Moisture movements in timber window frames

By Dr J. van der Kooi, TH Delft. Verfkroniek, 49/1976[1]

Introduction

This laboratory investigation serves to improve the understanding of moisture changes in wooden window members under practical conditions. A major issue is the question of how coatings with different water vapour permeability on the inside and outside of the window affects the moisture conditions. The goal is to avoid moisture buildup – particularly in pine – above 21 per cent (w/w) where the risk of fungal attack is considerably increased.

Other experiments have been made with blisterboxes or "blisterhouses" – in both cases using interior climates with very high (almost 100 %) relative humidity, however the present work has been carried out under climatic conditions more closely resembling practice.

Method

Two adjacent climate chambers, each 1 m * 1 m * 1 m, wereconstructed; one of them with a simulated exterior climate, the other with interior conditions. The chambers were separated by a PMMA-sheet equipped with thermal insulation on the cold (exterior) side. In total 40 test samples of pine, each 50 mm x 50 mm x 120 mm were mounted in openings 50 mm x 50 mm through the separating wall. The samples were fitted with one half in the interior climate, the other in the exterior. The axial direction was in parallel with the PMMA sheet in order to ensure moisture transportation across the grain – same as in timber windows. There were 4 test series, 10 samples each:

a) no coating inside / high diffusion resistance outside
b) high resistance inside / low resistance outside
c) no coating both sides
d) high resistance both sides

The samples were exposed 12 months to interior and exterior conditions similar to practice. The exterior climate values corresponded with information from KNMI De Bilt (The Dutch Meteorological Institute), whereas the interior conditions were based on own investigations in various buildings; the relative humidity values were however fixed at a 10 % higher level in order to have a certain security margin. The climatic conditions applied are listed in table 1.

As mentioned above every test series consisted of 10 samples. In order to check the influence from the initial moisture content, i.e. at the start of the exposure, wooden blocks in each series were preconditioned to different wood moisture levels varying from 10 % to 30 %. Care was taken to ensure an even moisture distribution within the individual samples. The moisture content during preconditioning was monitored by weighing, and then compared with the wood moisture determined

[1] Translated by Peter Svane, Coating Consultancy, Copenhagen, Denmark from "Het vochtgedrag in houten kozijnen" originally into Danish (1976?) and to English 2013. Jon Graystone of the Paint Research Association in London is thanked for proofreading

after the experiment by further weighing, drying and weighing. Half of the samples (5 from each series) were exposed for 10 months, the remaining samples for 12 months.

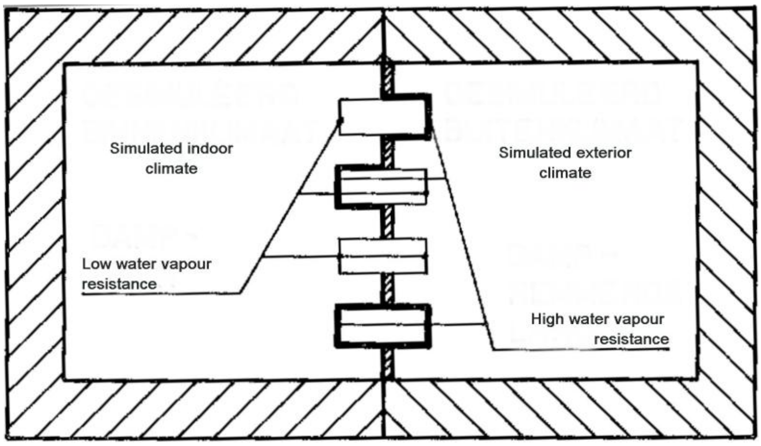


Fig. 1) Principle of test setup

Month	Interior climate		Exterior climate	
	Temp. (°C)	Rel. hum. (%)	Temperature (°C)	Rel. hum. (%)
January	19	51	2,3	88
February	19	51	2,5	84
March	20	52	4,9	78
April	21	54	7,8	73
May	23	58	12,4	70
June	23	61	14,8	70
July	23	63	16,6	73
August	23	62	16,0	76
September	23	59	13,6	80
October	22	54	9,6	85
November	20	52	5,0	87
December	20	52	2,9	89

Table 1) Monthly mean values of interior and exterior climate conditions

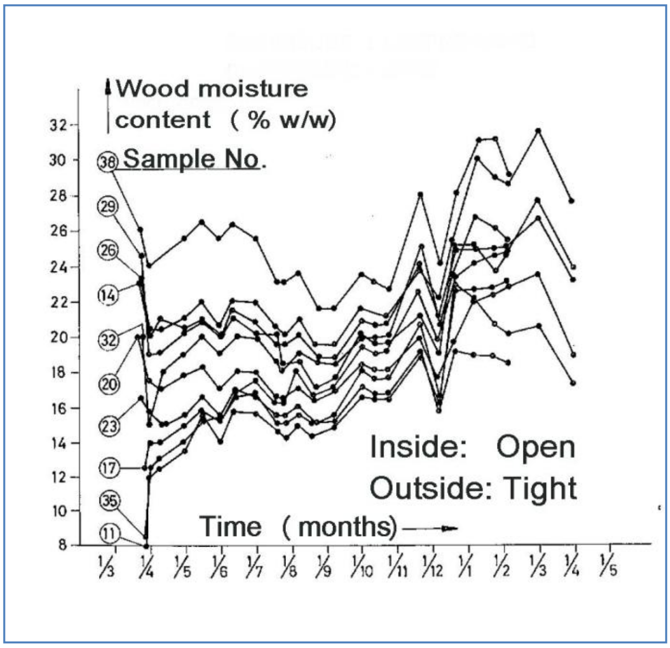
Results

The results from the four series (a, b, c and d) are shown in fig. 2, 3, 4 and 5. The graphs show the mean moisture content in the blocks starting April 1st and finishing the following year on February 1st and April 1st respectively. Furthermore the moisture distribution was determined at the end of the experiment, i.e. after 10 and 12 months of exposure respectively.

<u>Series a)</u>

Inside: No coating
Outside: Coating with high water vapour resistance (see fig. 2)
The blocks with high initial moisture content remained at a higher level throughout the experiment whereas those starting with lower moisture increased their moisture content considerably during the exposure period.

This is as expected. Due to the temperature gradient there is a moisture movement from the warm inner side towards the cold exterior; here however the moisture cannot escape because of the diffusion resistant coating. In the blocks starting with a high humidity level some moisture escapes to the interior climate at the beginning of the experiment, so that these samples remain at approximately the same level through the entire exposure period. Those that start from a dryer condition however take up so much moisture from the interior climate that they end up gaining considerably in moisture. Around December 1st the results become irregular and therefore less reliable. The explanation probably is condensation on the acrylic sheet causing capillary water uptake in some of the blocks.



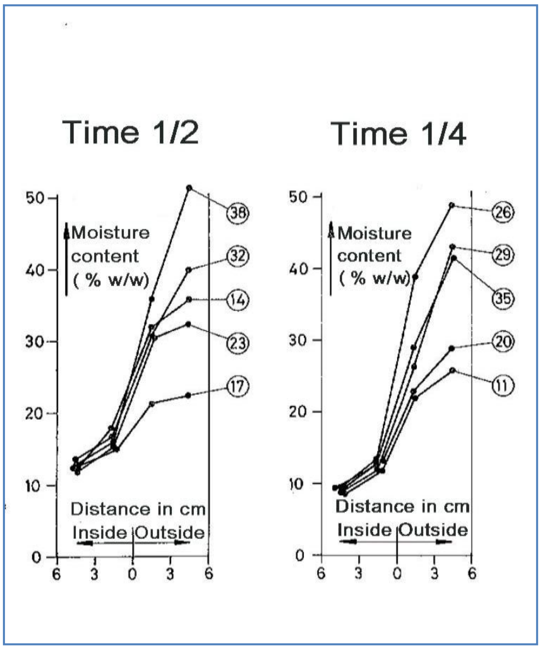


Fig. 2a) Mean moisture content in the wooden blocks (series a)

Fig. 2b) Moisture distribution in the wooden blocks (series a)

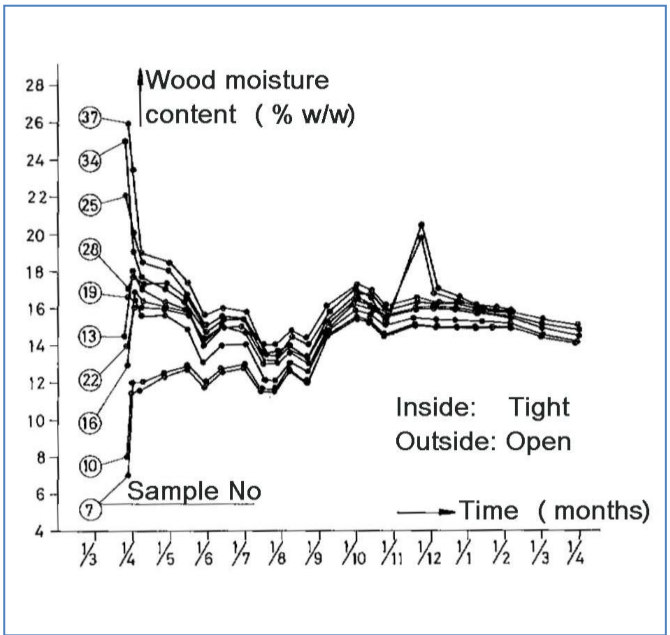
After the 10 and 12 months of exposure the overall mean moisture content for the two sets each with 5 samples was 23,8 % (w/w) and 21,9 % (w/w). The moisture distribution was very inhomogeneous: at the warm side the mean value was around 10 % whereas it varied between 20 and 50 % at the cold side.

Series b)

Inside: Coating with high water vapour resistance
Outside: Coating with low water vapour resistance (see fig. 3)

For the samples treated in this way it appeared that those starting with a high humidity very quickly lost their moisture whereas the samples starting dry took up some moisture. Except for the very dry or the very wet samples this regulation took place rather fast; equilibrium was reached within a few months. It is obvious that the moisture conditions for these blocks are much better than for series a. The mean moisture content of 5 samples for each of the two sets was 15,4 % after 10 months and 14,4 % (w/w) after 12 months.

The moisture distribution is much less steep compared to series a; at the inside the moisture was 8-10 % and at the outside 18-21 %



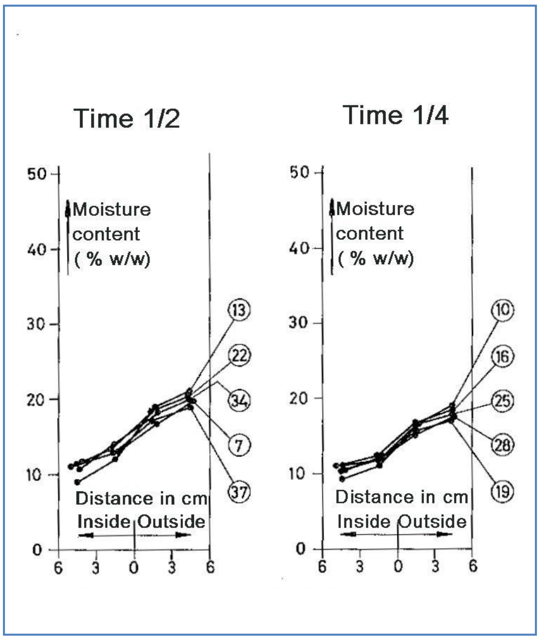


Fig. 3a) Mean moisture content in the wooden blocks (series b)

Fig. 3b) Moisture distribution in the wooden blocks (series b)

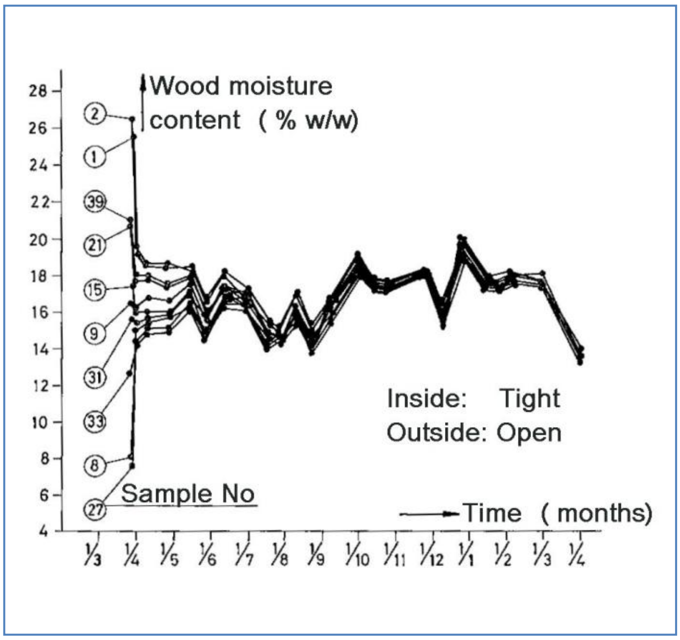
<u>Series c)</u>

Coating with low water vapour resistance on both sides (see fig. 4)

In this series the samples reach their moisture equilibrium even faster than in series b – the wet samples get dryer, the dry samples take up moisture – both within a couple of months. No influence from the original moisture content can be seen after 2-3 months.

The mean moisture content of 5 samples for each of the two sets was 17,0 % after 10 months and 14,0 % (w/w) after 12 months. However these values may be too high if liquid water (condensation) has been absorbed by some of the samples.

The moisture distribution is comparable to series b, i.e. 8-12 % inside and 17-23 % outside; the higher values are found after 10 months of exposure, the lower values after 12 months.



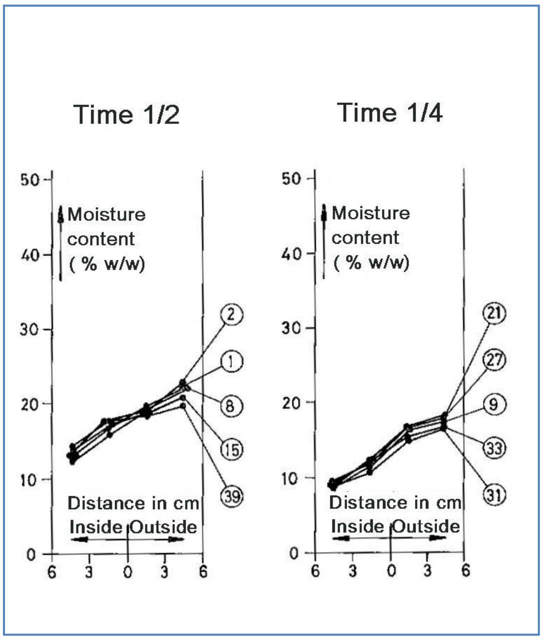


Fig. 4a) Mean moisture content in the wooden blocks (series c)

Fig. 4b) Moisture distribution in the wooden blocks (series c)

<u>Series d)</u>

Coating with high water vapour resistance on both sides (see fig. 4)

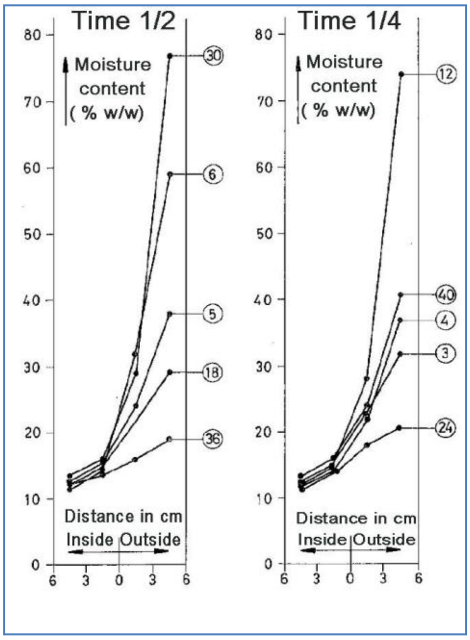


Fig. 5) Moisture distribution in the wooden blocks (series d)

As might be expected there is little information to gather from the measurements of mean moisture content in this series. Accordingly only one graph (fig. 5) showing the moisture distribution is presented. The tight coating virtually prevents any moisture penetration; therefore the mean moisture content practically does not change during the experiment. From fig. 5 is seen that there are very steep moisture gradients in this series, with moisture levels at the cold side up to 80 %.

Practical implications

In comparison with practice the investigation does not include the influence from sun and rain. The sun heats the exterior side of a window frame and dries the wood if it is coated with an open system. Too fast drying may even lead to crack formation. On the other hand an open system – particularly if the surface is cracked – will allow fast water entry during rainfall. Those facts should be borne in mind when transferring the experimental results to practice.

It appears from the measurements that the poorest solution of all is to provide a window with a diffusion resistant (“tight”) coating on both sides. If moisture for some reason gets into the wood e.g. through a crack, it has difficulties escaping from the material.

An open system inside and a tight system outside is another unfortunate combination; moisture migrates from the inside because of the temperature gradient and cannot evaporate once it has reached the barrier at the exterior side.

From a moisture dynamic point of view it is better to coat the exterior side with an "open" system and the inside with a "tight" coating. A dry window frame remains dry, and wet wood dries relatively quick as the moisture evaporates from the exterior side. A too open exterior coating will lead to crack formation because of too fast moisture induced movements (rain and sun) in the wood substrate. Accordingly a coating outside should be "open" but not too open. It should be sufficiently diffusion resistant to minimise wood cracking. Suitable diffusion resistance values may be determined by further experimental work under practical conditions.

The optimal solution seems to be an open coating system on both sides. Moisture then has the option to escape from either side of the window. Even here the coating should probably be sufficiently diffusion resistant to avoid cracking. It should finally be noted that those recommendations only apply to buildings with normal moisture conditions; under very humid conditions a tight coating system is preferable on the interior side.

Conclusions

It is demonstrated that timber windows in buildings with normal moisture conditions preferably should be coated with a relatively open system on both sides. That permits moisture to escape both from the inside and the outside. The system however should have sufficient diffusion resistance to avoid or minimise formation of cracks caused by fast moisture induced wood movements due to rain and sun. Quantitative recommendations as to suitable diffusion resistance values call for further experiments under practical conditions.

In humid rooms the interior coating should be moisture resistant and the exterior open.

Literature

1) Moree, J.C., Dooper, R. – Verfkroniek 51, September 1968, p. 321-26. Berekningen over het vochttransport door geschildert hout.
2) SBR-publikatie nr. 33. Het vochtgedrag in niet-geventileerde daken van cellenbeton. Samson, Alphen a/d Rijn, 1971

Postscript by the editor

Dr. ing. J. van Leoon has regularly published about the moisture mechanics in coated window frames of wood during the years 1960-65. In the articles he introduces the term "relative moisture resistance", i.e. a more tight treatment inside and a more open outside in order to avoid moisture build-up in the wood material. These findings are based on experiments carried out in rooms with reasonably high humidity. Later on TNO has calculated that the "tight" layer on the inside is less important under more normal humidity conditions like in central heated buildings. This is in good agreement with the above investigation of J. van der KOOI. So it is still recommended to coat the exterior side with a relatively open coating system.