

Water Vapor Permeability of Barrier Foils

– Application Note 24-02

Scope

This application notes shows the use of permeability measurements to characterize water vapor insulating films used in building constructions.

Introduction

Moisture control and management are important in building construction and planning. Depending on their properties, materials such as plasters or paints can help to regulate the indoor climate or protect facades from the effects of moisture and weathering. Also, special *vapor barriers* and *vapor retarders* play an important role in protecting buildings against harmful effects of moisture. These are used specifically on exterior walls and roof structures and are intended to protect the building components from waterlogging, which tends to occur at cold thermal bridges.

The term *vapor retarder* refers to a film system that allows diffusion in both directions. The amount depends on the film properties, expressed by the sd-value. Such films are therefore able to transport moisture in the direction of the concentration gradient (Fig. 2B).

A *vapor barrier*, in contrast, is vapor tight. This means that the moisture transport through the film is suppressed so that the moisture remains in the building (Fig. 2C).

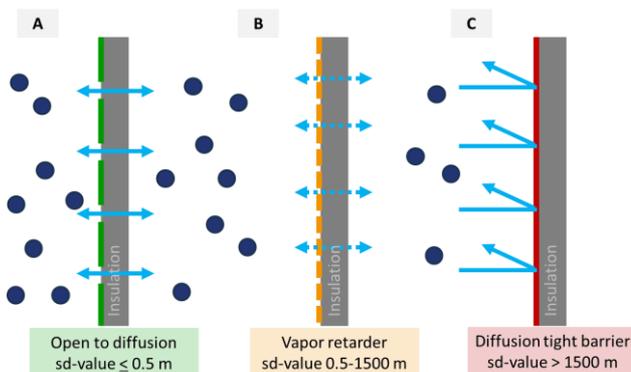


Fig. 1: Mechanism of vapor retarders and vapor tight barrier films

So-called *moisture-adaptive vapor retarders* are more recent developments in the field of moisture protection for buildings. With this type of foil system, the water vapor permeability adapts to the prevailing moisture conditions. If large amounts of moisture are present, the diffusion resistance increases, preventing large amounts of moisture from penetrating.

An optimized insulation system is therefore essential both for protecting a building and for ensuring a pleasant indoor climate, preventing waterlogging and mold growth.

Characterization of vapor barriers and retarders

Vapor barrier and retarder foils are categorized by their sd-value. The sd-value is a characteristic value for water vapor diffusion through the material. The sd-value defines the water vapor diffusion equivalent air layer thickness and therefore indicates the water vapor permeability of a material in comparison to an equivalent air layer thickness. The unit of the sd-value is therefore "meter".

Based on the sd-value, according to [2,3], materials are divided into 3 groups:

- sd < 0.5: Materials open to diffusion
- 0.5 < sd < 1500: Diffusion delayed, vapor retarder foils
- sd > 1500: No diffusion, vapor barrier foils

Calculation of characteristic values ^[2]

The sd-value is calculated by multiplying the vapor diffusion resistance coefficient μ with the thickness d of the material (Eq. 1).

$$sd = \mu \cdot d \quad [m] \quad \text{Eq. 1}$$

The vapor diffusion resistance coefficient μ is obtained from the quotient of the water vapor diffusion coefficient of the air δ_{air} and the material δ (Eq. 2).

$$\mu = \delta_{air} / \delta \quad [-] \quad \text{Eq. 2}$$

With δ_{air} according to Schirmer (Eq. 3)

$$\delta_{\text{air}} = \frac{0.083 \cdot p_0}{R_v \cdot T \cdot p \cdot 3600} \cdot \left(\frac{T}{273}\right)^{1.81} \quad [\text{kg/m} \cdot \text{s} \cdot \text{Pa}]$$

Eq. 3

R_v : Gas constant water vapor = 462 [m²/s² · K]

T: Temperature in climate chamber [K]

P: Average ambient pressure in climate chamber [Pa]

p_0 : Standard ambient air pressure [Pa]

The water vapor diffusion coefficient δ of the material is calculated from the product of the water vapor diffusion coefficient W and the material thickness d (Eq. 4).

$$\delta = W \cdot d \quad [\text{kg/m} \cdot \text{s} \cdot \text{Pa}] \quad \text{Eq. 4}$$

With W being the quotient from the water vapor transition rate $WVTR$ and the water vapor pressure difference Δp (Eq. 5) which is given for a specific test condition (Tab. 1).

$$W = WVTR / \Delta p \quad [\text{s/m}] \quad \text{Eq. 5}$$

Table 1: Vapor pressure difference depending on the test condition [4]

| Test condition [°C]- RH [%] | Δp [Pa] |
|-----------------------------|-----------------|
| 23 – 0/50 | 1404 |
| 23 – 50/90 | 1207 |
| 38 – 0/93 | 6157 |

The WVTR rate of the barrier foils can be determined by the proUmid Permeability Kit. Here special sample dishes are covered with the barrier material. By filling those dishes either with a desiccant, saturated salt solution or water, a difference to the partial water vapor pressure of the environment is generated, resulting in a migration of water molecules through the film. The result is a constant change of the sample dish weight measured automatically by the analytic balance of the SPS moisture sorption instrument.



An increase in weight indicates uptake of water molecules that have migrated through the membrane by the adsorbent placed inside the dish. A weight loss indicates the evaporation of water molecules from a salt solution or water-soaked sponge placed inside the dish and migrating through the membrane into the SPS chamber.

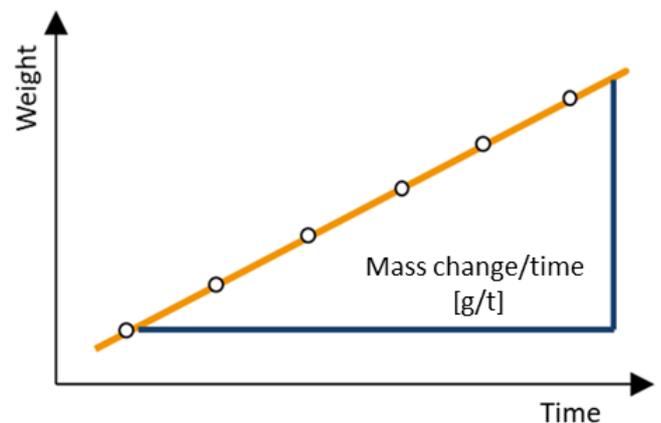


Fig. 2: Exemplary curve of a water vapor permeability measurement. Calculation of the WVTR is done according to the EN ISO 7783-1 Part 1 (Eq. 6).

$$WVTR = \frac{\Delta m}{\Delta t \cdot A \cdot 24} \quad [\text{g/m}^2 \cdot \text{d}] \quad \text{Eq. 6}$$

Δm : Mass change [g]; Δt : Time [h];

A: Sample test area [m²]; d: Day

For more information about the method, see Application note AN_12-01.

Results

The water vapor permeation through three different barrier foils was tested using the proUmid Permeability Kit. Measurements were run on a SPSx-1 μ -HighLoad.

The climatic conditions such as temperature and humidity were varied to determine the influence on the water vapor permeability of the barrier films

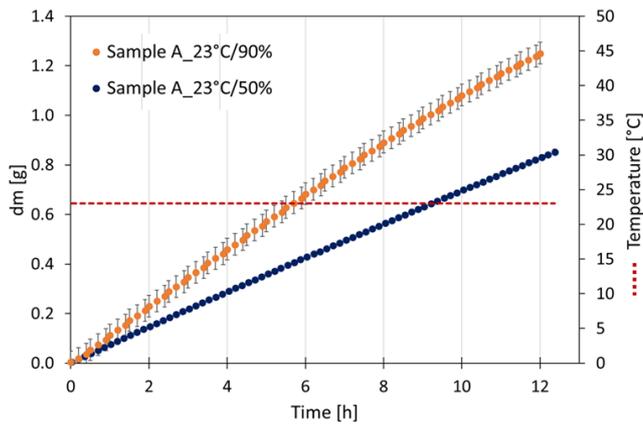


Fig. 3: Water vapor transmission through barrier foil A, Climate conditions: 23 °C, 50 % RH and 90 % RH

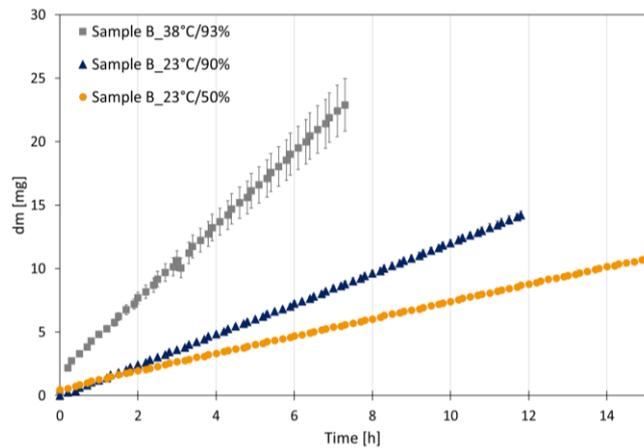


Fig. 4: Water vapor transmission through barrier foil B. Climate conditions: 50/90 % RH at 23 °C and 93 % R at 38 °C

In comparison, the obtained results from permeability testing showed that *Sample A* has a low resistance to water vapor permeation which is associated with a high WVTR and conversely results in a low sd-value of 0.05 m.

Fig. 3 - 5 show the results of water vapor transmission tests of different barrier foils under the climatic conditions of 23 °C and 38 °C with relative humidities of 50, 90 and 93 %. Based on these results, clear differences in the barrier properties of the foils can be identified.

By the increase in mass over time, the Water Vapor Transmission Rate (WVTR) was determined using the curves shown. From these, the relevant parameters for barrier films (Eq. 1-4) were determined. The calculated values are summarized in Table 2.

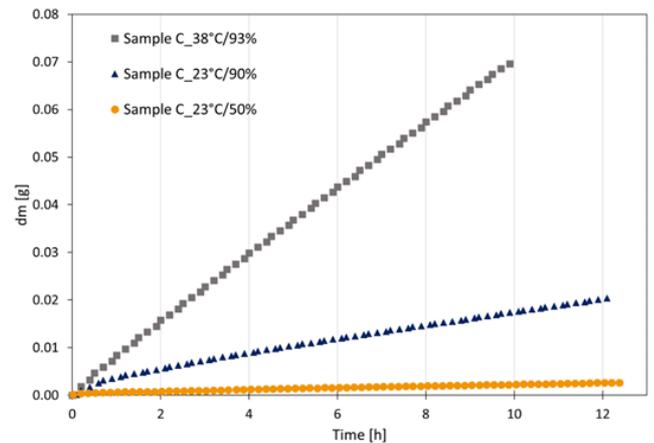


Fig. 5: Water vapor transmission through barrier foil C. Climate conditions: 50/90 % RH at 23 °C and 93 % RH at 38 °C

This result is consistent with the use of the tested product as an underlayment, which usually is assigned to the diffusion-open materials.

Samples B and Sample C can be categorized as vapor-retarding materials based on their sd-values (Table 2). However, a comparison of samples B and C shows differences in their functional properties. The sd-value is basically a climate-independent material property, which is confirmed by the measurement results of sample B. As summarized in Table 2, the sd-value for sample B, regardless of the climate tested, is ~ 5.5.

In contrast, the properties of sample C show a strong dependency on the prevailing climatic conditions. Here, the sd-value - and thus the resistance to water vapor permeability - decreases with increasing humidity and temperature. Such materials are referred to as climatic membranes.

Such variable membranes can adapt their water vapor permeability by changes in their molecular structure depending on humidity and temperature.

Similar to heat flow, moisture diffusion takes place in the direction of the gradient. This usually means from the warmer element - with the higher humidity - in the direction of the colder element with lower humidity.

Due to the lower water vapor absorption capacity of cold air, this can lead to condensation and dew water formation, which can cause damage to the building structure and favor mold growth.

To avoid this, climate membranes have a low water vapor permeability and a high sd-value in cool/dry conditions.

In contrast, in warm/humid conditions, the water vapor permeability increases while the sd-value decreases, allowing building components to dry out.

Table 2: Characteristic values of barrier foils A, B and C tested under climatic conditions of 23 °C -50/90 % RH and 38 °C/93 % RH

| Sample | RH [%] | T [°] | WVTR [g/(m ² * day)] | W [s/m] | Z [m/s] | d [s] | μ [-] | sd [m] |
|--------|--------|-------|---------------------------------|----------|----------|----------|----------|--------|
| A | 50 | 23 | 468.23 | 3.87E-09 | 2.58E+08 | 1.55E-12 | 125.81 | 0.05 |
| | 90 | | 779.87 | 3.57E-09 | 2.80E+08 | 1.43E-12 | 135.42 | 0.05 |
| Sample | RH [%] | T [°] | WVTR [g/(m ² * day)] | W [s/m] | Z [m/s] | d [s] | μ [-] | sd [m] |
| B | 50 | 23 | 4.33 | 3.58E-11 | 2.82E+10 | 1.15E-14 | 17242.93 | 5.52 |
| | 90 | | 7.58 | 3.48E-11 | 2.91E+10 | 1.11E-14 | 17718.30 | 5.67 |
| | 93 | 38 | 19.80 | 3.72E-11 | 2.72E+10 | 1.19E-14 | 17259.96 | 5.52 |
| Sample | RH [%] | T [°] | WVTR [g/(m ² * day)] | W [s/m] | Z [m/s] | d [s] | μ [-] | sd [m] |
| C | 50 | 23 | 1.23 | 1.02E-11 | 9.84E+10 | 3.05E-15 | 63915.45 | 19.17 |
| | 90 | | 10.05 | 4.61E-11 | 2.17E+10 | 1.38E-14 | 14007.69 | 4.20 |
| | 93 | 38 | 47.81 | 8.99E-11 | 1.11E+10 | 2.88E-14 | 7067.29 | 2.26 |

Conclusions

Specially developed insulation foils are available to prevent weather and climate-related damage to the building construction. These films differ in their properties regarding water vapor permeability depending on the planned location. The proUmid sorption test systems with the Permeability Kit enable simple and precise testing of the water vapor permeability of such films. As shown in the application note, the measurement results obtained in this way can be used to calculate the characteristic parameters of the insulating materials. This can be used in product development, for example, to specifically adapt product properties and optimize them for a certain application.

References

- [1] proUmid Application note AN_12-01, Water vapor permeability of films
- [2] P. Streben, Vergleichsuntersuchungen zur Wasserdampfdurchlässigkeit von Unterdeck und Unterspannbahnen und Dampfsperren, iBMB MPA, TU Braunschweig (2005)
- [3] DIN 4108-3:2018-10, Wärmeschutz und Energie-Einsparung in Gebäuden - Teil 3: Klimabedingter Feuchteschutz Anforderungen, Berechnungsverfahren und Hinweise für Planung und Ausführung, <https://dx.doi.org/10.31030/2873064>
- [4] DIN EN ISO 12572:2016, Wärme- und feuchtetechnisches Verhalten von Baustoffen und Bauprodukten – Bestimmung der Wasserdampfdurchlässigkeit – Verfahren mit einem Prüfgefäß, <https://dx.doi.org/10.31030/2429972>
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