The principles of composite construction penetrability waterproofing mortars with increased service life

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Summary. Investigated waterproofing penetrability mortars inflicted on concrete structures to improve their water resistance, durability, frost resistance. Optimized binder composition.

Key words: waterproofing mortars, portland cement, granulated blast furnace slag, natural zeolite, salts electrolytes, water absorption, durability, performance characteristics.

INTRODUCTION

Installation of waterproofing is the most difficult and responsible kind of works. That's why, only a systematic complex approach that includes the full research of buildings, can provide reliability and durability of technical solutions "material-construction-technology-exploitation" with all the factors influencing both a building as a whole and its individual elements [1].

In Ukraine materials of penetrating action, came on the market in the mid-90s of the last century. Today in Ukraine there are such permeable materials of penetrating action as Ceresit CR66 (Henkel Bautechnik, Ukraine), SikaTop®Seal-107 (Sika, Ukraine), Acwatron (Ukraine), Viatron (Ukraine), Aquamat Penetrat (Isomat, Georgia), Maxseal Super (Drizoro, Spain), Milenium (Satecma, Spain), Xypex (Canada), Penetron (Russia), Kalmatron (Russia), Lahta (Russia) [2].

Materials of penetrating action are got by using dry mixes based on portland cement, quartz sand and active mineral additives. The content of a large number of chemical additives in such of waterproofing mixes leads to the formation of efflorescence, cracking, peeling, reducing frost resistance, atmospheric durability and corrosion resistance, short-lived concrete and reinforced concrete structures. It should also be noted that the high cost of both the waterproofing material and repairs made, also cause some dissatisfaction of consumers [3].

To remove existing the shortcomings of waterproofing solutions of penetrating action it is necessary to adjust the composition of salts electrolytes and to create the opportunities for the phase regulation of transformations of binding extra alkalis (Na, K) into insoluble compounds (SO_2^{3-}, SO_4^{2-}, NO_3^{-}), followed by their participation in formation of with improved performance characteristics of artificial stone structure.

To manage processes of structure formation of portland cement compositions modified by active mineral additives, natural zeolites and salts electrolytes, will adjust the strength and deformation characteristics of artificial stone and open the possibility of creating effective materials as a basis for waterproofing solutions of penetrating action with given properties.

PURPOSE OF WORK

The purpose of work is development of durable waterproofing coverings of penetrate action with the increased operational properties on the basis the slag-contain cement modified by additives of natural zeolites and a complex additive of salts-electrolytes. The last will allow to synthesize ettringite like combinations which will serve as the crystallization centers for the low-main hydrosilicates of calcium.

MATERIALS AND METHOD OF TESTING

Experimental researches were conducted on the basis of cement composition consisted of Portland cement CEM I 500, the blast furnace granulated slag of Krivorozhsky plant (Ukraine) and natural zeolite-clinoptilolite (Ukraine). As components of chemically active complex action salts of alkaline metals such: sodium nitrates, sodium carbonates and sodium sulfates were accepted.

Mixture for receiving a waterproofing covering consisted of mineral binding and quarts sand sizes less than 0,63 mm. The ratio of a cement:sand made 1:1,5. The amount of water selected resulted from the need of ensuring sufficient mobility and spreadability of mix. Taking into account these requirements water:cement ratio was within W/C=0,45…0,5 and flow table test with using Vick's ring reached 200…210 mm.

As compositions of comparison widely known waterproofing materials of penetrating action (the Penetron and Kalmatron, production of Russia) were chosen. Physico-mechanical researches were made according to standards on dry construction mixes DSTU B.V.126:2011. Durability of the coverings put on a concrete basis, was defined with the help of non-destructive measurement of compressive strength by a sclerometer, and water tightness - by a Karsten's tube. Composition of products hydration was identified, using physical and chemical methods of researches: an X-ray phase, differential and thermal methods of the analysis and electronic microscopy.

RESULTS AND DISCUSSION

The analysis of the results showed that the lowest water absorption value (Tab.1) 7 (0.5 ml), 360 days (2.9 ml) and relatively high strength (7.97 and 8 5 MPa, respectively) (Fig.1, *a*) are the characterized of coatings based on Portland cement, blast furnace granulated slag, natural zeolite and salts electrolyte with a ratio of components Na_2CO_3: Na_2SO_4:$NaNO_3$ = 4:5:1 [4]. It should be noted that the use of waterproofing coatings containing proposed complex salts with natural zeolite makes it possible to reduce water absorption value at 17.7...21.4 times (7 days) and 2.5...4.4 times (360 days).

Volume of the entrained air recommended for concrete for marine engineering with freeze-thaw resistance (F > 200).

Table 1. Compressive strength and water absorption of coatings after 7 and 360 days of testing

№ composition	Compressive strength, MPa		Water absorption, ml	
	7 days	360 days	7 days	360 days
1	7,17	6,39	0,6	20
2	9,04	7,97	0,5	5,1
3	7,97	8,71	0,5	2,9
4	11,4	10,94	10,7	12,8
5	10,34	6,25	6,2	23
6	9,27	6,84	0,5	17

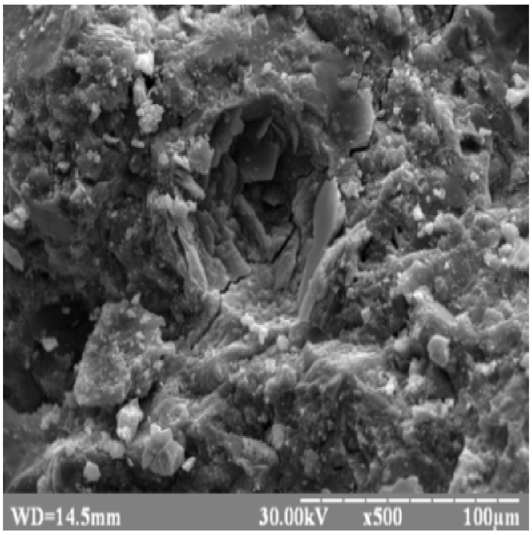
Remark: water absorption coverings based on slag contain cement with an additive of natural zeolite (composition 4) and with additives of sodium salts (carbonates, sulfates, nitrates), taken in various ratios (composition 1, 2, 3); comparative compositions of “Penetron” and “Kalmatron” (5, 6 respectively).

The designed coverage is competitive to the waterproofing material presented in Ukraine (compared “Penetron” has water absorption 6.2 ml and 23 ml respectively after 7 and 360 days, and the strength of the coating 10.34 MPa and 6.25 MPa, respectively, after 7 and 360 days; “Kalmatron” has water absorption of 0.5 ml and 17 ml respectively after 7 and 360 days, d strength of the coating 9.27 MPa and 6.84 MPa, respectively, after 7 and 360 days).

The phase composition of new formation was studied using an X-ray diffraction, differential thermal analysis and an electron microscopy for disclosing the mechanism of action of the optimum composition of binder systems.

It is discovered that the phase composition of new formation at the early stages of hydration of Portland cement modified by the addition of granulated blast furnace slag (28.5 %), natural zeolites (5.0 %) and salts electrolyte with optimal component Na_2CO_3: Na_2SO_4:$NaNO_3$ = 4:5:1, is represented mainly by hydrosilicates of calcium and a hydrosulphoaluminate type of ettringite structure (AFt that AFm), that occlude its pore space both reducing water absorption and water penetration in time.

From presented photomicrographs it's clear that after 1 year of hardening, composition the base on Portland cement with the addition of granulated blast furnace slag and natural zeolite (Fig.1, *b*), the formation of large amounts of hydrosilicates of calcium and randomly placed between unparalleled natural zeolites



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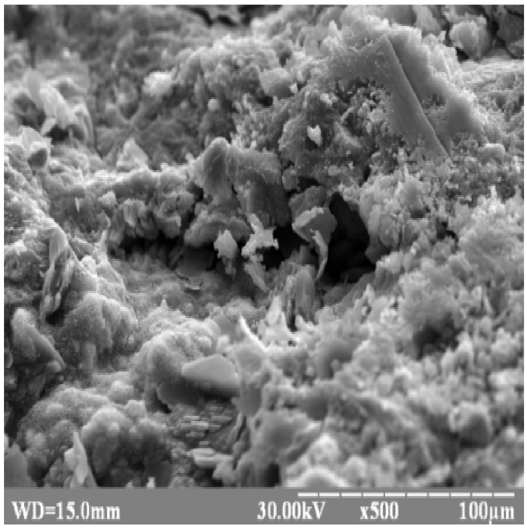

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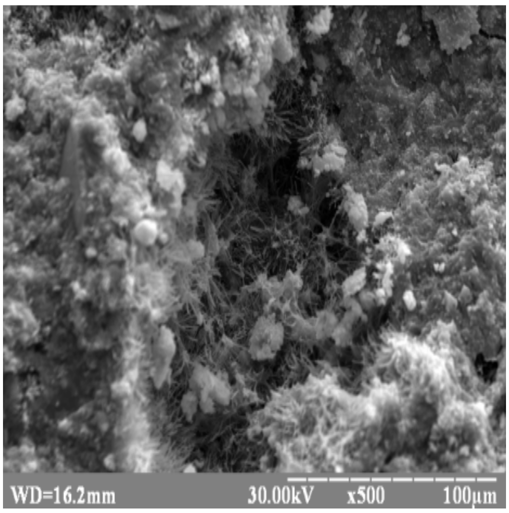


c

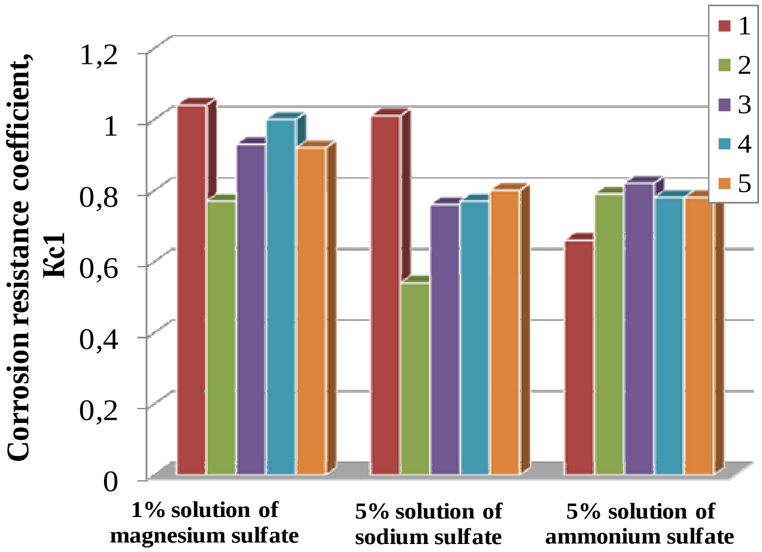
Fig. 1. SEM micrograph of the sample, after 1 year of hardening, based on Portland cement with the addition of granulated blast furnace slag *a* **with** the following modification of natural zeolite *b* or complex supplement containing natural zeolite and salt electrolytes *c*

like analcime and gmelenite are fixed.

Photomicrographs of this composition modified by a complex additive of salts electrolytes (Fig.1, *c*), show formation of solid solution ettringite, the modified by hydrosilicates of calcium and the new formation like zeolites type analcime and nosean.

The mechanism of penetration of active ingredients in the concrete structure is the main feature of materials of penetrating action. Researches were carried out with the aim to demonstrate how and how deep the active ingredients penetrate the waterproofing mortar concrete base.

Since the reaction products of salts $NaNO_3$, Na_2SO_4, Na_2CO_3 with composite cement is not only the formation of AFt and AFm phases but also alkali as NaOH, as an intermediate prod-



a

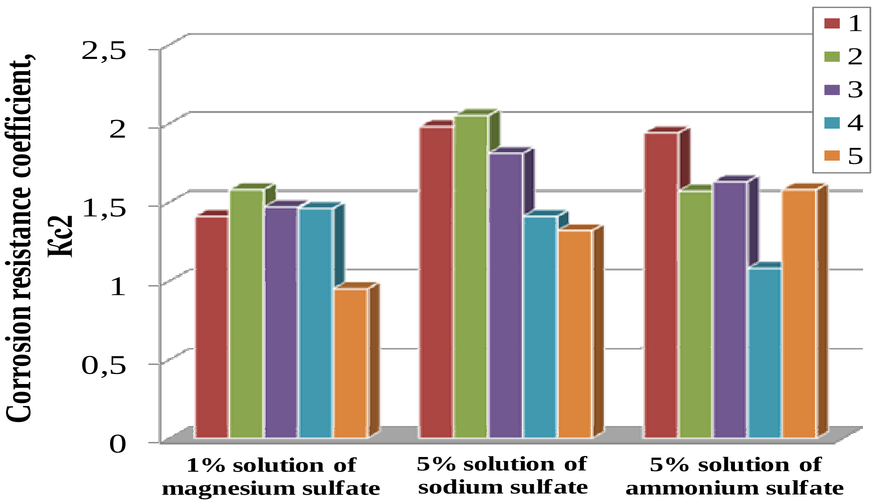


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Fig. 2. Variation of corrosion resistance coefficients K_{C1} (*a*) and K_{C2} (*b*) for coating compositions: ‘‘portland cement + granulated slag + natural zeolite + salts electrolytes’’ (1); ‘‘portland cement + granulated slag + salts electrolytes’’ (2); ‘‘portland cement + granulated slag + natural zeolite + salts electrolytes + GKJ 136-41 (3); Penetron (4); uncoated control sample (5) (after 126 days the test)

ucts of reactions, it's the next attempt to show the degree of penetration waterproofing material in the basis using the changes of color depending on the pH indicator solution of salts. To determine the alkaline environment (pH>7) alcoholic solution of phenolphthalein applied a fragments of sample was used.

When processing solution phenolphthalein cleavage surface samples of concrete, coated secure optimal composition (after 7 days curing), the entire area cleavage painted in rich crimson.

This effect describes the alkalinity formed by reaction environment interaction active component waterproofing materials and products of Portland cement hydration. It was established that the active components penetrate waterproofing material over the entire height of the samples, while the samples without applied coating did not change its color when applied phenolphthalein solution.

Using this solution for chemical treatment of surface fine concrete covering with waterproofing material of optimal composition (after 7 days curing), the whole area cleavage painted in a rich crimson color. That characterizes the alkalinity of the environment formed by reactions of active components of waterproofing materials and hydration products of Portland cement. In addition active ingredients of waterproofing material penetrate over the entire height of the samples, while samples with non applied coating did not change their color when phenolphthalein solution was applied.

The study porosity changes of the samples of fine concrete, coated with waterproofing solution of optimal composition after curing for 28 days and showed that the value of the porosity of the samples in the upper (1...3 cm) is much smaller than in the middle (7...9 cm) and lower ones (14...16 cm), which can be explained mudding pore space of cement formed by hydration products.

In order to reduce the amount of water absorption and extension of setting time for mortar mixtures, that meet the requirements of DSTU B.V.126:2011 on penetrating waterproofing action, as modifying additive GKJ 136-41 was used.

The obtained results show the effectiveness of the modification of waterproofing solutions of the developed composition by the additive of the repellent action, manifested primarily to reduce water absorption value (0.3 ml – after 7 days, 1 ml – after 28 days), expanding the terms of setting (start – after 30 minutes, the end – after 1 hour 25 minutes) and positive impact on the strength of binding systems, especially in the later stages of hardening (after 28 days), when the growth of strength is 25...45% compared to the strength characteristics of samples that do not contain some kind of additive GKJ 136-41 [5].

To assess the effectiveness of binders modified by complex additives for studied physical (high density, porosity and water absorption) and mechanical properties of the coating of developed samples were studied.

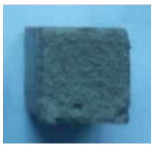
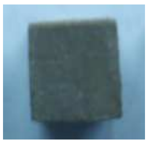
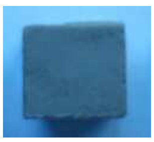
Analysis of the data allows to note the positive impact of complex additives introduced into the Portland cement on the physical characteristics of artificial stone after 7 and 365 days of curing. Thus, the use of salts electrolytes in the consist of binding compositions leads to a decrease in porosity (especially in 365 days curing) coatings formed almost 4 times. With the introduction of the mortar mixture of salts, electrolytes along with the addition of GKJ 136-41 water absorption value after 7 day, curing decrease from 1.24 to 0.05%, which is almost 24.8 times.

The corrosion resistance of waterproofing coatings of optimal composition in corrosive environments: 5% solution of sodium sulfate, 5% solution of ammonium sulfate and 1% solution of magnesium sulfate was studied.

It's established that the highest rates of corrosion resistance coefficient K_{C1} characterized for the concrete with a coating based on Portland cement with the addition of granulated blast slag, natural zeolite and salts electrolytes, after holding 1%-th solution of magnesium sulfate. The lowest rates of corrosion resistance coefficient (K_{C1} = 0.77) in this environment was showed that the concrete protected by coating based on Portland cement with the addition of granulated blast slag and salts-electrolytes (Tab.2).

The greatest of coefficient corrosion resistance in 5% solution of sodium sulfate was characterized the concrete samples protected by the reserved coated. The coefficient of corrosion resistance is K_{C1} = 1.01 compared with samples bearing the waterproofing coating "Penetron" (K_{C1} = 0.77) after 126 days. The samples witch protected by coating based only on portland cement, granulated blast slag and salts electrolytes are characterized by the least corrosion resistance coefficient.

Table 2. Outward of samples of waterproofing solutions depending on the type of aggressive environment after 180 days of holding

№ composition	The outward of specimens after holding in solution		
	1% $MgSO_4$	5% Na_2SO_4	5% $(NH_4)_2SO_4$
1			
2			
3			
Penetron			

The studies show that the samples with the greatest of corrosion resistance coefficient characterized samples protected by reserved coating based of the composition with the addition of GKJ 136-41 after holding a 5% solution of ammonium sulfate. The coefficient of corrosion resistance is K_{C1}=0.82 (after 126 days) compared with the samples bearing the waterproofing coating "Penetron" (K_{C1} = 0.78). The samples protected by reserved coated based on the composition that contains water-repellent additives are characterized the least of corrosion resistance coefficient (K_{C1} = 0.66). Thus, the use of additives GKJ 136-41 as a part of the developed waterproofing solution is essential for the protection of concrete that will be operated in solutions of ammonium sulfate.

Service properties of the composition of waterproofing coatings applied to concrete examples: reserve according to the strength cohesiveness to the base in air-dry conditions is 0.75 MPa, the strength cohesiveness to the base in water – 1.0 MPa; water tightness – W8; frost resistance – F150 [6].

CONCLUSIONS

1. Structures of waterproofing coverings of penetrating action on the bais of the slag-contain cement compositions are modified by natural zeolites and a complex of salts which have high operational characteristics and stability of properties in time are developed.
2. Introduction of natural zeolites in Portland cement and slag system allows to connect free alkali (Na, K) in insoluble hydroaluminosilicates and to occlude anions (SO_3^{2-}, SO_4^{2-}, NO_3^-) in difficult inorganic complexes that in turn serves as a guarantee of durability of a waterproofing covering in time.
3. The offered structures of waterproofing materials provide a durable covering with high operational characteristics (in 1 year hardening a compressive strength makes more than 8 MPa, and water absorption – less than 3 ml) which aren't inferior to characteristics of analogs of comparison of domestic and foreign production.
4. Service properties of the coating compositions developed on the basis of waterproofing solutions are investigated:

- strength of coatings: after 7 days is 17.5 MPa, after 365 days – at least 20 MPa;
- capillary water absorption after 24 hours of using tubes Carsten – 0.3 ml;
  corrosion resistance coefficient after holding: 1% solution of magnesium sulfate is 1.04; 5% solution of ammonium sulfate –

0.82; 5% solution of sodium sulfate – 1.01;
- the strength cohesiveness to the base in air-dry conditions is 0.75 MPa, the strength cohesiveness to the base in water – 1.0 MPa; water tightness – W8; frost resistance – F150.

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ПРИНЦИПЫ КОМПОЗИЦИОННОГО ПОСТРОЕНИЯ ГИДРОИЗОЛЯЦИОННЫХ РАСТВОРОВ ПРОНИКАЮЩЕГО ДЕЙСТВИЯ С ПОВЫШЕННЫМ СРОКОМ ЭКСПЛУАТАЦИИ

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Аннотация. Исследованы гидроизоляционные растворы проникающего действия, нанесенные на железобетонные конструкции для повышения их водостойкости, долговечности и морозостойкости.

Ключевые слова: гидроизоляционные растворы, портландцемент, доменный гранулированный шлак, природный цеолит, соли-электролиты, водопоглощение, долговечность, эксплуатационные свойства.