COMPARISON OF EFFECTS OF ALKALINE ACTIVATOR MOLARITY AND CURE TEMPERATURE FOR GEOPOLYMER SYNTHESIZED FROM ALTERNATIVE LATERITE SOURCES

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ABSTRACT: *Geological source material remains one of the options for developing countries to participate in deployment of geopolymer material technology for environmental friendly infrastructure development. Geological source materials for geopolymer are heterogeneous in nature. This study sort to investigate and provide information for aggregation of repository comparative information on geopolymer specimen properties of alternative source material and their response to effect of alkaline activator molarity and cure temperatures. Pulverized 750°c calcined laterite obtained from two alternate sources were activated with alkaline activator solution of NaOH of 8M, 10M, and 12M with NaSiO3 and sterile water of ratio 7:3:3 were properly mixed at activator to source material ratio of 0.45. $50 \times 50 \times 50$ specimen cubes were cast for density, porosity and comprehensive strength test for specimen cure at 27°c (room temperature), and 50°c and 90°c in oven temperature respectively for 28 days and 72 hours. The study shows that in each geopolymer specimen source material, the density of the specimen decreases with increased cure temperature while specimen porosity increases with increased cure temperature. Increased activator molarity increases the density of the specimen while specimen porosity does not follow a definite trend with activator molarity. Ekiti parapo pavilion laterite based geopolymer specimen has minimum density, porosity and comprehensive strength of 2.15 g/cm³, 5.27% and 1.74 N/mm². Geopolymer specimen based on polytechnic gate source material have density, porosity and compressive strength minimum values of 1.86 g/cm³, 11.46% and 0.58 N/mm². Their corresponding maximum values are respectively 2.40 g/cm³, 19.24% and 14.92 N/mm² for pavilion based geopolymer specimens, 2.33 g/cm³, 26.08% and 6.90 N/mm².*

KEYWORDS: *Geopolymer, Source, Laterite, Material, Activator.*

INTRODUCTION

The research and development of geopolymers in America, Europe, Asia, and Australia have grown significantly whilst very limited research has been performed in Africa (Yang *et al*., 2022). The study is taking off on Africa Continent: Egypt, Cameroon, Morocco and Nigeria (Matsimbe *et al*., 2022). Source materials for geopolymer development are diverse from industrial waste materials, agricultural wastes and geological sources (Ranjbar & Zhang, 2019). Geological source is readily available and accessible in developing countries but the intrinsic properties of suitable geopolymer geological source materials intrinsically vary from one location to the other considering active ingredients to participate in geopolymerization with activators. Geopolymer development is currently more pronounced in developed countries because of ready high availability of industrial waste and the relative advantage of protecting the environment.

Geopolymerization is a field of research that involves the use of solid waste and by-products to create a mature and cost-effective solution for treating and storing hazardous residue under critical environmental conditions (Cong & Cheng, 2021). The process of geopolymerization involves the use of silicates and aluminates of by-products to create an environmentally friendly material that requires moderate energy to produce (Davidovits, 1991; Cao *et al.,* 2019). Researchers necessarily need to investigate various factors that can affect the properties of geopolymer, including the environmental relative value, energy requirements, and the source material used (Mastimbe *et al.,* 2022). Existing geopolymer research gaps are critical; there is a need for understanding and regularizing geopolymer production, taking into consideration the diversity of processing and source materials in different localities (Hassan *et al.,* 2019).

Various factors, including the composition of the geopolymer materials, curing temperature and time, water-to-solid ratio, and pH, can influence the formation and properties of geopolymer (Castillo *et al*., 2021). Nadoushan and Ramezanianpour (2016) suggested that the alkaline activator used in the process must be carefully selected as it is likely to have different impacts on the properties of fresh geopolymer paste and development of mechanical strength in hardened geopolymers. The most common sources of aluminosilicates used for producing geopolymers are metakaolin and by-products from other industries, such as fly ash, mine tailings, red mud, and slags (Khan *et al*., 2021).

The synthesis of geopolymers is composed of three steps: the dissolution of aluminosilicate materials, the gel formation process involving the transformation of active monomers into geopolymeric fragments of cross-linked aluminosilicate oligomers, and the formation of geopolymer gel through the chain reaction of crystallization and polymerization (Zhang *et al*., 2011).

Geopolymer concrete (GPC) is estimated to have the capacity to reduce the carbon footprint in construction projects by 80% compared with ordinary Portland cement (Dang *et al*., 2016). To create a geopolymer with good compressive strength, various variables must be taken into account, including the type of aluminosilicate source, its composition, the composition and concentration of the alkaline activator, the amount of water used, and whether it is cured at ambient temperature or by adding heat (Castillo *et al*., 2021).

In this study, the effects of Sodium Hydroxide and Sodium Silicate solutions as alkaline activators concentration or molarities and cure temperature on geopolymer produced from

alternative geological sources specifically from the Federal Polytechnic Gate and Ekiti Parapo Pavillion laterite deposits at Ado Ekiti, Ekiti State, Nigeria. This study will help to compare the effects of alkaline activator and processing condition variation on heterogeneous geological geopolymer source material with the focus of amplification of specific factors effects on geopolymer from different geological source materials.

MATERIALS AND METHODS

Materials for this study include laterites extracted freely from deposits located at two alternative sources in Ado Ekiti, Ekiti State Nigeria. The two laterite sources for independent synthesis of geopolymer specimen were separately subjected to similar treatments of calcination at 750°C for 2hrs in furnace of Glass Technology Department, Federal Polytechnic Ado Ekiti. Samples of the alternate calcined laterites were chemically analyzed to establish the metallic oxides weight by percent present in samples of the geopolymer source material. In concentration of geopolymer, alkaline activator solution NaOH molarity was adjusted to 8, 10 and 12 in alkaline activator solution mix of NaOH to Na_2SiO_3 with sterile water at a ratio of 7:3:3. The three set activated solution were applied to calcined alternate laterite source at ratio of 0.45. Three set samples of respective geopolymer gel from alternate source were cast for cure at ambient temperature 27°C and in oven temperature of 50°C and 90°C for durations respectively at 28 days for ambient temperature and 72 hours for oven cure temperature.

RESULT AND DISCUSSIONS

Metallic oxides in calcined geopolymer source material were presented in Table 3.1. Critical oxides in geopolymer source material were identified as Silicon oxide and Al_2O_3. In table 1, the alternate geopolymer source material from Ekiti Pavilion and Federal Polytechnic School Gate laterite deposit indicates SiO_2 and Al_2O_3 to be 31.50% and 14.44% in the first case and the other 12.80% and 10.26% respectively. Silicon oxide to Aluminium Oxide is 2.5 in 1 and the other metallic oxide present in the sources are in a similar range. The result of test on geopolymer specimen of alternative condition variations follows.

Table 3.1: Chemical composition of alternate geopolymer source materials

PARAMETERS (%)	Ekiti Pavilion	Fed Poly School Gate
Na_2O	0.112 0.116	0.170 0.160
CaO	0.392 0.390	0.304 0.307
K_2O	0.132 0.130	0.152 0.148
MgO	3.150 3.156	2.100 2.085
Fe_2O_3	42.160 42.140	44.620 44.650

| Al$_2$O$_3$ | 14.440 | 10.260 |
	14.430	10.200
SiO$_2$	34.510	12.800
	34.506	12.720
MnO$_2$	0.083	0.103
	0.089	0.100

Density

Specimen densities presented in their graphical relationship presented in Figures 2.1 (a, b and c) were related to activator molarity and cure temperature. An increase in cure temperature reduces the density of the geopolymer specimen produced from the two alternate source materials. Increase in activator molarity increases the densities of the geopolymer specimen. Specimen based on pavilion laterite has a 'minimum density of 1.89g/cm3 and maximum of 2.40g/cm3. Geopolymer specimen density minimum value is 1.8096g/cm3 and maximum density of 2.32g/cm3 for Polytechnic gate laterite based geopolymer specimen. Corresponding specimen of similar activator molarity and cure temperature produced from Ekiti Parapo Pavillion geopolymer source materials generally have higher density compared to the specimen based on the polytechnic gate geopolymer source material.

(a)

(b)
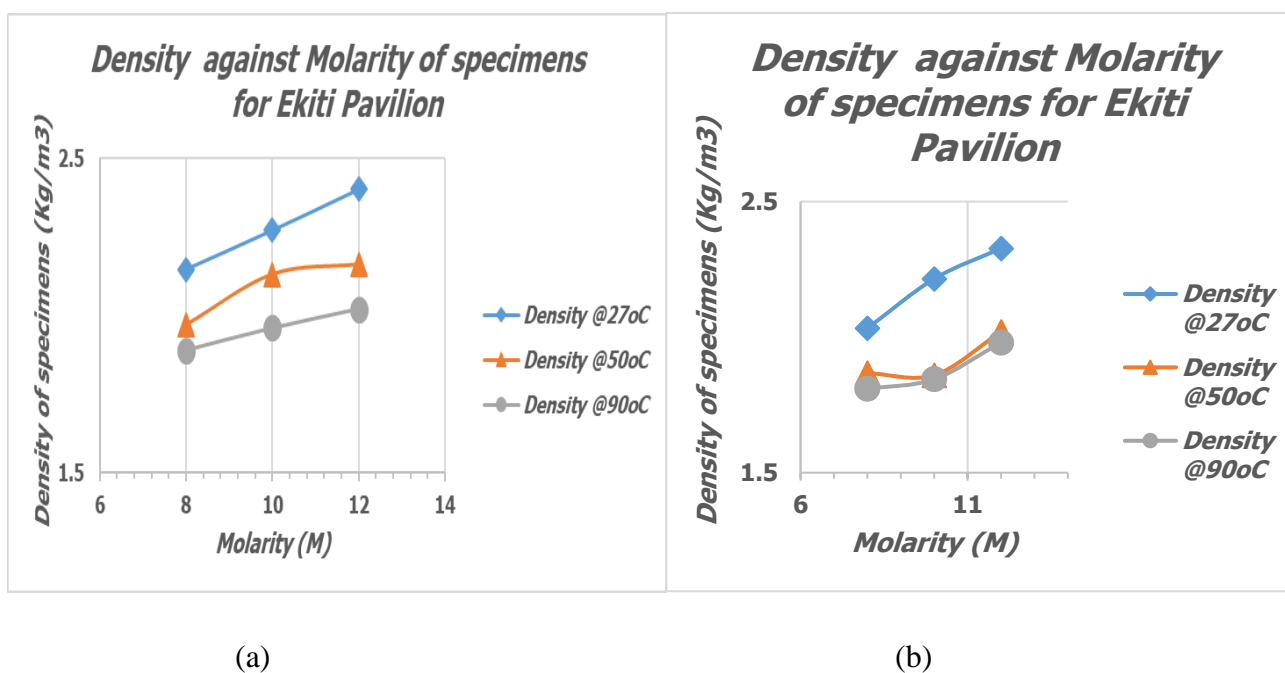
Figures 3.1(a and b): (a): Graph of Density against Molarity for each curing temperature for Ekiti Pavilion and; (b) Graph of Density against Molarity for each curing temperature for Federal Poly Gate.
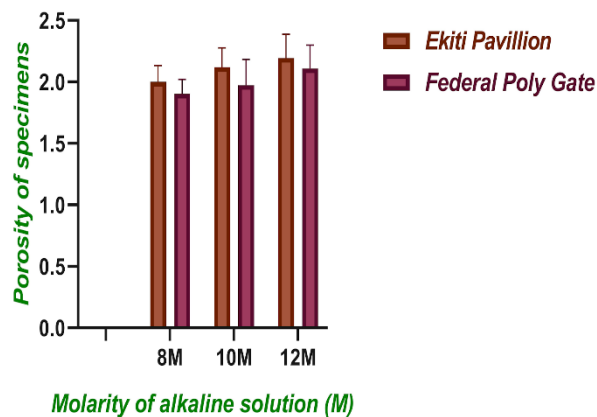
Porosity

Figures 3.1 (a, b and c) present the relationship between alkaline activator concentration and cure temperature to specimen porosity. The porosity of the geopolymer produced from alternate source material increased with increase in cure temperature; on the other hand, the porosity decreased with increasing molarity and curing temperature for Ekiti pavilion source.
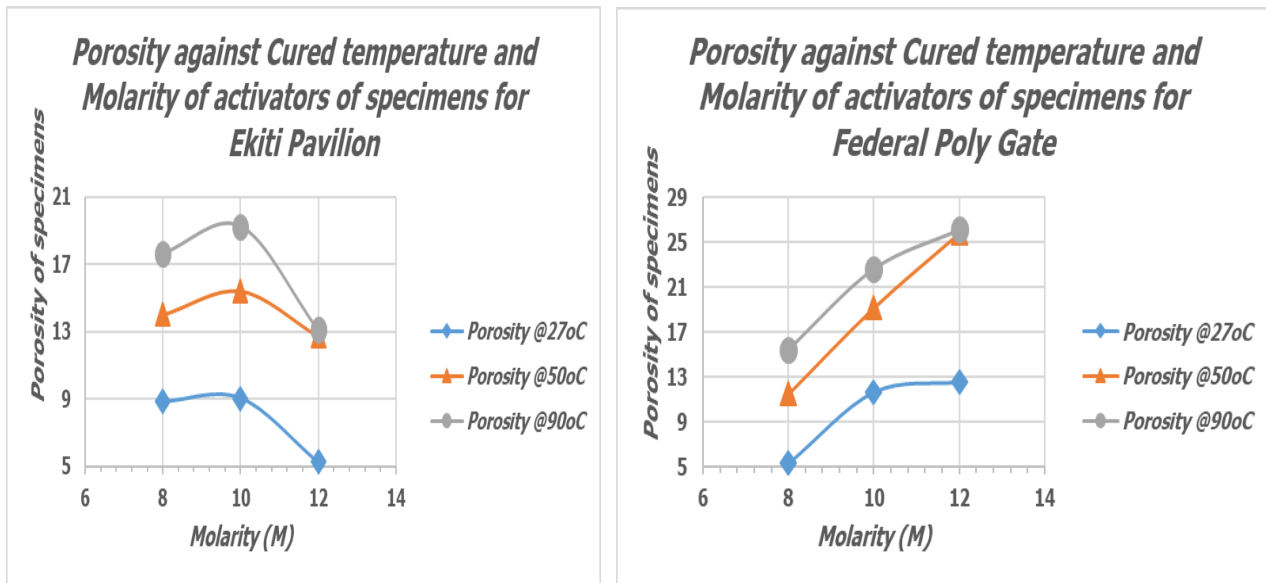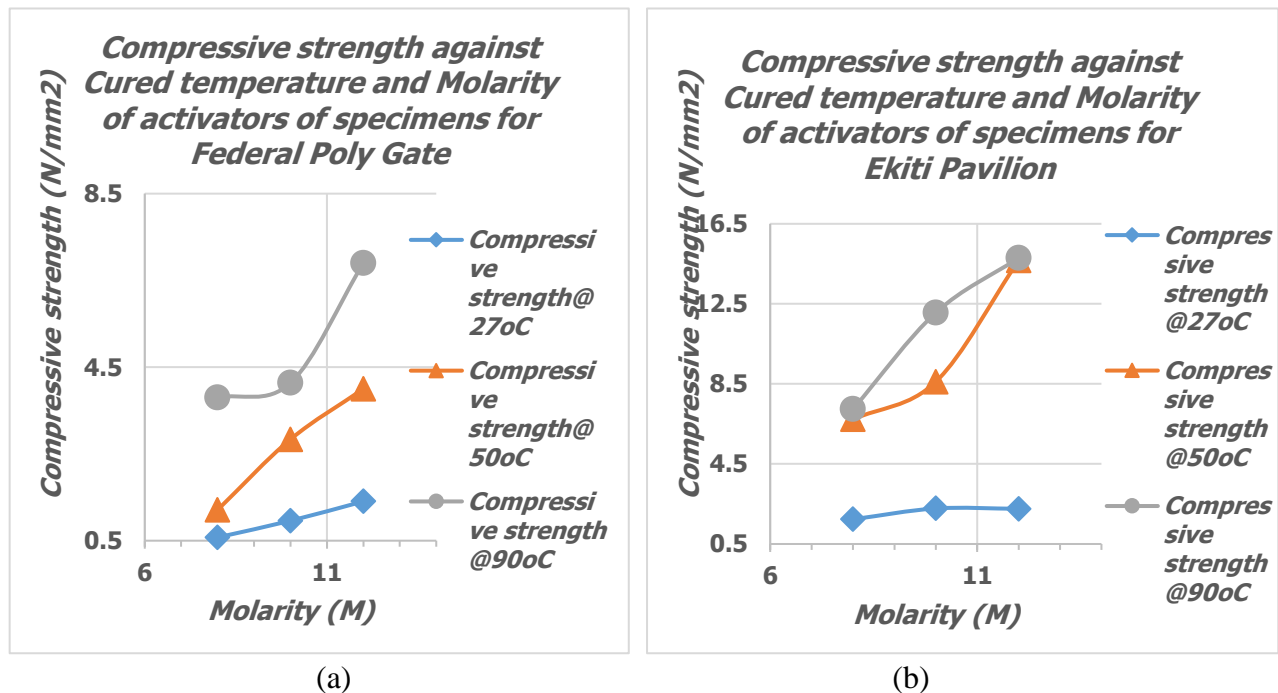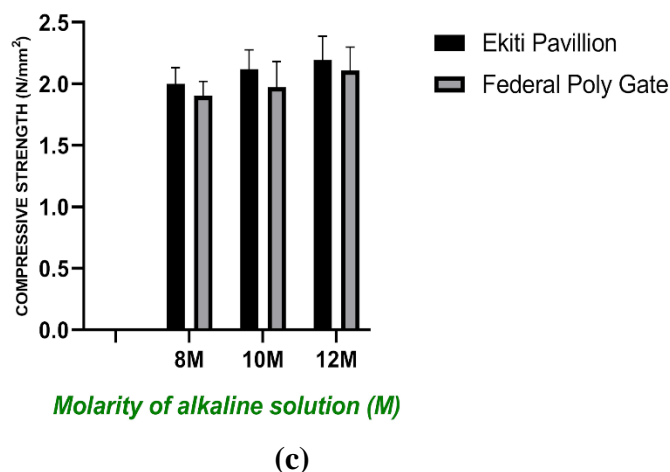
(a)

(b)

(c)

Figures 3.2 (a, b and c): (a): Graph of Porosity against Molarity for each curing temperature for Ekiti Pavilion and; (b) Graph of Porosity against Molarity for each curing temperature for Federal Poly Gate; (c): Combined charts of Porosity against Molarity.

Compressive Strength

Figures 3.3 (a, b and c) describe the effects of activator molarity and cured temperature on compressive strength of the specimens. The graphs in the charts indicate the compressive strength values increases for both locations under investigation. The temperature variation also shows significant factors in aiding the increase in compressive values obtained. The compressive values of the temperatures for each location and molarity increases proportionately.

(a)

(b)

(c)

Figures 3.3(a, b and c): (a): Graph of Compressive strength against Molarity for each curing temperature for Federal Poly Gate and; (b) Graph of Compressive strength against Molarity for each curing temperature for Ekiti Pavilion (c): Combined charts of Compressive strength against Molarity

Geopolymer specimens from the alternate source physical and mechanical properties respond similarly in the same pattern with activator molarity and cure temperature but pavilion-based geopolymer specimen present better performance for density, porosity and compressive strength.

CONCLUSION

From this study, the geopolymer specimen produced from the two alternate sourced geological materials show similarities of specimen density and porosity property behaviors in response to activator molarity and cure temperature variation with minimum and maximum values of density and porosity values at 1.89g/ccm^3 and 5.27% for pavilion specimen, 1.8096 g/ccm^3 and 5.32% for Federal Poly Gate specimens for minimum values and 2.40 g/ccm^3 and 19.24% for Ekiti pavilion, 2.33 g/ccm^3 and 26.08% at Federal Poly Gate for maximum values. Generally, the compressive strength of pavilion geopolymer specimen with minimum value of 1.7360 N/mm^2 and maximum value of 14.792N/mm^2 were higher than corresponding value of 0.578N/mm^2 and 6.90N/mm^2 of Federal Poly Gate geopolymer specimen. This difference can be associated with the ratio of SiO_2 to Al_3O_5 of 2.69 in Ekiti Pavilion source material to 1.2 at the Federal Poly Gate source materials. Better understanding of the micro structures associated with increasing porosity, cure temperature, and compressive strength of the specimen would be helpful vis-a-vis pore sizes and distributions for the materials for better understanding of the geopolymer specimen in engineering applications.

REFERENCES

[1]. Yang, H.; Liu, L.; Yang, W.; Liu, H.; Ahmad, W.; Ahmad, A.; Aslam, F.; Joyklad, P. A comprehensive overview of geopolymer composites: A bibliometric analysis and literature review. Case Stud. Constr. Mater. 2022, 16, e00830.

[2]. Matsimbe, J.; Dinka, M.; Olukanni, D.; Musonda, I. Geopolymer: A Systematic Review of Methodologies. Materials 2022, 15, 6852. https://doi.org/10.3390/ ma15196852.

[3]. Ranjbar N., & Zhang M. Cement and Concrete Composites · December 2019 DOI: https://doi.org/10.1016/j.cemconcomp.2019.103498.

[4]. Cong P., & Cheng M. Advances in geopolymer materials: A comprehensive review. Journal of Traffic Transportation Engineering (Engl. Ed.) 2021; 8 (3): 283e314 https://doi.org/10.1016/j.jtte.2021.03.004.

[5]. Davidovits, J. Geopolymer Chemistry and Applications, 5th ed.; Institut Géopolymère: Saint-Quentin, France, 2020.

[6]. Cao, V.D., Bui, T.Q., Kjoniksen, A.L., 2019. Thermal analysis of multi-layer walls containing geopolymer concrete and phase change materials for building applications. Energy 186, 115792.

[7]. Matsimbe, J.; Dinka, M.; Olukanni, D.; Musonda, I. A Bibliometric Analysis of Research Trends in Geopolymer. Materials 2022, 15, 6979. https://doi.org/10.3390/ ma15196979

[8]. Hassan, A.; Arif, M.; Shariq, M. Use of geopolymer concrete for a cleaner and sustainable environment—A review of mechanical properties and microstructure. J. Clean. Prod. 2019, 223, 704–728.

[9]. Castillo, H.; Collado, H.; Droguett, T.; Sánchez, S.; Vesely, M.; Garrido, P.; Palma, S. Factors Affecting the Compressive Strength of Geopolymers: A Review. Minerals 2021, 11, 1317. https://doi.org/ 10.3390/min11121317

[10]. Nadoushan, M.J.; Ramezanianpour, A.A. The effect of type and concentration of activators on flowability and compressive strength of natural pozzolan and slag-based geopolymers. Constr. Build. Mater. 2016, 111, 337–347.

[11]. Khan, K.A.; Raut, A.; Chandrudu, C.R.; Sashidhar, C. Design and development of sustainable geopolymer using industrial copper byproduct. J. Clean. Prod. 2021, 278, 123565.

[12]. Zhang, L.; Ahmari, S.; Zhang, J. Synthesis and characterization of fly ash modified mine tailings-based geopolymers. Constr. Build. Mater. 2011, 25, 3773–3781.

[13]. Dang, J.; Shen, X.; Castel, A.; Aldred, A.C.A.J. Monitoring Apparent pH Value in Geopolymer Concrete Using Glass Electrode. In Proceedings of the 33rd International Symposium on Automation and Robotics in Construction (ISARC); International Association for Automation and Robotics in Construction (IAARC), Auburn, AL, USA, 18–21 July 2016; pp. 547–554.