Experimental study of resistance of concrete to sulphate attack

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Abstract. According to the new standard of China, the effect of water binder ratio and the strength grade and mineral mixture on the resistance of concrete to sulphate attack was studied. The results of the study show that, reducing water binder ratio to enhance the strength of concrete can improve the resistance of concrete to sulfate attack; adding fly ash or slag into concrete can also improve the resistance of concrete to sulfate attack. The research results have certain reference value for the revision of China's standard of the resistance of concrete to sulfate erosion.

Introduction

In China lots of areas have sulfate. When constructing concrete structures in these areas, the sulfate will have an important impact on the durability of concrete structures [1-3]. Therefore, the study of the effect of the sulfate on the durability of concrete structures has important significance. Before 2009, China had not national standard on resistance of concrete to sulfate erosion; and when experiments of the resistance of concrete to sulfate attack were conducted, there were such several different test methods [4-5] as Qiao Hongxia's test method [3], Liang Yongning's test method [6], Leng Faguang's test method [5] and Feng Naiqian's test method [7]. Experiment processes of these methods are not unified resulting to the difference of the test results [8-13]. In 2009 China issued the standard on resistance of concrete to sulphate attack [14]. Since promulgation time of the standard is short and experimental process is too complex, reports used this standard is little.

Based on the new standard, this paper studied effect of water cement ratio and strength on the resistance of concrete to sulfate attack.

Experimental materials, instruments and methods

Experimental materials

Main materials used in paper are as follows:(1) Cement is produced by Jidong Cement Company and the type of cement is P.O 42.5 ordinary Portland cement. The density of cement is 3100kg/m^3. (2) Fly ash is I-Class fly ash meeting the national standard GB/T 1506-2005. The density of fly ash is 2300kg/m^3. (3) Slag powder is S95-Class slag powder meeting the national standard GB/T 18046-2000. The specific gravity is 2500 and the specific surface area is 443m^2/kg. (4) Sand is Ⅱ-Class medium sand. The density is 2650kg/m^3 and the fineness modulus is 2.8. (5) Stone is Ⅱ-Class Granite gravel. The particle size range is 5-30mm continuous grain. (6) Water reducer is polycarboxylate superplasticizer. The water-reducing rate is more than 20%. (7) Water is drinking water of Beijing.

Experimental instruments

The main instruments used in the experiment are as follows: (1) Concrete blender is single horizontal shaft forced concrete blender. The blender model is HJW-60. (2) Press machine is CSS-YAW servo pressure machine. (3) Oven is HF-1 common electric heating constant temperature oven and the highest temperature is 200 ℃。

Experimental methods

Considering such factors as types of mineral admixture, cementitious materials content and water cement ratio, different strength of concretes were prepared. Mineral admixture are fly ash and slag. powder. Content of fly ash and slag is 40% and 50% respectively. The water cement ratios are 0.55, 0.50, 0.45, 0.40 and 0.35. Mixture ratio of concrete is shown in table 1.

Tab. 1 The mixture ratio of concrete

Number	Design strength (MPa)	Cement (kg/m^3)	Water (kg/m^3)	Sand (kg/m^3)	Stone (kg/m^3)	Fly ash (kg/m^3)	Slag poweder (kg/m^3)	water reducer (kg/m^3)
G-1	30	380	209	650	1150	-	-	1.57
G-2	30	228	209	650	1150	152	-	1.57
G-3	30	190	209	650	1150	-	190	1.57
H-1	35	410	205	650	1110	-	-	1.73
H-2	35	246	205	650	1110	164	-	1.73
H-3	35	205	205	650	1110	-	205	1.73
I-1	40	450	202.5	650	1050	-	-	1.89
I-2	40	270	202.5	650	1050	180	-	1.88
I-3	40	225	202.5	650	1050	-	225	1.88
J-1	45	480	192	640	1030	-	-	2.11
J-2	45	288	192	640	1030	192	-	2.12
J-3	45	240	192	640	1030	-	240	2.12
K-1	50	510	178.5	620	1020	-	-	1.41
K-2	50	306	178.5	620	1020	204	-	1.56
K-3	50	255	178.5	620	1020	-	255	1.71

Sample preparation method

Mixing method of concrete refers to the standard of GB/T 50080-2002. The concrete admixtures are loaded into cubes dies with the length of 100mm. After one day, demould and cure to specified age.

Compressive strength test method

Compressive strength test method refers to ‘Standard for test method of mechanical properties on ordinary concrete’ (GB/T 50081-2002).

Test method of resistance of concrete to sulfate attack

Test method refers to ‘Standard for test methods of long-term performance and durability of ordinary concrete’ (GB/T 50082-2009). Resistance coefficient to sulfate attack of concrete is calculated based on the following formula:

$$K_f = \frac{f_n}{f_0} \times 100\% \quad (1)$$

Where: K_f is the resistance coefficient to sulfate attack of concrete，%; f_n is average value of compressive strength after N times sulfate attack, MPa; f_0 is average value of compressive strength of concrete at the same curing age as the concrete attacked by sulfate, MPa.

Experimental results and analysis

Experimental results of resistance to sulfate attack of concrete are shown form figure 1 to figure 5.

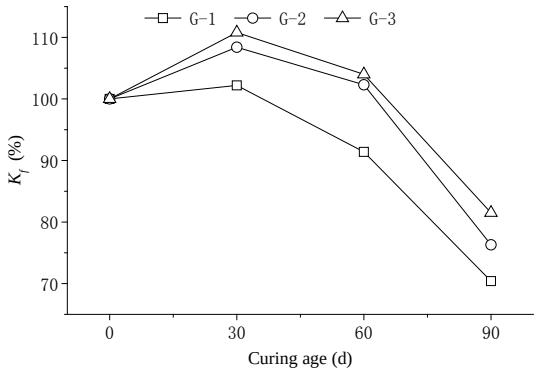

Fig. 1 Resistance coefficient to sulfate attack of concrete when water cement ratio is 0.55

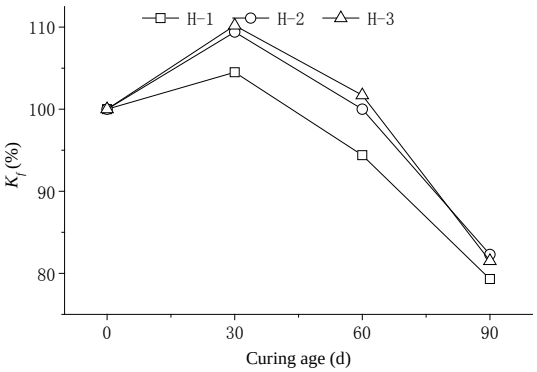

Fig. 2 Resistance coefficient to sulfate attack of concrete when water cement ratio is 0.50

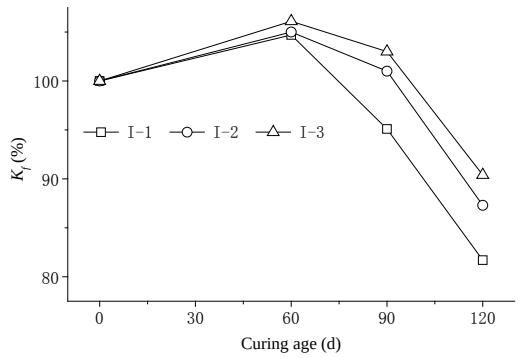

Fig. 3 Resistance coefficient to sulfate attack of concrete when water cement ratio is 0.45

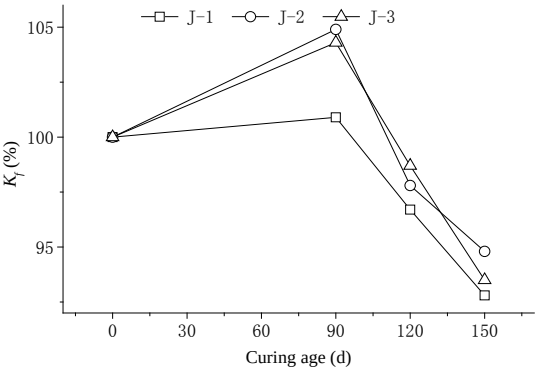

Fig. 4 Resistance coefficient to sulfate attack of concrete when water cement ratio is 0.40

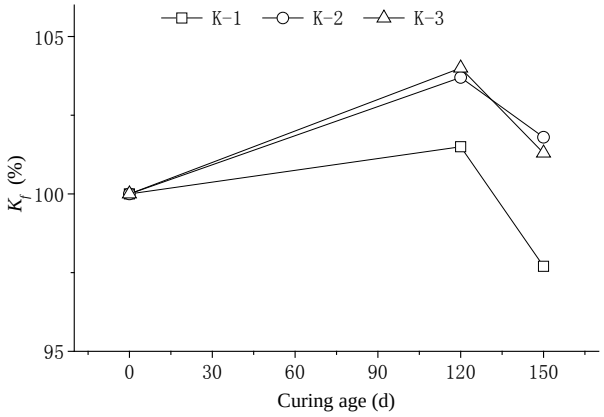

Fig. 5 Resistance coefficient to sulfate attack of concrete when water cement ratio is 0.35

It can be known from above figures:

(1) When concrete of different strength were immersed in sulfate solution, compressive strength increased slightly before a certain age and then decrease after that age. Meanwhile when strength grade of concrete is improved, the resistance to sulfate attack of concrete is better. For example strength of K group concretes still increased after 120d ages of sulfate attack; while the strength of G group concretes decreased after 90d ages of sulfate attack. The ages at which the resistance coefficient to sulfate attack of concrete is lower 100% are improved with the strength of concrete. This indicates that increasing the strength can improve the resistance coefficient to sulfate attack of concrete.

(2)For concrete of the same strength grade, when mineral admixtures were added into concrete, increment of concrete strength is greater than that of concrete without adding mineral admixture. For example when water cement ratio is 0.55, the resistance coefficient to sulfate attack of concrete

without any mineral admixture (G-1) is 102.2% after 30d of sulfate attack, while the resistance coefficients to sulfate attack of concrete with mineral admixtures (G-2 and G-3) are 108.4% and 110.8%. This shows that adding admixture into concrete can improve the resistance to sulfate attack of concrete.

Conclusion

(1) Decreasing the water cement ratio to improve strength of concrete can improve resistance to sulfate attack of concrete.

(2) When such mineral mixtures as fly ash or slag powder are added into concrete, resistance to sulfate attack of concrete can be improved greatly.

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