IIETA International Information and Engineering Technology Association
Advancing the World of Information and Engineering

Annales de Chimie - Science des Matériaux
Vol. 46, No. 3, June, 2022, pp. 117-125
Journal homepage: http://iieta.org/journals/acsm

Studying the Effect of High Temperature on the Content of Glass and Brick Waste Binders after Alkaline Activation

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https://doi.org/10.18280/acsm.460302

Received: 3 May 2022
Accepted: 10 June 2022

Keywords:
high temperature, alkaline activation, compressive strength, glass powder, brick waste, porosity

ABSTRACT

The high-temperature mechanical behaviour of a glass and brick waste alkaline to synthesize geopolymer mortar was studied. The mortar in question contained 100% glass powder GWP and 90% of a blend of brick waste GBWP, brick waste BWP and a solid activator (10 mol concentration of NaOH mixed with glass water (Na_2SiO_3). The material was tested during exposure to high temperatures to establish its density, weight loss, compressive strength, accessible porosity in water, expansion of pastes, XRD and TG-DSC analysis using an innovative methodology to notch the hydrated geopolymers paste specimens after exposed to five maximum temperatures, 100°C, 200°C, 400°C, 600°C and 800°C without any imposed load during the heating. The results were found that GBWP gave better values in compressive strength, reaching 38.3 MPa at 100°C and other proportional values at 400°C, 600°C respectively compared with GWP. As for the density, the high temperature contributed to its decrease, which caused the presence of high porosity at 800°C. On the other hand, the high temperature helped to improve the mechanical and physical behavior of BWP, where the resistance reached 24.91 MPa at 200°C. In addition, for the microstructure and different particles related to the interactions were identified through the XRD and TG-DSC analysis procedure, in order to know the highest temperatures that allow changing the structure and properties of this type of alternative binders.

1. INTRODUCTION

The idea of searching for minerals waste capable of withstanding the highest temperatures, after undergoing the alkaline activation process is considered an achievement, especially those that lack the pozzolanic effect and are classified under inert wastes, On the other hand, inert wastes can be transformed into effective once they are crushed with a high fineness that competes with cement or more, as a preliminary phase before stating the chemical activation process, This is called mechanical activation, which allows the appearance of the pozzolanic effect, All this in order to manufacture a material, which works on the construction of buildings and structures on a large scale, that is durable enough, and must be able to absorb energy and resist high temperatures, such as nuclear power stations, radioactive waste storage facilities and others [1], in addition to preserve and protect the environment from pollution, in order to reduce global warming, by reducing the proportion of Portland cement production, which allowed the field of scientific research to find alternative binders to cement based on waste materials, including alkaline activated materials (AAM) [2]. Among the industrial waste that has become used as a primary and basic material in the alkaline activation process, it was found that glass of all kinds, as well as red bricks, are classified into the list of alternative materials for cement materials, which can reduce energy consumption during manufacturing, thus, it allows giving materials called geopolymers, the success of geopolymers was based on the introduction of multiple industrial solid wastes during its manufacture [3]. This type of material is formulated with raw materials consisting mainly of aluminosilicates mixed with sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) as an alkaline solution that is curing in an ambient or at a high temperature [4], most of used industrial wastes in the alkaline activation process is rich in quartz (SiO_2) as an essential oxide or named silicate. Among the waste that has been successfully converted into useful products on a large scale such as blast furnace slag, fly ash and metkaolin [5, 6], ceramic materials and glass [7-9]. In addition, waste recycling also shows effective results in terms of saving raw materials, and positive in waste management as used with ceramic bricks [10]. These materials, some of which have been seen and depend on high temperature during the manufacture of bricks waste, are pozzolanic and have permanent activity. On the other hand, glass is used as an inert material with cement that works to improve the physical behavior more than the mechanical, so alkaline activators have been used that help strengthen chemical binders to give geopolymers materials. The geopolymer mixture must be designed to apply appropriate curing conditions with the selected alkaline activators [11, 12]. In other hand, for glass waste can be recycled and included into geopolymers in various ways such as an aggregate, part of activator, part of precursor, or as a source initiation material [13, 14].

In the previous researches, Torres-Carrasco and al, used the slag with glass waste (size < 45 μm) mixed with three different

activators NaOH, Na_2CO_3 and Na_2SiO_3 [15]. The most results demonstrated that samples activated with Na_2SiO_3 presented the best compressive strength between 1–28 days in ambient temperature [13]. There is also another parameter that controls the role of the material after it is entered into a mixture, which is the specific surface or fineness [16, 17]. For Cyr et al., [18] utilized one part of glass powder with fineness between 100–400 m^2/kg and three parts of sand to build geopolymer mortars, the source of glass it is just derivative from recycled bottles. Thus this kind of mineral waste greatly helped in the development of the structure of the alternative binders.

The reuse of inorganic materials by alkaline activation technology has been recently explored to be an important option [19-21]. There are other materials that can enter into the application and take a role, such as red brick waste, have been exposed to high temperatures for the manufacture, in some situation without adequate control; therefore, their reactivity can be reduced [22, 23]. Many researchers used the bricks waste with chemical activators. Such as, Zaharaki et al., [24] was using NaOH 10 M with thermal treatment at 80°C. Also Sun et al. [25] obtained a compressive strength of 71.1 MPa with urban ceramic waste activated with a mixture of KOH and NaOH and faced to a thermal treatment at 60°C for 28 days. Because, the geopolymerization process evaluated the reaction of an aluminosilicate raw material and a silicate solution in an alkaline milieu, and then the curing of the mixture under moderate conditions [26]. From this perspective, the role of aluminosilicate-based industrial wastes as clear when used for the preparation of high extra value materials by geopolymerization method [27, 28]. Also, when used the normal temperature between 20°C to 80°C for treated the geopolymers or alkaline activated materials (AAM) is good and helped for the hardness of structure. In other studies was exposed this type of material at high temperature for studied the general behavior. Tests of temperature effects supported out by various teams have substantiated the geopolymers' strong resistance to high temperature [29].

Davidovits [30] was proved that properly destined geopolymer binders can expose fire resistance or high temperature up to 1200°C. Sitarz and al, said at 100 -200°C, the material shrank only little due to water evaporate, about the range at 250-800°C range, the samples stored dimensional stability [29]. Bakharev [31] was studied fly ash-based geopolymer with an activator containing Na, was noted the shrinkage cracks and a rapid decrease in strength at 800°C. According to previous researchers, was explained that the dimensional stability and the strength to high temperature of geopolymers confined on binder composition, inclusive without limitation the Si/Al ratio, alkali substance and the liquid/solid relationship [32-34]. Abdulkareem et al. [35] observed that materials with superior amounts of activator solution presented the largest decrease in resistance when heated to 400, 600 and 800°C.

The use of alkaline activation technology and the consumption of waste materials rich in aluminosilicates in the production of geopolymers have become necessary nowadays. Most geopolymers rely on the principle of heat curing time and during temperature of their manufacture. The aim of this research to formulate geopolymer based on powder glass combined with brick waste and to find a relationship between the activated materials and the temperature of the heat in order to obtain a porous and refractory material suitable for better insulation.

2. MATERIALS AND EXPERIMENTAL METHODS

2.1 Materials

Two types of industrial waste were taken in this experiment: broken glass bottles and brick waste.

Glass waste **(**GW): glass bottles were obtained from garbage containers and technical backfill center. The glass bottles have been ground to reach 196 m^2/kg Blaine surface areas with specific gravity and bulk density were 2.61 g/cm^3 and 1.12 g/cm^3, respectively.

The Red brick waste **(**RBW)*:* taken from construction waste, which was crushed into particles with Blaine surface area, specific gravity and apparent density were 304 m^2/kg, 2.56 g/cm^3 and 1.09 g/cm^3, respectively. The chemical composition of glass waste and brick waste are shown in the Table 1.

The activators: Analytical grade NaOH (98%) and distilled water were mixed to prepare a 10M NaOH solution. The solutions were allowed to be cool for 24hr before mixing with sodium silicate. The activating solution was prepared by mixing sodium silicate (Na_2O - 10.6%, SiO_2 - 26.5%, H_2O-62.9%) with the NaOH solutions in a 1:1 ratio (wt.%) for 1 hr.

Table 1. Chemical composition of glass and red brick wastes

Component (%)	GW	RBW
Na_2O	12.8	0.91
MgO	3.28	3.63
AL_2O_3	1.10	14.5
SiO_2	70.8	57.2
SO_3	0.31	2.90
K_2O	0.32	2.34
CaO	10.4	10.8
Fe_2O_3	0.31	6.35
CuO	0.2	0.14
TiO_2	-	0.82
P_2O_5	0.25	0.24
ZnO	0.092	0.07
L.O.I	0,33	0,12

2.2 Preparation of geopolymers samples

Three mixtures were prepared in this study according to the following designation: (GWP) contained 100% of glass waste; (BWP) formulated with red brick and the last one (GBWP) mixture of 90% glass and 10% brick waste. Geopolymer pastes were prepared in a similar method as stated below.

Glass powder was mixed with activating solution in a mixer for 2 min. To increase the workability and the mix the activating solution to glass powder ratio was maintained at 2.5. The mix was filled to a prism mold of size 2.5 cm x 2.5 cm x10 cm and cubic mold of size 2.5 cm x 2.5 cm and tapped manually to remove any entrapped air bubbles. The samples were allowed to cure at ambient temperature (room temperature) and in an oven at 60°C for 24 hrs. and were placed at ambient temperature for 28 days.

At high temperatures, three samples per batch were examined and the mean strength was reported. At the 28 days, specimens are dried in an oven at 100°C, until stabilization of their mass. Then all samples were exposed to high temperatures according to the time-temperature schedule of ASTME119-00. The compression strength was accessed at ambient temperature and after exposure to distinct high temperatures of 100°C, 200°C, 400°C, 600°C and 800°C. The microstructure analyses of samples specimens were examined under XRD and TG-DSC analysis.

Loss weight calculated by the formula (1) [36]:

$$\Delta m = [(m_a - m_b)/m_b]. 100\ (\%) \quad (1)$$

where, Δm: Loss weight, ma: mass before thermal treatment, mb: mass after thermal treatment.

Accessible porosity in water calculated according to NF P18-459. The samples placing in water basin for 48 hours until they are saturated well, and absorb necessary water that fills the spaces and makes their mass fixed called (M_1), then they are placed in a container connected with a scale and immersed in water to be weighed in the middle of the water named (M_2), and finally it is placed in an oven for drying at 100 ± 5°C for 72 hours, approximately three days, until the mass obtained becomes constant for the sample (M_3). Figures 1 and 2 illustrated the diagram of using high temperature with geopolymers pastes.

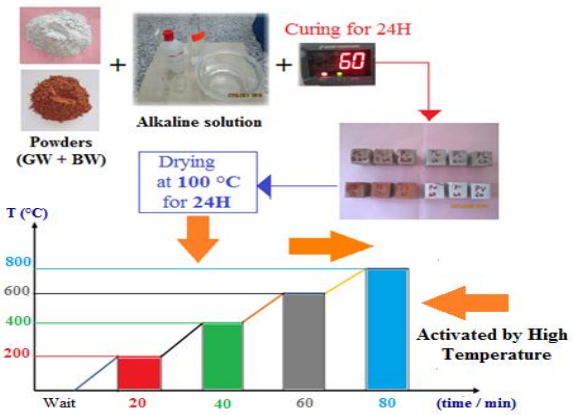

Figure 1. Diagram illustrated the principle of using high temperature with geopolymers pastes

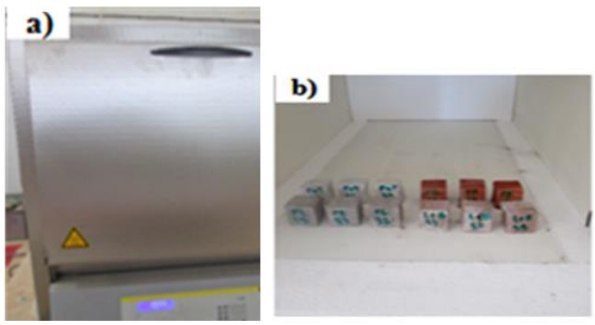

Figure 2. The oven (a) and the geopolymers samples under thermal treatment (b)

3. RESULTS AND DISCUSSION

3.1 Density of geopolymers at high temperature

Figure 3 shows the densities of geopolymers pastes GWP, GBWP and BWP depending on the temperature.

Between 20°C – 100°C, It was observed that the density of pastes GWP, GBWP and BWP has been decreased by 5.65%, 3.01% and 4.52% respectively. The paste GWP gives the highest value, as its density has reached 1.77 g/cm^3 compared with BWP (1.55 g/cm^3) at normal temperature 20°C. On the other hand, the replacement of 10% glass powder by red bricks (GBWP) contributed significantly to reduce the density about 6.21% at 20°C and 3.59% after exposed to 200°C compared to GWP.

In the range 600°C – 800°C, temperature increase clearly affects the density of samples, for example the pastes GWP and GBWP, where its reached 1.55 g/cm^3 to 1.32 g/cm^3 for GWP, as well as 1.29 g/cm^3 to 1.24 g/cm^3 for GBWP.

The mix BWP did not lose much density at each temperature because it is considered a refractor material.

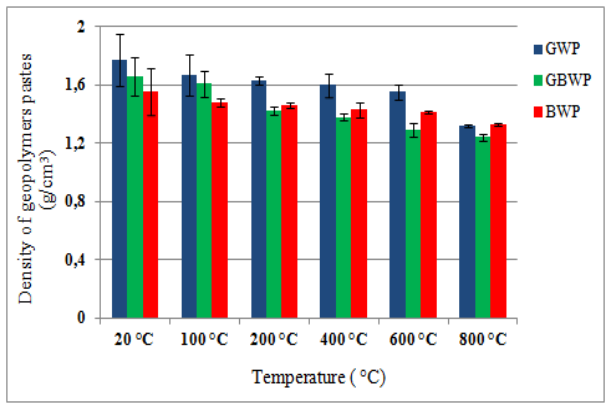

Figure 3. Density of geopolymers pastes depending on the temperature

3.2 Weight loss of geopolymers pastes

Figures 4 and 5 shows weight loss of geopolymers pastes in 100°C, 200°C, 400°C, 600°C and 800°C.

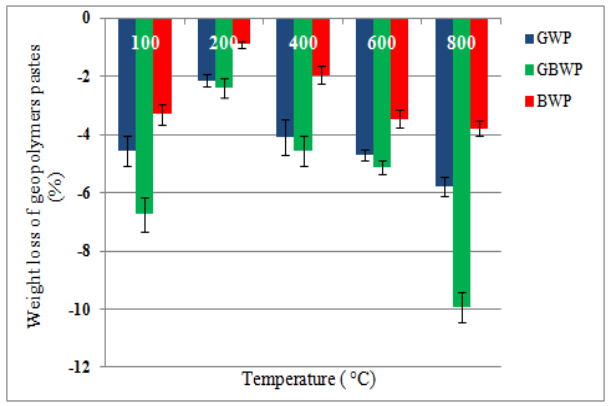

Figure 4. Weight loss of geopolymers pastes between 100°C and all high temperature

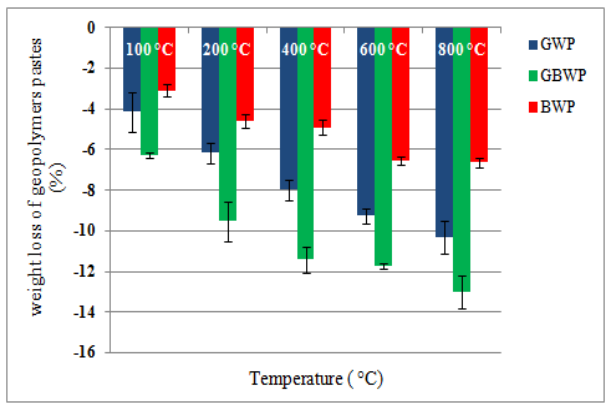

Figure 5. Weight loss of geopolymers pastes between 20°C and all high temperature

In 100°C to 800°C, the GBWP was indicating the high value of weight loss, which arrived to 6.74% to 9.93% respectively. As well as, for GWP gave 4.56% at 100°C and 5.79% at 800°C of weight loss.

A great reduction in the loss of weight has been observed for the GBWP at all temperatures exposed to it. This result can be explained by the high temperature in which caused the evaporation of the water between the molecules and thus contributed to the formation of voids and created other mineral components. The 10% of red brick increased the weight loss in each temperature arrived at 32.3%, 10.1%, 10.3%, 8.6% and 41.7% in 100°C, 200°C, 400°C, 600°C and 800°C respectively, compared with GWP.

At 200°C, the best weight loss for the all mixtures (GWP, BWP and GBWP) has been observed, because the most of water disappeared at 100°C. Therefore, the temperature that follows is the beginning of the formation of new hydration element that works to develop the structure of geopolymers binders. On the other hand, for BWP shows the value minimum of weight loss in 200°C estimated at 0.9% and the largest value is at 800°C estimated at 3.78%.

For the temperature 400°C and 600°C, low values of mass loss are observed because the density remains almost constant in all phases. The thermal treatment also decides an increase of total porosity of these materials; these pores are most probably determined by the air captured during the mixing of the NaOH solution with solid component of powder glass or other material [37].

3.3 Compressive strength

Figure 6 shows the compressive strength of geopolymers pastes after exposed at different temperature. The performance of the geopolymers pastes with and without red brick powder exposed to severe temperatures was determined by measuring the compressive strength after heating.

It was observed that the GWP had the best compressive strength at 20°C which achieved 73.9 MPa, then followed by the GBWP paste resistance of 59.2 MPa. Furthermore, the increase in temperature had an effect on on mixtures (GWP, GBWP) and led to a decrease in the mechanical strength, unlike the red brick mixture (BWP), which gave a positive effect at some temperature in 200°C arrived to 24.91 MPa. Between 400°C – 600°C, the compressive strength of geopolymers GWP and GBWP has been a significant increase by 8.2% and 27.3% respectively. While at a temperature of 200°C, there was agreement and evidence of compressive strength between the two previous samples as a transitional phase to alkaline reactions. Notably, the initial compressive strength of pastes containing glass GWP is clearly decreased at 400°C, followed by high drop at 600°C and then at 800°C it reaches its lowest value until it becomes close to zero. Pan et al. was informed that there was a diminution in the compressive strength of alkali activated pastes with slag or other material activated with sodium metasilicate after display to 300 and 600°C for 1.5 h [38]. The use of sodium silicate alkaline activators with sodium hydroxide had an active role with the temperature factor, thus the time used in the storage of the samples, which allowed the mechanical resistance to change. This study agrees with research of Li et al., they found a decrease in the compressive strength of alkali-activated slag paste activated with sodium silicate (Na_2SiO_3) curing at room temperature after exposure to range 100 – 1000°C [39]. In addition, Wang et al., was stated a lowering in the compressive strength of alkali-activated slag pastes by sodium hydroxide (NaOH) and sodium silicate solution (Na_2SiO_3) after contact with temperature to 500 and 800°C [40].

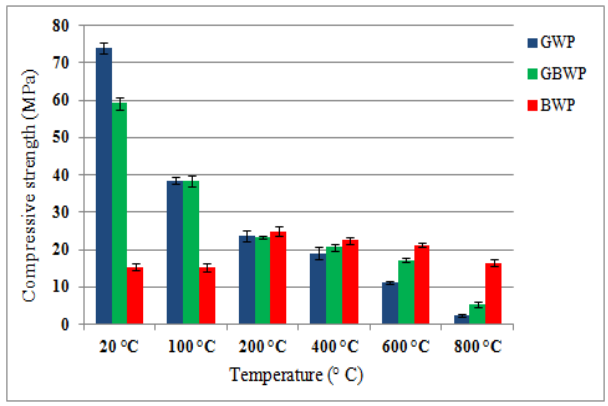

Figure 6. Compressive strength of geopolymers pastes after exposed at different temperature

3.4 Accessible porosity in water

Figure 7 shows the percentage of porosity of specimens after being exposed to high temperatures. As can be noted, the percentage of porosity increased by increasing of temperature with some mixtures.

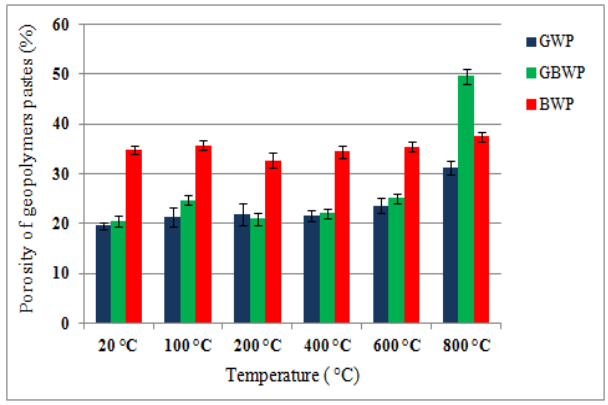

Figure 7. Porosity of geopolymers pastes in different high temperature

The GWP represents a difference in porosity at each temperature, and the highest value was at 800°C (reaching to 31.3% compared with BWP was arrived to 37.6% in the same temperature). Rashad *and al*, explained this result that the amount of glass increased as the percentage of water absorption increased [13]. For the BWP gave close results with each other in the chosen thermal range between 100°C and up 800°C in values ranged between 35.8% and 37.6%, this is due to the presence of stability in density and a decrease in weight loss. About GBWP the introduction of 10% of red brick augment the percentage of porosity; the big value was at 800°C reaching to 49.7%, the smallest value for the porosity is at 200°C for GBWP. There is a significant increase as well as in same time decrease of about 20.49% and 24.73% compared to the normal medium at 20°C and heat used during drying at 100°C. The development of porosity according to the temperature is due to the change in the internal shape or structure of the geopolymers pastes, especially that the samples are alkaline activated, and this will help to dissolve

chemical elements such as Si, K and Na or Al and form pores of various diameters and sizes that lead to high rate of absorption, and thus increases with it the porosity because there is a proportional relationship with each other.

3.5 Expansion of geopolymers pastes

Figure 8 and Figure 9 shows the expansion and the shapes of geopolymers pastes in different high temperature. About Figure 8 presents the variation of expansion in all mixtures samples in terms of temperature, and time spent in the oven at each step. 800°C is always considered an indicator of the nature of the alkaline activated pastes and allows giving an idea of its properties whether it is heat-resistant or perishable and other advantages. At 800°C the tow mixtures GBWP and GWP observed high expansion was arrived to 0.64 mm – 0.94 mm respectively. Also for GBWP shows high expansion at 600°C reached 0.166 mm, it is considered the beginning of the polymerization stage due to the use of alkaline activators that contain sodium as an essential component with constant concentration that helps in increasing the rate of expansion. For the temperatures of 200°C and 400°C, they gave a small amount of expansion 0.024- 0.058 mm and 0.041 -0.058 mm to each of the GWP and GBWP respectively, as they are classified within a transitional phase that contributes to the occurrence of an evaporation process or a link between chemical elements reactions. Finally, the BWP it gives less expansion in all temperature the maximum value at 800°C indicate 0.073 mm and the minor value at 200°C arrived to 0.028 mm, this temperature gave the better result in mechanical resistance for the geopolymer paste of red brick (BWP).

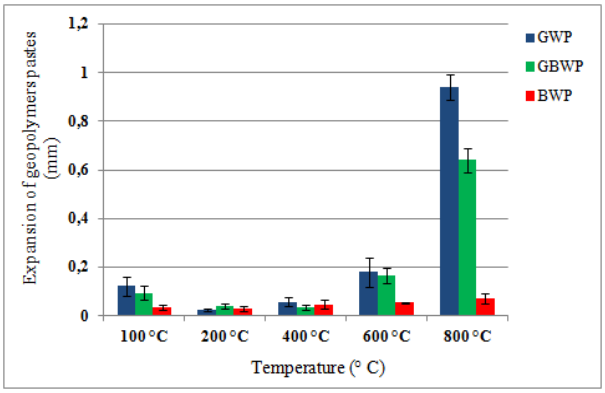

Figure 8. Expansion of geopolymers pastes in different high temperature

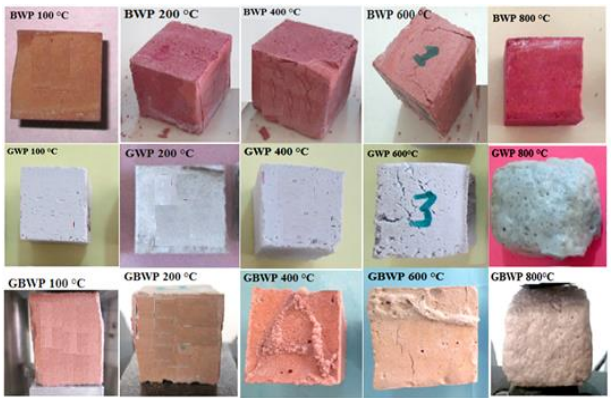

Figure 9. Colors of the samples after exposure to high temperatures

The Figure 9 it shows the extent of the effect of high temperatures on the external appearance of the geopolymers samples, as it was noticed that the heat led to a change the color; as the temperature increased, the color become darker. Especially when bricks BWP turn from orange at 100°C to dark red at 800°C, and the same for GWP that is white at 100°C and becomes gray at 600°C and 800°C. About the GBWP it turns from bright red at 20°C and 100°C to light pink at 800°C.

In terms of shape, the increase in temperature leads to deformation and the occurrence of a expansion process such as GWP at 800°C, GBWP at 600°C - 800°C that may cause superficial cracks to occur for GWP and GBWP at 600°C, for BWP at 600°C – 800°C, especially after the drying stage from 400°C and above to the maximum.

3.6 XRD analysis of geopolymers samples

a) XRD analysis before high temperature

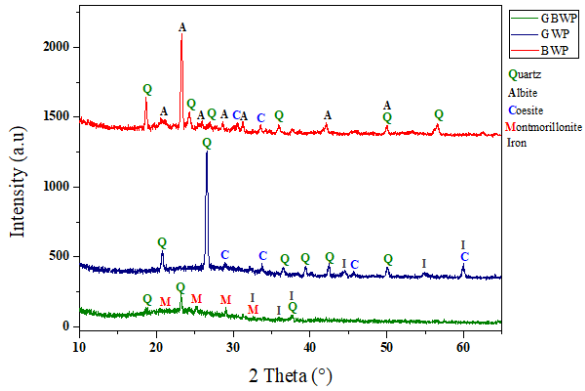

Figure 10. XRD of geopolymers pastes after 28 days curing at 20°C

Figure 10 demonstrates the XRD patterns of GWP, BWP and GBWP samples after 28 days. An indication of the amorphous phase of crystalline phases and systems, the period used here for 2θ between 10° to 65°, most of cambers or peaks are observed between 15 ° to 45° and are the main components formed after the alkaline activation process of the three mixtures. Robayo et al. [41] indicated that the semi-crystalline nature of the brick waste powder before used different concentration of NaOH between (2% to 10%) and different curing temperature (25°C - 70°C) by X-ray diffractogram. The quartz (SiO_2) is the major element of brick powder before transformed to paste in the main phase [41]. After turning it into paste with an alkaline effect, it was found that the principal crystalline component is Albite ($Na_{1.96}Ca_{0.04}Si_{5.96}Al_{2.04}O_{16}$; Ref. Pattern: 96-900-9664) has high intensity peak of 22.04° with Quartz (Si_3O_6, Ref. Pattern: 96-900-9667) represent high intensity at 18.86° and 25.64°. The rest mineral it's Coesite ($Si_{16}O_{32}$, Ref. Pattern: 96-900-7171) indicate the big peak at 29.35°. In addition, Sedira et al. [42], it was explained in its results the absence of the other crystalline phase in BWP is probability due to the low firing temperature of the brick. About the others samples, the GWP continent Quartz (Si_3O_6; Ref. Pattern: 96-900-9667) its principal component, was indicate high intensity 26.36° with minor crystalline components; Coesite and Iron (Fe_2, Ref. Pattern: 96-901-3475), for GBWP represent the same component like GWP only Coesite has been replaced by Montomorillonite ($Al_4Si_8O_{24}Ca$; Ref. Pattern: 96-900-2780), and the Quartz it's always indicate the elevated intensity at

24.34°. All the results obtained when curing at 60°C during 24H, and conserved at 20 ± 5°C with 60% of humidity.

b) XRD analysis after high temperature

Figure 11 presents the XRD patterns of GWP, BWP and GBWP after exposure to high temperature, in this step the samples that gave the best results were selected while measuring the compressive strength at different high temperatures between 100°C and up to a maximum of 800°C. Through the obtained results, a tray X-ray diffraction was performed on both the GWP and GBWP samples at 100°C, compared to BWP were at 200°C. In this stage, the range of 2θ were selected between 10° to 50° and most of the peaks appear at 20° to 40°. The previous research reported, that the formation of hydroxy sodalite, a crystalline zeolitic phase, at 2θ values of 25° and 35° [43]. In addition, the formation of zeolitic phases its results by effect of alkaline activation of low-calcium binders with high Al/Si ratio [44]. The more present components for GWP and GBWP are Trona ($Na_{12}C_8O_{32}H_{20}$; Ref. Pattern: 96-900-7657), Coesite ($Si_{16}O_{32}$; Ref. Pattern: 96-900-7167) they are characterized by high peaks at 33.95°, 29.15 and 26.85° for GWP, GBWP respectively. There is another common component between BWP at 200°C and GBWP at 100°C are Enstaite ($Ca_{0.6}Mg_{7.4}Si_8O_{24}$; Ref. Pattern: 96-900-5543) it's gave significant intensity in 28.32° and 29.86°, respectively. Also, on the other hand, it was observed that the three mixtures share another component named Anorthite ($O_{64}Ca_8Si_{16}Al_{16}$; Ref. Pattern: 96-100-0035), it's gave superior peaks at 27.91° and 21.99° for GWP, GBWP and BWP. About the crystalline minor components were identified: Hematite-proto ($Fe_{10.56}H_{0.36}O_{18}$; Ref. Pattern: 96-900-2161), Diopside ($Ca_{3.76}Na_{0.24}Mg_{3.86}Fe_{0.14}Si_8O_{24}$; Ref. Pattern: 96-900-9602) for the mixture paste of BWP. When comparing BWP between 600°C and 20°C, it is clear that the main component has become Quartz-low (Si_6O_6; Ref. Pattern: 96-101-1160) with high intensity at 26.66° and have hexagonal crystal system instead of Albite ($Na_2Al_2Si_6O_{16}$; Ref. Pattern: 96-900-1634). So for this the BWP paste represents the best compressive strength, it contains a large amount of silicate or quartz (SiO_2). The majority of the components obtained after thermal effect on the microstructure of the geopolymers pastes indicated by X-ray diffraction analysis that they possess a monoclinic crystal system.

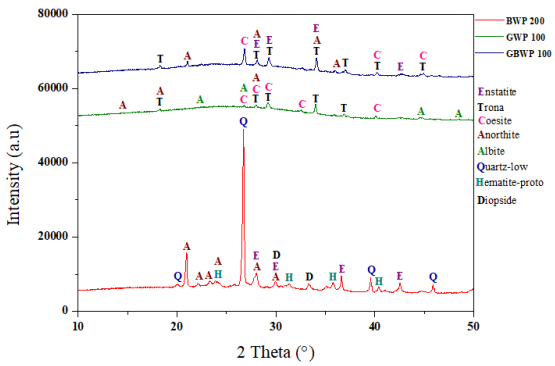

Figure 11. XRD of geopolymers pastes after exposed at high temperature

3.7 TG-DSC analysis for geopolymers samples

The results obtained through TG–DSC for the specimens with different combinations of BWP, GWP and GBWP are shows in Figure 12, Figure 13 and Figure 14. The samples had almost the same TG–DSC curves and a total weight loss of 10.96% for BWP, 17.23% for GWP and 24.66% for GBWP, in the range of 200°C to 800°C. Sedira et al. [42], it was found that samples up to 400°C they are considered among the amorphous and poorly crystalline hydrates. However, it's also probable that they are related with the decomposition of (N, C)–A–S–H and/or (N, K)–A–S–H gels [43]. More than 600°C, the three mixtures of pastes gave small and weak peaks for BWP indicate at 637.6°C and 731°C in TG between 3.3% and 3.87% to the DSC, about GWP it was between 5.07% - 6.34% and corresponds to the DSC peak at 655.3°C, also about the GBWP curve peak at temperature of 658.2°C in the range of 6.05% to 9.6% in DSC.Valášková et al. explained the weight losses in the temperature range nearly 600-800°C can be assigned to the loss of interlayer water and chemical water molecules, which are in liaison with the cations in the interlayer zone [45]. The most tested specimens showed a dehydration of gels occurring at approximately 800°C [46].

About the range between 25°C- 200°C, Fořt et al. explain in your research about the geopolymers based by brick powder, the free water evaporated up to near to 95°C; between 95 and 130°C the adsorbed water was removed [47]. So, in the differential thermogravimetry analysis of BWP Figure 12 the statement has been proven correct, and tow peaks were noted when 93.9°C and 124.1°C between 25°C – 200°C. Other authors, was observed also about the peak roughly 100 – 150°C, who resulting it to a weight loss of zeolites phases [48]. Also, for BWP more than 400°C presented minor humps mentioned a decomposition of sodium carbonate obtained in atmospheric carbonation of unreacted sodium hydroxide [49]. On other hand, for geopolymers when cured at 20°C and exposed to higher temperature at 600°C showed a superficial minimum at range of 700°C which reported decomposition of calcium carbonate [50-54].

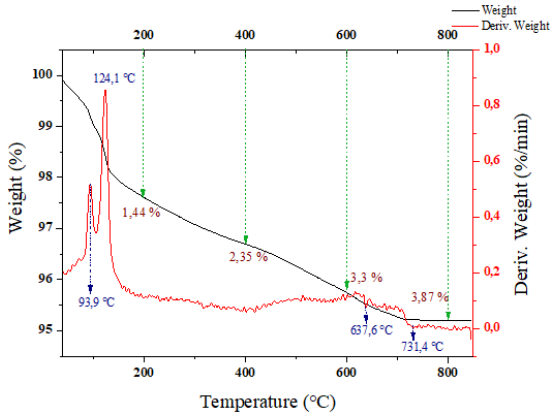

Figure 12. TG-DSC analysis of BWP samples

Figure 13 presents the TG-DSC curves of the GWP sample, the high value of weight loss was cleared before 100°C at 93.41°C. Rashad *and al*, was confirmed in your studied about the geopolymers based by glass mixed with slag and exposed at high temperature, was indicated A large weight loss below 200°C for glass sample without additions [13]. Rashad *and al*, also explain in other research, this weight loss could be caused to the free water evaporation and the dehydration of C-S-H (I) gel [14].

Figure 14 shows the TG-DSC curves of the GBWP sample, the major value of temperature which indicate by thermal analysis for measured the weight loss it's at 93.3°C and

122.2°C, it's before range of 200°C according to previous studies which noted in the studies [54-56].

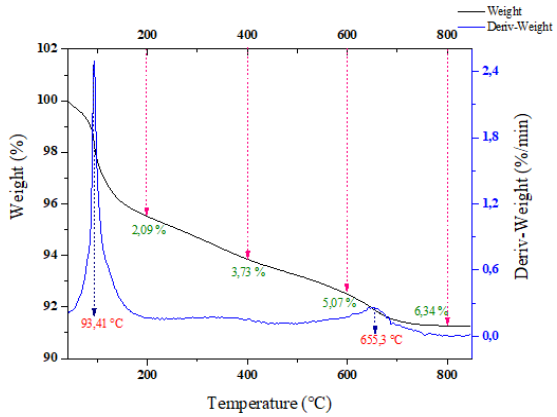

Figure 13. TG-DSC analysis of GWP samples

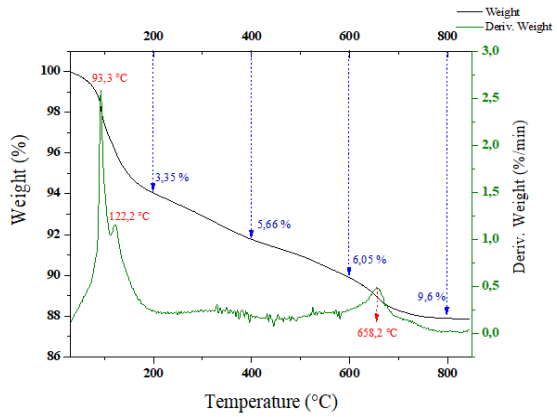

Figure 14. TG-DSC analysis of GBWP samples

4. CONCLUSIONS

From the above experimental results, the following conclusions are drawn:

- The resistance of geopoyler content of glass and brick waste binders to high temperature depends on many factors. In geopolymer paste, the paste becomes dehydrated and shrinks while aggregate volume increases. However, the size of the cracks visible to the naked eye in GWP and GBWP after heating to 600°C and 800°C are significantly greater than in geopolymer BWP;
- The compressive strength for BWP has better evolution in all high temperature compared to ambient temperature 20°C, especially in 200°C;
- The compressive strength of geopolymer BWP pastes increases after heating to 100°C, reaching 25 MPa of the initial value, which is most probably the result of the continued polymerisation process;
- The porosity reached the greatest extent for the three mixtures GWP, BWP and GBWP at a temperature of 800°C, which led to a change in color for the BWP and the shape through the appearance of internal bubbles for GWP, external bubbles for GBWP starting from 600°C;
- The research conducted has demonstrated that geopolymers BWP and GBWP pastes exhibit better thermal resistance than GWP, which loses its mechanical properties when heated to a temperature higher than that at which portlandite decomposes. The behavior of geopolymer binders at temperatures above 800°C is very interesting and requires additional research for future studies.

ACKNOWLEDGMENT

The authors thank the Geomaterial Development Laboratory of M'sila University, pedagogical laboratory for civil engineering of Bordj Bou-Arreridj University, also, to the director of the Emerging Materials Research Unit of Setif University and Directorate of Scientific Research and Technological Development (DGRSDT, MESRS, Algeria), all respect and appreciation is directed to Analytical laboratory in organic, inorganic and materials chemistry (French, Paris) for the assistance and support to complete this paper.

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NOMENCLATURE

Δm	The loss weight (%)
m_b	Mass before curing (g)
m_a	Mass after curing (g)

Subscripts

GW	Glass waste
RBW	Red brick waste
AAM	Alkaline activated materials
GWP	Paste of glass waste (100%)
BWP	Paste of brick waste (100%)
GBWP	Paste of glass (90%) and brick waste (10%)