Experimental research on alkali activated slag cement materials

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Abstract. There are many factors effecting the property of alkali-activated slag cementitious material. The setting time test, flexural strength test and compressive strength test were carried in the laboratory. The test results show that following the glass modulus increased, both setting times showed a trend of first decreasing and then increasing, while the flexural strength and compressive strength showed an opposite rule. The cement aggregate ratios 1:1.5 contributed the better performance of alkali slag cement. The compressive strength of curing alkali cementitious material increases with the prolonging of curing time.

Introduction

Alkali activated slag cementitious material is a cementitious material by a potential hydraulic material - slag and alkaline activator into reaction [1-3]. This properties such as compressive strength, flexural strength, resistance to acid and alkali corrosion, freeze-thaw resistance and carbonation resistance of cementitious materials are better than those of ordinary portland cement [4].

In addition, the preparation process of the slag cementing material is simple, which can handle a large amount of industrial waste slag [5]. Furthermore, alkali activated slag cementitious do not need to burn, and have low energy consumption. In addition, alkali activated slag cement and concrete have a series of excellent physico-mechanical properties and durability such as rapid hardening , high strength , low heat of hydration and durability and resistance to freeze-thaw , and high resistance to chemical attract. So the material is a kind of environmental protection type "green material".

At present, alkali activated slag cementitious has been used widely in many countries. However, there are still a lot of problems in alkali activated slag cement materials, such as the influence of water glass modulus and alkali equivalent on the setting time and strength of alkali activated slag cement are different, which restricted the expanded application [6-7]. In order to produced the best slag cementitious materials, this paper aimed at the influence factors of the performance of alkali activated slag cementitious materials.

Materials and experiments

Materials. A typical 52.5 portland cement was selected in this study, which was common used in China , China. The specific area, density, initial setting time and final setting time of the cement are 342 m^2/kg, 3.09 g/cm^3, 162 min and 226 min. Table 1 shows the chemical compositions of the cement. The slag used in this study was water quenched blast furnace slag, the specific area is 457m^2/kg, the density is 2.83g/cm^3, the activity coefficient is 0.31, the basic coefficient is 1.05 and the mass coefficient is 1.65. Table 2 shows the chemical compositions of the slag. The water reducer in this study is polycarboxylate superplasticizer and the alkali activator is NaOH. Table 3 shows the physical and chemical properties of the alkali activator. The standard sands used is produced from Guangxi province,which density is 2.6 g/cm^3.

Table 1 Compositions of the cement

Component	SiO_2	CaO	Al_2O_3	Fe_2O_3	MgO	SO_3	Loss
Content /%	26.44	53.84	7.45	4.31	2.36	2.36	1.92

Table 2 Compositions of the slag

Component	SiO_2	CaO	Al_2O_3	Fe_2O_3	MgO	TiO_2
Content /%	36.44	40.82	10.45	2.31	8.61	0.16

Table 3 Physical and chemical properties of the alkali activator

Component	SiO_2	Na_2O	M_s	Density/g/cm^3
Content /%	26.46	9.96	2.76	1.415

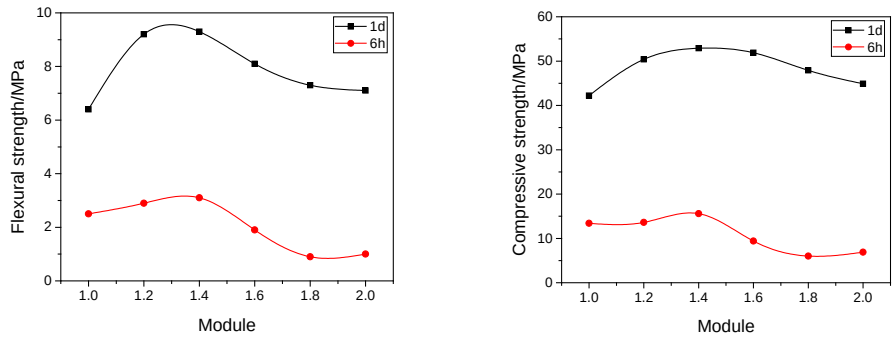
Specimen preparation. In this study, the alkali activated slag system was prepared by mechanical stirring. The slag and sand were added into the blender and then the NaOH was slowly added into for 2 min.

Experimental method. To research the properties of the cement mortar, the experimental in this study include setting time test, slump test, mortar density determination and gas content calculation.the mortar strength tests include flexural strength, compressive strength and tensile bond strength test.

Results and discussions

Effect of glass water module on the strength of alkali slag cement. When using water glass as alkali, alkali slag cement has the advantage of hardening fast and high strength, which has aroused widespread concern. Current studies have shown that the glass water module had a relationship with the performance of alkali slag cement . Fig.1 shows the influence of the modulus of water glass on the flexural and compressive strength of cement mortar. In the case of fixed water cement ratio, with the increase of the modulus of water glass, mortar 6h and 1d. The compressive strength showed a trend of increasing first and then decreasing.

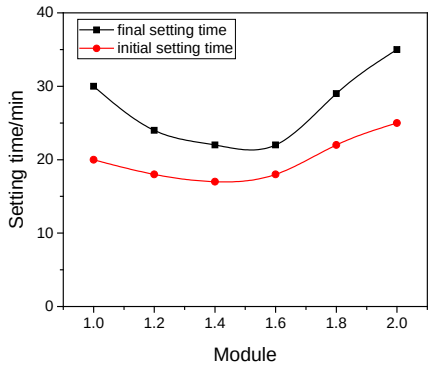
Taken the flexural strength as an example, with the glass water module increasing from 1.0 to 1.4, the flexural strength at 6 h increased near 54%, while following the glass water module increased from 1.4to 2.0, the flexural strength at 6 h decreased near 23%. The flexural strength at 1 d showed a similar pattern. At 6h and 1d, both flexural strength and compressive strength were reached the maximum at 1.4. More detailed when the glass water module was 1.4, the flexural strength and compressive strength was 3.1 MPa and 15.6 MPa at 6h, respectively. The compressive strength was 9.3 MPa and 52.9 MPa at 1d. From what has been discussed above, at the 1.4 for the glass water module, the stimulate slag cement had the highest mechanical strength.



(a) flexural strength, (b) compressive strength

Fig 1 Mechanical strengthof alkali slag cement

Effect of glass water module on the setting time of alkali slag cement. For research the effect of glass water module on the performance of alkali slag cement. This test fixed sand ratio 1:2, water cement ratio of 0.35, The content of alkali was 4%, and the water glass modulus was selected 1, 1.2, 1.4, 1.6, 1.8, and 2 of the water glass modulus. The curing conditions of the specimens were moist curing. The test results as shown in Fig 2.



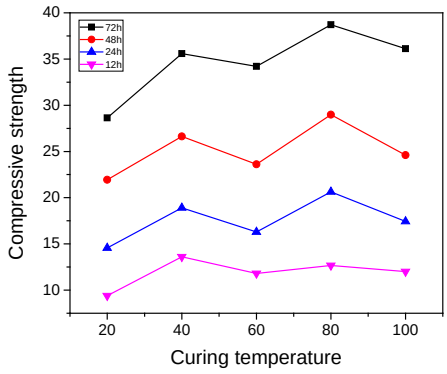


Fig 2 Setting time of alkali slag cement Fig 3 Curing temperature on alkali slag cement

Figure 2 shows the effect of the water glass modulus on the setting time, from which we can see that the alkali activated slag cement. The change of coagulation time of coagulation system is with the increase of the modulus of water glass, the trend of the first decreases and then increases. Taken the initial setting time as an example, when the glass water module increased from 1.0 to 1.4, the initial setting time decreased near 10%, while when the glass water module increased from 1.4 to 2.0, the initial setting time increased near 34%.

Furthermore, when the water glass modulus was 1.4, the coagulation time was the shortest, the initial setting was 17min, and the final setting was 22 min. When the water glass modulus is lower than 1.4, the Si-O bond content of the water glass is lower, so the concentration of Si-O in the liquid phase is lower. The reasons can be contribute that when the water glass modulu is higher that 1.4, the alkalinity decrease gradually, which affect the disintegrate of the slag particles. In addition, with the increase of the modulus, the root of the water in the glass decrease, while the polymer increase, which reduce the activation point of silica group and extent the setting time of alkali activated slag cement.

Effect of cement aggregate ratios on the performance of alkali slag cement. Previous studies have showed that the cement aggregate (C/A) ratios is an important factor affecting the mechanical properties of concrete. So this section aims to research the effect of cement aggregate ratios on the performance of alkali slag cement. According to the existing test results,the water glass modulus was 1.4 and the alkali content was 4%, the ratio of binder to sand was changed from 1:2 to 1:1.5, and the water glass modulus was 1.4 and the alkali content was 4%. The results were shown in Table 2.

Table 2 results of C/A on the performance of alkali slag cement

C/A ratios	Flexural strength		Compressive strength		Setting time	
	6 h	1 d	6 h	1 d	Initial	Final
1:2	3.3	9.5	15.7	52.7	15	19
1:1.5	3.8	10.6	22.6	56.4	12	17

It can be seen from table 2. The flexural strength, compressive strength and setting time have an obvious different for the different C/A ratios. Compared to the1:1.5 for C/A ratios, The value of the flexural strength, compressive strength and setting time seem lower than at the 1:2 C/A ratios.This suggested that the alkali slag cement at the 1:1.5 (C/A ratios) had the optimal performance. Furthermore, when cement aggregate ratios is 1:1.5, the flexural strength at 6h is 3.8 MPa, which meet the requirements, while the compressive strength at 6h is 22.6 MPa, which also meet the minimum strength requirements for opening traffic (flexural strength⩾3.5 MPa, compressive strength⩾20MPa).

Effect of curing temperature on the strength of alkali slag cement.

The curing system of cementitious materials, especially the curing temperature has a great influence on the formation and morphology of C-S-H gel in the hydration process. Improving the curing temperature could complete the activation of the gel material of the water hard activity of the excitation in a short period of time. When using activator, the alkali cementitious material can used a higher curing temperature, which is equivalent to the thermal excitation and chemical excitation. The

test module for 1.4 water glass as an activator. The influence of curing temperature on the compressive strength of alkali cementitious materials is shown in Figure 3.

From fig 3, it can be seen from the figure that the compressive strength of curing alkali cementitious material increases with the prolonging of curing time, which indicted the hydration reaction is effectively carried out with the prolonging of the curing time. When the curing time is 12 h, the compressive strength of the specimens cured at 20 ℃ is the lowest, while the compressive strength of the specimens cured at 40 ℃ is the highest.With the extension of curing time, the resistance of alkali cementitious materials cured at 80 ℃is better than that curing temperatures. This suggested that improving the curing temperature can significantly improve the compressive strength of alkali cementitious materials.

Summary

Through the investigate and survey technical of early strength for the cement. The performance of the alkali excitation slag matrix was studied in this paper. The setting time test , flexural strength test and compressive strength test were carried based different glass water module and cement aggregate ratios. Following conclusions can be drawn:

(1) For the initial and final setting times, when the water glass modulus increased, both setting times showed a trend of first decreasing and then increasing.

(2) For the flexural strength and compressive strength,when the water glass modulus increased, both strength showed a trend of first increasing and then decreasing.

(3) The optimal water glass modulu was 1.4 based on the results of setting time test , flexural strength test and compressive strength test.

(4) The cement aggregate ratios 1:1.5 could arrived the optimal performance of alkali slag cement, and could meet the minimum strength requirements.

(5) The compressive strength of curing alkali cementitious material increases with the prolonging of curing time.

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