P5 Presentation

Vapour-open, non-capillary active internally insulated historic solid brick masonry:

The influence of hygrothermal properties on the hygrothermal performance.

27 June 2023

Ninah Hubregtse
4595556

TU Delft abt

Canada's fires are getting fiercer – and rebuilding is becoming a challenge

A wildfire seen from a Canadian forces helicopter surveying the area near Mistissini, Quebec, on 12 June. Photograph: Canadian Forces/Reuters

In the days leading up to the Lytto
Columbia had broken heat records
and the arid land was more parche

Economists demand urgent action on energy bills to avert 'catastrophe'

Millions of vulnerable people will be harmed without radical policies to ease cost of living crisis, say experts

sical and financial damage to families across
Images/Alamy

Italy's 'once in a century' deadly floods are linked to climate crisis, researchers say

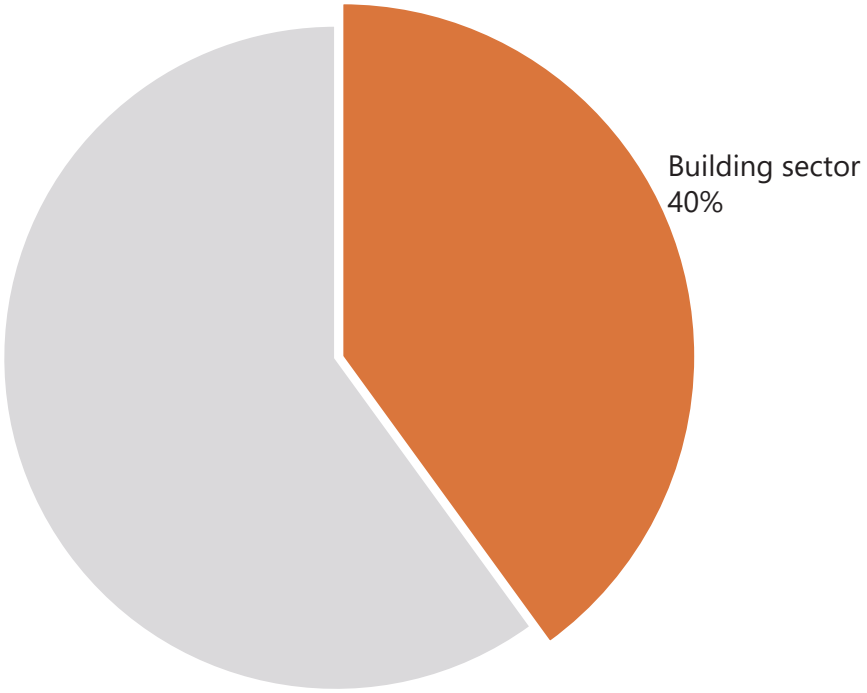
By Sharon Braithwaite and Sana Noor Haq, CNN

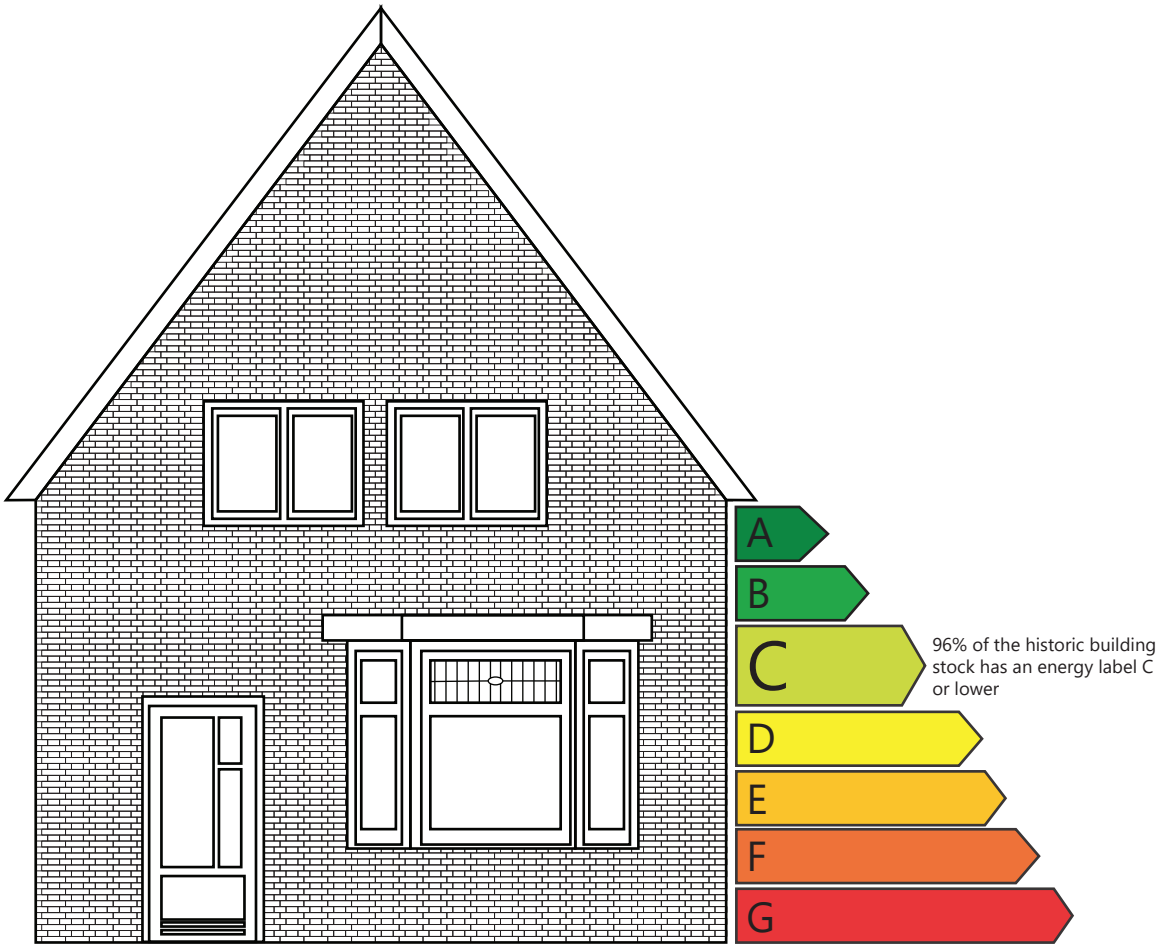
Published 10:51 AM EDT, Fri May 19, 2023

Claudia Greco/Reuters

A man wades through floodwaters in the town of Lugo on Friday. Researchers say the devastation is linked to the climate crisis.

European energy consumption

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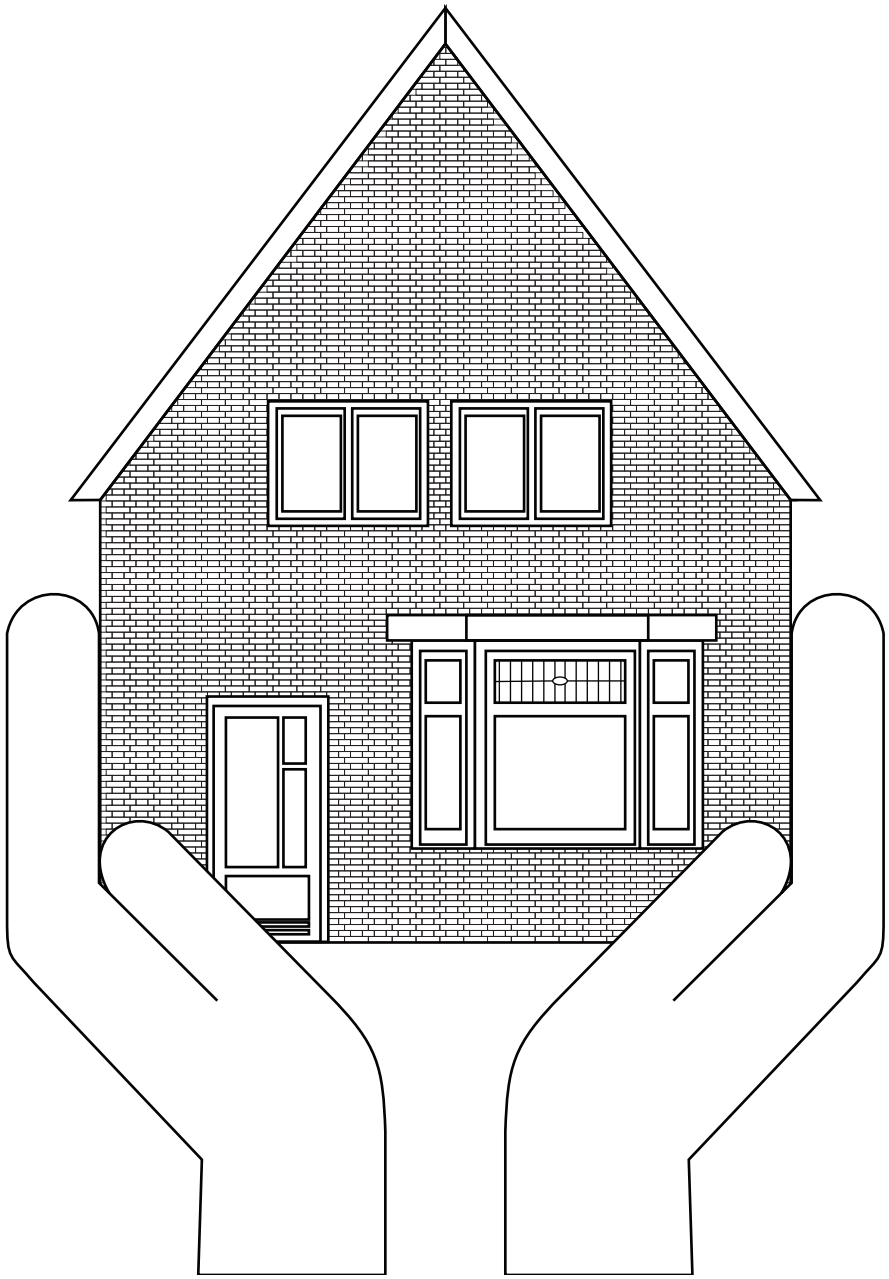
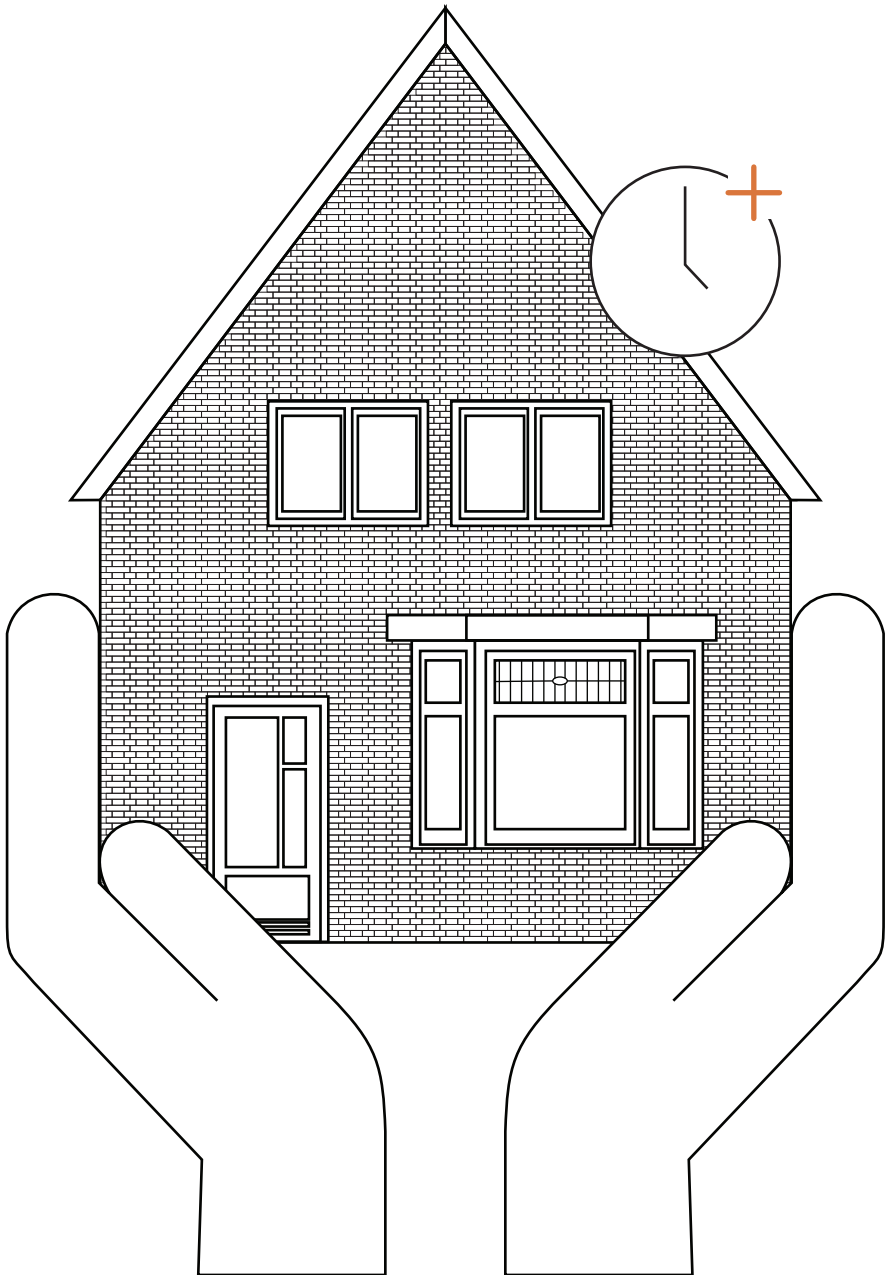
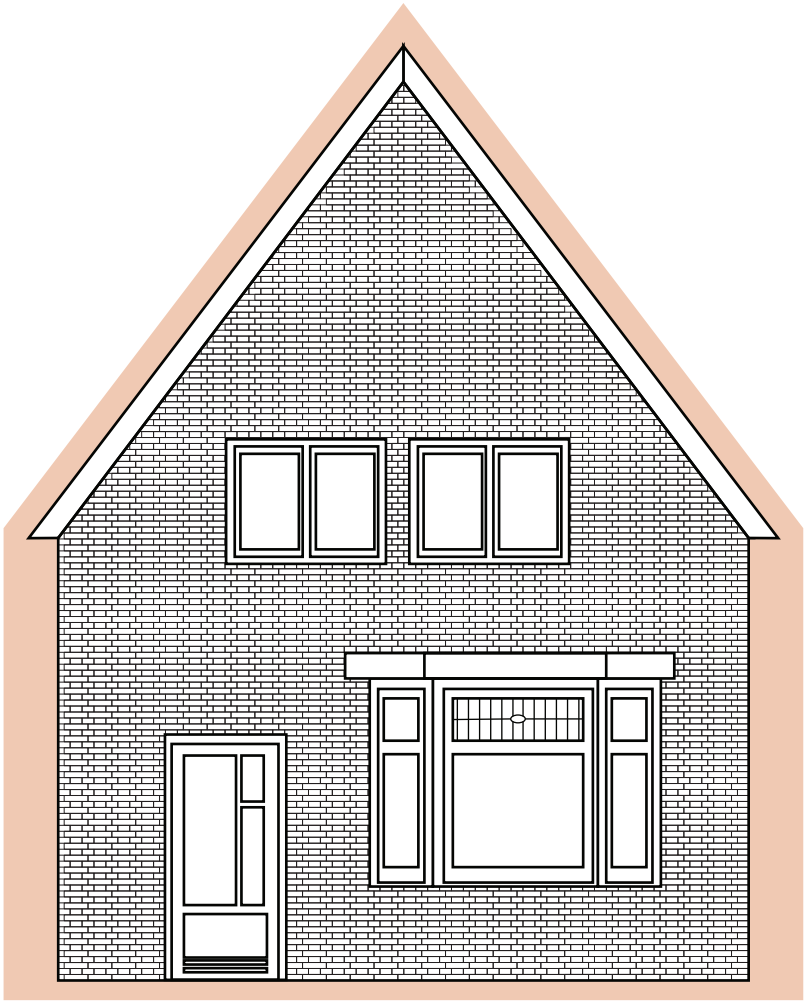
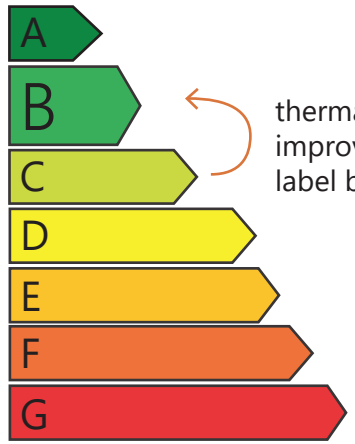
96% of the historic building stock has an energy label C or lower

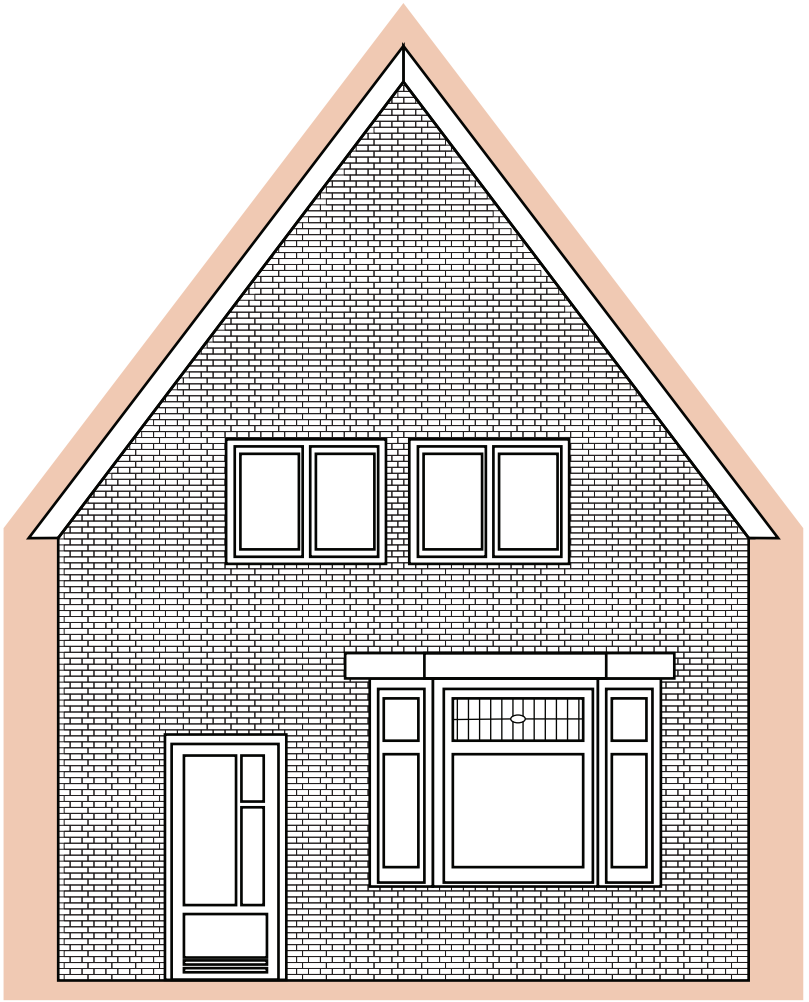


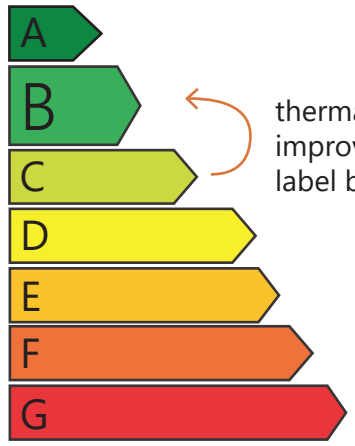






thermally upgrading improves the energy label by **one step**.





thermally upgrading improves the energy label by **one step**.

Saving circa 1.730.000.000 kg CO_2 emissions

27.000 persons

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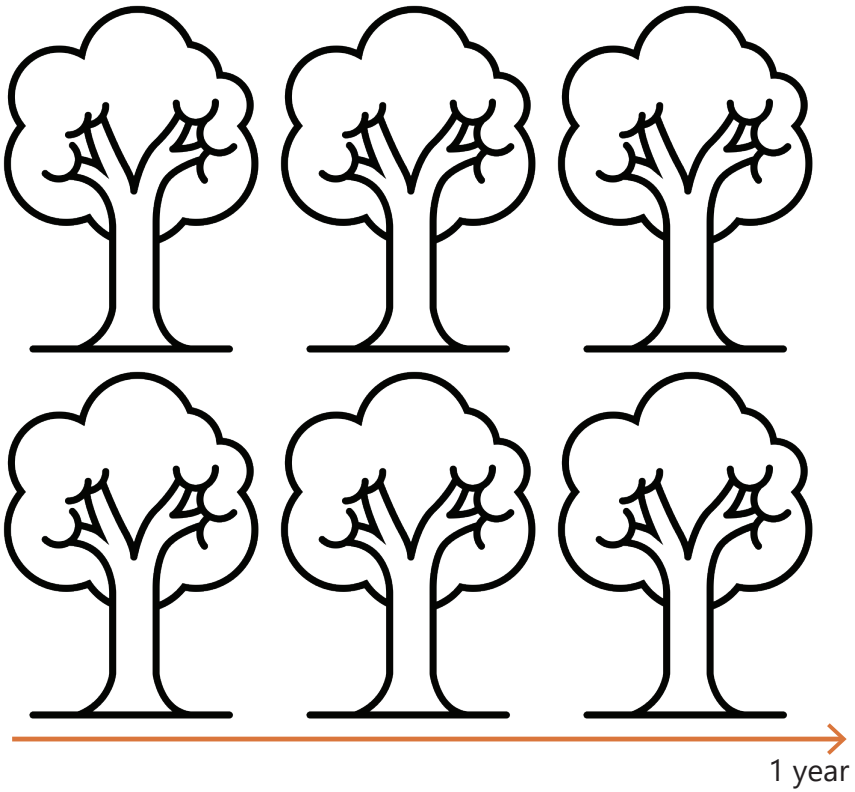
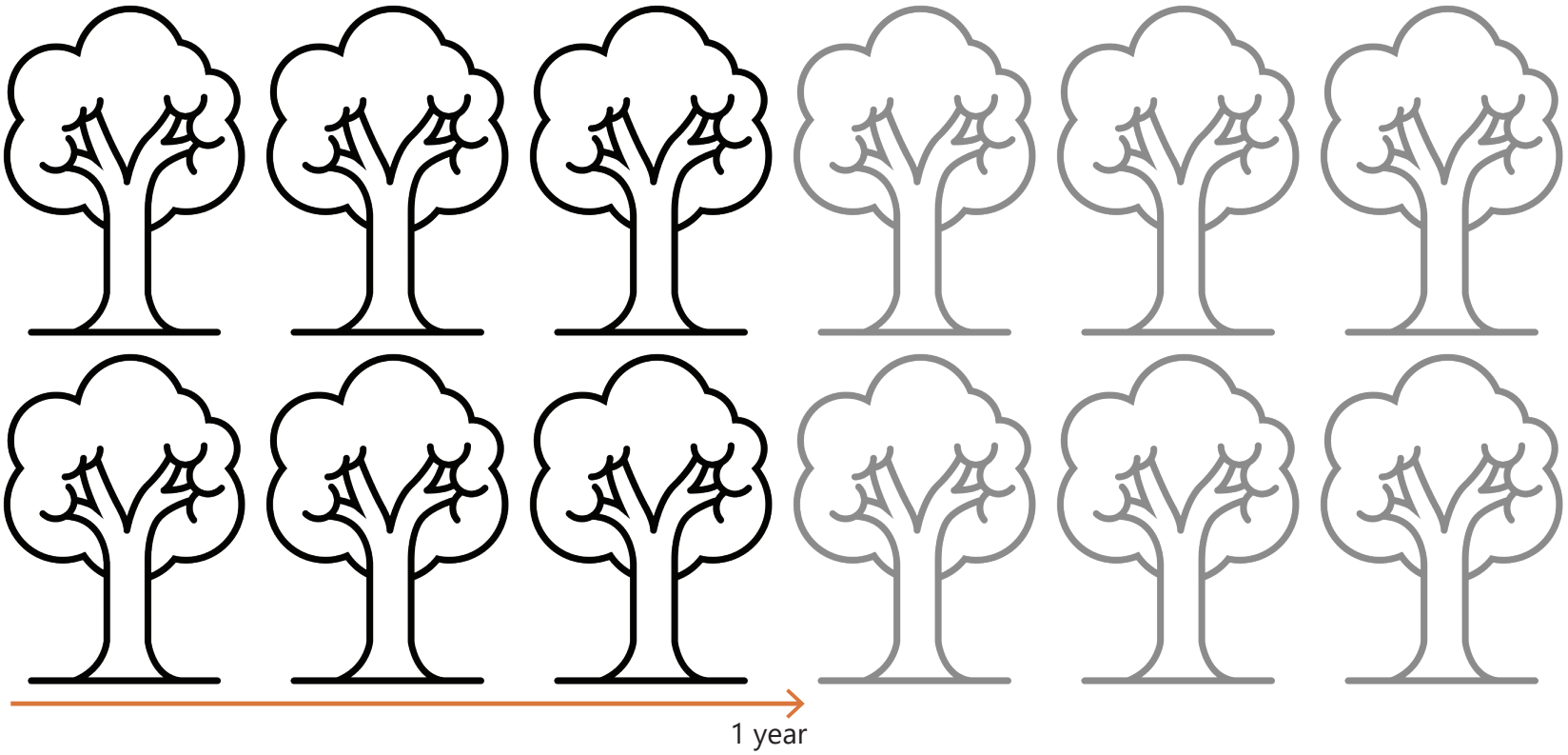
86.6 million trees

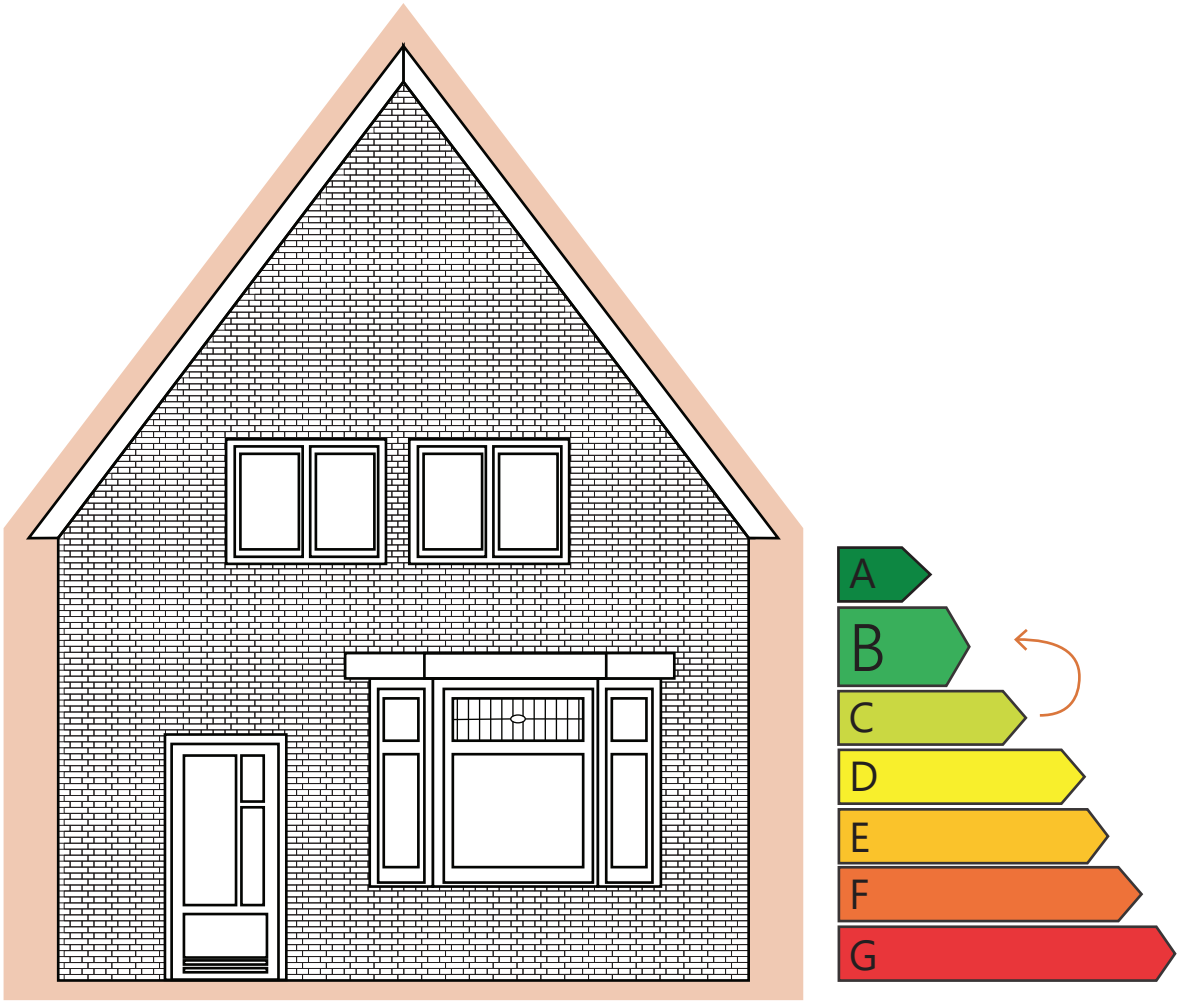


Saving circa 1.730.000.000 kg CO_2 emissions

86.6 million trees



Saving circa 1.730.000.000 kg CO_2 emissions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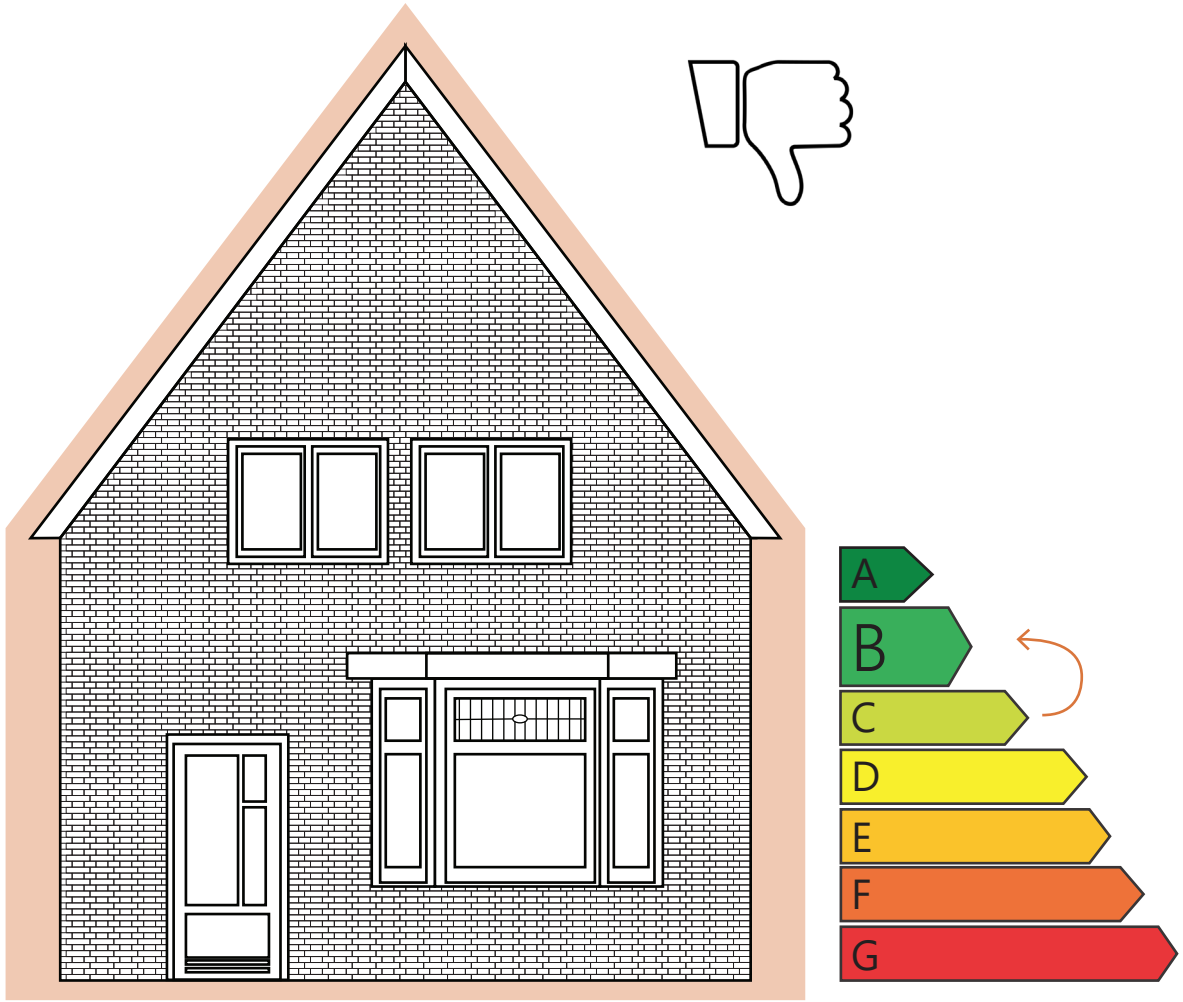
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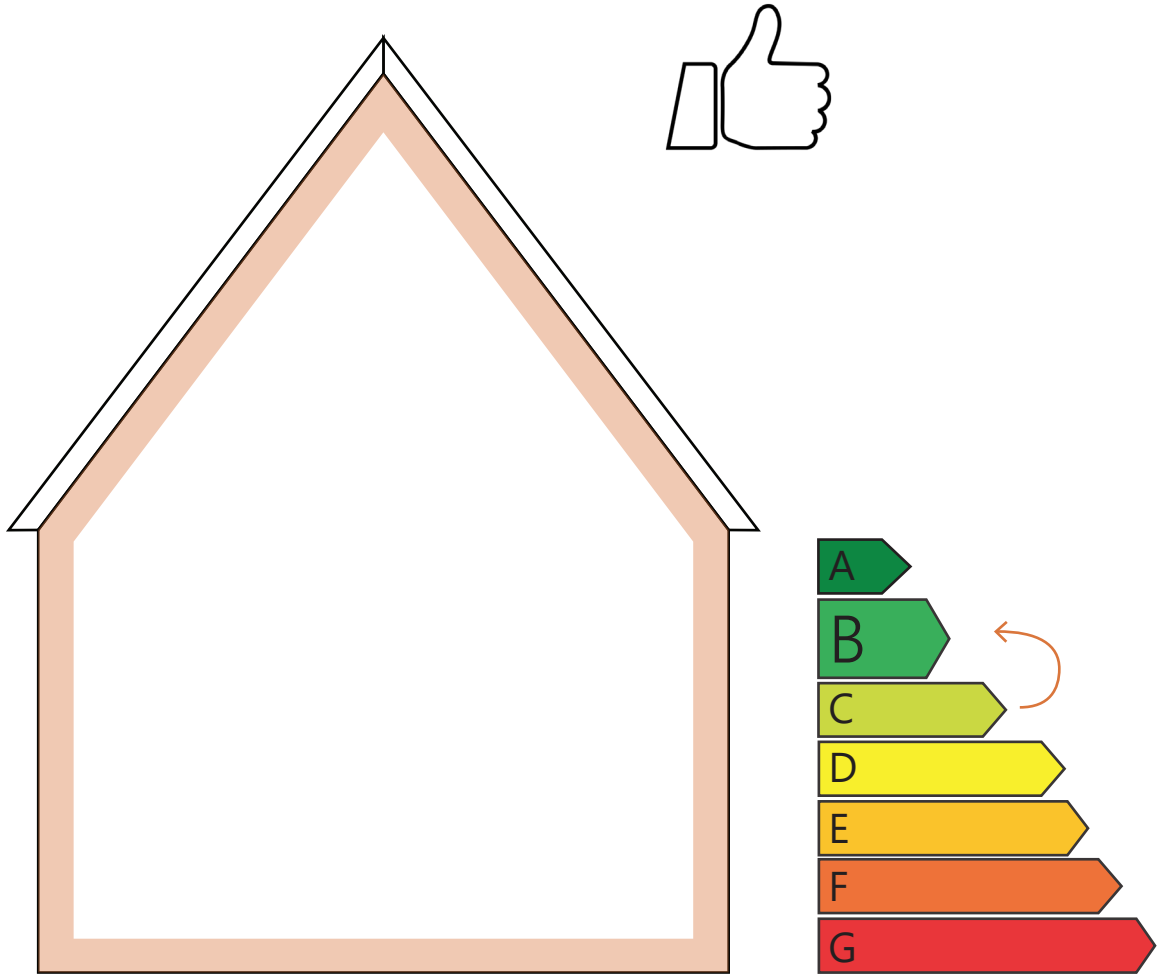
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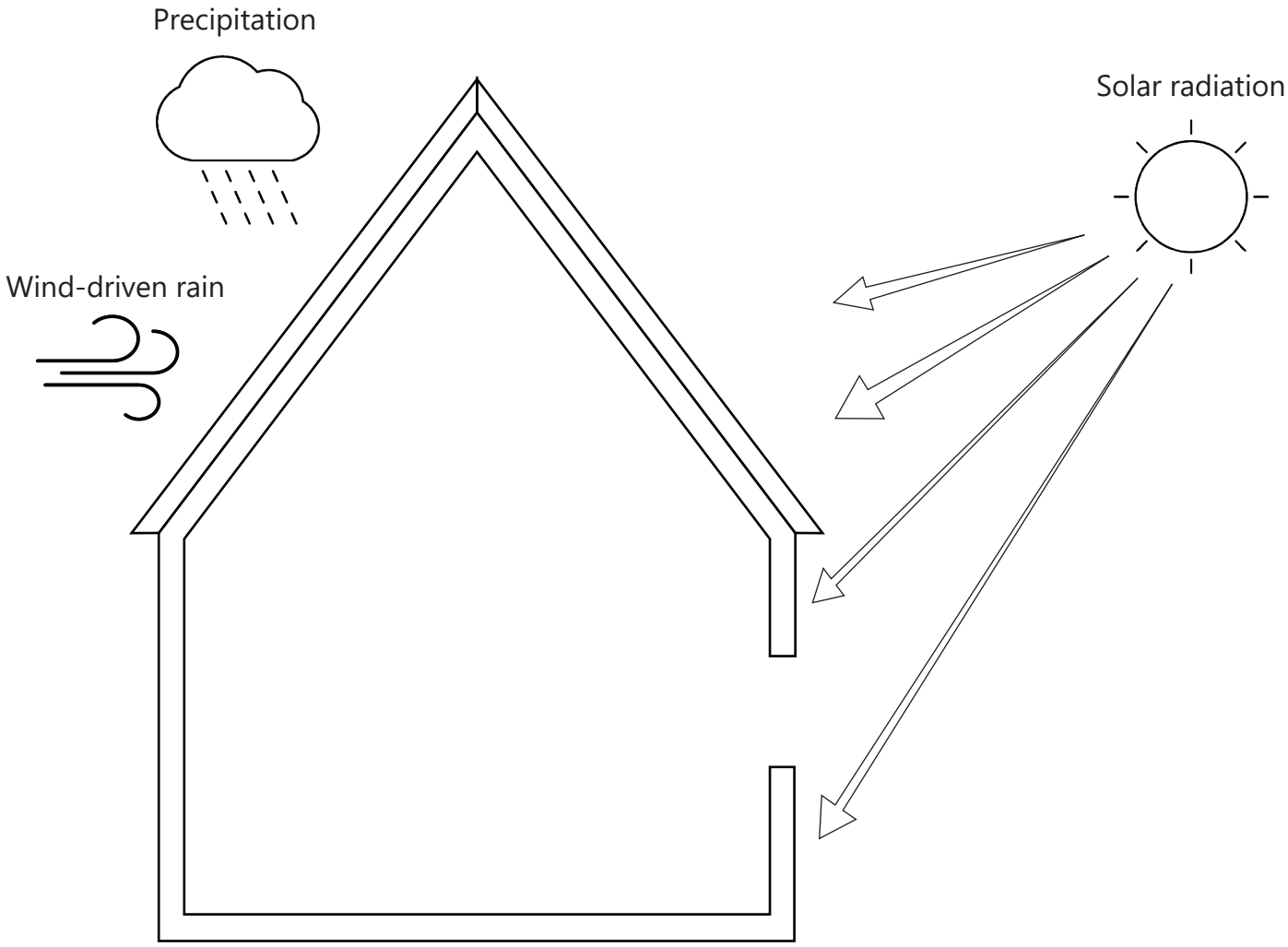
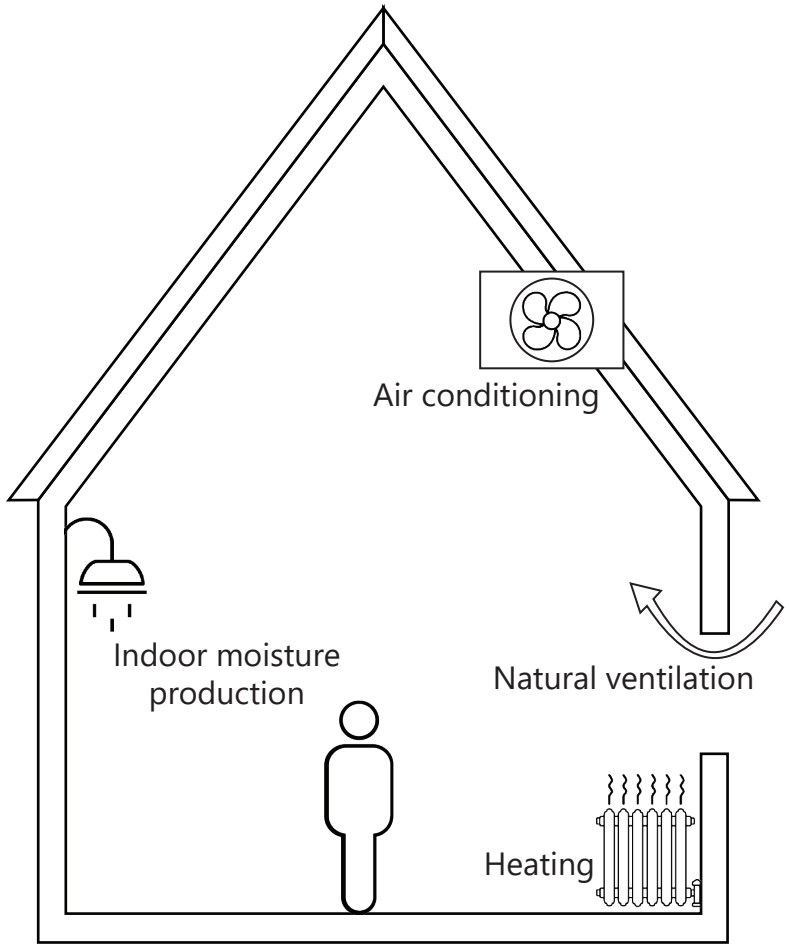
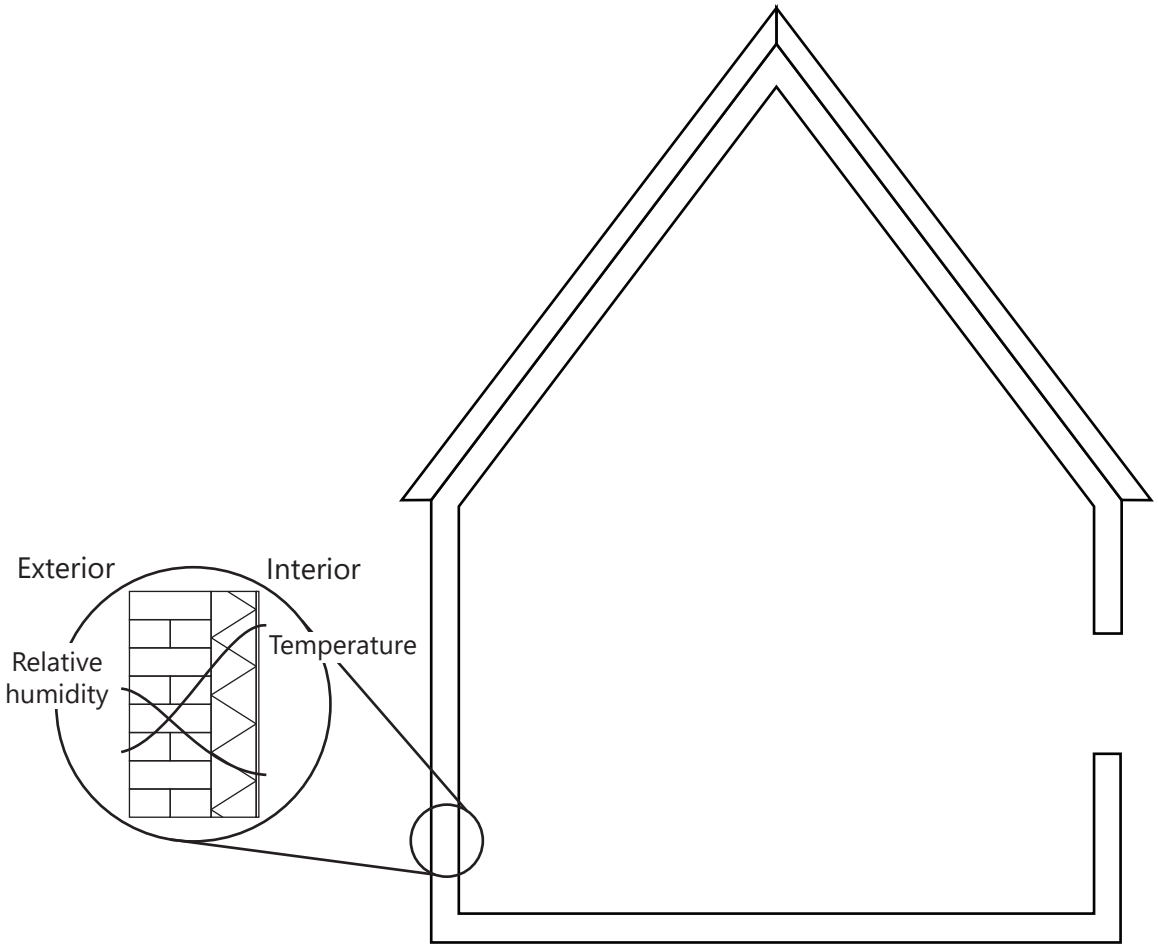
What is hygrothermal behaviour?

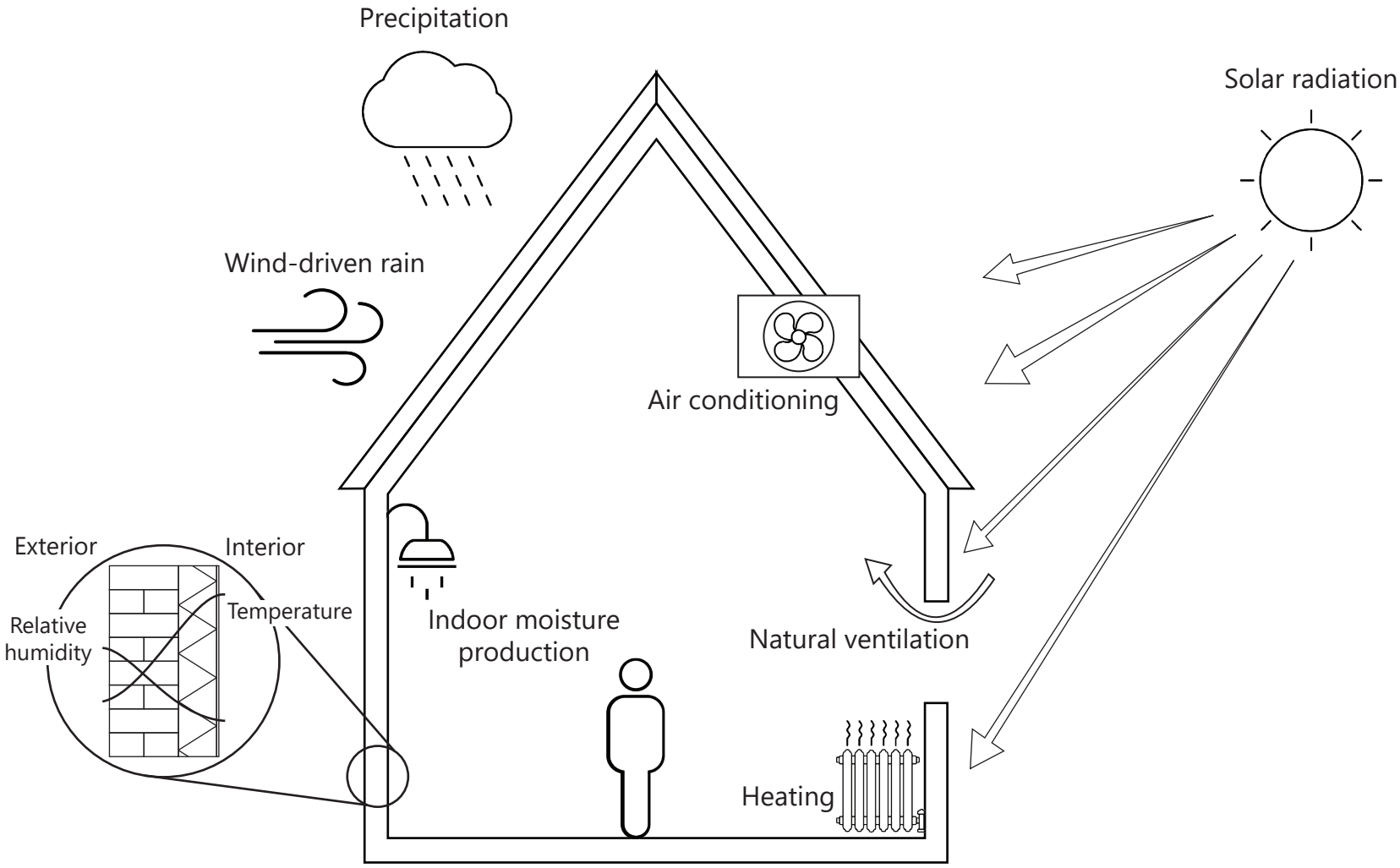
What is hygrothermal behaviour?

“the change in a material’s physical properties as a result of the simultaneous absorption, storage and release of both **heat** and **moisture**” (Hall & Casey, 2012).


Precipitation
Solar radiation
Wind-driven rain


Air conditioning
Indoor moisture production
Natural ventilation
Heating


Exterior
Interior
Relative humidity
Temperature


Precipitation
Solar radiation
Wind-driven rain
Air conditioning
Exterior
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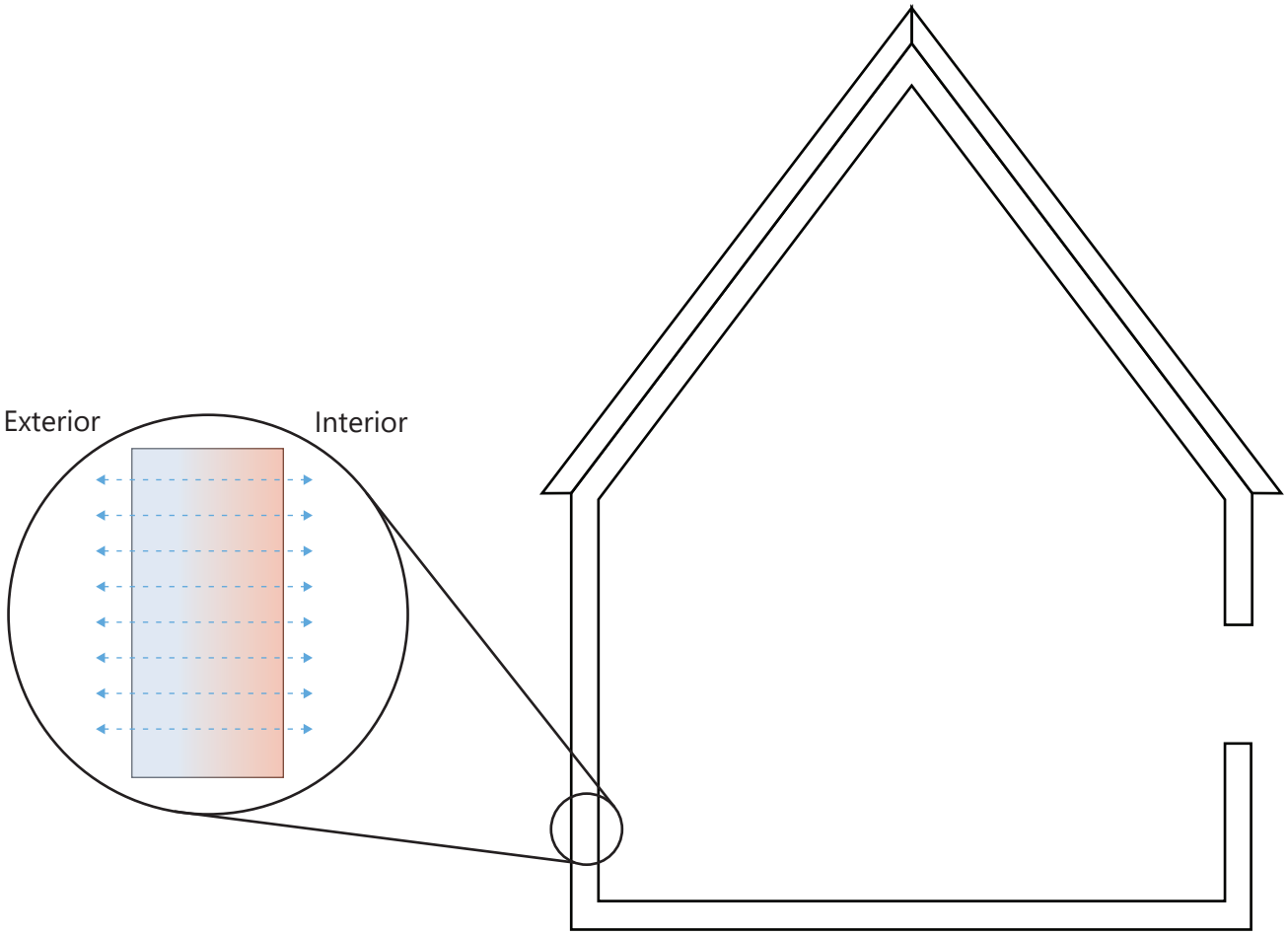
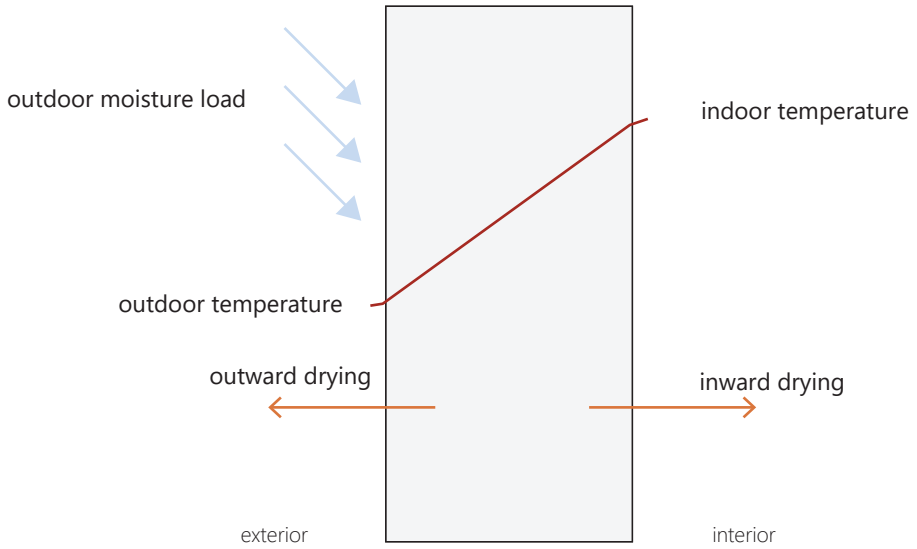
Natural ventilation
Heating



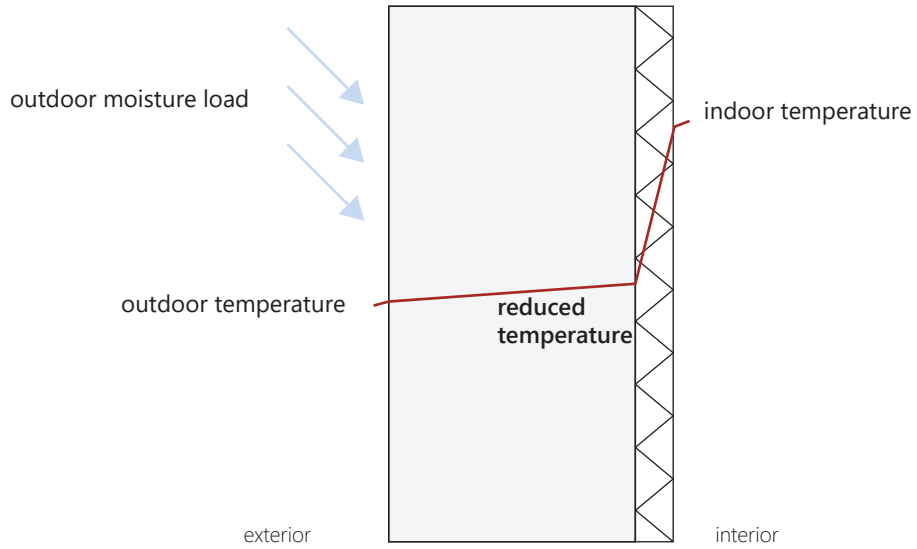



Exterior
Interior

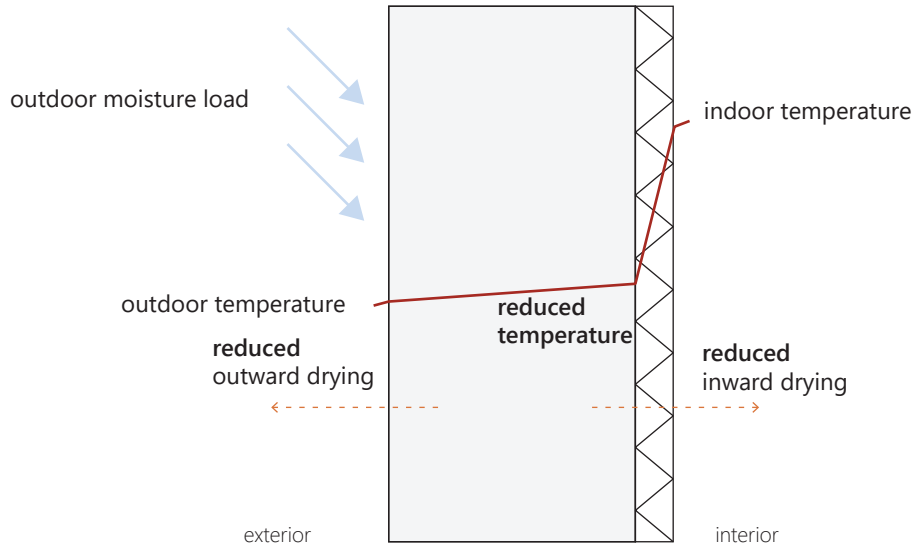
Hygrothermal behaviour **before** application of internal insulation



Hygrothermal behaviour **after** application of internal insulation



Hygrothermal behaviour **after** application of internal insulation



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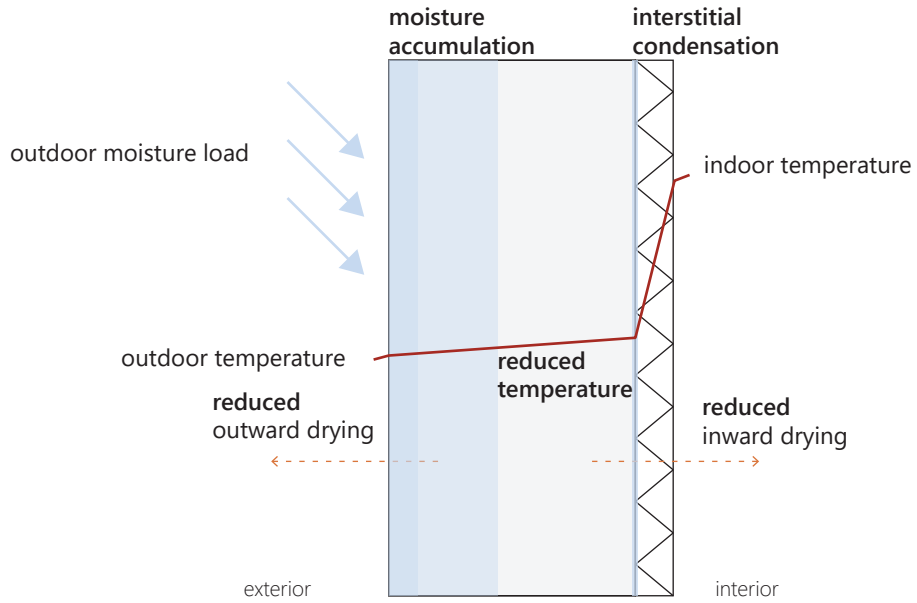
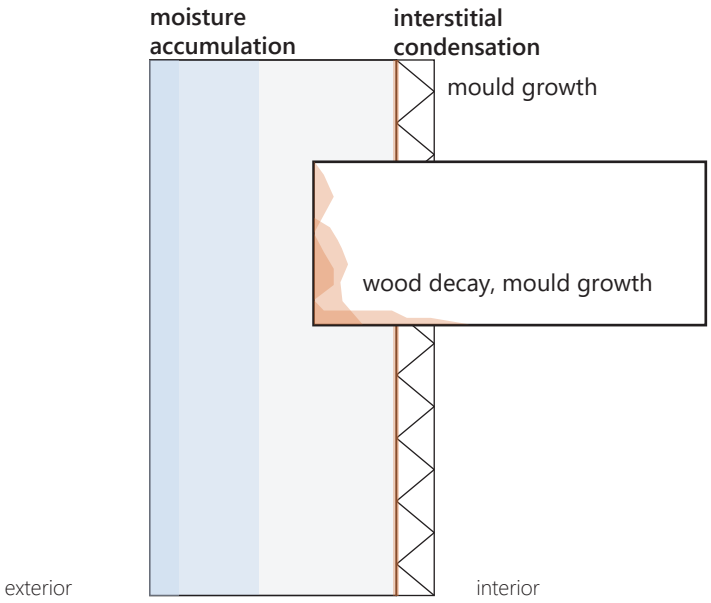
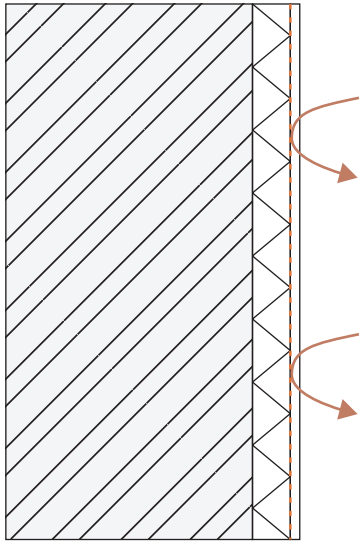
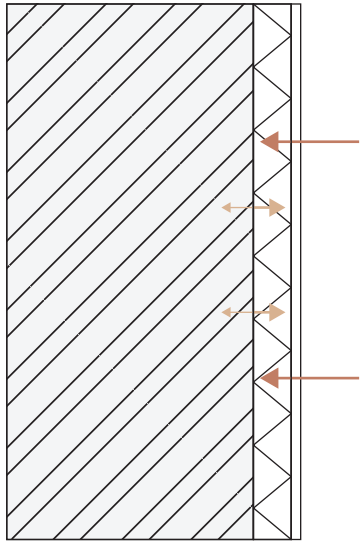



moisture accumulation
interstitial condensation
mould growth
wood decay, mould growth
exterior
interior

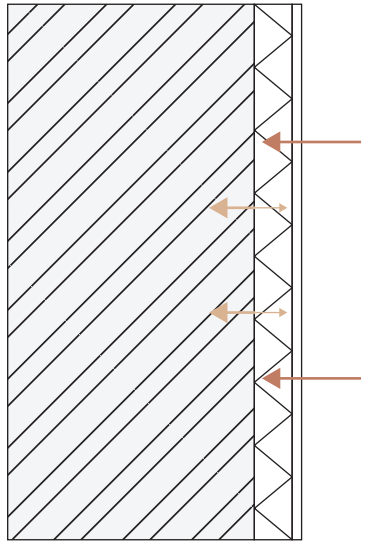
Vapour-tight

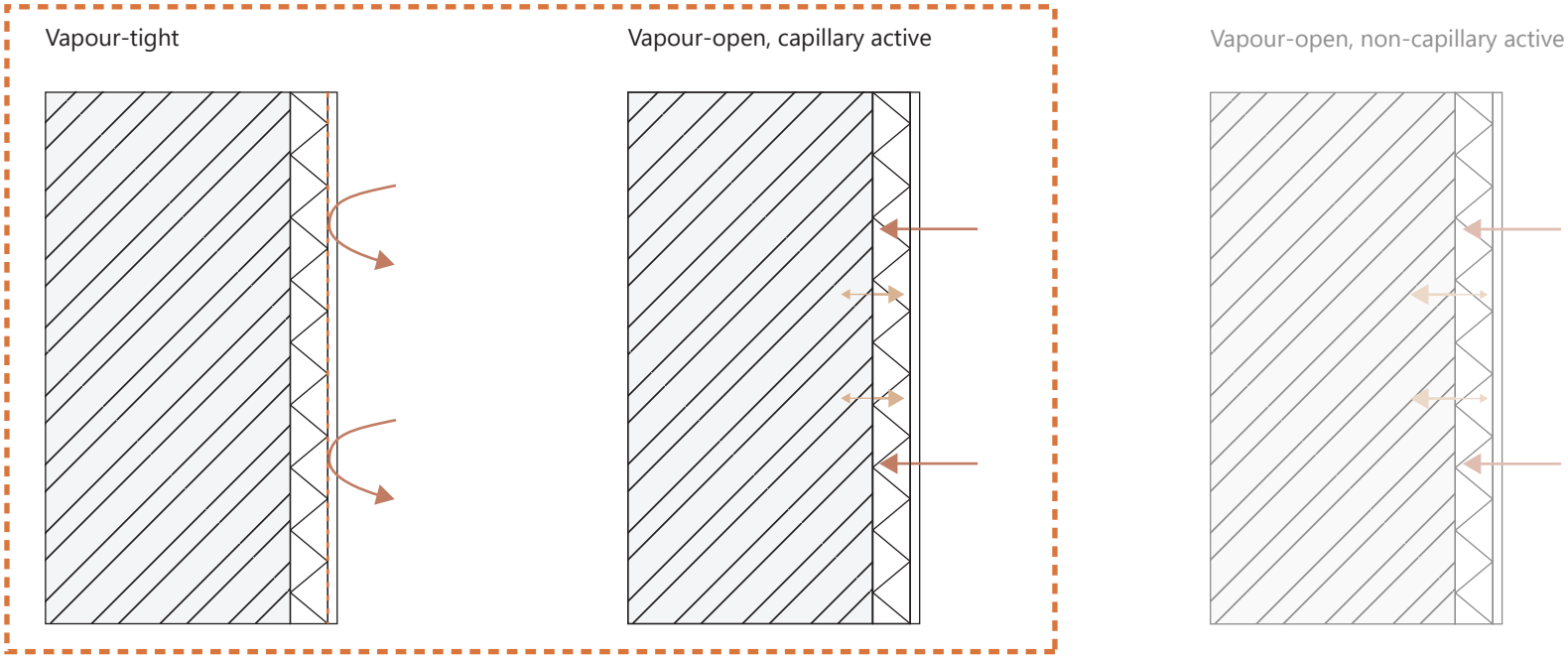


Vapour-open, capillary active

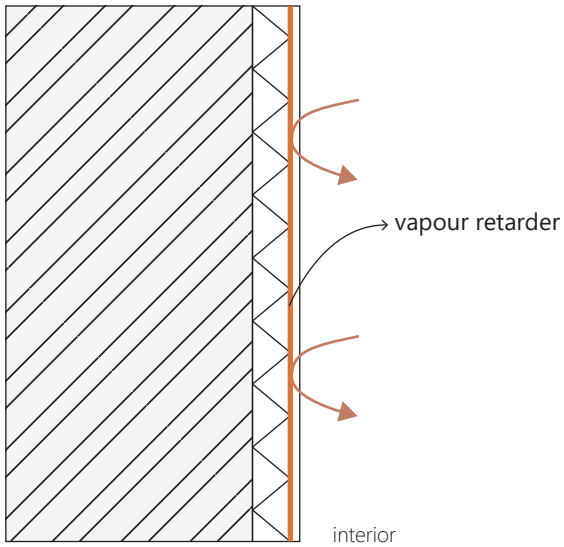


Vapour-open, non-capillary active

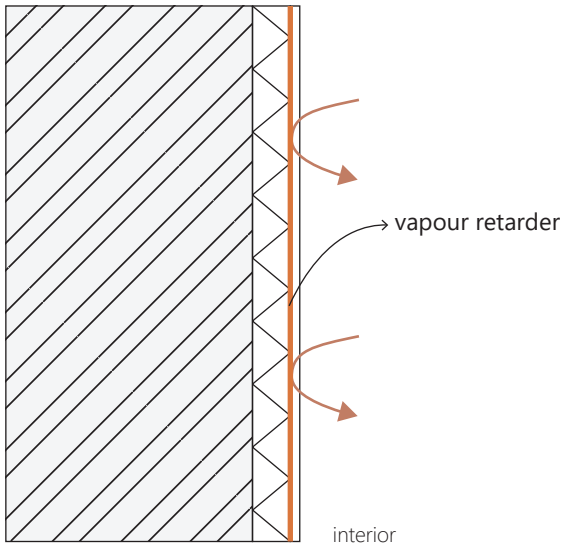


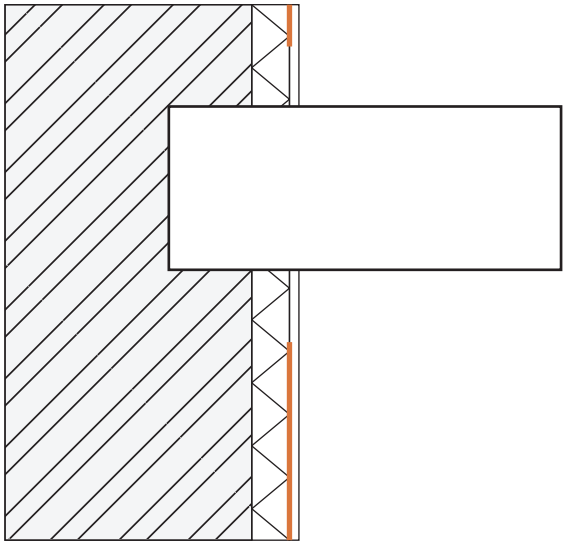

Vapour-tight
Vapour-open, capillary active
Vapour-open, non-capillary active

Vapour-tight

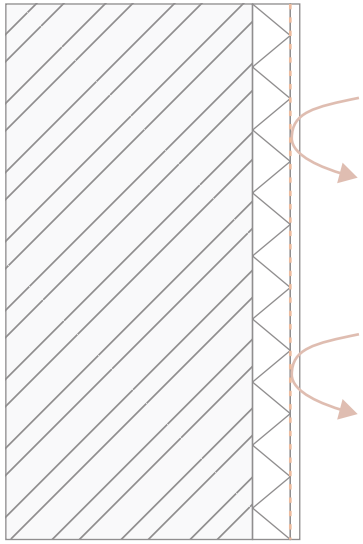


Vapour-tight

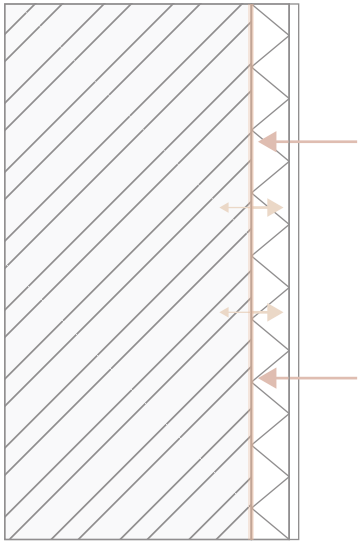




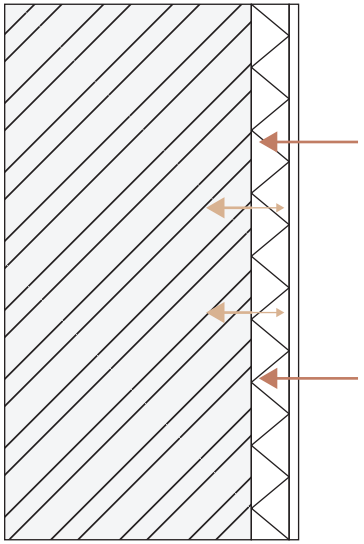
Vapour-tight



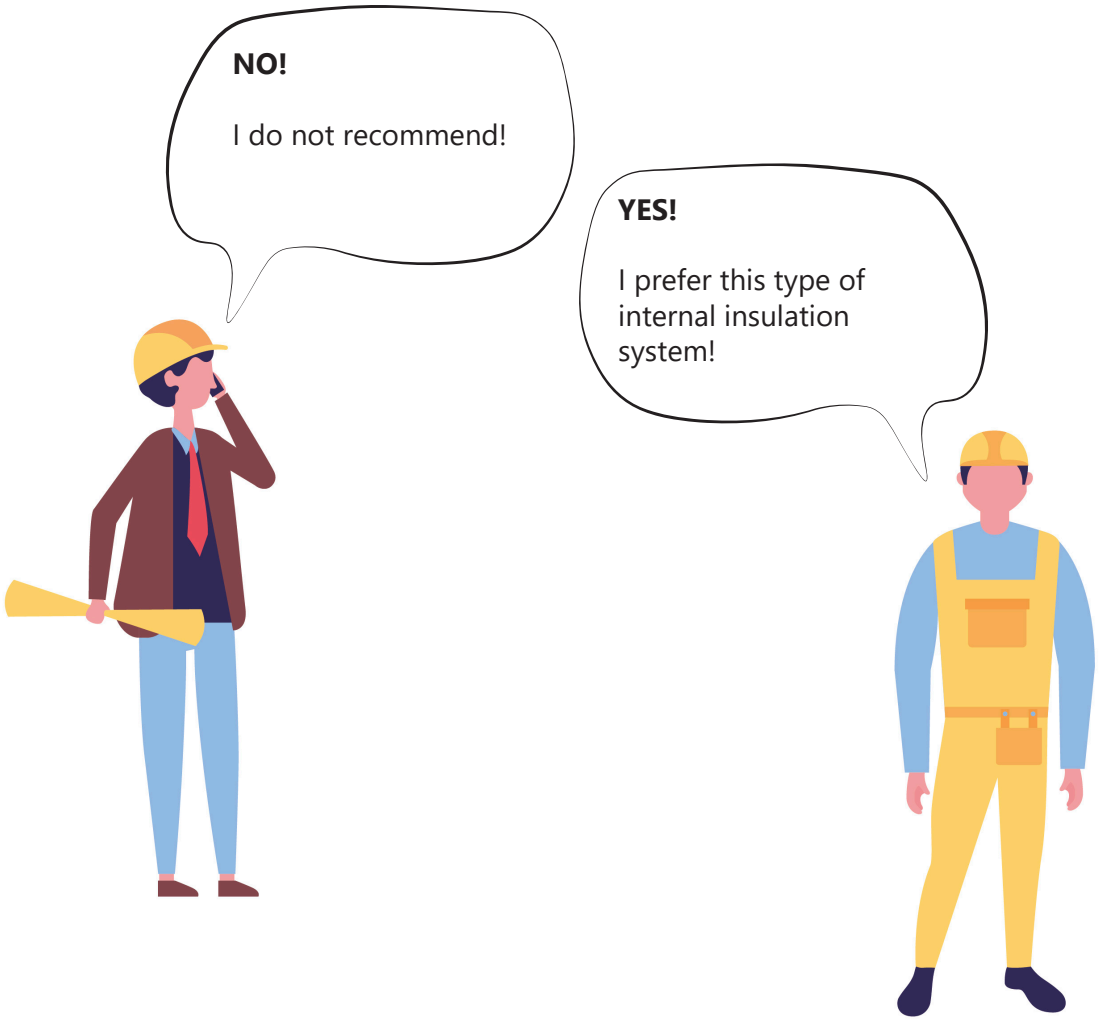
Vapour-open, capillary active



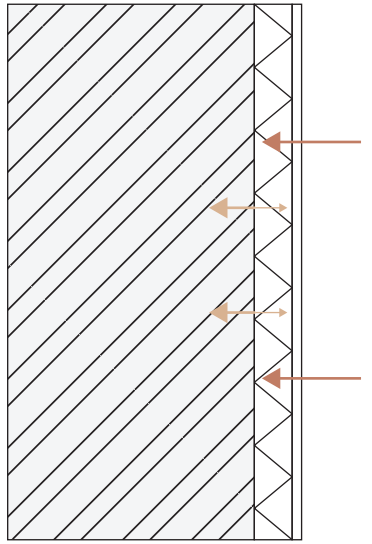
Vapour-open, non-capillary active



CONFLICT

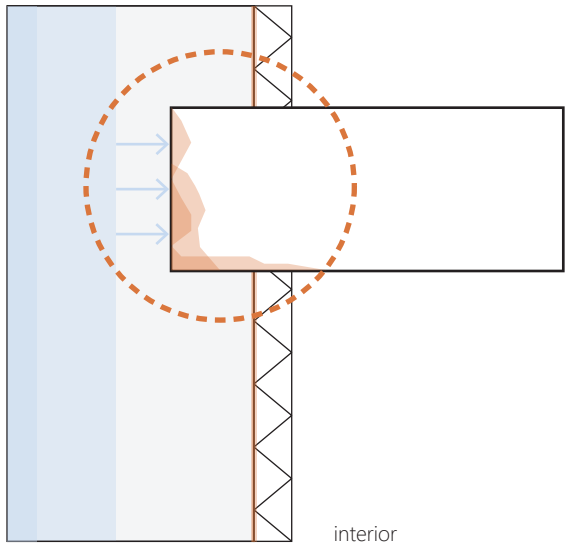


Vapour-open, non-capillary active



CONFLICT

Vapour-open, non-capillary active



Lack of knowledge about hygrothermal behaviour of vapour-open, non-capillary active internal insulation systems.

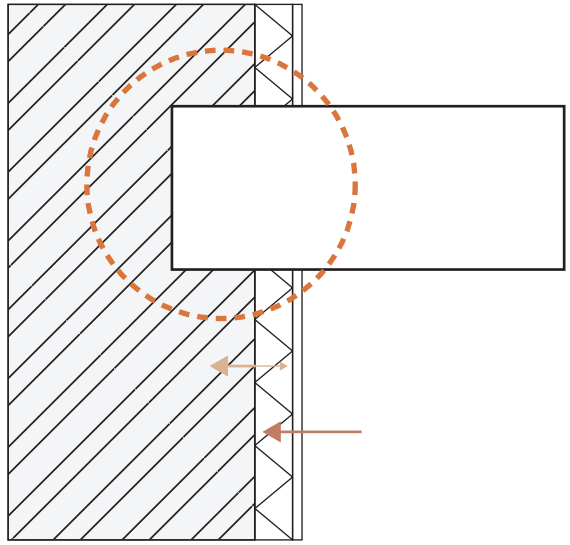
Missing link between theory and practice.

Problem

Main Problem Statement:

There is a **lack of knowlegde** about the **hygrothermal behaviour and risks** of vapour-open, non-capillary active internal insulation for solid brick masonry for historic residential buildings.

Vapour-open, non-capillary active



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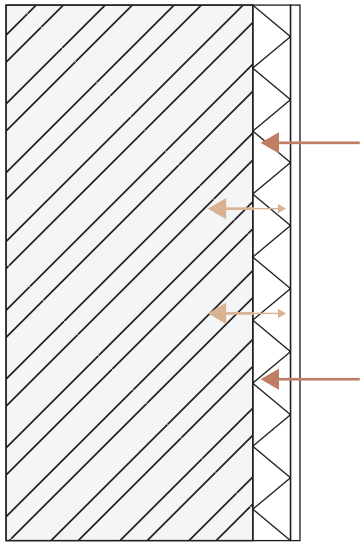
Vapour-open, non-capillary active

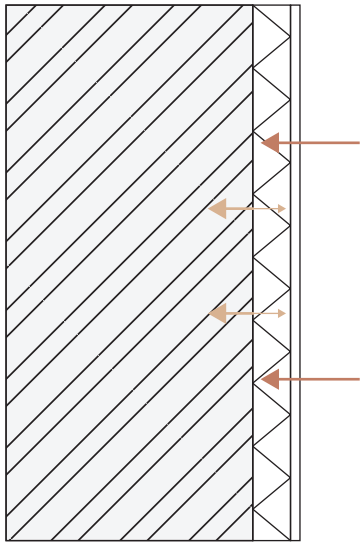


Objective

Main Objective:

To gain insight into the **most influential hygrothermal properties** of vapour-open, non-capillary active internal insulation for historic solid brick masonry.

Vapour-open, non-capillary active

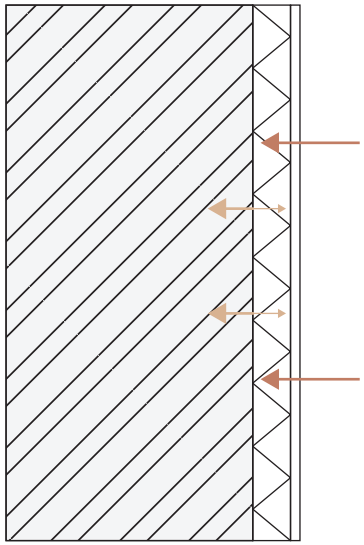


Research Question

Main Research Question:

What **hygrothermal property** of vapour-open, non-capillary active internal insulation for historic solid brick masonry **influences** the hygrothermal behaviour of this facade **most**?

Vapour-open, non-capillary active

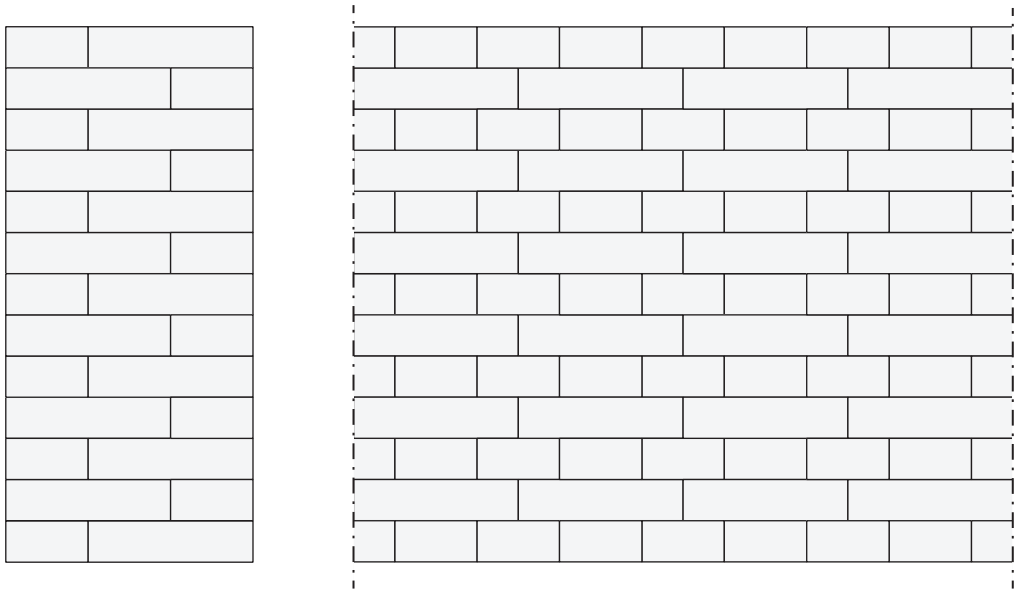


Content

1. Background research
2. Assessment hygrothermal performance
3. Parameter study
4. Conclusion
5. Recommendations
6. Discussion
7. Reflection

1. Background Research

Historic solid brick masonry



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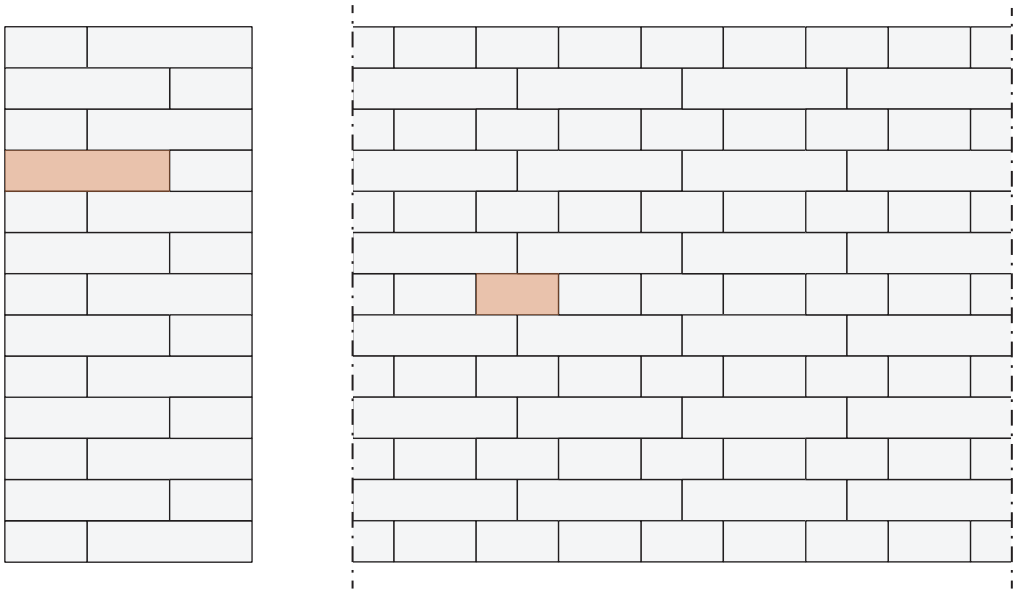
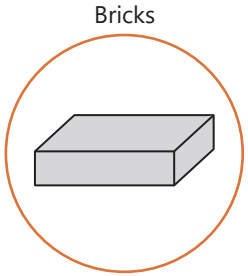
Historic solid brick masonry





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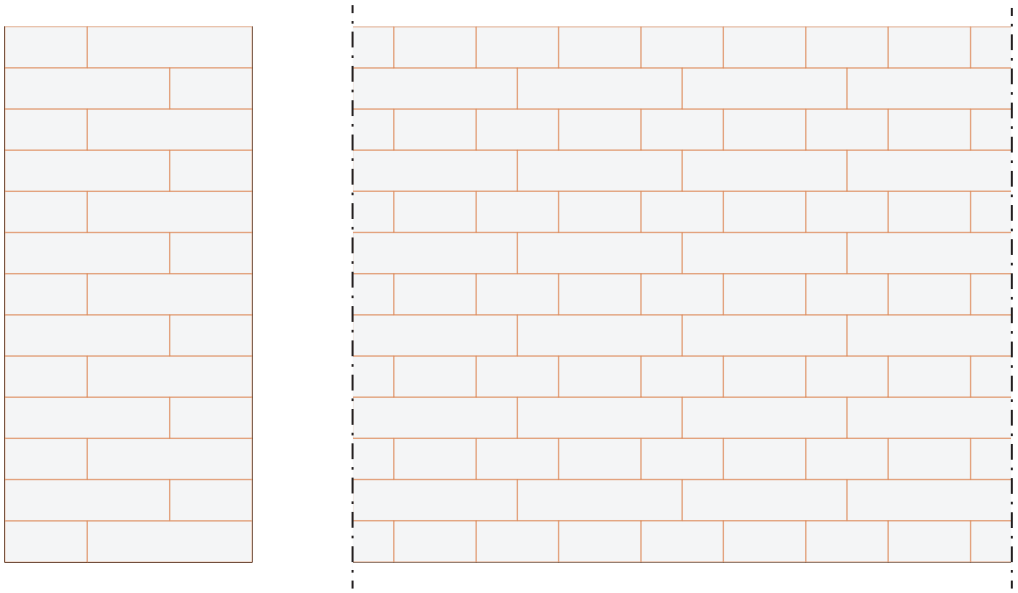
Historic solid brick masonry



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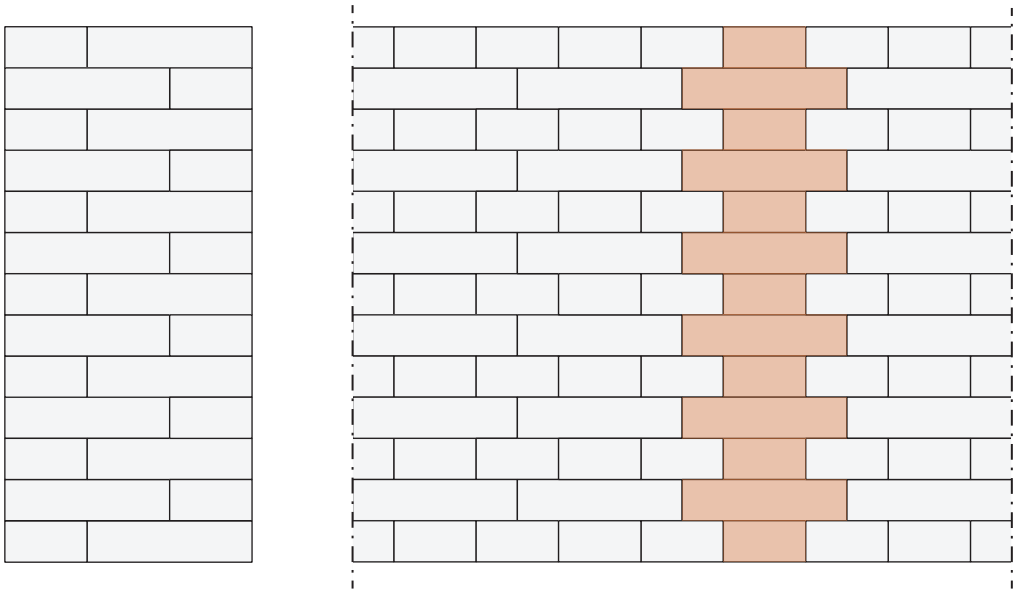
Historic solid brick masonry



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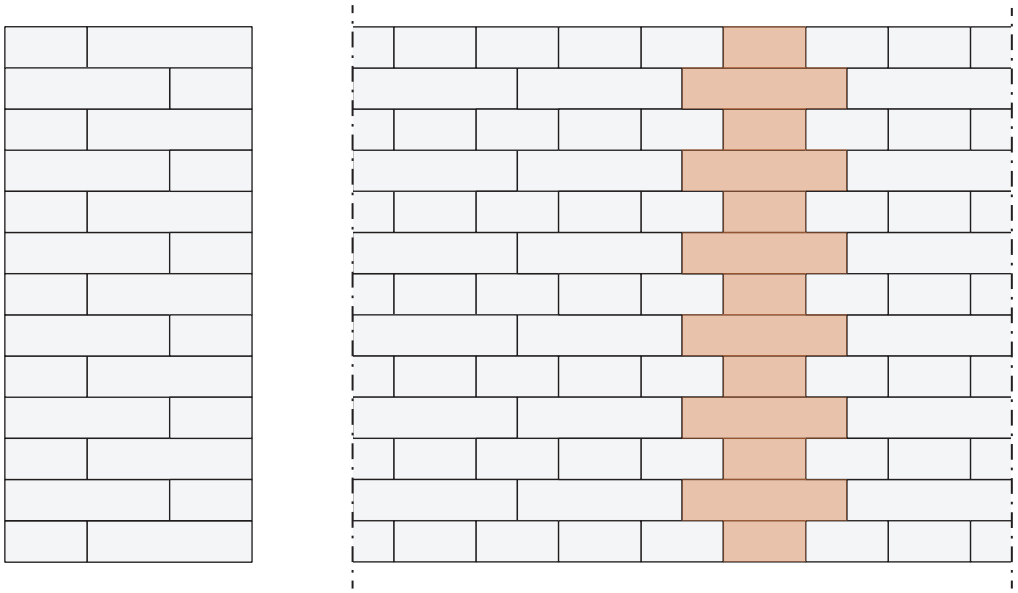
Historic solid brick masonry



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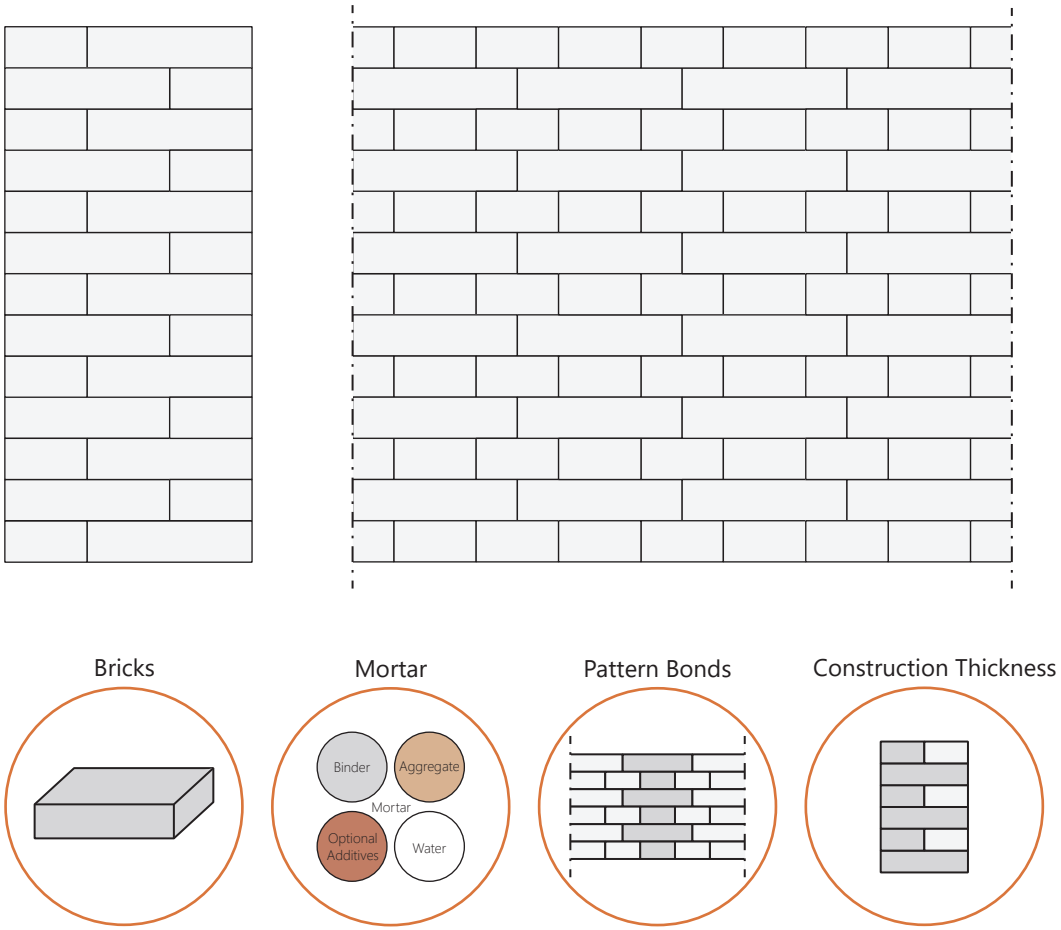
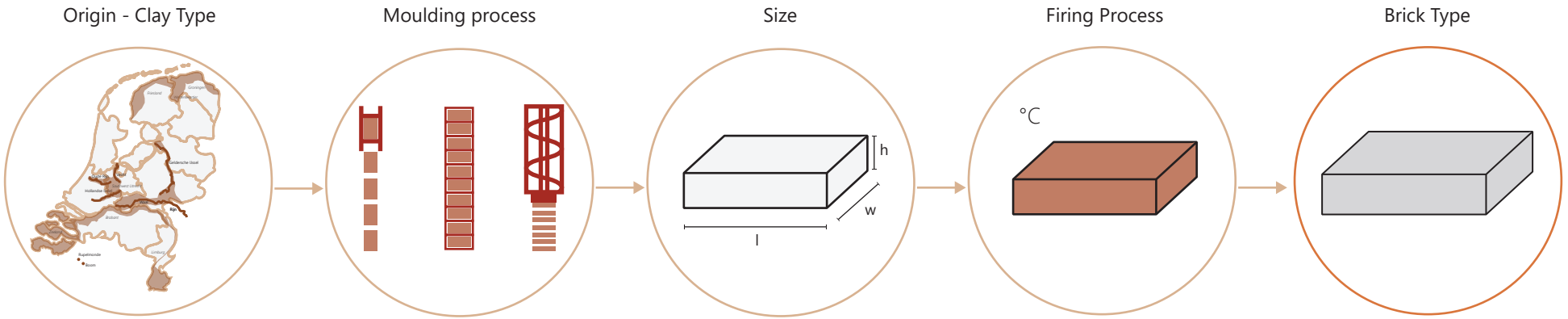


1. Background Research

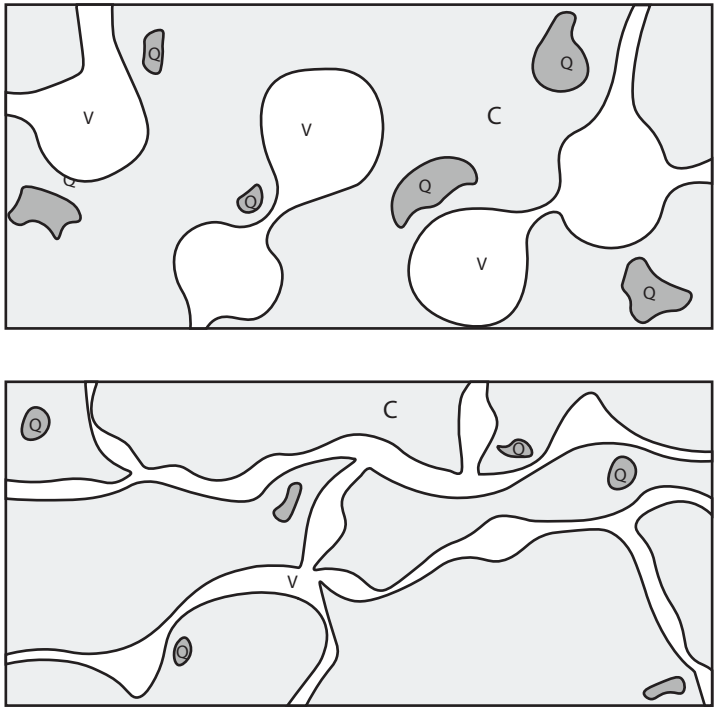
Historic solid brick masonry - bricks



1. Background Research

Historic solid brick masonry - bricks

Schematic pore structure brick

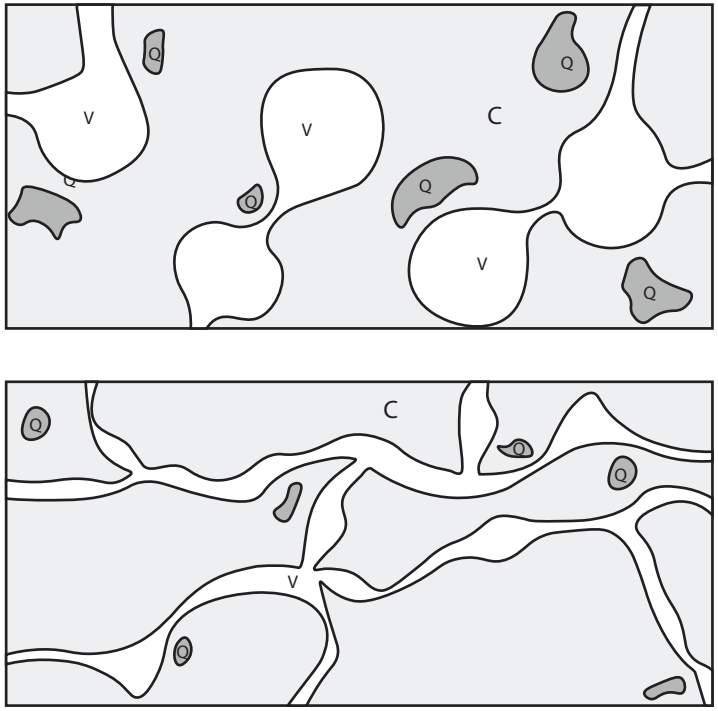


V - Void
C - Clay
Q - Quartz, sand

1. Background Research

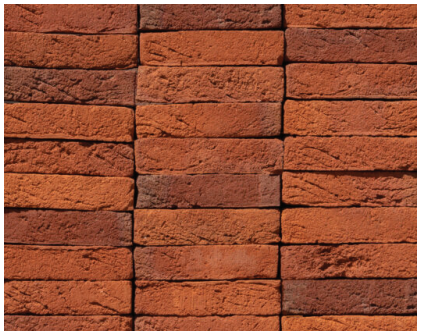
Historic solid brick masonry - bricks

Schematic pore structure brick



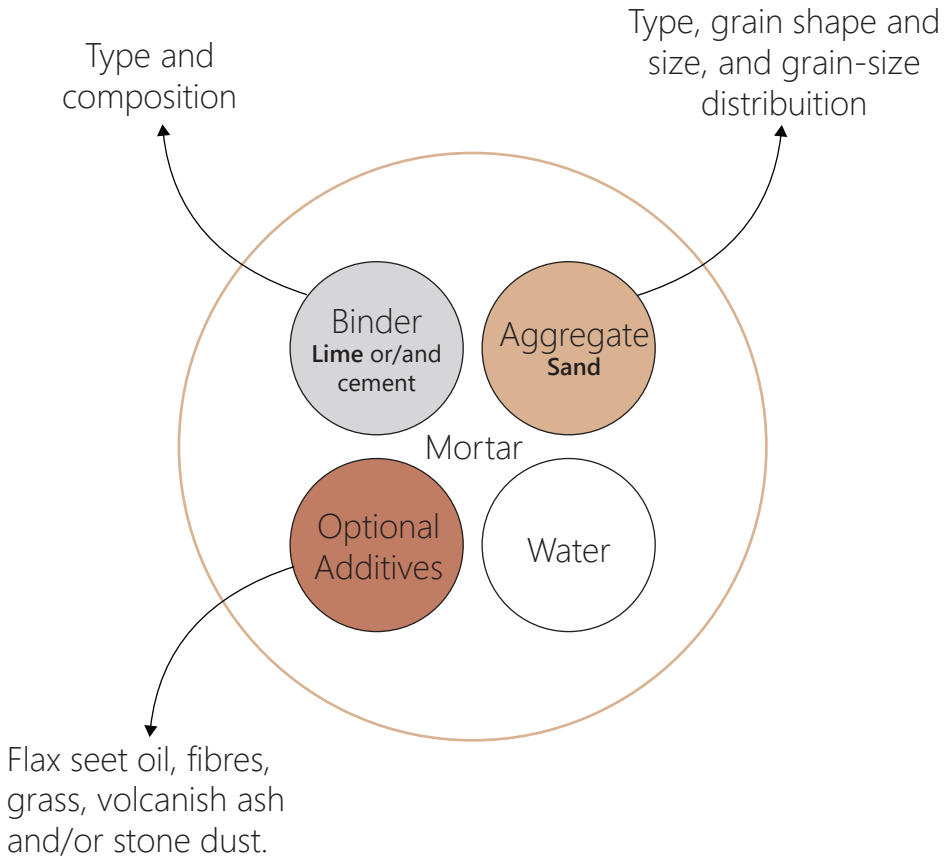
Tougher gray brick

Softer red brick



1. Background Research

Historic solid brick masonry - mortar



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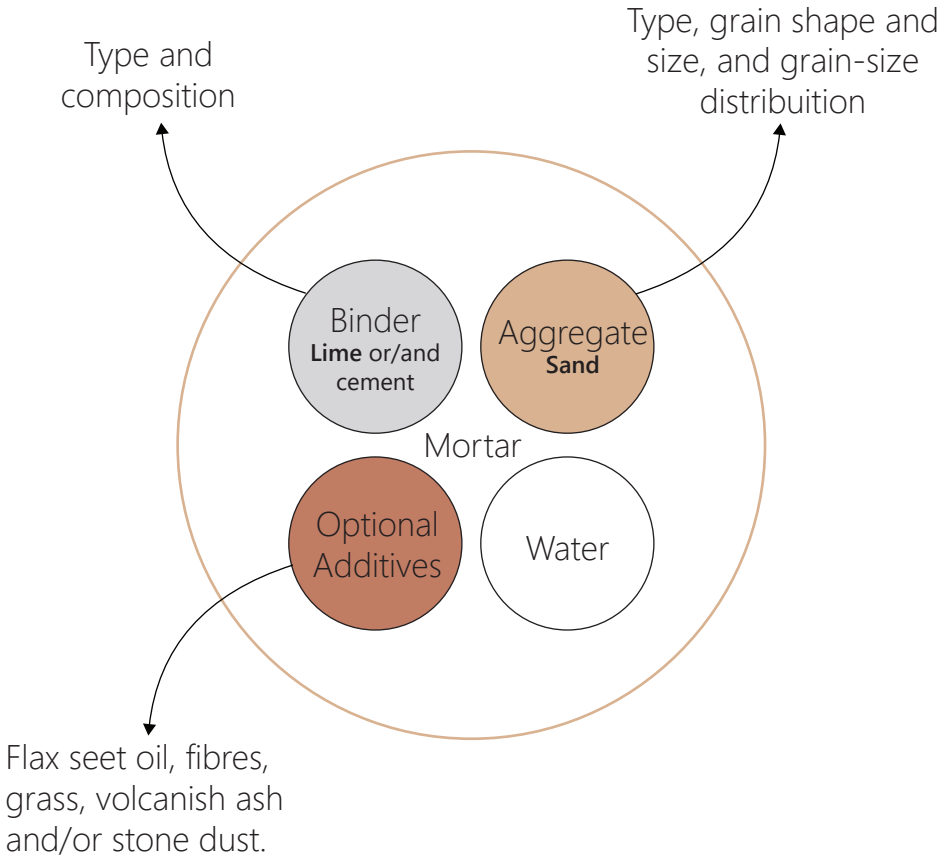
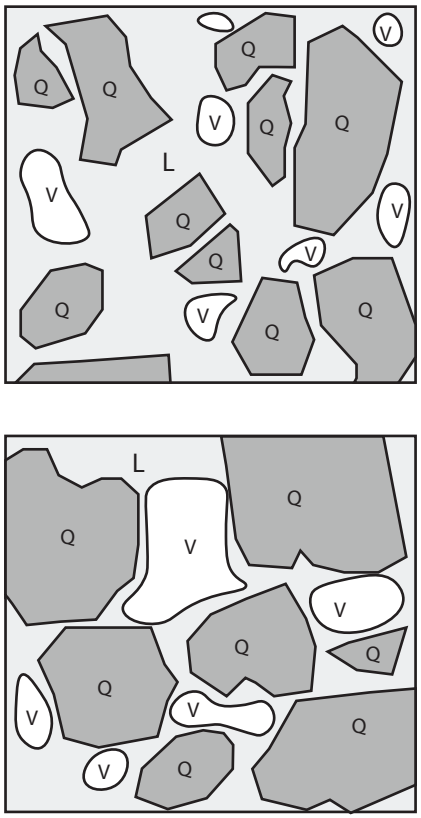
Historic solid brick masonry - mortar



Schematic pore structure mortar

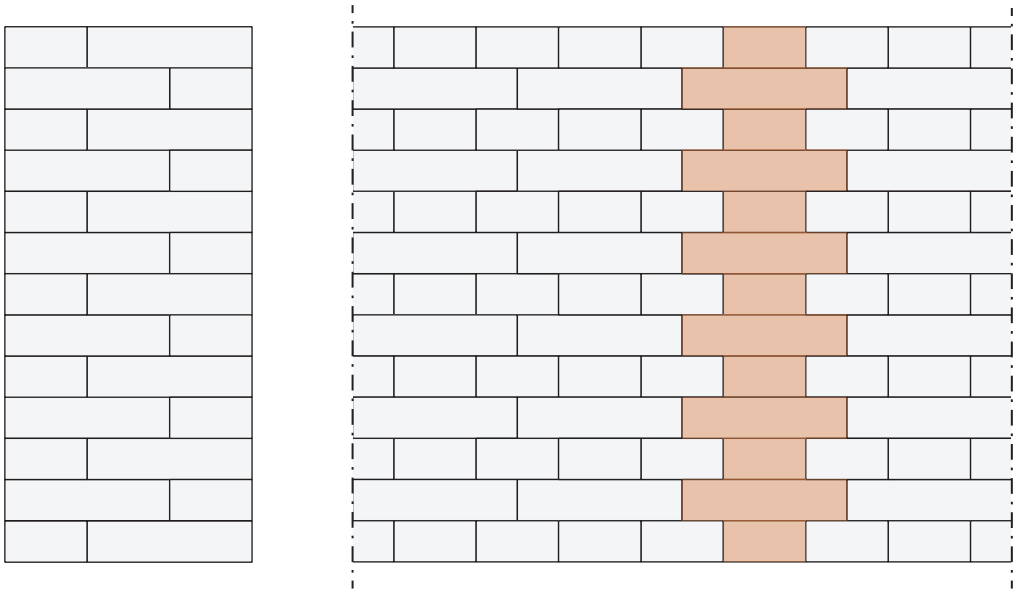


V - Void
L - Lime
Q - Quartz, sand

1. Background Research

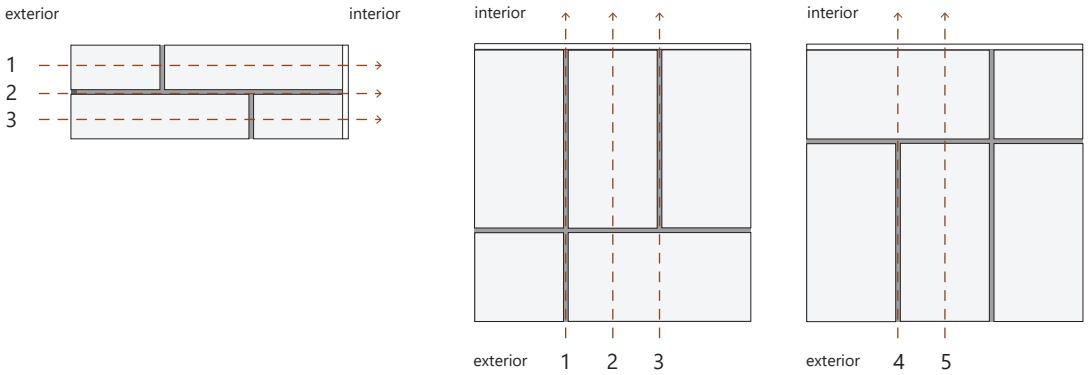
Historic solid brick masonry - pattern bond

English bond
[NL: staand verband]



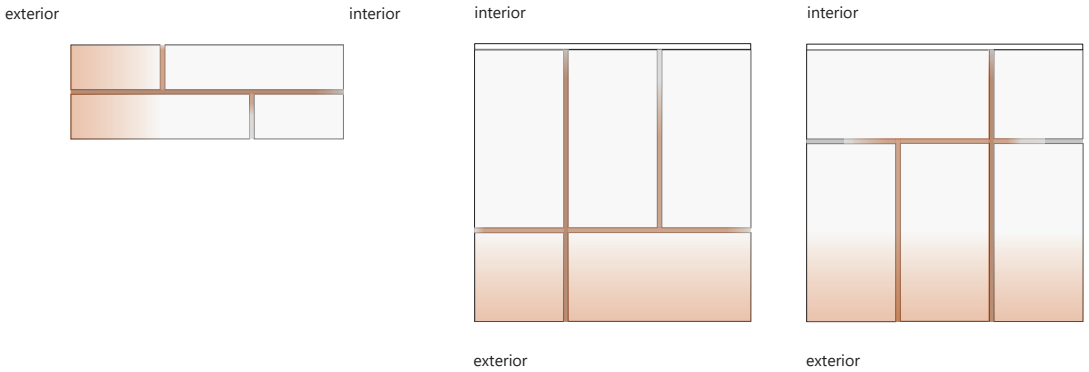
1. Background Research

Historic solid brick masonry - inhomogeneous



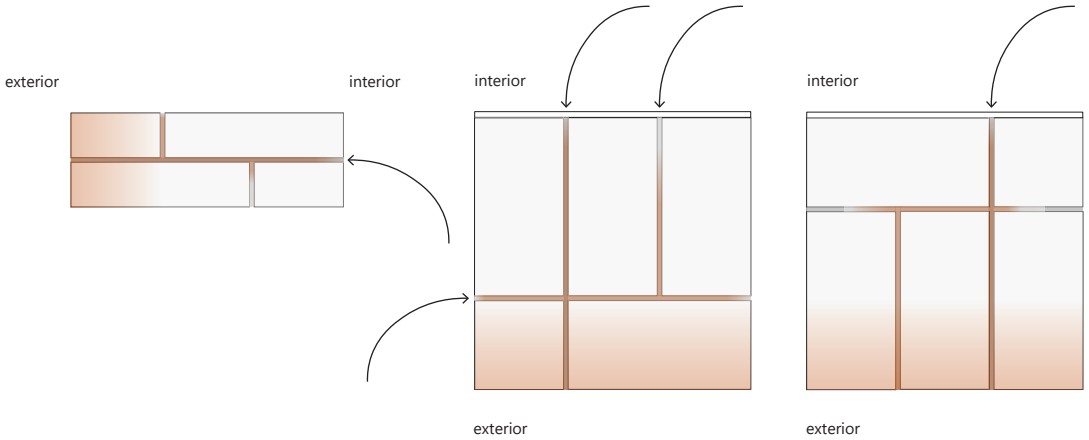
1. Background Research

Historic solid brick masonry - inhomogeneous



1. Background Research

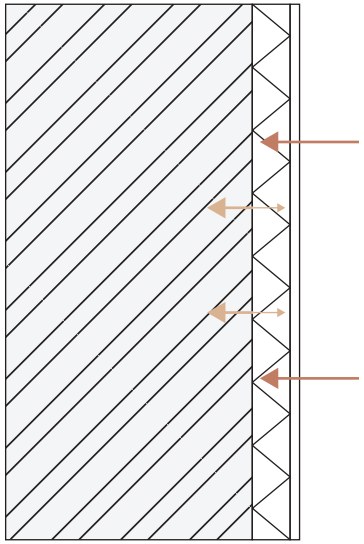
Historic solid brick masonry - inhomogeneous



1. Background Research

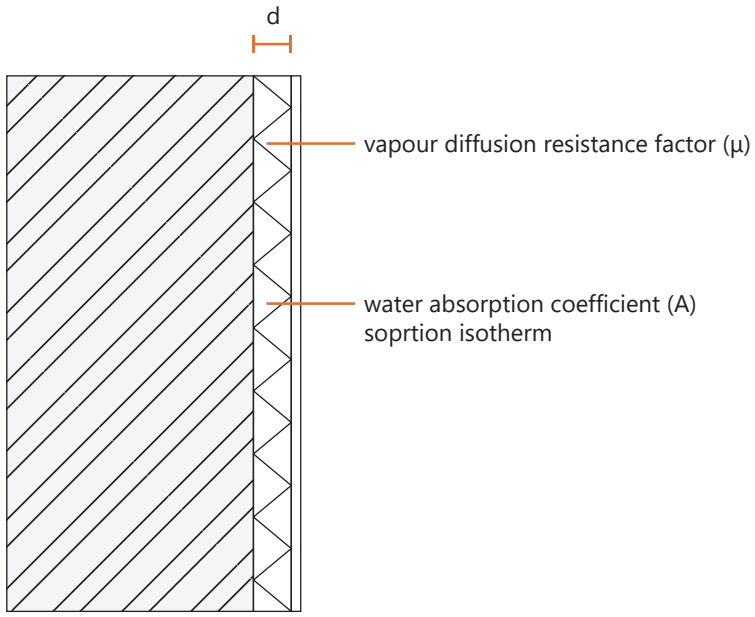
Vapour-open, non-capillary active insulation

Vapour-open, non-capillary active



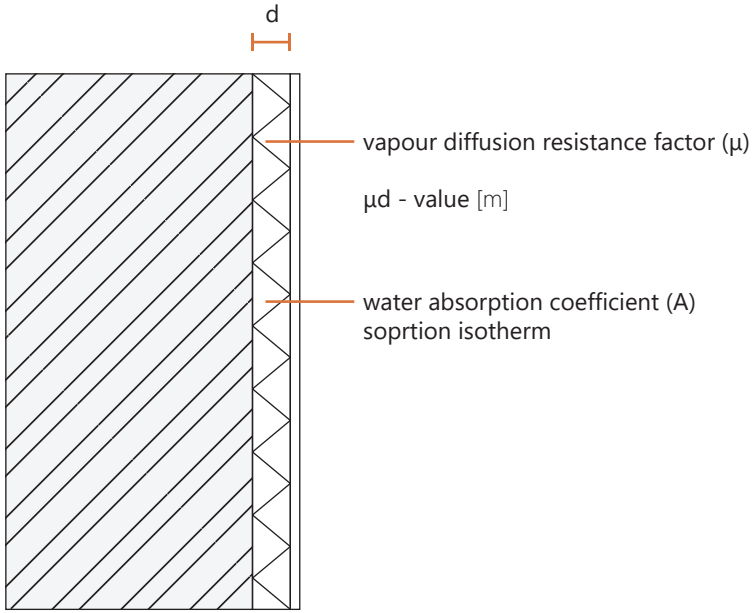
1. Background Research

Vapour-open, non-capillary active insulation



1. Background Research

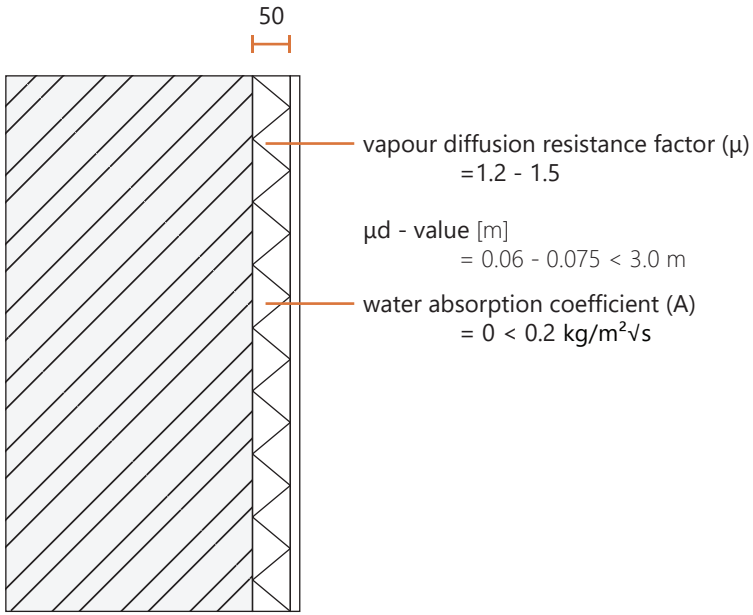
Vapour-open, non-capillary active insulation



System	Thermal conductivity coefficient (λ) [W/mK]	Vapour diffusion resistance factor (μ) [-]	Water absorption coefficient (A) [kg/m²√s]
Vapour-tight	Low, λ = 0.03 - 0.04 W/mK	μ > 60000 μd > 3 m	-
Vapour-open, non-capillary active	Low, λ = 0.03 - 0.04 W/mK	μ = 5 - 50 μd < 3 m	-
Vapour-open, capillary active	Medium, λ = 0.06 - 0.065 W/mK	μ = 5 - 15 μd < 3 m	High, A > 0.2 kg/m

1. Background Research

Vapour-open, non-capillary active insulation



Glass Wool

Rock Wool

Material		Thermal conductivity coefficient (λ) [W/mK]	Vapour diffusion resistance factor (μ) [-]	Water absorption coefficient (A) [kg/m²√s]
Traditional *these materials can be part of a vapour-tight or vapour-open. non-capillary active system.*	Cork	0.040 - 0.045	5 - 30	-
	Cellullar glass	0.042	5000 - 7000	-
	Glasswool	0.040	1.2	0
	Rockwool	0.040	1.5	0
	EPS	0.035	15 - 200	0.00001
	XPS	0.030	200 - 250	0
	PUR/PIR	0.030	60 - 80	0
Modern	Aerogel	0.013	3 - 5	0
	Vacuum panel	0.007	1500000	0.000008
Vapour-open, capillary active	Calcium silicate	0.060	6 - 9	0.8 - 1.1
	Wood fibre board	0045	10 - 16	0.2 - 0.3

Content

1. Background research

2. Assessment hygrothermal performance

3. Parameter study

4. Conclusion

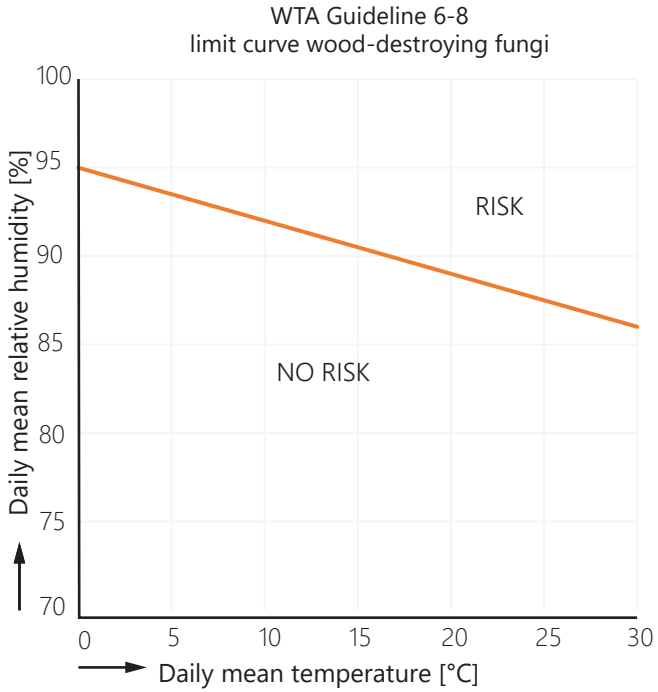
5. Recommendations

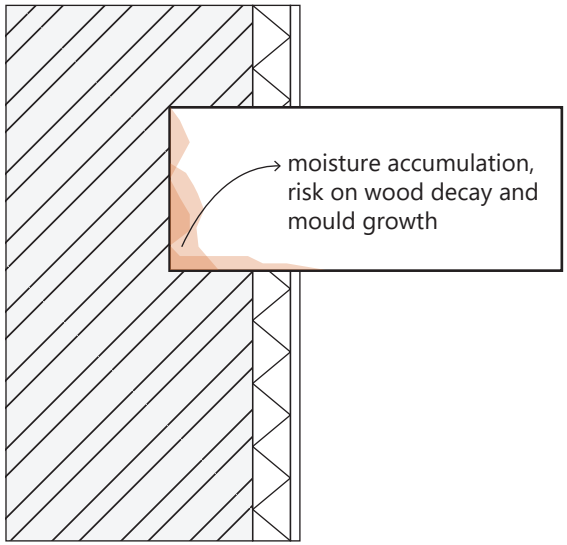
6. Discussion

7. Reflection

2. Assessment hygrothermal performance

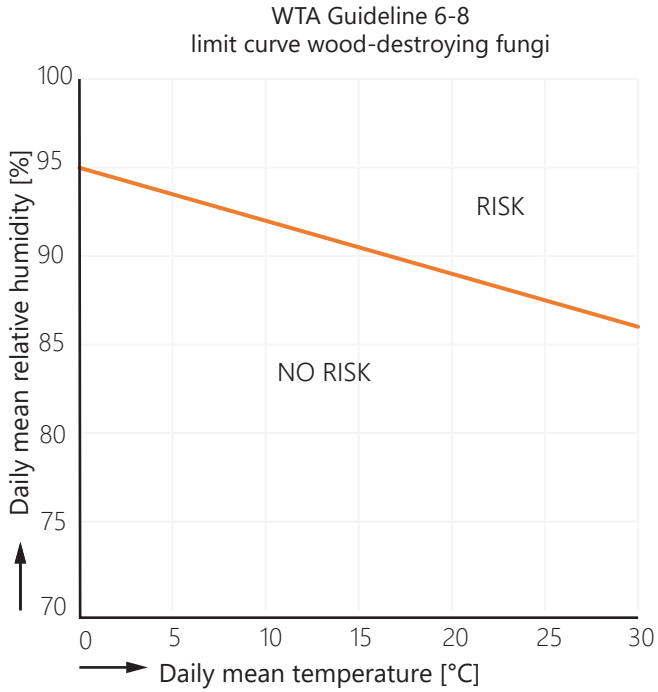
WTA Guideline 6-8

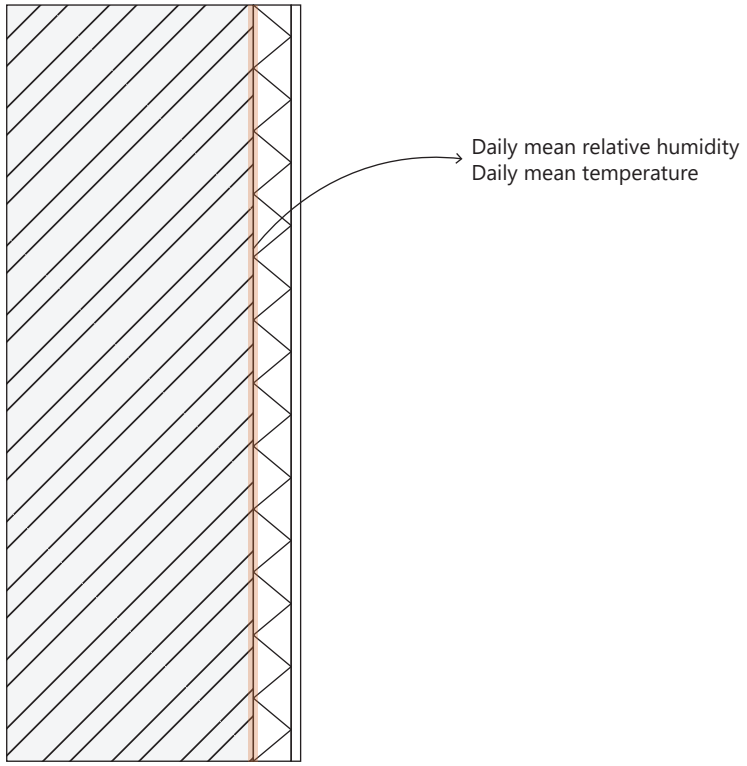




2. Assessment hygrothermal performance

WTA Guideline 6-8





Content

1. Background research

2. Assessment hygrothermal performance

3. Parameter study

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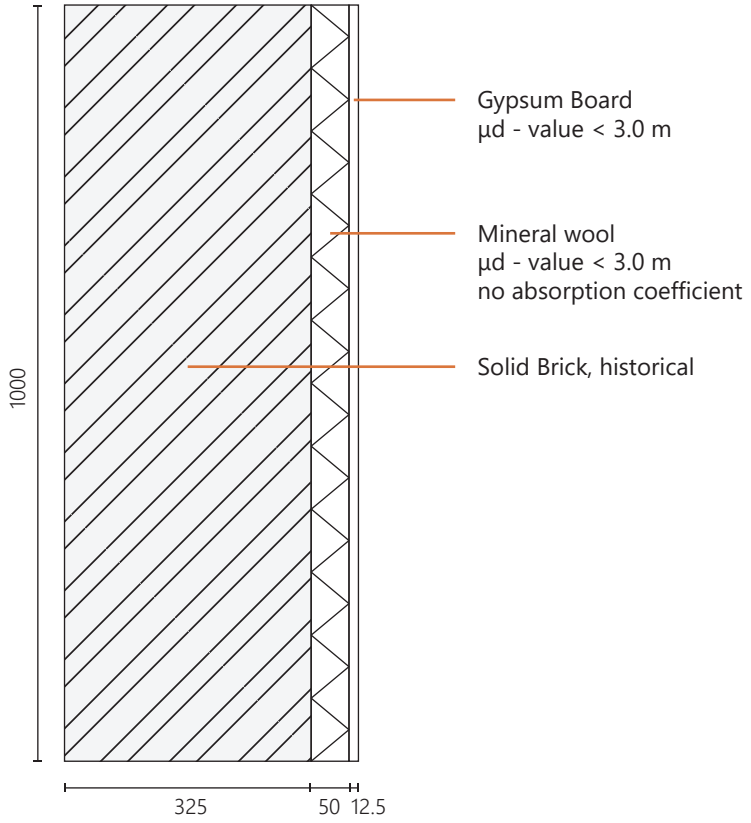
3. Parameter Study

Content

- Input
- Performance Indicator
- Parameters
- Single variation of parameters
- Combining parameters
- Variation of two parameters
- Relation maximum relative humidity and performance indicator
- Prediction method

3. Parameter Study

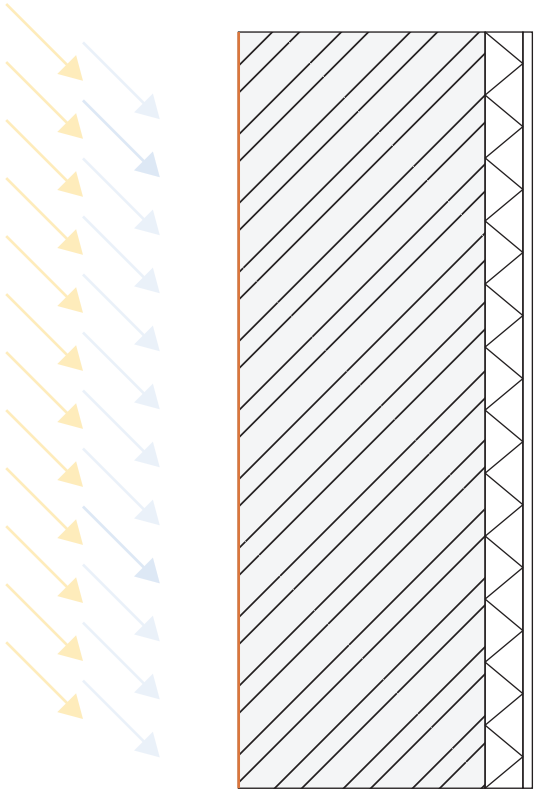
Input - materials

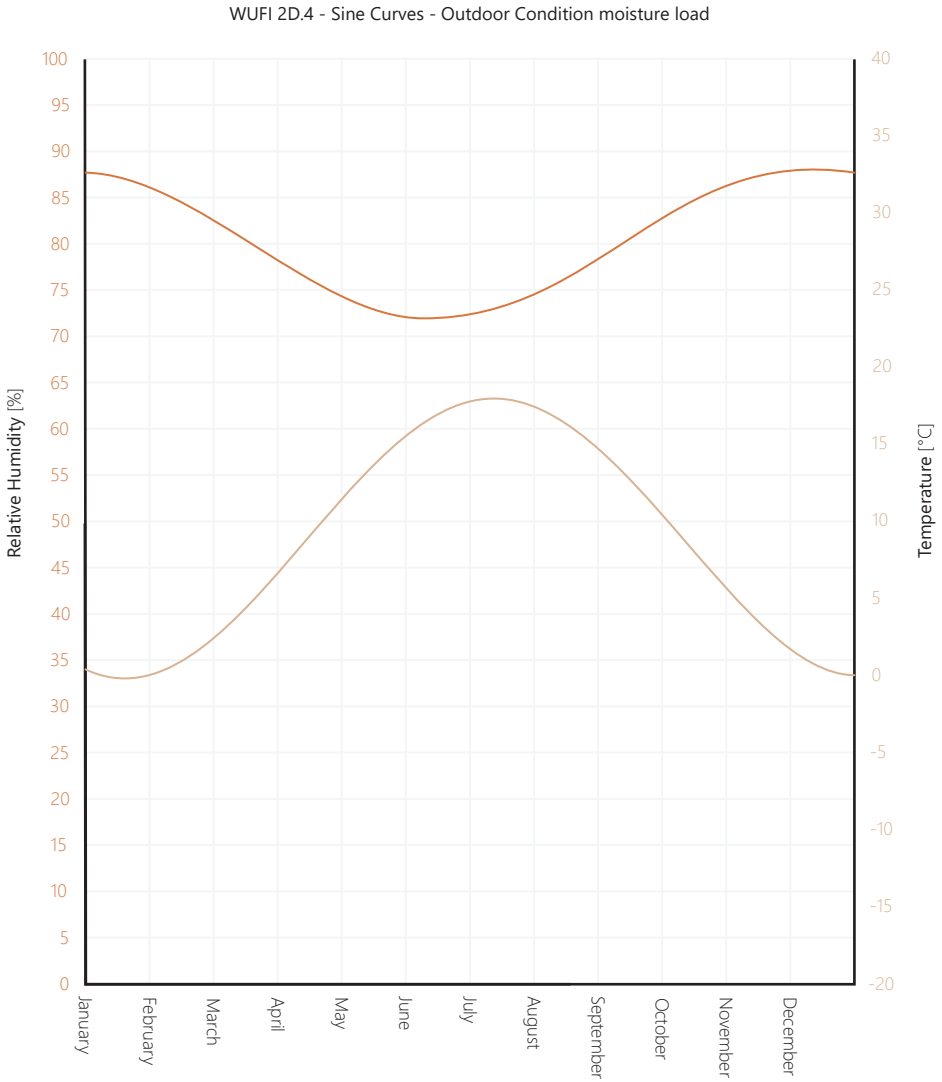


3. Parameter Study

Input - outdoor boundary condition

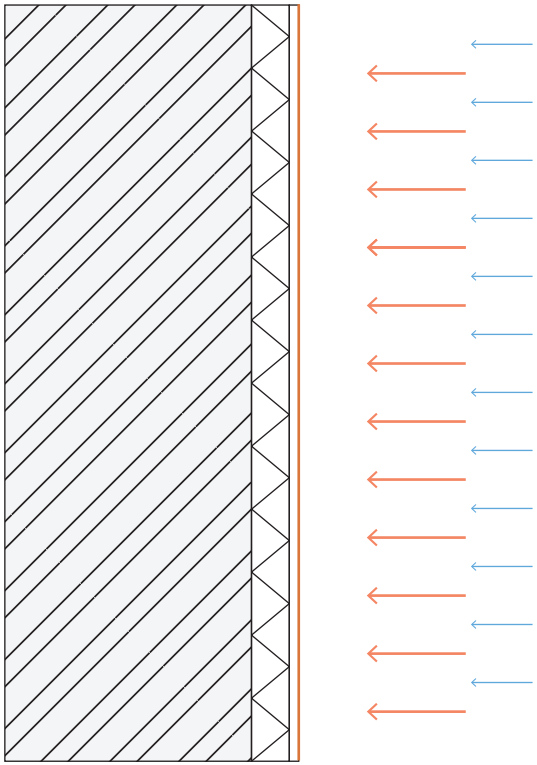
Outdoor temperature
Outdoor relative humidity





3. Parameter Study

Input - indoor boundary condition

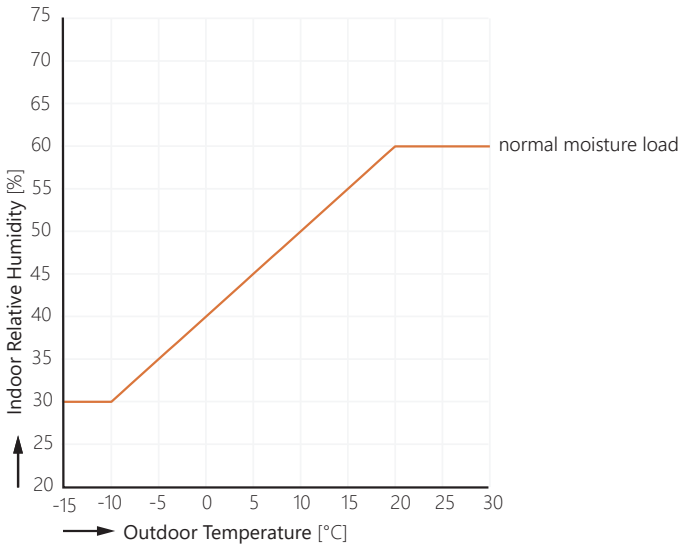


Indoor temperature
Indoor relative humidity

Normal moisture load: 'houses, normal situations, including kitchens and bathrooms'

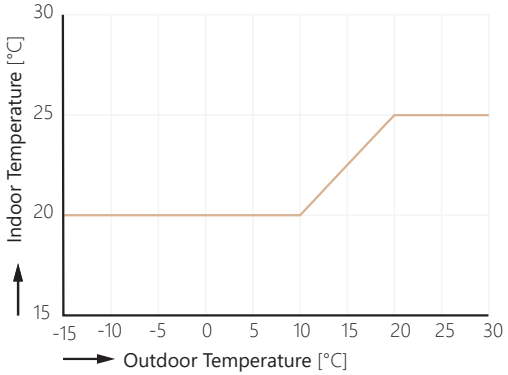
WTA Guideline 6-2

indoor climate classes - indoor relative humidity



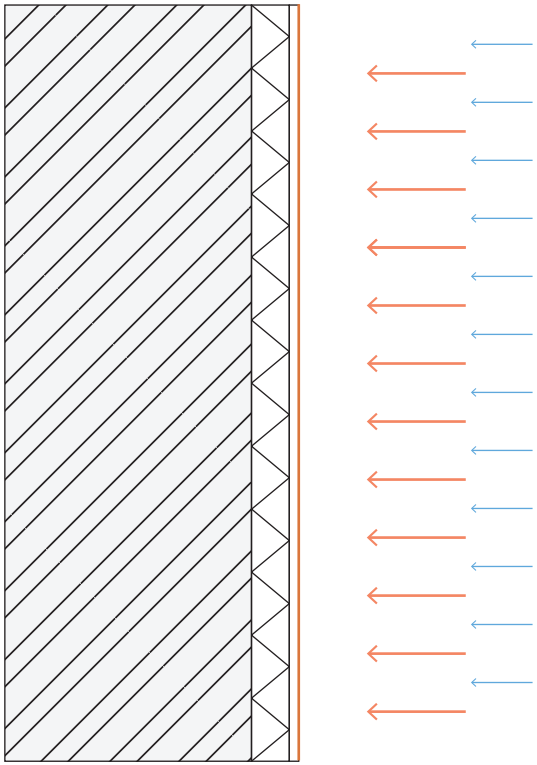
WTA Guideline 6-2

indoor climate classes - indoor temperature



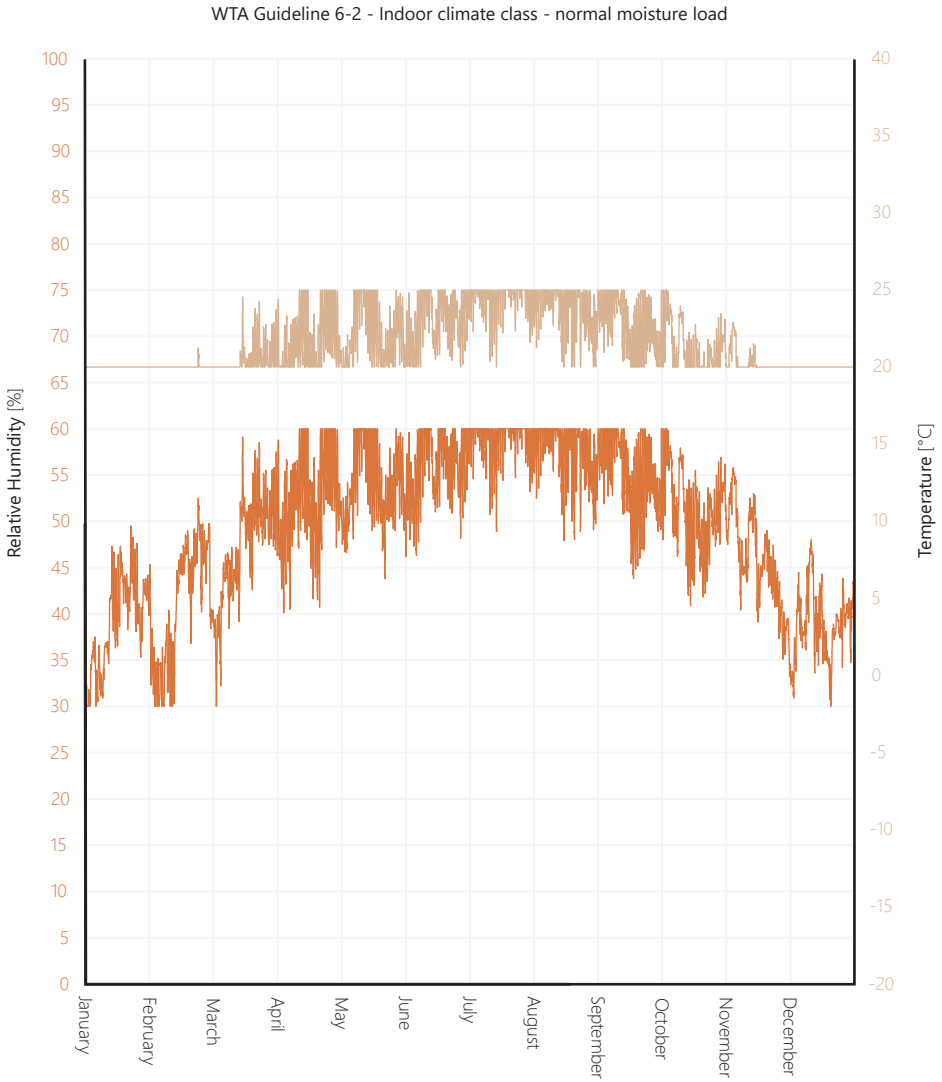
3. Parameter Study

Input - indoor boundary condition



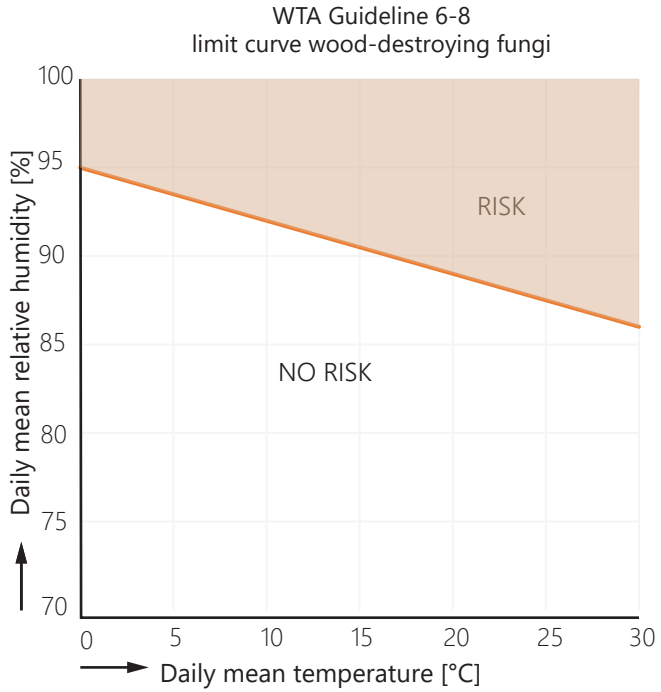
Indoor temperature
Indoor relative humidity

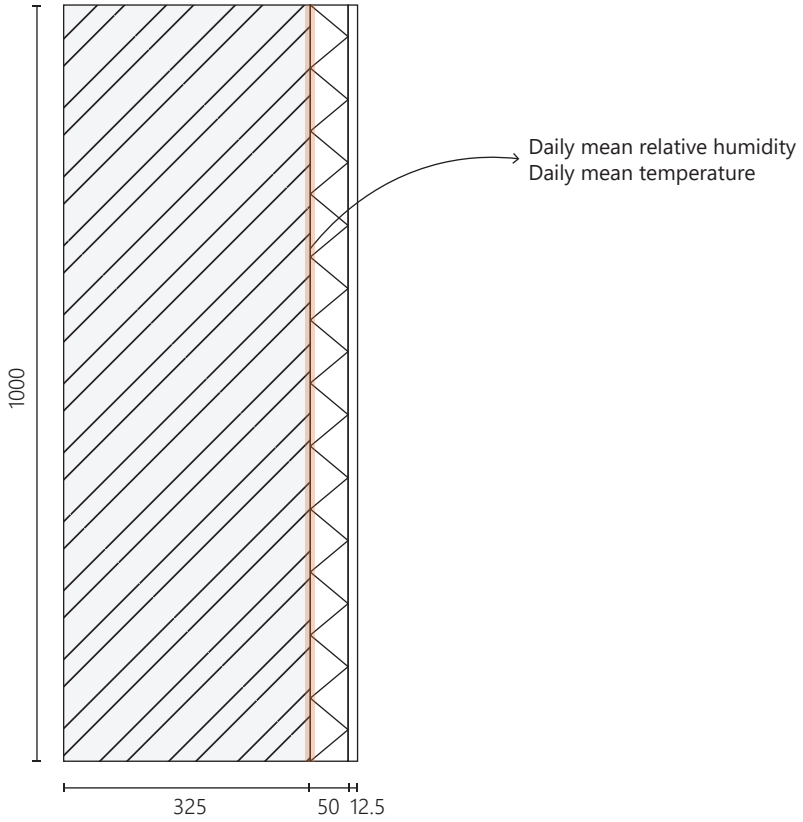
Normal moisture load: ‘houses, normal situations, including kitchens and bathrooms’



3. Parameter Study

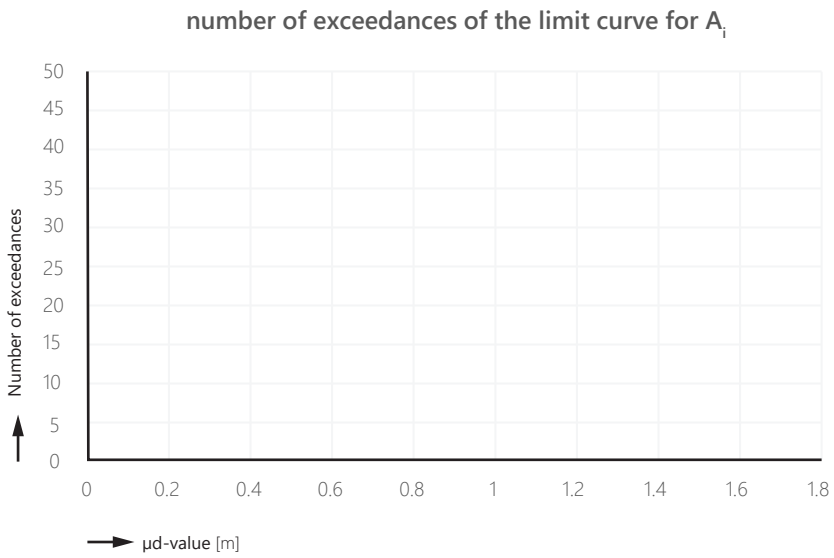
Performance indicator





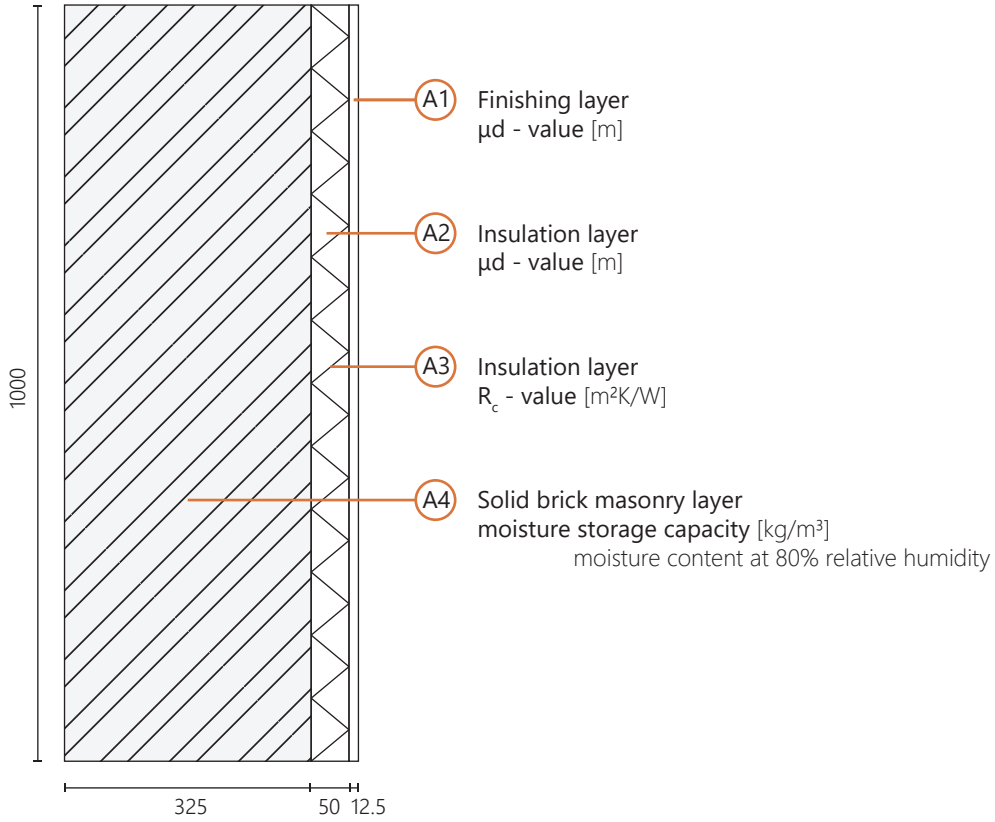
3. Parameter Study

Relation pererformance indicator and varied parameter - results



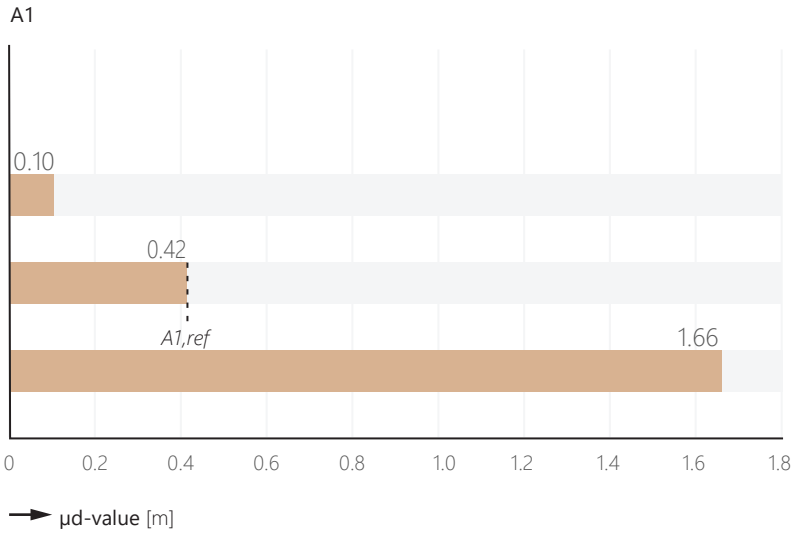
3. Parameter Study

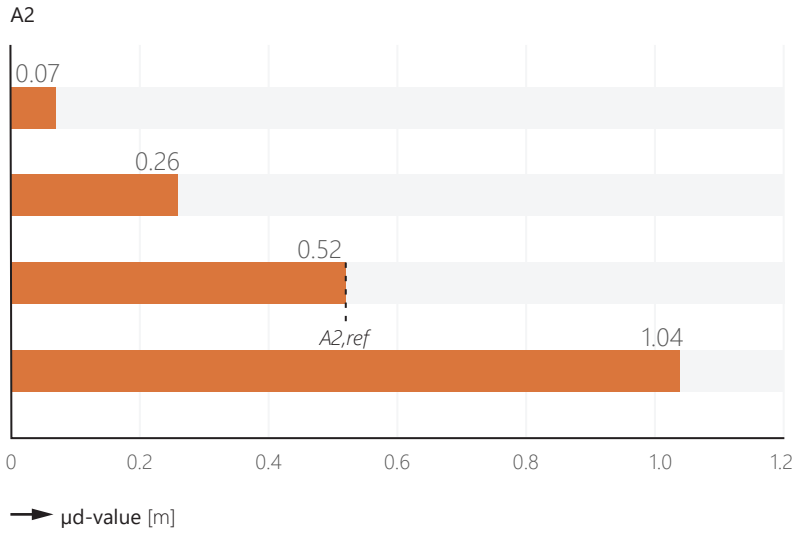
Parameters

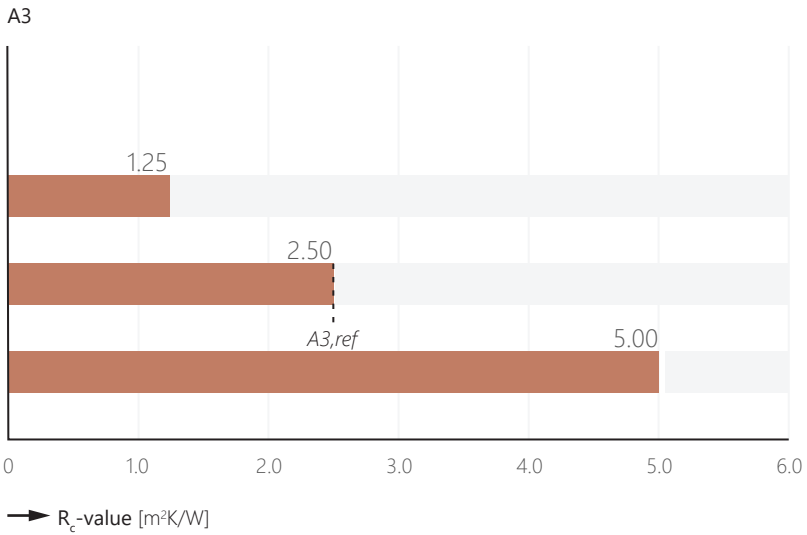


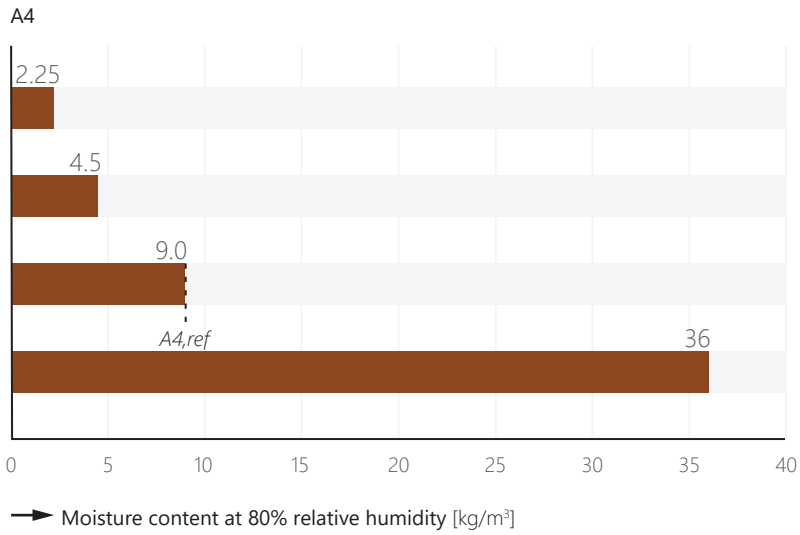
3. Parameter Study

Parameters - range of values



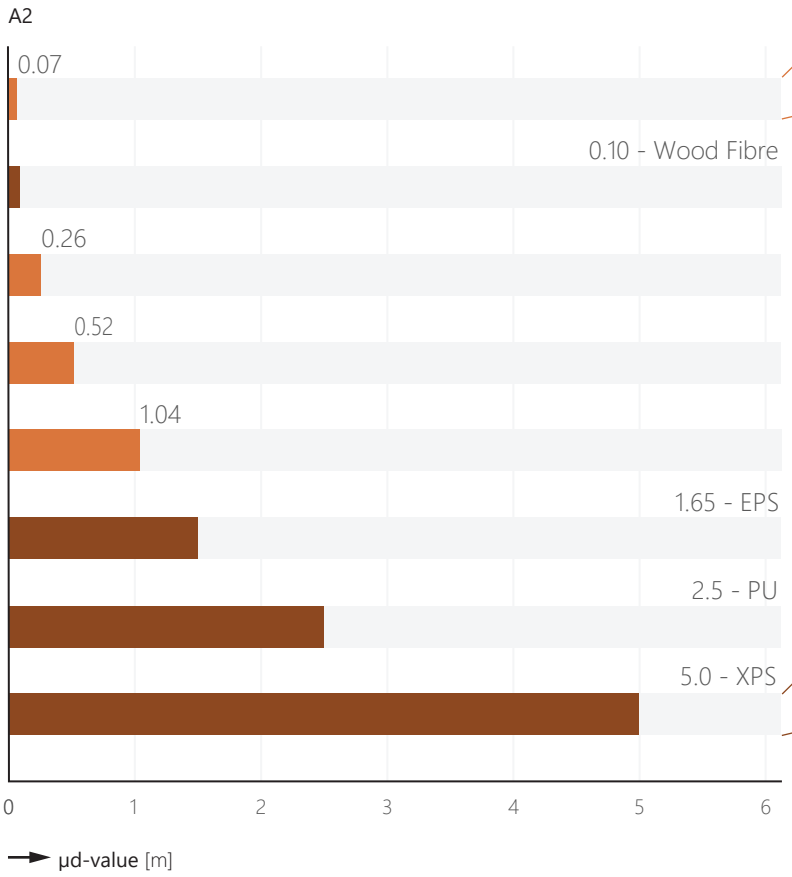






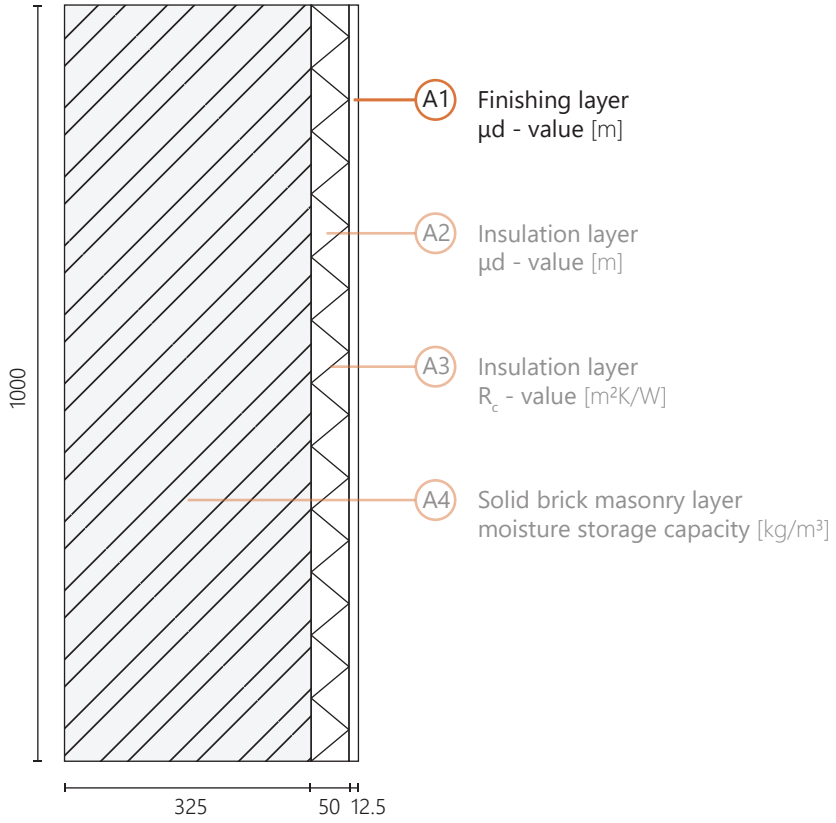
3. Parameter Study

Parameters - range of values



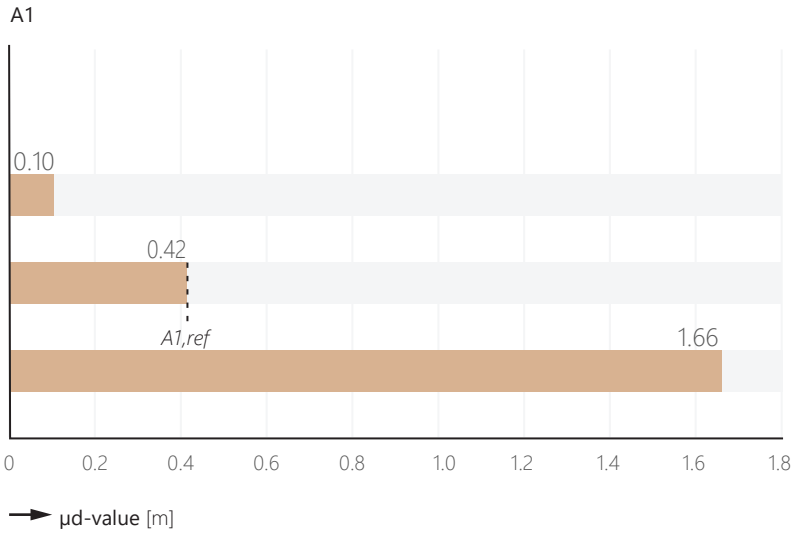
3. Parameter Study

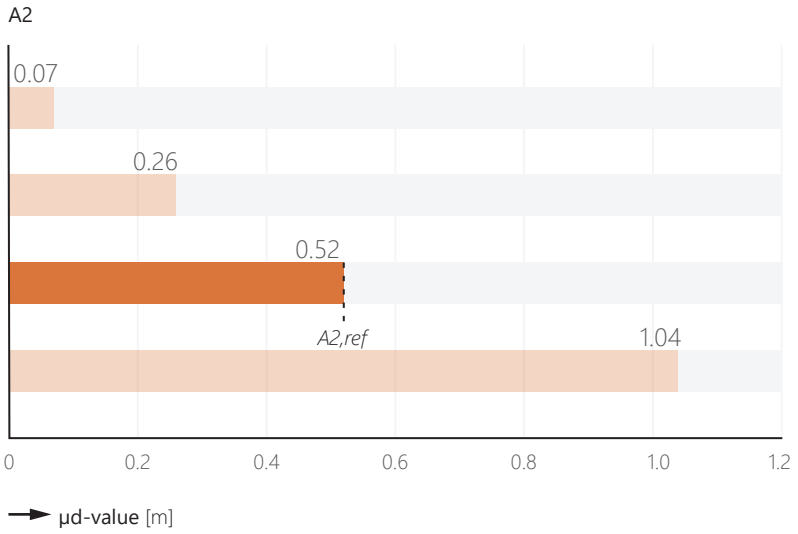
Single variation

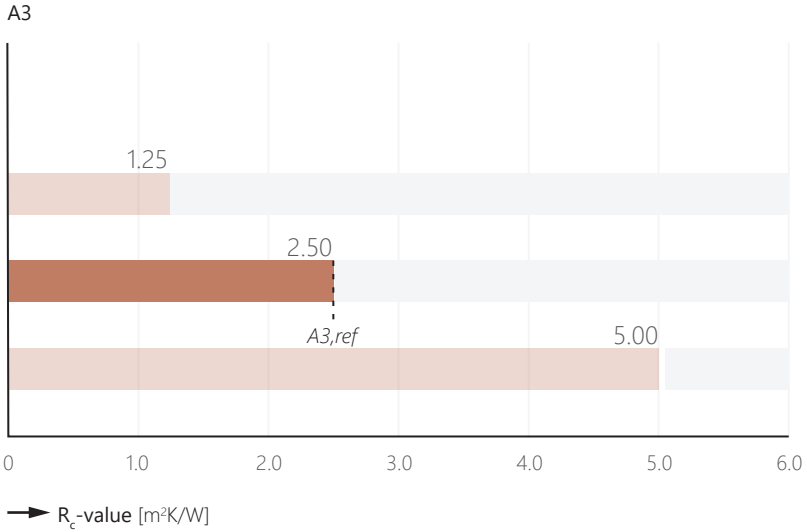


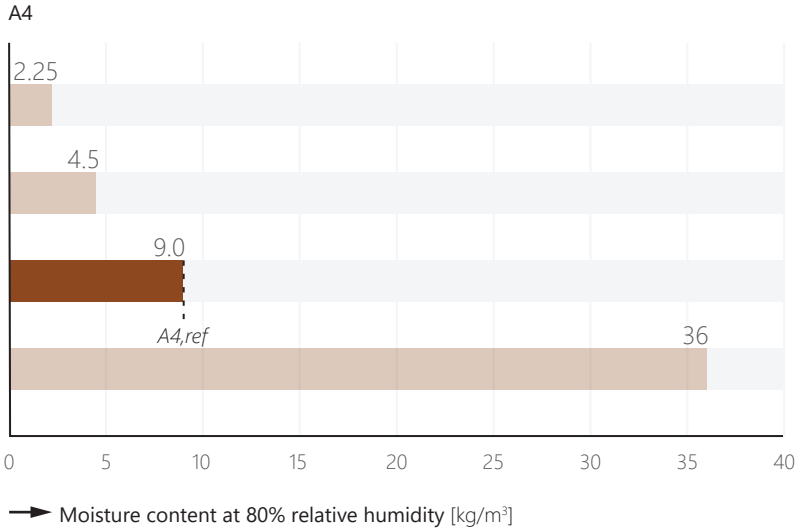
3. Parameter Study

Single variation



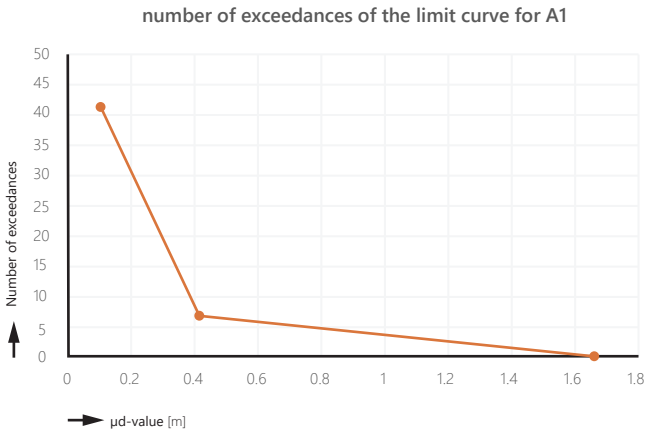


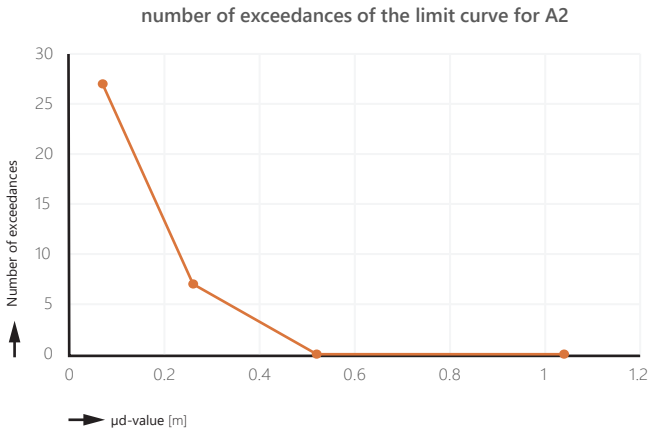


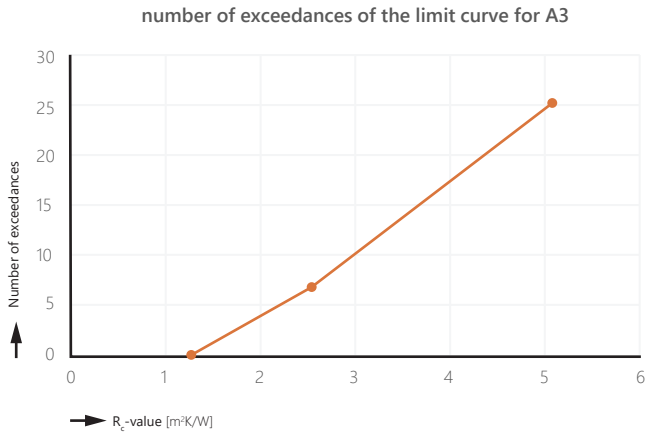


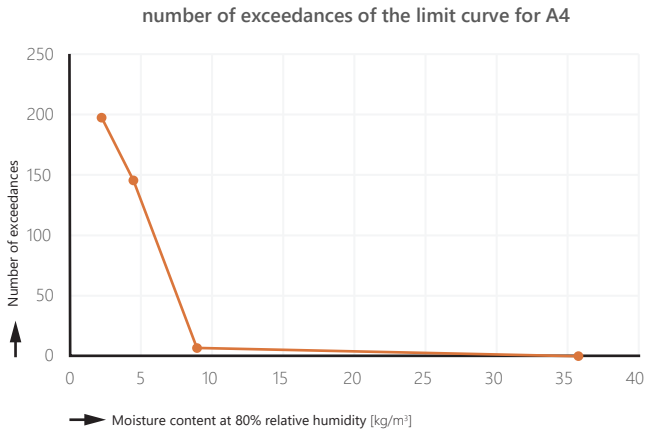
3. Parameter Study

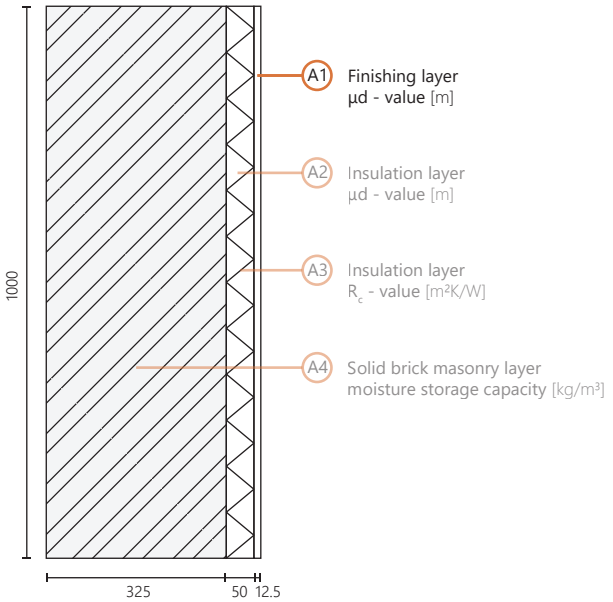
Single variation - results





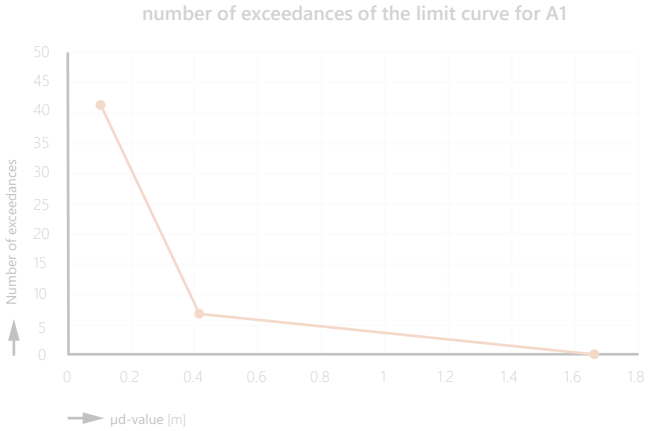


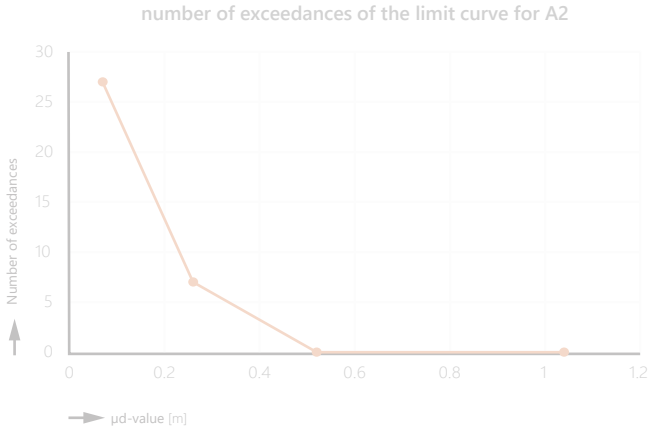


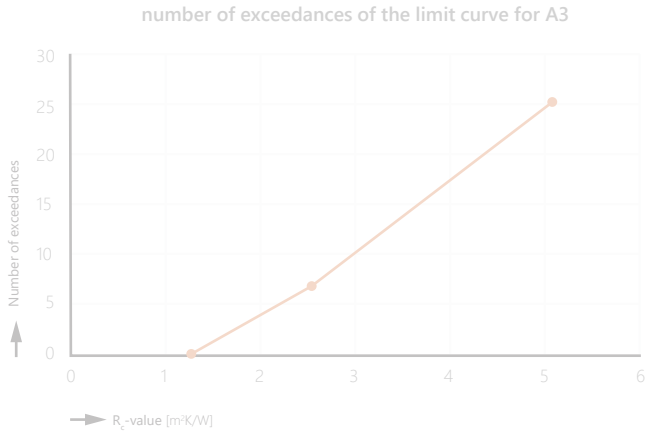


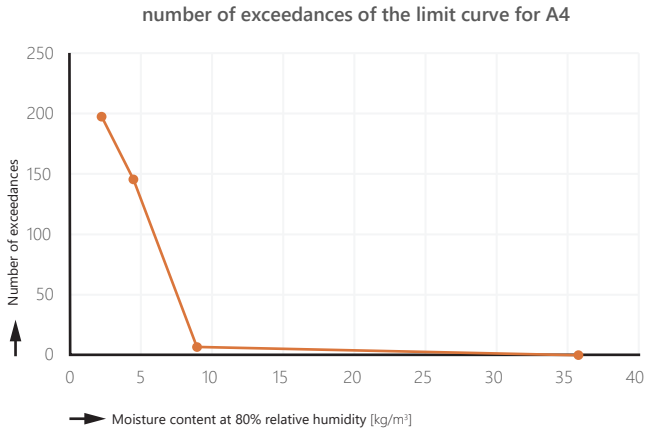
3. Parameter Study

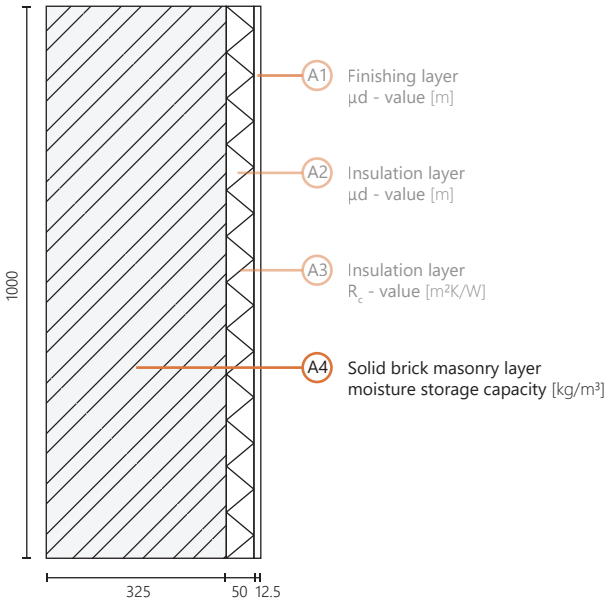
Single variation - results





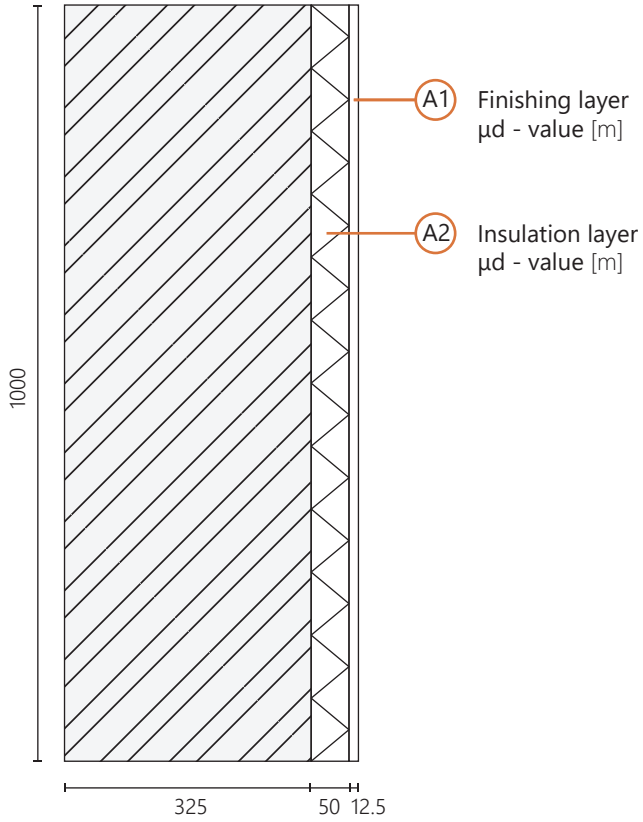






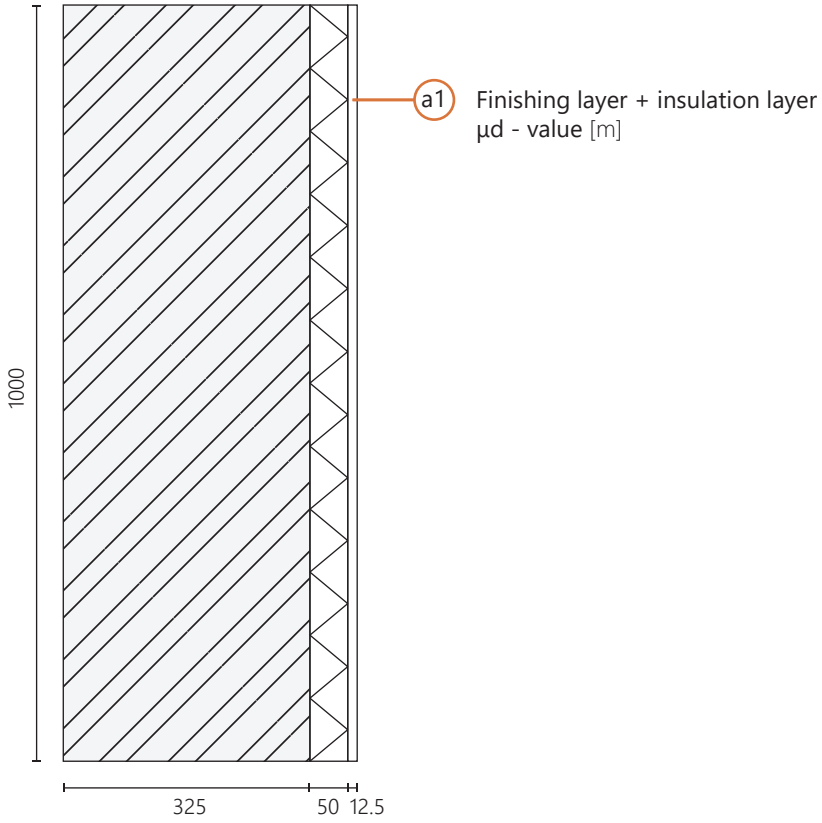
3. Parameter Study

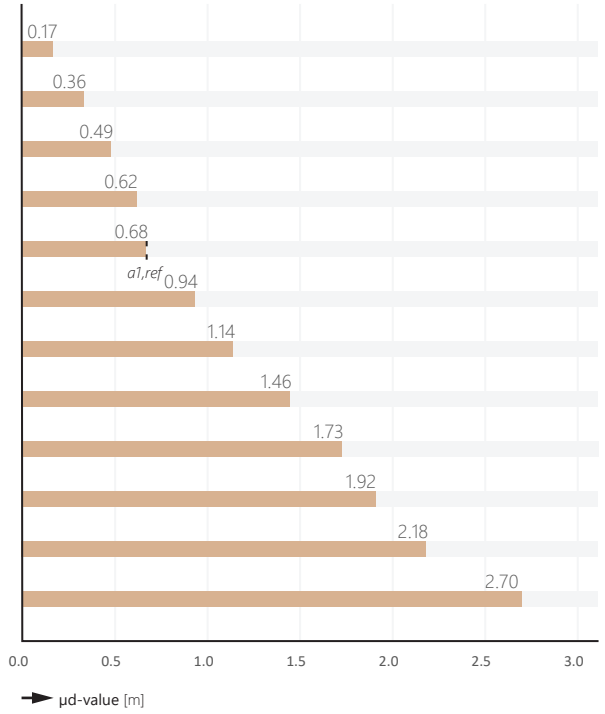
Combining parameters



3. Parameter Study

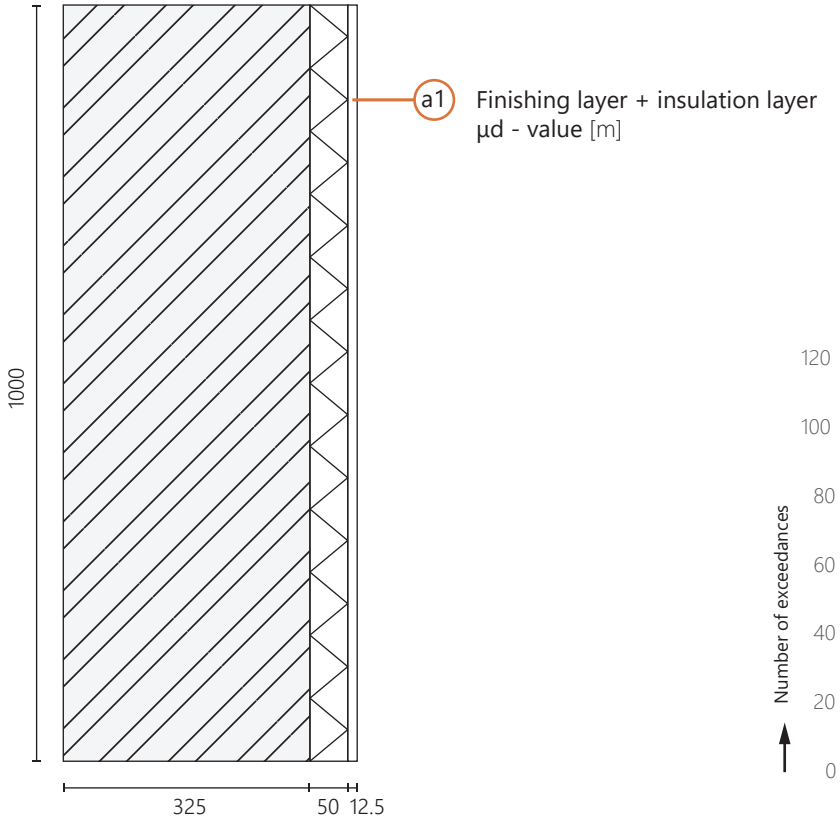
Combining parameters - range of values

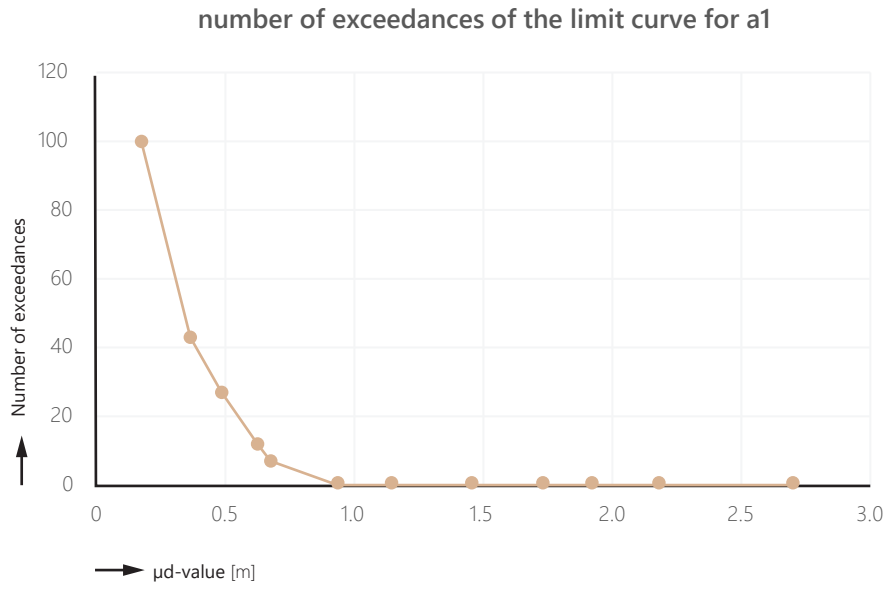




3. Parameter Study

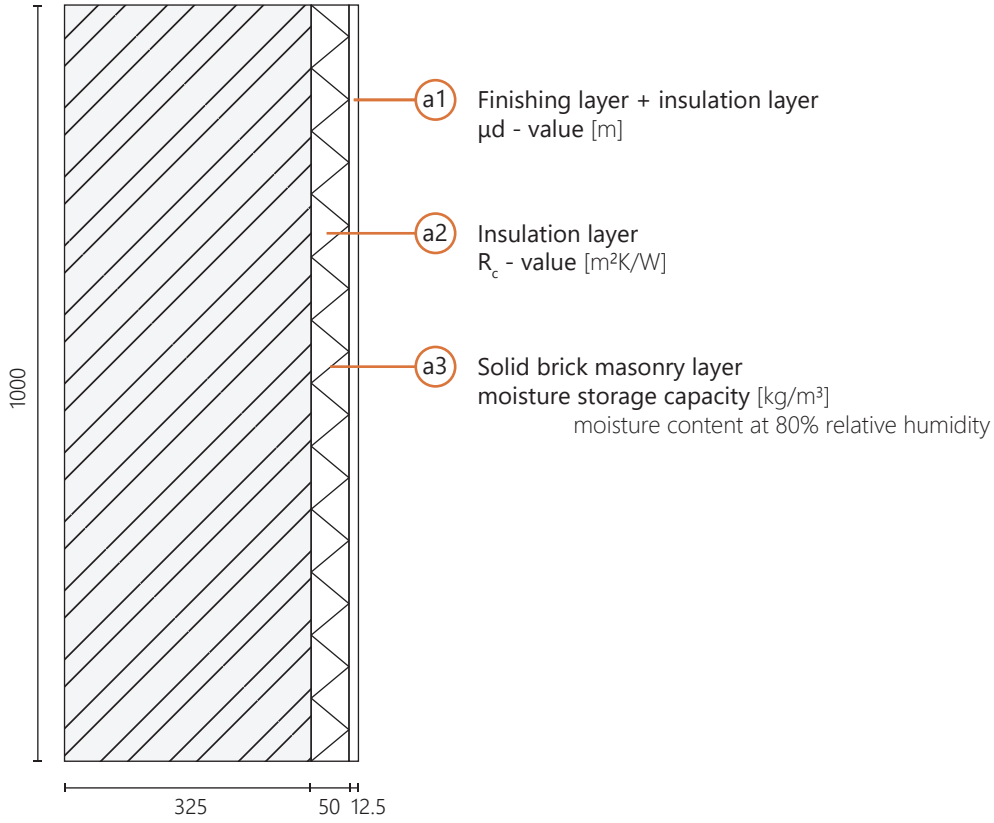
Combining parameters - results





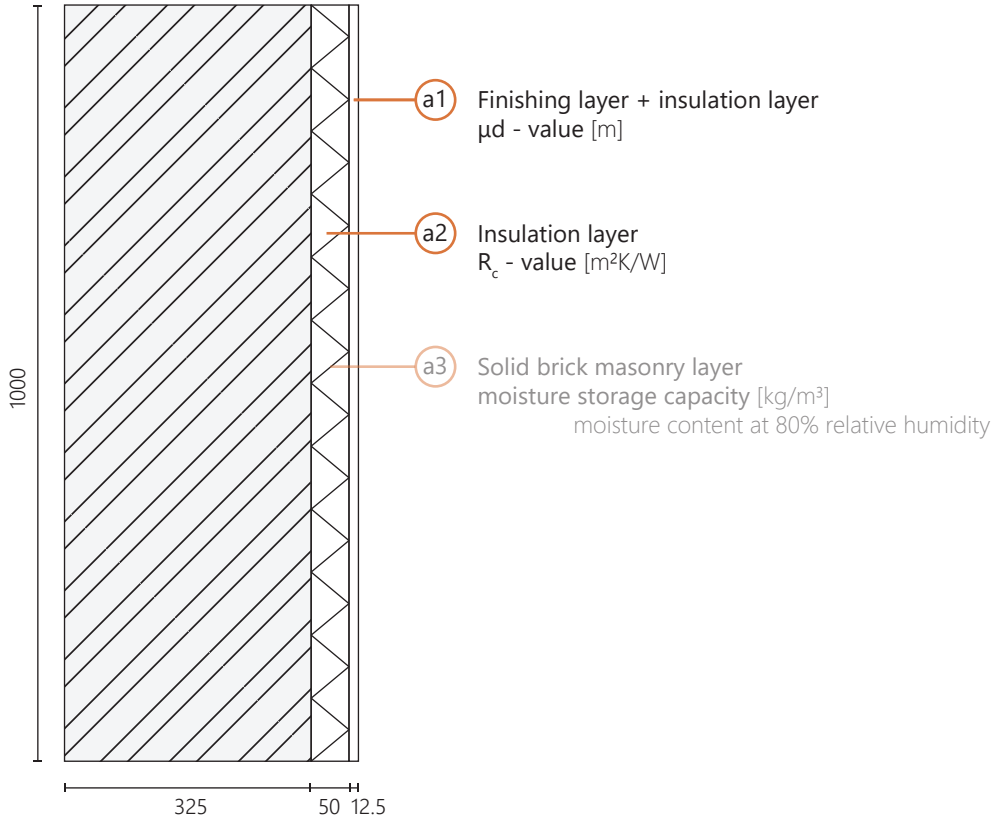
3. Parameter Study

Parameters



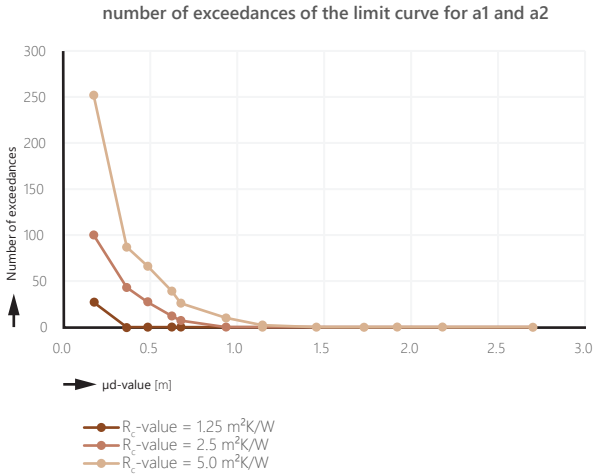
3. Parameter Study

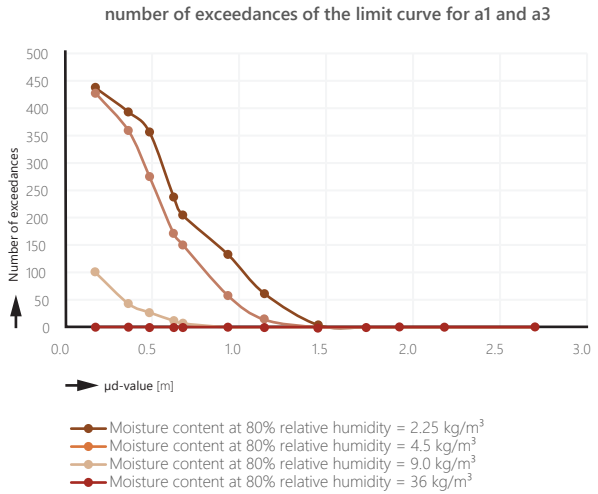
Variation of two parameters

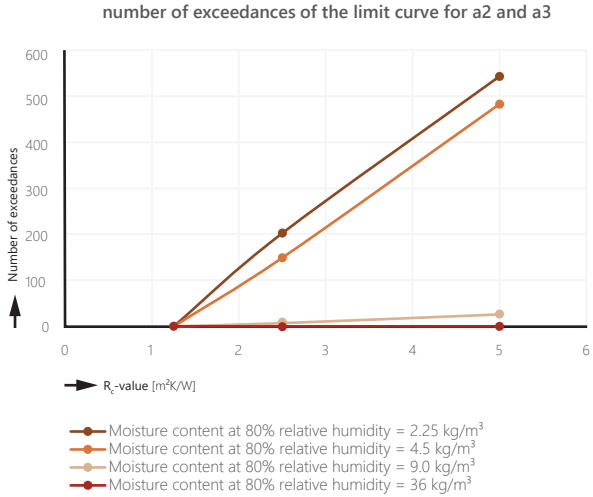


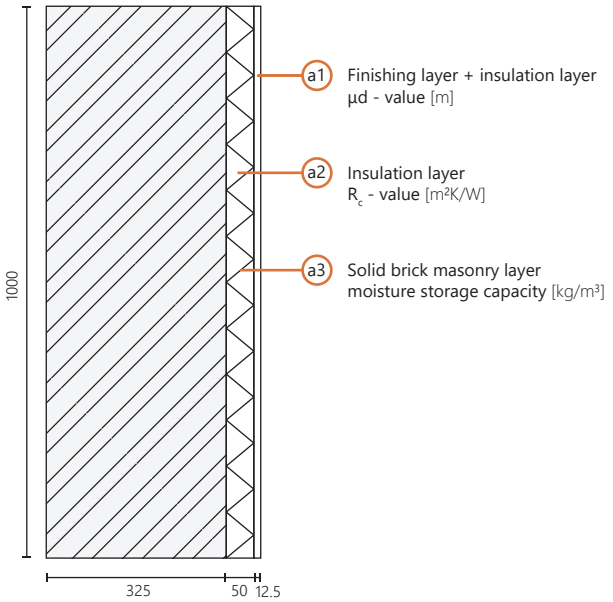
3. Parameter Study

Variation of two parameters - results



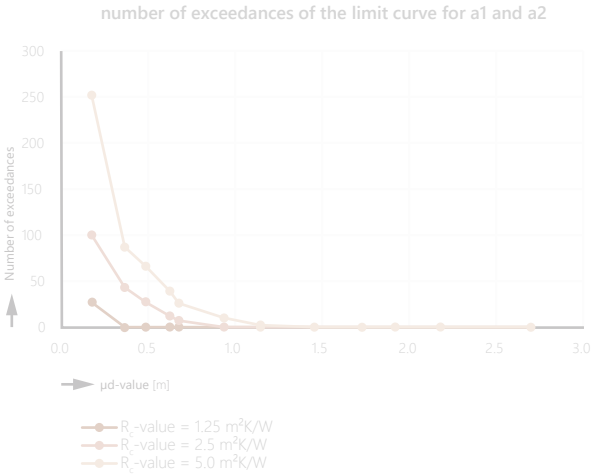


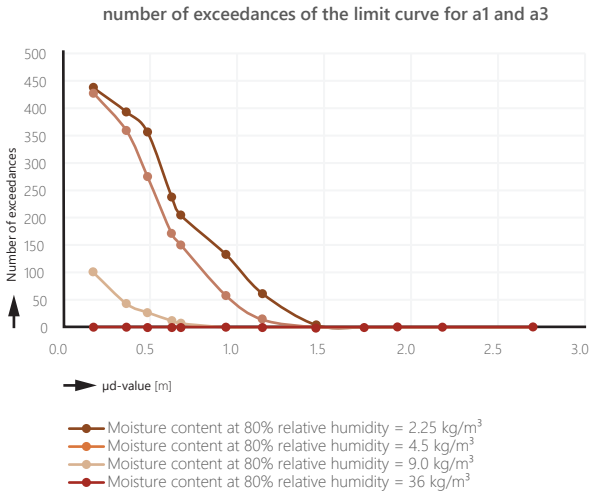


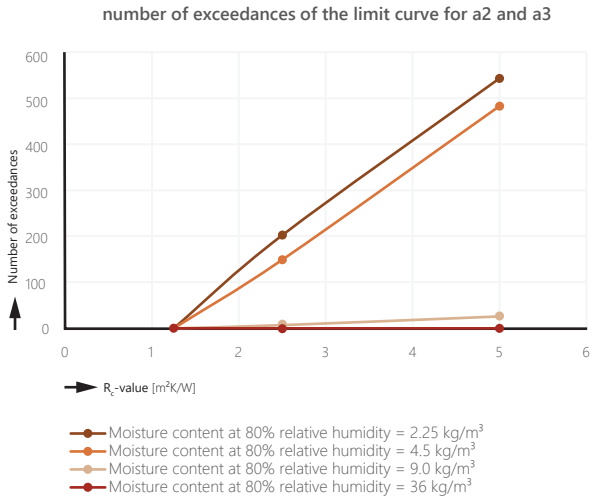


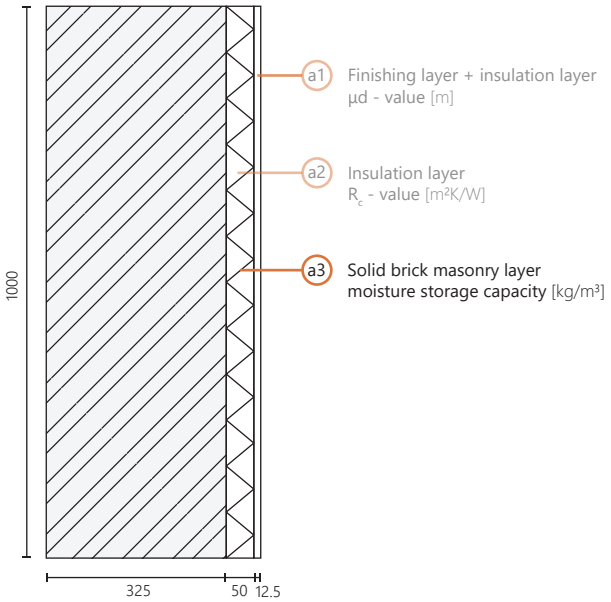
3. Parameter Study

Variation of two parameters - results



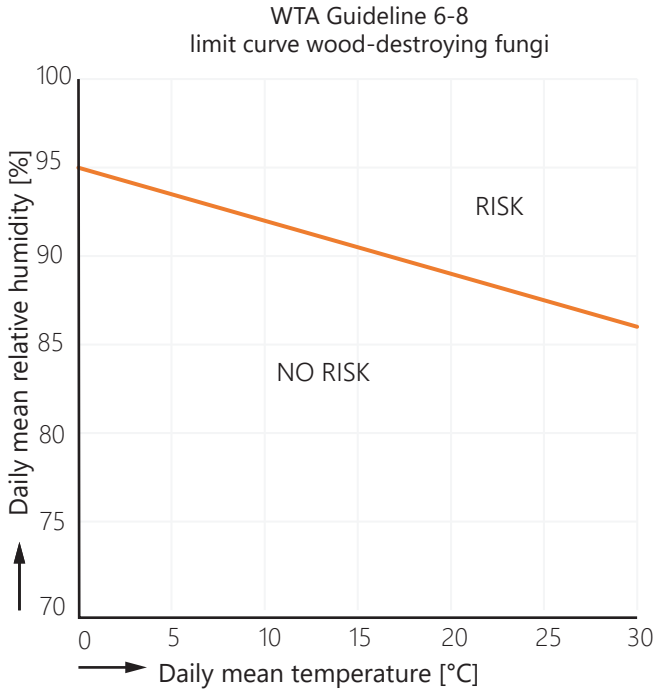






3. Parameter Study

Relation relative humidity and number of exceedances



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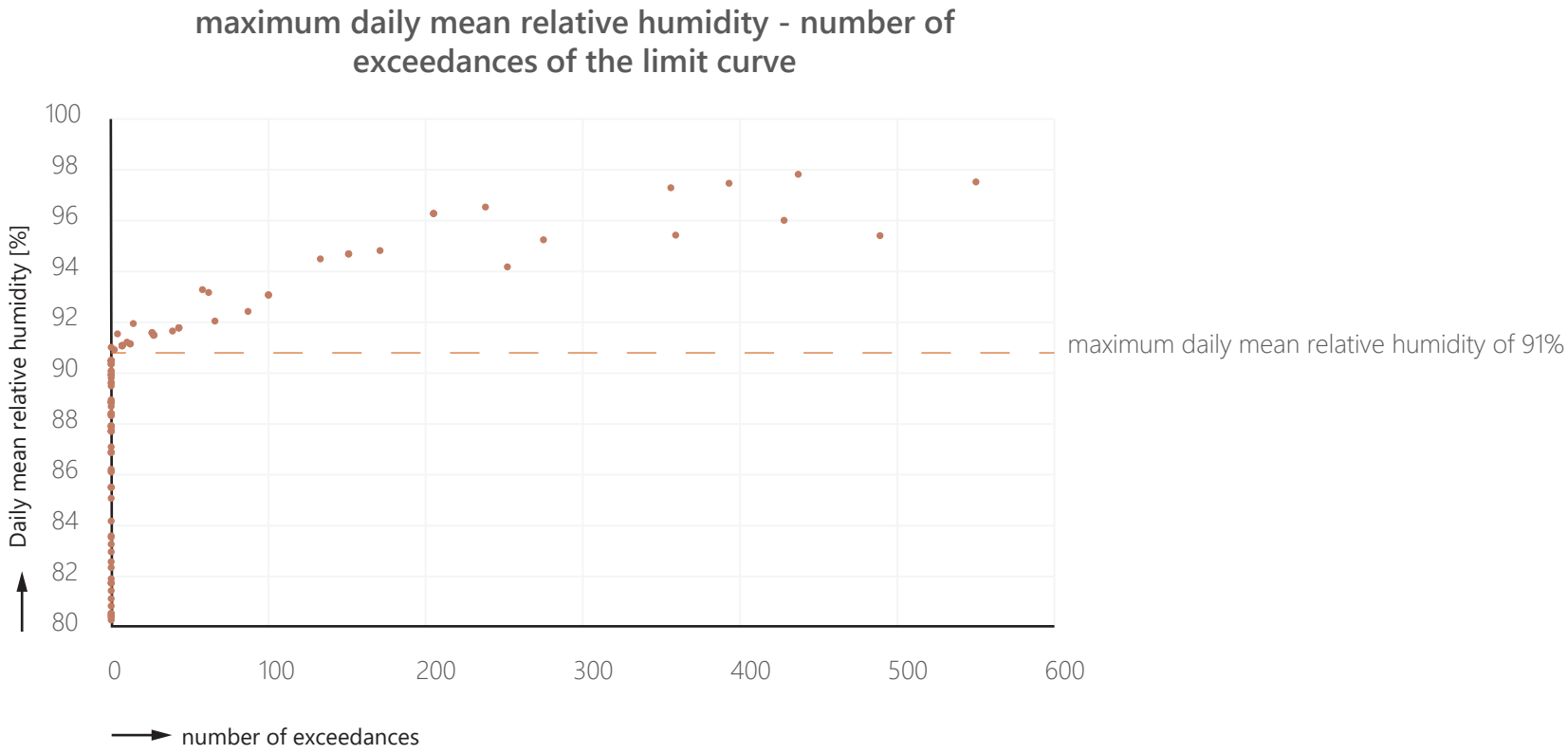
Relation relative humidity and number of exceedances



3. Parameter Study

Prediction Method

$$I = I_0 * (a_{1n})^{n11} * (a_{2n})^{n22} * (a_{3n})^{n33} * (a_{1n})^{n12*(a2n-1)} * (a_{1n})^{n13*(a3n-1)} * (a_{2n})^{n23*(a3n-1)}$$

Where,

$a_{1n} = a_1/a_{1,ref}$;
$a_{2n} = a_2/a_{2,ref}$;
$a_{3n} = a_3/a_{3,ref}$;

3. Parameter Study

Prediction Indicator

number of exceedances of the limit curve

$$I = I_0 * (a_{1n})^{n11} * (a_{2n})^{n22} * (a_{3n})^{n33} * (a_{1n})^{n12*(a2n-1)} * (a_{1n})^{n13*(a3n-1)} * (a_{2n})^{n23*(a3n-1)}$$

Where,

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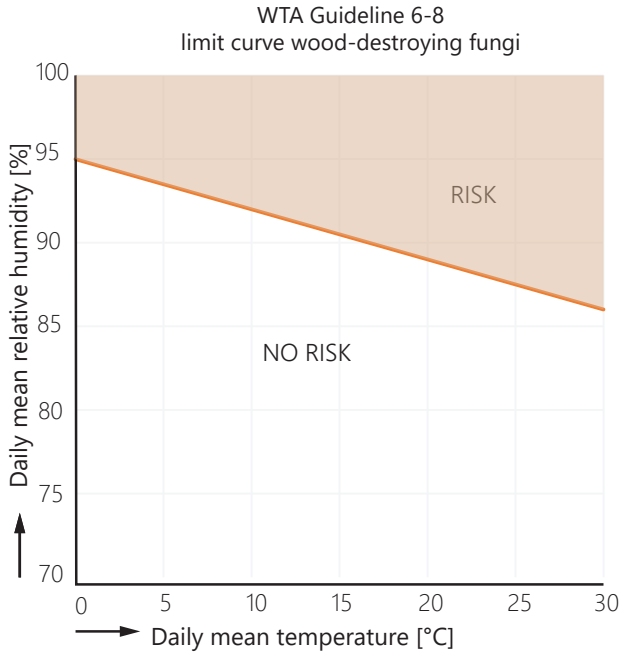


3. Parameter Study

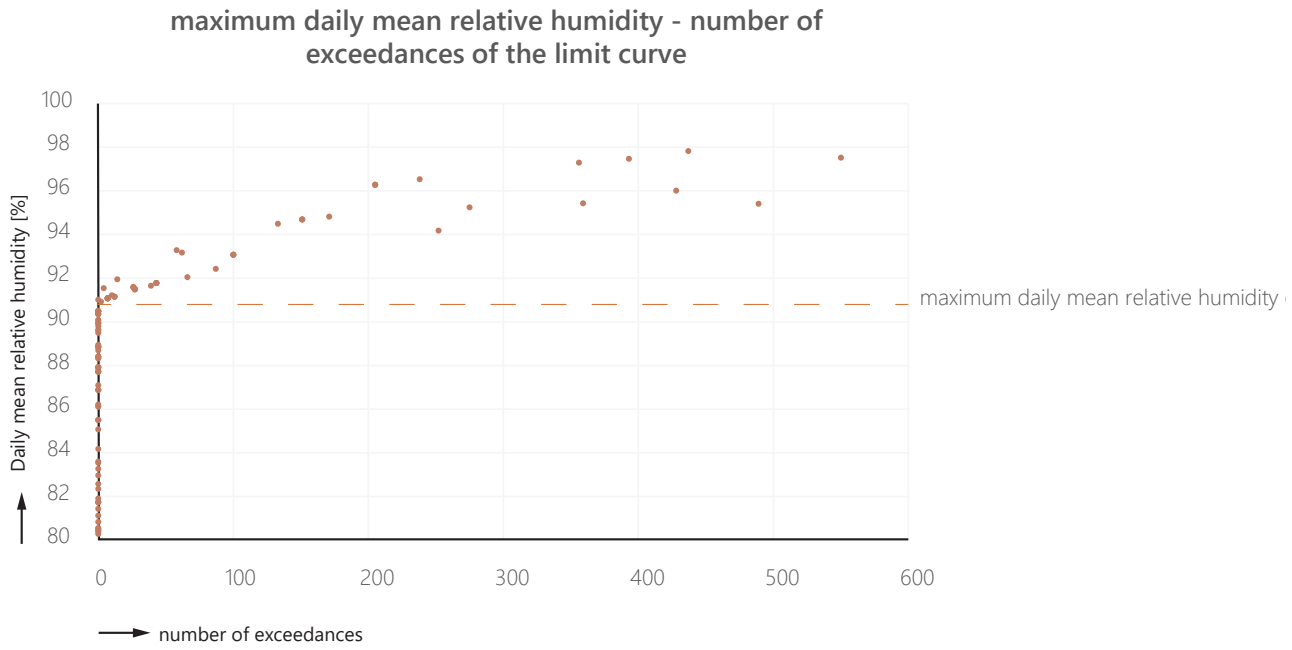
Prediction Indicator

maximum daily mean relative humidity

$$I = I_0 * (a_{1n})^{n11} * (a_{2n})^{n22} * (a_{3n})^{n33} * (a_{1n})^{n12*(a2n-1)} * (a_{1n})^{n13*(a3n-1)} * (a_{2n})^{n23*(a3n-1)}$$

Where,

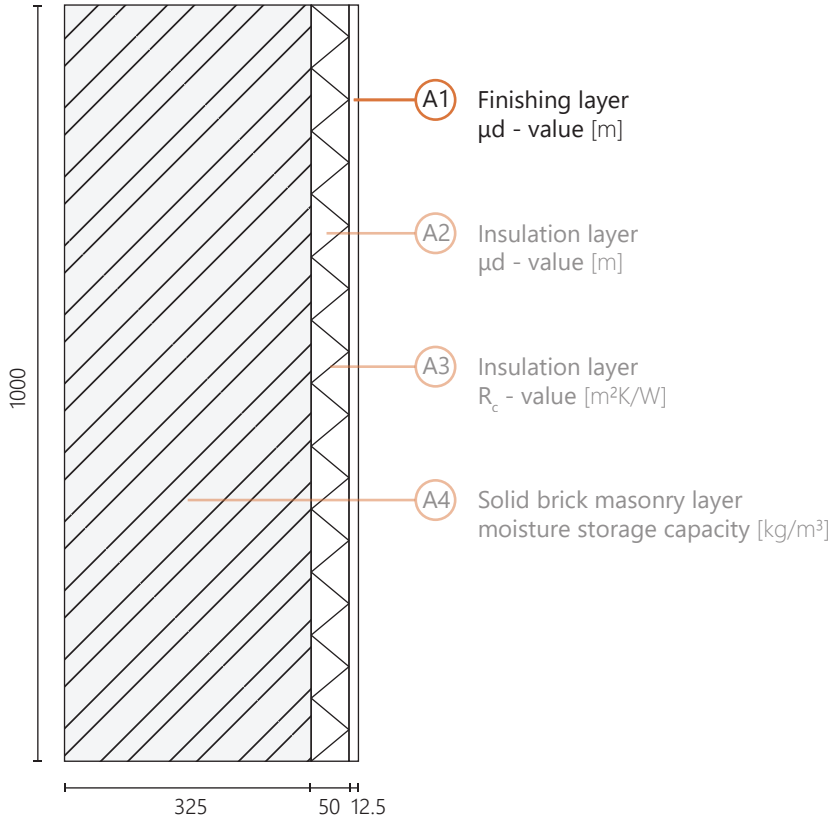
$a_{1n} = a_1/a_{1,ref}$;
$a_{2n} = a_2/a_{2,ref}$;
$a_{3n} = a_3/a_{3,ref}$;



3. Parameter Study

Prediction Method - results

Single variation



3. Parameter Study

Prediction Method - results

maximum daily mean relative humidity

$$I = I_0 * (a_{1n})^{n11} * (a_{2n})^{n22} * (a_{3n})^{n33} * (a_{1n})^{n12*(a2n-1)} * (a_{1n})^{n13*(a3n-1)} * (a_{2n})^{n23*(a3n-1)}$$

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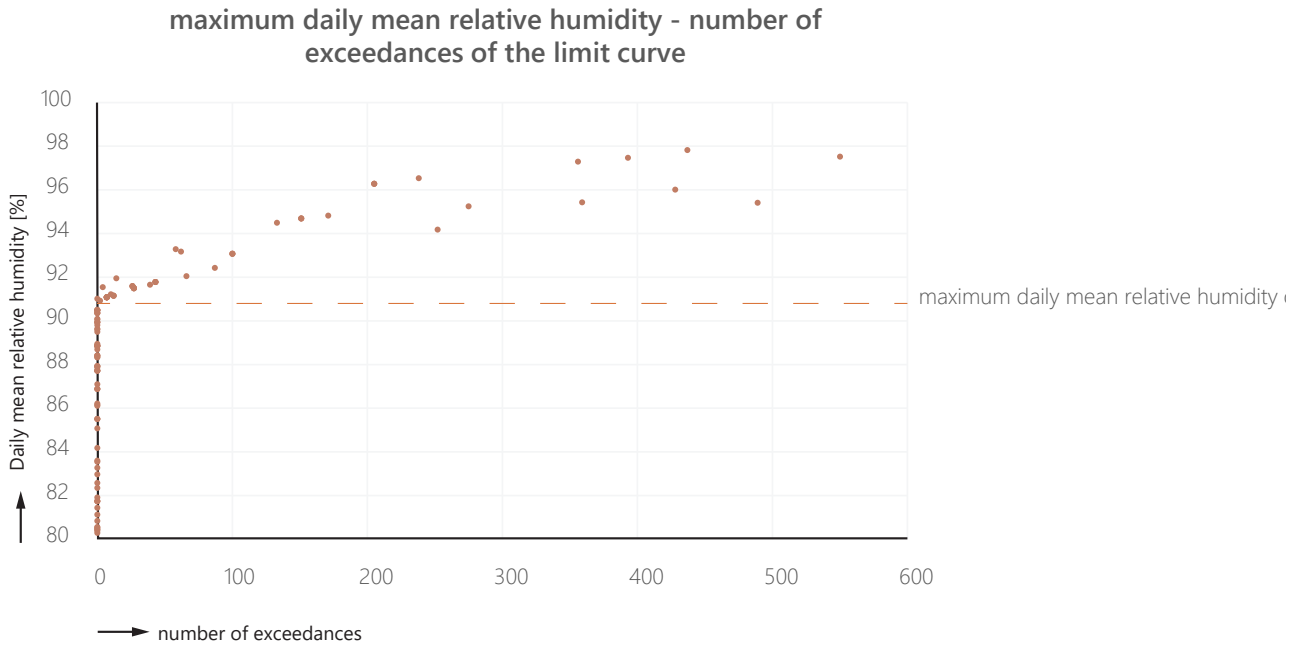

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4. Conclusion

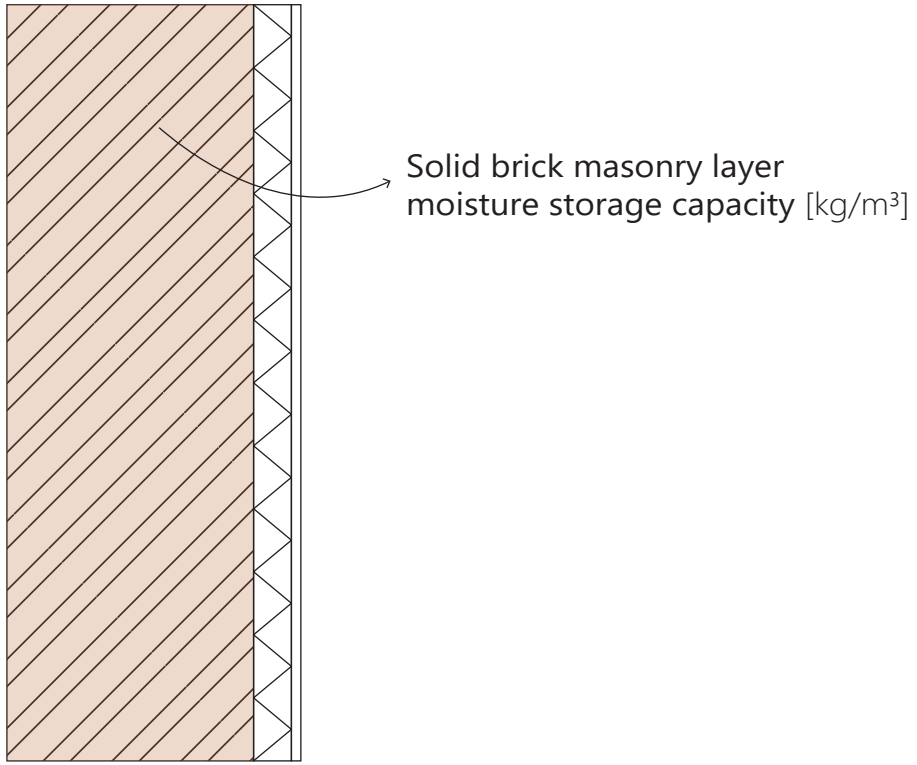
Main Research Question:

What **hygrothermal property** of vapour-open, non-capillary active internal insulation for historic solid brick masonry **influences** the hygrothermal behaviour of this facade **most**?

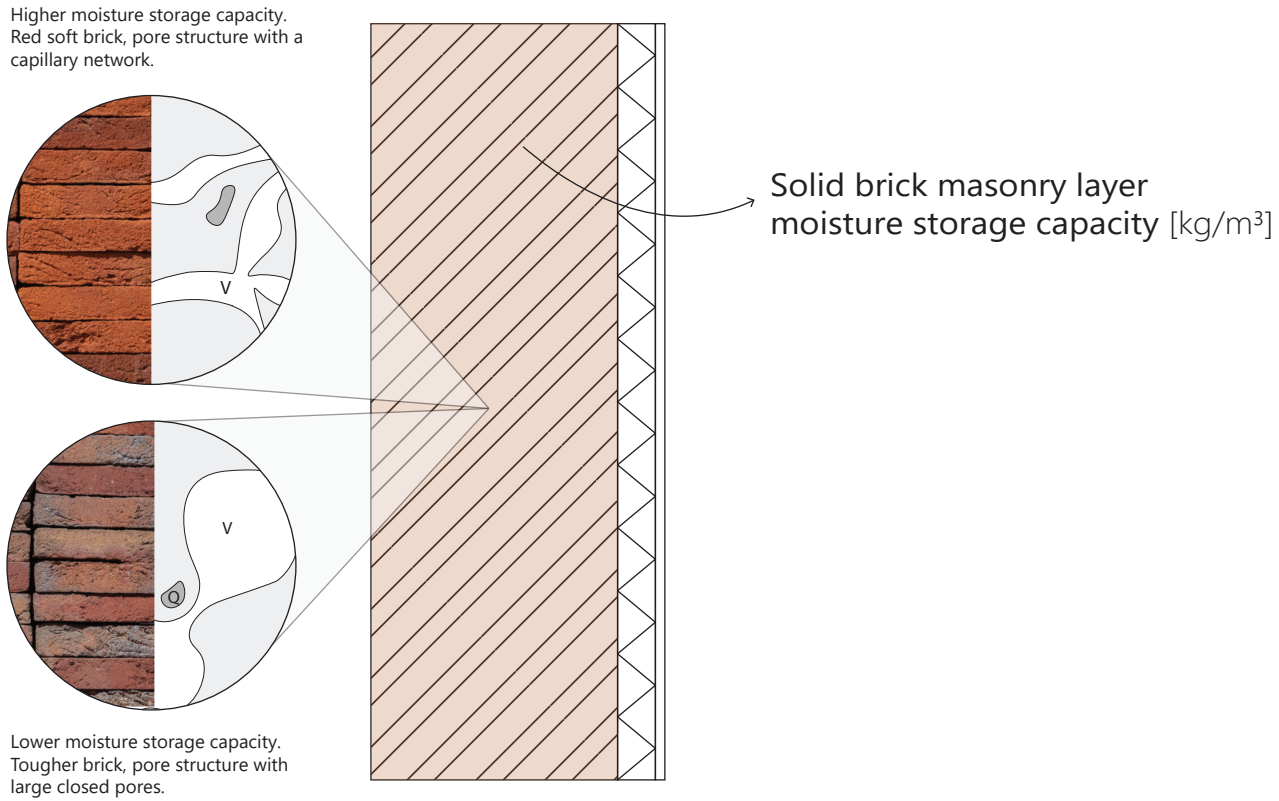
4. Conclusion

Main Research Question:

What **hygrothermal property** of vapour-open, non-capillary active internal insulation for historic solid brick masonry **influences** the hygrothermal behaviour of this facade **most**?



4. Conclusion



Content.

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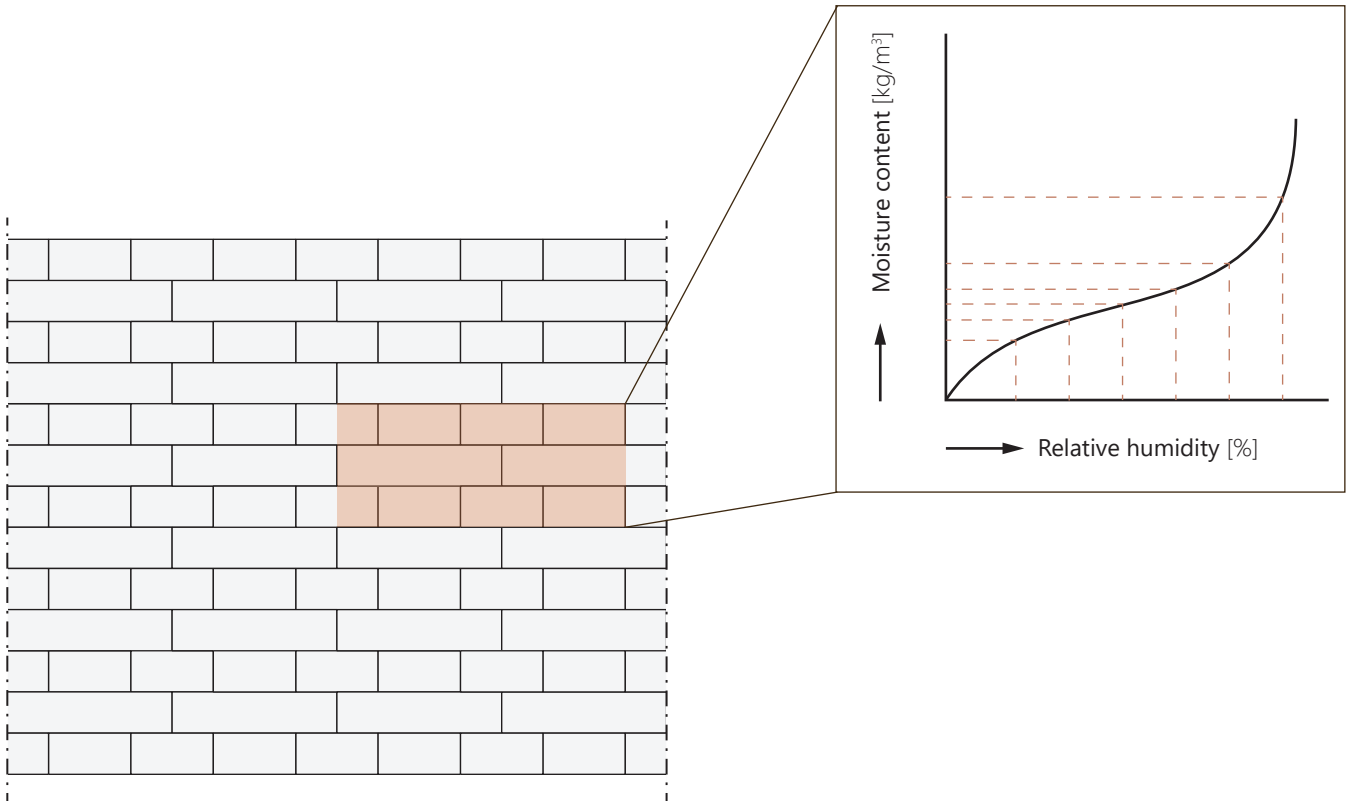
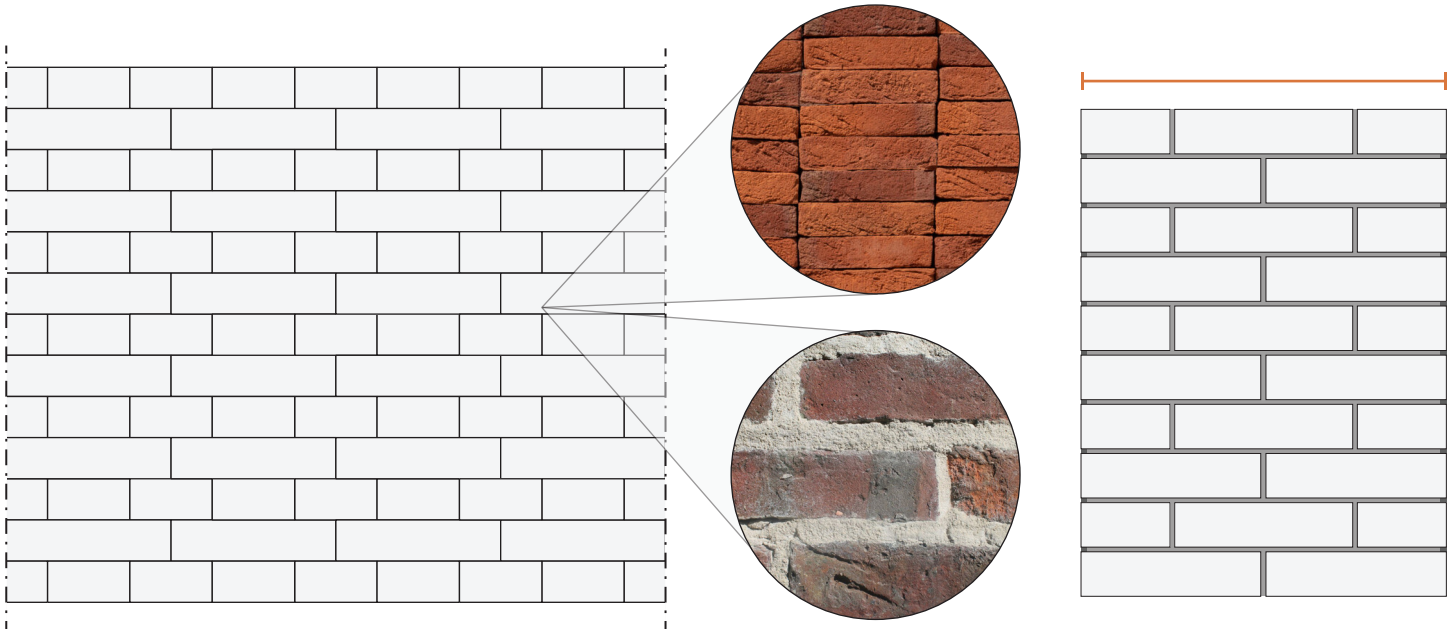
5. Recommendations

Moisture storage capacity of solid brick masonry



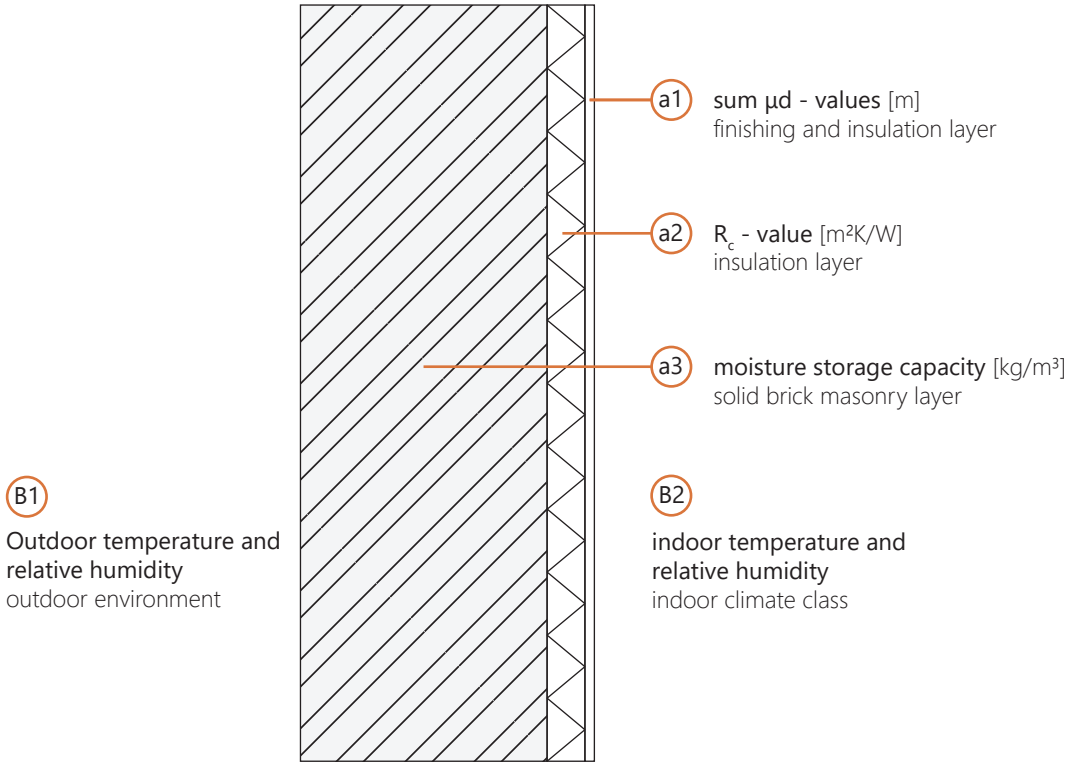
5. Recommendations

Moisture storage capacity of solid brick masonry



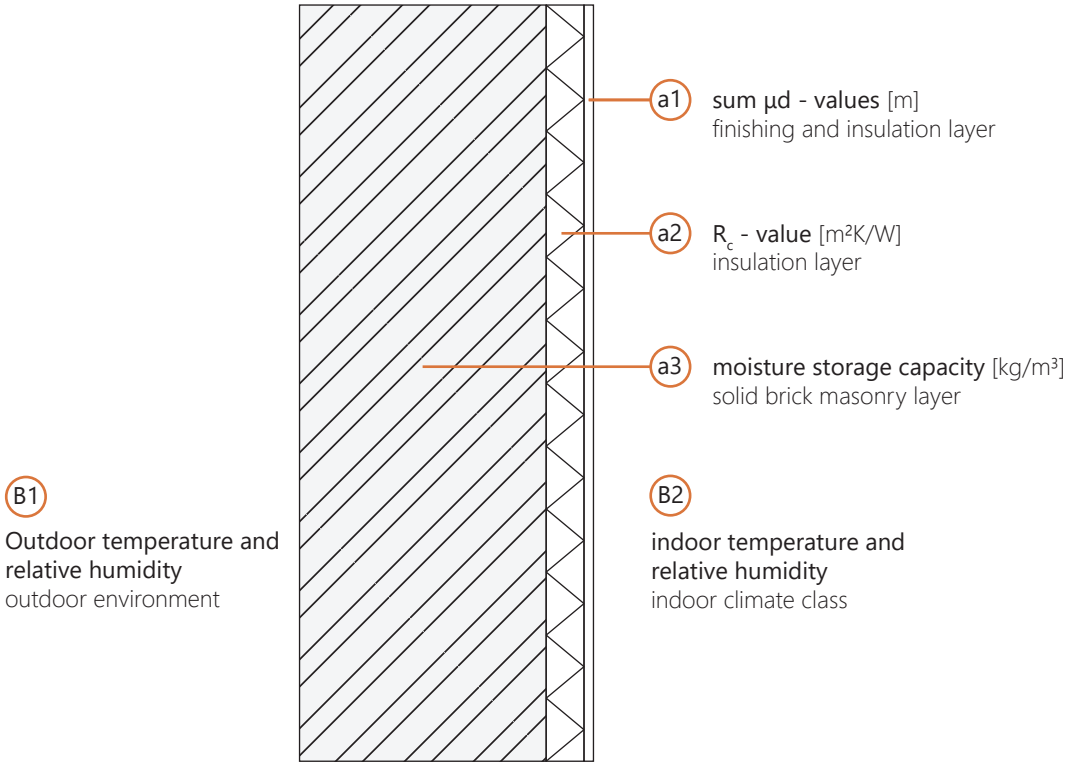
5. Recommendations

Guideline risk-free hygrothermal performance



5. Recommendations

Guideline risk-free hygrothermal performance



µd-value a1 [m]	Rc-value a2 [m^2K/W]	MC at 80% a3 [kg/m^3]
0.17 < a1 < 3.0	< 2.5	> 36
0.36 < a1 < 3.0	< 1.25	> 9
1.46 < a1 < 3.0	< 2.5	> 2.25
1.46 < a1 < 3.0	2.5 < a2 < 5	> 9
0.68 < a1 < 3.0	1.25 < a2 < 5	> 36
0.68 < a1 < 3.0	< 1.25	> 2.25

µd-value a1 [m]	Rc-value a2 [m^2K/W]	MC at 80% a3 [kg/m^3]
0.36 < a1 < 0.68	**< 1.25**	> 9
0.68 < a1 < 3.0	**< 1.25**	> 2.25
0.17 < a1 < 1.46	**< 2.5**	> 36
1.46 < a1 < 3.0	**< 2.5**	> 2.25
0.68 < a1 < 1.46	**< 5**	> 36
1.46 < a1 < 3.0	**< 5**	> 9

µd-value a1 [m]	Rc-value a2 [m^2K/W]	MC at 80% a3 [kg/m^3]
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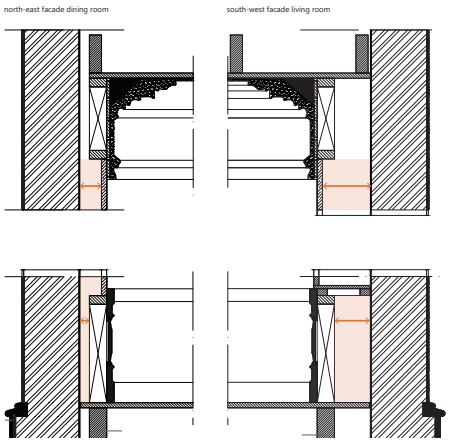
5. Recommendations

Case Study



5. Recommendations

Information must consist of:

- The properties of the existing and new façade materials;
- Hourly monitoring of:
    - The relative humidity and temperature at the interface between masonry and insulation layers;
    - The relative humidity and temperature of the indoor environment;
    - The outdoor environment, including temperature, relative humidity, wind-driven rain, solar radiation and precipitation;
- Monitoring for longer than one year in a building in use.

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6. Discussion

Content

- Methods
- Parameter study
- Future research

6. Discussion

Methods

- Research by simulations
- Improving by validated simulations

6. Discussion

Parameter study

- Homogeneous brick layer
- Parameters
- Range of values
- Hydrophobation

6. Discussion

Future research

- Variation of three parameters
- Representative outdoor environment
- Two- and three-dimensional situations
- Long-term research

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7. Reflection

- Dealing with different perspectives
- Abandoning initial plan
- Decision-making

Thank You!

TU Delft

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