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METHOD TO IMPROVE THE EFFICIENCY OF VOLUMETRIC HYDROPHOBISATION OF PROTECTIVE LAYERS OF BUILDING STRUCTURES

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Abstract
Introduction. The protection and repair of concrete structures are the challenges of high priority, some solutions of which are presented in standards such as EN 1504 and GOST 32016–2012. Application of waterproof compounds is one of the main methods to protect concrete structures from water impact. Sealants are widely used to preserve the concrete properties, providing surface or volumetric hydrophobization. **Purpose** of the study was to develop and substantiate a new method to improve the efficiency of volumetric hydrophobization of protective layers made of dry mix mortar (DMM) based on microcement. **Materials and Methods.** Microcement MC MicroOST brand produced by New Technologies LLC was used as the main component of dry mixes, aluminous (AC-35-40) and high aluminous (HAC-70) cements were considered as aluminate components. Comparative assessment of hydrophobic properties of the prepared formulations of DMM based on microcement was carried out by contact angle and water absorption indicators. **Results** of the study showed that samples with introduction of aluminate component, such as high alumina cement (HAC), demonstrated high level of hydrophobicity and faster completion of water uptake into the material, relative to samples with HAC-35-40, samples of control formulation K-1, or with alternative additives (formulation with Mapelastic). It was found that introduction of high alumina cement in amount of 10–15 % provides maximum hydrophobicity for the proposed method. Analysis of the form of the water contact angle revealed formation of water-repellent film on the treated surface of samples with 10 and 15 % of high alumina cement. With regard to other coatings, it has been noted that they are highly resistant to water penetration deep into the material. These results demonstrate high efficiency of the proposed method to improve volumetric hydrophobization of protective layers made of dry mix mortar and used to protect building structures from moisture and ensure their durability and strength.

Keywords: dry mix mortarres, hydrophobicity, aluminate component, contact angle, water absorption, protective layer, repair compounds.

Introduction

Modern world experience of urban development in big cities shows that optimal conditions for sustainable development and comfortable living in the city may be reached if the share of underground structures in the total number of constructed facilities is not less than 20–25 % (Popov and Demidova, 2013). Meanwhile, concrete is the most frequently used material for the construction of underground buildings and structures. It is classified as a capillary porous material and is therefore characterized by its ability to absorb and filter the water. Porosity under otherwise equal conditions depends on the quality of concrete mix laying, selected materials, and decrease in the performance characteristics of concrete over time is determined by operation of the structure in severe hydrogeological conditions. In this regard, in recent years, much attention was paid to the protection and repair of concrete and reinforced concrete structures.

The EN 1504 standard adopted in Europe in 2009 regulates requirements for materials and systems for protection and repair of concrete structures.

The Russian Federation in 2012 developed GOST 32016 standard aimed at harmonization with the above mentioned EU standard, the GOST standard sets out the principles and methods of protection and repair of concrete structures.

According to the requirements of regulatory documentation, the most available methods of protection of concrete structures from corrosion, excessive water absorption, and reduction of thermal protection properties are coatings with waterproof formulations (Kubal, 2012; Zarubina, 2011).

Special hydrophobic formulations, which can provide surface or volumetric hydrophobization according to the method of water impact protection (Fig. 1) are used for preservation of properties of concrete in structures.

It shall be noted that during surface hydrophobization the Formulations of Group 1 (Table 1) provide water resistance due to dense compaction of low permeability microstructure with polymer film, which provides water-resisting properties inside the matrix. The formulations

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of Group II increase water resistance by hydrophobization of the surface of capillaries, which blocks the penetration of water into cement structure.

According to this property, waterproof materials are classified as:

- materials preventing filtration of water under pressure;

- materials which do not absorb water by capillary water absorption when the surface of the product comes into contact with water.

Despite the availability of a wide range of various waterproofing materials, reliable results may be achieved only due to the correct choice of components, their compatibility and strict compliance with the Standard Operating Procedures. Moreover it is well known that hydrophobicity is determined not so much by properties of the material as a whole, but rather by the properties and structure of the near-surface layer, which is several micrometres thick (Boinovich and Emelyanenko, 2008). The design of hydrophobic coatings was guided by the principles of creation of such formulations, based on the latest achievements in the field of design of waterproof protective films (Zhao et. al., 2006; Selyaev et. al., 2019; Martuzaev et. al., 2021; Hao, 2021; Jihui et. al., 2022).

Beside high hydrophobicity, protective coatings should have high adhesion to the original concrete and the maximum compatibility with its structure. A popular method is the introduction of waterproofing additives directly into the cement-sand mixture. However, such cement-sand formulations are subject to shrinkage phenomena, which reduces the protective properties of the coatings. Therefore, in practice, waterproofing coatings based on a formulation of Portland cement and gypsum alumina cement, which provides the effect of shrinkage reduction or even slight expansion are widely used (Chumachenko et. al., 2016; Liang et. al., 2023; Maltseva, 2016; Lesovik et. al., 2014). According to research studies, the dosage of alumina-containing components used for the improvement of the waterproofing ability of the formulation of multipurpose dry mixtures varies from 1.5 to 50 % (Kuzmina, 2017). This is due to the fact that, hydration products of alumina cement in the formulation with Portland cement recrystallize over time from hexagonal calcium hydro aluminates into cubic hexahydrates of tricalcium aluminate, which leads to decrease in strength of products (Kalatozi et al., 2024). To prevent this transition, modifying additives that increase stability of hydrate neoplasms are introduced into the dry mix formulation. The effect of hydrate phases of alumina cement expansion allows to increase density of the matrix and thereby increase the degree of protection of concrete structures from water penetration.

Regulation of properties of such formulations is possible by application of various modifying additives, which not only determine the setting time and kinetics of the strength gain, but also provide the effect of waterproofing due to the impact on formation of hydrate phases with dense compaction of matrix and formation of a surface with low surface energy at the solid/liquid boundary.

It is possible to increase hydrophobicity of the surface by creation of special texture on the material surface with the application of fillers with multimodal particle size distribution embedded in the matrix of hydrophobic material, due to which a "*lotus effect*" is created on bumpy surface, when a drop of water cannot be evenly located on it, because it is prevented by surface tension forces (Pang et. al., 2023).

In the process of consideration of the principles and methods of protection, special attention should be paid to compatibility of applied materials for repair

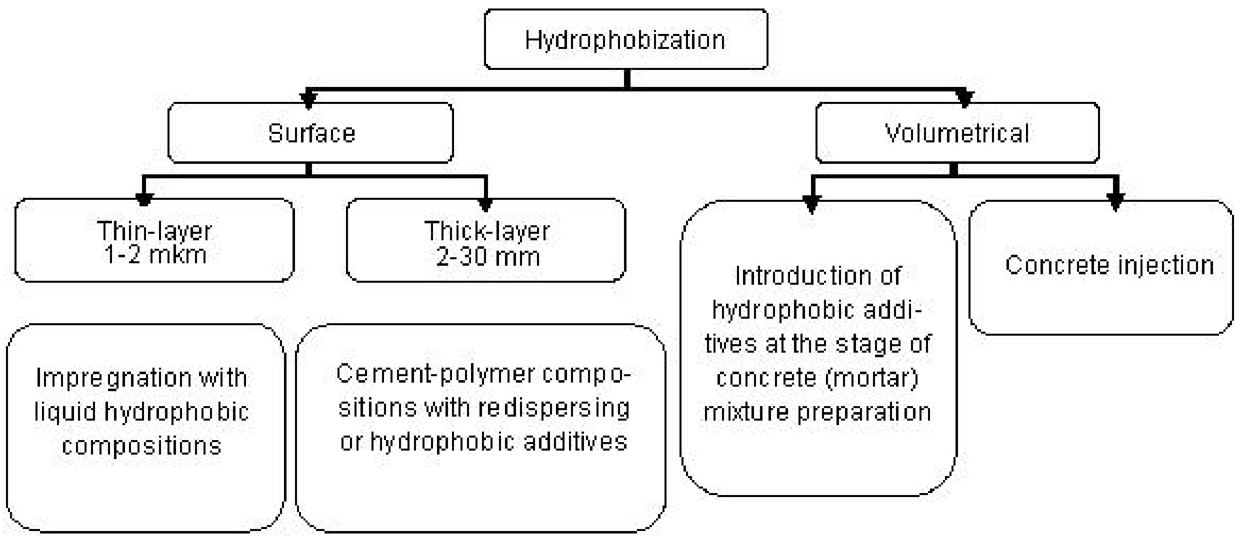

Fig. 1. Methods of concrete and reinforced concrete structures protection with the use of hydrophobic special formulations

Table 1. **Methods and Mechanisms Providing Water Resistance of Protective Coatings**

Formulation types	Waterproofing method	Waterproofing mechanisms	
Group I	Coatings preventing filtration of water under pressure	After hardening the coatings form microporous structures with low permeability (filtration coefficient Kf ≤ 1-10-10), withstanding water pressure up to 0.8–1.0 MPa and more (according to GOST 12730.5).	The coatings provide dense compaction of mineral components of the cement mix, as well as aggregate and filler particles due to the application of different functional additives that create a cement-polymer film with low microporous structure.
Group II	Coatings which do not absorb water by capillary water absorption when the surface comes into contact with water	Due to the effect of capillary surfaces hydrophobization, they form coatings that are not wetted by water and have water absorption approaching zero.	The coatings do not protect structures from penetration of pressurized water, but reduce the rate of its filtration through the coatings. These materials prevent moistening of fencing elements of the structure when they are exposed to heavy rainfall, in conditions of possible capillary rise of groundwater, when condensate is formed on the surface of structures due to the introduction of water-repelling agents into the mixtures.

and protection works with original concrete of the structure (Sokolova, 2010). Cement-based dry mix mortar that provide hydrophobic protective coatings are suitable for protection of concrete and stone surfaces from moisture, as well as brick and ceramic facades of buildings, paving slabs, swimming pools and terraces. The surface treatment with such formulations leads to formation of hydrophobic coating with low porosity, which reduces water absorption of the material and increases its service life (Abdalla et. al., 2009; Malgorzata et. al., 2023; Loganina et. al., 2013).

During production of dry mix mortars, joint grinding of Portland cement and functional additives provides homogeneity of mineral formulation of the product and its physical and mechanical properties, leads to simultaneous mechanical activation of all components, provides special properties by introduction of functional additives in the grinding process and guarantees high compatibility of microcement matrix and concrete structures (Shakhova et al., 2023).

Particle size of the formulation and uniform distribution of all components are of particular importance. Therefore the microcement was used during preparation of effective waterproofing coatings. Size of microcement particles is comparable with the size of capillaries and may penetrate deep into the body of concrete in the form of dilute aqueous suspensions, blocking water flows, as well as restoring the strength lost over time. The second component used was finely ground sand with an average particle size of less than 25 mkm.

In this regard, the purpose of the study was to prepare and substantiate the method of improvement of the efficiency of volumetric hydrophobization through introduction of alum-containing components into dry mix mortars based on microcement and determination of optimal ratio of these components, providing maximum contact angle, and minimum water absorption.

Methods

This study refers to investigation of the surface and hydrophysical properties of the prepared formulations of dry mix mortars based on microcement. The following components were used for the study: microcement of MC MicroOST brand produced by the New Technologies LLC (Shakhova et al., 2023); alumina (AC-35 40) and high alumina (HAC-70) cement produced by the Pashinsky Metallurgical and Cement Plant OJSC; gypsum produced by the Peshelansky Gypsum Plant LLC.

Quartz powder obtained by grinding of quartz sand produced by the New Technologies LLC (hereinafter — ground sand) was used as a filler.

Typical particle sizes and Blaine specific surface area of microcement and ground sand in the formulation are presented in Table 2.

To improve special properties to dry mixtures, a complex modifying additive consisting of setting regulators, dispersants and acrylic copolymers was additionally introduced.

To obtain a thin-layer coating formulation from the dry mix, mixing water was added until equal mobility was reached, which was evaluated by Kantro's slump test (Kantro, 1980).

Hydrophobic protective compounds were applied by brush to pre-cleaned surface of mortar samples with dimensions 40×40×160 mm (shape according to GOST 30744–2001) in 2 layers. Before application of the waterproofing layer, the surface of the samples was wetted. Thickness of the protective coating was 1–1.5 mm. Samples with a protective layer were stored in a normal hardening chamber at a temperature of (20±3) °C and relative humidity of (95±5) % during 28 days.

Samples of uncoated cement-sand mortar (K-1) and samples coated with Mapelastic, a 2-component mixture widely used for waterproofing concrete pavements, produced by Mapei, were taken as control samples to compare the hydrophobic properties of the prepared formulations.

The waterproofing coating was evaluated by two methods. Water absorption of samples was tested according to GOST 12730.3–2020. After 28 days of hardening, the coated samples were weighed and then immersed in water so that the water level was 50 mm above the top level of the samples. After every 24 h, the samples were removed from water and pre-wiped with a drained damp cloth. Test was carried out until the results of two consecutive weighings differed by not more than 0.1 %.

The second method was the well-known water droplet test, which was performed by optical measurement of the contact angle of the surface by a droplet (Iwamatsu, 2011; Mittal, 2018; Bormashenko., 2009; Antonini et. al., 2009). The contact angle of liquid on the surface of a porous capillary body may be formed only in presence of a film that prevents movement of liquid into the material under study.

It does not take into account the effect of water pressure on moisture penetration into the sample (Loganina and Sergeeva, 2020). During complete wetting of the surface the angle is 0 degrees, and during complete non-wetting the angle is 180 degrees, this is the main factor for determination of the hydrophobicity or hydrophilicity of material. The contact angle was measured with Kruss DSA 30 instrument. For this purpose, a drop of water was applied to the sample with protective coating, the fact of drop application was pictured. The treatment was carried out according to the instrument program.

Type and dosage of alumina cement, as well as content of ground sand varied in the dry mix formulations based on microcement (Table 3). We studied formulations with alumina cement content from 5 to 15 wt.%.

During calculation of the composite content based on hydrophobic cement formulations, we initially determined requirements for the final product, such as degree of hydrophobicity, strength, environmental resistance and other technical parameters. Then, we selected components including wetting agents, strength boosters, stabilizers and other auxiliary additives in order to provide the required properties. Next, we conducted laboratory studies and tests to determine the rational concentrations of components and their interactions, providing the desired technical characteristics and product quality (Selyaev et al., 2019; Badmaeva et al., 2022; Guvalov et al., 2018; Nguyen et al., 2023).

Thus, the following formulations were analyzed in this paper:

1. Samples of prepared DMM labeled GF-5, GF-10, and GF-15. Composite binder (microcement + alumina cement + gypsum) + ground sand + + complex additive. Microcement was used to improve performance characteristics of the composite. The purpose of its application is to get a denser and stronger surface, which contributes to the durability and aesthetic appearance of the product. Alumina cement was added to improve chemical resistance and strength of the composite. This type of cement has a high degree of resistance to aggressive chemicals and provides additional protection against degradation processes. In addition, a complex additive was used to regulate the time of the composite hardening, increase mobility of the mixture and provide hydrophobic effect. This additive enables precise monitoring of the time required for the composite to harden, which is particularly important in handling. Increasing mobility of the mixture makes the application easy and convenient, and the hydrophobic effect helps to

Table 2. **Typical Particle Sizes and Specific Surface Area**

Characteristics	Microcement MC MicroOst	Ground sand
Particle diameter at 95 wt%; D_{95}	16	65
Modal particle diameter, wt %; D_{cp}	7.5	15.7
Blaine specific surface area, m^2/kg	950	610

Table 3. **Formulations of dry mix mortars**

Formulation identification number	Composite binder, %				Ground sand, %	Complex modifying additive, %	w/c ratio
	MC	HAC-70	AC-35 40	Gypsum			
GF-5	40	–	5	1.65	53.1	0.25	0.25
GF-10	40	–	10	1.65	48.1	0.25	0.22
GF-15	40	–	15	1.65	43.1	0.25	0.24
GA-5	40	5	–	1.65	53.1	0.25	0.27
GA-10	40	10	–	1.65	48.1	0.25	0.265
GA-15	40	15	–	1.65	43.1	0.25	0.26

protect the structure from moisture and improve its resistance to external factors.

2. Samples of prepared DMM labeled GA-5, GA-10, and GA-15. Composite binder (microcement + + alumina cement + gypsum) + ground sand + + complex additive. High alumina cement was used to improve strength and resistance of the composite to aggressive impact. This type of cement is characterized by high alumina content, which provides it with exceptional resistance to chemical attack and abrasion. Addition of high alumina cement to the composite allows for creation of material that can withstand extreme operating conditions such as high temperatures, humidity, aggressive chemical environments and mechanical stresses. Advantages of the application of high alumina cement include its ability to form crystalline structures that have high strength and corrosion resistance. This contributes to significant extension of the service life of structures made of such composite and reduction of the risk of their destruction under impact of various factors.

3. Sample of uncoated cement-sand mortar (K-1) — as a reference mortar.

4. Sample coated with Mapelastic, a two-component mortar based on cement binder, fractionated fine aggregate, special additives and synthetic water-dispersion polymers mixed according to a formula originated by Mapei's own research laboratories.

Results and discussion

According to the test results of coatings shown in Figs. 2–4, it was found that the samples the surface of which is coated with formulations GA-10 and GA-15, which corresponds to contact angle values of 100° and 96°, respectively, have a hydrophobic effect. The formulations of such coatings include high alumina cement HAC-70, content of which is 10 % and 15 %, respectively. This means that formulations have the ability to repel water, which makes the surface of the material less susceptible to moisture penetration. As for other coatings, their high resistivity to water penetration deep into the material was observed. These coatings act as a barrier to water penetration into the matrix, preventing its destruction and preserving its structure and strength over time. Therefore, the results demonstrate effectiveness of GA-10 and GA-15 formulations with high alumina cement as hydrophobic coatings to protect materials from water and improve their performance properties. The lowest contact angle was measured in the formulation from Mapelastic (18).

The overall ranking of the samples according to contact angle increase is as follows:

К-1 → Mapelastic → GA-5 → GA-15 → GF-5 → → GF-10 → GA-15 → GA-10.

So, the introduction of high alumina cement from 10 to 15 % into the formulation allows reduction of surface energy at the solid/liquid interface.

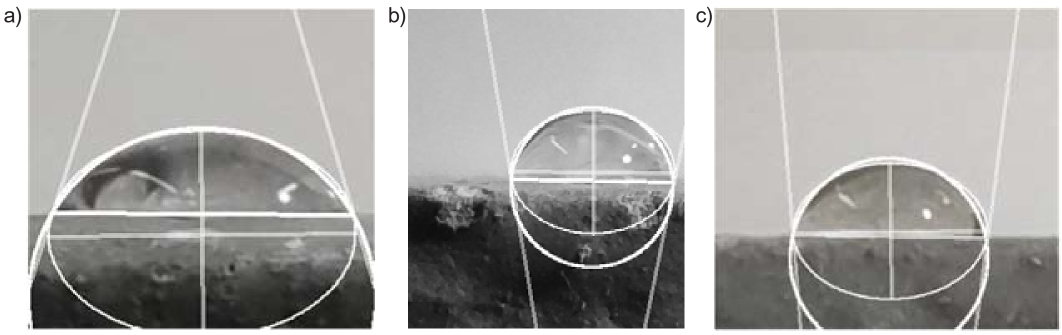

Fig. 2. Contact angle on the surface of the protective layer of the formulation containing AC-35-40:
a — GF-5 (θ = 76°); b — GF-10 (θ = 77°); c — GF-15 (θ = 75°)

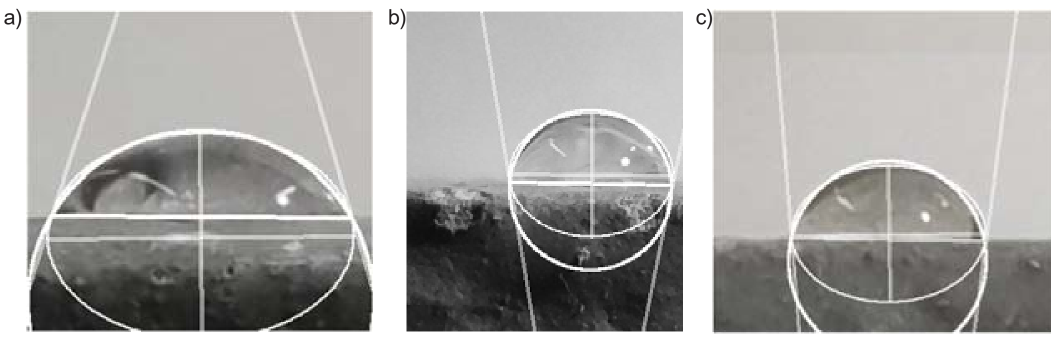

Fig. 3. Contact angle on the surface of the protective layer of the formulation containing HAC-70:
a — GA-5 (θ = 74°); b — GA-10 (θ = 100°); c — GA-15 (θ = 96°)

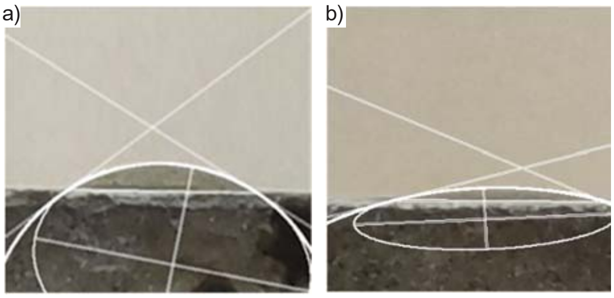

Fig. 4. Contact angle on the surface of the protective layer of the formulation: a — Mapelastic (θ = 34.2°); b — K-1 (θ = 18.3°)

An additional criterion contributing to the assessment of the level of hydrophobization of surface coatings is the water absorption. Protective layer shall have hydrophobic properties and a dense volumetric structure to prevent water penetration to the concrete or mortar substrate. Kinetics of water absorption by samples coated with protective layers of hydrophobic dry mixes is presented in Fig. 5.

Analysis of the graphs showed that all samples have high water absorption during the first 3 days of the experiment. This period is characterized by intensive penetration of water into the material, which is due to its structure and surface characteristics. Approximately by Day 7 (for samples with HAC-70) and by Day 11 (for samples with AC-35-40) a stabilization of the water absorption process was observed. This is manifested in the fact that the sample mass change ceases to exceed 0.1 %, which proves the completion of the process of water penetration into the material.

It should be noted that in the reference sample K-1, completion of the water absorption process occurred on Day 10, and in the sample with Mapelastic coating — on Day 15. This points to different speed and efficiency of material protection from moisture penetration depending on the type and formulation of the coating used.

Therefore, experimental results allow us to conclude about the kinetics of water absorption of samples and effectiveness of hydrophobic coatings for protection of materials from water.

Analysis of water absorption by samples with coatings made of prepared dry mix mortars revealed the following trends. Compared to the coatings made of hydrophobic DMM Mapelastic, all samples with coatings showed better water absorption kinetics. The samples containing aluminate cement AC-35-40 showed faster completion of water uptake by four days compared to Mapelastic. The samples with introduction of HAC-70 aluminate cement showed even higher performance, completing the water uptake process eight days earlier than Mapelastic. Compared to the reference sample K-1, water absorption process was completed faster only for samples containing HAC-70 aluminate cement, and this was achieved three days earlier.

So, the highest water absorption was observed in the reference formulation K-1 (10 %). Protective coatings may reduce water absorption to 5 % on Mapelastic and up to 4 % on all prepared formulations.

Compared to the sample coated with Mapelastic formulation, application of coatings of the formulation series GF-10 and GF-15 can reduce water absorption by 2.5–3 times (from 150 % to 200 %).

During introduction of aluminate cement HAC-70 (series GA-10 and GA-15) into the formulation of protective coating, the water absorption decreased 2.8–4 times (from 180 % to 280 %).

High water absorption was observed in formulations GA-5 and GF-5. It means that despite the fact that the contact angles for a series of GF formulations are approximately equal, with the content of alumina cement 5 %, it was not possible to obtain dense layer of protective coating.

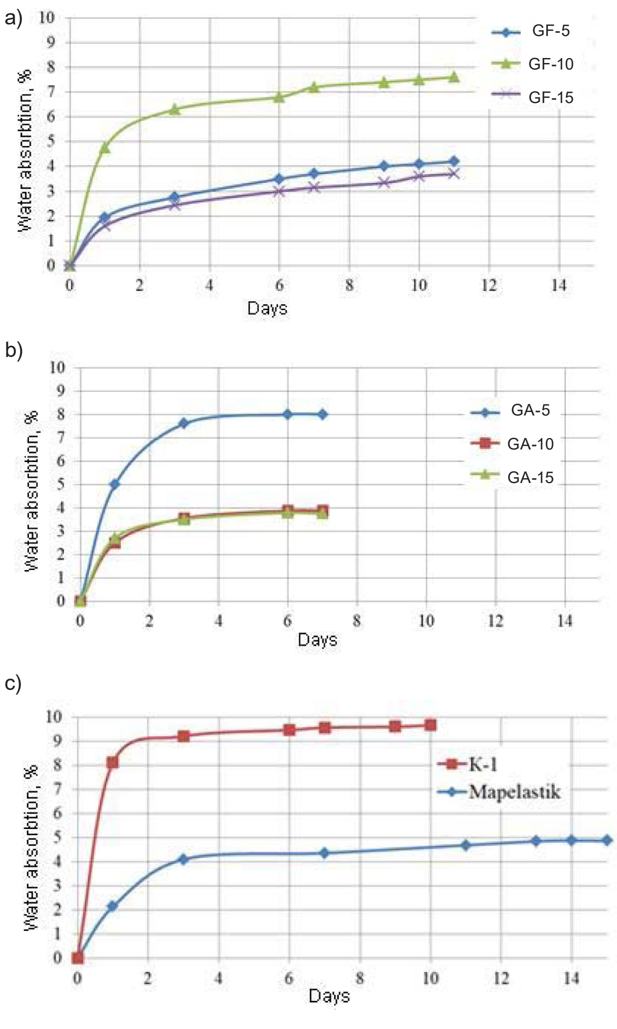

Fig. 5. Water absorption of cement-sand mortar samples with protective coatings depending on the formulation of dry mix: a — with the content of AC-35-40; b — with the content of HAC-70; c — control formulations Mapelastic and K-1.

The following trend of water absorption values growth relative to control samples (at 7 days) was established:

GF-15 → GA-15 → GF-10 → GA-10 →
→ Mapelastic → GF-15 → GA-5 → K-1.

The most effective value of the amount of absorbed water at the end of water penetration into material, among the samples containing aluminate cement AC-35-40, was shown by the formulation with GF-15 — (3.7 %) (on day 11). Among samples containing high alumina cement HAC-70, the most effective was the formulation with GA-15 — (3.74 %) (on Day 7). These samples are distinguished by their high performance over the long run due to their resistive capabilities, which means that they are able to maintain stable characteristics under prolonged exposure to moisture.

So, the obtained results emphasize the importance of selection of the right DMM formulation to achieve optimal moisture protection and ensure long-term stability of the material under different operating conditions. This supports the high efficiency of the proposed method of improvement of efficiency of volumetric hydrophobization of protective layers made of dry mix mortars and used to protect building structures from moisture and ensure their durability and strength. It should be noted as well that the obtained formulations have a high resistive ability to water penetration, so they play a role of a barrier for concrete building structures.

The following conclusions can be drawn from the conducted studies on selection of formulation of waterproofing coatings for concrete structures:

1. The highest contact angle was observed in formulations of protective coatings GA-10 and GA-15, the smallest contact angle in the Mapelastic formulation. The other tested formulations have a contact angle of about 75–76°.

2. Ability to reduce water absorption in the tested formulations GA-10, GA-15 and GF-10 and GF-15 are approximately equal (4 %), which is slightly higher than that of Mapelastic (5 %).

3. GA-5 and GF-5 formulations failed to produce a protective coating with low water absorption capacity.

4. The type of alumina cement and critical dosages were determined, at the introduction of which it was possible to obtain formulations with high resistivity to water:

- formulations containing alumina cement AC-35-40 in all dosages and formulation containing 5 % HAC during measurement of the contact angle;
- formulation containing 15 % of alumina cement AC-35-40 and formulations containing 10 and 15 % HAC during measurement of the water absorption index.

Conclusion

We have proposed and substantiated the introduction of aluminate components represented by alumina or high alumina cement into the formulations of dry mix mortars based on microcement in order to increase the efficiency of volumetric hydrophobization of protective coatings of concrete structures. The effectiveness of the originated approach was assessed by two methods: measurement of the contact angle and measurement of water absorption.

The study showed that introduction of aluminate cement into the formulation of dry mix mortars significantly improves their hydrophobic properties. Samples with addition of aluminate component — high alumina cement (HAC) showed a higher level of hydrophobization compared to samples without this component (reference formulation K-1) or with alternative additives (formulation with Mapelastic). Dosage of high alumina cement 10 % and 15 % is reasonable from the point of hydrophobicity increase.

BM containing aluminous cement as an aluminate component (AC-35-40) showed improved resistance to water absorption and faster completion of water absorption into the material, relative to samples with HAC, without this component (K-1) or with alternative additives (Mapelastic).

In water absorption studies, the most effective formulations were GA-10, GA-15 and GF-15.

Analysis of contact angle measurement showed availability of a water-repellent film on the treated surface of samples labeled GA-10 and GA-15 (samples containing HAC-70).

The obtained experimental data demonstrate the effectiveness of the proposed method of improvement of the volumetric hydrophobization, as well as the reasonable need for assessment of the quality of protective formulations by two methods aimed at assessment of the hydrophobic properties: measurement of contact angle and determination of water absorption.

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СПОСОБ ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ ОБЪЕМНОЙ ГИДРОФОБИЗАЦИИ ЗАЩИТНЫХ СЛОЕВ СТРОИТЕЛЬНЫХ КОНСТРУКЦИЙ

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Аннотация
Введение. Защита и ремонт бетонных конструкций являются приоритетными задачами, некоторые решения которых представлены в стандартах, таких как EN 1504 и ГОСТ 32016–2012. Применение гидроизоляционных составов – один из основных методов защиты бетонных конструкций от воздействия воды. Гидрофобные составы широко используются для сохранения свойств бетона, обеспечивая поверхностную или объемную гидрофобизацию. **Целью** исследования являлась разработка и обоснование нового способа повышения эффективности объемной гидрофобизации защитных слоев, выполненных из сухих строительных смесей (ССС) на основе микроцемента. **Материалы и методы.** В качестве основного компонента сухой смеси использован микроцемент марки МЦ МикроОСТ производства ООО «Новые технологии», в качестве алюминатных компонентов рассмотрены глиноземистый (ГЦ-35 40) и высокоглиноземистый (ВГЦ-70) цементы. Сравнительную оценку гидрофобных свойств разработанных составов сухих строительных смесей на основе микроцемента проводили по показателям угла смачивания и водопоглощения. **Результаты** исследования показали, что образцы с введением алюминатной составляющей, такой как высокоглиноземистый цемент (ВГЦ), проявили высокий уровень гидрофобности и более быстрое завершение процесса набора воды в материал, относительно образцов с ГЦ-35 40, образцов контрольного состава К-1 или с альтернативными добавками (состав с Mapelastic). Показано, что введение высокоглиноземистого цемента в количестве 10–15 % обеспечивает максимальную гидрофобность для предложенного способа. Анализ формы краевого угла смачивания выявил наличие водоотталкивающей пленки на обработанной поверхности у образцов с 10 и 15 % содержанием высокоглиноземистого цемента. В отношении других покрытий отмечается их высокая резистивная способность к проникновению воды вглубь материала. Эти результаты демонстрируют высокую эффективность предложенного способа повышения объемной гидрофобизации защитных слоев, изготовленных из сухих строительных смесей и применяемых для защиты строительных конструкций от воздействия влаги и обеспечении их долговечности и прочности.

Ключевые слова: сухие строительные смеси; гидрофобность; алюминатная составляющая; краевой угол смачивания; водопоглощение; защитный слой; ремонтные составы.