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MECHANISM OF MANIFESTATION OF STRUCTURAL AND PHASE TRANSFORMATIONS IN CEMENT AND SILICATE COMPOSITE MATERIALS

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The problem concerning the development of the corrosion front in concrete when exposed to an aggressive environment is considered, as well as studied. The article presents the results of studies that reflect the effect of a complex additive on the physical and mechanical properties of concrete under normal and aggressive conditions. The general state of the problem of protecting reinforced concrete elements from aggressive external influence is described. The article builds a response surface from the dependencies obtained.

Introduction. The task of the construction industry is to maximize the economy of material assets and technological energy consumption in the production of constructional works, with ensuring the maintenance and performance characteristics of structures. One of the most important ways to improve productivity in construction, aside to using modern equipment, is the addition of chemical admixtures for various purposes.

One of the big advantages of reinforced concrete in comparison with metals and other materials, is its high corrosion resistance. Concrete protects embedded steel from corrosion due to its alkaline nature. A high pH environment in concrete (usually above 13.0) leads to the formation of a passive and non-corrosive protective oxide membrane around the steel.

Task formulation. The study of various chemical admixtures and their effect on concrete.

Chemical additives are those ingredients in concrete, other than the binder, water, and aggregates that are added to the mixture immediately before or during mixing. The development of ideas concerning the mechanism of additives is inextricably linked with the progress in the theory of hydration and hardening of mineral binders. In addition, research related to the rational economy of heat treatment of reinforced concrete structures is very relevant, but they require the optimal class of the additive with its optimization with mineral binders.

The effectiveness of additives depends on factors such as its composition, the rate of addition, adding time, type, brand and amount of cementing materials, water content, total shape, gradation and proportions, mixing time, recession or sediment of concrete, and temperature of concrete.

In aggressive mediums, we take into consideration the environments in which the corrosion of building materials occur. In accordance with its state of aggregation, the aggressive mediums can be gaseous, liquid or solid, and in many cases multiphase. Based on the modern concept of physical and chemical phenomena and the theory of surface contact interactions, we can -in the desired direction- change the properties of the cement paste, concrete mix and concrete itself by introducing concrete additives (modifiers) into the cement system [1].

The concept of "corrosion" is defined as the process of irreversible deterioration of the technical characteristics of a building material (concrete) as a result of physicochemical, chemical, biological effects of the external environment or chemical processes occurring in the material itself, changing its structure and properties. We can say that the cause of corrosion of concrete is both the interaction of cement stone concrete with aggressive components and environmental factors, and the interaction between the components of cement stone, where it is represented in the form of electrochemical processes [2].

According to modern concepts, the corrosion of concrete and reinforced concrete is classified in liquid media into 3 types:

– Type I - corrosion associated with the exposure to aqueous media with a low salt content with a predominantly neutral reaction (pH = 6.8 ÷ 7.2);

– Type II - corrosion when exposed to very aggressive media, for example, acids, alkalis, some salts, such as sodium or magnesium chlorides;

– Type III - corrosion caused by the penetration into the pores of concrete of liquid media containing components forming insoluble crystalline compounds with a pore liquid or cement stone.

Each type of corrosion is characterized by its own characteristics, specific physico-chemical processes and reactions that determine the nature of corrosion damage [3].

The superplasticizer produced in the Polotsk State University [4], hydrophobizer GKJ-10, and carboxymethylcellulose CMC were used as the main additives improving the corrosion resistance, as well as strength and mobility.

Studies were carried out on fine-grained concrete of composition 1:3. As well as, portand cement M:300 and sand M_s- 2,1. The testing of the beams $40 \times 40 \times 160$ cm, were carried out according to the GOST-310.4-8 for determining the bending strength, were studied on the MII-100 installation, on the hydraulic press PSY-125 for determining the compressive strength, and also for the corrosion resistance according to the methods approved by NIIJB, based on the exploitation conditions of the studied structures. In quantitative terms, the admixtures from the weight of the cement in (%) were:

1) Superplasticizer: 0.3-1.0%;
2) CMC: 0.5-1.0 %;
3) GKJ-10: 0.2%.

All additives were introduced with the medium dissolved after preparation of dry cement-sand mixtures. The sample where put in a normally humid medium.

The tests computing the increase in strength, were characterized by the two additives S-NPI and CMC. The results showed that the additives increased the strength:

– Compression: 1.7 times;
– Bending: 1.4 times.

When determining the corrosion resistance, the samples were placed in a $CaCl_2$ solution (calcium chloride), of concentration 30 grams of salt per 100 ml of water at a temperature of 50°c. Intermediate tests of the samples were carried out after 7 days.

Table 1. – Levels and intervals of variation factors.

Parameter designation	Factor levels			The intervals of variation of factors
	Lower level	Main level	Higher level	
	-1	0	1	
X1	0	0.5	1	0.5
X2	0	0.01	0.02	0.01
X3	0	0.5	1	0.5

The model of a three-factor experiment is determined by the formula:

$$y = B_0 + B_1 \cdot X_1 + B_2 \cdot X_2 + B_3 \cdot X_1 \cdot X_2 + B_4 \cdot X_1^2 + B_5 \cdot X_2^2$$

Table 2. – Plan of the experiment in natural and normal variables.

X1	X2	X3	Superplastizer	GKJ-10	CMC
+	-	-	1	0	0
-	+	-	0	0.02	0
-	-	+	0	0	1
+	+	+	1	0.02	1
+	-	+	1	0	1
-	+	+	0	0.02	1
+	+	-	1	0.02	0
-	-	-	0	0	0
+	0	0	1	0.01	0.5
-	0	0	0	0.01	0.5
0	+	0	0.5	0.02	0.5
0	-	0	0.5	0	0.5
0	0	+	0.5	0.01	1
0	0	-	0.5	0.01	0
0	0	0	0.5	0.01	0.5

For this particular experiment, the polynomial is:

$$y = -42.6657 - 0.3899 \cdot X_1 + 0.4570 \cdot X_2$$

Table 3. – Strength measurement at different times in different mediums

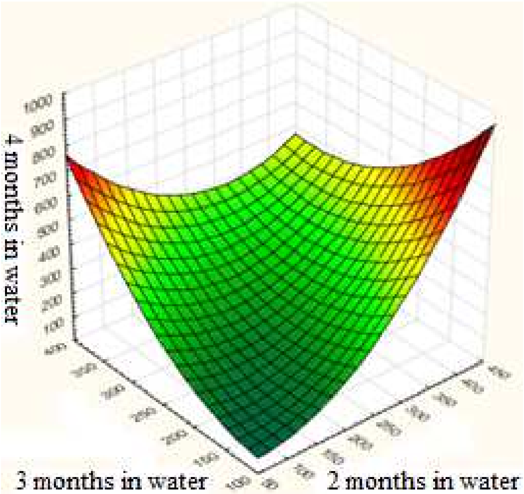
№	Code	S-NPI	GKJ-10	CMC	Measurement	28 days		3 months in water		2 months in salt		2 months in water		5 months		4 months in salt		4 months in water	
		X_1	X_2	X_3	Y_1^1	C	B	C	B	C	B	C	B	$\bar{S}_c^2$	$\bar{Y}_b^2$	C	B	C	B
1	a	1	0	0	2.2	460	54.6	384	57.2	421	114	409	66.5	326	73	364	77.5	400	44.8
2	b	0	0.02	0	2.2	324	44.7	292	37	297	72.6	323	39.9	258	32.9	200	62.7	302	44.6
3	c	0	0	1	3	248	33.4	169	30.9	192	40	221	41.6	156	41	155	43.1	138	38.6
4	abc	1	0.02	1	3	192	30.2	166	34.3	138	21	163	28.1	168	28.2	136	36.3	105	24.3
5	ac	1	0	1	2.8	162	25.5	116	23.9	80	22.85	93	14.6	104	12.8	73	30.7	71	21.3
6	bc	0	0.02	1	2.9	228	32.6	226	35.2	188	51.9	187	31.9	190	39.9	143	48.4	105	27.8
7	ab	1	0.02	0	2	456	48.1	377	44.4	370	51.9	308	49.4	306	37.9	203	57.7	358	46.9
8	-1	0	0	0	2.3	340	41.1	139	44.4	325	75.9	300	49.6	302	35.6	273	61.8	354	48.2
9	2a	1	0.01	0.5	2.9	200	26.8	152	29.4	186	50.6	163	324	169	29.6	91	31.6	153	25.8
10	(-2a)	0	0.01	0.5	2.8	224	31.3	209	35.7	117	53.4	178	30.1	184	33.4	137	39.6	151	34.5
11	2b	0.5	0.02	0.5	2.6	168	23.7	199	31.1	107	19.7	164	38.2	120	25.9	95	31	135	34.8
12	(-2b)	0.5	0	0.5	2.8	288	33.4	236	40	235	38.7	213	40.1	184	34.9	132	42.4	156	39.6
13	2c	0.5	0.01	1	3	218	37.5	208	35.7	163	30.7	203	35.5	136	28.5	108	34.1	193	36.2
14	(-2c)	0.5	0.01	0	2.3	314	34.2	332	46.4	385	81.3	296	45.5	242	415	161	71.4	260	53.2
15	0	0.5	0.01	0.5	3	212	20	184	30.6	195	33.7	150	35.2	213	37.2	101	35.1	140	36.5

Based on experimental calculations, a comparative analysis concerning the mechanism of the effect of additives on the coefficient of water saturation in a water and salt medium was performed. On the basis of calculations, the required amount of medium was established, where, with the shaking of sample mixtures, the spreading of the cone reaches 107 mm.

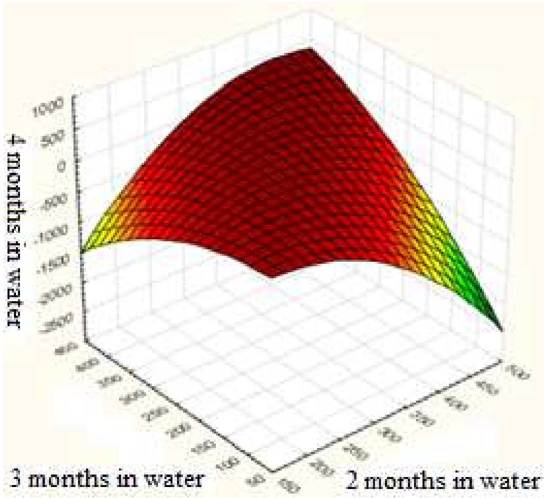
Table 4. – This table shows the variation in water saturation based on the medium

Line number			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mass of the solution in grams			1750	1680	1700	1600	1600	1675	1750	1750	1700	1650	1750	1650	1625	1750	1750
			1660	1580	1800	1590	1590	1750	1800	1750	1750	1650	1750	1850	1675	1800	1800
Average mass			1705	1630	1750	1595	1595	1712.5	1775	1750	1725	1650	1750	1750	1650	1775	1775
Water medium	Mass of dry samples	1	545	500	475	440	435	480	515	533	480	470	475	465	470	500	465
		2	545	510	490	480	435	480	512	500	485	475	450	490	425	505	470
	Mass of saturated samples	1	600	545	535	500	495	530	555	595	540	520	520	520	540	540	515
		2	580	550	550	535	495	530	560	555	535	530	500	550	555	550	520
	Water saturation coefficients	1	10.09	9	12.63	13.63	13.79	10.41	7.77	11.63	12.5	10.63	9.47	11.82	14.8	8	10.75
		2	6.42	7.84	12.24	11.45	13.79	10.41	9.38	11	10.3	11.1	11.1	12.24	12.24	8.91	10.64
		average	8.225	8.42	12.44	12.54	13.79	10.41	8.58	11.32	11.4	10.87	10.29	12.03	13.52	8.46	10.7
Salty medium	Mass of dry samples	1	555	505	475	465	445	505	510	540	475	505	500	490	480	520	485
		2	550	525	490	480	445	495	530	510	480	490	475	485	485	485	485
	Mass of saturated samples	1	595	540	530	530	515	565	560	590	540	555	550	545	575	570	540
		2	580	565	540	540	515	540	580	565	550	555	535	545	535	540	550
	Water saturation coefficients	1	7.2	6.93	11.57	13.9	15.7	11.88	9.8	9.25	13.68	9.9	10	11.22	13.54	9.61	11.34
		2	5.45	7.62	10.2	12.5	15.7	9.09	9.43	10.78	14.58	13.26	12.63	12.37	10.3	11.34	13.4
		average	6.31	7.28	10.89	13.2	15.7	10.49	9.62	10.02	14.13	11.58	11.32	11.8	11.92	10.48	12.37
The required amount of media shutter for slumping the cone by 107 mm			18 kgs. of the mixtures														
			2200 ml	2200 ml	3000 ml	3000 ml	2800 ml	2900 ml	2000 ml	2300 ml	2900 ml	2800 ml	2600 ml	2800 ml	3000 ml	2300 ml	3000 ml

The dependences obtained above allowed us to construct response surfaces that reflect the mechanisms for changing the set of compressive and flexural strengths in series, depending on the environment being exploited.

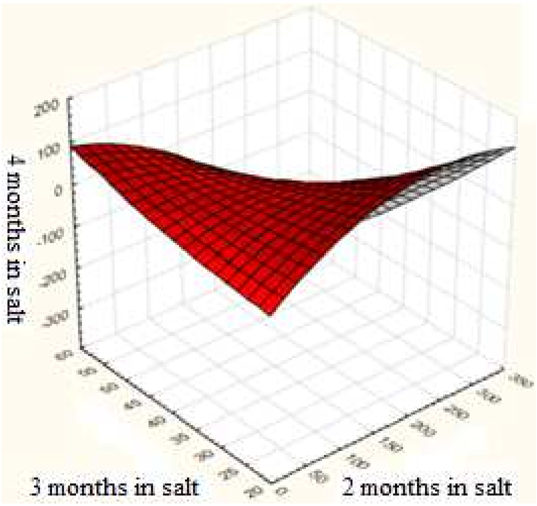


Compression

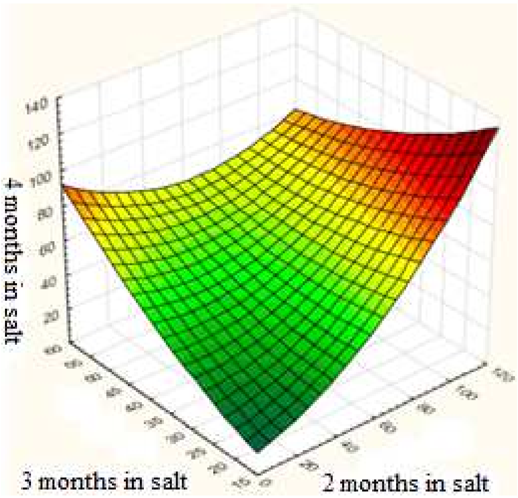


Bending

Figure 1. – The change in the compressive strength in water and salt



Compression



Bending

Figure 2. – The change in the bending strength in water and salt

After these studies, we can draw several conclusions:

1. The use of superplasticizer reduces the water-cement ratio, has a great effect on increasing the mobility of the concrete mix and significantly increases the strength of concrete in compression, as well as on bending.
2. The use of CMC helps in obtaining better concrete in the case of mobility while maintaining the strength of concrete. The use of CMC also increases the inhibition of corrosion of the concrete solution.
3. The use of GKJ-10 helps to preserve the durability of concrete by a large factor.
4. The use of complex additives, in our case the previous three, helps to maintain the durability of concrete while maintaining corrosion inhibition.

In order to describe the process of destruction of structural elements in an aggressive environment, additional parameters should be added to the system of defining parameters, taking into account the characteristic features of the impact of an aggressive environment. The characteristic features of an aggressive environment are described by complex mathematical and differential functions, which lead to difficulties in representing the work of the structure under a study. Consequently, the transition to computer simulation of the state of reinforced concrete structures when exposed to chloride corrosion, makes it much easier to study the physic-mechanical properties of reinforced concrete structures when changing the physic-chemical parameters of concrete [5].

Often, the results of virtual tests provide a wider picture of the processes occurring than a full-scale experiment, providing more opportunities for optimizing and improving performance, saving a considerable amount of time and money. In addition, the use of numerical-experimental research methods is practiced, when the results of field tests are complemented by the results of simulation modeling, which are unattainable in a field experiment.

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