STUDY OF THE STRUCTURE AND PROPERTIES OF CEMENT COMPOSITES BASED ON MINERAL TECHNOGENIC ADDITIVES

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Abstract: This study investigates the physical and mechanical properties of cement composites based on industrial waste materials. Technogenic mineral additives were introduced into Portland cement, and their effects on density, specific surface area, and volumetric stability were analyzed under laboratory conditions. The obtained results showed that the additives did not deteriorate the main technical properties of cement and, in some cases, even improved them. The research findings confirm the possibility of producing environmentally and economically efficient cement through the utilization of technogenic waste materials.

Keywords: Portland cement, technogenic waste, density, specific surface area, Le Chatelier method, environmental efficiency, clinker consumption.

Introduction

At present, Portland cement is the main binding material in the construction industry, and its production is associated with high energy consumption and significant environmental impact. Therefore, reducing clinker consumption and improving cement properties through the use of technogenic waste as mineral additives has become one of the most relevant research directions.

When incorporated into cement compositions, technogenic waste materials can positively influence the physical and mechanical properties of cement and contribute to the densification of its microstructure. In this study, the physical and mechanical

properties of cement composites based on industrial waste materials were investigated under laboratory conditions.

Main Part

Under laboratory conditions, a Portland cement sample was prepared using Sharg‘un coal mine waste as a mineral additive. The main objective of the study was to determine the density, specific surface area, and volumetric stability (expansion) of the cement paste. For the experiment, a cement mixture with a total mass of 3 kg was prepared, consisting of 78.3% clinker, 13.2% limestone, 3.5% gypsum, and 5% Sharg‘un coal mine waste. In terms of mass ratio, the mixture contained 2349 g of clinker, 396 g of limestone, 105 g of gypsum, and 150 g of waste material.

The prepared raw material components were ground in a laboratory ball mill for 1 hour to obtain a homogeneous mixture. After grinding, the cement powder was sieved through a standard 0.08 mm sieve to ensure a uniform granulometric composition of particles, after which further physicochemical tests were carried out.

Density Determination: The tests were carried out using a high-precision measuring device manufactured by the Micromeritics company. According to the results, the density of the cement sample containing 5% Sharg‘un coal mine waste was 3.08 g/cm³. The obtained result confirms that the technogenic mineral additive was uniformly distributed within the cement matrix and did not negatively affect the physical and mechanical properties of the material. In addition, this indicator demonstrates that the optimal densification of the cement composition was maintained after the incorporation of the additive.

Determination of Specific Surface Area: The specific surface area was determined using a Blaine Air Permeability Apparatus analyzer. At the initial stage of the study, the true density of the cement sample was determined, and based on the obtained values, the sample mass to be placed into the analyzer chamber was calculated according to a

special calibration table. This approach ensured the accuracy and repeatability of the measurement results.

Table 1. Mass quantities used for Blaine test

Mass used for density determination	
2.85 g/cm³-104.95g	3.07 g/cm³-113.05g
2.86 g/cm³-105.32g	**3.08 g/cm³-113.42g**
2.87 g/cm³-105.69g	3.09 g/cm³-113.79g
2.88 g/cm³-106.05g	310 g/cm³-114.16g
2.89 g/cm³-106.42g	3.11 g/cm³-114.52g
2.90 g/cm³-106.78g	3.12 g/cm³-114.89g
2.91 g/cm³-107.16g	3.13 g/cm³-115.26g
2.92 g/cm³-107.53g	3.14 g/cm³-115.63g
2.93 g/cm³-107.90g	3.15 g/cm³-116.00g
2.94 g/cm³-108.26g	3.16 g/cm³-116.37g
2.95 g/cm³-108.63g	3.17 g/cm³-116.73g
2.96 g/cm³-109.00g	3.18 g/cm³-117.10g
2.97 g/cm³-109.37g	3.19 g/cm³-117.47g
3.00 g/cm³-110.47g	3.20 g/cm³-117.84g
3.01 g/cm³-110.84g	3.21 g/cm³-118.21g
3.02 g/cm³-111.21g	3.22 g/cm³-118.57g
3.03 g/cm³-111.58g	3.23 g/cm³-118.94g
3.04 g/cm³-111.95g	3.24 g/cm³-119.31g
3.05 g/cm³-112.31g	3.25 g/cm³-119.68g
3.06 g/cm³-112.68g	

The density of the cement sample was determined to be 3.08 g/cm³, and in accordance with this value, the sample mass for the Blaine Air Permeability Apparatus analyzer was set at 113.42 g.

Table 2. Density and Specific Surface Area of Clinker, Conventional Cement, and Cement Samples Prepared with Sharg‘un Coal Mine Waste

T/r	Samples	Density of samples g/cm³	Specific surface area of samples g/cm²
1	Clinker	3,11	3175
2	Conventional cement	3,09	3161
3	Cement Sample Produced Using Sharg‘un Coal Ash Waste	3,08	3277

Volumetric Stability of Cement Paste: The volumetric stability of the cement paste was evaluated using the Le Chatelier Method. During the experiment, cement paste with standard consistency was placed into a Le Chatelier mold, and the upper and lower parts of the sample were tightly covered with glass plates. The prepared samples were stored in water at a temperature of 20°C for 24 hours. At the end of the specified period, the distance between the indicator needles of the mold was measured, and the initial expansion value was recorded.

In the next stage, the samples were placed in a water bath, where the temperature was gradually increased to 100°C and maintained under boiling conditions for 4 hours. After the heat treatment process, the samples were cooled to room temperature, and the distance between the indicator needles was measured again. Based on the difference between the initial and final measurements, the expansion value of the cement paste was determined in millimeters. The obtained results made it possible to evaluate the volumetric stability of the cement composition and to analyze the effect of free CaO and

MgO compounds during the hydration process. The research results are presented in Table 3.

Table 3. Results of Cement Paste Expansion Determination Using the Le Chatelier Ring Method

№	Samples	Initial width of Le Chatelet ring, mm	Width of Le Chatelet ring after 24 hours in water, mm	Width of Le Chatelet ring after boiling for 4 hours, mm
1	Clinker	11	12	13
2	Conventional cement	8	9	10
3	Cement Sample Produced Using Sharg‘un Coal Ash Waste	8	9	10

The research results showed that cement composites containing Sharg‘un coal mine waste do not contain free CaO and MgO oxides in critical amounts that could cause volumetric instability. The expansion values determined by the Le Chatelier Method were close to those of the control Portland cement samples, and all parameters were recorded within standard requirements.

The obtained results confirm that the technogenic mineral additive does not induce negative deformation processes in the cement system and maintains the volumetric stability of the matrix during hydration. Furthermore, the use of Sharg‘un coal mine waste demonstrates that it does not adversely affect the performance characteristics of cement, indicating its suitability as an environmentally and technologically efficient mineral additive.

RESULTS AND DISCUSSION

The conducted experiments demonstrated that the incorporation of Sharg‘un coal mine waste as a mineral additive into Portland cement does not adversely affect its main physical and mechanical properties. During the study, cement samples were comprehensively analyzed in terms of density, specific surface area, and volumetric stability.

According to the density determination results, the cement sample containing 5% Sharg‘un coal mine waste exhibited a density of 3.08 g/cm³. This result indicates a uniform distribution of the technogenic additive within the cement matrix and the formation of a compatible structure with clinker minerals. The proximity of the density values to those of standard Portland cement confirms that the additive does not negatively influence the physical state of the cement.

The specific surface area, which characterizes cement fineness, was determined using the Blaine method. The results showed that the fine dispersed particles present in Sharg‘un coal mine waste contribute positively to increasing the overall surface area of the cement. This effect may accelerate the hydration process and lead to the formation of a denser cement stone microstructure. As a result of the microfiller effect of the mineral additive, a reduction in voids within the cement matrix was observed, leading to increased structural compactness.

Volumetric stability tests conducted using the Le Chatelier Method confirmed that all samples met the required standards. It was found that the cement containing the additive did not exhibit critical amounts of free CaO and MgO oxides, which are responsible for volumetric expansion. The expansion values being close to those of the control samples indicate that the technogenic additive remains stable within the cement system, ensuring long-term structural integrity.

Overall, the obtained results confirm that Sharg‘un coal mine waste can be effectively utilized as a mineral additive in cement production. Its use contributes not only to the reduction of clinker consumption but also to the mitigation of environmental impacts through the recycling of industrial waste. Therefore, the application of this technogenic material in cement technology represents an important scientific and practical approach toward resource-efficient and environmentally sustainable construction materials.

CONCLUSION

The research results demonstrated that Sharg‘un coal mine waste can be effectively used as a mineral additive in Portland cement. The additive did not have a negative impact on key performance indicators such as density, specific surface area, and volumetric stability of cement.

The Le Chatelier Method results confirmed that all tested samples complied with standard requirements. Overall, the obtained findings indicate that the use of technogenic waste is a promising solution for reducing clinker consumption, improving environmental efficiency, and producing resource-efficient cement.

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