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# Influence of an Additive of Sol of Silicon Acid on Durability of Finishing Structures on the Basis of Lime

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## Abstract

Data about properties of an additive – sol of silicon acid in limy finishing mixes are provided. It is shown that use of sol of silicon acid promotes to increase of durability, decrease of shrinkage deformation of limy coverings

**Keywords:** sol of silicon acid, stability, aging, limy finishing compositions, durability

## 1 Introduction

The preservation of architectural heritage of the past providing restitution of monuments of architecture, and also sanitation of historical building quite often demand the use of specialized finishing materials. Limy compositions were traditional materials which were used for coloring for many years. However, application of limy compositions for restoration of architecture monuments causes the particular difficulties connected with their low durability and water resistance. For regulation of structure and properties of limy finishing compositions various modifying additives are entered into their compounding [1, 2, 3]. In this work results of researches of effectiveness of application in limy finishing compositions of sol of silicon acid are presented.

## 2 Experimental study

The ion-exchange column filled with cationite pitch KU-2, sodium liquid glass was applied for receiving sol of silicon acid, the concentration of solution of silicate of sodium made 6,2–6,6%. At using of sol as additive in limy compositions sol of silicon acid with pH 4,5–5 with a density 1013 kg/m$^3$ was applied.

For the characteristic of sol of silicon acid the particle sizes, mean squared shift of particles were defined, determination of particle size of sol of silicon acid was made by method of a turbidimetry [4].

Mean squared shift of a particle $\bar{\Delta}$ for a time term $\tau$ was determined by law of Einstein – Smolukhovsky:

$$\bar{\Delta}^2 = 2D\tau$$

where $D$ – a diffusion coefficient;

$\tau$ – time, s.

The diffusion coefficient *D* of dispersible particle was counted according to the Einstein's equation:

$$D = \frac{kT}{6\pi\eta r}$$

where $k$ – the Boltzmann's constant equal $1{,}38\cdot10^{-23}$ J/K;

$T$ – temperature, K;

$\eta$ – viscosity of the environment, Pa·s;

$r$ – radius of a particle, m.

Follow-up for an evaluation of stability of sol of silicon acid a thickness of a diffuse ionic layer was expected and the electrokinetic potential was measured.

Thickness of a diffuse ionic layer was counted on the equation

$$\lambda = \sqrt{\frac{\varepsilon\varepsilon_0 RT}{2F^2 I}}$$

where

$\varepsilon_0$ – electric constant, $e_0 = 8{,}85\cdot10^{-12}$ F/m;

$\varepsilon$ – the relative dielectric inductivity of the environment;
$R$ – the universal gas constant, J/(mol·K);
$T$ – temperature, K;
$F$ –Faraday's constant, F=96500 C/mol;
$I$ – ionic strength of solution,

$$I = \frac{1}{2}\sum_i c_i z_i^2$$

here $c_i$ – concentration of ion in solution, mol/m$^3$;
$z_i$ – electrolyte ion charge.

The electrokinetic potential ($\zeta$-potential) was determined by method of an electrophoresis [5].

For an evaluation of physical and chemical interaction of a lime with sol of silicon acid the work of adhesion of sol to a lime and wetting heat was estimated.

Values of work of liquid to a lime were counted on a formula

$$A = \sigma(1 - \cos\theta)$$

Determination of the interfacial tension was carried out by method of the account of drops (a stalagmometeric method). As a reference liquid a distilled water with a density $\rho_m^{20°C}$=0,9982 g/cm$^2$ and the interfacial tension $\sigma^{20°C}$ = 72,8 mN/m was used.

Measurement of a wetting power of sol of silicon acid was performed on wetting angle (a boundary angle $\theta$). The boundary angle of wetting was determined by a microscopic method.

The vacuum Dewar's bottle was applied for determination of wetting heat. The quantity of heat was counted on a formula

$$Q = \frac{c\Delta t m_{\text{H}}}{\text{m}}$$

where $c$ – specific heat, kJ/(kg·°C);
$\Delta t$ – change of temperature, °C;
$m_{\text{H}}$ – mass of shot, kg;
m – mass of lime, kg.

Shrinkage deformations of limy coverings based on finishing compositions were decided with help of an optical comparator of IZA-2. Exemplars after 28 days of air-dried concreting dried up at t = 105-110 °C to the constant weight, were placed in capacity with water and periodically change of the linear dimensions was measured. At the age of 90 days after achievement of constant values of deformations of swelling exemplars were taken from capacity and were in air-dried conditions at a temperature 18-20 °C and the relative humidity of 65-68%.

## 3 Results and discussion

Values of particle sizes of sol of silicon acid depending on aging term are given in table 1.

**Table 1:** Dependence of particles radius on the term of an aging of sol of silicon acid

| Aging term of siliceous, days | Radius of particles of sol, nm |
|---|---|
| 1 | 17 |
| 3 | 18 |
| 4 | 22 |
| 5 | 25 |
| 7 | 57 |
| 12 | 83 |
| 15 | 113 |
| 19 | 140 |

Results of the experimental studies testify that since the term of an aging 15 days, there is an integration of particles of sol of silicon acid, spacification of sol is visually observed that leads to decrease of its activity.

As padding confirmation of dependence of high activity of sol the data of calculation of mean squared shift were served.

For particle size radius $r$ =72 nm the mean squared shift of a particle $\overline{\Delta}$ makes

$$D = \frac{1{,}38 \cdot 10^{-23} \cdot 293}{6 \cdot 3{,}14 \cdot 10^{-3} \cdot 72 \cdot 10^{-9}} = 2{,}98 \cdot 10^{-12} m^2 / s$$

$$\overline{\Delta} = \sqrt{2 \cdot 2{,}98 \cdot 10^{-12} \cdot 10} = 7{,}72 \cdot 10^{-6} m$$

Results of calculation showed that for 10 seconds the mean squared shift of a particle with a radius 72 nanometers made $7{,}72 \cdot 10^{-6}$ m. The mean squared shift of a particle with a radius 17 nanometers made $1{,}89 \cdot 10^{-5}$ m that predetermines a high activity of sol of silicon acid at aging term 1 day (table 2).

**Table 2:** Mean squared shift of a particle

| Sol aging, days | Mean squared shift of a particle for 10 second, m |
|---|---|
| 1 | 1,89·10-5 |
| 5 | 1,51·10-5 |
| 10 | 7,72·10-6 |
| 15 | 5,83·10-6 |
| 19 | 5,34·10-6 |

Results of calculation show that the size of thickness of a diffuse layer is more than 10 nanometers at aging term to 15 days; therefore, sol of silicon acid can exist without violation of aggregate stability. The electrokinetic potential ($\zeta$-potential) was defined depending on aging term of siliceous. The received value of $\zeta$- potential testifies about stability of sol. Sol is steady at size $\zeta$-potential >0,03V. Sol of silicon acid is stable aged to 15 days. The electrokinetic potential makes 0,03–0,103 V. Further decrease of an electrokinetic potential is observed.

Values of durability of a limy composite at introduction to a compounding of sol of silicon acid are given in table 3.

**Table 3:** Value of a compressive strength, MPa

| Concreting time, days | Control composition, $R_{contr}$ | Relation lime : sol of silicon acid | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1:0,25 | | 1:0,5 | | 1:1 | |
| | | $R_c$ | $\Delta R$ | $R_c$ | $\Delta R$ | $R_c$ | $\Delta R$ |
| 7 | 0,25 | 0,33<br>0,50 | 0,08<br>0,25 | 0,45<br>0,68 | 0,20<br>0,43 | 0,54<br>0,93 | 0,29<br>0,68 |
| 14 | 0,51 | 0,55<br>0,72 | 0,04<br>0,21 | 0,68<br>0,97 | 0,17<br>0,46 | 0,85<br>1,25 | 0,34<br>0,74 |
| 28 | 0,85 | 0,88<br>0,95 | 0,03<br>0,10 | 0,93<br>1,23 | 0,08<br>0,38 | 1,10<br>1,70 | 0,25<br>0,85 |

Note. Over line values of a compressive strength at use of sol at the age of 15 days are indicated, below the line – at the age of 1 day.

It is established that use of more "aged" sol brings to a decrease of a compressive strength. So, at ratio L:S = 1:1 compressive strength at the age of 28 days at use of sol at the age of 1 day makes 1,7 MPa, and at use of sol at the age of 15 days – 1,1 MPa.

## 4 Conclusion

Results of calculation showed that the number of specific heat $Q$ allocated at wetting a lime with sol of silicon acid made 15,0 kJ/kg, and at wetting a lime with water – 10,6 kJ/kg.

Higher values of wetting heat, in our opinion, are caused by follow-up marked out warmth owing to interaction of a lime with sol.

At using sol of silicon acid as an additive the more favorable conditions for interaction with a lime are created. The boundary angle of wetting of a limy substrate with sol of silicon acid makes 58°, and with water – 53°, the size of the interfacial tension of sol practically does not differ from value of a interfacial tension of water and makes 0,0698 J/m$^2$. Results of calculation show that work of adhesion of water to a lime makes 0,0289 J/m$^2$, and sol of silicon acid – 0,0328 J/m$^2$ that causes the best conditions of interaction of sol with a lime.

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