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Geopolymer Concrete Containing off-ASTM Fly Ash and GGBFS: Experimental Development and ANN Modeling of Compressive Strength

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ABSTRACT

The existing research on geopolymer concrete has considered it as a promising alternative to normal concrete having great potential to reduce CO2 emissions. Compared to ordinary Portland cement (OPC) production, geopolymer concrete emits 80% less CO2 into the atmosphere by replacing OPC with industrial waste materials (slag and/or fly ash) and alkaline activator solution (AAS). Geopolymers can attain similar mechanical properties and better durability by showing high fire resistivity and lower susceptibility to chemical attacks. The properties of geopolymer concrete are affected by several parameters such as fly ash or slag ratio, alkaline liquid amount, type and concentration of alkaline activators, water content, and curing condition. Kazakhstan produces 19 million tons of fly ash per year and only 10% is used showing lower use capacity compared to developed countries. At present, Artificial Neural Networks (ANN) techniques can effectively predict mechanical and other properties of construction materials in civil engineering. The main objectives of this paper are (1) to develop geopolymer concrete using local off-ASTM fly ash (FA) and ground granulated blast furnace slag (GGBFS), (2) to develop ANN models to predict compressive strength.

Three progressive experimental studies were carried out: 1) the effect of fly ash-to-slag ratio and water-to-binder ratio; 2) the effect of slag-to-fly ash ratio and AAS-to-binder ratio; 3) the effect of binder and water content. The used sodium silicate to sodium hydroxide ratio and molarity were 2.5 and 12, respectively. Compressive strength and drying shrinkage were analyzed. To develop ANN models, 156 variables from the experimental part and the “Levenberg-Marquardt” training algorithm were used. In total, nine ANN models were developed with a hidden layer size between 2 and 100. The result of study I revealed that the optimum fly ash-to-slag ratio was 1 showing a good compressive strength and lower drying shrinkage. The optimum AAS-to-binder ratio based on the result of Study II was 0.35 showing comparative compressive strength and favorable drying shrinkage. The result of Study III showed that the optimum binder content was 41% reaching a compressive strength of 23 MPa. The ANN models showed a good performance in predicting compressive strength having average R^2 and mean average error (MAE) values of 0.92 and 2.62, respectively. The best prediction performance was given by the model with a hidden layer size of 10 showing R^2 and MAE metrics of 0.93 and 2.19, respectively.

The findings of the research showed that geopolymer concrete with local off-ASTM fly ash and GGBFS in the binder can reach comparable compressive strength. The ANN models can be used to predict mechanical properties and optimize mixture design.

Keywords: geopolymer composite, off-ASTM fly ash, ANN model prediction.

REFERENCES

Collins, F., & Sanjayan, J. G. (1999b). Strength and shrinkage properties of alkali-activated slag concrete placed into a large column. Cement and Concrete Research, 29(5), 659–666. https://doi.org/10.1016/S0008-8846(99)00011-3

de Hita, M. J., & Criado, M. (2022). Influence of the Fly Ash Content on the Fresh and Hardened Properties of Alkali-Activated Slag Pastes with Admixtures. Materials, 15(3). https://doi.org/10.3390/ma15030992

Deb, P. S., Nath, P., & Sarker, P. K. (2014). The effects of ground granulated blast-furnace slag blending with fly ash and activator content on the workability and strength properties of geopolymer concrete cured at ambient temperature. Materials and Design, 62, 32–39. https://doi.org/10.1016/j.matdes.2014.05.001

Hassan, A., Arif, M., & Shariq, M. (2019). Use of geopolymer concrete for a cleaner and sustainable environment – A review of mechanical properties and microstructure. Journal of Cleaner Production, 223, 704–728. https://doi.org/10.1016/j.jclepro.2019.03.051

Hojati, M., & Radlińska, A. (2017). Shrinkage and strength development of alkali-activated fly ash-slag binary cements. Construction and Building Materials, 150(April), 808–816. https://doi.org/10.1016/j.conbuildmat.2017.06.040

Humad, A. M., Kothari, A., Provis, J. L., & Cwirzen, A. (2019). The effect of blast furnace slag/fly ash ratio on setting, strength, and shrinkage of alkali-activated pastes and concretes. Frontiers in Materials, 6(February), 1–10. https://doi.org/10.3389/fmats.2019.00009

Tauanov, Z., Abylgazina, L., Spitas, C., Itskos, G., & Inglezakis, V. (2017). Mineralogical, Microstructural and Thermal Characterization of Coal Fly Ash Produced from Kazakhstani Power Plants. IOP Conference Series: Materials Science and Engineering, 230(1). https://doi.org/10.1088/1757-899X/230/1/012046