

EFFECT OF SODIUM HYDROXIDE SOLUTION ON THE PROPERTIES OF GEOPOLYMER BASED ON FLY ASH AND ALUMINIUM WASTE BLEND

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Abstract

Geopolymer is a new group of alumino-silicate materials. Because of its excellent engineering properties and ecofriendly processing, geopolymer attracts a lot of attention. In this study, the effect of sodium hydroxide (NaOH) solution on the properties of geopolymers produced from fly ash and aluminium waste was investigated. The geopolymers were prepared by mixing fly ash with aluminium waste from aluminium frame industry. Sodium silicate and sodium hydroxide were used as alkali activating solutions. The weight ratio of sodium silicate solution to sodium hydroxide solution of 2.5 was used. Three variable concentrations of sodium hydroxide were tested: 5, 10 and 15M. After curing at 80°C for 24 h, mechanical properties were measured. The microstructure was characterized using scanning electron microscopy (SEM). Bonding and phases of geopolymer were also analyzed.

Keywords: Geopolymer, Fly ash, Aluminium waste

Introduction

Portland cement manufacturing process uses high-energy and emits CO₂ into atmosphere. Currently, the use of pozzolans materials instead of partial Portland cement and development of other cementitious materials is called “geopolymer” (Guo *et al.*, 2010). The synthesis of geopolymer needs three sources via raw materials, inactive filler and geopolymer liquor (Phair 2001; Phair and Van Deventer

2001; Ikeda 2008). Geopolymer is made from alumino-silicate materials such as fly ash, slag and cullet mixed with alkali solution. The main compositions of raw materials are silica and alumina. The mixture can be cured at room temperature or at high temperature to increase reaction of geopolymer. Raw materials were dissolved by alkali solution. Silicon and aluminium atoms from raw

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materials made reorientation in solutions and setting via polycondensation reactions into geopolymer (Rattanasak and Chindaprasirt 2009). In this study, a replacement of fly ash with aluminium waste as Al_2O_3 source was investigated and effect of sodium hydroxide concentration on their properties was reported in this paper.

Materials and Methods

Materials

Fly ash (FA) from Mae Moh power plant in Lampang province, Thailand and aluminium waste (Al-waste) from aluminium frame industry in Samutprakarn province, Thailand were used for starting materials in geopolymer preparation. The chemical compositions are shown in Table 1. The mean particle sizes of fly ash and aluminium waste were $17\ \mu\text{m}$ and $100\ \mu\text{m}$, respectively. Sodium hydroxide solutions were prepared from solid analytical grade sodium hydroxide. Sodium silicate solutions with compositions of 10.15 wt% Na_2O , 31.38 wt% SiO_2 and

58.47 wt% H_2O were used to prepare alkali activators.

Preparation of Geopolymer Specimens

Fly ash and aluminium waste were used at proportions of FA:Al-waste of 100:0, 80:20, 60:40, and 40:60 by weight. Sodium hydroxide solution was diluted by tap water for concentrations of 5, 10, 15M. Sodium silicate solution and sodium hydroxide solution were used as the solution part of the mixture and premixed in another container. Then, the mixtures of fly ash and Al-waste were added into the solutions and mixed for 1 minute to achieve a good homogeneity. The mixtures were cast in a mould. Geopolymer specimens were cured at 80°C for 24h.

Characterization of Specimens

Compressive strength and bending strength were tested after geopolymer samples were aged for 7 days by using Instron testing machine 5882 and 5880. The sizes of the compressive and bending tested samples were $50 \times 50 \times 50\ \text{mm}$ and $18 \times 12 \times 90\ \text{mm}$, respectively. The span length of the bending

Table 1. Chemical composition of starting materials

Composition (wt %)	Fly ash	Al-waste
SiO_2	31.94	0.18
Al_2O_3	18.37	63.28
Fe_2O_3	17.39	0
CaO	19.84	0.01
Na_2O	1.20	0
TiO_2	0.50	0.01
MgO	1.86	0.31
K_2O	3.05	0.05
SO_3	5.13	<0.01
MnO	0.12	2.05
P_2O_5	0.22	0.01
LOI	0.29	34.02

strength was 80 mm.

The specimens were ground and passed through a 325 mesh screen to obtain the powder for phase analysis. The phase analysis was determined by using X-ray Diffractometer (XRD), Bruker D8 Advanced machine with the scanning angle of 5-702 θ .

Fourier transform infrared spectroscopy (FT-IR) was used to study bonding of geopolymer. FT-IR samples were prepared by mixing the powder with KBr at a concentration of 1.0 wt%.

Microstructure of the fractured sample was characterized by using scanning electron microscope (SEM).

Results and Discussion

Compressive strength and bending strength

Compressive strength and bending strength of prepared samples cured at 80°C 24h after 7 days of aging are shown in Figures 1 and 2. These figures also show the strength of

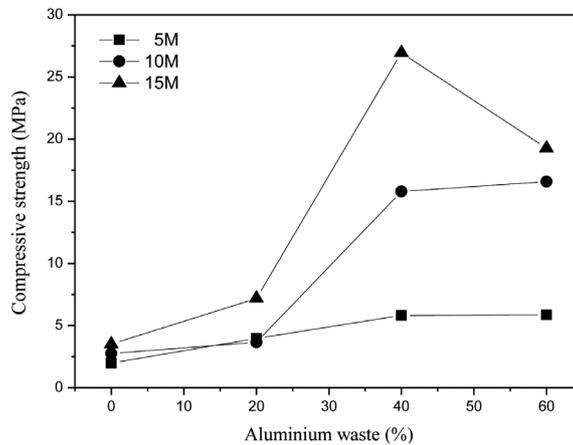


Figure 1. Compressive strength 7 days of geopolymer with 5, 10 and 15M NaOH cured at 80°C for 24h

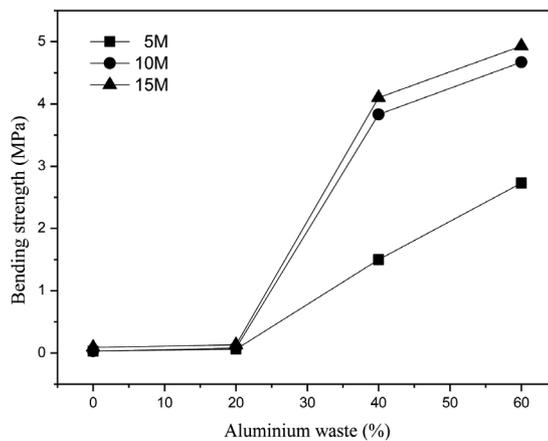


Figure 2. Bending strength 7 days of geopolymer with 5, 10 and 15M NaOH cured at 80°C for 24h

samples prepared by three different NaOH concentrations. The compressive strength and bending strength of prepared samples in all compositions increased with an increase of NaOH concentration (Puertas *et al.*, 2000). The strength increased with an increasing NaOH concentration because high concentrations of NaOH can increase dissolving rate of silicon and aluminium atoms in raw materials. The compressive strength and bending strength increased when aluminium waste was added. The highest values of compressive strength and bending strength were 26.95 and 4.93 MPa, respectively.

XRD analysis

XRD patterns in Figure 3 show that quartz, mullite and gibbsite were present as the major phases. The phases detected in the samples prepared with 5M NaOH after curing at 80°C for 24h. The peak intensity of gibbsite increased with an increasing of aluminium waste amount. The remaining gibbsite phase in geopolymer was the result of unreacted

Aluminium waste with alkali solution. It can be seen in the samples with Aluminium waste mixed with fly ash that a small number of cracks were found. Particle size of fly ash is very small when added in the composition the shrinkage of geopolymer was very high and cracks were found after hardening.

SEM analysis

SEM micrographs of fracture surface of samples prepared from fly ash replacing partially aluminium waste and 5, 10, 15 M NaOH after being cured at 80°C for 24h are shown in Figure 4. The matrix and voids were clearly seen as well as cracks. Moreover, un-reacted fly ash still remained in the matrix.

FT-IR results

FT-IR spectra of geopolymer are shown in Figure 5. The significant broad bands are located at approximately 3450 cm^{-1} and 1600-1650 cm^{-1} representing O-H stretching and O-H bending, respectively (Chindaprasit *et al.*, 2009). The band at near 460 cm^{-1}

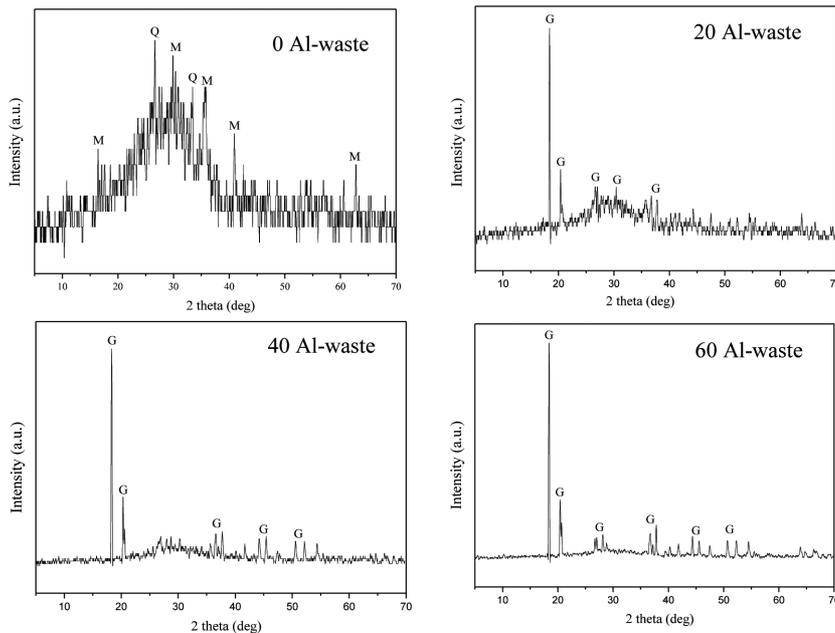


Figure 3. XRD patterns of specimens with 5M NaOH cured at 80°C for 24h (Q = Quartz M = Mullite G = Gibbsite)

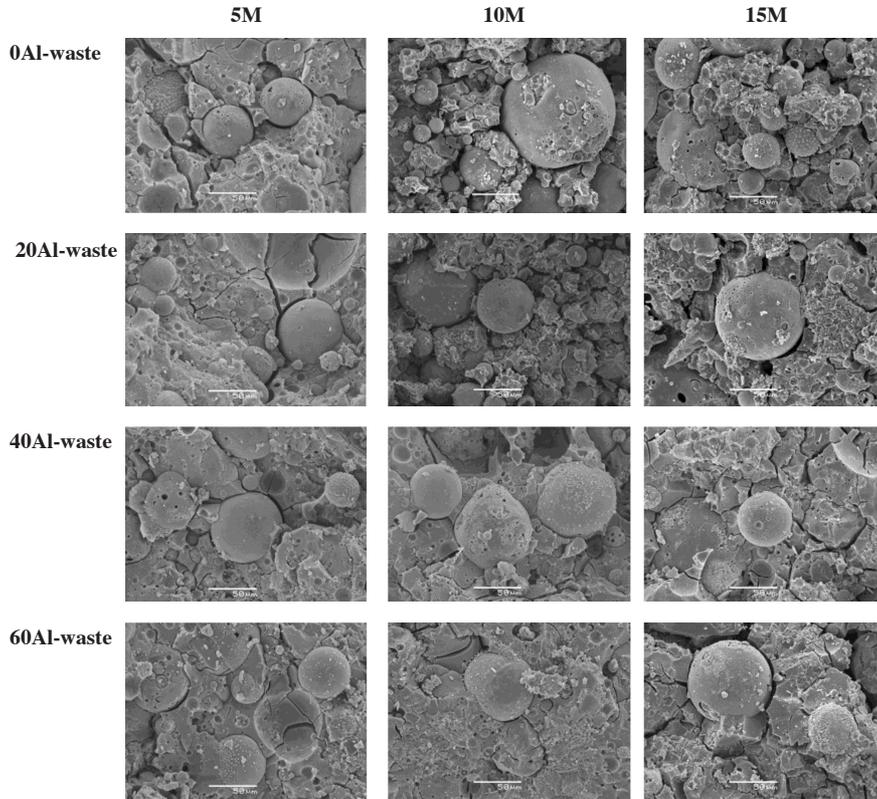


Figure 4. SEM taken from a broken portion of geopolymer sample

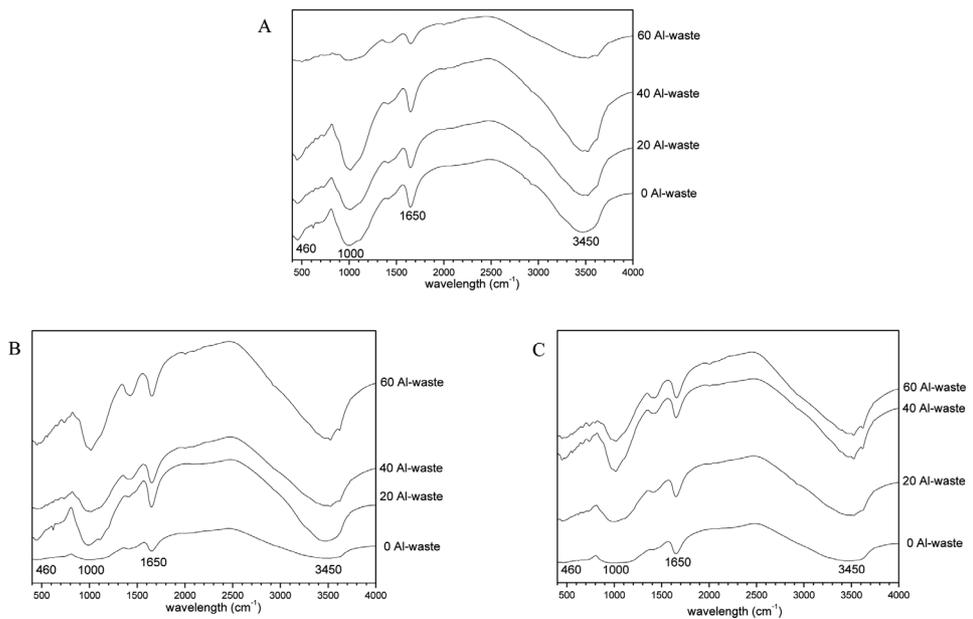


Figure 5. FT-IR analysis of geopolymer paste with (A) 5M (B) 10M (C) 15M NaOH cured at 80°C for 24h

represents O-Si-O bending mode. The Si-O-Si and Si-O-Al stretching vibrations were detected at the range of 950-1200 cm^{-1} .

Conclusions

The compressive strength and bending strength increased with an increasing amount of aluminium waste. The concentration of NaOH had an effect on the strength of geopolymer. The results also indicated that the bending strength increased with an increase of NaOH concentration. Quartz, mullite and gibbsite were found as the major phases in the prepared geopolymer.

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