USE OF TECHNOGENIC WASTE FOR REDUCING CLINKER CONSUMPTION AND ITS EFFECT ON CEMENT PROPERTIES

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Abstract: This study found that adding 7 % asphalt plant filter waste to Portland cement results in cement density, specific surface area, setting time, and compressive strength meeting standards, while reducing clinker consumption and improving both environmental and economic efficiency.

Keywords: Portland cement, clinker consumption, technogenic waste, asphalt plant filter dust, physical and mechanical properties, environmental efficiency.

Introduction

Currently, the cement industry is considered one of the most energy-intensive industrial sectors and a major source of environmental impact. In particular, the production of Portland cement clinker at temperatures of 1400–1450 °C requires significant energy consumption and leads to substantial emissions of CO_2 and other harmful gases into the atmosphere. Therefore, reducing clinker consumption and improving the environmental efficiency of cement production have become important scientific and practical challenges.

In recent years, considerable attention has been devoted to the utilization of technogenic mineral additives in cement systems. The recycling of industrial waste not only contributes to reducing environmental pollution but also enables the conservation of natural raw materials and the reduction of production costs. Moreover, mineral additives with pozzolanic or filler properties can improve the microstructure and long-term performance of cement composites.

In this study, technogenic waste generated during coal mining processes was investigated as a mineral additive in Portland cement production. The chemical composition, dispersion characteristics, and influence of the waste on the physical and mechanical properties of cement composites were experimentally evaluated under laboratory conditions. The obtained results demonstrated the possibility of reducing clinker consumption while improving the ecological and economic efficiency of cement production.

Main part

Compressive Strength of Cement: Standard prism-shaped cement specimens with dimensions of 4 × 4 × 16 cm were prepared and tested after 2, 7, and 28 days of curing using a laboratory compression testing machine. The experimental results demonstrated that the incorporation of coal mining waste as a technogenic mineral additive positively influenced the mechanical performance of Portland cement composites.

After 28 days of curing, the cement samples containing coal mining waste achieved a compressive strength of up to 42.7 N/mm², exceeding the standard requirements for SEM II/A-I 32.5N cement. The improvement in strength characteristics can be attributed to the high dispersion and mineral activity of the technogenic additive, which accelerated hydration reactions and promoted the formation of a denser C–S–H gel structure within the cement matrix.

The obtained results indicate that the addition of coal mining waste contributes not only to enhanced early hydration processes but also to improved long-term mechanical stability of the cement composite. The summarized experimental results are presented in Table 1.

Table 1. Compressive strength of conventional cement and cement samples based on asphalt plant waste

No.	Sample	2 days (N/mm²)	7 days (N/mm²)	28 days (N/mm²)
1	Conventional cement	13.9	24.7	33.1
2	Cement sample with asphalt plant filter waste	20.9	32.9	42.7

Determination of Cement Density Using a Micrometric Device: The determination of cement density is an important parameter for quality control and laboratory analysis. During the experiment, the cement sample was measured with high precision using a specialized micrometric device. According to the obtained results, the density of the cement produced with asphalt plant waste was 3.08 g/cm³. The determination of density serves as a key technological parameter for controlling production processes and assessing cement quality.

Blaine Specific Surface Area Analysis: The specific surface area of Portland cement was determined using a Blaine air permeability apparatus. From the cement sample with a density of 3.08 g/cm³, 113.42 g of material was weighed and tested according to the standard procedure (Table 2). The results showed that the cement containing asphalt plant filter waste had a specific surface area of 3334 cm²/g.

These values are consistent with the standard requirements of SEM II/A-I 32.5N Portland cement and confirm that cement produced with technogenic additives possesses sufficient fineness and hydraulic activity, ensuring appropriate technological and performance properties.

Table 2. 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	

Based on these results, the physical properties of the obtained cement sample were compared with those of conventional cement, and the results are summarized in Table 3.

Table 3. Density and specific surface area of conventional cement and cement samples based on asphalt plant waste

No.	Samples	Density (g/cm³)	Specific surface area (cm²/g)
1	Conventional cement	3.09	3232
2	Cement sample prepared from asphalt plant waste	3.08	3334

Normal Consistency and Setting Time of Cement Paste: The normal consistency and setting time of cement paste were determined using the Vicat apparatus. Normal consistency was defined as the condition when the Vicat needle penetrated 5–7 mm into the cement paste within 30 seconds, which allowed determination of the optimal water content for the mix. During the experiments, the water demand ranged from 22% to 28% of the cement mass.

The setting process was monitored using a needle attached to a 300 g plunger at 10–15 minute intervals. The initial setting time was recorded when the needle penetration reached 3–5 mm, while the final setting time was defined as the point when penetration decreased to 0–0.5 mm.

According to the results, in the cement sample containing asphalt plant filter waste, the initial setting occurred at 135 minutes, and the final setting was completed at 200 minutes (with a water content of 128 mL). The obtained results confirm that the setting times comply with standard requirements for Portland cement and demonstrate that technogenic additives do not negatively affect the workability and technological performance of the cement paste.

Table 4. Setting time and water demand of conventional cement and cement samples prepared from asphalt plant waste

No.	Daily samples	Initial setting time (min)	Final setting time (min)	Water demand (ml)
1	Conventional cement	132	180	125 ml
2	Cement sample prepared from asphalt plant waste	135	200	128 ml

Determination of Volume Expansion (Le Chatelier Method): The volumetric stability of Portland cement paste was evaluated using the Le Chatelier ring method. This method allows assessment of the influence of free CaO and MgO content on the volumetric changes of cement paste, which is crucial for reducing the risk of cracking in concrete and other construction materials.

For the experiment, freshly prepared cement paste was placed into a Le Chatelier mold, and glass plates were fixed on both sides of the ring. The expansion of the paste was monitored by measuring the distance between the indicator needles. The test was conducted under two temperature conditions: immersion in water at 20°C for 24 hours and exposure to 100°C for 4 hours.

The obtained results showed that for the cement sample containing asphalt plant waste, the expansion of the Le Chatelier ring was 9 mm at 20°C and 10 mm at 100°C. These values confirm that the cement exhibits satisfactory volume stability and demonstrate that technogenic additives do not adversely affect the dimensional stability of the cement paste.

Table 5. Expansion of cement paste measured by Le Chatelier ring method for conventional cement and cement containing asphalt plant waste

No.	Samples	Initial width of Le Chatelier ring (mm)	After 24 h in water (mm)	After 4 h boiling (mm)

1	Conventional cement	9	10	11
2	Cement sample prepared from asphalt plant waste	8	9	10

Conclusion and Practical Recommendations: The results of the study showed that the incorporation of 7% asphalt plant filter waste into Portland cement significantly improves its physical and mechanical properties. In this case, the density, specific surface area, compressive strength, and flexural strength of the cement comply with standard requirements and in some cases show improvement. The technogenic additive enhances the cement hydration kinetics and promotes the formation of a denser C–S–H gel structure, which ensures long-term mechanical stability.

In addition, the obtained results demonstrate the potential to reduce clinker consumption, thereby decreasing energy and raw material usage during production. As a result, both the environmental impact and the economic efficiency of cement production are improved.

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