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# Features of Obtaining Magnesial Binders from Various Raw Materials

L.B. Kabulova
Nukus State Pedagogical Institute named after Ajiniyaz, Uzbekistan

A. Sadikova
Karakalpak State University named after Berdakh, Uzbekistan

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**Abstract:** Background. Magnesium is used as a binding material to create magnesium-containing magnesium alloys. Purpose. The thermal decomposition of magnesian rocks resulting from the thermal decomposition of magnesian rocks leads to the occurrence of thermal processes, as a result of which magnesian rocks lose their energy and turn into magnesian rocks.
Methodology. Assessment and geological study of the suitability of magnesium-containing rocks for obtaining high-quality magnesium binders for construction purposes.
Scientific novelty. Principles of rational use of Uzbekistan's magnesium raw materials for the production of magnesium binders and construction materials based on them.
The obtained data. Obtaining a magnesium binder based on highly active dolomites, brusites, and magnesites allows for significant economic and environmental benefits.

**Keywords:** Magnesian binders, magnesite, brucite, dolomite.

**Features:**

- use of widespread magnesium raw materials;
- expand the raw material base for the production of binding agents.

**Introduction:**

In world practice, magnesian rocks and their processed products are used in various industries: metallurgical, construction, refractory, glass, ceramic, chemical, as well as in agriculture. Magnesium raw materials include minerals and rocks (magnesites, dolomites, dunites, serpentinites, magnesian skarns, brucite marbles, talcites, potassium-magnesium salts) that are sources of industrial magnesium compounds.

The mineral resource potential of Western Uzbekistan in relation to magnesian raw materials is primarily represented by magmatic formations of basic and ultrabasic composition, among which magnesites, dolomites, serpentinites are the most widely distributed in the area. [1].

Due to modern trends in construction production, which involve the rational use of energy and non-renewable natural resources, there is a growing interest among scientists and manufacturers in mineral binders based on magnesian rocks. All magnesium binders are obtained by thermal treatment of magnesium raw materials. When studying rocks intended for use as active mineral additives to building materials, it is necessary to determine their hydraulic activity.

Magnesian binders are finely dispersed powders, the main active component of which is free magnesium oxide. Magnesium binders have enormous potential, as products based on them have the ability to quickly gain high strength without heat treatment, high technological efficiency, resistance to petroleum products, fungi, bacteria, low wear resistance, and lack of sparking.

Magnesian binders are obtained from magnesium-containing rocks (magnesite, dolomite, brusite, etc.) by firing at appropriate temperatures.

The production of binders from high-magnesium raw materials - magnesites of various origins and brusites - is quite successfully developing in all countries. Moreover, active work is underway to introduce energy-saving technologies into production. The issue of obtaining a magnesium binder from high-magnesium rocks is the most studied, they are mainly obtained by moderate firing of natural crystalline magnesites, brusites, and dolomites at temperatures of 800...1000°C. [3].

## METHODS

Assessment and geological study of the suitability of magnesium-containing rocks for obtaining high-quality magnesium binders for construction purposes.

## RESULTS AND DISCUSSION

Magnesite is a mineral from the carbonate class, the calcite group, representing magnesium carbonate ($MgCO_3$) with theoretical composition MgO-47.62% and $CO_2$-52.38%, with isomorphic impurities - often Fe, less often Mn, Ca. Depending on the impurities, the color of the rock changes from white to black. The hardness on the Mohs scale is 3.5...4.5, and the density is 3g/cm3. During the firing of magnesite, thermal dissociation of magnesium carbonate occurs according to the scheme: $MgCO_3 = MgO + CO_2$

Magnesian rocks are composed of large or fine-crystalline magnesite with impurities of dolomite, calcite, quartz, pyrite, iron hydroxides, talc. The total amount of reserves of the A+B+C1 category (explored deposits) is 800 million tons, the C2 category (unexplored, identified outside the explored areas of deposits based on the interpretation of their geological structure by analogy with similar, thoroughly explored deposits) is 1776 million tons, and the off-balance reserves of magnesite are 228 million tons. [4].

In Uzbekistan, one of the raw materials for obtaining magnesium or magnesium chloride compounds can be the talc stone of the Zinelbuloq deposit located in the Sultanuvays district of the Republic of Karakalpakstan. It is considered the only talc stone deposit in Central Asia, with reserves estimated at approximately 450 million tons, according to geologists [4]. Therefore, the interest in studying this mineral and obtaining magnesium chloride is very relevant. Magnesium oxide is a key component in the production of refractory materials. The mineral composition of Zinelbuloq talcomagnesites is promising for their use as a priority raw material for the production of magnesium-containing products. The main minerals are talc and magnesite with a high content of magnesium (up to 31.7% by mass) and iron. These minerals have favorable morphological and strength characteristics, do not contain toxic substances, and are ideal raw materials for multi-industry use. The results of research on the firing of talcomagnesite at temperatures of 500-700°C, hydrochloric acid leaching to obtain magnesium chloride and chlorate from Zinelbuloq ore are presented.

A unique magnesian raw material is brucite. Brusite is a mineral from the hydroxyl group, with a chemical composition ($Mg(OH)_2$) and a theoretical content of MgO-69.1%, $H_2O$-30.9%. Magnesium can partially replace $Fe^{2+}$ or $Mn^{2+}$ (ferro- and manganobrusites). The color of brucite is white, gray, greenish, yellowish, or brownish, depending on the impurities. Moos hardness is 2.5, density is 2.4 g/cm3. During the heat treatment of the mineral brucite, its dehydration process occurs according to the following scheme: $Mg(OH)_2 = MgO + H_2O$

Due to the high content of MgO and the absence of $CO_2$ in its composition, the technological processing of brucite is more environmentally friendly than that of magnesite, however, industrial-scale brucite deposits are very rare. Brusites are a widespread mineral. In Uzbekistan, only one medium-sized Kumyshkan deposit with 4 million tons of category reserves and 6 million tons of off-balance reserves is accounted for by the state reserve balance. The brusites of the Kumushkan deposit in the Tashkent region have a bright white color and are of high quality. The rock also contains impurities such as dolomite, calcite, magnesite, quartzite, serpentines, hydromagnesite, and others, which can drastically reduce the quality of the raw material. [2, 4].

The main share of magnesites and brusites is in demand and is practically fully used in more profitable industries for the production of refractories, metallic magnesium, plastics, paper, in the chemical industry, etc. Moreover, the uneven distribution of magnesite and brusite deposits in Uzbekistan necessitates the transportation of raw materials or binder over long distances, which is associated with a significant increase in the cost of both the binder itself and the materials based on it.

Throughout the 20th century, researchers periodically addressed the issue of obtaining a binder from dolomites - the most common magnesium raw material in Russia, Europe, and Asia. But all attempts were mainly limited to laboratory tests. Recently, due to the introduction of energy- and resource-saving technologies in all industries, there has been an increased interest in studying the possibility of obtaining a magnesium binder from dolomites by industry, both in our country and abroad. [4].

Dolomite, a mineral from the carbonate group, is a double carbonate of calcium and magnesium $CaMg(CO_3)_2$. In its crystal lattice, $Ca^{2+}$ and $Mg^{2+}$ ions alternate along the triple axis. Dolomite is grayish-white, sometimes with a yellowish, brownish, or greenish tinge. Moos scale hardness is 3.5...4, density is 2.8...2.9 g/cm3. [2, 4].

The dolomites of Western Uzbekistan are confined to Paleozoic and Mesocainozoic deposits. The mineral resource base of dolomites is represented by numerous deposits and occurrences in the Central Kyzylkum, Malguzar, and Nurota Mountains.

The main consumer of dolomite is metallurgy, which uses dolomite refractories in large quantities. The quality of the consumed raw materials is determined primarily by the content of magnesium, silicon, aluminum, and iron oxides. The corresponding quality requirements of the refractory industry are of particular industrial interest, as they can be obtained by firing periclase as the main component of magnesian refractory products, which has the highest refractory properties within 2000°C.

The leading role of dolomite application is substantiated by the presence of a significant number of deposits and manifestations of this type of mineral in the republic. About forty dozen promising dolomite resources are known (within 10 of them accounting for the region under consideration), containing more than 20% magnesium oxide. By comparing the chemical compositions of the studied dolomites with such developed deposits in Russia (Shelkovskoye, Bilimbayevskoye, Nikitovskoye) [4, 5], it was established that the dolomites of Western Uzbekistan meet the first grade of quality in the raw materials used. Chemical composition of dolomites, in %): $SiO_2$-0.22; $Fe_2O_3$ - 0.62; MnO-0.11; $Al_2O_3$ - 0.67; CaO - 29.63; MgO - 21.8; $P_2O_5$-0.05; $SO_3$-0.01, which indicates a high magnesium content suitable for the production of magnesian energy-efficient building materials.

**Method of obtaining magnesian binders**

Obtaining a magnesium binder was carried out by hydration and roasting of the initial raw materials. The process included the following stages:

1. Raw material firing: The temperature range of 600-1200°C was investigated with a holding time of 1.5-2 hours.

2. Hydration of the fired material: The fired raw material was mixed with water in a liquid/solid ratio of 0.3 to 0.6.

3. Adding modifying additives: Chloride and sulfate salts were used in an amount of 5-10% of the binder's mass to regulate setting times and strength characteristics.

4. Molding and hardening of the samples: The prepared paste was poured into 40×40×40 mm molds and kept at a temperature of 20°C and a humidity of 95% for 24 hours.

**Initial materials and their preparation**

Various types of raw materials, including natural magnesium minerals (bischofite, caustic magnesite) and technogenic waste containing magnesium, were used for the research. The initial materials were pre-dried at a temperature of 105-110°C to a constant mass, after which they were ground to a fraction of less than 0.1 mm.

These data can be useful in selecting the appropriate composition of the magnesium binder based on the required properties (strength, heat resistance, setting time, etc.).

**Table 1**

**Here is an expanded table with external parameters, porosity**

| № experiments | Bischofit (%) | Caustic magnesite (%) | Technogenic waste (%) | Density (g/cm3) | Compressive strength (MPa) | Shrinkage time (min) | Porosity (%) | Thermal stability (°C) |
|---|---|---|---|---|---|---|---|---|
| MB 1 | 50 | 30 | 20 | 1. | 25 | 40 | 18 | 850 |
| MB 2 | 4 | 4 | 20 | 1.90 | 28 | 3 | 16 | 900 |

| № experiments | Bischofit (%) | Caustic magnesite (%) | Technogenic waste (%) | Density (g/cm3) | Compressive strength (MPa) | Shrinkage time (min) | Porosity (%) | Thermal stability (°C) |
|---|---|---|---|---|---|---|---|---|
| MB 3 | 30 | 50 | 20 | 1.95 | 30 | 30 | 15 | 950 |
| MB 4 | 60 | 20 | 20 | 1.80 | 2 | 45 | 20 | 800 |

**MV** 1 has a high bisophyte content, but low density and compressive strength. Optimal component ratio. Average porosity (18%) and good heat resistance (850°C). High strength (25 MPa). A device for general-purpose construction materials. MV 2 is characterized by a low content of bisophyte and caustic magnesite, but high density and rapid setting time. There may be an error in the data (bischofite and magnesite by 4% or 40%?). High strength (28 MPa), but too fast setting (3 minutes) causes discomfort in operation. Good heat resistance (900°C). MV 3 demonstrates optimal component balance, high strength, and heat resistance. Maximum heat resistance (950°C), strength (30 MPa), and high porosity (15%). A device for refractory materials and high-temperature applications. MV 4 has a high bisophyte content, but low compressive strength and heat resistance. High bischofite content (60%) led to a decrease in strength (2 MPa). High porosity (20%) reduces mechanical resistance. Can be used as a thermal insulation material.

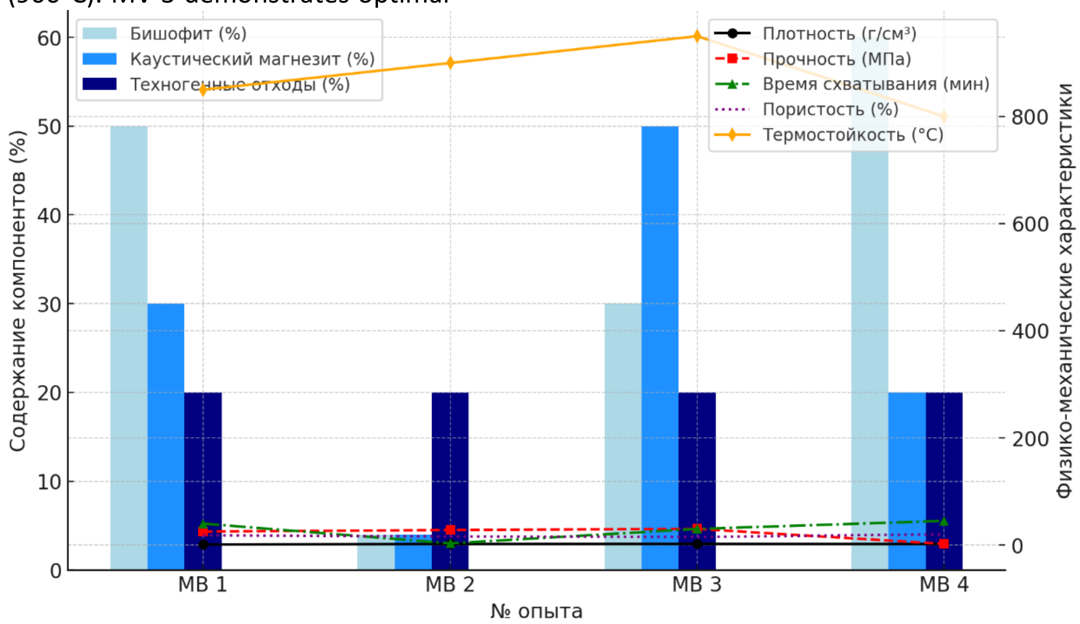


**Fig.1. Analysis of experimental compositions**

These data can be useful in selecting the appropriate composition of the magnesium binder based on the required properties (strength, heat resistance, setting time, etc.).

## Research methods

To assess the properties of the obtained magnesium binder, the following methods were used:

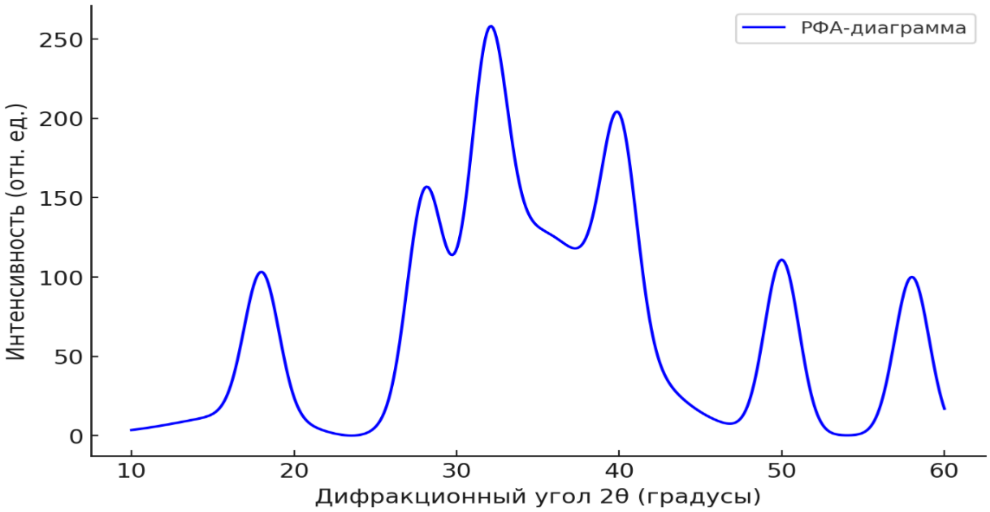


**Fig.2. X-ray phase analysis (XPA) - for determining the phase composition.**

18° (2θ) - Hydrated phases of magnesium (Mg (OH) 2, brushite)

28° (2θ) - MgCO3 (magnesite)

32° (2θ) - MgO (periclase)

40° (2θ) - MgCl2·6H2O (bisophyte)

50° (2θ) - MgSO4·H2O (epsomite)

58° (2θ) - MgO residual phases

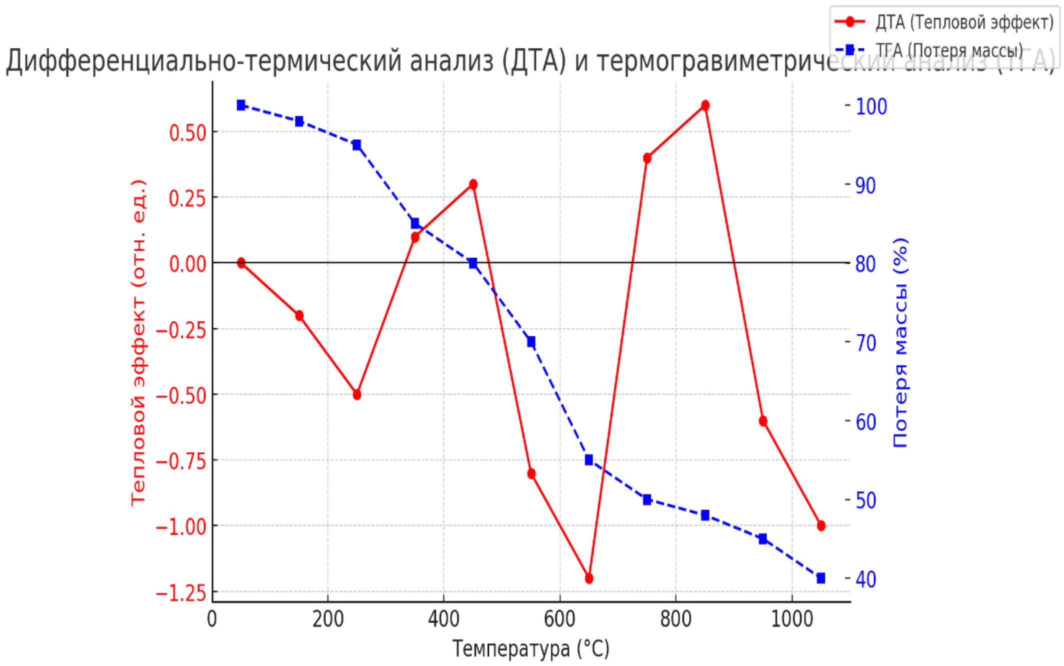


**Fig.3. Differential Thermal Analysis (DTA) - for the study of heat resistance.**

100-200°C - Loss of adsorbed water.

300-400°C - Decomposition of hydrated phases (Mg (OH) 2 → MgO + H2O).

600-800°C - Decarbonization of magnesite (MgCO3 → MgO + CO2).

900-1100°C - Crystallization of periclase MgO.

**Thermogravimetric analysis (TGA) - to study the mass loss of samples depending on temperature.**

100-200°C - Loss of adsorbed water (~2%).

300-400°C - Decomposition of hydroxides (~5%).

600-800°C - Decarbonization of MgCO3 (~15%).

900-1100°C - Completion of volatile component removal (~20%).

Strength tests - measuring compressive strength after 3, 7, and 28 days of hardening.

Determination of water resistance - testing of samples for stability in water at a temperature of 20°C for 28 days.

The research results were processed using statistical methods using software, analyzing the average values and standard deviations of the strength, water resistance, and phase composition parameters.

**Table 2**

**Minimal strength, water resistance**

| Structure | 3-day strength (MPa) | 7 day strength (MPa) | Strength of 28 days (MPa) | Water resistance (%) |
|---|---|---|---|---|
| MB 1 | 12.5 | 18.7 | 25.3 | 92.1 |
| MB 2 | 10.8 | 16.5 | 22.9 | 89.4 |
| MB 3 | 14.2 | 20.1 | 27.5 | 95.2 |
| MB 4 | 11.3 | 17.4 | 24.0 | 91.0 |

Data analysis:

1. Strength:

o The composition MV 3 exhibits the highest strength at all stages (3, 7 and 28 days).

The composition MV 2 has the lowest strength.

o All compositions show an increase in strength over time, which is characteristic of binding materials.

2. Water resistance:

o The highest water resistance is observed in composition MV 3 (95.2%).

o The lowest water resistance is observed in composition MV 2 (89.4%).

o All compositions have water resistance above 89%, indicating their suitability for use in high humidity conditions.

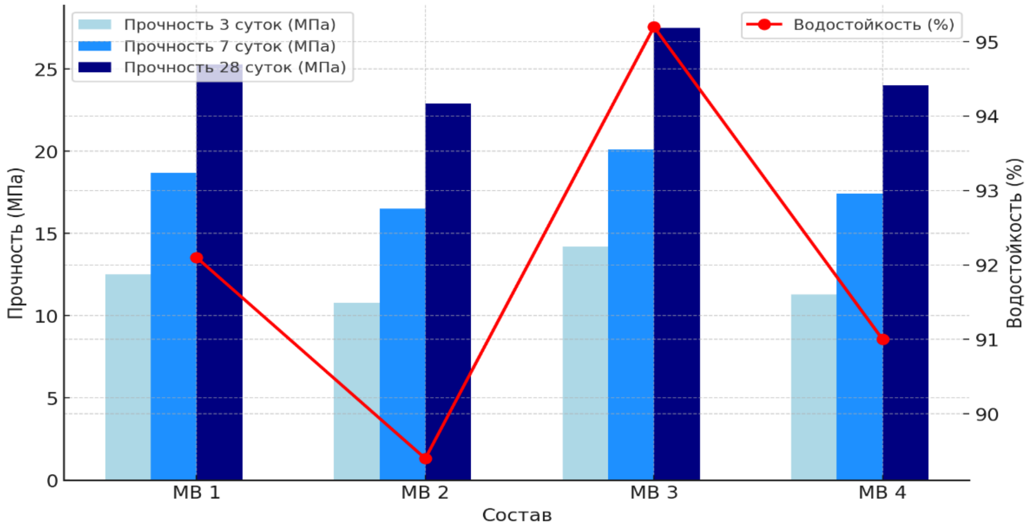


**Figure 4. Strength and water resistance of compositions**

• MV 3 is the most optimal composition for strength and water resistance.

• MV 2 has the lowest performance indicators, which may limit its use in high loads or humidity conditions.

• MV 1 and MV 4 demonstrate average indicators and can be used in less demanding conditions.

Based on the conducted research, the optimal composition of the magnesium binder is MB 3, as it has the highest compressive strength after 28 days (27.5 MPa), as well as good heat and water resistance indicators. This composition ensures a balanced combination of phase composition and mechanical properties, making it the most promising for practical application.

## CONCLUSION

Thus, the issue of obtaining a magnesium binder from high-magnesium rocks is the most studied. The production of a magnesium binder based on highly active dolomites, brusites, and magnesites allows achieving significant economic and environmental benefits both by reducing the firing temperature and the emission of carbon dioxide into the atmosphere, and can also be used as a promising raw material for the production of building materials of various purposes.

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