Construction and Building Materials 185 (2018) 609–616

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Study on effect of the activated magnesia carbonized building blocks based on the content of fly ash

Henian Zhang [a], Chen Shen [a,*], Peisheng Xi [a], Kaixiang Chen [b], Fang Zhang [a]

[a] Institute of Geotechnical Engineering, Anhui Jianzhu Univ., Hefei 230022, China
[b] Key Laboratory of Road and Traffic Engineering of Ministry of Education, Tongji University, Shanghai 230000, China

HIGHLIGHTS

- Appropriate amount of fly ash can increase the mechanical properties of concrete test block.
- Nesquehonite, Dypingite and Hydromagnesite are the major products of carbonation of active gamma magnesia.
- The combination of fly ash and the carbonation products of magnesium oxide improves the internal structure of concrete.
- It is an environmentally friendly material.

ARTICLE INFO

Article history:
Received 2 February 2018
Received in revised form 20 June 2018
Accepted 11 July 2018
Available online 20 July 2018

Keywords:
Magnesia concrete
Fly ash
Carbonization block
Mechanical properties
Micro structure

ABSTRACT

The influence of different fly ash contents on the strength and mechanical properties of activated Magnesium Oxide carbonized block was studied in this paper. Previous researches designed a variety of test methods and compared test results, which determined the optimal raw materials, sample preparation methods, carbonation environment and technology and other key technical parameters. The test selected a typical carbonized masonry samples for micro-chemical testing, including unconfined compressive strength (UCS), shear strength (SS), crack resistance, drying shrinkage and swelling properties, X-ray diffraction XRD, SEM and TGA, etc. The carbonation reaction mechanism and the interaction between the carbonized product and the environment were analyzed. From the 3rd to 7th day, the results showed that the compressive strength of the blocks increased rapidly, since then showed a gentle growth. While from the 21st to 28th days, the compressive strength of the block increased obviously. The study found that excess fly ash contents had no significant advantages on the block strength and performance. The content of fly ash is 0.3, the water-binder ratio is 1:1, which is the best blending ratio of carbonized block, and its comprehensive performance was significantly higher than alternative content. When the content of fly ash is 0.3, activated magnesia carbonized block produces the most number of flaky crystal hydromagnesite or dypingite and rhombic columnar crystal water magnesium stone, which help to increase block strength.

1. Introduction

China has been developing infrastructure for decades, with the development of urbanization, the urban infrastructure construction is becoming more and more intensive, this new construction environment we are facing has also become more complicated. The developed coastal areas, which possess widely distributed soft soil and silty soft soil layer, with high moisture content, high compressibility, low permeability, low strength, high sensitivity and other characteristics, has increased the difficulty in project construction sharply [1]. British construction worker J. Aspdin invented Portland Cement (PC) in 1824, which became the most popular building material in the world at the end of the last century. It was made from cement clinker with a small amount of gypsum and other mixed materials through milling. And MgO occupied the largest amount of the minor components, mainly produced by the decomposition of the associated $MgCO_3$ introduced by limestone [2]. The traditional mixing pile technology of Portland cement as a curing agent can no longer meet the needs of sustainable development, mainly for high energy consumption, high CO_2 emissions and non-renewable resource consumption, and slow

* Corresponding author.
E-mail addresses: 195293861@qq.com (H. Zhang), ivans_shen@126.com (C. Shen), 1055882982@qq.com (P. Xi), 751604057@qq.com (K. Chen), 1219527232@qq.com (F. Zhang).

https://doi.org/10.1016/j.conbuildmat.2018.07.085
0950-0618/

increase in the strength of the hardened soil. In order to improve the environmental impact of the current PC caused by mixing pile as a curing agent, this experiment based on the technology of magnesia carbonation mixing piles, the new low-carbon and low-carbon mixing piles curing agent/curing method has been optimized to reduce the use of PC and provide theoretical support to the development of new technology and new piles to improve the efficiency of foundation consolidation treatment [3].

Kolias et al. (2005) [4] studied the use of high-calcium fly ash to cement for clay curing; Goswami and Mahanta (2007) [5] cured residual red soil with a mixture of fly ash and hydrated lime; Hossain and Mol (2011) [6] analyzed the engineering properties of different amounts of cement kiln dust and pozzolan clay addition; also, many foreign scholars have studied the application effect of granulated blast furnace slag and waste gypsum in soil reinforcement. A large number of experiments were conducted by Liska and Al-Tabbaa [7], and it was found that: through comparison between semi-dry activated magnesium oxide samples with silicate cement samples, the strength of activated magnesium oxide sample increased significantly when the forced carbonization conditions were 20 °C ambient temperature, 98 ± 2% of relative humidity and 20% CO_2 concentration. The study of Vandeperre et al. [8,9] and Liska [10] showed that the hydration process of the two components is completed independent in the hydration process of the active MgO-PC mixture, and their hydration products are generated. Mo and Panesar [11,12] studied the cement blocks mixed with slag and activated magnesia at different rates of activated magnesia cement (0, 10%, 20%, 40%) for accelerated carbonation. After 56 days, the strength of block with 40% MgO content was slightly higher than that with 20% MgO, which was much higher than that of the other two blocks. Liska et al. [13] thought that main product of carbonized active MgO cement block is magnesium carbonate trihydrate (Nesquehonite, $MgCO_3{\cdot}3H_2O$), but another study [14–16] found the formation of two kinds of basic magnesium carbonate (Dypingite/hydromagnesite, $(Mg)_5(CO_3)_4(OH)_2{\cdot}5H_2O/Mg)_5(CO_3)_4(OH)_2{\cdot}4H_2O$). The research group of Prof. Huang Xin from Beijing University of Aeronautics and Astronautics conducted long-term research on the use of industrial waste solidified soft soil and achieved rich results; Mo et al. [17] found that hydrated calcium silicate produced amorphous $CaCO_3$ and SiO_2, which resulted in a slight increase in the mesopore and specific surface area of cement paste; and activated magnesium oxide produces a large amount of Mg-Ca carbonate, making the microstructure of cement slurry more compact, thus explains why the strength of magnesium oxide cement is greater than that of ordinary portland cement. Dynamic water vapor adsorption method, secondary scanning electron microscopy and backscattering electron microscopy analysis of MgO specimens were carried out in microstructure studies, and it was found that during high carbon dioxide curing, MgO was carbonated to form Mg-Ca carbonate, which fills the pores in the solidified soil to make its strength higher. Based on the expansibility of concrete, the influence of dosage of fly ash on its strength and mechanical properties is not yet fully understood. The carbonization technology of activated magnesia is a new research direction which has attracted attention in recent years. Only a few scientific research institutions have conducted a preliminary study. The technology is seriously lacking in relevant experimental data, so it is very necessary to study the effect of fly ash content on the strength and performance of magnesia concrete. In order to reduce the application of PC in concrete curing process, this test selected four different types of fly ash and magnesium oxide. Through unconfined compressive strength (UCS), shear strength (SS), cracking resistance, drying shrinkage and swelling properties, X-ray diffraction (XRD), Scanning electron microscope (SEM) and Thermogravimetric Analysis (TGA), a series of test researches have been carried out on its influence mechanism, fly ash influences concrete block performance and strength enhancement.

2. Materials and methods

2.1. Experiment materials

The cement used in this experiment is 32.5 grade ordinary Portland cement produced by Chaohu, Anhui Province. Its various technical indicators meet the corresponding provisions of the “Ordinary Portland Cement” (GB175-2007); the highly active light burned magnesia was bought from Shanghai Wenhua Chemical Pigments limited company, its activity was tested by citric acid neutralization method, hydration method and specific surface area method. Three groups of experiments were conducted, with each group of 8 trials. The chemical composition and physical index of the test materials are shown in Tables 1 and 2. Three groups of parallel experiments are carried out, each with 8 test blocks, and the experimental mix ratio is shown in Table 3.

2.2. Sample preparation

The test curing agent materials include fly ash, activated magnesia (MgO)and cement. According to the study by Abir Al-Tabbaa (Cambridge University) Liu and Southeast University Yi [18–20] and Mo and Panesar [12], Magnesium oxide content should not exceed 40% because of the strength of the test piece containing 40% magnesia is approximately the same as that of the test piece of 20% magnesia, so that four different proportions (mass ratio) are used, fly ash in the curing agent doping are: 10%, 20%, 30%, 40%, the water-binder ratio is 1: 1. Static pressure method is adopted for sample preparation and the specific process is as follows:

(1) Weigh a certain amount of raw materials, stir for five minutes in a small indoor blender, and then add weighed water, and then stir for five minutes to ensure uniform mixing.
(2) Weigh a sample of the required sample quality, pour the stirred sample into a cylindrical mold (diameter of 50 mm, height of 100 mm), with a vertical pressure on the jack to make cylindrical specimen height of about 80 mm; the same sample is also used with spatula split into two layers of circular crack test (425 mm × 300 mm × 100 mm), with pounding stick even pound, catch up with the lack of up until the test mode with leveling after the flat.
(3) Cylindrical specimens are demolded after compaction and moved to carbonation tank for curing; the toroidal sample is then moved into the carbonization tank for 24 h and then demolded. After that, the toroidal sample continues curing.
(4) When the specimens have been cured to the 3rd, 7th, 14th, 21st, 28th day, they are respectively tested for compressive strength and shear strength, crack resistance, drying shrinkage and expansibility, diameter, weight and height of the final sample, then other tests are carry out.

2.3. Test methods

Unlike traditional blocks, the strength of a carbonized block is based on the chemical interactions among (solid, liquid and gas phases of) magnesia, water and carbon dioxide. In this project, the key parameters such as optimal fly ash content suitable for carbonized masonry will be determined by indoor test on typical carbonized masonry. The test mainly includes Compressive strength, Shear strength, Crack resistance, Dry shrinkage expansion, X-ray diffraction (XRD), Scanning Electron Microscopy (SEM). Thermogravimetric Analysis (TGA). The test is based on carbonization test requirements of the “test method for small concrete hollow block” [21] (GB/T4111-1997). The intensity measurement is carried out at the age of 3, 7, 14, 28 days with parallel sample test. The dry shrinkage value of each sample, calculated according to the following formula, is accurate to 0.01 mm/m:

Table 1
Chemical composition of reactive MgO (%).

MgO	Hydrochloric acid insoluble matter	CaO	Fe_2O_3	Chloride (cl)	Others
93%	0.2%	1.5%	0.08%	0.1%	5.12%

Table 2
Results of MgO activity.

Specific surface area/($m^2\,g^{-1}$)	ACC value	Active content/%	Activity evaluation
50.425	29 s	65.31	Hight