Abstract. Information is provided on the use of synthetic polysaccharides in lime coatings intended for the restoration of historical buildings and finishing of newly constructed objects. It has been shown that lime compositions with the addition of polysaccharides are characterized by higher cohesive strength due to the high content of calcite and the formation of inter- and intracrystalline organic macromolecules. It has been established that the introduction of the Atren Cem LV additive contributes to a sharp increase in plastic strength compared to the control composition by 1.5 times at the time of mixing and by 2.6 times after 8 hours of hardening. The introduction of Sunbo PC 1021 plasticizer into the lime mixture helps reduce plastic strength. However, after 7 hours from the moment of mixing, an increase in plastic strength is observed, outstripping the increase in plastic strength of the control composition.

1 Introduction

Lime compositions are widely used for the restoration of historical buildings [1-3]. To increase the durability of coatings based on lime finishing compositions, various modifying additives are introduced into their formulation. To increase the resistance of lime coatings, works [4] proposed introducing synthesized hydrosilicates (HSS), silicic acid sol [5-11], synthesized hydroaluminosilicates [12,13], and organomineral additives [14] into the formulation. To restore historical masonry, in [15,16] it is proposed to use lime compositions, the formulation of which includes metakaolinite. Of interest is the use of polysilicate mortar in lime compositions for restoration and finishing of building walls. Polysilicates are a dispersion of colloidal silica in an aqueous solution of alkali metal silicates. Studies have shown the effectiveness of using polysilicate mortar in lime compositions as a modifying additive [17].

In work [18-20], a proposal was made as part of the implementation of restoration projects to use lime compositions, the formulation of which includes organic components (polysaccharides, proteins and fatty acids). The authors determined that the introduction of animal glue as an additive increases the mechanical strength of the solution by 2 times, increases the carbonization front by 2 times, and reduces porosity and pore size.

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Despite a significant amount of research devoted to methods for increasing the durability of lime composites, many issues of ensuring their durability, especially during the restoration of cultural heritage sites, remain unsolved. It is of interest to study the patterns of structure formation of lime compositions in the presence of synthetic polysaccharides.

2 Materials and research methods

The work used slaked lime (fluff) with a true density of 2230 kg/m³, bulk density of 280 kg/m³, activity of 71–76%, with a specific surface area Ssp of 559 m²/kg.

The water-soluble modified polysaccharide Atren Cem LV (TU 2458-062-63121839-2014) was used as an organic additive. Atren Cem LV additives are cellulose ether (hydroxyethylcellulose (HEC)) produced by reacting alkali cellulose with ethylene oxide (EO). Currently, the water-soluble modified polysaccharide Atren Cem LV is used in the manufacture of drilling fluids.

Sunbo RS 1021 additive (superplasticizer based on polycarboxylate ether) was used as a plasticizing additive. The additive is a whitish to light pink powder with a bulk density of 400 kg/m³. The activity of hydrogen ions (pH) of a 20% aqueous solution is 7-9. The additive was introduced together with the mixing water in an amount of 1% by weight of lime.

The cohesive strength of the coatings was determined by the axial tensile strength on samples measuring 10x10x50 mm and calculated using the formula

\[
\frac{R}{p} = \frac{P}{F}
\]

where \( P \) is the destructive force, N;
\( F \) is cross-sectional area of the sample before testing, m².

Rheological properties were assessed by plastic strength, which was determined using a KP-3 conical plastometer.

3 Research results

The kinetics curves for gaining plastic strength are shown in Fig. 1.

Data analysis shows that the introduction of the Atren Cem LV additive contributes to a sharp increase in plastic strength compared to the control composition by 1.5 times at the time of mixing and 2.6 times after 8 hours of hardening. The introduction of Sunbo PC 1021 plasticizer into the lime mixture helps reduce plastic strength. At the time of mixing, the plastic strength of the control composition was 100 kPa, and with the addition of Atren Cem LV additive and Sunbo PC 1021 plasticizer - 58 kPa. However, after 7 hours from the moment of mixing, an increase in plastic strength is observed, outstripping the increase in plastic strength of the control composition.

The results of assessing the cohesive strength of coatings are given in Table. 1.
Fig. 1. Change in the plastic strength of the lime mixture: 1-control composition; 2 – composition with the addition of Atren Cem LV and plasticizer Sunbo RS 1021; 3 – composition with the addition of Atren Cem LV.

Table 1. Tensile Strength of Lime Specimens.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Tensile strength, MPa</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Curing age 28 days</td>
</tr>
<tr>
<td>Control (lime+water)</td>
<td>0.22</td>
</tr>
<tr>
<td>Composition with the addition of Atren Cem LV in an amount of 1% by weight of lime</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>Curing age 3 months</td>
</tr>
<tr>
<td>Control (lime+water)</td>
<td>0.264</td>
</tr>
<tr>
<td>Composition with the addition of Atren Cem LV in an amount of 1% by weight of lime</td>
<td>0.47</td>
</tr>
<tr>
<td>Composition with the addition of Atren Cem LV in an amount of 0.5% by weight of lime</td>
<td>0.379</td>
</tr>
</tbody>
</table>

The results obtained indicate that lime compositions with the addition of Atren Cem LV polysaccharides are characterized by higher cohesive strength. As the age of hardening increases, the increase in cohesive strength of samples with the addition of synthetic polysaccharide Atren Cem LV is more pronounced. Thus, at the age of 28 days of hardening, the cohesive strength of samples based on the control composition is R 0.22 MPa, and with the addition of a polysaccharide - 0.24 MPa. At the age of 3 months of hardening, the differences in the values of cohesive strength are more pronounced. The cohesive strength of control samples is 0.264 MPa, and of samples with the addition of Atren Cem LV in an amount of 1% by weight of lime - 0.47 MPa, with the addition of Atren Cem LV in an amount of 0.5% by weight of lime - 0.379 MPa. Obviously, this is explained by a change in the structure of the lime composite with the introduction of an
additive that promotes the formation of inter- and intracrystalline organic macromolecules, which makes the lime coating more durable.

Analysis of the IR spectra shows a higher content of calcite in the sample with the addition of polysaccharide. Obviously, due to the water-holding capacity of polysaccharides, more favorable conditions are created for the carbonization of lime. Analysis of the IR spectra presented in Fig. 2 shows that the studied samples 2 and 3 are characterized by the presence of a significant number of absorption modes corresponding to their expected chemical composition - Ca(OH)2 + CaCO3. The infrared absorption spectra with maxima at 1424 cm\(^{-1}\) are due to the CO3 group in calcite crystals. There is also an intense narrow absorption band in the region of 876 cm\(^{-1}\), characteristic of calcite. The higher intensity of the peak in the region of 876 cm\(^{-1}\) indicates a higher content of calcite in the sample with the addition of polysaccharide.

**Fig. 2.** IR transmission spectra of the studied samples: 1 – water-soluble modified polysaccharide; 2 – control composition; 3 – composition with added polysaccharide.

The conclusions obtained from the study using IR spectroscopy were confirmed when studying the mineralogical composition of the lime composite (Fig. 3, 4).

X-ray phase analysis of lime samples was carried out using a D8Advans powder diffractometer (Germany). It was revealed that there is no chemical interaction between lime and Atren Cem LV polysaccharide. The mineralogical composition of the samples is the same, but the quantitative content of minerals is different. It has been established that in samples using a polysaccharide additive, the calcite content increases, amounting to 96.2%. In control samples, the calcite content is 93.2% (Fig. 3, 4). The higher degree of carbonization of samples with the addition of Atren Cem LV, in our opinion, is due to the greater water-holding capacity of the composition, which creates more favorable conditions for carbonation of lime.
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Fig. 3. Mineral content in control sample.

Fig. 4. Mineral content in a sample with the addition of Atren Cem LV in an amount of 1% by weight of lime.
4 Conclusions

Thus, the introduction of the Atren Cem LV polysaccharide additive helps to increase the physical and mechanical properties of lime composites due to the formation of inter- and intracrystalline organic macromolecules.

References

17. V. I. Loganina, M. V. Zaytseva, Key Engineering Materials 909 (2022)