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Forming Composite Strength in the Presence of Lime Silica Sol

Valentina Ivanovna Loganina

Department of Quality management and technology of building production, «Penza State University of Architecture and Construction», Penza, Russia

Olga Aleksandrovna Davydova

Department of Quality management and technology of building production, «Penza State University of Architecture and Construction», Penza, Russia

Ludmila Viktorovna Makarova

Department of Quality management and technology of building production, «Penza State University of Architecture and Construction», Penza, Russia

Roman Viktorovich Tarasov

Department of Quality management and technology of building production, «Penza State University of Architecture and Construction», Penza, Russia

Abstract

Provides information about the mechanism of hardening lime composite in the presence of silica sol. It is shown that lime composites are characterized by lower values of shrinkage strain when wet.

Keywords: lime, silica sol, curing, shrinkage deformation

1. Introduction

As practice shows, the best results at recovery of the surfaces plastered by limy plaster solutions are reached at use paints, the close on composition to historical analogs, i.e. limy.

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.

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%.

For the study of solid phase reactions occurring in the process of structure formation of lime finishing compositions were applied qualitative X-ray diffraction analyzes and thermodynamic possible reactions. X-ray diffraction analysis was performed on diffractometer brand Thermo Scientific ARL X'TRA model in the range of Bragg angle 2θ = 4-80º.

3 Results and discussion

As can be seen from the X-ray pattern lime-sand composition №1 (figure 1), on the content of $Ca(OH)_2$ indicate peaks with interplanar spacings 4.916 Å, 3.115 Å, 2.629 Å, 1.928 Å, 1.797 Å, 1.688 Å, 1.556 Å, 1.483 Å, 1.419 Å; peaks characteristic of calcite formed by carbonizing: 3.857 Å, 3.040 Å, 2.493 Å, 2.098 Å, 1.913 Å, 1.876 Å, 1.622 Å, 1.608 Å, 1.602 Å, 1.529 Å. Revealed peaks at 4.267 Å, 3.349 Å, 1.829 Å, 1.549 Å, 1.543 Å, 1.449 Å, 1.383 Å, belonging to β-quartz. Identified lines corresponding to kaolinite $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ – 7.177 Å, 4.491 Å, 3.571 Å, 2.567 Å, 2.343 Å, 1.981 Å.

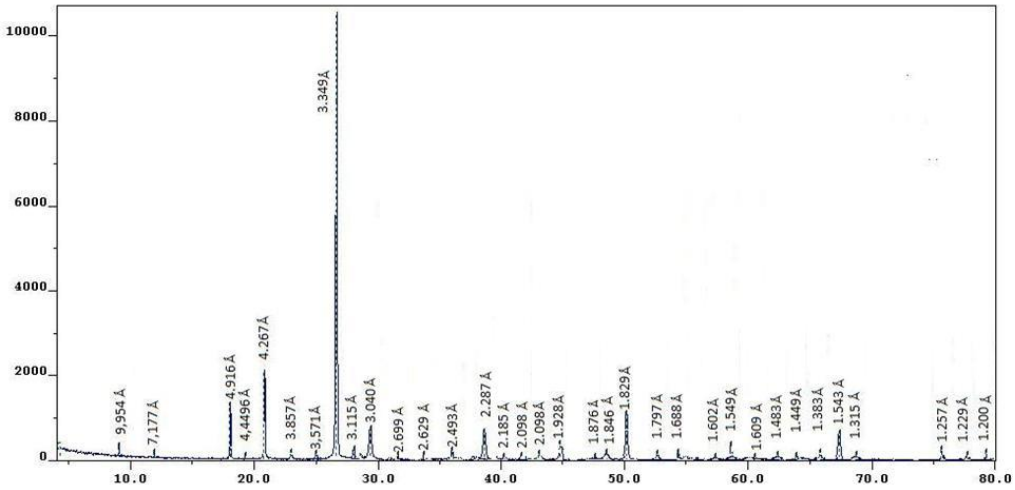

Figure 1: Radiographs lime control composition (no addition)

Hydromica, goethite, hematite are present in small quantities, it is obvious as to the impurity loam: $K_2O \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$ - hydromica type illite with d=[10.5; 9.5; 5.0; 4.50; 3.50; 3.34; 3.095; 2.86- 2.88; 2.56- 2.57; 1.49- 1.505] Å; α-Fe_2O_3 – hematite with d=[2.69- 2.71; 2.50- 2.51; 1.69; 1.84; 1.48; 1.451- 1.454;] Å; FeOOH or Fe_2O_3 H_2O with d= [4.16- 4.18; 2.45- 2.46; 2.69- 2.70; 1.720; 2.18- 2.19; 1.56- 1.55; 1.455] Å.

X-ray analysis of the sample (figure 2) supplemented with silica sol (Composition №2) showed that there are minerals that are typical of №1, but appear calcium silicate line C–S–H (II) c d = 2.847 Å, 2.381 Å, 2.130 Å, 2.109 Å, 1.628 Å, 1.526 Å, indicating interaction lime with a sol of silicic acid at ambient temperature. Intensity peaks indicating the content of lime $Ca(OH)_2$, decreases compared with a control composition.

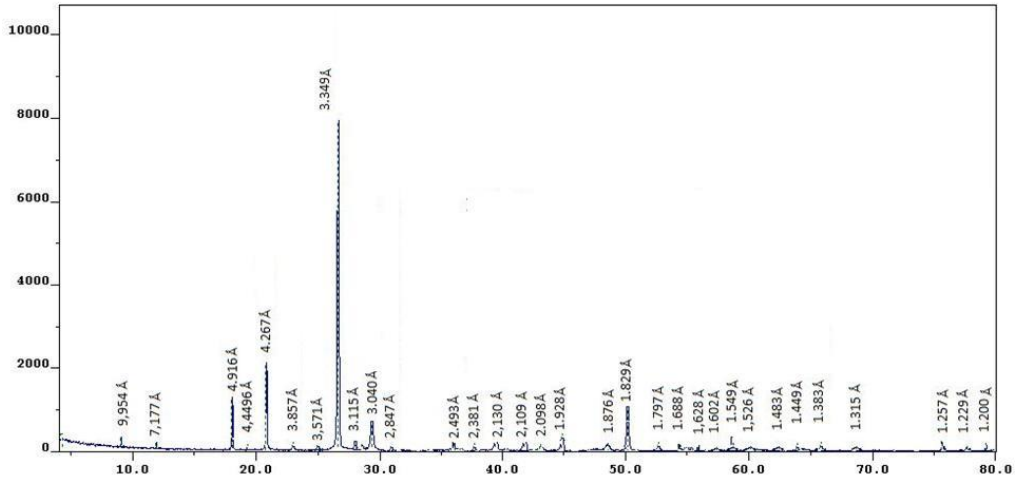

Figure 2: Radiographs of the lime with the addition of the silica sol

All samples containing amorphous and crystalline phases. A sample of control (without additives), there are two phases - the amorphous and crystalline phases with the ratio of 28% and 72%. In the presence of additive silica sol and integrated builder observed decrease in the amorphous phase and the growth of the crystal, are respectively 27 and 73%, 24 and 76%.

Thermodynamic analysis of possible solid phase isobaric-isothermal reaction was carried out in accordance with the second law of thermodynamics, which establishes a relationship between the thermal effect of chemically irreversible process and the work of the corresponding irreversible process and determined by the equation of Gibbs – Helmholtz:

$$\Delta G = \Delta H_p + T \cdot \frac{\partial \Delta G}{\partial T},$$

where ΔG – Gibbs energy;

ΔH_p – enthalpy process;

T – temperature, K.

Given that the system studied nucleation occurs at a temperature (293 K) and close to the standard (298 K), the heat of reaction and the change in Gibbs free energy is determined only at the standard state and is calculated as the difference between the respective amounts of the reaction products and the performance of the starting materials. The calculation results of the thermodynamic parameters are shown in table 1.

The results of calculations indicate the likelihood of reactions in the forward direction (negative values ΔH^0_{298}).

Larger numerical values ΔG^0_{298}, obtained for reactions of $2CaO \cdot SiO_2 \cdot 1{,}17H_2O$, $CaSO_4 \cdot 2H_2O$, $CaCO_3$ allow a reasonable probability of the possibility to talk of these reactions are not only at the standard temperature (25 °C) but also at other temperatures.

Results of thermodynamic calculations show that the possibility of the formation of calcium hydroaluminate ΔH^0_{298} is -866.9 kJ/mol. However, radiographs are not identified lines characteristic hydroaluminate calcium; Obviously, this is caused by a very small number of educated hydroaluminate.

In use decorative finishes are exposed to influence humidification - drying and, as a result, experience contraction- swelling deformations. Therefore practical interest is represented to estimate the moist deformations of finishing compositions.

Table 1: Thermodynamic parameters of the isobaric-isothermal solid phase reactions when the structure formation of lime finishing compositions

Number of responses	Formula of the compound	The heat of formation ΔH^0_{298}, kJ / mol (kcal / mol)	Gibbs energy of formation ΔG^0_{298}, kJ / mole (kcal / mol)	Reaction
1	$CaCO_3$	–112,7 (–26,9)	–75,0 (–17,9)	$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$
2	$2CaO \cdot SiO_2 \cdot 1{,}17H_2O$	–1461,1 (–348,7)	–1381,9 (–329,8)	$2Ca(OH)_2 + 2SiO_2 \cdot H_2O = 2CaO \cdot SiO_2 \cdot 1{,}17H_2O + 1{,}66\ H_2O$
3	$CaO \cdot 2SiO_2 \cdot 2H_2O$	–64,5 (–15,4)	–30,6 (–7,3)	$Ca(OH)_2 + 2SiO_2 \cdot H_2O = CaO \cdot 2SiO_2 \cdot 2H_2O + H_2O$
4	$CaSO_4 \cdot 2H_2O$	–499,9 (–119,3)	–458,0 (–109,3)	$3Ca(OH)_2 + Al_2(SO_4)_3 + 6H_2O = 3CaSO_4 \cdot 2H_2O + 2Al(OH)_3$
5	$CaO \cdot Al_2O_3 \cdot 5H_2O$	–866,9 (–206,9)	–	$Ca(OH)_2 + 2Al(OH)_3 + H_2O = CaO \cdot Al_2O_3 \cdot 5H_2O$

It is established that finishing based on limy compositions with use of sol of silicon acid are characterized by the under deformations of swelling (figure 3). Stabilization of deformations of swelling of coverings based on composition with use of ground loam with an additive of sol of silicon acid comes on 9 days, and control composition (without sol additive) – on 15 days. Values of deformations make respectively 1,0 and 1,6 mm/mm, decrease of deformations of swelling of composition with an additive of sol of silicon acid – 38%. For composition on sand of fraction of 0,314-0,14 mm with an additive of sol of silicon acid decrease of deformations of swelling is 13%. Decrease to 50% depending on granulometric composition of loam of deformations of swelling of limy compositions with the complex modifying additive is established.

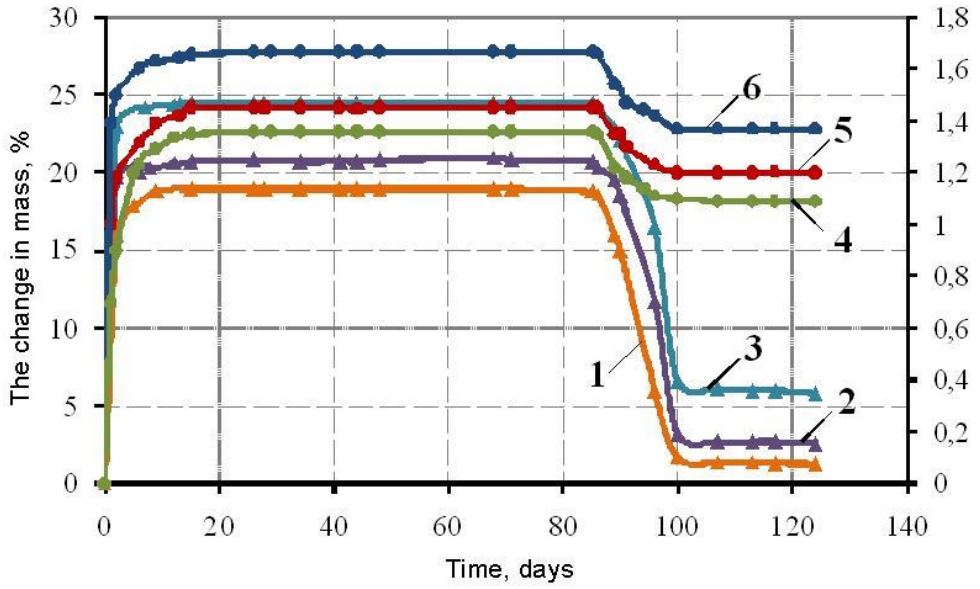

Figure 3: Influence of an additive of sol of silicon acid on swelling deformations – contractions (4–6) and change of mass (1–3) finishing compositions: 1 – L:S=1:4, W/L=1,2, sand of fraction of 0,314-0,14 mm with the complex modifying additive; 2 – L:S=1:4, W/L=1,2, sand of fraction 0,314–0,14 mm with a sol additive; 3 – L:S=1:4, W/L=1,2, sand of fraction 0,314–0,14 mm; 4 – the same, the complex modifying additive; 5 – the same, sol additive; 6 – the same

At a desiccation the greatest value of shrinkage deformations is characteristic for control composition on sand of fraction of 0,314-0,14 mm and makes 1,4 mm/mm at the age of 125 days, and for compositions with sol of silicon acid – 1,2 mm/mm.

This composition can be applied to finishing of a surface of constructions from cellular concretes, plaster and concrete surfaces.

Results of the conducted researches allowed to define optimum compoundings of colourful and decorative plaster compositions [4].

4 Conclusion

The formulation contains hydrated lime, silica sol, silica sand, pigment, aluminum sulfate. It is established that on technological and operational properties the developed compositions are more competitive in comparison with a prototype.

The cohesive and adhesion strength of limy colourful composition much higher and makes respectively 1,7-1,9 and 1,0–1,2 MPa, while at a prototype – 0,8–1,3 and 0,6–0,8 MPa. At viability at storage in open capacities (7–9 h) the composition-prototype surpasses the developed colourful composition which viability makes 5–7 h. The developed colourful composition is characterized by delayed times of drying. The drying period to degree 5 makes 47–50 min. while at composition-prototype is 22–31 min.

The proposed formulation and preparation technology of lime compositions allowed to be compatible with the surface previously painted limestone structures.

References

[1] V. I. Loganina, S. N. Kislitsyna, L. V. Makarova, M. A. Sadovnikova Rheological properties of composition limy knitting with use of synthetic zeolites. *News of higher educational institutions. Construction*. 2013. №. 4 (652). P.37- 42.

[2] V. I. Loganina, L. V. Makarova Plaster compositions for restoration works with application of the painted binders. *Regional architecture and construction*. 2009. № 1. P. 38 - 40.

[3] V. I. Loganina, S. N. Kislitsyna, V. V. Cheryachukin, E. R. Akzhigitova Effectiveness of application in dry construction mixes the organic and mineral additives based on the mixed layer clays. *Regional architecture and construction*. 2012. № 3. P.57 - 60.

[4] V. I. Loganina, O. A. Davydova Limy finishing compositions based on sol-gel technology. *Structural materials*. 2009. № 3. P. 50 - 51.

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