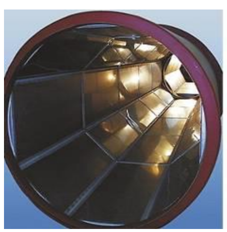
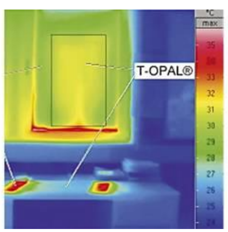
Handling of typical constructions

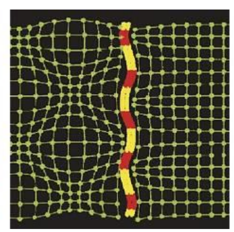
WUFI® Tutorial

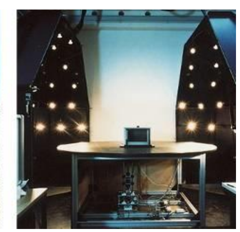
Version: November 2020

Auf Wissen bauen





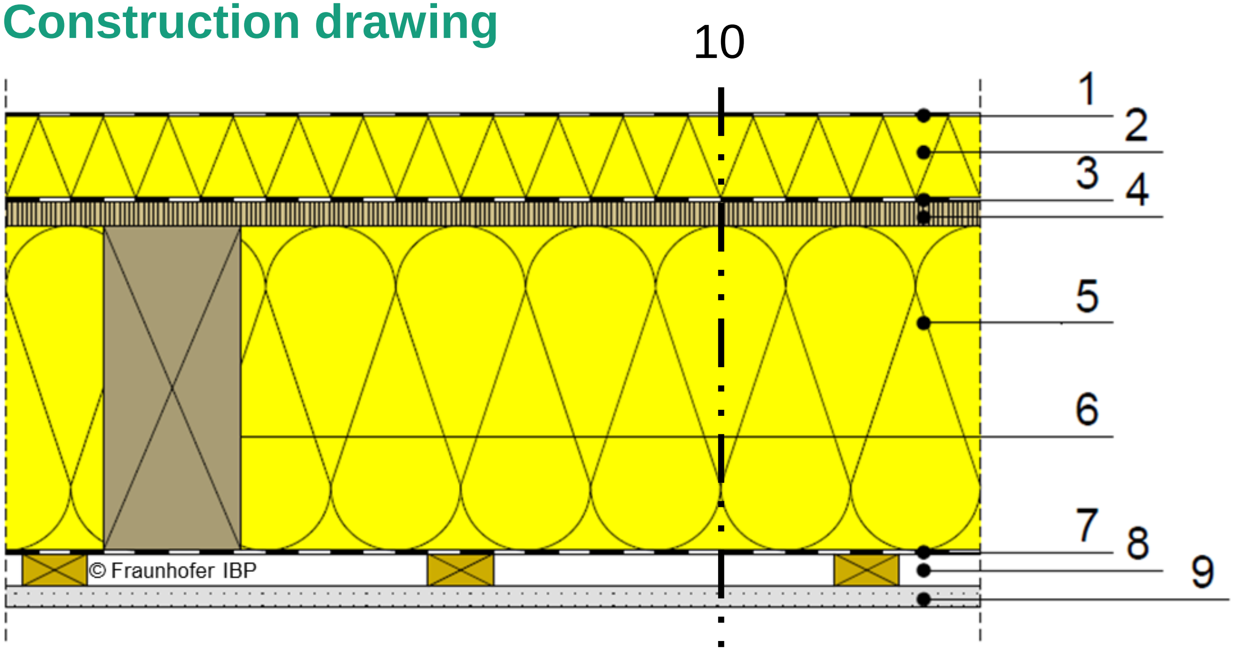



Fraunhofer IBP

Content

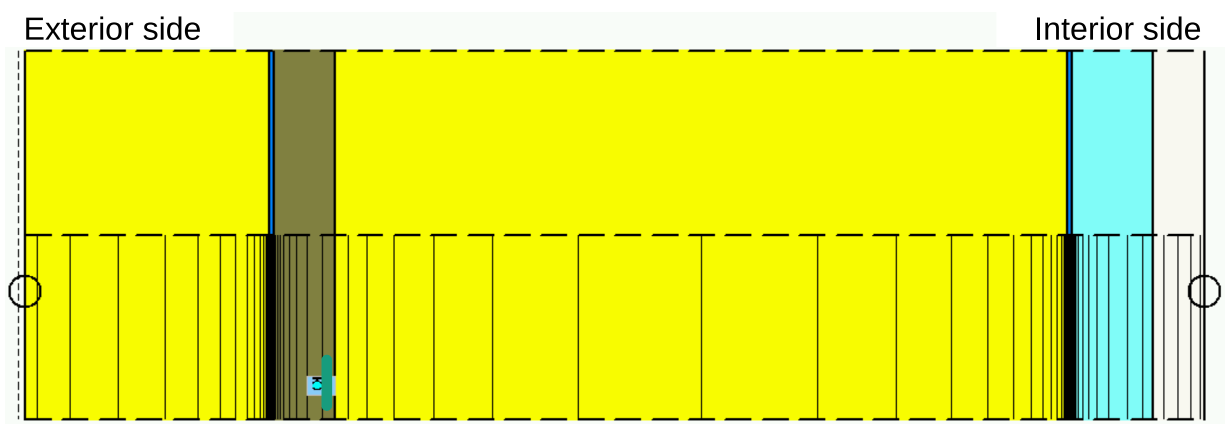
Flat roof

Construction drawing



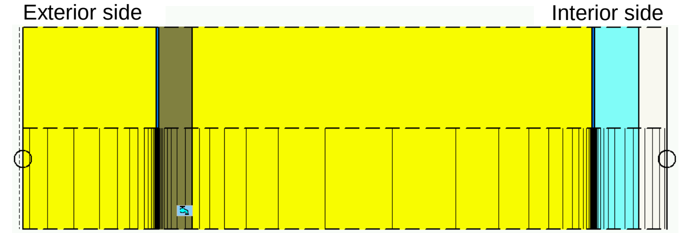
1 Roofing membrane
2 Exterior insulation
3 Vapor retarder
4 Wooden sheathing
5 Insulation
6 Rafter
7 Vapor retarder
8 Installation layer
9 Gypsum board
10 Simulated cross-section

Construction in WUFI



Flat roof

Please note



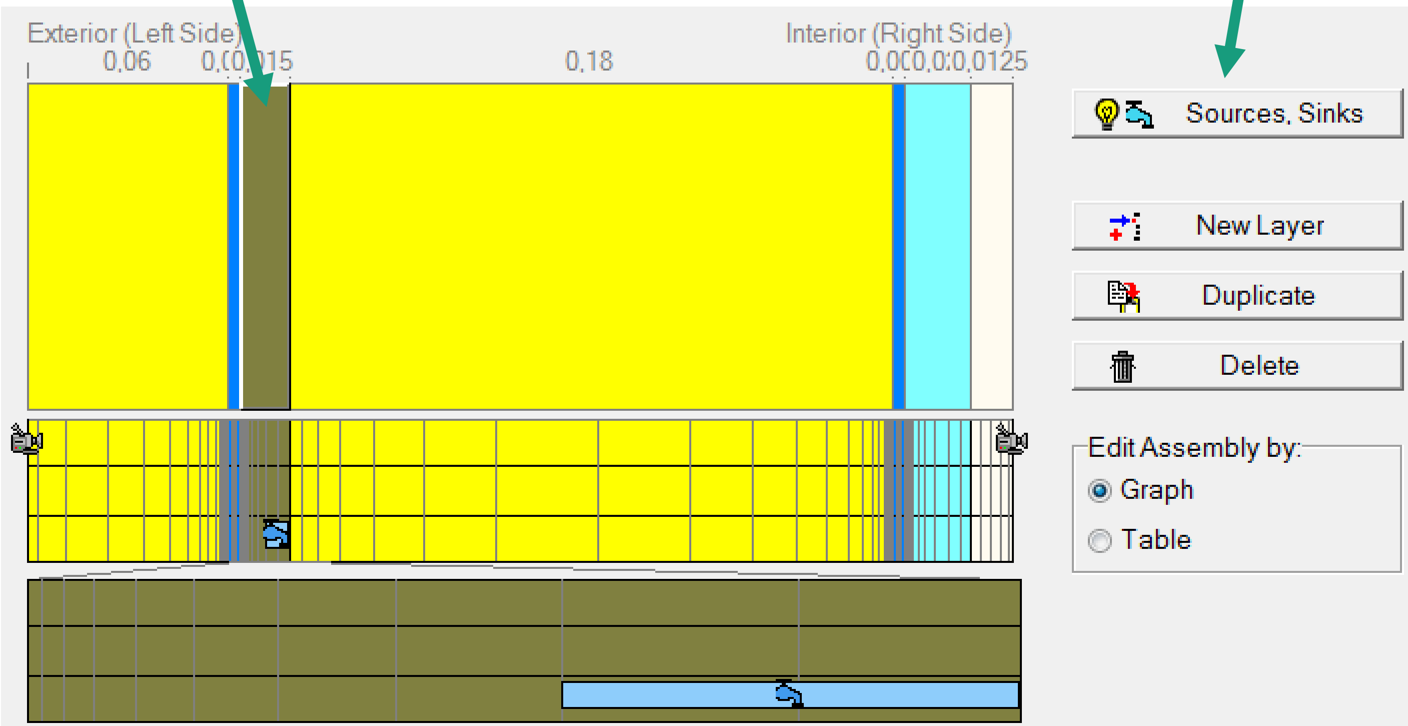
- Insert an air infiltration source at the cold side of the construction (at the position where condensation would occur) → source strength depending on the air tightness and height of the connected air column
- Orientation/ Inclination according to planning
- Heat transfer resistance „roof“
- Roofing membrane can be taken in account by using an s_d-value on the outer surface (numerical more favorable)
→ if doing so, use no roofing membrane in the construction setup
→ rain water absorption then has to be set to zero (“adhering fraction of rain”)
- Short wave radiation absorptivity depending on color of roof surface
- Long wave emissivity depending on the material of the surface
- Switch explicit radiation balance on

Flat roof

Moisture source setup

1. Select layer*

2. Select „Sources, Sinks“

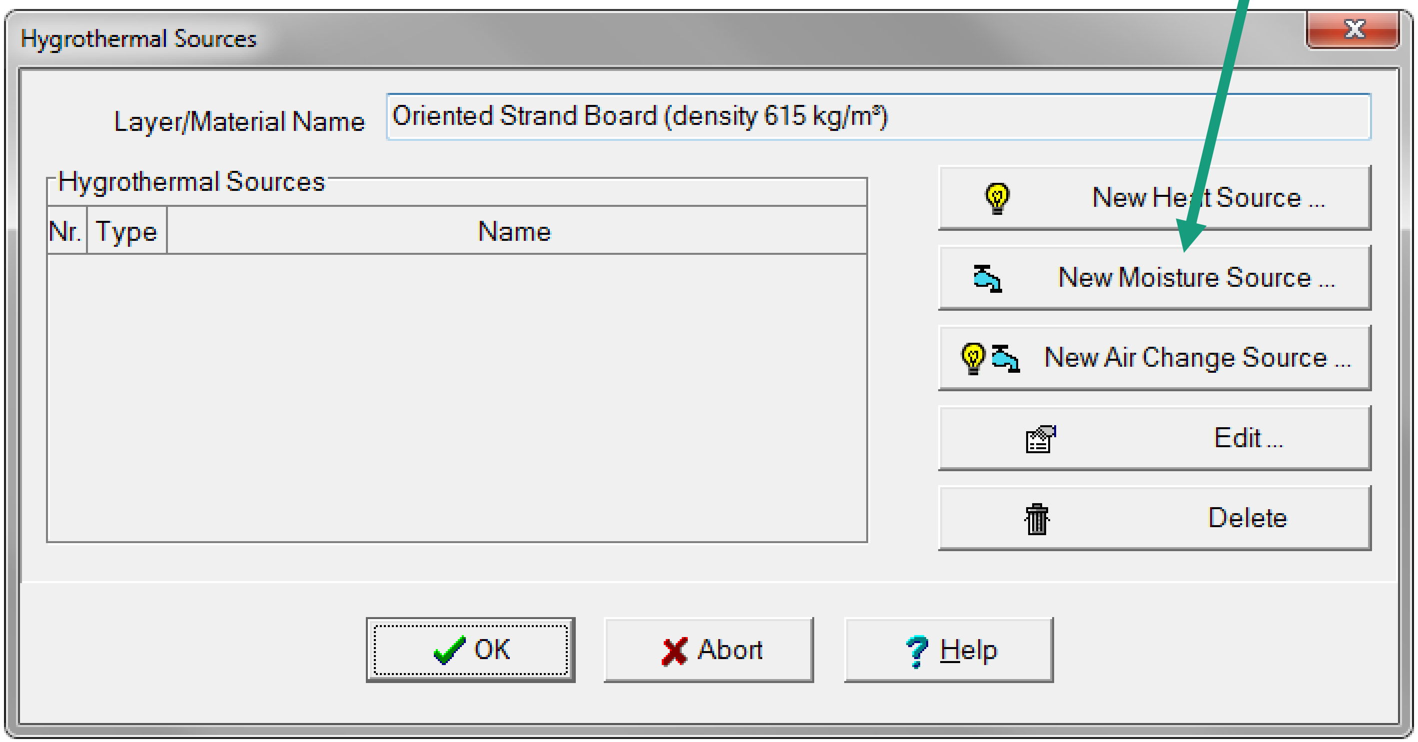


***) Material in which the condensate is expected due to convection which can not be simulated in a 1D program. The infiltration source is either in the inner 5 mm of the wooden sheathing or – if there is no sheathing – in the outer 5 mm of the insulation between the rafters.**

Flat roof

Moisture source setup

3. Select „New Moisture Source“

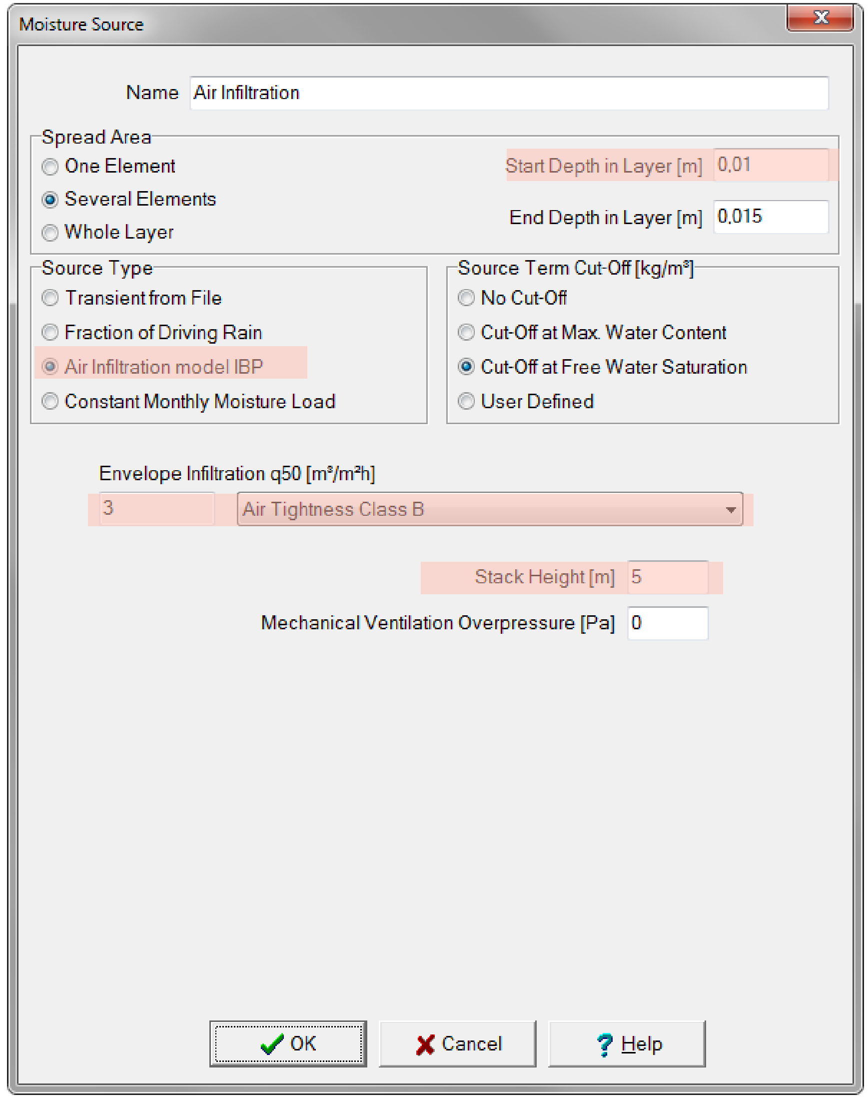


Fraunhofer IBP

Flat roof

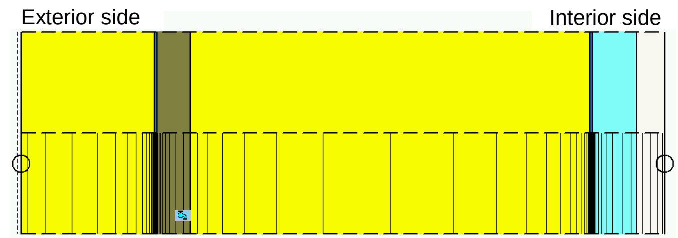
Moisture source setup

- Air Infiltration Model



Flat roof

Result analysis*



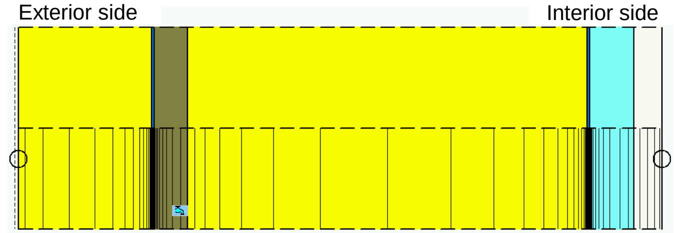
- Check total water content (accumulation of moisture in whole construction); must not keep increasing
- Check water content in wooden sheathing
- In a construction without wood-based or moisture sensitive materials: Examination of amount of dew water (max. 500 g/m² / 200 g/m² according to DIN 4108 / EN ISO 13788 which equals max. 50 kg/m³ / 20 kg/m³ in outer centimeter of insulation)

  Further check influence of moisture content on the thermal conductivity in the material data table „thermal conductivity, moisture-dependent"
- You may check moisture accumulation in the exterior insulation

*) Note: List not necessarily complete. Depending on boundary conditions additional critical positions may occur → Check in film display

Flat roof

Additional information



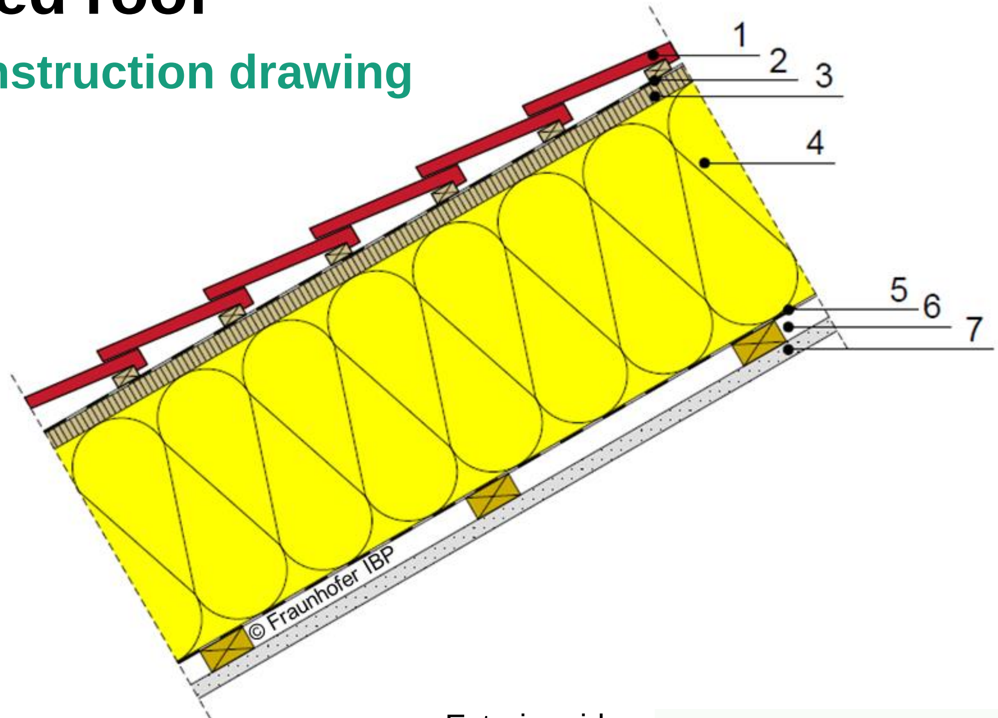
- Be careful with bright roofing membranes,
the drying potential of the construction is greatly reduced
- Shading / green roof can be treated by using more elaborate models (more information in the paper Verschattung von Holzflachdächern (only German) and in Guideline for the calculation of extensive green roofs)
- In case of modeling the roofing membrane as s_d-value on the exterior surface, this only models the vapor-retarding property of the membrane, not its rain-tightness → don't forget to switch off rain!
- Considering an insulated roof with rafters, usually the cross section through the insulation is relevant
- Metal roof: Metal layer is taken into account as sd-value at the exterior surface, absorptivity and emissivity according to material
- unsealed seams: effective sd-value around 25 m – 75 m
- sealed seams: effective sd-value > 300 m

Content

Fraunhofer IBP

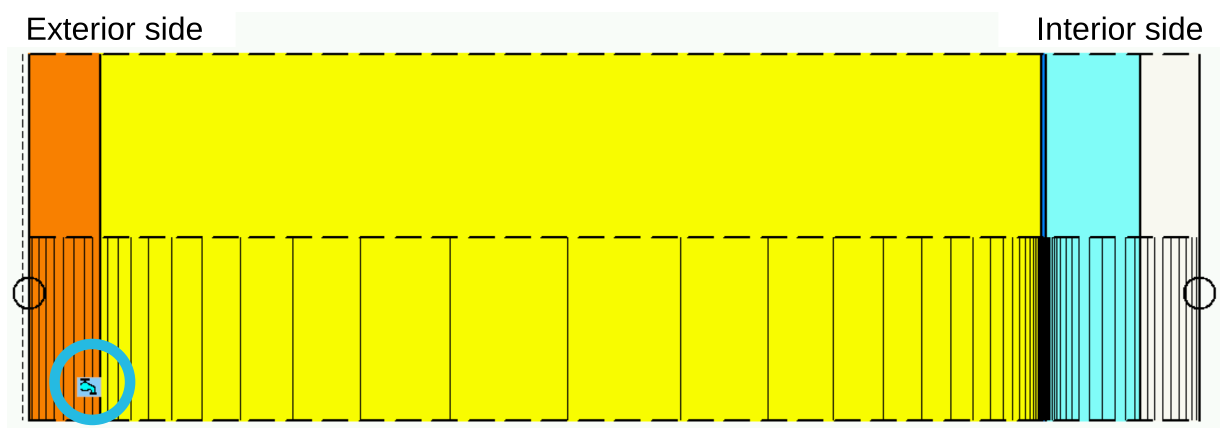
Pitched roof

Construction drawing



1 Roofing tiles and battens
2 Weather-protecting membrane
3 Wooden sheathing
4 Insulation
5 Vapor retarder
6 Installation layer
7 Gypsum board

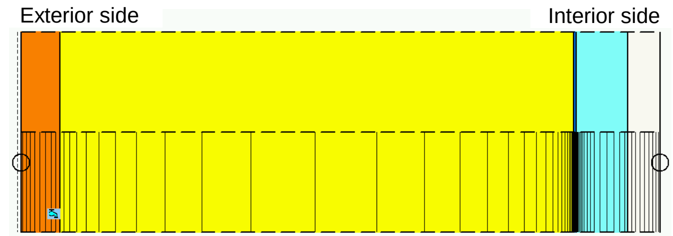
Construction in WUFI



Fraunhofer IBP

Pitched roof

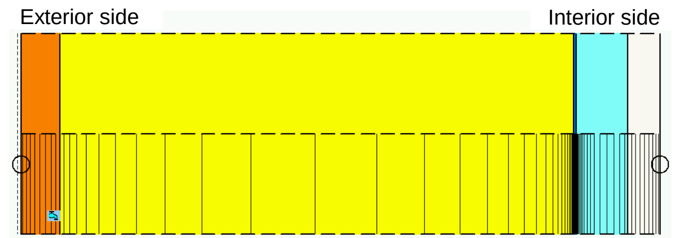
Please note



- Insert an air infiltration source at the cold side of the construction (at the position where condensation would occur) $\rightarrow$ source strength depending on the air tightness and height of the connected air column
- Relevant orientation: usually north
- Ventilated roofing is omitted for the calculation
$\rightarrow$ rain water absorption has to be set to zero (“adhering fraction of rain”)
- Weather-protection layer can be taken into account by using an s_d-value on the outer surface (selectable in the surface transfer coefficient dialog, numerical more favorable)
$\rightarrow$ if doing so use no roofing membrane in the construction setup

Pitched roof

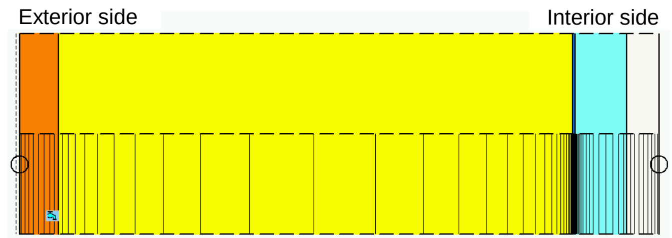
Please note



- Heat transfer coefficients according to table on slide 14 from "Hygrothermal Simulation of ventilated pitched roofs", value for the long-wave radiation parts is 0 W/m²K.
- Short-wave radiation absorptivity depending on color of roofing tiles, if applicable reduction according to table on slide 14
- Long-wave radiation emissivity depending on the material of roofing tiles
- Switch on explicit radiation balance

Pitched roof

Please note



	Eaves Position (coldest)	Middle Position	Ridge Position (warmest)
Strong ventilation	$a_{k,e}$ = 30 [W/m²K]		
	$a_e = a \cdot 0.7$	$a_e = a \cdot 0.9$	$a_e = a$
Normal ventilation	$a_{k,e}$ = 19 [W/m²K]		
	$a_e = a \cdot 0.7$	$a_e = a \cdot 0.9$	$a_e = a$
Low ventilation	$a_{k,e}$ = 13.5 [W/m²K]		
	$a_e = a \cdot 0.75$	$a_e = a \cdot 0.9$	$a_e = a$

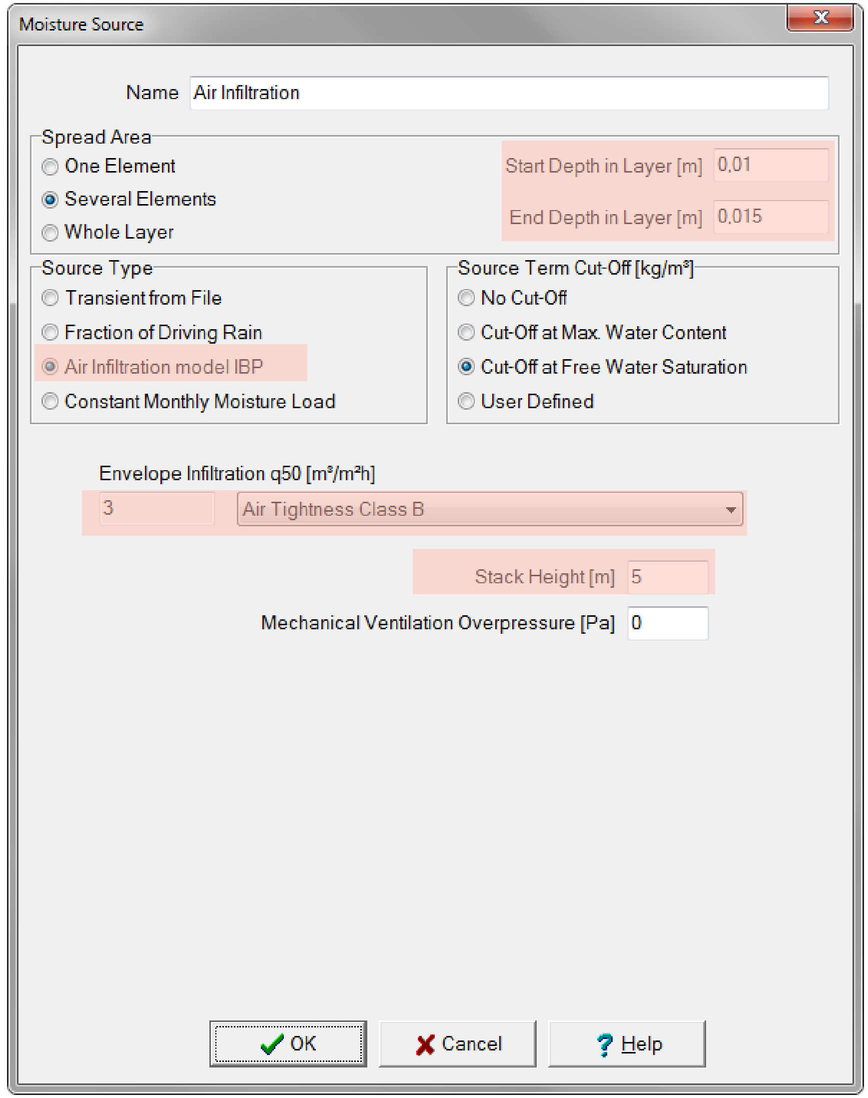
with $a_{k,e}$: convective heat transfer coefficient and a_e: effective short-wave coefficient of absorption

Strongly ventilated	Eaves open without any grid etc.	Ridge open with a low flow resistance	
Normal ventilated	Eaves openings with insect protection grid or eave comb	Ridge closed with ridge / arris role	
Low ventilated	Small openings at the eaves	Small openings at the ridge	No counter battens

Pitched roof

Moisture source setup

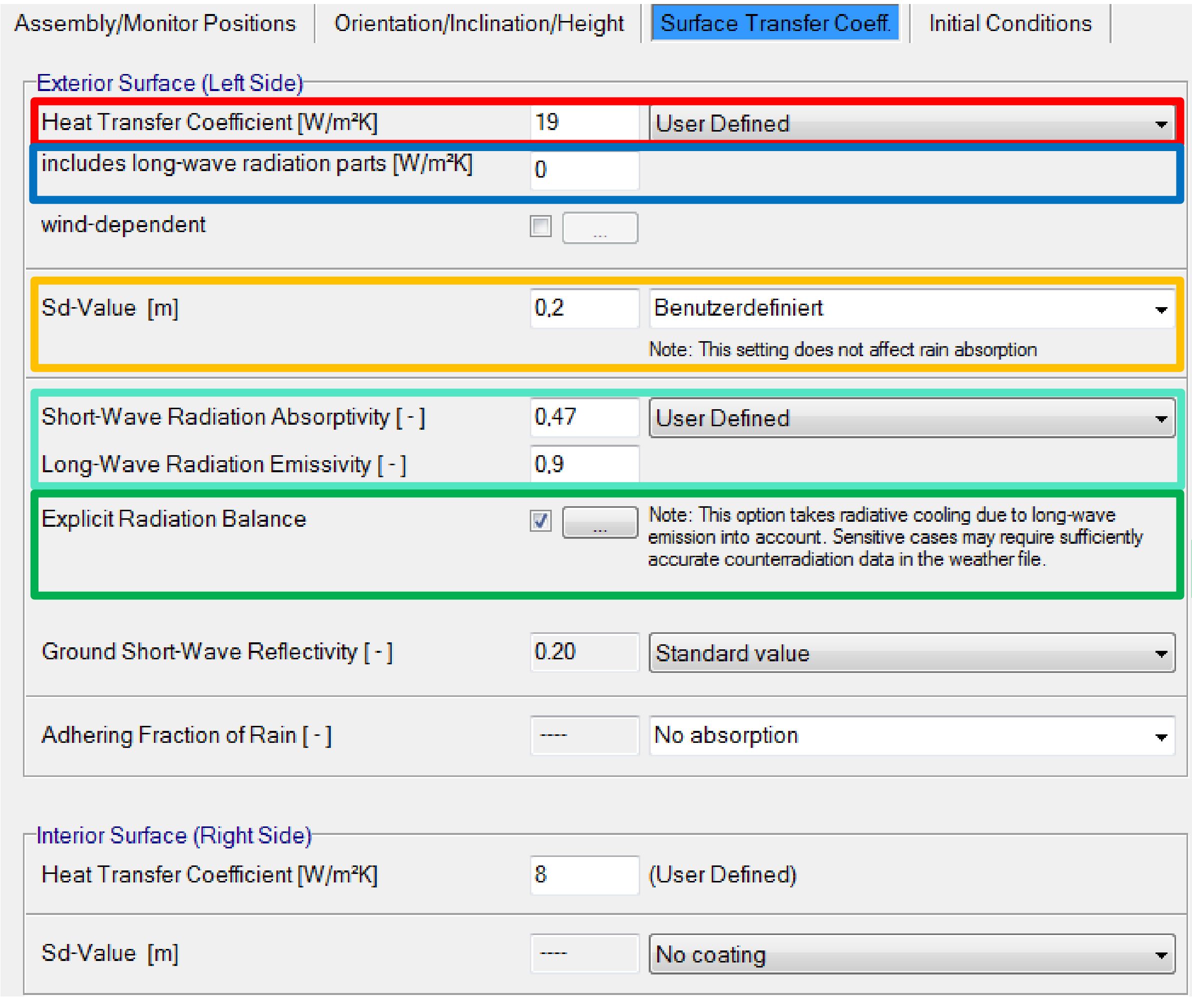
- Air Infiltration Model



For procedure see „flat roof“

Pitched roof

Surface Transfer setup



Heat transfer coefficient „User Defined“
here: 19 W/m²K for normal ventilation

Long-wave radiation parts: 0 W/m²K

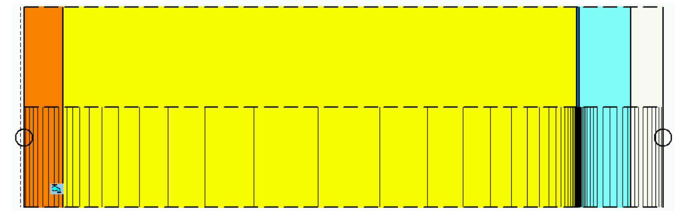
s_d-value of the weather-protection layer
here: s_d = 20 cm

Color of roofing tiles
here: red tiles (a = 0,67)
Eaves position ($a_e = a \cdot 0.7 = 0.47$)

Switch on explicit radiation balance

Pitched roof

Result analysis*



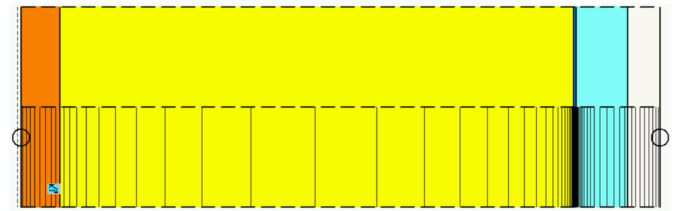
- Check total water content (accumulation of moisture in whole construction); must not keep increasing
- Check water content in wooden sheathing
- In a construction without wood-based or moisture sensitive materials: Examination of amount of dew water (max. 500 g/m² / 200 g/m² according to DIN 4108 / EN ISO 13788 which equals max. 50 kg/m³ / 20 kg/m³ in outer centimeter of insulation)

  Further check influence of moisture content on the thermal conductivity in the material data table „thermal conductivity, moisture-dependent“

*) Note: List not necessarily complete. Depending on boundary conditions additional critical positions may occur → Check in film display

Pitched roof

Additional information

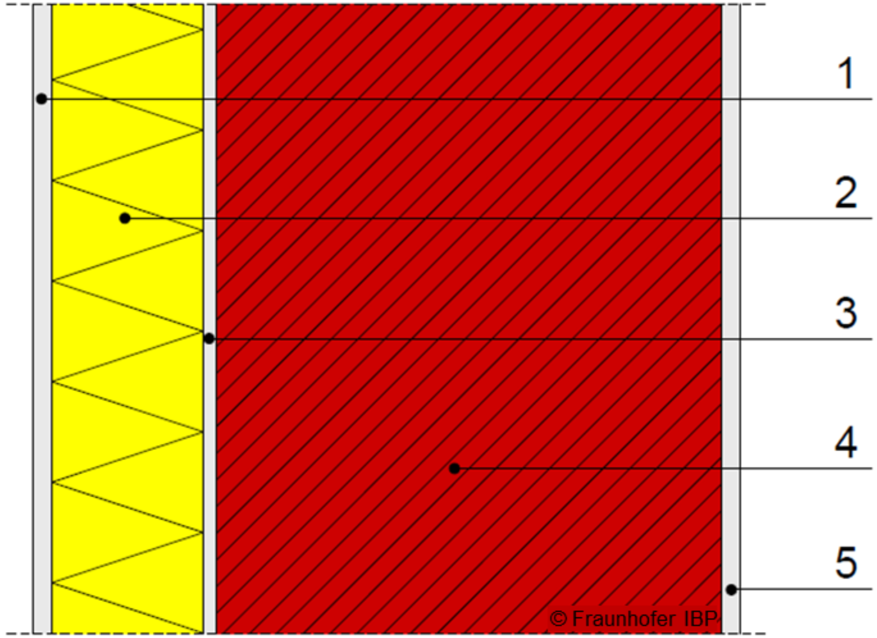


- Heat transfer coefficient according to the latest research results by Kölsch (Hygrothermal Simulation of ventilated pitched roofs)
- In case of modeling the roofing membrane as s_d-value on the exterior surface, this only models the vapor-retarding property of the membrane, not its rain-tightness → don't forget to switch off rain!
- Metal roof: Metal layer is taken into account as s_d-value at the exterior surface, absorptivity and emissivity according to material
  - unsealed seams: effective s_d-value around 25 m – 75 m
  - sealed seams: effective s_d-value > 300 m

Content

Exterior wall with ETICS

Construction drawing



1 Exterior plaster
2 Insulation
3 Plaster
4 Masonry / concrete
5 Interior plaster

Construction in WUFI

Fraunhofer IBP

Exterior wall with ETICS

Please note

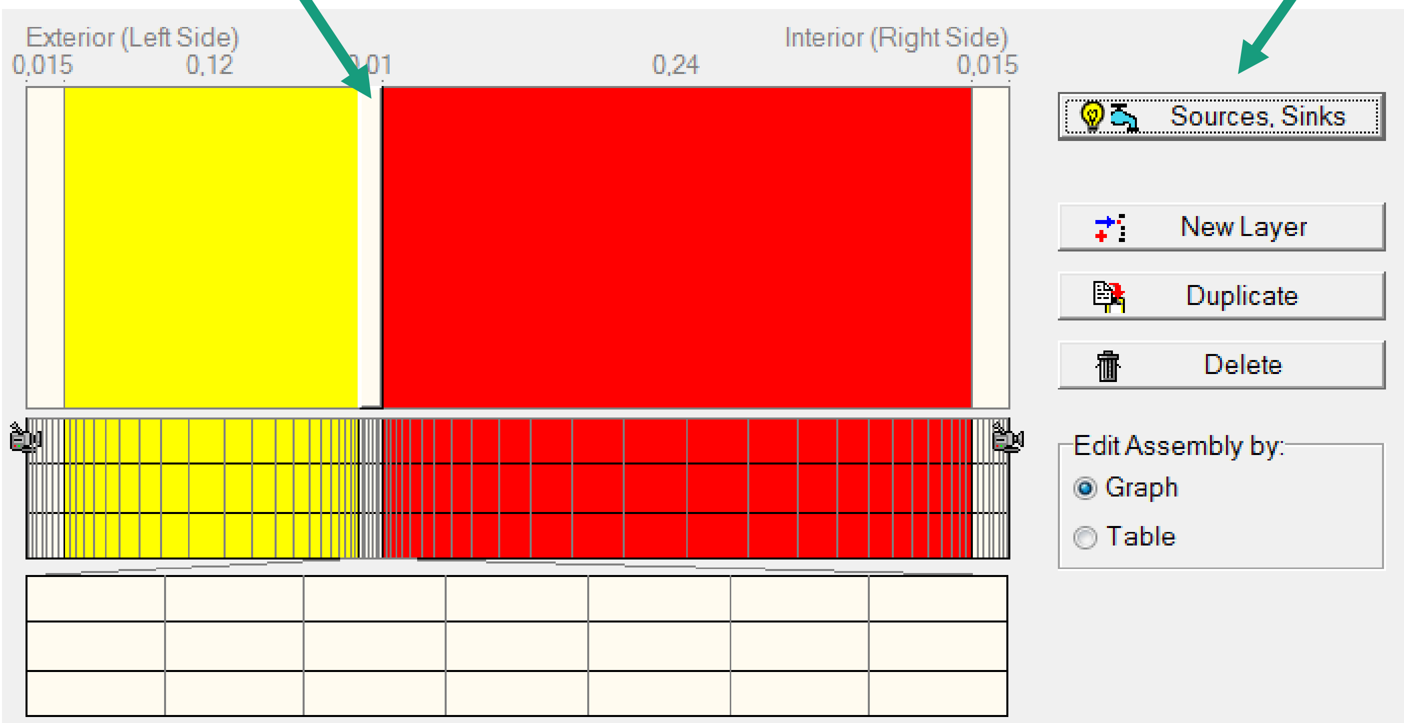
- Moisture source behind ETICS: 1 % of driving rain
- Relevant orientations: Prevailing direction of driving rain and north
- Short wave radiation absorptivity depending on color of exterior plaster
- Long wave radiation emissivity for plaster (if not known: 0.9)
- If the short-term hygrothermal behavior of the outer surface is to be evaluated (e.g. dew position), turn on explicit radiation balance
- “Adhering Fraction of Rain” according to inclination and construction type (vertical wall: 0.7)

Exterior wall with ETICS

Moisture source setup

1. Select layer*

2. Select „Sources, Sinks“

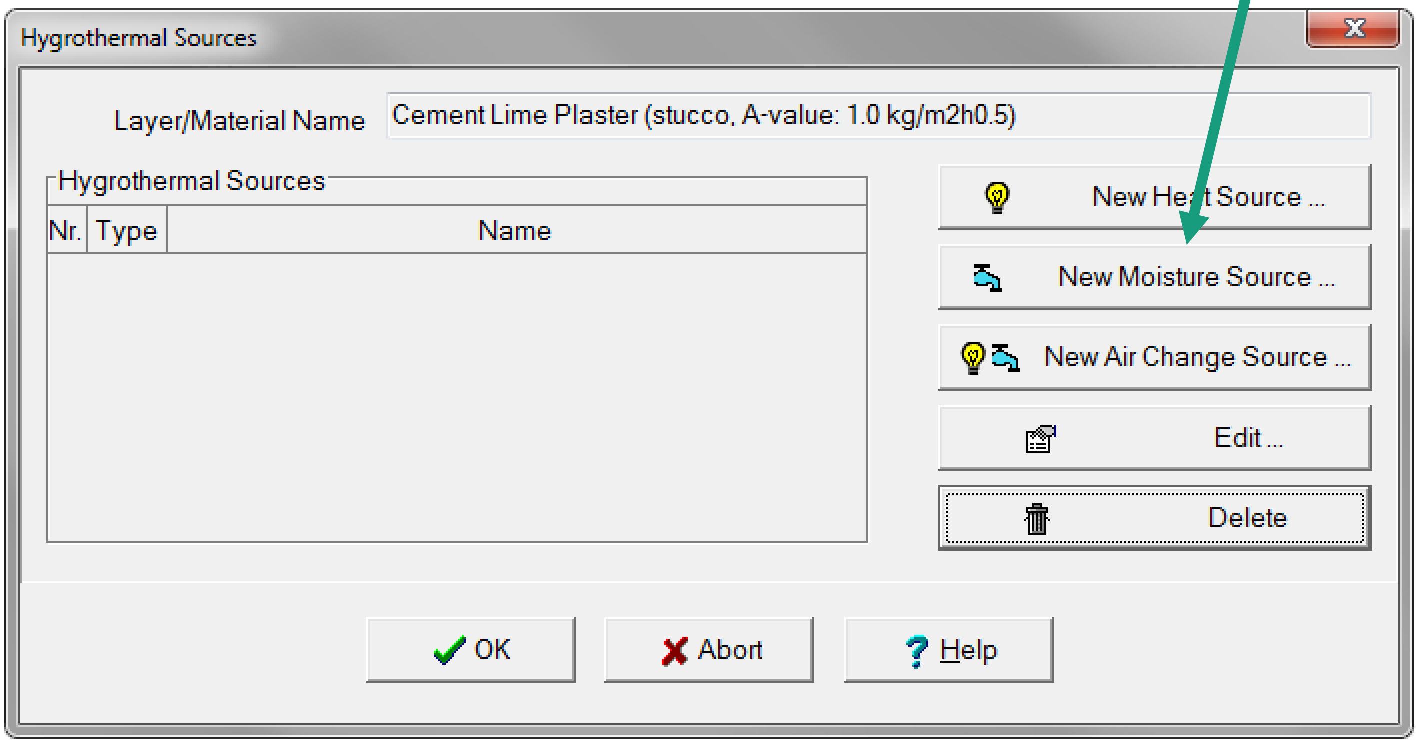


*) Driving Rain source is inserted in the outer 5 mm of the layer behind the insulation.

Exterior wall with ETICS

Moisture source setup

3. Select „New Moisture Source“

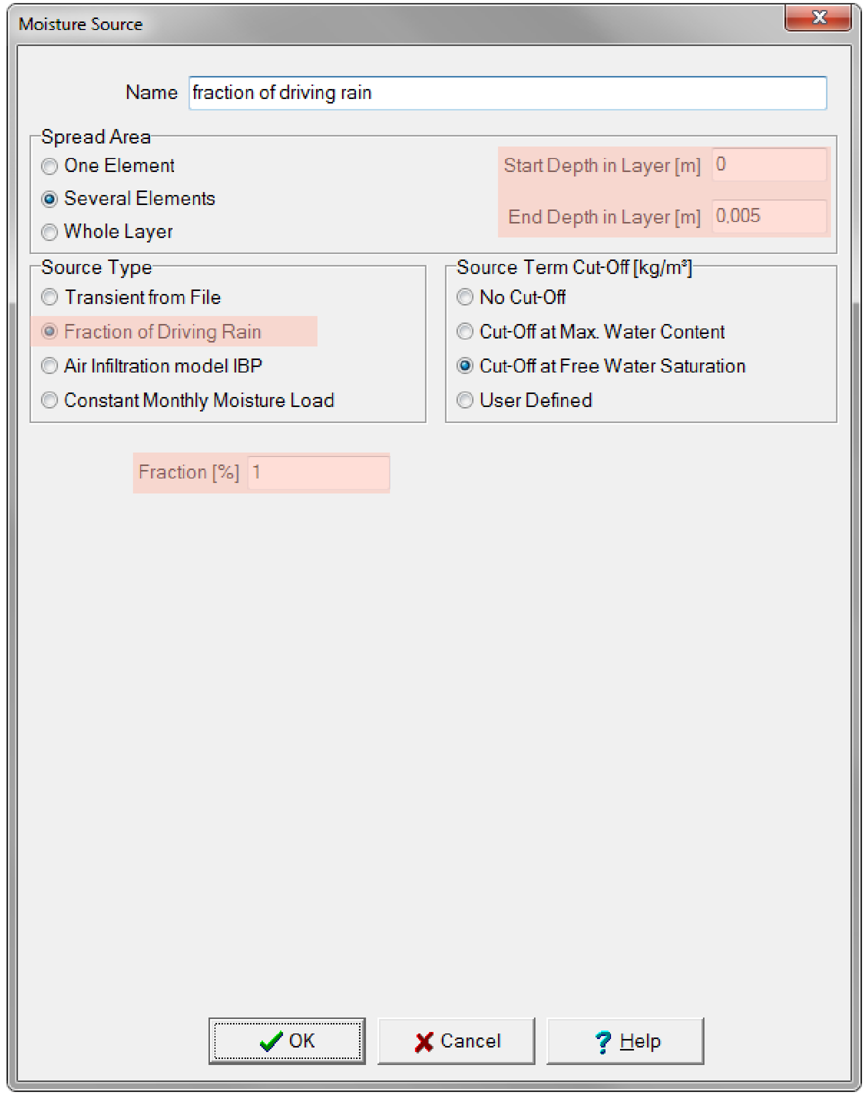


Fraunhofer IBP

Exterior wall with ETICS

Moisture source setup

- Fraction of driving rain



Exterior wall with ETICS

Result analysis*

- Check total water content (accumulation of moisture in whole construction); must not keep increasing
- Check water content in the insulation
  → Possible reduction of insulating capability
- Relative humidity at the interface between exterior plaster and insulation during winter time → risk of frost damage
- At warm and humid sites check relative humidity between insulation and wall (dew water and failure of adhesive may occur)

*) Note: List not necessarily complete. Depending on boundary condtions more critical positions may occur => Check in film display

Exterior wall with ETICS

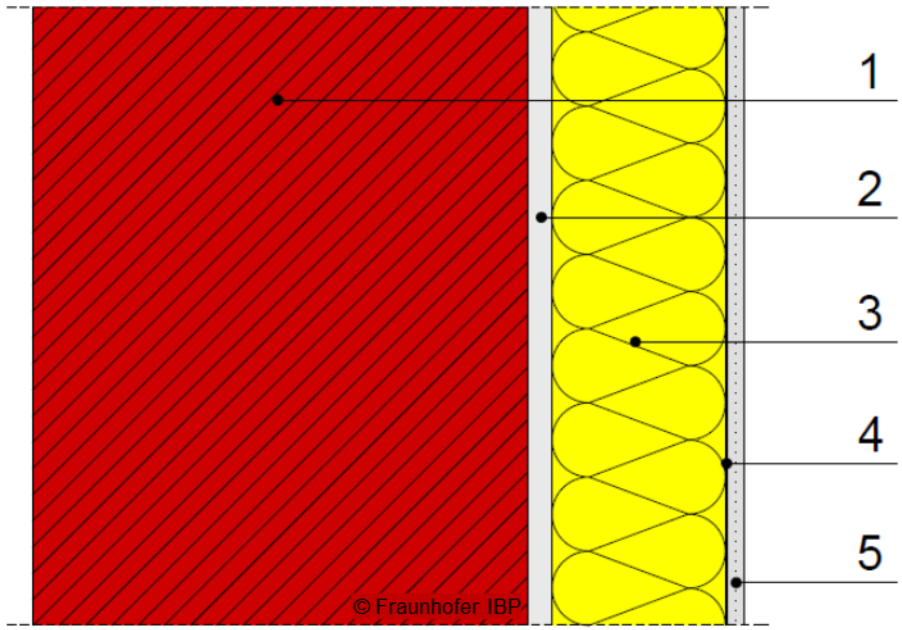
Additional information

- The prevailing direction of driving rain can be found by using the Climate Analysis dialog (usually west in Middle Europe)
- The moisture source of 1% of the driving rain behind the ETICS is regulated in the ASHRAE Standard 160 and represents critical positions e.g. in the area of window frames

Content

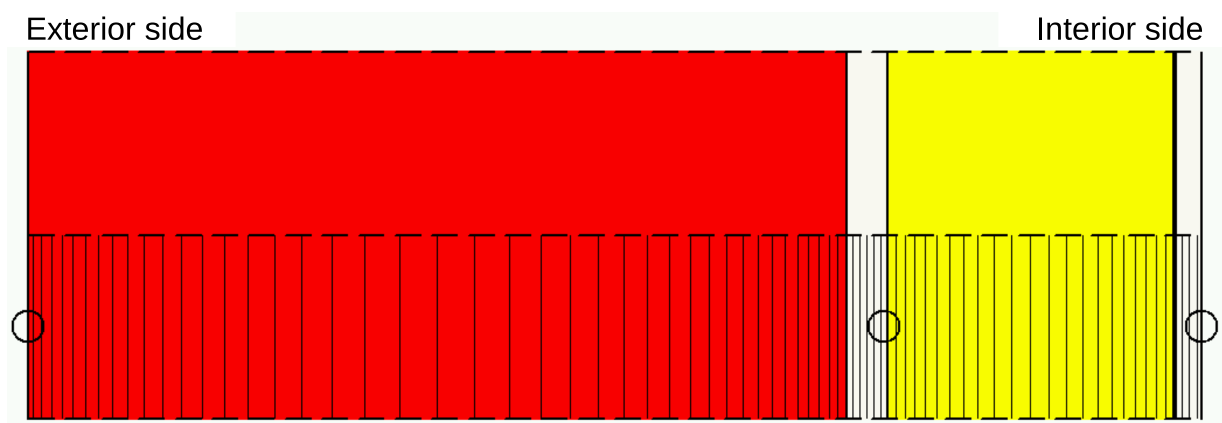
Exterior wall with interior insulation

Construction drawing

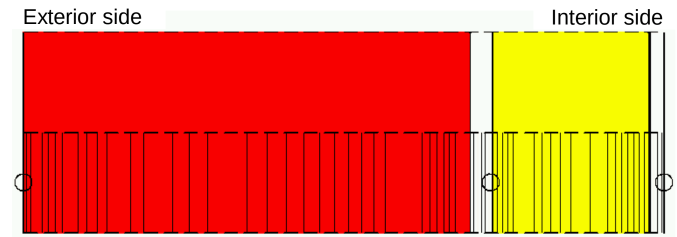


1 Facing brickwork
2 Interior plaster or adhesive
3 Interior insulation
4 Vapor retarder
5 Gypsum board

Construction in WUFI



Exterior wall with interior insulation



Please note

- Relevant orientations: Prevailing direction of driving rain and north
- Short-wave radiation absorptivity depending on color of exterior surface
- Long-wave radiation emissivity for exterior surface (if not known: 0.9)
- Explicit radiation balance usually not necessary
- “Adhering fraction of rain” according to inclination and construction type (vertical wall: 0.7)
- If needed: Water-repellent treatment of the exterior surface to reduce rain water absorption

Exterior wall with interior insulation

Water-repellent treatment of façades

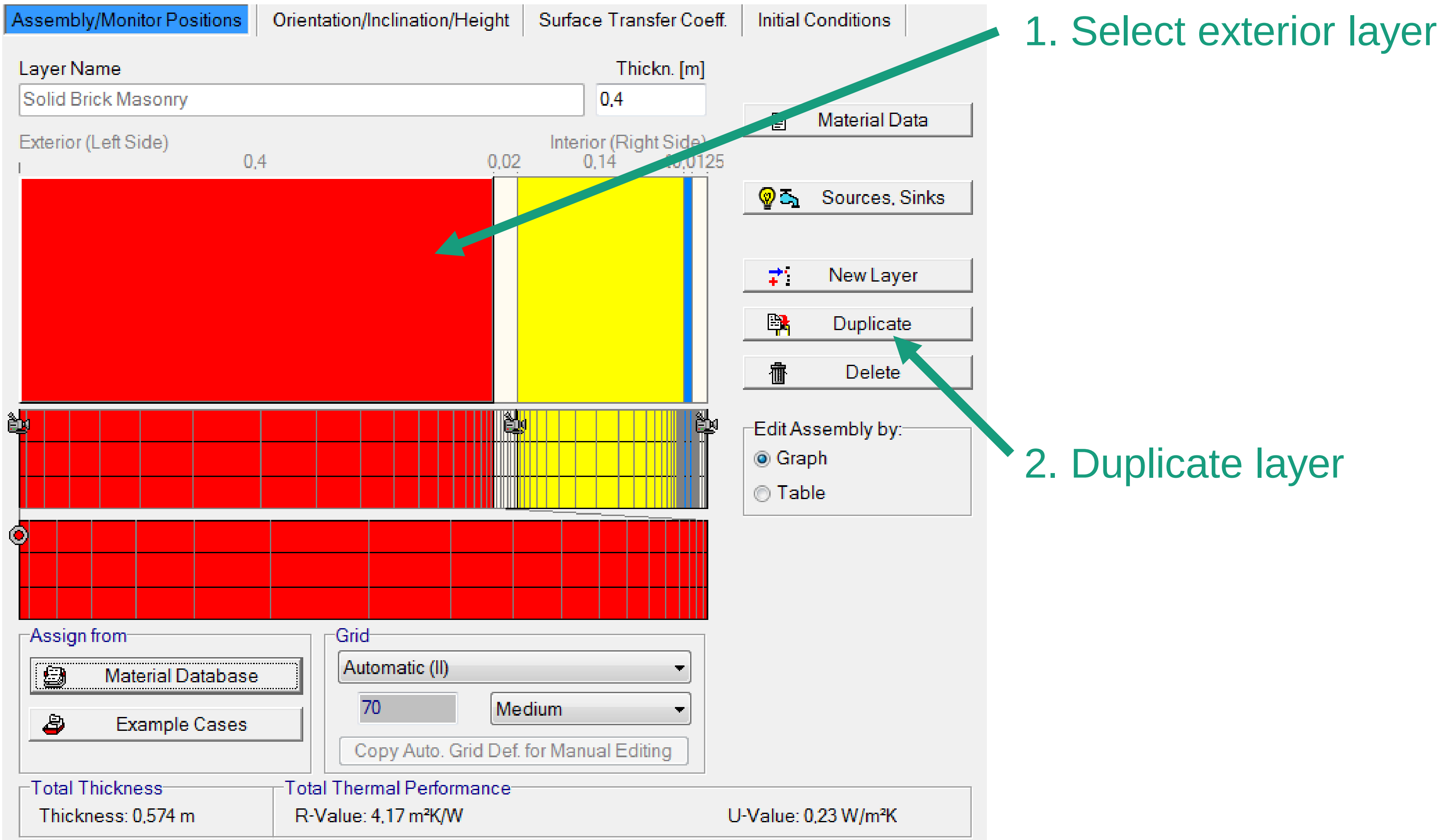
Modification of the A-value without influencing other material properties (e.g. s_d-value)

Step by step:

1) Split the exterior layer into a surface layer (0.5 – 1.0 cm depending on penetration depth of treatment) and the remaining layer. To do this, duplicate the original layer and then adjust the two thicknesses as needed.
2) Edit the material properties of the new exterior layer:
   - Unlock the material
   - For materials with a default moisture storage function:
switch “Moisture Storage Function” to “Approximate”
   - Switch “Liquid Transport Coefficients” for suction and redistribution to “generate”
   - Adjust “Water absorption coefficient”
Be careful with the units: [kg/m²√s] is the A-value in [kg/m²√h] divided by 60 !!!

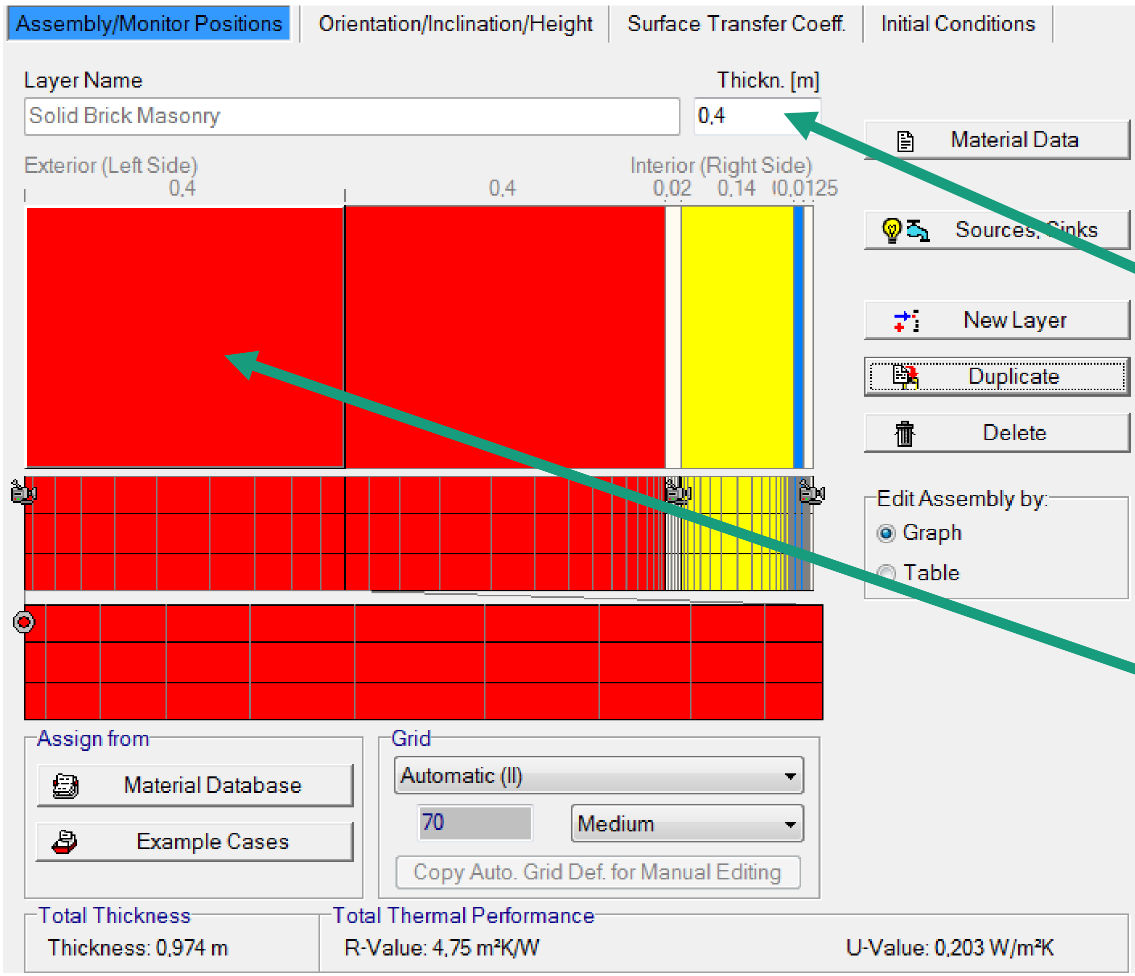
Exterior wall with interior insulation

Water-repellent treatment of façades



Exterior wall with interior insulation

Water-repellent treatment of façades

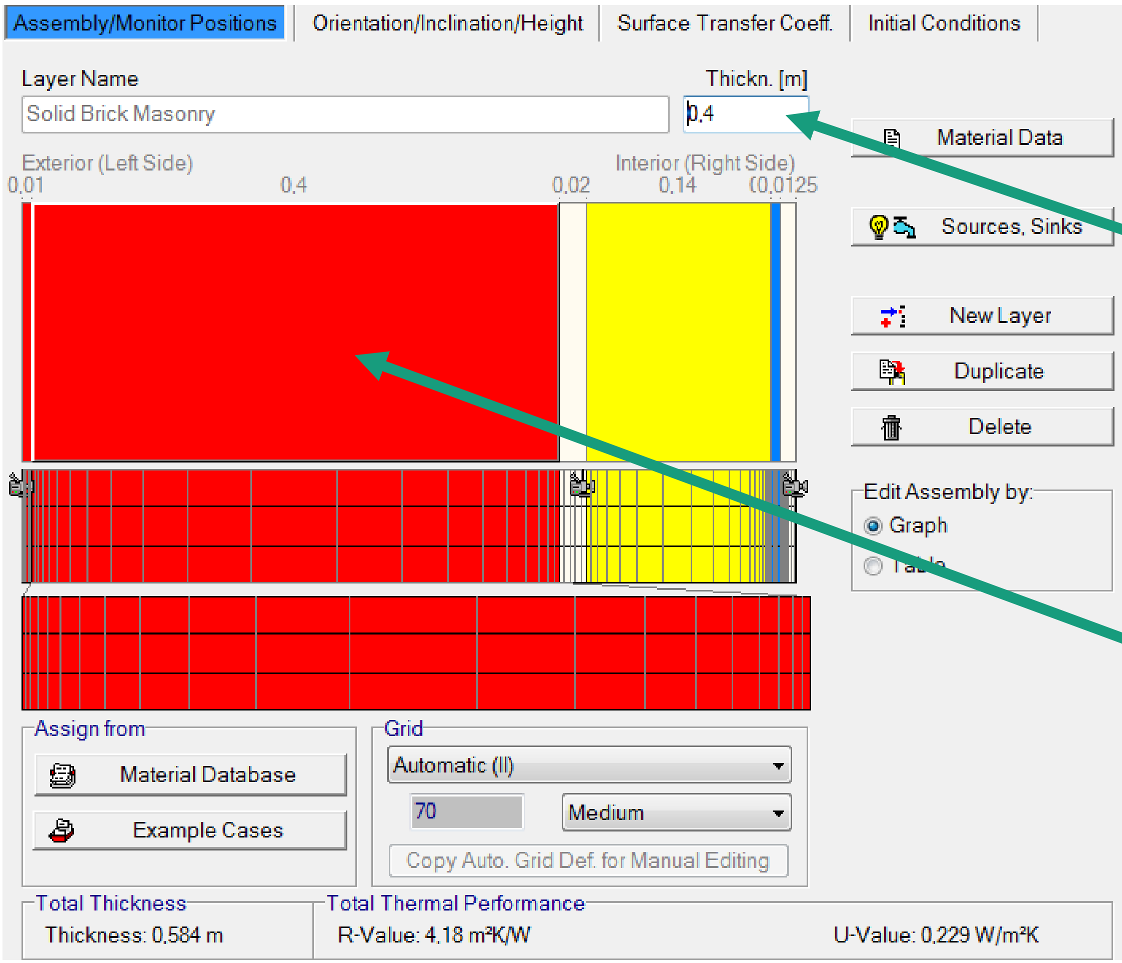


4. Reduce thickness e.g. 0.01 m

3. Select exterior layer

Exterior wall with interior insulation

Water-repellent treatment of façades

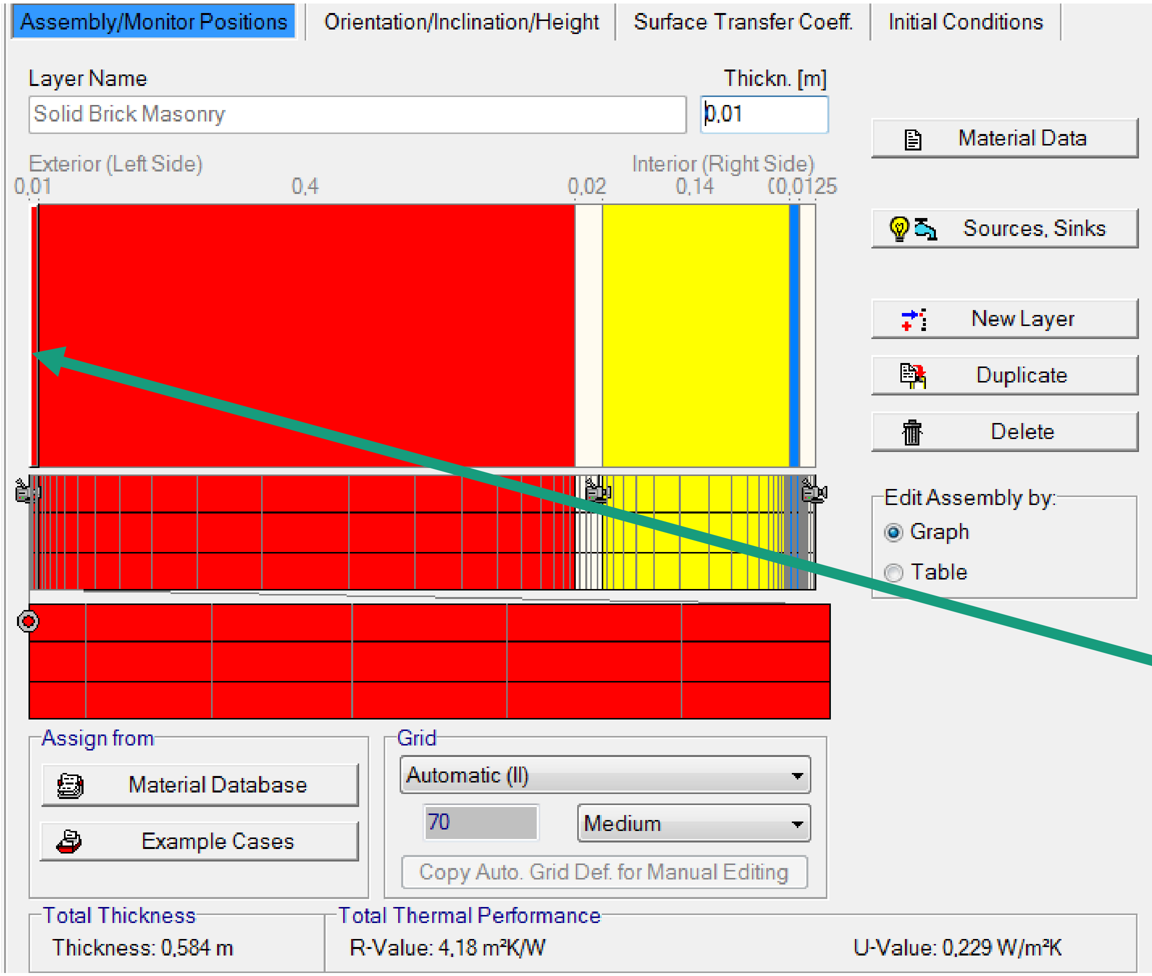


6. Change thickness e.g. original thickness minus 1 cm

5. Select layer

Exterior wall with interior insulation

Water-repellent treatment of façades



7. Double click on layer (or click „Material data“)

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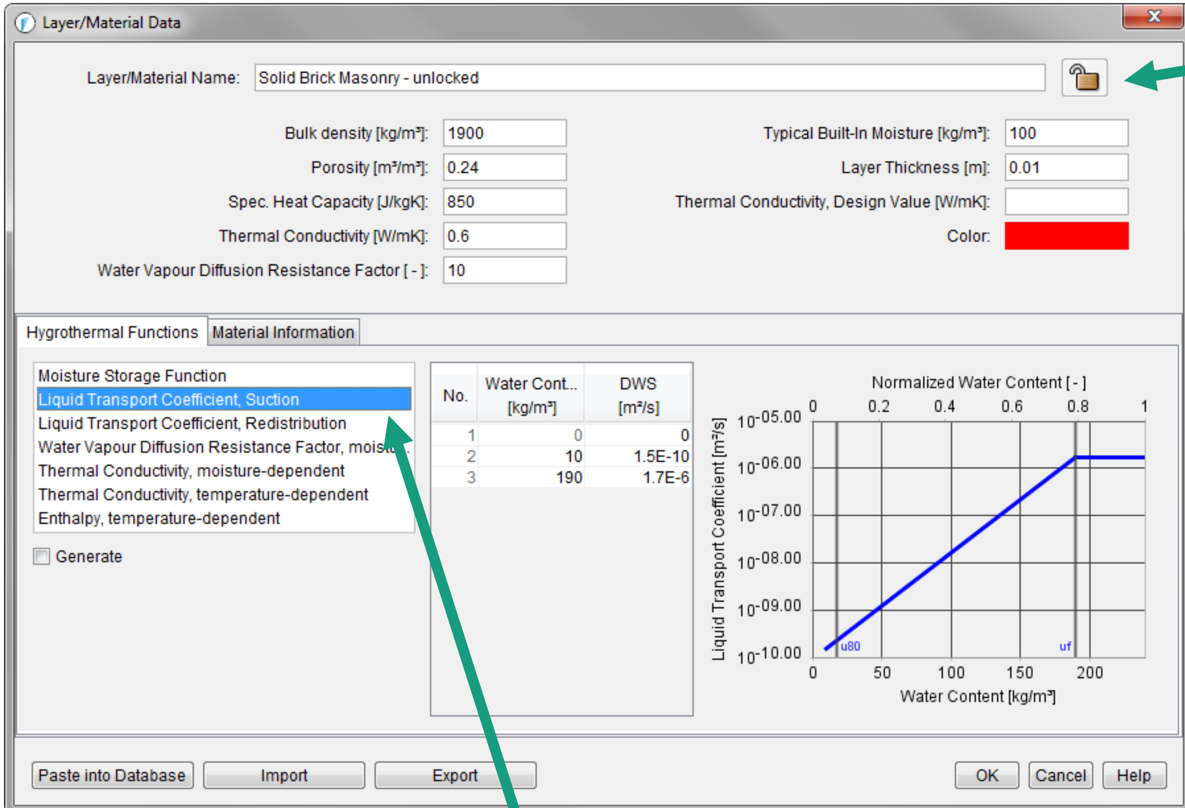
Exterior wall with interior insulation

Water-repellent treatment of façades

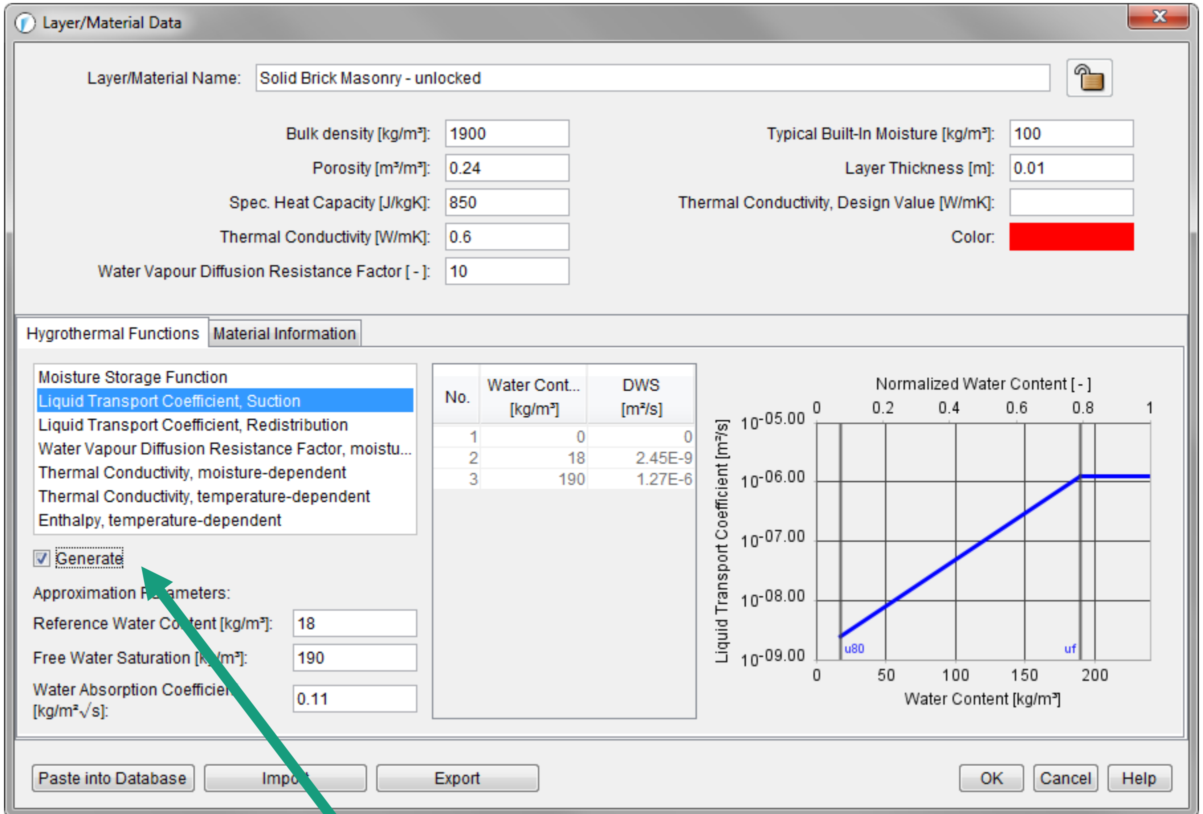


8. Unlock material

9. Select „Liquid Transport Coefficient, Suction“

Exterior wall with interior insulation

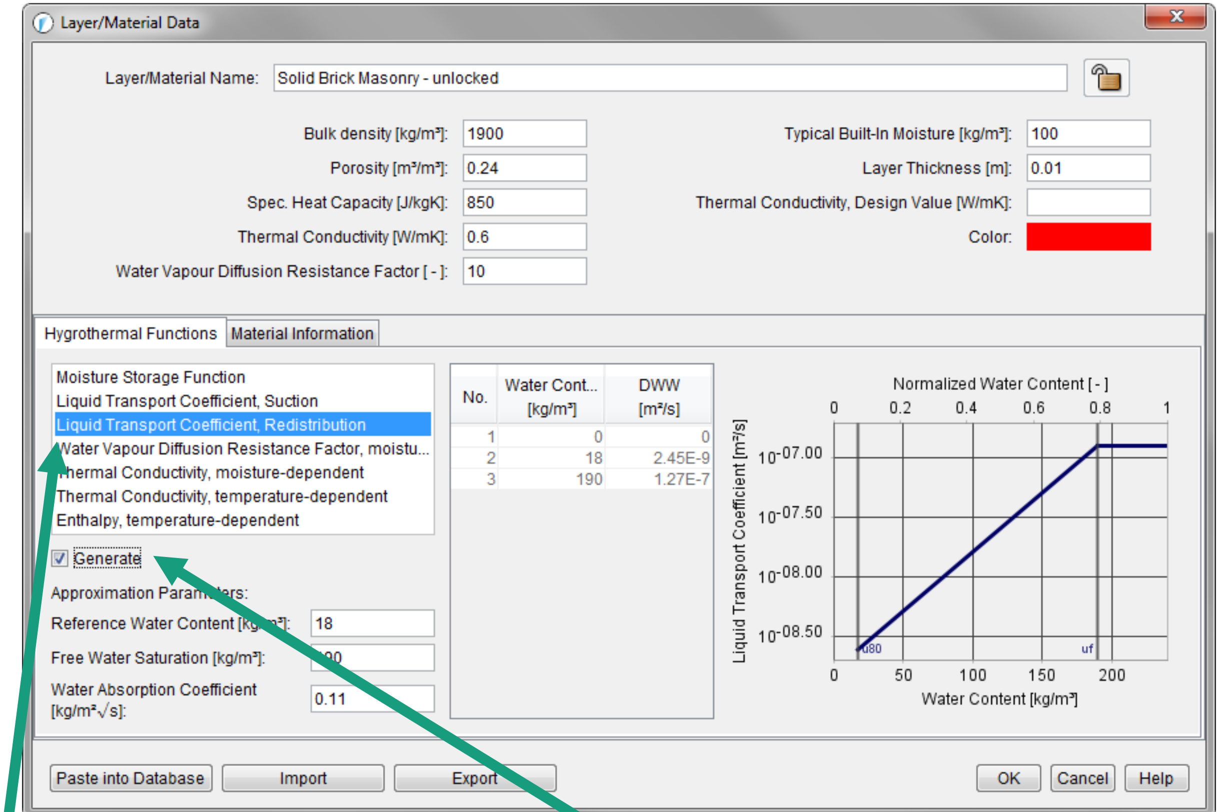
Water-repellent treatment of façades



10. Check „Generate“

Exterior wall with interior insulation

Water-repellent treatment of façades

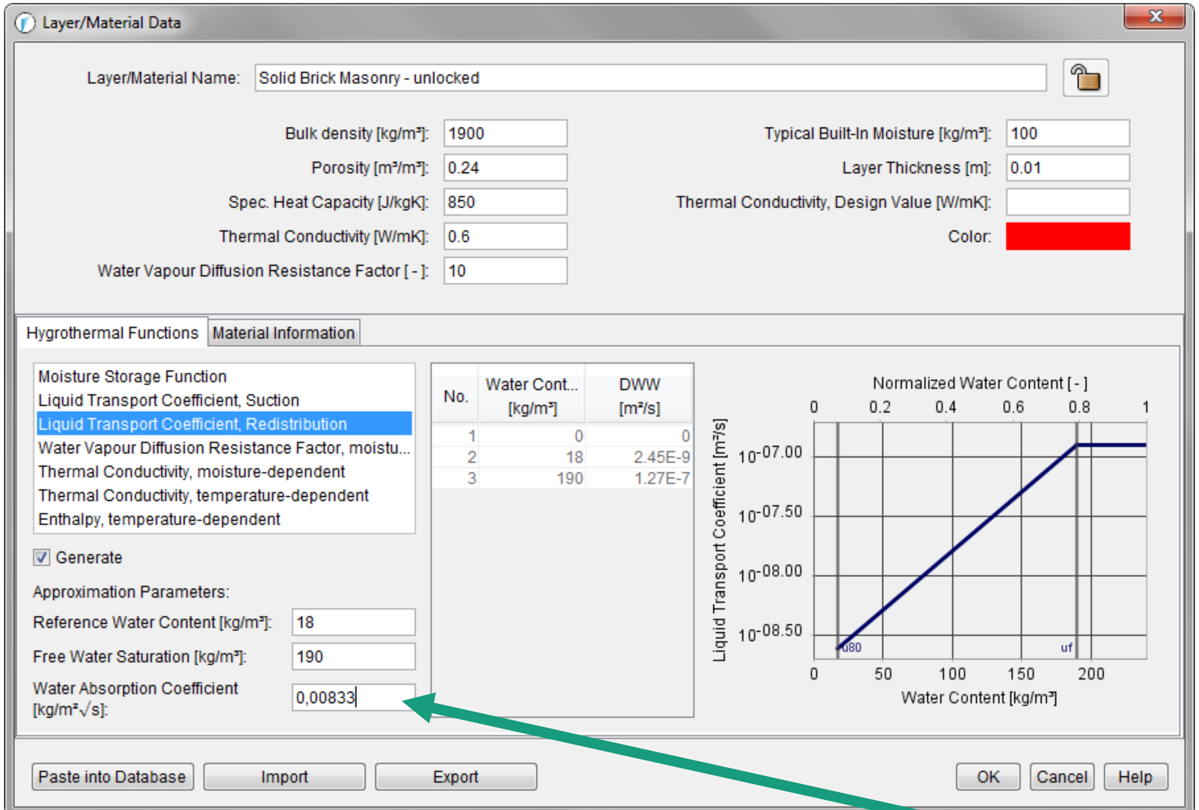


12. Check „Generate“

11. Select „Liquid Transport Coefficient, Redistribution“

Exterior wall with interior insulation

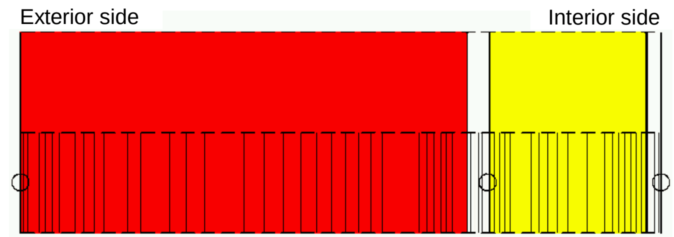
Water-repellent treatment of façades



13. Enter A-value
    In this case:
    0.5 kg/m²√h / 60
    = 0.00833 kg/m²√s

Exterior wall with interior insulation

Result analysis*

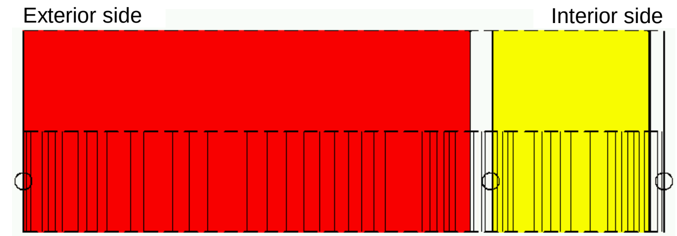


- Check total water content (accumulation of moisture in whole construction); must not keep increasing
- Relative humidity at the interface between interior plaster and interior insulation < 95 % r.F.
  → risk of frost damage
  → or: frost-resistance of materials necessary
  (Insulation system plaster, wall materials)

*) Note: List not necessarily complete. Depending on boundary conditions adittional critical positions may occur → Check in film display

Exterior wall with interior insulation

Additional information

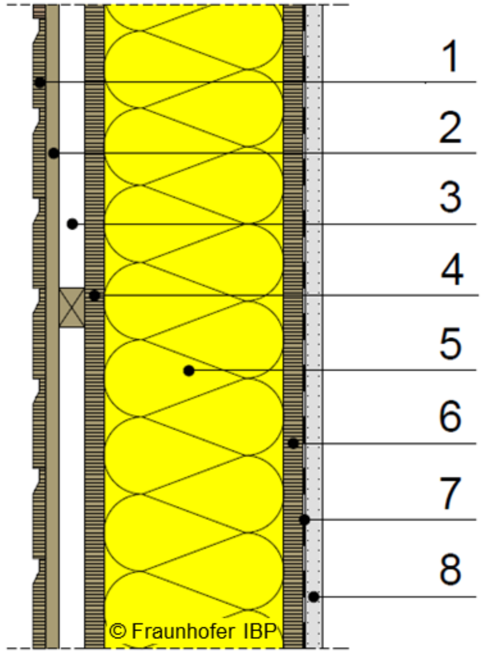


- An interior insulation reduces the drying potential of a construction due to a lower over-all temperature and a higher diffusion-resistance to the interior side
- The moisture content at the interface interior plaster / interior insulation usually can be reduced by an enhancement of the protection against driving rain (e.g. by water-repellent treatment, new exterior plaster, paint coat)
- Water-repellent treatment according to WTA:
  - A-value < 0.1 kg/m²√h
  - 50 % increase of the s_d-value
- Investigations of an exposed masonry need the knowledge of effective material properties, combining the properties of bricks and mortar
- A gypsum plaster at the interior surface usually has to be removed before applying an interior insulation
- Smart vapor retarders are favorable since the drying potential to the inside mainly remains unaffected.

Content

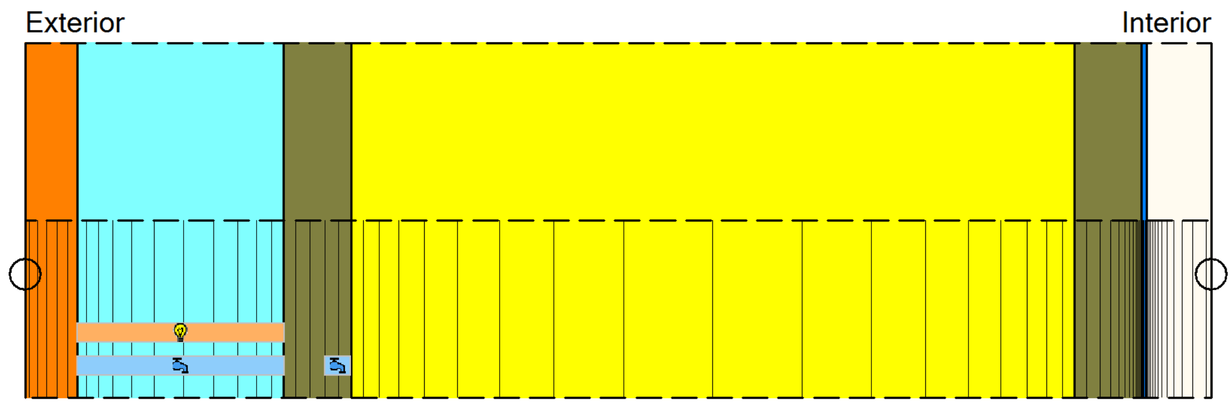
Ventilated timber frame construction

Construction drawing



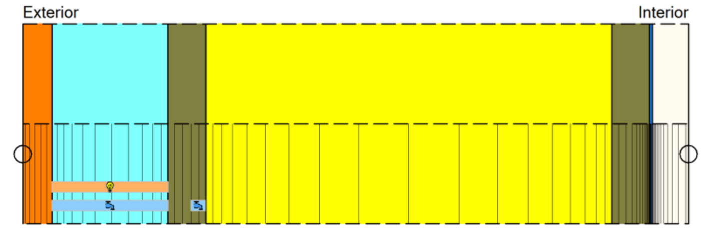
1 Planking
2 Battens
3 Counter battens
4 External cladding
5 Insulation
6 Internal Cladding
7 Vapour retarder
8 Gypsum board

Construction in WUFI



Ventilated timber frame construction

Please note



- Insert Air Change Source in air layer
  → The exchange rate is dependent on construction, surface color and ventilation openings
- Insert an air infiltration source at the cold side of the construction (at the position where condensation would occur) → source strength depending on the air tightness and height of the wall head
- Relevant orientation: usually north
- Short wave radiation absorptivity depending on color of surface
- Long wave radiation emissivity depending on material of surface
- If the short-term hygrothermal behavior of the outer surface is to be evaluated (e.g. dew position), turn on explicit radiation balance
- “Adhering fraction of rain” according to inclination and construction type (vertical wall: 0.7)

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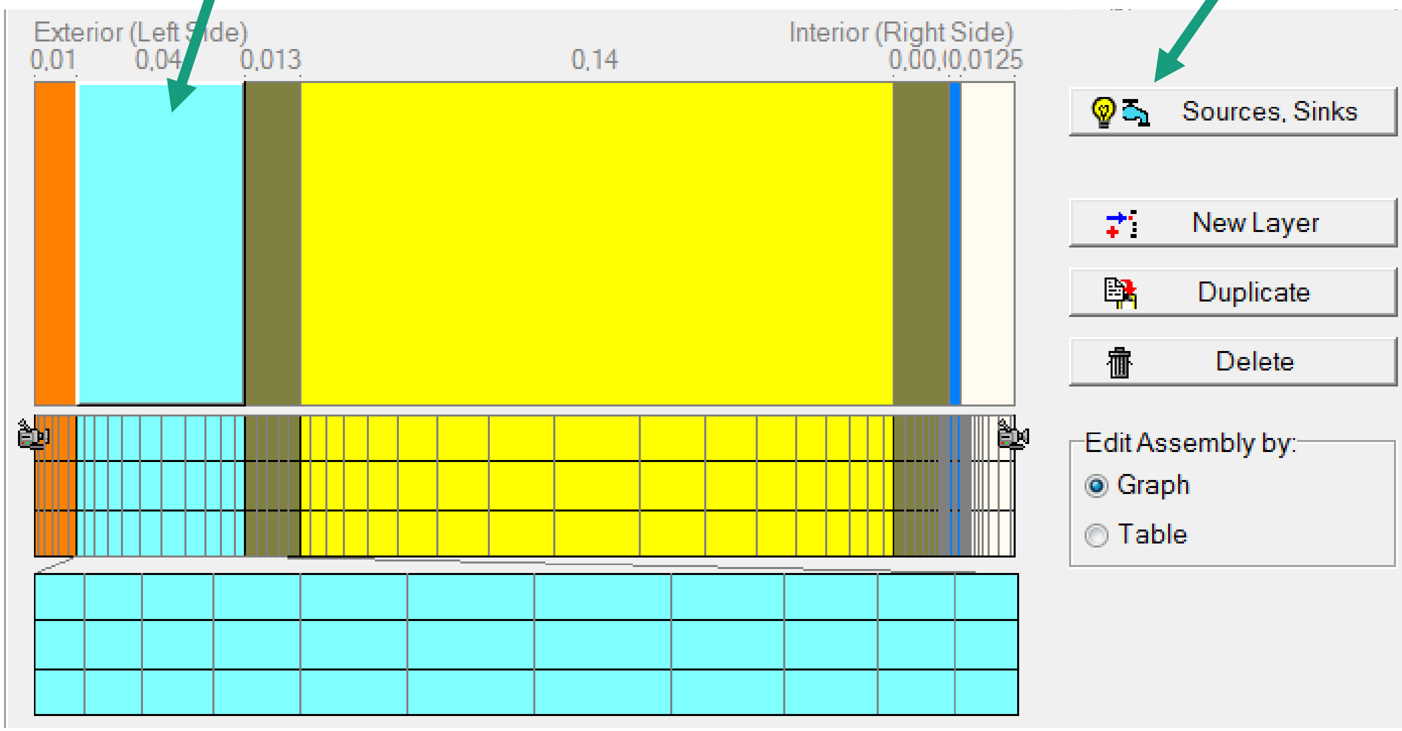
Ventilated timber frame construction

Air change source setup

1. Select air layer

2. Select „Sources, Sinks“

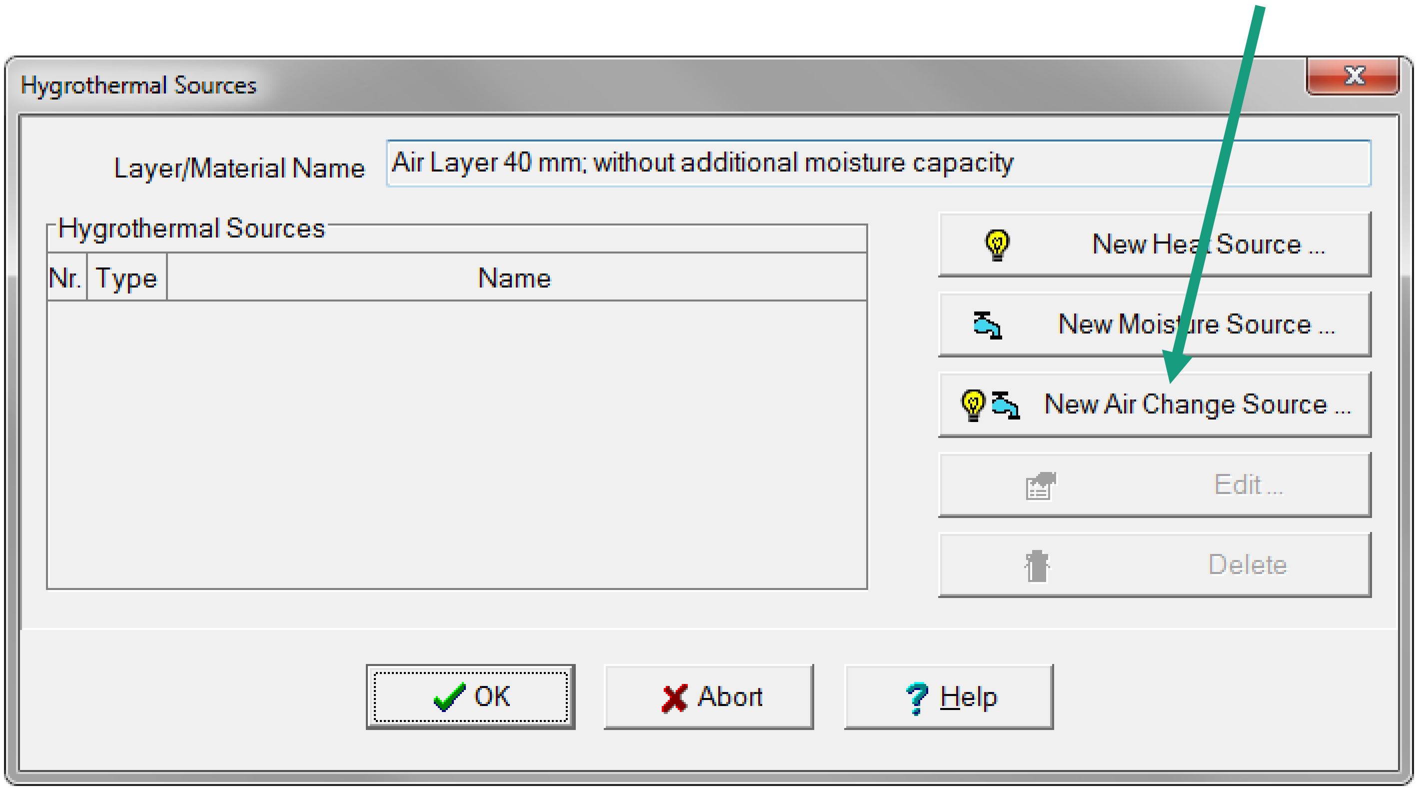


Fraunhofer IBP

Ventilated timber frame construction

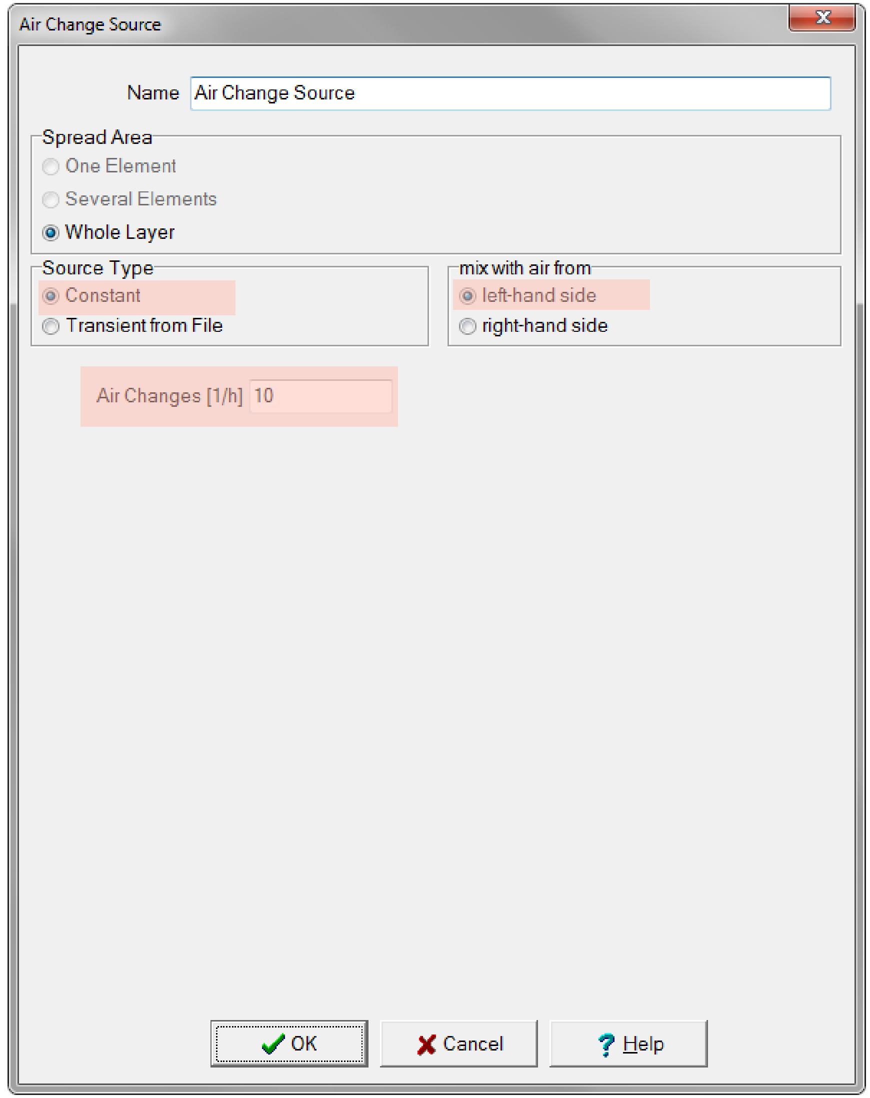
Air change source setup

3. Select „New Air Change Source“



Ventilated timber frame construction

Air change source setup

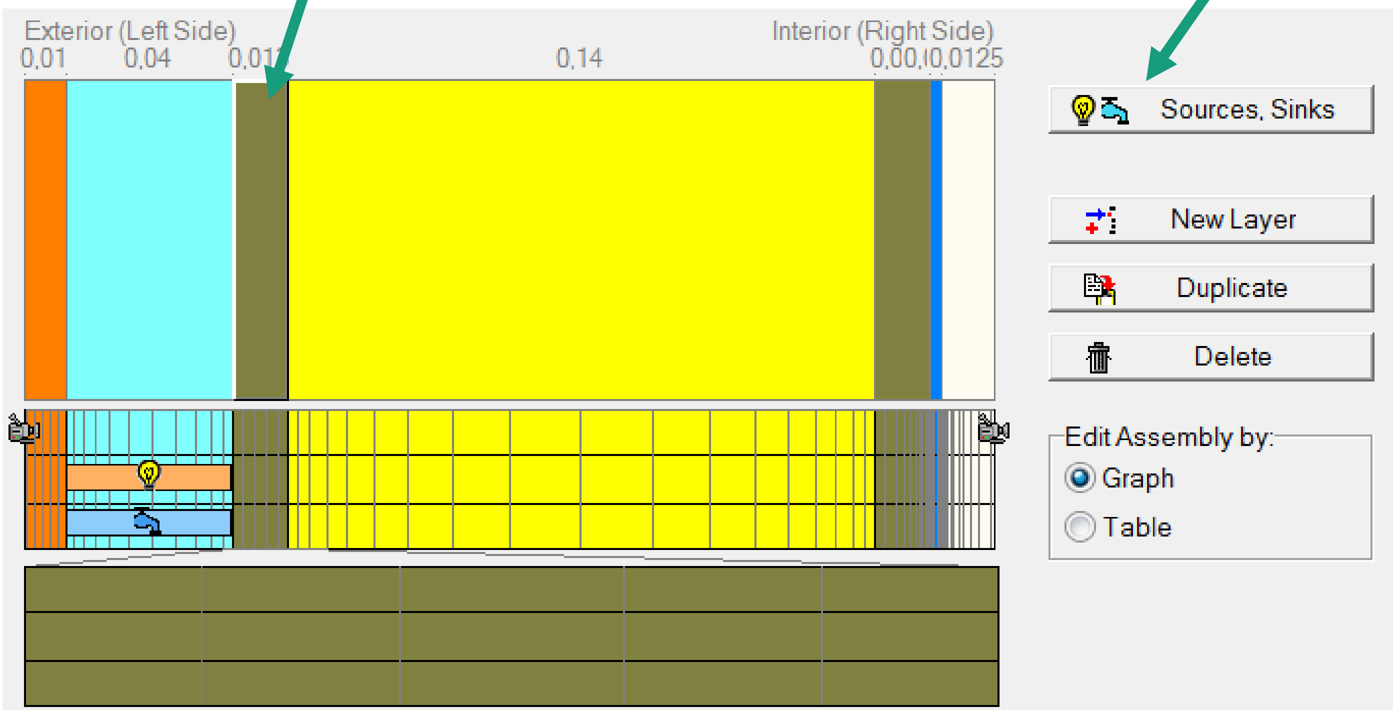


Ventilated timber frame construction

Moisture source setup

1. Select External cladding

2. Select „Sources, Sinks“



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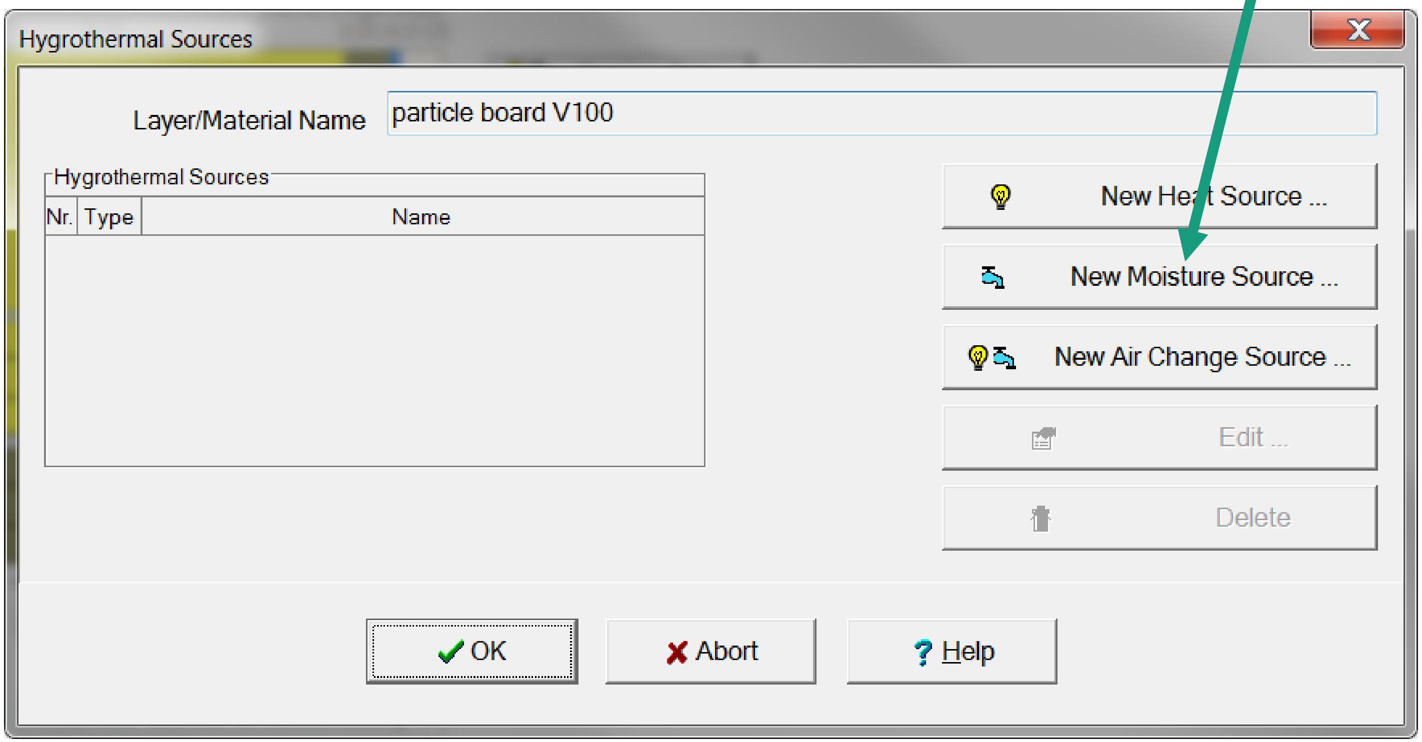
Ventilated timber frame construction

Moisture source setup

3. Select „New Moisture Source“



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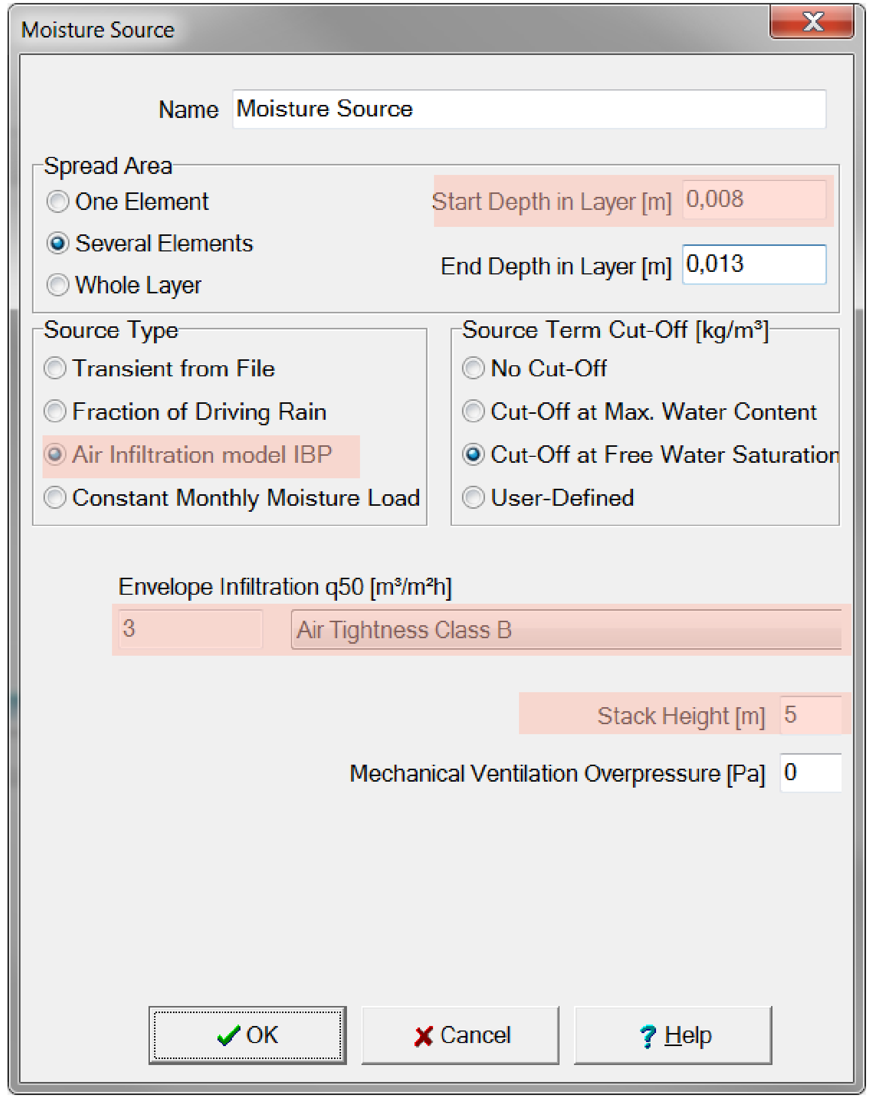
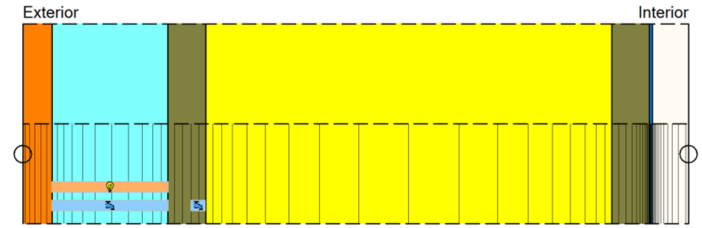
Ventilated timber frame construction

Moisture source setup



Ventilated timber frame construction

Result analysis*

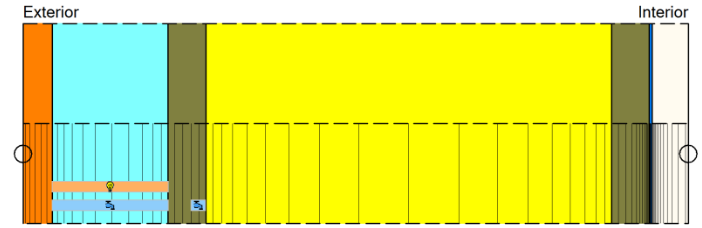


- Check total water content (accumulation of moisture in whole construction); must not keep increasing
- Check water content in the external cladding
- If necessary check moisture content of the insulation

*) Note: List not necessarily complete. Depending on boundary conditions additional critical positions may occur → Check in film display

Ventilated timber frame construction

Additional information

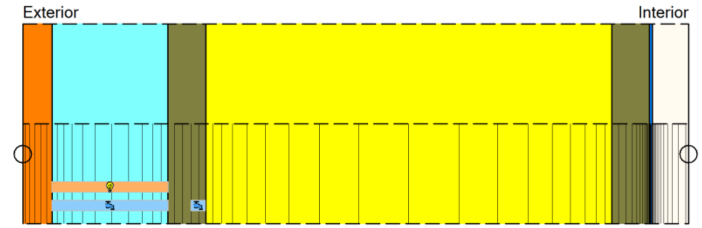


- As the occurring air exchange rates are often not known, it may be useful to vary the air exchange rate to see its influence on the hygrothermal behavior of the construction.
(Air exchange rates are usually between 10 and 200 1/h)

Ventilated timber frame construction

Additional information

- Examples for air change rates for ventilated facades



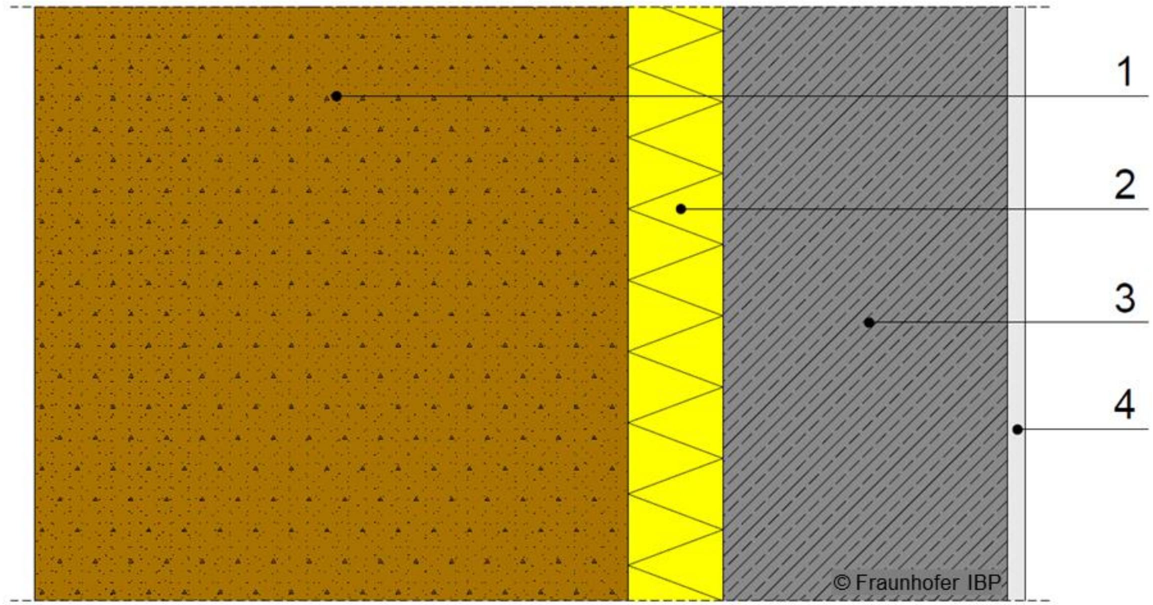
Guide values for air changes	Flow rate [(m³/h)/m²]	Gap [mm]	ACH [1/h]
Wood Siding	≈ 1,83	≈ 5	20
Vinyl Siding	≈ 9,14	≈ 5	200
Facing brick	≈ 2,74	≈ 25	10
Stucco (vented)	≈ 1,83	≈ 10	10
Sheathing flanking flow*	≈ 0,91	≈ 5	10

*The flank flow refers to the leaks in the area on the outer panel.

Content

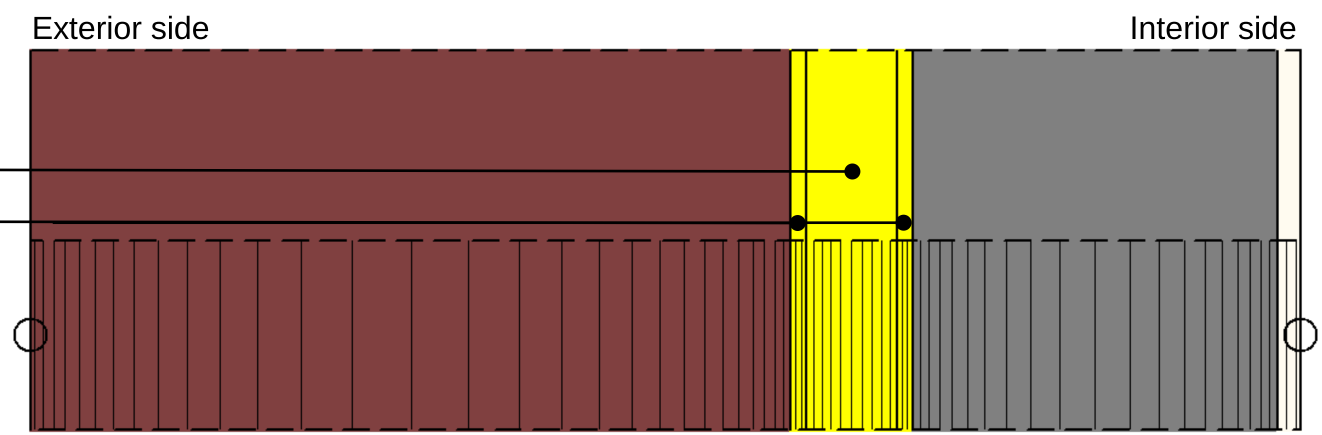
Basement wall (without ground water)

Construction drawing



1 Soil
2 Perimeter insulation
3 Concrete wall
4 Interior plaster

Construction in WUFI



XPS Core
XPS Surface Skin

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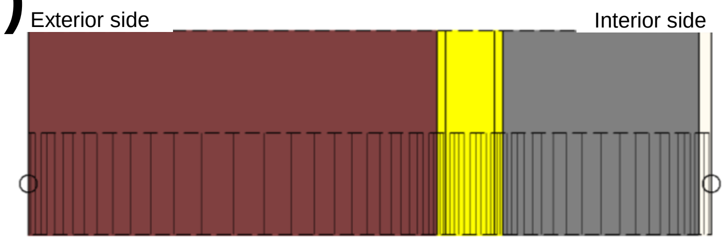
Basement wall (without ground water)

Please note

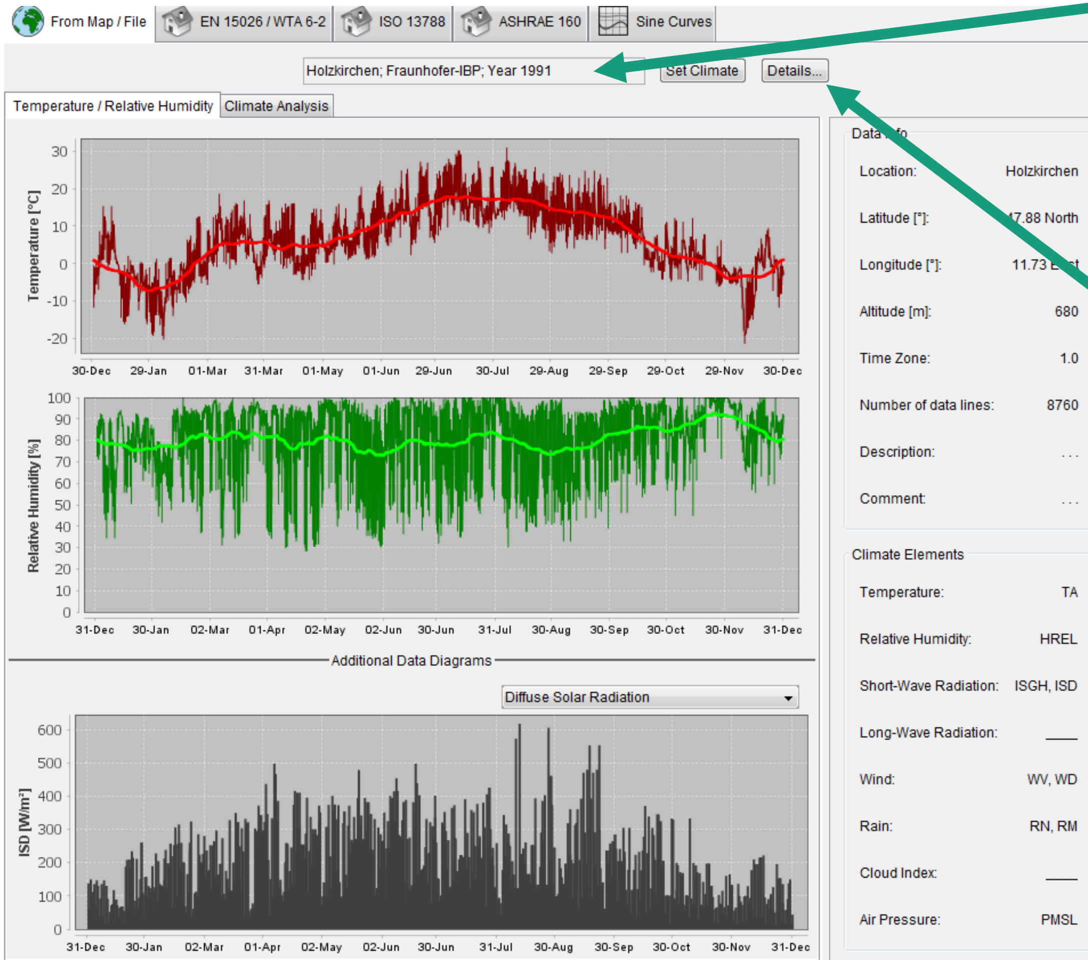


- Material data „Soil (Christian) DIN“ (see Generic Materials)
  Thickness about 0.5 m
- The XPS perimeter insulation is build up three layers: core and outer surface skins (thickness 1 cm).
- Heat transfer resistance „Basement“
- No radiation absorptivity / emissivity
- No rain water absorption
- Outdoor climate:
  - Soil temperature from the climate „Holzkirchen-IBP Year 1991“
  - Sinus curve according to the diagram on slide 58

  with constant relative humidity of 99 % or 100 % RH
- Set interior climate depending on utilization

Basement wall (without ground water)

Soil temperature setup (from climate Holzkirchen)



1. Select climate file „Holzkirchen; Fraunhofer-IBP; Year 1991“

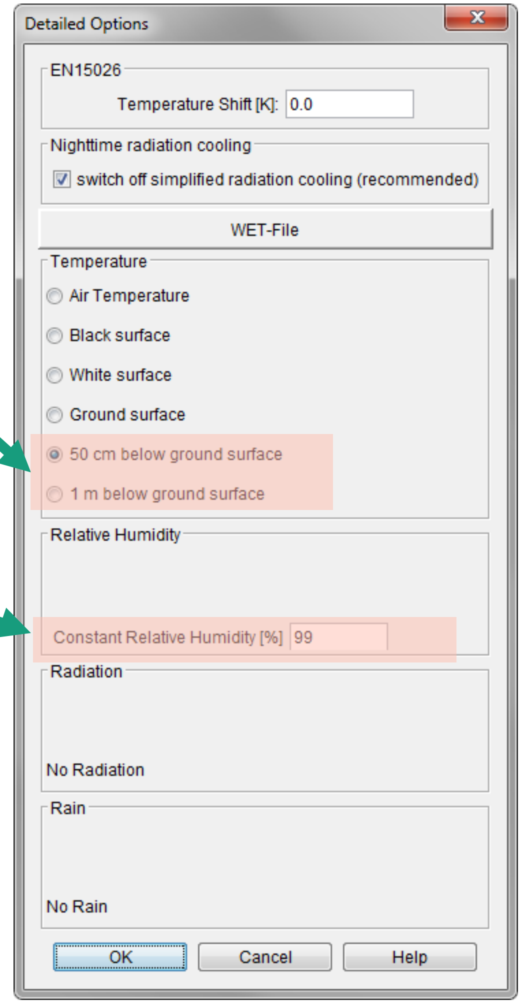
2. Select „Details…“

Basement wall (without ground water)

Soil temperature setup (from climate Holzkirchen)

3. Select ground temperature at 50 cm or 1 m depth

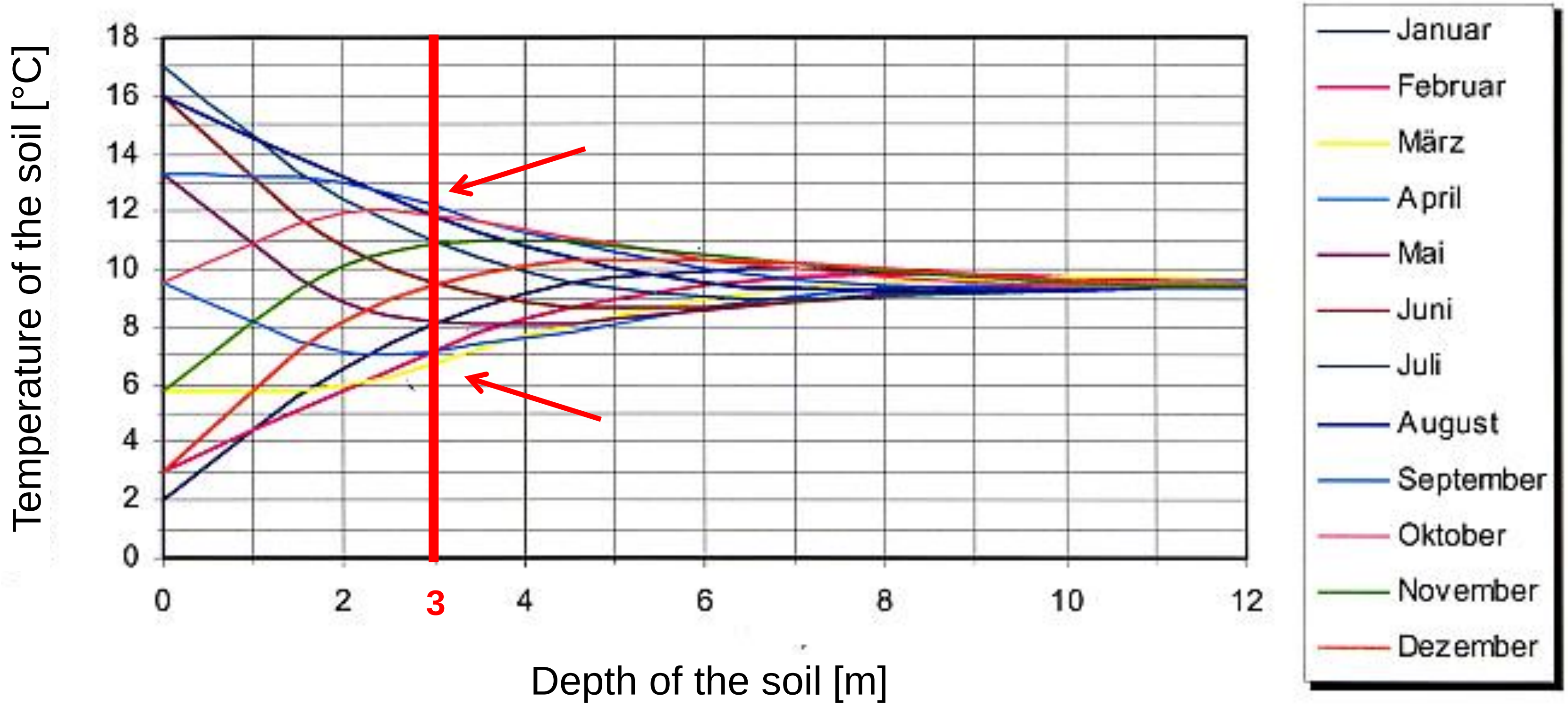
4. Enter Constant Relative Humidity of 99 % or 100 %



Basement wall (without ground water)

Soil temperature setup (from diagram)

Average soil temperature for each month depending on the depth of the soil

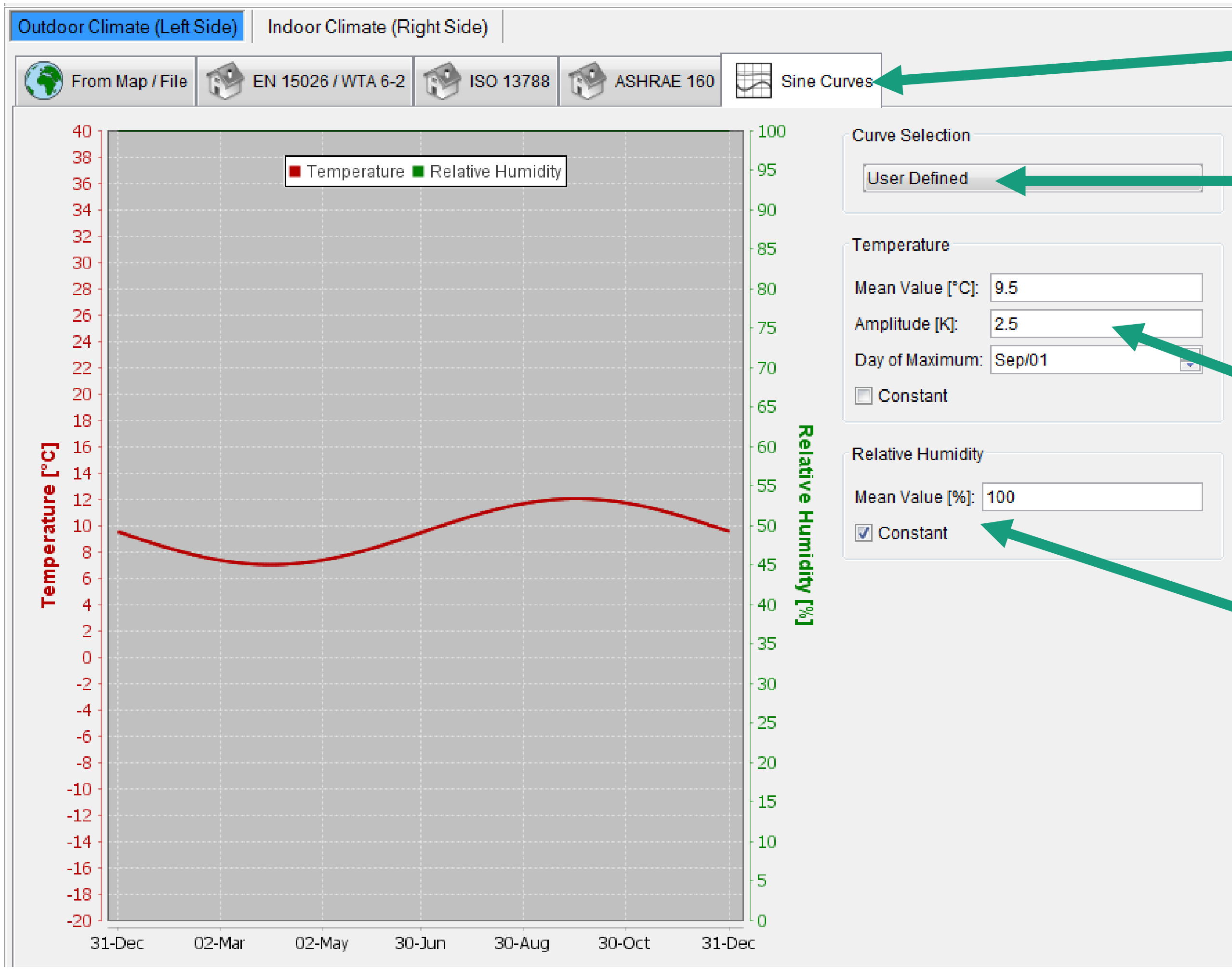


Example for a depth of 3 m:
Minimum of about 7 °C in March and
Maximum of about 12 °C in September

Ref: Heidreich, U.: Nutzung oberflächennaher Geothermie zum Heizen und Kühlen eines Bürogebäudes. Symposium Energetische Sanierung von Schul- und Verwaltungsgebäuden, FH Münster 2006.

Basement wall (without ground water)

Soil temperature setup (from diagram)



1. Sine Curves
2. Select „User Defined“
3. Enter Mean Value, Amplitude and Day of Maximum
4. Relative Humidity constant 99 % or 100 %

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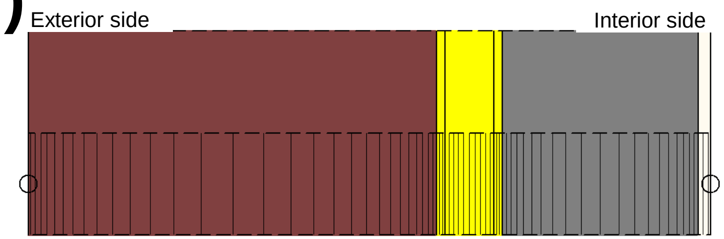
Basement wall (without ground water)

Result analysis*



- Check total water content (accumulation of moisture in whole construction); must not keep increasing
- Check water content of insulation
- Check water content in masonry / concrete

*) Note: List not necessarily complete. Depending on boundary conditions additional critical positions may occur → Check in film display

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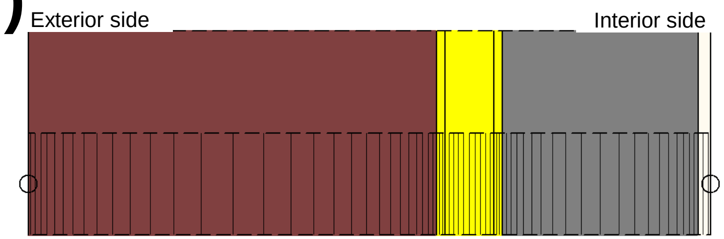
Basement wall (without ground water)

Additional information

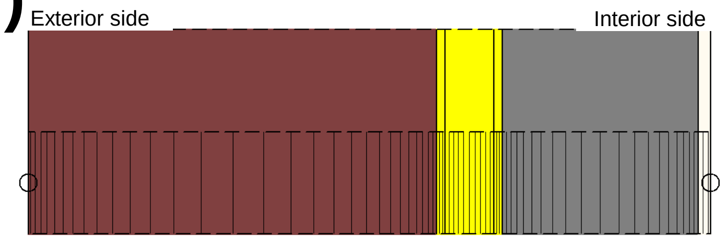


- The climate file from Holzkirchen 1991 contains measured temperatures in the ground at 50 cm and 100 cm depth.

  Furthermore one can use temperature values from the literature and implement them as sinusoidal curve (slide 56).
- By inserting a soil layer, the interaction between construction and soil can be taken into account in the simulation
- Set the initial water content in the soil to 99 % relative humidity in order to reach a steady state in the soil more quickly and thus reduce the computing time.

Basement wall (without ground water)

Additional information

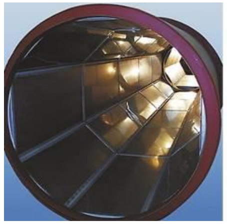
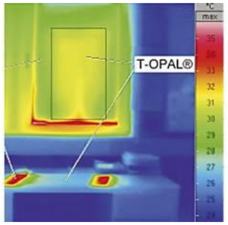


<u>Consideration of water in the soil:</u>

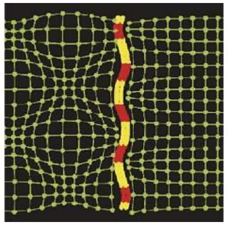
- Material data containing moisture storage function and moisture transport coefficients „Soil (Christian) FSP“ must be used. Further soil materials can be found in the “North American Database in the “Soil” section.
- The soil has to be saturated during the calculation period (check water content after calculation).
- Create a climate file, which contains rain for each time step (with CreateClimateFile.xls).
- Adhering Fraction of Rain (in „Surface Transfer Coefficient“) must be set to 1.
- Pressurized water can not be taken into account!

Handling of typical constructions

Auf Wissen bauen



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