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SOL-SILICATE PAINT FOR RESTORATION AND DECORATION OF BUILDING WALLS

ABSTRACT

The influence of the filler on the properties of the sol-silicate paint has been established. The interparticle interaction between the polysilicate binder and the pigment (filler) has been evaluated. It is shown that the use of microcalcite as a filler in sol-silicate paints contributes to obtaining a higher cohesive strength of coatings, due to an increase in the contribution of dispersion forces in the "filler-binder" system. It was revealed that the polysilicate solution is characterized by a large work of wetting and adhesion to the filler (pigment). An increase in the crack resistance of coatings based on sol-silicate paint has been established.

Keywords: sol-silicate paint, polysilicate mortar, interparticle interaction, cohesive strength

Introduction

The construction and maintenance of the working condition of buildings and structures require a large number of paints and varnishes. 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 the exterior and interior walls of buildings. However, coatings based on silicate paints have insufficient crack resistance. To increase the durability of silicate coatings, it was proposed to introduce acrylic latex into the formulation (up to 25%, Novopol 110). Coatings based on such compositions are resistant to high temperatures, frost resistance, and resistance to aggressive media [1]. Addition of acrylic dispersion (AD) in an amount of 5% in combination with an active silica component (sand, marshalite, perlite, aerosil), the amount of which depends on the nature, makes it possible to produce a one-pack silicate paint[2-4**Ошибка! Источник ссылки не найден.Ошибка! Источник ссылки не найден.Ошибка! Источник ссылки не найден.**].

In [5,6], it was proposed to introduce carbamide into the formulation of silicate paints in an amount of 0.5-1% by weight of liquid glass, which makes it possible to obtain compositions with increased thixotropic properties, with delayed structure formation.

Technical lignosulfonates have been proposed as a promising modifying additive for creating composite materials on liquid glass [7]. Studies have shown that lignosulfonates have a significant effect on the processes of hardening and structuring of liquid glass compositions. They improve the strength properties of the material. The introduction of 3% lignosulfonates with increased molecular weights into the composition of liquid glass leads to the formation of a finely porous structure of the forming gel, high water resistance, material strength and high performance

In recent years, the use of polymer silicate composite materials has begun to develop, which are water-soluble silicates with active additives of furan compounds. [8-10]. In the works [11,12], in order to increase the acid resistance, moisture resistance and strength of building materials based on liquid glass and expand the scope of their application, it is proposed to introduce a nanostructured component - tetrafurfuryl ester of orthosilicic acid into the formulation. The introduction of a nanostructuring component, tetrafurfuryl ester of orthosilicic acid (TFS), into the binder leads to the formation of SiO2 nanoparticles, which act as crystallization and nucleation centers, and furfuryl alcohol, which fills the silicic matrix and forms a network polymer. The authors found that the introduction of FS or TFS additives into the mixture leads to a significant decrease in the effect of capillary forces due to a decrease in the surface tension of the liquid in the capillaries [13].This helps to reduce the deformation of the composites.

The need to improve certain properties of silicate composite materials, such as water resistance and thermal properties, has led to the development of sol-silicate paints. To date, one of the most popular sol-silicate paints is Histolith Sol-Silikat paint manufactured by Caparol (Germany), CAYMAN paint manufactured by the German company Alligator, KEIM Soldalit paint (Gerania), Prochnin paint "(Russian firm "Friedlander")[14-17].

However, the share of sol-silicate paints on the market of paints and varnishes is very small. This is due to the fact that the technological process of creating sol-silicate paint is complex and it is not always possible to achieve the required characteristics. In this regard, it is relevant to develop a scientifically based technological solution for obtaining sol-silicate paints for finishing the walls of buildings, coatings based on which will have improved performance properties.

Materials and methods

A polysilicate solution obtained by mixing water glass and a silicic acid sol was used as a binder in the work. Nanosil 20 and Nanosil 30 silicic acid sols manufactured by Promsteklotsentr PC were used in the work. Characteristics of silica sol are shown in Table 1. Potassium liquid glass was used - with a modulus of M = 3.29 (GOST 13078).

Table 1 - Characteristics of silica sol

The name of indicators	Nanosil 20	Nanosil 30
pH	9-10.8	9-10.6
Mass concentration of silicon dioxide, g/l	220-237	329-362
Mass concentration of sodium oxide, g/l	3-7	2.5-6.5
Silicate module	50-90	55-100
Specific surface area, m^2/g	220-370	220-300

As pigments used:
– rutile titanium dioxide: grade CR-02, Crimean Titan CJSC (TU 2321-001-17547702-2014);
– chromium oxide Cr2O3 (GOST 2979 grade OHP-1, TU 6-18-23-87);
– ocher (GOST 8019-71, TU U-00204607-005-2000);
- iron minium (GOST 8135-74);
– cobalt oxide CoO (GOST 4467-79, TU 38.101254-72).
As a filler used:
– microcalcite brand LinCarb-2xk (GOST 56775-2015)
– microtalc brand MITAL (GOST 19284-79)
- marshalit brand "A" (GOST 9077-82)

The conditional viscosity of paints and varnishes was determined using a VZ-4 viscometer according to GOST 8420-74. “Paint materials. Methods for determining the conditional viscosity.

The surface tension was determined by the method of drop counting (stalagmometric method). According to the Dupre-Young thermodynamic equation, the work of adhesion of the paint composition to the cement substrate was calculated:

$$W_a = \sigma(1 + \cos\theta)$$

where W_a is the work of adhesion;

σ is surface tension;

θ is the equilibrium wetting angle.

The work of wetting was determined by the relation:

$$W_{см} = \sigma \cos \theta$$

Wetting was characterized by the wetting coefficient S and was determined by the ratio of the work of adhesion to the work of cohesion (relative adhesion):

$$S = \frac{W_a}{W_k},$$

Additionally, the spreading coefficient f was determined, since the gloss, evenness of the coating surface, the presence or absence of craters, and shagreens depend on this parameter. Spreading coefficient f was determined by the formula:

$$f = W_a - W_k$$

The relationship between the work of adhesion and the work of wetting was determined by the relation:

$$W_a = W_{cm} + \sigma_{ж-г}$$

The drying time was determined in accordance with GOST 19007-73 “Paint and varnish materials. Method for determining the time and degree of drying "

Then, the dispersion contribution to the intermolecular interaction was evaluated, for which the value of the complex Hamaker constant A* was additionally determined. The method for determining the complex Hamaker constant A* was as follows. We built a functional dependence cosθ=f(σ_{lig}). An aqueous solution of alcohol with a volume fraction of up to 50% was used as a liquid [18,19.]. The contact angle measurement data showed that for all the samples under study, a linear dependence cosθ=f(σ_{lig}) is observed. Extrapolating the dependence cosθ=f(σ_{lig}) to cosθ=1, the value of the critical surface tension of a solid surface was obtained. The wetting angle of the filler surface was measured on a KRUSS Easy Drop device, for which samples were made by pressing the appropriate filler under a load of 1.5 kPa with a diameter of 10 mm.

The interaction energy was estimated from the value of the Hamaker constant, calculated according to the equation:

$$\cos\theta - 1 = \frac{A^*}{12 h_{\min} \sigma_{ж}}$$

where h_{min} is the smallest film thickness that corresponds to the Van –der- Waals distance (0.24 nm

σ_{lig} is the surface tension of the liquid;

A* is the complex Hamaker constant in the interaction of a liquid with a solid at the boundary with air.

Results and Discussion

When developing a sol-silicate paint, the choice of filler, among other factors, was also carried out on the basis of thermodynamic criteria (critical surface tension, Hamaker's constant).

Analysis of the data given in Table 2 shows that microcalcite has a higher value of critical surface tension equal to σk=28.8 mN/m compared to other fillers. The value of the Hamaker constant for microcalcite is A=3.15·10-20 J, which characterizes a stronger interaction in the "filler-binder" system.

Table 2 - Values of surface tension of fillers

Type of filler	The value of the critical filler surface tension, mN/m	The value of the constant Gamaker $A10^{-20}$, J
Microtalc $H_3Mg_3O_{12}Si_4$	27.8	2.54
microcalcite $CaCO_3$	28.8	3.15
marshalit SiO_2	28.2	2.84

In continuation of further studies, the tensile strength of the coatings was determined. Table 3 shows the values of tensile strength of coatings depending on the type of filler.

Table 3 - Tensile strength values of coatings depending on the type of filler

Filler name	МПа Tensile strength of coatings, MPa
microcalcite	1.83
Microtalc	0.36
marshalit	1.23

Coatings based on sol-silicate paint are characterized by higher ultimate elongation., the ultimate elongation is 0.028 mm/mm[20].

It has been established that there is a linear relationship between the value of the Hamaker constant and the tensile strength of coatings (Figure 1). A mathematical model of cohesive strength is obtained depending on the Hamaker constant. The correlation coefficient is R=0.9307. Thus, the cohesive strength of coatings can be increased to a large extent by increasing the strength of the "filler-binder" interaction.

The work of adhesion of liquid glass and polysilicate solution to the pigment (filler) was calculated. The studies were carried out using equipment based on the Center for High Technologies of the Belarusian State Technical University. V.G. Shukhov. The contact angle was determined on the KRUSS DSA-30 instrument (Figure 2). To determine the contact angle, tablets with a diameter of 40 mm were formed from a mixture of pigment and filler using a Vaneox - 40t automatic hydraulic press with a pressure of 18 tons in 11 seconds. The powder was pressed in a dry state, without additional processing. The results of research and calculations are shown in Table 4.

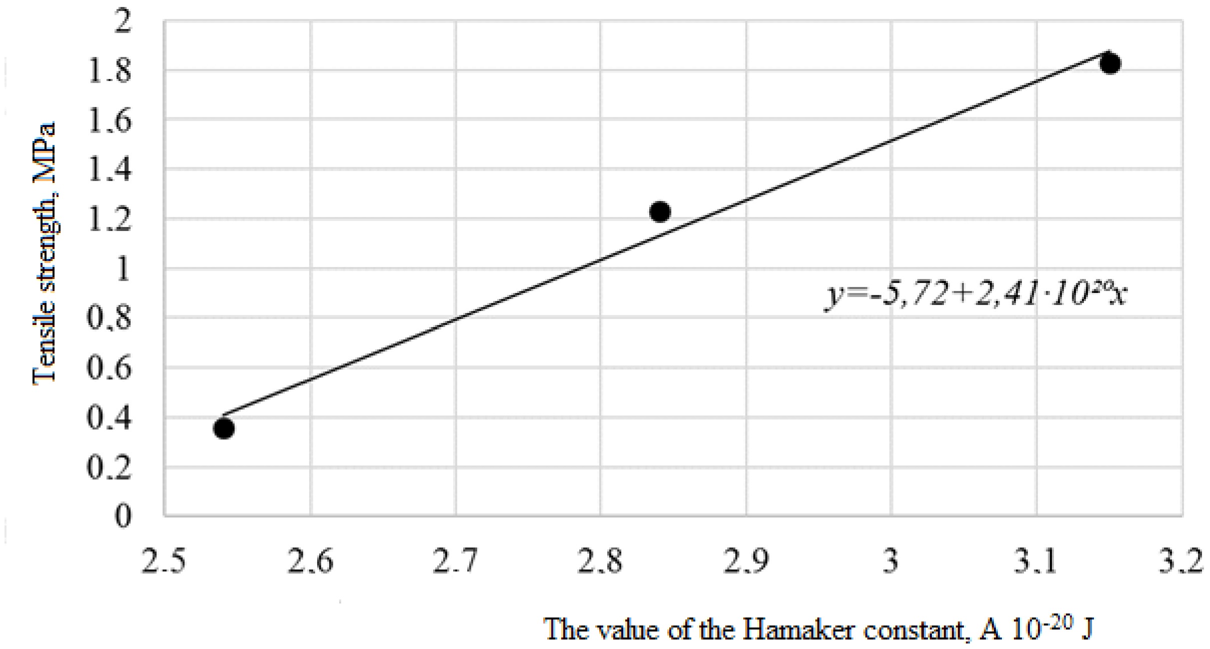

Figure 1 - Dependence of the cohesive strength of the coating on the strength of the interaction "filler-binder" - Hamaker's constant

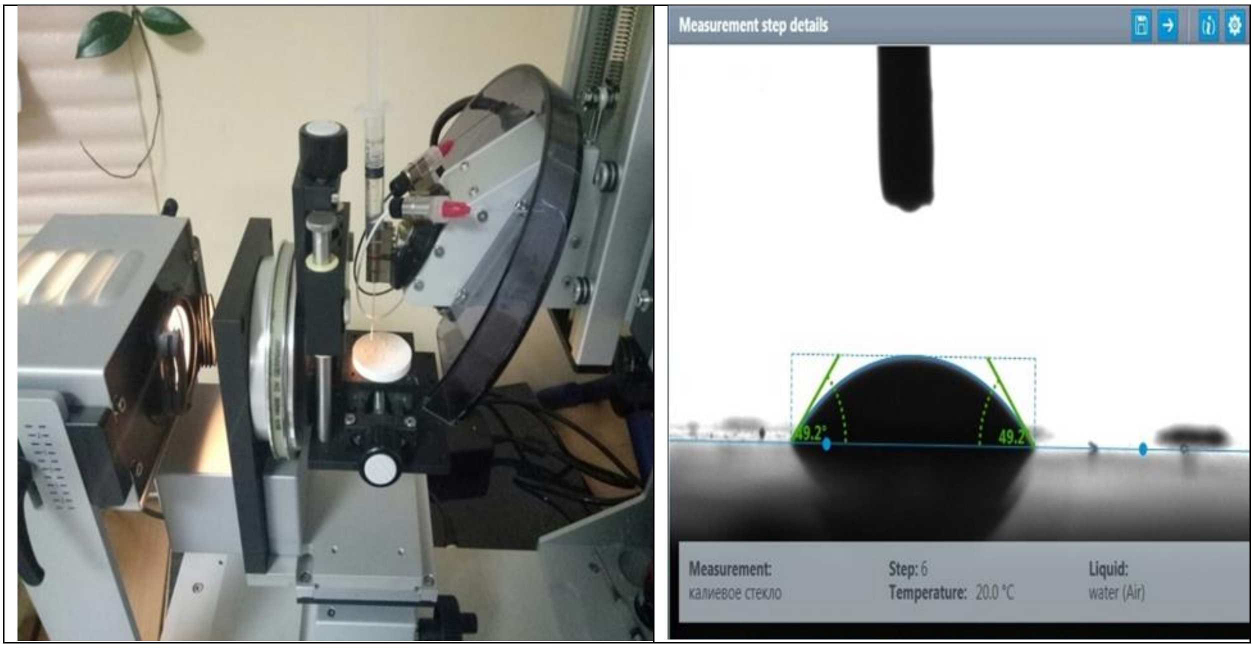

Figure 2 - KRUSS DSA30 contact angle measuring device

Table 4 - The work of adhesion of the polysilicate binder to the filler (pigment)

Name	Surface tension, mN/m	contact angle, °	Work of adhesion, mN/m	wetting work, mN/m
Water	72.8	46.2	123.18	50.38
Binder				
Potassium liquid glass	55.22	53.9	87.74	32.52
Potassium polysilicate solution (15% Nanosil20)	64.06	51.6	103.85	39.78

Analysis of the data given in Table 4 shows that the potassium polysilicate solution is characterized by a large work of adhesion to the filler (pigment), which is 103.85 mN/m, while the work of adhesion of potassium liquid glass is 87.74 mN/m. The presence of more complete wetting of the surface of the filler and pigment in the case of using a potassium polysilicate solution contributes to the formation of a denser coating structure and an increase in physical and mechanical properties.

The decorative properties of coatings based on sol-silicate paint correspond to GOST 9.407-2015 “ESZKS. Paint coatings. Appearance assessment method. The gloss of the coatings, measured on the FB-2 gloss meter, ranges from 3.07% to 4.3%, which corresponds to matte surfaces (Table 5,Figure 3)

Table 5 - Decorative properties of sol-silicate paints

<table>
<tr><th>Colour</th><th>Pigment name</th><th>Covering power, g/m²</th><th>Shine, %</th><th>Degree of chalking, score</th></tr>
<tr><td>White</td><td>titanium oxide</td><td>186.5</td><td>4.1</td><td>0</td></tr>
<tr><td>Red</td><td>Minium iron</td><td>197</td><td>3.66</td><td>0</td></tr>
<tr><td>Blue</td><td>cobalt oxide</td><td>116.4</td><td>3.07</td><td>0</td></tr>
<tr><td>Yellow</td><td>Ocher</td><td>108</td><td>3.1</td><td>0</td></tr>
<tr><td>Green</td><td>Chromium oxide</td><td>152</td><td>3.21</td><td>0</td></tr>
<tr><td rowspan="2">Blue</td><td>titanium oxide</td><td rowspan="2">112.3</td><td rowspan="2">4.3</td><td rowspan="2">0</td></tr>
<tr><td>cobalt oxide</td></tr>
</table>

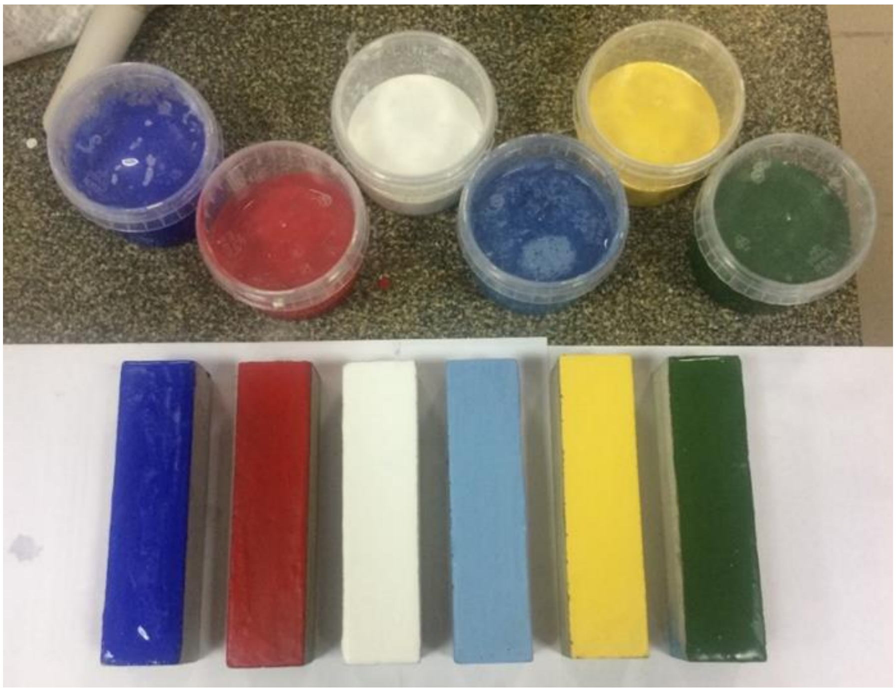

Figure 3 - Appearance of coatings based on sol-silicate paint

Table 6 show the decorative, protective, rheological properties of the paint and the operational properties of coatings based on it

Table 6 - Technological and operational properties of sol-silicate paints and coatings based on them

The name of indicators	Values
Viscosity according to VZ-4, s	25-30
Density, kg/m^3	1400
Drying time up to degree 5 at 20ºC, min, no more	41
Vapor permeability, g/(m^2 day) (GOST 33355-2015)	155
Tensile strength, MPa	2,30
Flammability group	Г1
Covering power, g/m^2	186,5
Frost resistance, brand	F35

Conclusions

It has been established that the use of microcalcite as a filler in sol-silicate paints contributes to obtaining a higher cohesive strength of coatings, due to an increase in the contribution of dispersion forces in the "filler-binder" system. Based on thermodynamic criteria (critical surface tension, Hamaker's constant), the filler composition for sol-silicate paint is optimized. It has been established that there is a linear relationship between the value of the interaction energy between the filler particles (Hamaker's constant) and the tensile strength of the coatings. The interparticle interaction between the polysilicate binder and the pigment (filler) has been studied. It was revealed that the polysilicate solution is characterized by a large work of wetting and adhesion to the filler (pigment). An increase in the crack resistance of coatings based on sol-silicate paint has been established. Coatings based on sol-silicate paint are characterized by higher tensile strength, higher ultimate elongation. The tensile strength of the coatings is Rp=2.3 MPa, the ultimate elongation is 0.028 mm/mm.

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