WORKABILITY AND MECHANICAL PROPERTIES OF SODIUM SILICATE ACTIVATED GEOPOLYMER CONCRETE

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1. INTRODUCTION

Because of the usage of industrial by-product and waste as raw material and less emission of CO_2 in production process, geopolymer (GP) has been recognized as an environmental-friendly cementitious material as a possible alternative to Ordinary Portland Cement (OPC). Geopolymer is synthesized by using alkaline activator (often soluble silicate or hydroxide) to activate alkaline binder (materials rich in alumino-silicate, fly ash, blast furnace slag, etc.), resulting in amorphous to semi-crystal tri-dimensional silico-aluminates.

Conventionally, alkaline activator used in GP is the mixed solution of NaOH and Na_2SiO_3. However the usage of NaOH is environmental-hostile and user-hostile because of its high causticity and large amount of CO_2 emission in production process. Therefore, in order to obtain user and environmental friendly GP, $Na_2SiO_3 \cdot 9H_2O$ was used as the only activator in this research.

The objective of this study includes (1) synthesize geopolymer concrete (GPC) from fly ash (FA) and blast furnace slag (BFS) activated by $Na_2SiO_3 \cdot 9H_2O$ and (2) investigate properties of such GPC with synthesis parameters.

2. EXPERIMENT METHOD

The alkaline binder used in this study are Class Ⅱ Fly ash and Class 4000 blast furnace slag. And $Na_2SiO_3 \cdot 9H_2O$ with molar ratio of Si/Na=1.04 was used as activator. River sand and gravel (G_{max}=20mm) were used as fine and coarse aggregates.

The synthesis parameters are (1) SS%: mass ratio of $Na_2SiO_3 \cdot 9H_2O$ to activator solution; (2) BFS%: mass ratio of BFS to total binder;(3) AA/AB: mass ratio of activator to binder;(4) AR%: mass ratio of total aggregates to concrete, (5) SR%: mass ratio of fine aggregate to total aggregates. The cases for compressive strength test were shown in Table 1. Case 1~5 investigated the effect of AA/AB on compressive strength when BFS% is 30%, case 6~12 are for GPC with BFS%=60%. Case 4 and Case 9 are also used to test other properties, namely elastic modulus, splitting tensile strength, flexural strength.

The preparation of specimens follows the following steps: (1) Raw materials, aggregates and $Na_2SiO_3 \cdot 9H_2O$ crystals are dryly mixed (2) Add water and mix for 4 minutes in total (3) Cast and cure in ambient temperature.

Table 1 Cases of GPC compressive strength test

Case	AR%	SR%	SS%	BFS%	AA/AB
1	76%	50%	30%	30%	0.58
2					0.60
3					0.62
4					0.64
5					0.66
6				60%	0.58
7					0.60
8					0.62
9					0.64
10					0.66
11					0.63
12					0.65

	Proportions (kg/m^3)						
Case	W	SS	FA	BS	S	G	Total
1	141	61	244	104	905	905	2360
2	146	63	244	104	905	905	2367
3	151	65	244	104	905	905	2374
4	156	67	244	104	905	905	2381
5	161	69	244	104	905	905	2388
6	141	61	139	209	905	905	2360
7	146	63	139	209	905	905	2367
8	151	65	139	209	905	905	2374
9	156	67	139	209	905	905	2381
10	161	69	139	209	905	905	2388
11	153	66	139	209	905	905	2377
12	158	68	139	209	905	905	2384

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3. RESULT AND DISCUSSION

3.1 Workability

Slump tests were carried out for fresh concrete after mixing. The result was shown in Figure 1.

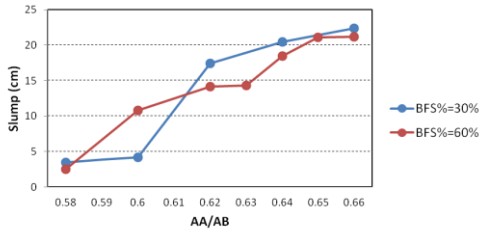

Figure 1 Relationship between slump and AA/AB

From which it can be seen that increase in AA/AB will significantly improve the workability of GPC. It is similar to OPC that increasing water cement ratio will increase workability. Also, though morphological effect of different particle shape of fly ash and slag could affect workability, it is not significant in our study.

3.2 Compressive strength

The results of compressive strength are shown in Figure 2.

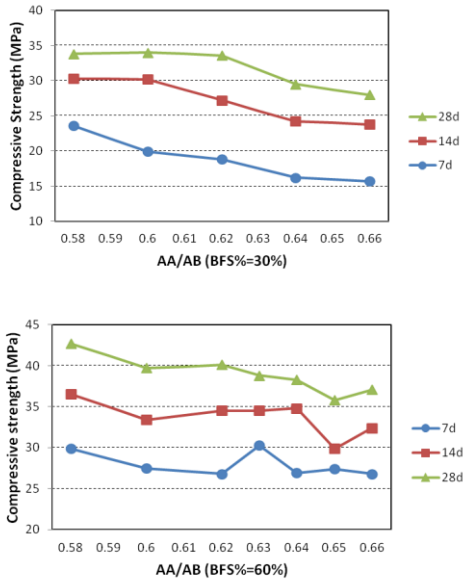

Figure 2 Relationship between compressive strength and AA/AB

Firstly, it can be observed that for every age, GPC with BFS=60% had higher strength than 30%, which indicates that increase in slag content will improve the compressive strength of GPC. First reason for this is that, higher slag content means higher Si/Al ratio which will result in more SiO_4 in polymeric chain and improve compressive strength. On the other hand, more slag will introduce more CaO into the raw material, the hydration of which will result in C-S-H and C-A-S-H that can provide extra strength. Experiment on porosity distribution confirmed that GP paste with higher BFS content tend to form smaller pore inside. Also, it is observed that increase AA/AB will reversely affect the compressive strength. This is because that the more water added, more fly ash particles will remain unreacted and more void will be left in the concrete after hardened and thus reduce compressive strength.

3.3 Elastic modulus

From this experiment, it is obtained that for case 4, elastic modulus of GPC was 17.8GPa for compressive strength of 28.6MPa; for case 9, elastic modulus was 22.2GPa for compressive strength of 38.4MPa. This result is lower comparing with OPC with same compressive strength, which is in accordance with conventional GPC activated by NaOH and sodium silicate.

3.4 Splitting tensile strength & Flexural strength

The result is shown in Table 2. From this experiment, it can be observed that the splitting tensile strength was around 1/10~1/15 of compressive strength, which is in line with previous studies on conventional GPC. In case of OPC, the ratio should be around 1/8~1/13, which is a little higher than GPC. And it is found that the flexural strength of GPC was around 1/8~1/10 of compressive strength, and the ratio of splitting tensile strength to flexural strength was 59.9%~67.6% which is in line with OPC whose ratio is 50%~75%.

Table 2 Splitting tensile strength and flexural strength

	Splitting tensile strength (MPa)		Flexural strength (Mpa)		Elastic modulus
Case	7 d	28 d	7 d	28 d	28d
4	1.59	1.99	6.32	3.32	17.8GPa
9	2.09	2.52	3.96	3.73	22.2Gpa

4. CONCLUSIONS

In this research, it is found that increasing AA/AB will significantly improve the workability of $Na_2SiO_3 \cdot 9H_2O$ activated GPC and inversely influence compressive strength. And increasing BFS% will improve compressive strength. Results from mechanical properties showed that this sodium silicate activated geopolymer has similar performance as conventional GPC and OPC.

REFERENCES

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