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Temperature sensitivity of MgO expansive agent and its application in temperature crack mitigation in shiplock mass concrete

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HIGHLIGHTS

- Expansion properties of MgO under different temperature histories were studied.
- Crack resistance of MgO with different reactivity values in concrete was studied.
- Thermal shrinkage compensation effect of MgO was verified through application.
- Reactivity of MgO should be selected according to temperature history of structure.

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ABSTRACT

The compensation of thermal shrinkage with the delayed expansion of MgO expansive agent has been used not only in mass concrete, but also in some underground sidewall in subway stations in China. This study investigated the expansion behaviors and crack resistance of three kinds of MgO with different reactivity values (90 s, 150 s and 250 s) in concrete based on a comprehensive test system including the length test using the differential strain gauge, a dual-ring test and the environment simulation test chamber. The results showed that the expansion behavior of MgO expansive agent was closely related to its reactivity value and the temperature history of concrete. MgO with lower reactivity value (90 s, 150 s) showed larger expansion in concrete than MgO with higher reactivity value (250 s) under the temperature history of low temperature rise and high cooling rate, while MgO with higher reactivity value showed larger expansion at temperature fall stage and better crack resistance under the temperature history of high temperature rise, low cooling rate and long cooling period. The results indicate that the reactivity value of MgO expansive agent should be properly selected according to the characteristics of temperature histories of different concrete structures to give full play of its shrinkage compensating efficiency.

1. Introduction

The compensation of thermal shrinkage with the delayed expansion of slow hydrating MgO has been proven effective in preventing the thermal cracking of mass concretes, such as dams, diversion tunnels, etc. [1–3]. Nowadays, the thermal shrinkage compensating property of MgO expansive agent has also been used in some underground sidewall in civil engineering in China [4]. MgO expansive agent has many advantages over other kinds of expansive agents, such as sulphoaluminate type, or CaO-type [5–7]. These advantages include the chemically stable hydration product, relatively low water requirement, and in particular the designable expansion properties [8,9]. MgO expansive agent is typically calcined from magnesite at high temperature. The calcination conditions affect the microstructure and hydration reactivity of MgO, and thereby affect its expansion properties in concrete. In China, significant researches have been conducted on the properties of MgO expansive agent and the performance of concrete containing MgO in laboratory. The results suggest that the expansion property of the MgO is more sensitive to the temperature

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compared to other types of expansive agent such as CaO-type, sulphoaluminate-type and so on [7–14]. However, most of the studies are focused on the effect of the calcination temperature of MgO [11] or the curing temperature of concrete [9,12–14]. While, as the temperature field of concrete in actual structure changes with time due to the heat of cement hydration and the heat exchange with environment, the expansion property of MgO in actual structure concrete cannot be predicted simply by that under different constant temperatures. Moreover, the temperature history is also different for different concrete structures, so the properties of MgO under different temperature histories should also be obtained. However, there are few reports about the expansive properties of MgO under variable temperature or different temperature histories, which may lead to incorrect usage of MgO expansive agent in actual projects.

As one of the main navigation structures in waterway transportation, shiplocks play a key role in river channelization and canal construction. However, severe early cracking and leakage phenomena seriously affect the normal use and service life of a shiplock [15,16]. Shiplock concrete usually belongs to large-volume or thin-wall special-shaped structure concrete. On the basis of their cracking positions, the cracks in the shiplock concrete are mainly divided into two categories: longitudinal cracks (located at the middle of the floor) and vertical cracks (at the sidewall of the gallery and lock chamber). In terms of cracking time, most cracks occur during the construction period due to the thermal shrinkage superposed with the autogenous shrinkage.

In order to select proper kind of MgO for thermal shrinkage compensating of shiplock mass concrete, this paper firstly studied the expansion properties of MgO expansive agent with different reactivity values in concrete under different temperature histories based on the length test method using the differential strain gauge combined with the environment simulation test chamber; then, the crack resistance of MgO expansive agent with different reactivity values in concrete was studies based on a dual-ring test method combined with the environment simulation test chamber. Based on this, the reactivity value of MgO was selected for the actual application, and the shrinkage compensating effects of MgO expansive agent were monitored.

2. Temperature sensitivity of MgO expansive agent

2.1. Raw materials and test methods

In this experiment, three kinds of laboratory-made MgO expansive agents with different reactivity values (90 s, 150 s and 250 s) and the same particle size distribution were studied. The chemical compositions and particle size distributions of MgO are shown in Table 1 and Fig. 1, respectively. The reactivity value of MgO was determined using citric acid neutralization and defined as the time required for complete neutralization with the citric acid solution. The mix proportions of concrete studied are shown in Table 2 in which the dosage of MgO is 0 and 4% (weight percentage of cementitious materials).

To study the expansion properties of MgO in concrete under different temperature histories (different maximum temperatures and temperature fall rates), the environment simulation test chamber (Fig. 2) was employed to install different temperature histories, and then the concrete specimens placed in would show the same temperature history as that installed. After mixing, the fresh concrete was poured into a bottom-sealed PVC pipe with the size of Φ110 mm × 400 mm in the middle of which the differential strain gauge according to Chinese Standard GB/T 3408. 1-2008 was pre-embedded, and then the upper surface of the concrete was sealed with plastic sheet and foil and placed in the test chamber. At the same time, the initial setting times of concrete were determined by capillary pressure according to Reference [17]. The temperature history installed by the environment simulation test chamber started immediately after the initial setting.

Table 1
Chemical compositions of MgO expansive agent.

No.	Reactivity value (s)	Chemical compositions (wt%)						
		MgO	CaO	SO_3	SiO_2	Al_2O_3	Fe_2O_3	Loss
MgO-90 s	90 ± 10	92.10	2.06	–	0.94	1.38	0.54	2.98
MgO-150 s	150 ± 10	91.80	1.57	–	1.71	1.35	0.48	3.09
MgO-250 s	250 ± 20	90.84	2.01	–	2.39	1.21	0.53	3.02

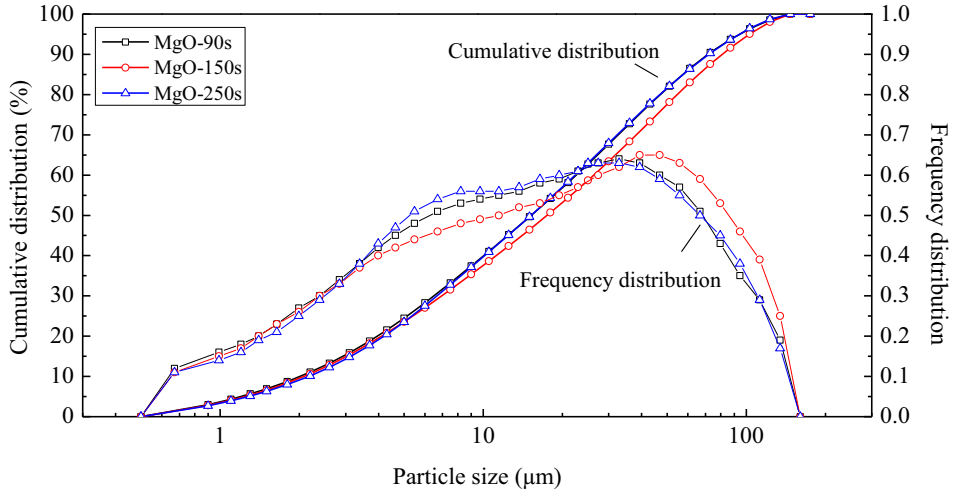

Fig. 1. Particle size distribution of MgO with different hydration reactivities.