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Factors Affecting the Moisture Permeability of Porous Materials and the Calculation of Moisture Transport and Condensation Hazard in Building Structures

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FACTORS AFFECTING THE MOISTURE PERMEABILITY OF POROUS MATERIALS AND THE CALCULATION OF MOISTURE TRANSPORT AND CONDENSATION HAZARD IN BUILDING STRUCTURES

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The transfer of heat and moisture in building materials and building structures is a very complex process. The heat and the moisture flow are both individually dependent on a number of factors of physical and structural nature and they are at the same time more or less interdependent. Due to the complexity of the process and our limited knowledge of it the heat flow and the mass flow are usually considered separately for calculation purposes. Existing equations, taking into account the mutual influence of heat and moisture, are in general inapplicable for technical calculations in practice. The reason is partly that a comprehensive calculation work is involved and particularly that the application of these equations in many cases presupposes knowledge of various physical data which have not yeat been established for more than some few materials. As an example may be mentioned the influence of temperature and moisture content on the suction properties and the moisture flow factors of the materials.

To get an idea of the condensation hazard in building structures some simplified calculation methods are often applied. A characteristic feature of these methods is the assumption of an one dimensional stationary flow. The temperature and vapour pressure pattern in the structure are calculated from certain in- and outside design temperatures and humidities using more or less average values of the heat conductivities and moisture permeabilities of the materials. For structures consisting of parallell layers of material, the thickness of the various layers is often represented in units of heat and vapour resistance instead of in units of length which gives the temperature and vapour pressure curves as straight lines. If the cumputed vapour pressure does not exeed nor is equal to the saturation pressure of water vapour at any point in the structure, there is assumed to be no or little condensation hazard.

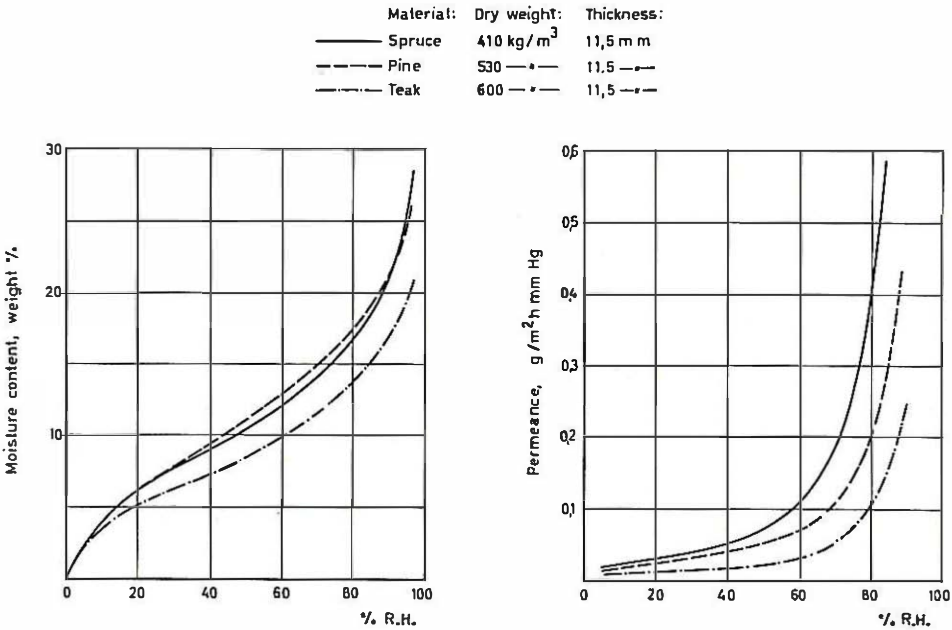
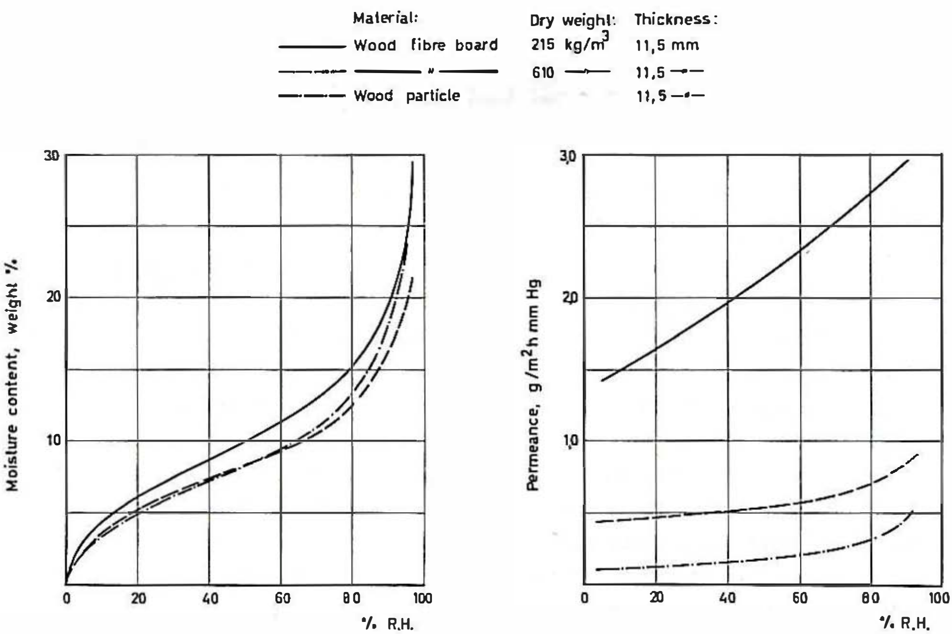

Material: Dry weight: Thickness:
Spruce 410 kg/m3 11,5 mm
Pine 530 11,5
Teak 600 11,5
Moisture content, weight %
Permeance, g/m2h mm Hg
% R.H.

Figure 1.


Material: Dry weight: Thickness:
Wood fibre board 215 kg/m3 11,5 mm
" 610 11,5
Wood particle 11,5
Moisture content, weight %
Permeance, g/m2h mm Hg
% R.H.

In spite of the fact that the basis of this calculation method is somewhat doubtful, the application of it has shown to be acceptable for practical purposes, as damages due to condensation have been fairly scarce. It must here be interposed that there have certainly been quite a lot of condensation troubles in lightweight roof constructions, but these have mostly been caused by air leakages. The reason why this calculation method seems to make good is that some of the simplifications being done tend to draw in a favourable direction. Whilst for insrance the moisture permeability of the materials are determined under temperature equilibrium the moisture transport will in practice be influenced by a temperature gradient. Another point is that the calculation of the moisture transport in structures in most cases is carried out under assumption of extremely unfavourable temperature and humidity conditions.

A third point is the influence of temperature and humidity on the moisture transport ability of porous materials. Experience has shown that the moisture permeability of certain materials depends very much on their moisture content, which within the hygroscopic range under equilibrium conditions is a function of ambient temperature and humidity. This appears for instance in the ASTM Designation: C355-54T as two different methods of measuring the water vapour transmission of materials at a low and a high humidity level, i.e. the "desiccant method" and the "water method". In calculations concerning the condensation hazard in structures no or little attention is paid to this effect of the moisture content.

Measurements[1]) which have been carried out in the laboratory of the Norwegian Building Research Institute clearly shows the great influence of the moisture content on the moisture transport ability of certain materials. Fig. 1 ··· 7 give an abstract of the results of the moisture sorption and moisture permeability measurements on various common, porous building materials at a temperature of 25°C.

Fig. 1 shows the relationship between the moisture permeance normal to fibre direction and ambient mean relative humidity for 11.5 mm thick specimens of spruce, pine and teak. The permeability is fairly low in the lower humidity range but increases rapidly when the relative humidity is greater than approximately 70 %. As will be seen from the sorption curves in the diagram to the left, this increase corresponds well to the increase in moisture content.

Fig. 2 and 3 show the sorption and permeability curves of some boards of wood fibres and wood particles. These materials have naturally much the same sorption properties as wood, but the moisture permeability is otherwise as the distribution of the fibre directions are at random and compared with wood the boards have not the same continuous capillary system. This leads to an increase

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[1]) These measurements are a part of a research work on moisture transport in porous materials which is being carried out as a cooperation of The Danish National Institute of Building Research, The State Institute for Technical Research in Finland, The Swedish National Council of Building Research and The Norwegian Building Research Institute.

Material: Dry weight: Thickness:
Wood fibre board 870 kg/m^3 3 mm
" 6% asph.impr. 960 " 3 "
" oil impr. 1040 " 3 "

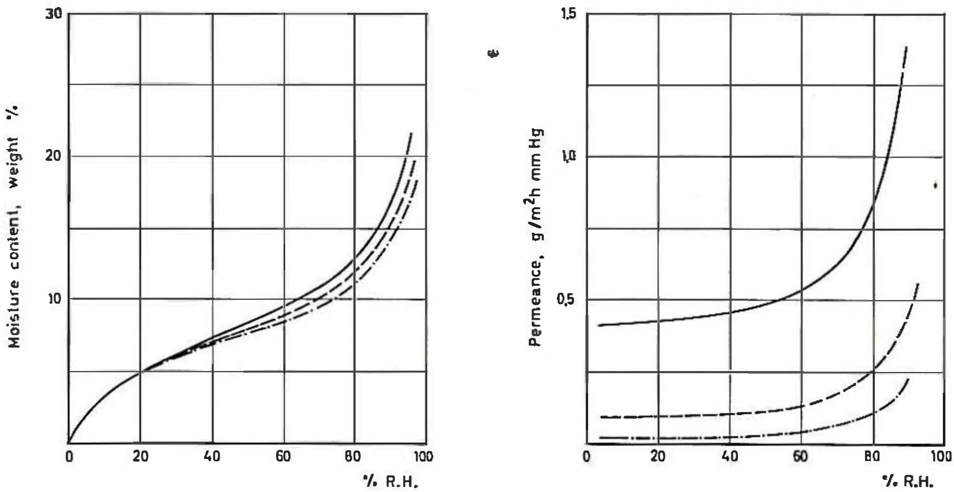


Figure 3.

Material: Dry weight: Thickness:
Sheathing felt unimpregnated 500 g/m^2 1,0 mm (permeance scale: 0 – 15 g/m^{2}h mm Hg)
" asph.saturated 600 " 0,7 " (" 0 – 0,

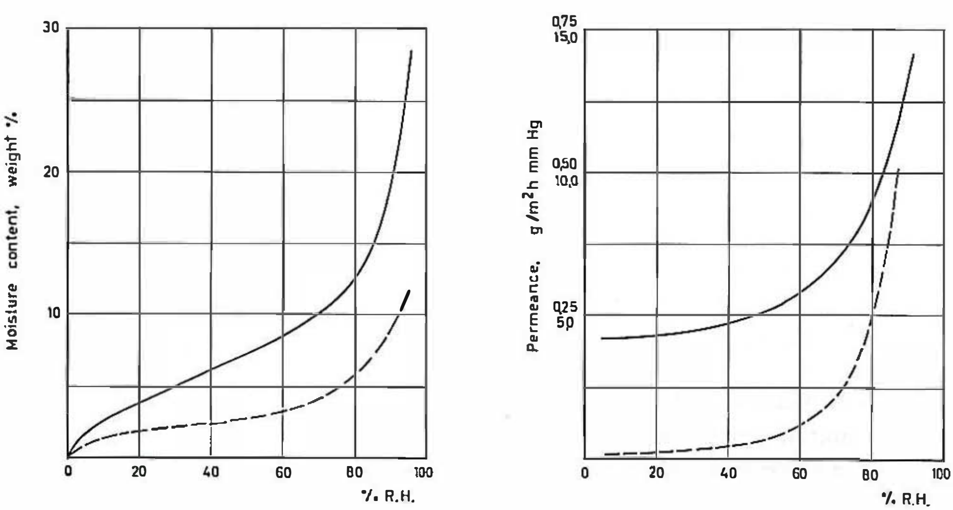


Figure 4.

in vapour diffusion in the lower humidity range and a decrease in liquid transport in the higher range. The slope of the curves of the heavier qualities of fibre boards as shown in Fig. 3 are, however, much the same as for wood. With regard to the sorption the effect of the impregnation is surprisingly small. The reduced permeability of the impregnated boards may be due to the impregnation, but it may also be attributed to the higher density of these boards.

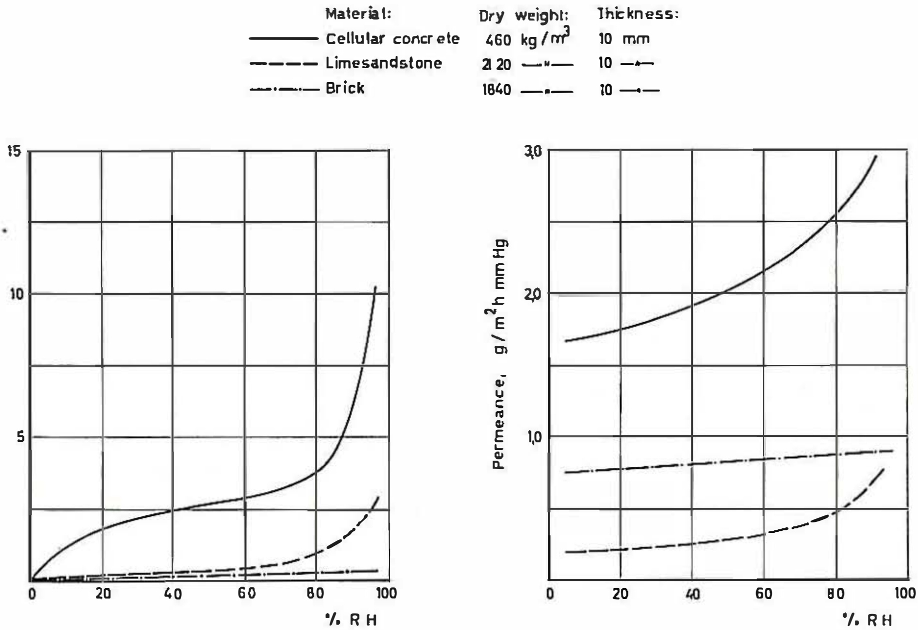
The moisture sorption and permeance of an unimpregnated and an asphalt saturated building felt are shown in Fig. 4. The saturated felt is intended for wind protection in exterior walls. As appears from the diagram, the moisture permeance increases very much with increasing relative humidity in the higher humidity range. This is a very favourable property of a sheathing felt, as it in a frame wall normally is placed just where the condensation hazard is greatest. If by some reason the relative humidity in the wall cavity is raised, the building felt will sorb moisture and increase its moisture permeability. This increased moisture permeability will tend to lower the vapour pressure and a new equilibrium may be reached.

The change in permeability of various, mostly inorganic materials as cellular concrete, lime-sandstone, brick, cement-asbestos boards etc. is given in Fig. 5 and 6. The hygroscopic moisture content of brick is very low and the permeability is almost independent on the relative humidity. This means that the pure vapour diffusion is predominating. Cellular concrete has a high permeability in the entire humidity range, and the vapour diffusion is predominating at the lower humidities. The measurements showed that the permeability of cellular concrete of the same density differed quite much from one quality to another depending on the pore structure. The permeability of lime-sandstone, cement-asbestos board and plaster board is also fairly high. The permeability of plaster board is increasing very much at a relative humidity of approx. 80 % corresponding to a marked increase in moisture content.

The permeability of mortars and concrete is also increasing with increasing humidity. As will be seen from Fig. 7, the permeability is also dependent on the relative content of binder, and increases when the amount of cement and lime is decreased.

In addition to the materials which have already been mentioned, approximately 30 other porous materials were also tested. Among these were different qualities of expanded or foamed plastics, cork materials, boards of mineral wool, other kinds of wood, brick, lightweight concrete etc.

The results of the permeability measurements have shown that the change in moisture permeability with the relative humidity primarily depends on the hygroscopic properties of the materials. The permeability of a material with no or little hygroscopicity is practically independent on the relative humidity. The moisture flow is essentially a pure vapour diffusion. If the material is very permeable to airflow, a molar vapour will occur if any pressure differences exist.



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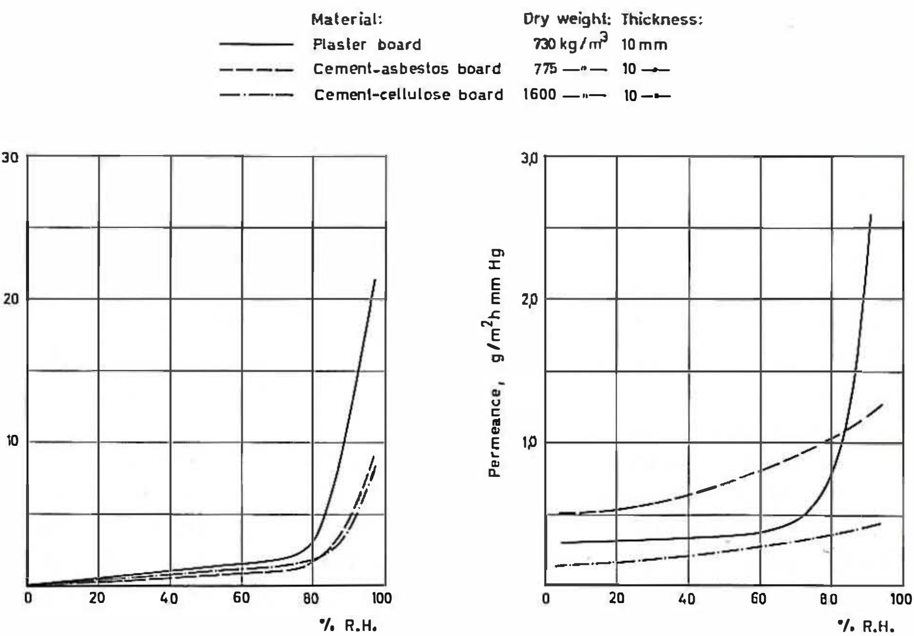

gure 6.

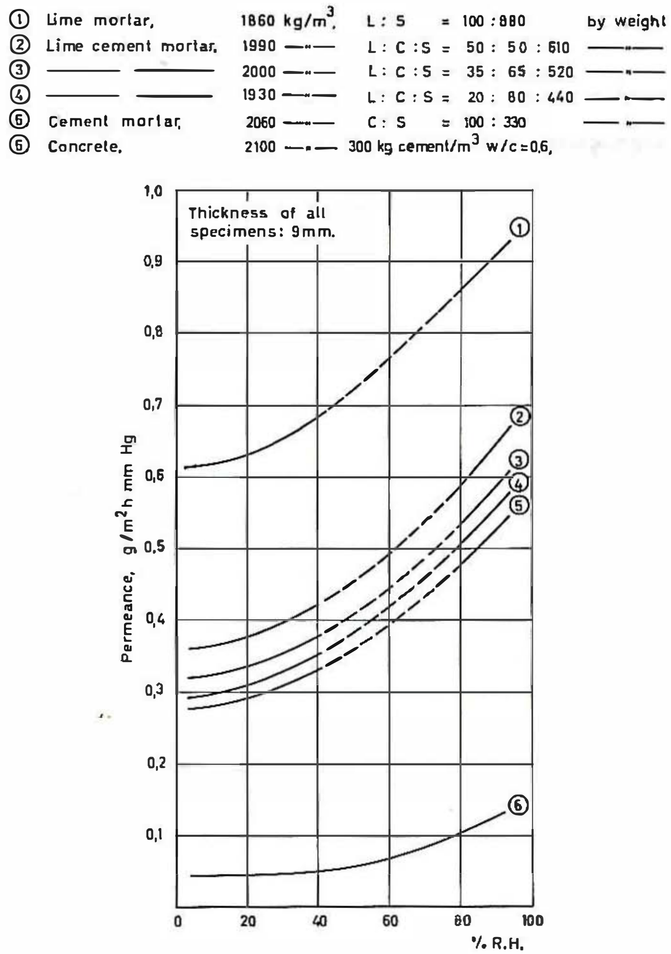

Figure 7.

Experience from practice has also shown that the calculations concerning condensation in lightweight structures easily becomes worthless because of air leakages in the structures.

The permeability of hygroscopic materials changes with the relative humidity depending on the degree of hygroscopicity and on the ability of the material to transport moisture in the liquid state or in the vapour state. The capillary suction properties and permeability to air flow are thus important factors. The permeability of many hygroscopic materials increases very much in the higher humidity ranges because of capillary condensation. This may lead to a reduced condensation hazard in structures as the moisture transport ability increases very much when the vapour pressure approaches the saturation pressure. Measurements have shown that the moisture transport ability of various kinds of sheathing felts and sheathing papers is some hundred times higher of the moist paper than for the dry paper. This kind of building papers are very effective in wood frame walls, as water condensed on them will disappear very quickly under more favourable conditions. The increased permeability of the material with increasing relative humidity and moisture content will also lower the condensation hazard in compact walls.

For non hygroscopic air permeable materials the water vapour permeability will change with temperature in the same manner as the permeability of water vapour in air, that means proportional to the square power of the absolute temperature. Materials of this kind are for instance mineral wools and certain kinds of plastic foams.

For a hygroscopic material which is very permeable to air flow the temperature effect is the same as mentioned above, because the vapour diffusion then is predominating. If on the other hand the liquid flow is predominating, the permeability decreases with increasing mean temperature, provided the mean relative humidity being kept constant. This is similar to the temperature effect on the sorption.

The influence of the temperature on the permeability of the materials will thus depend on the hygroscopicity, the air permeability and the capillary transport ability of the materials, the latter also including the surface creeping of the water molecules.

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Page	Line from above	beneath	Printed	Should be read
1	2		transport	transfer
1		15	yeat	yet
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3	8		the moisture permeability of the materials are determined	the moisture permeability of the materials is determined
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3		20	shows	show
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