

Comparative study between structural and electrical properties of geopolymers applied to a green concrete

A M Montaña^{1,2}, C P González², J Pérez¹, C Royero¹, D Sandoval¹ and J Gutiérrez¹

¹ Escuela de Química, Universidad Industrial de Santander, Bucaramanga, Colombia.

² Grupo de Investigación en Materiales - GIM, Departamento de Ciencias Básicas, Universidad Pontificia Bolivariana Seccional Bucaramanga, Floridablanca, Colombia.

E-mail: claudia.gonzalez@upb.edu.co

Abstract. This work shows a comparative analysis of geopolymers obtained by alkaline activation of two aluminosilicates: bentonite and metakaolin. With the goal of to replace some cement percentage, both aluminosilicates were added in several proportions (10, 20 and 30%) to concrete mixes. Portland Type I cement was used to prepare the reference concrete (without geopolymer). X-ray diffraction of geopolymers allowed to find new crystallographic phases that was not present in precursor's minerals. To evaluate mechanical properties of concrete prepared with geopolymers, test tubes with 7, 14, 28 and 90 days as setting time were used. Chemical resistance and Electrical impedance of concrete mixes were also measured. Results shows that cementitious material obtained from metakaolin exhibit the best compressive strength. On the other hand, those materials derived from bentonite, have a high electrical resistance so that, they protected reinforced concrete better that Portland does.

1. Introduction

Portland type I cement (PC), is the main component of concrete because of the high resistance that it offers in hardened state. Nevertheless, cement manufacturing, has remarkable consequences on environmental contamination due to the emission enormous during the process of obtaining Clinker. For that reason to search alternatives materials for cement it is necessary. Inorganic polymers, also called Geopolymers [1-5], are very interesting materials for both investigation and building industry for its mechanical resistance similar to that for Portland, representing one possibility for replacement. This study presents a comparative analysis of two geopolymers obtained by alkaline activation of bentonite (BEN) and metakaoline (MEC). This geopolymers were added as cement replacement in different concentrations to concrete mixes.

2. Experimental

Geopolymers synthesis starts by aluminosilicate (BEN and MEC) addition to alkaline solution of Na_2SiO_3 . Mix reaction was bring to 60-120 °C by 31 h and dried by 6 h, to obtain cementitious materials. Subsequently, geopolymers was ground to a particle size of 4,75 mm (according to ASTM C94 /C 94M – 09) [6] to elaborate concrete test tubes.(according to ICONTEC NTC 1377) [7] with Portland substitution of 10, 20 y 30%. It was prepared cylinders 75 mm in diameter and 150 mm high, for mechanical testing of each mixture. Test pieces of 2 cm diameter and 4 cm in length, was made for an electrochemical analysis [5]. The setting times employed was 7, 14, 28 and 90 days.



3. Results and discussion

BEN geopolymer diffractogram (figure-1) shows new crystalline phases which are not presents in bentonite: natrolite, microcline, gibbsite and corundum. These phases are coming from alluminosilicate structure transformation because of the alkaline solution. There are some phases that are conserved: illite, quartz and montmorillonite which showed a 0.5° shift at 2θ . Meanwhile, MEC geopolymer (figure 2) it has not a crystal structure this is an amorphous material with some phases like muscovite, anatase, microcline and quartz from kaolin starting material.

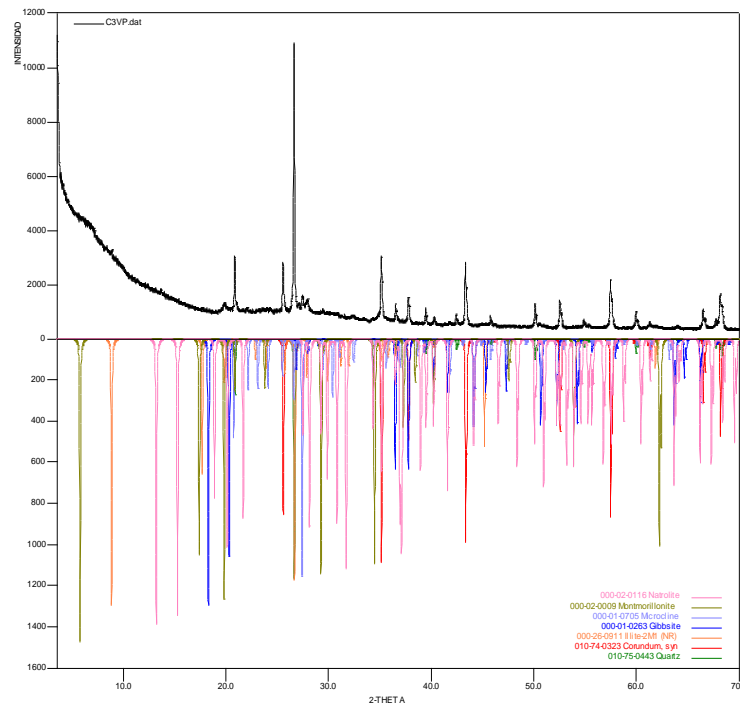


Figure 1. X- ray diffraction patterns of the BEN geopolymer.

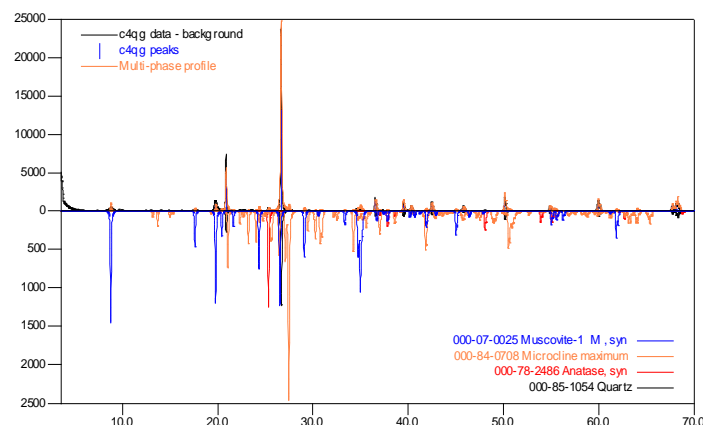


Figure 2. X- ray diffraction patterns of the MEC geopolymer.

Test to compressive strength of concrete were conducted. Test specimens which was replaced at 10, 20 and 30% Portland cement by geopolymer and reference (without replacement) were subjected

to a setting of 7, 14, 28, 90 and 120 days. In figure 3 and 4 shows compressive strength for concretes with BEN geopolymers (GP BEN) and MEC geopolymers (GP MEC) respectively.

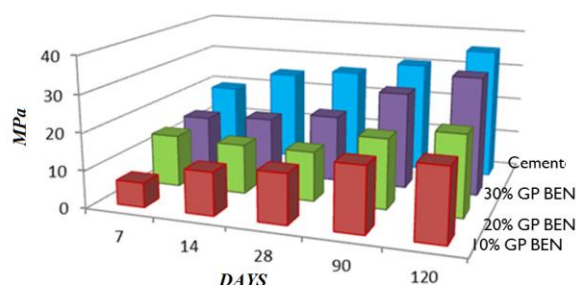


Figure 3. Compressive strength of the specimens with substitution of BEN geopolymer and reference probe.

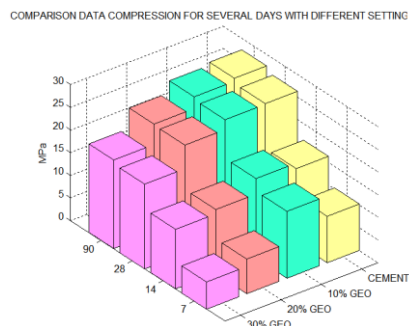


Figure 4. Compressive strength of the specimens with substitution of MEC geopolymer and reference probe.

For both concretes it is found that the best compressive strength corresponds to reference. However, in the samples with 30% GP BEN resistance value was higher than in the other replacement percentage. It can also be observed that as the curing time increases, also increases the resistance value, showing an almost linear behavior because, in concrete, the hydration reactions take place at high speed. High strength values for the samples tested with 120 days of curing with and without replacement of Portland. Similar behavior was observed in the specimens with GP MEC.

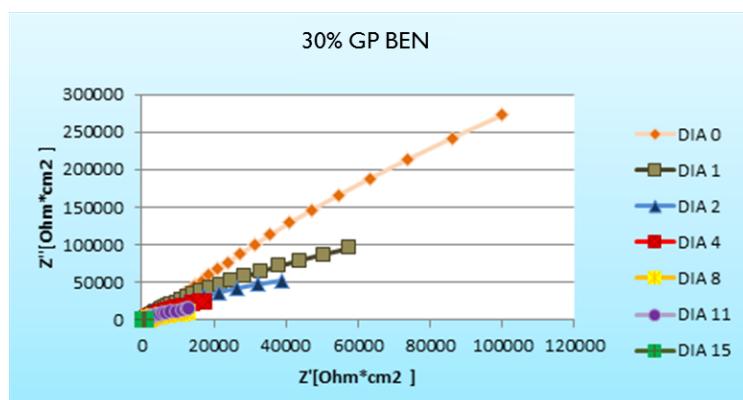


Figure 5. Nyquist graphs obtained for the specimen with 30% GP BEN.

Nyquist impedance spectrum at different times and different immersion substitutions geopolymer were performed. It was observed for all diagrams same tendency to increase the time of analysis, the value of resistance decreases, thereby increasing the corrosion process that occurs when exposing the steel to the 2% NaCl solution. Figures 5 and 6 show Nyquist diagrams of the impedance spectrum at different immersion times for the samples with 30% GP BEN and 10% GP MEC respectively. In the sample with 30% GP BEN, corrosion is less due to there is less charge transfer to the metal-mixture interface, thus presenting different electrochemical behavior for each mixture and setting time. Between 8 and 11 immersion days it was an increase in the impedance value then decreased again to the 15th measurement, following the same corrosive behavior that was submitted over time. This change in behavior of the material in time, is attributed to the oxide layer formed on the surface of the steel is shield type (which is an oxide that reduces the exchange of species from the solution to the material).

A comparable behavior in the test tubes was presented with 10% of the GP MEC for 11 days but with lower impedance values with respect to the GP BEN.

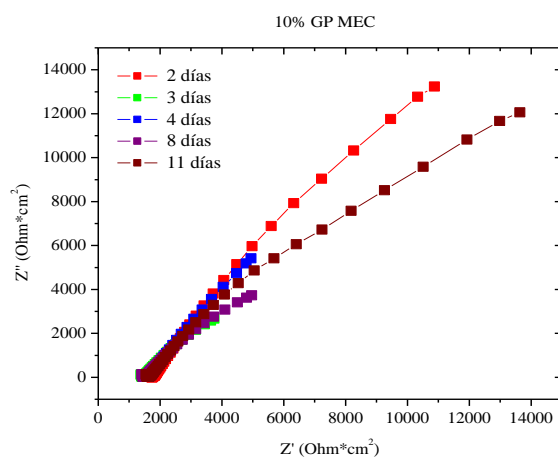


Figure 6. Nyquist graphs obtained for the specimen with 10% de GP MEC.

4. Conclusions

Cementitious materials formed from metakaolin showed the best mechanical resistance, while those made from bentonite, exhibited a high electrical resistance so that there was a greater protection against corrosion in reinforced concrete.

Electrical tests confirm that the optimum percentage of geopolymer MEC replacement for cement in a concrete mix should be 10%, since in these measures were reached high impedance value, indicating the increased electrical resistance.

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