AECB

the sustainable building association

2010 Annual Conference

Celebrating 21 years of the AECB

Something Old, Something New

1-2 October 2010 • WISE Building, CAT

Organised by:

AECB

the sustainable building association

In association with

Passivhaus Trust

The UK Passive House Organisation

Airtight Breathable/Vapour Diffusion Open Construction: Is there a combined Solution?

AECB Annual Conference
2nd October 2010

Niall Crosson, Technical Engineer, BTech,MEngSc,MIEI

pro clima
Intelligent
Airtight Systems

eco intelligent building solutions

Presentation Overview

•Introduction
•Breathable Construction, Facts and Fiction
•What is Airtightness?
•Airtightness: What are the benefits?
•Why diffusion open construction?
•Potential moisture penetration into structural elements
•Moisture management, Intelligent membranes and diffusion open materials
•Case Study: Brighton Flat roof
•Intelligent on-site solutions.
•Ensuring Quality control and measuring airtightness (International and national standards).
•Presentation summary
•Q & A

First Certified Non Domestic PassivHaus – Wales

First Certified Non Domestic PassivHaus – Wales

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St Lukes School – Wolverhampton
First BREEAM Excellent School

Zero Carbon House Birmingham

Denby Dale Passivhaus 2009

green building store

BERE Architects Ebbw Vale Passiv House

Low Energy House: Wicklow, Ireland

Walls: From the outside (U value- 0.12W/m2K)
- Weather board sheathing fixed to battens
- 50mm vented cavity
- 80mm Gutex Ultratherm
- Solitex WA
- Panelvent
- 225mm Cellulose in Stud
- Intello Plus
- 100mm GUTEX Thermoflex
- Plasterboard

Low Energy House: Wicklow
N 50 0.15 ACH
Q 50 0.17 m3/hr.m2

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pro clima airtight-systems in passive houses

The highest passive house in Europe:

Schiestlhaus 2.154 m

pro clima airtight-systems in passive houses

The highest passive house in Europe

Schiestlhaus 2.154 m

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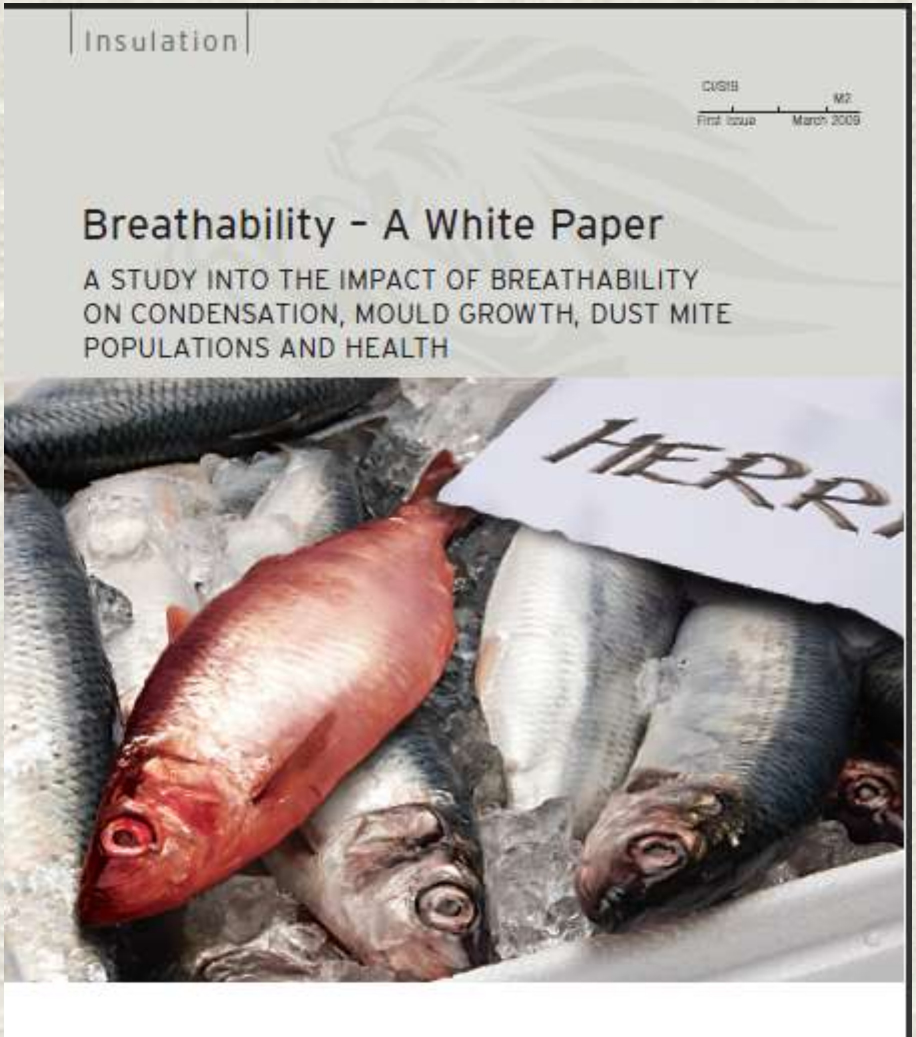
Breathability: Fact and fiction



95% of vapour transfer in buildings occurs through ventilation: **Fact**

“Breathable constructions and breathability of insulation products are therefore at best a side show, in reality there a complete red herring” : **let’s see....**

Breathable or diffusion open?

Breathing: is the process that moves air in and out of the lungs.

Diffusion: The process by which water vapour spreads or moves through permeable materials caused by a difference in water vapour pressure.

Ventilation: The replacement of stale or noxious air with fresh air.

Breathable or diffusion open?

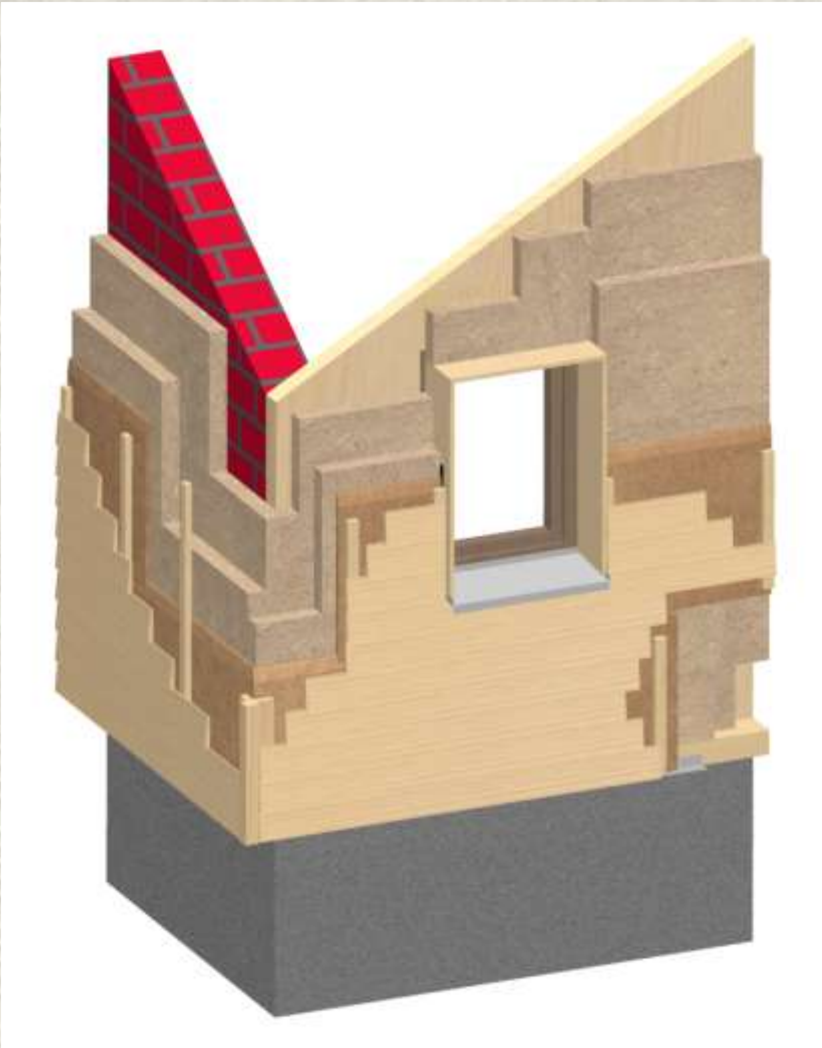
We want our building envelope to be airtight/draught proof and moisture resistant:

•Stop rain from the outside penetrating to the inside
•Outside it should be wind/water tight but vapour permeable (diffusion open).

•Don't want moisture to condense within the wall due to the transfer of heated air/vapour from the living space.
•On the inside to prevent excessive vapour penetration we require a vapour control layer (diffusion controlling).

•We need to regularly change the stale air in the living space with fresh air.
•Diffusion open constructions is not a substitute for an effective ventilation strategy

Diffusion Open Construction



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Breathable or diffusion open?

Water/Vapour interacts outside/inside our buildings by three key methods:

- Vapour Permeability: (the ability of a material to allow water vapour to pass through it
- Hyrgoscopicity: (the ability of a material to absorb and desorb water as a gas)
- Capillarity: (the ability of a material to absorb and desorb water as a liquid)

Why is it important to understand how water interacts with buildings:

Approximately 75% of building failures occur due to water

Water penetrations can:

- Effect the external surface of the building envelope
- Can effect the central layer of the envelope and lead to structural damage, thermal degradation and mould formation within the wall
- Mould growth on the inner surface on the external envelope
- Impair IAQ

Indoor Air Quality (IAQ)

IAQ can be affected by:

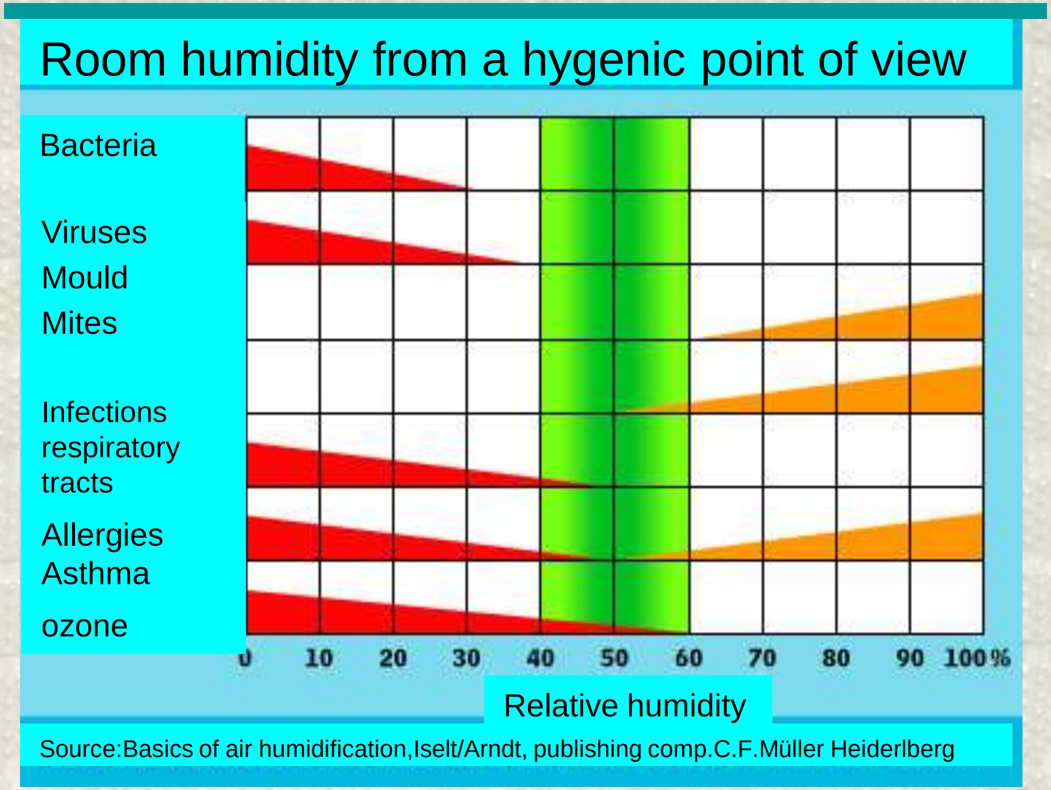
• microbial contaminants (moùld, bacteria),
•gases (including carbon monoxide, radon, volatile organic compounds),
•particulates,

90% of our time is spent within the living space. Using ventilation to dilute contaminants, filtration, and source control are the primary methods for improving indoor air quality in most buildings.

Common pollutants:

• Radon
•Moulds and other allergens
• Carbon monoxide
• Volatile organic compounds
•Legionella
• Asbestos fibers
•Carbon dioxide
• Ozone

IAQ


Room humidity from a hygenic point of view
Bacteria
Viruses
Mould
Mites
Infections respiratory tracts
Allergies Asthma
ozone
0 10 20 30 40 50 60 70 80 90 100%
Relative humidity
Source:Basics of air humidification,Iselt/Arndt, publishing comp.C.F.Müller Heiderlberg

Ventilation Systems

Natural Ventilation
•Trickle vents
•Passive Stack
•Supply air windows
•Opening windows

Mechanical ventilation
•Extract fans
•Whole house extract
•Room ventilator with heat recovery
•Whole house mechanical ventilation with heat recovery
•Demand Controlled Ventilation

Why Airtightness – Infiltration and Ventilation

Air Infiltration/Draughts and exfiltration – The uncontrolled entry or exit of outdoor or indoor air from the habitable space

Ventilation – The controlled/designed replacement of stale indoor air with fresh outdoor air

Airtightness – The elimination of uncontrolled air infiltration

BUILD TIGHT AND VENTILATE RIGHT!

Infiltration and Ventilation

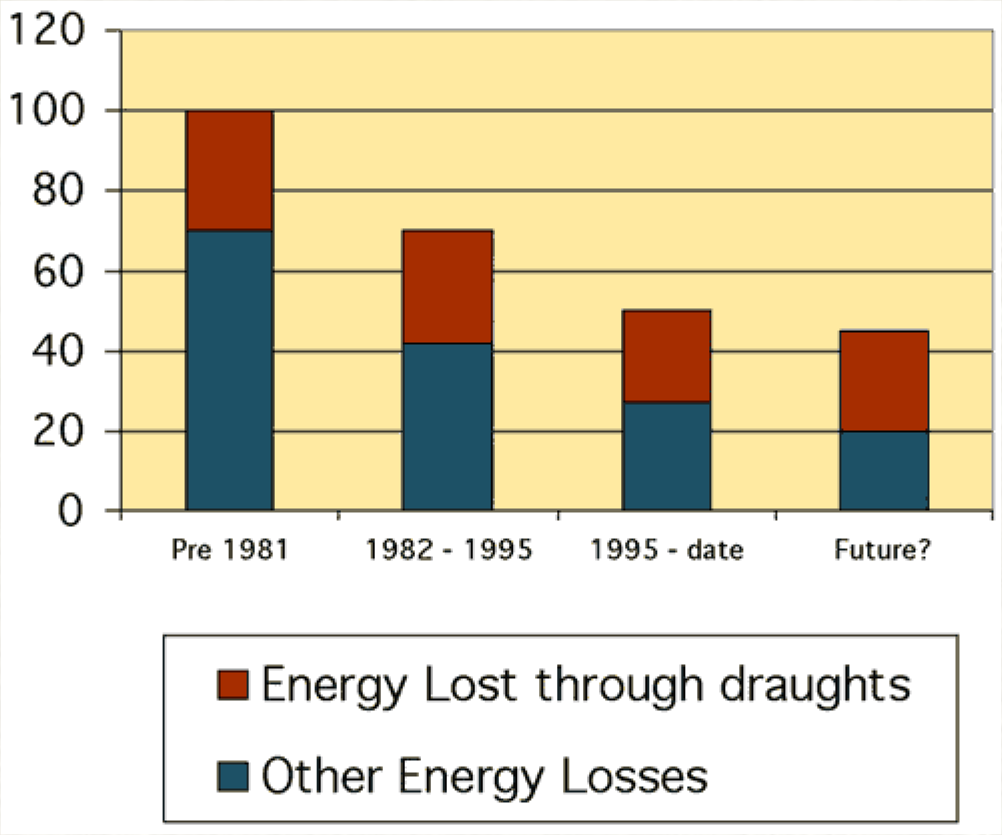
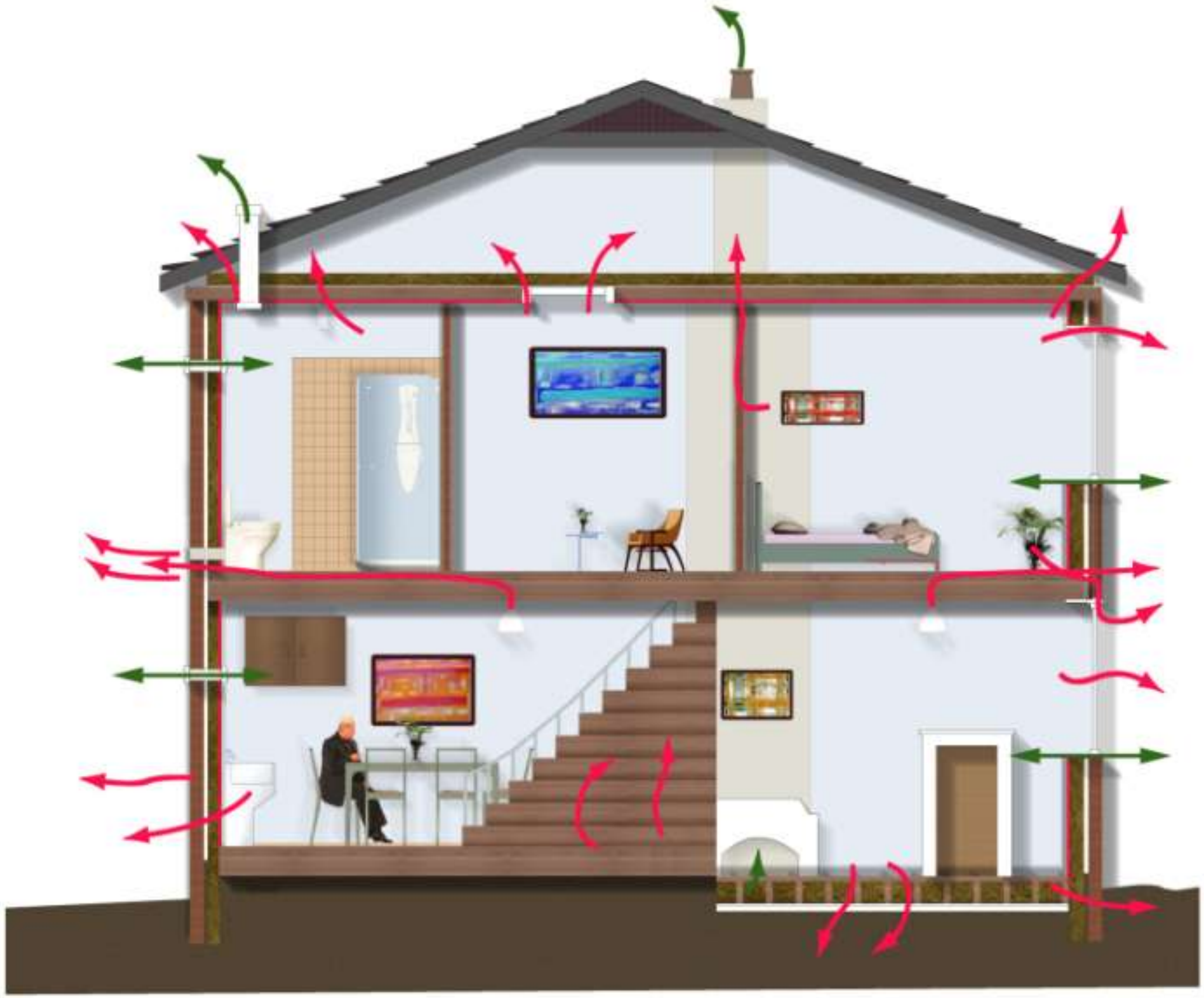
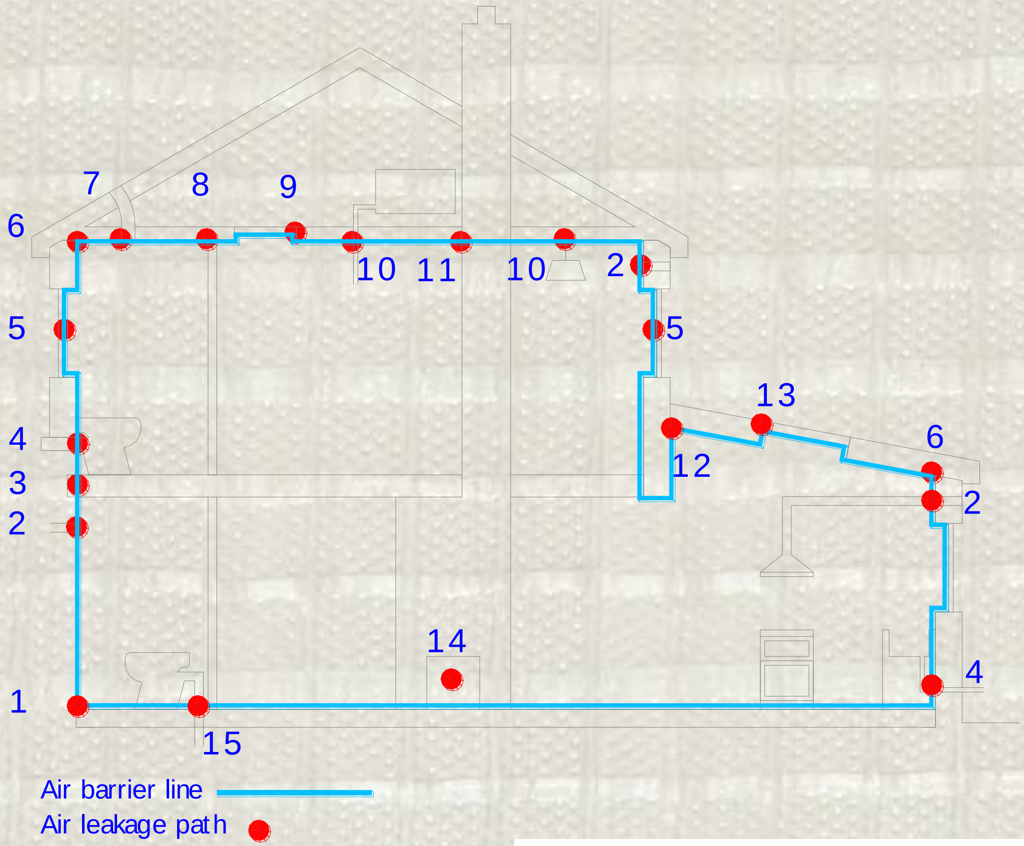


Figure of heat losses per P. Jennings, 'Airtightness in Buildings' Building for a Future Winter '00/'01



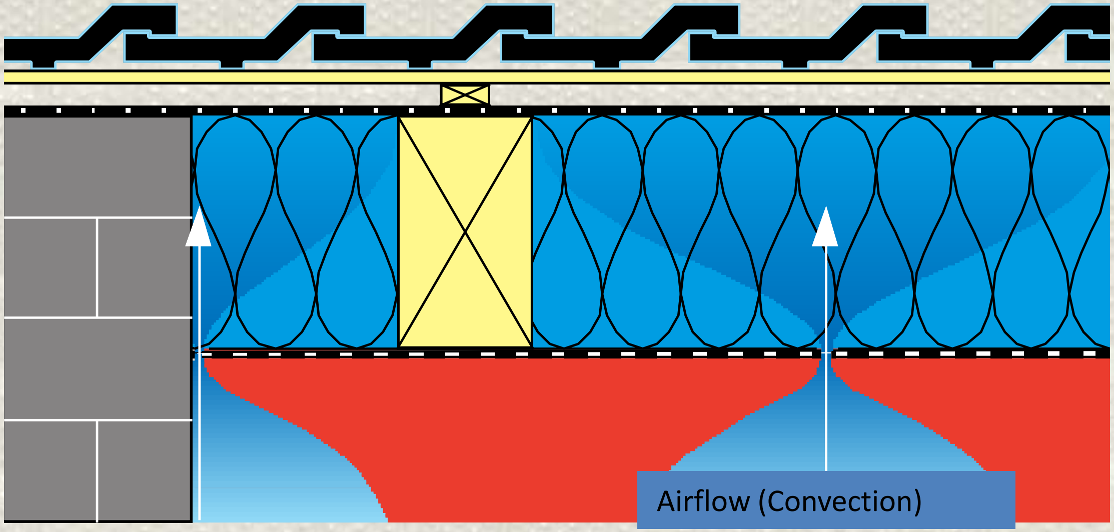
A draughty, “leaky” building

Clearly define air barrier layer and detail airtightness solutions



Build Tight, Ventilate Right!

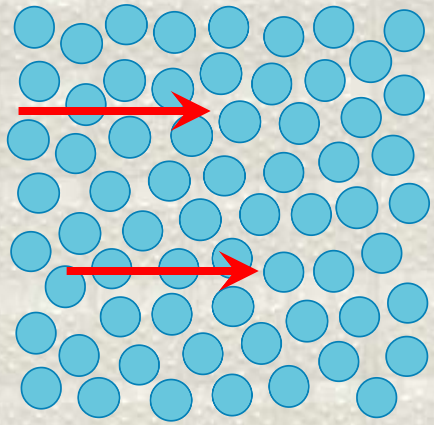
Typical construction situation



Consequences of defective air-tightness

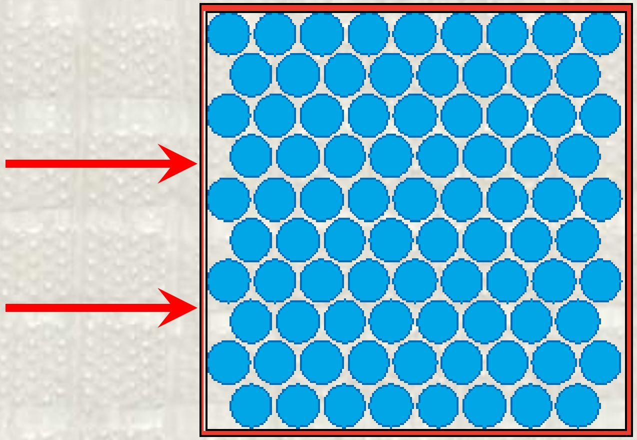
1. Heat loss
2. Building damage due to moisture
3. Deficient heat protection in summer
4. Deficient sound proofing

The principle of insulation

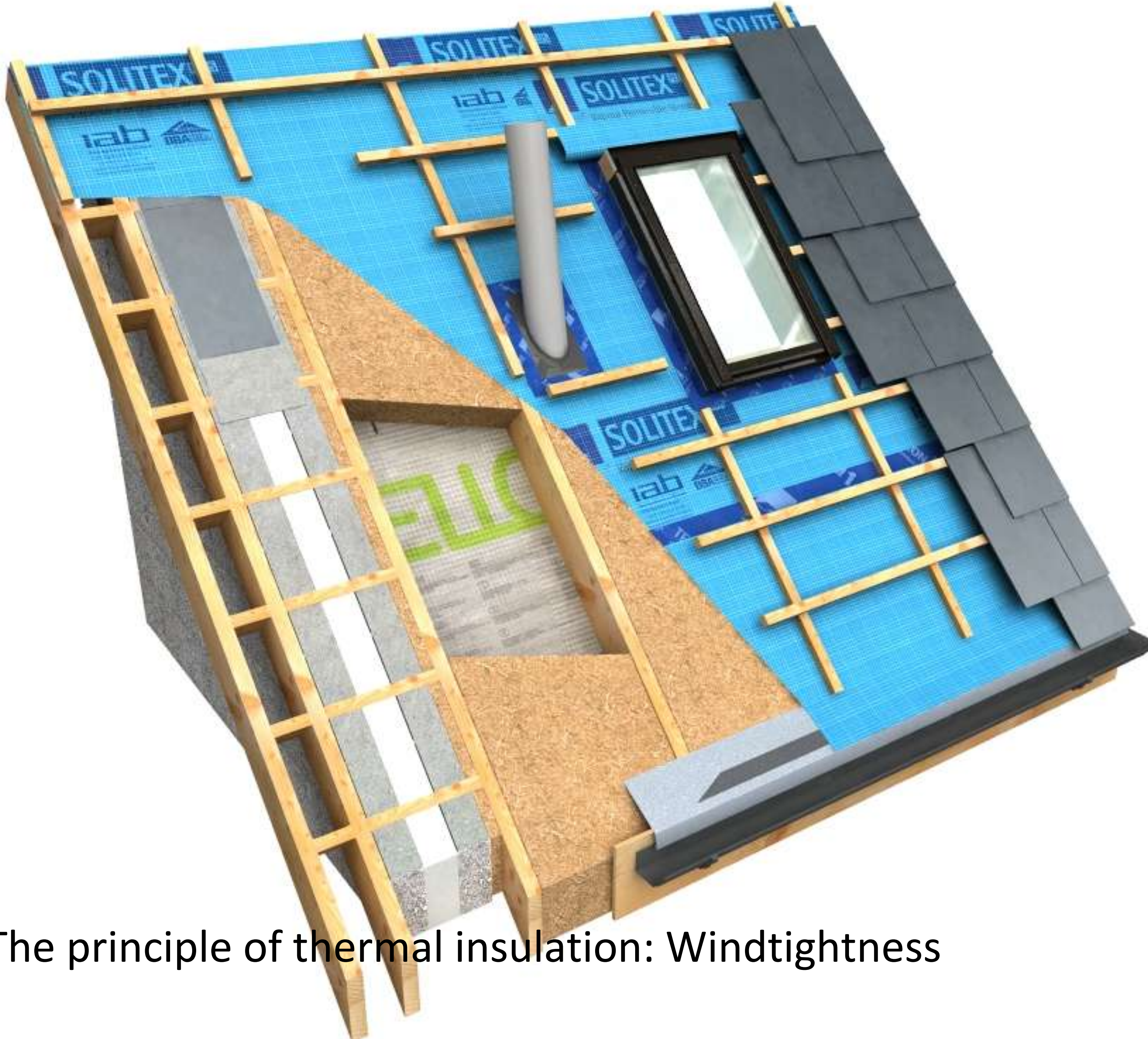


air movement

= heat transport

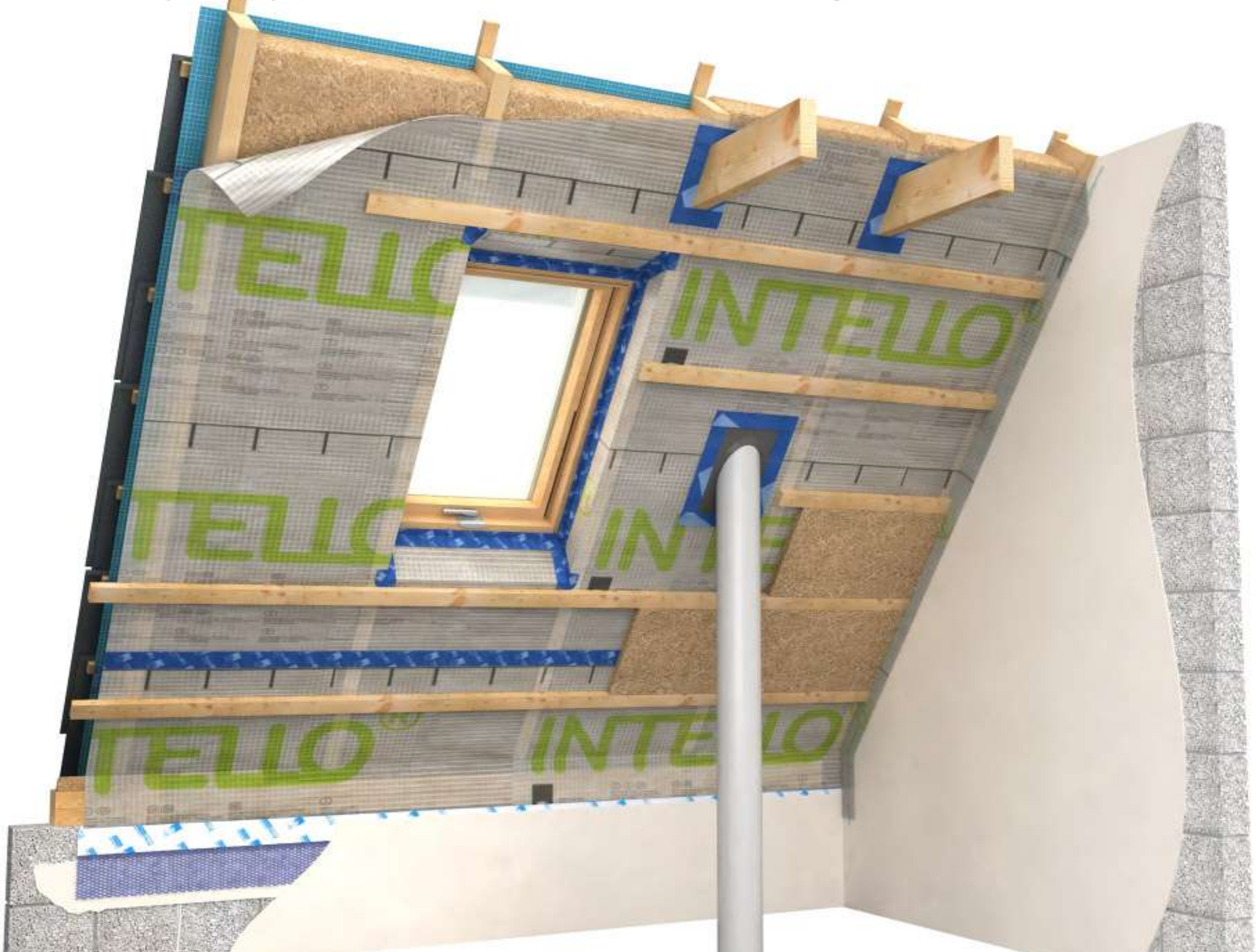


only inclusions of air that are protected against air movement insulate!

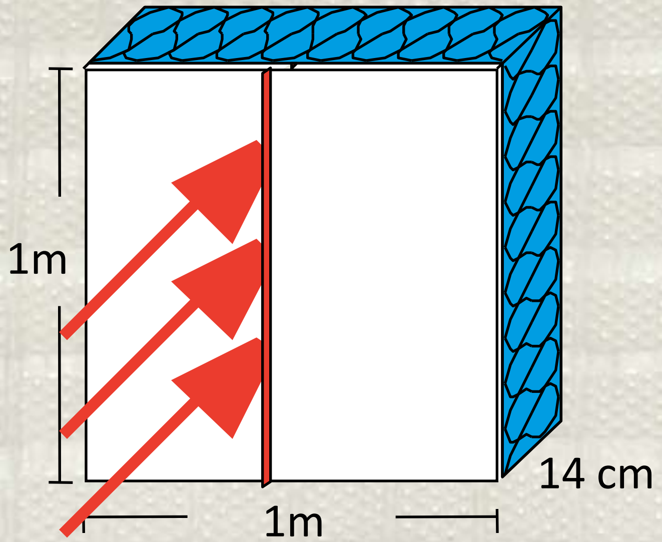


The principle of thermal insulation: Windtightness

The principle of thermal insulation: Airtightness



Heat losses due to Convection



Without gap: U-Value = 0,3 W/m²K

With 1 mm gap : U-Value = 1,44 W/m²K

Performance reduced by factor 4,8

Experiment set-up

Construction of insulating material

Gap in the vapour Check (air-tightening).

Frame conditions:
Inside temperature +20°C
Outside temperature -10°C
Pressure difference 20 Pa
= wind force 2-3

Measurement:
Institute of building physics, Stuttgart
Source: DBZ 12/89, page 1639ff

Assar Gabrielsson and Gustaf Larson ceated Volvo in 1927

‘Cars are driven by people. Therefore the guiding principle behind everything we make at Volvo is – and must remain – safety’

In 1959 Volvo introduced the seatbelt in its modern form as standard equipment in all their cars in Sweden.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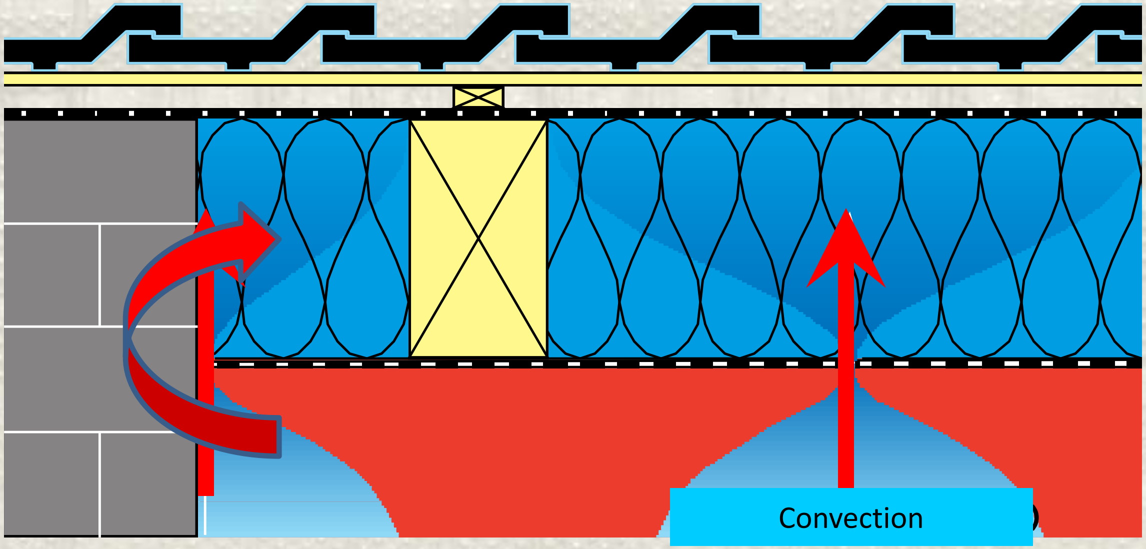
Improving the security of our building structures?

Structural Damage due to Moisture



Structural damage due to moisture

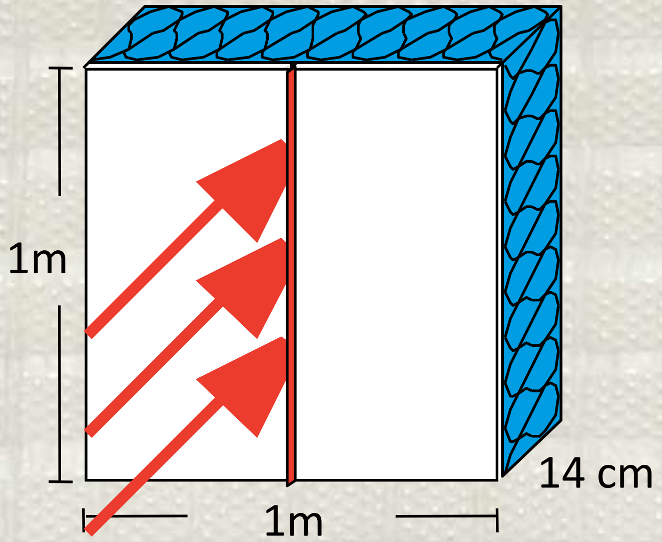
a. Diffusion

b. Convection

c. Moist installed construction materials

d. Flank Diffusion

Comparison diffusion/convection



Without gap: 0,5 g water/m²x24h

With 1 mm gap: 800 g water/m²x24h

Performance reduced by factor 1600

Experiment set-up constr.

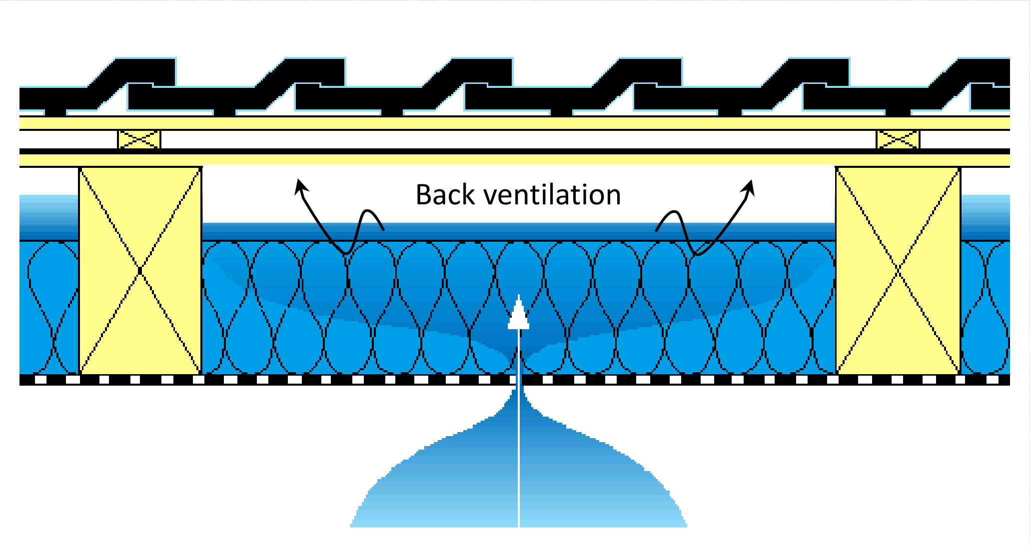
of insulating material

Inside vapour seal
s_d = 30 m (mvtr = 150 MNs/g])
Gap in the vapour Check
(air-tightening)

Frame conditions:
Inside temperature +20° C
Outside temperature -10° C
Pressure difference 20 Pa
= wind force 2-3

Measurement:
Institute of building physics, Stuttgart
Source: DBZ 12/89, page 1639ff

Building damage



Efficient back ventilation as measure to avoid building damage

Humidity due to leaks is removed.

Disadvantages

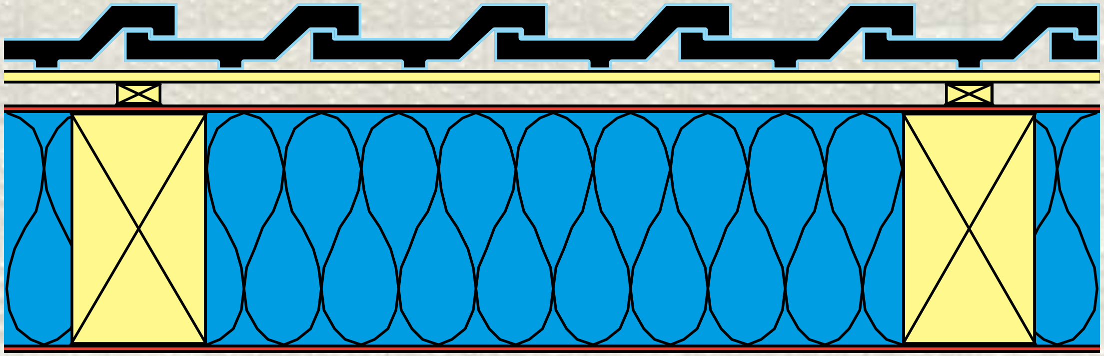
Less efficient thermal insulation

- Non-existent protective layer for insulation
- Smaller thickness of the insulation
- Higher rafters

Attack by insects possible

Ideal Situation: full rafter insulation

The perfect insulation constuction



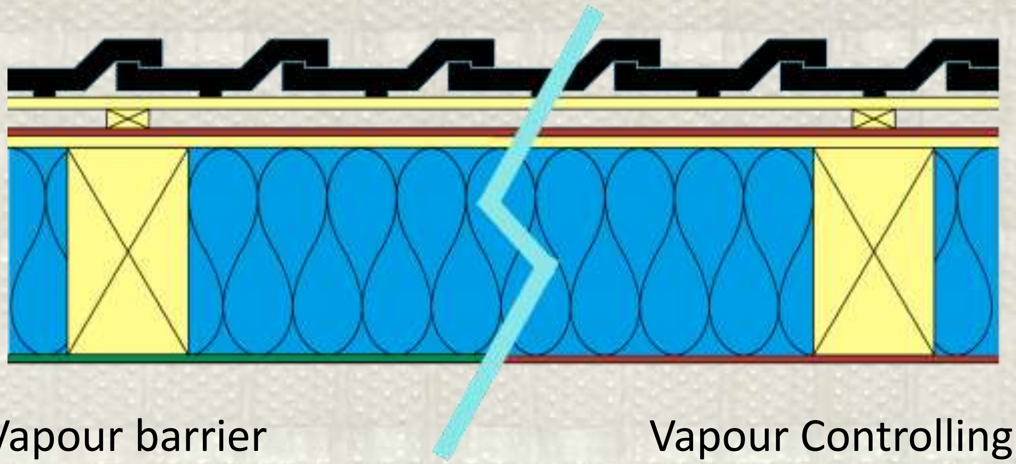
Protective layer outside the insulation

insulation

airtightening

Insulation with highest efficiency

Full rafter insulation



Vapour barrier

?

Vapour Controlling

?

Full rafter insulation, diffusion-tight on the outside

s_d-Value of the sub-roof = 300 m

Diffusion Resistance of Building Materials

Vapour diffusion resistance coefficients of the most common building materials according to EN ISO 13788

Material	μ	Material	μ
Lamb‘s wool, flax	1	Plasterboard	8
Mineral wool	1	lime Plaster	15-35
Cellulose insulating material	1-2	Wood	40
Wood fibre insulating board	2-5	Concrete	100
Cork	5-10	pro clima DB+	10.000
Brickwork	5-10	Polyethylene foil	100.000

Calculation of the equivalent air layer thickness: $s_d = \mu \times s$ [m]. $S_d \times 5.1$ =MNs/g

Material			s_d-Value
Plasterboard 10 mm	8 x 0,01	=	0,08 m
Brickwork 30 cm	7,5 x 0,30	=	2,25 m
pro clima DB+ 0,23 mm	10.000 x 0,00023	=	2,30 m
Wood 60 mm	40 x 0,06	=	2,40 m
Concrete 20 cm	100 x 0,2	=	20,00 m
Polyethylene foil 0,2 mm	100.000 x 0,0002	=	20,00 m
Bitumen roofing felt	80.000 x 0,003	=	240,00 m

Definition of range of vapour control layers

Vapour Check : 0.5m – 1500m

Vapour Barrier: >1500m

Source: BRE IP 2/05 Modelling and controlling Interstitial condensation in buildings

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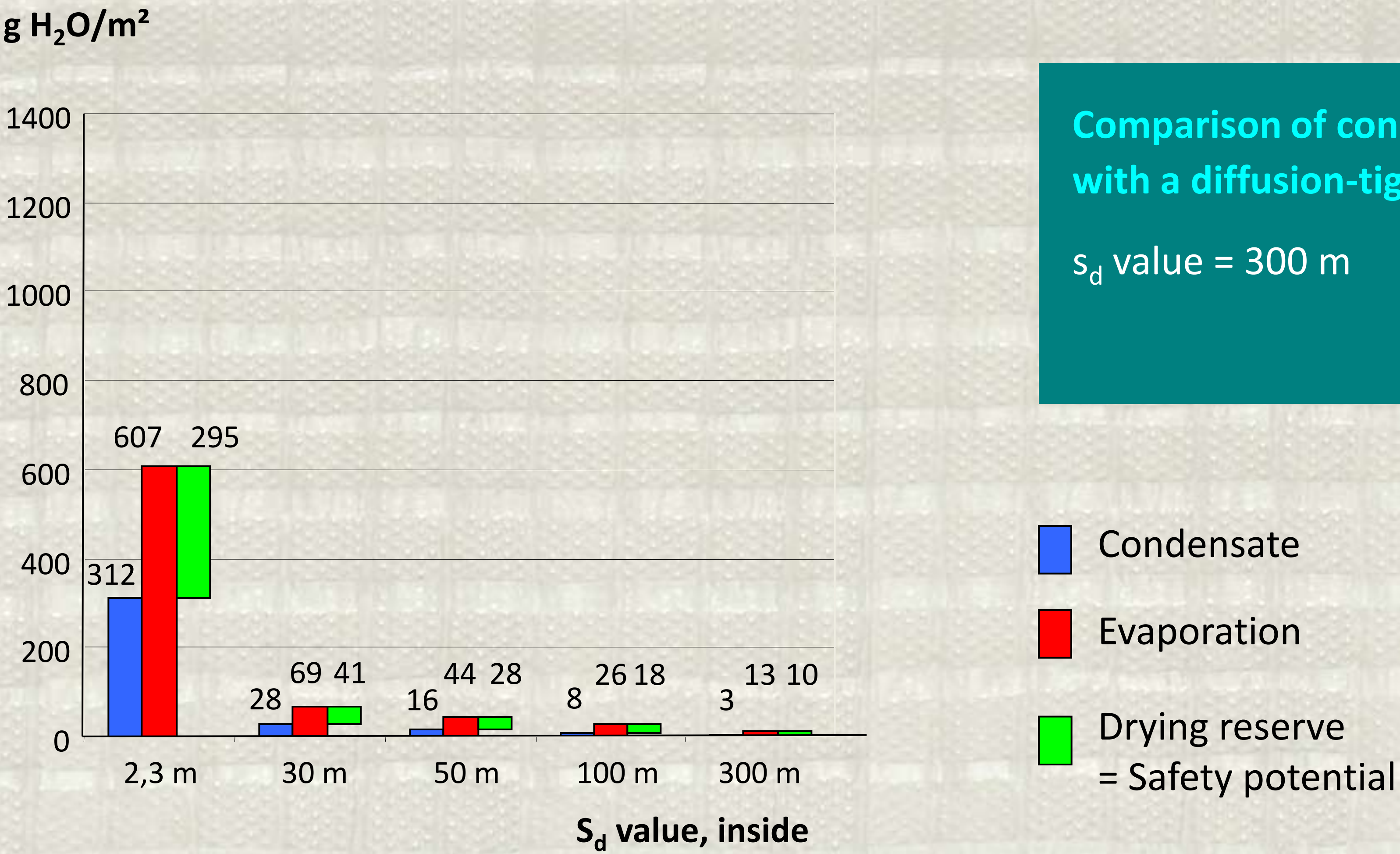
Safety Factor for Diffusion Tight Roof



Comparison of condensate with a diffusion-tight subroof

s_d value = 300 m

"Intelligent" Building Materials

Construction materials whose diffusion resistance changes as a function of its moisture content

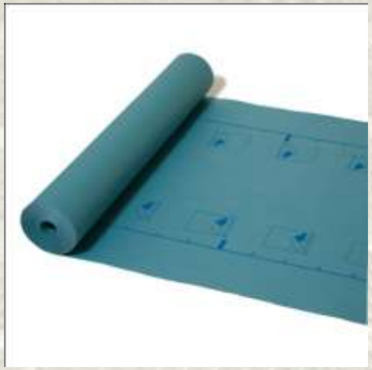
⇒ Wood according to DIN 4108

at 60 % wood moisture	$\mu = 12 – 15$
at 10 % wood moisture	$\mu = 200$

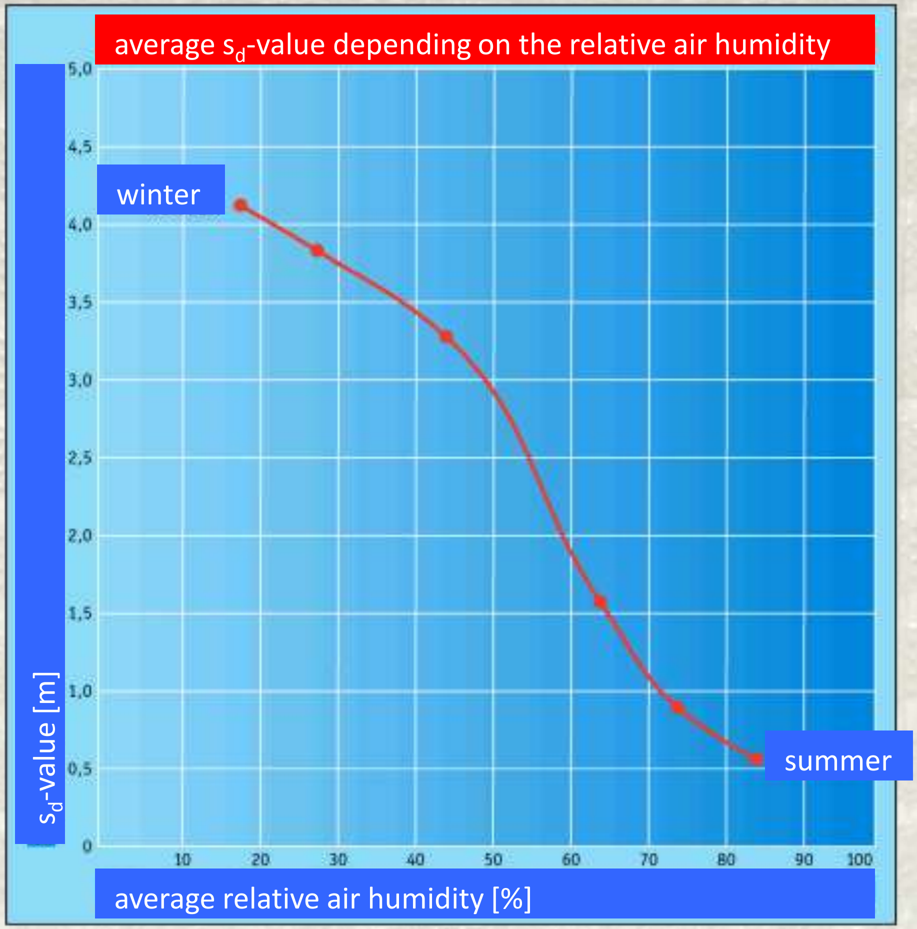
⇒ Lime plaster

dry	$\mu = 35$
moist	$\mu = 15$

⇒ **pro clima DB+ Cellulose vapour check has a variable s_d value**



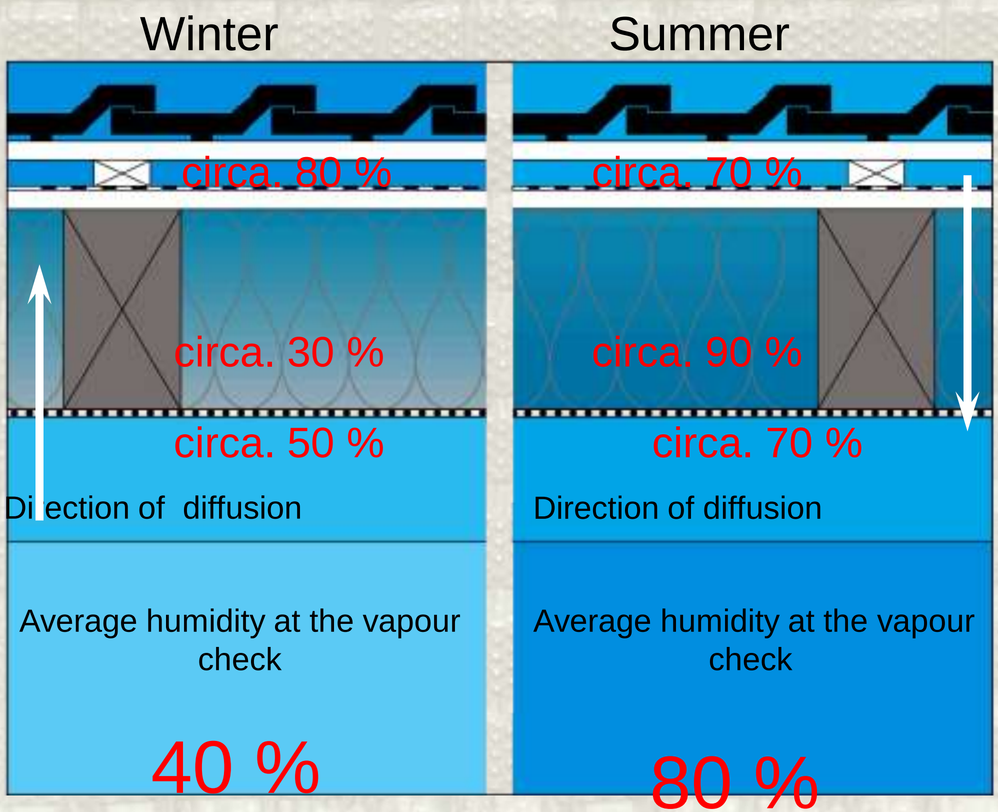
“Intelligent” Building Materials



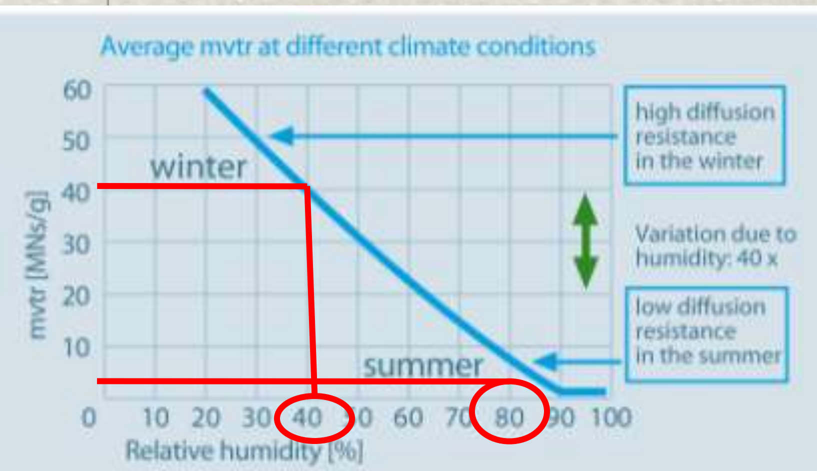
Humidity-variable diffusion resistance of the pro clima DB+

to avoid building damage

Humidity– variable diffusion resistance



Distribution of relative air humidity in the component's cross section



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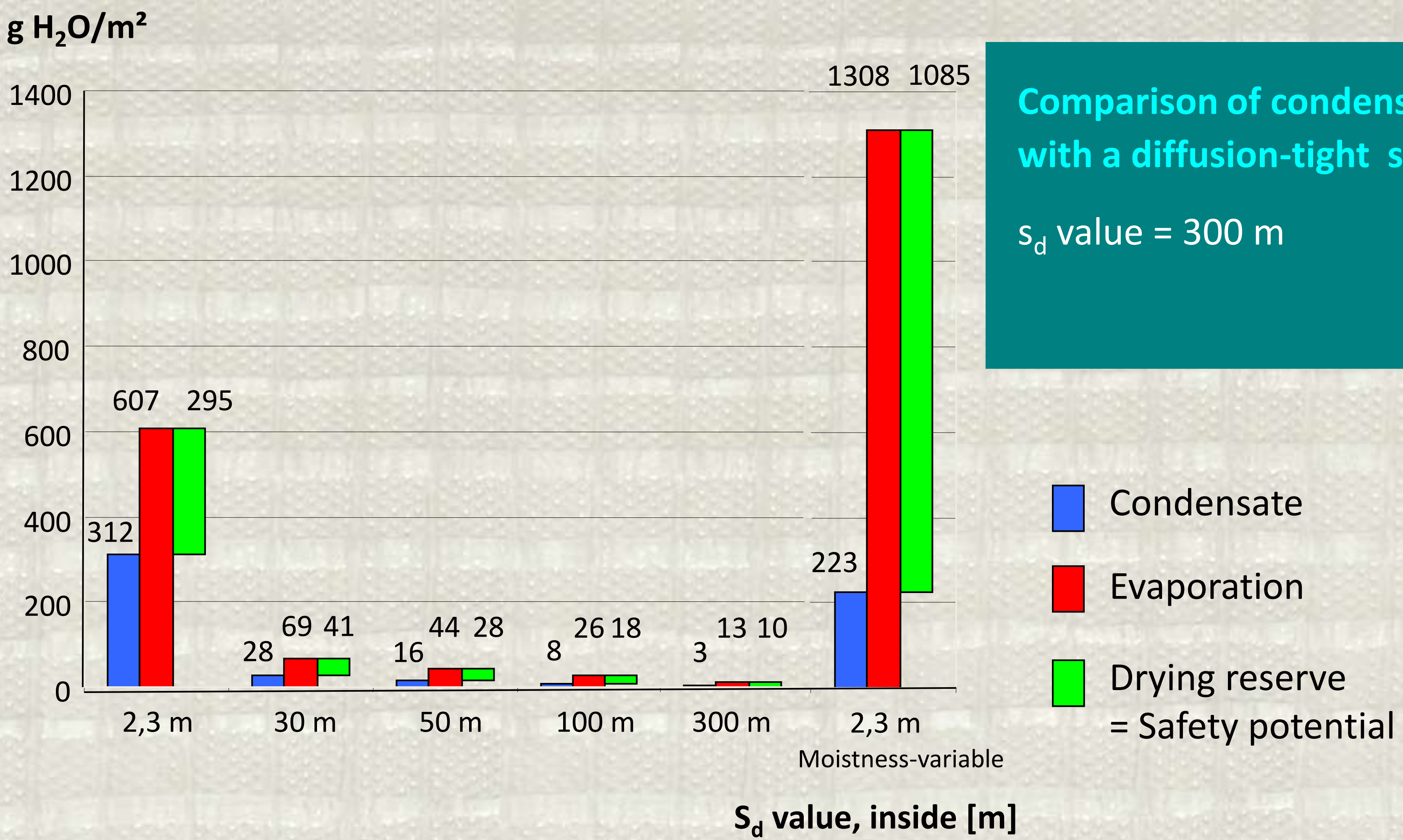
Security potential of a diffusion-tight roof



Comparison of condensate with a diffusion-tight subroof

s_d value = 300 m

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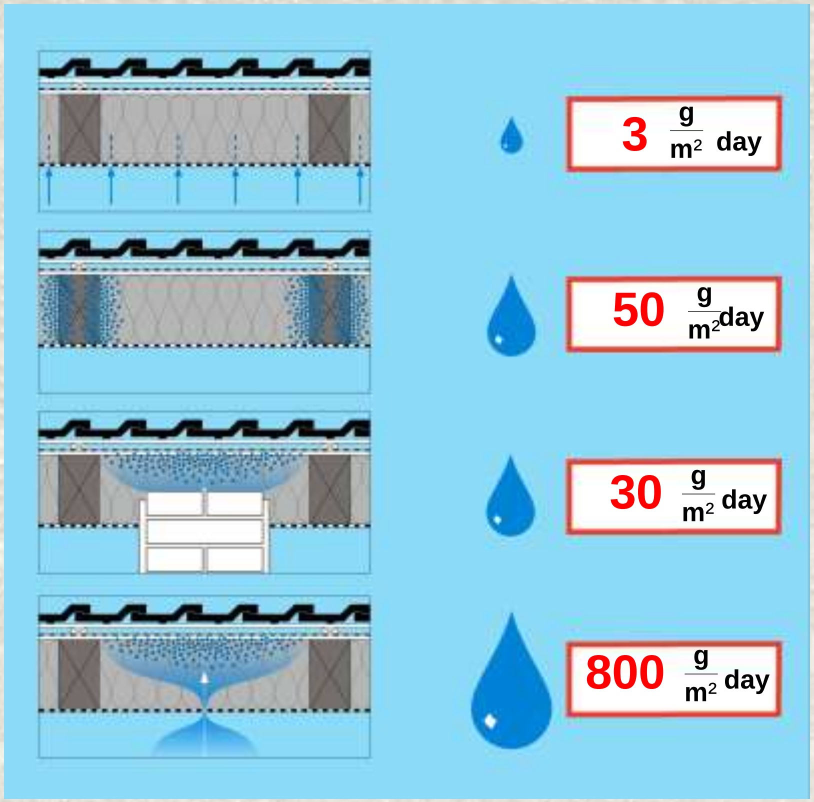
Consequences of faulty airtightness

Diffusion

Drying of wood

Flank diffusion

Convection 1 mm gap



In winter constructions are exposed to moisture

Conclusion:

There is no absolute protection against moisture

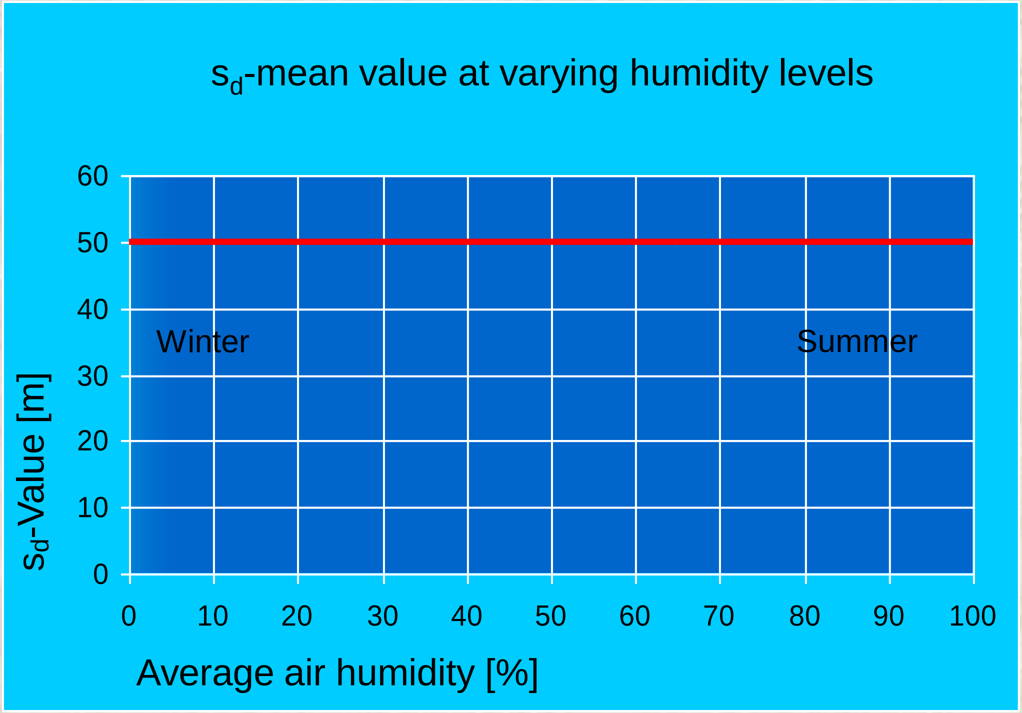
Consequences of faulty airtightness

There is no absolute protection against moisture

Solution:
Increase drying potential

Ideal:
More Diffusion open construction externally **where possible** and Intelligent membranes with Humidity – variable diffusion resistance on the inside

Constant High diffusion resistance: Vapour Barrier



Vapour barrier

e.g. PE-Foil s_d = 50 m (mvtr = 250 [MNs/g])

No possibility for constructions to dry out when unexpected moisture occurs

Continuous High Vapour Resistance

Back Diffusion in summertime

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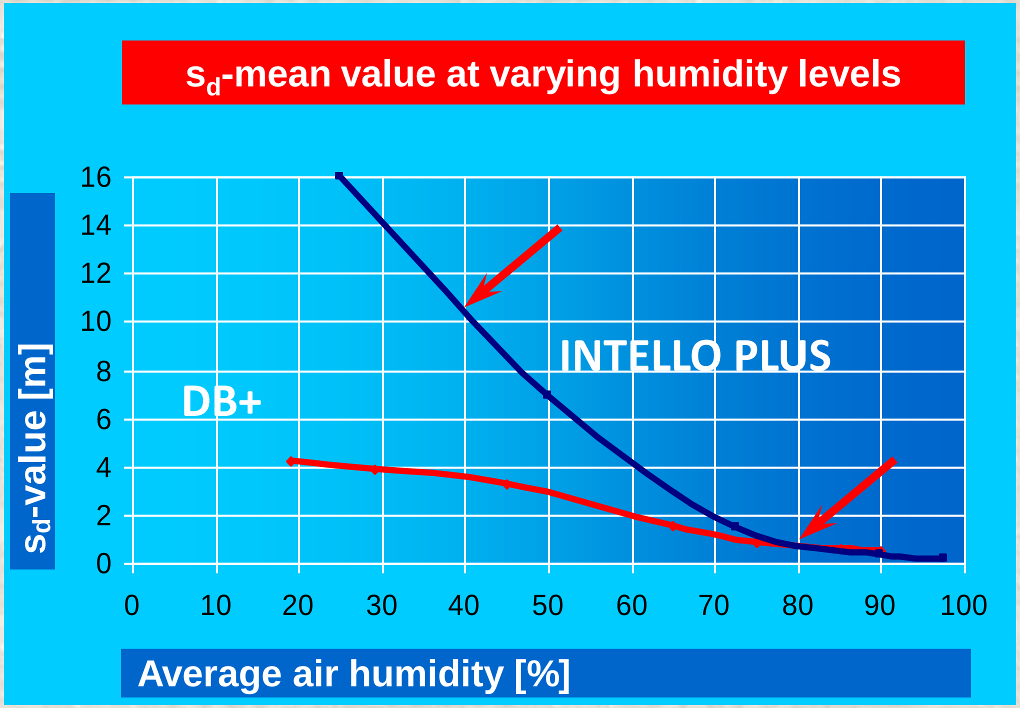
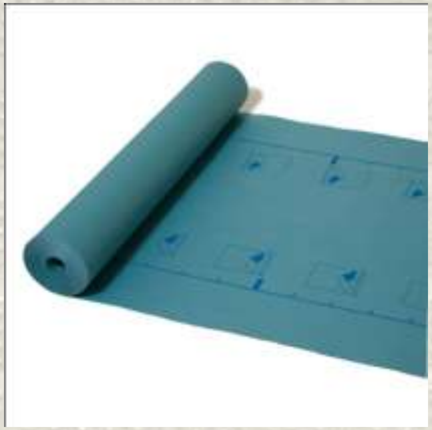
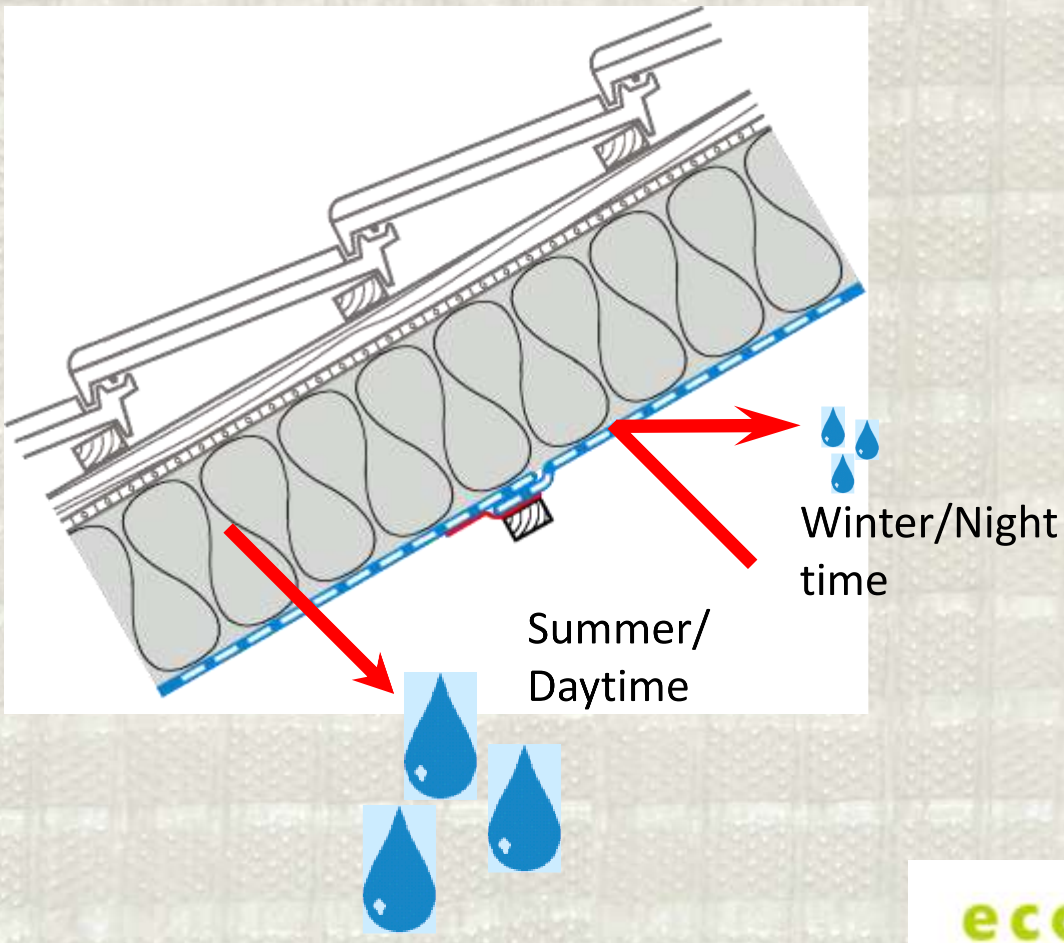
Humidity – variable diffusion resistance: Intelligent Technology





Vapour Checks with humidity – variable diffusion resistance



Freedom from structural damage due to vapour checks with
humidity – variable
diffusion resistance

In winter: protection against moisture entry

In summer: high drying potential

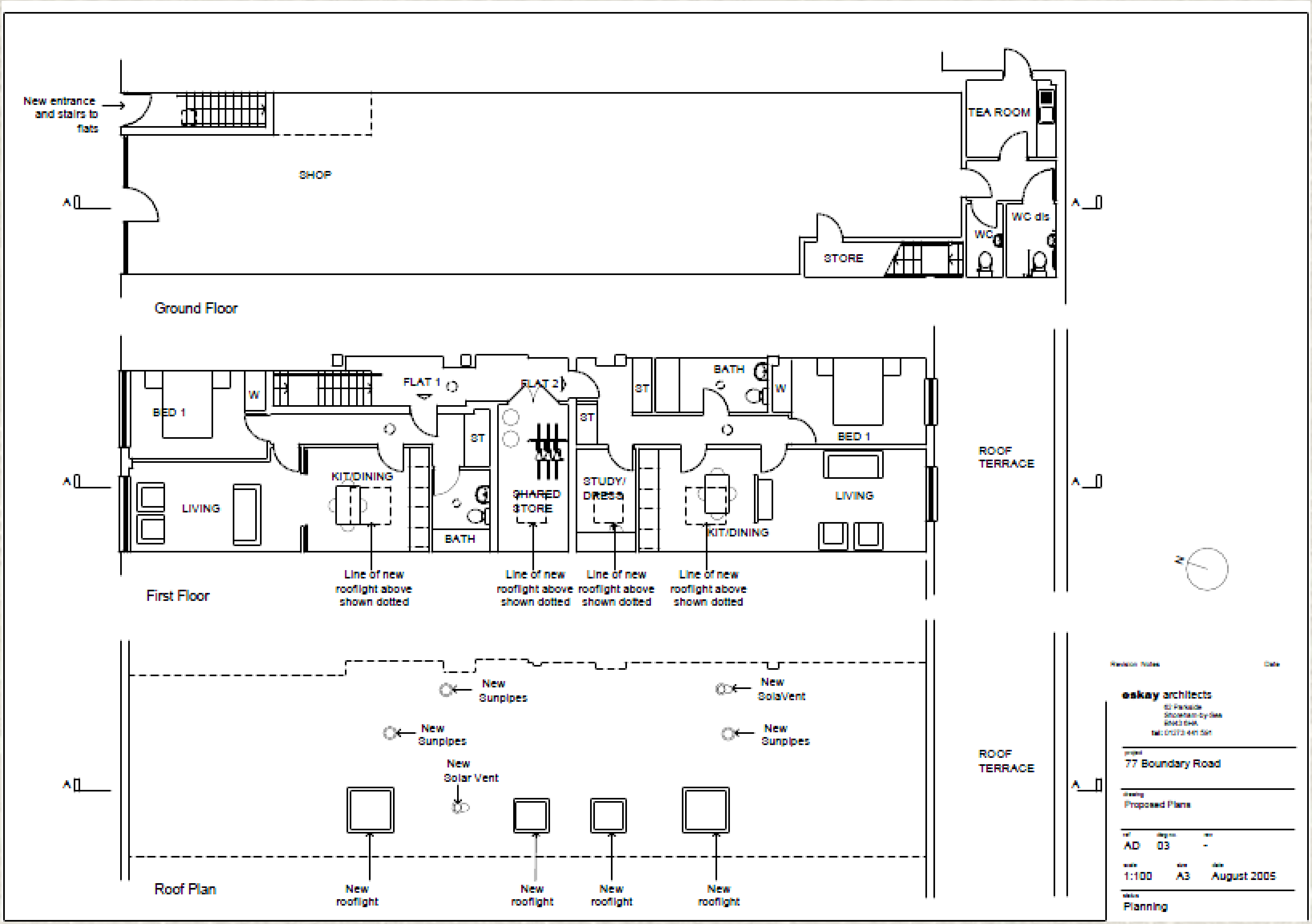
Case Study: 77 Boundry Road, Shoreham by Sea; November 2006

Architect: Sarah Kemp, Eskay architects, Shoreham by Sea

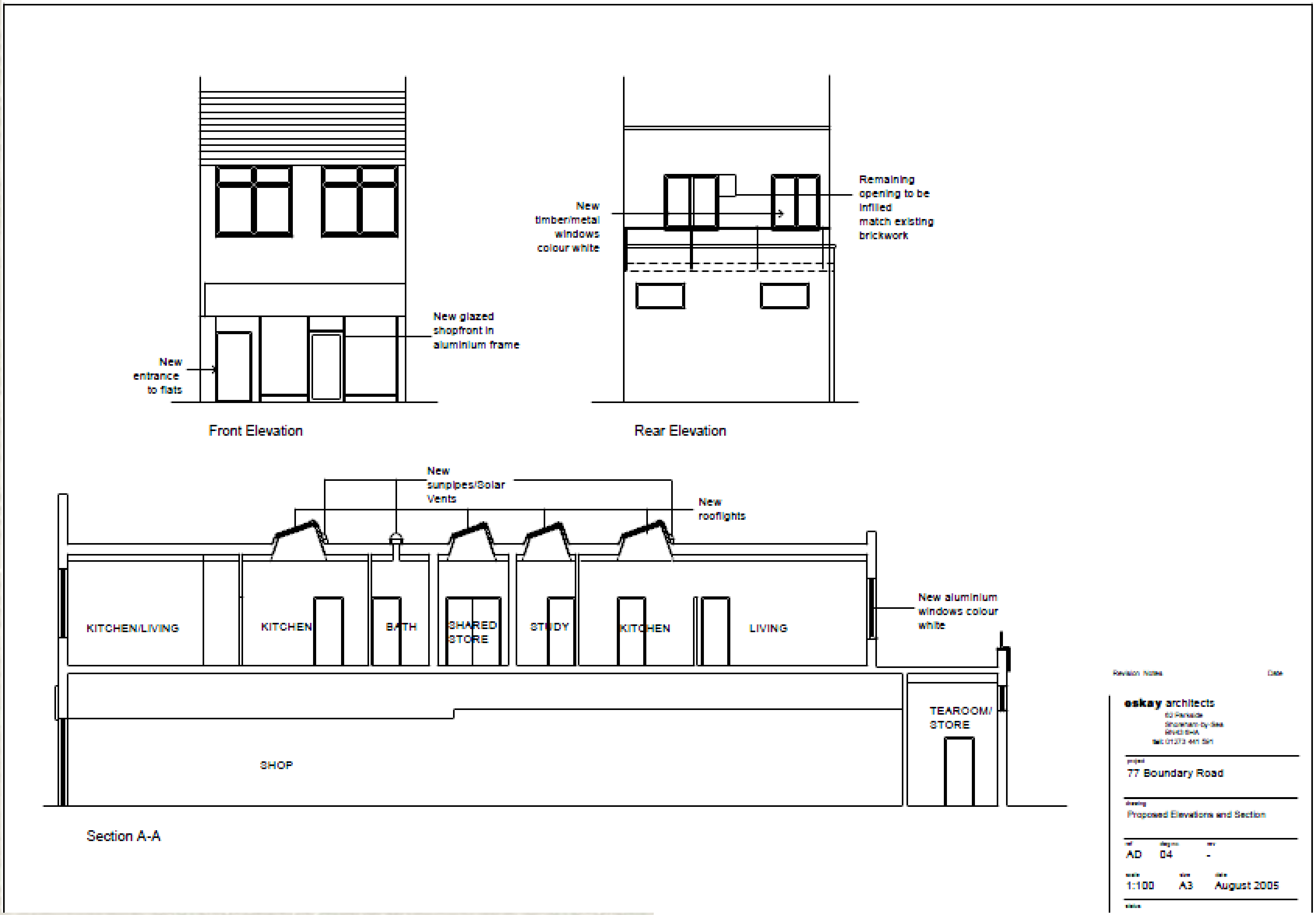
Original Construction, form the outside:

- Asphalt,
- Polystyrene (50mm)
- 19mm Ply

Case Study: 77 Boundry Road, Shoreham by Sea; November 2006



Case Study: 77 Boundry Road, Shoreham by Sea; November 2006



Case Study: 77 Boundry Road, Brighton; November 2006

Architect: Sarah Kemp, Eskay architects, Shoreham by Sea

Original Construction, form the outside:

- Asphalt,
- Polystyrene (50mm)
- 19mm Ply

Proposed Construction: Building Control

- Asphalt
- Polystyrene (50mm)
- 19mm Ply
- 50mm continuous Vented void
- 100mm Insulation
- Vapour barrier/Check
- Plasterboard

U value: 0.41W/m2K

Proposed Construction: pro clima

- Asphalt
- Polystyrene (50mm)
- 19mm Ply
- 150mm Insulation
- INTELLO PLUS Intelligent vapour check
- 25mm service zone
- Plasterboard

U value: 0.21W/m2K

Assessing building security against unforeseen moisture penetration

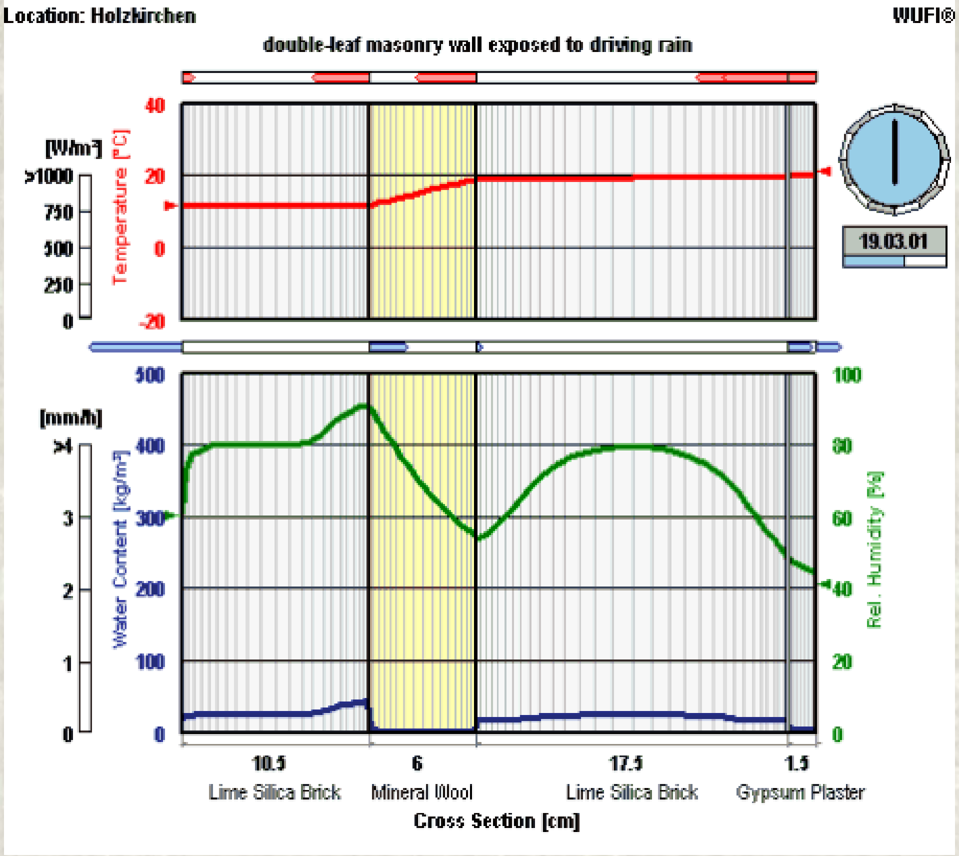
Calculation program

Computer- assisted simulation program for heat and humidity transports (dynamic) WUFI

- Real climatic data
- Inside and outside temperature
- Inside and outside humidity
- Light absorption
- Moisture storage capability
- Capillary action

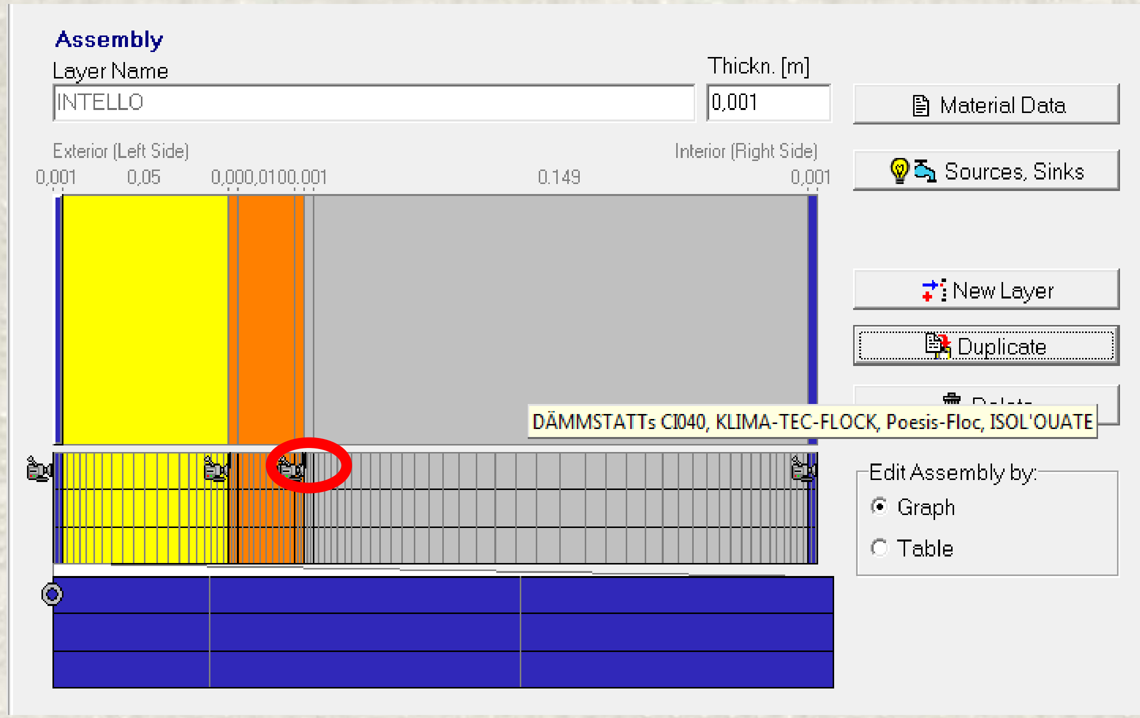
(Data of one reference year at intervals of 1 hour)

Current BS EN 15026: 2007 provides higher accuracy compared with EN 13788:2002 in BS 5250.



www.wufi.de

Calculating Potential Freedom from Structural Damage



1. Asphalt roofing membrane 3 mm thick: diffusion-tight
2. 50mm EPS
3. Plywood 19 mm
4. Cellulose 150 mm

Initial mositure: 20 kg/m³ = 3.6 l/m²

5. Vapour barrier/Intelligent vapour check

6 Service zone 20 mm

7. Gypsum plasterboard 12 mm

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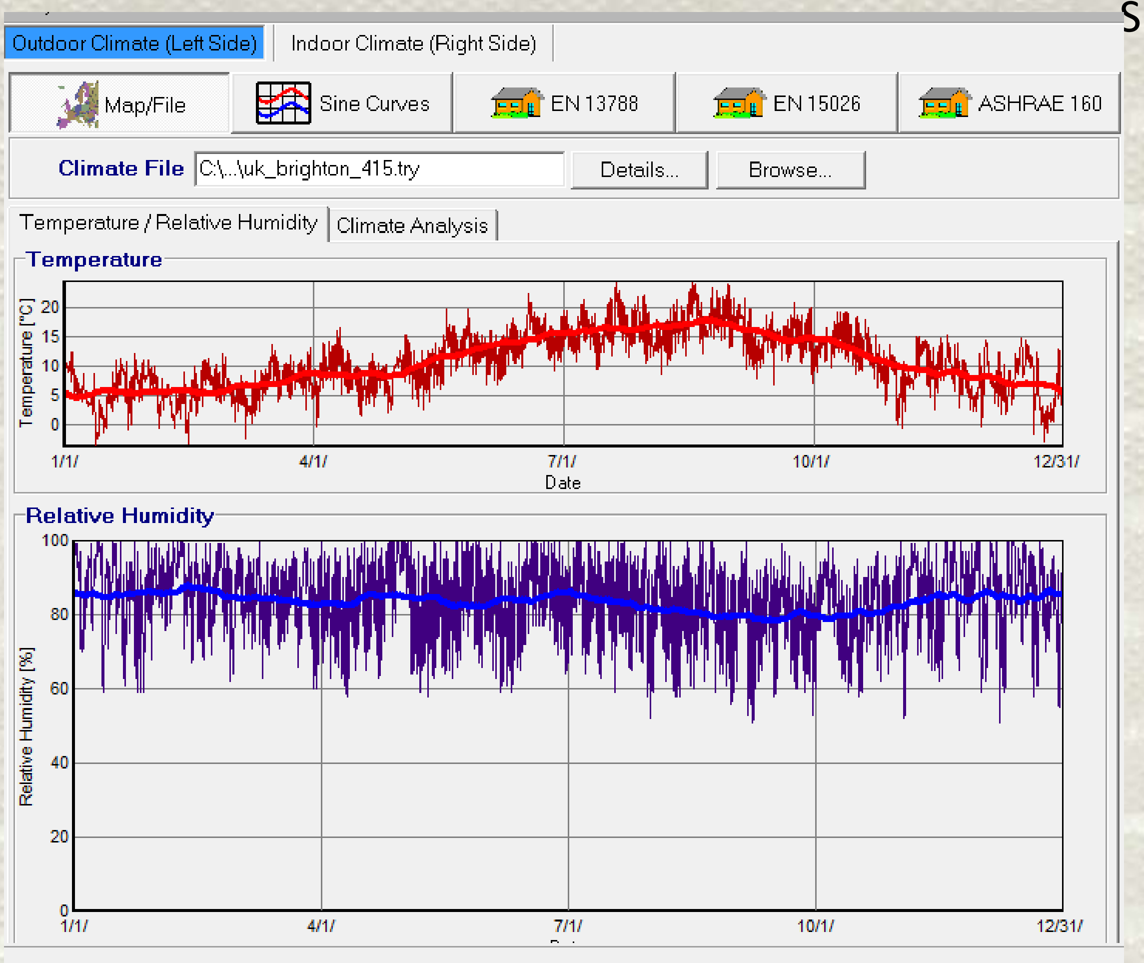
Potential Freedom from Structural Damage

Brighton



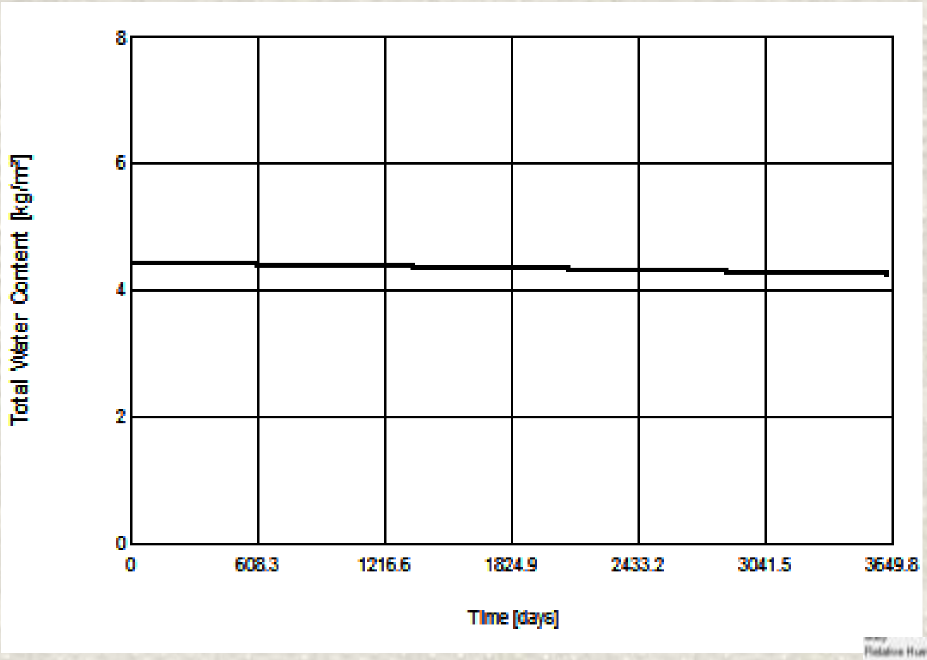
Summer:

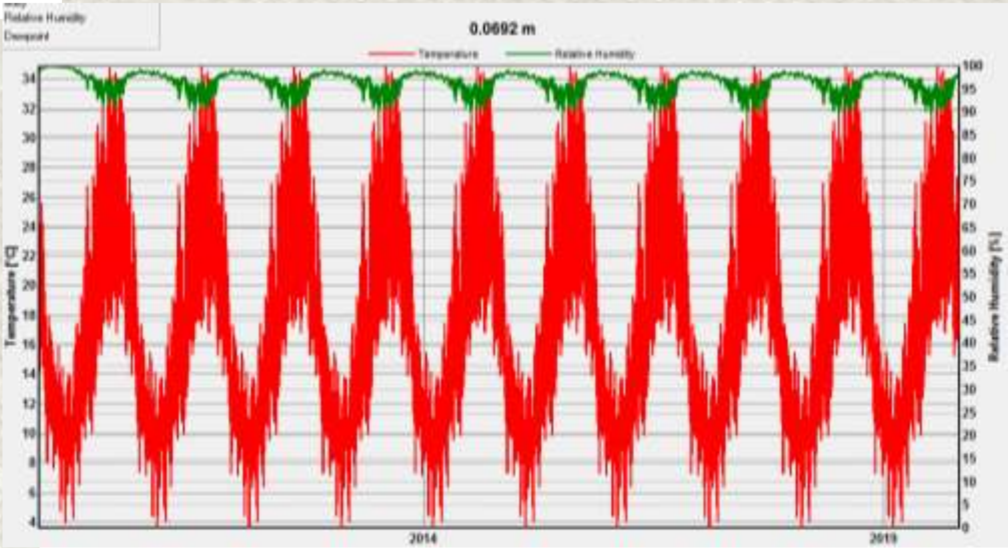
A lot of solar radiation

Winter:

Cloudy and mild

Vapour Barrier inside





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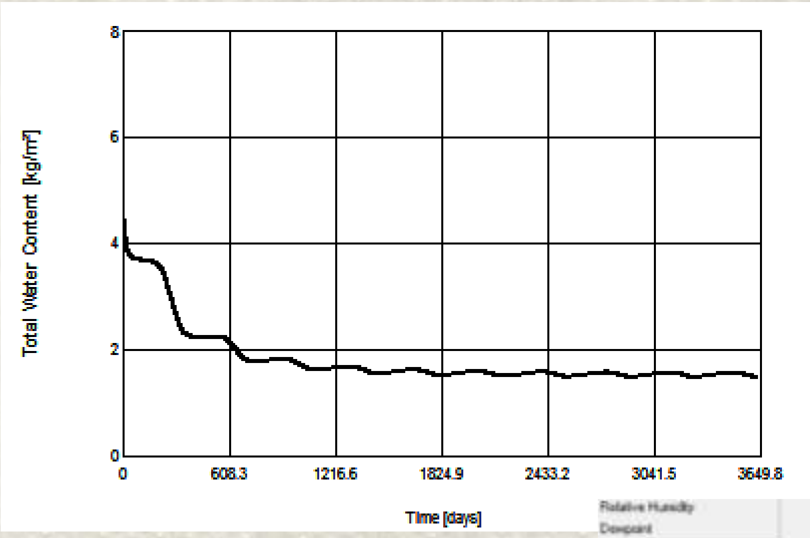
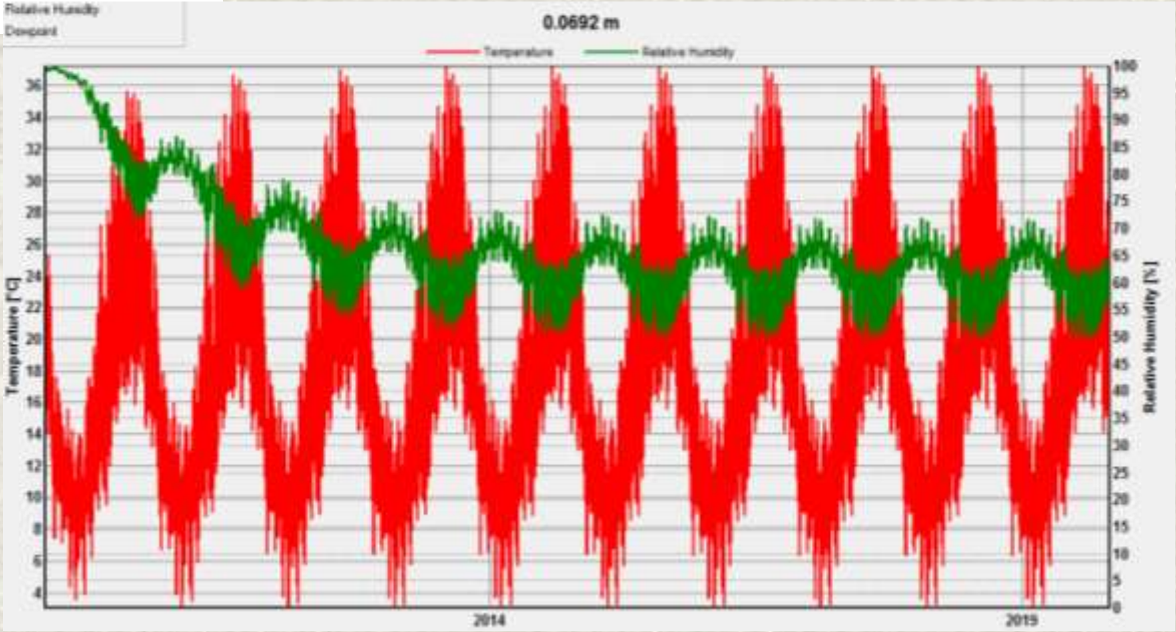
Intelligent vapour check inside





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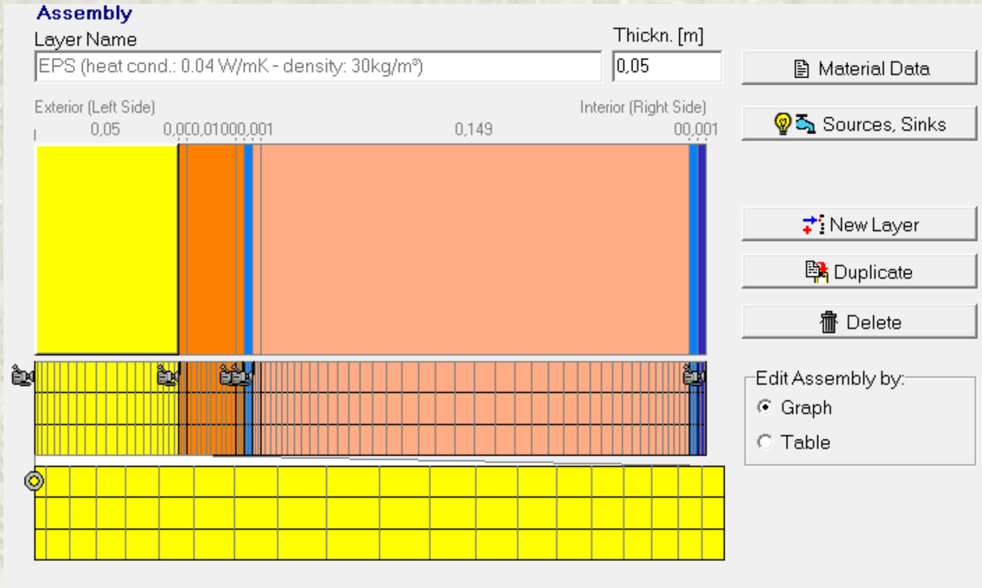


1. Asphalt roofing membrane 3 mm thick: diffusion-tight

2. 50mm EPS

3. Plywood 19 mm

4. PUR 150 mm

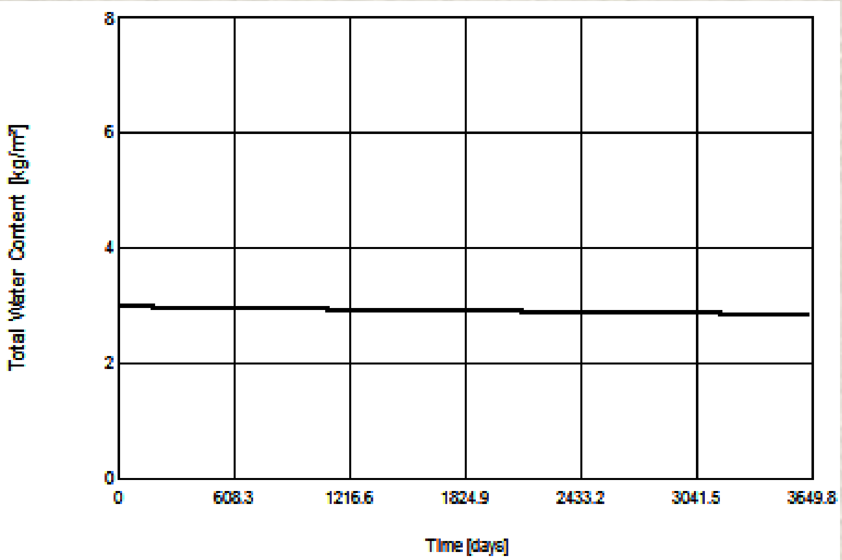
Initial moisture ply: 150 kg/m³

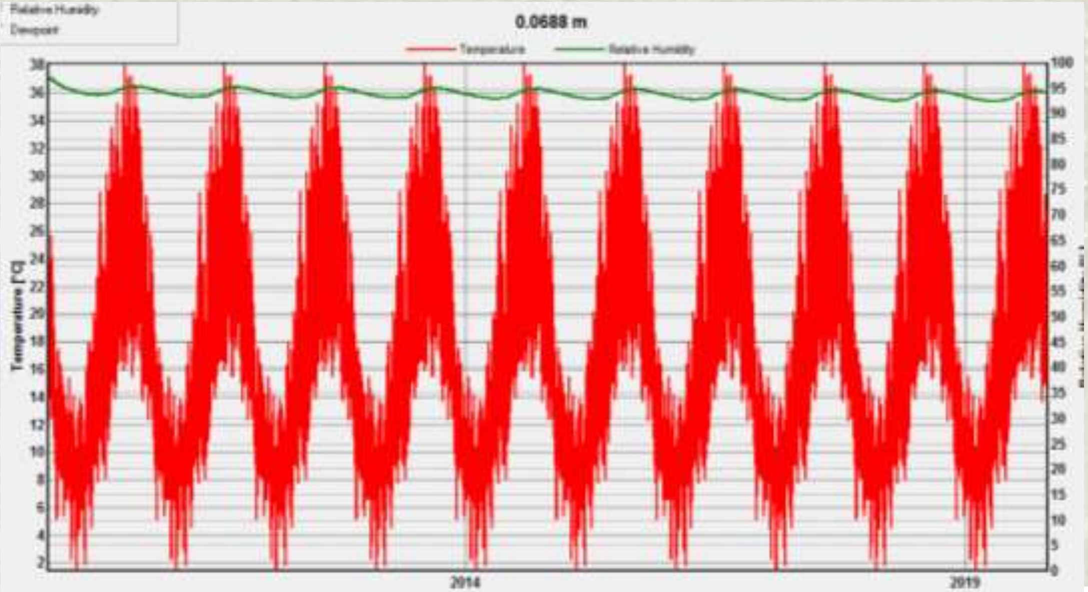
5. Vapour barrier/Intelligent vapour check

6 Service zone 20 mm

7. Gypsum plasterboard 12 mm

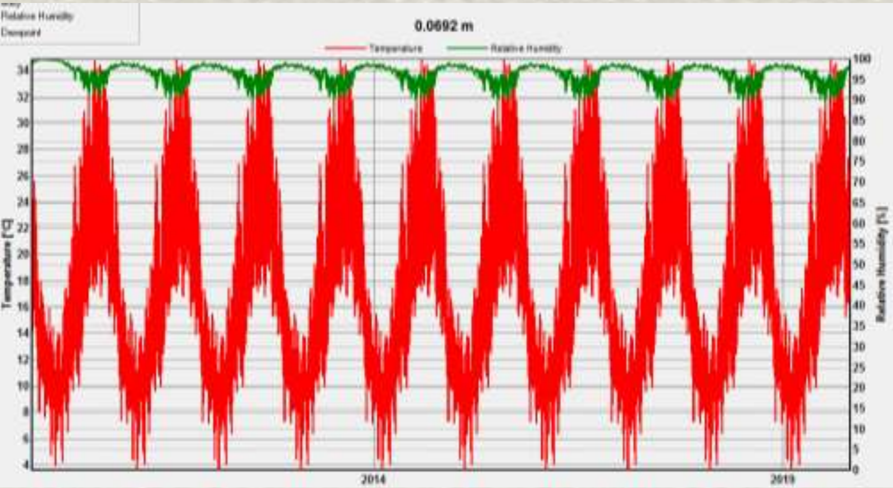
PUR insulation with Intelligent membrane inside



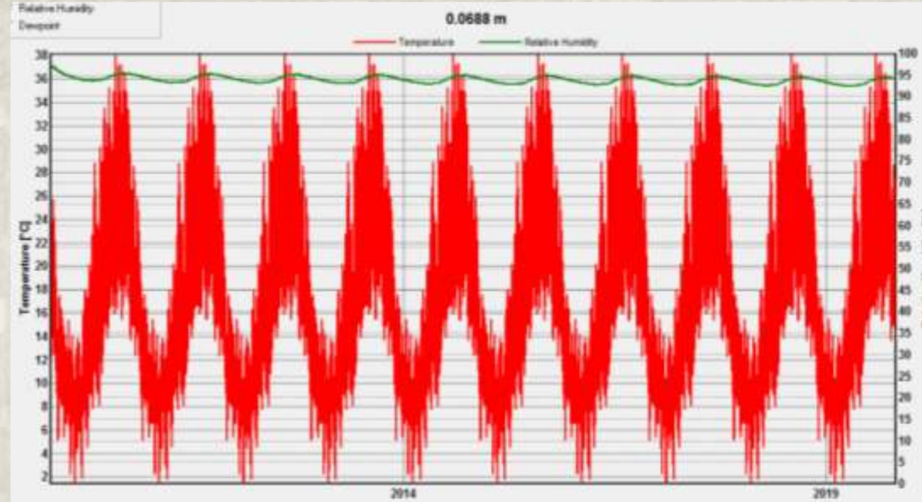


Calculation Summary

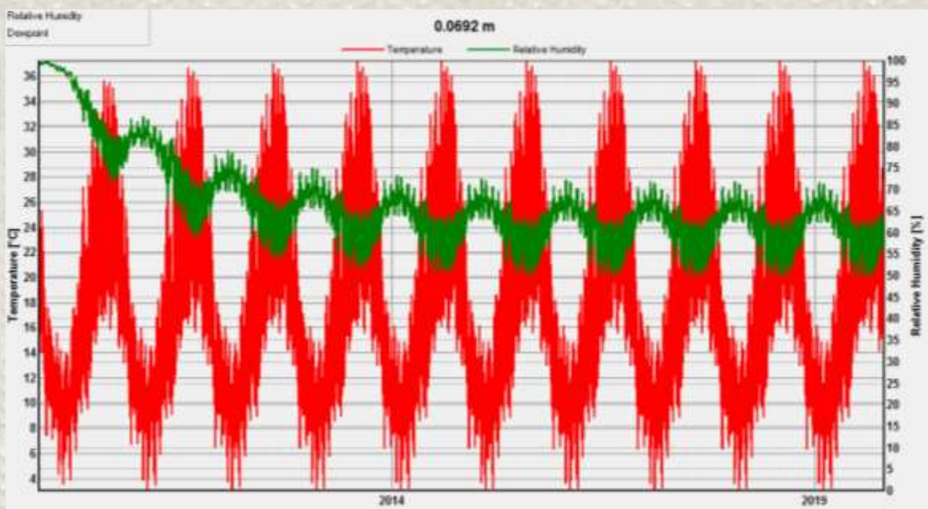
Vapour Barrier inside



Intelligent membrane inside and PUR bet rafters



Intelligent membrane inside and Cellulose insulation



To maximise potential freedom from structural damage……

Moisture loading > Drying reserves

= Structural damage

Drying reserves > Moisture loading

= No structural damage

Build with adequate reserves and
you will never have structural damage!

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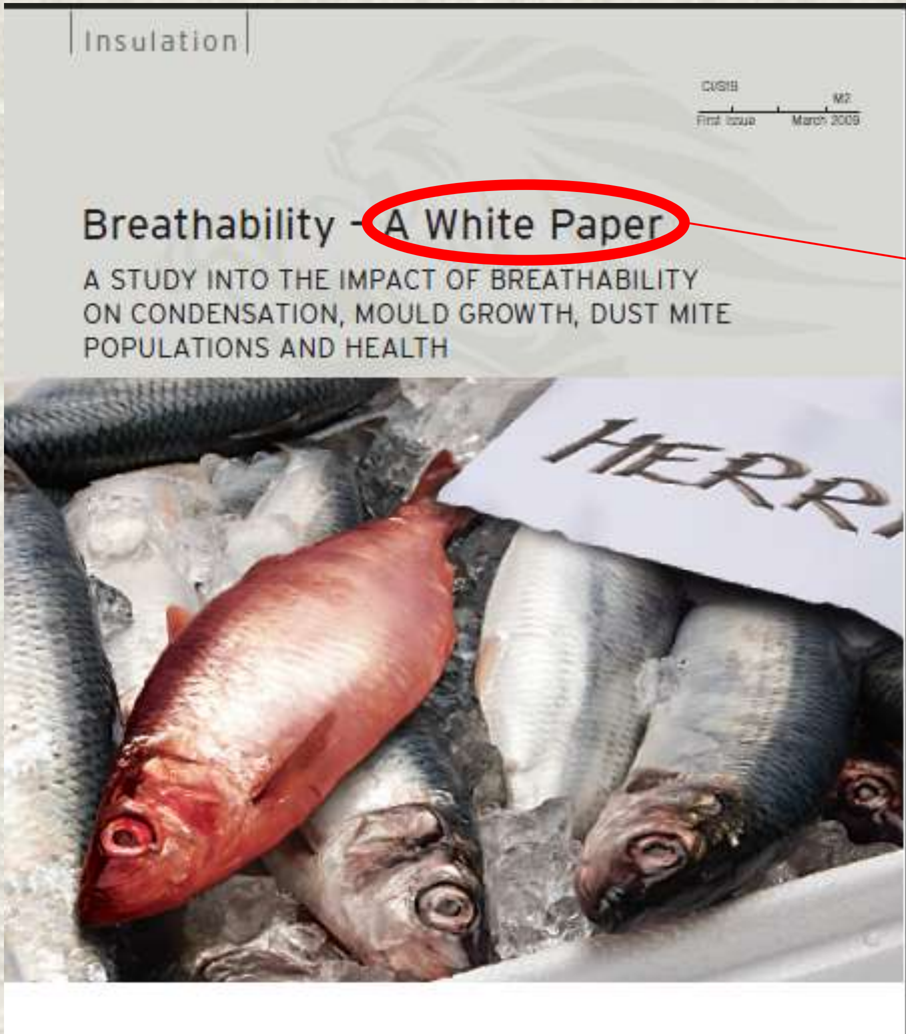
Breathability: Fact and fiction



95% of vapour transfer in buildings occurs through ventilation: **Fact**

Since the early 1990s, the term "white paper" has also come to refer to documents used by businesses as marketing or sales tools. **White papers of this sort argue that the benefits of a particular technology or product are superior for solving a specific problem.: Fact**
Source: wikipedia

"Breathable constructions and breathability of insulation products are therefore at best a side show, in reality there a complete red herring" : **Fiction**

Humidity-variable vapour checks

Membranes with
Humidity-variable diffusion resistance:

Not suitable for buildings with
permanent high air humidity:

- Swimming pools
- Gardening centres
- Commercial kitchens

Humidity-variable vapour checks

Preconditions for the functionality of humidity-variable vapour checks

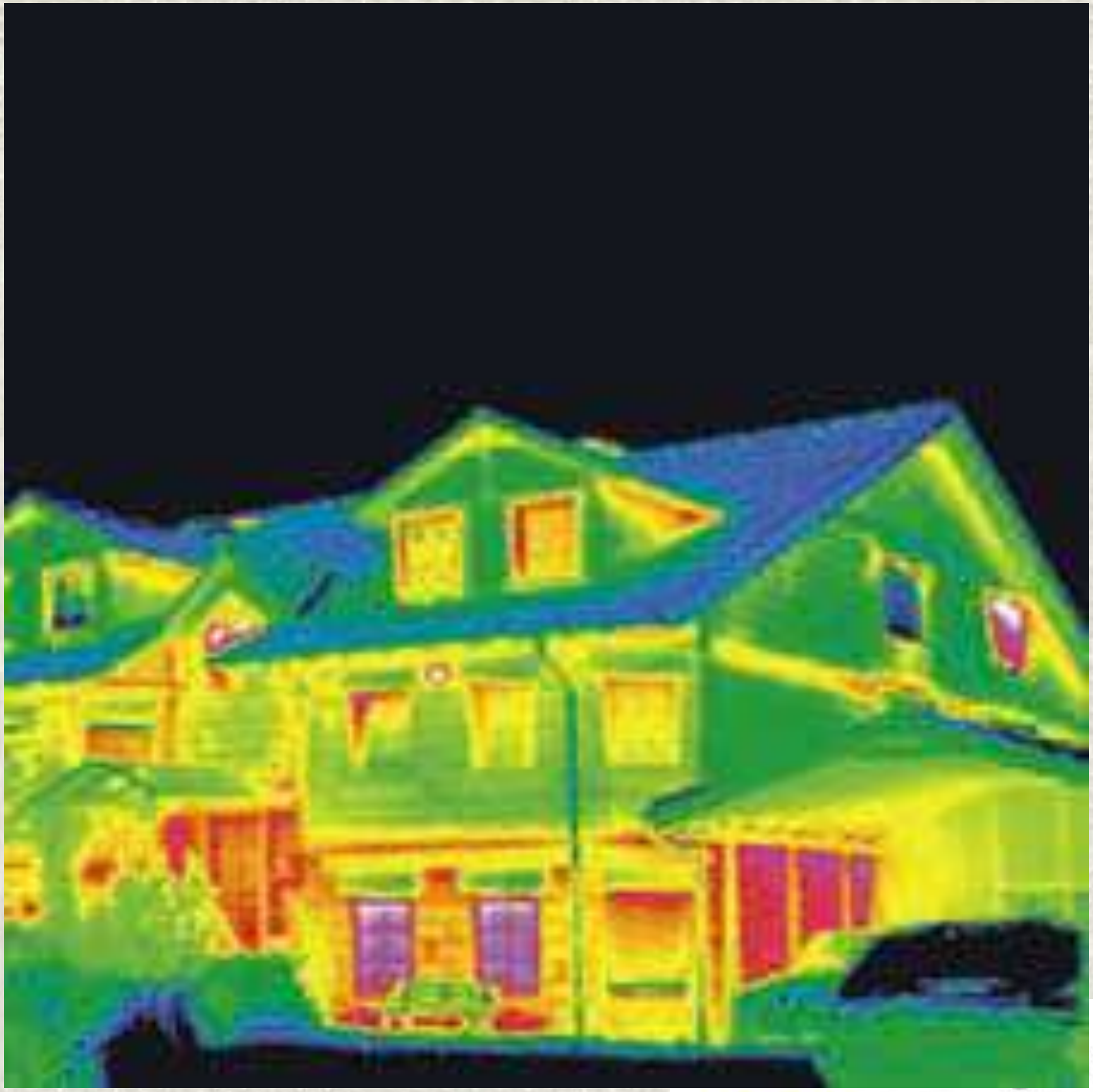
- No diffusion-hampering building materials on the interior side, e.g. OSB, Plywood, foil backed plasterboard
- Profiled timber sheathing, plasterboards and Heraklith BM boards with plaster are suitable

Humidity-variable vapour checks

Preconditions for the functionality of humidity-variable vapour checks

- No shade externally
    - Consider Solar Panels and their impact of radiant heat
    - Colour of the external layer, dark colours promote greater back diffusion
- Diffusion resistant foam insulation material
- Green roofs significantly reduce back diffusion and not compatible with non vented cold deck

Air leakage on site:



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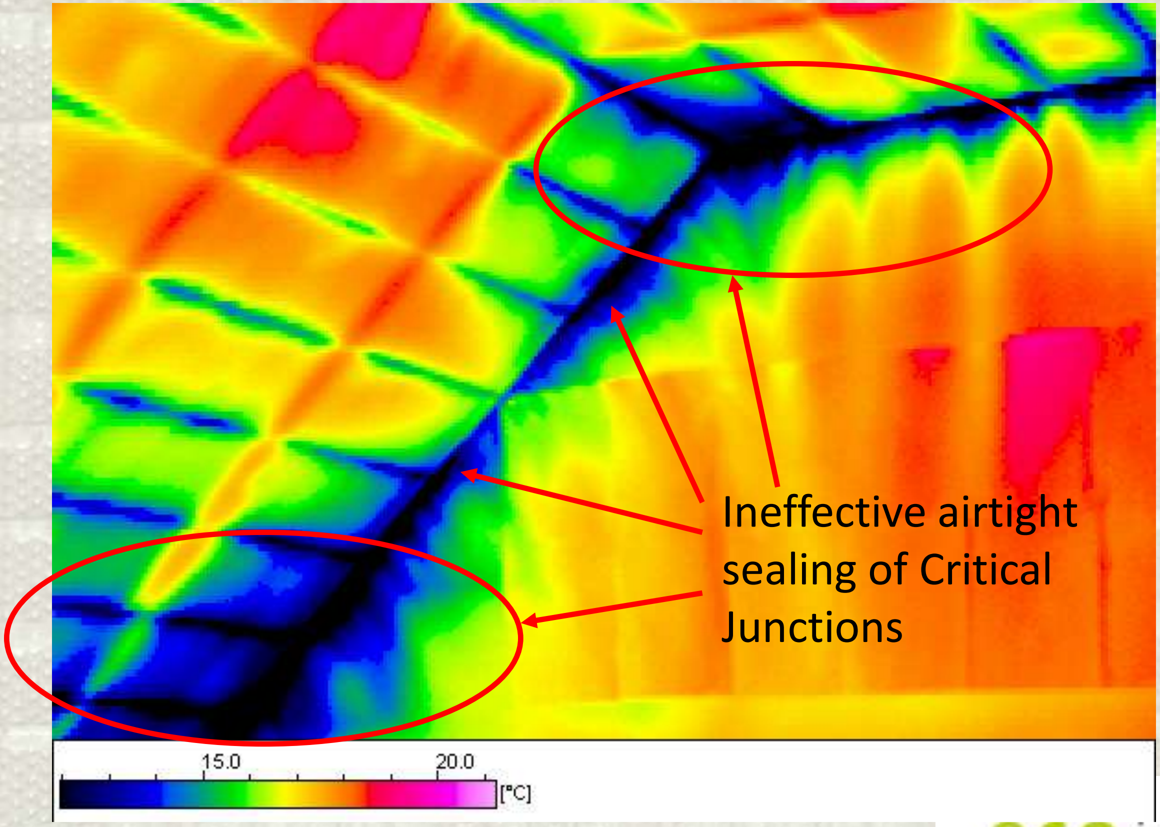
Common Gable Wall-Roof junction

Faulty but “common“ airtight connection

of vapour barriers

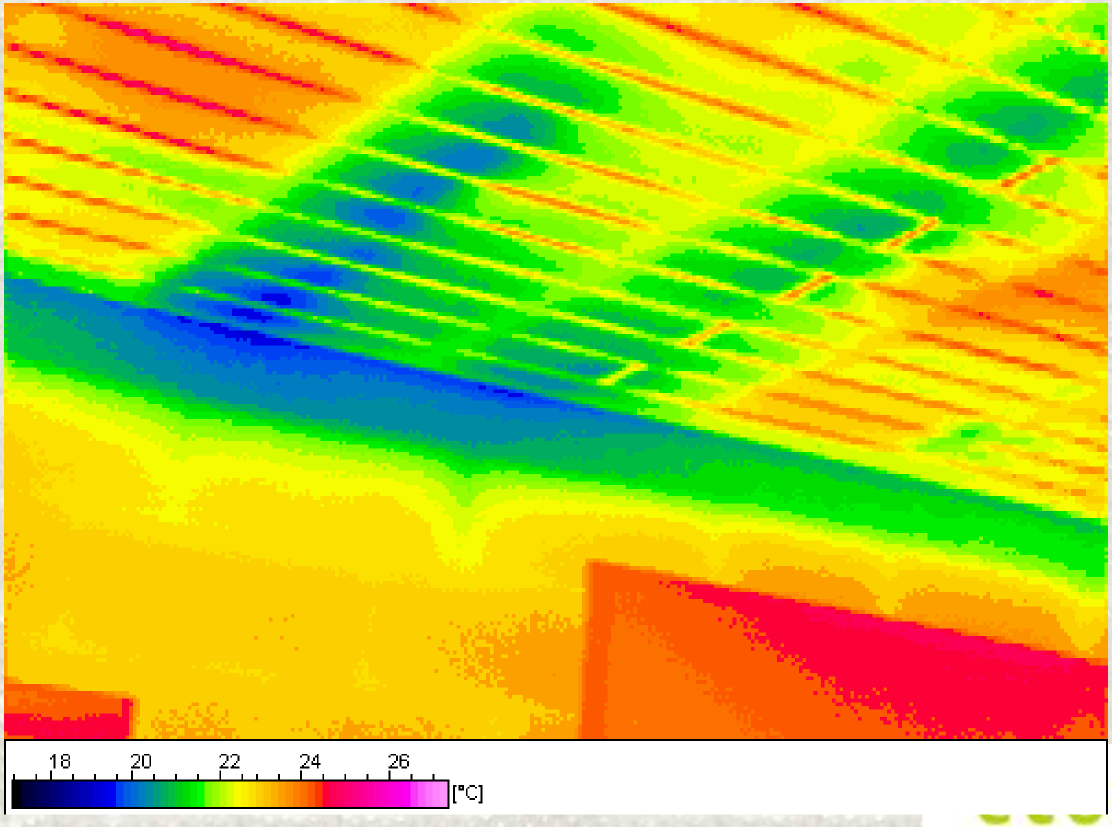
Thermo graphic images of faulty constructions



Infrared picture:

Gable wall-roof connection

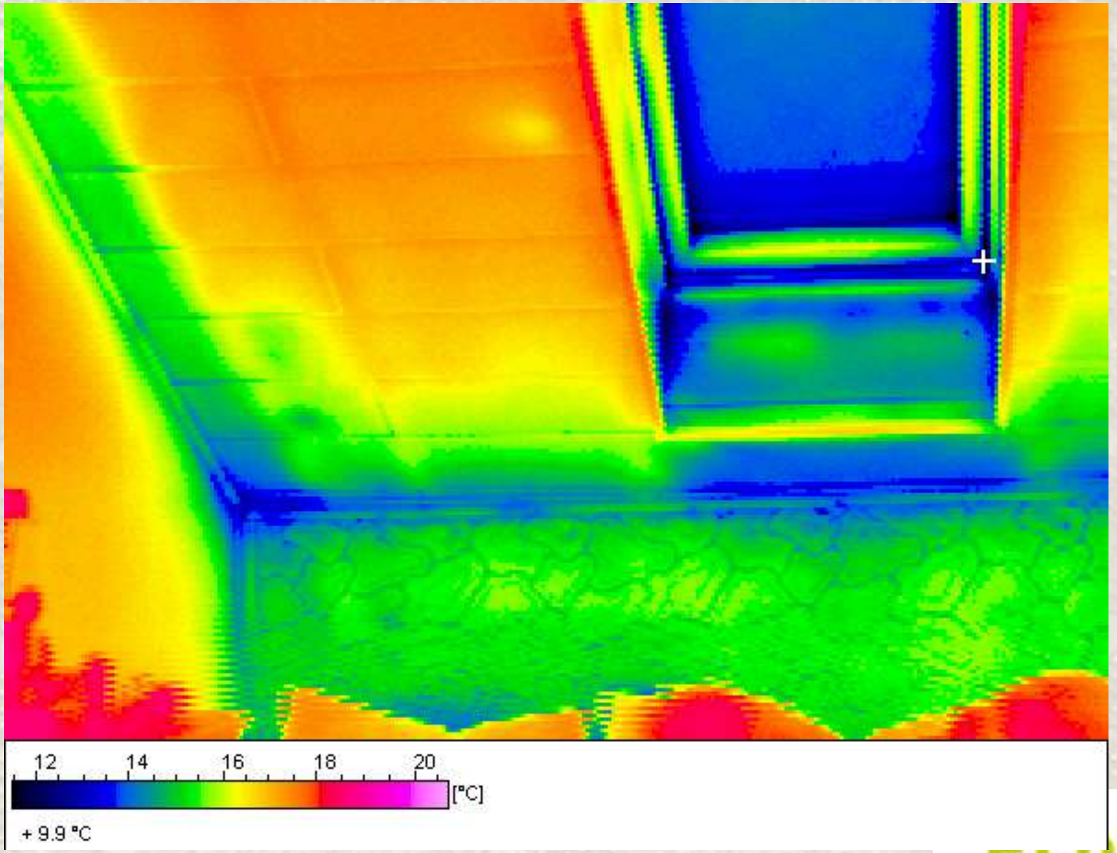
Thermo graphic images of faulty constructions



Infrared picture:

Wall-ceiling connection

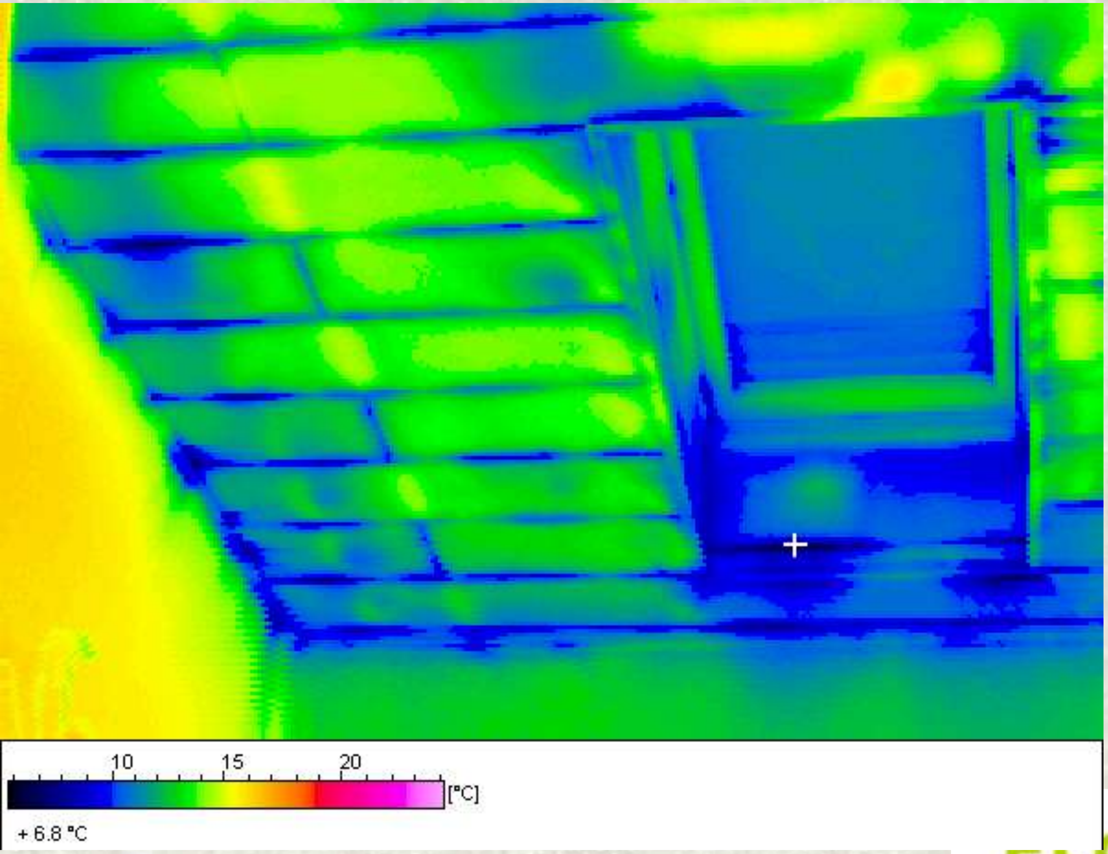
Thermo graphic images of faulty constructions



Infrared picture:

Roof window connection

Thermo graphic images of faulty constructions



Infrared picture:

Roof window joint at negative pressure
The cross shows 6,8 °C, which is lower than the dew point

=> Condensation

Airtight?????

Airtight?????

Ineffective Sealing of Critical Details

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Airtight?????

Airtight?????

Pre-Historic Blower Door

Prehistoric blower door.

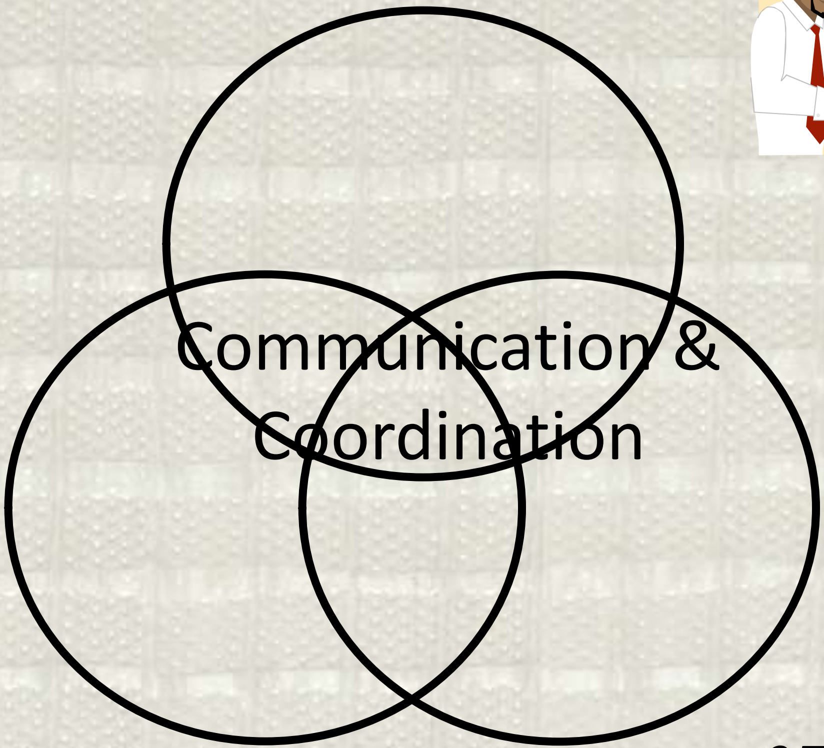
Airtightness…How?

IT DOESN'T HAPPEN BY ACCIDENT!

"It's time we face reality, my friends. … We're not exactly rocket scientists."

Airtightness…How?

1.To design for airtightness



2.Build to achieve airtightness

3.Test for airtightness

Airtightness must be planned….

ons

Sealing of overlaps

- Fix vapour check to timber studs securely
- Overlap joints by 50-60mm
- Seal all overlaps using suitable airtightness tapes

Airtightness must be planned….

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Airtightness must be planned….

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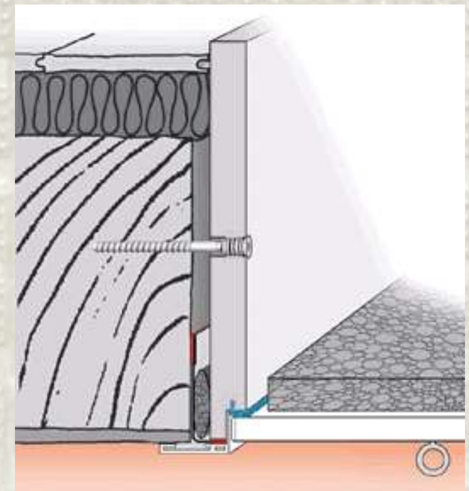
Airtight Solution: Airtight Attic Hatch

wellhöfer
TREPPEN AUS WÜRZBURG



Airtight Solution:
Optime airtight Downlight Housing

Safe Box
Maxiflex

Airtightness Quality Control – Wincon

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WINCON
... Quality assurance for airtightness

Airtightness measurement

Calculation of the air exchange rate with the Minneapolis BLOWER DOOR

Q50 = m3/(hr.m2) @ 50Pa.

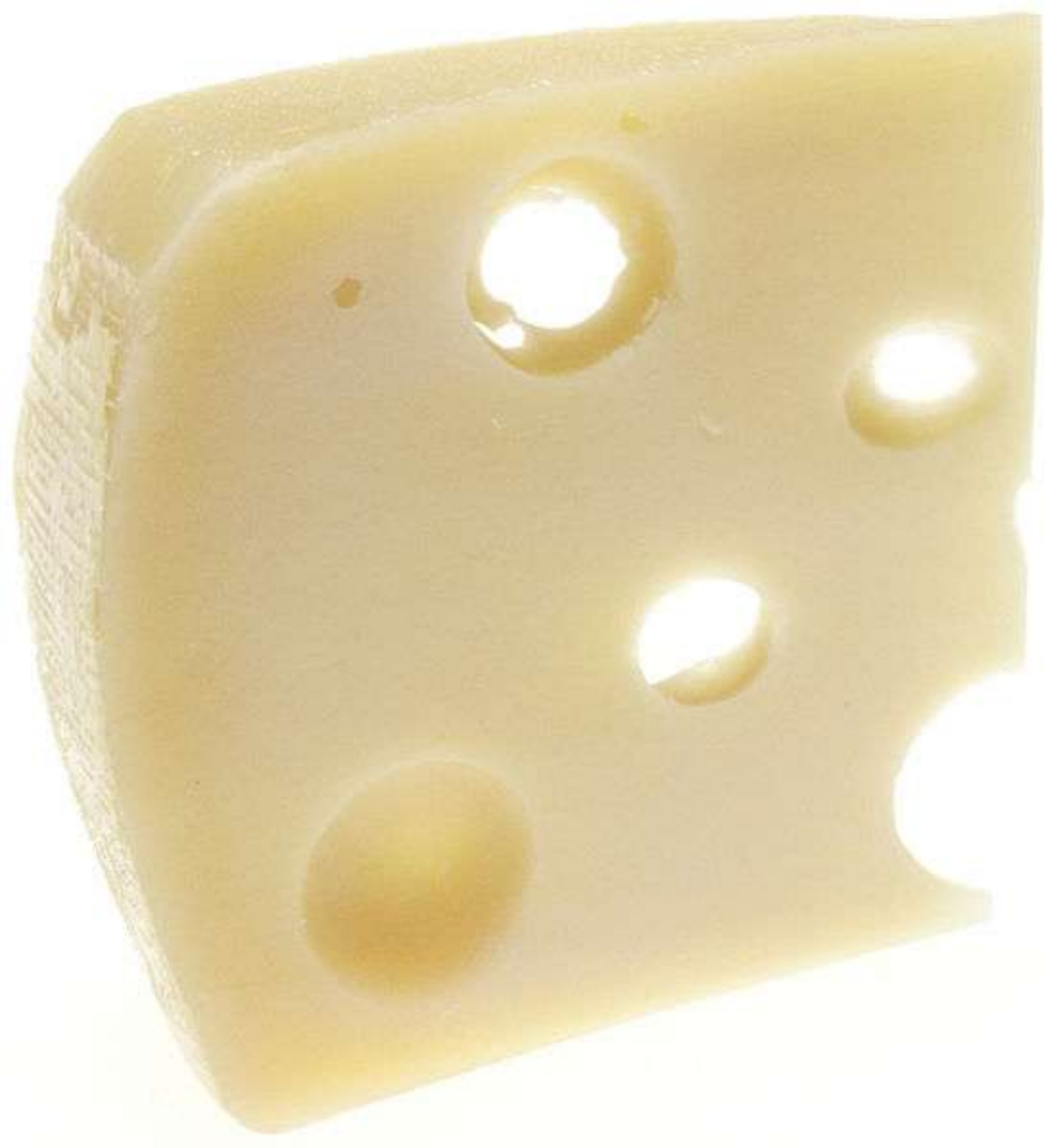
Testing of airtightness of Constructions: Standards

German building code ("EnEV" Energy Saving Standard) –
• Without a mechanical ventilation system the n50-airchange-values have to be less than 3 h-1,
• With a mechanical ventilation systems 1.5 h-1.

Passive house - The requirement is n50 not greater than 0.6 h-1.

Canadian Super E Standard - The requirement is n50 not greater than 1.5 h-1

England/Wales– Upper limit Air Permeability Q50 of < 10m3/hr/m2



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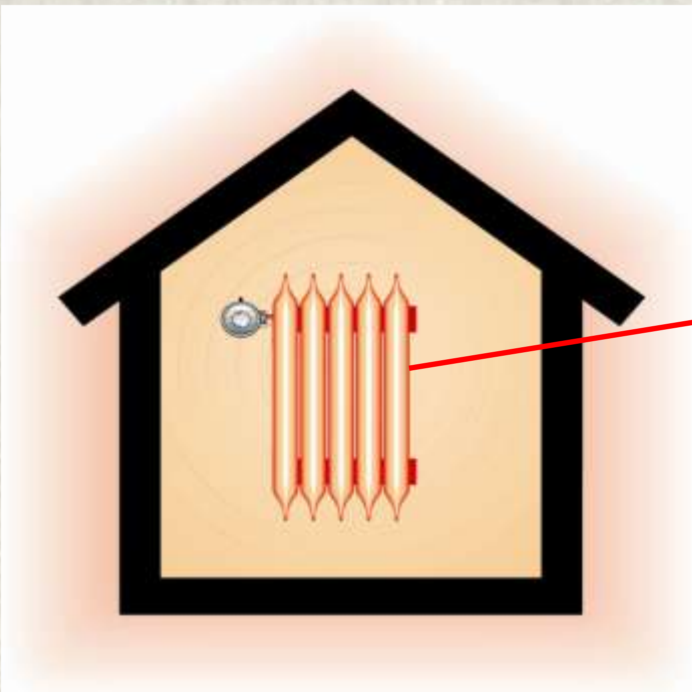
Testing of airtightness of Constructions: UK Standards

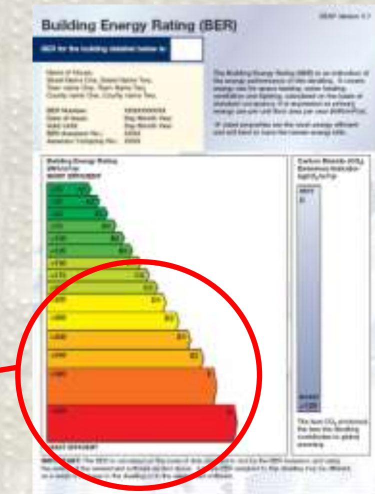
ATTMA – Technical Standard 1 – Measuring Air Permeability of Building Envelopes

Type	**Air Permeability**	
	m3/(h*m2) @ 50Pa	
	Best Practice	**Normal**
Offices		
Naturally ventilated	3	7
Mixed Mode	2.5	5
Air conditioned/low energy	2	5
Factories/warehouses	2	6
Superstores	1	5
Schools	3	9
Hospitals	5	9
Museums and archival stores	1	1.5
Cold Stores	0.2	0.35
Dwellings		
Naturally ventilated	3	9
Mechanically ventilated	3	5

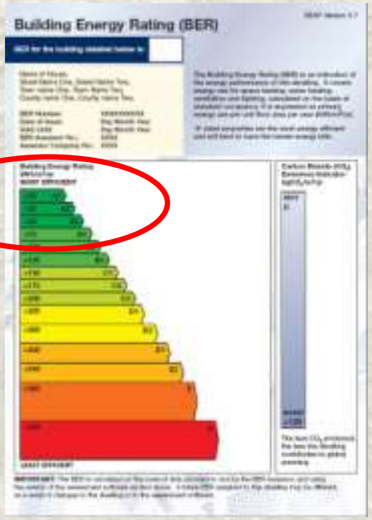
Energy Performance of Buildings Directive



Construction demonstrating high leakages



Energy Performance of Buildings Directive



Airtight construction

Airtightness Summary

“Random ‘holes’ are not designed into buildings, they are an amalgam of short cuts, poor design and poor quality control on site. Attention to detail and good quality assurance on site are key factors in achieving the required targets” (IN Potter: Envelope Integrity Demonstration Study; BSRIA 1999)

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Airtightness Summary:

Moisture loading > Drying reserves

= Structural damage

Drying reserves > Moisture loading

= No structural damage

Build with adequate reserves and
you will never have structural damage!

Airtightness Summary

Airtightness:

1. Determines the effectiveness of the insulation Layer
2. Reduces CO_2 emissions – critical for efficient BER
3. Enhances construction without structural faults
4. Creates a comfortable healthy room climate
5. Absolutely essential for low energy and passive house design

To achieve this the membranes must be meticulously sealed to one another and to proximal structural components

Diffusion open/"breathable" Construction Summary

- Significantly increases the constructions drying capacity in the event of unforeseen moisture penetrations, aiding their structural integrity.
- Improved efficiency and cost benefits.
- Less builder call backs
- Some insulation materials can contribute with ventilation to act as humidity and temperature regulators (e.g. Calsitherm/ woodfibre/hemp)
- Offset the risk of mould formation within the building envelope
- Decrease the risk of mould on internal surfaces based on hygroscopic properties

- Natural materials also produce much lower VOC's than many man made insulation products (i.e. Sentinel Haus)

Etc....

Questions?
www.ecologicalbuildingsystems.com

Structural damage due to moisture

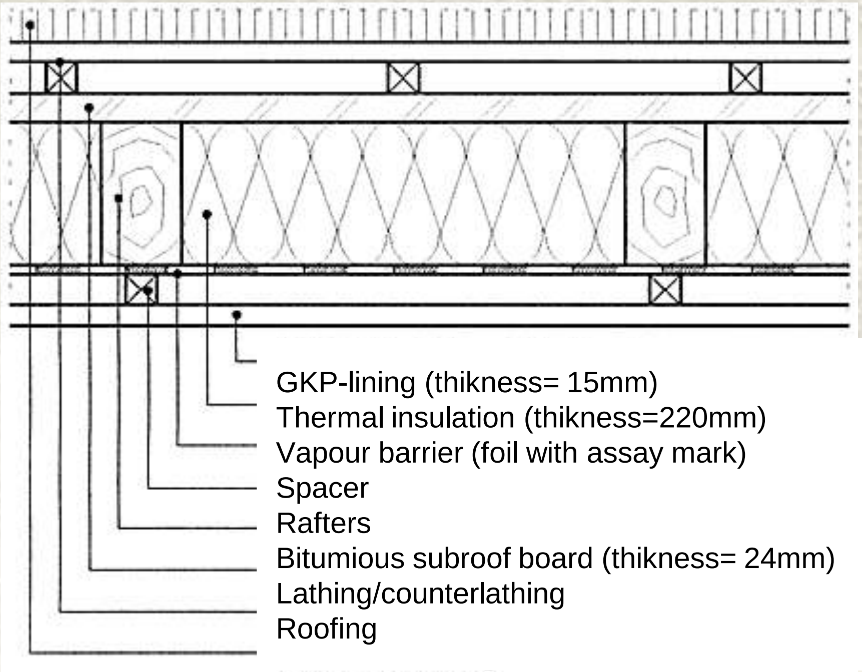

Fig.: Set-up of the roof construction

Residential park in Berlin: 25 terrace houses

Damage symptoms: 2 houses

- moisture at the connection between steep pitched roof/jamb wall
- Bulging of tiles

Set-up:

- Externally open to diffusion
- Construction free from condensate according to EN ISO 13788

Structural damage due to moisture

Fig.: Moisture damage and mould growth at the subroof (timber fiber board)

Residential park in Berlin: 25 terraced houses

Damage description:

Only at 2 houses:

- Bulging of tiles
- Plaster massively moistened at the jamb wall
- Softboard wet and mouldy

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Structural damage due to moisture

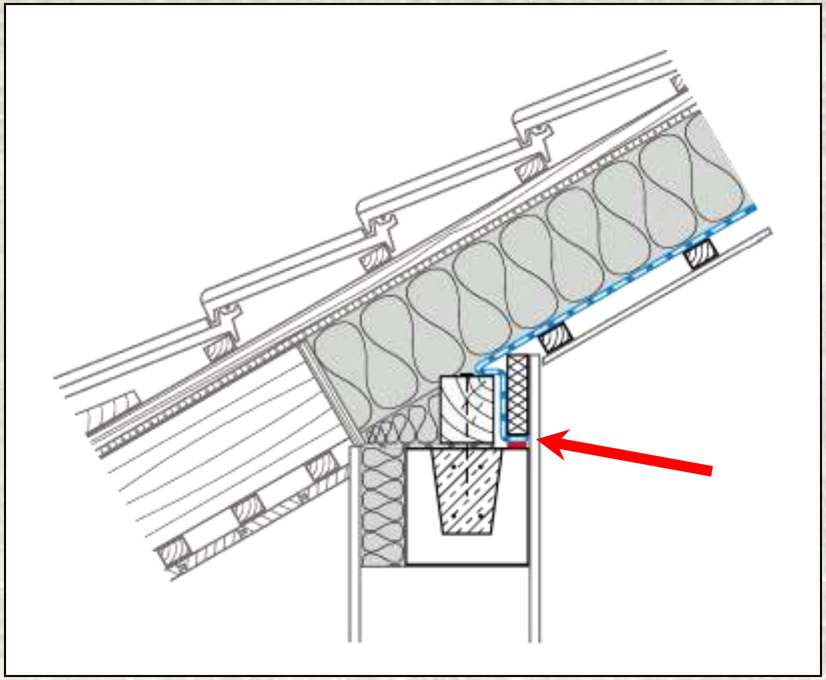

Fig.: Airtight connection at eaves purlin
(example)

Possible causes :

First assumption:

Faulty connection of the vapour barrier in the jamb wall region.

This assumption could not be confirmed

Structural damage due to moisture

Fig.: Moisture damage and mould growth at the subroof (timber fiber board)

Causes of damage?

Softboard is open to diffusion:

(mvtr = 0,50 [MNs/g])

Structural damage due to moisture

Fig.: Screed installation

Causes of damage:

Moisture entry due to faulty construction sequence:

1. Installation of the insulation
2. Installation of screed (gypsum)
3. Installation of vapour barrier.

Season: early September

⇒ **Heavy occurence of condensate at the timber fiber board.**

Structural damage due to moisture

Fig.: Moisture damage and mould growth on the subroof

Causes:

Diminished drying of the construction:

- Water film creates a vapour barrier at the diffusion open timber board
- Due to the installation of the interior vapour barrier
- Due to climatic data in autumn/winter

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Structural damage due to moisture

Fig.: Anew construction of a roof

Restoration:

- Complete removal of the roof to the rafters
- Treatment of the rafters with fungus repelling admixtures
- Anew conversion of the roof

Structural damage due to moisture

Fig.: View of the eaves

New building single-family-house 2002:
2 storeys

Illustration of damage: mould and plume of dirt underneath the cornice of the eaves

Structural damage due to moisture

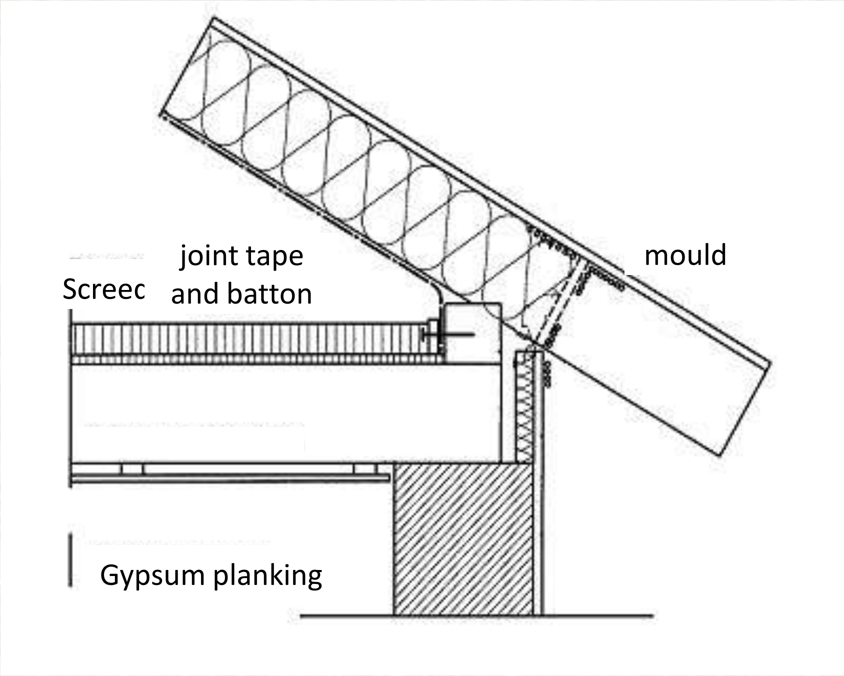

Fig.: Detail of an eaves

New building 2 storeys single-family-house 2002:

Set-up of the construction:

- Externally open to diffusion
- Mineral wool 200 mm
- Vapour barrier
- Ceiling topsided: chipboard and screed
- Eaves purlin and joist insulated by polystyrene boards.

Structural damage due to moisture

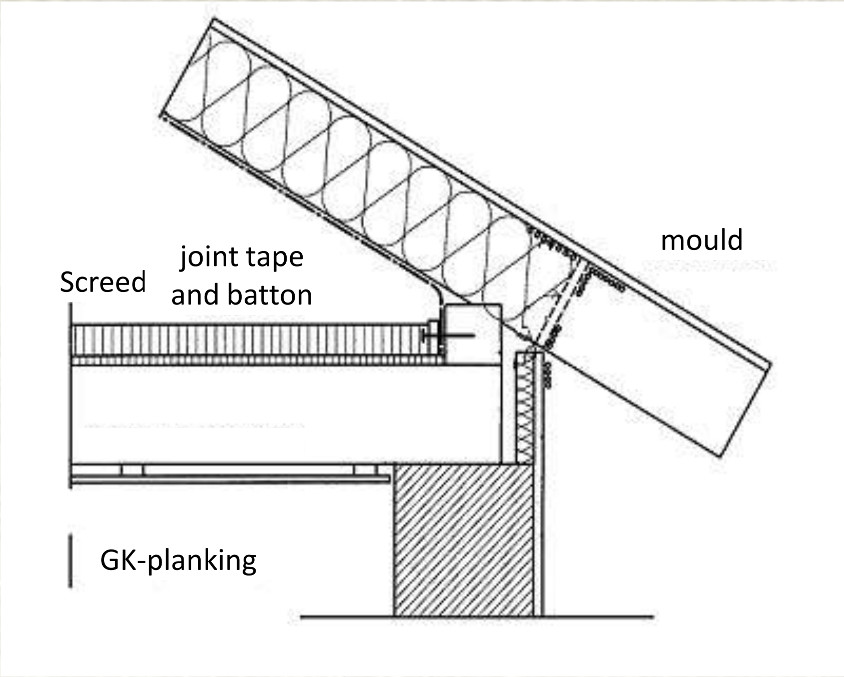

Fig.: Detail of an eaves

Reasons for water in eaves?

- Air leakiness ?

Structural damage due to moisture

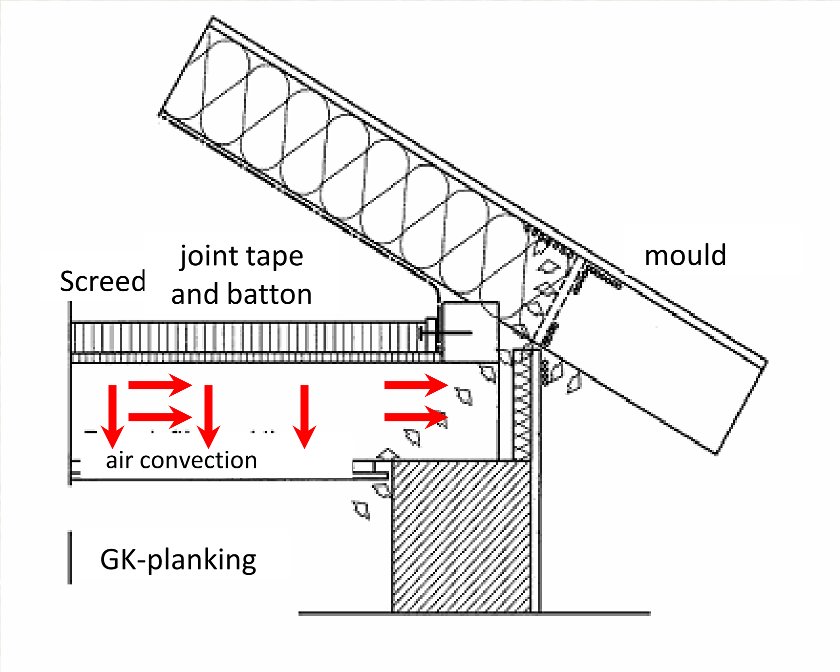

Fig.: Detail of an eaves

Causes of damage:

Air leakiness not in the roof, but in the ceiling construction:

- Lack of vapour checks in the ceiling region
- Lack of insulation in the ceiling region

Structural damage due to moisture

Fig.: View into a rafterfield

The consequences:

- Huge amounts of water in the construction
- Up to ca. 1 m of depth waterdrops on the sarking felt
- Mineral wool soaked in a depth of ca. 50 cm
- Mould growth inside and outside of the construction