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The Influence of Waste Glass Powder on the Chloride Binding Capacity of Fly Ash/Cement hardened paste

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ABSTRACT

The potential of using waste glass powder to increase the chloride binding capacity of fly ash/cement hardened paste was investigated. When only fly ash replacing cement, the chloride binding capacity was raised within 28d when the fly ash replacement level was in the range from 30-50% by mass. But at a longer age of 60 to 90d, the binding performance was increased at the replacement level of 10-30wt%. The chloride binding capacity of glass powder-fly ash-cement system was increased by adding glass powder of 2% and 4% by mass at 7d while those at larger addition and longer age reduced. The reduction was found to be related to the release of alkali ion due to the addition of glass powder in the paste.

Keywords: Waste glass powder, fly ash, hardened cement paste, chloride binding capacity

1.0 INTRODUCTION

Since the chloride induced corrosion pose threat to the durability of many concrete structures, it is important to control the chloride penetration in the hardened concrete. Mineral admixtures, especially those contained aluminum oxide, were used by some researchers to decrease the chloride penetration by increasing the chloride binding capacity of cement paste (Meng and T. Cheewaket 2010). It was reported that fly ash (simplified as FA) showed the ability mentioned above and was used popular as a major kind of cementitious materials (Sun 2016). But the hydration of fly ash is rather slow in concrete, it needs the alkali activation to increase its solubility as well as the chloride binding capacity (Shi 2005, Yang 2007). The powder of waste flat glass (simplified as GP) ,which contain Na_2O and show some degree of hydration, perhaps can be used in concrete to activate fly ash. In this paper, the mixtures with different ratio of GP and FA were added to cement paste. The influence of GP on the chloride binding effect of this composite system was investigated.

2.0 EXPERIMENTS PROCEDURE

2.1 Materials

Table 1 summarize the physical properties of control Portland cement produced in China. Table 2 gives the chemical composition of this cement. The chemical composition of FA and GP are given in Table 3 and Table 4 respectively. The specific surface of GP is 400m^2/kg. The analytic pure agent of NaCl was used in this research.

Table 1. Physical properties of control cement

fineness (mm)	density (g/cm^3)	Specific surface (m^2/kg)	consistency (%)	Soundness mm	
1.8	3.14	350	26.6	0.5	
Initial setting time	Final setting time	Flex-stren 7d Mpa	Flex- stren 28d Mpa	Comp-stren 7d Mpa	Comp-stren 28d Mpa
155	220	5.3	7.1	27.6	49.2

Table 2. Chemical composition of control cement

Item	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3
Mass %	54.86	26.10	6.33	4.22	2.6	2.66
Item	f-CaO	Cl	LOI			
Mass %	0.71	0.011	2.16			

Table 3. Chemical composition of fly ash

Item	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3
Mass %	6.84	52.43	26.45	6.17	2.05	1.13
Item	K_2O	Na_2O	TiO_2			
Mass %	2.27	0.94	1.10			

Table 4. Chemical composition of waste glass powder

Item	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3
Mass %	11.37	68.37	1.08	0.70	4.20	0.80

Item	K_2O	Na_2O	TiO_2
Mass %	0.36	12.81	0.23

2.2 Experiments methods

Fly ash cement paste

In this part, the influence of fly ash dosage on the chloride binding ability of cement paste was studied. The water binder ratio is 0.4 and 1.2% (by mass to binder) NaCl was added to this system. The size of FA cement paste is 40 mm×40 mm×160 mm. After demolding at 24 hours, the specimens were covered by preservative film and kept in standard curing room. The chloride binding capacity of the hardened paste was measured by following steps.

Firstly, grinding the hardened cement paste at planned age, the grains with size of 0.63-1.24 mm were selected. After drying 2 hours at 50±5℃ in an oven, the grains were cooling to room temperature in a desiccator. Then 30 g (precise to 0.01 g) sample was put in a conical flask, adding 200 ml distilled water and keep static for 24 hours after shaking violently 1-2 minutes. Thirdly, the filtrate's chloride concentration C1 （mol/L） was measured by potentiometric titration and V1 was the total volume.

The total chloride content in 30 g sample after 2 hours drying at 50 ℃ was measured by acid solution method (Meng 2010). The chloride concentration (mol/L) of volume V(ml) solution can be get by potentiometric titration. Then the binding chloride content, B (mg/g) in the paste can be calculated as following:

$$B=\frac{CV-C_1V_1}{30}\times 35.5 \qquad (1)$$

Composite powder cement paste

In this part, the chloride binding capacity of composite powder (GP and FA) was studied. A composite material was made by mixing waste glass powder and fly ash according to a ratio of GP: FA=1 : 4. An earlier research showed that this ratio benefit to the chloride binding ability (Gou 2011). After adding the different dosage of composite powder to the cement, the chloride binding capacity of hardened cement pastes were measured with the same method mentioned above.

XRD analysis of hardened paste

Shimadzu XRD-7000X was used to analyze the hardened paste samples. The parameters are as following: characteristic X ray wave length 1.54060 Å, tube current 30 mA, tube voltage 40kV, target material copper, scanning scale 10-70°, step length 0.02°.

Alkali metal concentration

When testing total chloride concentration of the hardened paste, the quantity of soluble K_2O and Na_2O were measured by flame photometer.

3.0 RESULTS AND DISCUSSION

3.1 Influence of FA on the chloride binding

The relation of FA dosage and chloride binding quantity is shown in Fig.1. It can be seen that the binding quantity of chloride increase with the replacement level at 7 days, but this trend changed when age is longer than 7 days. The longer the age, the biggest binding amount appeared on the smaller dosage.

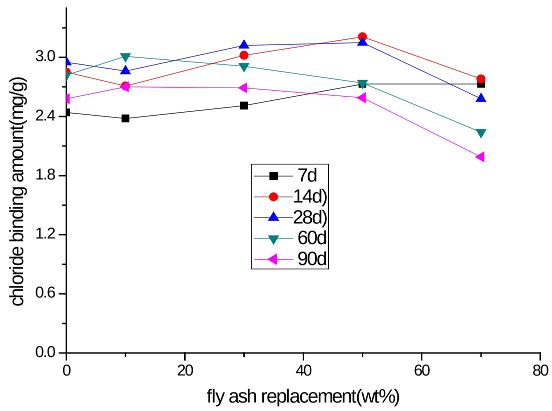

Fig. 1. The influence of fly ash dosage on the binding capacity of chloride

The influence of age on the different replacement level is shown in Fig. 2. It can be seen that the biggest binding capacity appeared at 14 days when FA replacing 50% or 70% cement. However, when no FA or the replacement level is 10%, the binding peak appeared at 60 days. When the replacement level of FA is 30%, the highest binding is at 30 days.

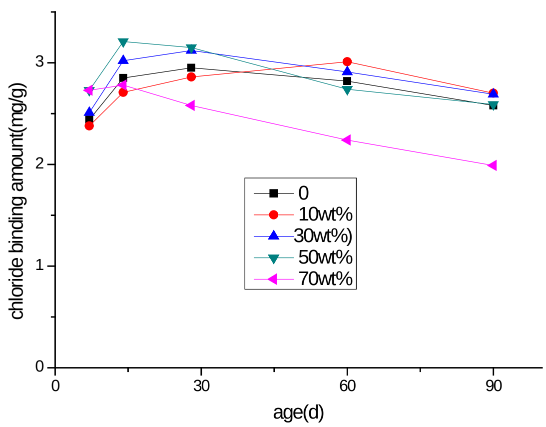

Fig. 2. The binding of chloride varies with age at different fly ash replacements

Compared with the control cement paste, at the age of 60 d or 90 d, only two replacement level of 10% and 30% showed an increased binding capacity. But at the age of 14 d or 28 d, the sample with 30% and 50% FA had a higher binding ability than the control.

Considering the above age influence, practically, the replacement level of FA should not be more than 30% (by mass) if want to increasing the chloride binding capacity.

3.2 XRD analysis of FA cement paste

The hydration of hardened pastes with NaCl and different fly ash level were terminated at 14 d or 28 d, then the grinding powder was analysed by XRD. The results are shown in Fig. 3.

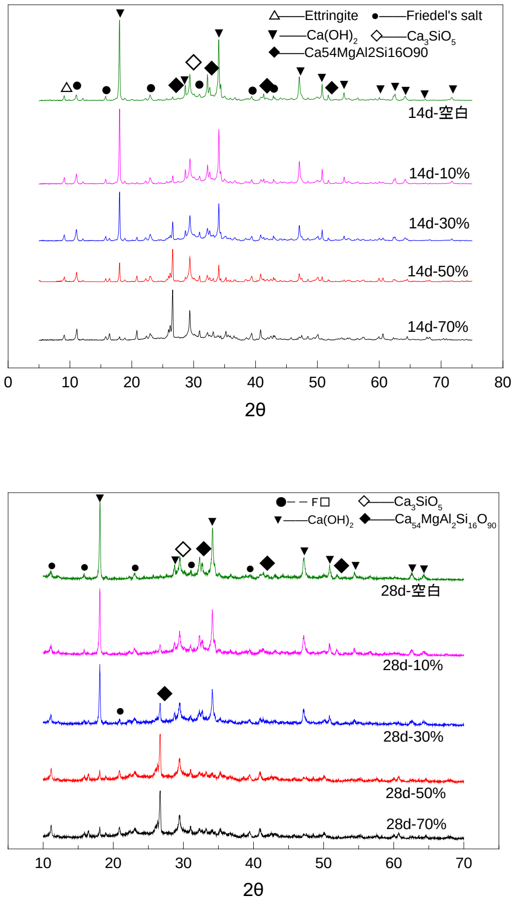

Fig. 3. XRD results of cement paste with fly ash at the age of 14 days and 28 days

From Fig. 3, it can be seen that the peak of calcium hydroxide decreases with aging while that of Friedel salt increase. When the FA replacement level is 50% or 70%, the quantity of calcium hydroxide is too little to support the forming of Friedel salt, which confirm the results shown in Figs.1 and 2. So high replacement level of fly ash does not help increase the chloride binding capacity.

3.3 Influence of composite of GP and FA on the chloride binding

A series of hardened paste with different dosage of composite powder were analyzed to get the chloride binding amount, which is shown in Table 5. As mentioned before, the ratio of GP to fly ash is 1:4 when adding composite powder to cement.

Table 5. Composite powder replacement plan

	1	2	3	4	5	6	7
Cement %	100	90	80	60	92	84	68
GP %	0	2	4	8	0	0	0
FA %	0	8	16	32	8	16	32

* by mass

The influence of composite powder on the chloride binding capacity can be seen in Fig. 4.

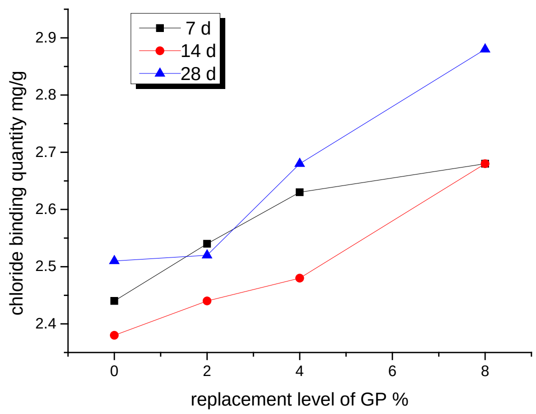

Fig. 4. Chloride binding when adding composite powder

It seems that the chloride binding capacity increases when the GP replacement level rise. The chloride binding capacity at the age of 7 d is higher than that of 14 d, and reach highest at the age of 28 d.

But this effect is a combined function of GP and FA. As shown in Table 5, column 2 corresponding to 2% GP + 8% FA. Fig.4 means that composite powder really works.

In order to further understand the effect of GP, the difference between column 2 and 5, column 3 and 6, column 4 and 7 (in Table 5) should be tested. The results at 7 d, 14 d and 28 d were shown in Fig. 5.

From Fig. 5, it can be seen that at early age such as 7 days, the GP+FA enhance the chloride binding capacity, but when the age increase, FA shows a better binding capacity. Though the difference is not so remarkable.

3.4 Alkali ions analysis of hardened paste

In order to understand the mechanism of the changes of chloride binding capacity when adding GP, the quantity of alkali ions, including K_2O and Na_2O, was analysed using the same solution for testing chloride content. The results is shown in Fig. 6.

It can be seen that the quantity of soluble alkali ions increases with the age as well as the replacement of waste glass powder, which means more alkali ions were released to the pore solution of hardened paste. And then the formation of Friedel salt will be reduced which explain the falling of chloride binding capacity. Some researchers had also mentioned that the high alkali ions will affect the C-S-H gel of cement paste inducing the poor capacity of chloride binding (Ipavec *et al.* 2013).

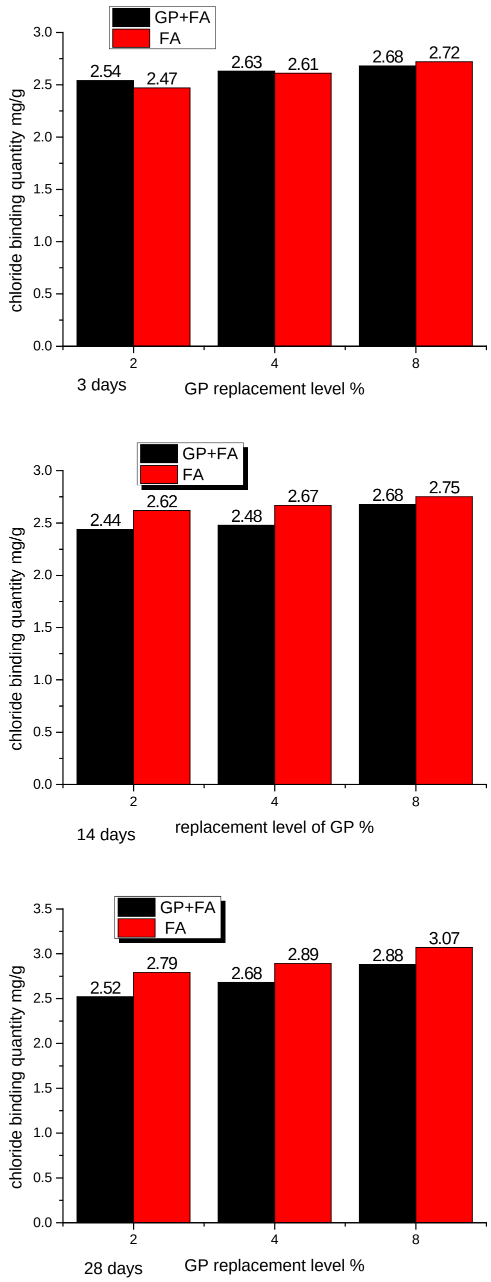

Fig. 5. chloride binding effect of GP and GP+FA

4.0 CONCLUSIONS

Based on a method to quantify the chloride binding capacity of cement paste, hardened paste of fly ash cement and composite powder adding cement were grinded to investigate the influence of a kind of glass powder as well as a local fly ash. Following conclusions can be made:

1. The chloride binding capacity of this kind of fly ash cement paste influenced by the age and replacement level.

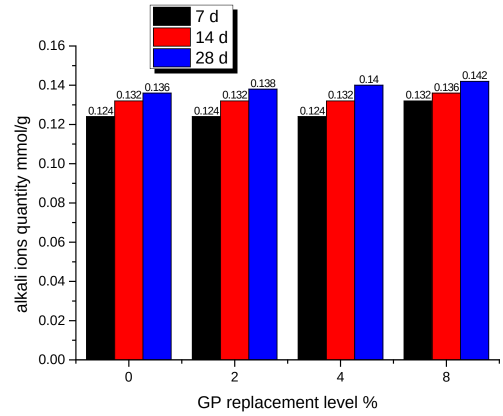

Fig. 6. soluble alkali ions in hardened paste

2. The highest binding capacity appeared at 14 days when FA replacing 50% or 70% cement. However, when no FA or the replacement level is 10%, the binding peak appeared at 60 days. The chloride binding behaviour of FA is related with the content of calcium hydroxide in the hardened cement paste.

3. The chloride binding ability can be increased by adding 2-8% waste glass powder to FA cement in the early age. The binding capacity will decrease when age become longer since more soluble alkali ions in the paste will affect the binding process adversely.

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