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Study on flexural properties of active magnesia carbonation concrete with fly ash content

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HIGHLIGHTS

- Appropriate amount of fly ash can increase the flexural and ductile properties of concrete test blocks.
- 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.

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ABSTRACT

The fly ash activated magnesia carbonized concrete developed based on cement carbonization technology is a new type of cement-based composite material, the effects of four different proportions of fly ash and active magnesium oxide on the flexural and ductile failure of carbonized concrete were studied. The results show that the early flexural strength of magnesia carbonized concrete decreases with the increase of fly ash content, the flexural strength increases obviously during 0–7 days of carbonation curing. Afterwards, there is a flat growth, then increases significantly after 21–28 days of curing. The increase of fly ash content has a high stimulatory effect on ductility, which slows down the brittle failure of the test block. However, excessive fly ash content will also have a negative impact on the strength and performance. The optimum value is verified by the relationship between strain-time curve, the optimum mixing amount of fly ash is 0.3, and the ratio of water to glue is 1:1. Microscopic test results verify the magnesium carbonized products of Nesquehonite, Dypingite and Hydromagnesite are the main reasons for improving the flexural properties.

1. Introduction

Concrete is a quasi-brittle material [1]. With the strength gradually improving, the increase of its brittleness may lead that its structure is destroyed suddenly. It is no doubt that the safety hazards of the complex large scale concrete structures will be increased. Meanwhile it does not meet the requirements of the structural design safety and limits the scope of application of high-strength concrete. Portland cement, the main raw material for ordinary concrete, has high CO_2 emissions, high energy consumption, slow strength growth and serious environmental pollution. Incorporating fly ash can reduce hydration heat, reduce cracks and improve concrete performance, Harison [2] et al. studied the effect of fly ash on compressive strength by replacing cement with different proportions of fly ash. The results show that with the increase of fly ash, the early strength of coagulation gradually decreases, and the later strength has Increased, but gradually decreased when it exceeds 20%. Therefore, it is one of the effective ways to improve the flexural strength and toughness of concrete by adding fly ash and active magnesium oxide into the matrix as curing agent, which can effectively solve the difficult problems of high energy consumption and high carbon emission, etc. caused by PC curing agent.

Vandeperre et al. (2008) [3,4] conducted carbonization tests on magnesium oxide cement and PC paste samples. It was found that the fly ash- magnesium oxide slurry could provide the same mechanical properties as the fly ash-Portland cement paste under 20% CO_2. The strength of PC block with only active magnesium oxide as curing agent could reach 2–3 times under forced

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carbonization, and the CO_2 of the same quality as magnesium oxide could be absorbed; Goswami & Mahanta [5] cured residual red soil with a mixture of fly ash and slaked lime. Formosaa [6] indicated that cement mortar formulate with a low-cost magnesium oxide by-product could be an interesting alternative to other repair mortars; Afshin [7] researched the stabilization of soil using olivine and the application of novel techniques utilizing alkaline activation and carbonation. Dung [8] studied enhance the microstructure and performance of magnesium oxide concrete mixes by increasing hydration and lowering water demand via the introduction of hydration and dispersion agents. Pu [9] investigated the carbonation potential, strength gain and microstructural development of magnesium oxide blocks and provides a comparison with Portland cement blocks. In addition, many foreign scholars have studied the application effect of granulated blast furnace slag and waste gypsum in soil reinforcement. Prof. Huang conducted a long-term research on the use of industrial waste solidified soft soil and achieved rich results; Fang [10] et al. put forward a GT-type soil curing agent based on high-calcium ash and desulfurized gypsum, supplemented with quicklime, cement, calcined gypsum, aluminum sulfate, and alumite; Liu and Li [11] found that magnesium oxide activity had a significant effect on carbonization and solidification. Zhang et al. [12] concluded that carbonized products of reactive magnesium oxide are mainly Hydromagnesite and Nesquehonite/Dypingite, with the higher amount of reactive magnesium oxide, the more carbonized products. Ye [13] found that in the early stage, with the increase of fly ash content, the strength of magnesia cement was obviously decreased. However, with the passage of time, the influence of fly ash content on the strength became smaller and smaller. When curing to the 90th day, the strength of the fly ash test piece was almost equivalent to that of the ordinary test piece, and even slightly increased. Zhang [14] concluded that under the low fly ash replacement rate, the reduction of the flexural strength is lower than the reduction of the high fly ash replacement rate. Yang [15] conducted a bending test on the trabecular beam with a replacement rate of fly ash of 0%, 15% and 25%. Rahul et al. [16] studied the effect of different proportions of fly ash on the flexural strength of coagulation. They concluded that with the increase of the proportion of fly ash, the late flexural strength will increase, and the proportion of fly ash will decrease when it exceeds 20%. At present, there are few studies on fly ash-magnesium oxide carbonized concrete by domestic and foreign scholars. There are many aspects that need to be further studied and analyzed.

This study provides a new method to improve the flexural performance of fly ash concrete, and through the combination of theory and experiment, it gives the best fly ash content of active magnesium oxide carbonation concrete block, reduces the waste gas produced by the cement industry and resources and energy consumption caused by the development of limestone. Designed to increase the flexural properties of concrete as much as possible with large amounts of fly ash.

2. Materials and methods

2.1. Experiment materials

The cement used in this experiment is 32.5 grade ordinary Portland cement. Its various technical indicators meet the corresponding provisions of the *Ordinary Portland Cement* (GB175-2007). The chemical composition of high activity magnesium oxide is shown in Table 1. The resistance strain gauge parameters are shown in Table 2. According to the size of the mold, two test blocks are a group, the test material composition ratios are shown in Table 3.

Table 1
Chemical composition of reactive magnesium oxide (%).

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
Strain gauge parameters.

Type Tipo BX120-50AA	Precision Grade A
Gage Resistance 119.9 ± 0.1 Gage Factor 2.08 ± 1%	Fence Long 50 * 3 mm Thermal Output 100 μm/m °C^{-1}

2.2. Sample preparation

According to the study by Al-Tabbaa and Yi [17–19] et al., and studies carried out by Mo and Panesar [20,21] et al., the strength of the test block containing 40% magnesium oxide is approximately the same as the strength of the test block of 20% magnesium oxide, and the amount of magnesia should not exceed 40%. Therefore, four different ratios (mass ratio) are used when fly ash is added. Fly ash in the curing agent doping as: 10%, 20%, 30%, 40%, the water-binder ratio of each dosage is 1:1. The specific process is as follows:

(1) Weigh a certain amount of raw materials, stir for five minutes in a small blender in the room, and then add weigh water and water reducer, then stir for five minutes to ensure uniform mixing.
(2) Weigh a sample of the required sample quality, the stirred sample is divided into two rounds and poured into a non-standard rectangular mold (400 mm × 100 mm × 100 mm). Tamp with the rod evenly, the upper mouth with the lack of follow-up until the test die level after scraping.
(3) The sample is first moved into a carbonization box for curing for 24 h and demolded, then the curing is continued. Carbonization conditions were 20 °C of ambient temperature, 98 ± 2% of relative humidity and 20% CO_2 concentration.

2.3. Flexural performance test

(1) Two specimens per group. When the test block was cured to the 3rd, 7th, 14th, 21st, 28th day removed respectively from the curing room and was wiped cleanly, then attach the strain gauge, they were counted as YB-1 and YB-2 layers respectively. The position of the strain gauge is shown in Fig. 1:
(2) Loading the test block. The universal testing machine is used to load the specimen at the middle three points of the test block. The bearing surface of the test piece is two relatively flat sides when the test block is formed, and the test block shall ensure that the test block is in close contact with a support and a roller, a cover plate is in close contact with the roller and a press on the testing machine. The loading device is shown in Fig. 2:
(3) The applied load should be uniform and continuous, the loading speed should be 0.5 mm per minute until the test block is damaged or the universal testing machine automatically stops working.
(4) Record the damage load and the fracture location of the test piece. According to "Ordinary Concrete Mechanical Properties Test Method Standard" [22], samples can be used in non-standard sizes. The flexural strength of the concrete test block is calculated according to the following formula: