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Corrosion resistant fine-grained ash concrete for repairs of constructions in the linen production

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Abstract. The article deals with the study of the compositions of corrosion-resistant concrete. They can be successfully used to prevent the destruction of structures in linen processing plants. Such plants include single workshops with an aggressive environment. Keeping retted stalks in compositions that are aggressive for structures is reflected in the condition of reinforced concrete and concrete structures of these workshops. Violation of the integrity of such structures can lead to severe environmental consequences. To eliminate such consequences, it is necessary to carry out reconstruction. Repair and reconstruction of structures must be organized through the use of innovative concrete. Such concretes must have a high density and resistance to corrosion. Analysis of information sources showed the effectiveness of using ashes with a high content of aluminosilicates. The work identified factors that determine the strength and density of concrete with the addition of ash. Based on the results of the work, recommendations were formed on the use of plasticizers. The composition of the organo-mineral complex has been developed.

1. Introduction

There are flax processing enterprises in the Tver region. A number of complex technological operations are used to obtain flax fiber. Among them, the operation of heat treatment of trusts stands out. During heat treatment, aggressive reagent solutions are used: caustic soda, soda ash, hydrochloric acid, engine oil. In addition, the use of steam during heat treatment additionally increases the aggressiveness of these reagents in terms of strength and durability of reinforced concrete structures of industrial buildings. Currently, many enterprises require reconstruction and repair of buildings and structures of flax factories. This will prevent large volumes of such aggressive polluted waste water from entering the soil, water bodies and groundwater. Therefore, the concrete mixtures used for reconstruction and repair must fully meet the requirements for corrosion resistance.

It is known that the use of ash as a component of fine-grained concrete increases its corrosion resistance and other performance properties. Therefore, ashes of thermal power plants are currently widely used in the production of building materials [8, 9, 10, 11] (raw materials for cements and clinker-free binders, sulfate-resistant concretes, porous aggregates, silicate, ceramic, heat-insulating and other materials), roadway construction and etc. For example, fly ash is effectively used to obtain aerated concrete composites based on geopolymer binder using acidic ash composition [11]. It should be noted that one of the most important characteristics of this composition was its granulometry.



Along with the mineral composition of this composite and its dispersion, granulometry is responsible for the formation of the optimal pore structure of the cellular composite.

In fine-grained concrete, ash acts as a binder. Researchers admit that the most valuable component in ash [7] is aluminum-containing structures - glass-crystalline aluminosilicate balls (microspheres). In terms of chemical composition, the shells of microspheres are mainly aluminum and silicon oxides in combination with small amounts of oxides of iron, calcium, magnesium, sodium, etc. The mineralogical composition of ash microspheres is represented mainly by highly basic aluminosilicate glass. But it can also contain several crystalline phases, including quartz, hematite, magnetite, mullite, anhydrite [5, 6]. Therefore, microspheres can participate in the formation of the structure of cement stone and concrete. They further enhance its corrosion resistance and strength.

Replacing part of the cement with ash can reduce production costs and improve the environmental situation. The amount of ash added to concrete can vary from 15% to 80% of the cement mass.

In this case, ashes can also help prevent the formation of cracks in concrete. For this, it is necessary to grind the ash to a higher dispersion [13]. Ash grinding together with a super plasticizer makes it possible to obtain a nano-modified organo-mineral additive. It can be highly homogeneous and highly reactive [14]. Such an additive can also reduce the water demand of the concrete mixture [14].

According to [14], the use of ash-based modifiers allows to reduce delamination, water separation, and also to reduce efflorescence of fine-grained concrete, which can also contribute to increasing the durability of structures in flax production plants [14].

In addition, according to [15], the use of organic and organomineral modifiers leads to the formation of a large number of crystallization centers and the formation of a fine-crystalline structure of cement stone, which contributes to the formation of a dense and durable structure of future concrete. Since conditions are created under which the rate of nucleation exceeds the rate of crystal growth.

Partial replacement of cement with fly ash also reduces heat release during the hydration of the binder [2], therefore, the risk of cracking of concrete at an early stage is reduced, following this, one can consider their use in rather massive structures, for example, in foundations, or those that require increased density [4, 9].

The durability of concrete is favorably influenced by additionally formed calcium hydrosilicates. When a nanomodifier based on mechanically activated fly ash is introduced into a multicomponent binder, additional crystals are formed, subsequently, the strength and density of concrete increases [14, 17]. In addition, according to the authors [1], fly ash has the properties of an independent hydration-hardening binder, which are enhanced by mechano-chemical activation of ash by grinding it with cement and setting regulator.

Introduction of up to 50% fly ash contributes to the preservation of the strength of fine-grained concrete [1, 14]. And the introduction of up to 40% of activated fly ash contributes to an increase in strength up to 50%. The strength of concrete increases by 30-50% in the case of using a nanomodifier, which is contained in the addition of mechanically activated fly ash in an amount of 0.5-1.0% in combination with the use of a superplasticizer [14]. Superplasticizer is able to improve the technological properties of the concrete mix and the physical and mechanical characteristics of the concrete stone [10].

The authors of the article [13] argue that an increase in the proportion of ash in the binder from 10 to 50% reduces the strength of concrete after heat treatment by 6-7 MPa. But they also note that the proportion of replacement of Portland cement with ash does not affect the strength of concrete after 6 months of hardening, therefore, crushed ash is considered a slowly hardening component of the binder. On the other hand, the progress of the reaction with ash depends on the presence of capillary pores where hydrates are deposited. Thus, the degree of ash reaction is higher in a system with a large amount of space filled with water [18].

However, the use of high calcium ashes with a significant content of free CaO in cement compositions is characterized by low durability. This is due to an increase in the volume of lime during its delayed hydration, which leads to the formation of cracks and a decrease in strength [9, 13].

Therefore, in order to increase the corrosion resistance, acid ashes are of interest - hydro removal waste.

At the same time, hydro removal ash can be represented by inhomogeneous particles with a rough surface texture and a porous microstructure. And this can lead to high absorption and increased water demand for cement and concrete. So, for example, to achieve a given workability of a mixture with hydro removal ash [19], researchers required a higher water content compared to the control mixtures.

The main oxides in the hydro-removal ash are SiO_2 , Al_2O_3 and CaO . While Fe_2O_3 , Na_2O , MgO , P_2O_5 , SO_3 and others are present in smaller quantities. The average aluminum content in ash, which was used in [19], was 14%. This indicates the suitability of such ash for the production of aerated concrete. The high aluminum content in the ash removal ash can also increase the resistance of concrete to chloride attack, due to the ability of amorphous alumina to bind chlorides. But with a high content of hydro removal ash, the content of heavy metals, sulfates, and phosphorus can also increase, which leads to an increase in the setting time and suppression of the development of strength.

The characteristics of the hydro removal ash, in particular its dispersion, suggest that this material can be suitable for use in concrete as a filler and fine aggregate. So, the use of ash from hydro removal led to an increase in strength (up to 70%) due to the effect of a higher content of fine particles. However, the permeability of the resulting mixtures also increases. In addition, due to the porous nature of the ash particles, thermal conductivity decreases [19].

Consequently, in order to reduce the water demand of binders with ash, improve its chemical and mineralogical composition, and also to increase its dispersion, it is necessary to remove the largest fractions and the organic part. For this you need to use enrichment.

Dispersion of ash from hydro removal allows increasing the area of intergrowth contacts between particles and greatly facilitating the transfer of electrons in the surface layer of the compositions [2, 14]. This leads to a change in the performance characteristics of the material compared to the original composition.

The use of an ultradispersed filler makes it possible to increase the physical and mechanical characteristics of ash-cement stone and ash-cement-sand concrete, while the compressive strength of ash-cement-sand concrete increases to 35%, and in bending up to 32.4%. The compressive strength of ash-cement stone increases to 30%, the thermal conductivity coefficient decreases by 6.5%. On the basis of the results obtained on the use of activated ash from hydro removal as an ultrafine filler, the authors determined the optimal ratio of ash to cement 30:70 [20]. Moreover, the researchers found fibrous crystals in the microstructure of the ash-cement stone. They "pierced" the pore space of the ash-cement stone and contributed to its strengthening. Thus, the ultrafine ash modifier not only compacted the structure of the material, but also participated in the processes of structure formation.

In this work, in order to increase the durability and corrosion resistance of repair compositions for restoring the structures of flax production, the influence of hydro removal ash and an organic-mineral modifier on the properties of fine-grained concrete was studied.

2. Materials and methods

In the work, a cement binder was used as the main binder - Portland cement, CEM II / A-I 42.5N, GOST 31108-2016. Manufacturer - LLC "Holsim (Rus) SM" Kolomna, Moscow region.

Hydraulic removal ash (Figure 1) - waste of the thermal power plant (TPP) was used as an active mineral additive. In order to increase the efficiency of using the ash from the hydraulic removal, its additional dispersion was carried out.

As part of fine-grained concrete, the following were also used:

- complex additive - organomineral modifier, which included domestically produced polycarboxylate and mineral finely dispersed filler, Leningrad region;
- building sand, GOST 8736-2014, Tver region;
- tap water, GOST 23732-2011.

To determine the physicomechanical properties of fine-grained concrete with the ash content of hydraulic removal and a complex additive, standard sample cubes were made based on cement, sand,

ash and a complex additive with a constant ratio of cement and sand ($C: P = 1: 3$) and a water-solid ratio ($V / C = 0.4$).

Concrete hardening was carried out in a special chamber with a humidity of $(90 \pm 5)\%$ at a temperature of $(20 \pm 2)^\circ \text{C}$ for 7 days.

Concrete samples were tested in full compliance with the requirements of standard methods. Compressive strength tests of samples were carried out on a laboratory hydraulic press (Figure 2, 3).



Figure 1. Ash.



Figure 2. Determination of concrete compressive strength.



Figure 3. Fine-grained concrete after tests of the determination compressive strength.

3. Results

The results of testing samples of fine-grained concrete for strength and density are shown in Figures 4-6. Figure 4 shows the dependence of the ultimate compressive strength of concrete on the addition of ash. It was found that the strength dependences for compositions with a complex additive content of 0 and 0.2% have a similar character. Maximum strength is achieved with the introduction of 10% ash. For a composition with a complex additive content of 0.1% - the dependence changes its character. With an increase in the additive content in the range from 5 to 15%, the strength increases monotonically. The maximum strength value in the investigated range is achieved for a composition with an ash content of 10% and a complex additive of 0.2% of the cement mass - 27.5 MPa. With an ash content of 15% and a complex additive of 0.1% by weight of cement, the highest strength value is 24.9 MPa.

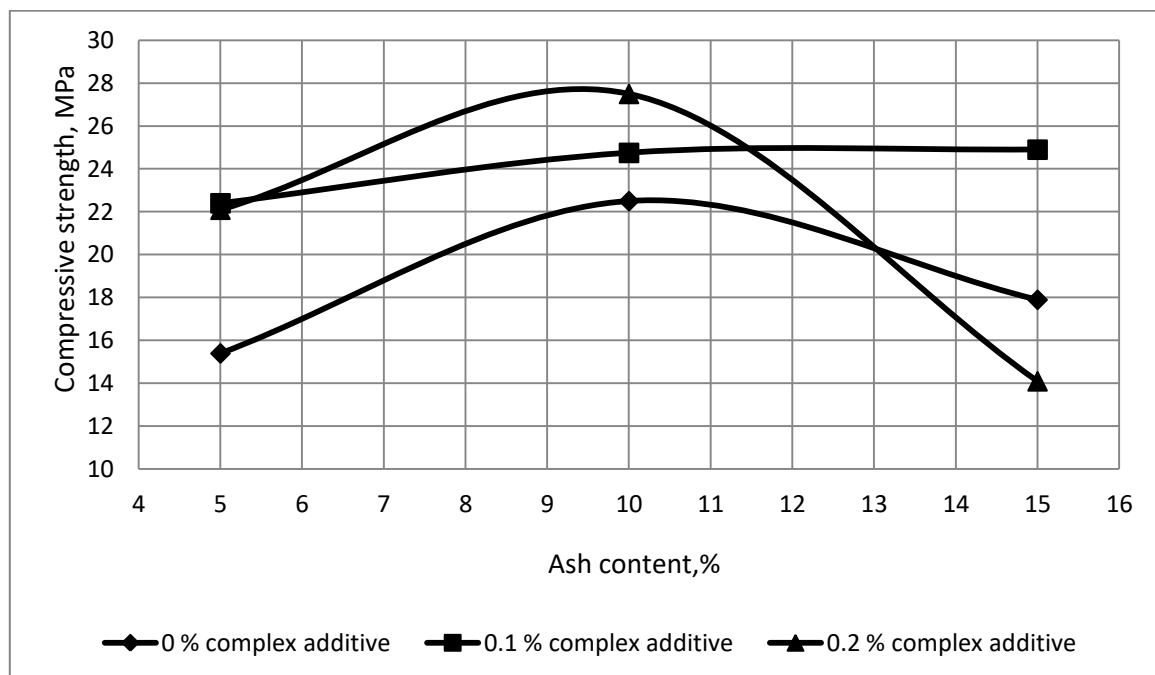


Figure 4. Influence of ash addition on the strength of fine-grained concrete.

The monotonic character of the increase in strength is also characteristic of the dependence of the ultimate strength on the content of the complex additive at an ash content of 10% (Figure 5). The increase in strength for the dependence with an ash content of 10% is 19% with an increase in the content of the complex additive from 0 to 0.2%. The dependence with an ash content of 15% is characterized by a curve with a pronounced maximum in the range of values of the complex additive content of 0.1%. At the same time, at the content of 0% and 0.2% of the complex additive, the strength sharply decreases. When the additive content is increased to 0.1%, the strength increases due to the improvement of the mixture rheology. An increased content of more than 0.1% of the additive, apparently, affects the hydration process. Also, when adding an additive in an amount of 0.2%, the porosity increases and the density of the material decreases (Figure 6).

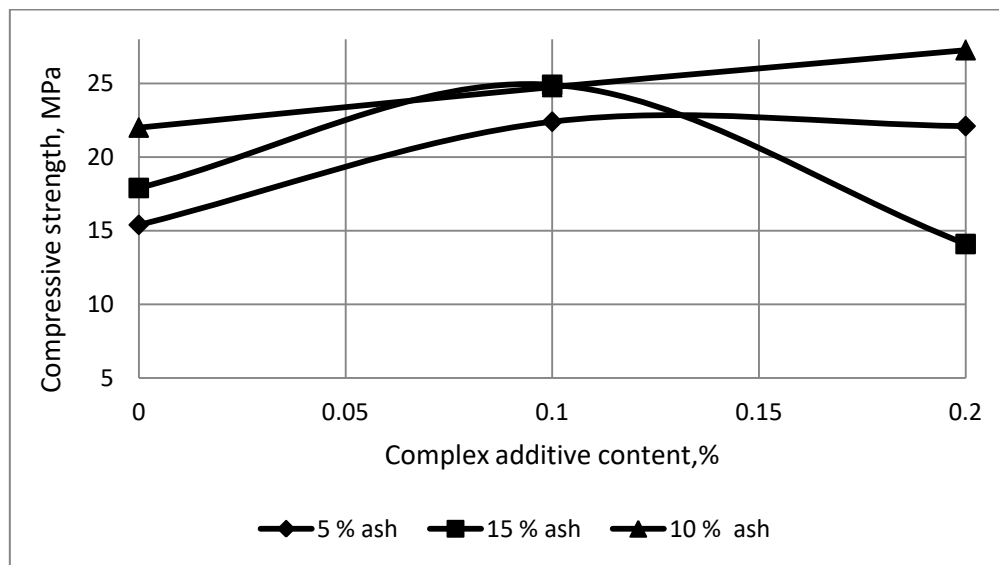


Figure 5. Influence of the content of a complex organic-mineral additive on the strength of fine-grained concrete.

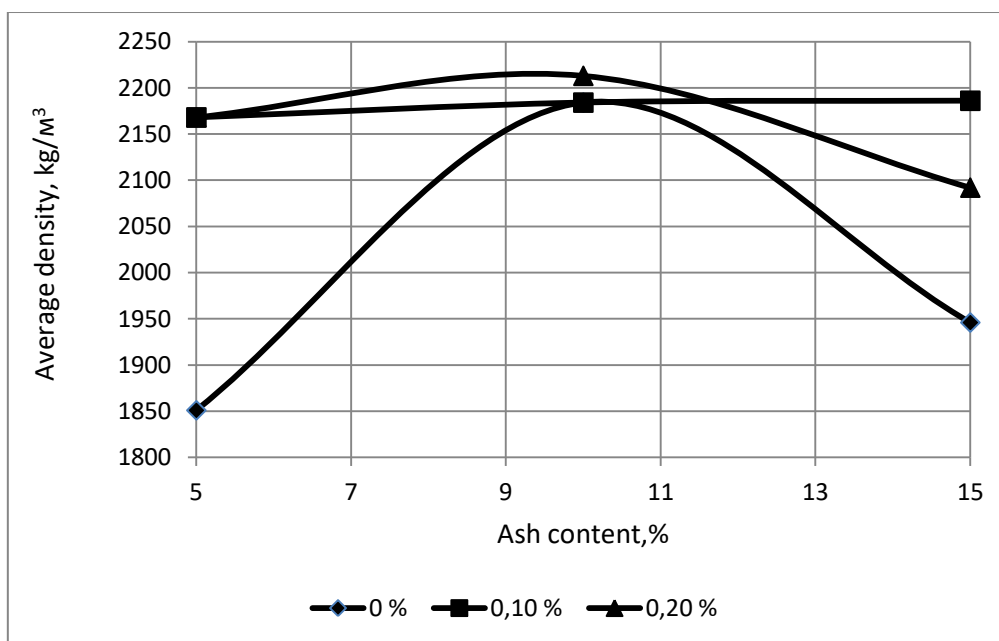


Figure 6. Influence of the complex additive and ash on the average density of fine-grained concrete.

With an ash content of 10%, the maximum in the studied range corresponds to the highest value of the additive content - 0.2%. For the dependence with an ash content of 5%, the maximum strength, apparently, as in the case of a 10% content, requires a higher content of the organomineral additive. The obtained strength data are consistent with the density data (Figure 4, 6). The synergistic effect of the additives makes it possible to increase the strength of concrete by more than 40%, with an increase in density by 20%.

The data obtained show that the physical and mechanical properties of concrete are reflected both by the effect of microdispersed ash particles and an organomineral additive. Aluminosilicate glass-crystalline components with high dispersion in the composition of fuel ash also increase the efficiency

of the use of surface-active additives in the complex modifier. Consequently, they contribute to the provision of such concrete properties as increased corrosion resistance, strength and average density.

4. Summary

Thus, the studies carried out confirm the possibility of obtaining repair compounds for use in agricultural buildings, first of all, with an aggressive environment. Improving the performance of fine-grained concrete by introducing ash and a complex additive into the raw mix ensures high quality and durability of the reconstruction.

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