INVESTIGATION OF THE HYGROSCOPIC PROPERTIES OF PEAT INSULATING SLABS

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Results are given of an experimental investigation of the hygroscopic properties of peat insulating slabs, and an equation for determining their equilibrium moisture content is presented. The bonding energy of moisture with the material has been determined from sorption isotherms.

Quite a number of papers [1–5] have been devoted to investigating the hygroscopicity of peat, but they have all been concerned with finely divided peat at room temperature, except [4], in which an investigation of the hygroscopic properties of peat was made in the temperature range 293°–378° K, though not with peats used for insulating slabs.

Characteristics of the Test Peat

Composition of the peat	Content %	Degree of dispersion	Type of peat
Moisture excess flake	5	—	—
Suction residue	isolated	—	—
Heather residue	rare	—	—
Sphagnum medium	15	10	top
Sphagnum fuscum	55	—	—
Sphagnum parvifolium	5	—	—
Sphagnum Duzenii	10	—	—
Sphagnum apiculatum	5	—	—
Sphagnum cuspidatum	5	—	—

As was established in [3], the hygroscopic moisture in peat and the shape of the sorption isotherm depend on the degree of subdivision, the methods of pretreatment of the peat, and the air temperature. As regards the effect of the botanical composition of the peat, opinions are contradictory, though the majority of investigators [1,2,4] consider that this has no substantial influence on the equilibrium moisture content. It should be noted that we did not find in the literature any sorption isotherms for peat insulating slabs at temperatures above room temperature.

A knowledge of the equilibrium moisture content in peat insulating slabs has great practical importance, both for drying-process calculations and for determining storage conditions, especially as the slabs are used as a building and thermal-insulation material.

We have therefore performed tests to determine the equilibrium moisture content of peat insulating slabs at room temperature (295° K) and at 343° and 363° K. The main purpose of the experiments was to study the nature of the moisture-material bond and to determine the binding energy from sorption isotherms, thus providing a scientific basis for choosing a method, and determining the optimum conditions, for drying peat insulating slabs.

The experimental equipment for making tests by the tensimetric method above room temperature comprised a thermostat and special semiconductor thermal regulators to maintain a constant temperature (to an accuracy of ±0.5°). The tests were done with peat insulating slabs of dimensions 2.5 • 2.5 • 0.4 cm, weighing 0.43 g (see table). Before the test the slabs were dehydrated in a desiccator at 373°–378° K.

The samples prepared in this way were placed over sulfuric acid solutions of various concentrations in specially prepared glass vessels with a ground-glass cover, which in turn had a ground-glass stopper with a catch. The distance of the peat insulating slab from the acid solution was the same in all the vessels, approximately 19–21 mm. To obtain the value of the equilibrium moisture content at $\varphi = 1$, the slab samples were placed in a container with distilled water. Weighing of the material during the experiment was done on an ADV—200 analytical balance specially adapted for the purpose. The tests lasted for 153 days until constant slab weight was attained, this being determined by two or three weighings.

From the test data, after processing, we were able to draw graphs of the dependence of the equilibrium moisture content u_e of a peat insulating slab on the relative air humidity φ at various temperatures (Fig. 1), in the form of sorption isotherms. The equilibrium moisture content u_e was calculated as kilograms of moisture in 1 kg of absolutely dry material.

The sorption isotherms constructed for temperatures of 295, 343, and 363° K indicate that the equilibrium moisture content of a peat insulating slab depends on the air temperature throughout the entire range of relative humidity from $\varphi = 0$ to $\varphi = 1$. The same relation for other kinds of peat was also established in [4].

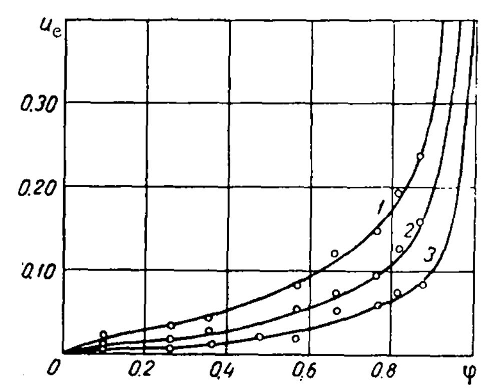

Fig. 1. Sorption isotherms of peat insulating slab: 1) at 295° K; 2) at 343° K; 3) at 363° K.

The influence of air temperature on the equilibrium moisture content over the whole range of the sorption isotherm is explained by the fact that the fraction of capillary moisture in the peat insulating slabs may be comparable with that bound by adsorption. As the moisture content of the slab increases, the fraction of adsorption-bonded moisture decreases, while that of the capillary-bonded moisture increases. The sorption isotherms obtained by the test method are approximated quite well by the equation

$$W_p = a\varphi/(b-\varphi), \tag{1}$$

where a and b are constants which depend on the air temperature and on the properties of the material.

The numerical values of the coefficients a and b for sections of the sorption isotherms with $\varphi = 0-0.85$ are as follows: T = 295° K, a = 13.8, b = 142; at T = = 343° K, a = 7.0, b = 133; at T = 363° K, a = 2.7, b = 112.

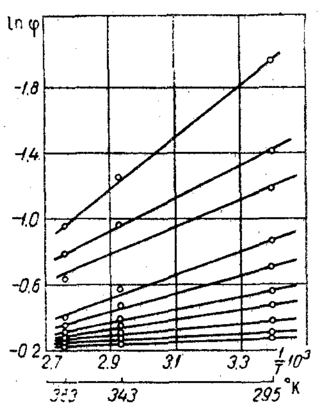

Fig. 3. Determination of heat of sorption.

In a number of heat- and mass-transfer calculations, it is necessary to know the specific isothermal mass capacity C'_T and the material transfer potential Θ_T. The values of these quantities may be determined from the sorption isotherms.

It has been shown experimentally by Maksimov [5] that the equilibrium moisture content of a material is fully determined for a given air humidity, independently of whether or not the body is in contact with others. This conclusion enables us to determine the transfer potential and the specific mass capacity from sorption isotherms of the body being examined and of a standard material (filter paper).

Using the values given in [6] for the transfer potential of filter paper at various temperatures and relative air humidities, we determined values of C'_T for the peat insulating slabs, and expressed the dependence of C'_T on u graphically (Fig. 2). Then the equilibrium moisture content of the material in the hygroscopic region is determined for the formula

$$u_p = c'_T \Theta_T .$$

In practical calculations of a drying process, it is very important to have not only a qualitative, but also a quantitative evaluation of the bond energy of the moisture with the material. The latter may be determined from the sorption isotherms of peat insulating slabs at various temperatures.

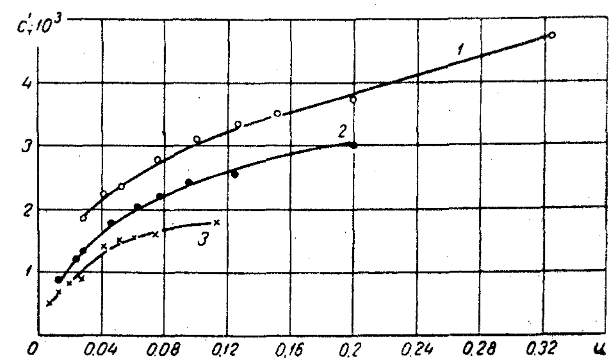

Fig. 2. Dependence of the specific mass capacity of a peat insulating slab on its moisture content: 1) at 295° K; 2) at 343° K; 3) 363° K.

As is known, the relation between the pressure of external forces and the liquid may be expressed as [7]

$$\ln\frac{P_0}{P_s} = \ln\varphi = -P_e v_l / R_c T. \tag{2}$$

Differentiating (2) with respect to temperature for the case of constant moisture content, i.e., when $P_e v_l$ does not depend on temperature, we obtain

$$\left[\frac{d\left(\ln\frac{P_0}{P_s}\right)}{d(1/T)}\right]_{u=\mathrm{const}} = -\frac{P_e v_l}{R_c}.$$

The product $P_e v_l$ is the bond energy of the liquid. The slope of the straight lines in Fig. 3 determines the bond energy of the moisture with the material. Figure 4 shows the sorption heat curve for a peat insulating slab (1), found according to the above-described method; plotted for comparison is the sorption heat curve of wood (2), taken from [7].

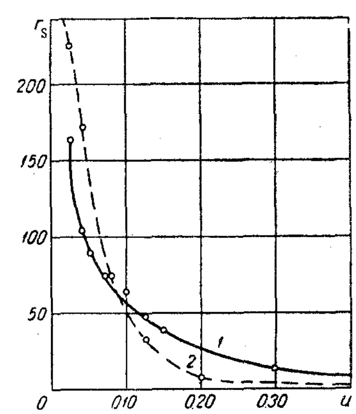

Fig. 4. Heat of sorption.

Since in drying the material the forces bonding the moisture to molecules of the material are overcome and the moisture evaporates, it is necessary in drying to expend energy in the phase transformation and in overcoming the bonding forces. It may be seen from Fig. 4 that during the drying of a peat insulating slab to a final moisture content W = 3–5%, the bond energy of the moisture with the material is considerable. Therefore, in the energy balance of the drying equipment for the thorough drying of peat insulating slabs, besides the heat of phase transformation, we must include the heat used in overcoming the bonding forces. Hence it follows also that in order to intensify the final stage of drying of peat insulating slabs, the drying must be carried out according to the counterflow principle.

NOTATION

φ) relative air humidity; T) absolute temperature; R_c) gas constant; p_e) pressure of external forces on the liquid; v_l) specific volume of the liquid; c_T') specific isothermal mass capacity; P_0, P_s) vapor pressure of water over the material and in the surrounding medium, respectively; Θ_T) mass transfer potential; r_s) heat of sorption.

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