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# Universal building mixtures on high-module silicate components

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***Abstract -*** *The article presents data on the results of research on the development of universal building mixtures. An example of the use of a mixture for laying walls of silicate brick to provide solidity in conditions of high seismic activity is given. Methods for regulating the setting time of unburned alkaline binders on high-modulus silicate components are proposed.*

***Keywords:*** *unburned alkaline binders, slag's, alkaline silicate components, liquid glass, setting time, rheological properties, electric double layer, contact zone, adhesion, cohesion.*

## INTRODUCTION

According to forecasts for the development of the building materials industry in the Republic of Uzbekistan for 2019 ... 2025, taking into account diversification and expanding the range of products, an increase in production volumes is envisaged, in multiple sizes [1].

The most important priority area of research in this field of science is the development of nana-technologies and innovative methods in the production of cement and cementations materials. Unburned alkaline binders are a new class of highly effective hydraulic binders, which have a number of advantages that can provide a reduction in energy consumption and closer production of binder to construction sites and as a result reduces the energy consumption of binder production to 85 ... 90%.

It is known that slag is a heterogeneous system, representing the basis of unburned alkaline binders. Slag when mixed with an alkaline component easily generates ions into the solution, which contribute to the rapid coagulation of silicate alkaline components (liquid glass). This causes a "false" setting of the mixture and reduces the physical and mechanical properties of the stone.

It is especially difficult to use alkaline compositions based on industrial highly modular sodium silicates, which at the same time have significant activity (70 ... 130 MPa) and are of the greatest interest in the preparation of universal mortar mixtures during finishing works in order to ensure monolithic in seismic regions.

The pilot industrial introduction of universal mortar mixtures based on an unburned binder containing silicate alkaline components has shown that they are characterized by low viability (they seize in 10 ... 20 min). At the same time, when used as a masonry mortar for silicate brick, high adhesion characteristics in the mortar joint are ensured. But from the point of view of application technology, they are very inconvenient due to the high viscosity of the mixture and short shelf life.

In this regard, we set the task of increasing the setting time of unburned alkaline binders, as well as obtaining masonry mortars with high adhesive-cohesive characteristics in the contact zone "masonry mortar-silicate brick", corresponding regulatory requirements taking into account the rheological properties.

**The proposed methodology, experiments, and results**

Studies have established that one of the ways to increase the shelf life of a mortar mixture is to create a screening film around the particles of the dispersed phase, which prevents the rapid interaction with the dispersed medium and thereby slows down the coagulation process of the system. So, for example, acidic slags and additives of substituted alkali metal salts can play this role in the manufacture of the composition.

The binder compositions after applying the above methods to increase the viability of the mixture and the test results are presented in the Table. 1.

*Table 1. Compositions and properties of unburned alkaline binders with adjustable setting time*

| The composition of the components of the binder, mass % | | | | | Setting time, min | | The limit of the post pressure during compression / bending, MPa, after | |
|---|---|---|---|---|---|---|---|---|
| Ground electro thermo phosphorus slag | Ground electric steelmaking slag | Sodium silicate with Ms= 2.8 | Monosubstituted sodium phosphate $NaH_2PO_4$ * $2H_2O$ | Potassium fluoride monosubstituted $KHF_2$ | start | end | heat moist processing | Normal hardening |
| 59,8 | 30 | 10 | 0,2 | - | 120 | 145 | 72,6<br>7,5 | 75,4<br>8,2 |
| 67,1 | 20 | 12,5 | 0,4 | - | 136 | 175 | 77,2<br>8,8 | 82,4<br>9,2 |
| 74,4 | 10 | 15 | 0,6 | - | 135 | 195 | 84,5<br>9,7 | 87,5<br>10,3 |
| 59,8 | 30 | 10 | - | 0,2 | 125 | 157 | 75,5<br>7,7 | 77,2<br>8,5 |
| 67,1 | 20 | 12,5 | - | 0,4 | 152 | 178 | 80,5<br>8,6 | 84,6<br>9,5 |
| 74,4 | 10 | 15 | - | 0,6 | 180 | 220 | 86,7<br>11,6 | 90,2<br>12,3 |
| 64,4 | 35 | 10,5 | 0,1 | - | 90 | 105 | 50,2<br>5,1 | 52,5<br>5,7 |
| 79,4 | 5 | 14,5 | 0,8 | - | 208 | 267 | 47,3<br>4,5 | 44,3<br>4,2 |
| 78 | - | 28 | - | - | 20 | 60 | 32,0<br>4,0 | 38,3<br>3,6 |
| 78 | - | 28 | - | - | 25 | 40 | 43,0<br>6,3 | 37,6<br>5,6 |

With the introduction of sodium phosphate monosubstituted or potassium fluoride monosubstituted compounds, the interaction of the alkaline components with the dispersed phase proceeds according to the usual hydrated scheme of unburned alkaline binders with a slowed intensity in the initial setting time under normal setting conditions.

Upon visual observation of the binder test after mixing, it was found that the addition of substituted alkali metal salts (sodium phosphate $NaH_2PO4*2H_2O$ or potassium fluoride $KHF_2$) as a 10% aqueous solution to the alkaline system forms a sour cream-like mass, i.e. the alkaline dispersed phase the medium is polarized, while the slag grains are, as it were, covered with a screening film. Accordingly, the mobility increases or the viscosity of the binder paste decreases from 200 ... 250 ***mPa*s*** to 60 ... 75 ***mPa*s***, which also indicates an increase in the induction period of structure formation of the mixture [2].

This phenomenon has a positive effect on the setting time of the knitting test in the initial period of hardening. The onset of setting increases from 17 to 180 minutes when using potassium fluoride (Fig. 1) and from 22 to 210 minutes when using sodium phosphate (Fig. 2).

Monosubstituted alkali metal salts were added to the binder together with liquid glass during the mixing of the aluminosilicate dispersed phases. It was found that in the process of mixing, an increase in the amount of additive proportionally increases the setting time of the binder; in addition, an increase in the amount of the additive in the range of 0.6 ... 0.8% of the mass negatively affects the activity of the binder due to the delayed action of the alkaline component on the dispersed phase and an increase in the induction hardening period of the composition.

The rheological and physic-mechanical properties of astringent disperse systems depend on a number of factors, including the structure of the double electric layer (***EDL***) arising at the phase boundary [3, 4, 5, 6,7].

Based on the rheological properties and visual observations, it can be assumed that when substituted alkali metal salts are added to the slag-alkaline mixture with a silicate alkaline component, an ***EDL*** is formed in the system. This is probably facilitated by the hydrogen group, which contains in the substituted salts of alkali metals, which, when interacting with a dispersed medium, form free $OH^-$ ions. As is known, ***EDL*** can beat one of the reasons for the increase in the induction period of structure formation, since the surface acquires a negative charge due to the dissociation of surface hydroxyl groups and adsorption of $OH^-$ ions, which prevents the leaching of $Na^+$ ions, complicates the process of hydration of the dispersed phase and lengthens the induction period of system formation of the system.

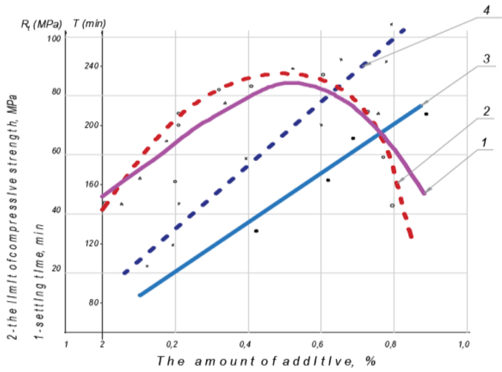


*Figure 1. Effect of* ***$NaH_2PO4*2H_2O$*** *additive on the activity and viability of a binder using silicate alkaline*

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*components (sodium silicate, with module Mc = 2.8, density 1300 kg / m³): 1-activity of a binder after the heat and moisture treatment; 2 the same, under conditions of normal hardening; 3-beginning of hardening; 4-end hardening*

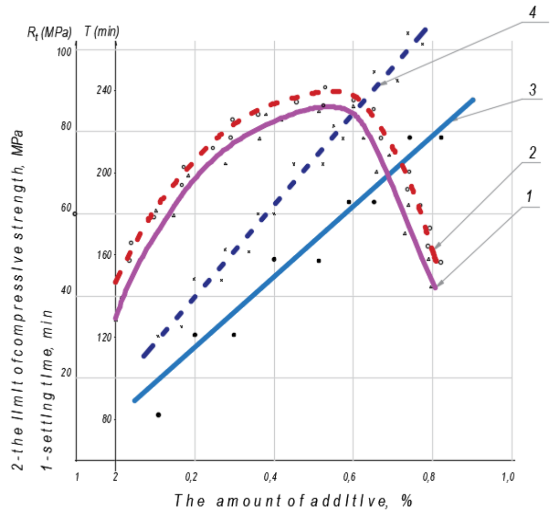



*Figure 2. Effect of **$KHF_2$** additive on the activity and viability of a binder using silicate alkaline components (sodium silicate, with module Mc = 2.8, density 1300 kg / m³): 1-activity of a binder after the heat and moisture treatment; 2 the same, under conditions of normal hardening; 3-beginning of hardening; 4-end hardening*

## DISCUSSIONS

Taking into account the above phenomena and the properties of disperse systems, we made an attempt to use ***EDL*** forces in the field of unburned alkaline binders with a silicate alkaline component to extend the viability and lower the viscosity of the mortar mixture. The developed results were used to prepare highly adhesive masonry mortars with improved rheological properties and viability of the mixture.

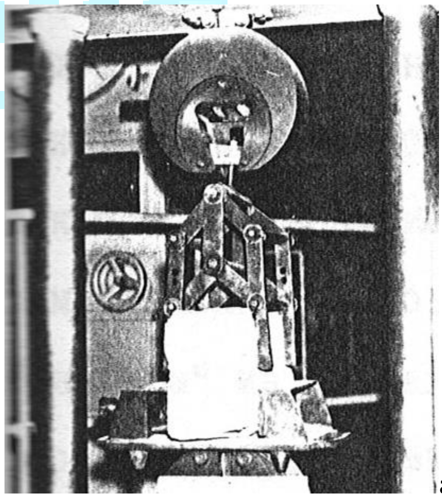
A masonry mortar mixture was prepared in the following sequence: the calculated amount of fine aggregate (building sand) was weighed and mixed with ground granulated slag for 2 minutes. The resulting mixture was closed with a calculated amount of a silicate alkaline component with certain additives, which was stirred for another 2 ... 3 min until a homogeneous mixture was obtained [8].

Studies have shown that the developed component of the solution has a high adhesive ability to silicate brick, while the adhesion strength reaches 0.36 ... 0.97 MPa Table 2. It was found that with an increase in the amount of the additive, the mobility and the viability of the mortar mixture proportionally increase within 65 ... 260 minutes.

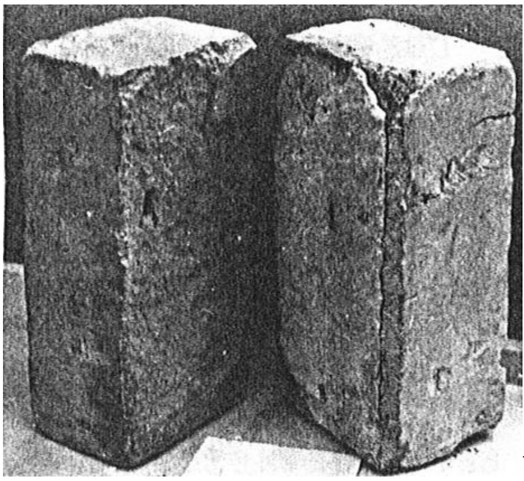
*Table 2. Components and properties of masonry mortars, rheological test results*

| The components of mortars, mass. % | | | | Mortar mobility | | The tensile strength of the mortar with silicate brick, MPa / nature of the destruction of the sample, in age, days | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Jointly ground slag | Fine aggregate | Sodium silicate with module Ms = 2.8 | Additive, superphosphate double $Ca(H_2PO_4)_2 \cdot H_2O$ | According to GOST 5802-86, mm | According to GOST 10181-2014, sec | 4 | 14 | 28 | 180 | 360 |
| 21,0 | 78,8 | 6,0 | 0,2 | 152 | - | 0,52 F | 0,74 F | 0,93 F | 0,97 B | 1,02 B |
| 19,5 | 75,1 | 5,25 | 0,15 | 145 | 2…8 | 0,47 F | 0,58 F | 0,77 F | 0,85 B | 0,91 B |
| 18,0 | 77,4 | 4,5 | 0,1 | 130 | 2…4 | 0,35 F | 0,42 F | 0,67 F | 0,78 F | 0,81 B |
| 16,5 | 79,7 | 3,75 | 0,05 | 102 | 3…6 | 0,28 F | 0,30 F | 0,33 F | 0,37 F | 0,45 F |
| 22,5 | 70,5 | 6,75 | 0,25 | 155 | - | 0,55 F | 0,55 F | 0,56 F | 0,42 F | 0,40 F |
| 24,0 | 68,2 | 7,5 | 0,3 | 165 | - | 0,35 F | 0,32 F | 0,27 Cz | 0,28 Cz | 0,29 Cz |
| 24,0 | 68,5 | 7,15 | - | - | - | 0,33 F | 0,27 F | 0,25 Cz | 0,26 Cz | 0,22 Cz |

Note: ***F*** - destruction by mortar failure; ***B***-destruction by brick; ***Cz***- destruction along the contact zone, see Fig. 3



**a)**



b)

c)

*Figure 3. The nature of the destruction of samples "double" to break: a) universal explosive machine UMM-5; b) destruction by mortar failure- **F**; c) destruction by brick- **B**, d) destruction along the contact zone - **Cz***

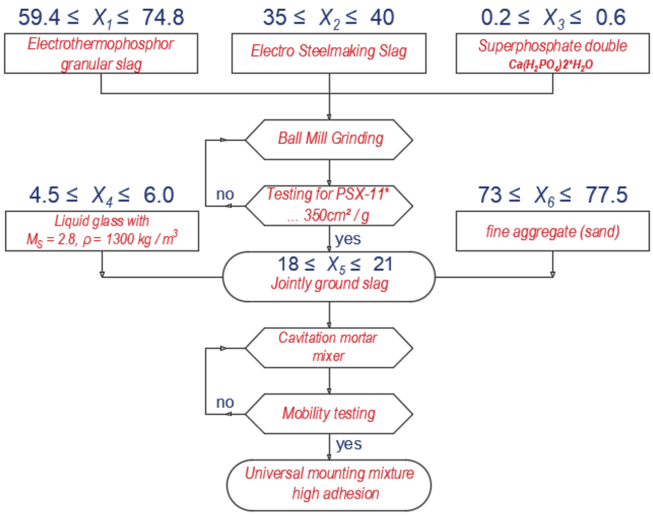



*Figure 4. Technological scheme of production of building mixture of high adhesion: $X_1 ... X_n$ - constituent components, wt.%*

## CONCLUSIONS

Thus, studies have established that using monosubstituted alkali metal salts ***($NaH2PO4*2H_2O$; $KHF_2$; $Ca(H_2PO_4)_2*H_2O$)***, the viability of mortar mixtures in the initial period of structure formation can be controlled with a decrease in the viscosity of the mixture, which is very important for obtaining workable mortars when carrying out masonry work from silicate brick.

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