Performance of Innovative Vapor Retarders Under Summer Conditions

Hartwig M. Kuenzel, Hans-Peter Leimer

(published in ASHRAE Transactions 2001 Vol. 107, Part 1)

Abstract

Moisture problems resulting from conventional vapor control strategies have inspired the development of innovative vapor retarders. The performance of two such retarders, the water permeable Hygrodiode and the humidity controlled Smart Retarder, has been examined by laboratory and field tests. The results show that both innovative retarders improve the drying potential of an assembly compared to a traditional polyethylene film. The degree of improvement depends on the application. The Smart Retarder is favored for walls because summer condensation is less pronounced than in roofs where both retarders perform equally well. For flat roofs with possible leaks in the membrane the Hygrodiode could be of advantage due to its capacity to absorb and transport liquid water.

1. Introduction

A conventional vapor retarder such as a polyethylene film provides effective protection against interstitial condensation during the heating season by reducing the vapor diffusion into the assembly to an acceptable minimum. However, the low vapor permeability of the film can also trap moisture in the assembly during summer time when good drying conditions prevail. Therefore, building experts have been reassessing the usefulness of a vapor retarder for roof [1] and wall assemblies [2]. This has led to the development of innovative retarders which provide a more flexible vapor control than the polyethylene film or a standard kraft paper. The performance of two such retarders, the Hygrodiode and the Smart Retarder, determined under laboratory conditions and in the test field is described in this paper.

2. Properties of the innovative retarders

The Hygrodiode is a water permeable retarder which is composed of a synthetic fabric sandwiched between staggered strips of polyethylene film. With a vapor permeability of 0.25 perm it is tighter than most kraft papers but liquid water can penetrate through capillary action via the sandwiched fabric. The Hygrodiode has a thickness of 440 µm (17 mil) and weighs 160 g/m². A more detailed description can be found in [3].

The Smart Retarder [4] is a nylon-based film with a thickness of 50 µm (2 mil). It has the tensile strength of a 6 mil-polyethylene film and a low flammability. By

---

Hartwig M. Künzel is head of the Division of Hygrothermics at the Fraunhofer Institute for Building Physics, Holzkirchen, Germany.
Hans-Peter Leimer is Director of the BBS-INGENIEURBÜRO for Building Physics, Wolfenbüttel, Germany.

absorbing water from the air and thereby opening the molecular pores it changes its vapor permeability with the ambient humidity conditions. Typically, its permeability lies below 1 perm during the heating season and between 10 and 20 perm in summer when the assembly should dry out. This can be explained by the difference in ambient conditions at the retarder between winter and summer due to the inversion of the temperature gradient in the assembly, which results in low R.H. at the warm side and high R.H. at the cold side.

3. Laboratory test (cup test)

The vapor permeabilities of the two innovative retarders and a conventional kraft paper were determined by a series of cup-tests. Because the Hygrodiode only becomes more permeable when condensation occurs, a special condensation-cup test was designed. Experimental results from a north oriented pitched roof in Central Europe [5] have shown that the mean roof surface temperature is about 2 K above the indoor air temperature during the summer months.

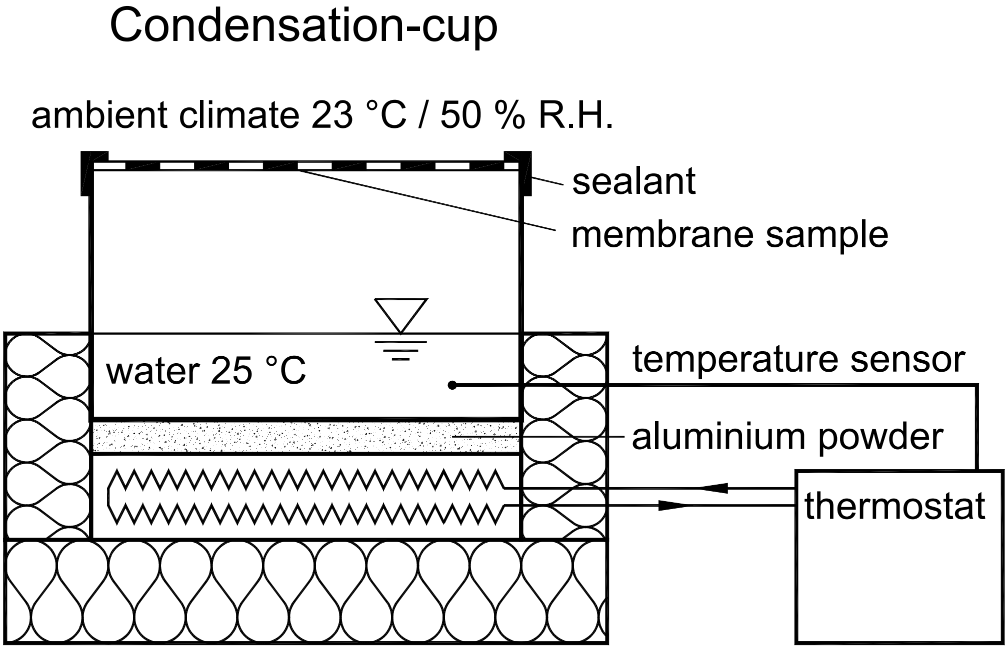


Fig. 1 *Test set-up for the condensation-cup measurement.*

The test set-up in Fig. 1 consists of a standard cup containing pure water which is kept at 25 °C by heating the bottom of the cup with a hot plate. This difference to the ambient air temperature ensures sufficient condensation on the bottom side of the tested retarder. The series started with a dry-cup test followed by a wet-cup test and the condensation-cup test. In the end another dry-cup test was carried out with the kraft paper in order to determine whether any irreversible alterations of the material could be detected.

Table 1 *Vapor permeability of the retarders measured by cup-tests (conditions in the cup are indicated below) in a climatic chamber at 23°C, 50% RH*

Vapor Retarder	Vapor Permeability [perm]			
	dry-cup 23°C/3% RH	wet cup 23°C/100% RH	condens.-cup 25°C/100% RH	dry-cup (repetition)
Hygrodiode	0.25	0.4 – 1.8	11	--
Smart Retarder	0.85	13	22	--
Kraft Paper	1.1	2.2	16	2.7

The results of the test series are listed in Table 1. The Hygrodiode has the lowest permeability under dry conditions. During the normal wet-cup test with pure water some condensation occurs but apparently not enough to get a continuous water film in the fabric. Therefore the permeability stays rather low but it increases over a period of several weeks from 0.4 perm to 1.8 perm. During the condensation-cup test the capillary transport started within 24 hours and led to an apparent vapor permeability of 11 perm. The smart retarder already becomes very permeable under normal wet-cup conditions (a factor of 15 compared to dry-cup value). But also here the condensation-cup increases the permeability to a peak of 22 perm. The kraft paper barely doubles its permeability from dry-cup to wet-cup but in the condensation-cup the permeability sharply rises to 16 perm. However, the initial vapor diffusion resistance under dry conditions was not regained during the final dry-cup test, showing that the moisture load led to an irreversible alteration of the kraft paper. Other kraft papers were also tested but the results cannot be reported here because the samples either decomposed or developed heavy mold growth. The two innovative retarders showed neither alterations of their properties nor any mold growth after the test series.

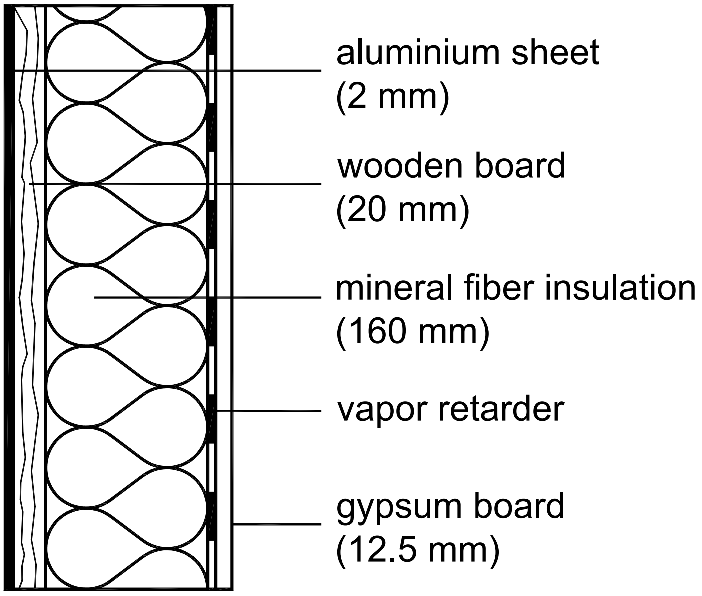
4. Field Tests

Laboratory tests and numerical simulations can provide useful information about the intrinsic properties and application prospects of new building materials or compounds. To predict their behavior under practice conditions necessitates comparative field tests which should be as close to the building reality as possible. The following field tests were carried out in Holzkirchen, a location 680 m above sea level close to the Bavarian Alps. The transferability to US-locations depends on the comparability of the climates.

4.1 Wall assembly

Wall elements as shown in Fig. 2 were exposed at the west and east oriented facades of a test wall with controlled interior conditions (20 °C, 50 % RH) during the heating season. The wall elements were sealed at the outside by an aluminum sheet. The wooden board beneath the aluminum sheet was immersed in water prior to assembling the elements until ca. 4 kg/m² of water were absorbed. This was done to simulate a rather extreme construction moisture (ca. 60 M.-%) in the wooden sheathing. The initially dry mineral fiber insulation was covered at the interior face by the Hygrodiode or the Smart Retarder before gypsum board was applied as interior finish. The test started in November '98 and ended in August '99. In time intervals of ca. 2 weeks the wall elements were weighed in order to determine their total water content. Since the elements were water and vapor tight at the exterior, moisture exchange could only take place to the interior of the test hall.

The changes in total water content of the elements with the two different retarders are shown in Fig. 3. There was hardly any difference in the moisture behavior of the west and the east wall elements, therefore the readings from both directions are averaged in Fig. 3. Until March the wall assemblies do not dry out because of the vapor drive from the interior. Due to the somewhat higher permeability of the Smart Retarder, the respective wall elements even show a minor gain in weight. When outdoor temperatures and solar radiation increase with spring time, the vapor pressure gradient to the interior inverses for more and more hours per month thus giving the elements a chance to dry out towards the interior of the test hall. This leads to an immediate and rapid drying process of the elements with the Smart Retarder while the drying of the elements with the Hygrodiode is delayed until June. This can be explained by the fact that the Hygrodiode needs a sufficient amount of condensation in order to start the capillary transport process whereas the Smart Retarder becomes rather permeable at humidity conditions above 70 % R.H. At the end of the test period in August, over 90 % of the initial moisture of the wall elements with the Smart Retarder has dried out compared to a 30 % dry out of the elements with the Hygrodiode.



<u>Fig. 2</u> *Composition of the exposed wall elements. The wooden board has a high initial water content.*

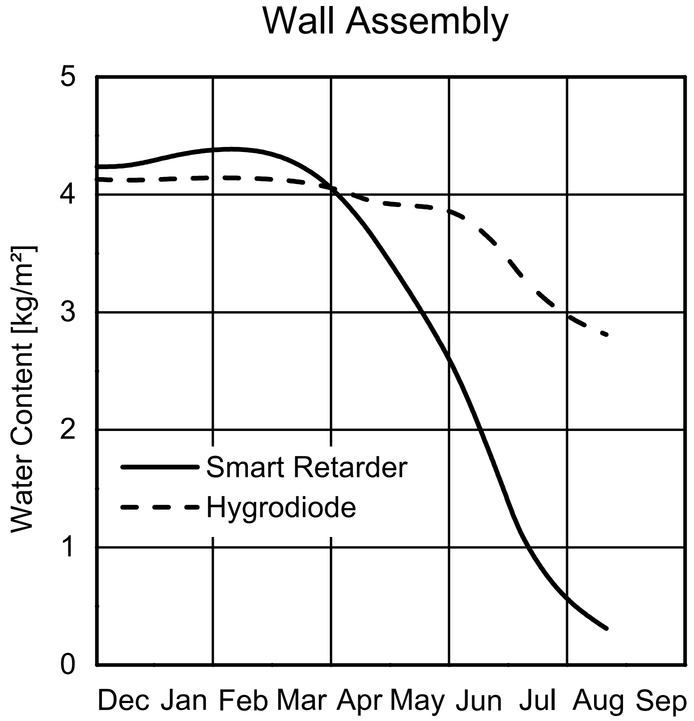


Fig. 3 *Water content of the wall elements after exposure in November determined by periodical weighing.*

4.2 Roof assembly

A detailed description of the roof tests can be found in [5]. The assembly considered is an unvented cathedral ceiling with a pitch of 50° oriented to the North. The composition from outside to inside is as follows: Zinc covering, wooden sheathing (initial moisture ca. 40 M.-%), 180 mm mineral wool insulation between the rafters, vapor retarder (Hygrodiode/Smart Retarder/PE-film), gypsum board. The moisture of the rafters and the sheathing was monitored continuously by electrical resistance sensors. The test field with the Hygrodiode was installed one year after the other test fields by replacing the PE-film. Therefore results from two different summers have to be compared.

Fig. 4 shows the measured wood moisture in the sheathing and at the interior surface of the rafters in the test fields from April to September. Starting from an elevated moisture well above the critical point of 20 M.-%, the sheathing dries under the influence of the sun and reaches uncritical conditions in late June in the test fields with the innovative retarders. Part of the moisture coming from the sheathing leads to a short term increase in water content at the interior surface of the rafters. But towards the end of the summer the effect of the Hygrodiode and the Smart Retarder alike result in dry conditions throughout the cathedral ceiling assembly, while the situation stays critical in the test field with the PE-film. This proves that the new retarders have a clear advantage over the conventional polyethylene retarder in unvented roof assemblies. Similar results have also been obtained previously in the same test roof by comparing the Smart Retarder to kraft paper [5].

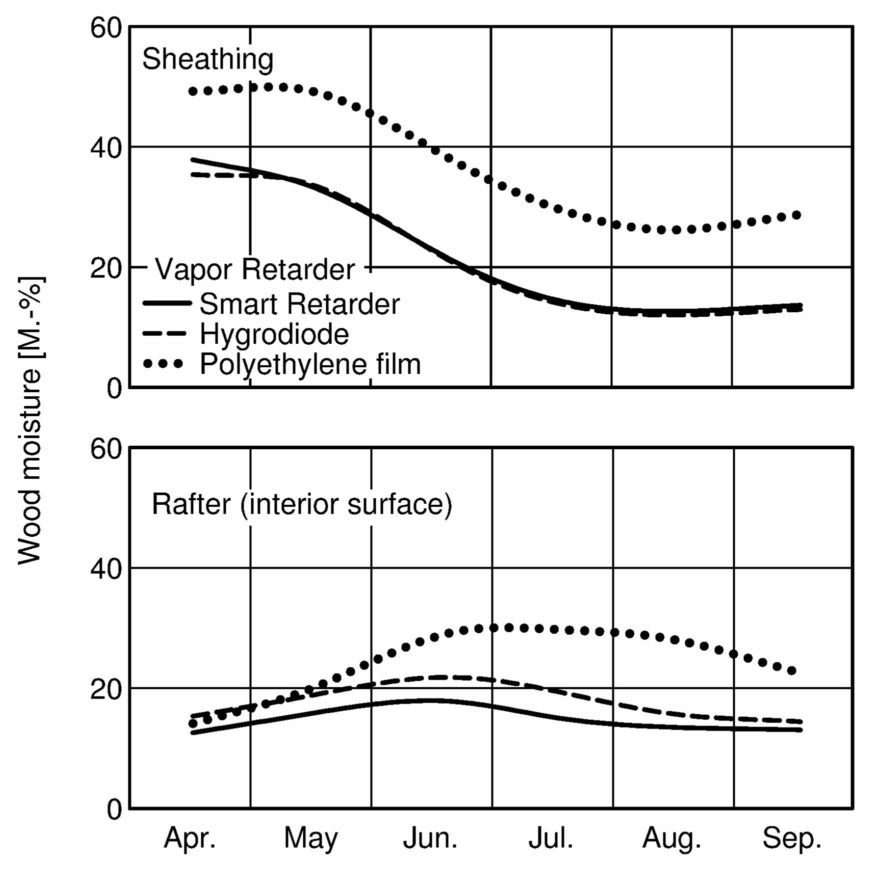


Fig. 4 *Moisture content of sheathing and rafters in the roof test fields with different vapor retarders during the drying period.*

5. Conclusions

The laboratory and field tests have shown that the innovative retarders considered are superior to conventional vapor retarders for the moisture safety of an assembly under Central European climate conditions. The Hygrodiode has a lower permeability than the Smart Retarder in winter with a slightly better protection against interstitial condensation. In summer, however the Hygrodiode can only be effective if enough condensate is formed to get the capillary transport in the sandwiched fabric started, whereas the Smart Retarder promotes the drying process as soon as the vapor pressure gradient is inversed. Wall assemblies are therefore performing better when equipped with the Smart Retarder. In roof assemblies, however, both innovative retarders perform equally well due to the higher solar radiation impact. Inverted wet-cup tests with the Hygrodiode [6] indicate that its water permeability can be up to ten times higher than the one determined by the condensation cup test when water seeps in from above. This could be an advantage for extracting moisture from flat roofs with leaky roofing membranes.

6. References

[1] Dejarlais, A.O. et al, Moisture Studies of a Self-Drying Roof. Tests in the Large-Scale Climate Simulator and Results from Thermal and Hygric Models. Conference Proceedings Thermal Envelopes VII, ASHRAE 1999, pp. 41-54.

[2] Karagiozis, A.N. and Salonvaara, M.H., Hygrothermal Performance of EIFS-Clad Walls: Effect of Vapor Diffusion and Air Leakage on the Drying of Construction Moisture, ASTM STP 1352, West Conshohocken, 1999, pp. 32-59.

[3] Korsgaard, V. and Pedersen, C.R., Laboratory and Practical Experience with a Novel Water-Permeable Vapor Retarder. Conference Proceedings Thermal Envelopes V, ASHRAE 1992, pp. 480-490.

[4] Künzel, H.M., More Moisture Load Tolerance of Construction Assemblies Through the Application of a Smart Vapor Retarder. Conference Proceedings Thermal Envelopes VII, ASHRAE 1999, pp. 129-132.

[5] Künzel, H.M., Flexible Vapor Control Solves Moisture Problems of Building Assemblies – Smart Retarder to Replace the Conventional PE-film. Journal of Thermal Envelope & Building Science, Vol. 23 (July 1999), pp. 95-102.

[6] Bernhardt, P., Feuchtedurchgang durch eine Hygrodioden-Folie. IBP-Prüfbericht FP-175/1991, Holzkirchen 1991.