Enhancing The Properties Of Expansive Soil Using Biopolymers-Xanthan Gum And Guar Gum

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Abstract. Expansive soil poses problems to civil engineers in general and geotechnical engineers in particular. When geotechnical engineering structures such as foundations, retaining walls, pavements, side walls, canal beds and linings are proposed on expansive soil, they result in detrimental cracking due to alternate swelling and shrinkage. The methods of treating soil with chemical and cement grout are used widely in geotechnical projects. These conventional soil treatment methods have several shortcomings, especially from an environmental perspective. An attempt is made to use environmentally friendly materials viz., biopolymers, to improve the soil properties. The present study illustrates the viability of two types of biopolymers, viz., Xanthan gum and guar gum, as environmentally friendly additives for soil stabilization. Unconfined compression strength and one-dimensional consolidation tests are performed on both treated and untreated soil samples. It is observed that at 1% of Xanthan gum there was an increase in strength of 630% and at 1.5% of guar gum, it showed an increase in strength of 100% for 0 days. Use of Xanthan gum and Guar gum enhances the properties of expansive soil, resulting in an eco-friendly and sustainable substitute to traditional soil stabilization method.

Keywords: Biopolymers; Expansive soil, Guar gum; Soil stabilization; Xanthan gum.

1 Introduction

Soils derived from the weathering of black trap rock, in particular, which are black, fine-grained, dense and climatologically suited to the growth of cotton is called as black cotton soils. Expansive clay is a clay soil that is prone to substantial volume changes. It shrinks and swells with decrease and increase in water content, respectively. This behaviour is attributed to the presence of a clay mineral called montmorillonite. Developing a universal system for identification and classification of the problematic and expansive soils in addition to the developments of the predictive models is a challenging task.

Expansive soil covers more than 20% of the geographical area of India. It is spread over Madhya Pradesh, Maharashtra, Andhra Pradesh, Gujarat, Tamil Nadu and Karnataka. Buildings in expansive soils have posed severe problems of distortion and cracking.

Expansive soil is a problematic soil that causes extensive damage to civil engineering structures. When engineering structures proposed on expansive soil, they result in detrimental cracking due to alternate swelling and shrinkage. The methods of treating soil with chemical and cement grout are used in geotechnical projects. Therefore an attempt is made to stabilize and enhance the engineering properties of the expansive soil with the help of environmental friendly biopolymers viz., xanthan gum and guar gum. M. H. Ghobadi, Y. Abdilor; R. Babazadeh carried out studies on the stabilization of soils using lime. The soil used for the study was collected from southwest of Hamedan City. The lime was added to soil in the order of 1,3,5 and 7% by weight.

Uniaxial compression test and direct shear tests were performed. The direct shear test was conducted at pH=3,5,7,9. The results showed an increase in unconfined compression strength with increase in lime per cent and curing time. The maximum cohesion and friction angle was achieved at pH 9. Nima Latifi, Suksun Horpibulusk, Christopher L, et al., studied the use of xanthan gum as an environmentally friendly stabilizer that can improve the engineering properties of both low and high swelling clays. The Microstructural analysis tests indicated that the chemical reaction between xanthan gum and soil particles at the micro level resulted in the formation of new cementitious products. Thus, improved the soil structure by welding soil particles together and filling the pore space in the soil matrix. Gujjula Kullayappa and Suresh Praveen Kumar gave guidelines for selecting potentially useful biopolymers for strengthening cohesion soil. The soil used in this study is expansive soil which was collected from the Thadigotla area near Krishnapuram, Kadapa in Andra Pradesh. The soaked CBR values for soil with 0.5 to 2.0% of guar gum showed an increment of 40 to 165%. The Unconfined compressive strength of admixed soil at 2.0% biopolymer for the sample tested with seven days curing period is 2.6 times that of the UCS of the natural soil. Strengthening effect of Guar gum was shown to have the most significant impact on expansive soil with curing periods.

Paulo J. Vendra Oliveira, Luis D. Freitas and Joao P.S.F. Carmona carried out work on the impact of soil type on the process of enzymatic $CaCO_3$ precipitation. The test results indicate that The process of enzymatic $CaCO_3$ precipitation is potentiated in sandy and silty soils. Also, The process of enzymatic $CaCO_3$ precipitation has a detrimental effect on organic soil, with a decrease in the strength and stiffness of approximately 50%. Noolu Venkatesh, Danish Ali, Rakesh J pillai & Heera Lal M carried out studies on lime stabilization to improve the engineering properties of black cotton soil including the resilient modulus value, which is essential for mechanistic flexible pavement design. The optimum lime content required for stabilization was determined using Atterberg's limits. The considerable increment was observed in unconfined compressive strength values and California bearing ratio values of black cotton soil stabilized with 6% lime. Repeated load triaxial tests under different confining pressures and deviatoric stress levels were conducted on the treated samples to determine the resilient modulus. The effect of the curing period and moisture content on the resilient modulus was investigated. To study the durability of lime stabilized clayey subgrade soil, the impact of wetting and drying cycles on the engineering properties of the treated material was examined. The results show that the strength and stiffness characteristics of lime treated clay have considerably reduced after five wetting and drying cycles. Chang, I., Im, J., Prasidhi, A. K., and Cho, G. C investigated the interaction between Xanthan gum biopolymer and soils. Experimental tests results show that there is a formation of hard plastic between uncharged particles due to the interaction between Xanthan Gum fibers and charged surface of clayey particles. The strengthening effect is dependent on the hydration level of the soil. In this study, it was concluded that the strengthening effect of Xanthan Gum is dependent on four factors Viz., type of soil, hydration level, amount of Xanthan gum added and method of mixing. The most effective concentration of Xanthan gum was observed to be 1−1.5% to the soil mass.

The objective of the present work is to study the effect of biopolymers on the strength, swelling properties, California Bearing Ratio and durability of expansive soil.

2 Experimental study

2.1 Materials used

The following materials were used for the present study.

Soil

. Locally available Expansive soil collected from a site near Kusugal Road, Karnataka is used for the present study. The soil properties are listed in Table 1.

Table 1. Properties of Expansive Soil

Sl. No	Property	Result
1.	Specific gravity	2.38
2.	Grain size analysis	
	Gravel (%)	1.26
	Sand (%)	16.84
	Silt (%)	43.64
	Clay (%)	38.26
3.	Liquid limit (%)	103.20
4.	Plastic limit (%)	57.12
5.	Shrinkage limit (%)	12.01
6.	Plasticity Index (%)	46.08
7.	IS Soil Classification	MH
8.	Optimum Moisture Content (%)	22.03
9.	Maximum Dry Density (g/cc)	1.45

Xanthan-Gum and Guar Gum.

. Xanthan Gum and Guar gum are biopolymers in powder form which are readily soluble in water. These are procured through online from Amazon.in. Xanthan Gum It is an effective thickening agent and stabilizer to prevent ingredients from separating. Guar gum shows excellent stability during freeze-thaw cycles.

2.2 Methodology

Atterberg limits, compaction characteristics, free swell index, unconfined compressive strength, California bearing ratio and durability of expansive soil stabilized with biopolymers are determined in this study.

Xanthan Gum and Guar Gum are added in a ratio of 0.5%, 1.0% and 1.5% of expansive soil, and UCS samples are prepared with optimum moisture content and maximum dry density obtained from Proctor test (IS: 2720-(Part 7) - 1980). These samples are cured for 0, 7 and 28 days and then tested for Unconfined compressive strength (IS: 2720 (Part 10) - 1973) to obtain optimum content of Xanthan Gum and Guar Gum.

The samples cured for seven days with 1% optimum content of Xanthan Gum is tested for durability using alternate wetting and drying. The samples were submerged in potable water at room temperature for 5 hours and then dried in over at 70° C for 42 hrs. The procedure constitutes one cycle for 48hrs. The process is repeated for 12 cycles, and the volume change of the specimen was determined.

3 Results and discussions

Figure 1 shows the percentage increase in strength Vs curing days for soil sample treated with varying concentration of Xanthan Gum. The soil sample is added with 0.5, 1 and 1.5% concentration of Xanthan Gum and tested for its unconfined compressive strength for 0, 7 and 28 days curing period. The test results indicate a 630% increase in strength at 1% concentration of Xanthan gum for 28 days curing.

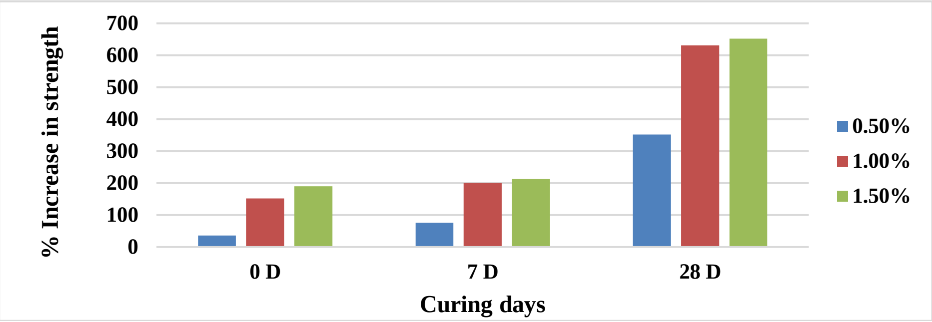

Fig. 1. Increase in strength Vs curing days for Xanthan Gum

Figure 2 shows the percentage increase in strength Vs curing days for soil sample treated with varying concentration of Guar Gum. The soil sample is added with 0.5, 1 and 1.5% concentration of Guar Gum and tested for its unconfined compressive strength for 0, 7 and 28 days curing period. The test results indicate 100% increase in strength at 1.5% concentration of Guar Gum for 0 days curing.

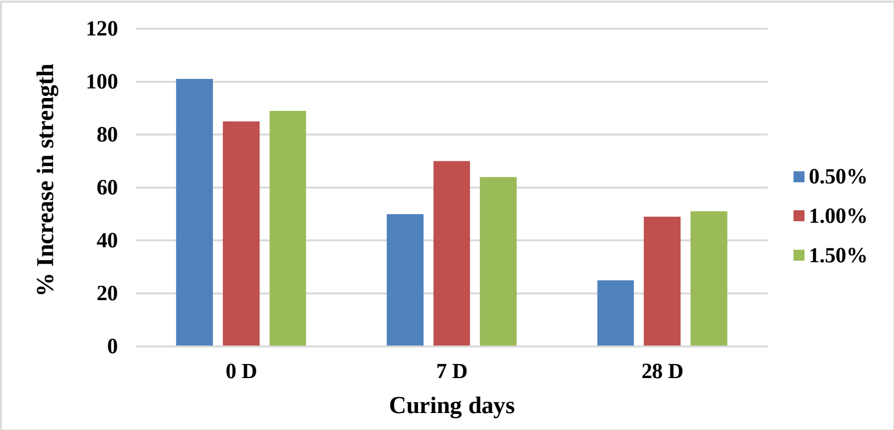

Fig. 2. Increase in strength Vs curing days for Guar Gum

Figure 3 shows unconfined compressive strength Vs soil sample treated with optimum content of Xanthan Gum and Guar Gum. The increase in strength is due to polysaccharides, which has the property of pseudo plasticity (i.e., viscosity degradation depending on the shear rate). Xanthan gum induces a substantial increase in the viscosity of a liquid. Xanthan Gum, unlike other biopolymers, displays higher stability and formation of hydrogen bonds. Whereas Guar Gum has the property of solubility, i.e. as curing period increases some part of the water evaporates which contains guar gum due to which strength is decreasing.

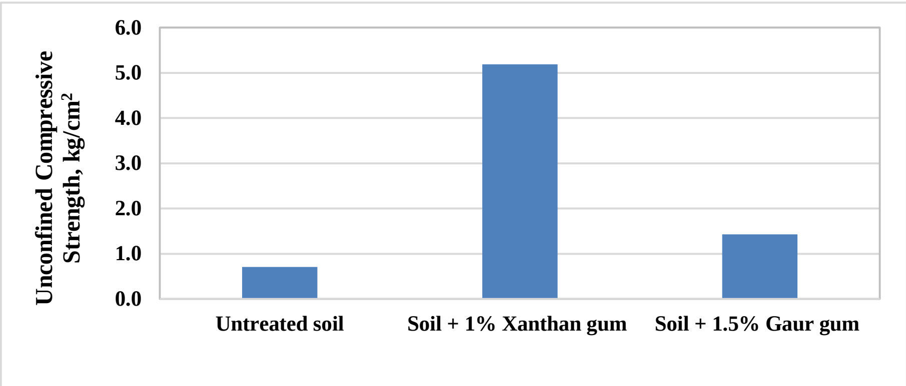

Fig. 3. Unconfined Compressive Strength Vs Soil samples

Consolidation test results for untreated soil and soil treated with 1% Xanthan Gum showed a decrease in the coefficient of consolidation by 32.46%. This decrease in Cv values is due to the formation of hydrogen or electrostatic bonds between xanthan monomers and the clay particles. Interaction between the xanthan gum and the particles forms large, firm biopolymer-soil matrices (with a flocculated structure), which yield a decrease in the soil void space and an increase in the treated soils' stiffness and load-bearing capacity.

Durability tests are performed on soil sample treated with 1% Xanthan Gum. Test results showed that the soil samples collapsed for the second cycle. As the Xanthan Gum loses the binding property at the early stage, the soil sample failed. In future studies, it is suggested to add cementitious material to this mixture, and the durability can be checked.

4 Conclusions

Based on the study of using biopolymers to stabilize expansive soil, the following conclusions are drawn;

- The results indicate the formation of cementitious properties due to chemical reactions between the biopolymers and soil particles at the micro level, which improves the soil structure by binding soil particles together and filling the pore space in the soil matrix.
- Xanthan Gum showed an increase in strength to 630% at an optimum value of 1% for 28days. This increase is due to polysaccharides, which are anionic reacts with cations, which give higher stability and forms hydrogen bonds.
- Guar Gum showed an increase in strength to 100% at an optimum value of 1.5% for 0 days. As the curing period increased, there is a decrease in strength due to the property of solubility.
- A mixture of these two biopolymers, Xanthan Gum and Guar Gum showed an increase in strength to 303% at an optimum value of 1% for 28 days.
- Free swell index decreases by 45.45% for an optimum value of Xanthan Gum. Mixing of biopolymer has resulted in decreasing the voids ratio and making soil particles to bind.
- Soaked C.B.R value for treated soil at optimum content of Xanthan Gum has shown a 24% increase when compared to the natural soil. There is no much effect of biopolymer on the CBR value of soil.
- Adding cementitious material along with Xanthan Gum will increase the durability of soil.

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