BUILDING MATERIALS AND PRODUCTS

UDC 691.327

Voronezh State University of Architecture and Civil Engineering

Academician of RAABS, D. Sc. in Engineering,

Prof. of Department of Building Products and Structures E. M. Chernyshov

Ph. D. in Engineering, Assoc. Prof. of Technology of Building Products

and Structures Department G. S. Slavcheva

Russia, Voronezh, tel.: +7(4732)71-52-35;

e-mail: vgasupb@mail.ru

E. M. Chernyshov, G. S. Slavcheva

HUMIDITY STATE OF CEMENT AND SILICATE CONCRETE IN CONNECTION WITH THEIR STRUCTURE

The results of experimental researches of processes of interaction of cement and silicate concretes of dense and macroporous structure with aqueous steam and water are discussed. Influence of parameters of structure on laws and intensity of interaction is shown.

Keywords: high-strength modified concrete, macroporous cement and silicate concretes, hygrometric features, parameters of structure.

Solving the issues of management of building materials technology, it is necessary to base on conditions of building-technical means supply not only at the moment of manufacturing, but during all maintenance period. This is clear, because the developing of material construction features is a result of its maintenance processes, accompanied by modification of the composition, structure and condition (thermodynamic, stressed, humidity etc.).

Durability of material and reliability of structures are defined by intensity of destructive processes in the material that results from total number of mechanic loads

and physical-climatic factors. Understanding of modification of mechanism and pattern of features in time and influence of different factors upon intensity of the process is very important in a practical way for management of durability and reliability of construction structures and improvement of technology of the materials with correspondent purposes.

Among all impacts of environments, it is humidity environment that influences constantly, and humidity state of material affects almost all structure features — durability, deformability, frost resistance, head conductivity. That is why the relevance of problem of humid state influence upon construction materials' features at maintenance is obvious. Despite a great number of scientific documentation covering this issue (works of P. A. Rebinder, B. V. Deryagin, S. V. Aleskandrovsky, A. A. Gvozdev, I. E. Prokopovich, A. E. Sheikin, P. L. Seryh, N. N. Skoblinskaya, G. I. Gorchakov, V. M. Moskvin, K. A. Piradov etc.), the researchers are still acute in view of active implementation of new generation construction materials into building, the features and structure of which contain more micro and nanostructure components.

On the one hand, these components provide for a new level of material quality, and on the other, having higher level of dispersibility and activity they can sufficiently affect parameters of material destruction in humid state, impact upon stability of their physicochemical, physicomechanical and other features and, in the end, upon operation life of materials.

This article considers the results of experimental studies of interconnections between intensity of processes of interaction with aqueous steam and water and structure of cement and silicate concretes, the article is connected with evaluation of management principles and conditions (developed with author's participation) efficiency concerning intensity of interaction of building materials with aqueous steam and water [2].

The essence of these principles and conditions has been stated on basis of adsorption, capillary condensation, moisture transfer mechanisms analysis, as a system of steam diffusion, capillary saturation and liquids filtration processes in the structure. That was the basis for developing and systematization of dynamics and factors of interaction in the system "material — environment" from the aspect of change of internal material energy reserve. Provisions of absorption, surface effects, capillarity, filtration theories permit to present these effects as, on the one hand, a function of structure and structural features of disperse porous systems, and, on the other, — parameters of environment condition. Management of the processes intensity at construction materials maintenance is connected with the regulation of those qualitative and quantitative characteristics of hard phase and porous space of material which determine the balance of powers of its bond with water, notably:

1) volume of hard phase in complex with internal surface size, available for gaseous and liquid phases of the environment, with energetic surface condition, power of hard and liquid phases interaction;

2) pores volume, volume distribution corresponding to pores size and accordingly energetic field in pores volume.

Efficiency of modification of these composition and structure parameters in material hygrometric characteristics is evaluated basing on results of experimental researches of cement and silicate concrete interaction with aqueous steam and water.

To characterize patters of kinetics and processes intensity concerning interaction of building materials with aqueous steam and water of maintenance environment, it is proposed to consider and analyze the total of hygrometric state criteria, allowing to perform a qualitative and complex evaluation of effectiveness of structural characteristics at hygrometric material state management (Table 1).

Table 1

Hygrometric state criteria

Criteria designation	Adsorption-condensation material capacity (***A***)	Capillary saturation (***KH***)	Water absorption, (***B***)
Quantitative characteristics of criteria	Content of liquid phase, % per volume		
	Content of liquid phase, % per weight		
	Level of pores filling with water-relation of liquid phase volume to pores volume, V_{lp}/V_{pores}		
	Relations between liquid and hard phases volumes in material, V_{lp}/V_{hp}.		

Here are included:

1) adsorption-condensation material capacity (***A***), characterizing the quantity of aqueous steam which can be absorbed by material via absorption and capillary condensation mechanism in the environment with known partial pressure and temperature at a rate of unit of volume or a unit of pores volume;
2) capillary saturation, characterizing the quantity of moisture absorbed by the material at its contact with water surface (***KH***);
3) water absorption, characterizing maximum quantity of moisture "assimilated" into the material after immersion into water (***B***).

The researches were realized in stages. At the first stage the cement and silicate microconcretes were under experiments, as it was considered that the results have mutual meaning for materials, in which the corresponding type of microconcrete acts as a matrix.

The "structural models" of cement and silicate microconcrete were used at experiments; structural parameters were widely varied (Table 2, 3).

Table 2

Parameters of cement microconcrete “model” specimens structures parameters

Serial number	Mineralogical makeup of cementing substance	Level of cement hydration, %	Filler characteristics			Contents, m^3/m^3				$S_{mв.ф}$, m^2/g	$Q_{h.ph}$, J/g	$r_{э,\ nm}$
			External look	S_{sp}, m^2/kg	Wetting warmth, kj/kg	V_{cs}	$V_{мн}$	V_{cg}	V_n			
1*	$Ca(OH)_2$, C-S-H (II), low-sulphate Calcium hydrosulphoa-luminates	70	No filler			0.53	-	0.23	0.18	470	15	7-13
2*		72				0.51	-	0.20	0.29	1820		43
3*		79	Ground silica sand	150	0.97	0.18	0.46	0.08	0.28	220	<2	84
4*	$Ca(OH)_2$, C-S-H (II)	65	Carbonate containing loss dust	120	2.77	0.17	0.39	0.1	0.34	480	5.7	-
5*	Mainly C-S-H (I)	75	Microsili-ca	20 000	-	0.45	0.13	0.18	0.24	1200	22	5-7

Table 3

Parameters of silicate microconcrete “model” specimens

Serial number	Contents of cementing substance, kg/kg	Mineralogical makeup of cementing substance	Contents, m^3/m^3			$(V_{ц.в}+V_n)/V_{мн}$	$S_{цв}$		$q_{цв}$		$r_{э,\ nm}$	Contents of pores with radius $r_{э\ в}$, % of total pores volume			
			V_{cs}	$V_{мн}$	V_n		m^2/g	M^2/cm^3	J/g	J/cm^3		< 10 nm	10—25 nm	25—100 nm	>100 nm
1	0.50	Mainly C-S-H (I)	0.35	0.32	0.33	2.12	300	500	33.2	27.7	12	44	32	11	13
2	-	C-S-H (I), tobermorit	0.3	0.27	0.43	2.70	255	360	26.4	19.9	20	18	66	11	5

End of the Table 3

Serial number	Contents of cementing substance, kg/kg	Mineralogical makeup of cementing substance	Contents, m^3/m^3			$(V_{ц.в}+V_n)/V_{мп}$	$S_{цв}$		$q_{цв}$		$r_{э,\,нм}$	Contents of pores with radius $r_{э\,в}$, % of total pores volume			
			V_{cs}	$V_{мп}$	V_n		m^2/g	M^2/cm^3	J/g	J/cm^3		< 10 nm	10—25 nm	25—100 nm	>100 nm
3	0.52	C-S-H (I), tobermorit	0.26	0.22	0.52	3.50	210	250	27.9	17.3	32	10	58	25	7
4	-	Tobermorit 1.13 nm and C-S-H (I)	0.22	0.19	0.60	4.55	155	150	21.0	11.2	59	4	16	74	6
5	0.55	Tobermorit 1.13 nm and C-S-H (I)	0.20	0.15	0.65	5.65	125	110	19.4	9.3	65	3	30	58	6

Notes on the table: 1. $V_{c.\,s.}$ — volume of cementing substance, V_{cg} — volume of cement residual grains, V_{mf} — volume of microfiller, V_p — pores volume, S_{sp} — specific area of surface and q_{se} — specific surface energy of cementing substance, r_e — equivalent pore radius.

2. Conditions of specimens preparation: 1) cement microconcrete: portland cement M500 D0, dosage of microfillers C: H=1:1.75 from weight; contents of modifier MB-01 (on basis of microsilica and superplastificator C-3) — 15 % from cement weight (series 5*); V/C=0.25…0.4; curing in normal conditions during 28 days; 2) silicate microconcrete: dispersibility of silica sand — 200 m2/kg, contents of active CaO in lime-sand mixture of joint milling — 18 %; contents of slag Portland cement — 7.5 %; gypsum — 2.5 % from raw material weight; B/T=0.2…1.0; autoclave treatment at excessive steam pressure 1.0 MPa at the regime of 2+7+4 hr.

For specimens of cement stone the volume of pore space V_n changed between 0.18—0.34 cm^3/cm^3, the volume of cementing substance accordingly — in the interval of 0.17—0.63 m^3/m^3, the volume of fillers — in the interval of 0—0.46 m^3/m^3, the dispersibility varied in the range of 60—1500 m^2/kg and water wetting temperature from 0.97 to 2.77 kj/kg, as a result, the characteristic of specific surface area $S_{h.p}$ and specific wetting warmth $q_{h.ph}$ changed in the rate of $S_{h.p} \approx$100—1800 m^2/kg and q_{hp}=2—22 kj/kg. The extreme values of average effective radius of pores $r_э$ of cement stone were very different (from 5 to 84 nm).

For specimens of silicate stone at relatively constant quantity of cementing substance $C_н$ (0.5—0.55 kg/kg), the volume of pore space V_p was measured in the range of

0.33—0.65 cm^3/cm^3 and the volume of hard phase accordingly — in the range of 0.67—0.35 m^3/m^3. Pore space of material of all models was presented by micropores with radius from 2 to 10^3 nm, with different distribution of pores per size, as a result the ultimate values of average effective pore radius r_e, as an evaluation of this distribution, were equal to 12 and 65 nm, thus being 5 times different. In view of known influence of free space volume upon the processes of crystallization the cementing substance in models was notably different in terms of dispersibility of constituent minerals and energetic characteristics which is accordingly shown via characteristics of its specific wetting warmth $q_{цв}$. Interaction of cement and silicate microconcrete with aqueous steam conform to general patterns of adsorption, capillary condensation of disperse capillary-porous bodies.

Isoterms of cement stone specimens adsorption (Fig. 1a), except for model series 3*, have a look typical to isotherm of IVth main form of Brunauer classification, characteristic of materials with high energy of surface interaction with adsorbate molecule. In the environment with p/p_o=0.17, in which adsorption of aqueous steam mainly happens due to adsorption mechanism, the level of aqueous steam adsorption can be 2 times higher.

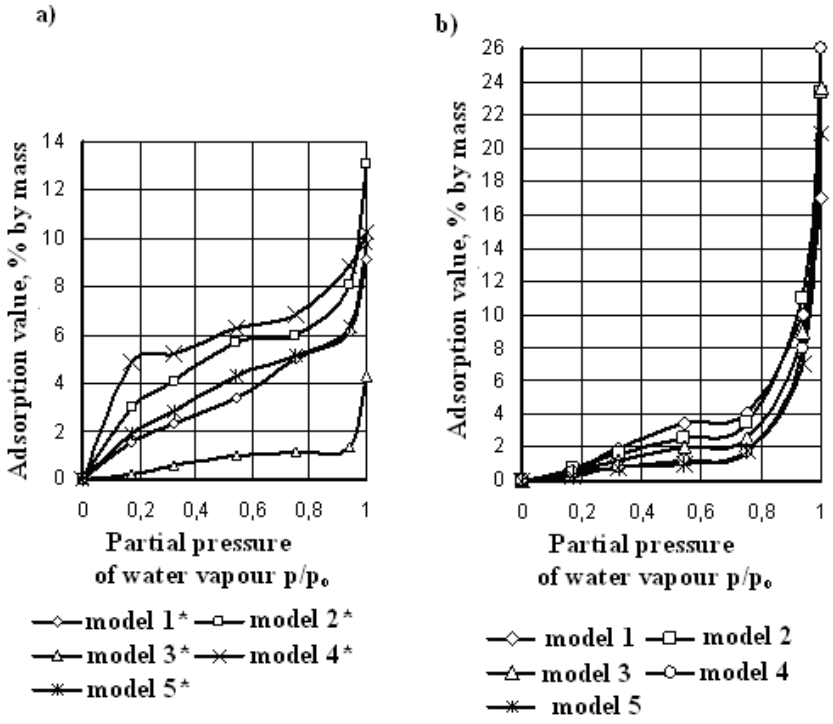


Fig. 1. Isotherms of aqueous steam adsorption by cement (a) and silicate (b) microconcrete

Growth of adsorption unit is naturally connected with growth of specific surface and specific surface energy of hard phase (see Table 2), that happen in the following cases:

- when the water/cement-relation increases with corresponding modifications of cementing substance structure and porosity;
- when the fillers are entered into the structure of cement stone, the filler have high dispersibility and activity in relation to water;

- when the microconcrete structure is fully modified by means of using replenishers of new generation of MB-01 type.

For silicate (see Fig. 1b) and a series of cement microconcrete specimens with volumic contents concerning inert ground sand in relation to water at the quantity of 0.46 m^3/m^3 isoterms of Vth main form of Brunauer are characteristic. This form is typical of materials which in case of development of adsorption, the forces of interaction between the adsorbent surface and adsorbate molecules there is more energy of mutual interaction between adsorbate molecules. Adsorption of aqueous steam in the environment with p/p_o=0.17 for these types of microconcrete does not exceed 1 % of the weight.

At partial pressure of $p/p_o \geq 0.5$ the adsorption of aqueous steam is usually fulfilled due to mechanism of polymolecular adsorption, and in the range of values of p/p_o=0.75—1.0 — capillary condensation. The influence of capillary condensation processes upon total value of aqueous steam adsorption is specially important for silicate stone specimens of 1st and 2nd series model and cement stone of series 1*, 2*, 4*, 5*, in which the main part of the porous space volume is presented by pores $r_e < 25$ nm at the large part of pores with $r_e < 10$ nm. That is particularly why the volume of adsorption-condensation container (Table 4) for cement and silicate stone can be 2.5—3.5 times different.

Table 4

Hygrometric characteristics of cement and silicate microconcrete

Hygrometric characteristics	Cement microconcrete					Silicate microconcrete				
	1*	2*	3*	4*	5*	1	2	3	4	5
Adsorption-condensation container, % per weight (above the line); the level of pores filling with water, V_{lp}/V_{pores}, m^3/m^3 (below the line) at p/p_0=0.98	9.14 0.94	13.1 0.67	4.3 0.28	10.3 0.98	9.8 0.73	17.0 0.86	23.3 0.76	23.7 0.54	26.1 0.43	20.9 0.27
Filling with water, per mass, %	14.5	20.9	11.9	24.6	5.86	27.2	35.1	49.2	65.1	74.2
Filling with water, per volume, %	29.1	35.9	22.2	36.3	11.1	43.4	48.2	57.1	59.2	61.1
Relation in water-filled state of liquid phase volume and original pores volume, V_{lp}/V_{pores}, m^3/m^3	1.61	1.2	0.78	1.06	0.61	1.26	1.25	1.09	0.99	0.94

End of Table 4

Hygrometric characteristics	Cement microconcrete					Silicate microconcrete				
	1*	2*	3*	4*	5*	1	2	3	4	5
Relation in water-filled state of liquid phase volume and hard phase volume, V_{lp}/V_{hp}, m^3/m^3	0.35	0.51	0.30	0.55	0.13	0.64	0.84	1.19	1.47	1.74
Capillary saturation, g/cm^2	1.19	1.43	0.78	1.45	0.84	7.4	5.7	4.4	5.3	4.6

Results of researches in adsorption and capillary condensation of aqueous steam processes basing on the example of cement and silicate microconcretes allow seeing the total picture of structural parameters influence upon the process.

It has been determined that the adsorption-condensation container of the material, in terms of quantity connected with energetic potential of hard phase fractions and porous space, increases (with other unchanged conditions) when the quantity of cementing substance and its pores' volume grow (see Fig. 1 and Table 4). Nevertheless, the determining role in material "activity" at interrelation with aqueous steam belongs to the structure qualitative characteristics. In terms of cementing substance the most important are its mineral and morphological contents, in terms of filler — its dispersibility and chemical-mineralogical contents, as the indexes of specific surface energy and specific area are connected with them, and for porous space — its volume distribution in pores radius. In practical relation in order to decrease the adsorption-condensation container of the material of given average density (porosity) and the contents of cementing substance, optimal in terms of durability, it is necessary to try to reach the synthesis of lowbased calcium hydro silicates, to form the porous space with average pores radius of more then 20—30 nm. The input of inert (in relation to water) fillers with reduced porosity can be considered an effective technique of impact upon intensity of aqueous steam absorption.

The level of capillary filling (Fig.2), depending on porous space "energy level", hard phase and its level of wetting, also consistently decreases; it happens, first of all, due to change of cementing substance contents (growth of low-based calcium silicates and tobermorit); secondly, in case the pores radius reduces, which is consistently connected with decreasing of capillary pressure; thirdly, in case the filler's dispersibility and wetting level decrease. Looking at the speed and limit value of capillary saturation, silicate stone models 1 and 2 appeared to be the most active ones (Fig. 2a). This is easy to explain, as the cementing substance of these models is characterized by the largest specific surface area, the best wetting level (higher value of specific wetting warmth), and the porous space is characterized by the lowest value of aver-

age effective radius of all pores. In other words, the structural parameters of the materials in these models predetermine the highest capillary pressure value of liquid rising in the frame of the experiments. As for cement microconcrete, the model series 2* and 4* are characterized by highest capillary saturation, they have the largest total pores volume, better wetting level of hard phase surface. It is necessary to mention that the lowest speed and saturation value was characteristic of modified cement microconcrete (series 5*), having minimum total pores volume with average equivalent radius of $r_e \approx 5$—7 nm.

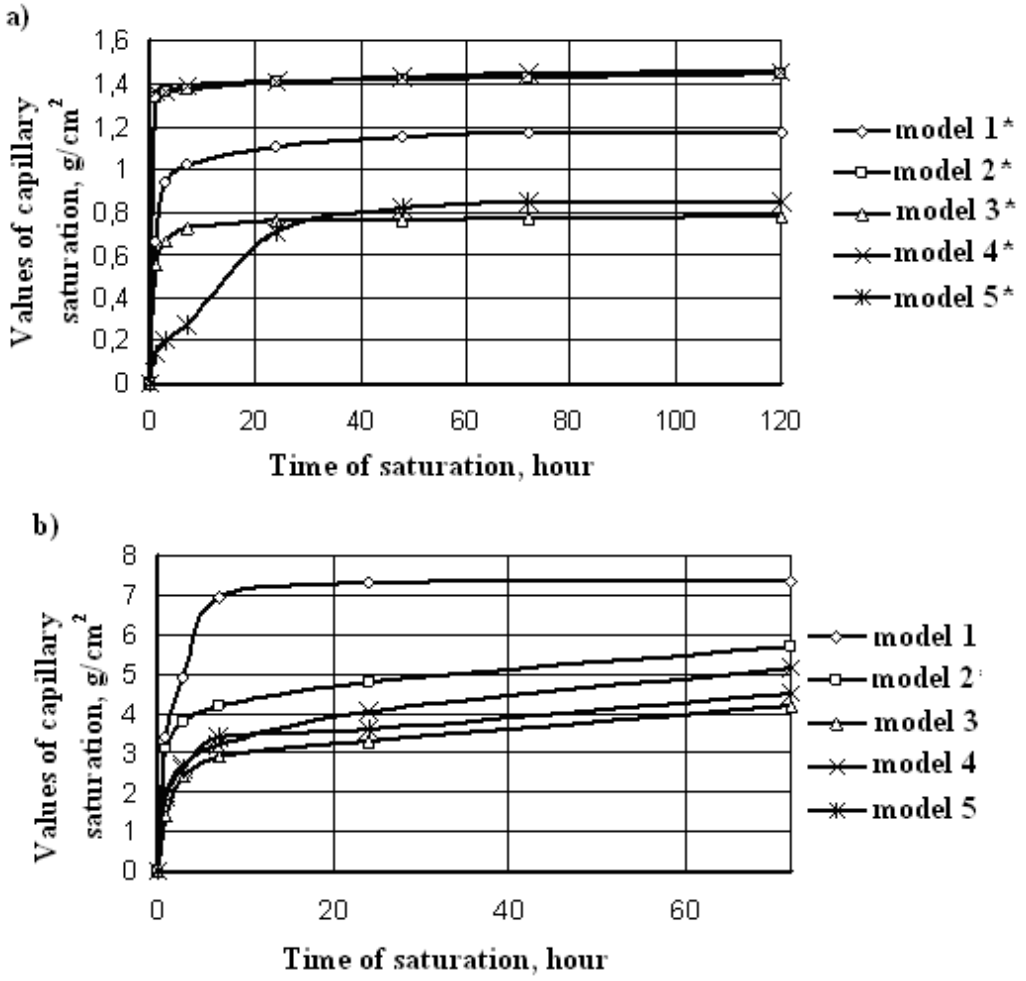


Fig. 2. Kinetics of capillary water-saturation of cement (a) and silicate (b) microconcrete

Material water-adsorption is a result of capillary pressure effect and liquid hydrostatic pressure. When the porous space of material is formed by pores with $r_e < 100$ nm, the most important role is given to the capillary filling component. In this case if there is a liquid pole under the specimens, almost all pores volume is expected to be filled. Actually, the relation of liquid phase volume and original porous space volume of cement and silicate specimens appears to be close to 1 or even higher. In accordance with the fact that almost all the porous space volume in cement and silicate stone gets filled with water, the absolute values of its water-absorption increase (see Table 4),

the hard phase wetting level grows, the volume enlarges and average pores radius decreases. Nevertheless the cement stone, modified by MB-01 replenisher (series 5*), in the porous space of which the pores of $r_э \approx 5—7$ nm prevail, is characterized by the lowest value of water-adsorption (5.86 %), and pores filling level is 0.61. With the pores so small, the material appears to be almost waterproof due to contre-capillary pressure forces, which do not allow to force the air out of pores. It is very significant, that for this series of specimens the equilibrium humidity, reached during aqueous steams adsorption, is almost two times higher then after water-adsorption.

The quantitative application of results and conclusions of experimental researches with microconcrete demands a follow-up and evaluation of corresponding influence of inherent inclusions in the microconcrete matrix (filler grains in dense concrete, aerated grains in aerated concrete). Due to this at the second stage of the researches the corresponding concretes were tested, notably:

1) high-strength modified concretes (HPC type),
2) non-autoclave cement porous concretes $\rho = 800—1600$ kg/m^3;
3) autoclave silicate concretes $\rho = 500—1100$ kg/m^3.

For the experiments the contents of high strength modified concretes corresponded to recommendations of NIIJB for industrial implementation in terms of cement consumption, small and large fillers. Variation of MB-01 modifier dosage was in the range of 0 to 30 % from cement weight. Due to modifier contents change the characteristics of cementing substance in terms of values of specific surface area S_{hp} and specific wetting warmth q_{hp} modified in the range of $S_{hp} \approx 500—1200$ m^2/kg and q_{hp}=15—22 kj/kg, pores volume — in the range of 0.06—0.13 m^3/m^3 with pores mainly of r = 5—7 nm in the structure of cementing substance of the concretes with a modifier and radius 30—40 in the structure of binding non-modified concrete of standard contents.

The experiments with cement porous concrete were held in two groups of specimens' series of small- and micro-grain structure. In the first group the specimens were examples of small- and micro-grain concrete of constant average density of ρ=800 kg/м^3, manufactured with different types of fillers (Table 5). To make small-grain filler specimens, silica sand of natural granulometry was used, micro-filler grains — ground silica sand, carbonate-calcium dust loss of cement production and dust loss of heat and power plant. Their features and constant correlation of С:П=1:1.75 for all types of porous concrete conform to contents of corresponding series of cement microconcrete (see Table 1).

Due to modification of dispersibility and fillers' features in the received series of porous concrete with constant contents of cementing substance the hard phase features in terms of specific surface area S_{hp} and specific wetting warmth q_{hp} changed in the range of $S_{hp} \approx 75—650$ m^2/kg and q_{hp}=2—6 kj/kg, the structure of porosity at its

total volume at all the series 0.7 m^3/m^3 was characterized by the change of average equivalent pores radius in the range of 400—800 mkm and micropores volume from 0.09 to 0.22 m^3/m^3. The second group of series is represented by the micro-grain concrete specimens on the silica sand, the variation of their average density was in the range of ρ=800—1600 kg/m^3, they were made in order to receive contents- and structure-constant material of inter-porous bridges, which is reached by means of having constant values of correlation C:П = 1:1.75 and water/cement-correlation for the series of porous concrete of different density.

Table 5

Hygrometric features of porous concretes with average density of 800 kg/m^3 on the basis of different filler types

Hygrometric features	Concrete type			
	Small-grain (at non-ground sand)	Micro-grain		
		At ground sand	At dust loss	At ashes loss
Adsorption-condensation container, % per weight (above the line); level of pores filling with water, V_{lp}/V_{pores}, m^3/m^3 (below the line) at p/p_0=0.98	4.4 0.06	5.9 0.07	8.7 0.1	8.8 0.1
Capillary saturation, g/cm^2	0.42	0.68	0.9	0.85
Water-adsorption per weight, %	14.6	21.2	28.5	23.9
Water-adsorption per volume, %	11.7	16.9	22.8	19.1
Level of pores filling with water in water-saturated state, V_{lp}/V_{pores}, m^3/m^3	0.17	0.24	0.34	0.28
Correlation of liquid and hard phase volumes in water-saturated state, $V_{lp}/V_{hp.}$, m^3/m^3	0.38	0.53	0.71	0.59

Silicate aerated concrete was also represented by two groups of specimens' series, the first one was manufactured regarding conditions of getting a constant average density, but different in terms of contents and structure of inter-porous bridges, for that in the series of specimens the B/T-relation varied. Due to this in the received series of aero-porous concrete the membrane microporosity changed at the range of 0.43—0.54 m^3/m^3, and correlation of micro- and macropores $\boldsymbol{V_{ap}/V_{mp}}$ from 2—9 to 1.5, the contents and compositions of cementing substance remained the same. The specimens of silicate aerated concrete of the second group were made in the range of changing its average density from 1100 to 500 kg/m^3 (at total porosity from 56 to 80 %) to receive constant contents and structure of membrane material, for that in the

technological manufacturing conditions only the dosage of gasifier was change at constant B/T-correlation. Parameters of membrane contents and structure had constant contents and features of cementing substance, membrane material porosity — 0.47 m^3/m^3) and comparable pores radius of 20—22.5 nm. In accordance with accepted value of average concrete density of 1100-500 kg/m^3 (or total porosity of 0.56—0.80 m^3/m^3), the aerated porosity was in the range of 0.14—0.62 m^3/m^3.

Detected during experimental researches quantitative patterns of interaction between intensity and interrelation extent with aqueous steam and water and parameters of structure, taken for research of concrete groups, allow to assume that this interaction is mainly defined by the contribution of constituent structure micro-level (matrix material, constituents) of cement and silicate concretes. The constituents of macro-level (grains of large and small filler, macropores) do not influence the type of interaction, but only intensify or weaken the effects of influence of microconcrete structure parameters.

Concerning high-strength modified concrete with small and large filler, the intensity of interaction with aqueous steam and water and a reached value of hygrometric features mainly depend on presence of complex modifier MB-01 (Fig. 3). Minimal values of adsorption-condensation container, capillary saturation and water-adsorption are characteristic both of microconcrete and of concretes with large and small filler at modifier dosage of 15—22 % from cement weight. Exactly this dosage provides for getting the constituent structure, which is characterized by minimal volume (up to 0.2 m^3/m^3) and pores radius (5—7 nm), which guarantees minimal material permeability for aqueous steam and water. A higher activity of concrete in relation to humidity influence is observed at dosage of ultra-disperse modifier MB-01 less then 12 % and more then 22 %, which results from decompression of the system (volume and pores radius increase) at simultaneous increasing of specific surface and specific surface energy of hard phase comparing to standard concrete without a modifier.

It is very important to underline, that the input of small and large filler into the structure of concretes without a modifier provides for fundamental change of its hygrometric features — the values of adsorption-condensation container, capillary saturation and water-adsorption decrease more then 5 times. Concerning these characteristics of modified microconcrete and concretes with small and large fillers this difference is sufficiently lower (1.5—2 times) which confirms the idea about the priority contribution of structural constituents of micro- and nanolevels into forming and realization of features of new generation concretes.

In accordance with the results of hygrometric researches both of porous concrete and microconcrete of corresponding series, it was established that the lowest intensity of interaction with aqueous steam and water and, correspondingly, the minimal structural linkage power with water were characteristic of the material which having equal average density and comparable specific contents of cementing substance has a lower value of specific surface area and specific wetting warmth of the filler (see Table 5),

and the porous space is formed by the pores with a larger value of average effective radius (in the range, being examined during experiments).

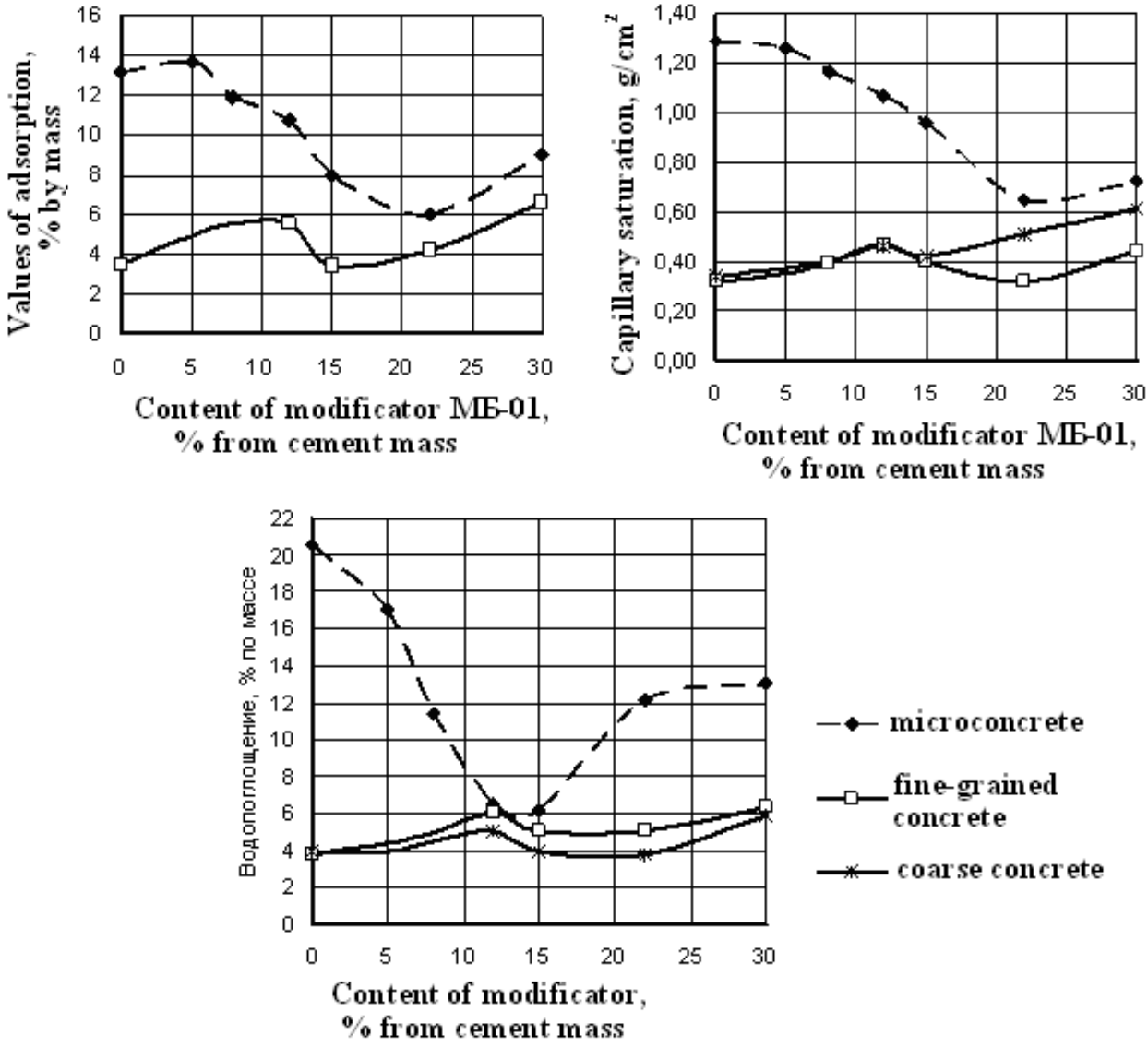


Fig. 3. Indexes of interaction of high-strength modified concrete with small and large filler with aqueous steam and water

The example of aerated concrete of medium density 600 kg/m^3, the matrix structure *pf* which was regulated by varying B/T value (Table 6), shows that increasing of micropores volume in the aerated concrete along with B/T growth should favor increasing of material saturation with aqueous steam and water. But at the same time decreasing of specific cementing substance surface, its wetting level, increasing of average effective pores radius, which is seen along with B/T growth, reducing of macropores volume could activate saturation decrease. Aggregate exposure of material parameters and structure influenced in such a manner that there appeared an optimum

area in the indexes of interaction with water, which corresponds to the value or correlation $\boldsymbol{V_{ap}/V_{mp}}$=1.9 (B/T=0.55), when the values of adsorption, capillary and water saturation, level of total pores filling with water and correlation of liquid and hard phases volumes in water-saturated material were minimal comparing to all values, received during experiments.

Table 6

Hygrometric features of silicate aerated concrete of medium density 600 kg/m^3

Hygromechanic features	**B/T-correlation**			
	0.38	**0.45**	**0.55**	**0.65**
	$\boldsymbol{V_{ap}/V_{mp}}$=2.9	$\boldsymbol{V_{ap}/V_{mp}}$=2.3	$\boldsymbol{V_{ap}/V_{mp}}$=1.9	$\boldsymbol{V_{ap}/V_{ap}}$=1.5
Adsorption-condensation container, % per weight (above the line); level of pores filling with water, V_{lp}/V_{pores}, m^3/m^3 (below the line) at p/p_0=0.98	10.6	10.5	8.9	9.1
Water-adsorption per weight, %	72.5	66.3	65.4	70.3
Water-adsorption per volume, %	46.3	42.5	39.6	44.1
Correlation of liquid phase volume and original volume at water-saturated state, V_{lp}/V_{pores}, m^3/m^3	0.59	0.55	0.52	0.55
Correlation of liquid and hard phase volume at water-saturated state, V_{lp}/V_{hp}, m^3/m^3	1.76	1.58	1.56	1.75
Capillary saturation, g/cm^2	5.9	2.9	2.6	3.3

Decreasing of medium density of macroporous concretes leads to increasing of estimated hygrometric features at 20—30 % for cement porous concretes (Table 7) and at 30—50 % for silicate aerated concretes (Table 8), which is naturally connected with increasing of diffuse material penetrability along with corresponding change of macropores volume fraction and average radius.

The management efficiency of material interaction with aqueous steam and water is defined by mutual influence (synergism) of all structural parameters of hard phase and porous space and is characterized (for cement and silicate concretes) by the possibility of systematic 3 times reducing of adsorption-condensation container, 1.5—2 times — speed and value of capillary saturation, correlation of liquid and hard phase volumes in water-saturated state in 2—3 times.

Table 7

Hygrometric features of small-grain porous concrete of different average density

Hygromechanic features	Compact	Porous		
		D1600	D1200	D800
	V_{pores}=22 %	V_{pores}=34 %	V_{pores}=54 %	V_{pores}=69 %
Adsorption-condensation container, % per weight (above the line); level of pores filling with water, V_{lp}/V_{pores}, m^3/m^3 (below the line) at p/p_0=0.98	3.1 0.28	3.8 0.17	4.1 0.09	4.4 0.06
Capillary saturation g/cm^2	0.63	0.62	0.55	0.42
Water-adsorption per weight, %	7.6	10.3	12.5	14.6
Water-adsorption per volume, %	15.2	16.5	15.0	11.7
Correlation of liquid phase volume and original volume at water-saturated state, $V_{жф}/V_{пор}$, m^3/m^3	0.69	0.45	0.27	0.17
Correlation of liquid and hard phase volumes in water-saturated state, V_{lp}/V_{hp}, m^3/m^3	0.19	0.25	0.33	0.38

Table 8

Hygromechanic features of silicate aerated concrete of different average density

Hygromechanic features	Average density, kg/m^3				
	1100	900	800	600	500
	V_{pores}=53 %	V_{pores}=64 %	V_{pores}=68 %	V_{pores} =75 %	V_{pores}=80 %
Adsorption-condensation container, % per weight (above the line); level of pores filling with water, V_{lp}/V_{pores}, m^3/m^3 (below the line) at p/p_0=0.98	8.7 0.16	9.4 0.15	9.6 0.14	10.2 0.13	10.4 0.13

End of Table 8

Hygromechanic features	Average density, kg/m^3				
	1100	900	800	600	500
	V_{pores}=53 %	V_{pores}=64 %	V_{pores}=68 %	V_{pores} =75 %	V_{pores}=80 %
Water-adsorption per weight, %	47.5	51.9	55.8	68.5	83.1
Water-adsorption per volume, %	46.1	44.1	40.0	38.5	38.1
Correlation of liquid phase volume and original volume at water-saturated state, V_{lp}/V_{pores}, m^3/m^3	0.83	0.69	0.59	0.50	0.50
Correlation of liquid and hard phase volumes in water-saturated state, V_{lp}/V_{hp}, m^3/m^3	1.11	1.23	1.25	1.61	2.05
Capillary saturation, g/cm^2	4.1	3.6	3.5	2.9	2.8

The experimental evaluation results concerning interconnection of hygrometric state criteria with features of material structure are a scientific and engineering basis for optimization of building materials' structure from the position of ensuring preset hygrometric features.

References

1. Chernyshov E. M. Physical and chemical nature of interrelation of properties of building materials with their humidity state / E. M. Chernyshov, G. S. Slavcheva // Academia. Architecture and construction. 2008. № 1. P. 87—92.

2. Chernyshov E. M. Management of intensity of interaction of building materials structures with aqueous steam and water / E. M. Chernyshov, G. S. Slavcheva // Academia. Architecture and construction. 2008. № 2. P. 77—83.

3. Humidity state and thermal resistance of two-layer (gas-silicate brick) external walls / E. M. Chernyshov [etc.] // Current state and prospect of development of building materials technology: materials of VIII Academic readings of RAABS. Samara, 2004. P. 398—403.

4. Slavcheva G. S. Operational deformability and hygrometric characteristics of cement porous concretes as function of their structure / G. S. Slavcheva // Scientific Herald of the Voronezh State University of Architecture and Civil Engineering. Construction and architecture. 2008. № 1. P. 79—85.