Estimation of porosity of coatings based on sol of silicate paint

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Abstract. Information on the properties of the sol of silicate paint is given. The porosity of coatings was studied. The fractal pore size of the coating was indentified. It was found that sol-silicate coatings are characterized by a high fractal pore dimension. The protective properties of the coatings evaluated. A decrease in water absorption values was observed during capillary suction of mortar samples stained with sol by silicate paint in comparison with samples stained with silicate paint. Information on the properties of the sol of silicate paint and coatings based on it is provided.

1. Introduction
The construction and maintenance of buildings and structures require a large number of paints. Growing competition in the market of finishing materials, increasing consumer demands require manufacturers to obtain high-quality painted surfaces. Silicate paints are widely used for finishing. In order to increase the duration of service of silicate coatings, a modification of film-forming — liquid glass with polymer additives (polymer dispersions, organosilicon compounds, etc.) has been proposed [1-7]. An analysis of the scientific and technical literature indicates that the use of polysilicate solutions as a binder provides higher performance properties of silicate coatings. In [8-10], it was proposed to use polysilicate solutions having a silicate module from 4 to 25 as a binder in silicate paints.

We have developed a paint composition based on a polysilicate binder obtained by mixing liquid glass with silica sol [11-15]. Coatings based on sol silicate paint are characterized by tensile strength $R_p = 2.29$ MPa, adhesion to the substrate 0.80 MPa, vapor permeability coefficient $\mu = 8.78 \times 10^{-3}$ mg/m$^2$/h/Pa, frost resistance F35. Coatings belong to the group of non-combustible materials Г1.

In continuation of further research, we evaluated the surface quality of coatings based on sol-silicate paint.

2. Methodology
In this paper, the following research tasks:
- evaluate the quality of the appearance of coatings;
- evaluate coating durability.

We used liquid glass with a module $M = 3.29$. Microcalcite MK-2 (TU 5743-001-91892010-2011), marshalite and tale MT-GShM (GOST 19284-79) were used as filler, and rutile titanium dioxide 230 (TU 2321-001-1754) was used as a pigment. 7702-2014). To obtain a polysilicate binder silicic acid sols Nanosil 20 and Nanosil 30 were used.
The method for determining filling was as follows. Paint with a viscosity was applied to a metal plate measuring 20 × 40 cm and quickly (no more than 2-3 minutes) was distributed with longitudinal and transverse brush movements over the entire surface. Then use a brush, a deep stroke was sharply drawn in the middle of the plate from one edge to the other, and the time was noted when the strokes from the brush disappeared and the surface became completely flat. Depending on the time required for the "filling" of paint, there are three ratings: 1 - satisfactory (no later than 10 minutes); 2 - slowed down (10-15 minutes); 3 - unsatisfactory (more than 15 minutes)

The quality of the appearance of the surface of coatings was determined in accordance with GOST 9.032-74.

To assess of the coating surface, scanning probe microscopy (SPM) methods were used. Processing of the obtained images was carried out using SPIP Image Metrology software and consisted in the analysis of surface roughness parameters.

The study of the structure of the coatings was carried out using the cut-off island method was used. For the implementation of this method, the complex (PC) was applied “Identification and analysis of the porosity of building materials”. Method allows to determine the total pore area of the composite under study and the pore size distribution [16-20].

3. Research results

By atomic force microscopy it was found that coatings based on sol-silicate paint are less rough. The surface roughness based on liquid glass is $R_s = 16.2$ microns, and on the basis of polysilicate solution - 6.2 microns.

The results of research show that the pore size of sol silicate coatings is up to 100 $\mu$m (figure 1). The maximum pore size is 174 microns. Number of pores per 1 cm$^2$ of the coating surface 564 pcs. The total area of pores on a 1 cm$^2$ coating is 1609526 $\mu$m$^2$. The relative area of pores with a radius of 0 to 10 $\mu$m is 0.02596%, pores with a radius of 10 to 50 $\mu$m – 0.67918%, pores with a radius of 50 to 100 $\mu$m — 0.65119%, pores with a radius of 100 to 200 $\mu$m, 0.25319% (figure 1).

![Figure 1](image-url)  
**Figure 1.** The relative pore area on the silicate coating.

The maximum pore size of coatings based on sol-silicate paint is 156 $\mu$m. However, the amount of pores per 1 cm$^2$ of the coating is less and amounts to 90 pcs. The total pore area on a 1 cm$^2$ coating is 227,141 $\mu$m$^2$ (figure 2). The relative area of pores with a radius of 0 to 10 $\mu$m is 0.004%, pores with a
radius of 10 to 50 μm are 0.09933%, pores with a radius of 50 to 100 μm are 0.07087%, and pores with a radius of 100 to 200 μm are 0.05294% (figure 2).

The magnitude of the fractal dimension was determined from the angle of inclination of the graph of changes in the pore areas from their perimeters, built in double logarithmic coordinates \( \log(A(\partial)) - \log(P(\partial)) \) (figure 3).

![Figure 2. The relative pore area on the sol silicate coating.](image)

![Figure 3. The relationship between perimeter and pore area: a - silicate coating; b - sol silicate coating.](image)

It was found that it can be seen that the relationship between the perimeter and the pore area obtained by scanning the studied surfaces with different resolutions of 4800 Dpi is described by a linear relationship with the coefficient of determination \( R^2 = 0.9973 - 0.9982 \) (figure 3).

It was found decrease in the fractal dimension of the porous structure of sol silicate coatings.
It was revealed that sol silicate paint has a good filling of 1 point. Coatings are characterized by high quality appearance, constituting AD1 and AZ1 (GOST 6992-68) (figure 4).

![Figure 4. Appearance of sol silicate coatings.](image)

The different porosities of silicate based coatings and sol silicate paints determine their various protective properties. It was identified decrease in water absorption that during capillary suction of mortar samples painted with a sol of silicate composition.

In Table 1 shows performance of the properties of the paint and coatings based on it.

**Table 1.** Properties of paint and coatings based on it.

| Title                                           | Values         |
|------------------------------------------------|----------------|
| Class of quality of appearance of coatings      | IV             |
| Viscosity B3-4 [c]                             | 17-20          |
| Viability, [day]                               | more 90        |
| Dryingtime, [min], to degree 5                 | 15-25          |
| Adhesion, [points]                             | 1              |
| Adhesion, [MPa]                                | 1,1-1,3        |
| Tensile strength, [MPa]                        | 2,296          |
| Vapor permeability, [mg/m²*hPa]                | 0,0087         |
| Washability, [g/m²]                            | No more 2      |
| Frost resistance, brand                        | F35            |

**4. Conclusion**

The use of polysilicate solution as a film-forming agent in silicate paints helps to increase the protective properties and durability of coatings. According to its properties coating based on it meet have a higher adhesion and cohesion, frost resistance brand F 35.

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