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Effect of Xanthan Gum on Shear Strength Parameters of Laterite Soil in Konkan Region

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Abstract: *Laterite formation is noticed about 70.7% in Konkan region. When laterite soil comes in contact with water it loses its strength. Use of biopolymers instead of other chemical compounds for soil treatment will develop a sustainable geotechnical system. The current study illustrates the potential of Xanthan gum polymer stabilized laterite soil. Xanthan gum in proportion 1%, 2% and 3% by mass is used for stabilization. For DST conducted on samples, cohesion increased by 35% and angle of internal friction decreased by 20% as we varied the xanthan gum content from 0% to 3%. The significant change in shear strength properties were observed for curing period of 3 days. The direct shear test was conducted using four different normal stresses of 0.5, 1, 1.5 and 2 kgcm^2.*

Keywords: *Biopolymer, Direct shear test, Laterite Soil, Shear strength, Xanthan gum (XG)*

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I. Introduction

Konkan region is covered by Laterite and Deccan trap. Ratnagiri and Sindhudurga district in Maharashtra consists of Laterite soil. Laterite formation occupies about 70% of the Konkan Region. During excavations in laterite soil, due to the lithomargic clay, engineering problems like instability of slopes, landslides, cavity formation in tunneling, foundation settlement can occur. Due to the heavy rainfall in Konkan region, water seeps through this pores of laterite soil, which has the tendency to gush out leading to engineering problems, safety problems and delays in project. Hence laterite soils in tropical regions often require some soil improvement be performed in order to use it in various civil engineering applications, such as soil stabilization. The laterite soil behaves as a hard material during dry season but when it comes in contact with water, it loses its strength and behaves like a liquid. It is a combination of hydrated iron and aluminum oxides with some impurities. Laterite soil is formed by sedimentation action of parent rock, „Laterite" (sedimentary rock). One of the most commonly utilized stabilization techniques for laterite soils is the application of additives that chemically react with the minerals present in soil to enhance its overall strength, effective soil stabilization can consequently result in significant cost savings for a given project. Several materials like cement and cementitious materials, polymers are used for soil strengthening. But the studies showed that, CO_2emission from usage of cementitious material is harmful to the environment. Hence, to strengthen the soil in environmental friendly manner, biopolymers can be used.

Biopolymers are the polymers produced by living organisms such as algae, fungus and bacteria. Among various types of biopolymers, xanthan gum is widely used due to its good strengthening efficiency and economic feasibility based on massive commercialization. The most advantageous characteristic of Xanthan gum is its 'pseudo-plasticity'. Under static conditions, a small amount of xanthan gum induces a large increase in viscosity of any liquid. Xanthan gum displays relatively high stability over a broad range of temperature and pHs. Its anionic and hydrophilic surface characteristics react with cations and various polysaccharides resulting in gel formation stabilizes and binds the soil. Use of biopolymers instead of cementitious materials or other chemical compounds for soil treatment or improvement will develop a sustainable geotechnical system and is also an important step towards reducing the emission of harmful gases leading to global warming.

Objectives of the Study

1. To determine the index properties of Laterite soil with biopolymer.
2. To determine shear strength parameters of Laterite soil with biopolymer.
3. To suggest the suitable proportion of biopolymer in Laterite soil.

II. Materials Used For Study

Laterite Soil

Laterite soil is reddish to yellow in color with a lower content of Nitrogen, and Manganese Oxides. The word laterite has been derived from the Latin word that means brick. The laterite soil is formed under conditions of high temperature and heavy rainfall with alternate wet and dry periods, which leads to leaching of soil, leaving only oxides of iron and aluminum. In India, laterite soil is widespread, covering over 10% of the total geographical area. In Maharashtra, laterites are found only in Ratnagiri and Karnataka. For project work, Laterite soil samples were collected from Ratnagiri, in Maharashtra.

Fig. 1 Laterite soil and location of procurement

Biopolymer-XanthanGum

Xanthan gum consists of polysaccharides, which are compounds consisting of mono-saccharides linked at certain locations. They are broadly distributed in nature and serve as skeletal structure forming substances, assimilative reserve substances, and water-binding substances. With their natural behavior, polysaccharides act as thickening agents, stabilizers, sweetening, and gel-forming agents. Accordingly, most applications utilizing biopolymers are in the fields of food production, agriculture, cosmetics, medicine. It is an effective thickening agent and stabilizer to prevent ingredients from separating. It can be produced from simple sugars using a fermentation process, and derives its name from the species of bacteria used, Xanthomonas compestris.

Fig. 2 Xanthan gum biopolymer

III. Sample Preparation

There are two methods of sample Preparation, dry and wet method. The Dry method was adopted for sample preparation. In this method, required amount of soil was taken(1), optimum moisture content obtained from Standard Proctor Test and desired content of additive (XG) was mixed (2,3 & 4). The mixture was oven dried (5).

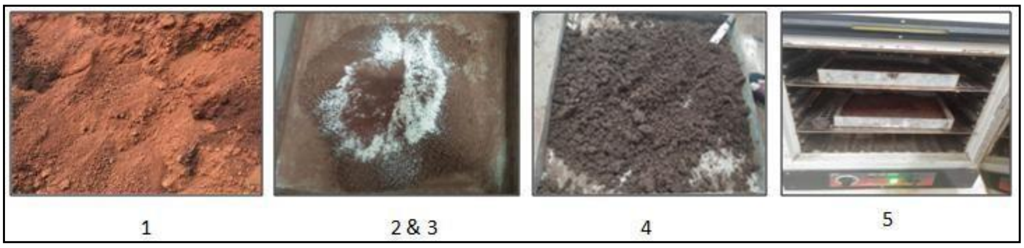

Fig. 3 Method for sample preparation

IV. Experimental Investigation

Specific gravity, Atterberg's limits and Sieve analysis are carried out as per IS 2720 (Part- II) 1964, IS 2720 (Part -V and IS 2720 (Part-IV) 1985 respectively. Direct Shear test is carried out as per IS 2720 (Part-39/sec-I) 1977 in the following manner. A direct shear testing device, as shown in figure 3 consists of fixed lower box and a moving upper shear box, has been used in this experiment. Both the shear boxes have same inside dimensions of 60 mm in length and 60 mm in width. The vertical load is applied to the laterite soil sample through a loading plate below the lower shear box. A reaction plate is placed on the soil in upper shear box. The applied shear force and horizontal displacement were recorded using proving ring and dial gauge respectively. Density of soil was kept constant. The test was conducted using four different normal stresses of 0.5, 1, 1.5 and 2 kg/cm^2. Test involved applying the normal stress and monitoring the horizontal displacement. The maximum divisions obtained during the shear process were recorded as the peak shear strength.

The shear strength is the maximum stability that a soil can offer against failure or its improper surface loading. The shear strength parameter for untreated and xanthan gum treated laterite soil in 1%, 2% & 3% proportion by the mass of soil are determined by Direct Shear Test.

Fig. 4 Direct shear test

V. Results and Discussions

Index Properties

Table 1- Observation and Calculation table for Index properties

Tests Conducted			**Without XG (0 % XG)**	**+1% XG**	**+2% XG**	**+3% XG**
Index Properties						
1	Specific Gravity		2.305	2.418	2.62	2.732
2	LL	%	62	76	81	84.8
3	PL	%	34	34	35.2	36.4

Shear Parameters

Table 2- Observation and Calculation table for Direct Shear Test conducted on Laterite soil

Normal Stress (kg/cm^2)	**Shear Stress (kg/cm^2)**
0.5	0.6041
1.0	0.9505
1.5	1.2486
2.0	1.4016

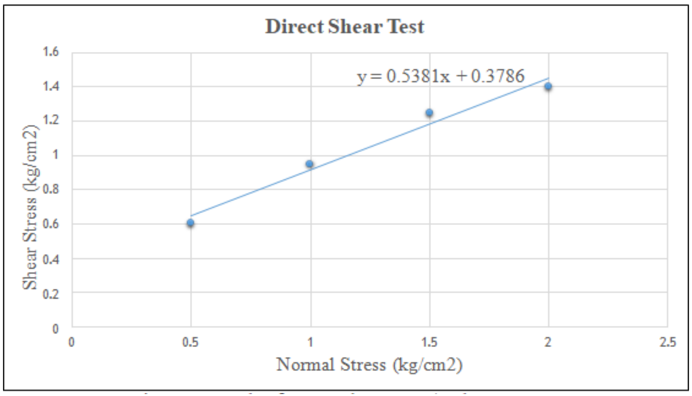

Fig. 5 Graph of Shear stress V/S Normal stress for laterite soil

Analytical Method for determination of Shear Strength Parameters Calculation of Shear Strength Parameters By Mohr-Coulomb Equation $\tau_f = C + \sigma \tan\phi$

$1.2486 = C + 1.5 \tan\phi$ .... (1)

$0.9565 = C + 1.0 \tan\phi$ .... (2)

Solving equation (1) &(2) ϕ

$= 30.29^o$

$C = 0.37 \text{ kg/cm}^2$

Table 3- Comparison of Shear Strength parameters

Shear Strength Parameters	
Analytically	**Graphically**
$\phi = 30.29^o$ $C = 0.3723 \text{ kg/cm}^2$	$\phi = 28.28^o$ $C = 0.3786 \text{ kg/cm}^2$

Table 4- Observation and calculation table for Direct Shear Strength (Laterite soil + xanthan gum)

Normal Stress (kg/cm^2)	**Shear Stress (kg/cm^2) For Soil having Xanthan Gum content-**		
	1%	**2%**	**3%**
0.5	0.636	0.700	0.684
1.0	1.015	1.047	1.063
1.5	1.248	1.321	1.224
2.0	1.442	1.490	1.409

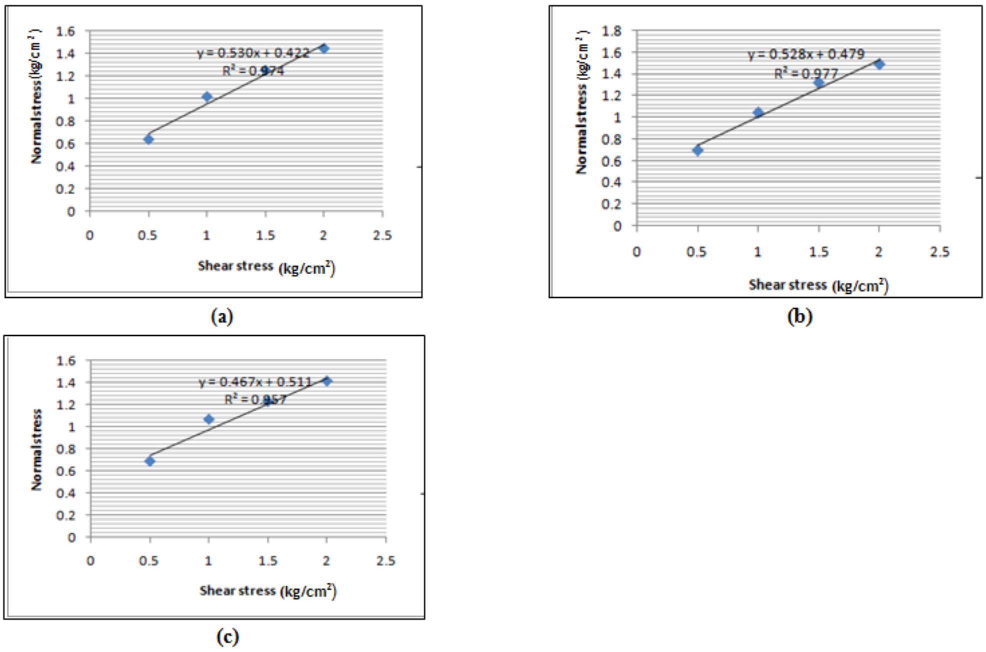

Fig.6 Normal Stress v/s Shear Stress for laterite soil + 1% (a), 2% (b) and 3% (c) XG content

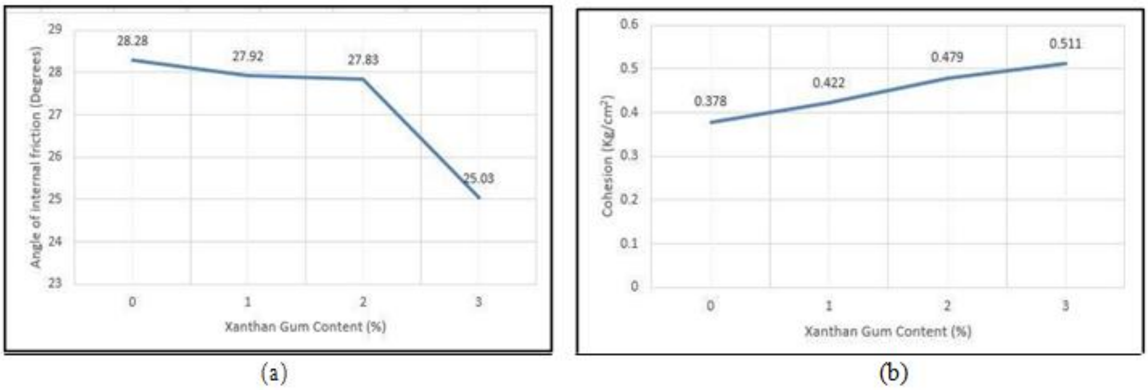

Fig.7 Comparison of Shear Strength Parameters for Various Contents of Xanthan Gum added in Laterite soil

Table 5- Observation and Calculation table for Direct Shear Test with XG content

Laterite Soil +	0% XG	1% XG	2 % XG	3 % XG
Φ (Degrees)	28.28	27.92	27.83	25.03
C (kg/cm^2)	0.378	0.422	0.479	0.511

The fig. 7 (a) and 7 (b) shows the relation between % xanthan gum and shear parameters of laterite soil samples. As shown in fig. 6(a), as xanthan gum content was varied from 0 to 3%, angle of internal friction decreased by 11.5% i.e. 28.28^o to 25.03^o, and for the same fig. 6(b) shows the increase in cohesion of laterite soil. Cohesion was increased by 35.18% i.e. 0.378 kg/cm^2 to 0.511 kg/cm^2.

From the predefined relations it was concluded that bearing capacity also increased as shear parameters improved.

VI. Conclusions

Based on the experimental work carried out in the present study the following conclusions are drawn for shear strength properties of laterite soil

1. Significant increase in index and engineering properties of laterite soil was observed as percentage of xanthan gum was increased in soil.
2. Liquid limit increased from 62% to 85% as the Xanthan Gum content was varied from 0% to 3% and slight increase in plastic limit was seen for the same.
3. From tests, it is seen that angle of internal friction was decreased by about 11.5% and cohesion was increased by 35.18% for xanthan gum content from 0% to3%.
4. The maximum improvement in shear parameters was observed for 2% to 3% of xanthan gum content, hence the most suitable proportion of xanthan gum is 3% by the mass of laterite soil.

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IS Codes

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