PU EUROPE
EXCELLENCE IN INSULATION
FEDERATION OF EUROPEAN RIGID POLYURETHANE FOAM ASSOCIATIONS

Factsheet n° 19

"Breathability" of building elements

PREREQUISITE FOR HEALTHY AND COMFORTABLE INDOOR AIR CLIMATE?

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EXECUTIVE SUMMARY

Certain market players claim that air-tight building structures cause unhealthy indoor climates. They are calling for "breathable" building elements and the use of "breathable" thermal insulation products. Only them could combine thermal insulation with protection against humidity, and evacuate humidity and hazardous substances through air exchange.

Such statements are misleading and several phenomena are mixed up by the term "breathability". Building physics and standardisation do not apply this term, but separate the relevant items such as water vapour condensation on inside surfaces, buffering of moisture within building elements, water vapour diffusion through external building elements and moisture transport by bulk air-exchange and controlled ventilation.

Research shows that comfortable and healthy buildings need a sufficient level of thermal insulation and a controlled bulk air-exchange by ventilation. It is however not relevant whether diffusion-open or diffusion-tight thermal insulation products are used. PU thermal insulation products offer superior insulation levels and respond to the requirements of low energy buildings.

Condensation of water vapour on cold inside room surfaces can provide breeding ground for mould growth. It can best be prevented by a sufficiently high insulation level of the building element. Care must be taken to avoid cold bridges, as they can cause local condensation, even in an otherwise well insulated building. Closed cell insulation products such as PU offer an additional advantage as they reduce the risk of condensation within the insulation layer. Diffusion-open insulants may require additional membranes.

Humidity levels in rooms change depending on the outside climate and the internal situation. Moisture buffering effects of surface layers on building elements can contribute to keeping humidity levels relatively stable. Research has shown that thermal insulation has only a marginal role to play, as the buffering effect is principally limited to the covering layer in direct contact with the indoor air. Therefore it will not be an advantage to use water-vapour open or "breathable" insulation.

Excess moisture in the indoor air must be evacuated through controlled ventilation. Even under extreme conditions, moisture exchange by diffusion ("breathability") through the building envelope can only account for a negligible part of total air exchange needs.

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INTRODUCTION

Whether in dwellings, schools, offices, factories or shopping centres, people are spending up to 90 % of their life in buildings. Ensuring a healthy and comfortable indoor climate in buildings is therefore of crucial importance **[1]**.

At the same time, new and existing buildings have to meet increasingly high energy efficiency levels requiring thicker thermal insulation layers and a high degree of air tightness of the building envelope to avoid thermal losses by uncontrolled air flows (**figure 2**).

Figure 1: PU passive house in Brussels with PU insulation (www.polyurethanes.org/passivehouse/)

Certain market players claim that air-tight building structures cause unhealthy indoor climates. A "breathable" insulation layer would be required to maintain healthy indoor humidity levels.

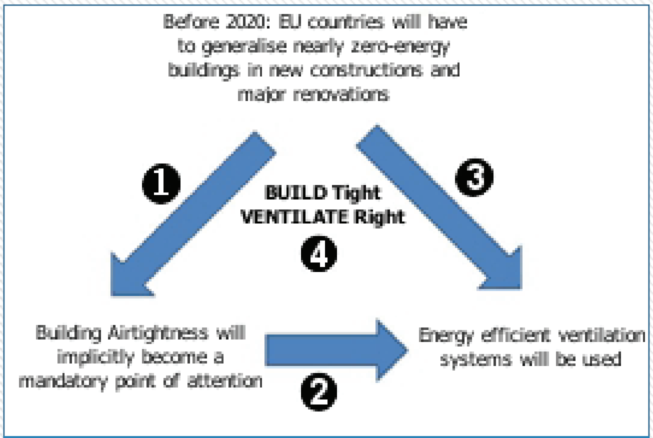

Figure 2: Air tightness of buildings **[1]**

In practice however, several phenomena are mixed up by the term "breathability". Building physics and standardisation do therefore not use this term but consider the phenomena separately:

- Water vapour condensation on inside surfaces
- Buffering of moisture within building elements
- Water vapour diffusion through external building elements
- Moisture transport by bulk air-exchange and controlled ventilation.

This factsheet will analyse those phenomena on the basis of two studies:

- Investigation about moisture buffering from VTT/Finland **[2]**: *A Survey of the*

Breathable Building Structure Concept: Effects of Insulation Materials

- Comparison of moisture transport by diffusion with bulk-air ventilation from Cambridge Architectural Research Ltd. (CAR) **[4]**: *Moisture transfer and the significance of breathability in buildings*

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INDOOR AIR COMFORT AND HUMIDITY CONDITIONS

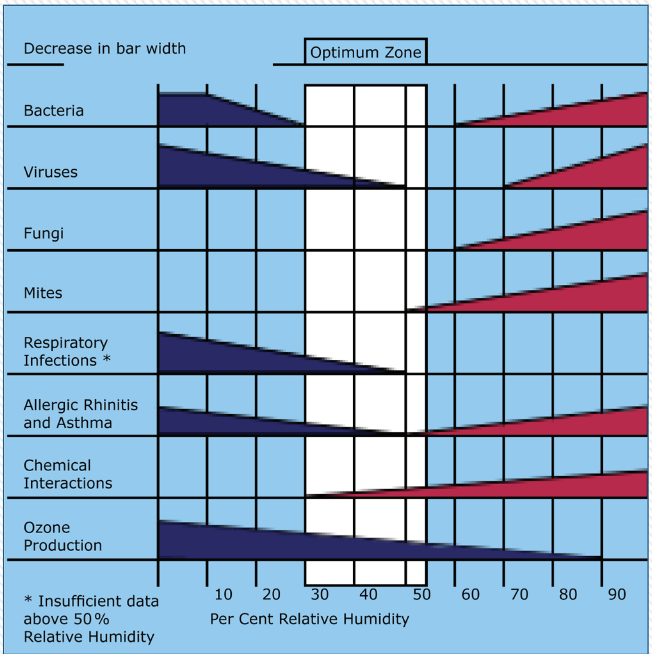

Figure 3: The effect of humidity on several health and IAQ parameters showing that a favourable range of indoor humidity is between 30 % RH and 55 % RH

The indoor humidity level depends on different factors like climatic conditions, moisture sources, ventilation rate, the volume of the space and the possible moisture absorption capacities of the building materials and their contact to indoor air.

Indoor air humidity conditions may have large daily variations depending on the thermal and moisture loads caused by the occupation of the spaces. Temperature and humidity of the indoor air are some of the most important factors having effect on the indoor comfort, both thermal comfort and perceived air quality. Especially too high humidity conditions may affect the indoor air comfort negatively.

Several methods can be used to lower the humidity peaks during occupation and, thus, improve the thermal comfort and acceptability of the indoor conditions. VTT investigated how this would be possible by using the moisture absorption capacity of building structures. CAR showed the importance of the bulk air-exchange by ventilation compared to the moisture transport by diffusion through diffusion-open building elements.

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CONDENSATION ON BUILDING ELEMENT SURFACES

A healthy indoor climate needs a certain level of humidity in the rooms **[2]**. The amount of moisture that can be kept within the air is depending on the temperature. If the temperature of the inside surface of the building elements falls below a critical value (e.g. in winter time), moisture will condensate on those cold surfaces and the risk of mould growth will increase significantly. DIN 4108 sets that critical inside surface temperature for Germany at 12.6 °C for relative humidity levels of up to 70 %.

There are two possibilities to avoid surface condensation:

- To reduce the content of moisture in the air by ventilation (opening of windows, etc.); but this will lead to energy losses and may reduce the level of humidity to a non-healthy level

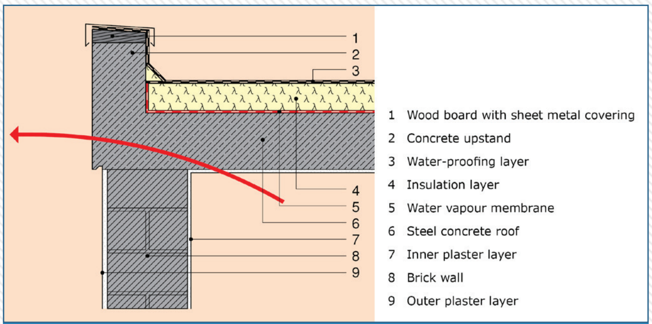

Figure 4: Cold bridge through attic (Source: IVPU guideline *Flachdach dämmen mit Polyurethan-Hartschaum*, 2011, page 8)

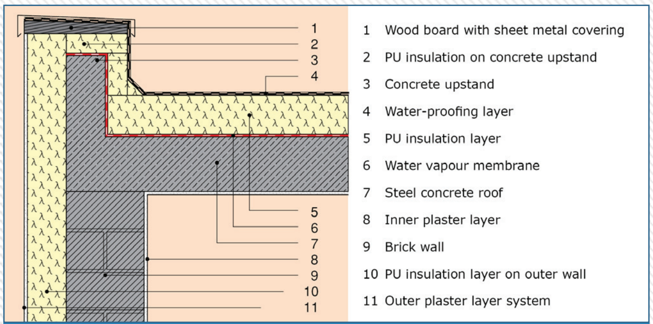

Figure 5: PU insulatin avoids cold bridge in attic area (Source: IVPU guideline *Flachdach dämmen mit Polyurethan-Hartschaum*, 2011, page 8)

- To increase the surface temperature by improving the insulation level of building envelope elements.

Cold bridges can also lead to critical local areas where low surface temperatures may cause moisture surface condensation. The example in **figure 4** shows a non-insulated wall roof slab connection resulting in heat loss and dropping of the inside surface temperature below the dew point. Thanks to the seamless insulation layer as shown in **figure 5**, cold bridges and hence condensation can be avoided.

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MOISTURE BUFFERING OF BUILDING STRUCTURES [2]

General

The concept of moisture buffering of building structures can be defined as hygrothermal interactions between building structures and the indoor air. These interactions may contribute to the indoor air comfort by reducing the temporary peak humidity values that could affect the thermal comfort and perceived indoor air quality. Such humidity peaks may for example occur in bedrooms during the night.

Moisture buffering products and building structures

With a view to improving the thermal comfort and perceived air quality of the indoor air by passive structural methods a Nordtest method **[3]** was developed. It allows quantifying the moisture buffering value of building material layers. **Figure 6** shows values of materials with their moisture buffering capacity.

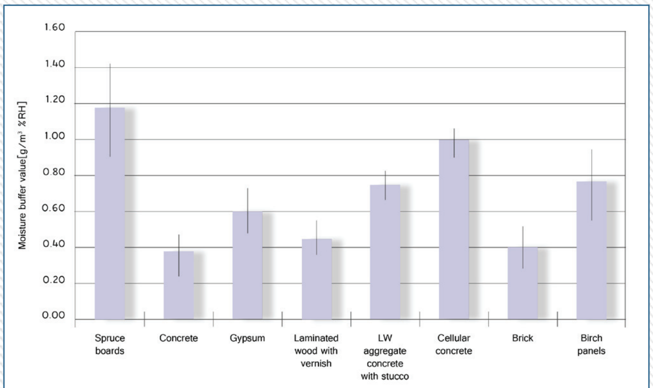

Figure 6: Moisture buffer value for some typical building materials, each measured in three different laboratories using three samples

VTT investigated in a numerical study how thermal insulation layers can contribute to this moisture buffering effect. The objective was to show how much moisture can be stored in the thermal insulation layer behind an inside wall board. **Table 1** represents the different cases covered by this exercise.

Case code	Interior layer	Performance properties	Thermal insulation	Performance properties	Other layers
Non-cap. + CFI	Non-capacitive layer	Very low capacity, low diffusion resistance	Cellulose fibre insulation	High capacity, low diffusion resistance	
G + CFI	Gypsum board	Low capacity, low diffusion resistance	Cellulose fibre insulation	High capacity, low diffusion resistance	
Pwfb + CFI	Porous wood fibre board	High capacity, low diffusion resistance	Cellulose fibre insulation	High capacity, low diffusion resistance	
Pwfb + PU	Porous wood fibre board	High capacity, low diffusion resistance	Polyurethane	Low capacity, high diffusion resistance	
Wooden panel + CFI	Wooden panel	High capacity, high diffusion resistance	Cellulose fibre insulation	High capacity, low diffusion resistance	
G + MW	Gypsum board	Low capacity, low diffusion resistance	Mineral wool	Low capacity, low diffusion resistance	
G + PU	Gypsum board	Low capacity, low diffusion resistance	Polyurethane	Low capacity, high diffusion resistance	
Paint + G + CFI	Gypsum board	Low capacity, low diffusion resistance	Cellulose fibre insulation	High capacity, low diffusion resistance	Interior paint, S_d = 0.2 m
Paint + G + PU	Gypsum board	Low capacity, low diffusion resistance	Polyurethane	Low capacity, high diffusion resistance	Interior paint, S_d = 0.2 m
G + pap + CFI	Gypsum board	Low capacity, low diffusion resistance	Cellulose fibre insulation	High capacity, low diffusion resistance	Building paper 1 mm, S_d = 0.8 m
G + pap + PU	Gypsum board	Low capacity, low diffusion resistance	Polyurethane	Low capacity, high diffusion resistance	Building paper 1 mm, S_d = 0.8 m

Table 1: Numerically solved cases

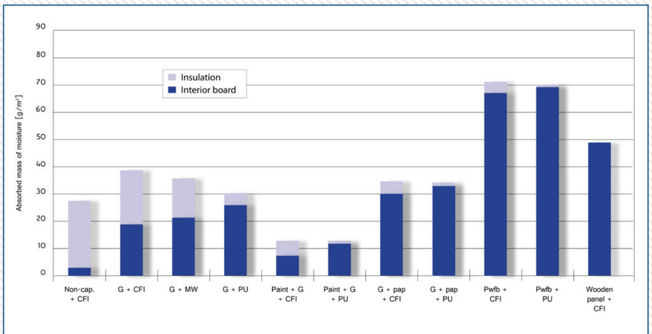

Figure 7: Moisture accumulation during the first 8 hours after the change in boundary conditions (from 50 % RH to 75 % RH)

These simulations show a marginal effect of the moisture capacity of the thermal insulation layer on the indoor air humidity conditions, if the buffering effect is achieved through the high moisture storage capacity of the inside surface layer material. The study shows that most moisture is stored in the porous wood fibre board (Pwfb) and that there is no real difference whether an open insulation material like cellulose fibre or a closed-cell PU board is used behind the wood fibre board (**figure 7**).

When surface layers with a lower buffering capacity are used (e.g. gypsum boards), some higher contribution was noted from an open insulation layer. Although the buffering effect of the PU board is lower, the overall buffering capacity of the wall element was about the same.

The main benefit of the moisture buffering capacity of structures is the reduction of the indoor humidity peak values during occupation periods. When the moisture buffering effect is to be efficiently used, the inside surface material should have a high buffering capacity. In these conditions, the moisture buffering properties of the thermal insulation layer will not be relevant.

VTT found that the buffering effect is relevant for smoothing down the daily humidity variations. However, when hygroscopic vapour open structures were compared with structures with a vapour-tight surface, the long-term (weeks and longer) average humidity values were almost the same. Bulk air-exchange by ventilation will then become very important for indoor moisture regulation. This has been investigated by CAR **[4]**.

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MOISTURE TRANSPORT BY DIFFUSION COMPARED TO VENTILATED AIR EXCHANGE [4, 5]

Air-borne moisture is transported in and out of buildings by two mechanisms, water vapour diffusion through roofs, walls and floors of a building and bulk air-exchange (intended or controlled ventilation) in and out of the building (**[5]**, **figure 8**).

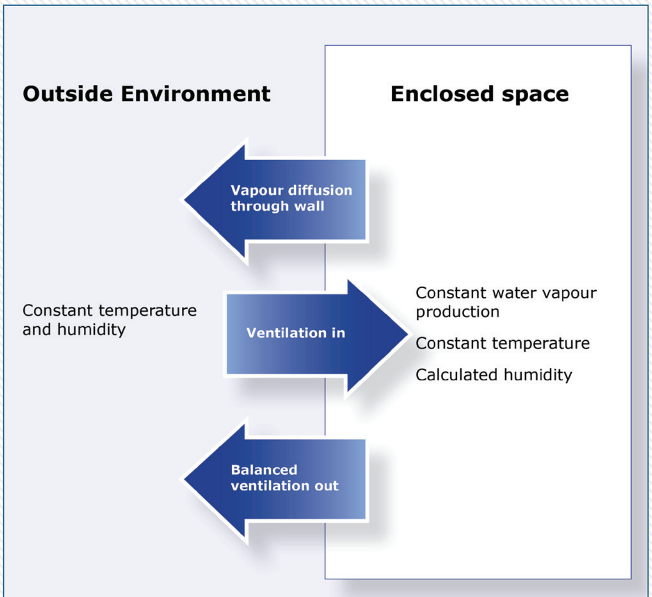

Figure 8: Air-borne moisture transport in and out of buildings

There are claims in the market regarding the benefits of diffusion open ("breathable") constructions in general and in particular of diffusion open insulation as ventilation is not functioning sufficiently especially in older renovated buildings. The supporters of such claims warn that moisture would build up in "non-breathable" structures or buildings leading to surface condensation. This in turn would lead to microbial growth (mould, dust mite) with all its negative consequences.

In order to verify these claims, Cambridge Architectural Research Ltd. (CAR) carried out a study of moisture transfer in buildings and the significance of transport of moisture through the building elements by diffusion compared to bulk air-exchange by ventilation **[4]**.

CAR investigated walls with different water vapour resistance assuming a bulk air-exchange rate of 0.5 air changes an hour. Lower levels are not recommended by scientists to avoid health problems. Even at this limit value, controlled ventilation accounts for 95 % of the vapour transfer from a house with diffusion open walls. The calculations demonstrate that water vapour diffusion through so-called "breathable" building structures does not make a significant contribution to the rate of vapour transport. Bulk air-exchange by controlled ventilation is necessary to maintain a healthy air exchange rate.

	Total Vapour Resistance of Walls (MN·s/g)	Calculated Internal Relative Humidity	Vapour Transfer by Diffusion
Wall 1	8	74 %	5.0 %
Wall 2	111	75 %	0.4 %
Wall 3	611	75 %	0.1 %

Table 2: CAR calculations of moisture transport through walls with different vapour resistance **[4]**

The following conclusion can be drawn:

The key to creating and maintaining comfortable and healthy indoor conditions is based on good thermal design and sufficient level of insulation, linked with adequate provision for bulk air-exchange through controlled ventilation. Whether the building structure is vapour open or tight does not play an important role.

References

[1] *PU and Health: Indoor Air Quality and Polyurethane Insulation* (PU Europe Factsheet 18, 2013)

[2] *A Survey of the Breathable Building Structure Concept: Effects of Insulation Materials*, VTT Expert Services Ltd., 2011

[3] Rode, C. a.o, *NORDTEST project on moisture buffer value of materials*, Proceedings of the AIVC Conference Energy Performance Regulations, Brussels, September 2005

[4] *Moisture transfer and the significance of breathability in buildings*, Cambridge Architectural Research Ltd. (CAR) – 2008

[5] Breathability White Paper, Issue 2, November 2009 – Kingspan Insulation Ltd