Study

Calculating Potential Freedom from Structural Damage of Thermal Insulation Structures in Timber-Built Systems

– Roof, Wall, Ceiling – in Ireland and Great Britain

Humidity-Variable Vapour Checks pro clima DB+ and INTELLO®

Computer-aided simulative calculation of coupled transport of heat and moisture in roof and wall systems, taking account of natural climatic conditions and transport of liquids within building materials

pro clima®

Content

1. Freedom from Structural Damage of Thermal Insulation in Timber-Built Structural Systems: A Question of Drying Reserves

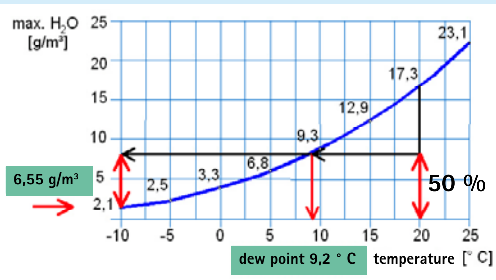
Atmospheric humidity

Atmospheric humidity increases when the air cools down.

Condensation develops below the dew-point temperature.

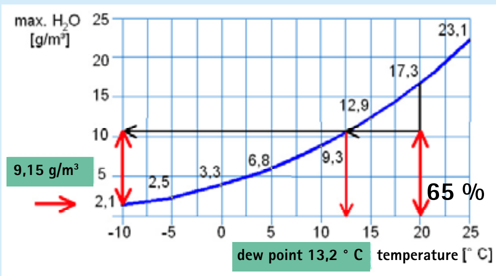
When the internal humidity increases the dew ⟶ point temperature rises and condensation develops sooner.

1. Development of condensation at 50% relative atmospheric humidity



Under normal climatic conditions (20° C/50 % rel. atmospheric humidity), dew point is reached at 9.2° C.
At -10°C, condensation precipitates at a rate of 6.55 g/m³ air.

2. Development of condensation at 65% relative atmospheric humidity



At a high internal rel. humidity of 65 %, dew point is already reached at 13.2° C.
Then, at -10°C condensation precipitates at a rate of 9.15 g/m³ air.

3. To convert to Irish and British standards:

$$s_d \text{ (m)} \times 5.1 = \text{mvtr (MNs/g)}$$

s_d = water vapour diffusion-equivalent air layer thickness
mvtr = moisture vapour transmission rate

1.1 Summary and Introduction

The following study describes how structural damage may arise in thermal insulation systems and how such systems may be reliably and safely protected from damage of this kind.

Structural damage occurs when the moisture stress on a structural system is greater than the system's drying capacity.

To prevent structural damage, the usual approach is to concentrate on reducing moisture stress. However, structural systems cannot be fully protected from the effect of humidity or moisture. Planned moisture stress produced by diffusion is virtually never the cause of structural damage, the usual culprit being unanticipated moisture stress that cannot be entirely ruled out by building design.

To exclude the probability of structural damage and mould growth, it is advisable, apart from considering moisture stress, to concentrate on the drying capacity of a structural system. Systems with a high drying capacity and a simultaneous reduction in moisture stress, as provided by vapour membranes with a variable s_d value, are still protected very safely and reliably against structural damage even if subjected to unanticipated moisture stress.

1.2 Condensation – Dew Point – Quantity of Condensation

Thermal insulation in timber-built structural systems separates warm indoor air with its high humidity content from cold outdoor air with low absolute humidity.

When warm inside air penetrates the structure, it cools – in wintry weather conditions outdoors – as it passes on its way through the structural system. Moisture may condense in the process, this precipitation of water being attributable to the physics of airborne humidity. Warm air can absorb more moisture than cold air. At a greater internal relative humidity (e.g. 65%), the dew-point temperature rises and, as a direct consequence, the quantity of condensation increases as well (see figures 1 and 2).

Condensation develops whenever a more diffusion-tight layer of building components is below the dew-point temperature, which means that:

Building-component layers which are more diffusion-tight on the outside of the thermal insulation than the layers on the inside are unsatisfactory.
A major problem is posed should warm air leak into the structure by convective streams, which happens as a result of leaks in the airtight layer.

Building components are deemed very open to diffusion when their mvtr is <1 MNs/g (s_d-value= less than 0.20 m). The s_d value is defined as the multiple of the vapour diffusion resistance coefficient (μ value) – as material constant – and the thickness of the component in metres:

$s_d = \mu \times s$ (m) $s_d \times 5.1$ = mvtr (MNs/g)
(see figure 3)

A low s_d value can thus be obtained by means of a low μ value and a greater layer thickness (e.g. wood fibre board), or by a higher μ value and a very small layer thickness (e.g. roofing felts). Water vapour is influenced in the first place by the μ value, and only then by the thickness of the building material. This means that precipitation of condensation begins earlier at a higher μ value than at a low one. Moreover, roofing felts produce only a low drop in vapour-pressure because there is little or no difference in temperature and humidity.

This explains why structural damage may still occur with diffusion-open roofing felts when the flow of moisture in the building component is high.

Roofing felts with non-porous, permeable membranes such as SOLITEX UD and SOLITEX PLUS are advantageous in this context, as diffusion proceeds actively along the molecular chains rather than passively through pores. Once water has condensed in a structural system, hoarfrost or even ice may develop underneath the roofing felt in cold winter conditions. Water and ice are impervious to water vapour and can cause an insulating sheet to act as a vapour barrier on the outside. Structural units with a diffusion-inhibiting or even a diffusion-tight layer on the outside are more exacting in terms of construction physics than building-component layers that are open to diffusion towards the outside. Diffusion-tight structural systems include steep-pitched roofs with diffusion-inhibiting underlays, e.g. bitumen felts, roofs with flexible metal sheeting, flat roofs and green roofs.

1.3 Moisture Stress on a Structural System

There are several different reasons for moisture stress within a thermal insulation system when building with timber. In the first place, water may penetrate through a leaking roof skin. Large volumes of moisture can develop, causing water to drip into the accommodation area. Minor leaks can lead to creeping moisturisation, which is often accompanied by mildew or mould on the materials contained in the structural system.
A structural system may also be subjected to moisture stress from the inside, due to

Foreseeable or planned moisture stress:
- diffusion processes

Unanticipated moisture stress:
- convection, i.e. air flow (leaks in the air barrier)
- heightened moisture in the building components used
- design-induced transport of moisture (e.g. flank diffusion through adjoining masonry)

1.3.1 Moisture Stress through Diffusion

The smaller the amount of moisture that can penetrate a structural system, the greatly reduced risk of structural damage is. At least that used to be the preceived opinion. In other words, very dense vapour barriers would prevent damage to the building. The fact that this is not actually true was already proven some ten years ago, by construction-physics calculations on the occasion of the market launch of pro clima's DB+ with its s_d value of 2.30 m (12 MNs/g).

Furthermore, investigations on outside walls conducted in North America in 1999 [1] demonstrated that the entry of moisture through a vapour barrier as a result of convection, even where professionally installed, produces a condensation quantity of about 250 g/m² per dew period. That corresponds to the quantity of condensation diffusing through a vapour check with a mvtr of 16.5 MNs/g (s_d-value=3.3 m) during one winter [2].

Summary:
Substantial quantities of moisture will still penetrate structural systems with vapour barriers having a calculated s_d value of 50, 100 m (250-500 MNs/g) or higher.
But vapour barriers do not permit subsequent evaporation, so moisture traps develop as a result.

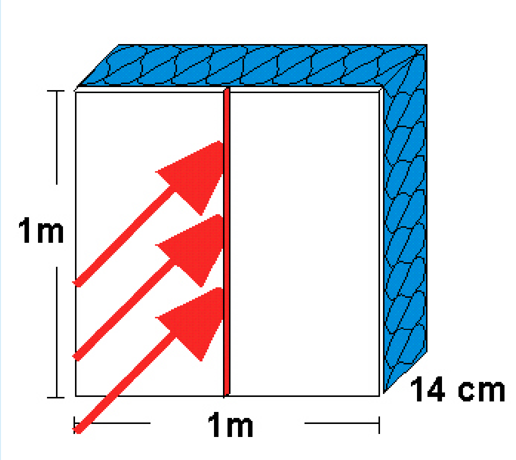
1.3.2 Moisture Stress through Convection

Convection, in other words airflow, transports substantially larger quantities of moisture into a structural system than diffusion does. The volume of moisture carried in by convection can easily exceed a thousand times the quantity introduced by diffusion. (see figure 4).

Once condensation develops convective quantities of moisture can, due to their high moisture load, present a risk to the outside even where building components are open to diffusion. Waterfilms can act as a vapour barrier in the same way as ice. Such a situation generally results in structural damage similar to where structural systems have diffusion-tight components on the outside.

Entry of moisture into the structural system due to leaks in the vapour barrier

4. 1 mm Gap = 800 g/24h per m Gap Length



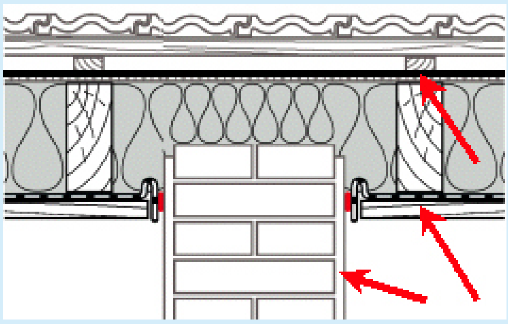
Moisture transfer
through vapour barrier: 0.5 g/m² x 24h
through 1 mm joint: 800 g/m² x 24h
Factor: 1,600

Boundary conditions:	
vapour barrier mvtr =	150 MNs/g (s_d-value = 30 m)
indoor temperature:	+20° C
outdoor temperature:	-10° C
pressure difference:	20 Pa corresponding to wind force 2-3

Measurements by:
Institute for Building Physics, Stuttgart

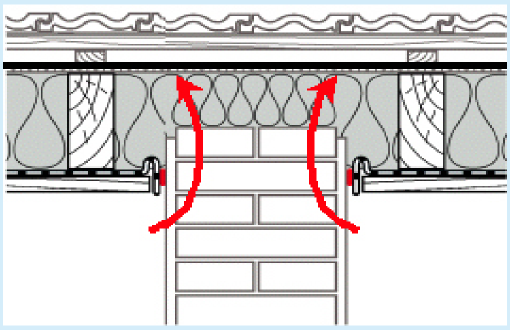
Flank Diffusion

5. Structural damage: Entry of moisture despite airtight junctions and the use of a vapour barrier



Airtight construction using a PE sheet and an airtight layer of plaster with bitumen felts on the outside

6. Cause of moisture entry: Moisture transfer across the flanks, here through masonry



Moisture entry due to flank diffusion through adjoining masonry

1.3.3 Design-Induced Moisture – Flank Diffusion

In practice, structural damage occurs in ways that cannot simply be explained by diffusion or convection processes. Ruhe [4] and Klopfer [5], [6] reported in 1995 and 1997 respectively on the problem of flank diffusion in an instance of structural damage.

The structural system in question comprised of a roof with timber decking and bitumen felt on the outside, a PE sheet on the inside, and mineral wool in between. Despite a perfect airtight seal, water dripped, in summer, from the junctions of the sheeting onto the adjoining building components underneath. It was initially assumed that the phenomenon was attributable to high incorporated moisture. However, this had to be ruled out because the dripping increased from year to year. After five years, the roof was opened. Most of the timber decking had already begun to rot.
The possibility of moisture entry as a result of flank diffusion was discussed. Flank diffusion is understood to mean the penetration of moisture into the roof via the flank or edge of the lateral airtight seal flashing, which comprised porous brickwork in the case investigated. The current of moisture virtually bypasses the vapour barrier (see figures 5 and 6).

The situation was much disputed among construction physicists at the outset, until Künze [7], in 1997, furnished mathematical proof of flank diffusion with the aid of two-dimensional calculations of heat and moisture transport using WUFI 2D 2.1 [8]. According to his calculation, wood moisture above the brickwork had risen to about 20% after just one year, thus already exceeding the mould-critical limit; after three years, the moisture content rose to 40%, and then to 50% after five years.

1.3.4 High Incorporated Moisture in Compound Units

Where building materials with a high moisture content are installed, it is essential to ensure that the structural system is capable of letting this moisture dry out again. Although it has become general practice by now to use dry timber for building purposes, just a shower of rain can increase the quantity of moisture in the wood.

Expressed in concrete figures:

A roof with 8/18 rafters and a rafter spacing of e = 0.70 m has 1.5 linear metres of rafters per m² of roof area. At 10 % moisture, this quota of rafters will contain about 1.1 litres of water. Consequently:
If the moisture of the wood is 30 % at the outset, it must be possible for 1.1 litres of water per m² of roof area to evaporate so as to come below the mould-critical moisture of 20%.

This sample calculation is consistent for 20-mm thick timber roof boarding as well. The moisture content at 10 % wood moisture amounts to approximately 1.2 litres of water.
At 30 % initial moisture, by no means a rarity after a day of rain, it is essential for 1.2 litres of water per m² of roof area to evaporate in order to fall below the mould limit.
Together, this amounts to about 2.3 litres per m² of roof area.
The total quantity of moisture is often underestimated. In concrete construction work, the humidity associated with new building work may add a further quantity of moisture. Structural damage rapidly ensues if a PE sheet is then placed on the inside and bitumen felt on the outside.

1.3.5 Moisture Stress Summarised

The numerous ways in which moisture can enter are a clear indication that, in everyday building practice, the possibility of moisture stress on a structural system can never be ruled out. When the object of the exercise is to build without likelihood of damage, the provision of increased drying reserves is a far more effective and reliable solution than any strict concentration on letting as little moisture as possible into the structural system.

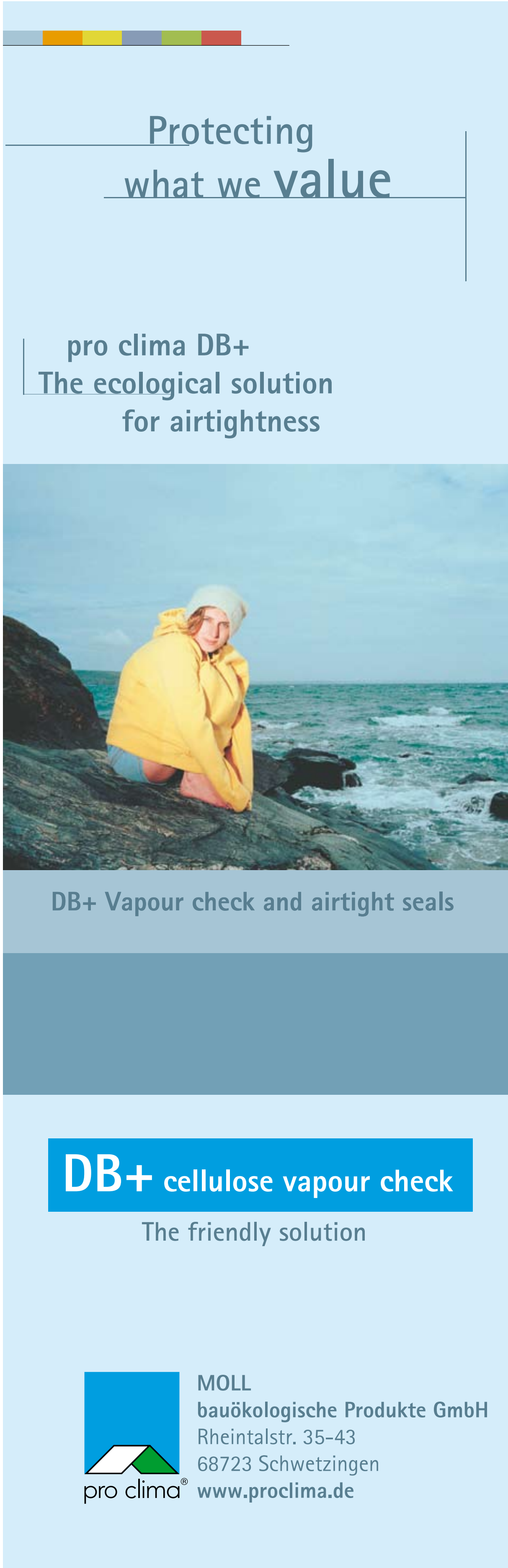
Safety Formula:

drying capacity > moisture stress
=> freedom from structural damage

Structural damage can only occur when drying capacity is less than moisture stress.

„The greater a structural system's reserves for drying, the greater the unanticipated moisture stress it can take and the structure still remain free from structural damage".

Structural systems that are open to diffusion on the outside have greater drying reserves than systems with a diffusion-tight exterior.



Structural humidity situation

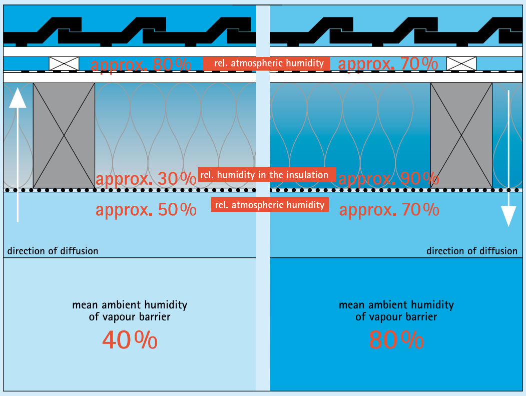
Diffusion stream always goes from the warm to the cold side:

In winter:
Increased humidity on the outside

In summer:
Increased humidity on the inside

7. The vapour check is exposed

- to dry atmospheric humidity in winter.
  > The humidity-variable vapour check is tighter against diffusion
- to high atmospheric humidity in summer.
  > The humidity-variable vapour check is more open to diffusion



Seasonal dependency of relative atmospheric humidity at the vapour check

8. Diffusion streams of the humidity-variable pro clima vapour check

Diffusion Current	W_{DD}-value in g/m² per week in winter	W_{DD}-value in g/m² per week in summer
Direction of diffusion	Towards sub-roof: Humidification	Towards vapour-membrane: Evaporation
DB+	28	175
INTELLO®	7	560

2.1 Drying towards the inside

Drying towards the inside is another important option for structural components. Whenever the temperature of an insulation layer is higher outside than inside, the diffusion stream reverses and moisture streams inwards out of the component. This can happen on sunny days in spring and autumn and all the more so during the summer months.

If a vapour check or airtightness layer were then to be open to diffusion, moisture that may be present in the structural system could dry out towards the interior.

However, a diffusion-open vapour check would let too much moisture diffuse into the structural system during winter and thus give rise to structural damage.

A structural system would appear at first glance to be well protected against moisture when equipped with vapour barriers. However, if moisture enters through convection, flank diffusion or high component moisture, the system is incapable of evaporating again towards the inside in the summer. Depending on its design, the vapour barrier becomes a moisture trap. A vapour check with a high diffusion-resistance in winter and a low diffusion resistance in summer is ideal.

„Intelligent“ vapour checks with a humidity-variable s_d value have proven their worth for years by now. They alter their diffusion resistance in relation to the relative atmospheric humidity.

In winter conditions, they become more diffusion-tight and protect the structural system from moisture.
In summer, they are more diffusion-open and thus allow moisture, which may be present in the system to evaporate towards the inside.

2.2 How Humidity-Variable Diffusion Resistance Functions

The direction of the diffusion stream is determined by the difference in water vapour partial pressure, which depends on the temperature and humidity content of the air inside and outside a building. Just to concentrate on the temperature aspect, moisture flows from the warm side to the cold side, so, in winter, from the inside to the outside, and, in summer, from the outside to the inside.

Measurements on roof systems have shown that, in winter, the transport of moisture within the roof space towards the outside leaves the vapour check at a mean ambient humidity of about 40 %. In summer, on the contrary, moisture in the roof space produces increased relative atmospheric humidity at the vapour check, sometimes even producing ‚summer condensation‘ (see figure 7).

Vapour checks having a humidity-variable diffusion resistance are tighter to diffusion in a dry environment and more open to diffusion in a humid environment.
pro clima DB+ has proven its worth in millions of square metres installed since 1991, its diffusion resistance ranging from 16.5 to 4 MNs/g (3.5 to 0.8 m).

Moll bauökologische Produkte GmbH developed their pro clima INTELLO® high-performance vapour check in 2004. INTELLO® has the world's most effective humidity-variable diffusion resistance, ranging from 1.25 to over 50 MNs/g (0.25 m to over 10 m) to suit every type of climate (see figures 9– 11).

2.2.1 High Diffusion Resistance in Winter

The diffusion resistance of the pro clima INTELLO© vapour check has been designed so that the membrane can provide a mvtr of over 50 MNs/g in winter conditions. As a result, the vapour check will allow almost no moisture to penetrate a structural system during winter, when humidity pressure on the system is at its highest. The same can also be said of extreme climatic conditions as encountered in alpine regions, where winters are cold and long. Effective protection against humidity is also provided for roofs with diffusion-tight underlay sheeting (e.g. bitumen sheeting), and roofs with flexible metal sheeting. In roofs with diffusion open sub roofs, the high mvtr is an obvious advantage in case of hoarfrost and ice formation (= diffusion barrier) on diffusion-open insulation sheeting. (see figure 10)

2.2.2 Lower Diffusion Resistance in Summer

Diffusion resistance in summer can be reduced to an mvtr of 1,25 MNs/g permitting moisture that may be present in the roof system to evaporate rapidly towards the inside.
Depending on the magnitude of the vapour pressure difference, this corresponds to an evaporation rate of 5 to 12 g/m² of H_2O per hour corresponding to approx. 80 g/m² of H_2O per day or 560 g/m² of H_2O per week. (see figure 7)
This high evaporation capacity means that a building component framework will start drying out rapidly by as early as spring.

2.2.3 Well-Balanced Diffusion Profile

In times of improved levels of airtightness with associated higher atmospheric humidity in new buildings made of masonry, diffusion resistance to cater for increased relative atmospheric humidity becomes an important factor, also for climates of high humidity like in Ireland.

2.2.3.1 New Buildings: The 60/10 Rule

Due to the recently completed construction work and short time of occupation, the internal relative humidity in new buildings is high. The diffusion resistance of a vapour check should be designed in such a way that an mvtr of at least 10 MNs/g is reached even at 60 % mean relative humidity in order to adequately protect the construction from moisture. At a relative humidity of 60 % INTELLO® has a s_d value of 20 MNs/g.

2.2.3.2 Construction Time: The 70/7,5 Rule

During the construction time, after plastering or installing a screed, the relative humidity in a building is very high. At a mean relative humidity of 70 %, the diffusion resistance of a vapour check should be above 7.5 MNs/g in order to protect the construction against excessive entry of moisture from the building site and from mould growth. An effective protection against moisture is needed particularly where derived-timber boards are installed on the outside of a structure. At 70 % with a mvtr of 7,5 MNs/g INTELLO exceeds this requirement by far.
Generally, building moisture should quickly escape from the structure via open windows. Dehumidifiers can speed up this process during the winter.

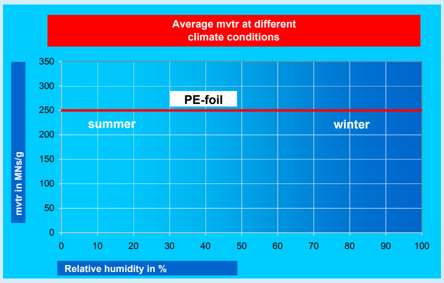
2.2.4 Maximum Safety

The 'intelligent' humidity-variable vapour checks provide for highly reliable, safely protected thermal insulating systems, even where moisture entry into the structural system cannot be anticipated, e.g. because of adverse weather conditions, leaks, flank diffusion, or a high moisture content in timber or insulation materials. The pro clima humidity-variable vapour checks act as a moisture transfer pump by actively extracting any unexpected moisture which may be present in a structural component. Pro clima DB+ and INTELLO provide high safety even in climates with high humidity such as in Ireland and in cold climates such as Scotland.

Diffusion Graphs for Various Vapour Membranes

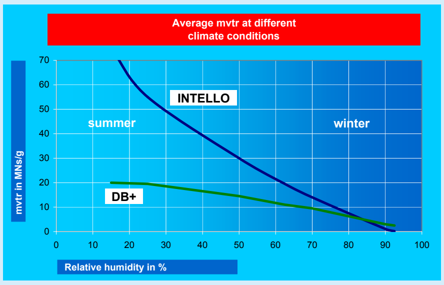
The more the diffusion resistance varies between winter and summer, the more safety and reliability is afforded by the vapour check.

9. Diffusion graph for a PE sheet. No humidity variability.



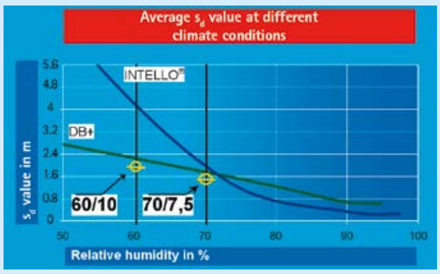
Constant mvtr
PE sheet

10. Diffusion graph pro clima DB+ and INTELLO. Medium and high humidity variability.



Humidity-variable mvtr
pro clima DB+ and INTELLO

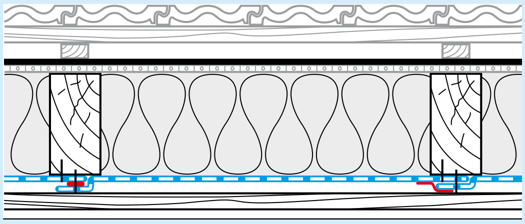
11. Diffusion graph INTELLO® High moisture variability



INTELLO and DB+ meet the 60/1 and 70/7,5 rule

Physical assessment of roof structure

12. Design of roof structure



- diffusion-tight on the outside (bitumen roof sheeting, mvtr = 1500 MNs/g (s_d value = 300 m)
- fibrous insulation
- vapour checks having different s_d values
- lathing
- gypsum plasterboard
- for alpine climates additionally 24 mm solid timber checking

Roof construction:
- steep-pitched with 40° pitch on north side, uncoloured light-grey roof tiles

3.1 Various Methods of Calculating Moisture Transports

Drying reserves are the consequence not only of diffusion processes, but also of sorption and capillarity processes within the building-component layers.

3.1.1 Calculation according to Glaser EN ISO 13788

EN ISO 13788 still relies heavily on Glaser's method, which calculates ensuing quantities of condensation in structural systems under the assumption of a monthly block climate.

3.1.2 Calculation of Coupled Heat and Moisture Transport under Natural Climatic Conditions

The Glaser method provides an approximation for the assessment of structural systems, but does not represent reality. On the one hand, the block climate data differs from the real climate, and, on the other hand, such important transport mechanisms e.g. sorption and capillarity are not taken into account.
EN ISO 13788 therefore points out that this method is not suitable as a means of verifying the freedom of green roof systems from structural damage, in which case heat and moisture transport has to be calculated by means of a non-transient simulation program.
Recognised software solutions in this area are Delphin by the Institut of Building Climatology in Dresden and WUFI by the Fraunhofer Institute of Building Physics in Holzkirchen.
These programs calculate the coupled transport of heat and moisture in multiple-layer building components under natural climatic conditions, jointly allowing for temperature and humidity, light absorption, wind, latent heat, sorption and capillarity.

The programs have been validated repeatedly, which is to say the result of their computations have been compared with those of field trials. Actual weather data over the period of 1 year is required for hourly values.
Climatic data is available throughout the world, viz. Europe, North America and Asia, including both temperate and extreme climatic regions.

To carry out a normal simulative calculation of the coupled transport of heat and moisture under natural climatic conditions, the building structure with its sequence of layers is entered into the program, and heat and moisture streams are analysed over a period of several years under boundary conditions closely conforming to reality.

The result then shows if moisture has accumulated in the structure, i.e. whether the overall moisture content of the structural system has risen over the period under observation, or if the component has remained dry.
However, it is not possible by this method to recognise the drying reserves of a structural system.

3.2 Calculating the Potential Freedom from Structural Damage for a Structural System

One further input is used in order to calculate how reliably and safely protected a structural system is against unanticipated entry of moisture, e.g. as a result of convection, flank diffusion, or heightened incorporated humidity:

The thermal insulation is moistened at the beginning of the calculation, and the rate at which this moisture dries out is duly examined. **The quantity of moisture that dries out of the structural system in relation to the extra moisture added to it represents the safety potential from structural damage of the structural system before it will suffer from structural damage.**
Using various vapour checks, calculations are performed on several structural systems deemed difficult from the construction physics point of view: under adverse conditions (north side), in different climatic zones (lowlands and alpine), with steep-pitched roofs.
Flat roofs and green roofs require a separate examination. Less sophisticated systems in terms of construction physics naturally offer even greater levels of safety potential.

3.2.1 Roof structures

Design of structure:
(see figure 12 on the left hand side)

Vapour checks:

- PE sheet mvtr/s_d value constant 25 MNs/g (s_d-value = 50 m)
- DB+ mvtr/s_d humidity-variable 12: 17-4 MNs/g (2.3 m: 3.5-0.8 m)
- INTELLO® mvtr/s_d humidity-variable 38: 50-1.25 MNs/g (7.5 m: 10-0.25 m)

Roof:

- steep-pitched with 40° pitch to north side, uncoloured light-grey roof tiles

Locations:

- Ireland:
  Dublin
  Belmullet (Westcoast)
- Great Britain:
  London
  Rhymney Valley (435 m above sea level) near Cardiff, Wales
  Inverness, Scotland

Calculation

- using WUFI 3.3 pro [10]
- initial moisture in thermal insulation: 4,000 g/m^2

3.2.2 Definition of Potential Freedom from Structural Damage

The potential freedom from structural damage describes how much moisture can enter unexpectedly into a construction with the building component still staying both free from structural damage and mould growth. One important factor in determining protection against structural damage and mould growth is the back-diffusion capacity in summer and, associated therewith, the ability of the structural system to evaporate towards the inside. Back-diffusion can occur when the partial vapour pressure on the outside of the insulation is greater than on the inside, or to put it more simply, when the temperature at the outside of the insulation is higher than in the living area.

The temperature at the outside of the insulation is influenced by surrounding air temperature and by exposure to sunlight.

3.3 Factors Determing the Extent of Potential Freedom from Structural Damage

The extent of back diffusion, i.e. the extent of dehumidification depends on the outdoor temperature. The higher the outdoor temperature is, the greater the back diffusion and the effect of dehumidification provided that humidity-variable vapour checks are used. Due to solar radiation the surface of the roof has a higher temperature than the air.

The level of temperature of the surface of the roof depends on the roof pitch, the orientation of the roof (north/ south) and the colour of the roof sheathing (rather light/rather dark).

Unfavourable factors are:
Roof pitch north orientated
High pitched roof (> 25°)
Light colours of the roof sheathing, e.g. uncoloured light-grey concrete tiles
Diffusion-tight sub-roof, e.g. bitumen felts
Cold climate (north of the country and mountains)

Favourable factors are:
Roof pitch south orientated
Low pitched roof (< 25°)
Dark colours of the roof sheathing (red or black tiles)
Diffusion-open sub-roof, e.g. Solitex
Warm climate (south of the country and lowlands)
Locations in the south (London, Dublin) result in a greater summerly dehumidification of the roof construction when humidity-variable vapour checks were used than locations in the north (Wick, Inverness) due to higher atmospheric temperature and a higher position of the sun.

For the calculation of potential freedom from structural damage the most unfavourable conditions were assumed:

Roof pitch north-orientated
Pitch of 40°
Light-grey uncoloured concrete tiles
Bitumen felts

The potential freedom from structural damage of the construction increases when more favourable conditions are chosen.
The present calculations show that a high degree of freedom from structural damage can be achieved in Ireland and in Great Britain even at most unfavourable conditions when pro clima INTELLO vapour check is used for roof constructions. Sufficient security for the construction can also be provided by using pro clima DB+.

3.4 Ireland

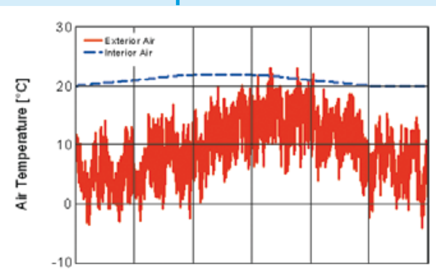
3.4.1 Climatic Data Ireland

Dublin is situated on the east coast of Ireland and is characterised by a temperate climate with moderate wind and humidity. Shannon is very similar to Dublin in these terms.
Belmullet is situated on the west coast and is renowned for its windy and extremely damp weather. The wind additionally cools the roof on the external side.
The following charts show the temperature pattern of the air and the temperature of the surfaces of the roofs with uncoloured light-grey tiles in Dublin and Belmullet. The red graphs show the outside temperature, the blue curve the indoor temperature.
Atmospheric temperature is rarely higher than the inside temperature. Since the temperature of the roof is often higher due to solar radiation, back diffusion is induced, i.e. an effective dehumidification of the construction, provided that humidity-variable vapour checks were used (see figures 13-16).

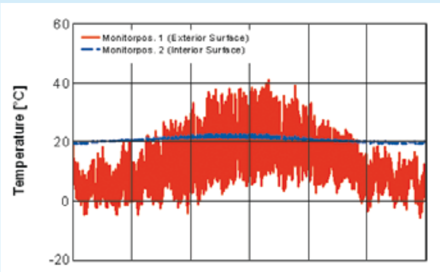
Temperature graphs Dublin (Eastcoast) and Belmullet (Westcoast)

Dublin:

13. Air temperature

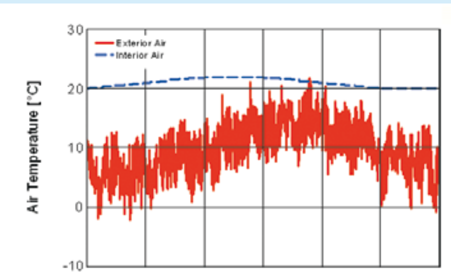


14. Temperature of the surface of the roof (roof pitch north-orientated 40° with uncoloured light-grey tiles)

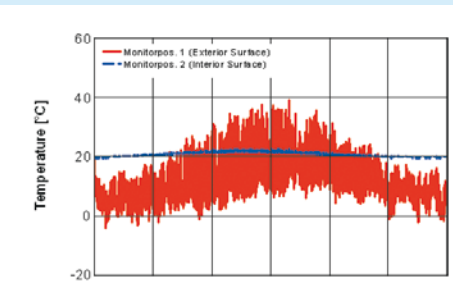


Belmullet:

15. Air temperature



16. Temperature of the surface of the roof (roof pitch north-orientated 40° with uncoloured light-grey tiles)



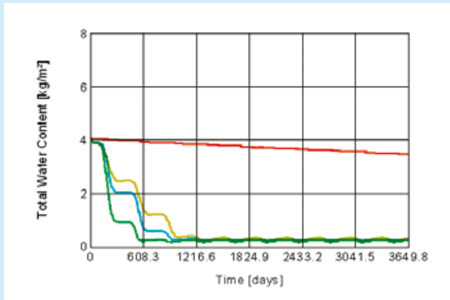
3.4.2 Calculating Potential Freedom from Structural Damage: Dublin

The speed of drying of initial moisture (which we assumed to be additionally 4.000 g/m²) describes the potential freedom from structural damage of a construction. It reveals how much moisture can enter unexpectedly into a construction with the building component still staying both free from structural damage and mould growth. The potential freedom from structural damage should add up to at least 300 g/m² to ensure a sufficient safeness. The higher the potential freedom from structural damage, the better of course.

INTELLO offers the highest level of potential freedom from structural damage for Dublin: 2.000 g/m² of moisture can enter unexpectedly into the construction annually without damaging it or causing mould growth. When using the vapour check pro clima DB+ it's 1.500 g/m². If black tiles are used instead of grey ones the potential freedom from structural damage increases: When using INTELLO up to more than 3.000 g/m², DB+ up to more than 2.500 g/m² a year. The same level of potential freedom from structural damage (3.000 g/m²) can be achieved with grey tiles and a roof pitch of 25° (instead of 40°).
A PE sheet offers the construction only a very low level of potential freedom from structural damage of approximately 10 g/m² a year. Moisture can not dry out to the inside when a PE sheet is used. The PE sheet becomes a humidity trap.

Potential Freedom from structural damage

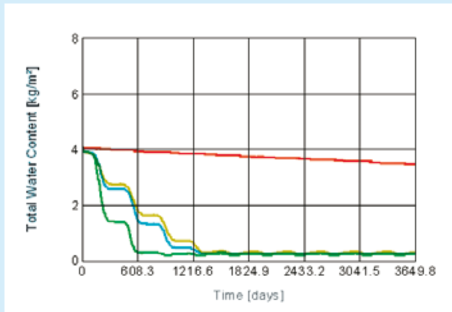
17. Dublin



Potential freedom from structural damage:

pro clima INTELLO® black tiles	= 3000 g/m² per year
pro clima INTELLO® grey tiles	= 2000 g/m² per year
pro cima DB+	= 1500 g/m² per year
PE sheet	= 10 g/m² per year

18. Belmullet



Potential freedom from structural damage:

pro clima INTELLO® black tiles	= 2500 g/m² per year
pro clima INTELLO® grey tiles	= 1700 g/m² per year
pro cima DB+	= 1300 g/m² per year
PE sheet	= 10 g/m² per year

3.4.3 Potential Freedom from Structural Damage: Belmullet

Belmullet is known for its extreme climate: high atmospheric humidity, high wind velocity and even in summer low temperatures. These climatic conditions are demanding on the construction. The potential freedom from structural damage of the construction is lower in Belmullet than in Dublin.
Intello offers the construction a potential freedom from structural damage of 1.700 g/m² despite the challenging climatic conditions on the west coast and in unfavourable conditions: grey tiles, roof pitch 40°, north-orientated, bitumen felts externally. This means that 1.700 g of moisture per m² can enter the roof construction within one year without causing structural damage or mould growth; using pro clima DB+ it's 1.300 g/m². When black tiles are used the potential freedom from structural damage increases with INTELLO to 2.500 g/m² and with DB+ to 1.800 g/m². The same level of potential freedom from structural damage (2.500 g/m² and 1.800 g/m²) can be achieved when grey tiles are used and the construction has a north-orientated roof pitch of 25° (instead of 40°).
A PE sheet offers the construction only a very low level of potential freedom from structural damage of approximately 10g/m² a year. Moisture can not dry out to the inside when a PE sheet is used. The PE sheet becomes a humidity trap (see figure 18).

3.4.4 Calculating Potential Freedom from Structural Damage: Shannon

Shannon has compared to Dublin 10% lower values for the potential freedom from structural damage.

3.4.5 Conclusions:

In Ireland INTELLO and DB+ offer a high level of potential freedom from structural damage for all pitched roof constructions even with the challenging and very wet climate in Ireland- even at the most unfavourable circumstances (pitched roof 40 ° north-orientated, externally diffusion-tight)
INTELLO –the vapour check with the world's highest variability of diffusion resistance that is effective in all climate zones- achieves a potential freedom from structural damage of more than 1.500 g/m². This provides great protection against mould growth for the construction and a healthy room climate for the residents even when unexpected moisture load occurs.

3.5 Great Britain

3.5.1 Climatic Data England and Wales

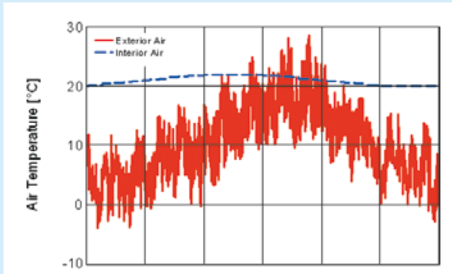
London is situated in a moderate climate. On many days of the year outdoor temperatures are higher than indoor temperatures. Temperatures of the roof of a north-orientated roof with a pitch of 40° often exceed 40°C when grey tiles are used.
Rhymney Valley's meteorological station is located in Wales near Cardiff at an altitude of 435 m and represents a mountain climate in England and Wales. Temperatures rarely exceed 20 °C and are always lower than the indoor temperature. The temperatures of the roof correspond to those of a typical mountainous climate.
They are considerably lower than in London and exceed 30° C, even at most unfavourable conditions (pitched roof 40° north-orientated)
(see figures 19-22).

3.5.2 Calculating Potential Freedom from Structural Damage: London

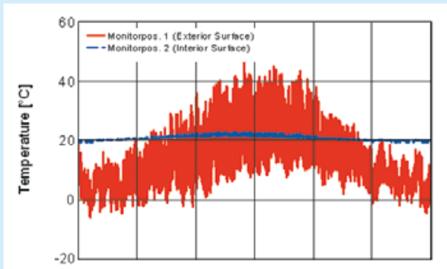
The speed of drying of initial moisture (which we assumed to be additionally 4.000 g/m²) describes the potential freedom from structural damage of a construction. It reveals how much moisture can enter unexpectedly into a construction with the building component still staying both free from structural damage and mould growth.
The potential freedom from structural damage should add up to at least 300 g/m² to ensure a sufficient safeness.
The higher the potential freedom from structural damage, the better of course.

Temperature graphs London and Rhymney Valley (mountain climate 435m)

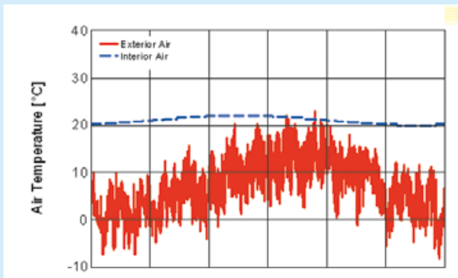
19. Air temperature London



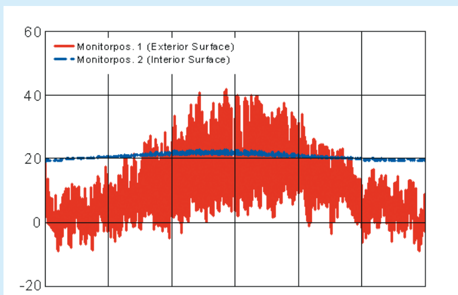
20. Temperature of the surface of the roof (roof pitch north-orientated 40° with uncoloured light-grey tiles)



21. Air temperature Rhymney Valley

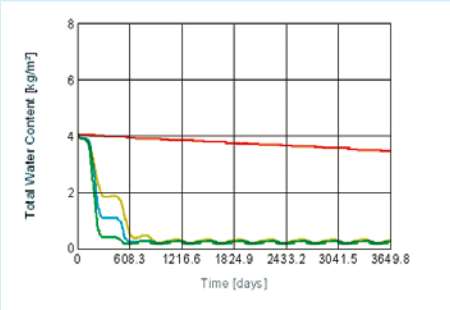


22. Temperature of the surface of the roof (roof pitch north-orientated 40° with uncoloured light-grey tiles)



Calculating Potential Freedom from Structural Damage

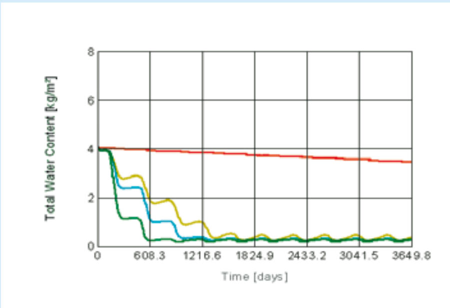
23. London



Potential freedom from structural damage:

pro clima INTELLO® black tiles	= 3800 g/m² per year
pro clima INTELLO® grey tiles	= 3000 g/m² per year
pro cima DB+	= 2000 g/m² per year
PE sheet	= 10 g/m² per year

24. Rhymney Valley



Potential freedom from structural damage:

pro clima INTELLO® black tiles	= 2500 g/m² per year
pro clima INTELLO® grey tiles	= 1500 g/m² per year
pro cima DB+	= 1000 g/m² per year
PE sheet	= 10 g/m² per year

INTELLO offers the highest level of potential freedom from structural damage for London:
Even at London's temperate climate and at most unfavourable conditions (pitched roof 40 ° north-orientated, externally diffusion-tight) 3.000 g/m² of moisture can enter unexpectedly into a construction with the building component still staying both free from structural damage and mould growth with the INTELLO vapour check. The potential freedom from structural damage amounts to 2.000 g/m² when the pro clima DB+ vapour check is used.

A PE sheet offers the construction only a very low level of potential freedom from structural damage of approximately 10 g/m² a year. Moisture can not dry out to the inside when a PE sheet is used. The PE sheet becomes a humidity trap.

3.5.3 Calculating Potential Freedom from Structural Damage: Rhymney Valley

The Rhymney Valley is situated in the mountains and is renowned for its rough climate. Constructions require a greater care due to low temperatures in winter and low temperatures in summer. Intello provides a potential freedom from structural damage of 1.500 m/g² despite the challenging climate and at most unfavourable conditions.
This means that up to 1.500 g/m² of moisture can enter unexpectedly into the construction within one year and still the construction remains both free from structural damage and mould growth.
With pro clima DB+ vapour check a potential freedom from structural damage of 1.000 g/m² is reached.
By using INTELLO, safety increases up to 2.500 g/m² when black tiles are used or with a minor roof pitch (and grey tiles).
A PE sheet offers the construction only a very low level of potential freedom from structural damage of approximately 10g/m ² a year. Moisture can not dry out to the inside when a PE sheet is used.
The PE sheet becomes a humidity trap (see figure 24).

3.5.4 Conclusions

INTELLO and DB+ offer a high level of potential freedom from structural damage not only in a temperate climate such as England and Wales but also in locations with mountainous climates – even at the most unfavourable circumstances (pitched roof 40 ° north-orientated, externally diffusion-tight) INTELLO – the vapour check with the world's highest variability of diffusion resistance that is effective in all climate zones- achieves a potential freedom from structural damage of more than 1.500 g/m². This provides great protection against mould growth for the construction and a healthy room climate for the residents even when unexpected moisture load occurs.

3.5.5 Climatic Data Scotland

Inverness is situated in the north of Scotland on the east coast. Only on a few days of a year temperatures get higher than 20°C; in winter air cools down to –10°C. Air humidity in Scotland is high and the angle of solar radiation is flat due to the geographical position in the north. Even at most unfavourable conditions (pitched roof 40 ° north-orientated with grey tiles) temperatures of the roof achieve nevertheless approximately 40°C. In mountainous regions of Scotland, for example the Centre Highlands, temperatures are lower by approximately 5 °C at 500 m above sea level.

A minor roof pitch (for example 25°) and dark tiles increase the temperature of the surface of the roof and thus the back diffusion or rather the potential for dehumidification of the construction.

3.5.6 Calculating Potential Freedom from Structural Damage: Inverness

The speed of drying of initial moisture (which we assumed to be additionally 4.000 g/m²) describes the potential freedom from structural damage of a construction. It reveals how much moisture can enter unexpectedly into a construction with the building component still staying both free from structural damage and mould growth. The potential freedom from structural damage should add up to at least 300 g/m² to ensure a sufficient safeness. The higher the potential freedom from structural damage, the better of course. In Scotland, particularly in locations in the north and in mountainous regions, hard sub-roofs are used due to the climatic circumstances. They consist of bituminised timber soft boards, solid timber decking or derived timber boards. Then, either a diffusion-open roof lining membrane or diffusion-tight roofing felt such as bitumen roofing felts are installed on them. The highest potential freedom from structural damage is offered by the bituminised timber soft boards. A solid timber decking is more favourable than derived timber boards, e.g. OSB boards.

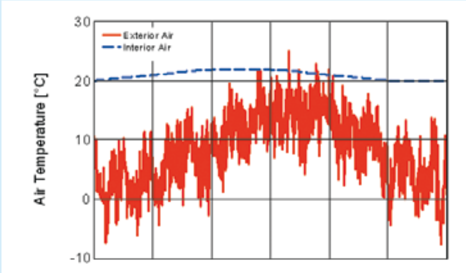
For the calculation of the potential freedom from structural damage a construction with a solid timber decking was chosen. The solid timber decking has a moisture content of approximately 1.600 g/m² (at 15% timber moisture). Together with the additional amount of moisture of 4.000 g/m² for the calculation of the potential freedom from structural damage moisture amounts to 5.600 g/m² at the beginning of the calculation. This signifies the following results of the calculation:

The construction is dry at a water content of 1.600 g/m². Then the construction has only the usual moisture content of the timber decking of 15%. If the construction dries more than 1.600 g/m², timber moisture decreases. At a total water content of 800 g/m² the timber decking has a moisture content of only 7%.

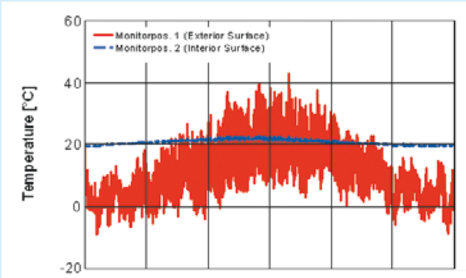
Even in the challenging climatic conditions in Scotland INTELLO offers the construction a very high level of potential freedom from structural damage.
In Inverness, roofing constructions still achieve a high level of freedom from structural damage of 800 g/m² with INTELLO even at most unfavourable conditions –grey tiles, 40° pitched roof, north-orientated, diffusion-tight roofing felts. This means that within one year 800 g/m² of unexpected moisture can enter the construction without causing a structural damage. With pro clima DB+ the potential freedom from structural damage amounts to approximately 300 g/m².
A PE sheet offers the construction only a very low level of potential freedom from structural damage of approximately 10 g/m² a year. Moisture can not dry out to the inside when a PE sheet is used. The PE sheet becomes a moisture trap. In order to increase the potential freedom from structural damage it should be taken into account to abate the roof pitch or to choose black tiles instead of grey ones. When diffusion-open roof lining membranes like SOLITEX are used instead of diffusion-tight bitumen felts the potential freedom from structural damage increases by several thousands g/m² a year.
To roofs with grey tiles and a north-orientated pitch of 25° and roofs with black tiles and a pitch of 40 ° INTELLO offers a potential freedom from structural damage of 1.500 g/m². This means that within one year 1.500 g of moisture can enter unexpectedly into the construction, which is externally diffusion-tight and a north-orientated roof pitch of 40° without causing structural damage. With pro clima DB+ this potential freedom from structural damage amounts to approximately 300 g/m². With INTELLO the potential freedom from structural damage increases up to 1.800 g/m² for roofs with black tiles and a north-orientated pitch of 40°, with pro clima DB+ up to 1.000 g/m². A PE sheet offers the construction only a low potential freedom from structural damage of less than 10g/m² a year. Moisture can not dry out to the inside when a PE sheet is used. The PE sheet becomes a humidity trap.

Temperature graphs Inverness

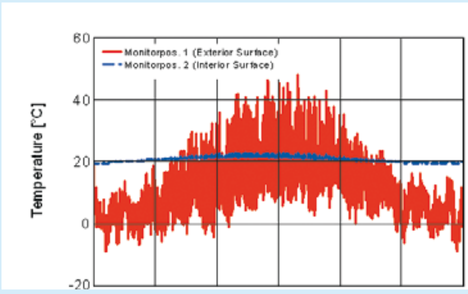
25. Air temperature Inverness



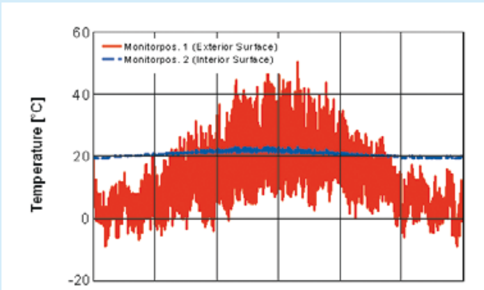
26. Temperature of the surface of the roof (roof pitch north-orientated 40° with uncoloured light-grey tiles)



27. Temperature of the surface of the roof (roof pitch north-orientated 25° with uncoloured light-grey tiles)

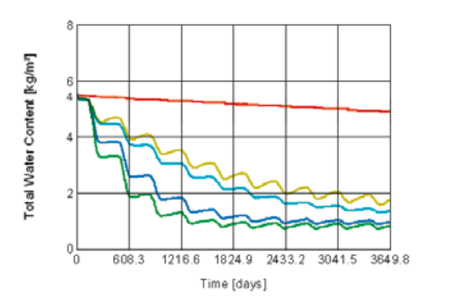


28. Temperature of the surface of the roof (roof pitch north-orientated 40° with black tiles)



Calculating Potential Freedom from Structural Damage Inverness

29. Inverness



Potential freedom from structural damage:

pro clima INTELLO® black tiles 40°	= 1800 g/m² per year
pro clima INTELLO® grey tiles 25°	= 1500 g/m² per year
pro clima INTELLO® grey tiles 40°	= 800 g/m² per year
pro cima DB+ grey tiles 40°	= 300 g/m² per year
PE sheet grey tiles 40°	= 10 g/m² per year

3.5.7 Lowlands Edinburgh and Glasgow

For Scottish Lowlands INTELLO and DB+ offer even for roofing constructions that are very demanding from the point of view of construction physics –light-grey tiles, pitched roof 40 ° north-orientated externally diffusion-tight (bitumen roofing felts)- a high level of safeness against structural damage and mould growth. In Edinburgh and Glasgow the potential freedom from structural damage of a roof with a north-orientated pitch of 40° and externally diffusion-tight roofing felts amounts with INTELLO to 1.000 g/m² and with DB+ approximately 400 g/m².

3.5.8 Midlands, Highlands and Centre Highlands north of Inverness

In the Midlands, Highlands and Centre Highlands 200 m to 600 m above sea level as well as in locations north of Inverness solar radiation is very low and thus the potential of back drying. Externally diffusion-tight constructions (bitumen roofing felts) with a steep pitch and grey tiles have a too low potential freedom from structural damage. Either a sub-roof of diffusion-open roof lining membranes (for example Solitex) or a roofing with black tiles and a pitch of 25° should be used. There is no climate data for locations above 600 m above sea level available. In this case the vapour check pro clima DB+ should be used only in connection with a diffusion-open sub-roof.

3.5.9 Conclusions:

For Great Britain INTELLO and DB+ offer a high level of potential freedom from structural damage for all pitched roof constructions even at the most unfavourable circumstances (pitched roof 40 ° north-orientated, externally diffusion-tight).
This provides effective protection against mould growth for the construction and a healthy room climate for the residents.

INTELLO –the vapour check with the world's highest variability of diffusion resistance that is effective in all climate zones- achieves in the southern part of the country (London) a potential freedom from structural damage of more than 3.000 g/m², in low mountain areas (435 m) as well as in northern parts (Edinburgh, Glasgow) more than 1.500 g/m², even at most unfavourable conditions.

For externally diffusion-tight constructions (bitumen felts) in the Scottish Midlands, Highlands and Centre Highlands 200 m to 600 m above sea level as well as north of Inverness it is recommended to use a roofing with black tiles or if grey tiles then a pitch of below 25°. INTELLO then achieves a potential freedom from structural damage of more than 1500 g/m². The vapour check pro clima DB+ should not be used for these constructions, which are extremely demanding from the point of view of construction physics.

3.6 Wall systems

3.6.1 Ireland, England, Wales

Wall systems, being vertical, absorb less light than roof structures, so there is less potential for back diffusion. Usually, unlike, roofs, walls are not diffusion-tight on the outside. Walls do not need to meet such high demands in respect of water-tightness as, say, a low pitched roof.

Temperatures of outside walls depend mainly on the colour of the façade. Insulation produces lower temperatures on light-coloured façades than on darker ones. The following temperature profiles on the outside wall are obtained from normal, light-coloured plaster façades. For wall systems too, the high-performance INTELLO® vapour check provides a substantial potential for freedom from structural damage. Wall systems should be and are constructed as diffusion-open as possible.

In timber frame constructions in Ireland and Great Britain OSB boards are used externally. These boards are only a slight vapour check (when 10 mm of thickness 10 MNs/g, when 20 mm of thickness 20 MNs/g). They should not be additionally covered with diffusion-hampering layers. For the protection of the boards against rain during the construction period and for the protection of the construction underneath the façade rainproof but diffusion-open felts like Solitex WA are suitable.

Solid wood constructions of porous and non-porous bricks also have a mvtr value of approximately 10 – 20 MNs/g.

From the point of view of construction physics quarrystone masonry is equal to concrete.

The construction´s potential freedom from structural damage depends on the climate, as already discussed for roof systems.

In temperate climates like in Ireland, England and Wales the external OSB boards in timber frame constructions should have a mvtr of below 20 MNs/g when INTELLO and DB+ are used.

Masonry constructions can additionally be thermally insulated both internally and externally. An external thermal insulation should not cause any problems from the point of view of construction physics. The masonry wall becomes a vapour check in an internal thermal insulation. Masonry has a high capability of diffusion and additionally transports moisture capillary. An internal thermal insulation should not cause any problems when INTELLO is used.

A concrete wall represents a massive vapour barrier, which, depending on the thickness of the wall, can have a mvtr of several hundred MNs/g. INTELLO offers these constructions in temperate climates protection against structural damage. However, the potential freedom from structural damage is no longer high.

You can increase it by using an external insulation of fibered insulation material in addition to the internal insulation. In this way the dew point is relocated more externally. Apart from this, a darker colour brings about advantages for back diffusion.

3.6.2 Constructions in Scotland

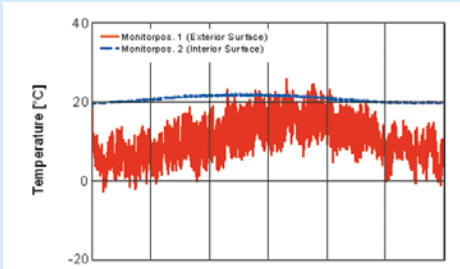
For the Lowlands the same recommendations are given as for England, but the vapour check pro clima DB+ should not be used for wall constructions in these locations.

Masonry constructions can be additionally insulated thermally by using INTELLO.

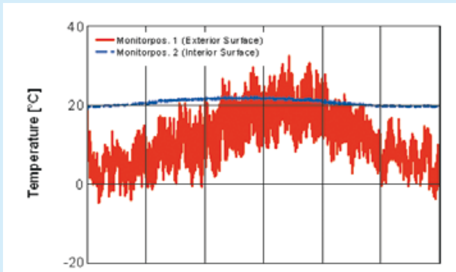
In concrete walls with internal insulation the moisture stress of the building components should be decreased constructively by using an external insulation of fibrous insulation material additionally to the internal insulation. Here, the external insulation should have the same thickness as the internal insulation.

Temperature graphs Temperature of the surface of wall façade normal light-coloured, north-orientated

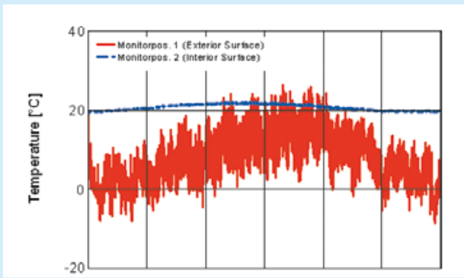
30. Belmullet



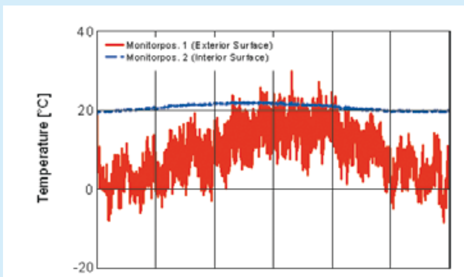
31. London



32. Rhymney Valley

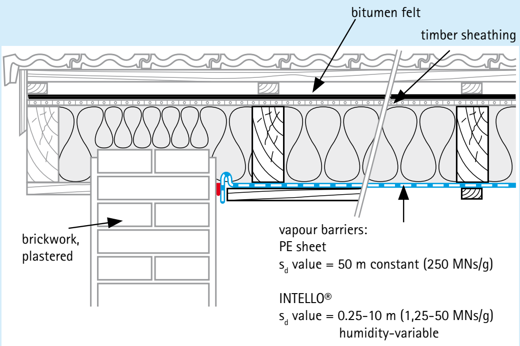


33. Inverness



2-dimensional calculation of the heat and moisture transports using WUFI

34. Design of structural system: Integrating wall

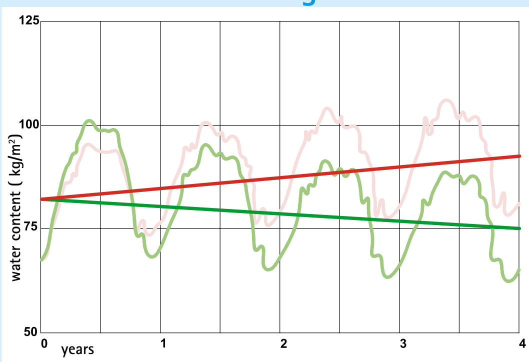


35. Increase in moisture when using a PE sheet

→ Saturation = structural damage

Reduction in moisture when using INTELLO®

→ EVAPORATION = freedom from structural damage



Increasing moisture content in the construction with PE sheet s_d value = 50 m constant (250 MNs/g)

Decreasing moisture content in the construction with INTELLO® s_d value = 0.25 – 10 m humidity-variable (1,25-50 MNs/g)

3.7 Flank Diffusion

To establish the impact of moisture entry via component flanks, the junctions between integrated outer walls and thermal insulation components need to be examined. On the outside, the structure comprises of diffusion-tight bitumen felts in the sub-roof system.
(see illustration 34)

Masonry usually has a considerably lower diffusion resistance than the vapour barrier and airtight seals of the adjoining timber structures. This facilitates the diffusion of moisture through the flanks into the thermal insulating components.

A new building will serve as an example here. In a new building, masonry and plaster have an average moisture content of 30 kg/m³. The fibrous insulating material has been dry-fitted, the relative moisture content of the timber in the roof is approximately 15 %.

One building is fitted with a diffusion-inhibiting PE sheet (50 MNs/g = $s_d$value 50 m). serving as a vapour barrier and airtight seal. The second building is fitted with the humidity-variable pro clima INTELLO® (1.25-50 MNs/g = $s_d$value 0.25 to 10 m).

3.7.1 Results of Two-Dimensional Simulative Calculation of Heat and Moisture Transports

The results shown in illustration 35 occur when a structural system is calculated using the 2-dimensional calculation method for heat and moisture transfer as implemented in WUFI 2D see 2.1 .

Following a seasonal increase in the moisture content, both structural systems virtually reach the same level of moisture. In the case of the PE sheet acting as a vapour barrier and an airtight seal, a distinct increase in the total water content can be observed for each year over a period of 4 years (see figure 35 red line). This system shows an accumulation of moisture in the building materials used as the PE sheet prevents subsequent drying towards the interior.

The result is mould growth on the timber and the onset of decay.

In the system using the high-performance INTELLO® vapour check, the moisture can escape towards the inside. The structural component is protected against accumulation of moisture, as moisture is swiftly released towards the inside (see figure 35 green line). Thus the moisture content decreases steadily over the 4-year period. This structural system shows a high potential freedom from structural damage.

4.1 Structural Systems

These construction-physics investigations based on real climatic data, demonstrate the extremely high potential freedom from structural damage provided when using the high-performance pro clima INTELLO® vapour check (which possesses the world's most effective variability of diffusion resistance in any climatic zone) and the pro clima DB+ humidity-variable vapour check which has proven its worth over a period of more than ten years by now.

pro clima DB+ and INTELLO® provide a high level of safety for structural systems even when under high moisture stress.
This requires an unshaded situation, i.e. no trees or neighbouring buildings providing shade.

4.2 Inside Structural Components

High safety reserves are dependent on unimpeded evaporation to the interior. Building component layers inside the humidity-variable vapour membrane that have a diffusion-inhibiting effect (timber materials like OSB boards or laminated boards) reduce the quantity of moisture back-evaporated towards the inside and thus minimise the potential freedom from structural damage. Materials having an open structure are more advantageous, for instance matchboard sheathing, wood wool slabs with plaster and gypsum boards.

4.3 Permanently Humid Spaces

Humidity-variable vapour checks cannot be used in permanently humid climatic conditions, for instance swimming pools, garden centres or large-scale catering establishments.

4.4 Humid/Damp Rooms in Residential Buildings

Wet or humid rooms in residential buildings are no more than temporarily subjected to increased humidity. Temporary humidity stress of this kind does not interfere with the function of and the safety provided by pro clima DB+ or INTELLO®.

4.5 Construction Moisture on the Site

The vapour check must be installed as soon as the thermal insulation has been put in place, so as to avoid the development of condensation in the insulation.

Additionally, relative humidity on the building site should not exceed 75% in winter. Care should be taken after plastering and screed work to ensure adequate ventilation. A commercial drying unit should be installed if necessary (i.e. dehumidifier).
The diffusion profile of the humidity-variable pro clima vapour check ensures that the diffusion resistance of the checks is over 5 MNs/g (s_d =1 m) at a relative humidity of 75%. The moisture stress on the structure during the construction phase due to unwanted entry of moisture can thus be minimised. However, increased atmospheric humidity during construction should be avoided as the potential freedom from structural damage would be reduced by the moisture stress.

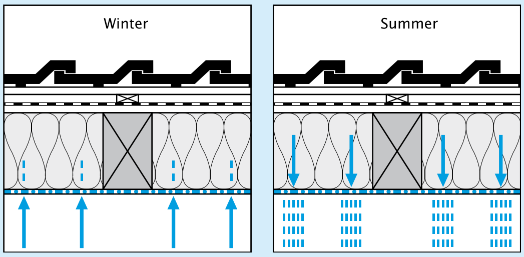
4.6 Sub-Roof System

Diffusion-open materials are the best choice for the sub-roof system (e.g. wood fibre soft boards, SOLITEX-roofing felts with non-porous, permeable membrane), provide excellent conditions for evaporating towards the outside.

Structural systems having diffusion-tight external components, for instance bitumen felts and roofs with flexible metal sheeting, reduce the safety of the structure from the construction-physics point of view. Solid timber decking provides greater safety than derived-timber-product boards (e.g. OSB), as wood has a humidity-variable diffusion resistance and is conductive by capillary action. INTELLO®'s high degree of humidity-variability provides a very high safety potential, similar to derived-timber-products as well. Panels or boards of this kind should be avoided on diffusion-tight roof support systems when using pro clima DB+.

Preconditions for the effectiveness of humidity-variable vapour checks

Only building components, which are open to diffusion, may be used on the inside in order to facilitate the evaporation of moisture by way of back-diffusion towards the interior.



Areas of application for INTELLO® and DB+

All roofs in Ireland, England and Wales	INTELLO®	pro clima DB+
Potential freedom from structural damage	>1.500g/m² anually	>1.000g/m² anually

Wall systems	Ireland England Wales, Scottish Lowlands	
	INTELLO®	pro clima DB+
Timber frame constructions, OSB externally, mvtr max. 25 MNs/g	**XXX**	**XX**
Masonry, mtvr max. 25 MNs/g	**XXX**	**X**
Quarrystone and concrete systems	**XX**	**0**

XXX = very safe
XX = safe
X = still recommended
0 = not recommended

Scottish Centre Highlands and Highlands		
Roof Systems north-orientated, externally diffusion-tight	Potential freedom from structural damage	
Colour of tiles	Roof pitch	INTELLO®
Uncoloured, light grey tiles	40°	Approx. 200 g/m² annually
Uncoloured, light grey tiles	25°	Approx. 500 g/m² annually
Black tiles	40°	Approx. 800 g/m² annually
Black tiles	25°	Approx. 1.500 g/m² annually

4.7 Ireland, England and Wales

4.7.1 Roof constructions

In Ireland, England and Wales all roofs, the diffuison-tight as well as the diffusion-open ones, low pitched and steep pitched ones, have a very high potential freedom from structural damage when the humidity-variable vapour checks INTELLO and pro clima DB+ are used. Intello offers the highest level of safeness.

4.7.2 Wall systems

Outer walls can be subdivided as follows:
Timber frame construction
Interior/exterior insulation of masonry
Interior/exterior insulation of quarrystone masonry
Interior/exterior insulation of concrete

In timber frame constructions it is usual to use stiffening timber boards externally, in most cases OSB boards. These boards can only be covered by diffusion-open felts (e.g. Solitex WA). Diffusion-inhibiting felts and building components that are laid directly on the OSB board lead to rapid mould growth on the board.
With INTELLO and pro clima DB+ usual timber constructions with external OSB planking achieve a high level of safety against structural damage.

Masonry has usually a lower diffusion resistance. An internal insulation of masonry is safe from the point of view of construction physics when the humidity-variable vapour checks INTELLO and pro clima DB+ are used. Quarrystone masonry can thus be as diffusion-tight as a concrete wall.
For the insulation of concrete and of quarrystone masonry, only INTELLO is safe from the point of view of construction physics.

4.8 Scottish Lowlands

Roofs and walls in the Scottish Lowlands, including Edinburgh and Glasgow have the same conditions as England.

4.9 Scottish Centre Highlands and Highlands

In the Scottish Centre Highlands and Highlands temperatures in winter and in summer are considerably lower than in the Lowlands and in England. This results in a lower back diffusion and a lower level of potential freedom from structural damage.

4.9.1 Roof constructions

For construction of roofs in the Scottish Centre Highlands and Highlands at an altitude of 200 – 600 m and north of Inverness the following regulations apply:
If the sub-roof is diffusion-open, both INTELLO and pro clima DB+ offer a high potential freedom from structural damage.
If the sub-roof is diffusion-tight, only INTELLO is suitable. However (e.g. covered by bitumen roofing felts), roofing should either consist of black tiles or, when grey tiles are used, the roof should have a pitch of below 25° to have a high level of potential freedom from structural damage.
For locations in the Scottish Centre Highlands and Highlands at an altitude of more than 600 m no climate data are available. But it is assumeable that a construction with black tiles and a roof pitch of below 25° provides a high level of safeness, too, if INTELLO is used.

There is also the possibility of back-ventilated diffusion-tight constructions.

4.9.2 Wall constructions

For wall constructions with external OSB boards and insulation between the studs in these locations no vapour checks or vapour barriers offer safe protection against structural damage. The problem of condensate has to be solved constructively:

In Central Europe timber frame constructions OSB boards are installed on the internal side and bitumenous timber soft boards on the external side. In this way constructions in central Europe have approved for many years, even those in high mountain climates.

If the OSB boards are to be installed externally they have alternatively to be insulated additionally on the external side. In this way the dew point is abated. The thickness of insulation apart from the OSB boards should be as high as the insulation between the posts.

Concrete masonry and quarrystone masonry should be insulated externally. An internal insulation should only be an additional insulation in connection with an external insulation.

5.1 For Board-Type and Mat-Type Insulating Materials

Install INTELLO® with foil side (lettering) facing the room.

INTELLO® will still function in construction-physics terms if it has been installed with the fabric on the room side. Press down the adhesive tapes firmly. Bonding on the smooth film side is preferable.
pro clima DB+ is symmetrically designed, so the side of the vapour check that faces towards the interior may be chosen at will.

5.2 Direction of Installation

pro clima INTELLO® and DB+ felts may be installed parallel or horizontal to the supporting structure. The overlapping of the sheets must be arranged on the structural timbers when installing in parallel. The maximum spacing of the structural-system timbers should be no more than 100 cm when installing horizontally.

5.3 Recommended pro clima System Components for Bonding

Any of pro clima's adhesive tapes are suitable for bonding the sheet overlaps. Particularly recommended are pro clima RAPID CELL quick application adhesive tapes and the UNI TAPE universal adhesive tape for pro clima DB+ and INTELLO®.
pro clima Profil adhesive tapes with the double- divided release film are the most suitable type for junctions with windows or doors and corner bonding.

ORCON F flashing/joining adhesive (for INTELLO®) and ECO COLL (for DB+) provides a reliable junction with adjacent compound units (plastered gable walls, for instance). CONTEGA PV flashing/joining tape with integrated plaster reinforcement ensures a well-defined connection to unplastered masonry.

Installation in five easy steps

1. Installation / Fixing

2. Bonding

3. Joining to gables

4. Joining to windows

5. Joining at intersection

5.4 Blown-In Thermal Insulating Materials

pro clima DB+ may be used as a confining layer for all kinds of blown-in thermal insulating material. A transverse batten should be placed on the inside at a spacing of at most 65 cm to take the weight of the insulating material.

Because it stretches very readily, the high-performance INTELLO® vapour check is not suitable as a means of confining blown-in thermal material on the inside. This purpose is best served by INTELLO® PLUS reinforced with robust PP fabric offering the same potential for freedom from structural damage.
A transverse batten should be placed on the inside at a spacing of at most 45 cm to take the weight of the insulating material.

5.5 Foam Insulating Materials

Variable diffusion-resistance is of little benefit in connection with foam-type insulating materials, because back-diffusion is substantially inhibited. Accordingly, foam insulating materials should be avoided in structural systems as they pose a challenge in respect of construction physics, for instance systems that are diffusion-tight on the outside.

5.6 Dimensional Stability

The high-performance INTELLO® vapour check will not shrink and it may be installed taut. INTELLO® is highly capable of stretching without tearing.

pro clima DB+ shrinks slightly after wetting and subsequent drying, so the sheet should not be stretched taut. An expansion loop must be arranged at junctions with adjoining components so as to take up component movements.

5.7 Mechanical Strength

INTELLO® and DB+ are highly resistant to the removal of nails, so the sheets are well protected at their bonding points against splitting and propagated tearing.

5.8 Translucent Structure

The high-performance INTELLO® vapour check is translucent, meaning that materials behind the sheet can be identified through it. INTELLO® is not fully transparent, so the edges of the sheets are readily visible, an advantage when attaching to adjacent compound units like ridge purlins, middle purlins, roof windows and chimneys,
and when bonding the sheet overlaps.

5.9 Recycling and Ecological Considerations

The high-performance INTELLO® vapour check and INTELLO®Plus is made from 100% polyolefin - the special check is made from a polyethylene copolymer and the fabric is polypropylene - so it is easily recycled.

pro clima DB+ comprises of 50% recyclable cellulose and can only be recycled thermally on account of its glass-fibre inlay.

6. Summary

Structural systems using DB+ and INTELLO® have extremely high safety reserves, thus preventing structural damage and mould. Even where moisture stress is unanticipated, or where it is unavoidable in normal building practice, the high drying reserves of these humidity-variable safety vapour checks provide structural systems with a very high potential freedom from a structural damage.

The high-performance INTELLO® vapour check has the world's most effective humidity-variable diffusion resistance in any climatic zone, offering thermal insulation systems the utmost in safe protection - whether the structural system is open to diffusion on the outside, or presents a more challenging example of construction physics like a roof with diffusion-tight underlay, or flexible metal sheet roof.

INTELLO® performs effectively under extreme climatic conditions too, like those encountered in high moisture locations like the west coast of Ireland and in low temperature zones like in Scotland. The proven pro clima DB+ provides a high degree of safety for constructions with medium stress.

Conforming to DIN Standard 68 800-2, chemical wood preservatives need not be used where humidity-variable vapour membranes are installed.

pro clima offers a six-year system warranty to provide even greater safety and protection.

Once again, with the vapour membranes and airbarrier INTELLO®and DB+, the pro clima safety rule is once more put into practice,

„The greater a structural system's reserves for evaporating, the greater the unexpected moisture stress it can absorb and still remain free from structural damage".

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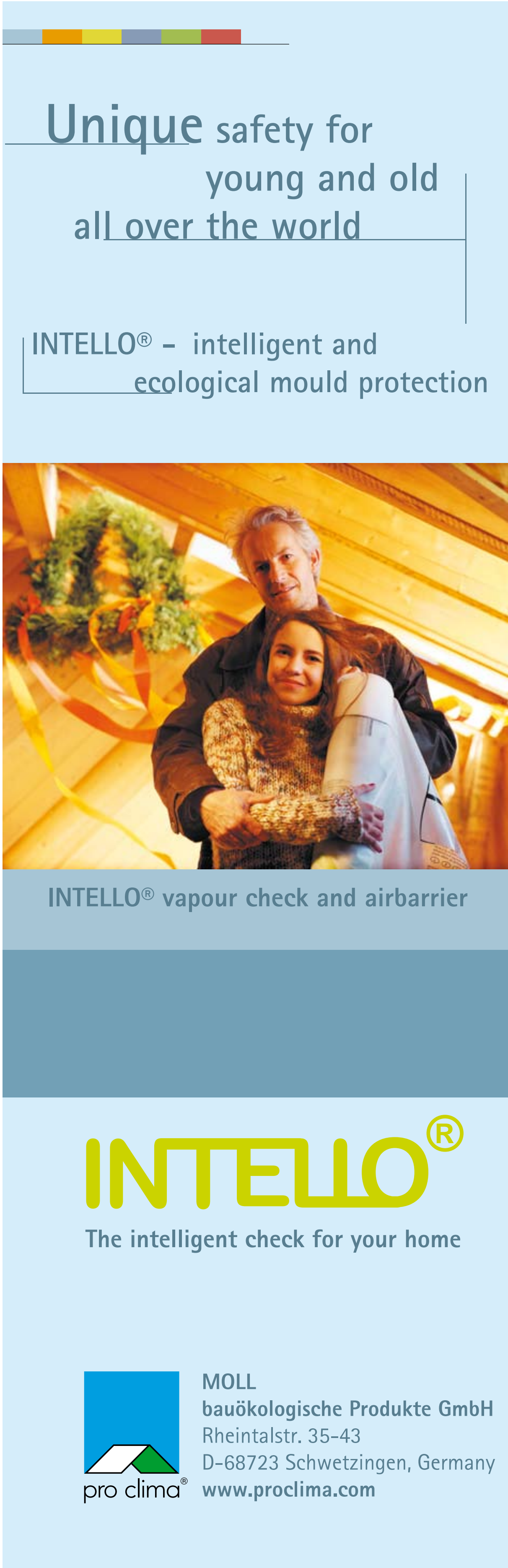

6. Bibliography

[1] TenWolde, A. et al.: "Air pressures in wood frame walls, proceedings thermal VII." Ashrae Publication Atlanta, 1999

[2] IBP Mitteilungen 355: „Dampfdiffusionsberechnung nach Glaser – quo vadis?"

[3] Deutsche Bauzeitung; Heft 12/89 Seite 1639ff

[4] DAB 1995; Seite 1479; Heft 8

[5] Klopfer, Heinz; Bauschäden-Sammlung, Band 11, Günter Zimmermann (Hrsg.), Stuttgart: Fraunhofer IRB Verlag, 1997

[6] Klopfer, Heinz; ARCONIS: Wissen zum Planen und Bauen und zum Baumarkt: Flankenübertragung bei der Wasserdampfdiffusion Heft 1/1997, Seite 8-10

[7] H.M. Künzel; Tauwasserschäden im Dach aufgrund von Diffusion durch angrenzendes Mauerwerk wksb 41/1996; Heft 37; Seite 34-36

[8] WUFI 2D 2.1 (Wärme- und Feuchte instationär); PC-Programm zur Berechnung des gekoppelten 2-dimensionalen Wärme- und Feuchtetransports in Bauteilen Fraunhofer Institut für Bauphysik Infos unter www.wufi.de

[9] DIN 4108-3: Wärmeschutz und Energieeinsparung in Gebäuden – Klimabedingter Feuchteschutz, Anforderungen, Berechnungsverfahren und Hinweise für Planung und Ausführung Beuth-Verlag, Berlin 07/2001

[10] WUFI 3.3 pro (Wärme- und Feuchte instationär); PC-Programm zur Berechnung des gekoppelten Wärme- und Feuchtetransports in Bauteilen Fraunhofer Institut für Bauphysik Infos unter www.wufi.de

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