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Production of binder by polymerization of glass powder from used bottles

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ABSTRACT
End-of-use glass bottles, considered as waste, cause many environmental problems. In order to reduce pollution due to this waste, this study consists of using it for the development of a mineral binder. The raw materials are glass powder, chamotte, sand and sodium hydroxide. Samples were made with the binder developed and introduced into an oven for thermal activation at 65°C for 3 h, 5 h, 8 h and 24 h. The raw materials and samples were respectively subjected to particle size and sediment analysis and then to the compressive strength test. The results showed that the granular class of the sand is 0/2, with a fineness modulus equal to 2.26. Glass and chamotte powders are respectively made up of 2% and 4% of particles with a diameter less than 0.002 mm, 36% each, between 0.002 and 0.06 mm, then 58% and 56%, between 0.06 and 0.1mm. The compressive strength test showed that from 7 to 28 days, the strength ranges from 0.7 to 1.8 MPa, from 1.1 to 3.5 MPa, from 2.1 to 4.4 MPa and from 2.3 to 4.5 MPa, respectively for activation times equal to 3 h, 5 h, 8 h and 24 h. The 28th day is considered as the maximum maturation time of the geopolymer and 8 hours, as the optimal thermal activation time. In conclusion, the binder made from glass powder, chamotte, sand and sodium hydroxide can be used to make hollow bricks after 8 hours of thermal activation.

Key words: waste, mineral binder, polymerization, powder, glass bottles

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I. INTRODUCTION

Glass, in particular glass bottles, are solid, non-crystalline, homogeneous bodies, resulting from the quenching of silica after melting. The raw materials used for their manufacture are sand, soda, dolomite and limestone to which cullet is sometimes added in order to reduce the effect of the melting temperature. Glass bottles have existed since 3000 years BC and are widely used for packaging liquid foods as well as a variety of other liquid products given their great chemical inertness. Glass production amounts to approximately 2.9 million tonnage per year according to [1]. However, end-of-use bottles, considered as waste, are thrown away and abandoned in nature, causing many environmental problems. However, they are non-biodegradable and are much more difficult to manage.

In order to reduce pollution due to this waste, this study was carried out with the aim of developing a mineral binder from the waste. This could be used in the construction sector. The purpose of this work is to design a binder by polymerization of glass powder from used bottles.

Indeed, a mineral binder is an element whose function is to ensure the agglomeration of materials together, particularly during setting and then hardening. The best known mineral binders are cement, clay, lime and plaster. The development of binders by the polymerization of glass bottles would make it possible to have a diversity of binders for different constructions and works, which could reduce the cost of certain binders and rid our bins of glass waste.

II. MATERIALS AND METHODS

2-1- Material

2-1-1-Raw materials

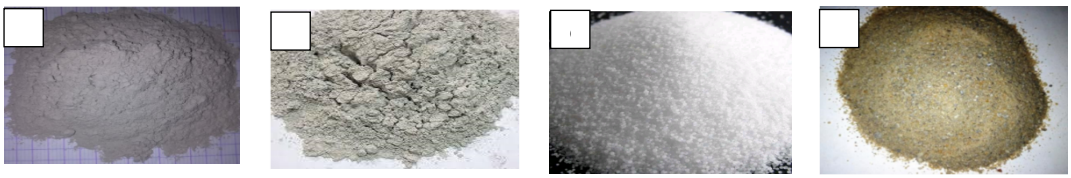
The raw materials used for the production of the geopolymer binder are glass powder from used bottles, chamotte powder, sodium hydroxide (NaOH) and sand.

Glass bottles come from household and industrial waste. For this study, only green and thin

bottles were collected. According to [2], glasses of this color have good mechanical resistance just like colorless and brown glasses.
Just like glass bottles, sanitary ware is also recovered from landfills in order to be treated and used. As for sodium hydroxide, a 25 kg bag in granulated form with 99% NaOH was used. Finally, quarry sand free of all impurities is chosen.

2-1-2- Physical treatment of glass bottles, sanitary ware and sand

The glass bottles and sanitary ware recovered from the garbage are first washed and dried at room temperature. Then, they are crushed and then ground using a ball mill. The powders obtained are sieved using a 250µm sieve. The passer of this sieve is collected then kept in a closed container to avoid any contamination. As for the sand, it is sieved using a 5 mm mesh sieve in order to eliminate coarse particles (ø < 5 mm). Figure 1 shows the different raw materials used to produce the binder.



a) glass powder b) sanitary powder (chamotte) c; sodium hydroxide d) sand

Figure 1: Different raw materials used to produce the binder

2-2 Study methods

2-2-1 Characterization of raw materials

The sand was the subject of a particle size analysis, while the glass and chamotte powders were the subject of a sedimentometric analysis. The granulometric analysis of sand is carried out according to standard [3] which consists of determining the weight distribution of soil particles as well as the granular class designated by the notation d/D and calculating the fineness modulus (Mf). The test was carried out using a sieve column with the following mesh sizes: 63µm, 125µm, 250µm, 500µm, 1mm, 2mm and 5mm. The calculation of the fineness modulus is given by equation 1.

(1)

The sedimentometric analysis consists of determining the weight distribution of soil grains whose particles are less than 0.063 mm. It was done according to the standard [4].

2-2-2 Preparation of samples

Firstly, the binder is produced from sodium hydroxide, glass powder and chamotte. A mass of 50 g of sodium hydroxide (NaOH) is dissolved in 275 ml of distilled water. After the NaOH grains have completely dissolved, 280g of glass powder (PV) is added. The mixture is kneaded for 2 minutes then 150 g of chamotte is added. The entire mixture is then homogenized for three (3) minutes.

Once the binder has been developed, we move on to making the samples. A mass of 735 g of the binder obtained is mixed with 2000 g of sand. The mortar obtained is introduced into molds measuring 4x4x16, then thermally activated at 65°C for 3 hours, 5 hours, 8 hours and 24 hours. The samples obtained after this step are stored at room temperature in the laboratory. Figure 2 presents the samples developed.

Figure 2: mortar samples composed of sand and geopolymer binder

2-2-3 Characterization of samples

The mortar samples made with the binder based on glass powder, chamotte and sodium hydroxide were subjected to mechanical tests, in particular compressive strength. This is defined as the measurement of the maximum resistance of a concrete or mortar specimen to an axial load. The mechanical test is generally carried out 28 days after making the samples. However, in this study, it will be done from the 7th day to the 28th day. The unit of measurement for resistance is the mega pascal (MPa). The compressive strengths of the mortars were carried out on the samples in accordance with the standard [5]. This is expressed according to equation 2:

$$RC=F/S \quad (2)$$

Rc (MPa): compressive strength; F: applied force; S: area

III. Results and discussion

3-1 Particle size analysis of sand

The results of the grain size analysis of the sand are presented in Figure 3.

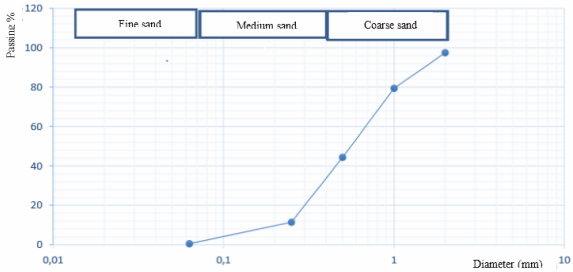


Figure 3: Sand particle size analysis result

Figure 3 shows the distribution of sand grains according to their diameters. It appears that the sand used is made up of 0.6% fine sand (0.08 mm < ø < 0.3 mm), 79.4% medium sand (0.3 mm < ø < 1.25 mm) and 18% coarse sand (1.25 mm < ø < 5 mm). The granular class is 0/2 and fineness modulus equals 2.26. This value is between 2.2 and 2.8; this corresponds to the interval of preferential sands for concrete according to [6]. It can therefore be used for making geopolymer mortars.

3-2 Sedimentometric analysis of glass powder and chamotte

Figure 4 illustrates the results obtained from the sedimentometric analysis of glass powder (a) and chamotte powder (b).

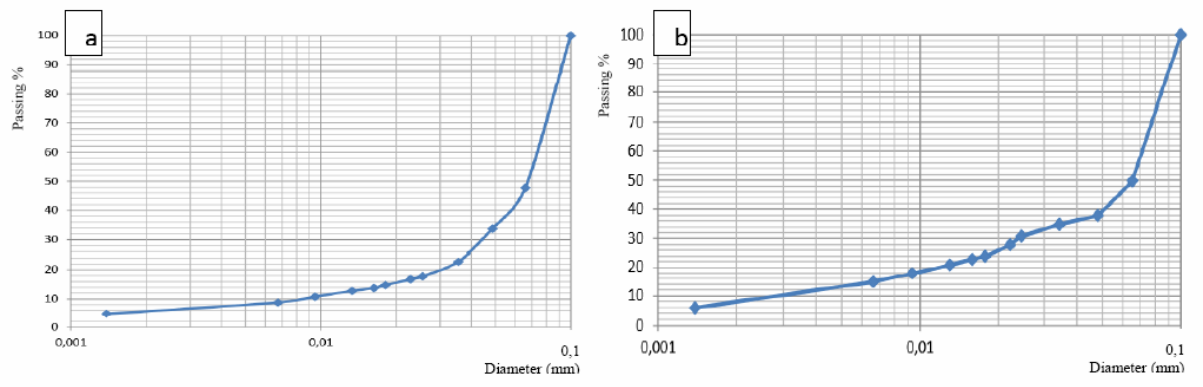


Figure 4: Results of sedimentometric analysis of glass powder (a) and chamotte (b)

Curves a) and b) of the sedimentometric analysis respectively show a variation in the percentage of passers-by depending on the dimension (or size) of the particles of the glass powder and those of the chamotte.

Figure 4-a shows that particles with diameters less than 0.002 mm represent 2% (Ø < 0.002 mm) of all glass powder particles. This particle size corresponds to that of clay particles. On the other hand, 36% of the glass powder particles have a diameter strictly between 0.002 mm and 0.06 mm. These sizes correspond to those of silt particles. Finally, 58% of the glass powder particles have a size between 0.06 mm and 0.1 mm. Particles of this size correspond to fine sand particles. This study made it possible to make the distribution of the grains of the glass powder and it appears that it contains more grains whose diameter is between 0.06 and 0.1 mm.

Figure 4-b shows that chamotte powder is made up of 4% of particles with a diameter less than 0.002 mm. However, 36% of chamotte powder particles have a diameter between 0.002 mm and 0.06 mm and 56 % of these particles have a diameter between 0.06 mm and 0.1 mm. The particle size distribution of chamotte powder is therefore slightly different from that of glass powder.

3-3 Compressive strength of samples

Figure 5 presents the results on the compressive strength of the samples. Compression tests are carried out from the 7th day because before this maturation period, the samples are very fragile and cannot be handled.

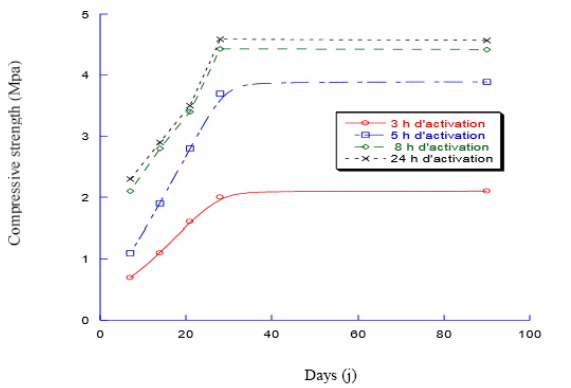


Figure 5: Compressive strength of the samples produced

Figure 5 shows the compressive strength of the samples as a function of maturation time and thermal activation duration.

Indeed, when the activation duration is short (3 h), the resistance of the sample is also low. When the activation duration increases (5h, 8h then 24h), the resistance of the samples also increases.

The activation duration therefore has an influence on the resistance of geopolymer samples. These results confirm those of [7]. According to this author, treating the fresh mixture at high temperature accelerates the development of the material's strengths. However, his work focused on geopolymers based on metakaolin treated at temperatures varying from 10°C to 80°C.

However, regardless of the activation duration (3h, 5h, 8h and 24h), the resistance of the samples increases from the 7th day to the 28th day of maturation. However, this increase is rapid for activation times of 5h (1.1 to 3.7 MPa), 8h (2.1 to 4.4 MPa) and 24h (2.3 to 4.7 MPa), and slow for the activation duration of 3 hours (0.7 to 1.8 MPa). Beyond the 28th day of maturation, the strength of the samples remains approximately constant regardless of the maturation period.

This result is explained by the fact that, from the 7th to the 27th day, the hardening of the

mortars is not yet definitive and stable because it takes place gradually. On the 28th day, the hardening is definitive and can no longer vary, which explains the maximum value and the constancy of the resistance of the materials from this date. Also, the geopolymer has acquired more than 90% of its final strength. This is the reason why it remains constant between the 28th and 90th day.

In addition, the results show that after 8 hours of thermal activation, the variation in the resistance of the material is very low. Thus, the 28th day is considered the optimal duration of maturation of the geopolymer while the 8 hours of thermal activation constitutes the optimal thermal activation duration. The results therefore show that the compressive strength increases with the maturation time and the duration of thermal activation of the samples.

However, this compressive strength of the samples may be due to the grain size of the glass powder obtained by grinding because the studies of [8] showed that reducing the particle size by grinding (grinding finely) reduces considerably reduces alkali-aggregate reactions and increases the mechanical compressive strength of concrete. The hardening of the samples shows that indeed the binder developed has the capacity to bind the sand particles after thermal activation.

This result is in agreement with the work of [9] who developed geopolymers based on glass powder using NaOH and KOH as alkaline activators with concentrations of 1, 5 and 10 mol. They showed that thermal activation of 40-60°C was necessary to develop mechanical properties and compressive strengths. Furthermore, [10] also showed that prolonged thermal activation at high temperature (85ºC) can weaken the structure of the geopolymer, due to the evaporation of water from the pores and, consequently, to the dehydration of the gel. geopolymers.

3-4 Effect of maturation time

The structure of geopolymers as a function of maturation time is presented in Figure 6 [11].

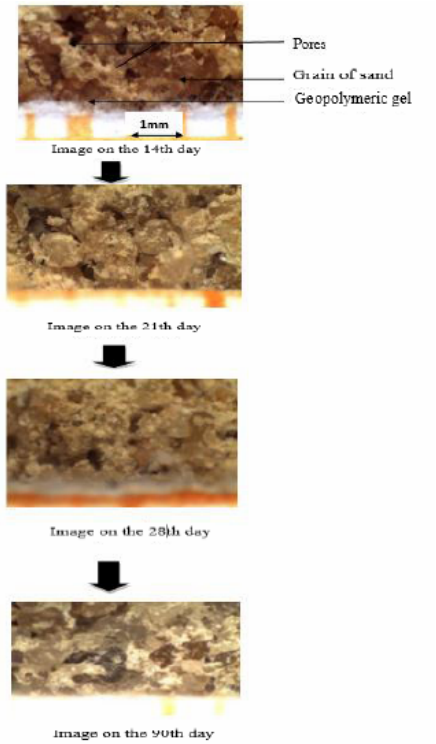


Figure 6: Structure of geopolymers

Under the microscope, Figure 6 shows the geopolymer structure of the samples. We observe between the grains of sand, the presence of a whitish tab, the quantity of which increases with the duration of maturation. This whitish tab is the geopolymeric gel obtained from the binder made with glass powder and chamotte. This gel ensures the connection between the grains of sand.

Studies have shown that after gel formation, rearrangement and reorganization continue in the system with increasing interconnectivity in the gel network. The end result is the formation of a three-dimensional network of aluminosilicate gel which is commonly attributed to gel [12]. This is what [13] justifies by showing that after the breaking of the Si-O-Si and Si-O-Al bonds to form reactive precursors Si(OH)4 and Al(OH)4- in the solution, Si(OH)4 and Al(OH)4- monomers react with each other to give AlSi2O2(OH)8 aluminosilicate oligomers which condense into a gel. As it thickens, this gel fills the spaces between the grains of sand.

V. CONCLUSION

At the end of this study, it appears that the recycling of used bottles can be used to produce a geopolymer binder. The binder reacts when thermally activated and the maximum thermal activation time is 8 hours. This increases the compressive strength of materials by up to 4 MPa. This value corresponds to the minimum resistance

of a hollow brick according to the standard [14]. Thus, the binder can be used to make hollow bricks.

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