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Review Paper on Assessment of Geotechnical Properties of Biopolymer Based Soil.

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Abstract - *Improvement of soil using biopolymers has attracted significant interest in current years. The use of conventional improvement methods like cement, lime, etc. has a potential impact on the environment. In recent days, attempts are made to contribute to sustainable developmentin geotechnical engineering. One such method is stabilization using biopolymer. The present paper aims to provide an overview of the assessment of biopolymers-treated soil as a binder in soil improvement, and the properties of soil treated with biopolymers. To assess the geotechnical properties of biopolymer-based soil, the treated soil needs to be subjected to different types of tests to evaluate its characteristics and its performance.*

***Key Words*: Biopolymer, Sustainable, Stabilization,Geotechnical properties.**

1. INTRODUCTION

The clayey and silty soil possess problematic properties such as Swelling and Shrinkage in case of clayey soil and low strength, low durability and high compressibility of silty soils. Hence arises the need for soil improvement.

Soil improvement is a process of altering or enhancing the geotechnical properties of soil to achieve desired engineering properties.

Main purpose of soil stabilization is to increase Bearing capacity, Shear strength and overall performance of in-situ soil. Recently, geotechnical engineers have attempted to develop biological soil treatment and ground improvement methods to alleviate environmental concerns related to high CO2 emitting cement in geotechnical engineering Practices.

Among the sustainable approaches for soil treatment and ground improvement, **Biopolymer-based soil treatment** has shown sufficient enhancement of geotechnical engineering properties of soil and successful field-scale implementation .

Biopolymers are derived from natural resources including polysaccharides such as cellulose, proteinssuch as gelatin, casein etc., and from microbial activities e.g., Xanthan gum, Gellan gum. The soil treated with these Bio-polymers are referred as Bio-polymer based soil.

By mixing several proportions of Bio-polymer to the soil, the physical properties of soil samples are studied by conducting Sieve analysis, Specific gravity, Atterberg limits, compaction test, Unconfined Compressive Strength test & Durability test accordingto IS 4332 Part 4 2010.

2. LITERATURE REVIEW

The extensive literature review was carried out by referring standard journals, reference books and conference proceedings. The major work carried out by the different researchers is summarized below.

1. Biopolymer soil stabilization as protection from slope erosion and shallow sliding (2022) Josif Josifovski, Aleksandra Nikolovska Atanasovska

The aim of the presented study was to investigate the effects of the xanthan gum as a compound and to develop an original biopolymer solution which will be later tested. The testing methodology was organized in two phases: laboratory tests on natural and biopolymer treated soil in the first phase, and experimental testing of biopolymer treated slope in the second phase. In the first phase, the classification and strength parameters of treated and untreated soil were determined through standard laboratory tests. The tests were performed on specimens with various percentages of the xanthan gum additive, moreover, specimens were tested on days 1, 7, and 14 to examine the curing effects. From the results, it was observed that Xanthan gum has significantly increased the strength of the soil, up to 50% after the 14 days of curing time.

2. Potential Of Natural Bio-polymers in Stabilization of Soil (2019) Ashwin Balaji p,

Ananthan S, Bharath kumar P,

Ms.M.Padmpriya

This investigation involved the stabilization of natural biopolymer in stabilization of a clayey soil. The experimental investigation involved the determination of the strength and bearing capacity of biopolymer stabilized soil. Basedon the results of the following can be concluded. Stabilization of the Clayey Soil using Natural biopolymer resulted in an increase strength in the soil. The optimal dosage of biopolymers for maximum strength came out to be 0.5% for both Xanthan gum and Guar gum. Guar gum performed 70% more better when compared to Xanthan gum in the stabilized soil. The Strength of the stabilized soil after7 days curing increases to 50% when 0.5% Guar gum is added. The bearing capacity ofthe soil may initially reduce for Xanthangum but increase for Guar gum.

3. Biopolymers as a sustainable solution for theenhancement of soil mechanical properties (2020) Antonio Soldo,Marta Miletic,Maria L.Auad

The main objectives of this research were to develop an eco-friendly, biopolymer-based soil improvement technique and to experimentally investigate the biopolymer effect on the soil mechanical properties. In order to achieve these objectives, five different biopolymer types (XG, BG, GG, CHI, and ALG), three different biopolymer concentrations (1%, 2%, and 4%), and several different curing times were investigated. Four mechanical strength tests were performed: UC, ST, DS, and UU tests.

4. Application of Biopolymers on Geotechnical Engineering And the strengthening Mechanisms between Typical Biopolymers and soils(2020) Jungyeon Jang

Xanthan gum-treated sand improves its cohesion and friction angle at initial and dry condition, whereas the use of xanthan gum to sand at the re-submerged condition decreases the shear strength parameter. Gellant gum-treated soil depends on the amount of clay in sand-clay mixtures. The formation of gellant gum-pure clay mixtures significantly increases their cohesion.

Proper mixing of coarse particles, clay particles, and gellan gum is thus expected to enhance the optimal strengthening effects because of the combination of increased connection effect between soil particles and gellan gum. Because of the long molecule structure of agar, more agar in clayey soils improves unconfined compressive strength. Even with a slight increase in the flow rate of PAM, we need to find the optimal flow rate of polyacrylamide because of the significant flushing effect on soils contaminated by oil. Guar gum is better able to increase the unconfined compressive strength and cohesion in biopolymertreated silt than other biopolymers such as modified starch and xanthan gum.

5. Biopolymers as Green Binders for soil Improvement in Geotechnical Applications (2021) Hadi Fatehi, Dominic E.L Ong, Jimmy Yu, Ilhan Chang

Adding biopolymer to act as a binder into the host soils is one of the most effective applications for soil treatment. In this study, a technical review has been conducted on the role of biopolymers in soil improvement and how they change the geotechnical properties of soils. Important points of the geotechnical characteristics ofbiopolymer-treated soils are as follows: The unconfined compressive test is usually considered the most common test method to evaluate the behavior of biopolymer- treated soils. The general conclusion is that biopolymers increase the UCS values; however, the UCS improvement could be variable depending on the biopolymer and the soil testing conditions. Xanthan-treatedsand achieved a compressive strength that was comparable to cement.

6. Application of Sustainable lignin stabilized Expansive soils in Highway Subgrade (2021) Debojit Sarker, Omar Shahrear Apu, Narendra Kumar, Jay X.Wang, Joann G.Lynam

A by-product of the paper and wood industries, lignin is produced abundantly worldwide due to the increasing demand for wood and paper-based products. Improper disposal or storage of lignin is not only a

misuse of natural resources but also poses a critical hazard to public health and the environment. Construction of highway subgrade has been identified as one of the feasible responses for consuming vast quantities of lignin to dispose of it in an ecologically sound manner, as it can be a low-cost and less energy-intensive chemical additive for soil stabilization. However, studies on the performance of lignin in stabilizing expansive soils in highway subgrade have been very constrained. Volume change resulting from seasonal moisture variations in expansive soil subgrades damages existing highways and complicates highway construction in expansive soil areas. To reduce expansive soil-induced geological disasters and utilize waste resources, the use of lignin could potentially be a sustainable solution for soil stabilization. In this research, a series of multi-scale laboratory tests were conducted to examine the Atterberg limits, the compaction and consolidation behavior, andthe Fourier-transform infrared spectroscopy (FTIR) characteristics of lignin-stabilized expansive soils.

7. Geotechnical properties and microstructure of lignin-treated silty clay in seasonally frozen regions (2021) Fu Zhu, Jiayu Li, Weizhi Dong, Shuang Zhang

Freeze–thaw weathering is critical to road engineering in seasonally frozen regions. To solve the adverse efects of inorganic stabilization materials on the environment, the lignin of the original polymer compound is used to improve the durability of silty clay. Lignin content, curing duration, and freeze-thawing were determined to have a significant influence on the geotechnical properties and microstructure of lignin-treated silty clay. An increase in lignin content resulted not only in an increase in the optimum moisture content, pH, and water absorptionof the soils, but also a decrease in the maximum dry density, plasticity index, specific gravity, thermal conductivity, and swelling capacity. In contrast, an increase in lignin content led to an initial increase followed by a decrease in the liquid limit, plastic limit, and California bearing ratio of the soils. After freeze-thawing, the thermal conductivity and California bearing ratio of lignin-treated silty clay decreased, whereas the swelling capacity and water absorption increased. The optimum lignin content for silty clay in the Jilin Province of China is approximately 4%.

8. Ligno-aliphatic complexes in soils revealed by an isolation procedure: implication for lignin fate (2013) Matthieu Thevenot,Marie-France Dignae, Mercedes Mendez- Millan, Haithem Bahri, Christine Hatte, Gerard Bardoux, Cornelia Rumped

For the last decades, the fate of lignin's in soil was analyzed mainly with cupric oxide (CuO) oxidation, which is traditionally used to quantify soil lignin content and characterize its state of degradation. This method presents limitations due to incomplete depolymerization of the lignin structure. In this study, we used a physicochemical soil lignin isolation procedure, which permits recovery of a milled wall enzymatic lignin (MWEL) fraction. The 13C natural abundance of isolated MWEL showed fasterincorporation of MWEL (17.4 % of renewed lignin's after 9 years) compared to total soil organic matter (9 % of total soil organic carbon (SOC) was renewed). This faster incorporation rate of MWEL compared to bulk soil organic matter is in agreement with lignin turnover observed by CuO oxidation. Radiocarbon dating of MWEL suggested a mean age of around 50 years. We conclude that lignin isolation allows (1) access to a different fraction compared to CuO oxidation and (2) a detailedcharacterization of lignin transformation in soil. We suggest that interaction with aliphatic compounds could be one possible pathway of lignin preservation in soil.

9. Durability and strength degradation of Xanthan gum based biopolymer treated soil subjected to severe weathering cycle (2022) Minhyeong Lee, Yeong-Man Kwon,Dong-Yeup Park, Ilhan Chang, Gye- Chun Cho

Biopolymer-based soil treatments have shown effectiveness in soil improvement, with successful field-scale implementation. In this study, we explored the effect of cyclic wetting–drying (W–D) and freezing– thawing (F–T) on the strength durability of biopolymer-treated soils. The results indicate that cyclic W–D and F–T gradually degrade soil strength owing to water adsorption and local biopolymer dilution. Poorly graded sand was highly vulnerable to these weathering effects; however, this problem was mitigated when the soil contained a fines content of 15–25%. These biopolymer-treated soils effectively resisted numerous cycles of both W–D andF–T, indicating that biopolymer-treated soils are suitable for earthen slope reinforcement.

10. Splitting tensile strength and microstructure of Xanthan gum-treated loess(2022) Tong Jiang, Jin-di Zhao, Jun-ran Zhang

The effect of different initial dry densities and xanthan gum (XG) contents on the microstructure and mechanical behavior of XG-treated loess was studied with a series of microscopic tests and splitting tensile tests based on the particle image velocimetry technique. The results show that the XG became concentrated and agglomerated during dehydration, forming bridge links between soil particles and covering their surfaces. The XG-treated loess had a significant concentration of micropores and mesopores, with greater peak pore size distribution values than untreated loess Splitting tensile tests were carried out on XG-treated loess with different XG contents and initial dry densities using a measurement technique based on particle image velocimetry. The microstructure of the specimens was qualitatively and quantitatively analyzed by scanning electron microscopy and mercury intrusion porosimetry.

11. Sustainable biopolymer soil stabilization in saline rich, arid conditions(2022) Samuel Armistead , Colin C. Smith, Sarah Stan land

In this study, the effect of salinity/aridity on biopolymer stabilized soil properties has been investigated through the micro and macro-scales, utilizing MEBAS-MBC-GV methodology optimized in our previous study42. Discussion of the experimental design for the MEBAS-MBC-GV pipeline, as well as alignment of trends through the pipeline and potential avenues of exploration, can be found within Armistead et al.42. Fe2O3 (abbreviated to Fe in sample names and henceforth in the text) was selected as the mineral of focus, due to its universal and consistent abundance in MT, and the relative activity of iron minerals within fresh MT material42. Furthermore, surprisingly, little research has focused on utilizing abundant Fe minerals for soil stabilization mechanisms. Therefore micro-scale MEBAS-MBC experiments have been used to investigate biopolymer affinities under different conditions.

12. Natural Fibers: An Alternative for the Reinforcement of Expansive soil(2022) Carlos J.Media-Martinez, Sergio A.Zamora-Castro

The reinforcement of soils is the technique that geotechnical engineers currently use to improve the shear strength and bearing capacity parameters, especially when the land available for the execution of a project is not able to withstand the structural loads to which it is subjected. One of the techniques, used for this purpose since ancient times, is the incorporation of fibers into the soil matrix; however, great interest in its study has only begun in the last two, mainly because it constitutes a low-cost and environmentally friendly alternative. In this paper, a brief bibliographic review is presented on seven of the natural fibers that are currently used in order to improve the mechanical behavior of expansive clay soils (bamboo, jute, coco, palm, sugar cane bagasse, rise husk, and sawdust). It can be concluded that in many cases, the addition of certain amounts of natural fibers increases the parameters of resistance to the cutting of soils.

13. Improvement of problematic soils with Biopolymer(2016) Nima Latifi, Suksun Horpibulsuk

Problematic soils with high compressibility and low shear strength are often treated with traditional chemical stabilizing additives such as cement and lime to improve their engineering properties. These additives are generally recognized as having less than ideal environmental impacts—in particular, the high quantity of greenhouse gases that are generally created during their production. With an increasing focus on the use of more environmentally friendly and sustainable materials in the built and natural environments, alternative eco-friendly additives to traditional chemical stabilizers have the potential to significantly change the field of soil improvement worldwide. The current study illustrates the viability of xanthan gum as an environmentally friendly stabilizer that can improve the engineering properties of both low- and high-swelling clays. Experimentalmechanical tests were performed on both untreated and xanthan gum–stabilized montmorillonite and kaolinite clays at various curing times, including unconfined compression strength (UCS) tests, direct shear tests, and one-dimensional (1D) consolidation tests.

14. Use of polymers and biopolymers for water retaining and soil stabilization in arid and semiarid regions (2010)A.Maghchiche, A.Haouam, B.Immirzi

The use of polymers as a soil-stabilizer additive has expanded significantly in agricultural use to control soil degradation and desertification and also to improve arid and semi arid soils. This research was conducted to determine the effects of different synthetic polymers and biopolymers at low concentration (0.03 % - 1%) at arid and semi arid soil of North Africa. Polystyrene, Polyacrylamide; Cellulose and the mixture of Polyacrylamide with other polymers were characterized by viscosity, infrared spectroscopy, X-ray Diffractometry, thermal analysis (TG and DSC) and Scanning electron micrographs (SEM). The results showed that the polymer composites (10 mg /L Polyacrylamide and 0.5g / L Cellulose) in soil could improve better soil physical properties and augment 60 % water retention at arid soils compared with application of any other polymer at the same concentration.

15. Surficial Soil Stabilization against Water-Induced Erosion Using Polymer-Modified Microbially Induced Carbonate Precipitation (2020) Xiangrong Wang, Junliang Tao, Ruotian Bao, Tri Tran, Stacey Tucker-Kulesza

Microbially induced carbonate precipitation (MICP)–based bio mediated soil improvement methods have been extensively studied recently due to their versatility, potential environmental sustainability, and potential low cost. However, an efficient MICP-based treatment method specifically designed for surficial soil stabilization against water-induced erosion is still urgently needed. This paper presents a preliminary experimental study on the application of a new polymer-modified MICP treatment for surficial soil stabilization to mitigate water-induced erosion. In the proposed method, the cementation solution for MICP is prepared in a water solution of polyvinyl alcohol (PVA) instead of water alone. The proposed method is then applied for bench-scale surficial stabilization of Ottawa sand. The performance of the surficial treatment is demonstrated by flume erosion tests, and the erodibility of the treated sand is evaluated more precisely using an erosion function apparatus (EFA)

METHODOLOGY

The main objective to develop a simplified methodology which can be used in an each stage of the collection and preparation of materials. The methodology is based on characteristics of Materials, Geotechnical Investigations and preparation of UCC samples with different curing .

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FLOW CHART OF DURABILITY TEST

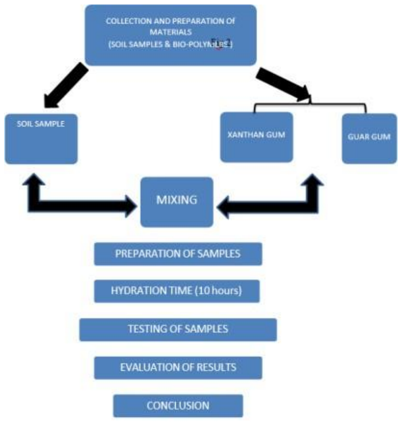


Fig. no - 1

RESULTS AND DISCUSSION

INDEX PROPERTIE

SPECIFIC GRAVITY TEST

- **SILT SOIL**

The silt soil which is used for treatment was brought from a site Nagarbhavi, Bengaluru, Karnataka. Whose natural moisture content was found to be 8.8% and the Specific gravity ofthe soil is 2.5.

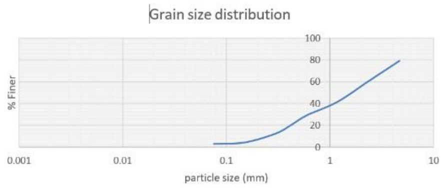
- **CLAY SOIL**

The clay soil was brought from Kalaburgi a district of Karnataka, whose natural moisture content was 2.68% and the Specific gravity of the same is 2.6.

GRAIN SIZE DISTRIBUTION

- **SILT SOIL**

The soil is taken such that it is poorly graded, the sieve analysis test shows that the Co- efficient of uniformity is 7.4 and Co-efficient of curvature is 0.9, which is represented by thegraph below,



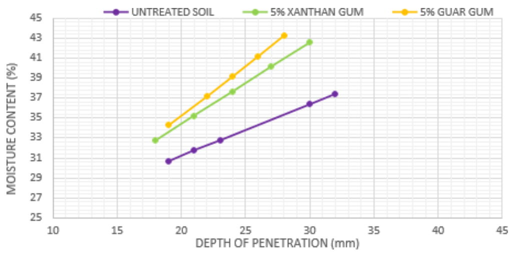
The poorly graded silt soil is more prone to soil liquefaction which can be overcame by adding Bio-polymers, since the bio-polymers impart cohesion between the soil particle making them less susceptible to soil liquefaction.

ATTERBERG'S LIMITS

SILT SOIL

LIQUID LIMIT (LL) LL was determined byusing Cone penetration test (IS 2720 Part 5).The value of moisture content corresponding to 20 mm of penetration is considered as the liquid limit. The liquid limit of the natural silt soil was found to be 31.3%.

As shown in Fig No- 3, Upon the addition ofsmall amounts of bio-polymer there was no significant variation in the liquid limit until the dosage reached 5%, addition of 5% of Xanthan gum by weight to the soil increased the liquid limit to 34.5%, and in case of Guar gum addition of 5% led to a increase in liquid limit to 35.3%, this increase in the Liquid limit was an effect of bio-polymers efficiency to absorb more water since they are Hydrophilic in nature.



SAMPLE	LIQUID LIMIT
UNTREATED SILT SOIL	31.3 %
SILT SOIL TREATED WITH 5% XANTHAN GUM	34.5 %
SILT SOIL TREATED WITH 5% GUAR GUM	35.3 %

PLASTIC LIMIT (PL)

Plastic limit is the moisture content at which the thread of soil just crumbles when it is rolled to a diameter of 3mm. It was found that

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the plastic limit is 15.3 % for the untreated soil, and in caseof the Biopolymer treated soil the PL were found increasing similar to the liquid limit test, whichare plotted below

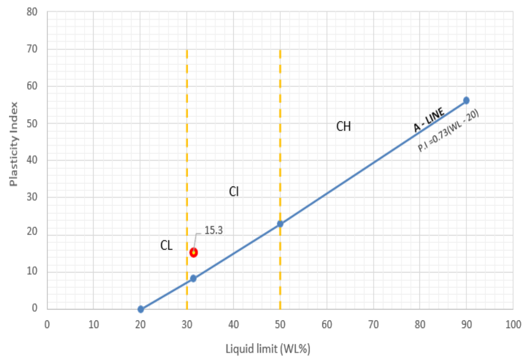

Fig. No.- 4

By observing the graph (Fig. No-3) it is concluded that the soil is a Clay of intermediate plasticity. The plasticity index is the size of the range of water contents where the soil exhibits plastic properties. The PI is the difference between the liquid limit and the plastic limit (PI = LL-PL). The plasticity index of untreated soil is 16.

The plastic limit of soil treated with 5% of Xanthan gum and Guar gum are 38.3 % and 45.6 % respectively, here the substantial increase in the plastic limit is due to the water absorbed by the biopolymer for the hydration which is necessary for the enhancement of the cohesion between soil particles. The plasticity index of biopolymer treated soil is considered as zero because the high plastic limit in comparison with liquid limit.

CLAY SOIL

LIQUID LIMIT (LL)

The liquid limit is determined by using Cone penetration test, the value of moisture content corresponding to a depth of penetration of 20 mm is considered as the liquid limit. The value of liquid limit for untreated / natural clay soil is 85.5 %, when treated with small amount of Xanthan gum there wasno significant changes in the liquid limit until the dosage crosses 4% and abovehence for optimum results 5% of Bio- polymers are added to the soil. When 5%of xanthan gum is added the liquid limit rises to 86.7% and when treated with 5% of Guar

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gum LL reached 87.8%

SAMPLE	LIQUID LIMIT
UNTREATED	85.5 %
TREATED WITH 5% XANTHAN GUM	86.7 %
TREATED WITH 5% GUAR GUM	87.8 %

PLASTIC LIMIT (PL)

Plastic limit of the untreated clay was found tobe 51.5%, hence the Plasticity index value is
34. But the plasticity index of the clay treated with 5% of the xanthan and guar gum are 60% and 62% respectively which occurs as a result ofhydrogen bonding between the soil particles and bio-polymer.

From the above figure/ graph it can be used to conclude that the soil sample is a Clay of high plasticity.

SAMPLE	PLASTIC LIMIT	PLASTICITY INDEX
UNTREATED	51.5 %	34
TREATED WITH 5% XANTHAN GUM	60 %	26.7
TREATED WITH 5% GUAR GUM	62 %	25.8

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COMPACTION TEST

SILT SOIL

As mentioned earlier the biopolymer treated soil absorbs more water than the untreated soil which leads to increase in optimum moisture content (OMC) But, we can witness the increase in the Maximum dry density (MDD) because of the increased compressibility resulted by the addition of Xanthan & Guar gum. The typical MDD v/s OMC graph I shown below which indicates the behavior of the biopolymer treated soil

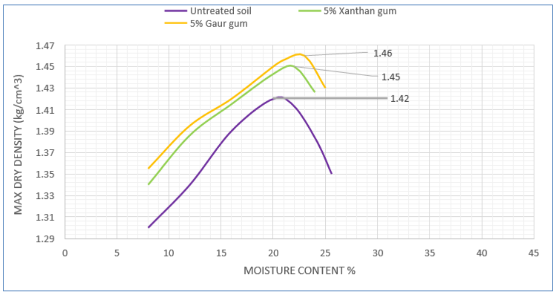

Fig. No- 7

The below table gives us a brief idea of the changes in OMC & MDD beforeand after addition of the Xanthan gum and Guar gum.

SAMPLE	OMC %	MDD (Kg/cm3)
UNTREATED	20	1.42
5 % XANTHAN GUM	22	1.45
5 % GUAR GUM	23	1.46

CLAY SOIL

The Proctor test was used to determine the MDD (maximum dry density) and OMC (optimum moisture content) for untreated as well as treated clay soil. The xanthan gum and guar gum being hydrophilic absorb more water and also fill the voids in between the soil particles resulting in an increase ofMDD and OMC

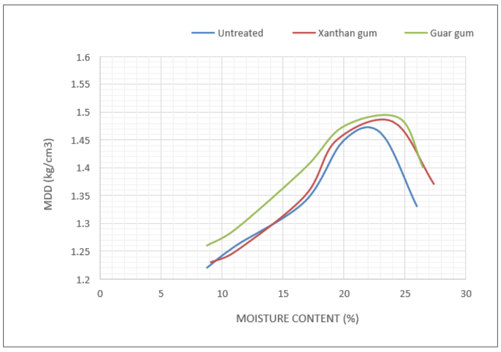

Fig. No - 8

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The below table shows the changes occurring in MDD and OMC of the claysoil after treatment with Bio-polymers.

SAMPLE	OMC %	MDD (Kg/cm3)
UNTREATED	23	1.463
5% XANTHAN GUM	24	1.483
5% GUAR GUM	24.5	1.49

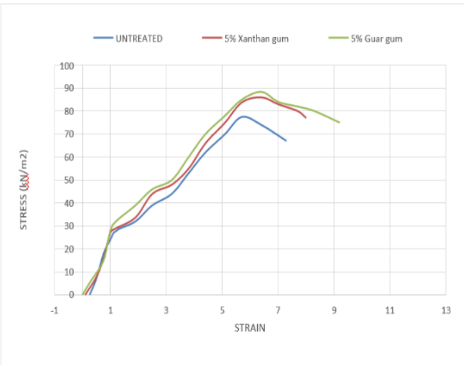
UCS TEST

SILT SOIL

The unconfined shear strength of the soil was tested for the both untreated and bio-polymer treated soil to give a comparison between them, which came out asshown in the below graph. The blue curve representing the Untreated soil whoseucs found to be 21.36 kN/m2, and that of treated with xanthan and guar are found to be 27.3 kN/m2 and 29 kN/m2 respectively. Which is a significant increase inucs in essence 27.8% in case of Xanthan treated soil and 35.7% in case of Guartreated soil.

Frictional angle of soil is a shear parameter of the soil and is used to describe the friction shear resistance of the soil. The untreated sample has frictional angle of 25° and when treated with 5% of xanthan gum and 5% of guar gum the frictional angle became 26° and 27° respectively.

There is an increase in the unconfined compressive strength of the Bio-polymer treated soil resulted by the enhancement in the cohesion and inter molecular attraction which is achieved byadding Xanthan gum and guar gum.



SAMPLE	UCS (kN/ m2)
UNTREATED	77.3
5% XANTHAN GUM	86
5% GUAR GUM	88.4

CONCLUSIONS

This investigation involves the stabilization of natural biopolymer in stabilization of a soil. The experimental investigation involves the determination of the strength and bearing capacity of biopolymer stabilized soil.

Shear strength of the treated soil will beincreased, the Durability of the bio- polymertreated soil with respect to drying andwetting cycles will be analyzed to assess thelife cycle of the bio-polymer treated soil.The enhancement in the physical propertiesare studied for different bio-polymers. The strength gained with respect to time for thedifferent dosage of bio-polymer is recorded.A comparison is made between bio-polymertreated and untreated soil to conclude theenhancement of the soil properties.

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