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Lightweight Geopolymer Made of Pumice with Various Aluminum Powder Ratios

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In this work, a lightweight geopolymer was prepared using various mass proportions of extra fine aluminum powder and pumice stone that is durable to heat and sound-proof. The effect of NaOH concentration, aluminum mass ratio, the curing temperature and the curing time of the mixture on the compressive strength of the lightweight geopolymers were examined. The concentration of NaOH was found to be 2 M while the mass proportion of Na_2SiO_3/NaOH was found to be 17.5 on the lightweight geopolymers that have the highest compressive strength and the best workability in experiments. The lightweight geopolymer attained the best compressive strength with 1.6 MPa on the 28th day of curing process at 40 °C. The mass proportion of aluminum used in the lightweight geopolymer was 2.5% as the density of the lightweight geopolymer obtained was 0.9 g/cm^3. Their properties were examined using the Fourier transform infrared spectroscopy, X-ray diffraction, and scanning electron microscopy.

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1. Introduction

Geopolymer materials have attracted attention as a new class of construction materials with amorphous to semi-crystalline nature due to their notable fire and chemical resistance, low density, low cost, easy processing, environmentally friendly nature, and excellent mechanical properties [1, 2]. Nowadays, lightweight (LW) construction materials are used to reduce the weight of building structures and improve thermal insulation efficiency of buildings [3, 4]. LW geopolymers made with natural aggregates and inorganic material exhibit great combination of thermal and mechanical properties [5]. The geopolymeric reaction occurs when alumina–silicate oxides reacts with alkali (NaOH, KOH) and soluble alkali polysilicates. Alumina silicate materials such as fly ash, blast furnace slag, and metakaolin are commonly used to prepare geopolymers and LW geopolymers but there is no report on preparation of LW geopolymer from pumice [6]. Pumice also used in concrete and tested against radiation shielding [7, 8]. Herein, we prepared LW geopolymer using pumice as alumina–silicate materials and Al powder as foaming agent [3].

2. Experimental

Sodium silicate (Na_2SiO_3) and NaOH were used as alkaline activators. NaOH and Na_2SiO_3 were mixed in a beaker for 2 min. For the preparation of LW geopolymer, pumice was dry mixed by commercially pure aluminum powder (Al powder) with various weight ratio. Alkali activator was then added to the mixture and entire content was mixed for 5 min. Finally, the specimens were rapidly poured into cubic molds with dimensions $40 \times 40 \times 40$ mm^3. In order to investigate the effect of the alkaline activator on the compressive strength of the geopolymer material, a series of NaOH solution with concentrations of 1, 2, 3, 5, 10, and 15 M and wt% Al powder of 0.5, 1, 1.68, 2, and 2.5 were used. Varying curing temperatures were applied on the prepared LW geopolymers such as at 25, 40, 60, and 80 °C.

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3. Results and discussion

Figure 1 shows the effect of weight of Al powder and NaOH concentration on compressive strength of LW geopolymers. It is seen from the figures that the compressive strength of LW geopolymers decreased with increase of % Al powder until 2% and then increased (Fig. 1a) while it first increased with increase of NaOH concentration until 2 M and then decreased (Fig. 1b). The mass proportion of Al powder used in the lightweight pumice geopolymer was 2.5 in the experiments. The highest compressive strength was obtained as 1.6 MPa at the 28th day of curing process at 40 °C (Fig. 2).

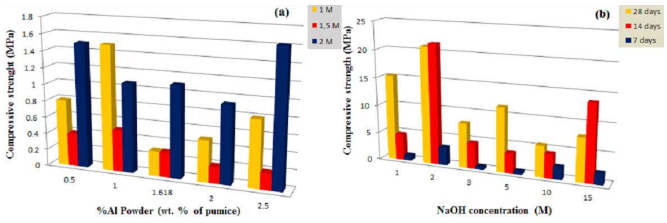

Fig. 1. (a) The effect of wt% of Al powder in the mixture and (b) NaOH concentration on the compressive strength of lightweight geopolymer.

X-ray diffraction patterns and the Fourier transform infrared (FTIR) spectrum of Al powder, pumice and LW geopolymers by varying curing temperature are presented

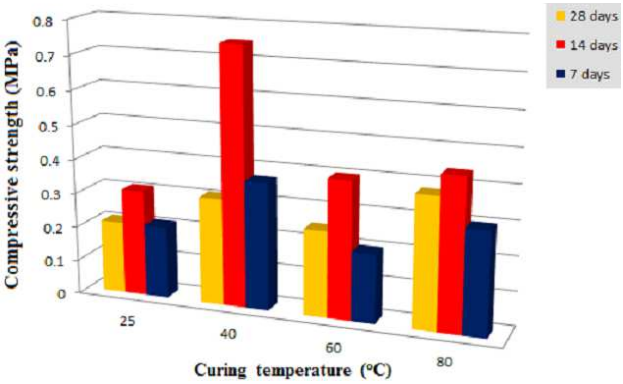

Fig. 2. Relations of compressive strength and curing temperature of lightweight geopolymer concrets.

in Fig. 3a and b, respectively. The characteristic diffraction peaks of pumice and Al powder were located at 23, 28 (2θ) and 40, 48, 65, and 80 (2θ), respectively (Fig. 3a). X-ray diffraction (XRD) pattern of LW geopolymer by varying curing temperature is similar to that of pure pumice such that there is no peak of Al powder. Figure 3b illustrates FTIR spectra of LW geopolymer and its raw materials. The bands observed between 990 and 1000 cm^{-1} correspond to Si–O and Al–O stretching vibration bands of pumice. It is noted in the figure that there is no band that belongs to Al powder [6].

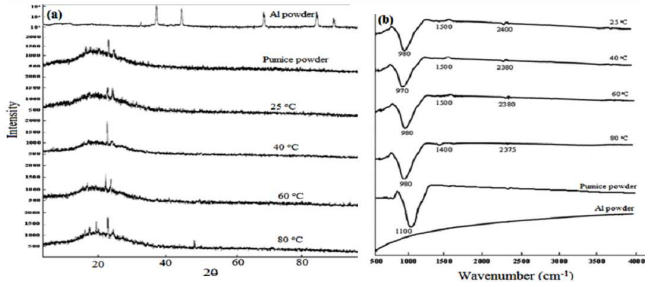

Fig. 3. (a) XRD patterns and (b) FTIR spectrum of Al powder, pumice and geopolymers by varying curing temperature (2 M NaOH; Na_2SiO_3/NaOH 17.5; Al powder (wt of pumice) 2.5%; curing time 28 days).

Scanning electron microscopy (SEM) micrographs of pumice, Al powder and LW geopolymers with varying curing temperatures are shown in Fig. 4. SEM observations of LW geopolymers indicate a hardened structure with increasing curing temperature. Also, it is seen that the LW geopolymers are more dense and homogeneous with increase of curing temperature.

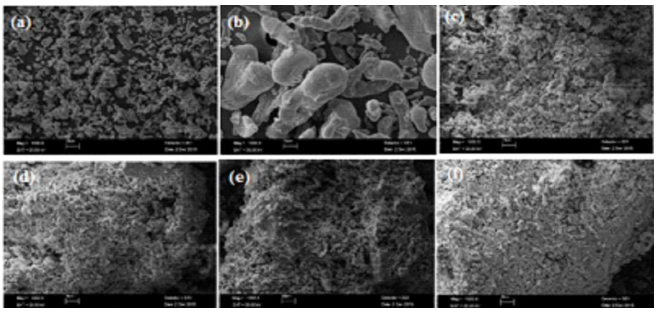

Fig. 4. SEM analyses of pumice, Al powder and geopolymers with varying curing temperatures: (a) pumice, (b) Al powder, (c) 25, (d) 40, (e) 60, (f) 80 °C (2 M NaOH; Na_2SiO_3/NaOH 17.5; Al powder (wt of pumice) 2.5%, curing time 28 days).

4. Conclusion

The LW geopolymers were successfully prepared through changing mass ratio of Al powder. The best compressive strength of 1.6 MPa was reached at 2 M concentration of NaOH, 17.5 Na_2SiO_3/NaOH mass ratio, 2.5% weight of Al powder in the mixture on the 28th day of curing process at 40 °C. The results show that the mass ratio of Al powder, NaOH concentration and curing temperature have great effect on compressive strength of LW geopolymers.

Acknowledgments

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