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Assessment of Kuttanad Soil Stabilized with Biopolymers

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***Abstract*: Kuttanad clay is an important soil group, well known for its low shear strength and high compressibility. The typical Kuttanad soil consists primarily of silt and clay fractions. The natural water content of the soil here is very high and close to liquid limit. Since Kuttanad is the rice bowl of Kerala, any technique adopted in this region should be eco-friendly and should never cause any harm to the soil and water. This paper discusses the stabilization of Kuttanad soil using biopolymers. To types of biopolymers were (Xanthan gum and Guar Gum) used in this study due to their availability with reasonable prices and their stable behavior. A laboratory study was conducted on Kuttanad soil treated with Xanthan Gum and Guar Gum, and variation in soil properties was analyzed. The biopolymer was added in different concentrations so as to identify an optimum dosage. From various tests it was observed that with the addition of Xanthan gum the optimum moisture content has decreased by about 7.4% and the Unconfined Compressive Strength has increased by 51.5% and with the addition of Guar Gum, the optimum moisture content has decreased by 17.6% and the Unconfined Compressive Strength has increased by 59.5%.**

***Keywords*: Kuttanad Soil, Xanthan Gum, Guar Gum, Compressive Strength**

1. Introduction

Mechanical properties of natural soil are insufficient in most of engineering applications. Therefore, soil stabilization is often employed to enhance the mechanical strength of the intact soils. In general, soil stabilization can be categorized to physical, chemical and biological approaches (Dejong et al., 2006). Among those methods, chemical stabilization is the oldest and most common method by which chemicals such as Portland cement, lime, etc. are added to the soil to improve particle interfacial bonds. But, chemical method is often prone to environmental hazards making them less desirable (Hataf et al., 2018). As an alternative, environment-friendly approaches that involve the use of biological material such as microbes and enzymes attempt to enhance the mechanical properties of soil (Taha et al., 2013). Microbial induced polymers have been introduced as a new type of construction binder, especially for soil treatment and improvement.

This paper attempts to understand and evaluate the effect of the behaviors of two biopolymers, namely Xanthan Gum and Guar Gum in terms of engineering properties to Kuttanad soil. Different concentrations of both the biopolymers were used in this study and 5 effects on compaction characteristics and compressive strength was evaluated.

2. Materials and experiments

A. Soil properties

Kuttanad denotes the low lying land, comprises of Vembanad Lake and its surrounding marshy land. The typical soil of the Kuttanad region is soft black or grey marine clay. The natural water contents are very high and even close to liquid limit. The soil is well known for its high compressibility and low shear strength. In this study, Kuttanad clay collected from Pallippad Region, Alappuzha district was used. Samples were collected from a depth of about 2m below the surface. The properties of soil were determined as per IS 2720. The properties of Kuttanad clay are given in table 1 and the grain size distribution curve is presented in Fig. 1.

Table 1
Properties of Kuttanad Soil

Property	Value
Specific gravity	2.06
Particle size range	
Clay (%)	46
Silt (%)	46.8
Sand (%)	7.2
Atterberg's limits	
Liquid limit, w_l	67
Plastic limit, w_p	54.7
Shrinkage limit, w_s	24
Plasticity index, i_p	12.3
Soil classification	Mh
Unconfined compressive strength, (kn/m^2)	59.6
Standard proctor compaction test	
Maximum dry density, (g/cc)	1.2
Optimum moisture content, (%)	32

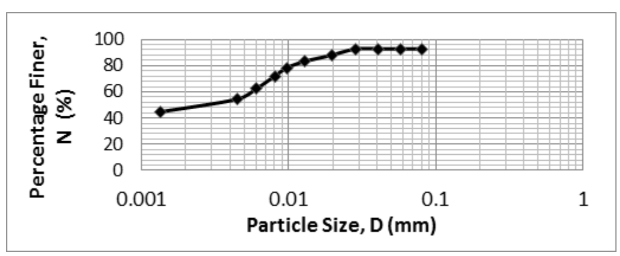

Fig. 1. Grain size distribution curve

B. Biopolymers

The biopolymers used in this study were chosen because of their availability at their reasonable prices compared to other biopolymers. Xanthan gum was procured from Kachabo Gums pvt. Ltd, Maharashtra and Guar Gum was procured from Swastik Gum Industries, Ahmedabad. Xanthan gum is a polysaccharide that is made by the Xanthomonascampestris bacterium, and is generally used as a viscosity thickener due to its hydrocolloid rheology. Xanthan gum has been introduced to geotechnical engineering to reduce the hydraulic conductivity of silty sand via pore filling as well as to increase the undrained shear strength of soil by increasing the liquid limit. Another recent study has reported possibilities for using Xanthan gum as soil strengtheners. (Ayeldeen et al., 2016). Guar gum is also a polysaccharide consisting of the galactose of sugars and mannose. The backbone in guar gum is a linear chain of β 1, 4 – linked mannose remains to which galactose residues are 1, 6 – linked at every second mannose, creating short side branches. Guar gum is more solvable than many other biopolymers and is a better stabilizer. (Ayeldeen et al., 2016)

C. Specimen preparation

The soil was oven dried for 24 h. The biopolymers used in this study were processed as powders and mixed with water to produce gels which can act as stabilizers and binders. The powder was gently added to water to avoid clumping, and then mixed until a homogenous solution was obtained. Biopolymer concentrations of 0.5, 1, 1.5 and 2% by weight were used in this study. Soil was mixed with the solution and tested for variation in properties.

D. Test procedure

A modified Proctor Compaction test as per IS 2720 part 7 was performed for determining the maximum dry density and its corresponding optimum moisture content. Unconfined compressive strength tests as per IS 2720 part 10 were performed on soil-biopolymer specimens. The specimen for the test had a diameter about 3.9cm and length of 7.5cm. As per the mentioned standard, the loading speed should be about 0.5 to 2% axial strain/min.

3. Results and discussion

A. Effect of biopolymers on compaction characteristics

Fig. 2, shows the variation of dry density for different concentrations of biopolymer contents.

In general, both gums show an increase in the compaction characteristics. With increasing gum concentrations, the maximum dry density was observed first to increase and then decreases with the biopolymers. For Xanthan gum, the optimum concentration was found as 2% with maximum dry density 1.33/cc and its corresponding optimum moisture content as 29.8%. Similarly, the optimum moisture content was observed first to decrease with increasing gum concentrations and then increases with the biopolymers For Guar gum, the optimum concentration was found as 1.5% with maximum dry density 1.36g/cc and its corresponding optimum moisture content as 27.2%.The increasing density upto optimum concentration can be explained based on the nature of the gum which reduces the friction between the particles. Beyond the optimal dosage, the biopolymer content increases the spaces between the clay particles and thereby increases the global volume of void spaces causing a reduction in dry density. Also, the high viscous nature of biopolymers disturbs the compaction mechanism, which causes the particles to shift away from each other, reduced the dry density. Therefore, higher concentrations of biopolymers produce lower densities.

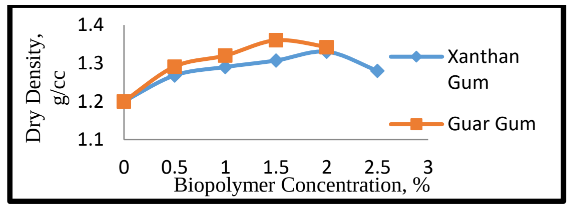

Fig. 2. Variation of dry density for different concentrations of biopolymers

B. Effect of biopolymers on compressive Strength

Fig. 3, shows the variation of compressive strength for different concentrations of biopolymer contents. The UCS value increases with increase in gum concentrations upto optimal content for both the biopolymers. This is because; the biopolymers can be directly bonded to clay particles via cation bridging and hydrogen bonding between the electrically charged fine particles which leads to higher mechanical enhancement. Beyond the optimal dosage, the UCS value decreases due to the higher viscosity, which result in lack of bonding between clay- gum- water mixtures. The maximum compressive strength for Xanthan gum was found as 90.3kN/m^2 and for Guar gum as 95.1kN/m^2.

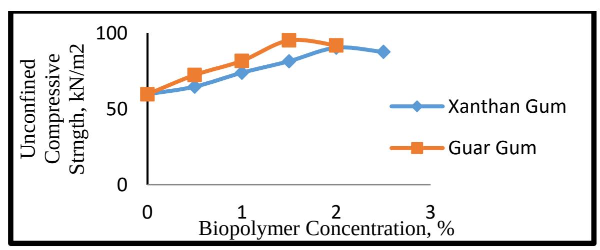

Fig. 3. Variation of compressive strength for different concentrations of biopolymers

4. Conclusion

This study investigates the effect of two biopolymers, namely Xanthan gum and Guar gum on Kuttanad soil with different concentrations. Using experimental investigations, the following conclusions can be drawn:

- Biopolymers are environmental friendly alternatives to conventional soil stabilizing agents like cement, lime etc.
- The dry unit weight increases with increasing concentrations for both Xanthan gum and Guar gum from 12kN/m^3 to about 13.6kN/m^3, while the optimum

water content reduces from 32% to 27.2% approximately.

- Mixing the soil with 2%of Xanthan gum and 1.5% of Guar gum leads to an increase in compressive strength as much as 60%.
- The dehydration of biopolymers leads to biopolymer accumulations inside the soils gaps as gel state gain more strength.
- Guar gum is more promising than Xanthan gum for increasing the dry density and compressive strength. However, higher viscosity of biopolymers can reduce the soil density, thereby, the strength also.

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