STRUCTURE AND STRENGTH OF MAGNESIA CEMENT FROM DOLOMITE

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СТРУКТУРА И ПРОЧНОСТЬ МАГНЕЗИТОВОГО ЦЕМЕНТА ИЗ ДОЛОМИТА

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DOLOMITDAN OLINGAN MAGNEZIYLI SEMENTNING TUZILISHI VA MUSTAHKAMLIGI

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Tayanch so'zlar: magniyali portlandtsement, dolomit, gidratatsiya, M-S-H fazalar, siqilish mustahkamligi, g'ovaklik.

Rezyume. Maqola Qoraqalpog'iston dolomitiga asoslangan magniyali portlandtsement (MPC)ni tadqiq etishga bag'ishlangan. Xomashyoning kimyoviy tarkibi tahlil qilindi, sement toshining mikrostrukturasi va gidratatsiya dinamikasi o'rganildi. Namunalarining siqilish mustahkamligi va g'ovakligi bo'yicha ma'lumotlar keltirilgan, agressiv muhitlarda magniyali portlandtsement qo'llashning afzalliklari hamda texnologiyani mintaqaviy darajada joriy etish istiqbollari muhokama qilinadi.

Ключевые слова: магнезиальный портландцемент, доломит, гидратация, M-S-H фазы, прочность на сжатие, пористость.

Резюме. Статья посвящена исследованию магнезиального портландцемента (МПЦ), изготовленного на основе доломита Каракалпакстана. Проведен анализ химического состава сырья, изучена микроструктура цементного камня и динамика гидратации. Приведены данные о прочности на сжатие и пористости образцов, обсуждены преимущества применения магнезиального портландцемента в агрессивных средах и перспективы внедрения технологии на региональном уровне.

Key words: magnesium Portland cement, dolomite, hydration, M-S-H phases, compressive strength, porosity.

Summary. The article is assigued to the study of magnesium Portland cement (MPC) produced from dolomite of Karakalpakstan. The chemical composition of the raw material was analyzed, while the microstructure of the cement stone and hydration dynamics were examined. Data on compressive strength and porosity of the samples are provided; the advantages of using MPC in aggressive environments and prospects for implementing this technology at the regional level are discussed.

Introduction. Magnesium Portland cement is a type of cement in which part of the calcium is replaced by magnesium. Such modification increases chemical resistance, accelerates strength development, and improves the durability of structures. Karakalpakstan possesses abundant deposits of high-quality dolomite, which makes the region promising for local production of magnesium Portland cement.

Magnesite has traditionally been used for obtaining magnesia binders, and therefore, for a long time the literature held the view that other magnesium-containing raw materials, including dolomite, due to their low magnesium oxide content, could not provide high-grade magnesia cement. It was claimed that while caustic magnesite yields compressive strengths of 60-80 MPa, caustic dolomite yields only 10-30 MPa.

Recent studies indicate that, contrary to earlier beliefs, binders comparable in their physical and mechanical properties to those based on caustic magnesite can indeed be produced from dolomite [1-5].

Literature data concerning dolomites from different deposits vary significantly in their conclusions. These differences concern both the mechanism of thermal dissociation and the process of phase formation during the mixing of caustic dolomite with magnesium salt solutions. The diversity of views on the thermal dissociation of dolomite and the composition of the hydration products of magnesium cement is primarily due to the fact that researchers worked with dolomites from different deposits containing varying impurities, which are known to influence decomposition processes. According to modern understanding, three stable solid phases may form in magnesium cement in various proportions: magnesium hydroxide, magnesium oxychloride ($5MgO \cdot MgCl_2 \cdot 13H_2O$), and magnesium oxychloride ($3MgO \cdot MgCl_2 \cdot 8H_2O$).

Magnesium cements have been actively studied in recent years. According to Holt (2018) and Liu et al. (2020), the use of MgO increases cement resistance to sulfates and chlorides. Mechanical and chemical activation of dolomite promotes the formation of magnesium–silicate hydrate (M-S-H), which is analogous to the C-S-H phases of ordinary Portland cement but has a denser structure and lower porosity [1, 2].

Magnesium Portland cement (MPC) is a modified type of cement in which part of calcium is replaced by magnesium. This substitution provides improved operational properties, including faster strength development, enhanced chemical resistance, and long-term durability. The use of magnesite or dolomite as magnesium sources enables the formation of M-S-H hydrates, which create a dense and durable cement stone microstructure.

The Karakalpakstan region has significant reserves of high-quality dolomite, offering prospects for local production of magnesium cement and reducing dependence on imported raw materials. In particular, the Jamansai deposit is characterized by high CaO and MgO contents, making it a potentially valuable resource for MPC production [6].

The aim of this work is to study the chemical composition of dolomites from the Jamansai deposit (Karakalpakstan), to investigate the microstructure of the cement stone and hydration dynamics, and to determine the features of the hardening process of magnesium Portland cement produced from this material.

Materials and methods. A sample of dolomite from the Jamansai deposit (Karakalpakstan) was selected for study. The chemical composition of the raw material is presented in Table 1. The contents of main oxides are, wt.%: CaO-31%, MgO-21%, SiO_2-4%, Fe_2O_3-<1%, Al_2O_3-<1%, loss on ignition – 46,5%.

Quartz sand and gypsum (as a setting regulator) were used as additives. These additives allow adjustment of clinker structure and hydration processes, ensuring optimal physical and mechanical properties of magnesium cement.

Table 1. Chemical composition of dolomite from the Jamansai deposit

Component	Content, wt.%
CaO	31
MgO	21
SiO_2	4
Fe_2O_3	<1
Al_2O_3	<1
LOI	46,5

Chemical analysis was performed to determine the oxide composition of the dolomite. The microstructure of the cement stone was studied using scanning electron microscopy (SEM), allowing for assessment of the form and distribution of hydration phases, density, and porosity. Hydrate phase identification – including M-S-H formation – was carried out by X-ray diffraction (XRD). Compressive strength testing was performed on 4×4×16 mm samples at 1, 3, 7, and 28 days. Measurements were conducted using a universal testing machine with ±1 MPa accuracy.

✓ The cement production process included the following stages:

✓ Crushing and grinding dolomite to particle sizes below 100 μm.

✓ Calcination at 950°C to achieve decarbonization and produce CaO and MgO.

✓ Mixing with quartz sand and gypsum to form clinker and regulate setting.

✓ Fine grinding of clinker to the required fineness.

✓ Hydration under standard conditions (20°C, 95% relative humidity) to study hardening dynamics.

Results. Analysis showed that the dolomite from the Jamansai deposit contains significant amounts of CaO (31%) and MgO (21%). The contents of silica, alumina, and iron oxides were relatively low (<5%), confirming the suitability of this raw material for MPC production. The loss on ignition was 46,5%, corresponding to a high carbonate content.

Microscopic examination revealed a dense and homogeneous structure with small pores. The images showed crystalline hydration phases uniformly distributed throughout the material. This structure contributes to increased strength and durability.

XRD analysis identified the formation of magnesium–silicate hydrates (M-S-H), along with small amounts of magnesium hydroxide and calcium hydroxide. Formation of M-S-H phases was observed early in hydration and continued to develop with age, creating a dense crystalline network responsible for strength development.

XRD revealed the following phases (relative intensity):

M-S-H – high

$Mg(OH)_2$ – medium

$Ca(OH)_2$ – low

The diffractogram shows broad amorphous or semi-crystalline peaks at 2θ≈12-25°, characteristic of hydrated magnesium–silicate phases, indicating gradual formation of a strong gel structure. A peak at 2θ≈18° corresponds to crystalline $Mg(OH)_2$ (brucite), formed during magnesium hydration. A peak at 2θ≈30° corresponds to $Ca(OH)_2$, indicating hydration of calcium-bearing phases.

Thus, the main hydration product is M-S-H gel, forming a dense cement stone structure. The presence of $Mg(OH)_2$ and $Ca(OH)_2$ reflects accompanying crystallization processes. The amorphous nature of

M-S-H is typical for magnesium cements and confirms the gradual development of a strong matrix.

Strength development showed:

20 MPa after 1 day,

50 MPa after 3 days,

80 MPa after 7 days,

~100 MPa after 28 days.

These results indicate rapid hydration and formation of a dense structure.

Table 2. Physical and mechanical properties of magnesium Portlandcement

Age, days	Density, g/cm³	Normal consistency, g/cm³	Setting time (start-end), min	Compressive strength, MPa
1	2,10	1,45	35-60	20
3	2,15	1,48	35-60	50
7	2,18	1,50	35-60	80
28	2,20	1,52	35-60	100

Discussion. The experimental results showed that the rapid strength development of MPC is due to the high reactivity of MgO and the formation of a dense M-S-H matrix. This structure ensures minimal porosity, which in turn increases resistance to aggressive chemical environments.

Using dolomite from the Jamansai deposit reduces cement production costs through reliance on local raw materials and decreased dependence on imports. The results indicate that MPC produced from this dolomite can be effectively used in hydraulic structures, marine facilities, and industrial constructions where high strength and chemical resistance are required.

Thus, the combination of active MgO, formation of an M-S-H matrix, and low porosity makes this cement promising for industrial applications, while the use of local raw materials offers economic benefits.

Conclusions. Magnesium Portland cement based on dolomite from the Jamansai deposit (Karakalpakstan) exhibits high strength and a dense microstructure.

The formation of M-S-H phases ensures durability and high resistance to aggressive chemical environments.

Use of local raw materials increases the economic efficiency of cement production and reduces dependence on imported components.

Further studies are recommended on optimal calcination regimes and mechanochemical activation to improve MgO reactivity and enhance cement performance.

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