COMPARATIVE EVALUATION OF METHODS USED FOR DETERMINING THE CRYOGENIC PHASE TRANSFORMATIONS OF MOISTURE IN CONSTRUCTION MATERIALS

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A comparative analysis is made of data pertaining to the phase content of moisture in construction materials at temperatures below 0°C and obtained by two methods: calorimetrically and electrometrically.

The phase content of water in construction materials at below-zero temperatures determined by dilatometric, calorimetric, or electrometric methods [1, 2]. Other methods are also known [3, 4] but, for various reasons, they have not found much use.

Unlike the dilatometric and the calorimetric method, the electrometric method is suitable for studying the cryogenic phase transformations of moisture not only in laboratory specimens but also directly in the field near a building. With the widespread use of the electrometric method for studying the kinetics of phase transformations in shelter structures, there has arisen the need to evaluate this method vis à vis the also widely used calorimetric method.

For this purpose, the authors undertook to measure the phase content in moisture at below-zero temperatures in pressurized-grade foam concrete (γ_0 = 850 kg/m^3) by both methods.

The electrometric method (measuring the electrical resistance) was applied in approximately 400 determinations of ice and unfrozen water within the 13-35% (weight) range of initial moisture content and over the 0 to -12°C temperature range. The electrometric data were evaluated on the basis of mathematical statistics and could then be presented in terms of the empirical relation

$$W_W = 7.56 - \frac{1.82W_M - 6.12}{t}. \tag{1}$$

TABLE 1. Quantity of Unfrozen Water (% weight), Determined by the Calorimetric Method (W_{cal}) and by the Electrometric Method (W_{el}), for Various Initial Moisture Contents (W_M) at below-Zero Temperatures (t, °C)

W_M	t_{fi}	t, °C	W_{cal}	W_{el}	ΔW	t, °C	W_{cal}	W_{el}	ΔW	t, °C	W_{cal}	W_{el}	ΔW
19,80	—2,4	—2,1	19,80	19,80	0	—5,0	13,60	13,54	—0,06	—10,0	10,80	10,55	—0,25
23,60	—2,3	—1,9	23,60	23,60	0	—5,2	15,22	14,93	—0,29	—10,1	11,82	11,21	—0,61
33,80	—2,1	—3,1	26,10	25,43	0,67	—9,8	14,77	13,21	—1,56	—10,9	14,33	12,64	—1,69

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Since

$$W_M = W_{fi} + W_I,$$

hence

$$W_I = W_M - 7.56 + \frac{1.82W_M - 6.12}{t}. \tag{2}$$

Relations (1) and (2) are valid under conditions when $t = t_{fi}$.

The temperature at which freezing starts t_{fi} is found by equating W_I in this expression to zero:

$$t_{fi} = -\frac{1.82W_M - 6.12}{7.56 - W_M}. \tag{3}$$

The quantities of unfrozen water in pressurized-grade foam concrete, measured by the calorimetric method and calculated by formula (1) for the identical conditions, are shown in Table 1.

The comparison indicates that the discrepancies between the two methods are unilateral, that they increase with lower temperature and with higher initial moisture content, and that they do not exceed 14% in relative magnitude. This points toward variable systematic errors in either one of the methods.

These discrepancies do not preclude the use of the electrometric method for studying cryogenic phase transformations in construction materials, within a practically acceptable accuracy and without additional restrictions.

NOTATION

W_M is the initial moisture content, % (weight);
W_W is the quantity of unfrozen water, % (weight);
W_I is the quantity of ice, % (weight);
t is the temperature, °C;
t_{fi} is the temperature of freezing start, °C.

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