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Lightweight concrete based on siliceous compositions of natural origin

Легкий бетон на основе кремнистых композиций природного происхождения

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Abstract. The focus in the release of construction materials is determined by waste recycling, saving energy costs and environmental management by means of reducing dump areas. The production of magnesia binders from dolomite waste meets all these requirements. There was made an effort to create a new material based on magnesia binder and lightweight silicate aggregate made from tripolith of Vladimir region deposit. In the course of the work, samples were synthesized and tested for strength and thermal conductivity, and also an optimal granulometric composition of the aggregate was defined. This research shows that the material is strong, cheap, alkali-silicate corrosion resisting and very promising in compare with classic Portland cement concretes.

Аннотация. Приоритет в выпуске строительных материалов определяется использованием отходов промышленности, снижением энергоемкости и решением экологических проблем за счет сокращения площадей занятых отвалами. Всем этим требованиям отвечает производство магнезиальных вяжущих из отходов доломитового производства. Была предпринята попытка создать новый материал на основе магнезиального вяжущего и легкого силикатного заполнителя, изготовленном из трепела Владимирского месторождения. В ходе работы были синтезированы образцы, которые были испытаны на прочность и теплопроводность, а также подобран оптимальный гранулометрический состав заполнителя. Исследование показывает, что материал является прочным, дешевым, стойким к щелочно-силикатной коррозии и очень перспективным по сравнению с классическими бетонами на основе портландцемента.

1. Introduction

Nowadays, the problem of high cost of housing is quite relevant for people of almost all countries in the world. At the same time, there are a lot of dolomite waste dumps in many countries including Russia. That is why magnesia concrete made from dolomite production waste was chosen as an object of this research. The works of P.P. Budnikov, M.I. Kuzmenkov, TN. Chernykh[1], A.E. Ivanov and many others[2, 3] are devoted to the issues of magnesia binders. The purpose of this work is to try to create cheap high-quality construction material from dolomite waste and reduce volumes of dolomite waste dumps.

The production of magnesia cements does not hold a prominent place in the national construction sector, which is completely unjustified by any arguments, because magnesia cements have exceptional distinct properties in strength, abrasion, and bactericidal power. Besides, their production history and applications are centuries old.

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Unlike magnesia concretes, cement ones as well as Portland cement mortars are known to have a delayed hardening, nonhomogeneous composition and conglomerate structure. Therefore, traditional concretes do not meet modern standards for abrasion and crack resistance. Being formed in the process of hydration, crystalline and colloidal newgrowths dry up and thicken over time, which is followed by the cement shrinkage[4–6].

Calcium hydroxide belongs to one of the silicate mineral products (alite and belite) which interact with water. It means that as a result of hardening, an alkaline medium always appears in a cement stone. This phenomenon also has its pros and cons. As it is known, there is no iron corrosion in an alkaline medium. Therefore, concretes based on Portland cement (and its varieties) protect steel reinforcement from corrosion. This is one of the key factors for high durability of reinforced concrete.

When using magnesia binders in mortars, there forms a dense, non-porous material, having high abrasion, petrol, oil and water resistance[1, 7, 8].

Unlike other binders, magnesia binders have a very high adhesion not only to mineral, but also to organic substances. Due to a high density of the material, low alkalinity and the presence of bischofite in the magnesia cement composition, the organic fillers do not rot in them. This fact makes it possible to make a hypothesis concerning bactericidal power and mold and fungus resistance of materials based on magnesia binders.

The use of magnesium salts as grouting fluid changes the hardening mechanism [9]. High concentration of magnesium salts promotes the formation of complex salts of various composition: MgCl2 · 5MgO · 17H2O (Sorel, 1867), MgCl2 · 5MgO · 8H2O (Bender, 1871), MgCl2 · 3MgO · 10H2O (Robinsson and Wagman, 1909), MgCl2 · 3MgO · 7H2O (Larman, 1911). Due to the formation of such compounds, magnesium hydroxide is removed from the solution, and new portions of magnesium oxide undergo a hydration reaction [10].

Table 1 presents the comparative analysis of Portland- and magnesia cements.

Table 1. Comparative analysis of Portland- and magnesia cements

Characteristics	**Type of cement**	
	Magnesia cement	Portland cement
Total composition	$3MgO{\cdot}MgCl_2{\cdot}11H_2O$	$12CaO{\cdot}6SiO_2{\cdot}7H_2O$
Structural formula	$[Mg_4^{2+}(OH)_6^-(H_2O)_6]^{2+}Cl_2^-{\cdot}2H_2O$	$Ca[Si_6O_{17}](OH)_{14}$ (hillebrandite)
Crystal structure	Roughly anisodesmic, formed by doubled chains of octahedra Mg (OH, H2O) 6, connected by chlorine ions and water molecules	Quasi-coordinated, poorly anisodesmic, band, represented by alternation of xonotlitic and portlandite elements: $Ca[Si_6O_{17}](OH)_2{\cdot}6Ca(OH)_2$
Macrostructure	Felted structure	Massive structure
Density ρ, g / m^3	1.86	2.69
Fragility HV (GPa)/ K_{1c}	0.5	3.8
Thermal conductivity λ, W / (m · K)	0.5–1.6	1.3–1.8
Compressive strength, σ_p, MPa	50–120	3.5–80

Unlike Portland cement, magnesia cement does not create an alkaline medium i.e. the solubility of magnesium hydroxide is insignificant, and its basic properties are not strong. So magnesia concrete eliminates alkali-silicate reaction in concrete, which can destroy the body of the concrete and promotes the formation of cracks, especially with a large-sized aggregate [11,12,13,14,15,16]. Organic aggregates are not destroyed in a neutral medium. In addition, magnesia cement prevents the development of microorganisms that can destroy the aggregate. The application of magnesium chloride solutions, which are considered to be good fire-resistant impregnations, makes these materials fire-proof[10].

The advantages of magnesian concretes are:

- Higher adhesion to different substrates (up to 3 MPa);