BIOPOLYMER MODIFIED SOIL: PROSPECTS OF A PROMISING GREEN TECHNOLOGY

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ABSTRACT: The benefit from using admixtures in soil to improve properties was discovered in ancient times. Various admixtures such as straw, bitumen, lime, salts, and pozzolans are conventional additions to soil, while cement, petrochemicals and bacteria are currently being increasingly used in an effort to improve and stabilize soil from both mechanical and chemical aspects. The conventional techniques which utilize cement, lime, petrochemicals etc. causes significant environmental degradation. With environmental awareness for materials and methods used in ground improvement generally growing, the trend towards using biopolymers as admixtures is expected to increase. This paper gives the concept and theory of ground improvement technique which employs biopolymers and describes the practical application of these techniques. Number of studies have been conducted in the past decades to check the suitability of various biopolymers in improving soil properties. Effectiveness of biopolymers for soil stabilization in agricultural, construction, and military applications have been recognized by many researchers. More efficient and scientific usage of these materials for soil improvement requires knowledge about interaction mechanisms involved in the modification of geotechnical properties of soil. Most of the studies in clay polymer interaction are from the field of medical engineering, where clay particles are suspended in the colloidal form and macromolecules are attached to them in different ways. The fundamental mechanism in biopolymer soil modification proposed by various researchers are also presented in this paper. The study reveals the prospects of this green technology in the current era of rapid deterioration of natural resources. Furthermore, the need of continuing research on a number of factors which controls the mechanism is suggested.

Keywords: biopolymer, soil stabilization, soil biopolymer Interaction.

1 INTRODUCTION

Enhancing the properties of soil is a long-established technical field. In the studies about cradle of civilization, researchers have noticed the use of a number of soil modification techniques. Antediluvian techniques where there for storing water, for retaining the fertile top soil, for constructing shelters over loose soil near their agricultural fields, and for many other basic needs. Evidences of using admixtures for soil improvement was revealed by archaeologists from different civilizations like Sumerian and Roman. For example, Vitruvius described the application of dried blood for air-entrainment and biopolymers for set retardation of gypsum (Rowland et al., 2001). Technologies improved with the advancement of civilization and materials used for soil improvement also changed to a great extent. In all fields of engineering the need for better results overruled environmental concerns including protection of nature. Even though many ancient philosophies encouraged growth with the nature, greed of one particular species ignored all those traditional wisdom and used many techniques to conquer biosphere which eventually caused extinction of many other species. The present generation identifies that the development in this style caused the deterioration of environment and it is inevitable to go for corrective measures. The land, water and air has been polluted to the alarming levels and now it is the time to cleanse them. Need of sustainable technology is a globally accepted fact now.

To improve/stabilize soil many techniques are there which includes soil modification using physical mechanical and chemical methods. In many of the engineering applications it is not viable to use mechanical or physical methods alone as the situation demands the usage of admixtures to enhance the engineering properties of soil under consideration to the desirable value. Using natural admixture like straw were found less effective compared to the cement or petrochemical additives and eventually whole world started using synthetic additives like 'Krilium' and poly vinyl alcohols for soil stabilization (Theng, 1982). Use of cement and lime continued along with this.

While considering the environmental impacts of chemical stabilization methods, studies should concentrate on the effects after the application of the chemical as well as the process involved in the production of these chemicals. Studying the impact of soil stabilization using cement will first point to the impact at the time of production of cement. The total quantity of green house gases released per ton of cement production is in the tune of 0.95 tons. With this the matrix stabilization which prevents the growth of vegetation on the top soil proves that cement stabilization is not a green technology. The extensive utilization of cement cause quite a lot of related issues in the habitat, such as increased runoff, air pollution and heat island. Moreover, it is not easy to return cement modified soil to their initial state (Chang et al., 2016).

From 1950's geotechnical engineers have started using chemically synthesized macromolecules such as lignosulfonates and polyacrylamides to replace the conventional binders. These comparatively new and effective chemically synthesized polymers raised concerns about contamination and toxicity problems. Need of restrictions to the uncontrolled use of chemically synthesized polymers are globally accepted in the present era (Karol, 2003). Electro-osmotic chemical treatment (ECT) has been proved to improve the strength of soft soils, but it requires injection of substantial quantity of chemical chelating agents for an increase in osmotic pressure (Ou et al., 2009). Application of geopolymers for soil stabilization is another growing field, but studies have shown that these novel materials are susceptible to significant strength reduction when saturated, in particular with acidic solutions, due to depolymerization and removal of silicic acid. The conventional techniques which utilize cement, lime, petrochemicals etc. causes significant environmental impacts. The trend towards employing biopolymers for engineering applications is expected to increase with an increase in environmental awareness.

Polymers or macromolecules are chemical compounds formed by the union of molecules of the same kind (monomers). Biopolymers are environment friendly polymers that are produced by living organisms. Biopolymers have a wide range of applications: in agriculture, biomedical engineering, food processing, the chemical industry, the energy sector as well as in environmental protection and remediation. Commonly used biopolymers in soil modification include guar gum (derived from the ground endosperm of a legume), xanthan gum (extracellular polysaccharide from bacteria xanthomonas-campestris) and chitosan (derived from chitin obtained from crustaceans), sodium alginate (derived from the cell walls of brown algae). Addition of biopolymer to soil may result in low permeability, higher shear strength characteristics, acceptable swell-shrink behaviour and high erosion resistance. Application of biopolymers to soil as a stabilizing and strengthening agent of aggregates was under consideration in the agricultural engineering from the 1940s (Karimi et al., 1997).

The World Health Organization (1975; 1987) performed toxicity studies for biopolymers guar gum and xanthan gum and found that they do not represent a hazard to health and that there was no need to establish an acceptable daily intake of the substances. Keeping these facts in mind biopolymer modification of soil can be considered as an environment friendly technology.

2 APPLICATION OF BIOPOLYMER IN SOIL ENGINEERING.

Use of biopolymers to reduce soil hydraulic conductivity for ground water control and containment applications has received attention in recent decades. Different works found that several biopolymers procurable from the market including chitosan, sodium alginate, xanthan gum, poly-hydroxybutyrate, poly glutamic acid and guar gum were capable of reducing the permeability of soil by up to five orders of magnitude (Khachatoorian et al., 2002; Bouazza et al., 2009; Blauw et al., 2009; Taytak et al., 2012; Wiszniewski et al., 2013) .

Erosion and slope stability issues are challenging, especially in the field of cultivation where use of synthetic polymers will cause significant impacts. Biopolymer induced stabilization of soil is a very good solution for these problems. Application of xanthan gum, chitosan, starch or polyacrylamide in furrow irrigation can reduce the erosion potential of soil. (Sojka et al.,2003; Orts et al.,2003). Application of biopolymers like cellulose, β-glucan and Xxnthan gum in clayey sand, silty sand, silty clay, loam and silt were found effective in stabilizing slope and controlling erosion (Maghchiche et al., 2010; Larson et al., 2012; Chang et al., 2015).

Biopolymers like beta-1,3/1,6-glucan biopolymer, xanthan gum etc. were added to different soils by researchers and found that the unconfined compressive strength enhances more than 150 percent (Chang et al.,2012; Liu et al.,2011; Chang et al. 2015). Studies on shear strength also shows considerable increase. the change is mainly on the cohesion intercept, and difference in angle of internal friction is negligible (Karimi,1997; Liu et al.,2011; Khatami et al., 2013).

Optimum water content and maximum dry unit weights are important when soil is used as an engineering material. Biopolymer modified soil shows a higher maximum dry density compared to that of virgin soil while change in optimum moisture content is negligible (Karimi, 1997; Taytak et al., 2012).

Variation of liquid limit of cohesive soils with biopolymers having different viscosity was studied by many researchers and found that liquid limit increases with addition of biopolymers. The variation of consistency limits will differ with the properties of biopolymers (Karimi, 1997; Nugent et al., 2009, Chen et al., 2013).

3 STABILIZATION MECHANISM IN BIOPOLYMER-SOIL GEOMATERIAL

From the numerous studies available it is evident that biopolymers are better alternative for conventional stabilizing agents like cement and synthetic polymers. For more efficient and scientific usage of these materials for soil improvement requires the knowledge about the mechanisms involved in biopolymer soil interaction. Clay polymer interaction is well studied by many of the biomedical engineers in which clay particles are suspended in the colloidal form and polymers can attach to it in different ways. (Theng 2012). In soil improvement the mechanism is different.

It has been shown by Geoghegan and Brian (1946) that bacterial polysaccharides exert a pronounced binding effect on soil particles. When biopolymers added to soil they form a thin coating over the aggregates with secondary bonds. Polar components in the biopolymer may get attached to charged surfaces, enhancing adhesion. For specific biopolymers ion exchange with soil is also expected. (Tingle et al., 2007). In soil biopolymer mixture a portion of the stabilizer enters the pore spaces while the other part falls on to the soil particle surface. It is possible for the ionic groups in the macromolecules to react with clay grain. Through ionic, hydrogen or Vander Waals bonds formed in the chemical reaction, biopolymers enwrap soil aggregates and interlink to form a viscous and elastic membrane structure. The modified structure causes an improvement in the engineering properties including strength and erosion resistance. The physicochemical reactions among biopolymer and soil particles usually need a few days. The increase in unconfined compressive strength of biopolymer modified soil, with an increase in curing duration supports this hypothesis (Liu et al., 2011). The effectiveness of stabilization depends on the interfacial reaction phenomena, the types of forces present at the boundary of soil particle and biopolymer. Chemisorption, hydrogen bonding and physical adsorption are possible at the soil biopolymer interface. Primary bonds which includes covalent and ionic/electrostatic bonds have the maximum bond energy, van der Waals forces, main reason for physical adsorption develop weakest bonds (Khatami et al., 2013).

The five categories of interactions within the soil aggregate, bio polymer, and cation system are aggregation of soil particles due to polymer addition; cation induced interlinking of biopolymers; formation of a interconnected network of polymer and clay via cation bridging; Change of thickness in the diffused double-layer on clay surfaces; and competing adsorption of biopolymer molecules and cations onto clay surfaces (Nugent et al., 2009). The stabilization mechanisms proposed by the researchers are still largely unsubstantiated, but the available data from literature and laboratory experiments tend to support them.

4 CONCLUSIONS

Acceptability of ground improvement techniques increased because of its cost effectiveness and wide rage applicability. Effectiveness of ground improvement techniques has been proven in the past for a wide range of engineering structures such as retaining structures, pavements, highways, runways, ports, bunds, railways, dams, excavations, tunneling and other infrastructure facilities. The conventional ground improvement techniques which utilize cement, lime, petrochemicals etc. causes significant environmental impacts. Soil stabilization using biopolymer is an environment friendly alternative. Studies provide evidence for the capability of biopolymers to strengthen soils, control permeability and for several other applications. Even though biopolymer stabilization got myriads of advantages still a number of impediment are there to solve. The durability issues and applicability to different soils are yet to be studied.

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