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STABILZATION OF KUTTANAD SOIL USING GUAR GUM

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Abstract: Kuttanad silt 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. These soils are low strength soft clay or silt deposits and this study focuses on the influence of sustainable biopolymers on kuttanad silt. The natural water content of the soil here is very high and close to liquid limit. This paper discusses the stabilization of Kuttanad soil using biopolymer (Guar gum). A laboratory study was conducted on Kuttanad soil treated with Guar Gum, and variation in soil properties such as unconfined compressive strength and hydraulic conductivity was analyzed. The biopolymer was added in different concentrations so as to identify an optimum dosage.

Index Terms - Kuttanad Soil, Guar Gum, Compressive Strength, hydraulic conductivity

I. 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 Guar Gum in terms of engineering properties when added to the Kuttanad soil (ML). Different concentrations of the biopolymer was used in this study and the effects on unconfined compressive strength and hydraulic conductivity was evaluated.

II. MATERIALS AND METHODS

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 silt collected from Kainakari, Alappuzha district was used. Samples were collected from a depth of about 2m below the ground surface. The properties of soil were determined as per IS 2720. The properties of Kuttanad silt are given in table 1. Figure. 1 shows the picture of the collected dry soil sample and the particle size distribution curve is presented in Fig. 2.

TABLE 1 PROPERTIES OF KUTTANAD SILT

Property	Measured value	Property	Measured value
Specific Gravity	2.2	UCC(kN/m^2)	38.8
Liquid limit (%)	22%	clay %	12
Plastic limit (%)	13.46	silt %	72
Plasticity index (%)	8.54	sand %	16
OMC (%)	33.06	Permeability cm/s	2.67*10^{-4}
MDD(g/cc)	1.34	IS Classification	ML

FIGURE 1

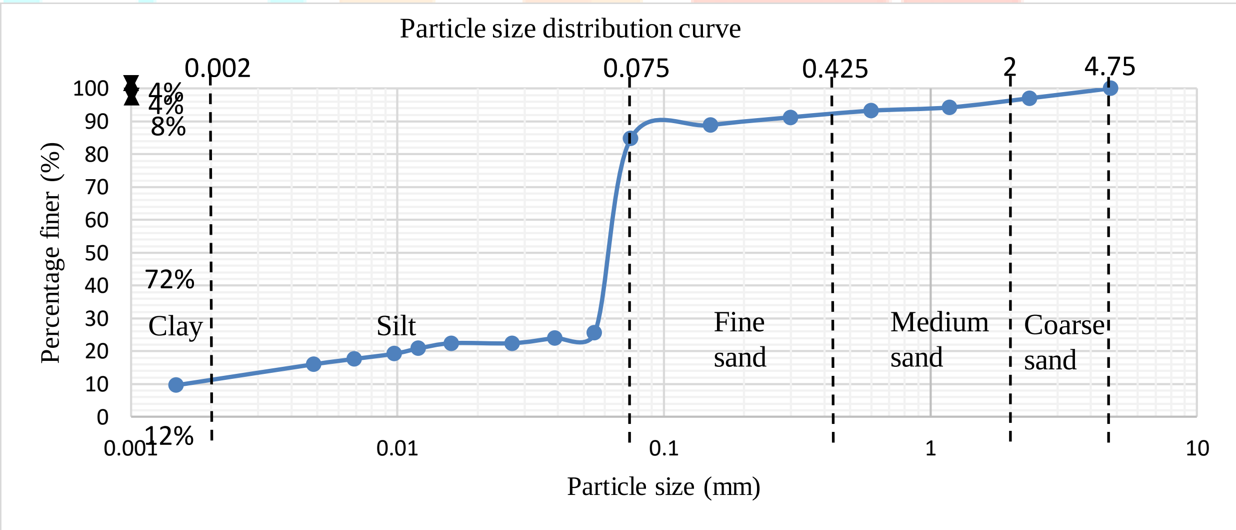

FIGURE 2

B. Biopolymers

The biopolymer used in this study was chosen because of their availability at their reasonable prices compared to other biopolymers. Guar Gum was collected from Swastik Gum Industries, Ahmedabad. Guar gum is 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). The chemical composition of Guar gum used in this study was determined using the X-Ray Fluorescence technique. The various percentages of the oxides present in the Guar gum is listed in Table 2 and Figure 3 shows the image of guar gum.

TABLE 2 VARIOUS PERCENTAGES OF THE OXIDES PRESENT IN THE GUAR GUM

Oxide	Concentration%	Oxide	Concentration%
K_2O	40.83	MgO	3.18
CaO	16.26	CuO	2.39
Fe_2O_3	10.24	Na_2O	1.78
SO_3	7.03	SiO_2	1.62
P_2O_5	5.84	Pd	1.07
PbO	4.50	ZnO	0.52
Cl	4.25	Al_2O_3	0.46

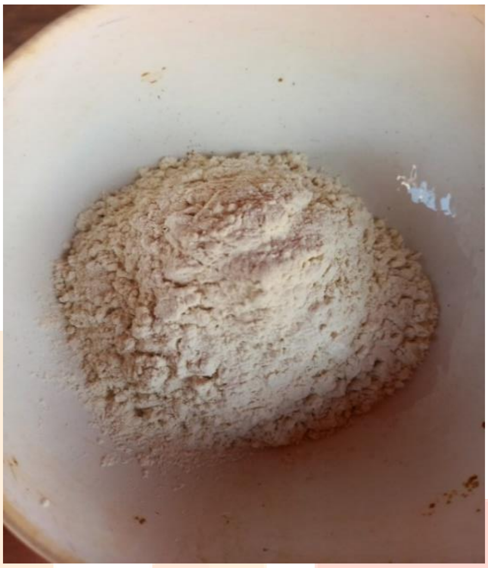

FIGURE 3

C. Specimen preparation

The soil was oven dried for 24 h. The biopolymer used in this study was 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, 2 and 2.5% by weight were used in this study. Soil was mixed with the solution and tested for variation in properties.

METHODOLOGY

The study investigates the effect of Guar gum treatment on unconfined compressive strength, and hydraulic conductivity of the soil. 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 2.5% axial strain/min.

For hydraulic conductivity, the test were done as per IS 2720 part 17. For a falling head test arrangement the specimen shall be connected through the top inlet to selected stand-pipe. The bottom outlet shall be opened and the time interval required for the water level to fall from a known initial head to a known final head as measured above the centre of the outlet shall be recorded. The stand-pipe shall be refilled with water and the test repeated till three successive observations give nearly same time interval.

Permeability k is calculated as

$$k = 2.303 \times \frac{aL}{At} \times \log_{10}\left(\frac{h1}{h2}\right)$$

III. Results and Discussion

A) Effect of Guar gum on compressive Strength

Figure 4 shows the variation of compressive strength for different concentrations of biopolymer contents. The UCS value increases with increase in Guar gum concentrations up to optimum content for the biopolymer. This is because; the biopolymer 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 silt- gum- water mixtures. Table 3 shows the variation of unconfined compressive strength according to the addition of guar gum content. The maximum compressive strength for Guar gum at 2% is 215.54kN/m^2.

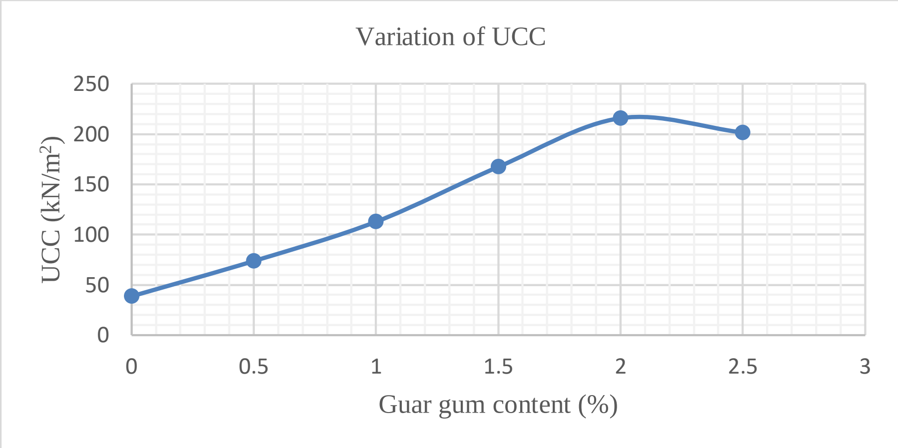

FIGURE 4

TABLE 3 VARIATION OF UNCONFINED COMPRESSIVE STRENGTH

Guar gum %	**UCS(kN/m^2)**
0	38.8
0.5	73.8
1	112.8
1.5	167.25
2	215.54
2.5	201.45

B) Effect of Guar gum on hydraulic conductivity

Figure 5 shows the variation in coefficient of permeability for different percentage of Guar gum contents. The hydraulic conductivity of soil decreases with addition of guar gum. The hydraulic conductivity of silt in this study was 2.6*10^{-4} cm/s. The results of the permeability tests shows that there is a significant decrease in the hydraulic conductivity of soil with the addition of guar gum. The biopolymer adsorbs water for the formation of hydrogels, which leads to the bio plugging of the pores and decreases the permeability. Table 4 shows the phenomenal reduction in hydraulic conductivity of the Guar gum addition ranging from 0% to 2.5% by weight of soil.

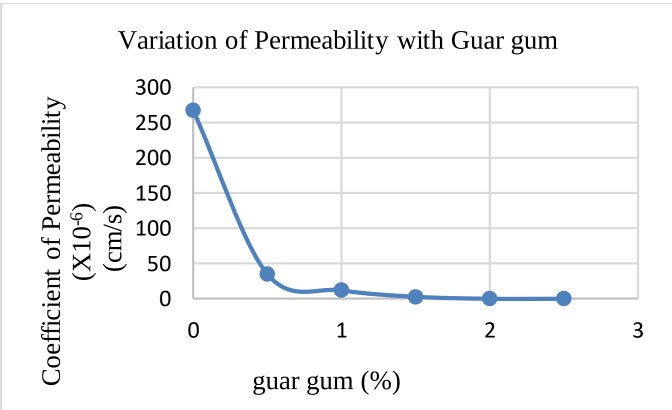

FIGURE 5

TABLE 4 REDUCTION IN HYDRAULIC CONDUCTIVITY

Guar gum in %	Coefficient of Permeability cm/s
0	$2.67*10^{-4}$
0.5	$3.51*10^{-5}$
1	$1.2*10^{-5}$
1.5	$2.89*10^{-6}$
2	$8.9*10^{-7}$
2.5	$2.6*10^{-8}$

CONCLUSION

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

1. Biopolymers are environmental friendly alternatives to conventional soil stabilizing agents like cement, lime etc.
2. Mixing the soil with 2% of Guar gum leads to an increase in compressive strength.
3. The dehydration of biopolymers leads to biopolymer accumulations inside the soils gaps as gel state gain more strength.
4. The hydraulic conductivity of the guar gum stabilized soil goes on decreasing with increase in dosage of the biopolymer.
5. Guar gum is a promising biopolymer for increasing compressive strength and decreasing the hydraulic conductivity. However, higher viscosity of biopolymers can reduce the soil density, thereby, the strength also.

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