STUDY OF NA AND K ALKALI ACTIVATORS ON THE CHARACTERISTICS OF A LEBANESE METAKAOLIN-BASED GEOPOLYMER MORTAR

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Abstract: This work investigates the influence of various alkaline activators (Na and K) on the properties of a Lebanese metakaolin-based geopolymer mortar. The first part of this work consisted to find and treat a local Lebanese source of kaolin. The metakaolin was later produced by the calcination of the local kaolin at a temperature reaching 700˚C. Once prepared the silica, alumina and alkali activator (either Na or K based) were mixed together in order to obtain the required mortars. Results indicated that the sodium based geopolymer mortars exhibit a greater compressive mechanical strength than the potassium based mortars.

Keywords: Geopolymers mortar, alkali mortar, Mechanical characteristics

1. INTRODUCTION

Geopolymers are a class of cementations aluminosilicate binder materials synthesized in the 70's by Joseph Davidovits [1]. They are inorganic materials with a chemical composition similar to that of zeolites. Geopolymers are produced by a geopolymerization reaction that occurs between aluminosilicate minerals and alkali activator solutions at ambient or high temperatures [2]. In recent years, geopolymers have shown a great potential in replacement of traditional Portland cement where it was observed that the new material has shown high thermal and chemical resistance properties when used in engineering applications [3]. At present, the influencing factors of different Si/Al ratios, amount of water, concentration and variety (Na or K) of alkali cations have been investigated on the mechanical properties, phase transitions and microstructural development of geopolymers [3]. Generally, the formation process of metakaolin-based geopolymer is divided into three main stages: (1) the dissolution of aluminosilicate precursors from the metakaolin particles to form free SiO_4 and AlO_4 tetrahedral units under the complex action of hydroxide ions [2], (2) partial orientation and internal restructuring of the tetrahedral units to yield amorphous geopolymers, (3) re-precipitation where the whole system sets into an inorganic cross-linked three-dimensional network [1].

2. MATERIALS AND SPECIMEN PREPARATION

In this study, the main source of aluminosilicate material was obtained from local deposits available in Taibe Baalbek, Lebanon (Latitude: 33°57', 9, 53°N; Longitude: 36°14'1, 28° E) where they were attained in different sizes. To start the experimental procedure, kaolin endured several processes [4]. First, Los Angeles test was applied in order to break the kaolin into smaller pieces that were then grinded manually and finally sieved by using Sieve analysis n°200 in order to obtain the fine powder form. Afterward, the grinded kaolin was calcined at 700°C for 5 hours to become metakaolin. In a second phase, two separate alkali activators were prepared one with NaOH pellets and SiO_2 and the second with KOH and SiO_2. The alkaline activators were sealed and stored for a minimum of 24 hours prior to use to obtain clear solutions and avoid exothermic reactions. In this work, (Na or K)$_2$O/Al_2O_3 stoichiometric ratios and the SiO_2/Na_2O or SiO_2/K_2O were kept constant and equal to 1.5prepared to [5].

First, the normalized sand and the metakaolin were first mixed and then the liquid activators (Na or K based) were added gradually and mixed at low and high speed to obtain the desired geopolymer mortars. Two different sets of samples were made: the first set up contained the sodium based alkali activator while the second set up was formulated by adding potassium based activators instead of sodium. Simultaneously, the geopolymer samples were then casted in cubic 4x4x4 cm steel molds in two consecutive layers and were vibrated for 1 minute on the vibrating table to eliminate unexpected air bubbles. The samples were inserted in the oven for 24 hours at 60ºC and then demolded and kept in a humid container at a room temperature (25±3 °C) for curing until the day of testing 1, 3 and 7 days. The samples were divided into two main categories; those containing KOH and SiO_2 and were identified as "K-G"; and those that enclosed NaOH pellets and SiO_2 and were identified as "Na-G".

3. RESULTS AND DISCUSSION

The characterization of mechanical properties of the geopolymer mortars shown in figure 1 was the objective of this study. The major influence of the type of the basic alkaline medium used in the mixtures (either sodium or potassium) was studied in order to assess the compressive strength.
The experimental results are represented on the average of three consecutive measurements for compression strength carried out with an automatic compression/flexural machine U test. Compressive strength is a mechanical property obtained from measuring the maximum compressive load before rupture of a material [5]. In our laboratory, the compressive strength was determined using a laboratory mechanical test respecting the ASTM C733 standard.

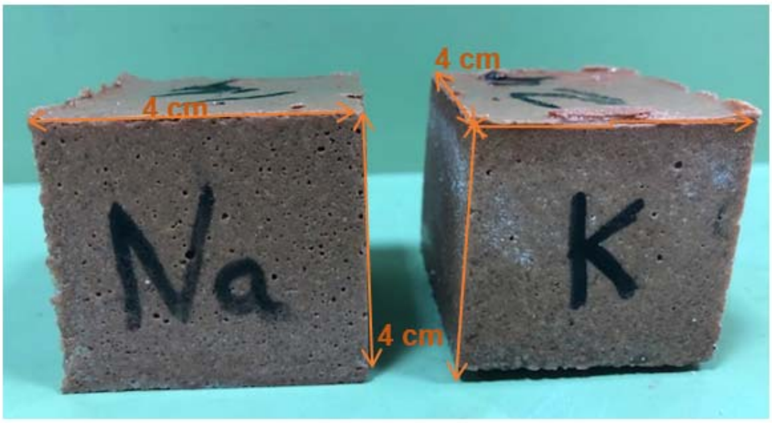

Fig.1. Geopolymer mortars.

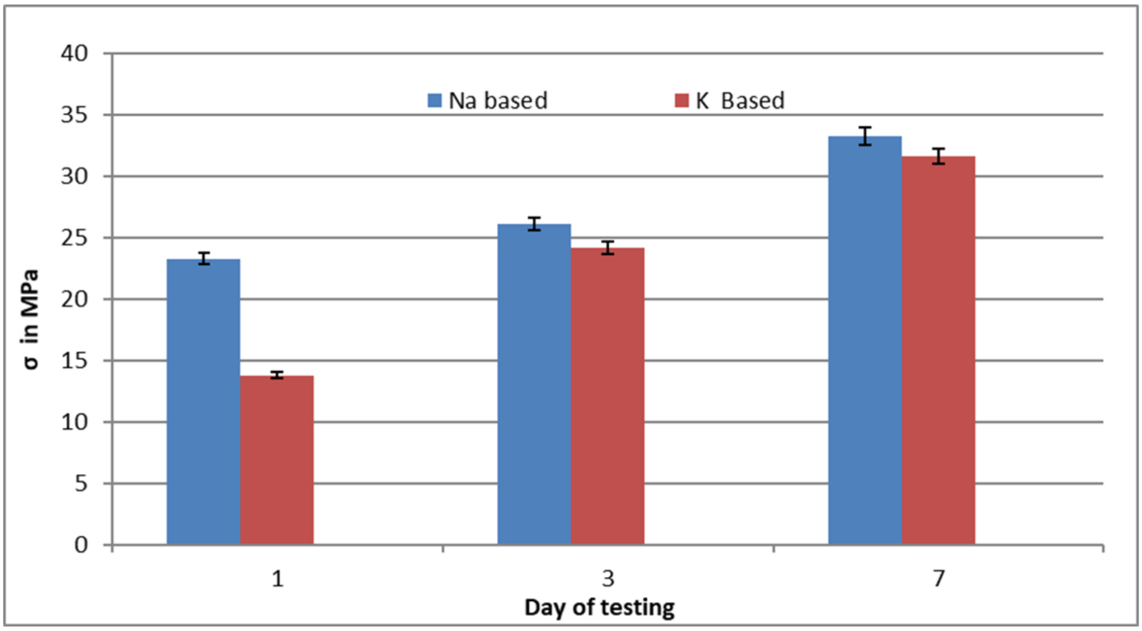

Fig.2. Compressive strength of geopolymers according to liquid activators.

As seen in figure 2, Na-based geopolymers appear to have greater compressive strength than the K- based mortars. This is primarily due to the activation of the binder that became stronger and quicker, and therefore the potassium silicate enhanced the solubility of the aluminosilicate. Furthermore, continuous slight increase seen in the NaOH liquid activator over the days from 1 to 7, can be explained by the less porous and more homogeneous structure when comparing with K based geopolymer. Nevertheless, with increasing days of testing, the mechanical properties taking into consideration the same Si/Al ratios, is quite low. The maximum compressive strength value obtained reached at day 7 a value of 33.3 MPa for Na-based geopolymers, while K- based had a value of 31.6 MPa. Once again, the relative difference calculated through equation (1) of the compressive strength between the 2 sets of specimens is reported in figure 3. The variation in percentage goes from 17% between K and Na at day 1 and reduces down to 5% at day 7. Therefore, the slightly higher values observed can be explained by several factors. The first one is the microstructural difference between sodium and potassium where each mineral has an important impact on the formation of geopolymers as it acts as charge balancing ions. The second factor is when an excess of ion (either K or Na) is available, the compressive strength of the mortars increases very slowly or even decrease according to the quantity of (Na or K) available in solution, thus hindering the water evaporation and strong structural formations [7]. In our experimental set-up, and according to the Na or K/ Si ratios used, the probable assumption of an excess of sodium content can explain the slight difference between Na and K- based geopolymer mortars.
In fact, it is known that when excess sodium content is available in a mix; sodium carbonate is formed by atmospheric carbonation, and this may decrease or disrupt the polymerization process with time [7].

$$\mathrm{Re}lative\ Difference = \frac{\sigma_{Na} - \sigma_{K}}{\sigma_{Na}} x100 \qquad (1)$$

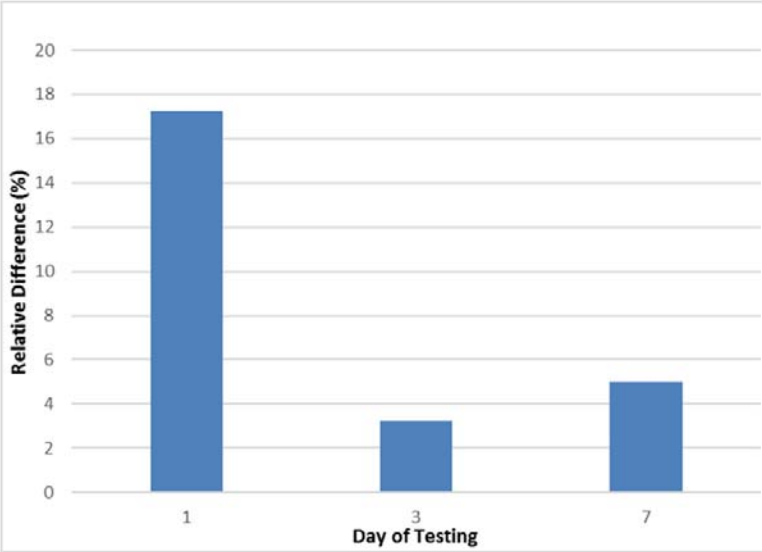

Fig.3. Relative difference of compressive strength between Na and K-based geopolymer mortars.

4. CONCLUSION

As a result; this work is mainly devoted to the study of the influence of the use of KOH and K_2SiO_3 alkali solutions and to the comparison with the most common activator solution that is made of NaOH pellets and Na_2SiO_3. In order to examine the influence of the two different activators, the metakaolin based geopolymer mortars produced on laboratory scale (4x4x4 cm) was studied through their mechanical properties. Once they are formed, samples are cured at 60˚C for 24 hours and were later on well-preserved for aging in appropriate conditions until respective mechanical properties were tested at 1, 3 and 7 days. Results showed that the type of the alkali-(Na or K) OH solutions changed the amount of the reacted metakaolin and the mechanical properties of the produced mortars.

The local metakaolin was seen as feasible to be used for the production of geopolymer mortars. The optimum compressive strength was obtained when NaOH alkali activator was used, even though the samples prepared with KOH alkali activator gave high mechanical properties as well. As a conclusion, geopolymers can provide a desirable alternative to Ordinary Portland Cement (OPC), not only for the environmental benefits arising from the avoidance of CO_2 emissions but also in terms of performance and durability. In the future, it is advised to study on a longer spam the effect of the microstructural characteristics, of Na and K -based geopolymers, on the mortar mechanical properties.

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