Setting Time and Workability of Geopolymerized Fly Ash- Phosphogypsum Paste and Mortar

Conference Paper · June 2024

DOI: 10.11159/iccste24.237

4 authors:

Jabulani Matsimbe
Malawi University of Business and Applied Sciences
30 PUBLICATIONS **108** CITATIONS
SEE PROFILE

Megersa Olumana Dinka
University of Johannesburg
136 PUBLICATIONS **1,594** CITATIONS
SEE PROFILE

David O. Olukanni
Covenant University Ota Ogun State, Nigeria
94 PUBLICATIONS **1,203** CITATIONS
SEE PROFILE

Innocent Musonda
University of Johannesburg
187 PUBLICATIONS **1,067** CITATIONS
SEE PROFILE

Proceedings of the 9th International Conference On Civil Structural and Transportation Engineering (ICCSTE 2024)
Chestnut Conference Centre - University of Toronto, Toronto, Canada – June 13-15, 2024
Paper No. 237
DOI: 10.11159/iccste24.237

Setting Time and Workability of Geopolymerized Fly Ash-Phosphogypsum Paste and Mortar

Jabulani Matsimbe[1, 2, 3], Megersa Dinka[1], David Olukanni[4], Innocent Musonda[2]
[1]Department of Civil Engineering Science, Faculty of Engineering and the Built Environment, University of Johannesburg, Johannesburg 2006, South Africa
[2]Centre for Applied Research and Innovation in the Built Environment (CARINBE), Faculty of Engineering and the Built Environment, University of Johannesburg, Johannesburg 2092, South Africa
[3]Department of Mining Engineering, Malawi University of Business and Applied Sciences, P/Bag 303, Chichiri, Blantyre3, Malawi
[4]Department of Civil Engineering, Covenant University, 10 Idiroko Road, Ota, Ogun State, Nigeria
jmatsimbe@mubas.ac.mw; mdinka@uj.ac.za; david.olukanni@covenantuniversity.edu.ng; imusonda@uj.ac.za

Extended Abstract

Geopolymer is no longer viewed as a concept for a greener society but rather as a pragmatic solution for reducing CO_2 emissions in the construction industry. It is commonly produced using industrial waste materials such as fly ash (FA) and phosphogypsum (PG). Globally, FA has an estimated annual production of around 1 billion tonnes and that of phosphogypsum is around 300 million tonnes, of which utilization stands at 50% and 15% of the total generated, respectively [1]. Geopolymers have been extensively studied as an alternative to ordinary Portland Cement (OPC) [2], [3] but to date, no study has been done to investigate the setting time and workability of geopolymerized fly ash-phosphogypsum paste and mortar.

This research investigates the setting time and workability of geopolymerized fly ash-phosphogypsum paste (GPP) and mortar (GPM) using a Vicat needle procedure per ASTM C191 and the flow table test per ASTM C1437, respectively. The materials used were PG, Class F FA, silica sand, NaOH pellets of 99% purity, and Na_2SiO_3 solution of the composition Na_2O = 8.3%, SiO_2 = 27.7%, H_2O = 64%, and Ms (SiO_2/Na_2O) = 3.34. The dissolution of NaOH pellets in water is an exothermic process [4] therefore the prepared NaOH solution was kept in a sealed glass bottle for 24 hours at room temperature to allow sufficient cooling before mixing with the Na_2SiO_3 solution. The specimens were prepared at 10M NaOH + Na_2SiO_3 Ms of 3.34, Na_2SiO_3/ NaOH ratio of 1.5, Alkaline Liquid/Precursor ratio of 0.4, Binder/Aggregate ratio of 1.0, and varying PG at 10 wt% increments. As per ASTM C305 for mixing pastes and mortars, the preparation of the specimens started with dry mixing the FA with PG in a conventional pan mixer for 3 minutes, followed by the gradual addition of alkaline solution and wet mixing for 5 minutes. Soon after wet mixing, the manufactured paste and mortar were tested for setting time and workability.

It was found that an increase in the PG wt% led to a decrease and/or acceleration in the initial setting time (INSET) and final setting time (FINSET) attributed to the rapid dissolution of Ca^{2+} in low alkaline concentrations outnumbering that of Al^{3+} and Si^{4+} and thus forming ettringite and C-A-S-H gel that facilitates hardening shortening the setting time [5], [6]. The INSET of GPP decreased from 37 min (at 10wt% PG) to 27 min (at 30 wt% PG) while the FINSET of GPP decreased from 155 min (at 10wt% PG) to 125 min (at 30 wt% PG). The INSET of GPM decreased from 29 min (at 10wt% PG) to 23 min (at 30 wt% PG) while the FINSET of GPM decreased from 142 min (at 10wt% PG) to 113 min (at 30 wt% PG). Furthermore, the workability of GPP and GPM decreased with an increase in PG wt% attributed to faster hydration activity, accelerated setting, and increased viscosity. The workability of GPP decreased from 176 mm (at 10 wt% PG) to 138 mm (at 30 wt% PG) while that of GPM decreased from 137 mm (at 10 wt% PG) to 112 mm (at 30 wt% PG). The development of GPP and GPM offers a sustainable circularity construction solution to minimize OPC usage and prevent the disposal of FA and PG in landfills. Future research should investigate the mechanical properties of GPP and GPM.

Acknowledgements

This research is funded by the Intra-Africa Mobility Scheme of the European Union in partnership with the African Union in the framework of the project 624204-PANAF-1-2020-1-ZA-PANAF-MOBAF under the Africa Sustainable Infrastructure Mobility (ASIM) scheme. Opinions and conclusions are those of the authors and are not necessarily attributable to ASIM. The work is part of collaborative research at the Centre of Applied Research and Innovation in the Built Environment (CARINBE).

References

[1] J. Matsimbe, M. Dinka, D. Olukanni, and I. Musonda, "Geopolymer: A Systematic Review of Methodologies," *Materials*, vol. 15, no. 19, p. 6852, Oct. 2022, doi: 10.3390/ma15196852.

[2] A. Odeh, A. Amin, M. Alghannam, M. Al-Ainya, H. Khalid, M. Al-Shugaa, B. Thomas, and M. Aswin, "Recent Progress in Geopolymer Concrete Technology: A Review," *Iranian Journal of Science and Technology, Transactions of Civil Engineering*, Mar. 2024, doi: 10.1007/s40996-024-01391-z.

[3] J. Matsimbe, M. Dinka, D. Olukanni, and I. Musonda, "Bibliometric trends of geopolymer research in Sub-Saharan Africa," *Mater Today Commun*, vol. 35, p. 106082, Jun. 2023, doi: 10.1016/j.mtcomm.2023.106082.

[4] T. Phoo-ngernkham, A. Maegawa, N. Mishima, S. Hatanaka, and P. Chindaprasirt, "Effects of sodium hydroxide and sodium silicate solutions on compressive and shear bond strengths of FA–GBFS geopolymer," *Constr Build Mater*, vol. 91, pp. 1–8, Aug. 2015, doi: 10.1016/j.conbuildmat.2015.05.001.

[5] S. Aldawsari, R. Kampmann, J. Harnisch, and C. Rohde, "Setting Time, Microstructure, and Durability Properties of Low Calcium Fly Ash/Slag Geopolymer: A Review," *Materials*, vol. 15, no. 3, p. 876, Jan. 2022, doi: 10.3390/ma15030876.

[6] G. Fang, H. Bahrami, and M. Zhang, "Mechanisms of autogenous shrinkage of alkali-activated fly ash-slag pastes cured at ambient temperature within 24 h," *Constr Build Mater*, vol. 171, pp. 377–387, May 2018, doi: 10.1016/j.conbuildmat.2018.03.155.