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Hygrothermal Aspects of Building Airtightness Solutions

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Departement of Civil Engineering
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Webinar – TightVent Europe
Building Airtightness Solutions:
System approach and characterisation of
air barrier and moisture management systems
October 8th, 2013

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Before 2020 :

EU countries will have to generalise
nearly zero-energy buildings
in new constructions and major renovations

Building and ductwork airtightness will implicitly become a mandatory concern

2

Energy efficient ventilation systems will have to be used

Figure from TightVent Europe

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Increased building airtightness by interior air barrier system


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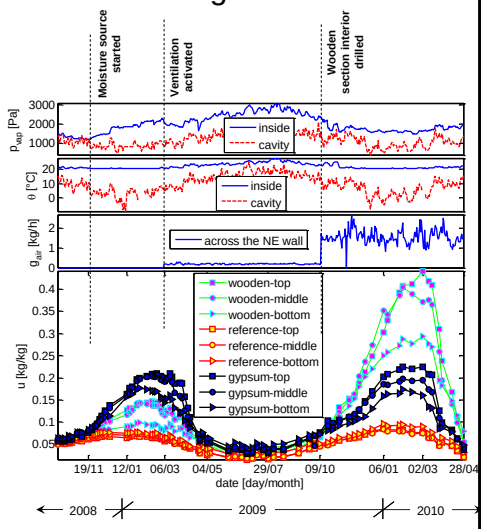
Interior air barrier not only for energy efficiency but also to avoid moisture damage



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Interior air barrier not only for energy efficiency
but also to avoid moisture damage

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Interior air barrier not only for energy efficiency
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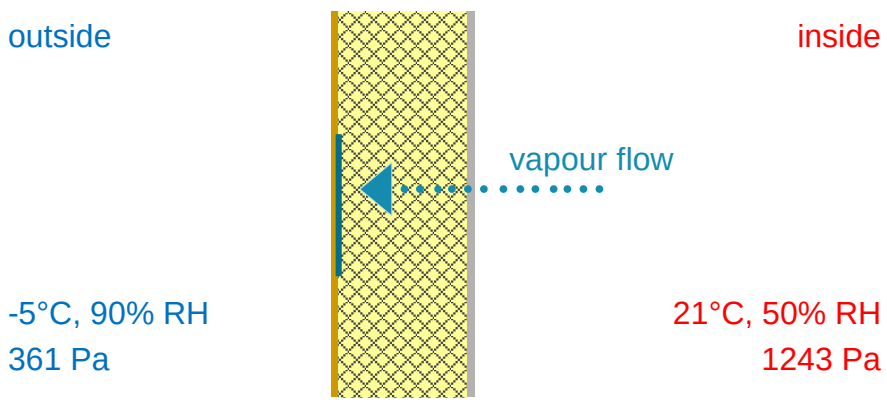

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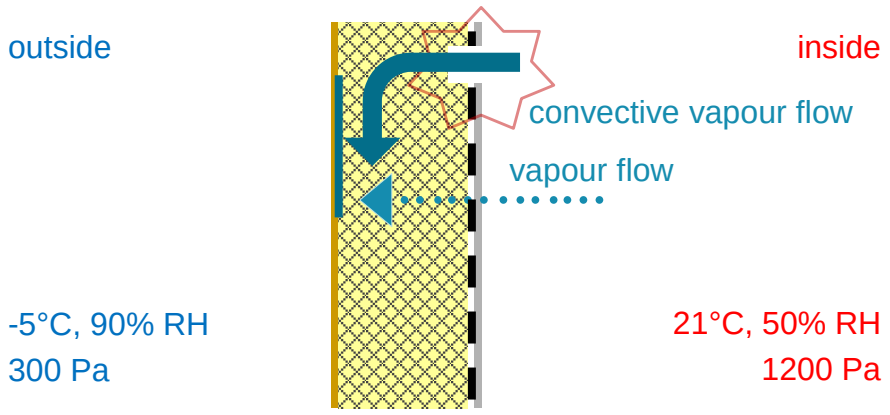
Interior air barrier not only for energy efficiency
but also to avoid moisture damage



continuous combined vapour and air barrier

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Increased building airtightness by interior air barrier system

Passive house standard: n_{50} = 0.6 1/h

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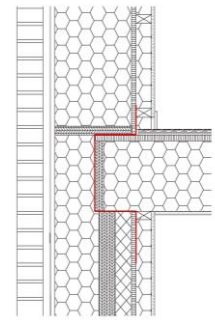
But, often complex details of interior air barriers



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As a result: tendency towards exterior air barriers

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Experience from Norway

Since 2009: stricter regulation: n_{50}<2.5 ACH

Legal requirement results in stepwise testing:

- First measurement $n_{50,w}$ in windtight stage
- Second measurement $n_{50,f}$ on finished building (with interior air barrier installed)




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Test case in Belgium

	n_{50} (1/h)
Exterior air barrier	0.60
Cellulose inflated	0.25
Interior air barrier	0.24

Workmanship

Interior barrier: +/-152h

Exterior barrier: +/-72h

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Complex details of interior air barriers

Exterior air barriers: potential to reduce labour costs

Problem: no longer control of the airtightness of interior barrier

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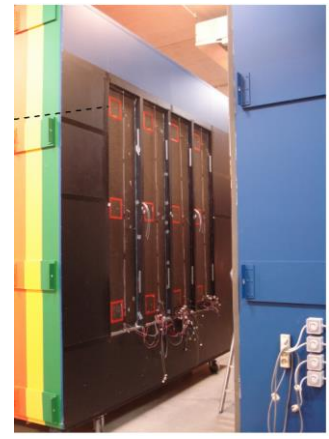
Experimental validation of hygrothermal risks



Hot Box / Cold Box experiment on 4 wall types

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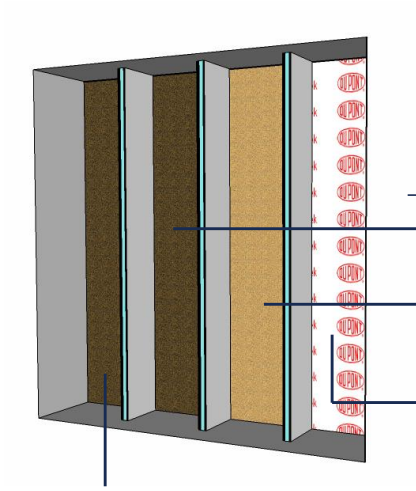

Ia: reference section

Test series I

Air barrier	Ka ($m^3/m^2/h/Pa$)	R (m^2K/W)	buffering
Ib	0.005	0.36	Yes
Ic	0.13	0.36	Yes
Id	<0.001	-	-

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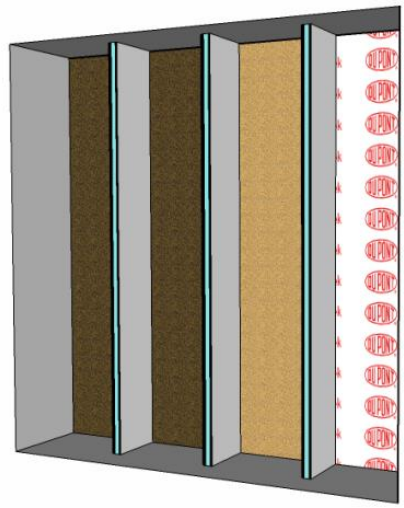

Ia Ib Ic Id

Different exterior sheeting
(Ka / R / buffer potential)

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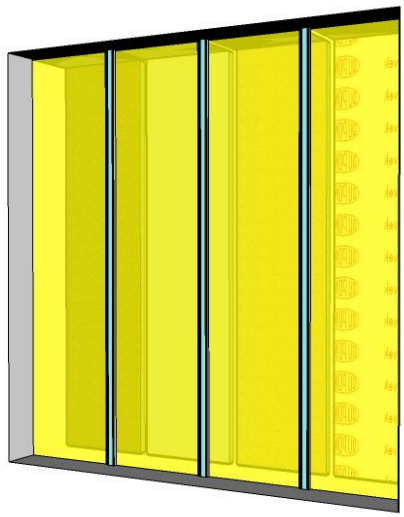

Ia Ib Ic Id

Different exterior sheeting
(Ka / R / buffer potential)

30 cm mineral wool (20 kg/m³) (15cm-15cm)

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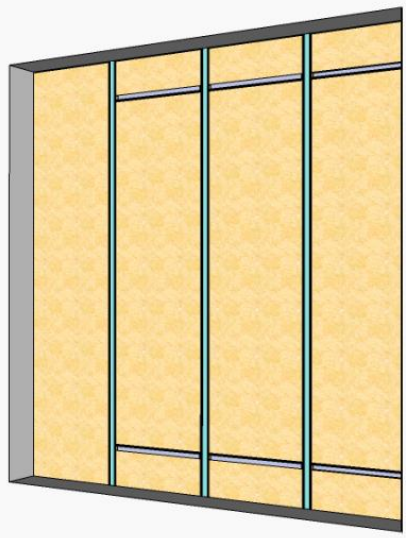

Ia Ib Ic Id

Different exterior sheeting
(Ka / R / buffer potential)

30 cm mineral wool (20 kg/m³) (15cm-15cm)

OSB interior panels
with top and bottom air gaps

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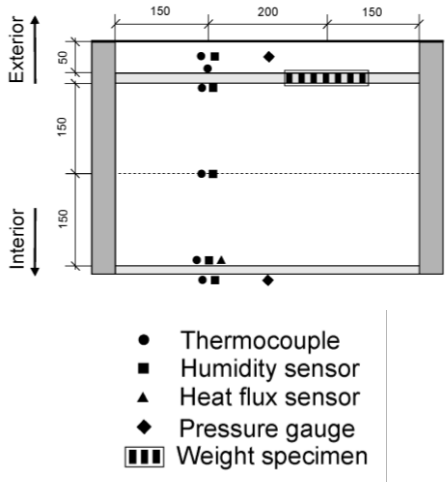
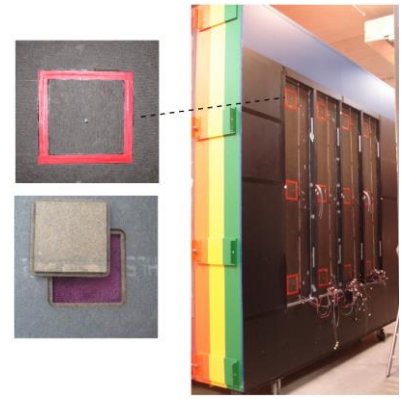
Installed sensors





gravimetric weight specimen
at three heights

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- Boundary conditions in HB/CB
  - T_{in} = 20°C and T_{ex} = 3°C
  - RH_{in} = 54% and RH_{ex} = 86%

3 steps in experimental setup:

1. Intact interior and exterior sheathing
2. Openings in interior sheathing (top/bottom)
3. Total air pressure difference

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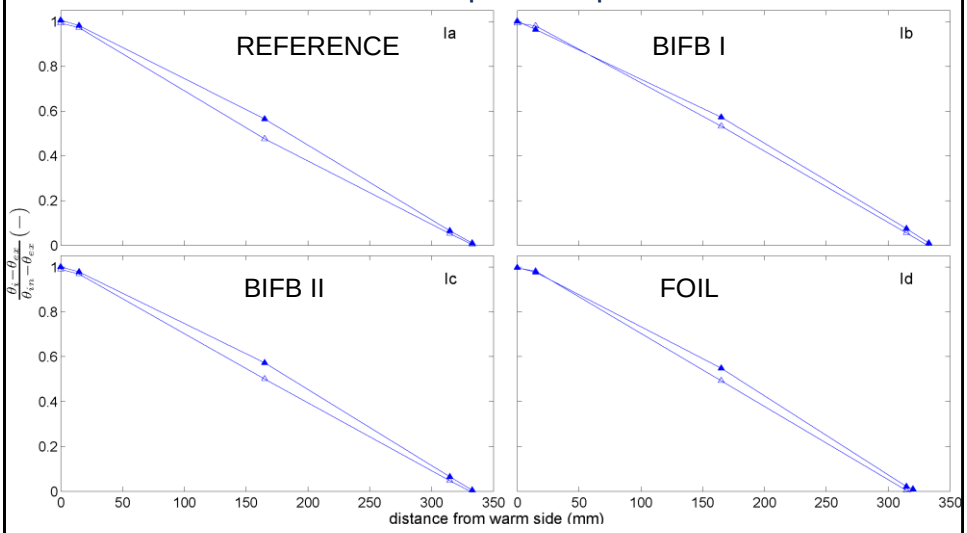
Observed temperature profiles



STEP 1

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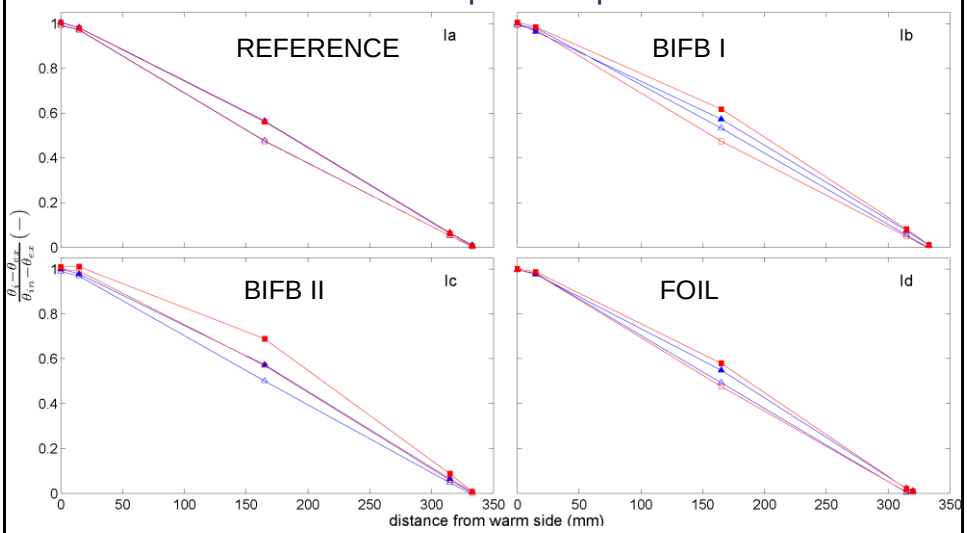
Observed temperature profiles



STEP 1 STEP 2

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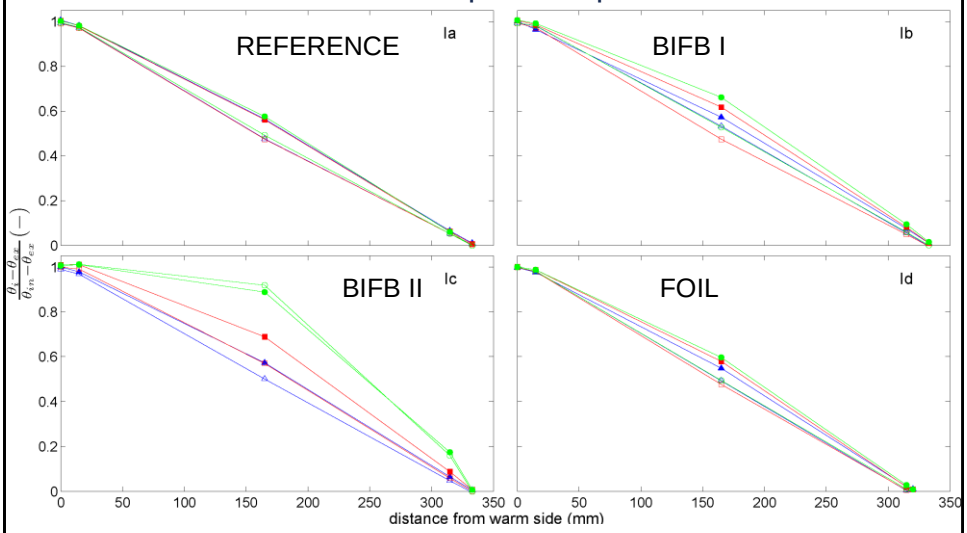
Observed temperature profiles



STEP 1 STEP 2 STEP 3

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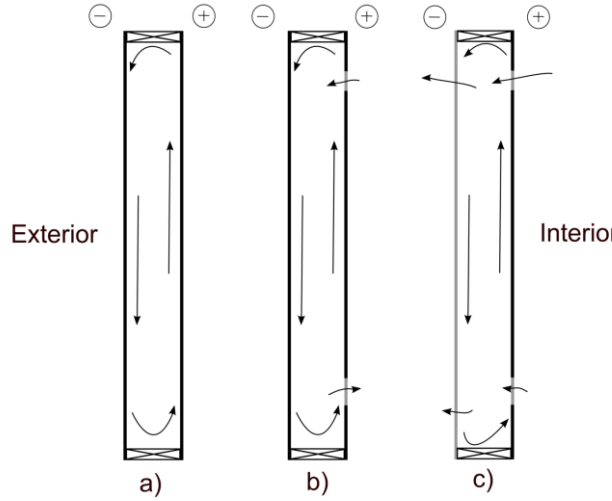
Observed air flow patterns



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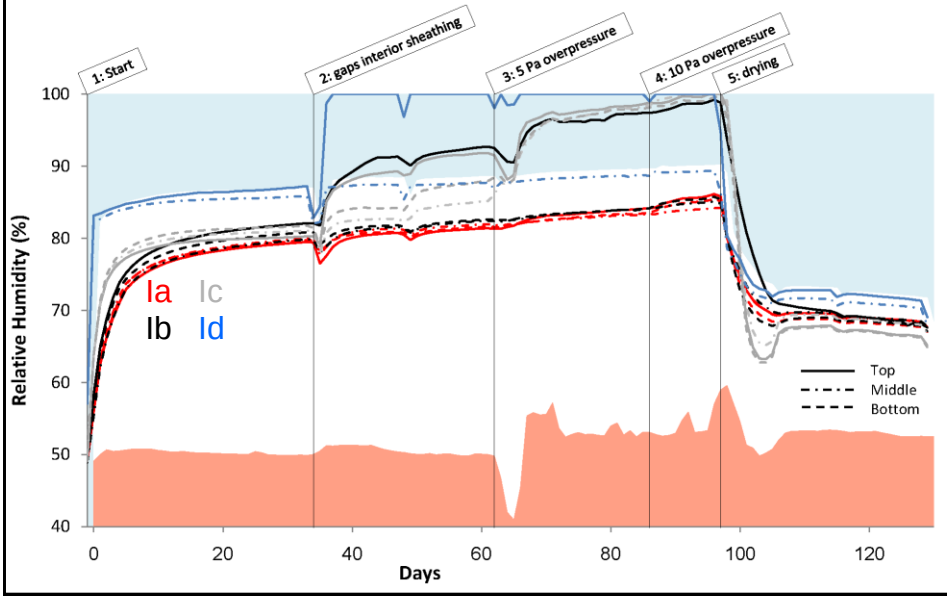
RH at inside of windbarrier



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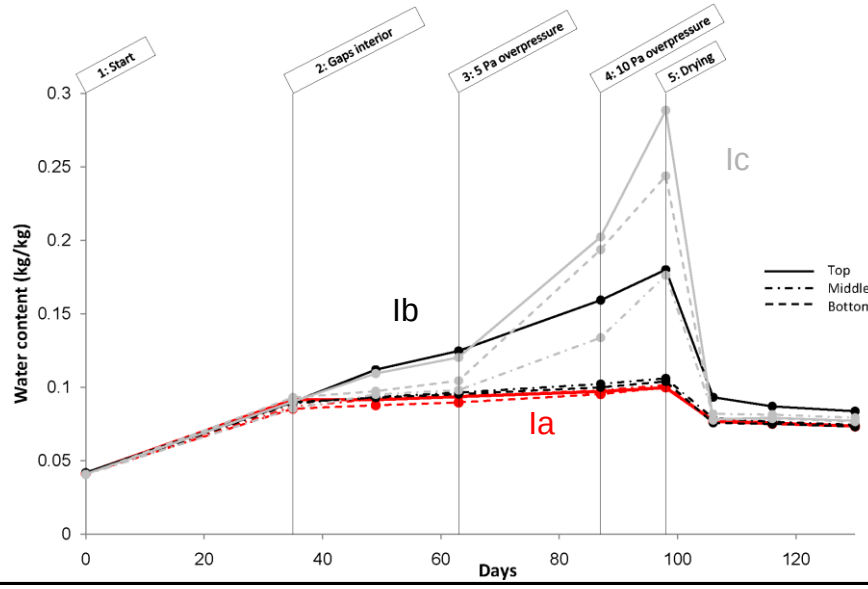
corresponding weight increase of wind barrier specimen



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severe conditions result in mould growth and interstitial condensation

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conclusions

- Air tightness is not only important from an energetic point of view, but is a prerequisite for a good hygrothermal performance of building components
- Stringent air tightness requirements resulted in a shift towards airtight windbarriers. This might hamper a control of the quality of the interior barrier.
- Laboratory experiments revealed the importance of air transport on heat and moisture response of light weight building components. This might result in hygrothermal risks of air flow in – even air tight – light weight constructions:
    - Natural convection in/around mineral wool blankets (workmanship!)
    - Increased risk for high moisture contents at upper cold parts
    - Mould growth and interstitial condensation was observed as a result of natural and forced convection

Thanks for your attention

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Evaluation of the long term durability of adhesive tapes and its substrates: Requirements and testing

Knauf Insulation
Dipl.-Ing, Architekt Armin Weissmueller

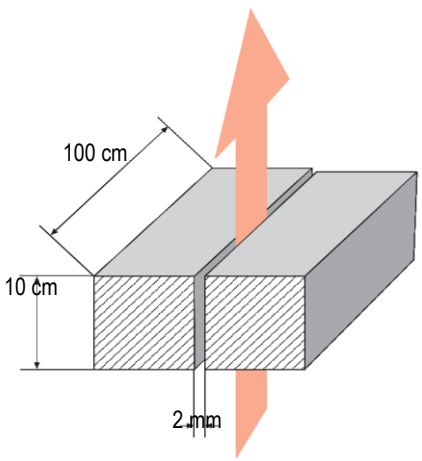
Leakages caused by unsuitable adhesive products ...

Why airtightness is so important

Evaluation of the long term durability of adhesive tapes

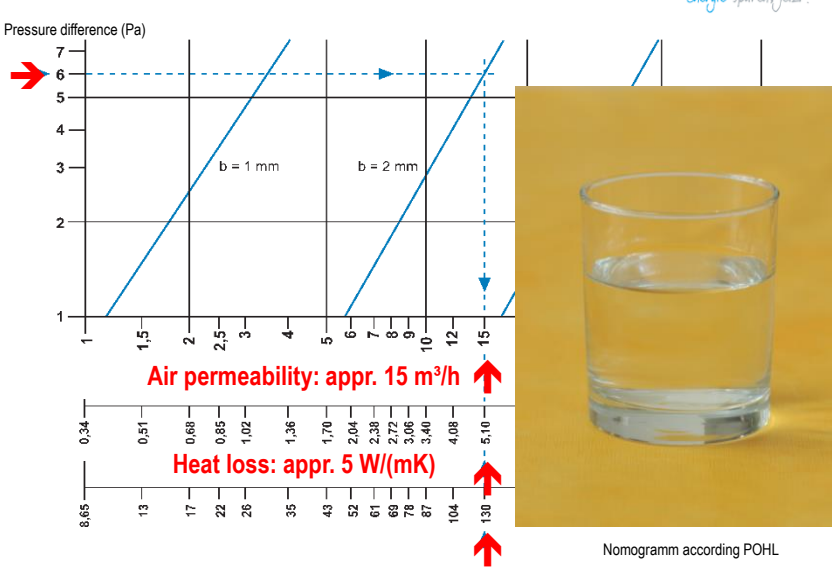
Calculation Example:

Precondition:
Air temperature: 20°C
rel. humidity: 50%



Why airtightness is so important

Evaluation of the long term durability of adhesive tapes



Nomogramm according POHL

130 g water in roof construction caused by condensation of water vapour.

Evaluation of the long term durability of adhesive tapes

Registered damages caused by wood-decaying fungi (Serpula lacrimans) in Germany: 200 Mio Euro/a

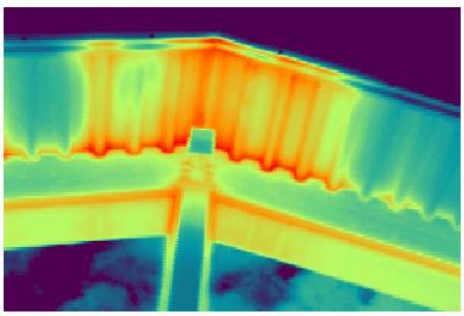
Why airtightness is so important

Evaluation of the long term durability of adhesive tapes

The blower-door fan is temporarily sealed into an exterior doorway using the door-panel system. The blower door fan is used to blow air into or out of the building, creating either a positive or negative pressure differential between inside and outside. This pressure difference forces air through all holes and penetrations in the building enclosure. The tighter the building (e.g. fewer holes), the less air is needed from the blower door fan to create a change in building pressure. Typically, only depressurization testing is performed.

A real risk to the installer: Bad workmanship can be detected easily

Evaluation of the long term durability of adhesive tapes



A real risk to the installer: Bad workmanship can be detected easily

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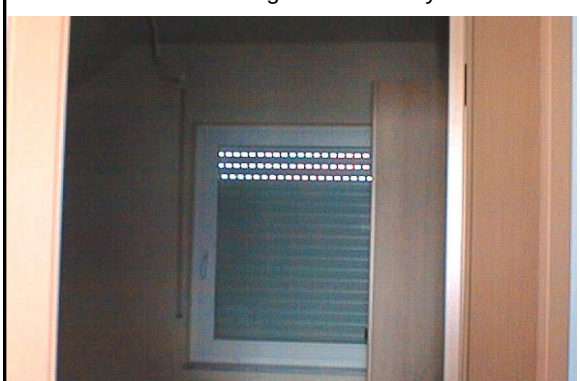
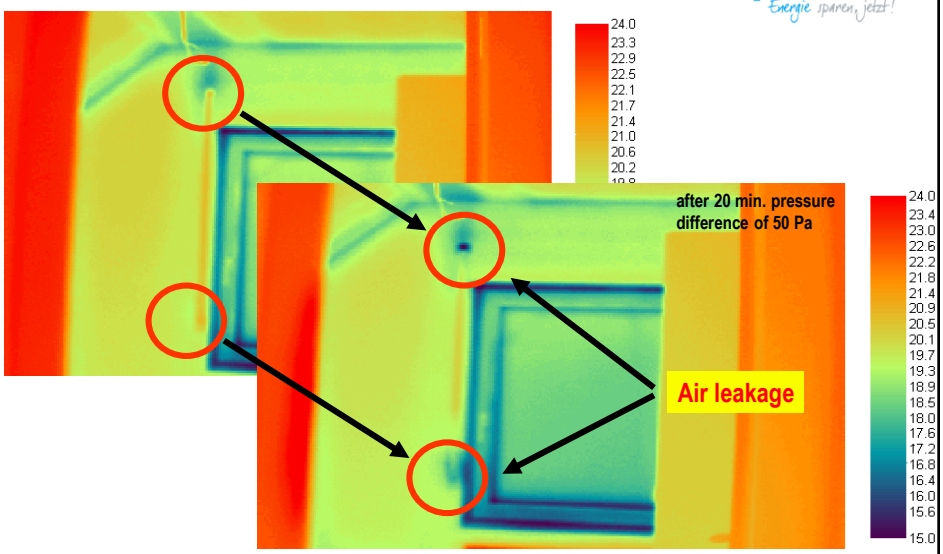


Separating thermal bridges from air leakages

A real risk to the installer: Bad workmanship can be detected easily

Evaluation of the long term durability of adhesive tapes



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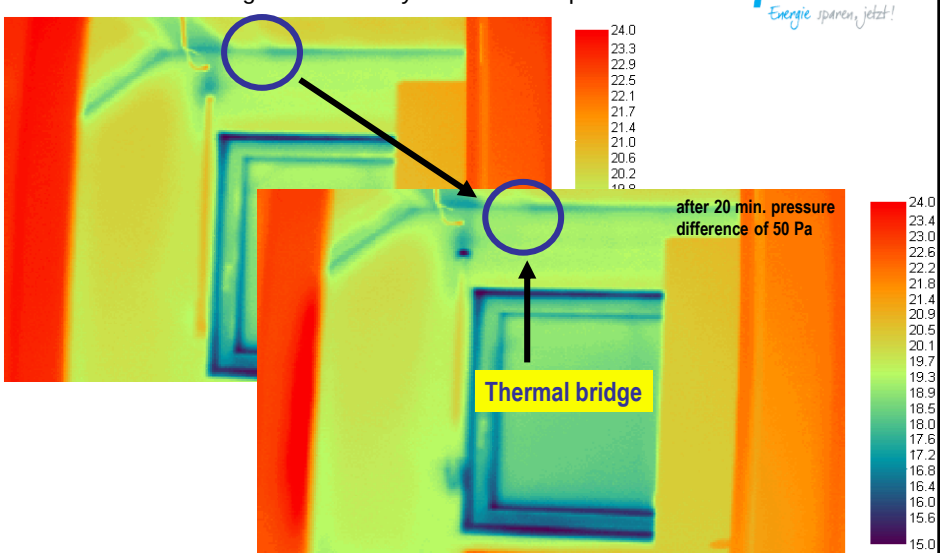
Evaluation of the long term durability of adhesive tapes



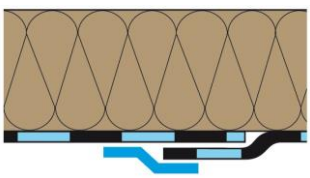
A real risk to the installer: Bad workmanship can be detected easily

Evaluation of the long term durability of adhesive tapes

A typical pressure sensitive adhesive tape designed for sealing joints in air tightness layers:

"60 mm wide, single-sided adhesive tape for sealing overlap seams in membranes. Specially designed for use with LDS membranes.
Adhesive amount: 260 gramm/m²"

Source: Knauf Insulation



Products and their application

Evaluation of the long term durability of adhesive tapes

backing, carrier; kraft paper, PE

release liner; siliconized paper

modified acrylic adhesive, 260 g/m²

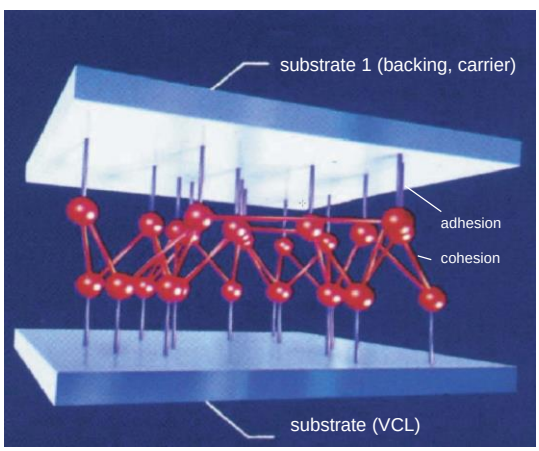
Used to create a secure and permanent seal of overlaps of membranes. Bonds overlaps between sheets of VCL and joints between wood-based panels (such as OSB). Comes supplied with release paper. Easy to tear by hand.

Products and their application

Evaluation of the long term durability of adhesive tapes

Factors that influence durable adhesion: Balanced adhesion and cohesion forces

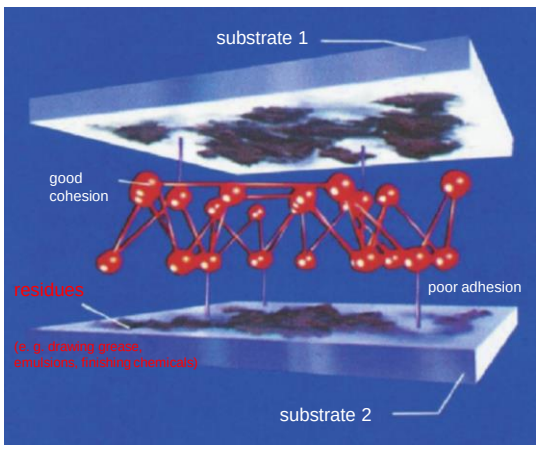
Evaluation of the long term durability of adhesive tapes



Source: „Der Loctite“ 1992

Factors that influence durable adhesion: Balanced adhesion and cohesion forces

Evaluation of the long term durability of adhesive tapes



Source: „Der Loctite“ 1992

Factors that influence durable adhesion: Balanced adhesion and cohesion forces

Evalua[illegible]e tapes

Source: Flexoplast

Within foil production (f. i. PE film extrusion), separating agents and lubricants are used to accelerate the process.

Their use have a negative impact on surface tension, wettability and adhesion.

Evaluation of the long term durability of adhesive tapes

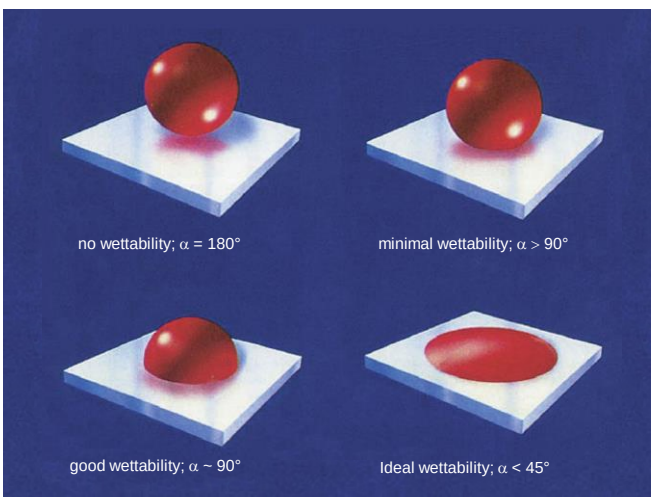
Source: Dynes-Testing

Easy testing of the existence of residues / wettability of films:

When a test pen is applied to the surface, the liquid will either form a continuous film on the surface or pull back into small droplets. If the test fluid remains as a film for 3 seconds, the substrate will have a minimum surface energy of that ink value, expressed in mN/m (dynes).

Factors that influence durable adhesion: Balanced adhesion and cohesion forces

Evaluation of the long term durability of adhesive tapes

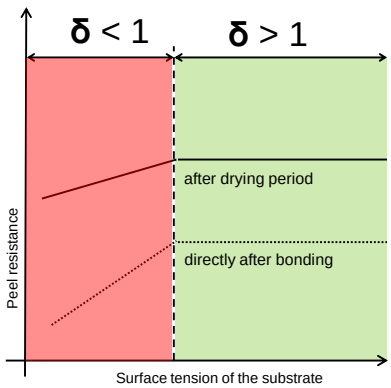


Source: „Der Loctite" 1992

Wettability and surface tension

Factors that influence durable adhesion: The right balance of surface tension of adhesive and substrate

Evaluation of the long term durability of adhesive tapes



Basic rule:
The surface tension of the adhesive must be lower than or equal to the surface tension of the substrate

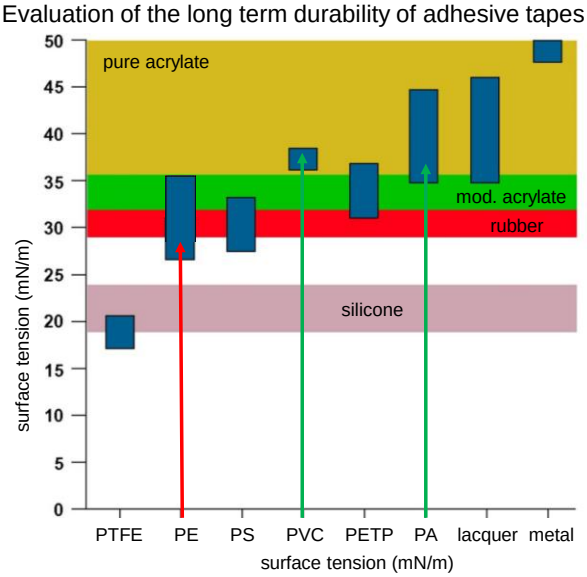
$$\sigma_S / \sigma_L = \delta$$

σ_L: surface tension of a liquid (adhesive)

σ_S: surface tension of the substrate

Factors that influence durable adhesion: The right balance of surface tension of adhesive and substrate

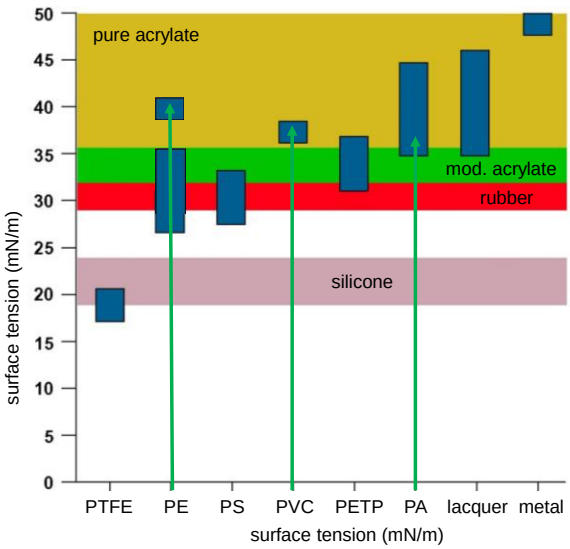
Evaluation of the long term durability of adhesive tapes



The design of durable material connections requires extensive knowledge of the manufacturing technology of the substrate materials and the interactions of the adhesives with the substrates.

Factors that influence durable adhesion: The right balance of surface tension of adhesive and substrate

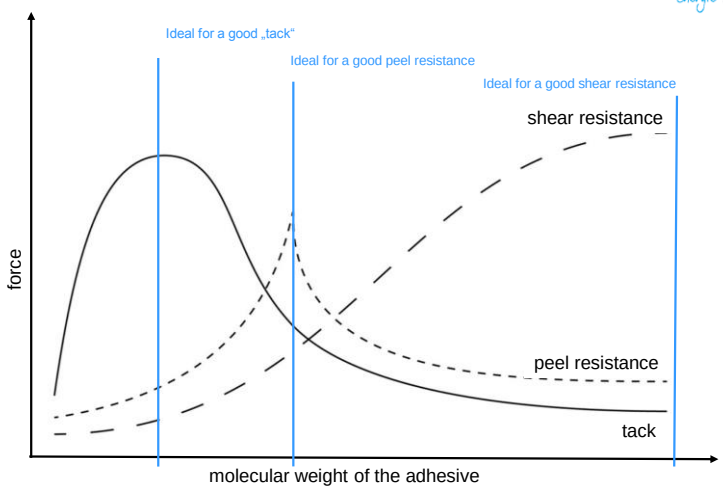
Evaluation of the long term durability of adhesive tapes



Once the surface tension of PE can be increased to 36 to 40 mN/m, a good bonding of modified acrylates is likely

Factors that influence durable adhesion: The right balance of surface tension of adhesive and substrate

Evaluation of the long term durability of adhesive tapes



Beneath the surface tension essential in the development of acrylic bonding components: the specification of a reasonable balance between the relevant adhesive properties

Factors that influence durable adhesion: The right balance of tack, peel- and shear resistance

Evaluation of the long term durability of adhesive tapes

Durable bonding in construction; requirements of the standards

Evaluation of the long term durability of adhesive tapes

NA 005-56-93 AA N 254

DEUTSCHE NORM **12. Vorlage** 2008-02-18

Wärmeschutz und Energie-Einsparung in Gebäuden — Teil 7: Luftdichtheit von Gebäuden, Anforderungen, Planungs- und Ausführungsempfehlungen sowie -beispiele

DIN 4108-7

ICS 91.120.10

Ersatz für DIN 4108-7:2001-08

Thermal insulation and energy economy in buildings — Part 7: Airtightness of buildings, requirements, recommendations and examples for planning and performance

Protection thermique et économie d'énergie dans la construction immobilière — Partie 7: Etanchéité à l'air des bâtiments, exigences, recommandations et exemples pour la conception et la performance

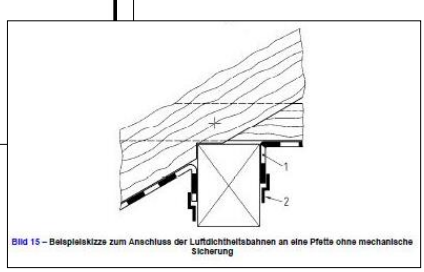


Bild 15 – Beispielskizze zum Anschluss der Luftdichtheitsbahnen an eine Pfette ohne mechanische Sicherung

Durable bonding in construction; requirements of the standards

Requirements of the Guideline for European Technical Approval of Timber Frame Building Kits

„(d) Working life (durability) and serviceability
The provisions, test and assessment methods in this guideline or referred to, have been written, based upon the assumed intended working life of the ***timber frame building kit for the intended use of 50 years for the loadbearing structure and for non-accessible components and materials****, and 25 years for repairable or replaceable components and materials like claddings, roofing materials, exterior trims, and integrated components like windows and doors, provided that the kit is subject to appropriate use and maintenance (cfr. ch. 7). The use of components and materials with shorter intended working life must be clearly stated in the ETA. These provisions are based upon the current state of art and the available knowledge and experience.“*

ETAG 007
Edition April 2001; GUIDELINE FOR EUROPEAN TECHNICAL APPROVAL OF **TIMBER FRAME BUILDING KITS**

Durable bonding in construction; requirements of the standards

Evaluation of the long term durability of adhesive tapes

Accelerated ageing of bonding samples: Exposion to climate 65°C/80% relative humidity for 60 weeks in climate chamber at Fraunhofer IBP/University of Kassel, Germany

How to assess the durability of adhesives, substrates and component connections?

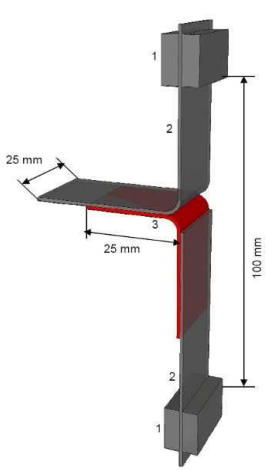
Scope of new standard DIN 4108-11

Examination of durability:

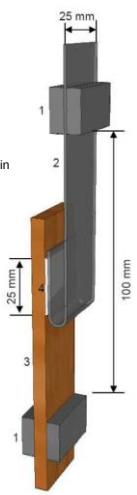
- Current draft of standard defines the minium requirements for ensuring durability of adhesive joints using adhesive masses and adhesive tapes for the manufacture of an air tight building envelope.
- The requirements of adhesives refer to the manufacture of air tight joints according to DIN 4108 part 7.
- Examination of reference samples 48 h after bonding to substrate
- Examination of samples after accelerated ageing of 80 and 120 days at 65 °C und 80 % r.h.
- The assessment of adhesives designed for permanent exposition to outdoor climate and permanent exposition to UV radiation is not in the scope of this standard.

How to assess the durability of adhesives, substrates and component connections?

Evaluation of the long term durability of adhesive tapes



crosshead speed 10 mm/min and 100 mm/min

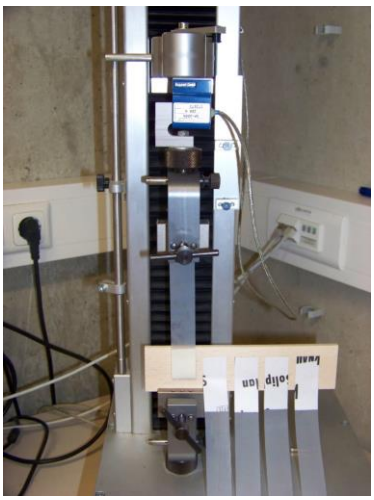


T-peel test according to EN 11339

180° peel test according to EN 1939

How to assess the durability of adhesives, substrates and component connections?

Evaluation of the long term durability of adhesive tapes



Included in draft DIN 4108 part 11: 180° peel test according to EN 1939

How to assess the durability of adhesives, substrates and component connections?

Evaluation of the long term durability of adhesive tapes

Durability tests of adhesive tapes (a brief summary of the definitions of the current draft DIN 4108 part 11

Test Description	Reference test	Pre-conditioning of components	Thermal load/ Moisture load during sample production	Minimum duration of ageing	Thermal load/ Moisture load during artificial ageing	Thermal load/ Moisture load during test	Test speed
Peeling forces	PET with PET	24 h 23±1 °C 50±5 % r. h.	23±1 °C 50 ± 5 % r. h.	-	-	23±1 °C 50±5 % r. h.	10 mm/min; 100 mm/min
Peeling forces after artificial ageing	PET with PET		23±1 °C 50 ± 5 % r. h. 48 h conditioning	80/120 d	65±1 °C 80 % r. h.		
Static peel strength 90°	Beech with PET		23±1 °C 50 ± 5 % r. h.	-	-	24 h 40±1 °C	-
Dynamic loads?	PET with PET		23±1 °C 50 ± 5 % r. h. 48 h conditioning	?	65±1 °C 80 % r. h.	23±1 °C 50±5 % r. h.	

How to assess the durability of adhesives, substrates and component connections?

Evaluation of the long term d

Certificate confirms a long term durability of more than 50 years

Applied testing standard:

ASTM 3611; „Standard Practise for Accelerated Aging of Pressure Sensitive Tapes“

UNIKASSEL VERSITÄT

Fachbereich 6 – Architektur, Stadtplanung, Landschaftsplanung
Fachgebiet Bauphysik
Univ.-Prof. Dr.-Ing. Gerd Hauser

Zertifikat

Thermisches Alterungsverhalten von Haftklebebändern LDS SOLIFLEX und LDS SOLIPLAN

Auftraggeber:	KNAUF INSULATION GmbH D-65232 Taunusstein
Prüfstelle:	Universität Kassel, Fachgebiet Bauphysik.
Gegenstand der Prüfung:	Gegenstand der Prüfung ist die Dauerhaftigkeit der Verklebungen von Folien und Spinnvliesbahnen. Die von KNAUF INSULATION GmbH vertriebenen, einseitig klebenden Bänder LDS SOLIFLEX und LDS SOLIPLAN werden auf zwei verschiedenen Substraten - der diffusionsoffenen Vordeck-/Unterspannbahn Thermolan® LDS 0,02 (die Oberflächenbeschaffenheit des Spinnvlieses ist laut Angaben des Auftraggebers identisch mit der Dampfbremse Thermolan® LDS 2) - der Dampfbremse Thermolan® LDS 100 /DIN 4102-B2 (PE-Folie) hinsichtlich ihrer Dauerhaftigkeit überprüft, indem sie einer künstlichen Alterung ausgesetzt werden. Die dazu verwendeten Proben werden im Liegen verklebt und mit 20 N angepresst. Die Probenbreite beträgt 25 mm, die Verklebung erfolgt über eine Länge von 75 mm. Die Verklebungen werden dem T-Peel Test (Folien) unterzogen.
Künstliche Alterung:	Die Durchführung der Versuche erfolgt in einem Aufbau gem. ASTM D 3611 bei einem Klima von 65 °C und 80 % rel. Luftfeuchte. Die Versuchsdauer wird auf 56, 112, 168 und 350 Tage festgelegt. In Satas (Satas, D. (ed.) „Handbook of Pressure Sensitive Adhesive Technology" Van Nostrand Reinhold, New York, 2nd Edition, 1989, S. 247 –249.) ist für die Umrechnung von Versuchsdauer auf die natürliche Alterung das Verhältnis von 7 Tagen zu ca. 1 Jahr angegeben. Für die genannten Versuchsdauern entspricht dies Zeiträumen von 8, 16, 24 und 50 Jahren.
Prüfergebnisse:	Die Belastung der Verklebungen durch thermische Alterung hat bei keinem der untersuchten Klebebänder und Substrate bei der gewählten Untersuchungsmethodik zu einem selbständigen Versagen der Verbindung geführt
Prüfbericht:	PB SO-126/02 vom 4. August 2003, Thermische Alterung von Verklebungen, 21 Seiten.

Kassel, den 4. August 2003

Dipl.-Ing. Rolf Gross (Prüfleiter)

Univ.-Prof. Dr.-Ing. Gerd Hauser (Leiter der Prüfstelle)

Evaluation of the long term durability of adhesive tapes

KNAUF INSULATION
Energie sparen, jetzt!

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Satas (Satas, D. (ed.) „Handbook of Pressure Sensitive Adhesive Technology“ is determining a ratio of **<u>one week to one year</u>** for the conversion of test duration of accelerated ageing according ASTM D 3611 into duration of natural ageing. In terms of ageing behaviour the performed testing period of 350 days equates to a real ageing at mid European testing conditions of 50 years.

Evaluation of the long term durability of adhesive tapes

Predicted loads of material joints

Pressure difference at VCL [Pa = N/m²]	Force per length of joint		
	[N/m]	[N/100 mm]	[N/25mm]
10	3,7	0,4	0,1
20	7,4	0,70	0,2
30	11,1	1,10	0,3
40	14,8	1,5	0,4
50	18,5	1,8	0,5
100	37	3,7	0,9
150	55,6	5,6	1,4
200	74,1	7,4	1,8
300	111,1	11,1	2,8
400	148,1	14,8	3,7
500	185,2	18,5	4,6

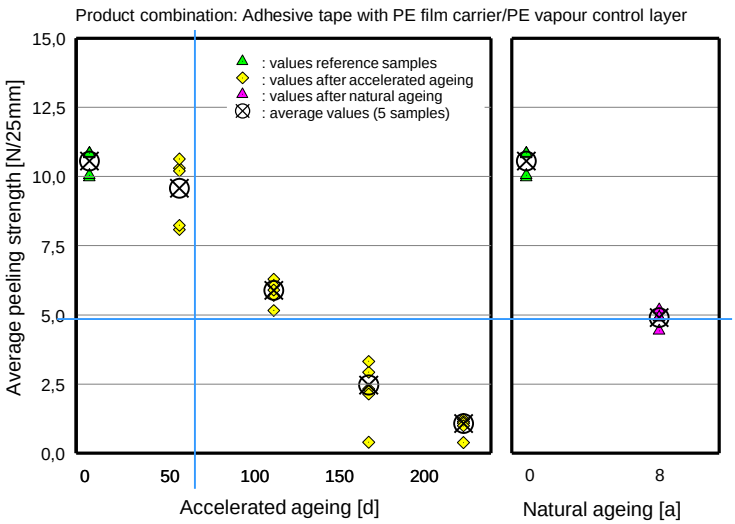
Measured wind loads; recalculation to force per length of joint

Minimum loads are defined in the standard specification, the fixed values of peel resistance are based on observations and measurements of wind loads in pitched roofs within Fraunhofer IBP research

Correlation of results from accelerated ageing (according to standard) and real ageing behaviour

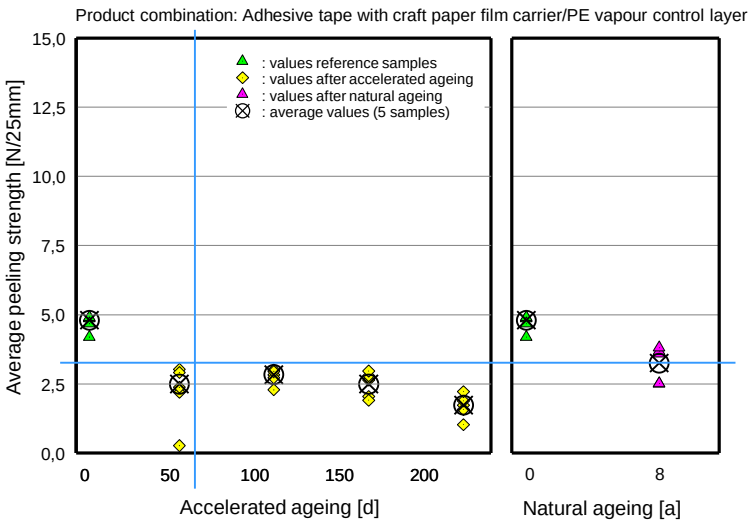
Evaluation of the long term durability of adhesive tapes

Product combination: Adhesive tape with PE film carrier/PE vapour control layer



Good correlation between interpretation according [Satas] and the peeling strength decrease after real ageing: According Satas 56 days of test duration equates to 8 years real ageing

Evaluation of the long term durability of adhesive tapes



Correlation of results from accelerated ageing (according to standard) and real ageing behaviour



Evaluation of an interior air barrier system with dynamic water vapour control

Guillaume Pandraud

2nd Industry Webinars – October 8th, 2013

Introduction

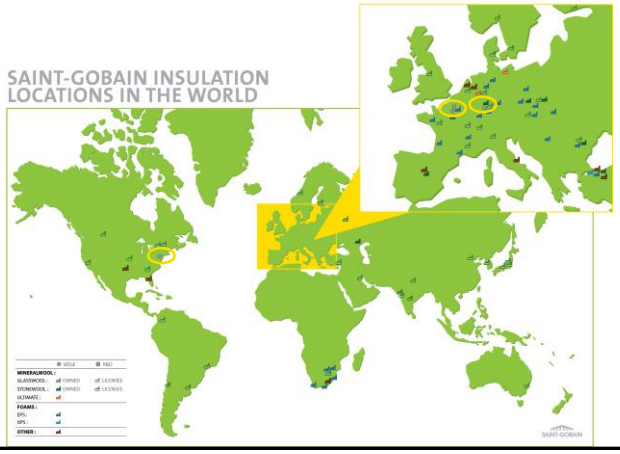
➤ **Saint-Gobain ISOVER and airtightness solutions**

- SG ISOVER, a producer of mineral wool?
- ISOVER presents itself as an expert of energy performance and comfort
- ISOVER solutions for airtightness and moisture control
  - Ex: Vario range
- ISOVER Vario: a complete system
  - Membrane
  - Tapes
  - Sealant
  - Special components
- **Necessity: product characterization**

ISOVER characterization facilities

➢ 3 Laboratories

- France, CRIR (near Paris; manager GP)
- Ladenburg, Germany
- Blue Bell, PA, USA



ISOVER characterization facilities

➢ Measurements in CRIR lab

- Metrology
  - Calibrations
  - Study of the influence of different parameters on the measured results
  - Link with standardization work
- Internal and external benchmarks
  - Comparisons of methods and results
  - Other SG labs for best practice exchanges
  - Reference institutes, suppliers…
- Characterization
  - ISOVER products
  - Competitors watch

ISOVER characterization facilities

- **Equipment in CRIR: 3 main types of tests**
  - Mechanical strength
    - Use of a traction machine
    - Membrane traction strength and nail tear strength
    - Shearing and peeling strength of adhesives
  - Airtightness
    - Airtightness system characterization setup
    - In situ measurements (Blower Door, Isov'Air test)
  - Water permeability
    - Measurement of Sd values
- **+ Others…**
  - Ageing
    - Oven, climatic chamber, UV test
  - "Exceptional" measurements
    - Mechanical resistance of metallic fixations.
    - …

Examples of applications: Adhesives quality control

- **ISOVER adhesives must be controlled before being sold**
  - Control must be on par with certification organisms
  - Checking the metrology by successive internal and external comparisons
- **Some of the parameters whose influence has been checked**
  - Machine speed (very high)
  - Room temperature and humidity (high)
  - Direction in which the membrane is cut (moderate)
  - Material on the machine grip (moderate)
  - Number of days before the test (low)
  - Method and weight used to press the adhesives (low)
  - Sensor sensibility (negligible)
  - **…**
- **Even following standards to the letter, there is room for differences**
  - Importance of communication, standardization, exchange of best practices

Examples of applications: Integra$_2$

➤ **Integra$_2$ fixations development**

- Customer: ISOVER France
- Objective: define components geometry
- Action: control leakages

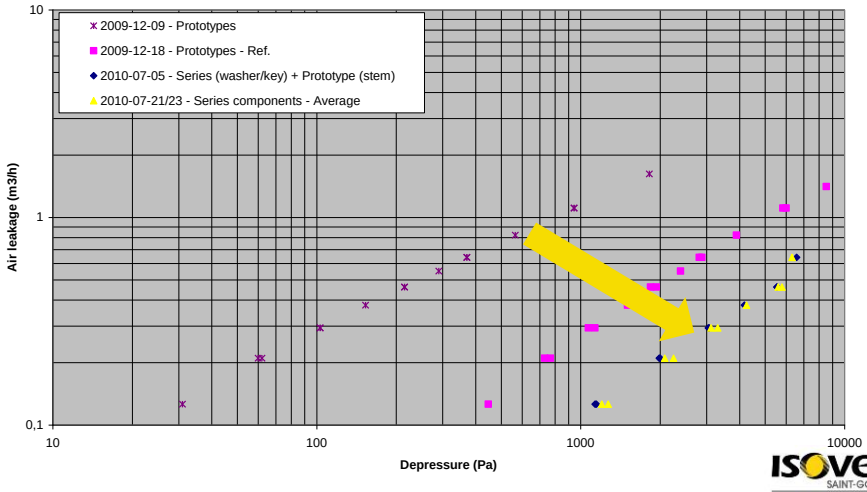
➤ **Activity**

- Device construction
  - Check suspensions in real conditions
  - Sample under depression
  - Flow rate control
- Setup calculation method (EN12114)
  - $V = C\Delta p^n$
- Calculate leakages at 4 Pa and 50 Pa

Examples of applications: Integra$_2$

➤ **Progressive reduction of leakages (by about 95% eventually)**

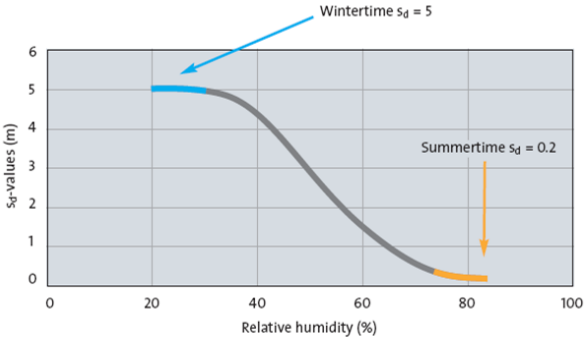
- Validated by measurements at CSTB: no leakage with 64 fixations

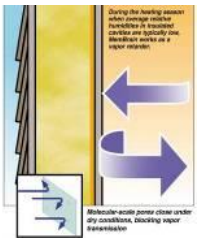


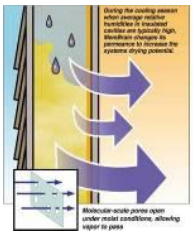
Examples of applications: Vario Xtra

➤ **Vario is a Smart Vapor Retarder**

- Humidity-dependant moisture diffusion
  - Higher at low humidities (usually in winter)
- ➔ Variable Sd value (equivalent air layer thickness)
  - Prevents moisture condensation in winter (low Sd values)
  - Allows moisture dry out in summer







Examples of applications: Vario Xtra

➤ **Technical validation of achieved solutions with WUFI program**

- Hygrothermal simulation software, couples heat and moisture transfer
- Control: Study of R&D solutions when applied to real configurations
  - Hygrothermal analysis: heat flow and water/moisture content
  - Critical moisture conditions (punctual observation)
  - Microbial growth (moisture in wood < 20% @ T > 10°C)

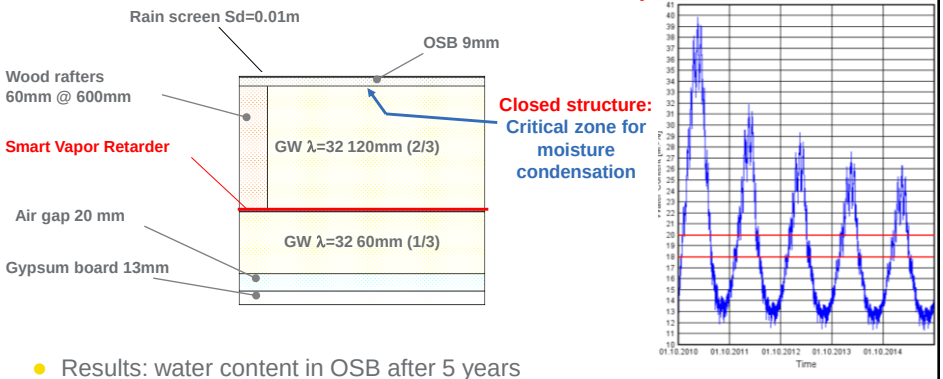
➤ **Some of the cases studied**

- Climates
  - Climate 1 : Germany (Holzkirchen) – Continental - Central EU
  - Climate 2 : France (Nancy) – Cold/humid winter – Extreme case
- Construction modes
  - 1. Temperate application: Pitch roof – Climate 1
  - 2. Critical application: Green/flat roof – Climate 1
  - 3. Extreme critical application: Wooden frame house (1/3 - 2/3) – Climate 2

Examples of applications: Vario Xtra

➤ **Wufi output – Case 3 – Extreme conditions: out of Vario KM range**

- Wood frame house, North-oriented wall, shaded, Nancy climate

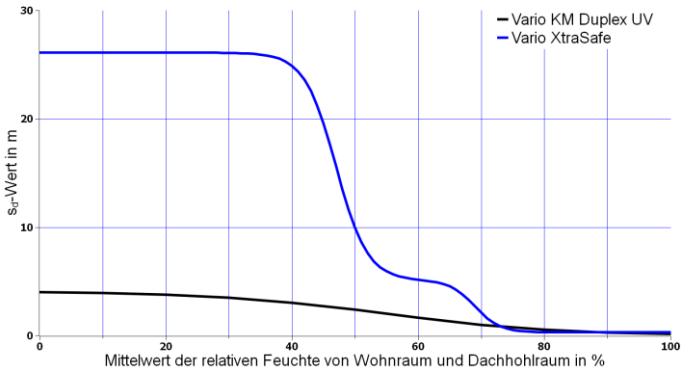


- Results: water content in OSB after 5 years
  - Probable mould growth
  - **Vario KM not prescribed for this combination of climate and construction type**

Examples of applications: Vario Xtra

➤ **Experimental and numerical study of a new prototype**

- Sd measurements of several prototypes, choice of the best one
- Drawing of the Sd curves ➔ inputs for Wufi model
- Best prototype validated ➔ Vario Xtra on the market



Conclusion

- **Saint-Gobain ISOVER is the leader in Energy Efficiency of Buildings**
- **Importance of the quality of its solutions**
  - Product development
  - Quality control
  - Standardization
- **Common basis for these axes: a good metrology**
  - Awareness of the importance of the metrological process
  - Improving constantly the metrology
- **Perspective: Influence of the products ageing**
  - How do different products react to high temperatures, humidity, cycles… ?
  - What tests are the more representative of reality?

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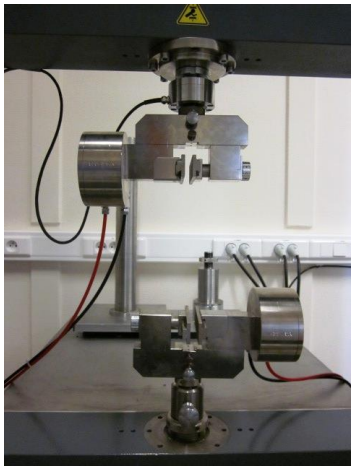
Traction machine



Airtightness characterization setup

Water vapour permeability