WATER VAPOR PERMEABILITY AND HYGROSCOPIC SORPTION CURVES FOR VARIOUS BUILDING MATERIALS

S. Geving, B. Time, P.J. Hovde

WATER VAPOUR PERMEABILITY AND HYGROSCOPIC SORPTION CURVES FOR VARIOUS BUILDING MATERIALS

Stig Geving[1], Berit Time[1], Per Jostein Hovde[2]

[1] Norwegian Building Research Institute, Trondheim Department, Høgskoleringen 7, N-7491 Trondheim, Norway.
[2] Norwegian University of Science and Technology (NTNU), Department of Building and Construction Engineering, N-7491 Trondheim, Norway.
EMail: stig.geving@byggforsk.no, berit.time@byggforsk.no, per.hovde@bygg.ntnu.no

Abstract

Water vapour permeability has been measured for aerated concrete, porous asphalt impregnated wood fibre board, wood fibre board (hardboard), exterior grade gypsum board, plywood, polyethylene film (vapour barrier), polypropylene film (wind barrier), spunbonded polyethylene film (wind barrier), PVC roofing membrane and spruce. Sorption curves were measured for aerated concrete, plywood, spruce, wood chipboard (particle board) and wood fibre board (hardboard).

Key words: water vapour permeability, sorption curve, building materials

1 Introduction

As a part of the research programme "Moisture in building materials and constructions" (1993-97), experiments were performed on different building envelope constructions at a test house in Trondheim, Norway. Besides evaluating the hygrothermal performance of the different constructions, one of the main purposes of the test house measurements was collecting data for comparison with computer simulations of transient moisture transfer in building constructions. To be able to simulate the hygrothermal conditions of the various constructions the material properties have to be known. The most important material properties in this context are probably the water vapour permeability and the hygroscopic sorption curves. These two properties have been measured for most of the materials used in the constructions in the test house, and the results are presented in this paper.

The measurements have been carried out in the laboratories of the Norwegian Building Research Institute (NBI) and Department of Building and Construction Engineering, NTNU, Trondheim, during the period 1995-97. A more detailed presentation of these measurements and results is given in [1].

2 Methods

2.1 Water vapour permeability

The method has mainly been based on a Nordtest Method [2]. In addition corrections for the effect of the masked edge, the vapour resistance of the air layer in the cup and the surface resistance above the specimen have been included. The effect of increasing thickness of the air layer in the cup caused by evaporation of the salt solution during the measurement period has also been taken into account.

The material to be tested is placed on top of a cup as a lid. With the aid of a saturated salt solution, a constant relative humidity (RH) is obtained in the cup. This constant RH is then different from the RH that is obtained outside the cup. This creates a vapour flow either into or out of the cup. The vapour flow, determined through regular weighings of the cup, gives a measure of the vapour transfer rate. Then, by calculation, water vapour permeance, diffusion resistance and permeability can be determined. The water vapour permeance of the specimen is given by:

$$W = \frac{g}{\Delta p_v} \tag{1}$$

where W is the vapour permeance ($kg \cdot m^{-2} \cdot Pa^{-1} \cdot s^{-1}$), g is the density of water vapour flow ($kg \cdot m^{-2} \cdot s^{-1}$) and Δp_v is the vapour pressure difference between the saturated salt solution in the cup and the air outside of the cup (Pa). The test was stopped when five successive determinations of change in mass per weighing interval for each test specimen were constant within ± 5 % of the mean value for that specimen.

2.2 Sorption curves

The procedure for determining sorption curves was in accordance with a draft European Standard [3]. Four specimens of each material were dried in an oven according to [4]. The drying temperature was 40 °C for the gypsum board and 70 °C for the rest of the materials. When the dry mass of the specimens had been determined, the specimens were subsequently placed in the sorption apparatus at increasing RH levels to determine the adsorption curve and then at decreasing RH levels to determine the desorption curve. At every RH level the specimen was weighed until it was in equilibrium with the environment (constant mass). Constant mass was reached when the change of mass between two consecutive weighings made 24 hours apart was less than 0.1 % of the total mass.

For the adsorption curve six RH levels were used, obtained with the following salt solutions; $MgCl_2$, $MgNO_3$, NaCl, KBr, KNO_3 and K_2SO_4. The starting point of the desorption curve was the last point on the adsorption curve (K_2SO_4). For the desorption curve four RH levels were used, obtained with the following salt solutions; NaCl, $MgNO_3$, $MgCl_2$ and LiCl. The highest value on the adsorption curve for the different materials is not necessarily the final moisture equilibrium as we had to stop the experiment at the 97 % level after approximately 700 hours because of mould growth.

3 Materials and test equipment

2.1 Water vapour permeability

For the measurements, five specimens for each of the investigated materials were sealed at the top of the permeability cups made of aluminium, see Figure 1. It should be noted that the spruce specimens were mounted on somewhat different permeability cups, see [5]. The cups were placed in a room with a constant relative humidity of 50 ± 2 % RH and a temperature of 23 ± 1 °C. The "wet-cup" method was applied for all materials. The salt solution used in the cups was KNO_3, which yields a relative humidity of 94.0 ± 0.6 % at a temperature of 23 °C [3]. The average relative humidity across the test specimen was therefore approximately 72 % RH. The spruce was also measured at two other average RH-levels, i.e. 31 % and 63%. The salt solutions that were used were then respectively LiCl and NaCl.

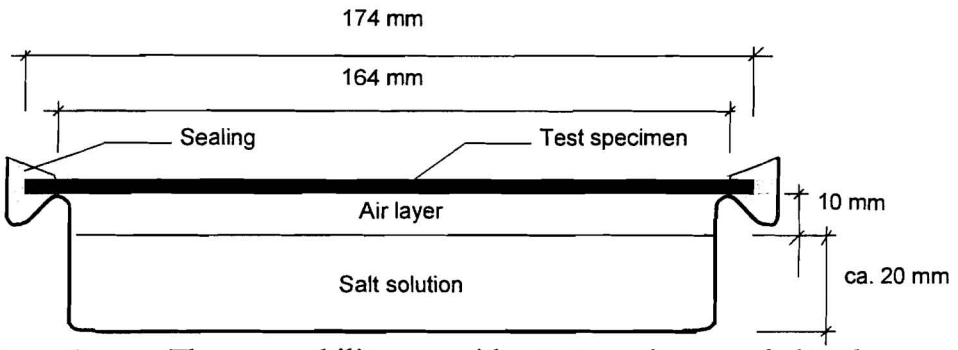

Figure 1 The permeability cup with a test specimen sealed to the cup.

2.2 Sorption curves

Between four and ten specimens of each of the five materials were prepared with a length and height of 70 mm and 50 mm, respectively. The thickness of the specimens equalled the thickness of the different board materials, however the specimens of aerated concrete and plywood were given a thickness of 40 mm and 9 mm, respectively. The thickness of spruce specimens varied between 2 mm and 10 mm. On each specimen a stainless steel hook was screwed approximately 2 mm into the specimen.

The sorption apparatus, which is a thin walled cylindrical polyethylene vessel with a top construction, is shown in Figure 2. The top construction includes a fan, a balance and the test specimens. The top construction can easily be moved from one vessel to another, so that the specimens quickly get into the next humidity level. The wanted RH-level is provided with shallow trays that are containing saturated salt solutions in the bottom of the vessels. The vessels are placed in a room with a fixed temperature at 23 ± 1 °C. Each vessel has six measuring points for temperature and three points for relative humidity. These values are logged every 30 minutes.

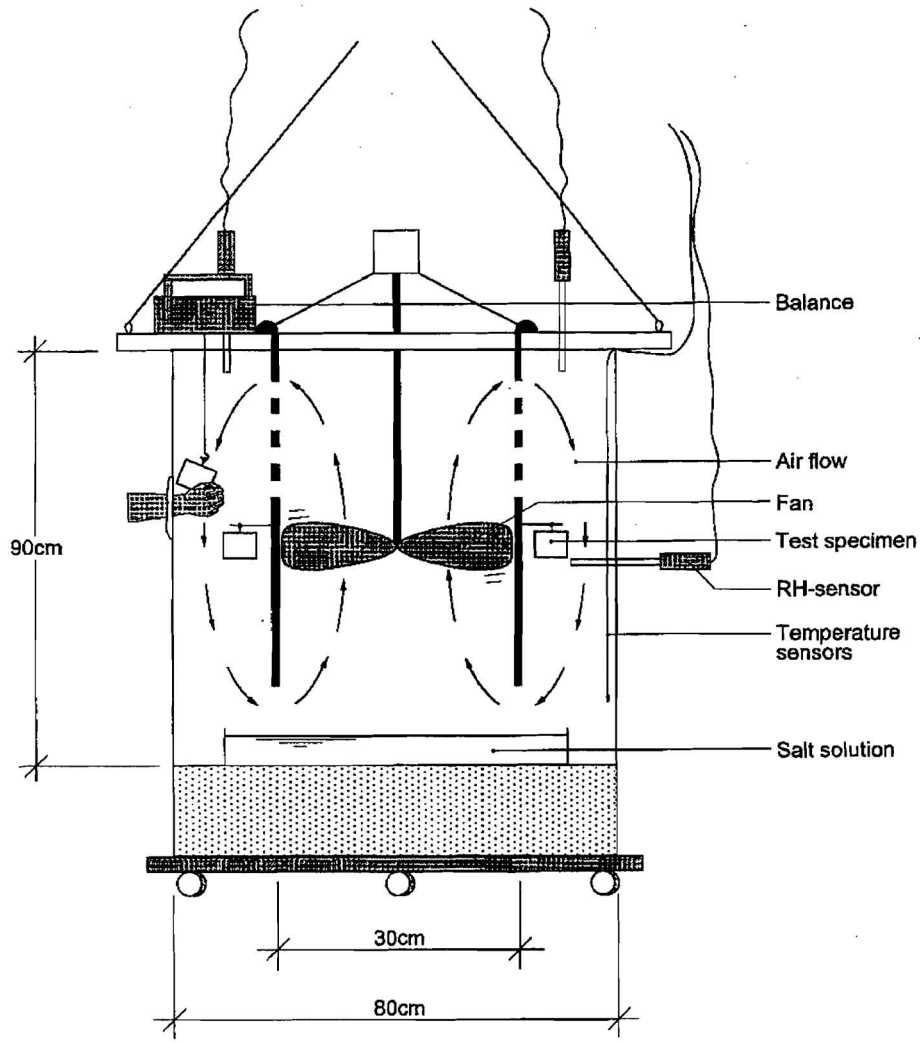

Figure 2 Cross section of the sorption apparatus.

4 Results

Table 1 Water vapour permeability for spruce measured in the transverse direction, i.e. a combined radial/tangential direction, for various RH-levels (with standard deviation σ). The values represent a mean value for thickness ranging from 2.4 mm to 10 mm.

Material	Density $kg \cdot m^{-3}$	Water vapour permeability ± σ ($10^{-12} \cdot kg \cdot m^{-1} \cdot Pa^{-1} \cdot s^{-1}$)		
		$\overline{RH}$: 31%	63%	72%
Spruce *	350-380	1.75 ± 0.34	6.01 ± 0.51	
Spruce *	440-465		3.94 ± 0.09	7.23 ± 0.26

* The measurements of the vapour permeability of spruce are more thoroughly reported in [5]. It should be noted that the procedures of those measurements may deviate to some extent from the procedures and methods described in the present paper.

Table 2 Measured water vapour permeance (with standard deviation σ). Average RH-level is 72 %.

Material	Thickn. mm	Density kg/m^3	Water vapour permeance ± σ (10^{-12}·kg·m^{-2}·Pa^{-1}·s^{-1})
Aerated concrete	21	474	1180 ± 70
Asphalt impregnated wood fibre board, porous	12	251	845 ± 264
Gypsum board, exterior grade	9	757	2430 ± 80
Plywood	22	411	145 ± 10
Polyethylene foil, vapour barrier	0.15		3.09 ± 0.57
Polypropylene foil, wind barrier	0,27		44.1 ± 3.3
PVC roofing membrane	1.3		15.0 ± 1.1
Spunbonded polyethylene foil, wind barrier	0.14		9720 ± 760
Wood fibre board, high density	11	803	371 ± 25

Table 3 Measured equilibrium moisture contents (weight-%) for adsorption and desorption curves.

	Wood chipboard		Wood fibre board (hardboard)		Plywood		Aerated concrete		Spruce	
RH (%)	Ads.	Des.	Ads.	Des.	Ads.	Des.	Ads.	Des.	Ads.	Des.
11.3	-	-	-	3.4	-	3.8	-	1.01	-	3.1
32.9	5.7	-	5.1	7.2	6.8	8.3	0.23	1.40	7.2	7.8
53.5	7.7	-	7.0	8.8	8.9	10.3	0.44	1.59	9.6	10.0
75.4	10.6	-	9.6	12.1	12.2	14.8	0.93	1.89	13.2	14.7
81.2	11.5	-	10.5	-	13.2	-	1.21	-	14.1	-
94	15.6	-	13.7	-	17.8	-	1.88	-	18.6	-
97.4	-	-	16.0	16.0	18.9	18.9	2.43	2.43	21.0	21.0

5 Discussion and conclusions

The measurements were compared with similar measurements documented in the literature, mainly from [6]. The results of the water vapour permeability measurements agree well with these previous measurements.

The measured results for sorption curves for different materials presented in this paper are however deviating more from results given in the literature. The following observations have been made:

- For the aerated concrete the difference in moisture content between the adsorption curve and the desorption curve is larger for all relative humidities in this report than in the corresponding measurements reported in [6]. This could imply that the final equilibrium values have not been attained, neither in adsorption nor desorption. However, the equilibrium criterion according to [3] has been fulfilled. The same effect has previously been observed for measurements on loose fill lightweight

expanded clay aggregates [7]. This equilibrium criterion might therefore not be suitable for materials that absorbs only small amounts of water (e.g. below 3 % by weight), and when the absorption and desorption processes are slow.

- For the wood based materials there are also significant deviations between the present results and other reported results. At the same time there are also significant deviations between the results from different laboratories, as reported in [6]. The moisture content of the wood fibreboard at the higher relative humidity levels are below values reported in the literature, a result which might imply that final equilibrium has not been attained. On the other hand, this is not the case for wood chipboard and plywood. The sorption curves reported for spruce, and the desorption isotherm in particular, are also relatively low compared to similar results reported in the literature. However, is known that measurements on sorption curves for spruce and pine vary quite a lot. A thorough comparison of sorption curves for spruce can be found in [5].

References

[1] E. Bergheim, S. Geving, B. Time. Hygroscopic material properties - Water vapour permeability and hygroscopic sorption curves for materials used in a test house. Project report 234, Norwegian Building Research Institute, Oslo, Norway, 1998.

[2] Building materials: Water vapour transfer rate, permeance and diffusion resistance. Nordtest Method NT Build 130 Edition 2, Nordtest, Espoo, Finland, 1990.

[3] Building materials - Determination of hygroscopic sorption curves. Working draft European Standard CEN/TC 89/WG 10 N 104, 1995

[4] Building materials - Determination of moisture content by drying at elevated temperature. Draft European Standard CEN/TC 89 N 338 E rev, 1995.

[5] B. Time. Hygroscopic Moisture Transport in Wood. Ph.D. Thesis. Norwegian University of Science and Technology (NTNU), Trondheim, Norway, 1998.

[6] M.K. Kumaran. Final Report Task 3: Material properties. IEA, Annex 24 HAMTIE. Laboratorium Bouwfysica, K.U.-Leuven, Belgium, 1996.