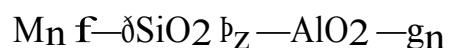


INTRODUCTION:

Soft or highly compressible soils are often encountered on many civil engineering project sites, which lack sufficient strength to support the loading either during construction or throughout the service life. To improve the strength and stiffness of those less competent soils, chemical stabilization with cementitious materials has been widely practiced. The commonly used stabilizers include ordinary Portland cement (OPC) and lime, with their stabilization mechanisms being relatively well understood. In cement stabilized soils, the stabilization mechanisms are associated with hydration and pozzolonic reactions. When lime is mixed with clayey soils, the clay particles become closer and the soil is stabilized through flocculation and pozzolanic reactions. A major issue with conventional soil stabilizers (i.e., OPC and lime) is that their production processes are energy intensive and emit a large quantity of CO₂. For instance, approximately one ton of CO₂ is emitted for the production of one ton of cement. Furthermore, the raw materials readily available for cement production are being over consumed.

Geopolymer is an inorganic aluminosilicate material formed through polycondensation of tetrahedral silica (SiO₄) and alumina (AlO₄), which are linked alternately by sharing all the oxygen atoms. The chemical structure of geopolymer can generally be expressed as:



where M is an alkali cation such as potassium (K^+) or sodium (Na^+) that balances the negative charge for Al, n is the degree of polycondensation, and z is the Si/Al molar ratio, ranging from 1 to 15, and up to 300. Three typical structures of geopolymer are: $M_n f-Si-O-Al-O-g_n$, $M_n f-Si-O-Al-O-Si-O-g_n$,

The geopolymerization can be simplified as two major steps that interact with each other along the reaction:

- (1) Amorphous aluminosilicate materials are dissolved by alkali hydroxide solution and/or alkaline silicate solution to form reactive silica and alumina.
- (2) The dissolved species then polycondense into amorphous or semi-crystalline oligomers which further polymerize and harden into synthetic aluminosilicate materials.

The reasonable synthesis temperature of geopolymer is in the range of 25–80 C. Consequently, energy consumption and CO₂ emission can be largely reduced by replacing OPC with geopolymer.

Moreover, geopolymers have excellent mechanical properties (e.g., compressive strength and stiffness) and exceptional resistance to heat, organic solvents and acids.

In addition, geopolymers can be synthesized from a wide range of low-cost aluminosilicate materials or even industrial wastes, such as metakaolin, fly ash, furnace slag, red mud, and rice husk ash. Considering all the above advantages, geopolymer renders itself to be a promising alternative to OPC in civil infrastructure construction. Finally,

geopolymers also have low shrinkage potential and excellent adhesion to aggregates, suggesting that they can be an effective soil stabilizer.

Recently, some researchers have investigated the effectiveness of both low calcium and high calcium-fly ash based geopolymers in deep soft soil improvement (i.e., grouting process). These studies were conducted by thoroughly mixing alkali activated fly ash slurry, the geopolymer precursor, with soft soils, and their results indicated that fly ash based geopolymers were comparable to cement and lime in the stabilization of deep soft soils.

This paper describes a different potential application of geopolymers: soil stabilization at shallow depth (e.g., sub grade, sub- base or base in pavement and airport construction, shallow foundation, embankment, etc.). Alkali activated metakaolin (MK) was selected to treat a lean clay, in an attempt to examine the feasibility of using geopolymer as a soil stabilizer. Metakaolin is an anhydrous aluminosilicate produced by the calcinations of kaolin at a temperature of 650–900 C, so it contains nearly exclusively amorphous silica and alumina, and hence is highly reactive during the alkali activation.

Although metakaolin is not necessarily more cost-effective or ‘greener’ than OPC, it is an ideal raw material that results in relatively pure geopolymer binders.

In this study, a synthesis recipe that yields metakaolin based geopolymers (MKG) with adequate mechanical properties was determined rest. The mechanical properties and workability of

geopolymers are significantly affected by Si/Al molar ratio and water content in the precursor. Therefore, MKG with nominal Si/ Al molar ratios ranging from 1.5 to 2.0, as reported in the literature that these Si/Al ratios render geopolymer with high mechanical strength, were synthesized for an optimal geopolymer precursor. A Na/Al molar ratio of 1 was selected in this study also because this value proved to yield MKG with high mechanical strength according to previous studies. To investigate the feasibility of MKG as a soil stabilizer, the following properties of the treated soil were determined: unconfined compressive strength (UCS), failure strain (ϵ_f), Young's Modulus (E) and volumetric shrinkage strain during curing period. One-way analysis of variance (ANOVA) was performed to determine the statistical trend of the dependence of mechanical properties on curing period and geopolymer concentrations. Furthermore, the micro structural change of the soil before and after the stabilization was investigated to elucidate the geo- polymer stabilization mechanisms, with the aid of X-ray diffraction (XRD), scanning electron microscopy (SEM), and energy dispersive X-ray spectroscopy (EDX) analyses.