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Strength Characteristics of Expansive Soils Using Eco-Friendly Xanthan Gum

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Abstract: ***Soil treatment as well as improvement is commonly performed in the field of geotechnical engineering. Methods and resources to achieve this such as soil stabilization in addition to mixing with cementations binders have been utilized in engineered soil applications since the beginning of human civilization. Demand for environment-friendly and sustainable alternatives is currently rising. Suitable eco-friendly replacement for conventional materials is required. Xanthan gum is a polysaccharide commonly used as a food additive and rheology modifier. It has been used as a soil improvement material in the present study and experimental tests were performed with expansive soils. Xanthan were identified for the study over a range of concentration (0.2%, 0.4%, 0.6%, 0.8%, 1.0%, 1.2%, & 1.4%). The results show that the Xanthan gum fibers interact directly with the charged surfaces of clayey particles while forming Xanthan matrices that resemble a hard plastic between uncharged particles. Through experiments with varying concentrations of Xanthan gum, it was found that the strengthening effect leveled off at higher concentrations. The strengthening effect was also shown to be greatly dependent on the hydration level of the soils. Overall, the strengthening effect of Xanthan gum is shown to be dependent on four factors: type of soil, hydration level (e.g., moisture content), Xanthan gum content, and mixing method. Moreover, continuing research is suggested to ensure performance in terms of practical implementation, reliability, and durability of in situ biopolymer applications for geotechnical engineering purposes.***

Keywords: Expansive soil, Xanthan Gum, Shear Strength, Environmentally-friendly

1. Introduction

Geotechnical engineering, especially the treatment and usage of soil (or earth) in construction, is a venerable technical field, dating to the beginning of human civilization. Soil stabilization in a wide-ranging sense includes various methods used for modify the properties of soil to improve its engineering performance. By stabilization the major properties of soil, i.e., volume stability, strength, compressibility, permeability, durability and dust control is improved, which makes the soil suitable for use.

There are different methods of stabilization, which include physical, chemical and polymer methods of stabilization. Physical methods involve physical processes to improve soil properties. This includes compaction methods and drainage. Compaction processes lead to increase in water resistance capacity of soil. Drainage is less common due to generally poor connection between method effectiveness and cost. But, compaction is very common method. Although, it makes soil more resistant to water, this resistance will be reducing over time. Chemical soil stabilization uses chemicals and emulsions as compaction aids, water repellents and binders. The most effective chemical soil stabilization is one which results in non-water-soluble and hard soil matrix. Polymer methods of stabilization have a number of significant advantages over physical and chemical methods. These polymers are cheaper and are more effective and drastically less dangerous for the environment as compared to many chemical solutions.

In the present study, expansive soils are considered for effectiveness of biopolymer stabilization. As an alternative to such traditional soil treatment and improvement techniques, biological approaches are now being actively investigated in the field of geotechnical engineering, including microbe injection and by product precipitation. In particular, microbial induced polymers—or biopolymers—have been introduced as a new kind of construction binder, especially for soil treatment and improvement. To date, most studies on these applications of biopolymers have been experimental efforts that have produced preliminary findings and analyses, and the number of theoretical explanations and case studies of practical implementation in the literature are still limited. In response, this paper provides a detailed review of biopolymer applications in geotechnical engineering including the most recent studies. In this review, strengthening mechanisms between typical biopolymers and soils based on microscopic inter-particle interactions are summarized. The advantages and disadvantages of biopolymer applications are compared with those of existing soil engineering methods. Finally, the potential for practical implementation is evaluated via an economic feasibility analysis, including environment-friendly considerations.

2. Objective of the Work

The objective of this research is to evaluate the strength behaviour of soil with natural biopolymers, and to determine the effect of the biopolymer stabilizers on engineering properties of expansive soils. Unconfined compressive strength and California Bearing Ratio (CBR) of biopolymer-soil specimen is measured. The biopolymers used are Xanthan Gum with concentration of (0.2%, 0.4%, 0.6%, 0.8%, 1.0%, 1.2%, 1.4%, & 1.6%) by weight of dry soil.

3. Materials

Following are the materials which are used in the present study:

1. Expansive Soil

The soil sample was locally collected from near Yogi Vemana University at Vemanapuram village kadapa district. The sample was extracted by 50 cm deep. The soil lumps were broken into small pieces and screened through 4.75 mm size sieve to make it free from roots, pebbles, gravel etc. The following table shows the various soil properties obtained:

Table 1: Properties of Expansive Soil

S.No	Properties	Expansive Soil
1	Specific Gravity	2.48
2	Free Swell Index	75%
3	Liquid Limit	68%
4	Plastic Limit	32%
5	Plasticity Index	35%
6	Standard Proctor Compaction	OMC-32%
		MDD-1.24g/cc
7	Unconfined Compressive Strength	0.12 Kg/cm^2
8	California Bearing Ratio	Unsoaked-3.92
		Soaked-2.05

2. Xanthan Gum

This anionic polysaccharide is produced by the bacteria Xanthomonas campestris. Xanthan gum's negative charge comes from its carboxylic acid (-COOH) groups, since hydrogen atoms easily dissociate from these carboxylic acid groups to form carboxylate (-COO−) anions. Xanthan gum can also form hydrogen bonds with its numerous hydroxyl (-OH) groups. Small amounts of xanthan gum significantly increase an aqueous system's viscosity, which makes it a commonly used commercial substance. However, since the xanthan gum solution is pseudoplastic, its viscosity decreases with an increased shear rate. Xanthan gum also forms a viscous hydrocolloid when mixed with water, so it can also be considered dissolved in water.

Figure 1: Xanthan Gum Powder

4. Sample Mixing

For the sample preparation, two different mixing methods can be adopted: dry mixing in which the biopolymer was directly mixed with the soil before adding water and wet mixing in which biopolymer was mixed with water to form hydro- solution before mixing in the soil. Dry mixing method was used. Soil sample mixed with various percentage of biopolymer (0.2%, 0.4%, 0.6%, 0.8%, 1.0%, 1.2%, & 1.4%).

5. Experimental Work

The soil sample mixed with Xanthan gum biopolymer concentration of 0.2%, 0.4%, 0.6%, 0.8%, 1.0%, 1.2%, & 1.4%. For the standard proctor test, specimens were prepared by compacting black soils with Xanthan gum in dry state and distributing three equal layers by 25 blows per layer and optimum moisture content obtained.

Unconfined Compression Test and California Bearing Ratio Tests were carried out in varying percentages of Xanthan Gum. UCS test were carried out for the determination of shear strength of the Black soil sample. A conventional laboratory testing method was used to determine the shear strength characteristics of the specimens. Experimental work was carried for Xanthan Gum with variation different biopolymer concentrations and kept for air dried condition for 7days. The sample prepared for the variation of biopolymer. The tests were performed as per procedures described in IS code 2720-10.

6. Results & Discussion

Results of experimental tests show that the strength values of the Xanthan gum treated soils mainly depend on four factors: (1) type of soil, (2) dehydration (e.g., moisture content), (3) Xanthan gum content, and (4) mixing method.

The strength increases with an increase in the Xanthan gum content, but the strengthening effect tends to decrease or level off at higher Xanthan concentrations. As for the type of soil, it was shown that fine soils have a better strengthening effect than coarse grained soils; however, the most effective soil type was a mixture of the two with a well graded size distribution. Also, for longer curing times, the water content within the soil decreased and, as a result, the compressive strength of the soils increased.

Finally, the dry mixing method was shown to yield a more even distribution of Xanthan gum within the soil, thereby maximizing the strengthening effect on the soil.

For pure fine soils, Xanthan gum polymers interact with soil particles independently and directly, rather than forming thread or textile type matrices. Moreover, the effect of curing (i.e., time) does not dramatically change the structural alignment of the Xanthan gum–a fine soil matrix , except for volumetric shrinkage due to drying. Thus, interactions remain ductile and the material does not become as brittle as that formed when using coarse grained soils.

A. Effect of Xanthan Gum on UCC of Soil:

The UCS value first increasing and then decreasing with variation of Xanthan gum content of 0.2%, 0.4%, 0.6%, 0.8%, 1.0%, 1.2% & 1.4%. The UCS value increases with air dried time from 0 to 7 days. The UCS value increases with the decreasing moisture content from optimum moisture content and decreases with the increasing moisture content from optimum moisture content. The UCS value increases for the dry side water content due to continuous Xanthan gum gel hardening due to the dehydration of residual moisture in

Xanthan gels. The results of unconfined compression test are shown in fig. of 7 days. The UCS value decreases for the 1% of Xanthan gum content due to the higher viscosity after 0.8% of Xanthan gum content.

High Xanthan gum content should be avoided due to material cost and workability (e.g. high viscosity leading to poor mixing) problems. The most economical and efficient concentration of Xanthan gum for soil treatment thus appears to be approximate 0.5-1%.

Table 2: Shear Strength Values with Varying Percentage of Xanthan Gum

Dosage of XanthanGum	Shear Strength Kg/cm^2	
	Uncured	Cured
X.G 0.0%	012	0.28
X.G 0.2%	0.76	1.55
X.G 0.4%	1.23	1.83
X.G 0.6%	1.46	2.42
X.G 0.8%	1.73	2.6
X.G 1.0%	2.1	2.85
X.G 1.2%	1.69	2.30
X.G 1.4%	0.76	2.06

The use of Xanthan gum for soil treatment shows viable results, reflecting that it can be used to greatly increase the compressive strength of soil as shown in figure 2.

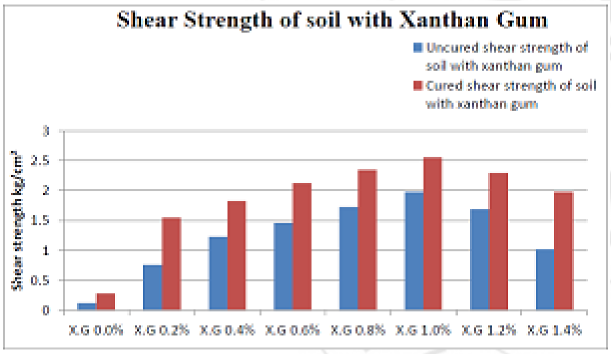
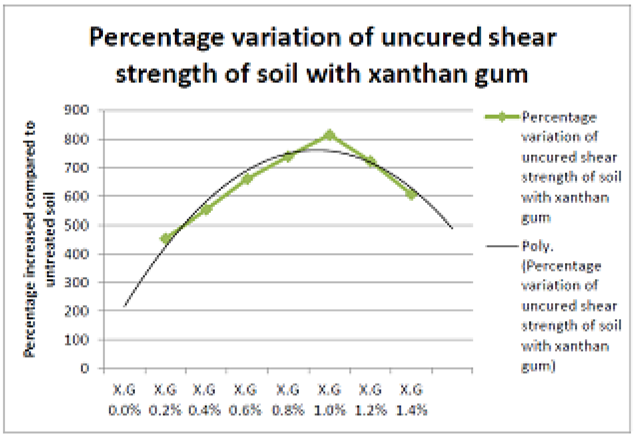


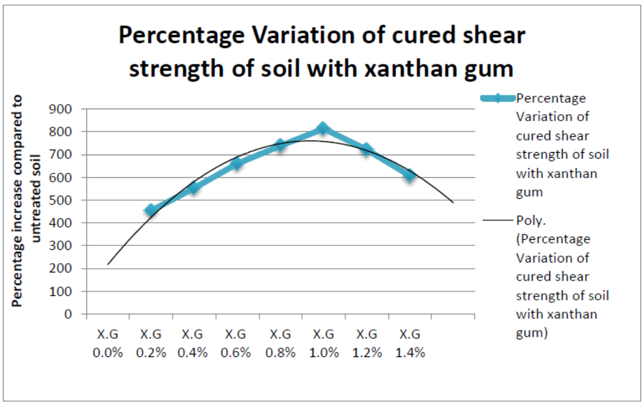
Figure 2: Shear strength of soil with Xanthan Gum

Up to increasing the 1% of Xanthan Gum, the uncured shear strength values are increases from 0.12 to 1.98 and the percentage increases is 1550 as shown in below graph.



Graph 1: percentage variation of uncured shear strength of xanthan soil.

Up to increasing the 1% of Xanthan Gum, the cured shear strength values are increases from 0.28 to 2.56 and the percentage increases is 714.29 as shown in below graph.



Graph 2: Percentage Variation of cured shear strength of xanthan soil

7. Conclusions

The use of cement for soil improvement may have many beneficial effects, but in terms of eco-friendliness cement has notable shortcomings. Accordingly, many eco-friendly methods for soil improvement have been studied.

Finally we conclude that:

- Xanthan gum is shown to have a significant strengthening effect on the treated soil. This strengthening is achieved by increasing the inter-particle relations within the soil and, thereby, increasing the cohesive forces within the soil.
- The majority of the strength of Xanthan treated fine grained soils originates from hydrogen or electrostatic bonding between Xanthan monomers and fine soil particles.
- Direct interaction between Xanthan gum and clayey soil forms firm biopolymer– soil matrices, which act as cementeous binders between particles.
- However, the soil strengthening induced by Xanthan gum treatment has other influencing factors such as the presence of ions (e.g., alkali- or alkali-earth metal ions), biopolymer rheology, soil composition and mineralogy, and so on. Further studies are thus recommended for deeper understanding of Xanthan gum soil treatment.
- The effect of soil strengthening with Xanthan gum content is shown to increase nonlinearly and level off at higher concentrations of Xanthan gum. Furthermore, high Xanthan gum content should be avoided due to material cost and workability (e.g., high viscosity leading to poor mixing) problems.
- The most economical and efficient concentration of Xanthan gum for soil treatment thus appears to be approximately 0.8–1.2%.
- With little or no adverse effects in terms of durability, as well as environmentally friendly properties, Xanthan gum can be recommended as a viable soil improvement material, especially for cases of dry soil.
- Above all, the findings from this study are expected to provide quantified, strong data for the application of

Xanthomonas campestris bacterium treated soil in the field of bio-soil implementation.

- Optimum Xanthan gum content is 1%

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