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Mechanical Properties of Artificial Lightweight GeopolymerAggregate (ALGA) Concreteusing Volcano Mud with Various Sintering Temperature

Rafiza Abdul Razak[1,a], Mohd Mustafa Al Bakri Abdullah[2,b], Kamarudin Hussin[3,c], Khairul Nizar Ismail[4,d], Djwantoro Hardjito[5,e], and Zarina Yahya[6,f]

[1,6]Center of Excellence Geopolymer and Green Technology, School of Materials Engineering, Universiti Malaysia Perlis (UniMAP), 01007, P.O Box 77, D/A PejabatPosBesar, Kangar, Perlis, Malaysia.

[2,3]Faculty of Engineering Technology, Universiti Malaysia Perlis (UniMAP), 01007, P.O Box 77, D/A PejabatPosBesar, Kangar, Perlis, Malaysia.

[4]School of Environmental Engineering, Universiti Malaysia Perlis (UniMAP), 02600 Jejawi, Perlis, Malaysia

[5]Civil Engineering Department, Petra Christian University, JalanSiwalankerto 121-131, Surabaya 60236 Indonesia

[a]rafizarazak@unimap.edu.my,[b]mustafa_albakri@unimap.edu.my, [c]vc@unimap.edu.my, [d]nizar@unimap.edu.my, [e]djwantoro.h@peter.petra.ac.id,[f]zarinayahya@unimap.edu.my

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Abstract. The mechanical propertiesof artificial lightweight geopolymer aggregate (ALGA) using volcano mud in concrete have been investigated at various sintering temperature. The volcano mud was mixed with alkaline activator, formed into spherical pellets, then sintered in the furnace at temperature of 500°C, 600°C, 700°C, 800°C, 900°C, 950°C, and 1000 °C. The lightweight concrete with density below than 1800 kg/m^3 can be achieved at sintering temperature ALGA of 950 °C. The optimum compressive strength of 30.1 MPa was achieved at 28 days of testing. The lower water absorption of ALGA concrete was produced with 5-8 % in range.

Introduction

Development of new techniques for managing wastes from industrial or natural material sources is one of the major areas of interest among researchers in recent days. Lightweight concrete is one of the high demand in the structure design, presently, as it reduce the mass of the structure and may reduce the total overall cost of the building [1]. The most widely used materials in the concrete industry are fly ash, ground granulated blast furnace slag, clay [2-7]and recently oil palm shell [8].

On 29 May 2006, a volcano mud started erupting in East Java, Surabaya, Indonesia, near the village of Sidoarjo.Locally, the volcano mud is called as LUSI (LU- lumpur 'mud' and SI-Sidoarjo), meaning volcano mud from Sidoarjo. This eruption can be labeled as industrial disaster, resulted from a hydrocarbon exploration[9-10].The mud has destroyed factories, schools, houses, a villages and displaced over 30,000 people[9, 11-12].Now, after eight years (2014), the eruption has swamped more than 640 hectares of areas. Many efforts have been done to solve the abundant of volcano mud from LUSI but none of them was truly successful.

Development of artificial lightweight geopolymer aggregate (ALGA) by using volcano mud has not been explored yet. The high content of Si and Al in volcano ash made this material has a potential to be used as raw material in geopolymer. The high demand on lightweight aggregate in concrete encourage this research to explore new material of volcano mud from LUSI (LU-lumpur, SI-Sidoarjo), Surabaya, Indonesia to be used as ALGA with excellent properties and performance in concrete application.

Experimental Methods

Preparation of Material. The original mud was medium gray in colour. Volcano mud was then dried in the oven at 105 °C for 48 hours. After drying, this material was then crushed and blendedto form the volcano ash with particle size less than 300 µm.

Mixing Process. The volcano mud was usedto be reacting with the geopolymer binder alkaline activator consisting of sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) solutions. The sodium silicate has a chemical composition of 30.1% SiO_2, 9.4% Na_2O and 60.5% H_2O (modulus $SiO_2/Na_2O=3.2$), specific gravity at 20 °C = 1.4 g/cm^3 and viscosity at 20 °C = 0.4 Pa s. The sodium hydroxide powder used was of 99% purity and fixed at 8M [13] in this study.

The sodium hydroxide and sodium silicate was first mixed and stir until homogeneous solution was achieved to form as alkaline activator. The ratio Na_2SiO_3/NaOH used was 0.6. Geopolymer paste were prepared by mixing volcano ash with the alkaline activator. The ratio of volcano ash/alkaline activator was 1.7 due to workability during palletizing the aggregate.The mixing material was mixed for five minutes to obtain a homogeneous paste mixture. Then the paste need to be palleted then the pelletized artificial geopolymer aggregate was sintered at temperature 500°C, 600°C, 700°C, 800°C, 900°C, 950°Cand 1000°C for 1 hour.

Coarse aggregate in the concrete was replaced by ALGA produced to be used in concrete. The calculation of proportionwas referred to ACI 211.2-98. The dry materials (ALGA, OPC, and fine aggregate) were mixed first. Then, the water will be added to the dry mixing then mixed. After that, the mixture will be placed in concrete cubes. Then, the cubes of concrete were cured in the water until testing day at 28 days.

Testing and Analyzing. The compressive strength was performed byInstron machine.The water absorption and specific gravity were tested according to the ASTM C 127 [14]to determine the stability of the artificial geopolymer aggregate produced.

Results & Discussion

Density. Fig. 1 shows the specific gravity of ALGA produced at different sintering temperature. The higher sintering temperature will result in lower specific gravity value. The lowest density of ALGA lightweight concrete was 1602 kg/m^3 at 1000 °C sintering temperature. At 950 °C, the density of ALGA lightweight concrete was 1767 kg/m^3. This shows that the lightweight concrete of ALGA can be produced at starting temperature of 950 °C with density less than 1800 kg/m^3 which can be classified as lightweight concrete. Study carried out by Le Anh-tuan [7] showed the density of fly ash mix with ground granulated blast furnace slag as lightweight aggregate in concrete was 1836-2056 kg/m^3. Meanwhile the density of fly ash lightweight aggregate concrete varied between 1980 kg/m^{3}and 2100 kg/m^{3}sintered at temperature up to 1100 °C [15]. This shows that the ALGA concrete used lower sintering temperature to produce ALGA and less density produced.

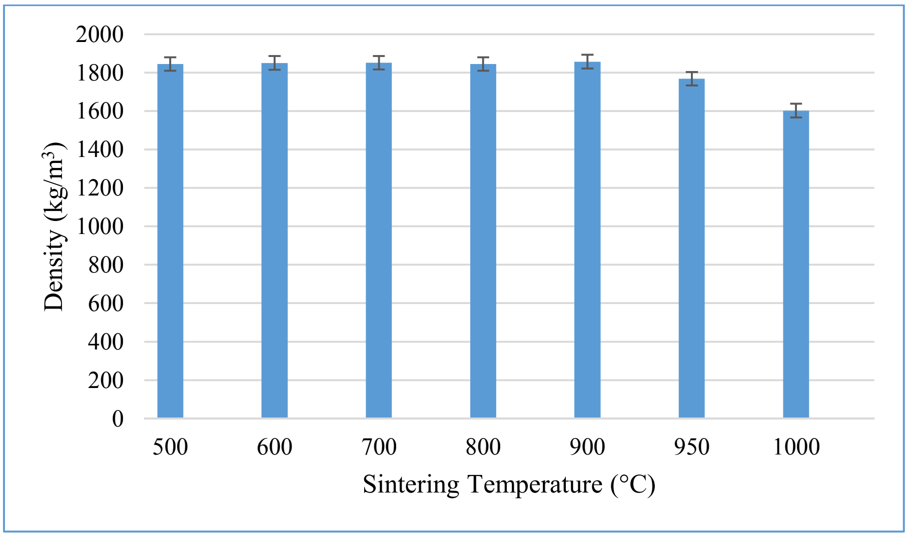

Fig. 1: The density of ALGA concrete produced at various sintering temperature.

Compressive strength. The compressive strength of ALGA concrete is shown in Fig. 2. The result shows that at sintering temperature of 900 °C, the highest compressive strength was achieved with 30.8 MPa at 28 days of testing. Meanwhile at sintering temperature of 950 °C, the compressive strength produced was 30.1 MPa. Due to very merely different of strength between 900 °C and 950 °C, and by taking into account the density of ALGA concrete produced (less than 1920 kg/m^3 according to ACI 213R-03), the best sintering temperature of 950 °C is selected.

Byung-wan et al. [6] found the compressive strength of alkali activated fly ash lightweight aggregate of 26.7 MPa at 28 days which is lower than ALGA concrete.For fly ash based oil palm shell geopolymer lightweight concrete, the compressive strength was achieved up to 32.63 MPa. Other researchers found the high strength of lightweight aggregate concrete up to 50 MPa at high sintering temperature (above 1100 °C) [15-16], but the AGLA concrete produced at lower sintering temperature of 950 °C.

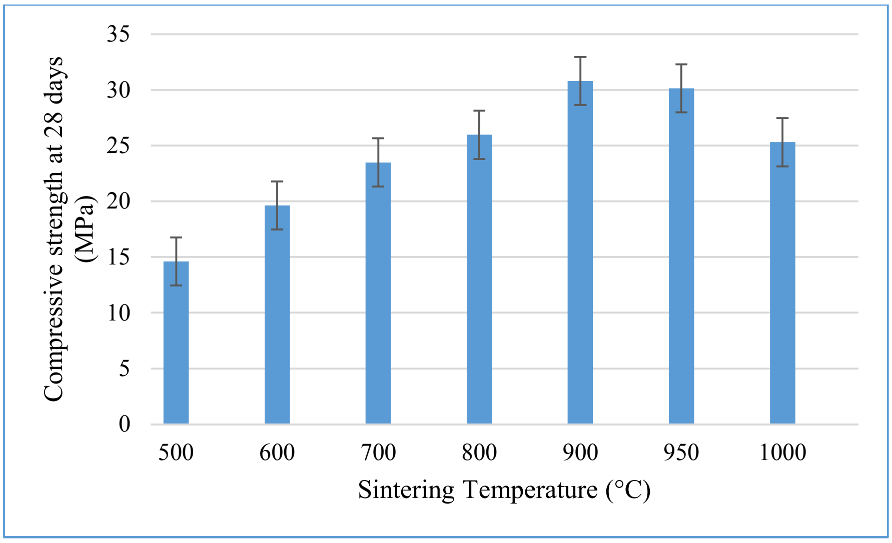

Fig. 2: The compressive strength of ALGA concrete at various sintering temperature.

Water absorption. Water absorption is a measure of the total pore volume accessible to water and it can be calculated from a specific gravity determination. The water absorption of lightweight aggregate should ideally be as low as possible. The highest water absorption was found at sintering temperature of 600 °C with 7.8 %. The lowest water absorption can be found at sintering temperature of 1000 °C with 5.7 % as shown in Fig. 3. So, the range of water absorption for ALGA using volcano mudin concrete was 5-8 %. This range is still lower than lightweight aggregate concrete produced by Erhan et al. [15] with 11.7 % water absorption. The further decrease in water absorption at 800 °C – 1000 °C may be due to the surface voids that is increasing as sintering temperature increasing by a less viscous liquid phase which also agreed by Monica et al. [2] study.

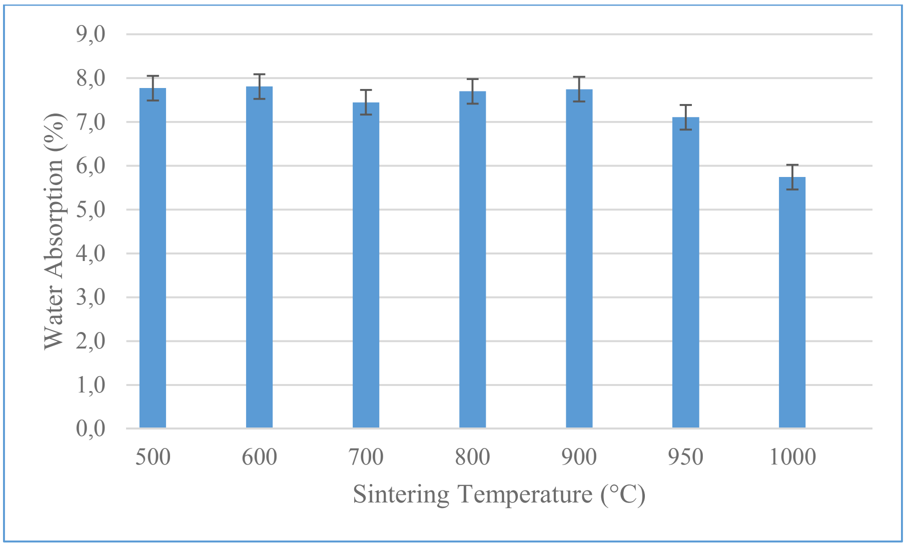

Fig. 3: The water absorption of ALGA concrete.

Conclusion.

It is evidence that the ALGA concrete using volcano mud is possible to be produced as structural lightweight concrete production. The density of ALGA concrete produced was in the range of 1602 – 1857 kg/m^3. The optimum compressive strength of ALGA concrete was 30.1 MPa at 950 °C sintering temperature at 28 days of testing. The lower water absorption was produced by ALGA concrete of 5-8 % in range.

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