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Hygroscopic material properties

Water vapour permeability and hygroscopic sorption curves for materials used in a test house

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PREFACE

This report presents a part of the work which is carried out within the Strategic Research Programme «Moisture in building materials and constructions». The programme is carried out in a four year period 1993-1997 as a cooperation between the Norwegian Building Research Institute (NBI) and Department of Building and Construction Engineering, Norwegian University of Science and Technology (NTNU). The programme is mainly funded by the Norwegian Research Council, and additionally by internal funding from the participating institutions.

The programme includes the following projects:

0. General activities and programme management
1. Literature survey
2. Moisture physics
3. Calculation programs
4. Material properties
5. Verification
6. Dr.ing. (PhD) studies
7. International cooperation

The work presented in this report has been carried out within project 4 "Material properties".

Trondheim, February 1998

Einar Bergheim Stig Geving Berit Time

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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 (Uvsløkk et.al, 1997). The external envelope of the test house consists of wall and roof elements of different constructions. The external surfaces were exposed to the ambient climate, while the indoor climate in the house was controlled at 23 °C and 50 % RH. Moisture and temperature conditions in the elements were monitored continously. 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 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 report. The measurements have been carried out in the laboratories of the Norwegian Building Research Institute (NBI) and Department of Building and Construction Engineering, NTNU, in Trondheim during the period 1995-97.

2 THEORY

The transient one-dimensional movement of water vapour within a porous material is given by the conservation of mass equation:

$$\rho \cdot \xi(T,\phi) \cdot \frac{\partial \phi}{\partial t} = \frac{\partial}{\partial x}\left(\delta_p(T,\phi) \cdot \frac{\partial}{\partial x}(\phi \cdot p_s(T))\right) \qquad (1)$$

where ρ is the dry density of the material (kg·m^{-3}), T is the temperature (°C), ϕ is relative humidity (%), t is time (s), $p_s(T)$ is saturated water vapour pressure (Pa), $\delta_p(T, \phi)$ is the water vapour permeability (kg·m^{-1}·Pa^{-1}·s^{-1}) and $\xi(T, \phi)$ is the specific moisture capacity (kg·kg^{-1}).

The water vapour permeability is a weak function of temperature, however the dependence of relative humidity may be strong for some types of materials. The specific moisture capacity is the slope of the sorption curve function u(T, ϕ) given by:

$$\xi(T,\phi) = \frac{\partial u(T,\phi)}{\partial \phi} \approx \frac{\partial u(\phi)}{\partial \phi} \qquad (2)$$

The sorption curve is the relationship between the moisture content of a material and the relative humidity of the ambient air at equilibrium with the environment, at a specified temperature. The sorption curve characterizes the storage of moisture within a material. A typical sorption curve is shown in Figure 1.

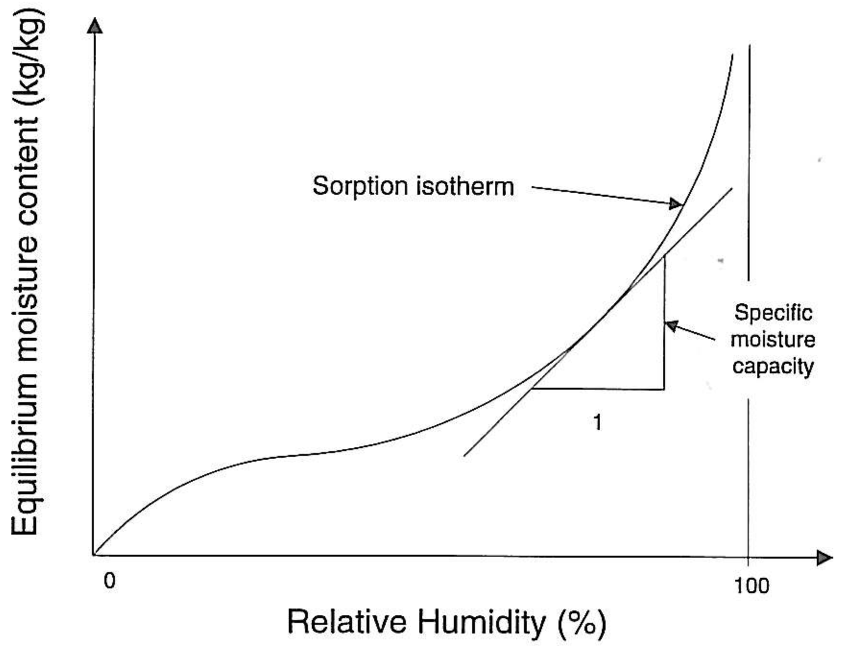

Figure 1 *A typical sorption curve*

3 DESCRIPTION OF TEST MATERIALS

The materials which have been tested are briefly described in Table 1.

Table 1 *Specification of materials for sorption and vapour permeability tests*

Material	Trade name in Norway / manufacturer *	Thickness [mm]	Density [kg/m^3]	Measured: Sorption curve	Vapour perm.
Aerated concrete	"Siporex vegg/tak element" / Siporex A/S, Norway	-	474	X	X
Asphalt impregnated wood fibre board, porous	"Asfalt vindtett" / Hunton Fiber A/S, Norway	12	251		X
Gypsum board, exterior grade	"GU, Utvendig gipsplate" / Norgips A/S, Norway	9	757		X
Plywood **	"WBP P-30, Vänerply takplater" / Vänerply AB, Sweden	22	411	X	X
Polyethylene foil, 0.15mm (PE-building membrane)	"Tenotett" / Rosenlew AB, Sweden	0.15			X
Polypropylene foil, wind barrier	"Rockwool airbarrier" / Reemay Inc., USA	0.27			X
PVC roofing membrane	"Sarnafil SE 3" / Protan A/S, Norway	1.3			X
Spruce (Picea abies)			350-465	X	X ****
Spunbonded polyethylene foil, wind barrier	"Tyvek" / Du Pont de Nemours, Luxemb.	0.14			X
Particle board	"Sponplate" / Norske skogindustrier A/S	12	554	X ***	
Wood fibre board (hardboard)	"Huntonit bygningsplate" / Hunton Fiber A/S, Norway	11	803	X	X

* Proprietary trade names are listed only as an aid to identify the material tested and do not constitute an endorsement of that product either by the NBI or by Dept. of Building and Construction Engineering. The reader is cautioned that manufacturers may change products over time while retaining the same brand name.

** Material of spruce or pine, number of layers = 7.

*** Only the adsorption curve was measured.

**** The measurements of the vapour permeability of spruce are more thoroughly reported in (Time, 1998). It should be noted that the procedures of those measurements may deviate to some extent from the procedures and metods described in the present report.

4 MEASUREMENTS OF WATER VAPOUR PERMEABILITY

4.1 Description of method

The experiments have mainly been based on the Nordtest method NT Build 130 (NT Build, 1990). 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 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 which 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 transfer rate is a function of various factors such as the difference in vapour pressure, temperature, air velocity above the specimen, air layer thickness below the specimen as well as the specific material properties.

The water vapour permeance of the specimen is given by:

$$W = \frac{g}{\Delta p_v} \tag{3}$$

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). For the tests of this report, Eq. 3 was corrected for the vapour transfer resistance of the air layer in the cup, the surface resistance above the specimen and the effect of the masked edge:

$$W = \frac{1}{\frac{\Delta t}{\Delta G} \cdot \Delta p_v \cdot A - Z_l - Z_o} \cdot \frac{1}{1 + \frac{g_0}{100}} \tag{4}$$

where Δt is the time interval between two successive weighings of the test assembly (s), ΔG is the difference in mass between two successive weighings of the test assembly (kg), A is the test area of the specimen (m^2), Z_l is the vapour transfer resistance of the air layer in the cup ($m^2 \cdot s \cdot Pa \cdot kg^{-1}$), Z_o is the surface vapour resistance above the specimen ($m^2 \cdot s \cdot Pa \cdot kg^{-1}$) and g_0 is the extra vapour flow caused by the effect of the masked edge given as a percentage of the vapour flow without the masked edge effect.

Accounting for the water vapour resistance of the air layer in the cup (Z_l) and the surface resistance (Z_o) becomes increasingly important as the permeance of the material increases. The vapour resistance of the air layer is calculated as:

$$Z_l = \frac{s_a}{\delta_a} \tag{5}$$

where s_a is the thickness of the air layer (m) and δ_a is the water vapour permeability of air ($kg \cdot m^{-1} \cdot Pa^{-1} \cdot s^{-1}$). The effect of increasing s_a caused by evaporation of the salt solution during the measurement period is taken into account:

$$s_{a,n} = s_{a,1} + \frac{\Delta m_s}{A \cdot \rho_v} \tag{6}$$

where $s_{a,n}$ is the thickness of the air layer at time n (m), $s_{a,1}$ is the thickness of the air layer at start (m), Δm_s is the weight change of the test assembly since start (kg), A is the area of the surface of the salt solution (m^2) and ρ_v is the density of water ($kg \cdot m^{-3}$). $s_{a,1}$ was 10 mm in these tests.

δ_a is calculated according to (CEN, 1994):

$$\delta_a = \frac{2.306 \cdot 10^{-5} \cdot p_0}{R_v \cdot T_a \cdot p} \left(\frac{T_a}{273} \right)^{1.81} \tag{7}$$

where R_v is the gas constant for water vapour (= 462 $J \cdot kg^{-1} \cdot K^{-1}$), T_a is the temperature of the air (K), p is the average atmospheric pressure during testing (Pa) and p_0 is the standard atmospheric pressure (= 10132.5 Pa).

The surface vapour resistance above the cup (Z_o) is dependent of the wind speed, given by the following formula (Welty, 1994):

$$Z_o = 0.0027 \cdot \frac{v^{-0.5011}}{\delta_a} \tag{8}$$

where v is the wind speed above the specimen (m/s). The wind speed above the specimen was approximately 0.3 m/s during these tests.

The extra vapour flow (given in %) caused by the effect of the masked edge of the sample was calculated according to the following formula (Nielsen, 1992):

$$g_0 = \frac{100 \cdot O \cdot d}{A \cdot \pi} \cdot \ln \left(\frac{2}{1 + \exp(-2\pi \cdot (b/d))} \right) \tag{9}$$

where d is the thickness of the specimen (m), b is the width of the masked edge (m), O is the perimeter of the test area (m) and A is the test area (m^2).

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.

It should be noted that the measurements on spruce followed a somewhat different procedure, see (Time, 1998).

4.2 Preparation of specimens and test equipment

All the specimens reported here were preconditioned at an RH of approximately 50% and a temperature of approximately 23 °C before they were sealed to the cup. For the measurements, five specimens for each of the investigated materials were sealed at the top of the permeability cups. The specimens were all 174 mm in diameter.

The cups were made from aluminium and were furnished with a protective coating inside to prevent the salt and the aluminium to react chemically. The specimen was first sealed around the edge with a sealing compound consisting of 70% plasticine and 30% bees wax, see Figure 2. The sealing of the edges was not applied for foil materials. Thereafter the specimen was sealed to the cup with the same sealing compound. The sealing of the specimen to the cup is shown in Figure 3. It should be noted that the spruce specimens were mounted in somewhat different permeability cups, see (Time, 1998).

The cups were placed in a room with a constant relative humidity of 50 ± 2 % RH and a temperature of 23 ± 1 °C. An electronic balance with an accuracy within the range of ± 0.001 g was used for the weighings.

The "wet-cup" method was applied for all materials. The salt solution used in the cups was potassium nitrate (KNO_3). At a temperature of 23 °C, a relative humidity of 94.0 ± 0.6 % (CEN, 1995b) is obtained above the saturated salt solution. The average relative humidity across the test specimen was therefore approximately 72 % RH.

For some of the materials the water vapour permeability was also measured at other RH-levels by placing the cup in sealed glass vessels. The glass vessels were maintained at a constant temperature of 23 ± 1 °C. The materials of which this applies are shown in Table 2, including RH levels and salt solutions used. However, spruce specimens at additional RH levels were not placed in the glass wessels, but were placed in the room with a constant relative humidity of 50 ± 2 % RH and a temperature of 23 ± 1 °C

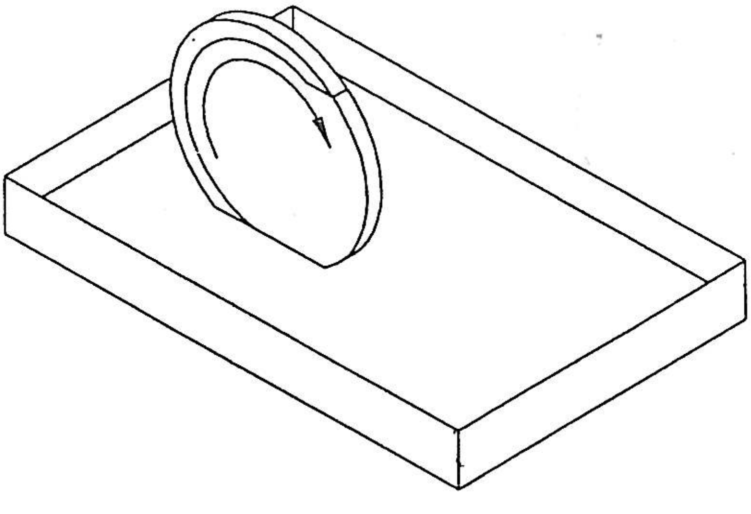

Figure 2 Sealing of edges of the specimen before sealing to the cup.

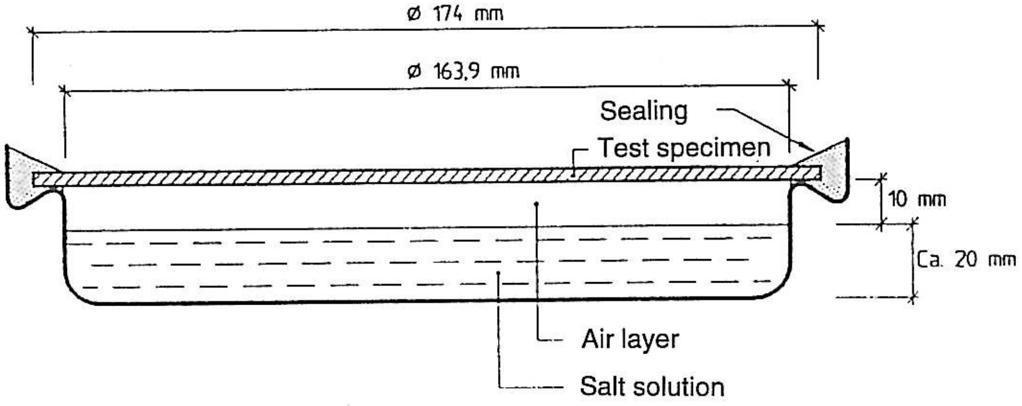

Figure 3 *The permeability cup with a test specimen sealed to the cup.*

Table 2 *Materials tested at extra RH-levels in <u>addition</u> to $\overline{RH} \approx 72\%$, showing the salt solutions used and the equilibrium RH at a temperature of 23 °C according to (CEN, 1995b).*

Material		**RH-levels and salt solutions**				
		$\overline{RH}$: **31 %**	**46 %**	**63 %**	**75 %**	**82 %**
PE-foil	Inside the cup		LiCl 11.3±0.3 %			
	Glass vessel		KBr 81.2±0.2 %			
PVC-membrane	Inside the cup				KI 69.3±0.3 %	KNO_3 94.0±0.6 %
	Glass vessel				KBr 81.2±0.2 %	KI 69.3±0.3 %
Spruce	Inside the cup	LiCl 11.3±0.3 %		NaCl 75.4±0.1		
	Room	50±2 %		50±2 %		
Wood fibre board (high density)	Inside the cup					KNO_3 94.0±0.6 %
	Glass vessel					KI 69.3±0.3 %

4.3 Results

The results of the measurements are shown in Table 3 and 4.

Table 3 Water vapour permeance measured for the foil materials and the materials with distinct layers (with standard deviation σ).

Material	**Thickness d (mm)**	**Water vapour permeance ± σ ($10^{-12}\cdot$kg$\cdot$m$^{-2}\cdot$Pa$^{-1}\cdot$s^{-1})**			
		$\overline{RH}$: **46%**	**72%**	**75%**	**82%**
Aerated concrete	21		1180 ± 73		
Asphalt impregnated wood fibre board, porous	12		845 ± 264		
Gypsum board, exterior grade	9		2430 ± 75		
Plywood	22		145 ± 10		
Polyethylene foil, vapour barrier	0.15	1.24 ± 0.70	3.09 ± 0.57		
Polypropylene foil, wind barrier	0,27		44.1 ± 3.3		
PVC roofing membrane	1.3		15.0 ± 1.1	8.15 ± 1.48	9.32 ± 1.83
Spunbonded polyethylene foil, wind barrier	0.14		9720 ± 763		
Wood fibre board, high density	11		371 ± 25		116 ± 17

Table 4 Water vapour permeability for spruce measured in a transverse direction, i.e. a combined radial/tangential direction (with standard deviation σ). The thickness of the specimens ranged 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 (Time, 1998). It should be noted that the procedures of those measurements may deviate to some extent from the procedures and metods described in the present report.

4.4 Discussion

The present measurements are compared with measurements documented in (Kumaran, 1996) and values given in the material database of the heat and moisture computer program MATCH (MATCH, 1991), see Table 5. The results seem to agree well with these previous measurements.

Table 5 Comparison between measured vapour permeability of this report and measurements from the literature ($\overline{RH} \approx 72\%$).

Material	Water vapour permeability ($kg \cdot m^{-1} \cdot Pa^{-1} \cdot s^{-1}$) Present measurements	Measurements from literature	References
Aerated concrete	$2.5 \cdot 10^{-11}$	$3.5 \cdot 10^{-11}$	(Kumaran, 1996)
Asphalt impregnated wood fibre board, porous	$1.0 \cdot 10^{-11}$	$3.6 \cdot 10^{-11}$	(Kumaran, 1996)
Gypsum board, exterior grade	$2.2 \cdot 10^{-11}$	$4.2 \cdot 10^{-11}$	(Kumaran, 1996)
Plywood	$3.2 \cdot 10^{-12}$	$5.0 \cdot 10^{-12}$	(Kumaran, 1996)
Polyethylene foil, vapour barrier	$4.7 \cdot 10^{-16}$	$6.9 \cdot 10^{-16}$	(Kumaran, 1996)
Polypropylene foil, wind barrier	$12 \cdot 10^{-15}$	$4.0 \cdot 10^{-15}$	(Kumaran, 1996)
PVC roofing membrane	$1.9 \cdot 10^{-14}$	$0.8 \cdot 10^{-14}$	(MATCH, 1991)
Spruce	$7.2 \cdot 10^{-12}$	$5.6 \cdot 10^{-12}$	(Kumaran, 1996)
Spunbonded polyethylene foil, wind barrier	$13 \cdot 10^{-13}$	$12 \cdot 10^{-13}$	(Kumaran, 1996)
Wood fibre board, high density	$4.1 \cdot 10^{-12}$	$2.3 \cdot 10^{-12}$	(MATCH, 1991)

5 MEASUREMENTS OF SORPTION CURVES

5.1 Description of method

Four specimens of each material were dried in an oven according to (CEN, 1995a). The drying temperature was 40 °C for the gypsum board and 70 °C for the rest of the materials. Constant mass was reached when the change of mass between three consecutive weighings made 24 hours apart was less than 0.1 % of the total mass.

It should also be mentioned that parallel measurements were performed on specimens that were desiccated above dry calcium-chloride ($CaCl_2$). The same criterion for constant mass was used as for drying in an oven. The equilibrium relative humidity above this desiccant should be 1.4 % according to (Richards et al., 1992). Desiccant drying was employed since it has been argued that oven drying for the purpose of removing moisture may also lead to removal of other volatiles and changes in the chemical or structural composition of the specimen (Richards et al., 1992). Later it was found, however, that the dry calcium-chloride did not yield 1.4 % RH, but a significantly higher RH. The results from these measurements are therefore left out from this report.

When the dry mass of the specimens had been determined, the specimens were subsequently placed in the sorption apparatus (see Chapter 5.2) at increasing RH levels to determine the adsorption curve and then at decreasing RH levels to determine the desorption curve. The procedure was in accordance with a draft European Standard (CEN, 1995b). 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. The moisture content u ($kg \cdot kg^{-1}$) was calculated as follows for each specimen:

$$u = \frac{m - m_0}{m_0} \tag{10}$$

where m is the mass of the specimen (kg) at equilibrium at the actual relative humidity and m_o is the dry mass of the specimen (kg).

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 equilibrium RH at 23 °C for the various salt solutions is shown in Table 5. Also shown in Table 6 is the measured average RH above the salt solution the last two days before the stability criterion was reached. As can be seen, there is some deviation between the assumed value and the measured values. During the measurements we were not able to obtain a stable temperature of 23 °C, and some of the deviations may be due to temperature fluctuations.

The starting point of the desorption curve was the last point on the adsorption curve (K_2SO_4). However, at the last point of the adsorption curve mould growth was observed at the surfaces of some of the woodbased specimens, especially visible at the particle board specimens. It was decided to brush off the visible mould and go directly to a relative humidity below 80 % to avoid more mould growth. For the desorption curve four RH levels were used, obtained with the following salt solutions; NaCl, $MgNO_3$, $MgCl_2$ and LiCl.

Table 6 Equilibrium relative humidities for saturated salt solutions at 23 °C according to (CEN, 1995b). The measured average RH above the salt solution during the last two days before stability criterion was reached is also shown.

Salt	Formula	Equilibrium RH (%)	Measured RH (%)	
			Adsorption	Desorption
Lithium chloride	LiCl	11.3 ± 0.4		10.9
Magnesium chloride	$MgCl_2$	32.9 ± 0.2	32.7	40.3
Magnesium nitrate	$MgNO_3$	53.5 ± 0.2	48.5	56.3
Sodium chloride	NaCl	75.4 ± 0.1	78.0	84.1
Potassium bromide	KBr	81.2 ± 0.2	86.1	
Potassium nitrate	KNO_3	94.0 ± 0.6	93.1	
Potassium sulphate	K_2SO_4	97.4 ± 0.5	96.1	

5.2 Description of specimens and sorption apparatus

The apparatus consists of a thin walled (2 - 3 mm thick) cylindrical polyethylene vessel with a diameter of 80 cm and a height of about 90 cm (Figure 4 and 5). Shallow trays containing saturated salt solutions are placed in the bottom of the vessel to provide a given relative humidity.

A construction containing the test specimens and a fan, is fixed to the top lid of the vessel (Figure 4). This construction consists of a cylindrical polymethylmethacrylate (PMMA) plastic slab (15 mm) with a polyvinyl chloride (PVC) tube in the middle. The PVC tube is hanging on the slab, though it is possible to turn the tube. The diameter of the slab is about 85 cm and the tube about 30 cm. Rigid steel wires, on which to hang the test specimens, are fastened symmetrically around the tube. Inside the tube there is a fan which makes the air circulate through the tube, out in top of the tube, passing by the specimens on the outside, going down above the trays containing the salt solution before it is drawn back up into the tube.

The top construction can easily be moved from one vessel to another, so that the specimens quickly get into the next humidity level. The top construction is mechanically lifted up so that the vessels can change place.

The test specimens are hung on to the rigid steel wires by small stainless steel hooks. The diameter of the hooks is 2,5 mm and they are screwed 2 - 3 mm into the test specimens.

The weighing of the specimens is done by moving them from their hanging position to a suspended hook below the balance. The balance has a fixed position on the top construction. By turning the PVC tube the specimens get into the right position for weighing. The moving of the specimens is done by putting ones hand through a flexible opening in the vessel. The opening is closed as soon as the hand is taken out.

An electronic precision balance is used for the weighings. The readability range is from 0 to 400 g with a precision of ± 0.001 g. The balance is placed on the top construction, and the scale of the balance is suspended in a thin, rigid metal wire which is led through the PMMA slab.

The vessels are placed in a room with a fixed temperature normally at 23 ± 1 °C. However, because of unusually high outdoor temperatures and the fact that the fan produced some heat, the temperatures in the vessels during some periods was higher than 23 °C. The temperatures varied between approximately 24 and 28 °C. Each vessel has six measuring points for temperature and three points for relative humidity. These values are logged every 30 minutes.

The air velocity around the specimens was measured at 16 levels, at four different heights and four different distances from the tube where the air flows. Values between 0.8 m/s and 2.1 m/s were found, with an average of 1.6 m/s.

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. A sketch of a specimen is shown in Figure 6.

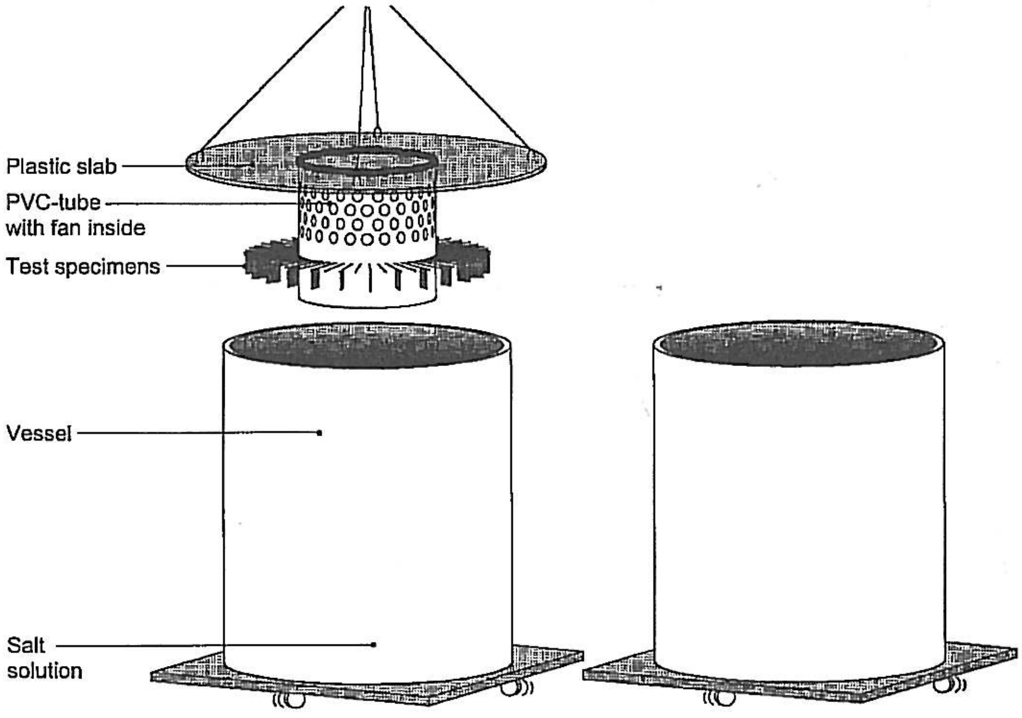

Figure 4 *Sketch of the apparatus, described in the text.*

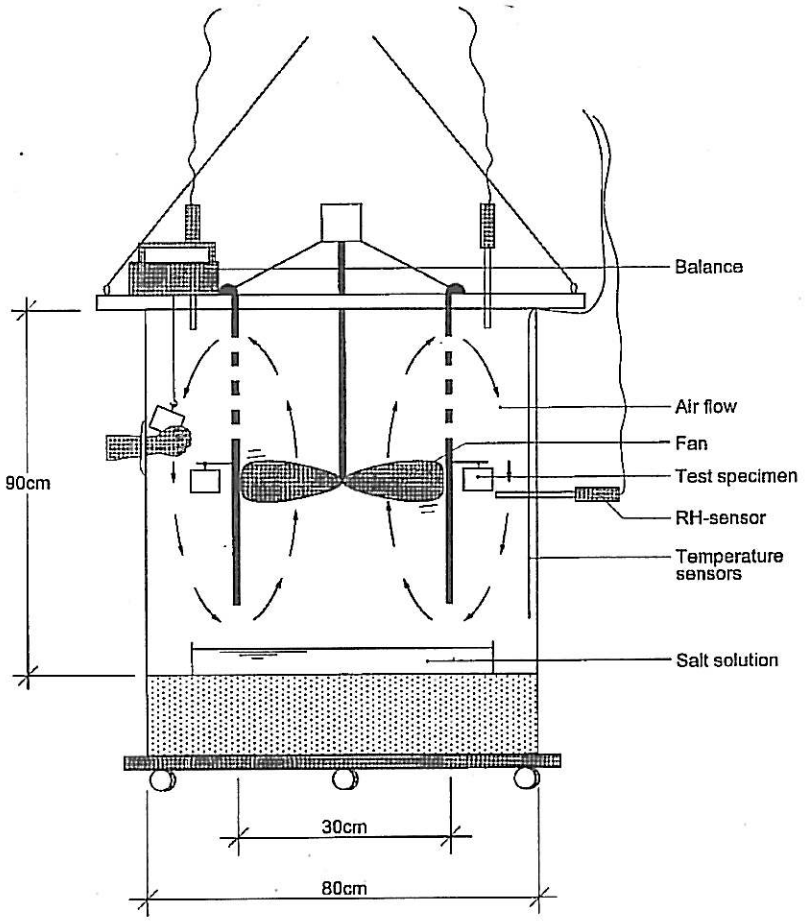

Figure 5 *Cross section of the apparatus described in the text.*

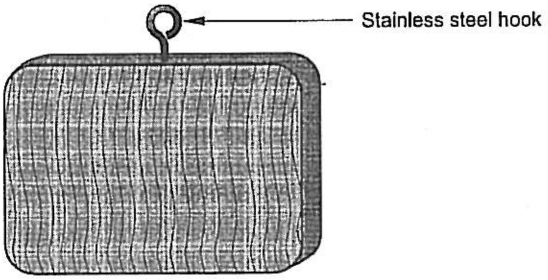

Figure 6 *The test specimen*

5.3 Results

The results from the measurements are shown in Figures 7-11 and Table 7. The relative humidity that is used in the figures and the table is the equilibrium relative humidity for the saturated salt solution at 23 °C according to Table 3 and (CEN, 1995b). It should be noted that the real relative humidities occurring may be deviating from these values, e.g., see the measured average RH above the salt solution during the last two days before the stability criterion was reached as shown in Table 3.

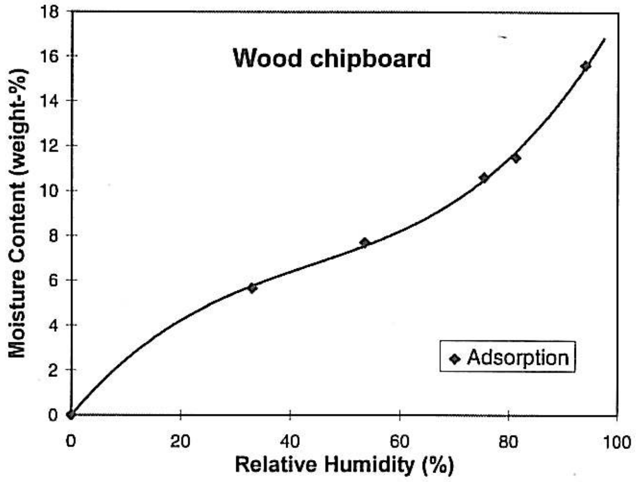

Figure 7 Adsorption curve for particle board. Desorption curve was not measured.

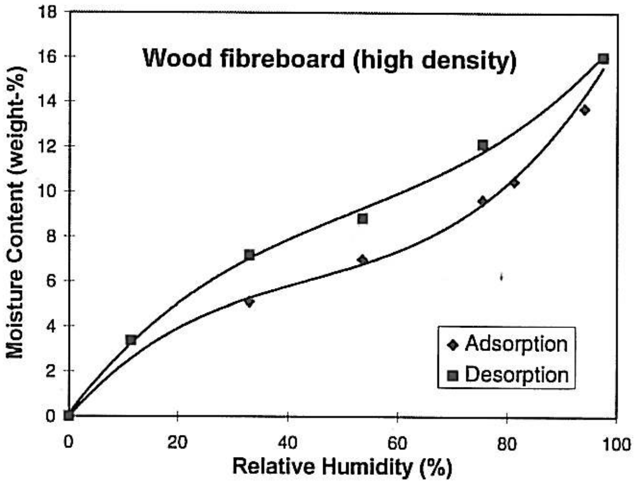

Figure 8 Sorption curves for wood fibreboard (hardboard).

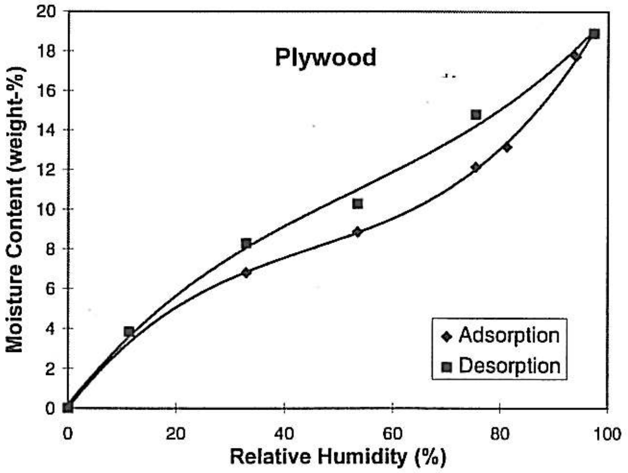

Figure 9 Sorption curves for plywood.

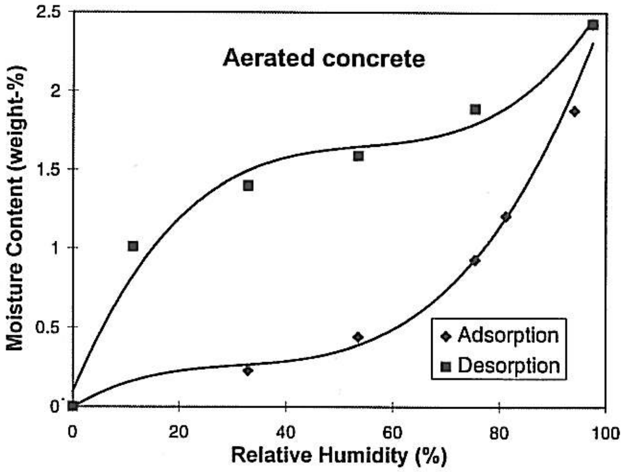

Figure 10 Sorption curves for aerated concrete.

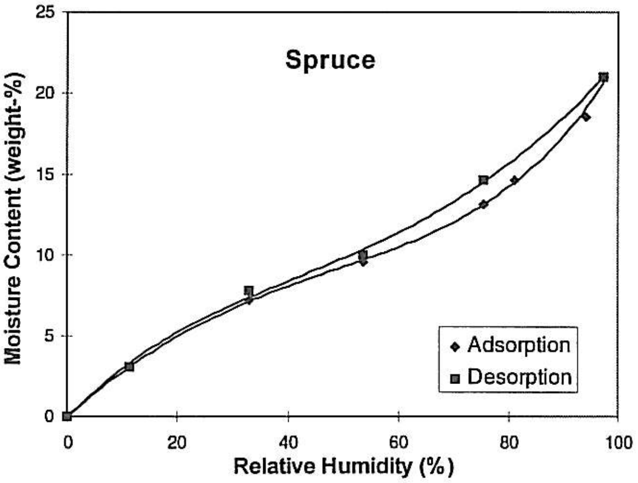

Figure 11 Sorption curves for spruce. Density is 390 kg/m^3.

Table 7 Measured equilibrium moisture contents (weight-%) for adsorption and desorption curves.

	Particle board		**Wood fibre board (hardboard)**		**Plywood**		**Aerated concrete**		**Spruce**	
RH (%)	Ads.	Des.	Ads.	Des.	Ads.	Des.	Ads.	Des.	Ads.	Des.
11.3	-	-	-	3.37	-	3.84	-	1.01	-	3.06
32.9	5.66	-	5.1	7.18	6.81	8.28	0.23	1.4	7.21	7.8
53.5	7.69	-	6.99	8.84	8.86	10.3	0.44	1.59	9.60	10.0
75.4	10.6	-	9.64	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

5.4 Discussion

The measured results for sorption curves for different materials presented in this report are deviating more from results given in the literature than the measured results for water vapour permeability. Compared to results from corresponding measurements reported in (Kumaran, 1996) 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 (Kumaran,1996). This could imply that the final equilibrium values have not been reached, neither in adsorption nor desorption. However, the equilibrium criterion according to (CEN, 1995b) has been fulfilled.
- For the woodbased 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 (Kumaran, 1996). The difference between the highest desorption curve and the lowest adsorption curve is varying between 2 and up to 10 weight %. 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 reached. On the other hand, this is not the case for particle board 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. A thorough comparison of sorption curves for spruce can be found in (Time,1998).

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.

Comparisons of results from different projects might be a bit unreliable, as there are differences between products of the same kind, which can affect the hygroscopisity. Such differences can be the density, the production process, types of admixtures etc.

The stability criterion as given in the test method (CEN, 1995b) might not be good enough for materials which absorb and desorb small amounts of moisture slowly.

6 CONCLUSIONS

Water vapour permeability and sorption curves were measured for various building materials. Water vapour permeability were measured for nine common materials, and the results reported here compare favourably with previously published data. Sorption curves were measured for four different materials. Some deviations between present results and previously published data were observed. The measurements were carried out in the laboratories of the Norwegian Building Research Institute (NBI) and Department of Building and Construction Engineering, NTNU, in Trondheim during the period 1995-97.

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