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IMPROVING THE TECHNOLOGY OF PORTLAND CEMENT PRODUCTION THROUGH EFFICIENT UTILIZATION OF INDUSTRIAL WASTE.

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Abstract

The conducted analyses revealed that the oxide composition of industrial waste complies with the regulatory requirements established for mineral additives used in Portland cement clinker production. It was determined that the incorporation of these oxide components into the cement system as mineral additives does not adversely affect the hydration process; on the contrary, it promotes and accelerates the hydration mechanism.

Technogenic mineral additives participate in the cement system as finely dispersed phases, accelerating the kinetics of hydration product formation and contributing to the densification and strengthening of the cement stone microstructure. As a result, the physical and mechanical properties of cement-based materials are improved, and their long-term durability and operational stability are enhanced.

The obtained results demonstrate that industrial waste has significant potential for application as an effective mineral additive in Portland cement production, contributing to both resource efficiency and sustainable waste management.

Keywords: Portland cement, technogenic waste, mineral additive, hydration, microstructure, clinker.

Introduction

Portland cement is one of the most important and widely used binding materials in the construction materials industry. Its production process is characterized by high-temperature operations and significant energy consumption. In particular, the clinker production stage accounts for the largest share of fuel and raw material consumption. Therefore, improving energy efficiency and ensuring the rational use of natural resources remain among the most pressing challenges in the cement industry.

In recent years, considerable research has been devoted to achieving environmental and economic benefits through the utilization of industrial waste in construction material technologies. The incorporation of technogenic waste into cement as a mineral additive not only helps address waste disposal issues but can also improve the physical and mechanical properties of cement.

Industrial waste generated by asphalt plants operating in the Surkhandarya region is currently not fully recycled and continues to pose environmental concerns. These wastes contain significant amounts of oxides such as SiO_2, CaO, Al_2O_3, and Fe_2O_3, which are important constituents of cement systems. Therefore, their application in Portland cement production is of considerable scientific and practical interest.

In this context, the main objective of the present study is to improve the technology of Portland cement production through the utilization of industrial waste, particularly asphalt plant waste, and to investigate its influence on the physicochemical properties of cement.

Main Part

The utilization of industrial waste is considered one of the promising approaches for improving Portland cement production technology. In the present study, industrial waste generated by asphalt plants in the Surkhandarya region was investigated for its potential use as a mineral additive in clinker-based cement. The chemical composition of the waste materials was analyzed, and the obtained results are presented in Table 1.

The physicochemical characteristics of the investigated wastes were determined through X-ray phase analysis and chemical analysis. Particular attention was given to the oxide composition, as the content of major oxides plays a crucial role in evaluating the suitability of these materials for application in cement systems. The obtained data provide important information regarding the potential of asphalt plant waste as a supplementary mineral component in Portland cement production.

Table 1. Chemical Composition of Asphalt Plant Waste Material

№	Oxide composition	Unit of measurement	Quantity (%)	According to the requirements of gost 5382-2019
1	SiO_2	%	33,29	—
2	Al_2O_3	%	5,31	—
3	Fe_2O_3	%	1,76	—
4	CaO	%	24,80	—
5	MgO	%	0,71	≤ 5 %
6	SO_3	%	1,55	—
7	Na_2O	%	0,90	—
8	K_2O	%	2,24	—
9	K/K	%	29,45	—
10	To‘plam	%	100	—

According to the obtained results, the investigated materials contain significant amounts of oxides essential for cement systems, namely SiO_2, CaO, Al_2O_3, and Fe_2O_3. The interaction between reactive amorphous SiO_2 present in the waste materials and $Ca(OH)_2$ was investigated through comprehensive experimental and microstructural analyses. The results demonstrated that amorphous SiO_2 participates in a pozzolanic reaction with $Ca(OH)_2$, leading to the formation of additional calcium silicate hydrate (C–S–H) phases during secondary hydration. This process contributes to the densification of the cement stone, reduction of porosity, and enhancement of mechanical strength (1). Consequently, the microstructure of the cement matrix becomes denser, resulting in significant improvements in its physical and mechanical properties.

$$xCa(OH)_2 + SiO_2 + (n-x)H_2O \rightarrow xCaO \cdot SiO_2 \cdot nH_2O \qquad (1)$$

Furthermore, the incorporation of asphalt plant waste as an alternative mineral additive into cement compositions enables a reduction in clinker content. This decreases the demand for clinker production, which is the most energy-intensive stage of cement manufacturing, thereby significantly reducing overall thermal energy consumption.

A lower clinker factor not only improves energy efficiency but also contributes to the reduction of CO_2 emissions, representing an important environmental benefit. In addition, the mineral constituents contained in asphalt plant waste act as active fillers or partially reactive additives within the cement system, positively influencing the microstructural development of cement stone.

As a result, the reduction in clinker consumption decreases production costs, promotes the efficient utilization of raw material resources, and enhances the economic competitiveness of cement products. Overall, this approach can be regarded as an effective technological solution that simultaneously provides energy savings, environmental sustainability, and economic benefits.

Conclusion and Practical Recommendations

The proportion of oxides identified in the investigated waste materials was found to be fully compliant with the current regulatory and technical requirements established for mineral additives used in Portland cement production. The conducted research demonstrated that wastes rich in amorphous SiO_2 actively participate in pozzolanic reactions with $Ca(OH)_2$, leading to the formation of additional C–S–H phases during secondary hydration. This process promotes the densification of the cement stone microstructure, reduces porosity, and significantly improves mechanical strength characteristics.

Furthermore, the incorporation of asphalt plant waste into cement systems as a supplementary mineral additive enables a reduction in clinker content. This contributes to lower thermal energy consumption during clinker production, improves energy efficiency, and decreases CO_2 emissions. As a result, the overall economic efficiency of cement manufacturing is enhanced, while the production cost of cement is reduced.

Practical Recommendation: Based on the obtained results, asphalt plant waste can be recommended as an effective supplementary mineral additive in Portland cement production. Its utilization contributes to sustainable waste management, conservation of natural resources, reduction of energy consumption, and improvement of cement performance, making it a promising alternative material for industrial-scale applications.

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