Prospects for application of magnesium binder in construction

A V Kiyanets

Department of Building Construction and Structural Theory, South Ural State University, 76, Lenin Avenue, Chelyabinsk 454080, Russia

E-mail: kiyanets2007@mail.ru

Abstract. It is possible to replace portland cement in various areas of construction by magnesium binder (magnesium oxychloride cement), which is a unique material in its properties. The materials, based on magnesium binder, do not require heat and moisture (autoclave) treatment for hardening, provide high fire resistance and low thermal conductivity, wear resistance, compressive strength and bending strength. The article summarizes the current knowledge of the processes of structure formation and hardening of the magnesium binder. When the caustic magnesite is closed with an aqueous solution of magnesium chloride, a complex process occurs in the formation of various phases of magnesium oxychloride and, in part, magnesium hydroxide. The optimal combination of different concentrations of the initial components provides high strength and performance characteristics of building composites based on the magnesium binder. The violation of the optimal composition leads to the processes of destruction and warpage of the material. It is concluded that the most promising areas of scientific research in the field of magnesium binders are the technologies for the construction of monolithic structures directly on the construction site, as well as controlling the properties of materials, depending on the temperature and humidity conditions of the medium.

1. Introduction

One of the most energy-consuming components in modern construction is cement. With the world economy maintaining the pace of its development, especially countries with intensively developing infrastructure, such as China, India, Brazil, Russia, Saudi Arabia, the United Arab Emirates and other countries, the consumption of cement will increase manyfold, and, consequently, energy consumption will also increase. From the point of view of sustainable growth of the world society, this is unacceptable [1]. Therefore, the most urgent problem of the modern world construction complex is the reduction of cement consumption, due to the wide introduction of other, less energy-intensive types of binders. For example, a magnesium binder (magnesium oxychloride cement) [2].

Researchers noted that many properties of materials and products based on caustic magnesite are better than Portland cement. They do not require heat and moisture (autoclave) treatment for hardening, provide high fire resistance and low thermal conductivity, wear resistance, compressive strength and bending strength [3,4]. Building composite materials on the magnesium binder are characterized by elasticity, high early strength, lightness, resistance to the action of oils, lubricants, varnishes and paints, salts, they have bactericidal properties, etc. [5,6]

However, the amount of magnesium binders used is very small, which is explained, on the one hand, by a weak production base, and on the other hand by an insignificant number of studies on obtaining a magnesium astringent with given properties [7,8].

The raw materials base of magnesites in the world is widely represented and explored. In Russia, significant reserves of crystalline magnesite are located in several regions: the Chelyabinsk region (Satka, Berezovskoe, Semibratskoe, Veselovskoye and other deposits); the Republic of Bashkortostan (Ismakayevsk, Kzyl-Tash, Yushinsky, etc.); the Krasnoyarsk Territory (Talsky, Kirghitae, Verkhoturov, etc.); the Irkutsk region (Savinskoye, Onotskoe); the Chita Region (Larginskoye, Luchuiskoye, Bereinsky and others). The deposits of crystalline magnesite, as a rule, have significant reserves.

Despite a large number of explored objects in the Russian Federation, magnesium raw materials are extracted only at the Satka, Kirigeyskoye and Kuldurskoye fields. To date, only the Satka deposit of crystalline magnesite is processed on an industrial scale, the extracted raw ore from which external consumers are not sold.

Minor estimated or proven reserves of amorphous magnesite in Russia are in the Orenburg region and the Republic of Bashkortostan. The deposits of this industrial type have small reserves and are unlikely ever to be claimed by the refractory industry as raw materials.

In addition to positive physicomechanical characteristics, the materials based on the magnesium binder revealed a number of disadvantages: low water resistance, reduced strength during operation, cracking, buckling. All these properties, both positive and negative, are closely related to the quality of the raw materials (MgO), the processes of structure formation and hardening of the material, and also to technological factors [9].

At present, in Russia, there is, unfortunately, no targeted production of raw materials for the purpose of specialized production of caustic magnesite from it for use in construction. As a raw material waste from the production of refractories of the Magnezit combine in Satka is used. The Satka magnesite deposit is the largest in Russia and the only one with a developed production cycle. Magnesite (rock) is crushed into pieces up to 40 mm in size and fired in rotary kilns. Together with the exhaust gases from the furnaces in the form of fine dust, up to 30% of the calcined magnesite is carried away. This dust is trapped by special electrostatic precipitators, and, in fact, is the raw material for the production of magnesium cement. The output of this dust is hundreds of thousands of tons per year. It should be noted that due to the heterogeneity of the properties, only a part of this dust is suitable for use as a magnesium binder. The main requirements for magnesium astringent are set forth in GOST 1216-87 [10,11]. According to this document, as well as the latest research, caustic magnesite, used for the production of magnesium binder, must meet the following requirements: MgO content in powder not less than 75%; the true density of caustic magnesite should be 3.25 ... 3.45 g/cm^3; compressive strength in the first day of hardening 10 ... 30 MPa, and more than 35 MPa on the 28th day of hardening; complete absence of cracks or insignificant surface radial cracks when hardening of binder samples in water; start grasping no later than 50 minutes, end of setting no later than 120 minutes.

Thus, using this raw material deals with the issues not only of construction, but also of rational nature management.

2. Hardening and structure formation of magnesium oxychloride cement

The modern views on the processes of structure formation and hardening of caustic magnesite are ambiguous. There are different views on these processes. This is due to the complex nature of the phenomena occurring.

According to one of the hypotheses at the beginning of the hydration processes in magnesian-caustic cement, metastable pentaoxyhydrochloride of magnesium ($5MgO \times MgCl_2 \times 13H_2O$) is formed, which determines the intensive increase in the strength of the magnesium stone, which gradually transforms to trihydroxychloride ($3MgO \times MgCl_2 \times 8H_2O$), which is accompanied by a decrease in the strength of the material.

The forming structure of the magnesium stone is unstable and prone to recrystallization, especially when exposed to water. It should be noted that the ratio of the initial components - astringent (caustic magnesite) and solvent (an aqueous solution of magnesium chloride) and their concentration -

determines the composition of the products of the reaction. With a lack of magnesium chloride in the magnesium cement, together with oxychlorides, a phase of magnesium hydroxide $Mg(OH)_2$ is detected. When hardening, the composition of the mixture changes and this is due to the activity and heat release of the magnesium binder, as well as the conditions for its aging [12].

In addition, the stability of the hardening products of magnesium cement is largely determined by the humidity and carbon dioxide content in the operating environment.

This is one of the reasons for the low water resistance of magnesium binders. Oxychlorides are unstable in water and decompose to form $Mg(OH)_2$ and $MgCl_2$ [13].

Carbon dioxide, present in the atmosphere, leads to the decomposition of oxychlorides and the formation of basic magnesium chlorocarbonates, and even after shutting down with a saturated aqueous solution of magnesium chloride in magnesium cement, the basic magnesium carbonate begins to form on its surface after four years.

The processes accompanying the splicing and recrystallization of oxychloride phases and magnesium hydroxide give the cement stone strength and density, and also determine the longevity of the stone in conditions of variable humidity.

Thus, the features of the formation of the structure of the magnesium, stone are determined by the characteristics of the magnesium cement, the concentration and kind of the solvent, as well as the conditions of hardening. With an unfavorable combination of these factors, the structure of the stone is formed from metastable magnesium oxychloride, which subsequently leads to recrystallization or destruction at the micro and macro levels [14].

Consequently, the magnesium binder, when hardened, depending on the ratio of the astringent and the curing agent components, and also on the hardening temperature, forms a magnesium stone comprising magnesium hydroxide, pentaoxyhydrochloride and magnesium trioxide hydrochloride. In addition, the structure for a long time also contains the original magnesium oxide [15].

3. Construction materials and technologies based on magnesia binder

To increase water resistance and durability of magnesium stone, the most promising is the use of various kinds of mineral additives. For example, the introduction of complex fine-dispersed mineral admixtures of blast-furnace slag and natural magnesium hydrosilicate into the magnesium binder promotes the modification of the structure formation and the enhancement of a number of operational and technological properties of the magnesium stone [16,17].

As a result of studies based on such a modified magnesium cement, the compositions of concretes and solutions with improved physical and mechanical properties were selected: rapid strength set (30 ...40% of twenty-eight daily for a short time of hardening), high strength - over 40 MPa at compression, low abrasion - less than 0,6 g/cm^2, crack resistance at hardening and operation, coefficient of water resistance over 0,8 [18].

These characteristics are provided not only by the properties of the modified magnesium binder, but also by the selected structure of the resulting composite.

Currently, the most common magnesium binder in construction has received as a material for the manufacture of various construction products [19]. Based on the magnesium binder are produced, mainly, heat-insulating and finishing sheet materials [20]. These materials are widely used for the production of various types of finishing, facade and even concrete work. Although, for the use of such materials in the formwork (non-removable formwork), special solutions for waterproofing (Figure 1).

Also widely used are glass-magnesium sheets, which are analogues of such materials as gypsum plasterboard (gypsum board) and gypsum-fiber sheet. But, the magnesium binder has developed most of all as a basis for materials of durable and wear-resistant floors.

The technology of monolithic magnesium flooring currently used is based on the use of fine-grained concrete on mineral aggregates [21,22]. Such floors are wear-resistant, dust-free and decorative, which provides a wide range of their application (Figure 2).

Figure 1. Application of materials based on magnesium oxychloride cement as a heater.

Figure 2. Technology of monolithic magnesium flooring.

4. Conclusions

Thus, by now a knowledge base on the processes of structure formation and hardening of building composite materials based on magnesium oxychloride cement has been created. The main properties of these materials are known and studied. The raw material base and the technology of obtaining a building binder with specified properties are explored. There is experience in the use and operation of these materials. Given the need for alternative types of binders (more economical than portland cement), magnesium oxychloride cement can serve as one of the solutions to this problem.

The most promising directions of scientific research in the field of magnesium binder, which can significantly expand the scope and scope of its application, are the technologies for the construction of monolithic structures directly on the construction site, as well as controlling the properties of materials depending on the temperature and humidity conditions of the medium.

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