

## Researching of properties of expanded clay concrete on cement-ash binder.

### Investigación de las propiedades del hormigón de arcilla expandida sobre aglutinante cemento- ceniza.

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#### ABSTRACT

Ukraine is a state with a powerful industrial base, the waste of which is ash. The use of ash as a binder for the production of expanded clay concrete solves the problem of its disposal. Studies of expanded clay concrete on carbonates and cement-ash binder were carried out. The research results showed that it is possible to manufacture building structures from this material, including load-bearing ones. Experiments have confirmed the effectiveness of using a cement-ash binder [Vilkov, 1984]. The article provides recommendations on the technology of production of expanded clay concrete mixture and determination of optimal composition. Were made and tested samples of expanded clay concrete on a cement-ash binder with varying degrees of reinforcement with dimensions of 100x150x1200mm. The bearing capacity, crack resistance and deformability of expanded clay concrete were determined by testing on hydraulic press. The compressive strength of the studied expanded clay concrete was tested by loading samples with dimensions of 10x10x10cm and 10x10x40cm. The perspectives of using expanded clay concrete on a cement-ash binder are analyzed.

**Keywords:** expanded clay concrete, industrial waste, binding material, ash, carbonate sand, strength, deflection, deformation, building construction.

## RESUMEN

Ucrania es un estado con una poderosa base industrial, cuyo desperdicio son cenizas. El uso de cenizas como aglutinante para la producción de hormigón de arcilla expandida resuelve el problema de su eliminación. Se realizaron estudios de hormigón de arcilla expandida sobre carbonatos y aglutinante de cemento-cenizas, los resultados de la investigación mostraron que es posible fabricar estructuras de construcción a partir de este material, incluidas las portantes. Los experimentos han confirmado la eficacia de utilizar un aglutinante de cemento y cenizas [Vilkov, 1984]. El artículo proporciona recomendaciones sobre la tecnología de producción de mezcla de hormigón de arcilla expandida y determinación de la composición óptima. Se realizaron y ensayaron muestras de hormigón de arcilla expandida sobre un aglutinante de cemento-ceniza con distintos grados de refuerzo con dimensiones de 100x150x1200mm. La capacidad de carga, la resistencia al agrietamiento y la deformabilidad del hormigón de arcilla expandida se determinaron mediante pruebas en una prensa hidráulica. La resistencia a la compresión del hormigón de arcilla expandida estudiado se probó cargando muestras con dimensiones de 10x10x10cm y 10x10x40cm. Se analizan las perspectivas de utilizar hormigón de arcilla expandida sobre un aglutinante de cenizas de cemento.

**Palabras clave:** hormigón de arcilla expandida, residuos industriales, material aglutinante, cenizas, envío de carbonato, resistencia, deflexión, deformación, construcción de edificios.

## RELEVANCE

For a country in which a large number of industrial enterprises are concentrated, it is important to have an effective technology for the disposal, processing or further use of industrial waste. As a result of the functioning of metallurgical, energy, glass-smelting and other enterprises, the technological process of which includes fuel combustion, a large amount of ash is generated. Ash is a good binding material, so it is advisable to use it in the manufacture of concrete, in particular expanded clay concrete on carbonate sand [Mikhailov et.al,1985; Stroyizdat, 1989]. After reviewing the literature, it was established that a large number of scientific studies and works are devoted to this topic, including at the Odessa State Academy of Civil Engineering and Architecture. The properties of expanded clay concrete on an earth-ash binder were studied in his dissertation work by prof. A. I. Kostyuk [1981]. This type of expanded clay concrete has not been fully studied and is only gaining popularity, which indicates the relevance of the research topic.

## THE MAIN IDEA

To study the properties and characteristics of expanded clay concrete on carbonate sand and ash binder and to create a technological algorithm for its production, studies were carried out. For testing, prototypes of various sizes and configurations were made, depending on the type of test. The selection of rational compositions of expanded clay concrete on carbonate sand and cement binder with the addition of fly ash was carried out. Investigations of the strength and deformative properties of expanded clay concrete and their change over time were carried out under short-term and long-term action of loads. The determination of the critical stress intensity factor (SIF) for assessing the fracture toughness of expanded clay concrete has been carried out. The stress-strain state of bent reinforced concrete elements and structures was investigated under short-term and long-term action

of loads, including prestressed ones [Stroyizdat, 1981; Kostyuk,1992, Sukhanov, 1987].

The selection of the composition of structural expanded clay concrete was reduced to determining the most rational ratio between expanded clay, carbonates and, ash, cement and water. The composition was selected to ensure the workability and compaction of the mixture. For the rational selection of the composition, the method of mathematical planning of the experiment was used. The analysis of the obtained dependencies made it possible to obtain the boundary values for the used variable factors. This made it possible to prescribe compositions for concretes of classes C10/12.5 – C16/20 [Stroyizdat, 1986; Kostyuk,1992].

To test of centrally compressed elements expanded clay concrete on carbonate sand and a cement-ash binder test cubes with dimensions of 10x10x10cm and prism samples with dimensions of 10x10x40cm were made. All samples were tested after heat and humidity treatment at the age of 28, 180 and 360 days. After studying the strength properties, quadratic regression equations were obtained. Their analysis showed that the consumption of the cement-ash binder and the volumetric content of expanded clay gravel in concrete have a significant effect on the cube strength of steamed expanded clay concrete [Buzhevich,1978; Stroyizdat, 1989; Kostyuk,1992].

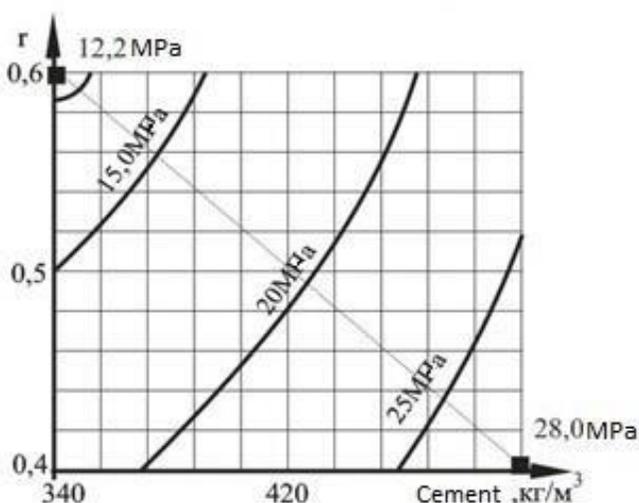


Fig. 1. Influence of composition factors on cube strength where  $r$  – aggregate-Structural factor;  $\rho_3$  – cement-ash binder

The test results showed that the strength of expanded clay concrete on carbonate sand and cement-ash binder increases after heat and moisture treatment. Concrete continues to gain strength after 28 days, and to 360 day its strength is on average 19% higher [Romanov, 1971].

The bearing capacity, crack resistance and deformability of expanded clay concrete were determined by testing of experimental beams with dimensions of 100x150x1200mm. The destruction process of the experimental bending elements depended on the nature of the reinforcement. It was found that with an increase in the percentage of reinforcement, the height and cross-sectional area of the compressed zone of concrete increases, which leads to an increase in the breaking moment of expanded clay concrete beams. The results were obtained by measuring the strains of tensile reinforcement and concrete in the compressed zone, deflections of beams and crack widths [Kostyuk, 1992].

Most often, building structures are affected by a long-term load, it is especially important to study the work of bending elements under

the influence of this type of load. For testing bending elements made of expanded clay concrete on carbonate sand and a cement-ash binder, prototypes were made - two types of beams, which differed in the percentage of reinforcement and the level of long-term loading. Their dimensions were 100x150x2200 mm and were reinforced with A400C reinforcement. The strength of the beams was  $R(28) = 18.1$  MPa and the percentage of reinforcement  $\mu = 1.21\%$  and  $\mu = 1.74\%$ , they were loaded with a continuous load equal from 0.5 and 0.7 of the breaking load, respectively. To compare the results, a beam (type III) with strength  $R(28) = 23.1$  MPa with a percentage of reinforcement  $\mu = 1.21\%$  was added, it was loaded with a continuous load equal to 0.5 of the breaking load [Kostyuk, 1992].

Tests of bending elements for the effect of a long-acting load have shown that with an increase in the load, the relative compressed zone of concrete increases. This is caused by creep deformations of compressed concrete and, to a lesser extent, by deformations of tensile reinforcement. The growth rate over time depends on the amount of longitudinal reinforcement.

The deflections of the beams developed intensively in the first 120-150 days and were completely stabilized by the 300th day. The average bearing capacity, determined from the results of tests of 3 beams under short-term loading at the age of 28 days, for beam series was:

I series - 7312 Nm ( $C_v = 0.065$ );

II series - 9710 Nm ( $C_v = 0.06$ );

III series - 7632 Nm ( $C_v = 0.05$ ).

The test results of expanded clay concrete beams on carbonate sand and a cement-ash binder are shown in Table 1 [Kostyuk, 1992].

Table 1. Results of initial deflections and deformations of test beams

Series	Beam type	Continuous load level	$A_s$ , mm <sup>2</sup>	$\varepsilon_{s,m}^o(t) \cdot 10^5$	$\varepsilon_{b,m}^o(t) \cdot 10^5$	$f_0$ mm
I	BD-I -1	0,5	1,57	78	122	6,7
	BD-I -2	0,7	2,26	102	157	9,2
II	BD-II -1	0,5	1,57	93	134	7,1
	BD-II -2	0,7	2,26	126	182	11,2
III	BD-III-1	0,5	1,57	108	160	7,5

Where  $A_s$  – cross-sectional area of reinforcement;

$\varepsilon_{s,m}^o$  = average strains of tensile reinforcement;

$\varepsilon_{b,m}^o$  average deformations of concrete in the compressed zone;  $f_0$  – deflections of beams.

## CONCLUSIONS AND RESULTS

As a result of testing prototypes of expanded clay concrete on carbonate sand and a cement-ash binder, a method for selecting the optimal composition was determined. The bearing capacity, crack resistance and deformability of the prototypes were determined. The tests of the centrally compressed elements and beams for the influence of the long-acting load have been carried out. Tests have shown good characteristics, properties and strength characteristics of beams made of this material, in comparison with structures made of other types of lightweight concrete. The results obtained during the experiment show the effectiveness of using a cement-ash binder for the manufacture of building structures, including load-bearing ones. The expediency of using this type of binder confirms the need for rational processing and further use of industrial waste, which is ash. The experiment can be

considered successful, since the assigned tasks have been completed.

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