

SYNTHESIS OF FOAMING MATERIALS FROM GLASS BASED GEOPOLYMERS AND YEAST ADDITIVES

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Abstract- Light-weight porous materials (foaming geopolymers) were prepared via alkali activation of glass waste by utilizing of sodium hydroxide without/with different weight percentages additions of yeast 0.5,1,1.5 and 2 as pore forming agent. All specimens were formulated by shaped, cured and subjected for heat treatment at various temperatures 400, 500, 600, 700 and 800 °C per 1 hour. Chemical and mineralogical analysis, microstructure, mechanical and physical properties were investigated. High volume changes were recorded for all compositions due to foaming phenomena which was noticed at temperatures 600, 700 and 800 °C. Also, the percentage of weight loss for MGY1.5-N8 and MGY2-N8 samples increases with increasing the thermal treatment temperature i.e., 9.03-11.64% and 9.43-11.18% respectively. Furthermore, the yeast additives to the glass waste powder resulted in lower thermal conductivity ($K \approx 0.6$ kw/m.k) compared with the paste without yeast addition ($K=0.68$ kw/m.k). This is due to the formation of higher porosity with different sizes according to the SEM observation. Through the yeast additions, these resulting foaming geopolymers can be applied in the construction as thermal insulation material, fire protective and sound absorption.

Keywords: Glass Waste Powder, Yeast, Thermal Treatment, Foaming Geopolymers.

1. INTRODUCTION

According to the manufactured products, glass is considered used widely in the world such as sheets, bottles, glassware and vacuum tubing [1]. It contributes in building materials (bricks and ceramic industries), ore materials maintain and therefore energy consumption lowering with the proportion of waste which is sent to landfill [2]. Nowadays, a wide variety of municipal and industrial wastes are recycled or reused. Consequently, this represents a significant field for research due to economic and environment with legal aspects [3]. Glass wastes can be recycled and reused according to one attractive option could worthily participate for obviating or fully reducing of the ecological contamination [4-6].

It is worth mention, more than 80% flat sheets and container of glass are produced in Europe [7, 8]. So, and according to the studies which were performed for recycling and utilizing of glass wastes for numerous industries such as building materials industry; wherefore considered a solution with eco-friendly for running the glass waste [8-10].

Geopolymer materials (inorganic polymers); considered as a new material and ecologically friendly that can be obtained from a vast domain of municipal or industrial wastes. Also, these new materials able to be fabricated according to the alkaline activator for glass using NaOH/KOH solutions with heat therapy between 40 to 60 °C [11]. Furthermore, a polymeric structure of AlO_4 and SiO_4 tetrahedral (three-dimensional) yield due to the alkali-activated of aluminosilicate materials [12]. The physical characteristics of synthesized geopolymers are influenced by SiO_2/Al_2O_3 ratio of the resulting materials.

Previously, foamed (porous) geopolymers are obtained by expelling the compositional water bubbles at high ratio of SiO_2/Al_2O_3 (i.e., over than 24 to 300) [13, 14]. Additionally, bubbles formation due to the heating increase of hardened geopolymers in 100-500 °C [15]. and this process is considered as energy-consumption. These materials with foam behavior have the characteristics of light weight and thermal insulation due to the formation of many fine internal pores in their structure with different sizes [16] As a result, another category of porous geopolymer with lightweight has been widely studied due to its easily fabricated, perfect thermal properties, acid resistance and eco-friendly in nature [17]. Also, foamed geopolymers most probably manufactured by using foaming agent [13] like peroxides, perforates, etc. So, creation of porous materials ordinarily has low mechanical properties consequent for the large pores distribution with magnitude nearly 0.5 to 3 mm [18]. This behavior has imposed some constraints on its enforcement.

Finally, in this work and for the first time we assess the probability to create a novel foaming material through the thermal processing for geopolymers synthesized by the activation of glass waste without/with yeast admixtures.

2. EXPERIMENTAL SECTION

2.1. Raw Materials

Glass from the municipal bottle wastes was grinded with various colors (i.e., green, brown and transparent) with a view to achieve glass powder (MG) and used as solid raw component. Table 1 illustrates the chemical composition of studied glass powder.

Table 1. Chemical composition of glass powder MG

Sample	Oxide Component (%)									
	SiO ₂	Na ₂ O	K ₂ O	TiO ₂	CaO	Al ₂ O ₃	Fe ₂ O ₃	MgO	SO ₃	LOI
Glass Powder (MG)	76.71	15.75	0.12	0.08	4.96	0.83	0.55	0.58	0.02	0.36

Figure 1 illustrates the distribution of particles, mean diameter and specific surface area of glass powder ($D_{0.5} = 31.626 \mu\text{m}$ and $0.364 \text{ m}^2/\text{g}$) respectively and these results were assessed by MASTERSIZER 2000 (MALVERN) [19, 20].

- *Yeast (Y)* type (Saf-instant from the market) was used as pore forming agent.
- The activator solution used was sodium hydroxide NaOH 8M as alkali component and abbreviated (N8) prepared two hours before its use.

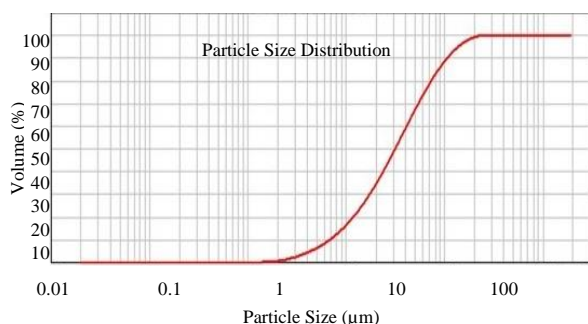


Figure 1. Distributions of particle size for glass powder

2.2. Method

For paste specimen's preparation; five formulas of glass based-Geopolymers were synthesized as shown in Table 2. The alkaline solution (NaOH 8M) was added to the base components (means the glass powder with/without yeast additives). Through conducting several experiments, it was found that the optimum ratio of adding sodium hydroxide solution to the solid mixture is $L/S=0.22$. So, as to procure a paste with adequate workability. The resulting paste materials were poured in a cubic mold $20 \times 20 \times 20 \text{ mm}$ and then shakes for three minutes. All molds with these pastes were enveloped by thin nylon cover and subjected for heat curing in oven at $75 \text{ }^\circ\text{C}$ for 24 hours. Subsequently, molds dismantled and exposed the samples to atmosphere $20 \pm 2 \text{ }^\circ\text{C}$ for 6 days. Thereafter, the specimens subjected to thermal curing towards various temperatures include 400, 500, 600, 700 and $800 \text{ }^\circ\text{C}$ for 1 hour in the electrical furnace with $10 \text{ }^\circ\text{C}$ per minute as heating rate. Finally, the specimens were left in the same furnace for cooling up to next day. It is worth mentioning, these thermal experiments done twice to each stage for accuracy.

The percentage of volume and mass changes for the studied paste specimens were evaluated by the Equations (1 and 2) [19, 20]:

$$\Delta V\% = [(V_f - V_i) / V_i] \times 100(\%) \quad (1)$$

where, V_i and V_f are volume of samples initial and final of thermal treatment respectively.

$$\Delta W\% = [(W_f - W_i) / W_i] \times 100(\%) \quad (2)$$

where, W_f and W_i are mass of samples initial and final of thermal treatment, respectively.

Table 2. The component of studied pastes

Formula	Solid material		Liquid material	L/S Ratio
MG-N8	Mixed glass powder (MG)	Without additive	NaOH solution (N8)	0.22
MGY0.5-N8	Mixed glass powder (MG)	<i>Yeast(Y)</i> 0.5wt.%		
MGY1-N8	Mixed glass powder (MG)	<i>Yeast(Y)</i> 1wt.%		
MGY1.5-N8	Mixed glass powder (MG)	<i>Yeast(Y)</i> 1.5wt.%		
MGY2-N8	Mixed glass powder (MG)	<i>Yeast(Y)</i> 2wt.%		

The Energy Dispersive X-ray Spectroscopy (EDS) with Scanning Electron Microscopy (SEM) analysis achieved to all studied pastes after covered by (30 nm) of Au using type TESCAN-MIRA III microscope. Compressive strength values for resulted material before and after thermally treated was determined by using (ELFa, turkey) testing machine. Also, the thermal conductivity coefficient was tested for studied pastes by disc Lee device.

3. RESULTS AND DISCUSSIONS

3.1. Thermal Treatment

To assess the thermal treatment for all the prepared paste specimens. Firstly, they were thermally treated from $400\text{-}800 \text{ }^\circ\text{C}$ for 1 hour. Thereafter, sintered specimens cooled in the same furnace for 24 hours as illustrated in Figures 2-6.



Figure 2. MG-N8 specimen's images before and after thermally curing between $400\text{-}800 \text{ }^\circ\text{C} / 1 \text{ hour}$



Figure 3. MGY0.5-N8 specimen's mages before and after thermally curing between $400\text{-}800 \text{ }^\circ\text{C} / 1 \text{ hour}$

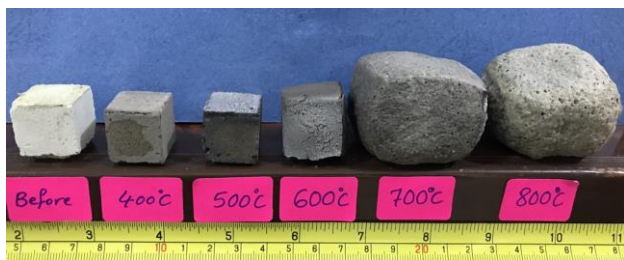


Figure 4. MGY1-N8 specimen's mages before and after thermally curing between 400-800 °C / 1 hour



Figure 5. MGY1.5-N8 specimen's mages before and after thermally curing between 400-800 °C / 1 hour



Figure 6. MGY2-N8 specimen's mages before and after thermally curing between 400-800 °C / 1 hour

3.2. Volume Change

Figure 7 illustrates the percentage of volume changes for all studied geopolymer pastes after thermally treated between 400-800 °C by using Equation 1. It was noticed that; the contraction (decreasing in volume) of the specimens was recorded after thermally curing at 400 °C and 500 °C; this is owing for sodium/calcium silicate-aluminate dehydration. The increasing in volume was recorded for all studied formulas after thermally treated at 600, 700 and 800 °C due to increasing presence of porosity (i.e., foaming behavior as shown in Figures 2-6). Also, can be clarified by the superposition process that locates the increasing in porosity and volume: i.e., the desiccation and deviation of sodium/calcium silicate-aluminate produced during activation process using alkaline solution (NaOH) for glass powder.

3.3. Weight Change

Figure 8 shows the percentage of weight changes of geopolymer pastes after thermal curing from 400 °C to 800 °C by using Equation 2. The higher weight loss (16.15%) recorded for MG-N8 paste (without yeast additive) at temperature 700 °C. Also, for MGY1.5-N8 and MGY2-N8 samples; the percentage of weight loss increases with increasing the thermal treatment temperature i.e., 9.03-11.64% and 9.43-11.18%, respectively. These losses in weight are important owing to the diversion and desiccation of sodium/calcium silicate-aluminate and this is representing the foaming behavior of material [8-12], [16], [19-23].

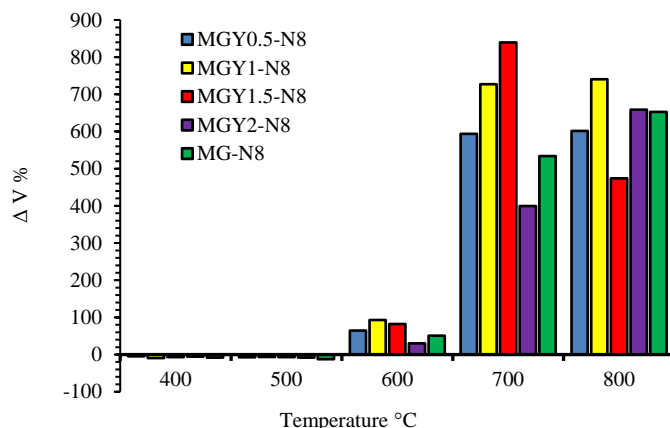


Figure 7. The percentage of volume changes of MG-N8, MGY0.5-N8, MGY1-N8, MGY1.5-N8 and MGY2-N8 formulas after thermally treated at 400-800 °C / 1 hour

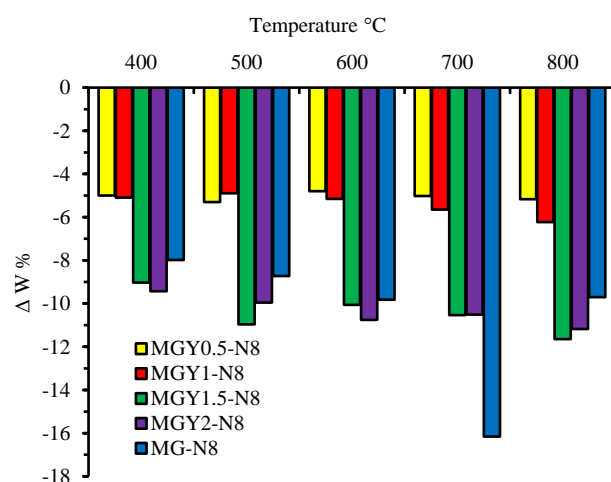


Figure 8. Weight changes of MGY0.5-N8, MGY1-N8, MGY1.5-N8, MGY2-N8 and MG-N8 formulas after thermally treated at 400-800 °C / 1 hour

3.4. Microstructure

Figures 9, presents the SEM images and EDS analysis for MG-N8, MGY0.5-N8, MGY1-N8, MGY1.5-N8 and MGY2-N8 pastes before thermal treatment (i.e., cured 24 hours at 75 °C and 6 days at 20 °C). It can be noticed the grains of glass comprised in the continuous network formed mostly from sodium/calcium silicate-aluminate resulted by the glass powder alkali activated. Porosity with various sizes is appeared on the SEM photographs (yellow arrows in Figure 9). This spherical various shape of porous result mainly during the mixing of pastes by air retention [19-24]. Also, the EDS analysis emphasize the existence of Si, Na, Ca in the studied specimens.

Figures 10-12 show the SEM images of geopolymers specimens (broken surfaces) after thermally treated between 400-800 °C. Images of SEM with yeast additives 0.5, 1.0, 1.5 and 2 wt.%; appear a spherical shape with various dimensions of the porous due to tendencies of sodium silicate for decomposition and generation a stabled pressure on the walls surrounding consequently, this fixed pressure awards mostly a sphere appearance (see red arrows). So, manifest contrasting is noticed in the morphology due to various additives of yeast content.

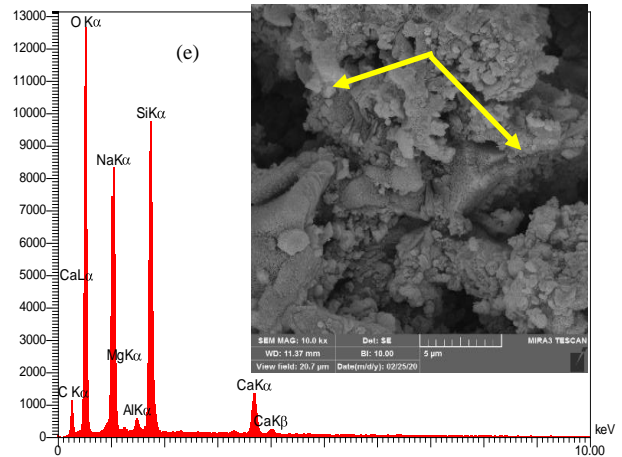
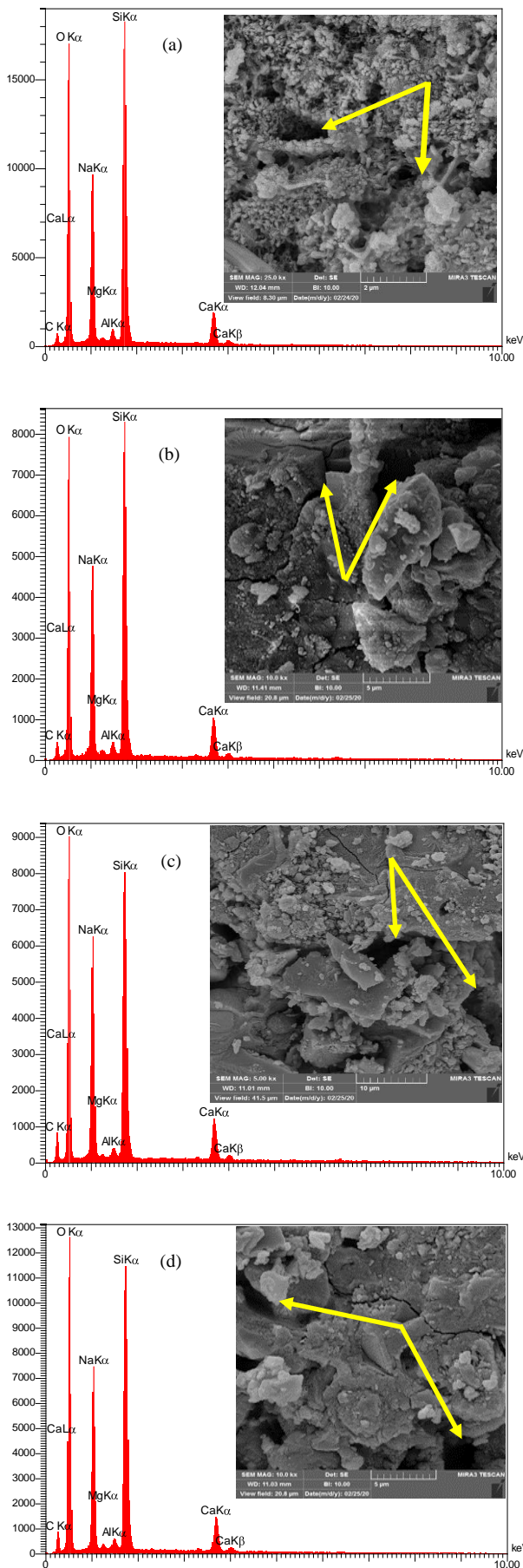


Figure 9. SEM images and EDS analysis of (a. MG-N8, b.b MGY0.5-N8, c. MGY1-N8, d. MGY1.5-N8, e. MGY2-N8) geopolymer pastes before thermal treatment

3.5. Thermal Conductivity Coefficient

Figure 13 clarifies the thermal conductivity coefficient (K) of geopolymer pastes studied without/with different ratio of yeast additions 0.5, 1, 1.5 and 2 wt.%. It was found that the addition of yeast to the mixed color glass waste powder resulted in lower thermal conductivity ($K \approx 0.6$ kw/m.k) compared with the paste without yeast addition (i.e. $K=0.68$ kw/m.k for MG-N8). This is due to the formation of higher porosity with different sizes and shapes according to the SEM observation (Figures 9-12), the geopolymer pastes with yeast additions had further micro-porosities among the large cavities; this is considered one of the important causes in the lowering of thermal conductivity.

Foamed geopolymers are fire-resistant materials [23], [25-28]. Consequently, synthesizing of lightweight materials which have improve of the thermal resistivity; this enables to considered as an efficient route of their application [29, 30].

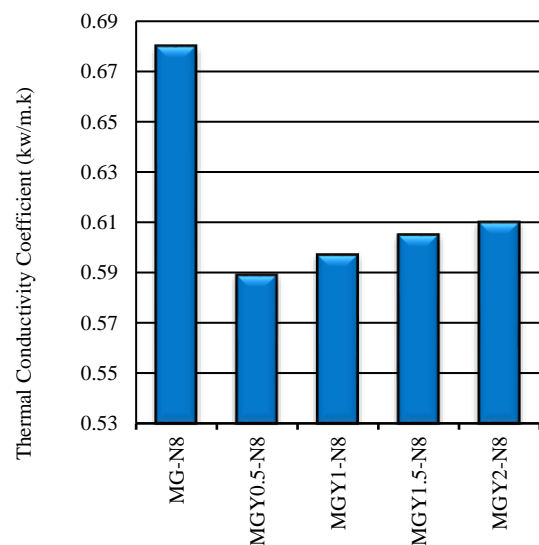


Figure 13. Thermal conductivity coefficient for geopolymer pastes studied without/with various ratio of yeast additions 0.5, 1, 1.5 and 2 wt.%

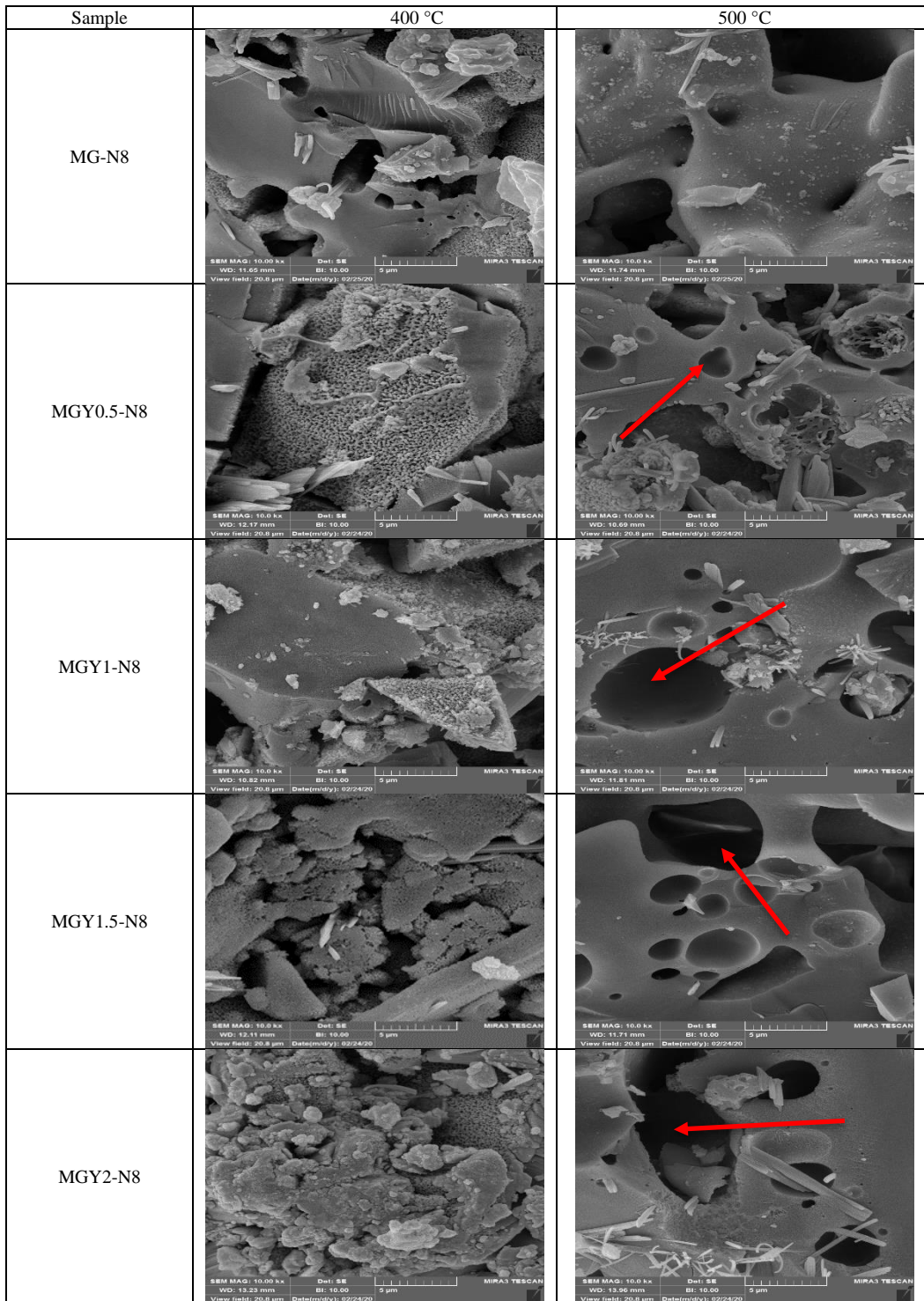
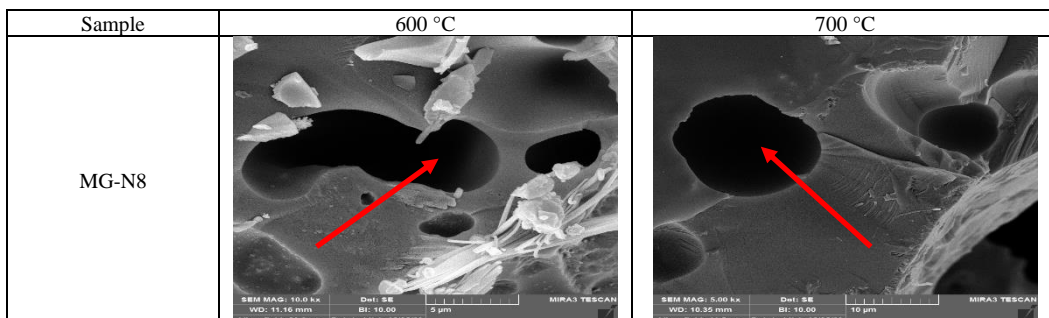


Figure 10. SEM images of (MG-N8, MGY0.5-N8, MGY1-N8, MGY1.5-N8 and MGY2-N8) geopolymer pastes after thermally treated at 400 and 500 °C / 1 hour



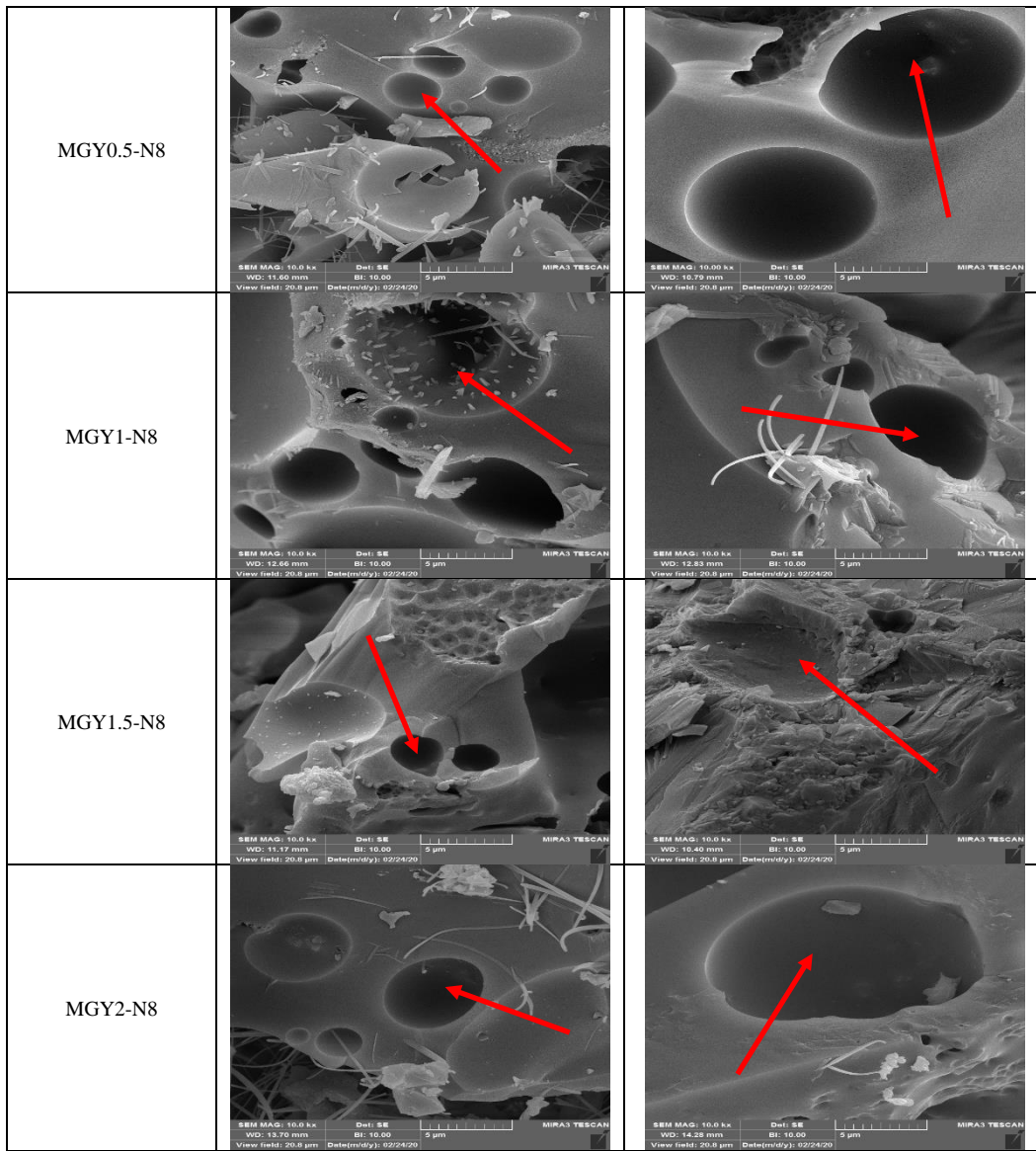
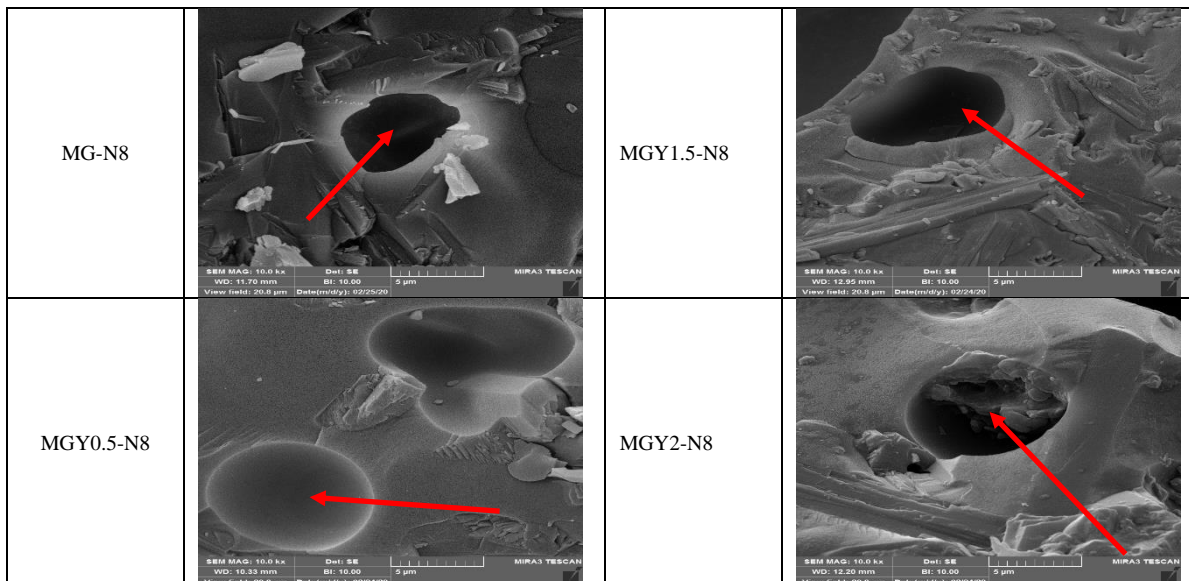


Figure 11. SEM images of (MG-N8, MGY0.5-N8, MGY1-N8, MGY1.5-N8 and MGY2-N8) geopolymer pastes after thermally treated at 600 and 700 °C / 1 hour



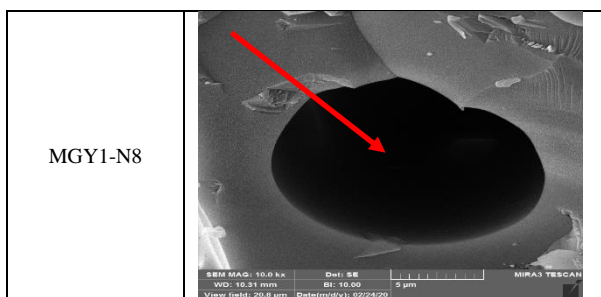


Figure 12. SEM images of (MG-N8, MGY0.5-N8, MGY1-N8, MGY1.5-N8 and MGY2-N8) geopolymer pastes after thermal treatment at 800 °C / 1 hour

3.6. Compressive Strength

Figures 14 and 15 are clarifying the compressive strength values for the studied specimens before and after thermally treated respectively. Generally, it can be noticed according to the results from Figure 14; a lowering of compressive strength value with regards to studied paste specimens through yeast additions 0.5, 1, 1.5 and 2 wt.% as compared with the base paste (i.e., MG-N8).

The compressive strength (MPa) of the studied specimens depends upon the yeast additives after thermal curing from 400 to 800 °C for 1 hour as shown in Figure 15. A decrease in compressive strength values to 5MPa for MGY1.5-N8 and MGY2-N8 pastes was noticed after thermally treated at 700 and 800 °C. As expected, this is due to the formation of porosity with different sizes and increases in volume after thermally treated. Nevertheless, 2 to 5 MPa as compressive strength values symbolize to typical consequence of foamed materials. It is recognized that compressive strength value for any specimen is inversely associated with porosity content.

It is noteworthy, the compressive strength still high (10 MPa) and not affects directly according to thermally curing at 400 and 500 °C with regards to MGY0.5-N8 and MGY1-N8 specimens. This is due to the specimen's shrinkage during its densification as shown in Figures 3 and 4.

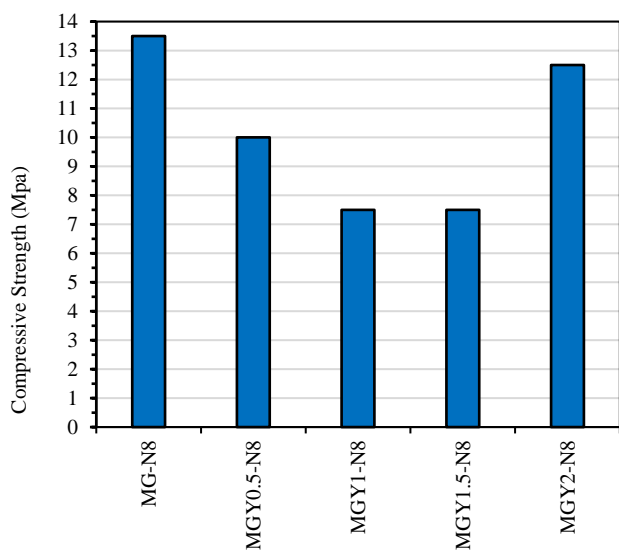


Figure 14. Compressive strength of MG-N8, MGY0.5-N8, MGY1-N8, MGY1.5-N8 and MGY2-N8 pastes specimen's before thermally treated

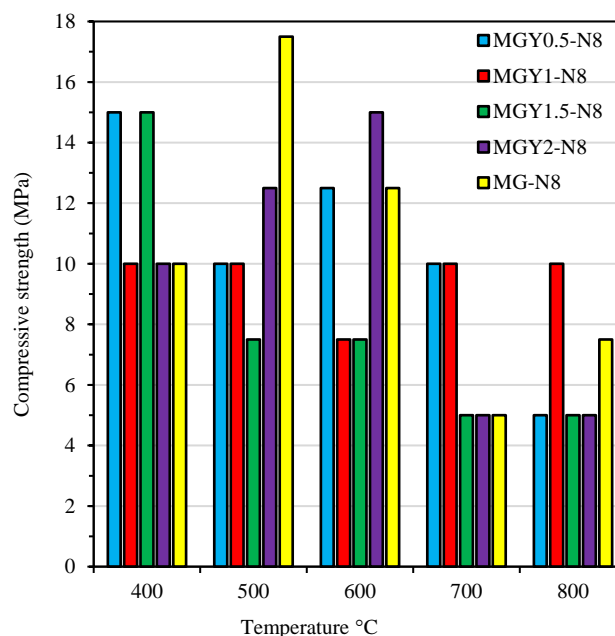


Figure 15. The Compressive strength of MG-N8, MGY0.5-N8, MGY1-N8, MGY1.5-N8 and MGY2-N8 pastes specimen's after thermally treated between 400 and 800 °C / 1 hour

4. CONCLUSIONS

Foamed geopolymers were effectively prepared by alkali activated of glass powder without/with yeast additions at different weight ratio in accordance with thermally curing especially at 600, 700 and 800 °C. These new materials induced a large change in volume with micro-open pores inside the geopolymer matrix with a view to thermal resistance reinforcement and appropriate of mechanical properties (i.e., compressive strength). Thermal insulation products constitute the most factual side of minimizing the heat seeps in buildings; thus, lowering of power needs. Currently, insulation products are linked as a negative influence regarding to toxicity. This work exposes the results of studying that has investigated the effect of yeast additives with different weight ratio on the characteristics of foaming geopolymers glass-based. Results showed the yeast additives with 0.5, 1, 1.5, 2 wt.% to the geopolymer matrix leading to a lower of thermal conductivity coefficient. Generally, the compressive strength values reduced after the yeast additives before thermal treatment. Whereas, the compressive strength values of MGY1.5-N8 and MGY2-N8 were 5MPa after thermally treated at 700 and 800 °C; this is a worthy result for foaming materials. Whereas, for MGY0.5-N8 and MGY1-N8 were still high value.

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BIOGRAPHIES



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