Investigation of the influence of organosilicon compounds on fiber cement panels' characteristics

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Abstract. The article presents the results of experimental research of the influence of organosilicone compounds on porosity parameters, contact angle of fiber cement panels based on cellulosic fiber in superficial expansion and volumetric methods of hydrophobization.

1. Introduction

Due the fact that asbestos fibres are cancerogenic materials, in many countries of the world, especially in those where there are no natural stocks of asbestos, there are research aimed at the partial or complete replacement of asbestos in building materials with other types of fibers of organic or inorganic origin.

Fiber cement panels (FCP) based on cellulosic fibers have been widely disseminated in the decoration of facades. They have several advantages: they do not ignite and do not spread fire, shockproof, environmentally safe and resistant to aggressive environments. In addition, they are much lighter than porcelain tile and asbestos cement, so they can be successfully used for facing and reconstruction of buildings with limited load on the foundation. Our earlier research on the optimization of FCP composition [1, 2] has allowed to receive FCP with the following features: average density 1.6 g/cm3, flexural strength up to 25 MPa, toughness 2 kJ/m2 and water adsorption 16 %.

The disadvantage of FCP based on cellulosic fibers is high water adsorption and therefore rolling resistance to atmospheric forcing. For that reason the research of ways to improve the water resistance of FCP used for facing of buildings is a relevant intervention.

Currently, to improve the water resistance of building materials are used methods and techniques directed at increasing of density, using paint proofing, wax and paraffin-rosin emulsions.

However, it should be noted that disadvantage of paint coat is non-durability related to ultraviolet solar radiation. Our experimental research had determined that wax and paraffin-rosin emulsions lower water adsorption in only 2-3% which is insufficient for FCP used for external facing. More effective results were obtained with the use of organosilicon compounds, which were accepted for further reserach on increasing the water resistance of FCP.

In building construction organosilicon compounds are widely used for reduction water adsorption and cement concrete and it is effective water-repellent agent.

GOST 24211-2008 "Admixtures for concretes and mortars. General specifications" classified organosilicon compounds are referred to the grade of additives giving concretes and mortars special properties. The main effect of the action of organosilicon compounds is to impart water-repellent properties as a result water absorption decreases and the frost resistance of building materials increases.

The research of properties, field of application of silicone products and their influence on the properties of building materials was considered in work [3-5].

The water-repellant agents, used to protect building materials, shall penetrate deep into pores, shall not form condensated surface when its drying, shall not prevent water evaporation of material, shall sustain color and surface texture, as well as it shall have high chemical stability, thermal stability and weather resistance, shall be harmless and economy [3]. Organosilicone compounds including potassium methylsiliconeate (GKJ-11K) and polyphenylethoxysiloxane (FES-50), which have been taken to FCP's modification, meet requirements adequately.

There are two ways of increase water resistance of building materials - volume and surface hydrofobisation. They differ from each other by the technology, consumption of water-repellent materials and effectiveness. That is why versions of volume and surface hydrofobisation are studied.

2. Materials and Methods

Potassium methylsiliconeate (GKJ-11K) and polyphenylethoxysiloxane (FES-50), produced by the OAO "Khimprom" Novocheboksarsk, Russia, were ntroduced in the quantity of 0.1-0.2 % by mass of cement into fiber cement formulation for volume hydrofobisation.

Surface hydrofobisation was obtained by impregnation with water solution of potassium methylsiliconeate (3-50 %) and paraffin solution of polyphenylethoxysiloxane (3-50 %).

Water resistance was estimated by the value of water absorption and contact angle. Water absorption was determined according to the method described in GOST 8747-88 "Asbestos-cement sheet products. Test methods". The essence of this method is mass determination of the item in the dried and water-saturated states with their subsequent comparison.

The determination of contact angle of FCP surface was done by drop-spreading technique. Balanced contact angle θ_0 is defined by the mechanical balance on the line of three-phase contact by principal dimensions of globule of fluid, applied to FCP test samples: in height "h" and basal diameter of drop "d". The value cos. θ was calculated according to the formula θ_0 [6]:

$$\cos\theta = \frac{(d/2)^2 - h^2}{(d/2)^2 + h^2}; \quad (1)$$

In addition the determination of contact angle θ_0 was determined by software package «AutoCad». Photos of the test samples before and after hydrofobisation are presented in figure 1.

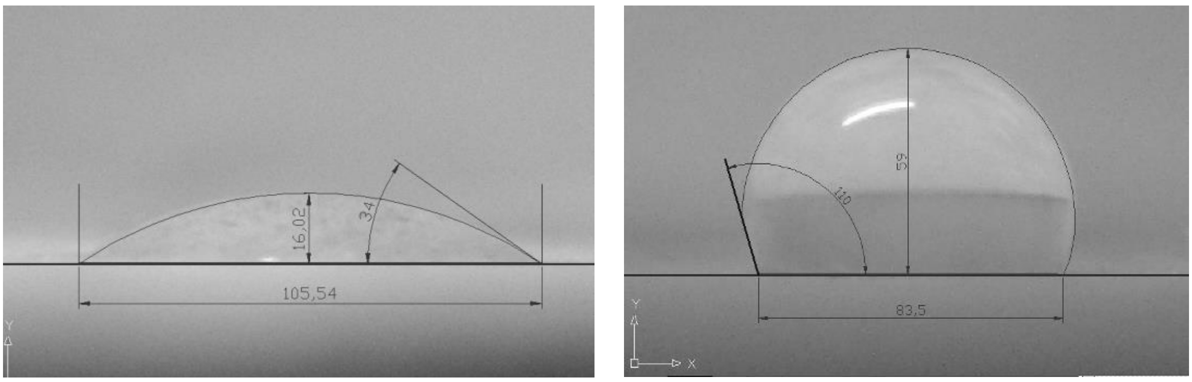

Figure 1. Photos of the test samples before and after hydrofobisation.

3. Results and Discussion

The results of the influence of water-repellant agents on water absorption kinetics of FCP and values of contact angle in volume and surface hydrofobisation are shown at the Tables 1, 2. The influence of kind and content of organosilicone compounds in composition on porosity parameters is shown at the Table 3, in surface hydrofobisation – Table 4.

Table 1. Water absorption kinetic of the test samples in volume hydrofobisation.

Organosilicone compound	Content of organosilicone compound, % by mass of portland cement	Water absorption, %			Contact angle θ, grad.
		6 hrs.	12 hrs.	24hrs.	
-	-	10.4	13.3	16	34
GKJ-11K	0.1	8.5	12.5	14.6	40
	0.15	8.1	11.9	14.3	41
	0.20	8	11.8	14.2	41
FES-50	0.1	2.9	3.6	4.3	95
	0.15	2	2.6	3	103
	0.20	2	2.5	2.9	103

As shown in Table 1, studied organosilicone compounds reduces water absorption at all testing time. However, quintessence reduction was observed while FES-50 in amount of 0.15-0.2 % by mass of cement was used.

Table 2. Water absorption kinetic of the test samples in surface hydrofobisation.

Organosilicone compound	Content of organosilicone compound, %	Water absorption, %			Contact angle θ, grad.
		6 hrs.	6 hrs.	6 hrs.	
-	-	10.4	13.3	16	34
GKJ-11K	50	3.19	4	5.65	90
	25	1.89	2.61	3.08	102
	12	2.39	3.12	3.17	102
	6	1.95	2.68	3.83	98
	3	3.72	5.46	7.3	81
FES-50	50	1.15	1.38	1.83	110
	25	1.4	1.64	2.1	107
	12	1.66	2.14	2.61	105
	6	2.16	2.43	2.97	103
	3	2.29	2.7	3.32	101

As shown in Table 2, organosilicone compounds significantly reduce water absorption of FCP test samples. Herewith impregnation with paraffin solution FES-50 with optimum concentration 50 % enables to reduce water absorption in 8.7 times, while as impregnation with water solution GKJ-11K reduces water absorption only in 5.2 times.

It is important to note that volume and surface hydrofobisation have similar effectiveness.

Organosilicone compounds allows wall of capillary and pores to provide waterproofing ability. The use of kerosene as a solvent with high penetrability provides deep penetration to organosilicone compound FES-50 into material.

Table 3. Porosity parameters of FCP test samples in volume hydrofobisation.

Organosilicone compound	Content of organosilicone compound, %	Porosity parameters				
		Total pore volume, (P_t)	Volume of open capillary pores, (P_o)	Volume of open non-capillary pores, (P_{on})	Volume of conditionally closed pores, (P_c)	Value of microporosity, ($P_{мс}$)
-	-	19.2	16	2.1	1.1	0.64
GKJ-11K	0.1	19	14.6	1.8	2.6	0.7
	0.15	18.9	14.3	1.7	2.9	0.72
	0.2	18.8	14.2	1.7	2.9	0.73
FES-50	0.1	16.6	4.3	0.25	12.05	1.32
	0.15	16.2	3	0.2	13	2.13
	0.2	16	2.9	0.2	12.9	2.15

As is well known, there is a certain link between the water absorption and the porosity of the material. Usually, higher water absorption is characteristic for materials with high porosity primarily capillary. The porosity of fiber cement panels was determined according to GOST 12730.4-78 "Concretes. Methods of determination of porosity parameters".

Experimental research of influence of studied organosilicon compounds on porosity parameters of the FCP are shown in Table. 3, from which it can be seen that organosilicon compounds have a significant impact on the nature of the change in the pore structure of the material. Table. 3 shows the highest possible porosity is characteristic for test samples without any additives. In test samples with additives total pore volume is reduced by 0.2-3.2 %, volume of open capillary pores are reduced by 1.4-13.1 %, volume of open non-capillary pores are reduced by 0.3-1.9%, volume of conditionally closed pores increases by 1.5-11.9 %, value of microporosity increases by 0.06-1.51%.

Table 4 shows the influence of GKJ-11K and FES-50 on porosity parameters of the test samples in surface hydrofobisation. The surface hydrofobisation was carried out by full-immersion of FCP test samples into pre-mix solutions for 7 hours.

Table 4. Porosity parameters of FCP test samples in surface hydrofobisation.

Organosilicone compound	Content of organosilicone compound, %	Porosity parameters		
		Volume of open capillary pores, (P_o)	Volume of open non-capillary pores, (P_{on})	Volume of conditionally closed pores, (P_c)
-	-	16	2.1	1.1
GKJ-11K	50	5.65	0.19	9.66
	25	3.83	0.20	13.07
	12	3.08	1.45	13.07
	6	3.17	1.60	14.03
	3	7.69	1.65	9.76
FES-50	50	1.83	0.29	12.88
	25	2.1	0.19	14.21
	12	2.61	0.58	13.99
	6	2.97	0.60	14.63
	3	3.31	0.98	14.61

As shown in Table 4, surface hydrofobisation influences not only total pore volume but also nature of pore distribution. The volume of open capillary pores is reduced by 16-1.83%, in our view it was due to formation of calcium salts of organosilicon compounds conducive to colmatage pores. Significant distribution of volume of open capillary pores and volume of conditionally closed pores occur while reducing total pore volume. At this rate volume of open non-capillary pores is reduced by 2.1-0.19 % and volume of conditionally closed pores is increased by 1.1-14.63 %.

4. Conclusions

In the light of the figures in the table, it will be noticed that studied organosilicon compounds are effective water-repellant agents allow for a significant increase water resistance of FCP. These organosilicon compounds in volume and surface hydrofobisation reduce total pore volume and change considerably nature of pore distribution. Polyphenylethoxysiloxane FES-50 is the most effective organosilicon compound in volume and surface hydrofobisation. The reduction of water absorption is most significant for surface hydrofobisation of the items by 50 % paraffin solution, wherein optimum porosity is occurred of test samples that included FES-50 in amount of 0.15-0.2 % by mass of cement.

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