Flexible Vapor Control Solves Moisture Problems of Building Assemblies - Smart Retarder to Replace the Conventional PE-Film

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1. INTRODUCTION

Insulated building assemblies require a vapor retarder at the warm side to avoid interstitial condensation during the heating season in cold and mixed climates. However, the low permeability of a traditional vapor retarder can be a severe drawback concerning the drying potential of the assembly in summer time. Because moisture is more harmful to the structure when temperatures are high, the evaporation of moisture from the assembly must be as effective as possible. Flexible vapor control means that the retarder is tight enough to avoid critical condensation in winter while being sufficiently vapor permeable in summer to guarantee a fast drying process by adapting its performance to the seasonal changes in environmental conditions. In this paper the principle of the smart retarder is explained and experiences from field tests are reported.

2. PRINCIPLE AND DEVELOPMENT OF THE SMART RETARDER

During the heating period, the smart retarder acts like a conventional retarder at the interior side of the assembly where humidity conditions are generally low. However, situated at the cold side where a higher relative humidity prevails, it can become as permeable as gypsum board. Its vapor permeability measured by cup tests is plotted as a function of relative humidity in Fig. 1. Below 50 % R.H. the permeability of the smart retarder (a 2-mil nylon film) is less than 1 perm. At ambient conditions above 50 % R.H. it is becoming more and more permeable and reaches a value of 36 perm at 90 % R.H. (determined by an inverted cup test in a climatic chamber at 80 % R.H.). Between this value and the permeability in the dry state (< 20 % R.H.) lies a factor of 50. Humidity depending variation of vapor permeability is not unusual for plastic films. The extend of this variation and the specific permeability under dry and humid conditions are a novelty in building physics.

The specifications have been evolved by heat and moisture transport calculations [1]. Several moisture problem cases as for example the interior insulation of timer-framed houses or the insulation of cathedral ceilings with vapor tight top, were examined by computer simulations. In order to solve the problems parametric studies were carried out which resulted in well defined requirements for vapor retarders. Searching for a product that meets these calculated

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requirements led to the discovery of the smart retarder [2]. Despite the fact that the specified hygrothermal properties were derived to suit Central European climate conditions, they seem to be of more universal relevance as a computational study by Karagiozis and Kumaran [3] concerning the drying potential of EIFS walls in North Carolina has shown.

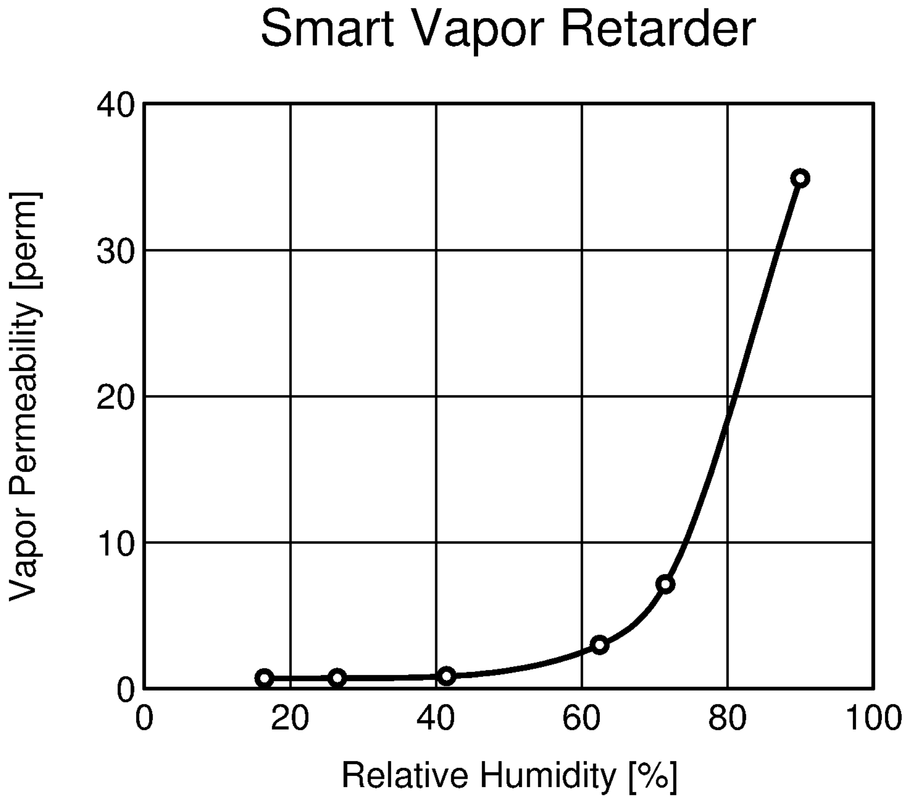

FIGURE 1 Variation of the vapor permeability of the smart retarder (a nylon based film) with the ambient relative humidity, determined by cup tests.

The smart vapor retarder consists of a nylon-based membrane. Nylon film is used as sausage skin and for food packaging, which proves that is poses no health hazard. It is impermeable to organic pollutants and gases (e.g. radon). The humidity-dependent vapor permeability is due to its capacity to absorb water, which creates its own selective pores in the material. Nylon is a rather tough plastic material with high tensile strength. Therefore, a membrane of about 50 µm (2 mils) has mechanical properties equivalent to a polyethylene film of 150 µm (6 mils) thickness. Another advantage of nylon film is its low flammability even without any fire protecting chemicals. Therefore it can be used without any additives which makes it easy to recycle.

3. FIELD TEST: UNVENTED CATHEDRAL CEILING

Calculations have shown that moisture problems due to vapor diffusion in unvented assemblies with a vapor-tight exterior layer can be excluded by applying the smart retarder [2]. But other sources of moisture such as the initial moisture in rafters and joists or air infiltration through imperfections in the interior lining might pose a risk which has to be considered. Because unvented assemblies become for good reasons more widespread, a field test with unvented fully insulated cathedral ceilings in a roof with a pitch of 50 ° was carried out at the test site of the Fraunhofer-Institute in Holzkirchen, which is located close to the Alps between Munich and the Austrian border at 680 m above sea level. A common moisture source in this type of construction is the initial moisture in the rafters or in the wooden sheathing beneath the roof covering. For the roof considered here rafters which had not been dried sufficiently were used and the sheathing was watered several hours with a hose (simulating rain fall during construction) before the vapor-tight metal zinc covering was applied. Fig. 2 shows a cross-section of the assembly indicating also the positions of the wood moisture sensors (discontinuous measurement of electric conductivity) and the capacitive relative humidity sensors (continuous recording).

The roof surfaces were oriented to the north and to the south. There area was divided into 3 sections each with different interior finish. During the first test from August 1996 till September 1997 the 3 sections had different vapor retarders, kraft paper (ca. 1.5 perm), polyethylene film (0.07 perm) and the smart retarder (vapor permeability see Fig. 1). The second test started after rehumidification of sheathing and rafters in November 1997 and ended in September 1998. The 3 sections at both orientations were reassembled as follows: Smart vapor retarder (SVR) and gypsum board, SVR and particle board and as reference gypsum board laminated with polyethylene (0.3 perm). Apart from the first autumn when the drying of the concrete floor let to a high indoor humidity the conditions were kept between 20 °C, 40 % R.H. in winter and 23 °C, 60 % R.H. in summer.

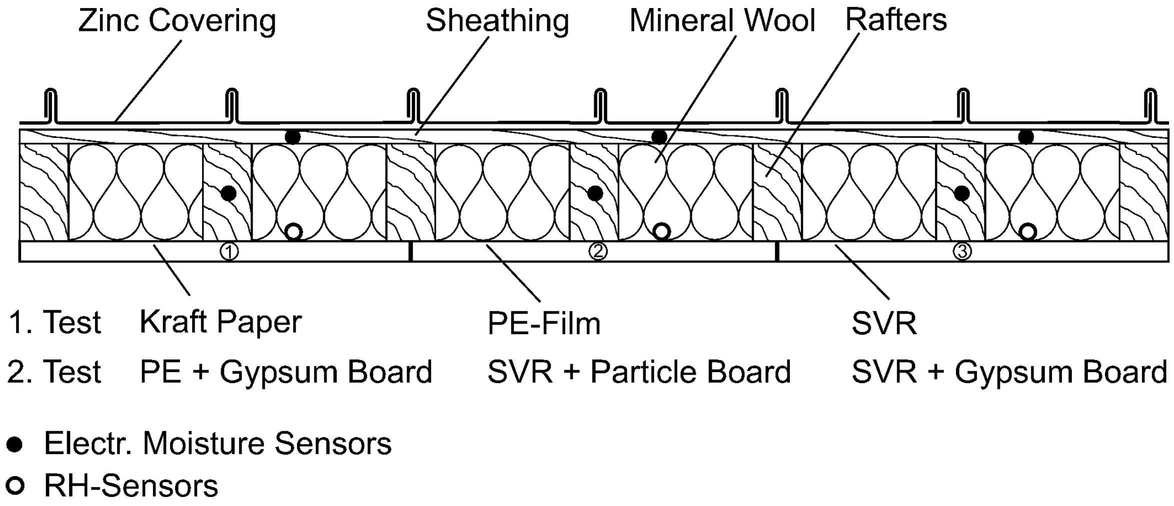

FIGURE 2: Cross-section of the examined cathedral ceiling.

4. TEST RESULTS

In the test sections facing south the initial moisture of the wooden sheathing was already below the critical water content of 20 mass-% at the start of the recording, because the high solar radiation during the installation of the zinc covering dried the boards very fast. The moisture in the rafters fell within a few months below the critical value almost irrespective of the vapor retarder applied. This is due to summer condensation caused by high surface temperatures of the zinc covering - uncorroded zinc has a low long-wave emissivity resulting in high surface temperatures during sunshine - up to 80 °C (176 °F). The condensate formed visibly on the outward facing side of the retarder and ran off to the bottom joist due to the steep pitch of the roof. This let to the formation of condensation stains and mold growth on the kraft paper while no such problems were observed in the sections with the smart retarder and the polyethylene film. Because of the high drying rate the structure was safe in all south oriented test sections.

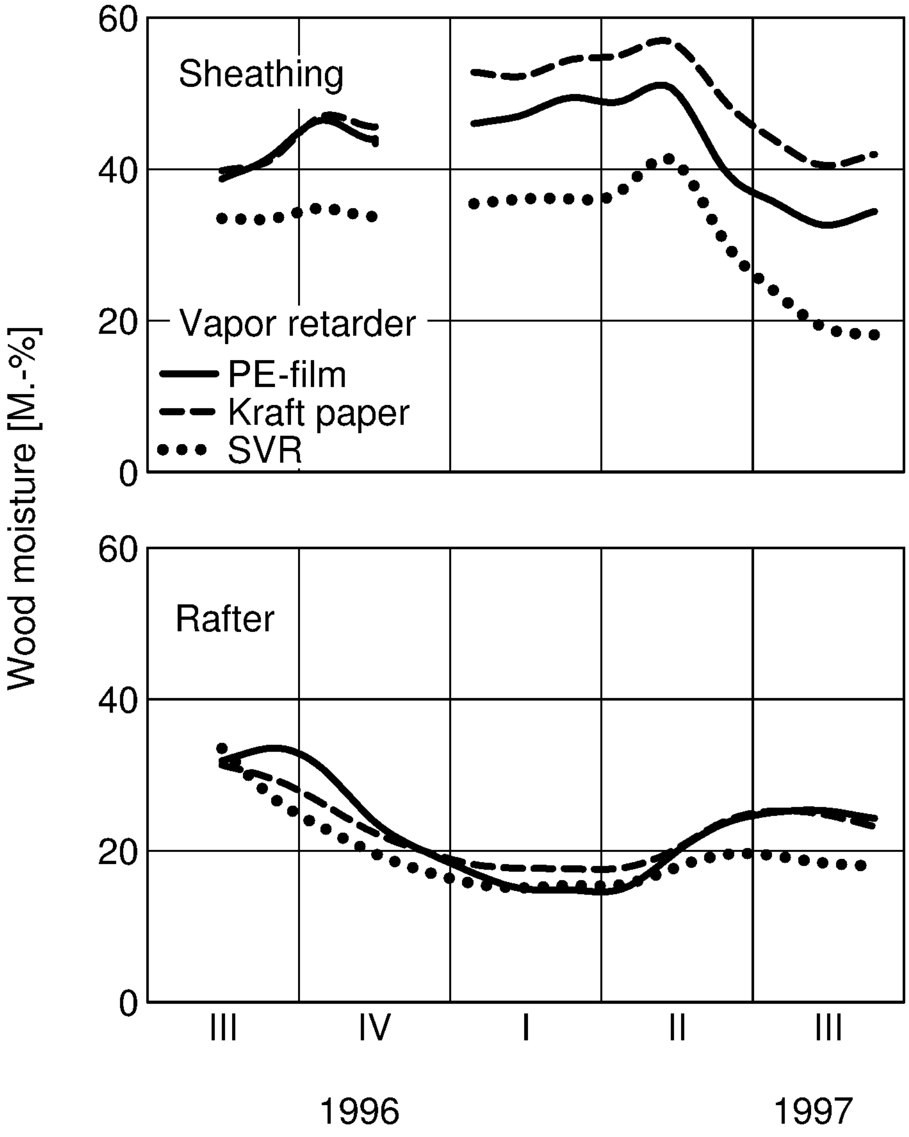

FIGURE 3: Moisture in the rafters and the wooden sheathing beneath the zinc covering over a period of one year in the test sections with the different retarders. The roman numerals indicate the quarters. The readings of the moisture in the sheathing are only shown for temperatures above 0 °C because ice formation due to the high water content impairs the moisture measurements by electric resistance. This explains the missing data during winter time in the top figure.

In the north-oriented part of the roof no condensation on the retarder was observed in the first summer, because the zinc covering temperatures were much lower there. This explains the slower drying process visible in Fig. 3. The initial moisture of the rafters was about the same as in the south-oriented part but it took more time for the moisture to reach uncritical conditions, 3 months in the test section with the smart retarder and 4 months in the other test sections. However, regarding the moisture increase of the wooden sheathing in the test section with the polyethylene film and the kraft paper it seams that the moisture of the rafters did not dry to the interior as much as the bottom graphs would suggest. While the moisture in the rafters beneath the smart retarder stays below 20 mass-% until the end of the test period it reaches 25 mass-% in the other test sections during the next summer. This moisture increase is caused by a redistribution of the water from the wooden sheathing into the rafters as can be deduced from the curves above. Only the smart retarder allows the unvented roof to dry out sufficiently so that the rafters and the wooden sheathing are below critical conditions at the end of the test period whereas the kraft paper and the polyethylene film trap too much water in the assembly, thus increasing the probability of moisture damage.

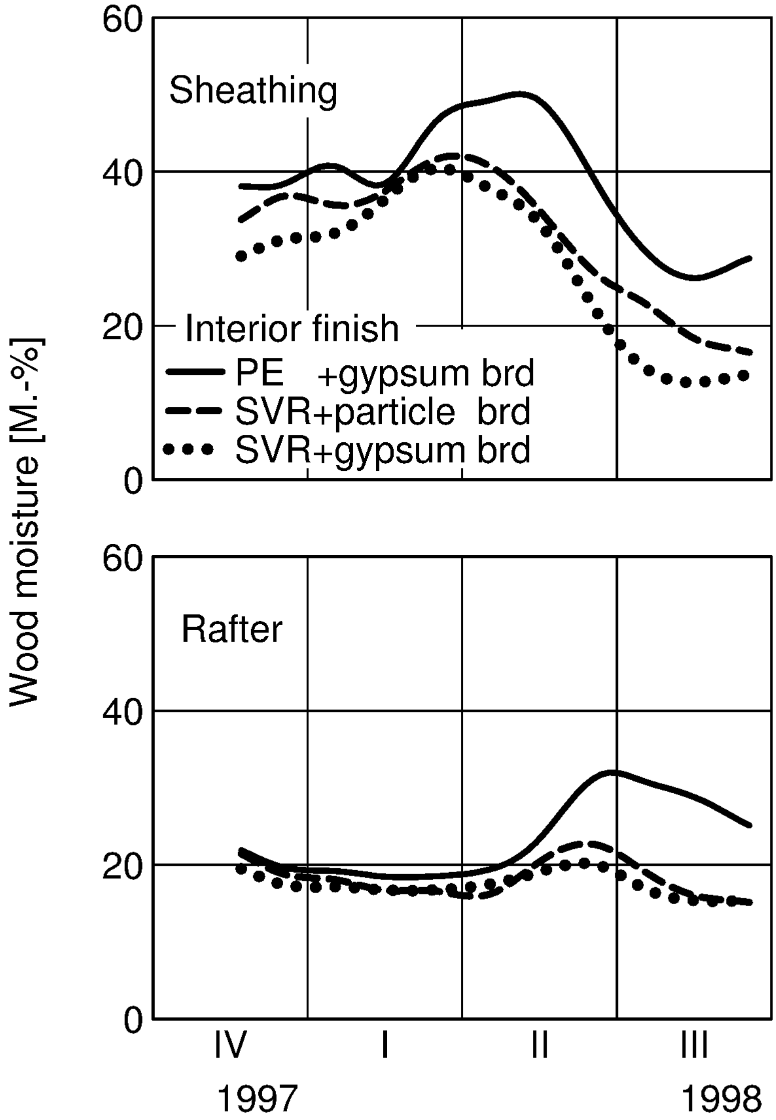

FIGURE 4: Moisture in rafters and sheathing of the north oriented roof sections during the second test period.

Before the next test period the roof sections were again conditioned to a uniform initial moisture. During the second period the influence of the interior finish on the drying behavior of the north oriented roof sections was examined. Fig. 4 shows the temporal evolution of the moisture in the sheathing and the rafters between November and September of the next year. Towards the end of the test period the moisture of sheathing and rafters is below critical conditions in the test sections with the smart retarder, however, the advantage of the gypsum board over the particle board concerning the drying process can be clearly detected. In the reference section with the polyethylene laminated gypsum board critical moisture conditions (> 20 mass.-%) prevail throughout the test. In order to explain the differences in drying rates the monthly mean values of the roof surface temperature compared to the outdoor air temperature and the relative humidity between insulation and vapor retarder are plotted in Fig. 5. In winter when the roof surface temperature is close to the outdoor air temperature the moisture in all test sheathing and rafters is below critical conditions in the test sections with the smart retarder, however, the advantage of the gypsum board over the particle board concerning the drying section accumulates in the cold sheathing. This leads to a relative humidity of about

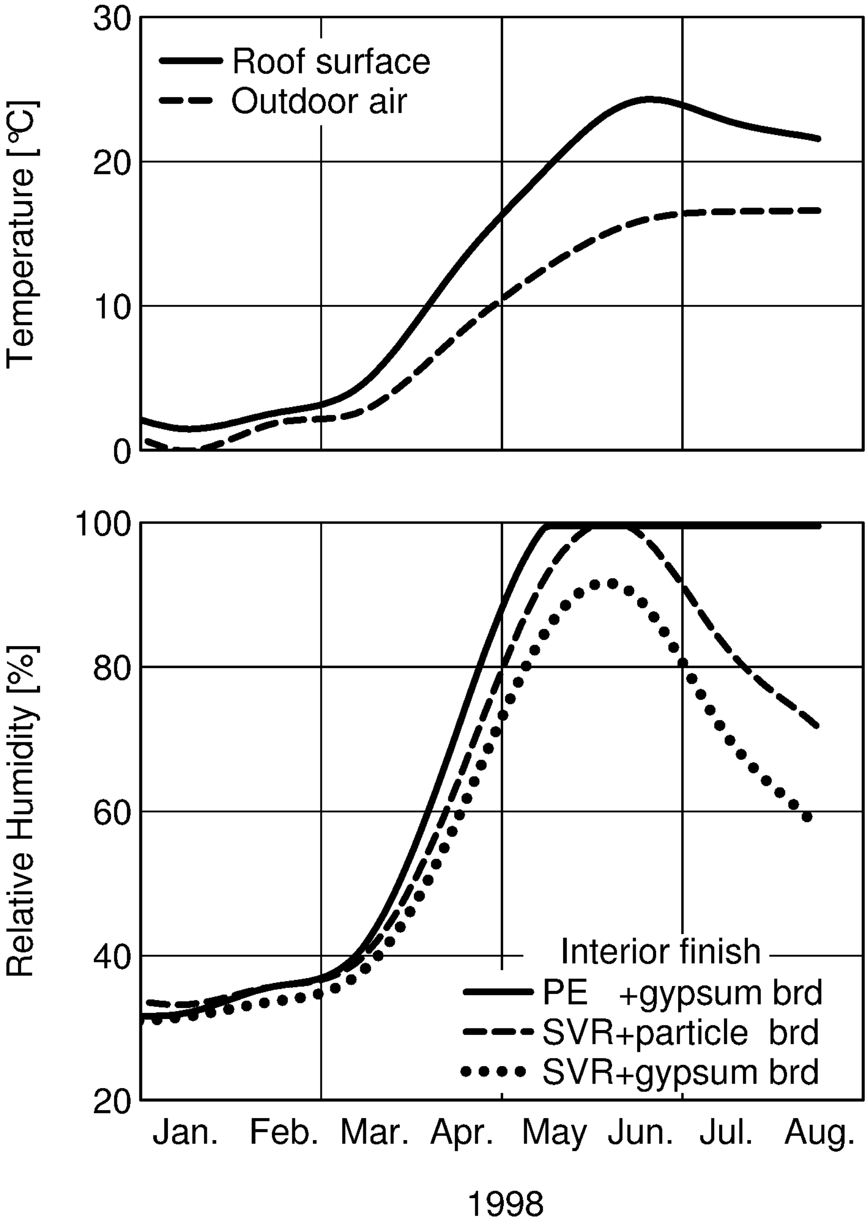

FIGURE 5: Monthly mean values of the roof surface temperature compared to the outdoor air temperature and evolution of the relative humidity between retarder and insulation beneath the interior finish during the second test period

30 % at the outward facing side of the vapor retarder. Under these ambient conditions (indoor R.H. ca. 45 %) the smart retarder assumes a permeability of 0.8 perm and protects the assembly from interstitial condensation. When the roof surface temperature starts to rise above the indoor air temperature in May the vapor drive is inverted and moisture from the sheathing can lead to condensation on the vapor retarder (100 % R.H. in Fig. 5). However, if the vapor retarder opens up, the inward driven moisture evaporates to the room air and will not condens on the retarder. This is the case in the assembly with the smart retarder and the gypsum board. The peak in mean relative humidity there, is about 90 %. If gypsum board is exchanged with particle board, considerable resistance to the vapor drive is added and condensation occurs until the end of June when the total water content in the assembly drops below critical conditions in the rafters. The reference test section in contrast does not dry out sufficiently therefore the time of condensation lasts from middle of May until the end of the test period in August.

5. CONCLUSIONS AND MARKET SUCCESS

The results of the field tests presented here confirm other experimental [4] and calculation results [3] which show that the smart vapor retarder effectively reduces the moisture damage risk in the building envelope by increasing the moisture load tolerance of an assembly. Due to the steep rise in vapor permeability above 70 % R.H. the smart retarder should not be used without further examination for buildings with an exceptionally high indoor humidity such as swimming pools. Short peaks in the indoor air humidity as in bathrooms or kitchens do not affect the performance of the smart retarder because the interior lining acts as a humidity buffer. The humidity controlled permeability together with its other advantageous properties like high thermal and mechanical resistance, tightness against pollutants etc., has made the patented smart retarder a big success in the German construction market. It has sold 3 million m^2 (33 million ft^2) in 1997 and more than 6 million m^2 (66 million ft^2) in 1998. This year companies in other European countries will introduce it to their market several US and Canadian companies have also manifested their willingness to consider its distribution.

REFERENCES

[1] Künzel H.M.: Simultaneous Heat and Moisture Transport in Building Components. - One- and two-dimensional calculation using simple parameters. IRB Verlag (1995).

[2] Künzel, H.M.: The Smart Vapor Retarder: An Innovation Inspired by Computer Simulations. ASHRAE Transactions 1998, Vol. 104/2, pp. 903-907.

[3] Karagiozis, A. and Kumaran, K.: Drying Potential of EIFS Walls: Innovative Vapor Control Strategies. Third ASTM Symposium on EIFS, San Diego, Oct. 1997.

[4] Künzel, H.M.: Humidity Controlled Vapor Retarder Reduce Risk of Moisture Damages. Proceedings 4. Symposium of Building Physics in the Nordic Countries, Espoo 1996, pp. 755-762.