On properties of the modified clay-gypsum binder based on the clay-gypsumfrom the Khojakul deposit

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ABSTRACT-- *The article presents the results of studies on the properties of a modified clay-gypsum binder based onthe clay-gypsum from the Khojakul deposit (Republic of Karakalpakstan). The studies have shown that the best results are reached when using the following additives to the composition of a modified clay-gypsum binder: a superplasticizer C-3 and a hardening retarder – citric acid.*

Key words-- *gypsum, clay, properties, strength, heat, setting time, binder, hydration, kinetics, superplasticizer, citric acid, modification, stabilization*.

I. INTRODUCTION

Clay gypsum rock as a building material has been known since the 10th century AD. It has found widespread use in Central Asia and the Caucasus [1, 2]. Clay-gypsum mortars, used in antiquity, were distinguished by exceptional water resistance, as evidenced by the numerous ancient buildings perfectly preserved to this day. Clay gypsum is one of the best plaster materials and is superior to cement and lime plasters. Clay gypsum has the best and uniform tinction, a pleasant texture, high heat- gas- and sound insulation properties.Numerous studies are currently underway to substantiate the possibility of using clay as a binding material for stucco mixes. In particular, in the Republic of Karakalpakstan, the use of imported from other regions of Uzbekistan expensive gypsum for the production of dry mixes leads to50%increase in the cost of the material. Despite the historical experience and long-term use of clay-gypsum in construction, it can be stated that the issues related to the study of clay-gypsum, are insufficiently covered in literature [3, 4].

World and domestic experience in the use of dry mixes in construction confirms their high efficiency and advantages compared to traditional mixes based on sand, cement and, sometimes, additives, and prepared directly at the construction site. The presence of clay minerals (montmorillonite, illite, kaolin) in the composition of the feedstock in one way or another affects the properties of clay-gypsum. This effect increases as a result of

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technological (including thermal) processing of the feedstock and is manifested, in particular, in a change in the binder activity, setting time, softening coefficient and shrinkage. Correction of the properties of clay-gypsum binders (CGB) can be carried out by the introduction of various additives [5,6,7]. Given the above, the authors conducted comprehensive studies to investigate the properties of clay-gypsum binder based on the clay-gypsum from the Khojakul deposit (Republic of Karakalpakstan); the basic results of the study are given in this paper.

II. RESEARCH METHODOLOGY

The kinetics of hydration of clay-gypsum binder without additives, stabilized and modified bystandardized methods, was determined by the method of heat release assessment. A study of the hydration kinetics of a clay-gypsum binder based on the dynamics of heat release allows us to establish the relationship between the binder material composition, its hydration characteristics and the kinetics of hydration structure formation [8, 9, 10].

In experimental studies, the dynamics and kinetics of heat release (as a function of temperature increase of an isolated material) were studied in clay-gypsum binder without additives,in stabilized clay-gypsum (with the addition of 1% of C-3) andinmodified clay-gypsum(with the addition of 1% of C-3 and 0.06% of hardening retarder – citric acid).

III. RESEARCH RESULTS

The results of the tests with clay-gypsum without additives (Figure 1, Table 1) show that the temperature of the test material reaches its maximum value after 48 minutes, holds for 5 minutes and drops to a constant temperature, the drop occurs gradually over 250 minutes. According to the Dewar method, the test of gypsum takes 1 hour, but in our studies the cooling mode was also recorded.

Based on the temperature difference determined by thermometers and the additive heat capacity of the mix, the heat release of the mixes (q, kJ/kg) is calculated. The calculation results are presented in table 1, and their graphical interpretation is given in figure 1.

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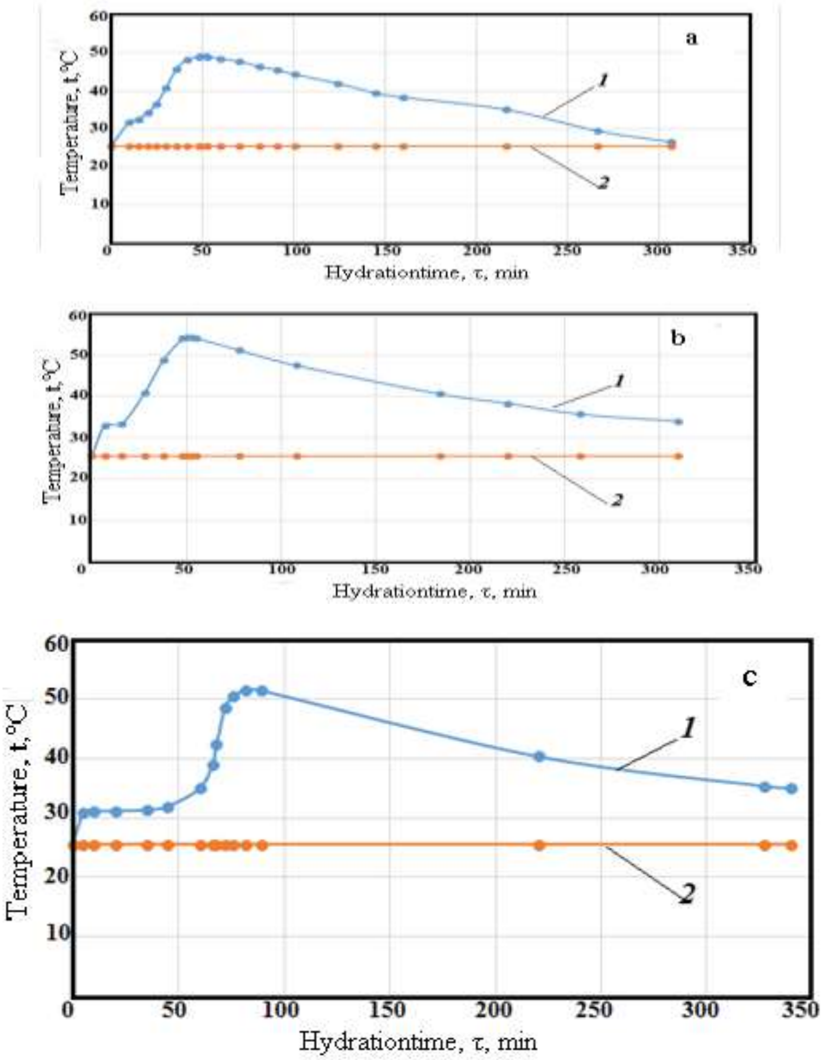

Figure 1 : Dynamics of temperature changes in testing: *a* - clay-gypsum binder without additives; *b* - clay-gypsum binder with the addition of 1% of C-3; *c* - clay-gypsum binder with the additionof 1% of C-3 and 0.06% of retarder; *1* - the temperature of the clay-gypsum binder; 2 - the ambient temperature

Differential curves (changes in heat release rate) were obtained by graphicaldifferentiating the integral curves over time.In a stabilized clay-gypsum binder (with C-3 additive), the temperature at the 50thminute was 54.2°C, it held for 4 minutes till the end of the 53rd minute (Figure 1, b, table 1). At the end of the test, at the 310thminute, the temperature was 34°C. Thus, the C-3 superplasticizer does not significantly affect the hydration kinetics of a clay-gypsum binder. The increase in the maximum degree of hydration due to the introduction of C-3 additive is significant: in terms of heat release q from 488.8 to 616.3 kJ/kg (a maximum is 100%).

Table 1 : Temperature and heat release of clay-gypsum binder (room temperature, t_0 = 25.6 °C)

Time, min	Clay gypsum binder		
	No additives	With the addition of 1% of C-3	With the addition of 1% of C-3 and 0.06% of retarder

	Temperature t_x, °C	Heat release, q, kJ/kg	Degreeofhydration α, %	Temperature, t_x, °C	Heat release, q, kJ/kg	Degreeofhydration α, %	Temperature, t_x, °C	Heat release, q, kJ/kg	Degreeofhydration α, %
0	25.6	0	0	25.6	0	0	25.6	0	0
10	31.9	127.5	21	33.2	170.0	28	31.2	85.0	14
20	34.4	191.2	31	37.9	255.0	41	31.2	106.3	17
30	40.8	318.8	52	44.2	403.8	66	31.3	127.5	21
40	48.0	467.5	76	54.0	595.0	97	31.8	148.8	24
50	49.1	488.8	79	54.2	616.3	100	33.4	170.0	28
60	—	—	—	—	—	—	35.0	191.3	31
70	—	—	—	—	—	—	45.5	425.0	69
80	—	—	—	—	—	—	51.6	552.5	90

With the introduction of a complex additive (C-3 superplasticizer and a hardening retarder), the hydration

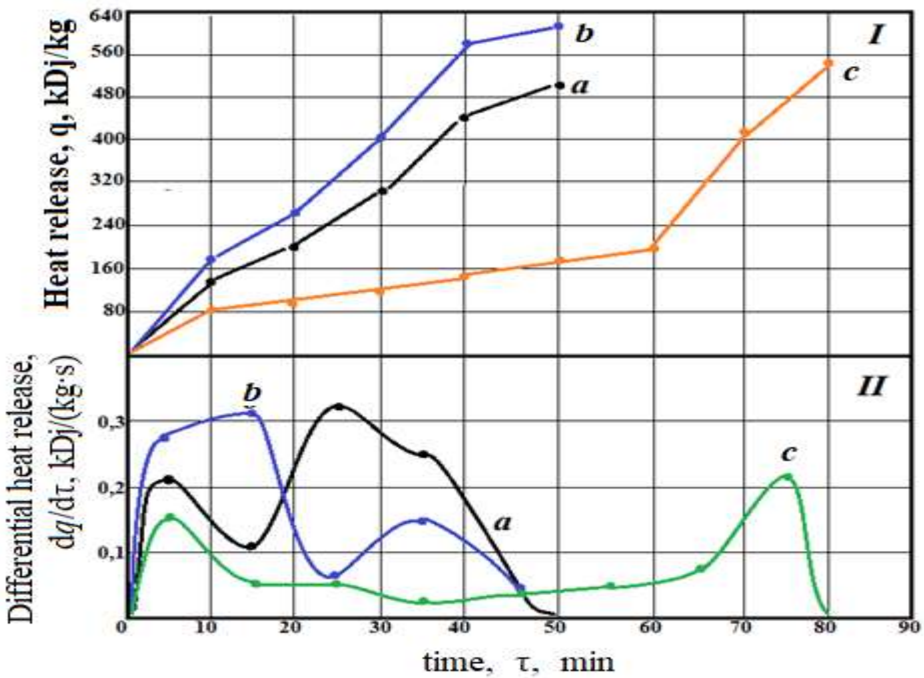

Figure 2 : Heat release of clay-gypsum binder over time: *a* - binder without additives; *b* - binder with the addition of 1% of C-3; *c* - binder with the addition of 1% of C-3 and 0.06% of retarder; I - integral curves, II– differential curves

temperature reaches its maximum at the 82nd minute and holds for 7 minutes. Experimental studies were completed at the 340thminute with a temperature of 34 ºC (Figure 2). Estimated by heat release, the maximum degree of hydration of the modified clay-gypsum binder turns out to be somewhat less than for the stabilized clay-gypsum binder: 552.5 kJ/kg.

Experimental studies have shown that the greatest values of heat release are in mixes with the addition of superplasticizer C-3, the least ones - in clay-gypsum without additives. According to the heat release rateat the early stages, clay-gypsum binder with the addition of superplasticizer C-3 manifests itself to the greatest extent (maximum values of the heat release rate in the range of 12–15 min).

The heat release rate of clay-gypsum binder without additives is in the time interval of 14–16 min. The heat release rate of clay-gypsum binder with the addition of C-3 and a hardening retarder - citric acid, falls on a time interval of 73–76 minutes.

The degree of hydration α was estimated as the ratio of the current heat release to the maximum one (q_{max} = 616.6 kJ/kg). The results of calculating the change in the degree of hydration over time are presented in figure 3.

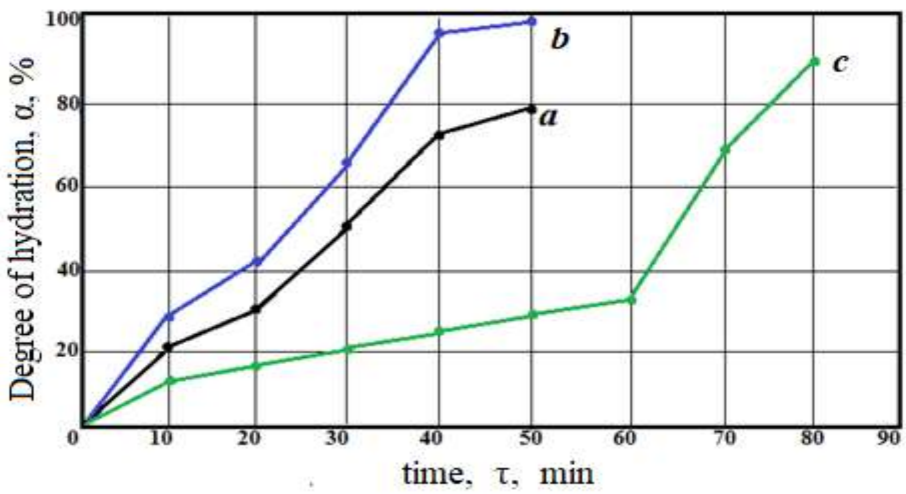

Figure 3 : The degree of hydration of clay-gypsum binder over time: *a* - binder without additives; *b* - binder with the addition of 1% of C-3; *c* - binder with the addition of 1% of C-3 and 0.06% of retarder

IV. CONCLUSIONS

Studies have shown that a binder based on clay-gypsum with the addition of superplasticizer C-3 has the greatest heat release. The use of ahardening retarder - citric acid, slightly reduces the maximum degree of hydration and increases the duration of the process. At the same time, the degree of hydration of the binder with the addition of C-3 and a hardening retarder - citric acid is higher thanin the clay-gypsum binder without additives.

When conducting plastering work indoors, the retard of the time of hydration allows applying the plaster layers more efficiently. The heat release peak at hydration of a clay gypsum binder with a superplasticizer and hardening retarder - citric acid, which occurs at the beginning of the second hour of hardening, will contribute to uniform and quality drying of the plaster coating, i.e. it is technologically substantiated.

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