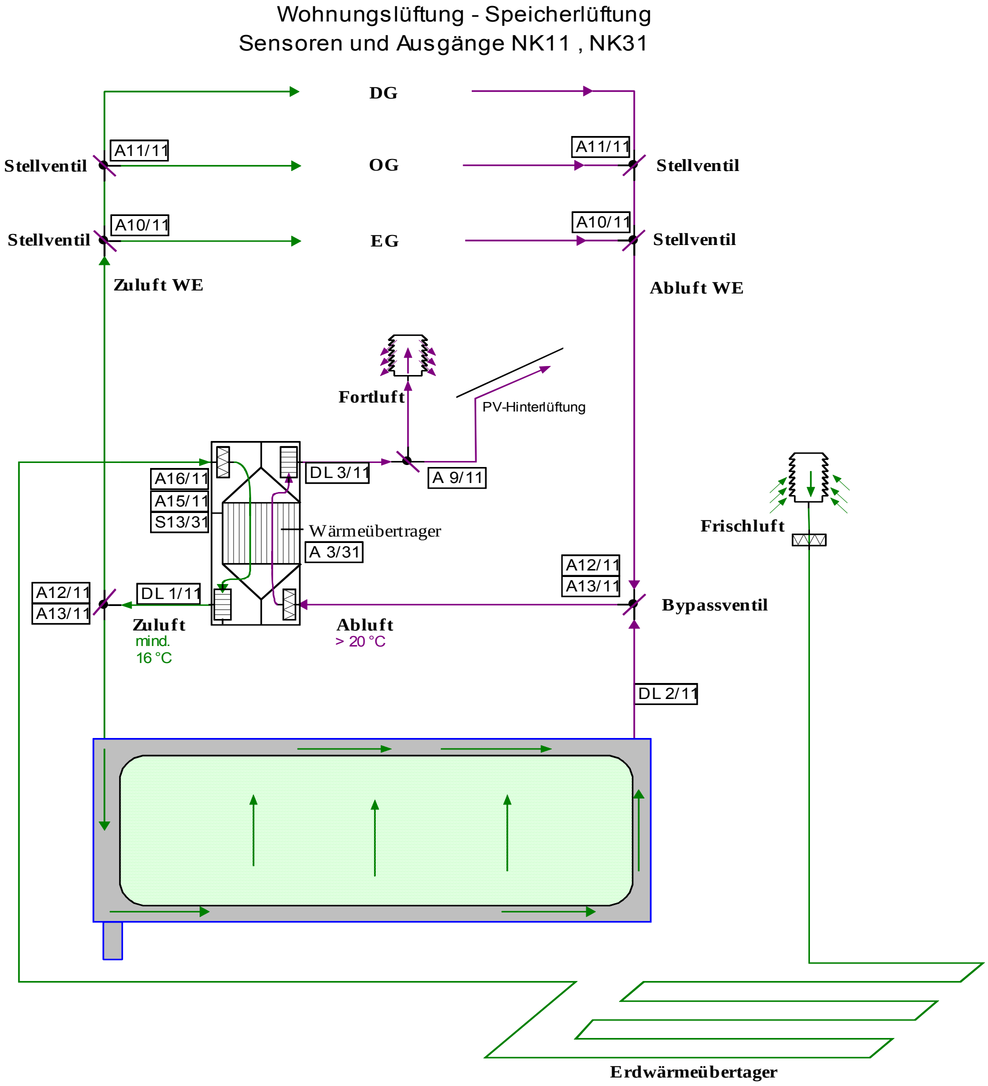








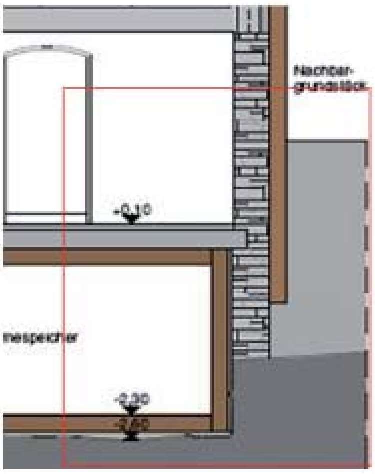
Ventilation system with heat recovery, PV – Cooling

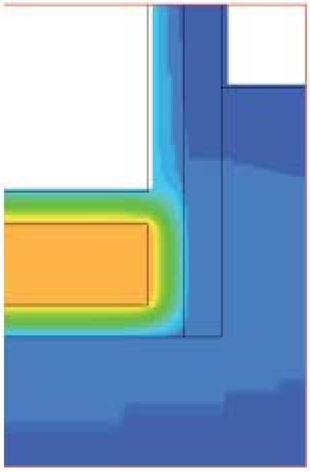


System design:

1. Geothermal heat exchanger
2. Ventilation system with heat recovery
3. Memory dehumidification
4. PV cooling
5. Control unit

Solar thermal energy and Seasonal storage



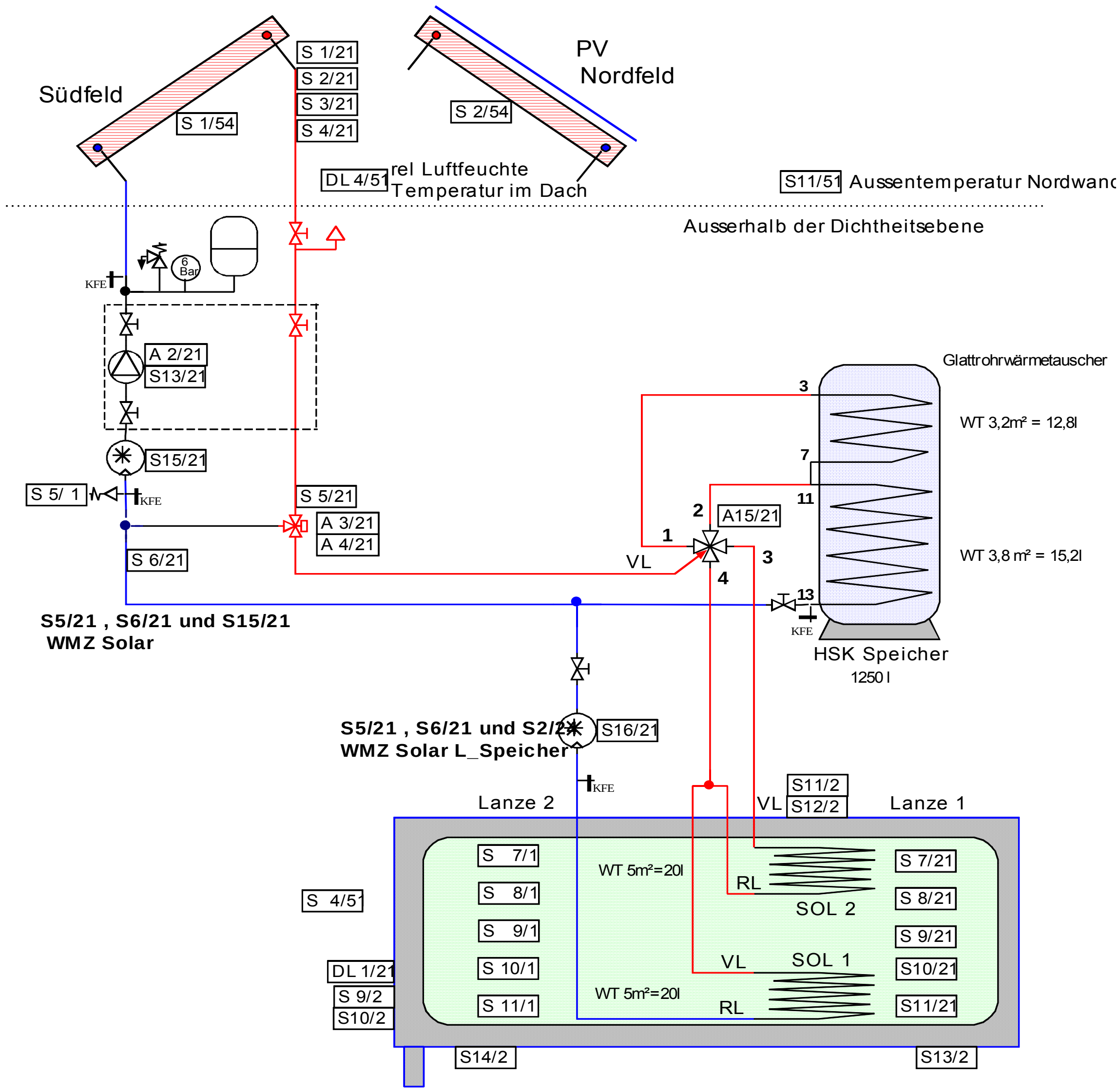


Planning

Simulation

Implementation

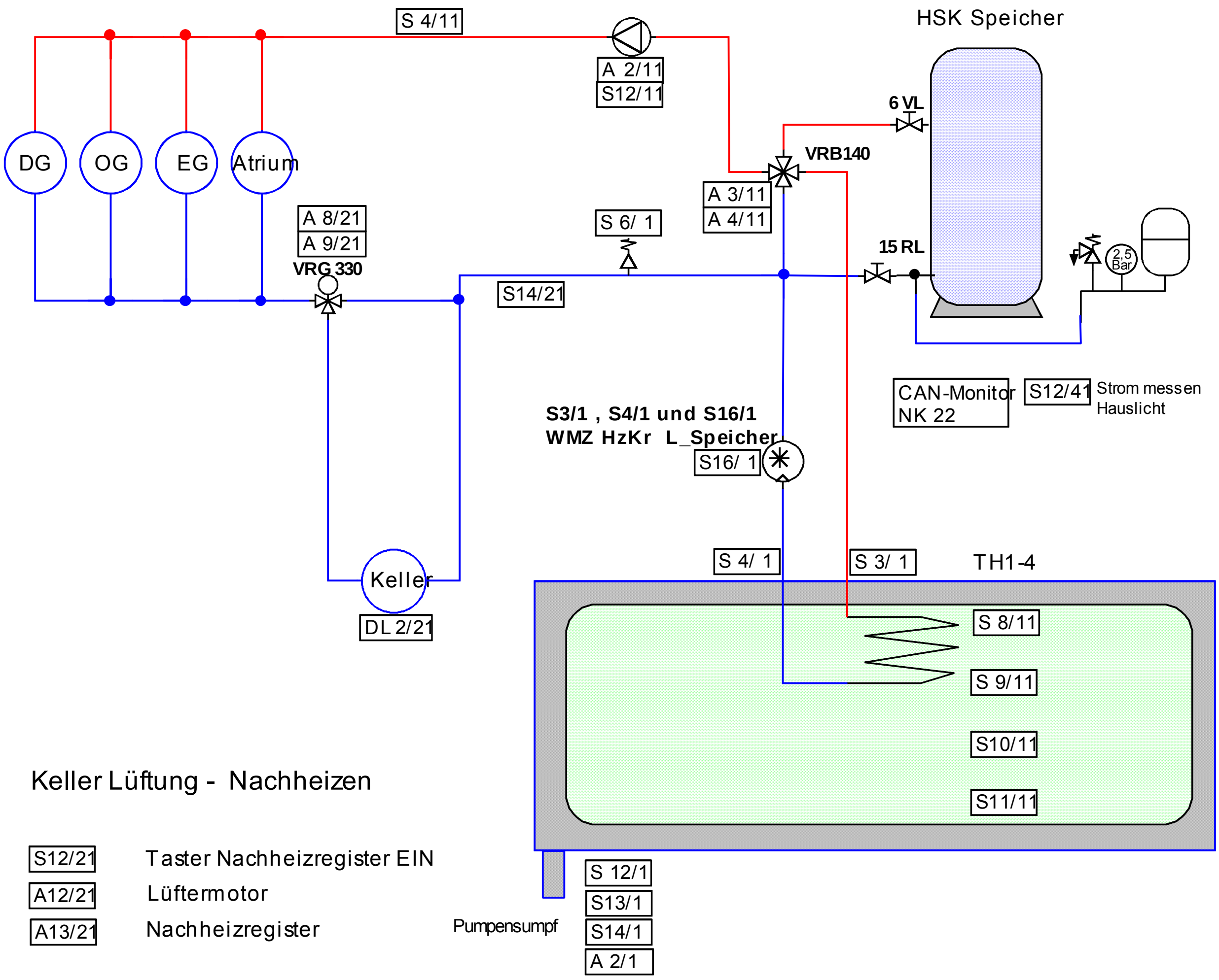
Thorough planning: recording of the geometry and the materials: The elimination of thermal bridges, the installation of insulation, passive house windows and ventilation system with heat recovery and air tightness to reduce the heating energy requirement already by 95% to 20 kWh/m²a. For hot water production and to cover the total heating demand a solar thermal system was installed. The solar surpluses from the summer months are stored in a 75 m wide, seasonal storage for the winter months. For this purpose, the foundation of the rear building built a new type of hot water tank storage.



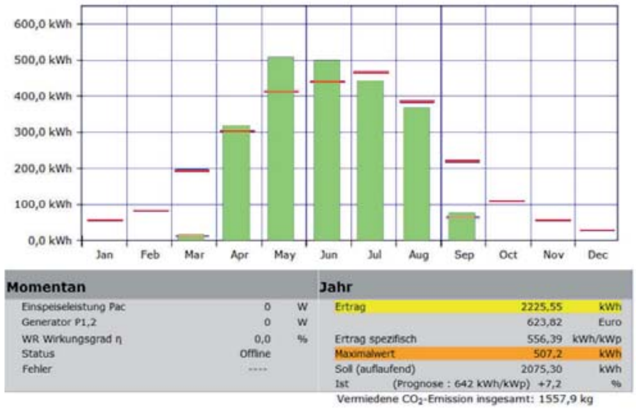
System design:

1. collector
2. solar pump
3. 3 - way valve
4. 5-way switching valve
5. HSK - Memory
6. Long-term storage

heating circuits



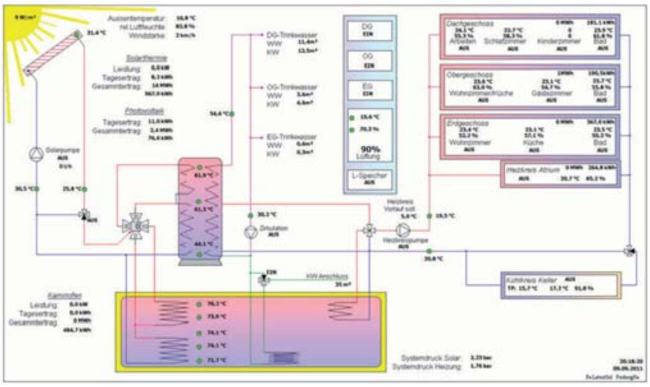
Photovoltaic system



PV panels north side solar income

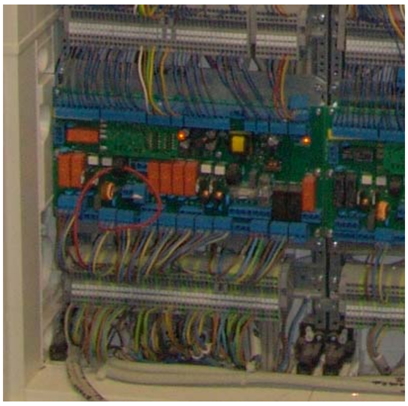
An additional photovoltaic plant with a capacity of 4.8 kWp provides electrical power generation. The electrical energy consumption has been optimized so that the PV system generates more electricity in the balance sheet when the house in total. Excess electricity is fed. The cooling of the photovoltaic system on the ventilation system with heat recovery increases the photovoltaic yields.

3.1.4 Hygrothermal and environmental monitoring



Online pattern - graphical representation of the solar system Weather station

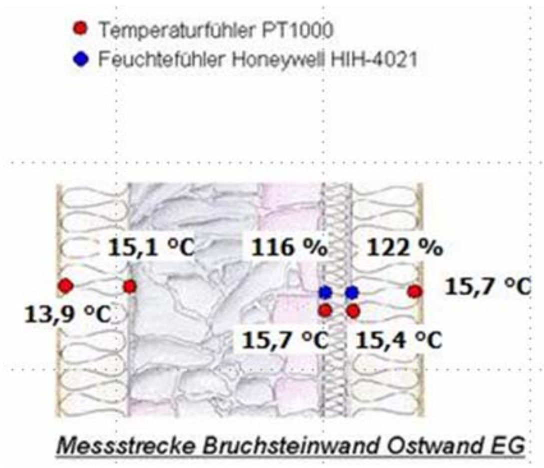
The individual units of the building services such as solar panels, storage, ventilation, floor heating, and summer heat protection are controlled by the control UVR1611. The controller increases the living comfort and reduces energy consumption. Individual consumers are switched preferred if the solar panels provide enough energy is available (for example: washing machine, dishwasher, refrigerator). In total, over 300 input and output states recorded to assess long-term monitoring of the individual measures.



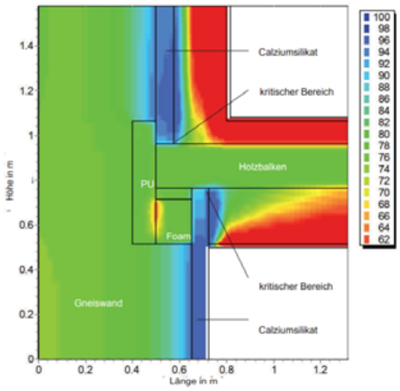
Control systems, data acquisition for analysis (DIN 18599)

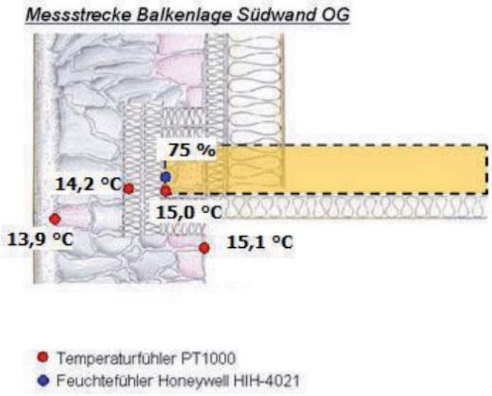
Test sections

- **Test section 1: gneiss masonry**



- **Test section 2: joist end**

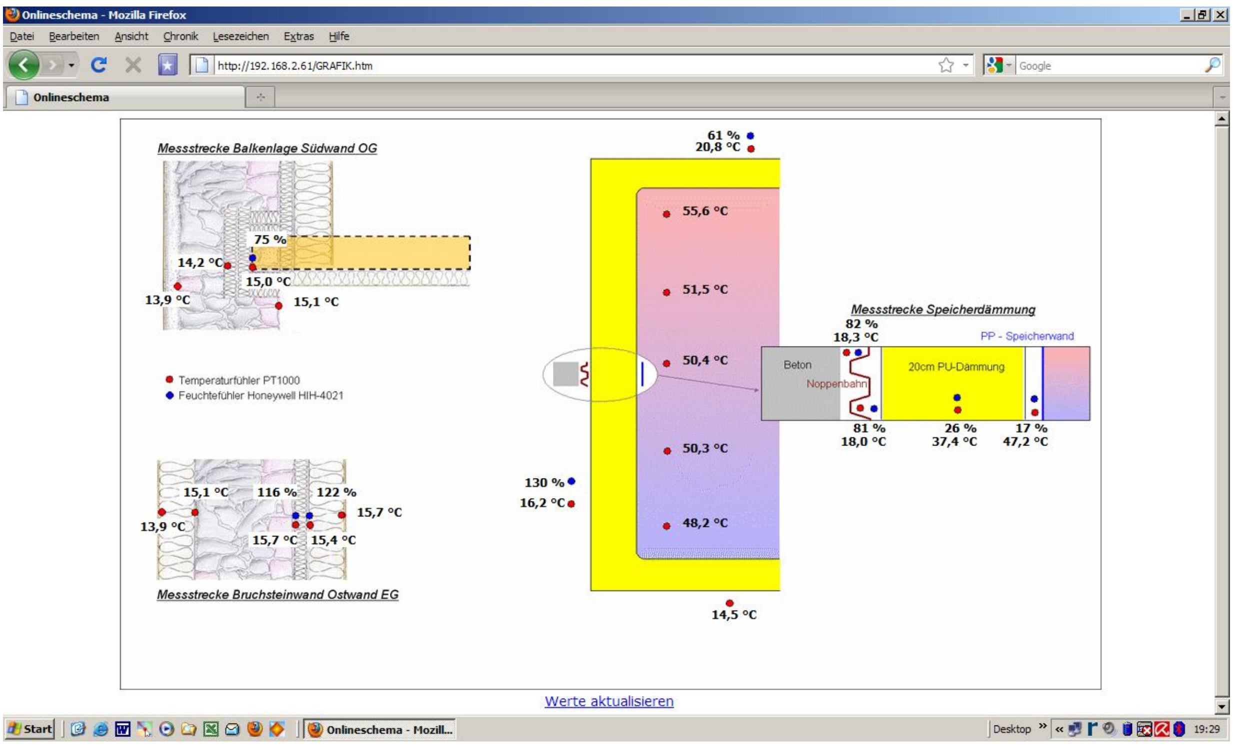




Hygrothermal simulation - bar head south wall

Online scheme - Graphical representation

The long-term monitoring to verify the calculations for the renovation. An example of condensation on timber heads in the gneiss masonry. Here simulations are compared with the measured data. The experiences and results of this pilot project are to be processed so far, that one or the other detail can also comes in future remediation projects for the application and the low energy refurbishment could be standard.



5 Annex 1 - PHPP calculation for status pre-intervention

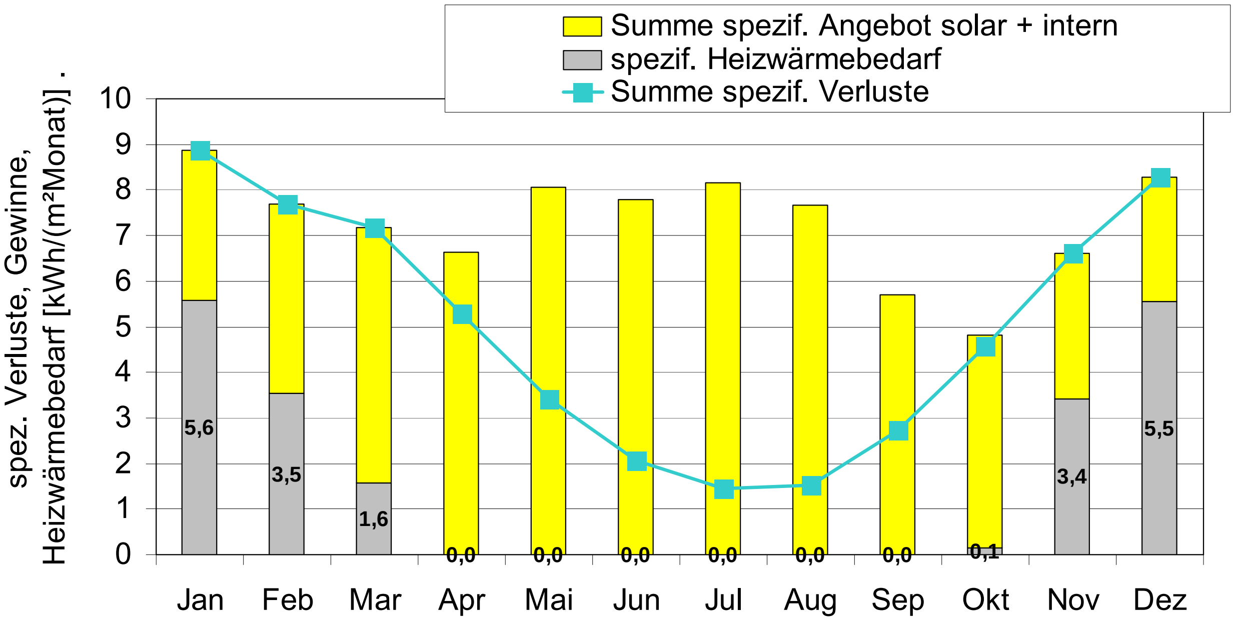


Figure 5.1: Heating energy consumption (according to PHPP).

This represents an annual heating energy requirement of 4140 kWh / year (19.7 kWh / m² a). Add to that a hot water requirement is of 2226 kWh / a (warming of 8 ° C to 50 ° C, 25l/ persons /day, 5 persons total heat consumption. 6366 kWh / year

6 Annex 2 - Description of the monitoring system

The freely programmable universal controls UVR 1611 use for facility management and measuring sections

	Windspeed	Radiation	Rel. humidity sensor	Temperature sensor	Heat flow meter	Volume Flow	Heat quantity counter	Electric meter (Ahlborn)	Output variables	**Sum**
Weather station	1	1	1	2						4
Indoor climate			13	12						25
User conduct									12	12
Measuring sections										
1. external wall 1st floor east			2	5						7
2. external wall 2nd floor south			1	5						6
Building connections						1		3		4
Solar heating system		2		32		2	2	1	12	51
Circuit of hot water				4		1	1		1	7
Solid fuel boiler				4		1	1	1	4	11
Heater loops				8		4	4	1	14	31
Air exchange system			6	8				1	6	21
Domestic hot water				10		6	6			22
Photovoltaic system				4				2		6
Sum	1	3	23	94	0	15	14	9	49	207

Figure. Overview measuring points

Figure 5.1: 1st floor, the freely programmable universal control UVR 1611(as conductor board).

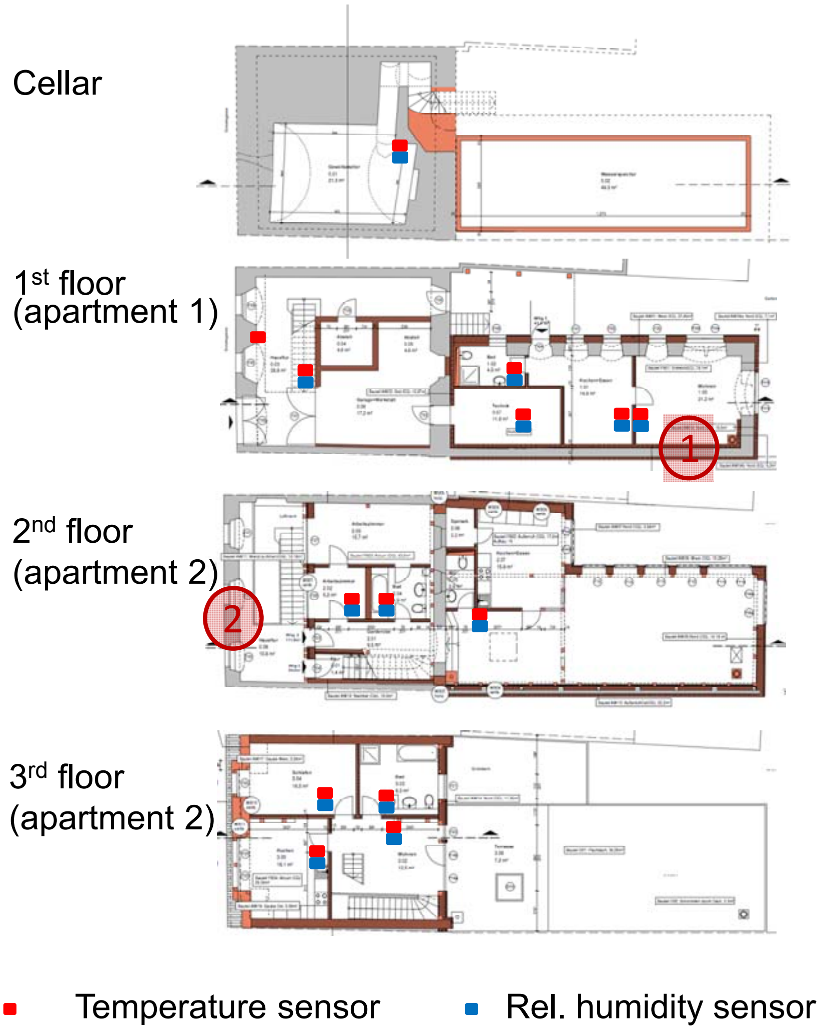


Figure 5.2: Positions of the Sensors for inner climate and measuring sections.

Measuring sections 1-2 installed into external wall constructions

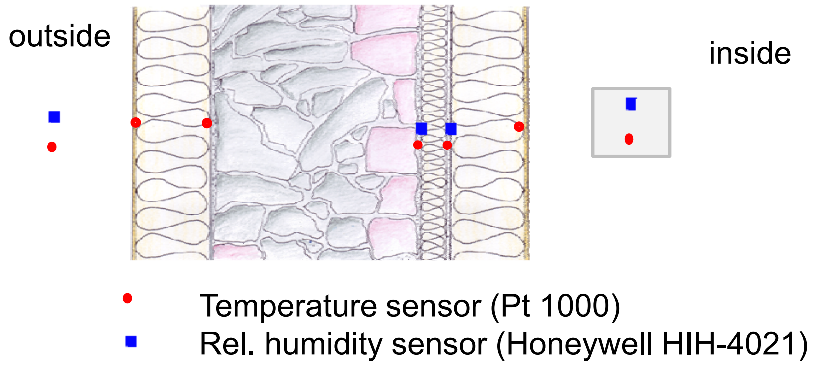


Figure 5.3: Measuring section 1 installed into external wall constructions 1st floor east.

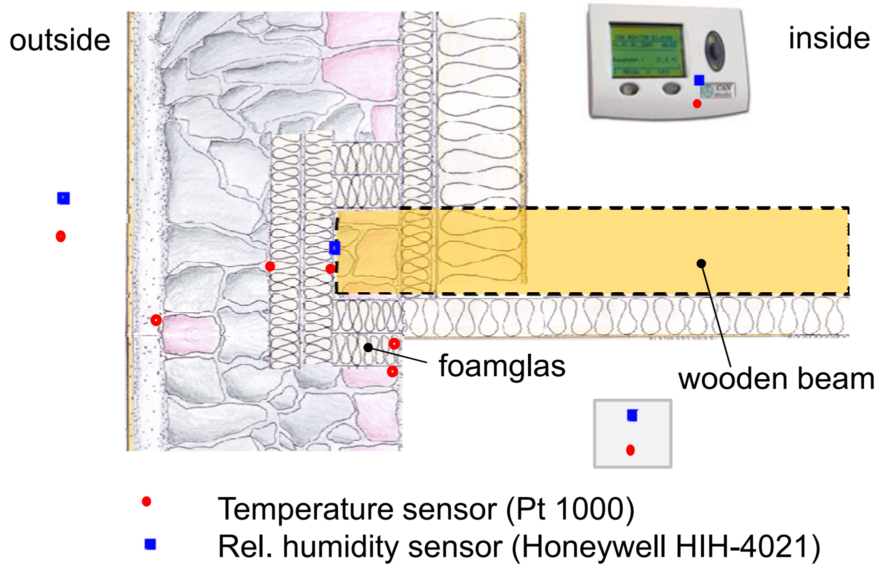


Figure 5.4: Measuring section 2 installed into external wall constructions 2nd floor south.

The illustration of the measurement data employing project pictures and diagrams, helps to discern the coherence and potential disfunctions in capturing measurement data more easily.

For the sections of measurement and the recording of the outer and inner climate the project diagrams can be produced with the program WINSOL and Bl-Net with the "Onlineschema".

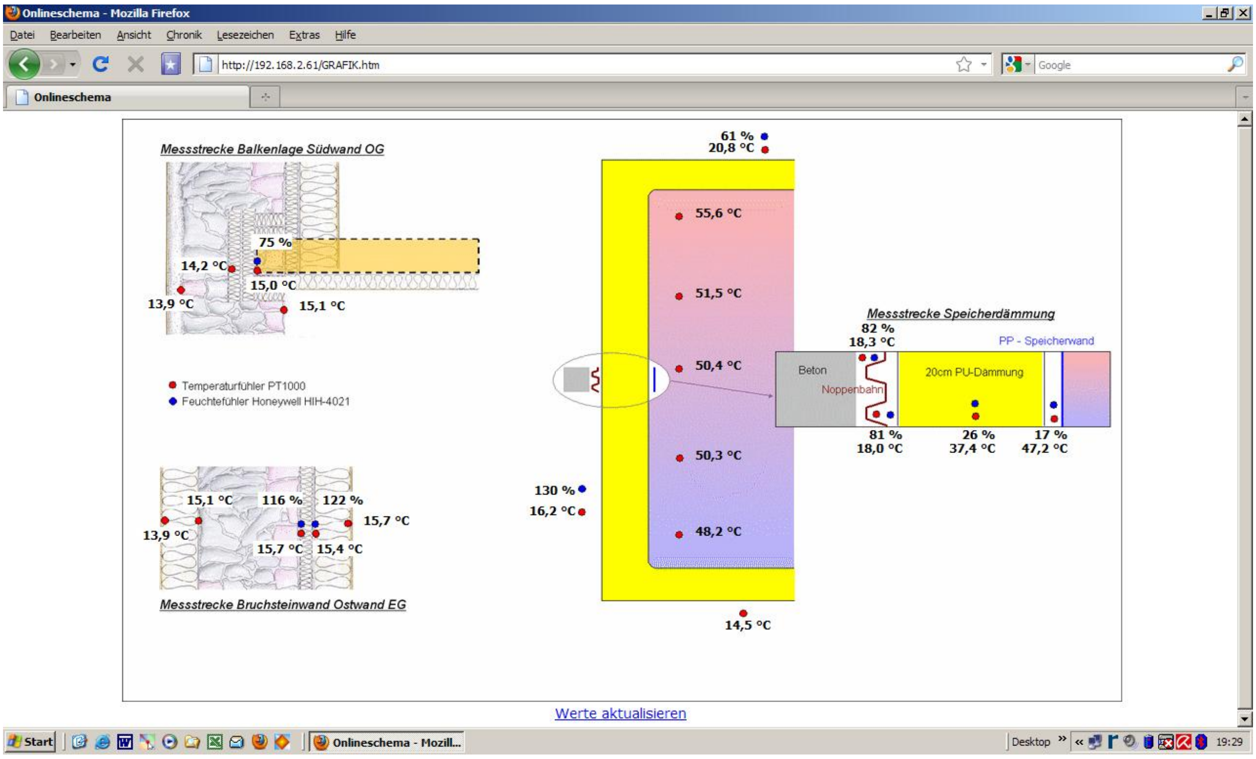


Figure 5.4: Visualization of plant technology and measuring sections with the “Onlineschema”.