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Tashkent State Transport University had the opportunity to publish the scientific-technical and scientific innovation publication “Journal of Transport” based on the Certificate No. 1150 of the Information and Mass Communications Agency under the Administration of the President of the Republic of Uzbekistan. Articles in the journal are published in Uzbek, Russian and English languages.

CONTEXT / MUNDARIJA

Development and research of complex modified concretes of a new generation for non-heating and low-temperature technologies based on local raw materials

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Abstract: The article presents the results of the development and research of complex modified concretes of a new generation intended for use in heat-free and low-heat technologies based on local raw materials. Approaches to the modification of concrete mixtures in order to increase their thermal stability and accelerate the strength gain at low temperatures are considered. The analysis of the effectiveness of the use of various additives, as well as the effect of the composition of concretes on their physical, mechanical and operational characteristics is carried out. Special attention is paid to the use of local mineral components to improve the environmental and economic efficiency of construction.

Keywords: complex modified concrete, non-heating technology, low-temperature technology, local raw materials, multifunctional additive, mineral filler, modification of concrete mixtures, ecology of construction

1. Introduction

In the world, in terms of production volume and level of technical and economic indicators, concrete and reinforced concrete structures are recognized as the most popular materials among construction products. Concrete, which is called the "material of the 20th century", remains the main construction material in the 21st century. Modern requirements for the quality of construction indicate the need to use building materials with a relatively low cost, low production costs, superior in operational properties to existing analogues.

In recent years, the global construction industry has paid special attention to the development of low-energy technology for "concrete of the future" based on complex modifiers. Such an innovative approach provides a solution to urgent problems, such as environmental safety, economic efficiency and rational use of resources, and the implementation of such an approach allows for a significant increase in the strength of concrete - up to 70% or more - at early stages of hardening. New promising solutions - the use of complex modifiers based on polyfunctional additives and mineral modifiers, open up opportunities for the transition to resource-saving low-heating and non-heating technologies for the production of reinforced concrete products and structures, contributing to the acceleration of construction processes and ensuring the production of cement composites with predetermined properties that meet modern requirements for strength, durability and environmental sustainability.

In the Republic of Uzbekistan, in the rapidly developing construction industry, significant results have been achieved in the production of complex-modified concrete and reinforced concrete structures based on highly effective additives. This has reduced their cost, as well as improved the quality and performance properties of cement concrete. As an alternative, the use of complex additives has become more effective. Numerous studies have been conducted to improve the reliability and durability of building materials, which helps to increase the service life of structures and reduce operating costs. Practical recommendations are being developed to significantly improve the physical, mechanical and operational performance of such materials. One of the key aspects in implementing these tasks is the development and improvement of existing technologies for production using resource-saving low-heating or no-heating methods to ensure the required grade strength of finished products and structures with improved performance properties. This is achieved through the combined use of mineral microfillers of technogenic origin and polyfunctional chemical additives.

This article is devoted to the study of the development and study of complex-modified concretes of a new generation, intended for use in non-heating and low-heating technologies using local raw materials.

2. Materials and methods

In the article, Portland cement CEMI 32.5N from the Akhangarancement plant was used as a binder, steelmaking waste from the Foundry and Mechanical Plant of JSC Uzbek Railways was used as a fine filler, and a new generation of highly effective superplasticizer based on polycarboxylate esters and ammonia water POLIMIXJBI and superplasticizer based on polycarboxylate esters POLIMIX from ARMENT CONSTRUCTION CHEMICALS were used as a chemical additive.

The pH environment of hydrating cement suspensions with and without mineral additives was assessed using a pH meter. Both standard and modified concrete mixtures with various additives were used to study the kinetics of temperature changes during hydration of cement systems. The temperature measurement process was carried out using the calorimetry method with isothermal and adiabatic control of hardening conditions.

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The plastic strength was studied on cement paste samples during the first hours after mixing. Penetrometric tests were used for this purpose using an automatic cone penetrometer, which records the resistance to cone penetration into the dough. Measurements were taken at 10-minute time intervals. This approach allowed us to obtain data on the rate of increase in plastic strength depending on the composition of the cement mixture.

Standard compression testing methods were used to study the kinetics of cement stone strength gain. Test samples were prepared from cement pastes with various additives and modifiers, which were formed into special forms and maintained under standard hardening conditions (20°C, humidity 95%). Strength tests were conducted at different stages of hydration: after 1, 3, 7, 28, 90 days.

3. Results and discussions

The alkalinity of the pore fluid of concrete is an important factor for preventing corrosion of steel reinforcement in reinforced concrete structures. To ensure the durability of the reinforcement, the minimum alkalinity level, expressed through pH, should not be lower than 11.8, according to most scientific studies. The introduction of amorphous silicon into the cement structure can facilitate the binding of calcium hydroxide ($Ca(OH)_2$) and, due to the transition to high-strength calcium hydrosilicates, provide a significant decrease in the alkalinity of the system. To test this hypothesis, we conducted additional studies of the effect of SLW on changes in the alkaline environment in cement.

Based on the literature review, the composition of modified cement stone using Novoangren fly ash (FA) was compared to evaluate the efficiency of SLW in the cement system. In the development of compositions, based on previous experiments, FA was adopted in the amount of 30% of the cement weight. The following compositions were used in the studies: 1. Reference composition of pure Portland cement (PC); 2. PC + FA (30%); 3. PC + SLW (25%); 4. PC + POLIMIX; 5. PC + POLIMIXJBI; 6. PC + POLIMIX + SLW (25%); 7. PC + POLIMIXJBI + SLW (25%); 8. PC + POLIMIXJBI + FA (30%). The results are presented in Table 1.

Table 1

pH values of the studied compositions

Time	Compound №1	Compound №2	Compound в №3	Compound в №4	Compound №5	Compound №6	Compound №7	Compound №8
10 min	12,41	12,31	12,34	12,31	12,31	12,31	12,31	12,31
20 min	12,41	12,31	12,34	12,41	12,31	12,31	12,31	12,31
30 min	12,56	12,42	12,45	12,56	12,44	12,42	12,41	12,34
40 min	12,56	12,42	12,45	12,56	12,44	12,42	12,41	12,34
60 min	12,74	12,42	12,45	12,56	12,44	12,42	12,41	12,34
1 day	12,74	12,42	12,65	12,74	12,72	12,66	12,66	12,65
10 day	12,71	12,42	12,65	12,74	12,72	12,66	12,66	12,65
20 day	12,71	12,02	12,65	12,72	12,7	12,66	12,64	12,2
30 day	12,71	11,98	12,1	12,71	12,68	12,64	12,62	12,1
60 day	12,71	10,8	12,1	12,71	12,68	12,64	12,62	11,6

As can be seen from the data in Table 1, the polyfunctional chemical additive and the mineral modifier from the SLW do not lead to a critical decrease in the pH value, which, accordingly, does not have a significant effect on the corrosion of steel reinforcement. However, the use of the ZU both independently and in combination with the polyfunctional additive does not achieve the required pH level of the pore fluid. Therefore, when using this type of mineral additive, it is necessary to take additional measures to protect the reinforcement.

To achieve the objectives of the study of the transition to resource-saving low-heating and non-heating technologies, it is necessary to evaluate the effect of a multifunctional additive (PFA) and steelmaking waste (SW) on the exothermy of cement (heat release). The use of exothermic heating allows for a significant reduction in energy costs when accelerating the hardening of concrete both in the production of prefabricated products and in monolithic construction (Fig. 5).

In our case, it is advisable to compare the effect of various modified cement compositions on the exothermy of the cement composite. The following compositions were used in the studies: 1. Reference composition of PC; 2. PC + POLIMIX; 3. PC + POLIMIXJBI; 4. PC + POLIMIX + SLW (25%); 5. PC + POLIMIXJBI + SLW (25%).

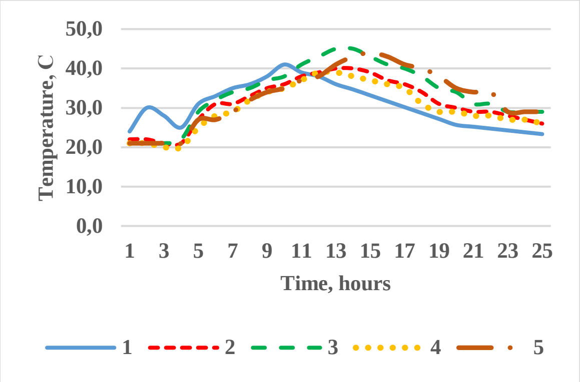

Fig. 5. Kinetics of temperature change of the studied compositions (1-standard; 2-PC+POLIMIX; 3-PC+POLIMIXJBI; 4-PC+POLIMIX+SLW (25%); 5-PC+POLIMIXJBI+SLW (25%))

Analysis of the data in Fig. 5 shows that chemical additives (superplasticizer and polyfunctional additive) significantly slow down the process of cement hydration at the initial stage. This is due to the fact that the additive molecules partially "block" the surfaces of the binder particles and prevent their reaction with water. Comparison of temperature dependencies during the hardening of compositions with NFA and SLW revealed that the exothermy of the modified cement composite increased by 4°C compared to the 1st and 2nd compositions and by 9°C compared to the 4th composition. This is explained by the fact that the ammonia additive in the NFA composition increases the solubility of the cement particles, which leads to an increase in temperature.

The crystal-coagulation period of cement binder structure formation is the phase of initial formation and development of the crystalline structure of cement stone, which begins after mixing with water and continues until a stable crystalline matrix is formed. At this stage, the water phase is saturated and calcium hydrosilicate crystals (C-S-H) are formed, as well as the particles are coagulated, which helps to strengthen and stabilize the cement stone. This period is critical for the formation of a strong structure of the cement binder and its physical and mechanical properties. The influence of additives and modifiers can significantly change the speed and quality of structure formation, which affects the performance characteristics of the material.

To study the duration of these processes, an assessment was made of the plastic strength of the cement system with various additives and its individual components, as well as their influence on the kinetics of plastic strength growth (Fig. 6) and the change in strength over time (Fig. 7). The plastic strength was assessed based on the ultimate shear stress measured during cone immersion.

The following compositions were used in the studies: 1. Reference composition of PC; 2. PC + POLIMIX; 3. PC + POLIMIXJBI; 4. PC + POLIMIX + SLW (25%); 5. PC + POLIMIXJBI + SLW (25%).

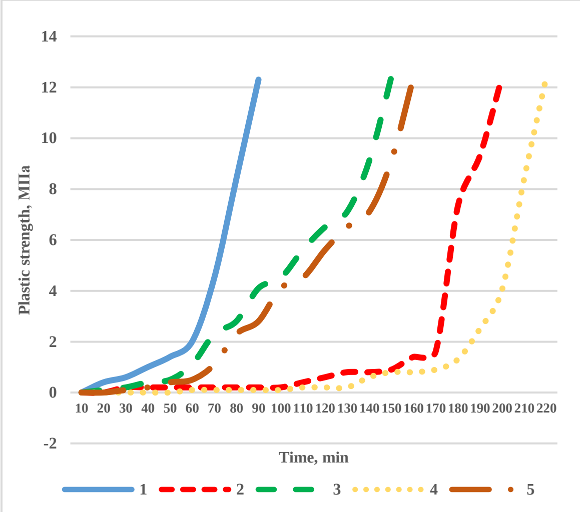

Fig. 6. Kinetics of increase in plastic strength of the studied compositions (1-standard; 2-PC+POLIMIX; 3-PC+POLIMIXJBI; 4-C+POLIMIX+SLW (25%); 5-PC+POLIMIXJBI+SLW (25%))

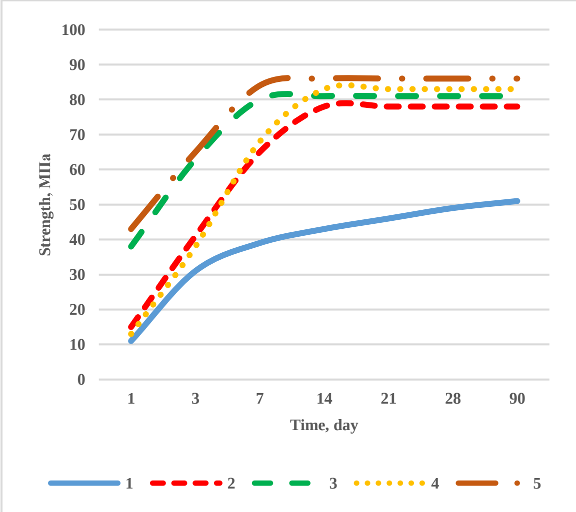

Fig. 7. Kinetics of compressive strength of the studied compositions (1-standard; 2-PC+POLIMIX; 3-PC+POLIMIXJBI; 4-C+POLIMIX+SLW (25%); 5-PC+POLIMIXJBI+SLW (25%))

The data in Fig. 6 show that induction hardening using the POLIMIX superplasticizer (compositions No. 2 and No. 4) increases the cycle time by 160-190 minutes. This is due to the formation of a film on the surface of the cement particles, which temporarily limits water adsorption and slows down hydrolysis. Over time, the film dissolves due to increased alkalinity and the intensive stage of structure formation of the system begins. In compositions No. 3 and No. 5, acceleration of the hardening process is observed. The use of NFA reduces the induction period from 160 to 60 minutes compared to composition No. 2. NFA accelerates hardening due to the activation of the reaction between cement and water, where the modifiers act as catalysts, accelerating the formation of hydrates.

Analysis of Fig. 7 shows that the POLIMIX superplasticizer slows down the growth of cement stone strength at the initial stage of hardening, but accelerates it in subsequent periods due to high water reduction. The introduction of NFA and SLW increases strength compared to the reference composition by 59-61% in the initial period, and compared to compositions No. 2 and No. 4 - by 8-10%. Modified compositions with NFA demonstrate the highest strength indicators both on the 1st and 28th day, which is important for the technology of low-heating and non-heating concrete.

4. Conclusion

The conducted studies have shown that the use of complex additives based on NFA and SLW in cement systems does not lead to a significant decrease in the pH level, which allows for reliable protection of reinforcement from corrosion throughout the entire observation period. A slight decrease in pH by 0.2% in the control composition to a level of 12.68 indicates the preservation of a favorable alkaline environment for the passivation of reinforcement steel.

Analysis of the exothermic kinetics of hydration processes showed that the addition of ammonia accelerates cement hardening and increases the peak temperature by 4°C compared to reference samples. This confirms the possibility of using the proposed composition for concrete production technologies for non-heating or low-heating technologies.

In addition, the obtained data confirm that the use of complex additives based on NFA and SLW allows achieving the strength of cement stone up to 87 MPa due to the improvement of its microstructure and acceleration of hydration processes. These results can serve as a basis for further improvement of low-heating and non-heating concreting technologies using local raw materials.

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