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Dynamic Properties of Non-Cement Matrix Based on Blast Furnace Slag and Polysilicon Sludge Ratio and Addition Rate of Alkali Activator†

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With the advancement of photovoltaic industry, 2 tons of sludge are generated from the production of 1 ton polysilicon, which is the main raw material of the solar module used for solar power generation. The polysilicon sludge that is generated in this way is disposed of as waste in whole quantity because there is no recycling method. Therefore, this study is intended to analyze the dynamic properties of non-cement matrix using NaOH, the alkali activator and blast furnace slag and polysilicon sludge which are the industrial byproducts without using any cement. The results of the experiment showed that optimum addition rate of NaOH was 7 % and optimum substitution rate of polysilicon sludge was 15 %.

Keywords: Blast furnace slag, Polysilicon sludge, Solar power generation, Non-cement.

INTRODUCTION

As the environmental contamination related to global warming worldwide has come in force, the cement commonly used in construction industry is causing a massive amount of carbon dioxide during the sintering process, thus exacerbating the global warming[1].

Furthermore, photovoltaic industry has grown rapidly at an annual average rate of over 30 %, the fastest rate. However, the photovoltaic industry faces major environmental challenge because 2 tons of sludge are generated from the production of 1 ton polysilicon, the main raw material of the solar module used for solar power generation. The polysilicon sludge generated in this way is disposed of as waste in whole quantity due to unavailability of recycling method. This practice is leading to another environmental contamination in the course of eco-friendly green energy production[2].

As a result, the solar photovoltaic power is expected to surpass the consumption of fossil fuels from 2040 and a growing number of polysilicon production plants have been built worldwide. However, little research has been conducted to develop polysilicon sludge recycling process, which makes it urgent to push forward the research in this field.

The purpose of this study was to explore the measures for recycling the polysilicon sludge by making use of blast furnace slag and polysilicon sludge, the industrial by-products, without using any cement and to analyze dynamic characteristics of non-cement matrix through the addition of NaOH, the alkali activator.

EXPERIMENTAL

The materials used in this study were the blast furnace slag (BFS), polysilicon sludge (PS) and NaOH, the alkali activator. The blast furnace slag used in this study was the type III which had a density of 2.91 g/cm^3 and fineness of 4,460 cm^2/g while the polysilicon sludge, the high purity multi-crystal molecules, had a density of 1.75 g/cm^3 and fineness of 7,120 cm^2/g. Meanwhile, NaOH was a 98 % high-purity powder type and had a density of 2.13 g/cm^3. Table-1 presents chemical component of blast furnace slag and polysilicon sludge.

Experimental setup: This experiment had the factor and levels as shown in Table-2, fixed W/B to 0.4 and used the blast furnace slag and polysilicon sludge as binders. Regarding the ratio of binder and alkali activator, 5 % NaOH was firstly added at a ratio of BFS 85:PS 15. Secondly, the NaOH 3, 5 and 7 (%) was added at a ratio of BFS 80:PS 20.

Finally, 5 % NaOH was added at a ratio of BFS 75:PS 25. Those ratios were defined to derive optimum ratio of blast furnace slag and polysilicon sludge, along with optimum addition amount of alkali activator. In addition, the polysilicon

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TABLE-1
CHEMICAL COMPONENT OF USING MATERIALS

Materials	Chemical components (%)							
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	TiO_2
BFS	35.08	13.87	0.52	41.10	3.60	2.36	–	1.20
PS	46.60	0.57	–	45.16	0.69	0.16	2.16	–

TABLE-2
EXPERIMENTAL FACTOR AND LEVEL

Factor	Level			
W/B	0.4			1
Binder	BFS (Blast furnace slag), PS (Polysilicon sludge)			2
Binder and alkali activator ratio	BFS 85: PS 15 NaOH 5 %	BFS 80: PS 20 NaOH 3, 5, 7 %	BFS 75: PS 25 NaOH 5 %	5
Curing condition	Relative humidity (80 ± 5) %, Temperature (20 ± 2) °C			1
Test item	Table flow, pH, density, water absorption ratio, flexural strength, compressive strength			6

Fig. 1. Polysilicon sludge pulverization process

sludge was used to substitute the blast furnace slag while the alkali activator was added to the binder. The curing was made in constant temperature and constant humidity condition. The test items were the table flow, pH, density, water absorption ratio, flexural strength, compressive strength, *etc*.

Methodology: As the polysilicon sludge contains large amount of water, it underwent drying process and separate pulverization process as shown in Fig. 1 before being used as binder. The NaOH, the powder type, was dissolved in the mixing water for use. Regarding the mixing method, the blast furnace slag and polysilicon sludge were mixed for 90 seconds and then added with the mixing water containing the dissolved NaOH and mixed for 120 seconds before being discharged.

RESULTS AND DISCUSSION

Flowability and pH: Fig. 2 presents the measurement of flowability and pH. The flowability tended to increase as the addition rate of NaOH increased and tended to decrease as the replacement ratio of polysilicon sludge increased. That is considered attributable to active reaction with binder and resultant increase in flowability when the addition rate of NaOH increases.

When the replacement ratio of polysilicon sludge increased, the flowability decreased as the replacement ratio increased due to low density and high degree of fineness of polysilicon sludge, a high-purity multi-crystal molecular structure. The pH tended to increase slightly as the addition rate of NaOH is increased and exhibited high basicity in all test specimens.

Density and water absorption ratio: Fig. 3 presents the measurements of density and water absorption ratio. The density tended to increase as the addition rate of NaOH increased. Meanwhile, the density tended to decrease as the replacement ratio of polysilicon sludge increase. Such tendency is considered to be closely related to the unit volume weight of the material itself. The density is considered to have decreased as the replacement ratio of polysilicon sludge, which has relatively low density, increased. Regarding the water absorption ratio,

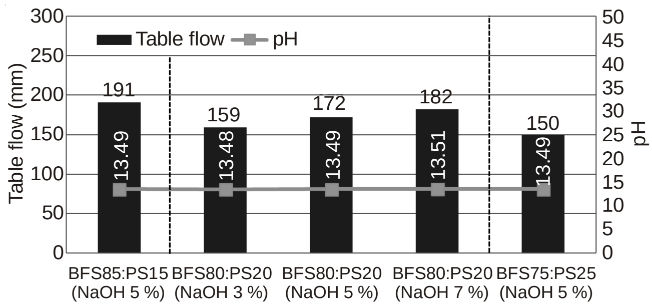

Fig. 2. Flowability and pH

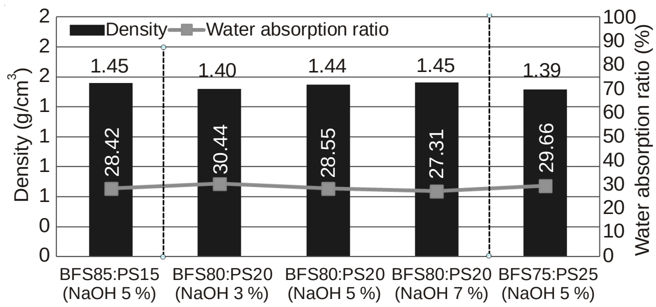

Fig. 3 Density and water absorption ratio

the water absorption ratio tended to decrease as the addition rate of NaOH increased.

However, the water absorption ratio tended to increase as the replacement ratio of polysilicon sludge increase. This suggests that the test specimen was densely filled due to the high reactivity with binder when the addition rate of NaOH increased. When the replacement ratio of polysilicon sludge increased, the water absorption ratio is considered to have increased due to the high degree of fineness of polysilicon sludge in the same way as the results of flowability.

Flexural strength and compressive strength: Fig. 4 presents the measurements of flexural strength and compressive strength, showing that the flexural strength tended to decrease as the age increased. Meanwhile, the flexural strength increased as the addition rate of NaOH increased. As the replacement ratio of polysilicon sludge increased, the flexural strength increased until the replacement ratio of 20 % was reached and decreased when the replacement ratio of 20 % was exceeded. This suggests that the flexural strength decreased as the age increased due to the crack which could be observed visually in the surface of test specimen.

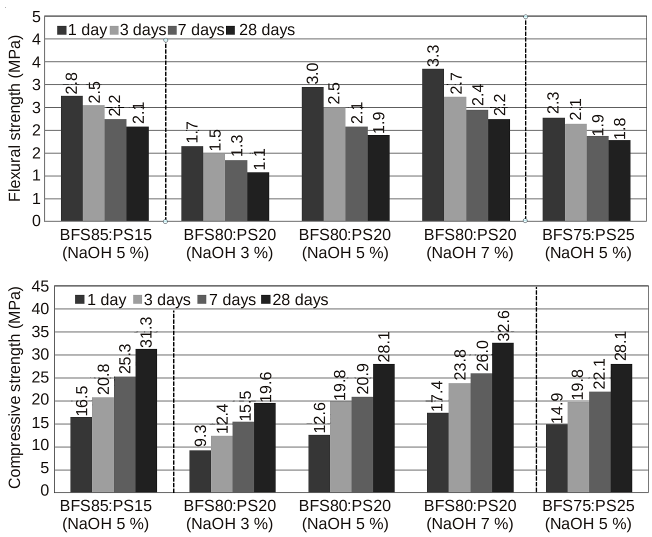

Fig. 4. Flexural strength and compressive strength

The compressive strength increased as the addition rate of NaOH increased, but decreased as the replacement ratio of polysilicon sludge increased. This suggest that the compressive strength decreased with the increase in replacement ratio of polysilicon sludge as the amount of pores increased in the test specimen due to H_2 generated by non-reacted Si component contained partially in polysilicon sludge that has the form of silicon oxide.

Conclusions

The dynamic properties of non-cement matrix were analyzed based on the ratio of blast furnace slag and polysilicon sludge and addition rate of alkali activator. The results of analysis are as follows.

• The flowability was the highest in the test specimen at the ratio of BFS 85: PS 15 (NaOH 5 %). The flowability increased as the addition rate of NaOH rose. The pH showed high basicity in all test specimens.

• The density increased as the addition rate of NaOH rose while the water absorption ratio tended to decrease. By contrast, the density decreased as the replacement ratio of polysilicon sludge increased while the absorption tended to increase.

• The flexural strength and compressive strength increased in overall way as the addition rate of NaOH rose. Meanwhile, the strength tended to decrease as the replacement ratio of polysilicon sludge increased. The flexural strength tended to decrease as the age increased due to the crack in the surface. The compressive strength was 31.3 MPa, the most excellent result, at the age of 28 days at the ratio of BFS 85: 15 among the 3 test specimens (BFS 85: PS 15, BFS 80 : 20, BFS 75 : PS 25) added with NaOH 5 % uniformLy.

Thus, it is considered that the optimum addition rate of NaOH is 7 % while the optimum substitution rate of polysilicon sludge is 15 %.

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