STUDY ON STRENGTH IMPROVEMENT OF RED EARTH USING BIOPOLYMER AND OTHER ADDITIVES

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Abstract— This paper focus on the studies conducted on red earth improved with biopolymer and other additives from a perspective of strength improvement. This may serve as an eco-friendly alternative to various other stabilization techniques in vogue. Also this study focus on amending lateritic red soil, which is the dominating soil type in Kerala. Amending indigenous soil types to obtain improved engineering properties so as to meet various requirements is expected to be a relevant study. Xanthan gum biopolymer is used for the study. For strength improvement fly ash and coir fiber are also incorporated with biopolymer. Soil is mixed with different combinations of biopolymer, fly ash and coir fiber and its density-water content relations are obtained using standard proctor test. Unconfined compressive strength test is conducted to analyse the variation in strength characteristics.

Index Terms— Lateritic red soil, biopolymer, standard proctor test, unconfined compressive strength.

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1 INTRODUCTION

Lateritic red earth soil is the predominant soil type in Kerala. This soil is mostly found in silty-clayey nature. Though the soil suffice the strength requirements for normal building construction works, it may not satisfy heavy construction works and other constructions like that of soil liners. Various methods are already being adopted for amending and stabilizing indigenous soils. In the current scenario of high demand for environmental conservation, eco-friendly methods are the most desired.

Polymers are being used in almost all the fields now. Its use in soil also have been subjected to numerous studies. Even at very small concentrations within soils, various polymers have been shown to increase water retention and reduce erosion, increase soil shear strength, and support soil structure. A wide range of polymers have been used to address problems ranging from the prevention of desertification to the reinforcement of roadbeds. Biopolymers in particular offer a more eco-friendly alternative to traditional chemical additives, such as ordinary cement, which may generate a large amount of carbon dioxide during production or cause lasting environmental damage.

Xanthan gum biopolymer is a natural polysaccharide and it is widely used in industries. It was discovered in the 1950s at the Northern Regional Research Laboratories (NRRL) of the United States Department of Agriculture. The polysaccharide B- 1459, or Xanthan gum, produced by the bacterium Xanthomonas campestris NRRL B-1459 was extensively studied because of its properties that would allow it to supplement other known natural and synthetic water-soluble gums. Xanthan gum is a hetero polysaccharide with a primary structure consisting of repeated pentasaccharide units formed by two glucose units, two mannose units, and one glucuronic acid unit, in the molar ratio 2.8:2.0:2.0. Solutions of Xanthan obtained by dissolution at moderate temperatures tend to be highly viscous even at low concentrations. The increase in the viscosity of Xanthan solution with increase in polymer concentration is strongly attributed to the intermolecular interaction or entanglement, increasing the effective macromolecule dimensions and molecular weight. The presence of salts in solution influences the Xanthan viscosity [1]. The solutions exhibit a non- Newtonian rheology.

For Xanthan gum stabilized soil, cementitious products develop in soil matrix over time and weld the soil particles together and fill the pores in the Xanthan gum– soil matrix. The UCS results of Xanthan gum treated soils show greater improvement when compared to traditional stabilization methods using lime and cement [2]. Using Xanthan gum, a reduction of at least four orders of magnitude was achieved using as little as 0.5%, highlighting its superior pore plugging effect [3].

Azzam (2013) [4] studied the microstructural modification by biopolymers on clay. The creation of nano-composites effectively decreased and absorbed the excess water within the clay sample thereby modifying the plasticity of clay. The existence of such nano-composites can significantly increase the clay stiffness and reduce the compression index. The swelling behaviours of stabilized samples were partially or totally elim-

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inated due to constructed nano-filler which acted as hydrophobic materials. The action of composite also mitigate and reduce volumetric shrinkage.

Along with biopolymers, locally available materials such as coir fibers and industrial waste products like fly ash are also suitable candidates for soil amendments. Sivakumarbabu et al. (2008) [5] discussed the improvements in engineering properties of expansive soils with incorporation of coir fiber. They conducted triaxial tests and swell index tests and established a definitive improvement in strength and ability to withstand failure. Inclusion of coir fibers also helped reduce swell properties and compression index values.

2 MATERIALS AND METHODS

Materials

Lateritic red earth for the study was collected from Cochin university campus. The collected soil was air dried and preserved. The basic engineering properties of soil is given in Table 1.

TABLE 1
GEOTECHNICAL PROPERTIES OF UNTREATED RED SOIL

Property	Value
Specific gravity	2.54
Liquid limit	0.6
Plastic limit	0.28
Maximum dry density	1.87g/cc
Optimum moisture content	0.14
Unconfined compressive strength	260 kPa

The biopolymer used, Xanthan gum was obtained from Bangalore. Coir fiber used for study was collected from Kerala Coir Corporation. Flyash was collected from Hindustan Newsprint Ltd., Piravam.

Methods

Tests were according to Indian standard codes to obtain density water content relations and unconfined compressive strengths.

Standard proctor test (IS 2720 PART VII : 1980)

To determine the dry density and moisture content relation of soil and to find OMC and MDD from the relationship, standard proctor test is done. By standard proctor test relationship between the moisture content and density of soils compacted in a mould of a given size with a 2.5 kg rammer dropped from a height of 30 cm is obtained. Proctor mould having a capacity of 944 cc with an internal diameter of 10.2 cm and a height of 11.6 cm is used. Compaction process helps in increasing the bulk density by driving out the air from the voids. The theory used in the experiment is that for any compactive effort, the dry density depends upon the moisture content in the soil. The maximum dry density (MDD) is achieved when the soil is compacted at relatively high moisture content and almost all the air is driven out, this moisture content is called optimum moisture content (OMC).After the OMC value the dry density decreases with further increase in water content. After plotting the data from the experiment with water content as the abscissa and dry unit weight as the ordinate, OMC and MDD can be obtained.

Unconfined Compressive Strength Test (IS 2720 PART X: 1991)

The unconfined compressive strength (qu) is defined as the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple axial compression test. The corrected cross-sectional area was calculated by dividing the area by (1- ε) and then the compressive stress for each step was calculated by dividing the load with the corrected area. Stress-strain curve is plotted and the maximum value of the axial stress gives the unconfined compressive strength (qu). Axial strain also computed for maximum unconfined compressive strength.

UCC tests were done to determine strength characteristics of untreated sample, sample treated with Xanthan gum, samples treated with fly ash and Xanthan gum and samples treated with coir fiber and Xanthan gum. The samples were prepared at optimum moisture content and at 95% of maximum dry density.

3 RESULTS AND DISCUSSIONS

Compaction characteristics

Standard proctor test were conducted on untreated sample and on samples treated with varying percentages of Xanthan gum by weight (0.5%,1%,1.5%,2%). After obtaining optimum percentage of fly ash and coir fiber to be added with Xanthan gum from unconfined compressive strength test, compaction test was done with those combinations also.

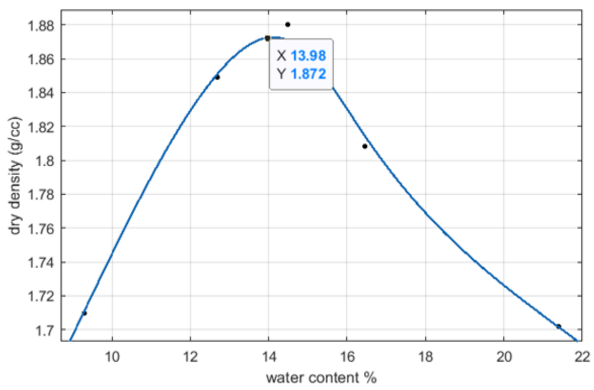

Fig. 1. Compaction curve for untreated sample.

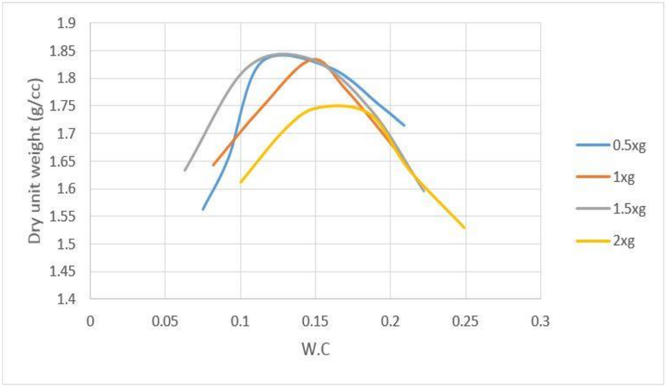

Fig. 2. Compaction curve for Xanthan gum treated sample

TABLE 2
MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE CONTENT FOR SOIL MIXED WITH DIFFERENT PERCENTAGES OF XANTHAN GUM

COMBINATION	MDD (g/cc)	OMC (%)
SOIL + 0.5% XG	1.829	15.9
SOIL + 1% XG	1.83	15
SOIL + 1.5% XG	1.83	14.7
SOIL + 2% XG	1.72	15.2

Soil mixed with 0.5%, 1% and 1.5% biopolymer showed similar range of maximum dry density as well as optimum moisture content. With further addition of biopolymer, the maximum dry density was found to decrease.

Since Xanthan gum polymer has highly viscous property, with addition of increased polymer content the Xanthan molecules adsorbs water and forms highly viscous suspension in between the soil particles. This will lead to increase in volume of soil sample, resulting in eventual reduction of dry unit weight.

Unconfined compressive strength characteristics

UCS tests were performed on untreated soil specimens and biopolymer treated soils. In order to improve strength fly ash and coir fiber were added along with Xanthan gum and tested after 24 hrs. Each combination of soil and additives were tested three times and average value is taken as the final strength. Optimum strength results were obtained by comparing the graphs obtained from UCC tests of different combinations of Xanthan gum and other additives.

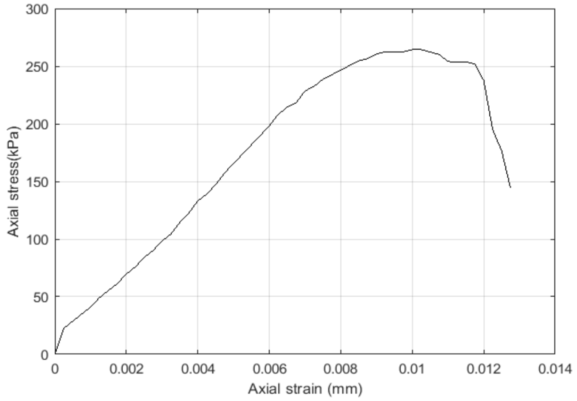

Fig. 3. UCC curve for untreated sample

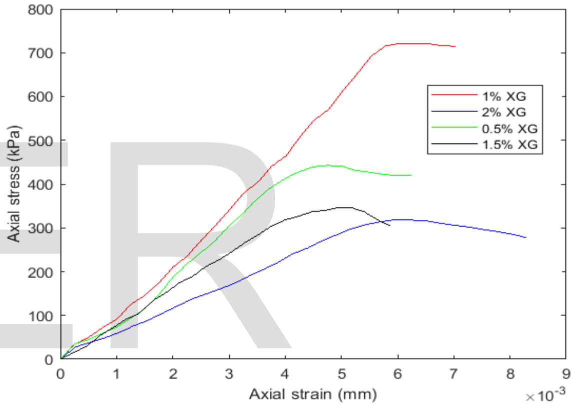

Fig. 4. UCC curve for soil treated with varying percentages of Xanthan gum

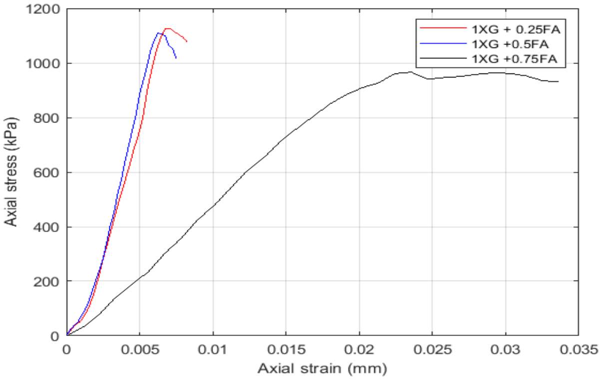

Fig. 5. UCC curve for soil treated with 1% Xanthan gum and different percentages of fly ash

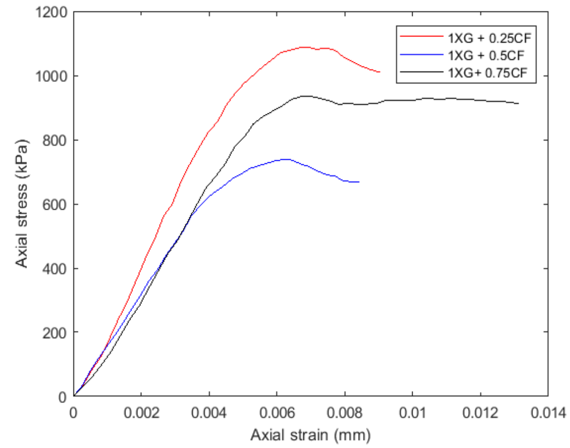

Fig. 6. UCC curve for soil treated with 1% Xanthan gum and different percentages of coir fiber

TABLE 3
UNCONFINED COMPRESSIVE STRENGTH OF SOIL SAMPLES TREATED WITH DIFFERENT ADDITIVES.

Samples	Unconfined compressive strength
Untreated sample	260 kPa
Soil +0.5XG	442.3 kPa
Soil +1XG	721.1 kPa
Soil +1.5XG	346.2 kPa
Soil +2XG	317.9 kPa
Soil +1XG +0.25 CF	1088 kPa
Soil +1XG + 0.5CF	738.1 kPa
Soil +1XG +0.75CF	935.2 kPa
Soil +1 XG +0.25FA	1465 kPa
Soil +1XG+0.5FA	1308 kPa
Soil +1XG +0.75FA	1133 kPa

Different percentages of biopolymer is added to soil samples and unconfined compressive strength was obtained after 24 hrs of curing. 1% Xanthan gum addition shows maximum value of UCS, 721.1 kpa which is 177% more than the value obtained for untreated soil. With increase in biopolymer content, the strength seemed to be decreasing. Biopolymer has pseudo plastic characteristics and they form highly viscous suspension even at low water content. With increase in polymer content the viscous effect increases and this may lead to decreased strength.

1% Xanthan gum is mixed with different percentages of fly ash and tested. Samples added with 0.25% and 0.5% fly ash showed similar strength while sample added with 0.75% fly ash gave decreased strength. The slope of the curve obtained (stress vs. strain) is steeper for 0.25 and 0.5% fly ash, indicating higher E value. The curve for 0.75% fly ash addition shows lesser slope with lesser E value. As optimum value, 1% Xanthan gum with 0.25 % fly ash is selected. The strength was nearly 4.5 times that of untreated soil for 0.25% fly ash added with 1% biopolymer. This improvement in strength may be attributed to the enhancement of soil matrix formation by the fine particles of soil and biopolymer. Presence of fly ash in small quantities is making the soil more brittle even though strength is improved. With 0.75% addition of fly ash, the soil becomes more workable.

Different percentages of coir fiber is added with 1% Xanthan gum to the soil and tested. 0.25% coir fiber addition gave maximum value and it seems to be decreasing with increase in percentage of coir fiber. From the literatures it is known that biopolymers act well with fine grained soils and with the addition of fibers strength characteristics might have affected. Fibers may affect the close matrix formation in soil or the close bonding of soil particles with biopolymer may occur immediately around fibers. This will result in non-uniform strength distribution in soil since the percentage of coir fiber added is less, and thereby reduction in strength.

4 CONCLUSION

- The compaction test shows a decreasing maximum dry density with increased biopolymer content. This effect may be attributed to efficient interaction of biopolymer with fine grains in soil. With increased biopolymer content, the soil matrix will have more dispersed arrangement due to increased viscosity and water absorption by polymer. This results in to slightly decreasing maximum dry density
- Addition of biopolymer to the soil shows improvement in strength initially, reaching up to 177% of UCS for untreated soil. A reduction in strength is observed with increased polymer content. Highly viscous property of biopolymer makes the soil plastic and workable but affects strength. 1% Xanthan gum addition is selected as optimum.
- When additives are added along with selected optimum dosage, strength is found to be increasing. Both fly ash and coir fiber gives increased strength results. The strength of treated soil seems to be increased by more than 4.5 times with incorporation of other additives.

REFERENCES

[1] Garcia-Ochoa F., Santos V.E., Casas J.A., Gomez E. (2000), "Xanthan gum: production, recovery, and properties", Biotechnology Advances 18- Science direct, P. 549-579.

[2] Latifi N, Horpibulsuk S., Christopher L. M., Muhd.Zaimi Abd Majid, and Ahmad Safuan A. Rashid5 (2016), "Xanthan gum biopolymer: an eco-friendly additive for stabilization of tropical organic peat", Environ Earth Sci - Crossmark (2016) 75:825.

[3] Bouazza A., Gates W.P. And Ranjith P. G. (2009) , "Hydraulic Conductivity Of Biopolymer-Treated Silty Sand", Department Of Civil Engineering, Monash University, Melbourne, Australia, Geotech-

nique 59, No. 1, 71–72.

[4] Azzam W.R (2014),” Behavior of modified clay microstructure using polymer nanocomposites technique”, Alexandria Engineering Journal, P.143-150.

[5] Sivakumar Babu G. L. , VasudevanA. K. & Sayida M. K. (2008), “Use of Coir Fibers for Improving the Engineering Properties of Expansive Soils”,Journal of Natural Fibers,5:1, 61-75