Utilisation of glass for the production of inorganic polymeric materials for construction industry.

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Introduction

The geopolymerization technology and therefore the study of the properties of the materials produced that are called geopolymers are an issue of on-going extensive research worldwide. Geopolymers are a class of aluminosilicate-based materials with the potential to replace Portland cement in a variety of applications, particularly where chemical or thermal resistance is require. Geopolymers are formed by the reaction between an alkaline solution and an aluminosilicate source. The hardened material has an amorphous to semi-crystalline three-dimensional structure similar to that of an aluminosilicate glass. The reaction is exothermic and takes place at atmospheric pressure and temperatures below 100 ^{o}C. This paper aims at studying the geopolymerization of the glass coming from municipal wastes generated in order to develop novel inorganic polymeric materials for construction purposes. One of the main issues for the construction materials is the combination of high mechanical strength and low water absorption.

Experimental

Table 1 Chemical Analysis of Glass

Oxides	XRF Method
SiO_2	68.9
Al_2O_3	0.6
Na_2O	13.2
MgO	2.6
CaO	11.22

The chemical analysis of the glass is given in the Table 1. The X-ray Fluorescence (XRF) method (Spectro Xepos) was used to determine the chemical composition of the glass. As shown in Table 1, the glass is very rich in silicon oxides and is relatively high in sodium, calcium and magnesium oxides.

The following series of experiments were performed to study the behavior of glass geopolymers. NaOH was used as alkaline activator instead of KOH, and the reason is that the final application of the materials must show materials with high mechanical properties. NaOH as the most active solubilizes the amorphous Si and Al in the solid raw material to create a more stable mesh.

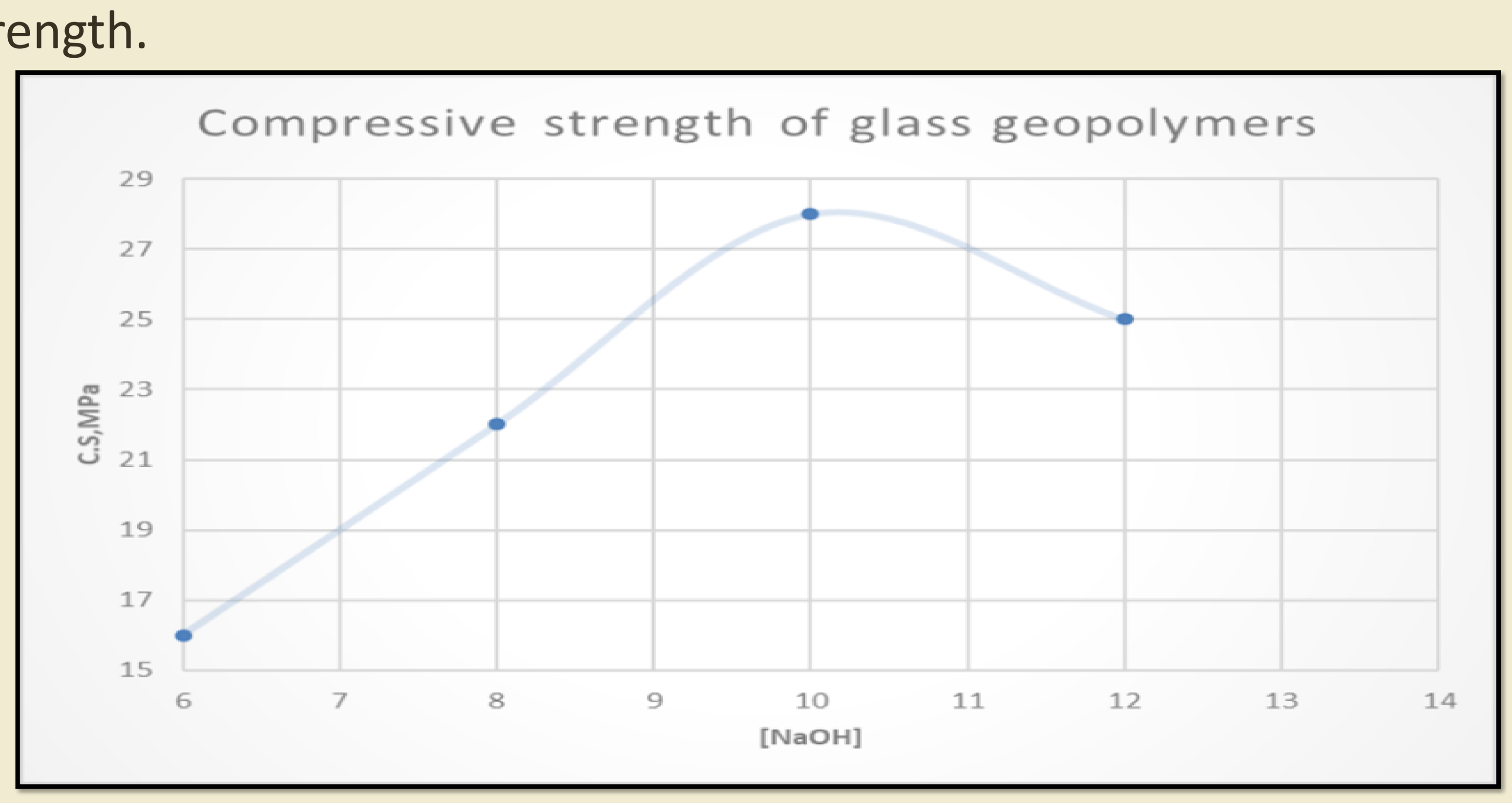
The first set of experiments concerns the study of the effect of alkali concentration on the strength of the finished material, with values of 6M, 8M, 10M and 12M. The purpose of the materials produced is to develop a compressive strength of at least 10 MPa, which is considered suitable for use as a sidewalk slab. The hardening temperatures of the geopolymers selected for experimental study in this series of experiments were 60 °C. In all experiments, the relative maturation humidity of the geopolymers was 70%.

Alkality (M)	Density (Kg / m^3)	Water Absorption (%)	pH Initial	Final
6	1521,85	1,01	6,65	11,137
8	1591,00	0,84	5,55	11,557
10	1692,21	0,79	6,38	11,195
12	1734,42	0,77	6,24	11,104

In this work the development of an added value geopolymer materials, using glass as a raw material, is described.

1.Geopolymer material achieved a 28 MPa compressive strength with a <1 % water absorption. This material has comparable or superior properties in relation to the commonly used construction materials (normal and high strength concretes).

2.The increase of the alkalinity did not result to higher compressive strength.



The glass was mixed with an alkaline sodium silicate solution (NaOH and SiO2), used as an aqueous activator, in order to create a viscous paste that was subsequently molded in cubic 50x50x50mm molds and cured in a laboratory-scale oven for 72 hours, under atmospheric pressure, temperature 60 o C and relative humidity 70 %. The formed cubic specimens were kept in closed molds for the first six hours of curing. Thereafter, they were demolded and left in the oven until curing. The cured specimens were left to cool for 48 hours at ambient conditions, before any test and analysis was carried out. The compressive strength according to ASTM C-109 and the cold water absorption according to the EN 771-1: 2003 standard tests were determined.

Results

After the geopolymer hardening, their apparent density, water absorption and alkalinity were tested. The geopolymers of all the experiments showed high alkalinity and remained unchanged after being in water for 24 hours. In general, geopolymers are highly alkaline materials due to the high concentration of sodium hydroxide in their mass and the unreacted free alkali. In addition of the synthesis conditions of the geopolymers followed in this experimental study, the appearance of the specimens is not directly affected by the alkali concentration. Upon the completion of hardening of the geopolymers (28 days) at the temperatures studied, two of the three geopolymer specimens of each experiment were subjected to uniaxial compression after being kept at ambient conditions for 24 hours. As shown in Figure 2 , the ultimate mechanical strength of the geopolymers is illustrated as a function of their alkalinity and their ultimate resistance in uniaxial compression appears to be substantially affected by alkalinity. Moreover, the increase in alkalinity is resulted in a decrease – stabilization of the mechanical strength of the geopolymers and this was due to the excessive amount of NaOH in the system relative to the amorphous silicon and aluminium contained in the raw material. The alkalinity of 10 M is obviously the maximum amount of alkali that can dissolve the insoluble silicon particles in the glass.

More specifically, the total strength increased as the initial NaOH concentration increased from 6 M to 10 M, reaching a maximum value of 28 MPa. Further increase of the initial NaOH concentration to 12 M resulted in a decrease in the competitive force. Sodium hydroxide is concentrated in the alkaline wash of the glass in order to remove soluble amounts of silicon and aluminium from the glass. The rate of this divergence is directly related to the concentration of hydroxide ions in the liquid phase and generally increases with the increase of these ions. Increased concentrations of Si and Al in the liquid phase are necessary to maintain the oligomers of Si and Al complex species. The creation of such species accelerates the process of polycondensation which results in the development of complex polymer structures that are important for the development of geopolymers. In addition more properties were measured as shown in the following table indicating the specific material as promising building material.

GOAL Product Characteristics	
Alkiline Activator (concentration)	Sodium Hydroxide (10M)
Compressive Strength	28MPa
Flexural Strength	4.2 - 6.7 MPa
Young's Modulus	5.3 GPa
Indirect Tensile Strength	2.94 MPa

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