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Polymers for stabilization of soft clay soils

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Abstract

In this study, the influence of two chemical additives, (i.e., poly(vinyl alcohol), PVA and 1,2,3,4 Butane Tetra Carboxylic Acid, BTCA on the engineering properties of an expansive clay soil is investigated. The effect of polymers on the unconfined compression strength of soil samples prepared at maximum dry unit weight (i.e., 16.2 kN/m^3 and 17% water content) and a lower dry unit weight (i.e. 10.8 kN/m^3 and 48% water content) was evaluated. PVA and BTCA added at dosages of 0.1% to 1.5% and 0.1% to 0.5% respectively to both compacted soil samples and cured for 1 and 14 days. The results of unconfined compression tests on clay soil samples stabilized with different PVA and BTCA contents cured for 1 and 14 days indicated that such hydrophilic polymers improve the compression strength of both dense and soft clay soils significantly and their strength even increases with curing time. However, the efficiency of the additives is highly dependent on the unit weight of the soil. Furthermore, the durability of stabilized samples was also examined using soaking tests and results revealed that these polymers improve the durability of clay soils once they are soaked under water.

Keywords: Soft clay soils; Unconfined compression strength test; Strain energy; Poly(vinyl alcohol); 1,2,3,4 Butane Tetra Carboxylic Acid

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1. Introduction

The stability of the embankments is highly vulnerable to the presence of weak water-stable clay aggregates that may result in erosion during wet season [1]. Therefore, highways, railways and other engineering structures founded on soft soils may suffer an excessive settlement in wet season if adequate improvement measures are not sought. Fortunately there are a number of reported and well documented soil stabilization/reinforcement techniques that can mitigate the adverse effect of problematic soils (especially expansive clays and soft clay soils). Lime, fly ash and cement are amongst the traditional soil stabilizing agents that are widely popular between practicing geo-engineers to suppress the swelling properties and increase the compressive strength of expansive soils [2,3,4]. Such additives generally contain calcium that flocculate clay particles by balancing the electrostatic charges of the clay soil particles and by reducing the intra-particle's repulsive electrochemical forces. This leads to adhesion of clay particles together and forming flocculated particles with improved engineering properties including higher strength, lower plasticity, increased workability and alleviated swelling pressure [5,6,7]. The abovementioned chemical reactions occur in two phases, with both immediate and long-term (i.e., pozzolanic reaction) improvement in soil strength [8].

Nontraditional stabilizers have also become increasingly available for civil and military applications. These include salts, acids, enzymes, lignosulfonates, petroleum emulsions, polymers, and resins. These chemicals improve the engineering behavior of soil by forming physical/chemical bonds with clay minerals within the soil. Polymers have been reported to develop a substantial strength improvement effect in clay soils due to formation of bond between clay minerals and polar end groups of polymer. There are also several commercial chemical stabilizers that are claimed to increase the strength with less curing time and higher durability compared to traditional stabilizing additives. However, the constituents of these chemicals are typically neither disclosed by the supplier nor documented elsewhere.

Ajayi-Majebi et al. [9] reported the improving effect of an epoxy resin (bisphenol A/epichlorohydrin) and a polyamide hardener on clay-silt soils. In their study, 3-day cured stabilized soil samples with 4% additives showed significant increase in unsoaked California Bearing Ratio (CBR). Tingle and Santori [10] reported successful application of lignosulfonate and synthetic polymers for improving the unconfined compression strength of both lean and fat clay soils. Page [11] reported significant benefit of spraying poly(vinyl alcohol) to prevent crust formation and enhance the stability of clay soils subjected to simulated heavy rain. Mirzababaei et al. [12] also investigated the effect of two polymers including 3 to 10% poly(methyl methacrylate) and 1 to 3% poly(vinyl acetate), respectively on the free swell potential of 3 different fat clay soils. They reported significant reduction in free swell potential and formation of aggregated clay-granular matrices with the addition of polymers.

This article discusses the application of poly(vinyl alcohol) (PVA) as a polymeric binder for stabilizing soft clay soils. PVA is the largest water-soluble biodegradable polymer chain that has excellent film forming and adhesive properties [13]. It is also resistant to grease, oil, and solvent. It is highly hydrophilic and PVA solutions can be prepared easily by dissolving PVA in water [14]. On the other hand, water based polymers like polyvinyl alcohol (PVA) are known to be eco-friendly (i.e., nontoxic and odorless) and are widely used in cosmetics. PVA is a non-ionic water-soluble polymer possessing high ability of aggregating clay soils [15]. However, PVA-encapsulated clay particles are still vulnerable to water and may tend to disperse with increase in moisture content of the soil. Cay and Miraftab suggested to make PVA, water insoluble using a crosslinking method such as freezing/thawing, methanol treatment, chemical crosslinking, or irradiation. In their study, 1,2,3,4 butanetetracarboxylic acid (BTCA) was used to crosslink PVA to form hydrogel structures that are three-dimensional hydrophilic polymer networks capable of absorbing large amounts of water. The results of their research indicated that crosslinking with BTCA improve the water stability of PVA membranes and make them resistant after water treatment.

In this study PVA was used as the main stabilizing additive along with 1,2,3,4-Butanetetracarboxylic acid (BTCA) as crosslinking agent. A series of unconfined compression strength tests was carried out on highly plastic clay soil samples treated with proportionate quantities of PVA and BTCA. A number of samples also cured for 14 days to investigate the effect of stabilizing additives on the unconfined compression strength of the clay soils in the long-term. Samples with optimum PVA/BTCA contents also soaked in water to investigate the stability of stabilized samples subjected to excessive wetting.