E3S Web of Conferences **264**, 02064 (2021) https://doi.org/10.1051/e3sconf/202126402064
CONMECHYDRO - 2021

The effect of a complex additive on the structure formation of cement stone in conditions of dry hot climate and saline soils

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Abstract. In DHC and saline soils and groundwater conditions, the cement mix quickly loses its mobility and workability. In this regard, it is necessary to plasticize it by introducing various surfactants. However, the surfactant additive used should not slow down the process of hydration and hardening. To ensure salt resistance, it is necessary to increase the density and the strength of concrete. The proposed complex additive was obtained by joint grinding in a ball mill of a soda-sulfate alloy (SSA) and gossypol resin (GR) to a specific surface area of 2800 cm^2/g at the rate of 05, -1.5%, and 0.1-0.3%, respectively, of the cement mass. The complex additive was introduced into the mixing water of the cement mix. From the research results obtained, it is seen that with an increase in the content of GR from 0.1 to 0.3%, the normal density decreases by 1.4-4 points, and the setting time (due to the accelerating action of the SSA) decreases at the beginning by 20-50 minutes, and at the end by 60-240 minutes. In 28 days, the control cement gained the strength of 56 MPa, and with a complex addition - 60-68 MPa. The introduction of a complex additive led to an increase in the salt resistance coefficient in the reference cement up to 0.55-0.65, and in the cement with a complex additive up to 0.80-0.86; an increase was observed due to the strength and density of the samples. By increasing the strength, it is possible to save 17-21% of cement.

1 Introduction

In connection with the development of new mineral deposits in the Republic of Uzbekistan, capital construction is developing in desert regions characterized by a dry, hot climate (DHC) and saline soils and groundwater. The increase in saline areas is due to the drying up of the Aral Sea and the entrainment of large amounts of salt.

As is well-known, chemical additives primarily affect the structure formation and properties of cement paste and stone.

The research was conducted to study the effect of a complex chemical additive based on gossypol resin (GR), waste of oil and fat plant and soda-sulfate alloy melt (SSA), waste from caprolactam production, on the properties of cement paste, stone, and the salt resistance coefficient.

Among the important reasons that determine the need for the use of complex chemical additives, the following aspects should be noted: the multi-functionality of the action, i.e.,

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the ability to influence several characteristics of cement (concrete) at once; the possibility of enhancing and deepening any effect that is maximally achieved with the introduction of any one-component additive; reduction and elimination of undesirable side effects of a separate component of a complex additive; great versatility of their action, which is understood as the independence of the effect obtained from the chemical and mineralogical composition of cement and, to a certain extent from the composition of the concrete mix. What dictates the composition of the proposed complex additive from the point of view of the mechanism of its effect on the cement system under conditions of DHC and salt corrosion?

2 Materials and Methods

It is known that in conditions of DHC, at high temperatures, the cement mix quickly loses its mobility and workability. Therefore, it is necessary to plasticize it by introducing additives of surfactants. At the same time, the addition of surfactants should not slow down the process of hydration and hardening of the cement. To ensure salt resistance, it is necessary to increase the density of concrete, reduce capillary permeability, and accumulate salts in its pores.

Individual surfactants cannot provide such an effect. For example, plasticizing additives slow down the hydration and hardening of cement. In the DHC conditions, the surfactant additive must simultaneously have a plasticizing and accelerating effect on hydration and hardening of cement. This cannot be achieved by introducing a single component supplement. To increase the salt resistance of concrete, it is necessary not only to improve its pore structure but also to hydrophobized it, i.e., to impart water-repellent properties in volume. Therefore, it became necessary to use a complex additive, including a plasticizer and a hardening accelerator. Let us analyze the expediency of using the proposed complex additive.

It is known that hydrophobic agents, from the point of view of plasticizing action, are effective for lean mix concrete, i.e., with low cement content. GR is a hydrophobic agent, and, therefore, it plasticizes lean mix concrete well. The compositions of concrete mix for monolithic foundations refer to this cement. Since water-repelling substances, including GR, are water-insoluble, water-borne emulsions are obtained from them by special technology using emulsifiers. Hydrophobizing additives have a polyfunctional effect: they plasticize concrete mixes and, being adsorbed in the pores, give the concrete water-repellent properties, thereby increasing the density, water resistance, frost, and salt resistance. However, they slow down the hydration and hardening of cement.

To compensate for this effect of GR in the composition of a complex additive, it is recommended to use SSA - a hardening accelerator. Na_2SO_4 and Na CL contained in SSA increase the solubility of the initial minerals of cement clinker, slow down the formation of ettringite, and shielding shells around cement particles, thereby accelerating the processes of setting and hardening of the binder.

To obtain complex additives (besides the liquid ones), a method of agglomeration of hydrophobic agents in the form of a dry combined product (briquettes of granules, tablets, granular powder) is proposed. However, additives in the form of briquettes, granules, and tablets differ in the complexity of the compositions, methods of preparation, and the technology of their introduction.

3 Results and Discussions

With this in mind, the proposed complex additive was obtained by joint grinding of SSA and GR at the rate of 0.5-1.5% and 0.1-0.3%, respectively, of the cement mass. The complex additive was ground in a ball mill to a specific surface area of 2800-3000 cm^2/g. The resulting additive was introduced into the mixing water of the cement mix. In the course of the research, the effect of the additive on the normal density of the cement paste, the setting time, the plastic and cube strength of the cement stone was studied. The cement of the Akhangaran cement plant was used as a binder. The plastic strength of a cement stone of normal density was determined within the period of its setting. The research results are presented in Table 1 and Figures 1 and 2.

From Table 1, it is seen that with an increase in the content of GR from 0.1 to 0.3%, the normal density of the cement paste decreases by 1.5-4 points, and the setting time, due to the accelerating effect of the SSA, decreases at the beginning by 20-50 minutes, and at the end by 60-240 min.

Table 1. The effect of the complex additive on the normal density and setting time of Portland cement

Content of additives,% by mass of cement	Normal cement paste density, %	Setting time, h-min	
		beginning	end
Without additive	27.5	1-20	7-40
SSA+GR 0.5+0.1 1.0+0.2 1.5+0.3	 26 24.5 23.5	 1-00 0-50 0.3	 6-40 6-00 5-00

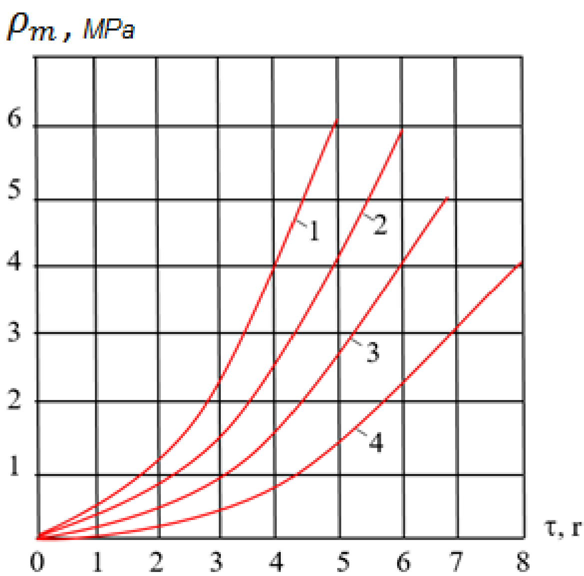

Fig. 1. Change in plastic strength of cement paste with time: 1, 2, 3 is cement paste with complex additives, SSA+GR (1.5+0.3); (1.0+0.2) and (0.5+0.1%), respectively

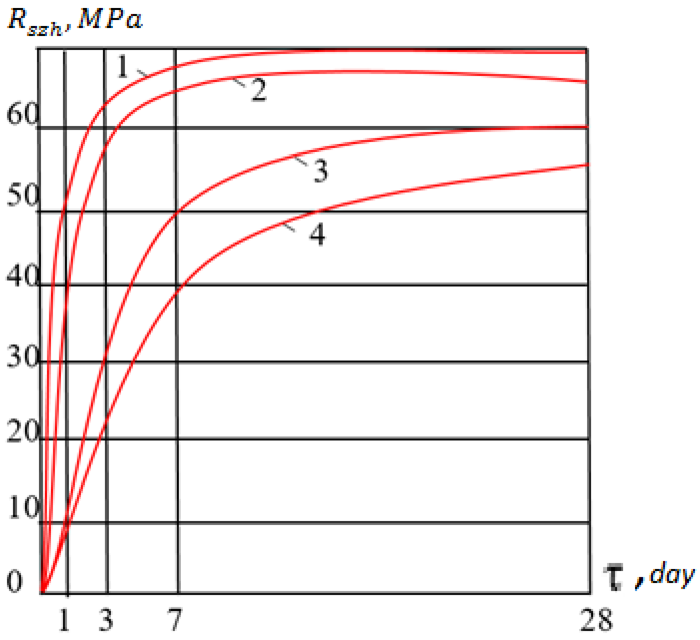

Fig. 2. The strength gain of the cement stone with time: 1, 2, 3 is cement paste with complex additives, SSA + GR (1.5 + 0.3); (1.0 + 0.2) and (0.5 + 0.1%), respectively, 4 is cement paste without additive

From the data obtained, it is seen that the best results in terms of plasticizing and accelerating action on the cement system are provided with a complex additive with SSA + GR at the rate of 1.0 + 0.2%. This is evidenced by the data of the effect of the additive on the process of the initial structure formation of the cement binder (Fig. 1). Fig. 1 shows that the complex additive accelerates the process of structure formation to a greater extent, the higher the content of SSA. In addition, there is a 25-57% increase in the plastic strength (Pm) of the hardening cement compared to the reference strength. At the same time, with a relatively longer duration of the coagulation period of structure formation with the addition of SSA + GR 1.0 + 0.2%, it is insignificantly lower by the end of the setting time of the binder than at a rate of 1, + 0.3%. This has a positive effect on the growth of cube strength with time (Figure 2).

When hardened under normal conditions for 28 days, reference cement gains the strength of 56 MPa, and with a complex additive, it gains the strength of 60-68 MPa, or 15-24% higher. One of the ways to increase the salt resistance is related to a decrease in its permeability; this is achieved by increasing its density and the strength in the initial periods of hardening, which is confirmed by the data obtained. With the introduction of a complex additive into the composition of the cement mix at the initial time of hardening, a 2.5-3.5 times increase in the cement stone strength is observed.

The effect of the complex additive on the salt resistance of the samples was determined in two solutions: 55% Na_2SO_4 and 55% Na_2SO_4 + 5.5% Na_2 Cl. Resistance coefficient (Kres) was determined by the following formula

$$K_{CT} = \frac{R_{b.c}}{R_{н.у}}$$

where $R_{b.c}$ is the strength of the samples, MPa, after testing the samples for capillary absorption and evaporation of the saline solution in 6 months;

$R_{n.u}$ is the strength of samples of normal hardening for 28 days.

The data obtained indicate that the complex additive actually increased the salt resistance of the samples (0.55-0.65 - for the reference samples and 0.80-0.86 for the samples with the complex additives). The increase in salt resistance in samples with complex additives can be explained by an increase in the density of the samples.

4 Conclusions

A simple technology for obtaining a complex additive by joint grinding of SSA and GR in a ball mill to a specific surface of 2800 cm^2/g was proposed.

The positive effect of the complex additive on the properties of cement paste and cement stone was revealed, and a rational dosage of SSA and GR in the composition of the complex additive (1.0 + 0.2%) of the cement mass was established. With an increase in the content of GR, the normal density of the cement paste decreases, and the setting time, due to the accelerating effect of the SSA, is reduced. It was observed that an increase in the plastic strength of the hardening cement amounted to 25-57% compared to the reference cement. In 28 days, the reference cement gained the strength of 56 MPa, and the cement with a complex additive gained the strength of 60-68 MPa.

The complex additive increased the coefficient of salt resistance of the samples; for the reference samples, it was 0.55-0.65 and for the samples with the complex additive is was 0.80-0.86. An increase in the salt resistance coefficient was observed due to an increase in the strength and density of the samples. Thus, by increasing the strength, it is possible to save 17-21% of cement.

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