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Test research on effects of ceramic polishing powder on carbonation and sulphate-corrosion resistance of concrete ☆

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HIGHLIGHTS

- Ceramic polishing powder is a type of waste produced in the production of ceramic polishing bricks.
- Ceramic polishing powder was taken as a supplementary cementing material in concrete.
- Ceramic polishing powder lowered the carbonation resistance of concrete.
- Ceramic polishing powder improved the sulphate corrosion resistance of concrete.

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ABSTRACT

In this research, ceramic polishing powder was taken as a supplementary cementing material to replace cement partly in concrete to produce concrete, in order to research the effects of ceramic polishing powder on the resistance of concrete to carbonation and sulphate corrosion. Twelve groups of concrete (C30) were designed, including 1 group of control concrete; 4 groups of concrete mixed with ceramic polishing powder, with a cement substitution rate of 10%, 20%, 30%, 40% respectively; 4 groups of concrete mixed with fly ash, with a cement substitution rate of 10%, 20%, 30%, 40% respectively; 3 groups of concrete mixed with ceramic polishing powder and fly ash simultaneously, with a cement substitution rate of 10% (ceramic polishing powder) + 20% (fly ash), 20% (ceramic polishing powder) + 10% (fly ash), 20% (ceramic polishing powder) + 20% (fly ash) respectively. After the concrete carbonation and sulphate corrosion tests were carried out, and some results were obtained. Firstly, the carbonation resistance of concrete mixed with ceramic polishing powder is lower than that of the control concrete, and with the increase in cement substitution rate, the carbonation resistance of concrete shows a declined trend. Secondly, under the same cement substitution rate conditions, the concrete mixed with ceramic polishing powder shows similar carbonation resistance to the concrete mixed with fly ash, and the carbonation resistance of concrete mixed with both ceramic polishing powder and fly ash is similar to that of concrete mixed with either. Thirdly, the sulphate corrosion resistance of concrete mixed with ceramic polishing powder is better than that of the control concrete, and with the increase in cement substitution rate, the sulphate corrosion resistance of concrete shows a rising trend. Finally, under the same cement substitution rate conditions, the sulphate corrosion resistance of concrete mixed with fly ash is better than that of concrete mixed with ceramic polishing powder, and the sulphate corrosion resistance of concrete mixed with both ceramic polishing powder and fly ash is better than that of concrete mixed with either.

1. Introduction

Ceramic polishing powder is a type of waste produced in the production of ceramic polishing bricks. Usually, a surface layer of 0.5–0.7 mm in thickness, even 1–2 mm when a big firing deformation occurs, needs to be removed from brick surface in the polishing process [1]. Ceramic polishing bricks, as one of the key ceramic products used in buildings, has an annual output of over 800 million square meters across China, while about 1.9 kg of ceramic polishing powder is produced from the production of each square meter of ceramic polishing bricks, so the discharge of ceramic polishing powder is amazingly high [2]. With the rapid development of the ceramic industry, more and more wastes from ceramic

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processing are being discharged [3–9], which not only exerts a huge impact on environment, but impose a restriction on the sustainable development of the ceramic industry [10–16]. At present, there is not yet any effective means to treat or utilize ceramic polishing powder, most of which is piled up in the open air or treated just by means of land filling, thus bringing a serious environmental problem.

Considering its particle size, components and chemical activity, it is quite possible to take ceramic polishing powder as a supplementary cementing material in concrete production. Previous studies used to focus on analyzing the properties of ceramic polishing powder, and as for its application in concrete, researches paid more attention to the effects of ceramic polishing powder on concrete strength, but less to the durability of concrete. The resistance of concrete to carbonation and sulphate corrosion is an important property of concrete [17–22]. This paper relates to the effects of ceramic polishing powder on concrete's resistance to both carbonation and sulphate corrosion.

2. Test materials and mix proportion of concrete

2.1. Materials

(1) *Cement*: ordinary Portland cement, produced by Dalian Xiaoyetian Cement Co., Ltd., in China. The mineral compositions of clinker, chemical compositions and main properties of cement are as shown in Tables 1–3.
(2) *Coarse aggregate*: natural gravel, density 2830 kg/m^3; particle size distribution is as shown in Table 4.
(3) *Fine aggregate*: natural sand, density 2760 kg/m^3, fineness modulus 2.71; particle size distribution is as shown in Table 5.
(4) *Ceramic polishing powder*: ceramic polishing powder was obtained from a ceramics enterprise in Liaoning province, China. The particle shape is as shown in Fig. 1, the particle size analysis as shown in Fig. 2, the chemical components as shown in Table 6, and the XRD diffraction pattern as shown in Fig. 3. As can be seen from Fig. 3, quartz is the main mineral component of ceramic polishing powder, and according to the literature [2], we can conclude that there is some glass phase in the ceramic polishing powder. Activity tests showed [23] that ceramic polishing powder has potential hydraulicity, the compressive strength ratio of cement mortar at the curing time of 28d is 86.62%, and the pozzolanic activity of ceramic polishing powder is qualified.
(5) *Fly ash*: fly ash was sampled from Shenhai Thermal Power Plant, Liaoning province, China, with a density of 2220 kg/m^3. The chemical components of the fly ash are as shown in Table 7.
(6) *Water*: drinking water.

2.2. Mix proportion

Twelve groups of concrete were devised, including 1 group of control concrete (C-0); 4 groups of concrete mixed with ceramic polishing powder (CC-1, CC-2, CC-3 and CC-4), with a cement substitution rate of 10%, 20%, 30% and 40% respectively; 4 groups of concrete mixed with fly ash (FC-1, FC-2, FC-3, and FC-4), with a cement substitution rate of 10%, 20%, 30% and 40% respectively; 3 groups of concrete (FCC-1, FCC-2 and FCC-3) mixed with ceramic polishing powder and fly ash simultaneously, with a cement substitution rate of 10% (ceramic polishing powder) + 20% (fly ash), 20% (ceramic polishing powder) + 10% (fly ash), 20% (ceramic polishing powder) + 20% (fly ash) respectively, that is, ceramic polishing powder is mixed with fly ash in the proportion of 1:2, 2:1 and 1:1 respectively aiming at the difference of effect between ceramic polishing powder and fly ash. In this research, the purpose of introducing groups FC and FCC is to compare the effects of ceramic waste powder with that of fly ash on concrete, because fly ash has been widely used in concrete as a supplementary cementing material.

The concrete is designed with a strength grade of C30 and a slump of 70–90 mm. The mix proportions of concrete are as shown in Table 8.

Table 1
Mineral components of cement, wt%.

C_3S	C_2S	C_3A	C_4AF
52	22.4	8	10

Table 2
Chemical compositions of cement, wt%.

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	LOI
21.36	5.1	3.34	63.76	1.54	2.46	3.8

Table 3
Main properties of cement.

Setting time (min)		Soundness	Compressive strength (MPa)		Flexural strength (MPa)	
Initial	Final		3d	28d	3d	28d
140	195	Qualified	32	56	6.5	9.2

Table 4
Particle size distribution of coarse aggregate.

Side length of square hole sieve (mm)	2.36	4.75	9.5	16.0	19.0	26.5	31.5
Cumulative percentage retained (%)	100	98.5	86.1	75.3	37.9	18.1	1.7

Table 5
Particle size distribution of fine aggregate.

Side length of square hole sieve (mm)	9.50	4.75	2.36	1.18	0.60	0.30	0.15
Cumulative percentage retained (%)	0	9.3	21.8	30.5	59.6	90.6	96.8

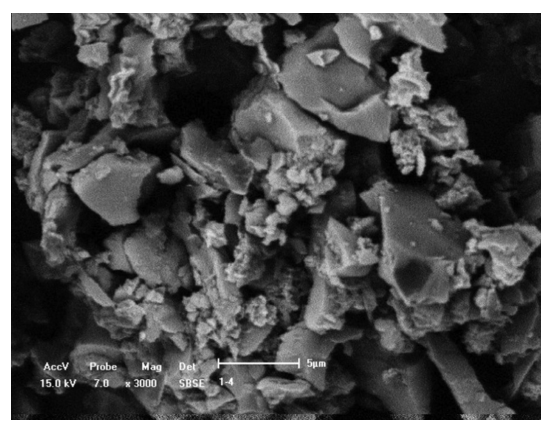

Fig. 1. Particle shape of ceramic polishing powder.

3. Testing for resistance of concrete to carbonation

Tests were conducted according to *Standard for Test Methods of Long-term Performance and Durability of Ordinary Concrete* (National standard of the People's Republic of China, GB/T50082-2009).

There were three specimens in each group, in the shape of rectangular solid (100 mm × 100 mm × 400 mm). Take out specimens at the curing time of 3d, 7d, 14d and 28d respectively, and split them off from one end. Spray phenolphthalein alcohol solution onto the section, and select ten measuring points on a 10 mm basis and measure the carbonation depth at each point. The average value of carbonation depth at all points was taken as the measured value of carbonation depth. After measure of 3d, 7d and 14d, the splitting surfaces were sealed up with paraffin. The test results are as shown in Table 9.