CHEMICAL SCIENCES

INFLUENCE OF EXPANDED CLAY WASTE ON CONCRETE PROPERTIES

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Abstract

The chemical composition of expanded clay, its physicochemical properties and granulometric composition were studied. The effect of expanded clay dust additive – waste from expanded clay production (Azerbaijan) on the compressive and flexural strength of concrete was investigated. It was found that the introduction of expanded clay additive in the amount of 2-10% slightly reduces the compressive strength from 46.2 to 44.5 MPa, and the compressive strength from 29.8 to 28.3 MPa passing through a maximum at 4% expanded clay to 30 MPa, respectively. An increase in the expanded clay content above 10% is accompanied by a decrease in the strength of concrete.

Keywords: solid production waste, expanded clay, strength, cement, concrete.

Introduction

Cement production is one of the largest-scale industries both globally and in Azerbaijan. Over the past 20 years, due to the growth in construction of residential and industrial buildings, cement production has increased significantly.

The clinker manufacturing process is energy-intensive and associated with significant emissions of carbon dioxide into the atmosphere, negatively impacting the planet's ecology and contributing to the greenhouse effect. Therefore, research aimed at reducing natural raw material usage by incorporating various additives industrial wastes (such as ash, slag, expanded clay, microsilica, etc.) is promising both economically and ecologically [1-8].

Among industries capable of consuming industrial (technogenic) waste, the construction materials sector is the most significant. Production waste or industrial by-products serve as secondary material resources. Many wastes have compositions and properties similar to natural raw materials. It has been established that using industrial waste can cover up to 40% of construction material needs. Utilizing industrial waste reduces costs for manufacturing construction materials by 10–30% compared to production from natural raw materials, enables the creation of new construction materials with superior technical and economic characteristics, and also decreases environmental pollution [7-9].

In expanded clay production plants, large amounts of dust particles wastes with varying dispersity and chemical composition similar to the main production product are generated as by-products.

In the production of expanded clay gravel, the disposal of expanded clay dust, collected in dust collection systems such as settling chambers, cyclones, and filters, poses a significant challenge. Major expanded clay plants can generate up to 7–8 tons of expanded clay dust daily.

Despite the effectiveness of dust-collecting devices, expanded clay-containing wastes infiltrate all gaps in non-hermetic equipment, polluting the environment. During inspections of one expanded clay plant, four types of expanded clay dust waste were identified, with total daily emissions exceeding one hundred cubic meters. The harmful environmental impact of aluminosilicate wastes, which include expanded clay dust, is associated with the content of aluminum, silicon, iron, and their compounds, and sulfates.

The utilization of ultrafine ceramic brick production wastes as active micro-fillers for concrete is one of the most effective solutions to critical issues in the construction industry. This approach helps obtain high-strength, particularly dense, and durable concretes and reinforced concrete structures, reduces the energy intensity of concrete production, and, when necessary, saves cement.

Despite the variety of cement additives available, their selection is not always justified. Insufficient research has been conducted into the optimal ratios and dispersity of additives relative to cement [5-8].

Currently, there are individual studies on concrete properties using expanded clay dust from various enterprises. However, systematic comprehensive studies on the type, composition, dispersity, and content of expanded clay dust additives on cement and concrete properties and related composite materials have not been performed.

Experimental

The purpose of this study is to investigate the physicochemical properties of cement concrete with expanded clay dust additives collected from cyclones and filters at the AZKERAMZIT plant in Sumgait, Azerbaijan.

Standard methods were employed to study the properties and structure of raw components, including determining hydraulic activity, grinding fineness, setting time of binders, strength indicators, softening coefficients, etc.

Compression tests were conducted on a computerized flexural-compression testing machine, YAW-300D, with maximum flexural and compressive forces of 300 and 10 kN, respectively. Concrete specimens for compression tests were prepared in special molds measuring 40×40×40 mm. After molding and special thermal treatment, samples were conditioned according to standards at room temperature for 24 hours. Compressive strength was calculated using the formula:

$$\sigma = F / A$$

where σ is compressive strength in MPa; A is the cross-sectional area of the sample in mm²; and F is the maximum compressive force in N.

Results and discussion

As a result of the conducted studies, the chemical composition and physicochemical properties of expanded clay dust were determined (Tables 1, 2).

Table 1

Chemical composition of expanded clay dust Content in % on a dry weight basis

SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3
62,2	17,1	8,1	4,0	2,8	2,5	0,7	1,2	0,3	0,1	0,7

Table 2

Physical and mechanical properties of expanded clay dust

№	Indicator name	Numerical value
1	Mass density, kg/m3	750-770
2	Grinding fineness (passing through sieve h/c 0.14%)	65÷70
3	Fireresistance, ˚C	1240-1250

Tables 3 and 4 provide data on the determination of the granulometric composition of the types of expanded clay dust selected for the studies and the hydraulic activity based on lime absorption of expanded clay dust with different grinding fineness.

Table 3

Granulometric composition of expanded clay dust (ECW)

№	Samples	Passing through sieve, %			
		1 mm	0,5 mm	0,2 mm	0,1 mm
1	2	3	5	6	7
1	ECW-1	32	32	29	9
2	ECW-2	9	8	8	67

The feasibility of grinding active mineral additives to 500-600 m²/kg, introduced into slag-alkaline binders, is also discussed in the work [9-11].

Table 4.

Hydraulic activity for CaO absorption of expanded clay dust with different grinding fineness

Expanded clay waste	Grinding fineness, m²/kg	Activity, mg/g
Clay waste	250	330
	500	459
	800	464

Analysis of research results (presented in Table 4) shows that grinding expanded clay dust to a specific surface area of 500 m²/kg increases its hydraulic activity. Further grinding to 800 m²/kg results in only slight increases, likely due to flocculation of finely ground particles.

Analyzing the composition and temperature range of expanded clay dust formation (normal to approximately 800°C) indicates it should be viewed not as a ceramic material but as thermally activated clay.

The results of the study on the dependence of concrete strength in compression and bending with the addition of expanded clay waste from 2% to 10% are shown in fig. 1, 2.

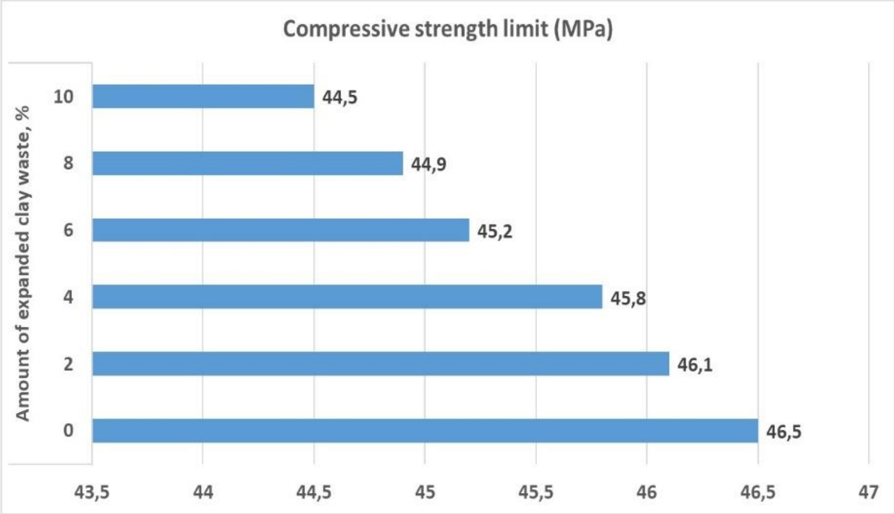

Fig 1. Dependence of concrete compressive strength on the amount of clay filler

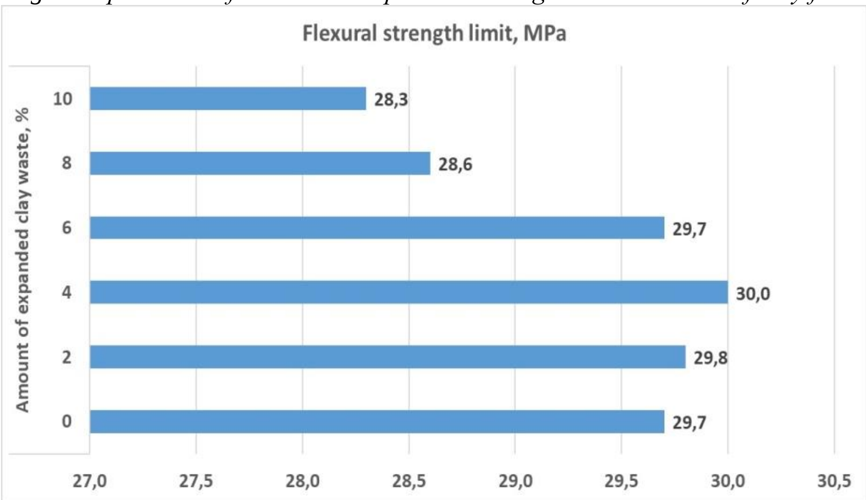

Fig. 2. Dependence of concrete flexural strength on the amount of clay filler

Conclusion

The hydraulic activity of expanded clay powder with different grinding fineness for CaO absorption has been determined. As the grinding fineness value increases, the hydraulic activity increases. Accordingly, when the fineness is 250, 500, 800, the hydraulic activity is 330, 459, 464.

The study of the compressive and bending strength of concrete with the addition of expanded clay dust in an amount of 2 to 10% showed a slight decrease from 46.2 to 44.5 MPa and 29.8 to 28.3 MPa, respectively (fig.1,2)/ Considering the importance of the task of implementing the waste and the environmental factor, such a slight decrease in the strength of concrete does not detract from the relevance of the study and the possibility of using modified concrete.

Environmental and economic importance – The cement production process results in high energy consumption and CO_2 emissions. In addition, the use of industrial waste (ash, slag, ceramic powder, ceramic dust generated in ceramic production, etc.) is efficient. In addition to improving the mechanical and thermal properties of concrete, it reduces the environmental impact of industrial waste.

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