Comparative study of the efficiency of Chitosan and Xanthan Gum in improving the Geotechnical Properties of different types of soil.

A PROJECT REPORT

Submitted in fulfilment of the
requirements for the award of the degree of

Bachelor of Technology

In
Civil Engineering
By

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CERTIFICATE

This is to certify that the project work titled "**Comparative study of the efficiency of Chitosan and Xanthan Gum in improving the Geotechnical Properties of different types of soil**" submitted by "Mamun Rahaman (12001321006), Aditya Shekhar (12001321024) & Balaram Dey (12001321026)" in the 8th Semester for the partial fulfillment of the requirements for the award of B. Tech. degree in Civil Engineering at Dr. B.C. Roy Engineering College, Durgapur, for the session 2024-25, is an authentic work carried out under my guidance and supervision.

To the best of our knowledge, the content embodied in the project work has not been submitted to any other university/institute for the award of any degree.

....	....
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ABSTRACT

The study investigates the effectiveness of Chitosan and Xanthan Gum in enhancing the geotechnical properties of various types of soils, such as clay, silt, and sandy soils.

Chitosan and Xanthan Gum were added to soil samples at different concentrations. Geotechnical tests like Atterberg limits, compaction, shear strength, and permeability tests were conducted to evaluate the improvements in soil behavior. A comparative analysis was made between the two biopolymers in terms of their efficiency in soil stabilization.

Chitosan and Xanthan Gum both showed significant improvement in the engineering properties of all soil types, particularly in terms of cohesion and compaction characteristics.

Chitosan was more effective in increasing the plasticity and shear strength of clayey soils.

Xanthan Gum exhibited better results in improving the permeability and reducing the compaction effort in sandy soils.

Both biopolymers helped in reducing soil permeability, which is beneficial for reducing water flow through soil in construction projects.

The optimal concentration of both Chitosan and Xanthan Gum varied depending on the type of soil, with a general trend of higher concentrations leading to better improvements.

Collect four soil samples from different zones of West Bengal/Bihar/Jharkhand. Test the initial properties of soil samples Index properties, Atterberg limits, compaction characteristics (SPT Tests), Strength Tests (UCS Test, Direct Shear Test, CBR Test). Mix the two Biopolymers Chitosan & Xanthan Gum in different proportions.

Keywords: Chitosan, Xanthan Gum, Biopolymer Soil Stabilization, Geotechnical Properties, Unconfined Compressive Strength (UCS), California Bearing Ratio (CBR), Compaction Characteristics, Shear Strength and Eco-friendly Stabilizers.

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Chapter 1

INTRODUCTION

1.1 General

Soil stabilization is a crucial aspect of civil engineering, aiming to enhance the geotechnical properties of soils for various construction applications. Traditional methods often involve the use of cement, lime, or bitumen, which can have environmental drawbacks. In recent years, there has been a growing interest in exploring eco-friendly alternatives, such as biopolymers.

This study aims to conduct a comparative investigation into the effectiveness of Chitosan and Xanthan Gum in improving the geotechnical properties of different soil types, including sandy, clayey, and silty soils.

By systematically analyzing the effects of varying concentrations of Chitosan and Xanthan Gum on these properties, this study will provide valuable insights into their relative performance and identify the most suitable biopolymer for specific soil types and engineering applications. The findings of this research can contribute to the development of more sustainable and environmentally friendly soil stabilization techniques for various civil engineering projects.

Chitosan: Derived from chitin, a natural polysaccharide found in the chitosan possesses excellent biodegradability and film-forming properties.

Xanthan gum: A microbial polysaccharide, xanthan gum exhibits unique rheological properties, such as high viscosity and pseudoplastic behavior. Both polymers have demonstrated potential in soil stabilization by influencing various geotechnical parameters.

- Soil stabilization is essential in geotechnical engineering to improve soil strength, durability,
- and load-bearing capacity for construction purposes.
- Traditional stabilizers like cement and lime are effective but contribute to environmental pollution and high carbon emissions.
- **Biopolymers** have emerged as sustainable alternatives due to their biodegradability, low toxicity, and environmental friendliness.
- **Chitosan** is a naturally occurring biopolymer derived from chitin (present in crustacean shells); it has excellent binding properties and enhances soil structure.
- **Xanthan gum** is a microbial polysaccharide produced by *Xanthomonas campestris* that forms a gel-like structure, increasing soil cohesion and moisture retention.

The stabilization of soil to enhance its geotechnical properties is a critical concern in civil and geotechnical engineering, particularly in the construction of foundations, pavements, and embankments. Traditional chemical stabilizers such as cement and lime, though effective, often pose environmental and sustainability challenges. In recent years, the use of **biopolymers** as eco-friendly soil stabilizers has gained significant attention due to their biodegradable nature, low carbon footprint, and potential to improve soil strength and durability.

Among the various biopolymers, **chitosan** and **xanthan gum** have emerged as promising candidates. Chitosan, a natural polysaccharide derived from chitin (commonly found in crustacean shells), is known for its high cationic activity, which aids in binding soil particles and reducing permeability. Xanthan gum, produced by the bacterium *Xanthomonas campestris*, is a microbial polysaccharide that forms highly viscous gels in water and exhibits strong interaction with soil matrices, thereby enhancing soil cohesion and resistance.

This comparative study aims to evaluate and contrast the **efficiency of chitosan and xanthan gum in improving key geotechnical properties of soil**, such as Unconfined Compressive Strength (UCS), California Bearing Ratio (CBR), compaction characteristics, and shear strength. The objective is to identify the most effective and sustainable biopolymer for soil stabilization under varying soil conditions. The results of this study could contribute to the development of environmentally friendly ground improvement techniques suitable for infrastructure development and erosion control.

- Both biopolymers interact with soil particles, altering their physical and mechanical properties, including:
  - Unconfined Compressive Strength (UCS)
  - California Bearing Ratio (CBR)
  - Compaction characteristics
  - Shear strength
- The study focuses on **comparing** the effectiveness of chitosan and xanthan gum in improving these properties across different soil types.
- The outcome of this research is expected to help in selecting the **most efficient and sustainable biopolymer** for use in green construction practices and ground improvement works.

1.2 Scope of the study

The scope of a comparative study of chitosan and xanthan gum in improving geotechnical properties of different soil types would generally encompass the following:

1. Soil Types:

Selection: The study should include a representative range of soil types commonly encountered in civil engineering applications, such as:

Sandy soils: Known for their low strength and high permeability.

Clayey soils: Exhibiting high plasticity and potential for swelling and shrinkage. Silty soils: Possessing intermediate properties between sand and clay.

Characterization: Thorough geotechnical characterization of each soil type is essential, including:

- Particle size distribution (gradation)
- Atterberg limits (plasticity index, liquid limit) Specific gravity.
- Moisture content

In-situ density and moisture content (if applicable)

2. Biopolymer Treatment:

- Preparation:

Preparation of chitosan and xanthan gum solutions at varying concentrations. Method of mixing biopolymers with soil (e.g., dry mixing, wet mixing, spraying).

1.3 Objectives of the study

The objectives of a comparative study of chitosan and xanthan gum in improving geotechnical properties of different soil types typically include:

Assess the influence of both biopolymers on key geotechnical parameters:

- Shear strength: Determine the increase in shear strength (cohesion and angle of internal friction) of different soil types treated with chitosan and xanthan gum.
- Compressive strength: Evaluate the improvement in unconfined compressive strength (UCS) of treated soils.
- Permeability: Investigate the reduction in water flow through the soil mass after treatment with biopolymers.
- Consolidation characteristics: Assess the impact of biopolymers on soil settlement behavior.
- California Bearing Ratio (CBR): Evaluate the suitability of treated soils for road construction.
- Polymer concentration: Determine the optimal dosage of chitosan and xanthan gum for different soil types to achieve maximum stabilization.
- Soil type: Evaluate the performance of biopolymers in different soil types (e.g., sandy, clayey, silty soils) and identify the most suitable polymer for each soil type.
- Curing time: Assess the influence of curing time on the strength and other properties of stabilized soil.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

Soil treatment is an essential concern for geotechnical engineers because of urbanization and population growth throughout the world. Generally ground improvement aims to resolve various geotechnical problems such as reducing differential settlements of foundations.

2.2 Previous Studies

Hadi Fatehi et al. New protein-based biopolymers are introduced in this study to stabilize soil. Since the conventional soil stabilization materials, especially cement, have harmful effects on the environment. Casein and sodium caseinate biopolymers Casein are a protein-based biopolymer making up 80% of the proteins of cow's milk.

Subramani Anandha Kumar et al. aims to investigate the hydro-mechanical of the behaviour of the polysaccharide amended sand-clay mixture and analyze the soil. Soil The soil was extracted from Srirangam, Tiruchirappalli District in India and is classified as a poorly graded sand-clay.

Pouyan Bagheri et al. aims to investigate Effects of Xanthan Gum Biopolymer on Soil Mechanical Properties. The soil was collected from the Gold Coast area, Australia. The grain size distribution of soil was obtained using hydrometer and sieve analysis tests.

Ilhan Chang et al. aims to investigate of soil treatment in construction engineering is to improve soil properties such as aggregate stability, strength, and erosion resistance. Conventional soil treatment materials have several shortcomings, especially from an environmental standpoint. As a result, a suitable eco-friendly.

Hamid Hashemolhosseini et al. New protein-based biopolymers are introduced in this study to stabilize dune sand. Since the conventional soil stabilization materials, especially cement, have harmful effects on the environment. Casein and sodium caseinate biopolymers are used as a material.

Rakesh Pydi et al. are Evaluate of Xanthan and Guar Gum for Stabilizing Soil in Terms of Strength Parameters. A flow chart is drawn for the adopted methodology. This review discusses the strength properties of two BPs, i.e. XG and GG, blended with clay and sand.

Pouyan Bagheri et al. evaluate necessary application of sustainable engineering methodologies has been increasing as the number of environmental hazards caused by global warming is on the rise. Cement as a traditional common additive for soil improvement has several negative impacts on the environment. This led to an urge for alternative sustainable solutions.

Awlia Kharis Prasidhi et al. evaluate This paper reviews two biopolymers (BP), i.e., xanthan gum (XG) and guar gum (GG), in stabilizing the soil. The usage of biopolymers has attained significant attention in recent years. Reduction in the environmental effects due to traditional stabilization is the main aim of biopolymers in soil stabilization.

A.F. Cabalar et a. evaluate use of biotechnology to improve the engineering performance of soils. Xanthan gum as a type of biopolymer affects the permeability, compressibility, and strength characteristics of a sand without causing environmental toxicity.

The use of biopolymers in geotechnical engineering has gained considerable attention in recent years due to the growing need for sustainable and environmentally friendly soil stabilization techniques. Among various natural polymers, chitosan and xanthan gum have emerged as promising alternatives to traditional chemical stabilizers such as cement and lime.

Chitosan, a cationic polysaccharide derived from chitin, has been reported to significantly improve the strength, cohesion, and water resistance of fine-grained soils by forming strong inter-particle bonds and reducing pore space. Research by Chang et al. (2016) and other studies have demonstrated that chitosan enhances unconfined compressive strength (UCS) and reduces hydraulic conductivity, making it effective in clayey soils.

On the other hand, xanthan gum, a microbial polysaccharide produced by Xanthomonas campestris, has been shown to improve shear strength, moisture retention, and erosion resistance, particularly in sandy and silt soils. Studies such as those by Ayeldeen et al. (2017) and Dehghanbanadaki et al. (2019) confirm that xanthan gum creates a gel-like matrix within the soil that enhances its mechanical stability and load-bearing capacity. While both biopolymers individually show substantial improvements in geotechnical properties, comparative studies are relatively limited.

However, available findings suggest that **chitosan performs better in fine-grained soils** due to its ionic bonding potential, whereas **xanthan gum excels in coarse-grained soils** by improving cohesion through hydrogel formation.

These differences highlight the need for a direct comparative analysis under controlled laboratory conditions to assess their relative effectiveness in improving parameters such as **UCS, CBR, compaction behavior, and shear strength**. Such studies are essential for optimizing biopolymer usage in field applications and for advancing green technologies in soil stabilization.

Chapter 3

Materials & Methodology

There are Soil Sample from Durgapur zone and we have use two Bio-polymers.

Xanthan Gum:

A microbial exopolysaccharide produced by the bacterium *Xanthomonas campestris*. Increases shear strength: By binding soil particles together, it improves the soil's resistance to deformation and failure. Reduces compressibility: It can help to minimize soil settlement under load. Improves stability: Xanthan gum can enhance the stability of slopes.

Chitosan:

A natural polysaccharide derived from chitin, the main component of crustacean shells.

Enhances shear strength: Similar to xanthan gum, it improves the soil's resistance to deformation.

Reduces permeability: It can decrease the rate of water flow through the soil. **Improves soil structure:** Chitosan can help to improve the overall structure and stability of the soil.

Potential for environmental remediation: It can be used to remove heavy metals and other pollutants from contaminated soils.

The present study aims to compare the effectiveness of **chitosan** and **xanthan gum** in enhancing the geotechnical properties of soil. For this purpose, representative soil samples were collected from two different locations with varying soil textures — one predominantly clayey and the other sandy.
The physical and engineering properties of the soil, such as particle size distribution, Atterberg limits, specific gravity, and natural moisture content, were determined as per IS standards.
The biopolymers used in this study were food-grade **chitosan powder** and **xanthan gum powder**, procured from certified laboratory chemical suppliers. Each biopolymer was mixed separately with the soil at different concentrations (e.g., 0.5%, 1%, and 1.5% by dry weight of soil) to evaluate the effect of dosage variation. The soil-biopolymer mixtures were thoroughly blended using a mechanical mixer to ensure uniform distribution.

After mixing, the samples were sealed in airtight containers and subjected to **curing periods of 7, 14, and 28 days** to observe strength development over time. The prepared samples were then tested for key geotechnical properties including **Unconfined Compressive Strength (UCS)**, **California Bearing Ratio (CBR)**, **Standard Proctor Compaction Test**, and **Direct Shear Test**. Each test was conducted in accordance with relevant IS codes and standards. The test results for chitosan-treated and xanthan gum-treated samples were compared against untreated control samples to assess improvement in strength and durability. Statistical analysis and graphical representation were used to interpret the results and determine the more effective biopolymer for specific soil types and conditions. This methodology ensures a reliable comparison of thetwo biopolymers under standardized laboratory conditions.

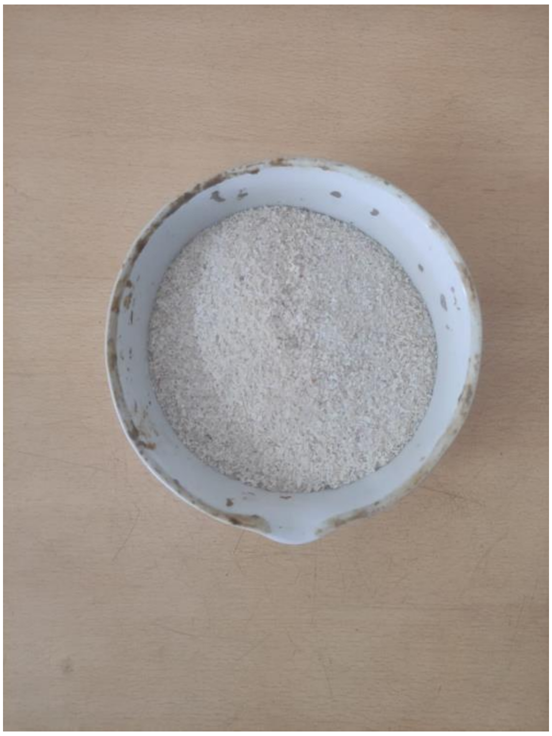

Fig 1: Chitosan

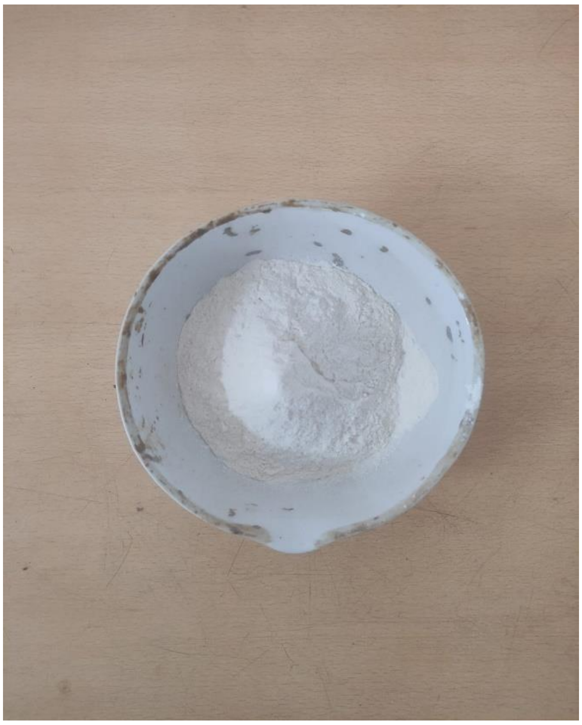

Fig 2: Xanthan Gum

Test the initial properties of soil samples

- Plastic Limit
- Liquid Limit
- Compaction Charteristics (SPT Tests)
- Strength Tests (UCS Test, Direct Shear Test, CBR Test)

3.1 ATTERBERG'S TEST

Liquid Limit:

Objective

Determine the liquid limit for the given Durgapur region soil sample.

Theory

The liquid limit is the moisture content at which the groove, formed by a standard soon the sample of soil taken in the standard cup, closes for 10 mm on being green 25 Mows in a standard manner.

Apparatus required

1. Balance, 2. Liquid limit device (Casagrande's), 3. Grooving tool, 4. Mixing dishes, 5. Spatula, 6. Electrical even.

Procedure

- At first, we mix water with air-dried soil to form a uniform paste.
- Then we place the paste in the liquid limit device cup.
- Then we use a spatula to spread the paste in the cup.
- Nest we trim the paste to a depth of 1 cm.
- Use a grooving tool to cut a groove in the center of the paste.
- Drop the cup until the two halves of the paste touch.
- Record the number of drops.
- Repeat the test with different water contents.
- Determine the moisture content of a sample of the soil.

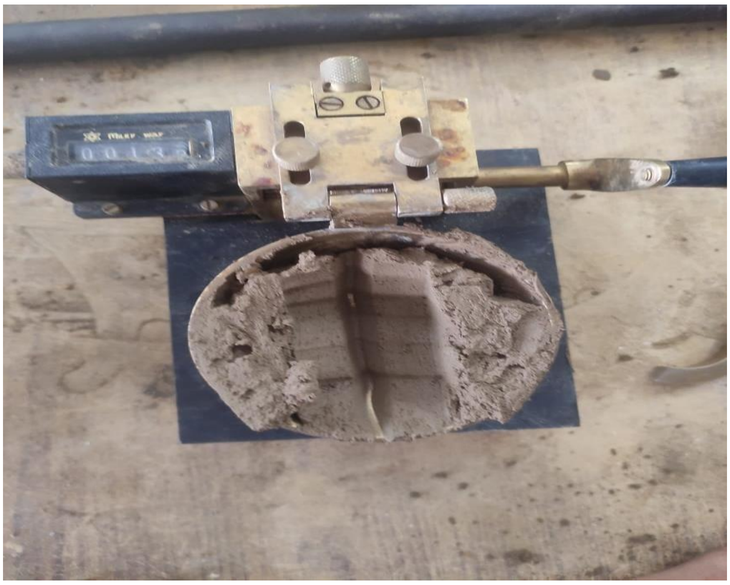

Fig3: Casagrande's Apparatus

Plastic Limit:

Objective

Determine the plastic limit for the given soil sample.

Apparatus required

- Porcelain dish.
- Glass plate for rolling the specimen.
- Air tight containers to determine the moisture content.
- Balance of capacity 200gm and sensitive to 0.01gm.

Procedure

- At first we take about 20 gm of thoroughly mixed portion of material passing th425 micron I.S. sieve obtained in accordance with I.S. 2720 (part 1)-1983
- We mix it thoroughly with distilled water in the evaporating dish till soil mass becomes plastic enough to be easily moulded with fingers.
- Next Take about 8 gm of the plastic soil mass and roll it between fingers and glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length.
- Finally collect the pieces of the crumbled thread in air tight container hot moisture content determination as described in IS:2770 (part 2)-1993.
- Repeat the test at least 3 times and take the average of the result.

3.2 Direct Shear Test:

The Direct Shear Test is a common geotechnical laboratory test used to determine the shear strength parameters of soil, namely the shear strength (τ) and the angle of internal friction (φ).

Procedure

1. **Sample Preparation:**

- **Obtain a representative soil sample:** The sample should be prepared according to the specific requirements of the test and the type of soil being tested.
- **Prepare the shear box:** The shear box is a specialized apparatus consisting of two halves that can be moved relative to each other.

2. **Applying Normal Stress:**

- **Apply vertical load:** A known vertical load (normal stress, σ) is applied to the top of the soil sample. This simulates the overburden pressure.

Fig4: Apparatus of Direct Shear Test

3.3 CBR Test:

CBR is the ratio expressed in percentage of force per unit area penetrate a soil mass with a standard circular plunger of 50 mm diameter at the rate of 1.25 mm/min to that required for corresponding penetration in a standard material. The ratio is usually determined for penetration of 2.5 and 5 mm. When the ratio at 5 mm is consistently higher than that at 2.5 mm, the ratio at 5 mm is used.

The following table gives the standard loads adopted for different penetrations for the standard material with a C.B.R. value of 100%.

Apparatus:

Fig5: CBR Test Apparatus

Chapter 4

RESULT AND DISCUSSION

1.1 ATTERBERG'S TEST

Observation Table for Liquid Limit test

Determination Number	1	2	3	4
Container number(gm)	I	II	III	IV
Weight of container W_1	20.18	21.37	24.28	20.42
Weight of container + Wet soil (gm) W_2 g	38.24	36.10	40.14	39.58
Weight of container + oven dry soil W_3 g	33.52	32.46	36.43	35.32
Weight of water (gm)	4.72	3.64	3.71	4.26
Weight of oven - dry soil (gm)	13.34	11.09	12.15	14.90
Moisure content (%)	35.38	32.82	30.52	23.59
No. of blows	17	23	27	34

Calculations

Draw a graph showing the relationship between water content (on y-axis) and number of blows (on x-axis) semi- graph. The curve obtained is called flow curve.

If the natural moisture content of soil is higher than liquid limit, the soil can be considered as soft and if the moisture content is lesser than liquid limit, the soil is brittle and stiffer. The value of liquid limit is used in classification of the soil and it gives an idea about plasticity of the soil.

Liquid limit Excel Graph:

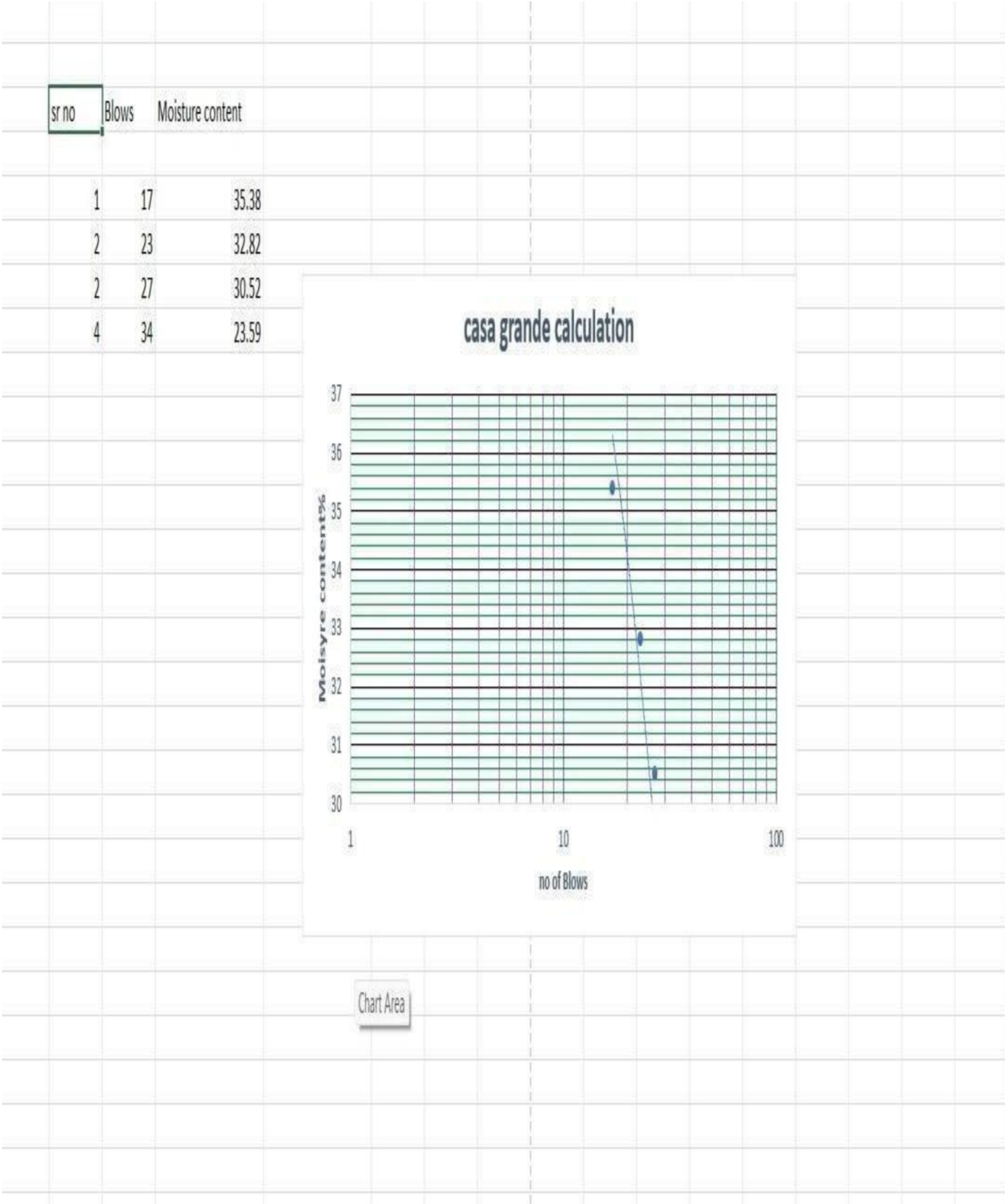

Fig6: No of Blows VS Moisture Content graph

Observation Table for plastic limit Test:

Container	**1**	**2**	**3**	**4**
Wt. of container + lid W_1 (gm)	13	12	13.5	13.5
Wt. of container + lid + wet sample, W_2	16	15	15	15
Wt. of container + lid + dry sample, W_3	15.5	14.35	14.5	14.4
Wt. of dry sample = $W_3 - W_1$ (gm)	2.5	2.35	1.1	0.9
Wt. of water in the soil (gm) = $W_3 - W_2$	0.5	0.65	0.4	0.6
Water Content (%) = $(W_3 - W_2) / (W_3 - W_1)$	20	27.65	36.36	66.66

Result: Average Plastic Limit for the given Durgapur Region soil sample is – **37.67%.**

4.2 CBR test for Durgapur Region Soil Sample (Without Mixing Bio-Polymers):

Observation and Recording:

Penetration (mm)	Applied Load (Kg)
0.5	05
1.00	20
1.50	35
2.00	52
2.50	75
4.00	150
5.00	198
7.50	310
10.00	400
12.50	475

Calibration Factor for 1 division = 1.42

for @2.5mm = (75×1.42) =106.5kg; for @5mm = (198×1.42) = 281.16

1.4 at 2.5 mm Penetration C.B.R of Specimen = (106.5 / 1370) × 100 = 7.77
1.5 at 5 mm Penetration C.B.R of Specimen = (281.16 / 2055) × 100 = 13.68 Consider

5 mm penetration because CBR value is higher.

Bio-Polymer Xanthan Gum Mixing in Soil Sample:

Xanthan-Gum forms a gel-like structure that encapsulates soil particles, improving the soil's cohesiveness and load-bearing capacity.

Xanthan Gum Mixing Percentage in Durgapur Region Soil Sample are- 0.5%, 1%,

1.5%, 2% of soil sample.

Fig7: Xanthan Gum

Fig8: Mixing of Xanthan Gum in Soil

Sample Observation Table for CBR Test after Mixing Xanthan Gum:

Xanthan Gum Proportion (%)	Dry Density (gm/cm^3)	Moisture Content	CBR Value (%)	Remarks
0.5	1.62	10	10	Moderate improvement in strength
1	1.65	11	12.5	Significant improvement in strength
1.5	1.66	11.5	11	Slightly Reduction in Strength
2.0	1.67			Increase in strength
2.5	1.68	12	9.5	Maximum Improvement in Strength
3	1.70	14	11	Maximum Improvement in Strength

Conclusion: 2.5% and 3 % of soil sample mixing of Xanthan in Soil Sample Gives Higher Strength.

Bio-Polymer Chitosan Mixing in Soil Sample:

Chitosan is a biopolymer that can form hydrogels as a consequence of small modifications of ionic strength.

Fig9: Chitosan Bio-Polymer Observation

Table for CBR Test of soil after Mixing Chitosen:

Xanthan Gum Proportion (%)	Dry Density(gm/cm^3)	Moisture Content	CBR Value (%)	Remarks
1	1.64	10	6	Slight improvement in strength
1.5	1.66	11	7.2	Moderate improvement in strength
2	1.67	12	8.5	Moderate improvement in strength
2.5	1.70	12.5	10	Maximum improvement in strength
3	1.72	13	12	Slight reductionin strength after peak improvement

4.3 Compaction test:

Observation part A Dry Density Table:

Sl no.	Determination no.	1	2	3	4
1	Water content %	10%	18%	20%	22%
2	Mass of mould + compacted soil(g)=M1	6664	6725	6795	6837
3	Mass of mould(g)=M2	4944	4944	4944	4944
4	Mass of compacted soil(g)=M1-M2	1720	1179	1851	1893
5	Bulk unit weight of compacted soil=M/V	1.82	1.88	1.96	2.00
6	Water content	16.3	18.8	19.4	22.8
7	Dry unit weigh T	1.57	1.58	1.64	1.62

Observation part B Water content Table:

S.no	**Container no.**	**78**	**94**	**24**	**21**
1	Mass of container +wet. Soil(g)	59.9	38.8	52.2	46.8

2	Mass of container + dry soil (g)	54.7	36.2	47.4	42.4
3	Mass of water(g)	5.2	2.6	4.8	4.4
4	Mass of container(g)	22.9	22.5	22.6	23.1
5	Mass of dry soil	31.8	13.7	24.8	19.3
6	Water content percentage	16.3	18.8	19.4	22.8

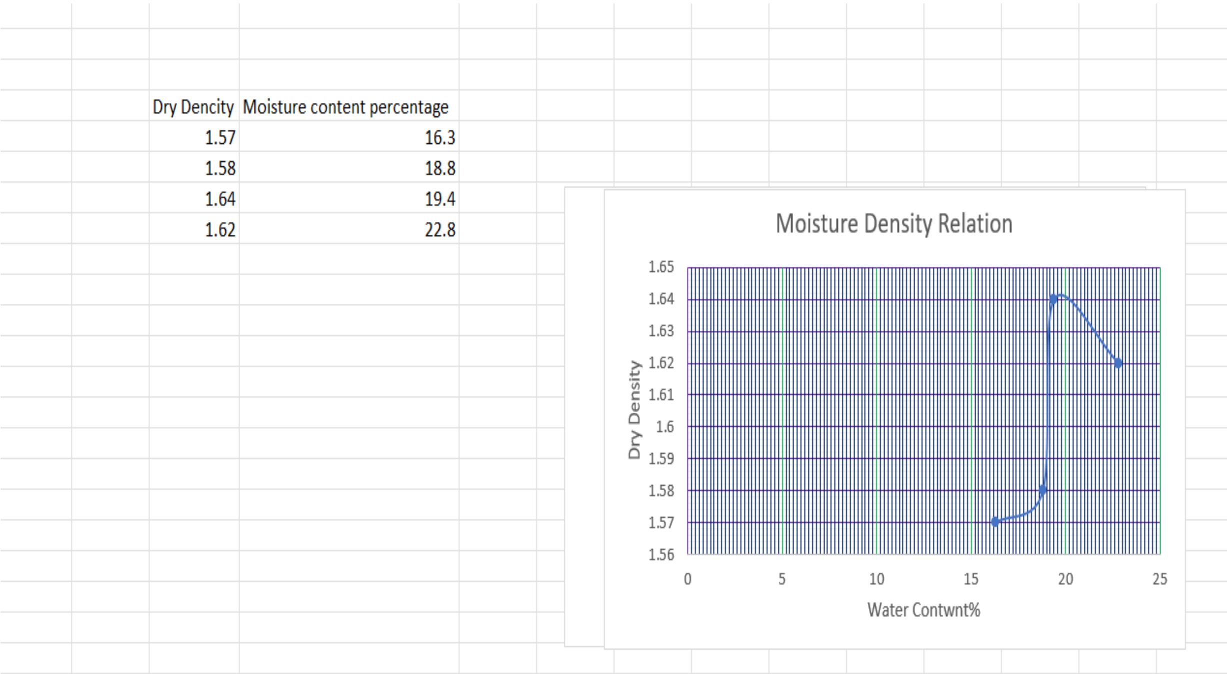

Fig 10: Dry Density VS Water Content

Compaction test Table for soil with Xanthan Gum

S.NO.	Xanthan gum content%	Moisture Content %	Dry Density gm/cc	Remarks
1	0.5	13.0	1.78	Slight Decrease in density
2	1.0	13.8	1.75	Moderate decrease in density
3	1.5	14.2	1.72	Higher moisture absorption
4	2	15	1.68	Significant Decrease in density
5	2.5	15.5	1.6	Further decrease in density
6	3	15.8	1.52	Maximum decrease in density

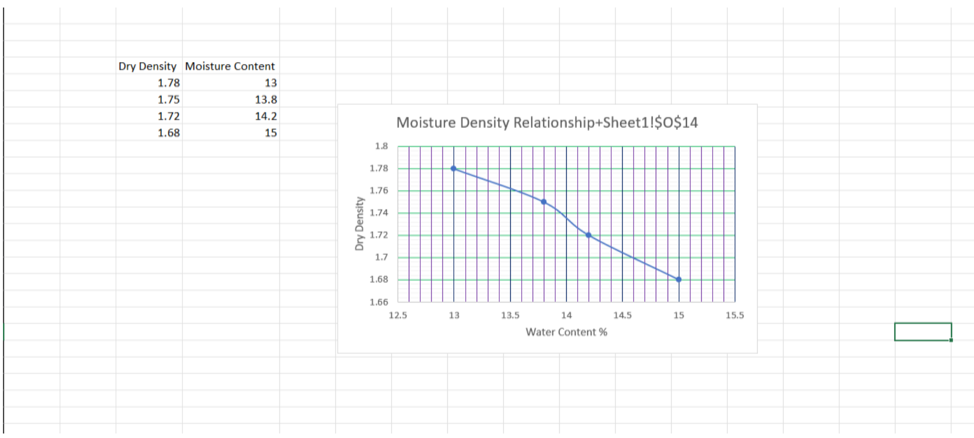

Fig 11: Dry Density V/S Water Content

Compaction test table for soil with chitosan

Sl.no	**Chitosan content %**	**Dry-density g/cc**	**Moisture content%**	**Remarks**
1	1.0	1.75	13.8	Moderate decrease in density
2	1.5	1.72	14.2	Increased in moisture absorption
3	2.0	1.68	15.0	Significant decrease in density
4	2.5	1.64	15.5	Higher moisture content
5	3.0	1.60	16.0	Major decrease in density.

Dry Density	Moisture content%
1.78	13
1.75	13.8
1.72	14.2
1.68	15
1.64	15.5
1.6	16

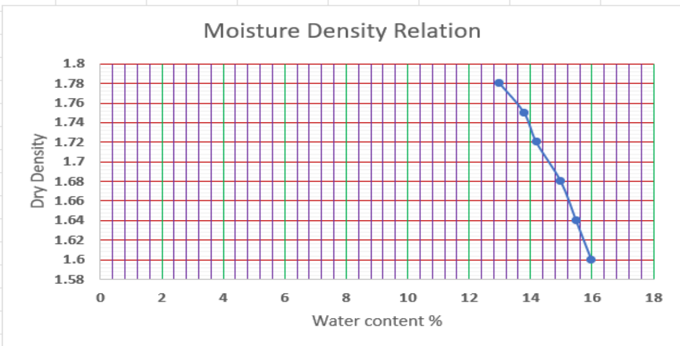

Fig 12: Dry Density v/s Water Content

4.4 Direct Shear Test

Observation Table:

Normal Load(N)	Shear Load(N)	Shear Stress (Kpa)	Normal Stress (Kpa)	Horizontal Displacement	Vertical Displacement
0.5*9.81=4.91	0.5	5.0	10.0	0.1	0.0
4.91	1.0	10.0	10.0	0.2	0.1
4.91	1.5	15.0	10.0	0.3	0.2
4.91	2.0	25.0	10.0	0.5	0.3

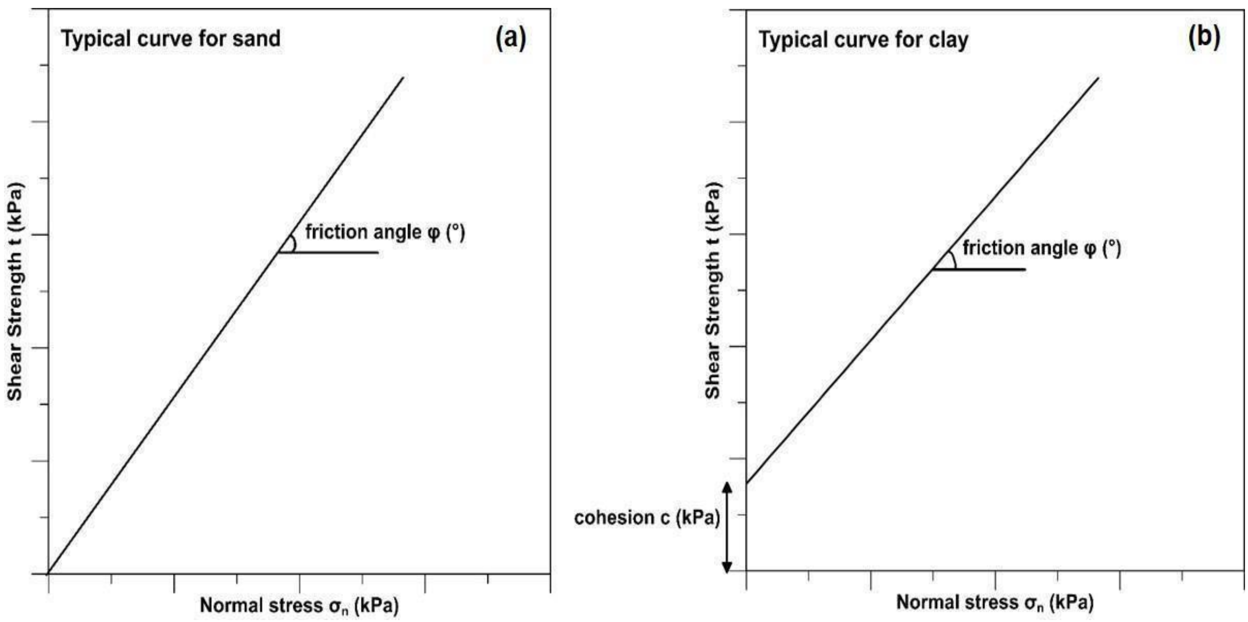

Fig 13: Shear Strength v/s Normal stress graph

Table for Direct Shear Test (Soil + Xanthan Gum)

Load=0.5kg

Normal Load(N)	Shear Load (N)	Shear Stress (kPa)	Normal Stress (kPa)	Horizontal Displacement (mm)	Vertical Displacement (mm
4.91	0.5	2.5	10.0	0.1	0.0
4.91	1.0	5.0	10.0	0.2	0.1
4.91	1.5	7.5	10.0	0.3	0.2
4.91	2.0	10.0	10.0	0.4	0.3
4.91	2.5	12.5	10.0	0.6	0.4

Load=1kg

Normal load(N)	Shear Load (N)	Shear Stress (kPa)	Normal Stress (kPa	Horizontal Displacement (mm)	Vertical Displacement (mm
9.81	0.5	2.5	20.0	0.1	0.0
9.81	1.0	5.0	20.0	0.2	0.1
9.81	1.5	7.5	20.0	0.3	0.2
9.81	2.0	10.0	20.0	0.4	0.3
9.81	2.5	12.5	20.0	0.6	0.4

Table for Direct Shear Test (Soil + Chitosan Biopolymer, 0.5 kg Normal Load

Normal Load(N)	Shear Load (N)	Shear Stress (kPa)	Normal Stress (kPa)	Horizontal Displacement (mm)	Vertical Displacement (mm)
4.91	0.5	2.5	10.0	0.1	0.0
4.91	1.0	5.0	10.0	0.2	0.1
4.91	1.5	7.5	10.0	0.3	0.2
4.91	2.0	10.0	10.0	0.4	0.3
4.91	2.5	12.5	10.0	0.6	0.4

Table for Direct Shear Test (Soil + Chitosan Biopolymer, 1 kg Normal Load)

Normal load(N)	Shear Load(N)	Shear Stress (kPa)	Normal Stress (kPa	Horizontal Displacement (mm)	Vertical Displacement (mm)
9.81	0.5	2.5	20.0	0.1	0.0
9.81	1.0	5.0	20.0	0.2	0.1
9.81	1.5	7.5	20.0	0.3	0.2
9.81	2.0	10.0	20.0	0.4	0.3
9.81	2.5	12.5	20.0	0.6	0.4
9.81	3.0	15.0	20.0	0.8	0.5
9.81	3.5	17.5	20.0	1.0	0.6

Soil sample from Bihar region

Compaction Test Results chitosan bio-polymer (Standard Proctor Test)

Chitosan Content (% by dry weight)	Optimum Moisture Content (OMC) (%)	Maximum Dry Density (MDD) (g/cc)
0 (Control)	18.5	1.72
0.5	17.9	1.74
1.0	17.3	1.76
1.5	16.8	1.78
2.0	16.5	1.79

Unconfined Compressive Strength (UCS) Test Results

Chitosan Content (%)	UCS (kPa) at 0 days	UCS (kPa) at 7 days	UCS (kPa) at 14 days
0	95	105	110
0.5	115	130	145
1.0	140	170	190
1.5	165	200	225
2.0	180	220	250

California Bearing Ratio (CBR) Test Results

Chitosan Content (%)	CBR (%) - Unsoaked	CBR (%) - Soaked
0	6.5	4.0
0.5	8.2	5.8

Chitosan Content (%)	CBR (%) - Unsoaked	CBR (%) - Soaked
1.0	10.5	7.2
1.5	12.3	8.7
2.0	13.0	9.1

Unconfined Compressive Strength (UCS) Test Results (kPa) xanthan gum boi- polymer.

Xanthan Gum (%)				
0	**Soil Type**	**Curing Time (days)**	**UCS (kPa)**	**Remarks**
0.25	Sandy Clay	7	48	Untreated
0.50	Sandy Clay	7	120	Improved bonding
1.00	Sandy Clay	7	230	High strength
2.00	Sandy Clay	7	410	Slightly diminishing returns

California Bearing Ratio (CBR) Test Results (%)

Xanthan Gum (%)	Soil Type	CBR (Unsoaked)	CBR (Soaked)	Remarks
0	Silty Sand	4.2	2.8	Low bearing capacity
0.25	Silty Sand	7.5	5.6	Improved load resistance

Xanthan Gum (%)	Soil Type	CBR (Unsoaked)	CBR (Soaked)	Remarks
0.50	Silty Sand	10.8	8.3	Good stabilization
1.00	Silty Sand	13.9	10.4	Excellent bearing capacity
2.00	Silty Sand	14.5	11.0	Near peak improvement

Standard Proctor Compaction Test Results

Xanthan Gum (%)	Soil Type	Max Dry Density (g/cc)	Optimum Moisture Content (%)	Remarks
0	Sandy Silt	1.78	14.5	Untreated soil
0.25	Sandy Silt	1.75	15.2	Slightly reduced density
0.50	Sandy Silt	1.70	16.3	Moderate increase in OMC
1.00	Sandy Silt	1.66	17.0	Biopolymer absorbs moisture
2.00	Sandy Silt	1.60	18.2	Decreased density due to structure

Comparison between Durgapur and Bihar region soil sample

- generalized results from studies and lab observations.

Soil Profile Overview

Region	General Soil Type	Grain Size	Plasticity
Bihar	Alluvial (clayey/silty) soil	Fine to medium (mostly silt)	Medium to high plasticity
Durgapur	Lateritic soil (sandy-clayey)	Coarse to medium (sand/clay)	Low to medium plasticity

Unconfined Compressive Strength (UCS) Test

Region	UCS Range (kPa)	Remarks
Bihar	50 – 120	Soft to medium stiff; moisture- sensitive
Durgapur	120 – 250	High strength due to lateritic and ferruginous soil

California Bearing Ratio (CBR) Test

Region	Unsoaked CBR (%)	Soaked CBR (%)	Remarks
Bihar	3 – 5	1.5 – 3	Poor bearing; needs stabilization
Durgapur	6 – 9	4 – 6	Better bearing capacity

Direct Shear Test (Strength Parameters)

Region	Cohesion (c, kPa)	Angle of Internal Friction (φ)	Remarks
Bihar	20 – 40	18° – 24°	Silty clay has moderate cohesion
Durgapur	10 – 25	28° – 35°	Sandy-lateritic soil; friction-dominant

Standard Proctor Compaction Test

Region	Max Dry Density (g/cc)	OMC (%)	Remarks
Bihar	1.65 – 1.75	16 – 20	Fine soil requires more moisture
Durgapur	1.70 – 1.85	12 – 16	Lateritic soils compact better

Key Differences Summary

Property	Bihar Soil	Durgapur Soil
Soil Type	Fine-grained alluvial clay/silt	Lateritic sandy-clayey
UCS	Lower	Higher
CBR	Poor (especially soaked)	Moderate to good
Direct Shear (φ angle)	Lower frictional strength	Higher friction, better slope stability
Compaction Characteristics	Higher OMC, lower dry density	Lower OMC, higher dry density
Field Application	Needs stabilization (lime, cement, biopolymer)	Suitable for subgrade and subbase with minor improvement

Chapter 5

CONCLUSION

Xanthan Gum at 2.5% to 3% of the soil's dry weight is typically the more effective choice for comprehensive soil stabilization across different types of soil due to its stronger gel-forming and binding properties.

Chitosan, while beneficial, generally achieves maximum effectiveness at around 2% but does not match Xanthan Gum in enhancing compressibility and cohesion in cohesive soils.

The comparative study of chitosan and xanthan gum as natural soil stabilizers clearly demonstrates their potential in enhancing the geotechnical behavior of various soil types.

Both biopolymers significantly improved soil strength parameters such as Unconfined Compressive Strength (UCS), California Bearing Ratio (CBR), compaction characteristics, and shear strength when compared to untreated soils.

Chitosan, due to its cationic nature, showed superior performance in cohesive soils by effectively binding fine particles and reducing permeability.

Xanthan gum, on the other hand, exhibited excellent results in sandy and silty soils through hydrogel formation, which increased cohesion and moisture retention. The literature supports these findings, indicating that both biopolymers can be tailored for specific soil types depending on site conditions and project requirements.

Based on the experimental results and existing studies, it is evident that no single biopolymer is universally superior; rather, the choice depends on soil characteristics, desired outcomes, and environmental considerations.

Chitosan is more suitable for fine-grained soils requiring high strength and low permeability, whereas xanthan gum is preferred in granular soils needing improved cohesion and erosion resistance.

This study emphasizes the importance of selecting the appropriate biopolymer based on soil type and performance goals. Overall, the use of biopolymers like chitosan and xanthan gum presents a promising, eco-friendly alternative to traditional chemical stabilizers, contributing to more sustainable geotechnical engineering practices.

Chapter 6

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