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Properties of Fresh Palm Oil Fuel Ash Based Geopolymer Material

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ABSTRACT

In this paper, palm oil fuel ash (POFA) was used as the soul material to produce geopolymer binder. Sodium silicate mixed with sodium hydroxide was used as alkaline activator to activate the palm oil fuel ash. Activator concentration, curing temperature, setting time and workability represented by flow table test were studied for POFA paste to evaluate the utilization of this ash in geopolymer technology. Compressive strength was used to evaluate the strength of the paste in three different ages (7, 14, and 28) days. The results showed that alkali activation of palm oil fuel ash as a soul material with different activators concentration can produce paste with 30.75 MPa at the age of 28 days. The results showed good potential in palm oil fuel ash to be used as a promising material in geopolymer technology.

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INTRODUCTION

Geopolymer technology or alkali activation technology has showed the ability of producing new kind of materials that can be used in binder production as an alternative of OPC to produce green concrete [1, 2]. The term Geopolymers was invented by a French scientist (Joseph Davidovits) around 1970-1972 which is derived from the fact that aluminosilicate raw materials can be used with chemical activators to produce new binders [3, 4]. The geopolymer technology has been identified to be one of the technologies that can be incorporated in the trend of producing new (low carbon cement) or cement minimum CO_2 emissions and friend to the Earth environment [5, 6]. The investigations about finding a new binders that can be used as alternatives to the traditional cements by the implementation of the alkaline activation process of different martials resulted from industry as by-products, are in a continues pursuit and became a very important and crucial target for the scientific community. Different characterizations made this new geopolymer cement one of the main alternatives for OPC, such as their performance in mechanical properties, low energy cost, low energy consumption, very low harmful gas emissions, and essentially it can be produced from waste materials such as fly ash, ggbs, and metakaolin [2, 7-11]. Two models of alkali-activated binding systems in the geopolymer technology have been introduced by Palomo et al [12].

The alkali activation of blast furnace slag having the system of (Si+Ca) was considered as the first model, which is described as more complicated with its reaction products of calcium silicate hydrate (CSH). Class F fly ash and metakaolin (Si+Al) is the second system with a reaction products as zeolite-like polymers. Searching for new materials to be used in geopolymer technology to produce new binder was the motivation to use bio-mass by product materials. Malaysia is considered as the leader and the largest producer country in palm oil industry in the world. Four million tons per year of POFA are resulted from this industry [13], which push towards huge criticisms and complain. Large amounts of POFA are being used in landfill and ash ponds which causes environmental problem, and huge volumes of POFA is still not used. Palm oil fuel ash (POFA) is a by-product

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material produced as a waste ash from palm oil power plant factories, and it is an aluminosilicate material [14, 15]. The objective of this study is to investigate for the first time the ability of activating ground Palm oil fuel ash by the alkali activator and develop a new geopolymer binder (biomass geopolymer binder). Investigate the fresh properties and compressive strength to have better idea about the behavior of this new material in geopolymer technology and evaluate its performance to be used in green concrete.

Materials:

The main material in this investigation was the palm oil fuel ash (POFA). It is a bio-mass by product from Palm oil industry. Palm oil fuel ash is a by-product and waste material collected from local palm oil mill located in Johor State in Malaysia. Chemical composition showed the availability of Al_2O_3 and SiO_2 with CaO as the main components. The alkaline activator was sodium silicate (Na_2SiO_3) with different concentrations supplied by a local company and consisted of 9.4% Na_2O, 30.1% SiO_2, and 60.5% H_2O (Ms ratio by weight between 3.2-3.3). Sodium hydroxide NaOH in pellet form with 97% purity also used [16-21].

Mixing, Casting and Curing:

The alkaline activator was prepared one day before mixing with the ash. Sodium hydroxide pellets were mixed distilled water in order to prepare different concentrations. Hobart mixer was used in all mixes. After adding the activator to the ash, mixing time was one minute with the normal speed (gear one), the mixer stopped for 5-10 seconds to scrap un mixed ash on the sides of the paddle and the pan, then mixing was continued with medium speed (gear two) for another one minute. Paste then casted in 50*50*50 mm iron molds and manual vibration was used. Oven curing was implemented directly after casting with 60 °C to 80 °C for 24 hours. The specimens after de-molding were kept in a plastic bag to prevent any moisture lost and kept to the date of testing. One set of specimens were cured at ambient temperature.

RESULTS AND DISCUSSIONS

Each value of the test results discussed or presented in the figures is the mean of 3 tests results. Ground POFA was used in this investigation passing 90% sieve number 325. Based on previous research by [22] it is decided to use grounded POFA rather than POFA without sieving or PFOA sieved passing 300 micron. It was an evident that grinding is an effective activation process with alkaline activator. Dissolution ability has been increased with the decrease of POFA particle size.

Setting time:

The paste set was measured by monitoring the paste inside the oven; each 15 minutes the molds were checked to evaluate the hardening and geopolymerization process. The six pastes which are produced with different concentration, presented the same behavior of setting. The setting time were (131, 123, 137, 136, 171, 152) minutes for mixes with (6, 8, 10, 12, 14, and 16) M alkaline concentration respectively. It is obvious that the final setting time which is the hardening time for all POFA geopolymer pastes is not less than 2 hours and not more than 3 hours by suing oven curing method at 60 C. For the mix with ambient temperature, the final setting time or hardening time was 18 hours, which it is related to the CaO content in POFA. The experimental work showed that POFA geopolymer paste will change from slurry phase to the gel phase gradually during the first 90 minutes, while the rest period (20-30) minutes was required to the mix to have full hardening.

Workability:

The flow table results of POFA geopolymer paste with various activator concentrations are presented in figure 1. The conjoined effect of chemical water content as the water to binder ratio is represented in figure 2. Figure 1 showed that the flow measurements were decreased with the increase of alkaline activator concentration. This behavior can be attributed to the increase of the solid content in the alkaline. The solid is referred to SiO_2, and Na_2O which is the main constituents for the final alkaline. The increase of NaOH concentration for the same mix proportions will increase the Na ions in the system; the same conclusion was presented by Mustafa Al Bakri [16]. From the other side; increasing the concentration is associated with water content decrease in the liquid.

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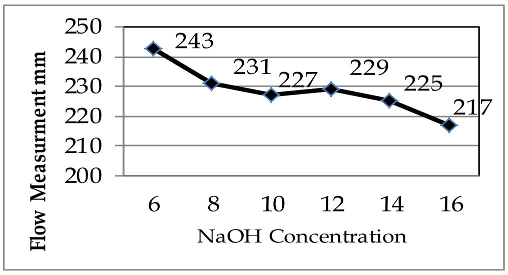

Fig. 1: Flow measurement verses sodium hydroxide concentration.

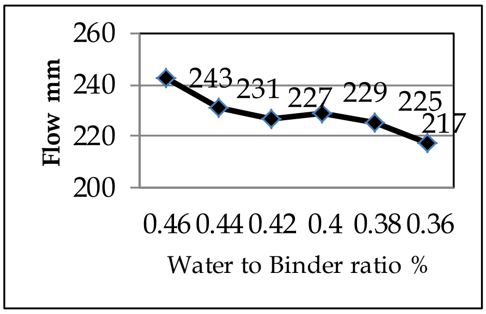

Fig. 2: Flow measurement verses water to binder ratio.

The effect of curing regime:

Two curing regime has been implemented in this work, the oven curing with 60 and 80 °C and the ambient temperature. POFA geopolymer paste was able to be set and harden at ambient temperature but it required not less than 18 hours to 24 hours. Oven curing at 60 °C and 80 °C was the most effective regime in order to have faster setting time and higher early strength. The experimental work with POFA as the soul material in the geopolymer technology is reflecting the same curing parameters as low calcium fly ash [23]. Oven curing for 24 hours resulted in shrinkage at the top of the specimens with cracks, as illustrated in figure 3.

Fig. 3: Cracks on the top of specimens after 24 hours oven curing.

Qualitative Observations:

POFA geopolymer pastes were black in its color, figures 4. This black color was attributed to the original color which is dark brown of POFA. Evaporable water was not observed inside the plastic bags; however, most of the samples showed sweating on the top face of the specimen, figure 5. This is related to the alkaline activator concentration and the chemical reactions with the POFA. It is concluded that chemical reaction is still continuous at the top face of the specimen which is the only path for the water evaporation process or the reaction gasses that evaporate outside the body of the specimen. Sweating is not observed on the other faces of the specimens. Figure

6, and 7 shows that efflorescence is appeared on the surface of the specimens and increased with the increase of the alkaline activator concentration. The efflorescence is attributed to the reaction between the air and the excess sodium [24].

Compressive strength:

Compressive strength results of POFA geopolymer paste with different concentrations of alkaline activators are illustrated in figure 8 to 13. Strength development was observed with age for each mix; which is an evidence of the effective activation process of POFA with different concentrations. It is clear that compressive strength increased with the increase of activator concentration. This behavior can be attributed to the increase of Na ions in the system which is considered as an important factor for the geopolymerization process. The positive sodium ion role is to balance the negative charge that appeared with the aluminum molecules and then forming the alumino-silicate networks to be the glue and the binder in the mixture [16]. This behavior is mainly due to the fact that concentration of NaOH solution used for geopolymer synthesis has a positive influence on dissolution, hydrolysis and condensation of the silicate species [25].

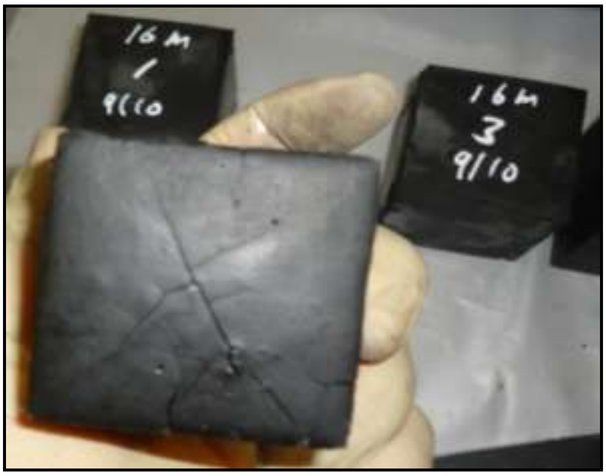

Fig. 4: POFA Geopolymer paste with black color.

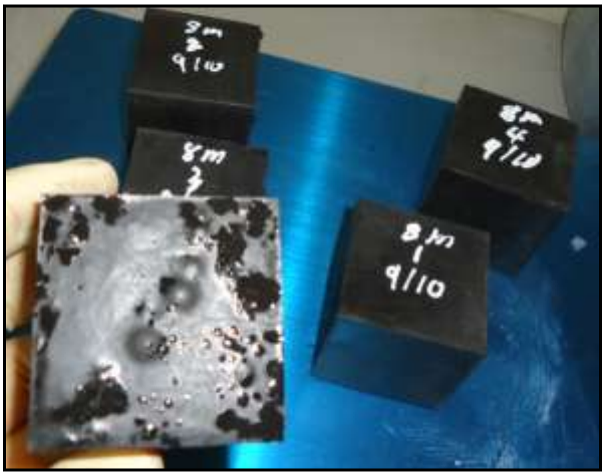

Fig. 5: Sweating on the top surface of POFA Geopolymer paste.

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Fig. 6: Efflorescence.

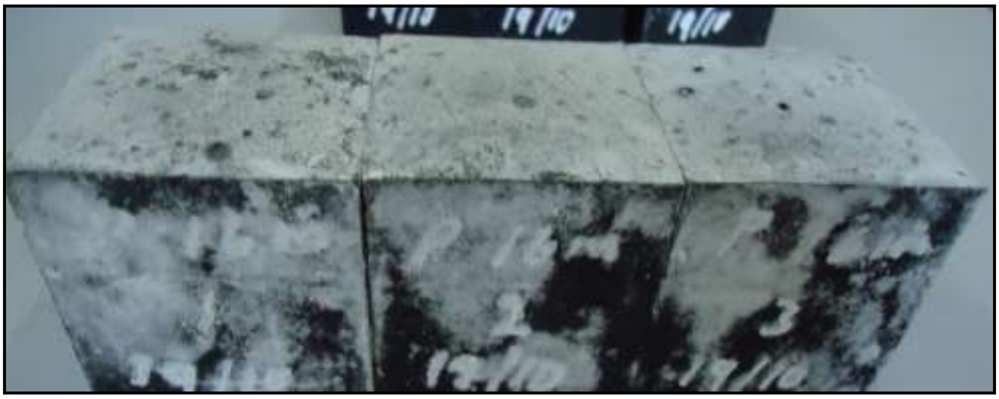

Fig. 7: Efflorescence increased with the increase of activator concentration.

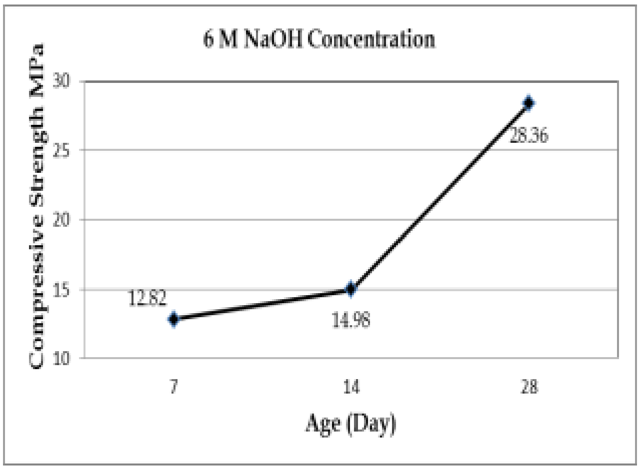

Fig. 8: Compressive strength results with 6 M.

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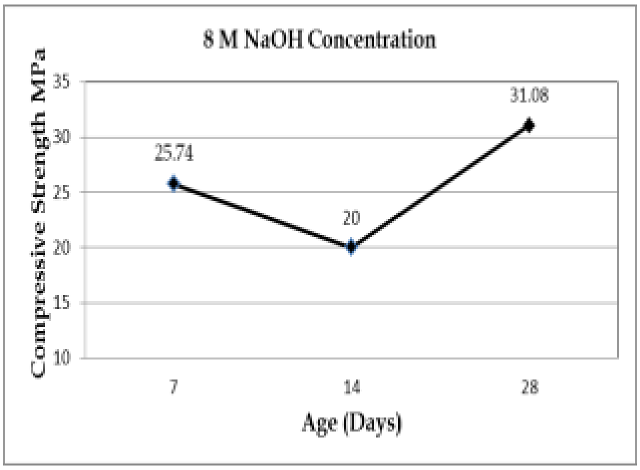

Fig. 9: Compressive strength results with 8 M.

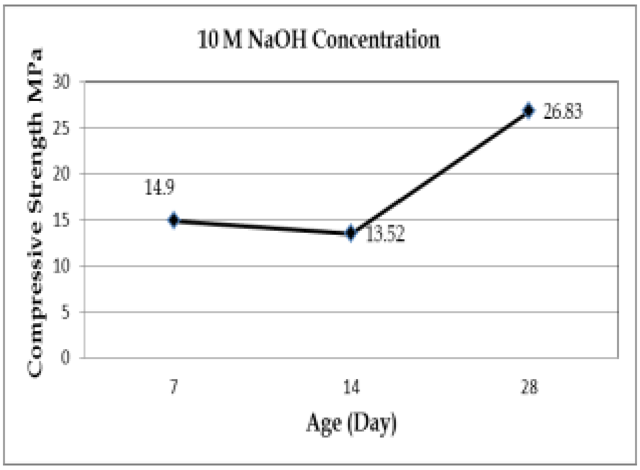

Fig. 10: Compressive strength results with 10 M.

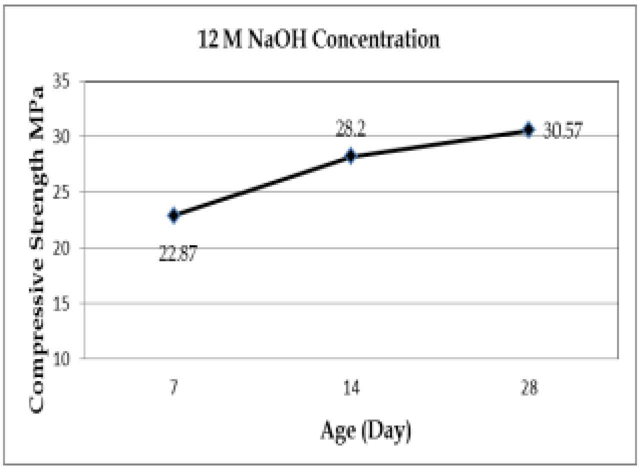

Fig. 11: Compressive strength results with 12 M.

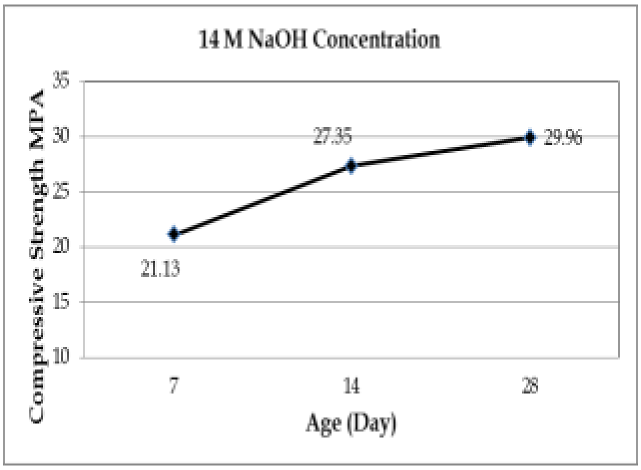

Fig. 12: Compressive strength results with 14 M.

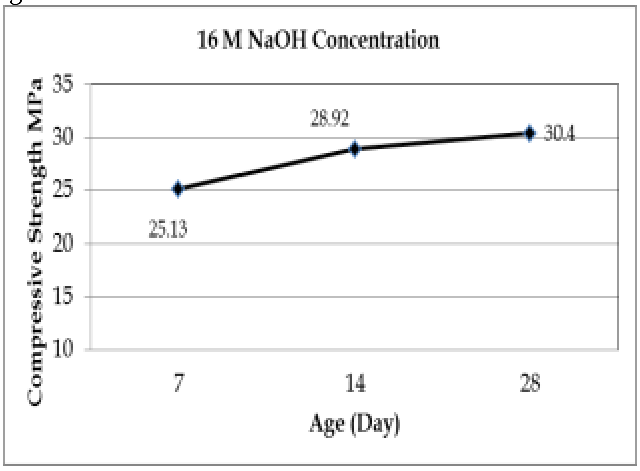

Fig. 13: Compressive strength results with 16 M.

Conclusion:

This paper presents for the first time the activation of new biomass by-product material; ground palm oil fuel ash (Ground POFA) by mixing with alkaline activator prepared in different concentrations. The experimental results showed the ability of utilize POFA in geopolymer technology to produce new geopolymer binder which can be classified after more work and development as new geopolymer cement. Different activator concentrations were able to activate this biomass ash; however, the results revealed that as higher concentration introduced to this system, higher strength can be achieved. From the other side; efflorescence appeared with higher concentrations which can be considered as challenge in this material.

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REFERENCES

[1] Kupaei, R.H., U.J. Alengaram, M.Z.B. Jumaat and H. Nikraz, 2013. "Mix design for fly ash based oil palm shell geopolymer lightweight concrete," *Construction and Building Materials*, 43: 490-496.

[2] Ahmari, S., X. Ren, V. Toufigh and L. Zhang, 2012. "Production of geopolymeric binder from blended waste concrete powder and fly ash," *Construction and Building Materials*, 35: 718-729.

[3] Davidovits, J., 2002. "30 years of successes and failures in geopolymer applications. Market trends and potential breakthroughs," in *Keynote Conference on Geopolymer Conference,* Saint-Quentin (France).
[4] Davidovits, J., 2011. *Geopolymer Chemistry and Applications*, 3rd ed. Saint Quentin France: Institute Geopolymere.
[5] Derobert, E. and M. Tolba, World Business Council for Sustainable Development [Online].
[6] Hasanbeigi, A., L. Price and E. Lin, 2013. "Emerging Energy-efficiency and CO2 Emission-reduction Technologies for Cement and Concrete Production," ed. USA.
[7] Puertas, F. and A. Fernández-Jiménez, 2003. "Mineralogical and microstructural characterisation of alkali-activated fly ash/slag pastes," *Cement and Concrete Composites,* 25: 287-292.
[8] Hardjito, D., C.C. Cheak and C.H.L. Ing, 2009. "Strength and setting times of low calcium fly ash-based geopolymer mortar," *Modern Applied Science*, 2: 3.
[9] Bakharev, T., J.G. Sanjayan and Y.B. Cheng, 1999. "Alkali activation of Australian slag cements," *Cement and Concrete Research,* 29: 113-120.
[10] Elimbi, A., H.K. Tchakoute and D. Njopwouo, 2011. "Effects of calcination temperature of kaolinite clays on the properties of geopolymer cements," *Construction and Building Materials*, 25: 2805-2812.
[11] Kong, D.L.Y., J.G. Sanjayan and K. Sagoe-Crentsil, 2007. "Comparative performance of geopolymers made with metakaolin and fly ash after exposure to elevated temperatures," *Cement and Concrete Research,* 37: 1583-1589.
[12] Palomo, A., M.W. Grutzeck and M.T. Blanco, 1999. "Alkali-activated fly ashes: A cement for the future," *Cement and Concrete Research,* 29: 1323-1329.
[13] Foo, K.Y. and B.H. Hameed, 2009. "Value-added utilization of oil palm ash: A superior recycling of the industrial agricultural waste," *Journal of Hazardous Materials*, 172: 523-531.
[14] Awal, A.S.M.A. and M.W. Hussin, 1997. "The effectiveness of palm oil fuel ash in preventing expansion due to alkali-silica reaction," *Cement and Concrete Composites,* 19: 367-372.
[15] Sata, V., C. Jaturapitakkul and K. Kiattikomol, 2004. "Utilization of palm oil fuel ash in high-strength concrete," *Journal of Materials in Civil Engineering,* 16: 623-628.
[16] Abdullah, M., H. Kamarudin, M. Bnhussain, I. Khairul Nizar, A. Rafiza and Y. Zarina, 2011. "The relationship of NaOH molarity, Na2SiO3/NaOH ratio, fly Ash/Alkaline activator ratio, and curing temperature to the strength of fly ash-based geopolymer," *Advanced Materials Research,* 328: 1475-1482.
[17] Al Bakri, M., A. Mohd, H. Kamarudin, O.A. Abdulkareem, C. Ruzaidi, A. Rafiza and M. Norazian, 2012. "Optimization of alkaline activator/fly ash ratio on the compressive strength of manufacturing fly ash-based geopolymer," *Applied Mechanics and Materials,* 110: 734-739.
[18] Al Bakri, A.M., H. Kamarudin, I. Khairul Nizar, M. Bnhussain, Y. Zarina and A. Rafiza, 2012. "Correlation between Na2SiO3/NaOH ratio and fly ash/alkaline activator ratio to the strength of geopolymer," *Advanced Materials Research,* 341: 189-193.
[19] Hardjito, D. and B.V. Rangan, 2005. "Development and properties of low-calcium fly ash-based geopolymer concrete," *Perth, Australia: Faculty of Engineering Curtin University of Technology*.
[20] Wallah, S. and B. Rangan, 2006. "Low-calcium fly ash-based geopolymer concrete: Long-term properties," *Res. Report-GC2, Curtin University, Australia,* pp: 76-80.
[21] Liew, Y.M., H. Kamarudin, A.M.M.A. Bakri, M. Binhussain, M. Luqman, I.K. Nizar, C.M. Ruzaidi and C.Y. Heah, 2011. "Influence of Solids-to-liquid and Activator Ratios on Calcined Kaolin Cement Powder," *Physics Procedia,* 22: 312-317.
[22] Moslih Amer Salih, Abang Abdullah Abang Ali and R. Demirboga, 2012. "Effect of Na_2SiO_3/NaOH ratio and binder/activator ratio on compressive strength of POFA blended with GGBS to produce geopolymer cement," *Archives Des Sciences,* 65: 149-158.
[23] Rashad, A.M. and S.R. Zeedan, 2011. "The effect of activator concentration on the residual strength of alkali-activated fly ash pastes subjected to thermal load," *Construction and Building Materials,* 25: 3098-3107.
[24] Najafi Kani, E., A. Allahverdi and J.L. Provis, 2012. "Efflorescence control in geopolymer binders based on natural pozzolan," *Cement and Concrete Composites,* 34: 25-33.
[25] Sagoe-Crentsil, K. and L. Weng, 2007. "Dissolution processes, hydrolysis and condensation reactions during geopolymer synthesis: Part II. High Si/Al ratio systems," *Journal of materials science,* 42: 3007-3014.