Schöck Bauteile GmbH

Building Physics Report No.:1

Building Physics Analyses and Isokorb Specifications

International Product Management Department - IPM
14.03.2012

Contents

1. Intention

Schöck has specialised on building physics and development of Isokorb with respect to quality assurance. Since more than 30 years Schöck provides Isokorb to clients and more than 10 million Isokorb products have been installed. Besides of continuous improvement of products Schöck has several Approvals in other countries like France, Netherlands, Germany, UK, Canada, Russia and many more other countries. These Approvals are based on same Isokorb ranges. In the following chapters some Isokorb-features and properties (of used types) will be explained with respect to this project and the relationship between structural requirements and building physics will be shown since thermal efficiency is considered and calculated.

2. Building physics generally

Thermal bridges are localised regions in building envelope details which display increased thermal losses. The increased thermal losses can be caused by the component geometry (‘geometric thermal bridges’) or by the localised inclusion of materials with a higher thermal conductivity in affected component 8’material based thermal bridges’).

In the area of a thermal bridge, the local increase in thermal losses causes the temperature of inside to drop. Mould will form as soon as the surface temperature drops below the so-called “mould temperature θ_s”. If the surface temperature drops even further – to below the dewpoint temperature θ_T – the moisture present in the room air will condense on the cold surfaces in the form of droplets.

Once mould has formed in the area of a thermal bridge, the spores released by it into the room can represent a serious health hazard to anybody living in the room. Mould spores are allergens which can cause severe allergic reactions in humans, such as sinusitis, rhinitis and asthma. As exposure inside the house or apartment is usually prolonged, there is a high risk that these allergic reactions can develop into chronic conditions.

In summary, the effects of thermal bridges are therefore:

- Risk of mould formation
- Risk of health damage (allergies etc.)
- Risk of condensation
- Increase wastage of heating energy
- Disturbing living comfort due to different temperature zones in living room

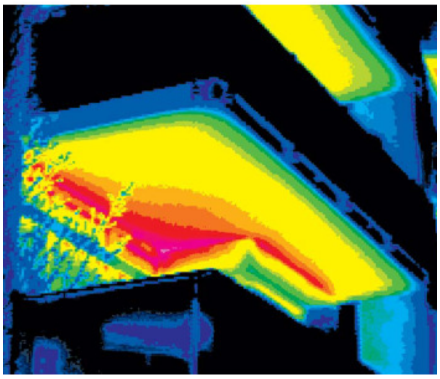
Schöck Isokorb is developed for preventing this kind of risks and is integrated in constructions as bearing elements with high quality properties (approved and certified). Quality is a must criterion hence using of wrong thermal break elements or thermal break elements with “bad” equipment cause afterwards more problems like maintenance of balconies due to cracks or moisture attack with finally mould increase. In the following some reasons are listed which should picture the necessity of thermally improved products like Isokorb with required quality assurance.

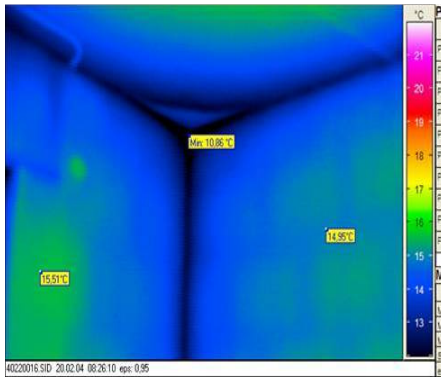
2.1 Reasons for using Schöck Isokorb

Schöck Isokorb® as thermal insulation to reduce the thermal transmission loss factor

The thermal transmission loss factor is the amount of heat that a building emits to its environment through its heat transferring building shell (entire façade including connections) due to a temperature difference (inside – outside) if every part of a face is airproof (losses of energy from the air stream are incorporated into the ventilated thermal loss).

At localized sites in the building shell such as corners or cantilever components (for example balconies, parapets and balustrades) a higher thermal flow seal exists what means losses of heat related to the components surface. The effects are thermal bridges in these areas and hence higher thermal transmission loss factors with more consumption of energy for compensation of the sought room temperature. The Schöck Isokorb® avoids the development of thermal bridges by being located structural-constructive as a supporting heat insulation component at localized sites in the façade between inner (roof) and outer (balconies, parapets, balustrades etc.) components. Also it reduces the loss of thermal flow to a minimum, raises the resistance of outlet of heat of the building shell and hence also reduces the loss of heat and energy noticeably through its optimized thermal insulation features.





A lot of European countries have regulations for thermal insulation (WSV) or saving energy (ENEV) which are demanding and also setting legitimate minimum values (U-value) for the usage of energy for buildings. Countries that are in an advanced stage like European countries do even keep the thermal bridge in mind which pours in the energy verification in the form of thermal bridges loss factors (PSI-values) or rather are put in estimated depending on the model of the construction. Nevertheless the PSI-values are still too high so that noticeably reduced PSI-values are achieved with the Schöck Isokorb®. Meanwhile this represents the standard and even in other countries there are regulations for low energy conditions at building.

Schöck Isokorb® with moisture proofing to avoid damages

Due to higher thermal losses at localized sites (thermal bridges) in the façade (such as balcony connections etc…) the inner surface temperature drops. Depending on the amount of moisture and the temperature that prevails in the room steam occurs. That means that water which is bound in the air (H_20) roams to the colder surfaces of the components, is settling there and condenses. So it's getting fluid (same effect as e.g. getting a bottle of beer out of the fridge and leave it behind in summer). Hence there will be perfect conditions for mould formation which will actually occur at an undercut of a certain surface temperature which is for example a room temperature of 20℃ and 50% rel. humidity. The higher the temperature difference between the outer and the inner temperature or the rel. humidity the higher is the risk of the mould formation.

Therefore thermal bridges at buildings are local areas which are predestined for mould formation. The reconstruction of these damages is complex and expensive. Mostly this can actually never be avoided entirely because new mould damages are developed after the reconstruction. Also a later constructive prevention through insulation is often not possible. If damages due to mould are not discovered immediately for example because of a wall covering they can lead to health problems (especially for children and toddlers) as their spurs can lead to allergies (fierce rashes) or asthma (weakening of the immune system).

Schöck Isokorb® enhances the <u>comfort of living</u> and the <u>comfort feeling</u>

New studies came to the result that within the area of living a difference in temperature of 3-5 ℃ is perceived a lot higher. If you consider that the loss of heat at the thermal bridges (balconies etc.) is higher and the effect is a decrease of the inner surface temperature, the result is that different temperature zones exist within one room.

Especially in climate zones where bigger temperature differences between the inner building and the outside world prevail (as in winter), temperature differences up to 10℃ can adjust within one room if the building is insulated bad or not at all. Even in insulated buildings with thermal bridges there are temperature differences between 6 ℃ - 8℃ at the adjacent surfaces of components (inner walls, floors and ceilings). The higher the temperature difference is within one room the more sensitive is the comfort feeling of the residents. Often the residents don't feel comfortable any more if they are sitting in their apartment and want to enjoy the view outside, sit or even walk bare foot within the room close to adjacent components with temperature differences. Thus as a result of thermal bridges the comfort of living decreases.

The Schöck Isokorb® does not only ensure the reduction of thermal losses and enables the saving of energy as well as prevents formation of mould and damages in construction but also increases the comfort feeling and comfort of living. Due to its optimum improvement in heat-protecting technology the Isokorb® is able to reduce temperature differences to its minimum so that the comfort feeling is fostered lasting and there's offered optimum comfort of living for the residents.

3. Service and structurally required conditions for using Isokorb®

The using of thermal break elements requires more than only product knowledge or product performance. Especially in the selection of right products there are several conditions and further product requirements, which should be taken in consideration!

In the selection of right products, following requirements should be checked:

- Static requirements like forces and resistance parameters of products
- Selection of right products for the right cases (free cantilever, loggia or supported constructions)
- Quality assurance of company and product (ISO certification, external quality control)
- Provided Service of engineering team (competence, structural design, advice)
- Thermal performance of chosen products (Lambda values, energy performance)
- Documentation of product use like manuals, installation instructions
- Approvals test verifications of products like fatigue and static test with expert reports
- Fire requirements and fire resistance of used products (verified with fire test reports)
- Quality of used materials due to corrosion, long-term actions and stress capability
- Handling of product on-site (installation costs, security, and required additional reinforcement)

As mentioned above, Schöck specializes in service advice and owns products which were tested several times. Concerning tests Schöck has performed for all available products static tests and fatigue tests which are always forgotten by selecting thermal break elements (durability for more than 50 years)! Due to preformed tests and experience of nearly 50 years, Schöck has established user guides and documentations for designer to avoid afterward mistakes, like alignement of expansion joints, deflections, and additional reinforcement for preventing crack development at edges or building physics analyses.

3.1 Fire resistance of Isokorb products

In case of fire requirements Isokorb is equipped with fire protecting slabs, and ensures fire resistance between 90 and 120 minutes (verified by several preformed fire tests). The reason for using fire protecting slabs which are based on cement tied, weather proofed material, is caused that Isokorb consists of Neopor. The experience and tests have shown that no artificial insulation materials (EPS, PUR, XPS, PIR etc…) without additional fire slabs equipment or equal protection is capable to resist fire more than 30 minutes. And all natural insulation materials (mineral wool, glass wool etc…) have very good fire properties, but could not be used as separation element since they absorb water and due to absorption the water-cement ratio of concrete decreases and residual stresses causes cracks. Furthermore all thermal conductivity properties of natural insulation get lost because of the absorbed water.

In the following all materials which are used for Isokorb are listed:

HTE Modules	thrust bearing elements are made of UHPC (Ultra High Performance Concrete) with concrete strength of more than 150 MPa and special mixture of fibres with regard to better ductility, fire resistance and high temperature efficiency
reinforcing steel	BSt 500 (Grade 500) with f_{ys} = 500 MPa
corrosion-resistant steel:	1.4362 acc. Standard EN 100088 with designation X2CrNiN23-4 Correspondence: ASTM with designation 2304 Structure: duplex
insulation material:	Neopor – polystyrene rigid foam plastic with additional graphite additives for low thermal conductivity
fire protecting plates:	cement tied, weather proofed fire protection slabs according to required fire classification

3.2 Used stainless steel

The internal quality control of Schöck (part of ISO 9001 certification and approval) assures that each hour all steel materials were testes due to welding, tension stresses and buckling effects. The tension bars are made of stainless steel with grade 1.4362 (designation see above). Due to alkaline environment of concrete, the welding of reinforcing and stainless steel is possible and without any risk, since passivation is assured! Furthermore the electrical potential between both steel members is not enough for contact corrosion development. And since corrosion resistant material is used in gap, durability is assured. One big advantage of used stainless steel for Isokorb is that it can be used in sea and chloride environment. Not all stainless steels (like 1.4301) can be used for that environment, what is also often forgotten. The used grade 1.4362 has duplex structure, which is also an advantage in contrast to austenitic structure. The duplex steel, grade 1.4362, has yield stress of 700 MPa. But for design of tension bars the yield stress of reinforcing steel (f_{yk} = 500 MPa) is dominant (safety which is not considered!). Austenitic steels are always limited in yield stress properties.

3.3 HTE modules – thrust bearing elements

Schöck is also specialist in concrete development and Schöck has developed an ultra-high performance concrete (UHPC) with very low thermal conductivity of 0,8 W/mK. This special concrete is used for compression elements (HTE Modules). The mixture is filled in plastic covers and is part of product. Because of it shapes the HTE Modules act like hinges and movement due to temperature impact is possible. In Contrast to steel plot bearings, which are also effective, the HTE Modules have the advantage of very low thermal conductivity (stainless steel has 15 W/mK instead of 0,8 W/mK).

3.4 Suspended shear bars, tension bars and anchoring

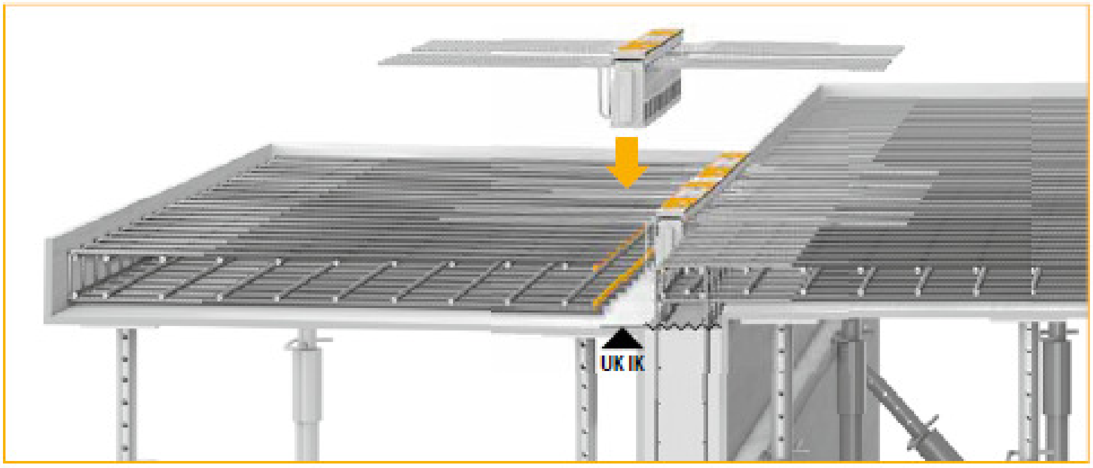
The special form of the shear bars allows that the anchoring is done in tension zone. This was created by Schöck and verified in several tests. The advantage of such shear bars is that the utilization of tension stresses is assured in tension zone and furthermore easy installation is possible. The suspended form of shear bars allow first the reinforcing of balconies and slabs without considering the Isokorb reinforcement. Finally Isokorb with equipment can be placed in the gap and concreting can start. This saves costs and time. Since the anchorage length of shear bars and tension bars were calculated and designed for end anchoring, overlapping is not required, but often recommended (like in technical manuals). The verification of anchoring and suspended shear bars is done by accredited external institutions and is calculated due to EC2 (if required this can be handed out!).

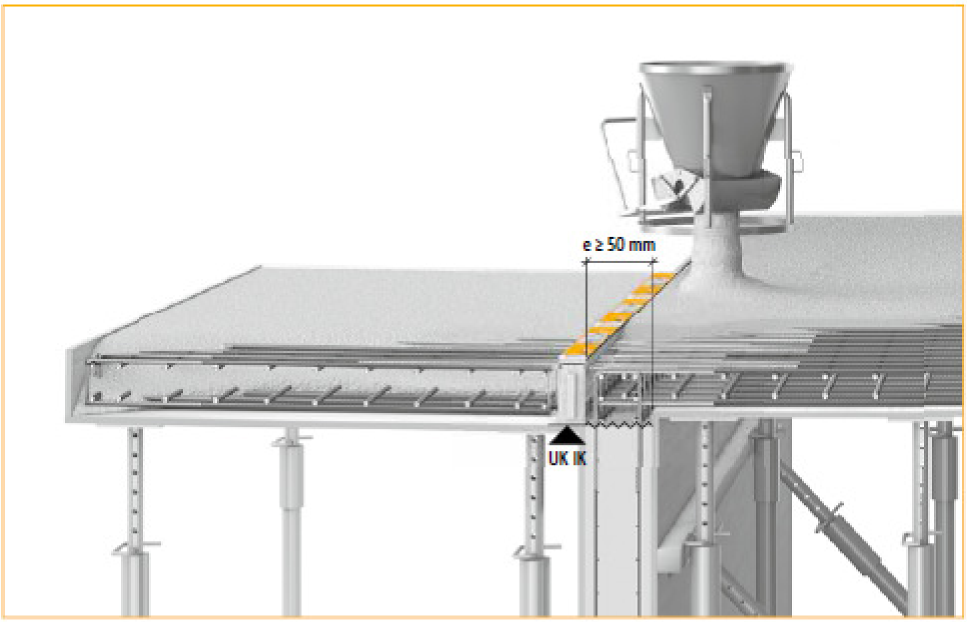
Furthermore the fixations of tension bars are ensured by a grid systems hence slipping of bars are not possible and rigidity is assured. In contrast to other solutions, like fixation of tension bars with crossed bars along tension bars, Isokorb doesn’t require this kind of bars. If fixation of tension bars is done as described, then only for further safeties and not for structural use. These are often forgotten because other suppliers do calculate the fixation bars as structural reinforcement and reduce anchorage length of tension bars. According to EC2 this is possible, but it is often forgotten that on-site these bars will be cut (otherwise installation is not always possible) and anchorage length is finally missing. For preventing such problems, all Isokorb tension bars are calculated and designed as end anchorage due to EC2.

3.4.1 Installation facilities with easy handling with Schöck Isokorb

Figure 1: pre-camber of formwork due to installation instructions

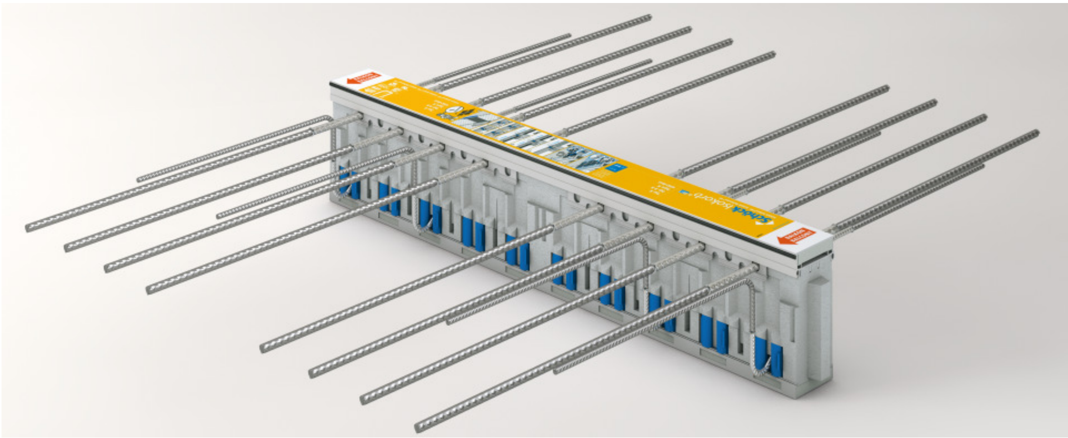
Figure 2: placing of Isokorb on formwork

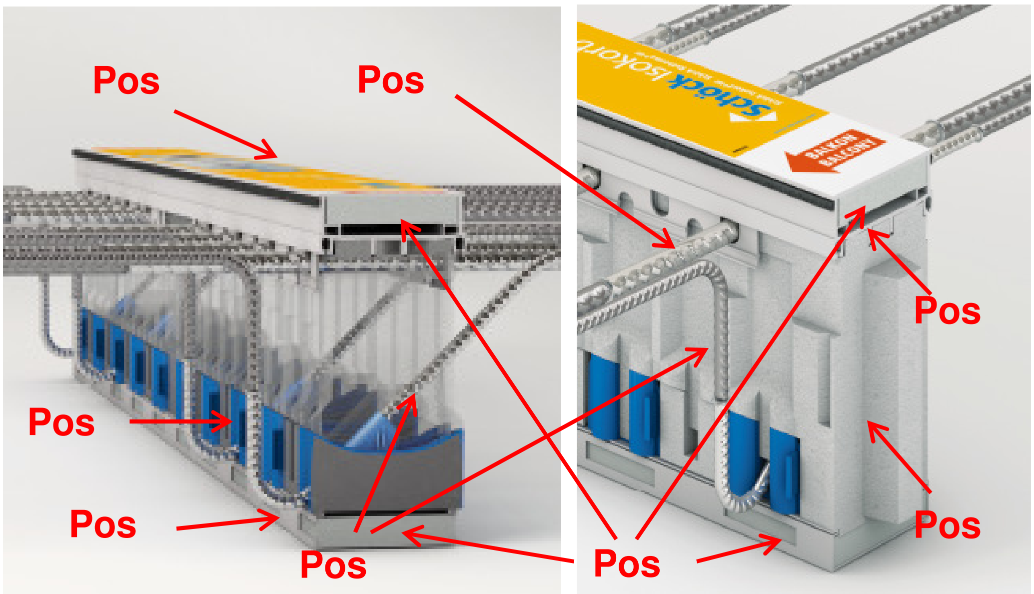




3.5 Description of Isokorb and thermal conductivity values

Next to its static features which are indispensable and definitely necessary for the usage of the Schöck Isokorb, furthermore it has to fulfill building physical features. However as the Isokorb has to consist out of bearing components to transfer the loads which are arising from the balcony slab as well as from its usage the Isokorb is equipped with materials that contain a very low thermal conductivity and have been optimized and will be optimized depending on the usage.





Thermal conductivity values of used materials:

Pos	Name	Material	λ-values [W/mK]
1	Tension rods	Non-rusting concrete steel	15
2	Q-rods	Non-rusting concrete steel	15
3	HTE modules	Pressure bearing out of UHPC	0.8
4	Insulation element	Neopor made out of EPS	0.032
5	A-rail		-
6	U-rail		-
7	Sticker		-
8	Fire safety boards	Aestuver	0.14

The equivalent thermal conductivity λ-eq of each Isokorb type can be calculated out of its equipment. Hence λ-eq is the thermal specific product value (as with each material) and can be used for further building physics calculations (such as PSI-value calculation). The λ-eq value is a **one dimensional** value whereat next to the length of the Isokorb (standard 1m) also the height is incorporated. Hence every Isokorb which has a different height has a different λ-eq value. As the equipment is substantial, every Isokorb type that is depending on the load level has a different equivalent thermal conductivity again. The thickness of the Isokorb is not incorporated in the calculation at one dimensional value. If thickness is considered, then the thermal resistance values (R_{eq}) can be calculated. The thermal resistance values (R_{eq}) are more important if thickness is decisive for thermal efficiency of products. Especially for this reason Schöck has developed **Isokorb KXT** which consists of **120 mm thickness** and has certification for “Passivhaus” buildings (zero energy buildings).

For Isokorb XT range the R_{eq} – values are decisive since the characteristically one dimensional Lambda values does not consider this condition of thickness! Of course the 3-dimensional calculation of Lambda values are also possible and can be done by several software tools (like ANTHERM, TRISCO, HEAT etc…). With these software tools the 3 - dimensional Lambda values are more specific and detailed then the one dimensional Lambda values.

The building physics department of Schöck (IPB) works also with building physics tools (like ANTHERM), but uses these tools mainly for calculating of PSI-values or 3- dimensional Lambda values, if required. Because PSI-values (thermal bridge coefficient) are considering the whole construction with focusing at thermal bridge and all details of construction has to be clear. It is often forgotten that also PSI-values are depending on construction parameters and afterwards changes of construction could give a completely different picture of calculated thermal performance. Therefore it makes no sense to calculate PSI values before all boundary conditions are not clear and if the performance of Isokorb should be evaluated. Nevertheless Schöck offers this service to all clients who desires this service and advises with more information (even in project meetings).

For real thermal efficiency and performance of Schöck products the one dimensional values are more informative and easier to calculate (technical manual). The equipped amount of bars represents an overall surface (A_s) which is again multiplied with the according thermal conductivity of the material. The same procedure is done for each system components (tension and shear bars, HTE-modules, insulating elements etc…) and the result is an equivalent thermal conductivity which is the one dimensional λ-eq value for each Isokorb. This easy way of calculation and consideration allows planners more transparency and comparison between different products. Thus Schöck had decided to offer in technical manuals the one dimensional Lambda values since everybody can check them. Of course, if required Schöck can also provide 3 dimensional Lambda values.

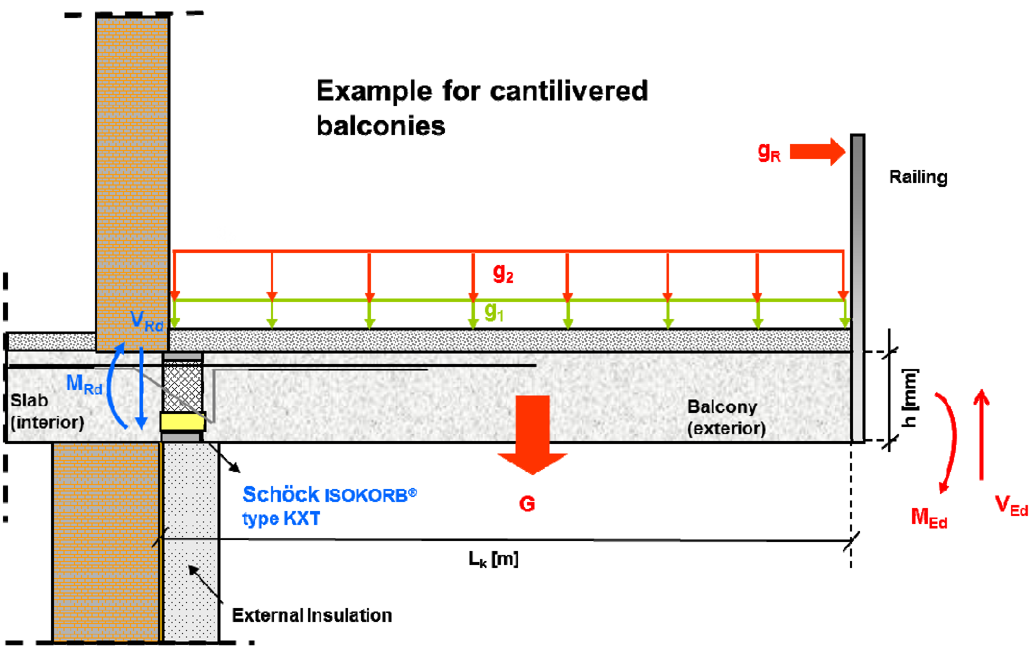
3. Building Physics Analyses of some Isokorb types

In the following the building physics part of listed Isokorb types should be analysed and verified for better understanding of thermal performance due to utilization for projects.

- Schöck Isokorb K50-CV30-V8-H200
- Schöck Isokorb K30-CV30-V8-H230
- Schöck Isokorb K50-CV30-V6-H200
- Schöck Isokorb K30-CV30-V6-H230
- **Schöck Isokorb KXT50-CV30-V6-H200**
- **Schöck Isokorb KXT30-CV30-V6-H230**

The way of calculating and thermal design is similar for all other products. This calculation should just give the improvement possibilities which product is more useful hence optimization of thermal efficiency.

Sketch: cantilivered balconies with loading



In the following first the way and values of one dimensional lambda values are calculated. These calculations should picture some more details of way of calculating and transparency for planners. Furthermore in first part of consideration the degree of thermal improvement with and without Isokorb is shown and also the moisture proof analysis. In the second part of this report the 3 dimensional values and PSI-values of all above mentioned types were calculated. Finally the summary with a comparison between the Isokorb products should give the planners the opportunity to choose between possible solutions which is at the end the required for project Jan Turpin.

3.1 One dimensional calculation of Lambda values with Schöck software

In this chapter the one dimensional Lambda values of all mentioned types will be designed and calculated. This calculation includes furthermore thermal efficiency analysis according to ISO EN 4108-4 and moisture protection analysis. Schöck has developed special calculation tool for comparison between solutions with and without thermal break elements. But to give a better picture of thermal performance and show the way of calculating Lambda values, this software tool will be used at first. The consideration of one dimensional Lambda values is only valid for Isokorb type K with 80 mm insulation thickness. As mentioned in chapter 2, for the calculation of Isokorb XT range the R_{eq} value, equivalent thermal resistance values, is decisive and will be considered in following chapters.

3.1.1 One-dimensional λeq value for Isokorb K30-CV30-V8-H230

Analysis of Building Pyhsics

Isokorb Type: **K30-CV30-V8-H230**

Length of one piece:	**1000**	mm	**Height of elements:**		**230 mm**
Assembly of Isokorb:	**A / Ø**	**Quantity**	**A_{tot} [mm²]**		**required**
1. Used rension bars:	**8 mm**	**12**	**603,2**		**YES**
2. Used shear bars:	**8 mm**	**7**	**351,9**		**YES**
3. Used compression bars:	**0 mm**		**0,0**		**NO**
4. HTE - Modules:	**980 mm**	**7 HTE**	**6860,0**		**YES**
5. Insulation:			**222185,0**		**YES**
6. Fire protecting plates:			**22500**		**YES**

Thermal properties of used Materials (Thermal conductivities - Λ):

1. Material:	stainless steel:	15	W/mK	
	Polystyrol (Neopor):	0,032	W/mK	
	HTE- Modules:	0,78	W/mK	(special)
	Fire plates:	0,14	W/mK	
	Used RC on-site (2%):	2,4	W/mK	(standard)
2. Isokorb:	equivalent Thermal Conductivity - Λ_{eq}			
	Λ_{eq} =	**0,124**	w/mK	

1. Thermal efficiency analysis according ISO EN 4108-4:

1. Thickness of used Isokorb:	d_i =	0,08	m
2. Thermal resistance inside (acc. Codes):	R_{si} =	0,13	m²K/W
3. Thermal resistance outside (acc. Codes):	R_{se} =	0,04	m²K/W
4. Thickness of main wall construction:	d_w =	0,30	m
5. Thicknes of whole construction:	d_{tot} =	0,38	m
6. Thermal restistance with Isokorb:	$R_{isokorb}$ =	3,232	m²K/W
7. Thermal resistance without Isokorb:	$R_{concreted}$ =	0,158	m²K/W
8. Heat tranfer coefficient with Isokorb:	$U_{isokorb}$ =	**0,29399**	W /(m²K)
9. Heat transfer coefficient concreted:	$U_{concreted}$ =	3,04569	W/(m²K)

→ **Thermal degree of improvement with Isokorb:** **90%**

3.1.2 One-dimensional λeq value for Isokorb K30-CV30-V6-H230

Analysis of Building Pyhsics

Isokorb Type: **K30-CV30-V6-H230**

Length of one piece:	**1000** mm		**Height of elements:**		**230 mm**
Assembly of Isokorb:	**A / Ø**	**Quantity**	**A_{tot} [mm²]**		**required**
1. Used rension bars:	**8 mm**	**12**	**603,2**		**YES**
2. Used shear bars:	**6 mm**	**6**	**169,6**		**YES**
3. Used compression bars:	**0 mm**		**0,0**		**NO**
4. HTE - Modules:	**980 mm**	**7 HTE**	**6860,0**		**YES**
5. Insulation:			**222367,2**		**YES**
6. Fire protecting plates:			**22500**		**YES**

Thermal properties of used Materials (Thermal conductivities - Λ):

1. Material:	stainless steel:	15	W/mK	
	Polystyrol (Neopor):	0,032	W/mK	
	HTE- Modules:	0,78	W/mK	(special)
	Fire plates:	0,14	W/mK	
	Used RC on-site (2%):	2,4	W/mK	(standard)

2. Isokorb: equivalent Thermal Conductivity - Λ_{eq}

Λ_{eq} = **0,114** w/mK

1. Thermal efficiency analysis according ISO EN 4108-4:

1. Thickness of used Isokorb:	d_i =	0,08	m
2. Thermal resistance inside (acc. Codes):	R_{si} =	0,13	m²K/W
3. Thermal resistance outside (acc. Codes):	R_{se} =	0,04	m²K/W
4. Thickness of main wall construction:	d_w =	0,30	m
5. Thicknes of whole construction:	d_{tot} =	0,38	m
6. Thermal restistance with Isokorb:	$R_{isokorb}$ =	3,504	m²K/W
7. Thermal resistance without Isokorb:	$R_{concreted}$ =	0,158	m²K/W
8. Heat tranfer coefficient with Isokorb:	$U_{isokorb}$ =	**0,27216**	W /(m²K)
9. Heat transfer coefficient concreted:	$U_{concreted}$ =	3,04569	W/(m²K)

→ **Thermal degree of improvement with Isokorb:** **91%**

3.1.3 One-dimensional λeq value for Isokorb K50-CV30-V8-H200

Analysis of Building Pyhsics

Isokorb Type: **K50-CV30-V8-H200**

Length of one piece:	**1000**	**mm**	**Height of elements:**		**200 mm**
Assembly of Isokorb:		**A / Ø**	**Quantity**	**A_{tot} [mm²]**	**required**
1. Used rension bars:		**8 mm**	**16**	**804,2**	**YES**
2. Used shear bars:		**8 mm**	**7**	**351,9**	**YES**
3. Used compression bars:		**0 mm**		**0,0**	**NO**
4. HTE - Modules:		**980 mm**	**10 HTE**	**9800,0**	**YES**
5. Insulation:				**189043,9**	**YES**
6. Fire protecting plates:				**22500**	**YES**

Thermal properties of used Materials (Thermal conductivities - Λ):

1. Material:	stainless steel:	15	W/mK	
	Polystyrol (Neopor):	0,032	W/mK	
	HTE- Modules:	0,78	W/mK	(special)
	Fire plates:	0,14	W/mK	
	Used RC on-site (2%):	2,4	W/mK	(standard)
2. Isokorb:	equivalent Thermal Conductivity - $Λ_{eq}$			
	$Λ_{eq}$ =	**0,161**	w/mK	

1. Thermal efficiency analysis according ISO EN 4108-4:

1. Thickness of used Isokorb:	d_i =	0,08	m
2. Thermal resistance inside (acc. Codes):	R_{si} =	0,13	m²K/W
3. Thermal resistance outside (acc. Codes):	R_{se} =	0,04	m²K/W
4. Thickness of main wall construction:	d_w =	0,30	m
5. Thicknes of whole construction:	d_{tot} =	0,38	m
6. Thermal restistance with Isokorb:	$R_{isokorb}$ =	2,523	m²K/W
7. Thermal resistance without Isokorb:	$R_{concreted}$ =	0,158	m²K/W
8. Heat tranfer coefficient with Isokorb:	$U_{isokorb}$ =	**0,37127**	W /(m²K)
9. Heat transfer coefficient concreted:	$U_{concreted}$ =	3,04569	W/(m²K)

→ **Thermal degree of improvement with Isokorb:** **88%**

3.1.4 One-dimensional λeq value for Isokorb K50-CV30-V6-H230

Analysis of Building Pyhsics

Isokorb Type: **K50-CV30-V6-H200**

Length of one piece:	**1000**	**mm**	**Height of elements:**		**200 mm**
Assembly of Isokorb:	**A / Ø**	**Quantity**	**A_{tot} [mm²]**		**required**
1. Used rension bars:	**8 mm**	**16**	**804,2**		**YES**
2. Used shear bars:	**6 mm**	**6**	**169,6**		**YES**
3. Used compression bars:	**0 mm**		**0,0**		**NO**
4. HTE - Modules:	**980 mm**	**10 HTE**	**9800,0**		**YES**
5. Insulation:			**189226,1**		**YES**
6. Fire protecting plates:			**22500**		**YES**

Thermal properties of used Materials (Thermal conductivities - Λ):

1. Material:	stainless steel:	15	W/mK	
	Polystyrol (Neopor):	0,032	W/mK	
	HTE- Modules:	0,78	W/mK	(special)
	Fire plates:	0,14	W/mK	
	Used RC on-site (2%):	2,4	W/mK	(standard)
2. Isokorb:	equivalent Thermal Conductivity - Λ_{eq}			
		Λ_{eq} = **0,148**	w/mK	

1. Thermal efficiency analysis according ISO EN 4108-4:

1. Thickness of used Isokorb:	d_i =	0,08	m
2. Thermal resistance inside (acc. Codes):	R_{si} =	0,13	m²K/W
3. Thermal resistance outside (acc. Codes):	R_{se} =	0,04	m²K/W
4. Thickness of main wall construction:	d_w =	0,30	m
5. Thicknes of whole construction:	d_{tot} =	0,38	m
6. Thermal restistance with Isokorb:	$R_{isokorb}$ =	2,728	m²K/W
7. Thermal resistance without Isokorb:	$R_{concreted}$ =	0,158	m²K/W
8. Heat tranfer coefficient with Isokorb:	$U_{isokorb}$ =	**0,34501**	W /(m²K)
9. Heat transfer coefficient concreted:	$U_{concreted}$ =	3,04569	W/(m²K)

→ **Thermal degree of improvement with Isokorb:** **89%**

3.1.5 Summary of calculated one-dimensional Lambda values

Isokorb type	1 dim- λ_{eq} value	Improvement*
K30-CV30-V8-H230	0,124 W/mK	90%
K30-CV30-V6-H230	0,114 W/mK	91%
K50-CV30-V8-H200	0,161 W/mK	88%
K50-CV30-V6-H200	0,148 W/mK	89%

* **The improvement is much better, if calculation is done by software tools ANTHERM**

According to static verifications with respect to EC2 which were done by the international design department of Schöck, the shear capacity V6 can carry off 42,2 kN/m. This would ensure that the higher shear capacity (V8, with 7 x Ø8) is not necessary for this project.

3.2 Building physics calculation of Isokorb with ANTHERM software

In the following all important values for better consideration and comparison is done by using building physics software ANTHERM. Following values were calculated:

- 3 dimensional Lambda values (detailed consideration)
- R- values (Thermal resistance factor)
- PSI-values (thermal bridge coefficient factor)
- Surface temperature inside θ_i
- f_{rsi} values (thermal bridge factor)

3.2.1 Three dimensional Lambda λ_{eq} values of Isokorb products

The values which are presented are taken form software calculation and can be considered as a very specific and detailed calculation which contain also the one dimensional Lambda values. In the table below all values are listed:

Isokorb type	**3 - dim- λ_{eq} value**	**1 - dim- λ_{eq} value**
K30-CV30-V8-H230	0,113 W/mK	0,124 W/mK
K30-CV30-V6-H230	**0,108 W/mK**	**0,113 W/mK**
K50-CV30-V8-H200	0,145 W/mK	0,161 W/mK
K50-CV30-V6-H200	**0,139 W/mK**	**0,148 W/mK**
K50-CV30-V8-H230	0,130 W/mK	0,145 W/mK
K50-CV30-V6-H230	**0,124 W/mK**	**0,133 W/mK**

3.2.2 R_{eq} –values of Schöck Isokorb

In the table below the R_{eq} values, thermal resistance values are listed. As described in chapter 2, the thermal resistance values are considering the insulation thickness. This is very important for the energy performance of Isokorb products. Therefore Isokorb KXT, with 120 mm insulation thickness will be considered optionally too. The higher the R_{eq} values the better thermal efficiency of Isokorb product (opposite of λ_{eq} values, because the resistance should be as high as possible):

Isokorb type	**3 - dim - R_{eq} values**	**1 - dim - R_{eq} values**
K30-CV30-V6-H230	**7,4074 m²K/W**	**7,0796 m²K/W**
K50-CV30-V8-H200	5,5172 m²K/W	4,9382 m²K/W
K50-CV30-V6-H200	**5,7553 m²K/W**	**5,4054 m²K/W**
K50-CV30-V8-H230	6,1302 m²K/W	5,51724 m²K/W
K50-CV30-V6-H230	**6,4257 m²K/W**	**6,0150 m²K/W**
KXT50-CV30-V6-H200	**8,5714 m²K/W**	**8,0536 m²K/W**

3.2.3 PSI - values and f_{rsi} values of Schöck Isokorb

As in chapter 2 mentioned the Psi- values, thermal bridge coefficient and frsi values, thermal bridge factor, are very important for determining the thermal performance of thermal bridge elements. The lower the thermal coefficient values are (PSI values) the better the construction with chosen Isokorb. The higher the thermal bridge factor are (frsi values) the better the protection against moisture and mould. In this calculation the construction details of Jan Turpin project are contained, since the whole construction is evaluated.

Isokorb type	PSI- values	f_{rsi}- values
K30-CV30-V6-H230	**0,156 W/mK**	**0,94**
K50-CV30-V8-H200	0,195 W/mK	0,93
K50-CV30-V6-H200	**0,186 W/mK**	**0,93**
K50-CV30-V8-H230	0,196 W/mK	0,93
K50-CV30-V6-H230	**0,187 W/mK**	**0,93**
KXT50-CV30-V6-H200	**0,122 W/mK**	**0,94**

3.2.4 θ_i - Inside Surface temperature with Schöck Isokorb

The surface temperature is also important for preventing moisture and mould, because if inside surface temperature is below the dew point, moisture can start. In most cases the dew point of surface temperature for starting moisture takes 12,5 °C. The temperature for mould developing starts already at lower temperatures. The higher the inside temperature the better the construction itself and energy lost is prevented too.

Isokorb type	Θi – value [°C]
K30-CV30-V6-H230	**18,74**
K50-CV30-V8-H200	18,62
K50-CV30-V6-H200	**18,64**
K50-CV30-V8-H230	18,62
K50-CV30-V6-H230	**18,65**
KXT50-CV30-V6-H200	**18,83**

3.3 Results with ANTHERM of building physics analysis

3.3.1 Building physics analysis Isokorb K30-V6-H230

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http://www.schoeck.com/

AnTherm (WALTER/UDO/KLAUS)
Version 6.108 2012.03.04

15.03.2012

Datei: D:\Kundenberatung\Vergleich Plaka\Plaka_aufbau_K30-V6.antherm

Angaben zur Modellierung der Bauteilkonstruktion

Räume :
Raumbez.: Außen
Rs=0,0400 m²K/W : Außen
Raumbez.: Innen
Rs=0,1300 m²K/W : Innen

Wärmequellen : keine

Baustoffe :
λ= 0,17 W/(m K) : Brandschutzplatte
λ= 0,034 W/(m K) : Dämmstoff
λ= 2,3 W/(m K) : Decke
λ= 0,804 W/(m K) : Drucklager
λ= 15 W/(m K) : Edelstahl
λ= 2,3 W/(m K) : Innenwand/ Wandkolonnen
λ= 0,065 W/(m K) : Luftschicht/ Luchtspouw
λ= 0,9 W/(m K) : Mauerwerk/ Parament Netselwerk.
λ= 0,04 W/(m K) : PUR

Schichtaufbauten und U-Wert Berechnungen

Außen <-> Innen @ BottomBack: (-200, -2500, 0) x (150, -2500, 0)

Baustoff / Oberfläche	λ [W/mK]	d [mm]	Rs [m²K/W]	α [W/m²K]	R [m²K/W]	Raum
Außen/Außen			0,0400	25,0000	0,0400	Außen
Mauerwerk/ Parament Netselwerk.	0,9000	90,0000			0,1000	
Luftschicht/ Luchtspouw	0,0650	30,0000			0,4615	
PUR	0,0400	80,0000			2,0000	
Innenwand/ Wandkolonnen	2,3000	150,0000			0,0652	
Innen/Innen			0,1300	7,6923	0,1300	Innen
		350,0000	**U-Wert:**	**0,3576**	**[W/m²K]**	

Außen <-> Innen @ BottomFront: (-200, -2500, 1000) x (150, -2500, 1000)

Baustoff / Oberfläche	λ [W/mK]	d [mm]	Rs [m²K/W]	α [W/m²K]	R [m²K/W]	Raum
Außen/Außen			0,0400	25,0000	0,0400	Außen
Mauerwerk/ Parament Netselwerk.	0,9000	90,0000			0,1000	
Luftschicht/ Luchtspouw	0,0650	30,0000			0,4615	
PUR	0,0400	80,0000			2,0000	

Innenwand/ Wandkolonnen	2,3000	150,0000			0,0652	
Innen/Innen			0,1300	7,6923	0,1300	Innen
		350,0000	**U-Wert:**	**0,3576**	**[W/m²K]**	

Außen <-> Innen @ TopBack: (-200, 2500, 0) x (150, 2500, 0)

	λ	d	Rs	α	R	
Baustoff / Oberfläche	[W/mK]	[mm]	[m²K/W]	[W/m²K]	[m²K/W]	Raum
Außen/Außen			0,0400	25,0000	0,0400	Außen
Mauerwerk/ Parament Netselwerk.	0,9000	90,0000			0,1000	
Luftschicht/ Luchtspouw	0,0650	30,0000			0,4615	
PUR	0,0400	80,0000			2,0000	
Innenwand/ Wandkolonnen	2,3000	150,0000			0,0652	
Innen/Innen			0,1300	7,6923	0,1300	Innen
		350,0000	**U-Wert:**	**0,3576**	**[W/m²K]**	

Außen <-> Innen @ TopFront: (-200, 2500, 1000) x (150, 2500, 1000)

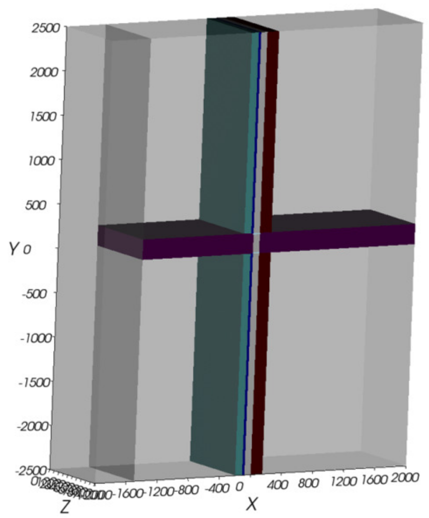
	λ	d	Rs	α	R	
Baustoff / Oberfläche	[W/mK]	[mm]	[m²K/W]	[W/m²K]	[m²K/W]	Raum
Außen/Außen			0,0400	25,0000	0,0400	Außen
Mauerwerk/ Parament Netselwerk.	0,9000	90,0000			0,1000	
Luftschicht/ Luchtspouw	0,0650	30,0000			0,4615	
PUR	0,0400	80,0000			2,0000	
Innenwand/ Wandkolonnen	2,3000	150,0000			0,0652	
Innen/Innen			0,1300	7,6923	0,1300	Innen
		350,0000	**U-Wert:**	**0,3576**	**[W/m²K]**	

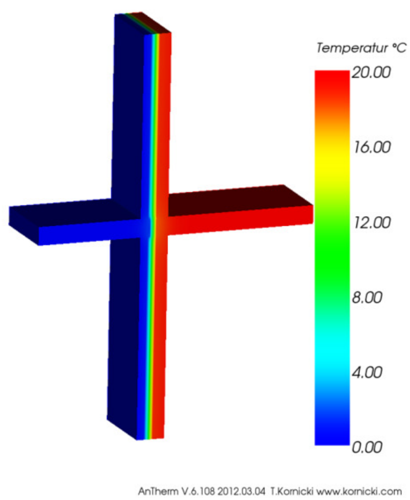
Innen <-> Innen @ BackRight: (2000, 230, 0) x (2000, 0, 0)

	λ	d	Rs	α	R	
Baustoff / Oberfläche	[W/mK]	[mm]	[m²K/W]	[W/m²K]	[m²K/W]	Raum
Innen/Innen			0,1300	7,6923	0,1300	Innen
Decke	2,3000	230,0000			0,1000	
Innen/Innen			0,1300	7,6923	0,1300	Innen
		230,0000	**U-Wert:**	**2,7778**	**[W/m²K]**	

Innen <-> Innen @ FrontRight: (2000, 230, 1000) x (2000, 0, 1000)

	λ	d	Rs	α	R	
Baustoff / Oberfläche	[W/mK]	[mm]	[m²K/W]	[W/m²K]	[m²K/W]	Raum
Innen/Innen			0,1300	7,6923	0,1300	Innen
Decke	2,3000	230,0000			0,1000	
Innen/Innen			0,1300	7,6923	0,1300	Innen
		230,0000	**U-Wert:**	**2,7778**	**[W/m²K]**	





3.3.2 Building physics analysis Isokorb K50-V8-H200

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AnTherm (WALTER/UDO/KLAUS)
Version 6.108 2012.03.04

15.03.2012

Datei: D:\Kundenberatung\Vergleich Plaka\Plaka_aufbau_K50-V8-h200.antherm

Angaben zur Modellierung der Bauteilkonstruktion

Räume :
Raumbez.: Außen
Rs=0,0400 m²K/W : Außen
Raumbez.: Innen
Rs=0,1300 m²K/W : Innen

Wärmequellen : keine

Baustoffe :
λ= 0,17 W/(m K) : Brandschutzplatte
λ= 0,034 W/(m K) : Dämmstoff
λ= 2,3 W/(m K) : Decke
λ= 0,804 W/(m K) : Drucklager
λ= 15 W/(m K) : Edelstahl
λ= 2,3 W/(m K) : Innenwand/ Wandkolonnen
λ= 0,065 W/(m K) : Luftschicht/ Luchtspouw
λ= 0,9 W/(m K) : Mauerwerk/ Parament Netselwerk.
λ= 0,04 W/(m K) : PUR

Außen <-> Innen @ BottomBack: (-200, -2500, 0) x (150, -2500, 0)

	λ	d	Rs	α	R	
Baustoff / Oberfläche	[W/mK]	[mm]	[m²K/W]	[W/m²K]	[m²K/W]	Raum
Außen/Außen			0,0400	25,0000	0,0400	Außen
Mauerwerk/ Parament Netselwerk.	0,9000	90,0000			0,1000	
Luftschicht/ Luchtspouw	0,0650	30,0000			0,4615	
PUR	0,0400	80,0000			2,0000	
Innenwand/ Wandkolonnen	2,3000	150,0000			0,0652	
Innen/Innen			0,1300	7,6923	0,1300	Innen
		350,0000	**U-Wert:**	**0,3576**	**[W/m²K]**	

Außen <-> Innen @ BottomFront: (-200, -2500, 1000) x (150, -2500, 1000)

	λ	d	Rs	α	R	
Baustoff / Oberfläche	[W/mK]	[mm]	[m²K/W]	[W/m²K]	[m²K/W]	Raum
Außen/Außen			0,0400	25,0000	0,0400	Außen
Mauerwerk/ Parament Netselwerk.	0,9000	90,0000			0,1000	
Luftschicht/ Luchtspouw	0,0650	30,0000			0,4615	
PUR	0,0400	80,0000			2,0000	
Innenwand/ Wandkolonnen	2,3000	150,0000			0,0652	
Innen/Innen			0,1300	7,6923	0,1300	Innen
		350,0000	**U-Wert:**	**0,3576**	**[W/m²K]**	

Außen <-> Innen @ TopBack: (-200, 2500, 0) x (150, 2500, 0)

	λ	d	Rs	α	R	
Baustoff / Oberfläche	[W/mK]	[mm]	[m²K/W]	[W/m²K]	[m²K/W]	Raum
Außen/Außen			0,0400	25,0000	0,0400	Außen
Mauerwerk/ Parament Netselwerk.	0,9000	90,0000			0,1000	
Luftschicht/ Luchtspouw	0,0650	30,0000			0,4615	
PUR	0,0400	80,0000			2,0000	
Innenwand/ Wandkolonnen	2,3000	150,0000			0,0652	
Innen/Innen			0,1300	7,6923	0,1300	Innen
		350,0000	**U-Wert:**	**0,3576**	**[W/m²K]**	

Außen <-> Innen @ TopFront: (-200, 2500, 1000) x (150, 2500, 1000)

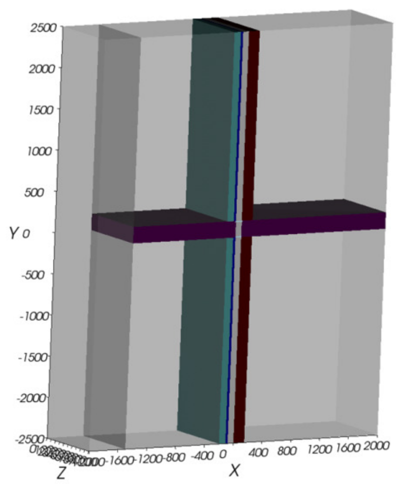
	λ	d	Rs	α	R	
Baustoff / Oberfläche	[W/mK]	[mm]	[m²K/W]	[W/m²K]	[m²K/W]	Raum
Außen/Außen			0,0400	25,0000	0,0400	Außen
Mauerwerk/ Parament Netselwerk.	0,9000	90,0000			0,1000	
Luftschicht/ Luchtspouw	0,0650	30,0000			0,4615	
PUR	0,0400	80,0000			2,0000	
Innenwand/ Wandkolonnen	2,3000	150,0000			0,0652	
Innen/Innen			0,1300	7,6923	0,1300	Innen
		350,0000	**U-Wert:**	**0,3576**	**[W/m²K]**	

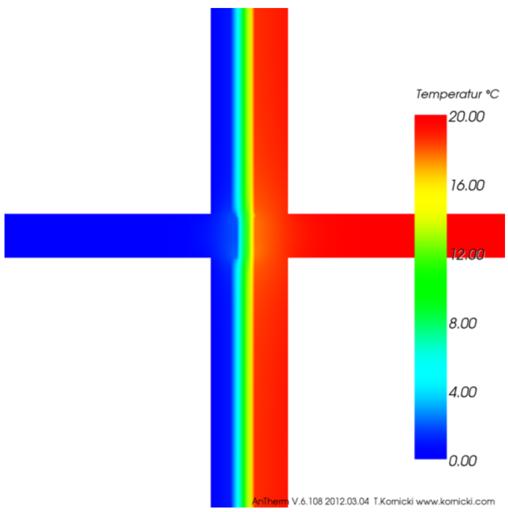
Innen <-> Innen @ BackRight: (2000, 200, 0) x (2000, 0, 0)

	λ	d	Rs	α	R	
Baustoff / Oberfläche	[W/mK]	[mm]	[m²K/W]	[W/m²K]	[m²K/W]	Raum
Innen/Innen			0,1300	7,6923	0,1300	Innen
Decke	2,3000	200,0000			0,0870	
Innen/Innen			0,1300	7,6923	0,1300	Innen
		200,0000	**U-Wert:**	**2,8822**	**[W/m²K]**	

Innen <-> Innen @ FrontRight: (2000, 200, 1000) x (2000, 0, 1000)

	λ	d	Rs	α	R	
Baustoff / Oberfläche	[W/mK]	[mm]	[m²K/W]	[W/m²K]	[m²K/W]	Raum
Innen/Innen			0,1300	7,6923	0,1300	Innen
Decke	2,3000	200,0000			0,0870	
Innen/Innen			0,1300	7,6923	0,1300	Innen
		200,0000	**U-Wert:**	**2,8822**	**[W/m²K]**	





3.3.3 Building physics values of temperature and graphics

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Vimbucher Straße 2
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http://www.schoeck.com/

AnTherm (WALTER/UDO/KLAUS)
Version 6.108 2012.03.04

16.03.2012

Datei: D:\Kundenberatung\Vergleich Plaka\Plaka_aufbau_K30-V6.antherm

Anzahl der bilanzierten Zellen: 2479275 (Knotenzahl > 19834200)

Randbedingungen und resultierende Oberflächentemperaturen / Grenzfeuchten d. Raumluft

	Raumtemperatur	min. Temperatur	max. Temperatur	Kondensat. rF		f^*_{Rsi}
	[°C]	[°C]	[°C]	[%]		
Außen	0,00	0,00	0,71	100,00	%	
Innen	20,00	18,74	20,00	92,45	%	0,94

Gewichte für den kältesten Oberflächenpunkt eines jeden Raumes

	Außen	Innen
g(Außen)	0,999999	0,063094
g(Innen)	0,000001	0,936906

Koordinaten (x,y,z) des kältesten Oberflächenpunktes eines jeden Raumes

	x [mm]	y [mm]	z [mm]	Temp.[°C]	f^*_{Rsi}
Außen	-1500,0000	0,0000	10,0000	0,00	
Innen	150,0000	-22,0000	528,0000	18,74	0,94

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Version 6.108 2012.03.04

16.03.2012

Datei: D:\Kundenberatung\Vergleich Plaka\Plaka_aufbau_K50-V8-h200.antherm

Anzahl der bilanzierten Zellen: 2887440 (Knotenzahl > 23099520)

Randbedingungen und resultierende Oberflächentemperaturen / Grenzfeuchten d. Raumluft

	Raumtemperatur	min. Temperatur	max. Temperatur	Kondensat. rF		f^*_{Rsi}
	[°C]	[°C]	[°C]	[%]		
Außen	0,00	0,00	0,82	100,00	%	
Innen	20,00	18,62	20,00	91,75	%	0,93

Gewichte für den kältesten Oberflächenpunkt eines jeden Raumes

	Außen	Innen
g(Außen)	1,000000	0,069154
g(Innen)	0,000000	0,930846

Koordinaten (x,y,z) des kältesten Oberflächenpunktes eines jeden Raumes

	x [mm]	y [mm]	z [mm]	Temp.[°C]	f^*_{Rsi}
Außen	-1500,0000	200,0000	155,2000	0,00	
Innen	150,0000	-22,0000	696,0000	18,62	0,93

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Version 6.108 2012.03.04

16.03.2012

Datei: D:\Kundenberatung\Vergleich Plaka\Plaka_aufbau_K50-V8.antherm

Anzahl der bilanzierten Zellen: 2920035 (Knotenzahl > 23360280)

Randbedingungen und resultierende Oberflächentemperaturen / Grenzfeuchten d. Raumluft

	Raumtemperatur	min. Temperatur	max. Temperatur	Kondensat. rF		f^{*}_{Rsi}
	[°C]	[°C]	[°C]	[%]		
Außen	0,00	0,00	0,81	100,00	%	
Innen	20,00	18,62	20,00	91,79	%	0,93

Gewichte für den kältesten Oberflächenpunkt eines jeden Raumes

	Außen	Innen
g(Außen)	0,999999	0,068837
g(Innen)	0,000001	0,931163

Koordinaten (x,y,z) des kältesten Oberflächenpunktes eines jeden Raumes

	x [mm]	y [mm]	z [mm]	Temp.[°C]	f^{*}_{Rsi}
Außen	-1500,0000	0,0000	0,0000	0,00	
Innen	150,0000	-22,0000	690,0000	18,62	0,93

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16.03.2012

Datei: D:\Kundenberatung\Vergleich Plaka\Plaka_aufbau_K50-V6-h200_2.antherm

Anzahl der bilanzierten Zellen: 2931024 (Knotenzahl > 23448192)

Randbedingungen und resultierende Oberflächentemperaturen / Grenzfeuchten d. Raumluft

	Raumtemperatur	min. Temperatur	max. Temperatur	Kondensat. rF		f^{*}_{Rsi}
	[°C]	[°C]	[°C]	[%]		
Außen	0,00	0,00	0,80	100,00	%	
Innen	20,00	18,64	20,00	91,90	%	0,93

Gewichte für den kältesten Oberflächenpunkt eines jeden Raumes

	Außen	Innen
g(Außen)	1,000000	0,067864
g(Innen)	0,000000	0,932136

Koordinaten (x,y,z) des kältesten Oberflächenpunktes eines jeden Raumes

	x [mm]	y [mm]	z [mm]	Temp.[°C]	f^{*}_{Rsi}
Außen	-1500,0000	200,0000	249,0000	0,00	
Innen	150,0000	-22,0000	743,5000	18,64	0,93

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http://www.schoeck.com/

AnTherm (WALTER/UDO/KLAUS)
Version 6.108 2012.03.04

16.03.2012

Datei: D:\Kundenberatung\Vergleich Plaka\Plaka_aufbau_K50-V6.antherm

Anzahl der bilanzierten Zellen: 2964111 (Knotenzahl > 23712888)

Randbedingungen und resultierende Oberflächentemperaturen / Grenzfeuchten d. Raumluft

	Raumtemperatur	min. Temperatur	max. Temperatur	Kondensat. rF	f^*_{Rsi}
	[°C]	[°C]	[°C]	[%]	
Außen	0,00	0,00	0,79	100,00 %	
Innen	20,00	18,65	20,00	91,94 %	0,93

Gewichte für den kältesten Oberflächenpunkt eines jeden Raumes

	Außen	Innen
g(Außen)	0,999999	0,067554
g(Innen)	0,000001	0,932446

Koordinaten (x,y,z) des kältesten Oberflächenpunktes eines jeden Raumes

	x [mm]	y [mm]	z [mm]	Temp.[°C]	f^*_{Rsi}
Außen	-1500,0000	0,0000	6,5000	0,00	
Innen	150,0000	-22,0000	739,0000	18,65	0,93

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Vimbucher Straße 2
76534 Baden-Baden/Steinbach
http://www.schoeck.com/

AnTherm (WALTER/UDO/KLAUS)
Version 6.108 2012.03.04

16.03.2012

Datei: D:\Kundenberatung\Vergleich Plaka\Plaka_aufbau_KXT50-V6-h200.antherm

Anzahl der bilanzierten Zellen: 2878830 (Knotenzahl > 23030640)

Randbedingungen und resultierende Oberflächentemperaturen / Grenzfeuchten d. Raumluft

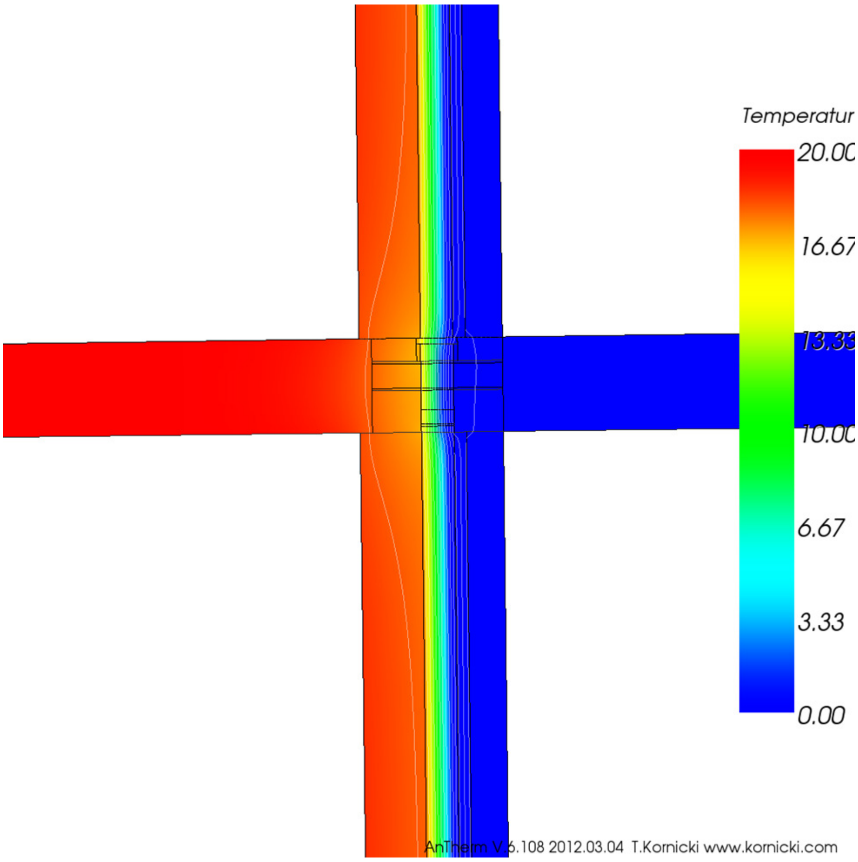
	Raumtemperatur	min. Temperatur	max. Temperatur	Kondensat. rF	f^*_{Rsi}
	[°C]	[°C]	[°C]	[%]	
Außen	0,00	0,00	0,64	100,00 %	
Innen	20,00	18,83	20,00	92,97 %	0,94

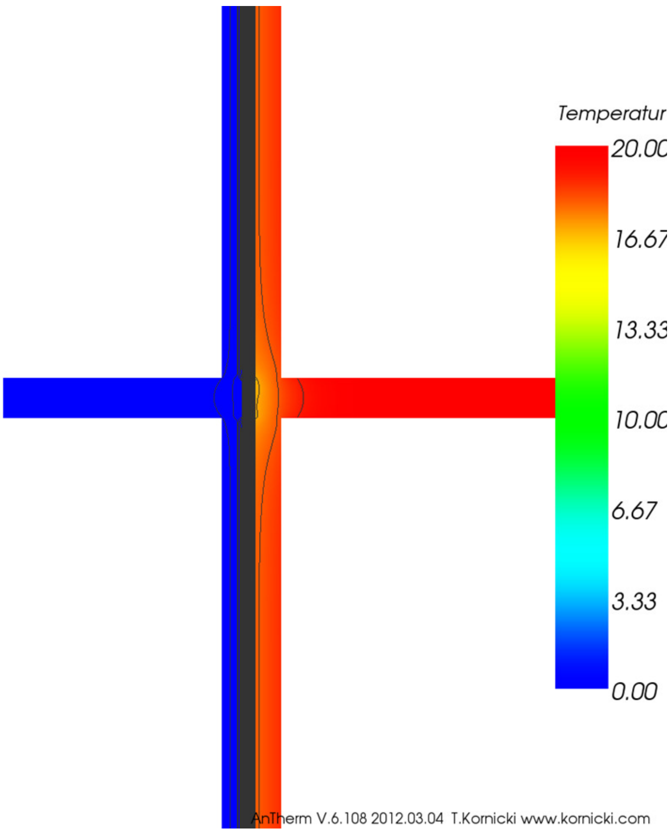
Gewichte für den kältesten Oberflächenpunkt eines jeden Raumes

	Außen	Innen
g(Außen)	1,000000	0,058642
g(Innen)	0,000000	0,941358

Koordinaten (x,y,z) des kältesten Oberflächenpunktes eines jeden Raumes

	x [mm]	y [mm]	z [mm]	Temp.[°C]	f^*_{Rsi}
Außen	-1500,0000	0,0000	6,5000	0,00	
Innen	150,0000	222,0000	783,0000	18,83	0,94


Temperatur
20.00
16.67
13.33
10.00
6.67
3.33
0.00
AnTherm V.6.108 2012.03.04 T.Kornicki www.kornicki.com


Temperatur
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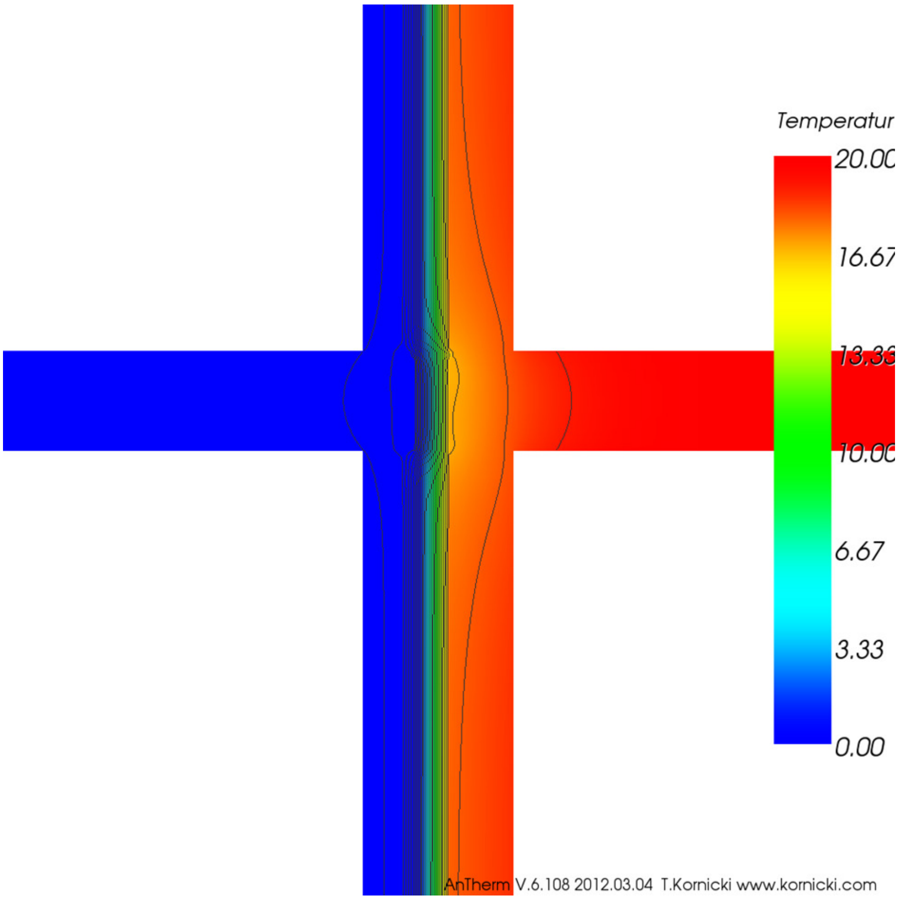
16.67
13.33
10.00
6.67
3.33
0.00
AnTherm V.6.108 2012.03.04 T.Kornicki www.kornicki.com


Temperatur
20.00
16.67
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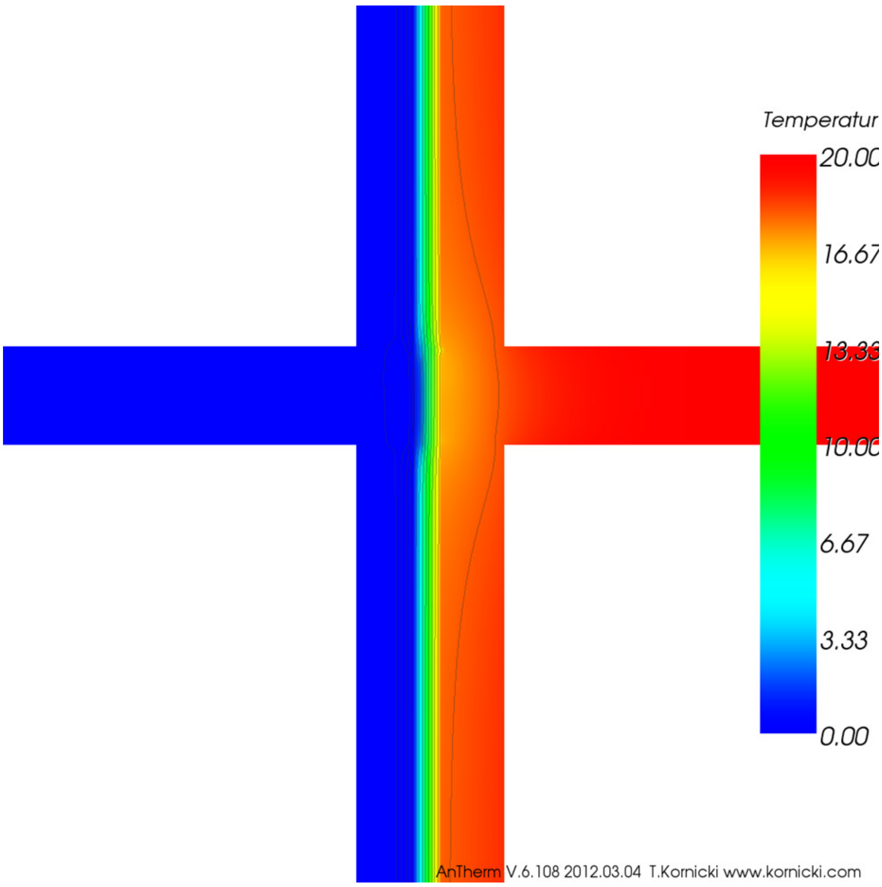
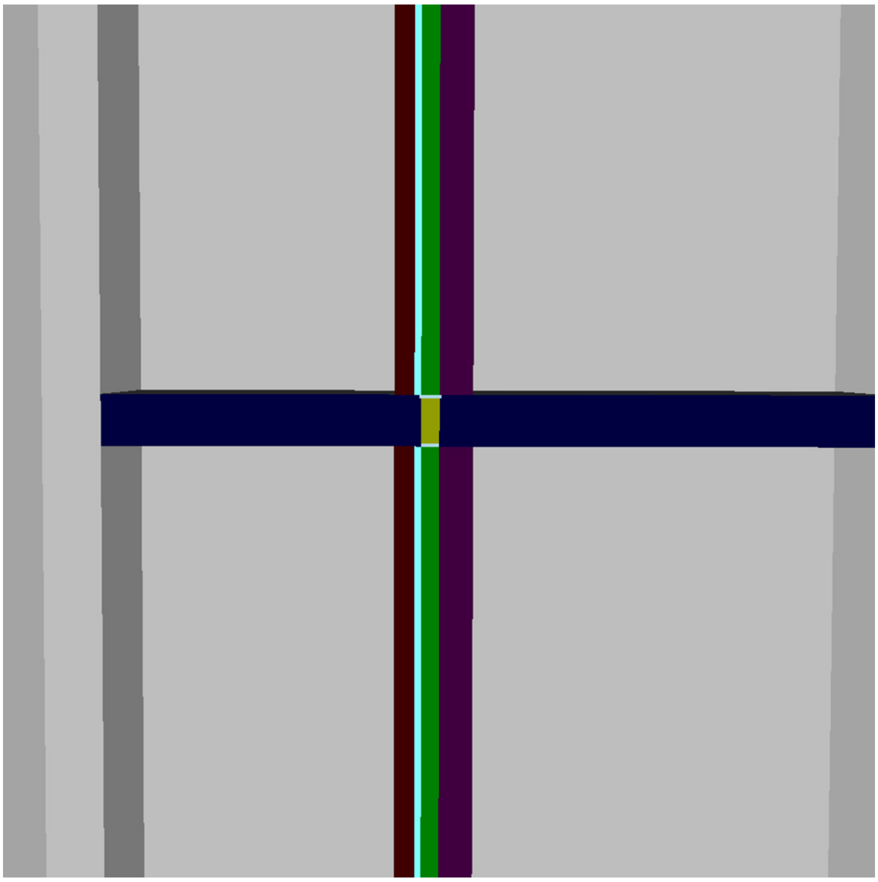
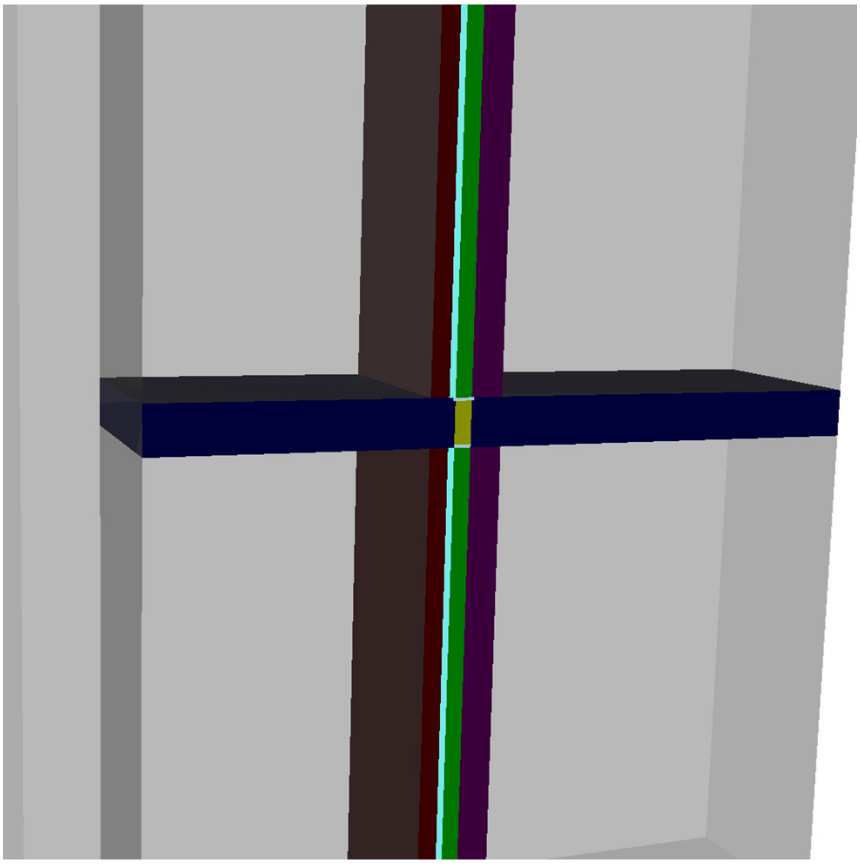
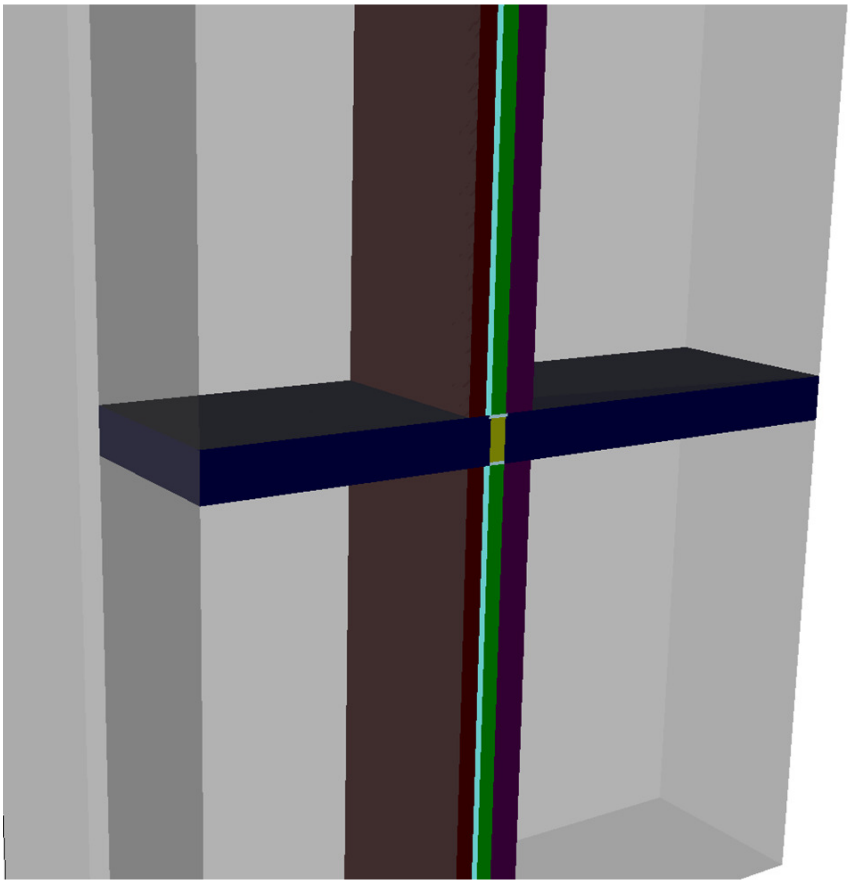
0.00
AnTherm V.6.108 2012.03.04 T.Kornicki www.kornicki.com


Temperatur
20.00
16.67
13.33
10.00
6.67
3.33
0.00
AnTherm V.6.108 2012.03.04 T.Kornicki www.kornicki.com







4. Conclusion

This special report verifies that all assumptions and is normally valid for building physics calculation. Furthermore the calculation has shown that all products and calculated Isokorb types fulfil the boundary conditions for being used as to improve the whole construction. According to the thermal requirements there are several possibilities especially with KXT (standard in Finland) and even the Isokorb use for slab height with 200mm meets the required thermal conditions. This report verifies also the material qualities and structural properties of Schöck Isokorb. Although Schöck knows that Isokorb is at the moment the best developed thermal break element with best thermal properties (up to 60 %) and quality properties, this report doesn't contain any comparisons to other thermal break elements.

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