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Effect of curing conditions on the permeability of concrete with high volume mineral admixtures

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HIGHLIGHTS

- The influence of curing conditions on the sorptivity, electric flux and carbonation depth were investigated.
- Longer curing time, higher humidity and appropriate temperature was helpful to improve the impermeability of concrete.
- The relationship between water absorption and other permeability was discussed.

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ABSTRACT

The influence of mineral admixtures and curing conditions on the permeability of concrete with high volume mineral admixtures is investigated. Fly ash and ground granulated blast furnace slag (GGBFS) are used to replace 50% cement, the water absorption, capillary water absorption, sorptivity coefficient, electric flux and carbonation depth of concrete with mineral admixtures are tested under different curing conditions, such as the curing time, curing humidity and curing temperature. The test results show that the water absorption, capillary water absorption, sorptivity coefficient, electric flux and carbonation depth of concrete decrease with the longer standard curing time, higher curing humidity and appropriate curing temperature, and decrease with the increasing of GGBFS content. It is also shown that the permeability of concrete with high volume mineral admixtures is very sensitive to the curing conditions.

1. Introduction

Curing is a process during which hydraulic-cement concrete develops hardened properties through the hydration of the cement in the presence of water and heat. Without effective curing, significant disadvantage to long-term durability of concrete can result, and concretes typically appear some defects, such as visible cracking, microcracking, and weak surface. Good curing condition is favorable to the development of the strength and durability of concrete, and can effectively improve the microstructure of concrete and enhance the ability of concrete to resist the erosion of external medium. The permeability of concrete is used as an indication of durability, and substantially affected by the curing conditions [1–4]. The penetration of water, chloride ion and gas into concrete is closely related to the porosity and pore characteristics of concrete, especially that of surface concrete. Mineral admixtures have significant contribution to the permeability of concrete [5] and it has generally been accepted that curing is more critical for concrete with mineral admixtures than for normal concrete [6–9].

Tasdemir [10] investigated the combined effects of mineral admixtures and curing conditions on the sorptivity of concrete, the sorptivity coefficient of concrete was very sensitive to the curing condition, and the effect of curing condition on the sorptivity coefficient of concrete seems to be higher in low-strength concretes. Sakai et al. [11] reported that the curing had significant effect on the permeation rate of water in concrete. The test results obtained by Boga et al. [12] show that it is very important that water cure is done for 56 days and also that quite durable concretes against corrosion can be produced by using fly ash at 15% ratios replace by cement. The test results obtained by Cakie et al. [13] show that the capillarity coefficient of slag replaced mortars is lower than control mortars, and the decrease in the capillarity coefficient of slag replaced mortars cured at 20 °C is higher than slag replaced mortars cured at 40 °C. Liu et al. [14] studied the effect of curing methods and wet curing duration on the properties

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of concrete, the results shown that the proper curing methods could effectively increase the strength, reduce the central temperature due to hydration heat and the early shrinkage strain and improve the chloride impermeability, and longer wet curing duration was essential to achieve higher strength, durability and corrosion resistance characteristics, especially for slag cement concrete. The results of Sisomphon et al. [15] show the significance of 7 days curing period on carbonation resistance of the mixtures, and the depths of carbonation of blast-furnace slag cement with or without fly ash are dramatically reduced by extending the curing period from 3 days to 7 days.

When cement is replaced by 50% mineral admixtures, the curing conditions have a greater impact on the quality of concrete, especially the surface quality. Water absorption is used to determine the amount of water absorbed under specified conditions which indicates the degree of porosity of a material [16], and the capillary water absorption, chloride ion penetration and carbonation of concrete are more or less related to the open pores on the concrete surface. This paper mainly studies the effect of the curing time, curing humidity and curing temperature on the permeability of concrete with high volume mineral admixtures, and the relationship between the water absorption and other properties of concrete is analyzed.

2. Experimental programs

2.1. Materials

The cement (C) used is 42.5 ordinary Portland cement, its density is 3.15 g/cm^3, its specific surface area is 350 m^2/kg, and 28d compressive strength is 48.6 MPa. Fly ash (FA) is class Ⅱ fly ash, its specific surface area is 380 m^2/kg, and its density is 2.41 g/cm^3. The specific surface area of ground granulated blast furnace slag (GGBFS) is 440 m^2/kg, and its density is 2.87 g/cm^3. The chemical compositions of binders are shown in Table 1. The fine aggregate is river sand, and its fineness modulus is 2.7. The coarse aggregate with nominal maximum size of 15 mm is limestone gravel, and its crushing value is 8.0%. A polycarboxylate superplasticizer (SP) is used in the mixes and its water reduction rate is 30%.

2.2. Mix proportions

In all mixes, the content of cement, aggregate, water and superplasticizer is kept constant, and the content of mineral admixtures is 50% of the mass of binders, but the content of fly ash and GGBFS is changed. The mix proportions and compressive strength are shown in Table 2.

2.3. Experimental methods

2.3.1. Water absorption

Water absorption measurements carry out according to GB/T 9966 [17]. The specimens with dimensions of 100 × 100×100 mm are placed in the oven with the temperature of 110 ± 5 °C for 48 hours (short for h), and the mass of the test specimen is m_0 after cooling to room temperature, and then the specimen is immersed in water for 3d, and the mass of the specimen with the saturated surface dry state is weighed as m_1. Then the water absorption α can be calculated as following:

$$\alpha = \frac{m_1 - m_0}{m_0} \times 100\% \tag{1}$$

2.3.2. Capillary water absorption

Capillary water absorption (sorptivity) measurements carry out according to ASTM C 1585 [18]. For this test, three specimens having dimensions of Φ100×50 mm are employed. At first, the specimens are put into oven at 110 ± 5 °C until a constant weight and

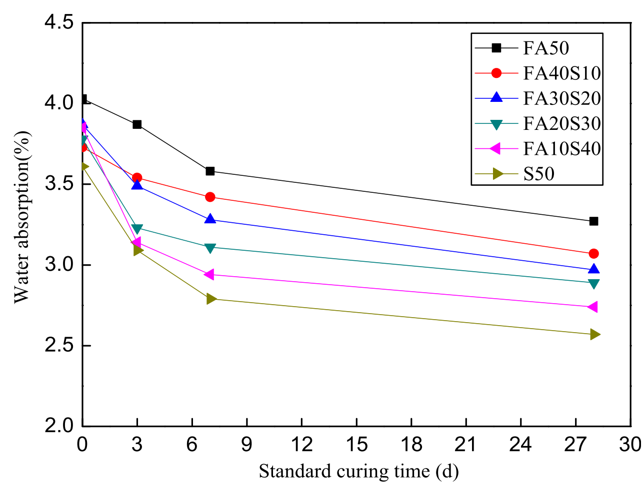

Fig. 1. Influence of curing time on water absorption of concrete.

Table 1
Chemical composition of binders (%).

Material	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	LOI
Cement	4.3	21.1	2.5	0.1	65.9	1.5	0	0.5	3.2
Fly ash	26.9	55.2	5.6	1.7	2.7	1.0	0.9	2.4	2.9
GGBFS	15.0	31.0	0.3	0.9	37.4	9.4	0	0.5	4.0

Table 2
Mix proportion and compressive strength of concrete (kg/m^3).

Mix code	C	FA	GGBFS	Sand	Gravel	Water	SP	Compressive strength (MPa)*
FA50	190	190	0	660	1080	209	0.50%	31.7
FA40S10	190	152	38	660	1080	209	0.50%	33.2
FA30S20	190	114	76	660	1080	209	0.50%	34.4
FA20S30	190	76	114	660	1080	209	0.50%	34.8
FA10S40	190	38	152	660	1080	209	0.50%	36.3
S50	190	0	190	660	1080	209	0.50%	36.4

* 28-day (short for d) compressive strength with 28d standard curing.