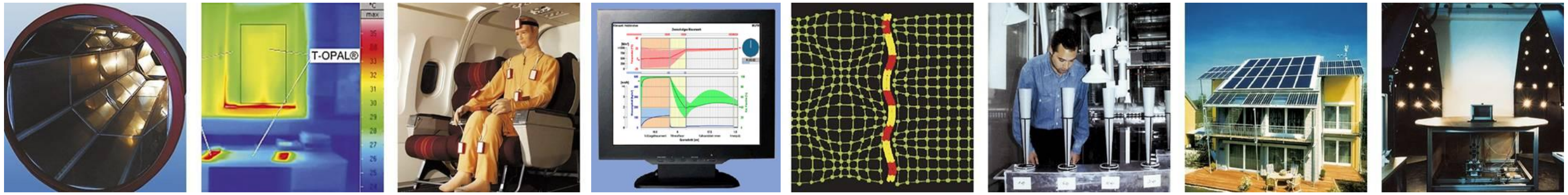


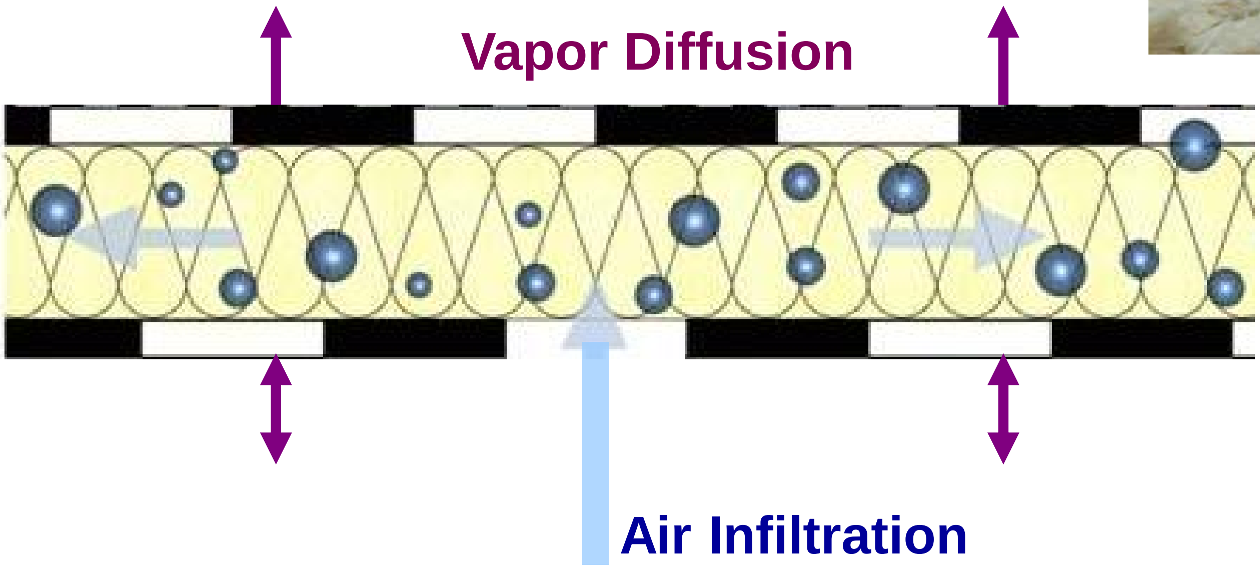
NSB 2011 in Tampere

Vapour control design of wooden structures including moisture sources due to air exfiltration

Hartwig M. Künzel
Daniel Zirkelbach
Beate Schafaczek

Fraunhofer
IBP

Damage caused by Air Infiltration



Problem:
Moisture entry by air infiltration > Drying by vapor diffusion

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Introduction: Air infiltration

Building component evaluations: one-dimensional check of the normal cross section.

Assumption: ideally tight structure against air and liquid water

Diffusion tight structures mostly perform very well in simulation - but often get problems in reality.

Why?

- **Ideal tightness hardly occurs in practice**
- **Leakages allow infiltration of air and precipitation water**
- **Moisture cannot dry out any more**

Air infiltration is the rule, not the exception for lightweight structures

Introduction: Air infiltration

The question is not: Is there any moisture entry into the construction due to air infiltration? But:

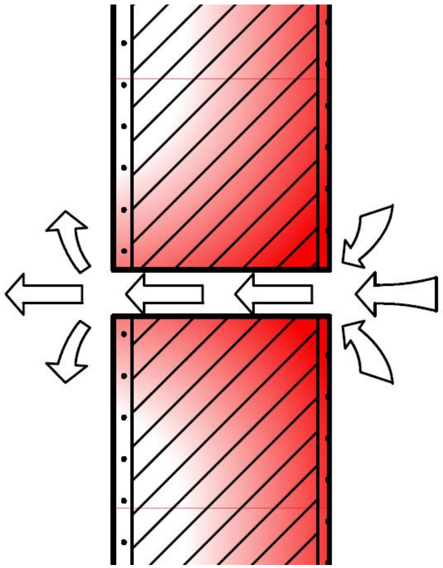
How much moisture enters depending on the boundary conditions?
How much drying potential is needed to prevent a damage?

Constructions must be designed to remain damage free considering additional moisture entry due to air infiltration through normal leakages which occur also in best practice enclosures.

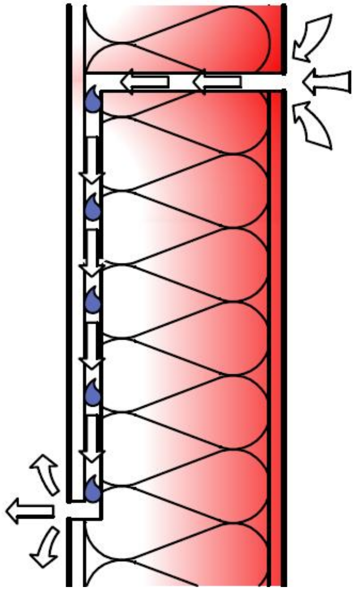
Introduction: Air infiltration

Not all types of air leaks result in a relevant increase of moisture – what kind of leakages are responsible for moisture damages?

Energy leak



Moisture leak



Warming of the flow path in case of strong air flux ⇨
No or only little condensation

Cooling of the air in case of slow and tortuous air flux ⇨
potential of serious condensation

Introduction: Air infiltration

No reliable information about the air flow passage - the distribution of small and large gaps, cracks or leaking joints - but:

TenWolde et al. (1998):

- **Moisture entry caused by infiltration corresponds to the amount of moisture which can permeate (by vapor diffusion) a vapor retarder with an s_d-value of 3.3 m (1 perm)**
- **Basis: test building with American lightweight constructions (in 1990s) – air-tightness according to best practice**

Künzel (1999):

- **Transfer of American results for German conditions: ca. 250 g/m² during the heating period**
- **This amount was proposed to serve as “safety buffer” for vapor diffusion (Glaser) calculations.**

The approach to include a safety buffer of 250 g/m²a to account for vapour convection has been adopted by the German standard on wood protection (DIN 68800-2) in building envelope assemblies

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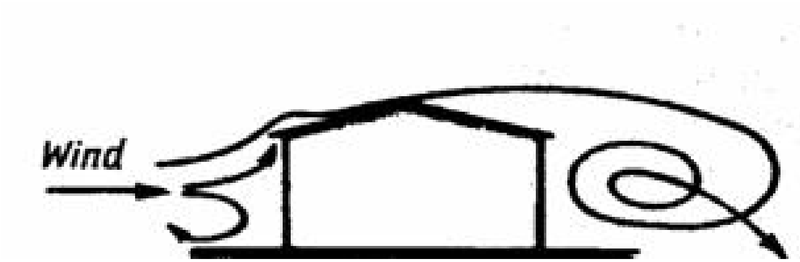
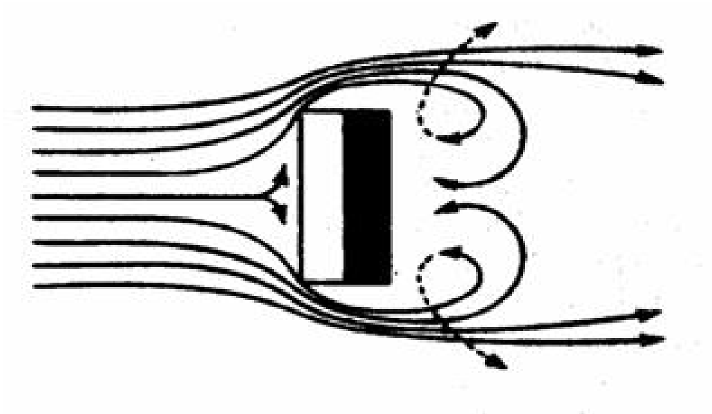
Reasons for overpressure in buildings: 1. wind





Overpressures only on the lee-ward side

Problem

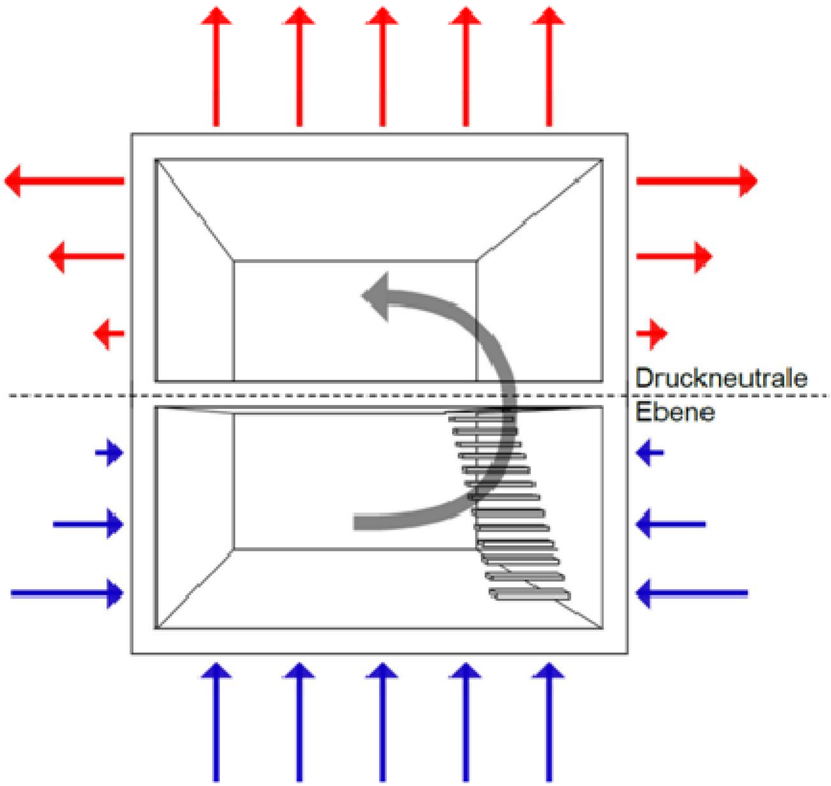
Air pressure differentials depend on:
- wind speed and direction
- topography, neighboring buildings
- building height and geometry

Simplification

Wind effects are neglected because:
- changing direction leads to alternating condensation – drying processes
- wind blows only temporarily
- strong wind turns some moisture leaks into energy leak

Simplifications and Transient Model

Reasons for overpressure in buildings: 2. stack effect



Overpressure due to buoyancy (stack effect) permanently present in winter absent in summer

$$\Delta P = \rho \cdot \frac{T_a - T_i}{T_i} \cdot g \cdot \frac{h}{2}$$

ΔP pressure difference inside-outside [Pa]
ρ density of the exterior air = 1,3 kg/m³
T_a air temperature outside [K]
T_i air temperature inside [K]
g gravitational acceleration = 9,81 m/s²
h indoor stack height [m]

Overpressure depends on

- temperature difference between indoors and outdoors
- height of connected indoor air volume

Simplifications and Transient Model

Flow paths through building envelope components are 3D-phenomena of random nature.

They defy even sophisticated models. Therefore a simple 1D approach has been developed.

$$q_{CL} = k_{CL} \cdot (P_i - P_e)$$

CL = Component Leakage

q_{CL}	$[m^3/m^2h]$	**Air flow through moisture leaks**
k_{CL}	$[m^3/m^2h \cdot Pa]$	**Air permeability of moisture leaks**

k_{CL} is determined from back-calculations

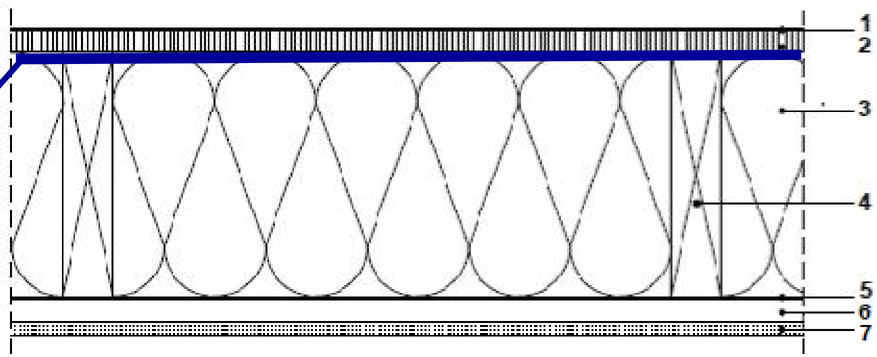
Transient moisture sources S_{CL} resulting from vapour convection

$$S_{CL} = q_{CL} \cdot \left(c_i - c_{sat,x_p}\right)$$

c_i	[kg/m³]	indoor vapour concentration
$c_{sat,xp}$	[kg/m³]	sat. vap. con. at position x_p

Example flat roof:

convective condensation plane



Model assumptions and prerequisites:

- Heat effects of penetrating air (sensible and latent) are neglected
- Only condensation at position x_p is considered – i.e. no sorption at high RH
- Position x_p has to be selected according to practical experience

Simplifications and Transient Model

Transient moisture sources S_{CL} resulting from vapour convection

Specifications in DIN 68800-2 for 250 g/m² are based on the infiltration moisture amount in a north facing stud wall of a two-storey building in Holzkirchen.

Resulting air permeability of moisture leaks by applying the new model:
k_{CL} = 0,007 m³/(m²h·Pa) (top of north-oriented wall)

Comparison with component air permeabilities given in ASHRAE Std. 160-2009 (all leaks):

Standard case: k_{CL} = 0,060 m³/(m²h·Pa)

Air-tight case: k_{CL} = 0,010 m³/(m²h·Pa)

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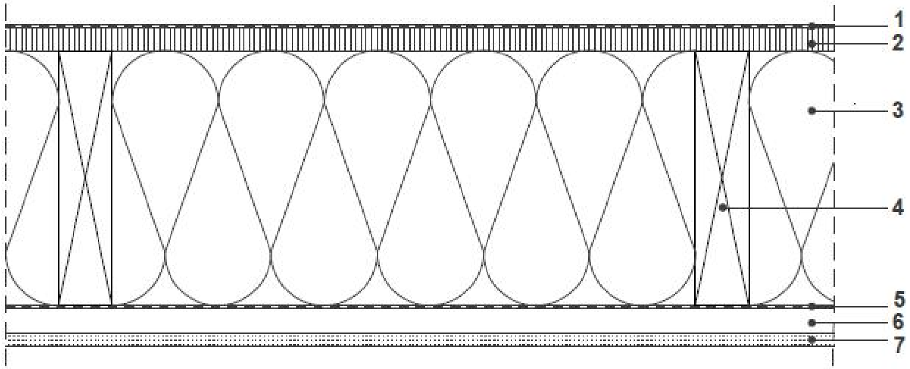
Example Case Flat Roof

Construction:



1	roofing membrane	
2	OSB	22 mm
3	mineral fiber insulation	240 mm
4	load bearing structure	240 mm
5	vapor barrier	
6	air layer	24 mm
7	gypsum board	12,5 mm

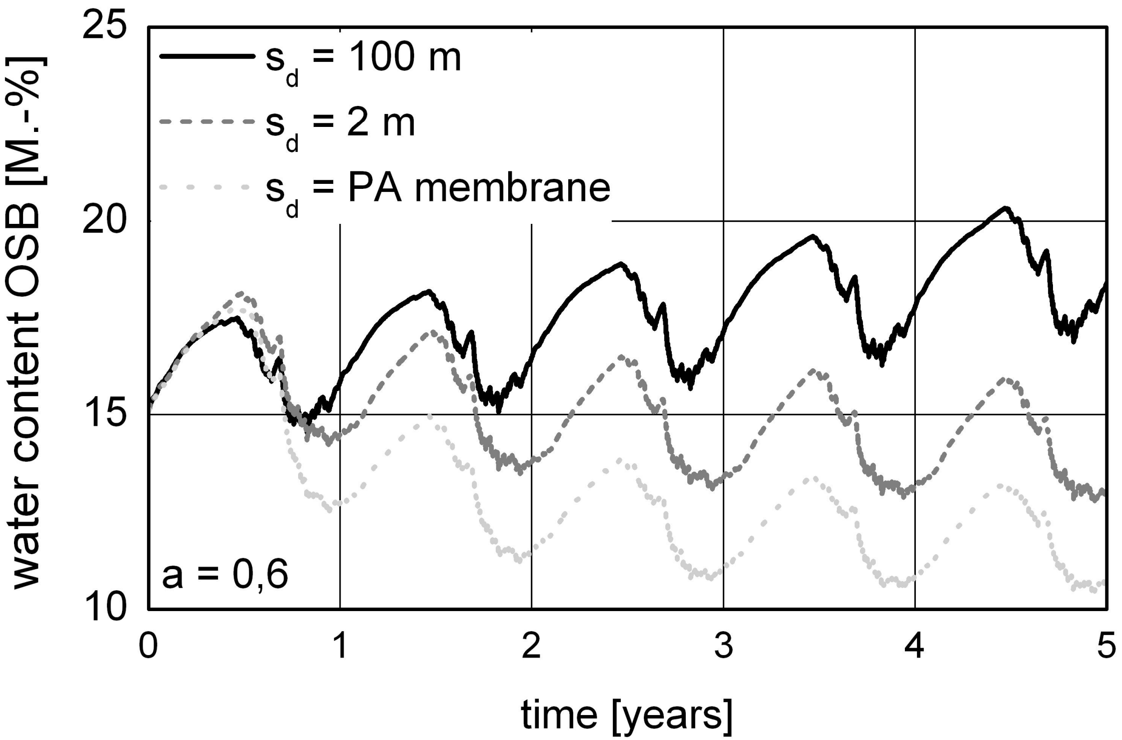
The humidification caused by infiltration can now be simulated according to the specific structure and its boundary conditions:

- **air flow path**
- **indoor stack height**
- **outdoor climate and operation**

Example Case Flat Roof

Evaluation of the wood moisture in the exterior OSB

- different vapor retarders
- Holzkirchen
- stack height of 5 m
- grey roofing membrane



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Example Case Flat Roof

Evaluation of the wood moisture in the exterior OSB

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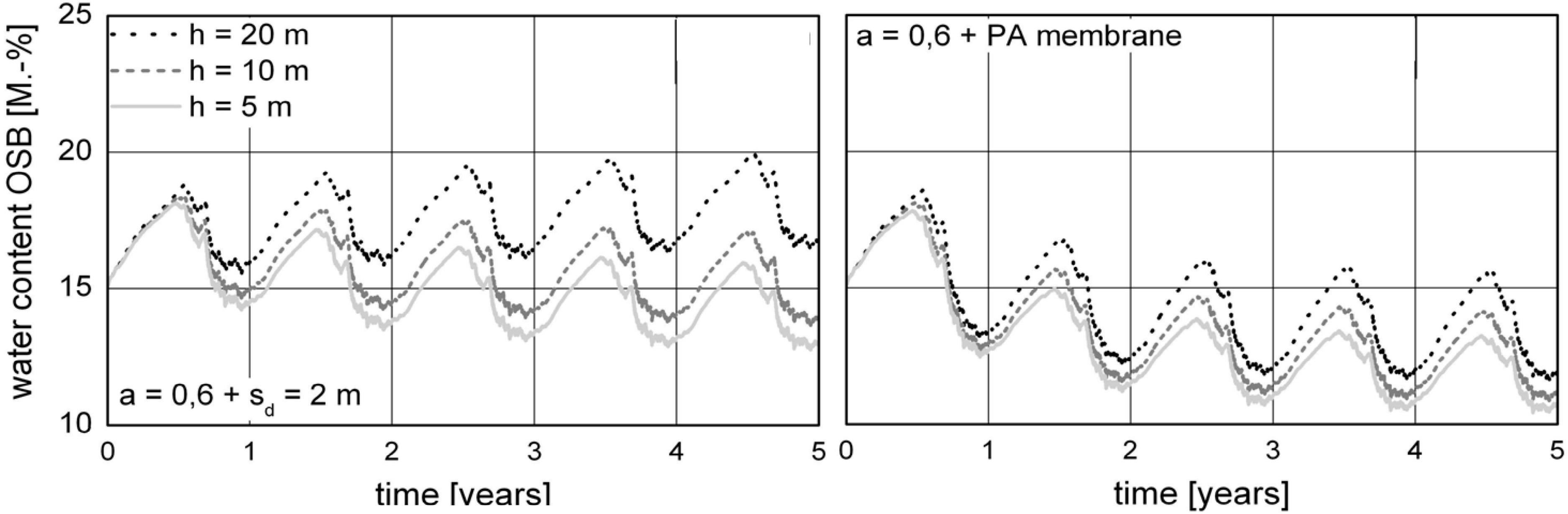
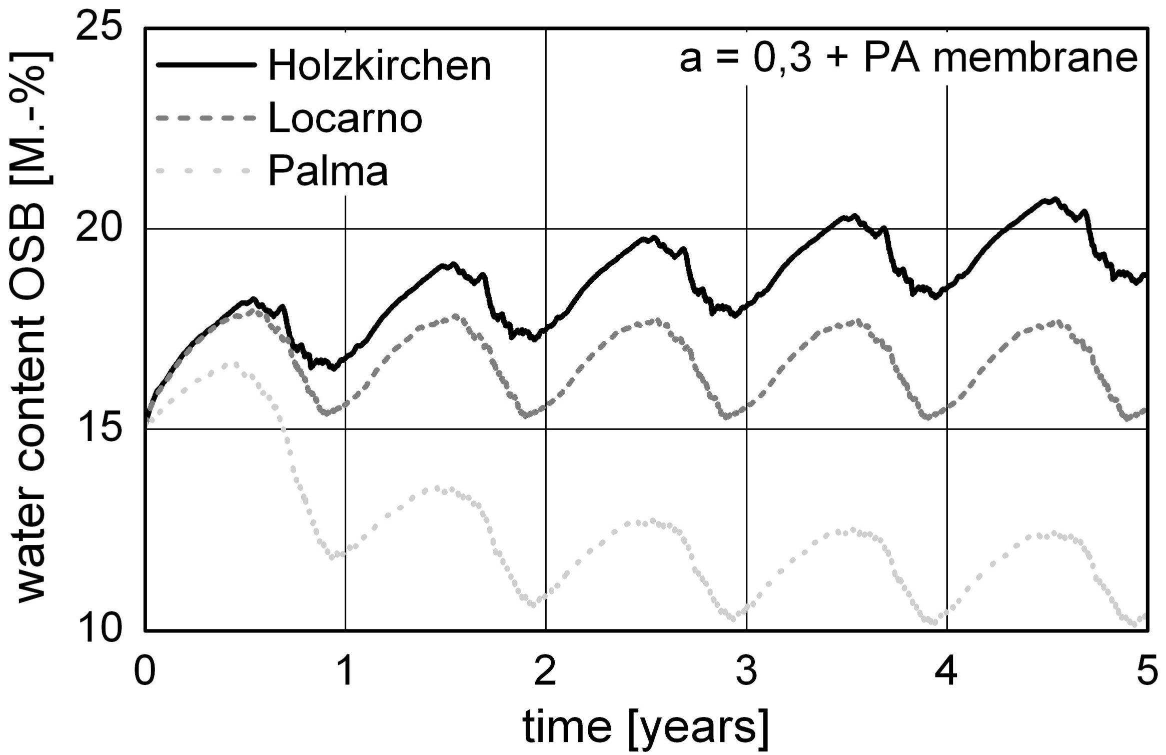


Example Case Flat Roof

Evaluation of the wood moisture in the exterior OSB

- PA membrane
- different locations
- stack height 5 m
- white roofing membrane



Summary and Outlook

<u>The new model allows a specific analysis of the humidification risk due to infiltration depending on:</u>

- stack height
- outdoor climate and operation conditions
- construction type and potential position of condensation

<u>The approach helps to quantify the moisture tolerance of building structures under different boundary conditions, e.g.</u>

- Double sided vapour tightness is discouraged
- Cool roofs don't work in cold and moderate climates
- Components of high buildings and those with high indoor temperature are more at risk when vapour convection is considered

<u>Outlook</u>

- Currently validation ongoing by comparing model results to experimental investigations from KUL and Syracuse University

Thank you for your Attention!

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