Technological features of application of plaster solutions with ground quicklime

B V Zhadanovsky, V E Bazanov
Moscow State University of Civil Engineering, 26, Yaroslavskoye Shosse, Moscow 129337, Russia
E-mail: bazanov_kim@mail.ru

Abstract. Lime plaster is widely used in new construction, repair and restoration works. The most common are plaster mortars based on killed lime. However, mortars based on ground unkill lime might be preferable in some cases. They are characterized by fast setting and strength development; intensive heat emission during unkill lime hydration makes it possible to carry out work at low temperatures. The paper discusses properties of compound plaster mortars based on ground unkill lime. The dynamics of temperature and fluidity depending on time have been analyzed for different compositions, as well as mortar compression strength dependence on hold duration before usage for work, and time curves of mortar strength depending on the water to lime relation. To clarify requirements to the physical properties of mortars for mechanical applications, mortar fluidity and temperature were measured during mortar transportation in a mortar pump.

1. Introduction
Lime plaster has been used through the ages thanks to its availability and good functional performance. Being an environmentally friendly material, lime plasters feature high vapor permeability, bactericidal, heat insulating and refractory properties, elasticity and long life. Lime mortars are characterized by high adhesion to bases from various materials, plasticity, ease of application and workability [1-3]. Lime plasters are widely used in new construction, during repair and restoration works.

Acceleration of hardening processes and improvement of mechanical properties are achieved through use of various admixtures of natural and artificial origin [4-8]. Heat and sound insulating properties of lime plasters are raised by introduction of plant or mineral fillers [9-12]. Papers [13,14] give data concerning selection of formulations of dry mixtures based on local materials (lime and clay). Versatility of historic sites that require repair and restoration necessitates additional investigation of lime mixture properties to ensure compatibility of materials’ physical and chemical properties [15-19]. Some practical recommendations are contained in [20] and concern usage of currently popular ‘live’ lime plaster mortars (based on unkill and hydraulic lime).

A vast majority of papers on lime compositions including current technical regulations [21] concern mortars based on killed lime. However, mortars based on ground unkill lime might be preferable in some cases. Mortars based on killed lime are characterized by slow setting (several days) and strength development; mortars based on unkill lime set within up to one hour from water
addition depending on composition and reach 3-4 MPa strength within a month. Intensive heat emission during unskilled lime hydration makes it possible to carry out work at low temperatures [22].

The paper discusses the properties of compound lime-gypsum and lime-clay mortars on the basis of ground unskilled lime.

2. Materials and methods
For compositions with different correlations of components, temperature and fluidity changes depending on time have been analyzed, as well as mortar compression strength depending on the duration of hold before usage for work, and mortar strength characteristics through time depending on water to lime relation. To clarify requirements to the physical properties of mortars for mechanical applications, mortar fluidity and temperature were measured during mortar transportation in a mortar pump. Mortars were prepared in the following order: at first, dry materials were mixed – sand, ground unskilled lime and clay; thereafter, water was added to the dry mixture. Mortar fluidity and strength were determined according to GOST 5802-86 “Mortars. Test methods.”

3. Results and discussion
On the basis of lime, simple (lime) and compound (lime-gypsum, lime-cement, lime-clay, etc.) mortars are made. Mortars having different compositions were chosen for the study. Time-dependent temperature curves of mortars are shown on Figure 1.

As reference, simple mortar with composition 1:4.6 (ground unskilled lime:sand) was chosen. Compound mortars based on ground unskilled lime warm up later compared to the reference mortar, the maximal temperature being reached within 60 to 90 minutes from water addition. The temperature of compound mortars is approximately twice lower than that of the reference mortar during the first 30 minutes. Loss of fluidity of compound mortars depends on the type of admixtures: mortars with hemihydrate gypsum (#1, #3) lose fluidity faster than an admixture-free mortar; as regards lime-clay mortar #2, its plasticity decreases approximately twice lower than that of a lime mortar.

Strength dynamics of a mortar with composition 1:4.6 (ground unskilled lime:sand, by volume) depending on the water to lime relation (W/L) and mortar age is shown on Figure 2.

Compression strength differs significantly during the initial period (7-day strength differs by 30-50%), mortars with lower water to lime relation have a higher strength. However, with time (28 days), all mortars having the same composition but different water to lime relations acquire an approximately equal strength.
Figure 2. Dependence of mortar strength on water to lime relation:
1 - W/L=1.0; 2 - W/L= 1.5; 3 - W/L=1.75; 4 - W/L=2.0.

The dependence of a lime mortar on time elapsed from mortar preparation to its application onto a surface (before use for work) is of interest. Diagrams on Figure 3 show compression strength dynamics for composition 1:3.1 (ground unkill lime:sand, by volume) depending on the mortar hold duration before fabrication of samples.

Figure 3. Influence of mortar hold time on its strength:
1 – strength on the 7th day, 2 – strength on the 14th day.

This dependence manifests especially vividly during the first 30-35 minutes: a mortar laid immediately after water addition is twice stronger than a mortar applied in 30 minutes. The hardening process of ground unkill lime is characterized by a short period of setting (fast coagulation of forming calcium hydroxide and crystallization producing a lime frame). In case of some delay in applying a mortar onto walls (mixing, transportation via a pipeline and feeding through a nozzle), the partially formed structure breaks down entailing formation of unrelated fine particles of killed lime and strength reduction. Further, setting of such mortars goes slower, same as mortars based on killed lime. Hence, it is better to use mortars based on ground unkill lime within 30 minutes from water addition.

Changes in the physical properties of mortars in case of mechanical feeding were checked by pumping with a mortar pump over a 16-meter ring pipeline having a diameter of 37 mm. Fluidity, lamination and temperature of mortars were measured. Works were carried out using lime and clay mortars and involved laboratory selection of optimal compositions. Mechanical transportation of lime
mortars via pipelines becomes practically impossible without clay admixtures because at minute 10-15 their placeability reaches 1-2 cm by the reference cone (Figure 1).

It has been experimentally established that satisfactory results of mechanical plastering operations can be obtained with mortar fluidity of not less than 3.5-4 cm. As one can see from the diagrams of mortar fluidity dependence on the duration of their pumping with a mortar pump (Figure 4), pumping renders almost no influence on fluidity dynamics.

Figure 4. Dynamics of fluidity of mortars with ground unkillied lime in time depending on the duration of mortar pumping with a mortar pump: 1, 3 – composition 1:0.3:3.1 correspondingly after preparation (without pumping) and after 5 minutes of pumping; 2, 4 – composition 1:0.58:3.1 without pumping and after 10 minutes of pumping.

This allows applying mortars within 25-35 minutes after preparation without mortar hardening in a mortar pump and hoses. Mortars with a clay admixture not only retain fluidity longer but warm up longer as well; their maximal temperature is lower compared to mortars without admixtures. Depending on the type of surface being coated with plaster and mortar composition, a rise or fall of plaster temperature is observed (Figure 5).

Figure 5. Temperature curves of plasters with ground unkillied lime in the course of setting in case of mechanical application: wooden wall: 1 – composition 1:0.3:3.1; 2 – composition 1:0.58:3.1; 3 – composition 1:0.6:4.6 (ground unkillied lime:clay:sand, by volume); stone wall – same compositions 4, 5, 6 respectively.

4. Conclusion
The investigations of mechanical transportation and application of mortars prepared based on ground unkillied lime (with admixtures of clay, gypsum) determined permissible time parameters of application (use, utilization) of plaster mortars having different compositions and strength characteristics of plaster coating depending on the mortar preparation time. To obtain the greatest strength of plaster, mortars from unkillied lime should be applied within 25-30 minutes after
preparation. Thanks to the property of mortars based on ground unkill lime with optimal water to lime relation to set and harden fast, it is possible to apply one layer of 30-35mm-thick plaster or one- or two-layer plaster instead of three-four layers. Shortage of codes and specifications concerning application of plaster mortars based on ground unkill lime necessitates conducting additional investigations and experiments to work out specific recommendations on the selection of compositions and operating practices of their usage.

References
[1] Volzhenskij A V, Burov YU S and Koloko'nikov V S Mineral'nye vyazhushchie veshchestva: tekhnologiya i svojstva (Moscow: Strojizdat) p 476
[2] Smireskaya V N, Antipina S A and Sokolova S N 2009 Himicheskaya tehnologiya vyazhushchih materialov (Tomsk: Publishing house of Tomsk Polytechnic University) p 200
[3] Asaul A N, Kazakov YU N i Ipanov V I 2005 Rekonstrukciya i restavracija ob"ektov nedvizhimosti (Sankt-Peterburg: Gumanistka) p 288
[4] Bakatovich A, Vishniakova J and Koltunov A 2013 To the question of the application of fine-dispersed filling agent in finishing mortars Vestnik of Polotsk State University Part F. Constr. Applied Sciences 61–67
[5] Logolina V I 2014 Pattern formation in the presence of lime composites synthesized additives based on aluminosilicates Modern Scientific Researches and Innovations 8 1 (Electronic journal). http://web.snauka.ru/en/issues/2014/08/37335
[6] Kanga S-H, Kwonb Y-H and Mooncd J 2020 Controlling the hydration and carbonation in lime-based materials: Advantage of slow carbonation in CO2 curable construction materials Construction and Building Materials 249 118749. DOI:10.1016/j.conbuildmat.2020.118749
[7] Goura K A, Ramadoss R and Selvaraj T 2018 Revamping the traditional air lime mortar using the natural polymer – Areca nut for restoration application Construction and Building Materials 164 255–64. DOI:10.1016/j.conbuildmat.2017.12.056
[8] Fošt J, Čáchová M, Vejmelková E and Černý R 2018 Mechanical and hygric properties of lime plasters modified by biomass fly ash IOP Conference Series: Materials Science and Engineering 365 Issue 3. DOI:10.1088/1757-899X/365/3/032059
[9] Logolina V I and Frolov M V 2016 Effectiveness of thermal insulation plaster with the use of microspheres for finishing aerated concrete walling News of higher educational institutions. Construction 5(689) 55–62
[10] Degrave-Lemeurs M, Gléa P and Hellouin de Menibus A 2018 Acoustical properties of hemp concretes for buildings thermal insulation: Application to clay and lime binders Construction and Building Materials 160 pp 462–74. DOI:10.1016/j.conbuildmat.2017.11.064
[11] Arizzi A, Cultrone G, Brümmer M and Vilesa H 2015 A chemical, morphological and mineralogical study on the interaction between hemp hurds and aerial and natural hydraulic lime particles: Implications for mortar manufacturing Construction and Building Materials 75 375–84. DOI:10.1016/j.conbuildmat.2014.11.026
[12] Carbonaro C, Tedesco S, Thiebat F, Fantucci S, Serra V and Dutto M 2016 An integrated design approach to the development of a vegetal-based thermal plaster for the energy retrofit of buildings Energy and Buildings 124 46–59. DOI:10.1016/j.enbuild.2016.03.063
[13] Logolina V I 2019 Dry mixes for building walls decoration based on local materials PGUAS Bulletin: Construction, Science and Education 1(8) 14–18
[14] Hurtado-Figueroa O, Vega-Vanegas EJ and Cárdenas-Gutiérrez JA 2019 J. Phys.: Conf. Ser. 1386 012071
[15] Aggelakopoulou E, Bakolas A and Moropoulou A 2019 Lime putty versus hydrated lime powder: Physicochemical and mechanical characteristics of lime based mortars Construction and Building Materials 225 633–41. DOI:10.1016/j.conbuildmat.2019.07.218
[16] Moropoulou A, Bakolas A, Moundoulas P, Aggelakopoulou E and Anagnostopoulou S 2005 Strength development and lime reaction in mortars for repairing historic masonries Cement and Concrete Composites 27(2) 289–94. DOI:10.1016/j.cemconcomp.2004.02.017

[17] Zhang D, Zhao J, Wang D, Xu C, Zhai M and Ma X 2018 Comparative study on the properties of three hydraulic lime mortar systems: Natural hydraulic lime mortar, cement-aerial lime-based mortar and slag-aerial lime-based mortar Construction and Building Materials 186 42–52. DOI:10.1016/j.conbuildmat.2018.07.053

[18] Apostolopoulou M, Aggelakopoulou E, Bakolas A and Moropoulou A 2018 Compatible mortars for the sustainable conservation of stone in masonry Advanced Materials for the Conservation of Stone ed Hosseini M and Karapanagiotis I (Springer, Cham) pp 97-123 DOI:10.1007/978-3-319-72260-3_5

[19] İpekci E, Sağın EU and Böke H 2019 Interior plastering of Ottoman bath buildings Case Studies in Construction Materials 11 e00295. DOI:10.1016/j.cscm.2019.e00295

[20] Lipatov A A 2004 Essay on the coatings under destruction. Materials of the investigation on lime coatings of the church in Trakumla (Gotland, Sweden) Archaeological News 11 233–43

[21] SP 82-101-98 Prigotovlenie i primenenie rastvorov stroitel'nyh (Moscow:Gosstroj Rossii) p 38 (Manufacturing and usage of solutions in construction industry) (in Russia)

[22] Chistov YU D and Tarasov A S 2003 Ross. Khim. Zhurn. (Zhurn. Ross. Khim. ob-va im. D.I. Mendeleeva) XLVII 4 12–17