Efficiency of Additives for Aluminate Cement-based Dry Mixes for Self-Levelling Floors

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Abstract. This article examined the properties of non-shrinking binders for floor coverings. The main goal of the experiment is to develop a dry self-levelling, non-shrinking mixture for monolithic seamless flooring. The possibility of obtaining a non-shrinking dry mixture based on aluminate cements and gypsum is considered. The main structural component in the experiments is ettringite. Additive-modifying agents for rheological properties that work effectively with a two-component binder were selected experimentally. The results of rheological studies, measurements of expansion and shrinkage deformations, physical and mechanical properties of the hardened solution are given.

1. Introduction
The floors of industrial, sports and so on buildings must have the whole complex of properties: high strength and abrasion resistance, absolute resistance to cracking, absence of dust, hygienic properties etc. Another important property of the floors material is their ease of manufacturing. The most interesting materials from this point of view are self-levelling floors on the base of aluminate cement [1, 4].

When developing non-shrinking dry mixes for floorings of industrial enterprises, it becomes necessary to impart self-levelling properties to them. Self-levelling dry mixes are the floor dry mixes that can, under the action of gravity, self-level the bases (on which they were laid) and can create flat horizontal surfaces. The definition is given in accordance with GOST 31189-2015 “Dry building mixes. Classification”.

Traditional cement mixtures are coagulation systems. From the point of view of rheology, they are plastic viscous bodies. They can acquire the effect of self-levelling only if this structure is destroyed, minimizing the plastic component. In conventional concrete mixtures, structural fracturing is achieved by using vibration. The idea of self-levelling mixtures eliminates this possibility. In such mixtures, the plastic component can be minimized by increasing the amount of mixing resources and with the help of plasticizing additives.

These methods of destruction of the coagulation structure simultaneously allow to significantly lower the viscosity of the system and achieve its sedimentation. In this case, the water content in the upper layer of the stacked composition is increased, which significantly worsens its properties (strength, hardness, wear resistance etc.). This cannot be allowed to happen in compositions intended for facial floor coverings.
Two methods are mainly used to prevent sedimentation in concrete technology, the first being water binding by adding fine additives, the second - increasing the viscosity of the liquid phase with the help of polymeric thickening (water-retaining) additives. Both methods can be recommended for the tested compositions. The former method can be realized by increasing the specific consumption of binder in the mixture and optimizing of the grain composition of fillers and the degree of filling.

It is impossible to completely solve the problem by increasing the fraction of fine additives alone, because these additives cause the formation of new coagulation structures. Therefore, it becomes necessary to use water-soluble polymeric thickening additives. The mechanism of action of such additives is explained by the fact that solutions of high-molecular substances at low concentrations (0.5...2%) have a high viscosity and do not form coagulation structures.

Thus, to achieve self-alignment, it is necessary to use two types of additives: regulators of rheological properties and plasticizing and thickening (water-retaining) additives.

2. Methods and materials

Using aluminate cement as a main component for dry mixtures for self-levelling floors requires an adequate selection of the superplasticizer. Supplements of three main groups were selected for study: polymeric sulfonmelamine (Peramin SMF20 Perstorp Construction Chemicals Inc., Sweden) modified with polyethylene glycol (Melflux PP100F, Melflux PP200F, SKV Polymers GmbH, Germany) and polycarboxylate (Sika Viscocrete 105P, Swiss). Evaluating of the effectiveness of the superplasticizer joint venture was carried out in accordance with GOST 30459-2008 “Admixtures for concretes and mortars. Determination and estimate of efficiency” (EN 934-6:2002 Admixtures for concrete, mortars and grout – Part 6 Sampling, conformity control and evaluation of conformity). All the properties were determined on the samples with dimensions of 4x4x16 cm according to ASTM and GOST for the tests. Water-reducing effect is 57...63%. The study works were done by the equipment of MSUCE.

For the experiment, two cements were chosen: high-alumina cement (HAC) of domestic production and SRB 710 (France) with a high Al2O3 content (approximately 70%). Two major minerals – calcium monoauminate (CA) and calcium dialuminate (CA2) – dominate in the composition of selected cements. Basically, as a result of hardening, calcium hydroaluminate of composition CAH10 is formed. After 72 hours, the degree of hydration is about 80% for the CA and about 50% for the CA2. As a second binder component, which is necessary for expansion, we use natural dihydrate gypsum and semi-aquatic gypsum brand G-7. In the study we take the composition of the binder (aluminate cement:gypsum)=2:1.

According to the manufacturer, aluminate cement SRB 710 does not contain additives, though it works well with all types of superplasticizer additives. The rheological properties of the binder allow it to be used for casting, spraying, and using in self-levelling mortars. SRB 710 cement has a high curing rate.

3. Results and discussions

In previously made research, we have proposed compositions based on aluminate cements for the production of non-shrinking dry construction mixtures for coating industrial floors. The expansion of these compositions is associated with the controlled formation of ettringite – calcium hydroaluminate (3CaO•Al2O3•3CaSO4•31-32H2O). Such expansion binds a lot of water. The method was confirmed by several experiments on expansion and shrinkage deformations when producing a non-shrink two-component binder based on high-aluminous aluminate cement and gypsum [2,3].

Deformation of curing two-component binder developed as a result of the superposition of two competing processes: the expansion due to the formation of CASH and formation on its basis of the cement stone structure and shrinkage caused by the evaporation of water from the curing composition (Figure 1).
In the initial period, the formation of cement stone structure is very active, the rapid expansion, reaching 0.6…0.8 mm/m after 4…5 hours could be observed. As a result, the deceleration rate of hydration, sealing, but not the extension of curing system due to hydration products (indicated by a rapid increase of the strength of the composition after 4…5 hours after mixing) and the evaporation of water from the cured material, we observe a sharp decline in the rate of expansion, and then the resulting transition effect process after 5…6 hours from expansion to shrinkage. Although at this time, continues the process of expansion by hydration of the remaining share of CA and, in particular, CA₂. After 3…4 days the rate of shrinkage is stabilized and the initial expansion is compensated by shrinkage. The shrinkage of the composition is terminated after 10…12 days at a value of shrinkage of 0.8…0.9 mm/m. (to compare according to our measurements of Portland cement, it is about 8…10 times higher) [4-8].

![Figure 1. Dynamic change of deformation types of various binders in time: 1 – two-component binder; 2 – Portland cement](image)

Compatibility with the used two-component binder based on aluminosilicate cement is essential in the selection of additives – regulators of rheological properties. Their compatibility and mutual influence on each other are also very important. It is necessary to choose a complex of modifying additives that works effectively with a non-shrinking binder – a superplasticizer and a water-retaining additive (thickener).

The properties of aluminosilicate cements, superplasticizers and water-retaining additives from different manufacturers for experiments were analysed.

Products from different manufacturers were considered when choosing aluminosilicate cement. The table below shows data on the chemical composition and properties of aluminosilicate cements of domestic and foreign production (Table 1).
Table 1. Chemical composition and properties of aluminate cements

| Value                     | Chemical composition, % | Specific surface area, m²/kg | Curing time: the beginning – the end, hour | Compressive strength, 24 h, MPa |
|---------------------------|-------------------------|-------------------------------|---------------------------------|-------------------------------|
| LUMNITE (Germany)         | 38-42                   | 36-40                         | 310-370                         | not earlier than 2, not later than 5 | 35                          |
| ISTRA 40 (Germany)        | 39-42                   | 37-40                         | 300-340                         | not earlier than 1, not later than 5 | 65-75                       |
| Secar 51 (France)         | 50.8-54.2               | 36-39                         | 375-425                         | not earlier than 4, not later than 7 | 55-85                       |
| CRHAC-70-1 (Russia)       | no less than 70         | no less than 20               | no less than 450                | not earlier than 2, not later than 12 | 35-40                       |
| CRHAC-75-0,5 (Russia)     | no less than 75         | no less than 20               | no less than 450                | not earlier than 2, not later than 12 | 35-40                       |
| SRB 710 (France)          | 68.7-70.5               | 28.5 – 30.5                   | 400-425                         | not earlier than 3, not later than 4 | 40-55                       |

Aluminate cement-based mixtures with superplasticizers rapidly lose flowability. Due to this, studies for saving flowability of mixture after 10, 20 and 30 minutes after mixing were made. Additives were introduced in the amounts recommended by the manufacturer. Saving of flowability (decrease no more than 10% in 30 minutes) was seen only for superplasticizers based on polyethylene glycol Melflux PP 100 F (Figure 2).

![Figure 2](image)

**Figure 2.** Dependence of the spread of the ring on time for a mixture prepared with cement SRB 710

An additive based on cellulose ethers Mecellose FMC 60150 from Lotte Fine Chemicals (Korea) was chosen as a water-retaining additive thickener.

According to the manufacturer, this modification of the product is specially designed for the production of dry self-levelling compounds. These mixes are used at the device of self-levelling floors. The additive is a fine powder, easily soluble even in cold water without slow swelling. Mecellose FMC 60150 retains water in the mortar mixture well, reduces the rate of evaporation from the working surface...
and prevents the adsorption of water by absorbent porous base. Moreover, the additive provides thickening of the solution, prevents sedimentation and improves adhesion properties.

The effectiveness of combined additives when used in compositions based on aluminates were another subject of research. Sika Viscocrete 105P (polycarboxylate) and Melflux PP 100 F (modified polyethylene glycol) as superplasticizers and Mecellose FMC 60150 cellulose as a thickener and viscosity modifier were selected for the studies.

The mobility of the mortar mixture with modifying additives was determined by spreading the ring in accordance with GOST 31356-2007 “Dry building mixes on cement binder. Test methods”. Table 2 selectively shows data on the preservation of mobility of modified non-shrinkable mixtures based on selected aluminates over time. A water-holding thickener additive was introduced into the mortar mixture (Mecellose FMC 60150 cellulose ether). A superplasticizer was also added to the solvent in dosages recommended by the manufacturer. The results of experiment showed that the use of Mecellose FMC 60150 cellulose ether together with a superplasticizer allows to obtain mixtures for flooring that are mobile for at least 30 minutes.

| Table 2. The mobility of the modified mortar mixtures |
|-----------------------------------------------------|
| Cement type | Cellulose ether additive | Time, min | Mobility % |
| CRHAC-70-1 (Russia) | Mecellose FMC 60150 in an amount, % by weight of the binder | 0 | 100 |
| | | 10 | 95 |
| | | 20 | 85 |
| | | 30 | 70 |
| | | 0 | 100 |
| | | 10 | 101 |
| | | 20 | 91 |
| | | 30 | 102 |
| | | 0 | 100 |
| | | 10 | 102 |
| | | 20 | 101 |
| | | 30 | 96 |
| SBR 710 (France) | | 0 | 100 |
| | | 10 | 100 |
| | | 20 | 100 |
| | | 30 | 105 |

The two-component composition based on a two-component binder, filled with quartz sand (Binder:Sand=1:2) and modified by superplasticizers based on polyethylene glycol (Melflux PP 100 F) and additive based on cellulose ethers Mecellose FMC 60150 characterized by the following technological properties:
- saving of self-levelling properties for 30 minutes after mixing;
- setting time: beginning – 2 h 00 m…2 h 20 m;
- strength of composition: compressive strength after 7 hours – 5…6 MPa, after 1 day – 23…25 MPa, after 3 days – 42…44 MPa;
- flexural strength after 3 days – 11…12 MPa.

4. Conclusions
The usage of aluminates cement-based dry mixes for self-levelling floors could be effective solution for making floors of technical premises. The production of aluminates cements causes less damage to the environment. Moreover, the use of aluminates cements eliminates losses caused by corrosion of cement stone.
Producing dry mixtures for self-levelling floors became possible after the creation of modern superplasticizers, which provide large shear strength. To achieve self-alignment, it is necessary to use two types of additives: regulators of rheological properties and plasticizing and thickening (water-retaining) additives. Compatibility with the used two-component binder based on aluminate cement is essential in the selection of additives – regulators of rheological properties. Their compatibility and mutual influence on each other are also very important. It is necessary to choose a complex of modifying additives that works effectively with a non-shrinking binder – a superplasticizer and a water-retaining additive.

References
[1] K.N. Popov, M.B. Kaddo, A.A. Popov, Teoreticheskie osnovy polucheniya samovyavravnyayushchihsya bezusadochnyh polimercementnyh kompozicij dlya pokrytij polov, Konstrukcii iz kompozicionnyh materialov, vol. 2, 2006.
[2] T. Le-Bihan, J.F. Georgin, M. Michel, J. Ambroise, F. Morestin, Measurements and modeling of base materials deformation at early age: The case of sulfo-aluminous cement, Cem. and Concr. Research. vol. 42, p. 1055, 2012.
[3] F. Rajabipour, G. Sant, J. Weiss, Interactions between shrinkage reducing admixtures (SRA) and cement paste's pore solution, Cem. and Concr. Research. vol. 38, p. 606, 2008.
[4] M. Kaddo. Dry mixtures based on aluminate cements for self-levelling floors, MATEC Web Conf. vol. 6, p. 106, 2017.
[5] Kaddo M. Possibilities of using aluminate cements in high-rise construction, E3S Web of Conf. “High-Rise Constr. 2017”, 2018, C. 02056.
[6] M. Kaddo, M. Sinotova, Study of dry mixes with aluminate cements for self-levelling floors. IOP Conf. Series: Mat. Sci. and Eng. FORM-2018, 2018. C. 032035.
[7] A. Mezhov, E. Shokodko, M. Kaddo, Mortars prepared with mechanochemical treated asbestos-containing waste, MATEC Web of Conf. 251, 01009, 2018.
[8] M.B. Kaddo, M.V. Sinotova, E.A. Fedorova, Bezusadochnye kompozitsii dlja pokrytij polov. Perspektivy nauki. vol. 2 (101). p. 46-48, 2018.