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Utilizing residual red mud by geopolymerization process – From an expansive soil to a rock-like material

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ABSTRACT

From a sustainable point of view, waste materials are usually reutilized in other industries, such as metal recovery, construction materials, landfills, etc. Red mud (RM) stored in Ajka, Hungary, was investigated for metal recovery, and residual red mud (RRM) was taken in this research to analyze its behavior. RRM has been investigated by required geotechnical tests and was a highly expansive soil. Expansive soils are the most problematic soil type. They can damage adjacent structures and generally cannot transfer loads safely due to high swelling-shrinkage capacity, causing severe cracking when water content changes. Stabilization of RRM becomes a necessity to avoid a catastrophic event when stored RRM collapses. This research aimed to stabilize RRM to be reutilized in geotechnical and construction applications such as the bases of roads. By taking advantage of being amorphous alumino-silicate, RRM has been chemically stabilized by utilizing the geopolymerization process. Geopolymers are considered green construction materials. RRM-synthesized geopolymers were tested for stability against volumetric shrinkage as a result of the change in water content. They demonstrated the same stability as Portland cement with zero volumetric shrinkage. The physical properties and non-destructive results confirmed the stability of synthesized geopolymers. All test results were comparable to Portland cement artificial stone (PC), either increased or decreased in a narrow range. The compressive strength (f_{cu}) of the synthesized geopolymers was considered to be a function of two variables: Na_2O/Al_2O_3 and H_2O/Na_2O molar ratios, to design full factorial experiments of two levels that yielded five samples. All samples were cured under ambient conditions and tested at 28 days. Three samples showed higher f_{cu} values than PC's; two had lower values; however, all synthesized geopolymers demonstrated applicability in geotechnical applications since the maximum and minimum f_{cu} values were 20.3–11.2 MPa, respectively. These values exceeded the base and subgrade limitations: 4.1–2.1 MPa. Zeta potential results showed that all synthesized geopolymers demonstrated a gel formation type N-A-S-H, which proved the binding characteristics. The advantage of ambient geopolymerization of RRM makes it feasible to establish stable geotechnical bases that meet sustainability and waste management requirements.

1. Introduction

Bayer process of bauxite, in which alumina products are manufactured, generates a massive amount of red mud (RM) as a by-product material. RM is characterized as a high-alkalinity material with the presence of ultrafine particles that can negatively affect human health and the environment (Ye et al., 2016). Based on the quality of bauxite ores, the produced quantity of RM ranges from 0.8 to 1.5 tons for each ton of alumina production (Li et al., 2019). RM's annual growth rate has increased from 0.07 to 0.15 billion tons between 2016 and 2021 (Nguyen et al., 2022); approximately four billion tons of RM are accumulated worldwide in large reservoirs in an open environment (Nguyen et al., 2022). To minimize these wastes, they can be reused in other practices to achieve sustainability (N. Kumar et al., 2021). One of the promising solutions is to reutilize the use of RM in geopolymer production as an alternative to Portland cement; it is known that geopolymers have been characterized as materials with a low carbon footprint compared to Portland cement (J. Davidovits, 1993).

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