DCEA DISASTER IN CIVIL ENGINEERING AND ARCHITECTURE

POPULAR SCIENTIST

RESEARCH ARTICLE

Soil Stabilization Using Xanthan Gum: An Eco-Friendly Approach to Improve Peat Soil Properties

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Articles History: **Received:** 14 March 2025; **Revised:** 17 April 2025; **Accepted:** 24 April 2025; **Published:** 28 April 2025

ABSTRACT

Peat soil presents significant challenges in geotechnical engineering due to its high moisture content, low shear strength, and high compressibility, making it unsuitable for construction. Traditional stabilization methods such as cement and lime have been widely used but raise environmental concerns due to their high carbon emissions. This study explores the effectiveness of xanthan gum, a biodegradable biopolymer, as an alternative stabilizing agent for peat soil. The research aims to assess its impact on moisture content regulation, plasticity behavior, compaction characteristics, and overall soil stability. A series of laboratory experiments, including Atterberg limits tests, moisture content analysis, and compaction tests, were conducted to evaluate the engineering properties of xanthan gum-treated peat soil. Three xanthan gum concentrations (0%, 2%, and 4% by weight) were tested to determine the optimal dosage for soil stabilization. The results indicate that xanthan gum significantly reduces moisture content, with a decrease from 135.42% in untreated soil to 39.5% at 4% xanthan gum concentration. The liquid limit and plastic limit increased, indicating enhanced soil cohesion and workability. Compaction tests revealed that while 2% xanthan gum resulted in lower dry density, 4% xanthan gum improved compaction efficiency, suggesting an optimal concentration range for stabilization. The study confirms that xanthan gum is an effective, sustainable alternative to traditional soil stabilizers, providing significant benefits in peat soil stabilization. However, further research is needed to investigate its long-term durability under environmental variations, large-scale field applications, and hybrid stabilization techniques. By addressing these challenges, xanthan gum could become a mainstream solution for sustainable geotechnical engineering applications.

Keywords: Peat Soil, Xanthan Gum, Biopolymer, Moisture Content, Plasticity, Compaction

INTRODUCTION

Peat soils are widely recognized for their challenging engineering properties, posing significant constraints in construction and geotechnical applications.

Due to their high organic matter content, these soils exhibit excessive water retention, low shear strength, and high compressibility, making them structurally unsuitable for supporting loads [1-3]. The fibrous and heterogeneous composition of peat results in substantial settlement when subjected to even moderate loading conditions, leading to differential ground subsidence and potential failure of infrastructure built upon them [2,3]. Additionally, the high moisture retention of peat complicates construction efforts by increasing the risk of long-term instability and degradation of foundational structures [1][3,4]. This inherent instability necessitates extensive ground improvement techniques, as highlighted in previous studies, which emphasize the importance of pre-construction site assessments and the implementation of adequate drainage systems to mitigate risks associated with peat soil foundations [3][5]. As urban expansion and infrastructure development continue to encroach upon peatlands, finding effective and sustainable stabilization solutions becomes an urgent necessity in civil engineering.

Given these engineering challenges, various soil stabilization techniques have been developed to improve the performance of peat soils, primarily by reducing moisture content, enhancing compressive strength, and mitigating settlement risks. Traditional stabilization approaches include the use of chemical binders such as lime, cement, fly ash, and ground granulated blast-furnace slag (GGBS), all of which have been extensively studied and applied in geotechnical engineering [6,7]. For example, studies on GGBS stabilization have demonstrated significant improvements in the compaction characteristics of peat, increasing its load-bearing capacity and overall structural integrity [6][8]. Similarly, ultrafine cement (UFC) has been explored as an effective agent for enhancing the mechanical performance of cement-treated peat soils, yielding promising results in terms of long-term strength and durability [9,10]. However, despite their effectiveness, these traditional stabilization methods present environmental and economic drawbacks, particularly due to the substantial carbon emissions associated with cement production and the high costs of large-scale application [11,12]. Consequently, there is a growing demand for alternative stabilization techniques that maintain soil performance while reducing environmental impact.

In response to these concerns, recent advancements in geotechnical research have turned toward biopolymers, particularly xanthan gum, as a potential alternative soil stabilizer. Xanthan gum is a microbial exopolysaccharide with remarkable hydrophilic and rheological properties, making it highly effective in modifying soil behavior [13,14]. Its ability to absorb and retain moisture allows it to significantly enhance soil cohesion and compaction while reducing permeability and settlement potential [15,16]. Unlike cement and lime, xanthan gum stabilization does not contribute to carbon emissions and is biodegradable, aligning with global efforts to promote sustainable construction practices. These characteristics make xanthan gum a promising material for soil stabilization, particularly in environmentally sensitive areas such as peatlands.

A growing body of literature supports the feasibility of xanthan gum as a stabilizing agent for problematic soils, including peat. Studies have shown that xanthan gum improves compressive strength and soil cohesion, making it a viable alternative to conventional stabilizers [14][17]. Furthermore, laboratory experiments have demonstrated that xanthan gum-treated soils exhibit enhanced plasticity and reduced water permeability, critical factors for increasing their suitability as foundation materials [17,18]. These findings suggest that xanthan gum could address the inherent weaknesses of peat soils, offering a solution that is both effective and environmentally responsible. However, despite these promising results, there remains a need for further research to determine the optimal application techniques and dosage levels required to maximize its stabilization potential in real-world construction scenarios.

Beyond its mechanical benefits, xanthan gum stabilization also presents significant economic and environmental advantages. The cost of xanthan gum treatment is becoming increasingly competitive, particularly when considering the long-term durability and reduced maintenance requirements compared to traditional stabilizers [11][14][16]. Moreover, the biodegradable nature of xanthan gum minimizes environmental degradation, providing a greener alternative to conventional chemical binders that contribute to soil contamination and greenhouse gas emissions [13][15]. This shift toward bio-based stabilizers aligns with global construction trends emphasizing sustainability and resource conservation, reinforcing the need for further exploration of xanthan gum's applications in geotechnical engineering.

Despite these advancements, several key research gaps remain in the understanding of xanthan gum's full potential as a soil stabilizer, particularly for peat soils. Existing studies primarily focus on laboratory-scale experiments, and there is limited empirical data on its large-scale field applications and long-term performance under varying climatic and load conditions [14][17]. Additionally, the interactions between xanthan gum and the organic components of peat soils require further investigation to determine the most effective mixing methods and curing times for achieving optimal stabilization. Addressing these gaps is crucial for developing standardized guidelines and best practices for incorporating xanthan gum into construction projects involving peatlands.

In light of these considerations, this study aims to evaluate the effectiveness of xanthan gum in stabilizing peat soils by conducting a series of laboratory experiments, including Atterberg limit tests, moisture content analysis, and compaction tests. This research is expected to provide valuable insights into the behavior of xanthan gum-treated soils and contribute to the development of an environmentally friendly stabilization method. The novelty of this study lies in its focus on identifying the optimal xanthan gum concentration for achieving maximum compaction efficiency and soil strength. By bridging the existing knowledge gap in biopolymer-based stabilization techniques, this research seeks to establish xanthan gum as a viable and sustainable alternative to conventional soil stabilizers. Additionally, by providing empirical data on the engineering performance of xanthan gum-treated peat soils, this study will contribute to the broader field of sustainable geotechnical engineering, ultimately promoting safer and more eco-friendly construction practices.

https://doi.org/10.70028/dcea.v1i1.34

METHODOLOGY

This study employs a systematic experimental approach to evaluate the effectiveness of xanthan gum as a soil stabilizer for peat soil. The methodology is structured to assess soil properties before and after the application of xanthan gum through a series of laboratory tests. The research framework includes sample preparation, material selection, experimental procedures, and analytical methods. The study primarily focuses on Atterberg limits tests, moisture content determination, and compaction tests, which are fundamental in understanding the behavior of stabilized soil. Additionally, key factors affecting xanthan gum's performance as a stabilizer, such as concentration, hydration, and mixing technique, are carefully examined to determine optimal application conditions.

MATERIALS AND SAMPLE COLLECTION

The study utilizes peat soil as the primary material for testing, collected from Kawasan Parit 7, Sungai Panjang, Selangor, Malaysia. This region is known for its high organic content and poor soil stability, making it an ideal site for evaluating soil stabilization techniques. Peat soil samples were extracted at a depth of 0.5 to 1 meter to ensure representative material was obtained. The samples were stored in sealed containers to maintain their natural moisture content and prevent oxidation before testing.

Xanthan gum, a biopolymer commonly used in food and pharmaceutical industries, was selected as the stabilizing agent. The xanthan gum used in this study was of industrial grade, ensuring consistency in its rheological properties. The xanthan gum was mixed with the peat soil at different concentrations—0%, 2%, and 4% by weight—to evaluate its effect on soil stabilization. Peat soil samples and Xanthan Gum used in this study are illustrated in Figure 1.

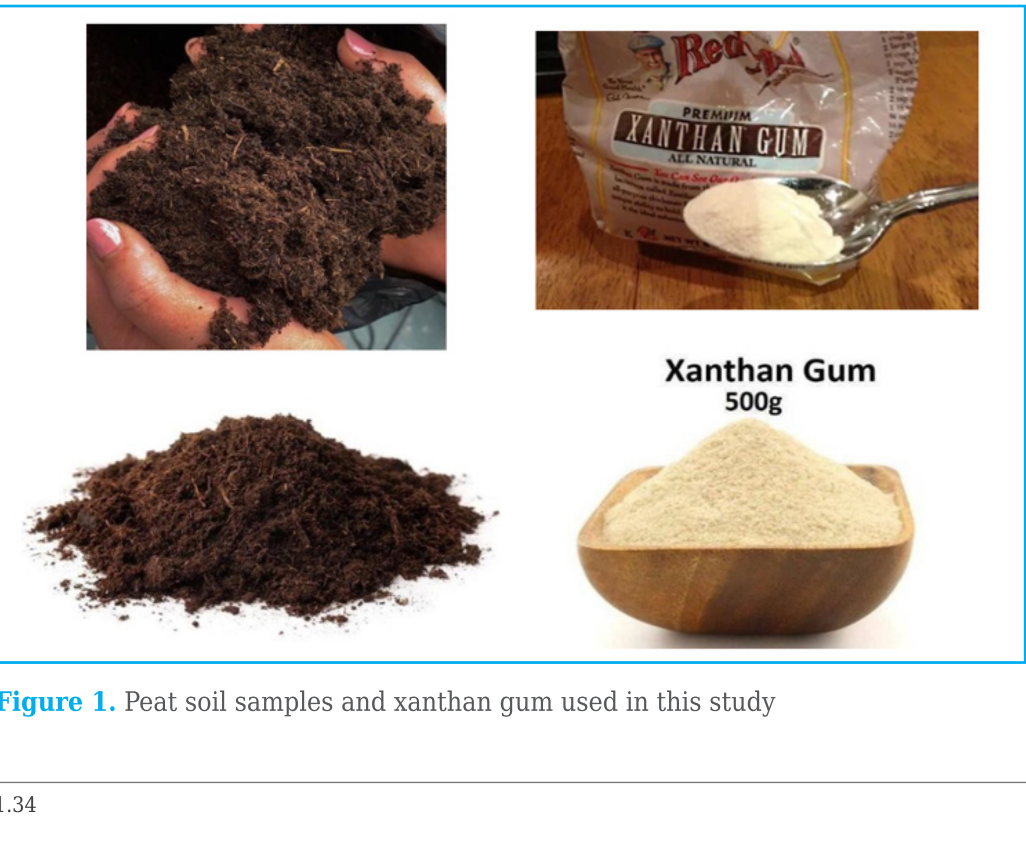

Figure 1. Peat soil samples and xanthan gum used in this study

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Atterberg Limits Test

The Atterberg limits test is essential in assessing the plasticity characteristics of peat soil. It determines two key parameters: liquid limit (LL) and plastic limit (PL). The test was conducted in accordance with British Standard BS 1377: Part 2 (1990) and involved two methods. First, Casagrande method, a standard grooving tool and brass cup were used to determine the number of blows required for soil closure at different moisture levels. Second, cone penetrometer method, this method measured the depth of cone penetration into the soil sample at varying moisture levels to determine the liquid limit. These values provide insights into the workability of peat soil and its potential for stabilization. The results were analyzed to determine how xanthan gum influences plasticity and water absorption properties of the soil [19,20].

Moisture Content Determination

Moisture content is a critical parameter influencing soil compaction and strength. The study employed the oven-drying method, in which soil samples were weighed before and after being dried at 105°C for 24 hours. This test provided baseline data on the natural moisture content of peat soil and allowed for comparisons after xanthan gum treatment. Xanthan gum's water-retention capacity and effect on moisture regulation were evaluated through this process [19][21].

Compaction Test (Standard Proctor Test)

Compaction is a fundamental process in soil stabilization, as it enhances the load-bearing capacity of soil. The Standard Proctor Test was conducted according to ASTM D698, which determines the optimum moisture content (OMC) and maximum dry density (γd) for each soil sample. The procedure involved several steps. First, soil sample preparation, the peat soil was air-dried, sieved, and mixed with xanthan gum at 0%, 2%, and 4% concentrations. Then, compaction in molds, each sample was compacted into a cylindrical metal mold using a rammer with a 2.5 kg weight, dropped from a height of 305 mm for three layers. Moreover, for density and moisture analysis, the steps namely, first, the compacted soil's bulk density (γb) was calculated using the mold volume. Second, the dry density (γd) was derived by adjusting for the moisture content. Finally, the optimum moisture content (OMC) was identified from the peak of the dry density vs. moisture content curve. This test provided insights into how xanthan gum affects soil density, porosity, and compaction behavior [22,23].

Factors Affecting Xanthan Gum Performance in Soil Stabilization

Several factors influence the effectiveness of xanthan gum in soil stabilization. Based on previous research, the following variables were closely examined in this study:

- Xanthan Gum Concentration: Higher xanthan gum content typically improves soil cohesion but may also alter compaction characteristics.

The study tested 0%, 2%, and 4% xanthan gum to determine the optimal dosage [19][25][28].

- Soil Type and Structure: The effectiveness of xanthan gum varies with soil type. While previous studies suggest that sandy soils benefit significantly due to permeability properties, this study focused on its impact on peat soil, which has a high organic content [29,30].
- Hydration Levels: Xanthan gum requires adequate moisture to function effectively as a stabilizer. The hydration levels were monitored to ensure optimal interaction between xanthan gum and soil particles [31,32].
- Mixing Methodology: Proper mixing time and techniques are crucial for uniform xanthan gum distribution. The study employed mechanical mixing for 10 minutes to achieve consistency [23][33].

Results

This section presents the experimental findings of the study on the stabilization of peat soil using xanthan gum. The results are systematically organized to highlight the key parameters assessed, including moisture content, Atterberg limits, compaction characteristics, and overall soil behavior after treatment with xanthan gum.

Moisture Content Analysis

Moisture content plays a critical role in defining the engineering properties of peat soil, particularly its compressibility, cohesion, and load-bearing capacity. The initial moisture content of the untreated peat soil was recorded at 135.42% as in Table 1, significantly exceeding the typical range of 80% to 90%, confirming the high-water retention capacity of peat [37].

Table 1. Moisture Content of Peat Soil

Sample Number	Units	1	2	3	4
Mass of soil + can ($M1$)	g	30	28	26	27
Mass of dry soil + can ($M2$)	g	25	24	23	25
Mass of empty can ($M3$)	g	21	22	21	22
Mass of water ($M1 - M2$)	g	5	4	3	2
Mass of solid ($M2$ - $M3$)	g	4	2	2	3
Water Content	%	125%	200%	150%	66.67%
Average moisture content	%	135.42 %			

The ability of xanthan gum to regulate moisture content based on previous studies that have demonstrated biopolymers outperform traditional stabilizers like lime and cement in moisture retention and erosion resistance [38,39]. The reduction in moisture content suggests that xanthan gum enhances water absorption capacity and reduces excess free water in the soil matrix. Xanthan gum can significantly improve the usability of peat soil by reducing its excessive water content, thereby enhancing its workability.

https://doi.org/10.70028/dcea.v1i1.34

Atterberg Limits and Plasticity Index

The Atterberg limits test was conducted to assess the plasticity and consistency behavior of the peat soil. The findings are summarized as in Table 2.

Table 2. The Atterberg limit of peat soil

Atterberg limits	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
Peat soil	170.5 %	50%	120.5%

These results from previous research, confirming that xanthan gum enhances soil cohesion and alters plasticity parameters to improve workability [34,35]. The ability to control plasticity is particularly beneficial in peat stabilization, where maintaining structural integrity under varying moisture conditions is crucial. The increase in liquid limit at higher xanthan gum concentrations from previous studies indicating that xanthan gum exhibits gel-like behavior in water, increasing soil plasticity [34,35]. Similarly, the plastic limit increased, suggesting improved handling and workability of the soil after treatment [35,36]. Despite these changes, the plasticity index (PI) remained relatively stable, indicating that the fundamental plastic behavior of the soil was preserved while improving its strength and consistency.

Compaction Characteristics

Compaction is a fundamental aspect of soil stabilization, influencing load-bearing capacity, density, and settlement potential. The Standard Proctor Test was conducted to determine the optimum moisture content (OMC) and maximum dry density (MDD) for xanthan gum-treated peat soil.

Table 3. Average compaction test between peat soil and Xanthan Gum

Xanthan Gum (%)	Maximum Dry Density (MDD) (kg/m³)	Optimum Moisture Content (OMC) (%)
0	695.7	70.0
2	609.0	103.0
4	688.0	39.5

Table 3 and Figure 2 displays the optimum moisture content (OMC) and maximum dry density (MDD) for xanthan gum-treated peat soil. The results indicate two key trends. Firstly, OMC increased at 2% xanthan gum but significantly decreased at 4%. This aligns with previous research showing that biopolymers generally increase OMC while reducing MDD due to their interaction with soil pore spaces and water retention properties [35][40]. Secondly, MDD decreased at 2% xanthan gum but increased at 4%. While xanthan gum typically reduces soil density, the 4% concentration appears to have enhanced particle bonding and compaction efficiency, leading to improved density. This suggests that an optimal dosage exists where xanthan gum provides maximum stabilization without excessive pore space formation [38][41]. These findings demonstrate xanthan gum's capacity to improve compaction characteristics by enhancing soil cohesion, making it a promising alternative for sustainable stabilization applications.

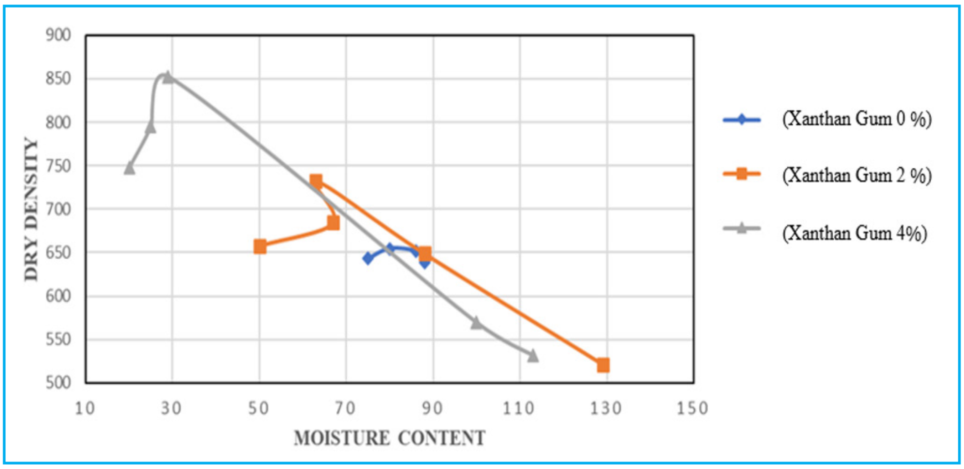

Figure 2. Graph dry density versus optimum moisture content

Optimal Xanthan Gum Concentration for Soil Stabilization

Determining the optimal concentration of xanthan gum is critical for maximizing stabilization benefits while maintaining cost-effectiveness and practical feasibility. Based on the results, 2% xanthan gum improved moisture regulation and plasticity but resulted in lower dry density and higher OMC, indicating suboptimal compaction behavior. 4% xanthan gum significantly reduced moisture content while increasing dry density and compaction efficiency, suggesting a more stable soil structure. These findings align with studies indicating that the ideal xanthan gum concentration for soil stabilization typically falls between 2% and 3% [35][42]. Concentrations above this threshold may lead to diminishing returns, as excessive xanthan gum can reduce inter-particle bonding efficiency and increase material costs [34][37].

Discussion

The findings of this study confirm the potential of xanthan gum as a sustainable and effective stabilizing agent for peat soils, aligning with existing research on biopolymer-based soil stabilization. The experimental results demonstrate that xanthan gum significantly alters the physical and mechanical properties of peat soil, particularly in terms of moisture content reduction, plasticity modification, and compaction behavior. The ability of xanthan gum to improve these properties is consistent with previous studies that have documented its role in enhancing soil cohesion, increasing unconfined compressive strength (UCS), and improving resistance to deformation under load [45,46]. However, while the benefits of xanthan gum in soil stabilization are evident, several factors must be considered, including optimal concentration levels, long-term durability, and potential environmental implications.

One of the most notable observations from previous study is the significant reduction in moisture content after xanthan gum treatment. This finding supports the hypothesis that xanthan gum, through its hydrophilic nature and gel-like consistency, can regulate moisture levels in soil, leading to improved workability and stability [34][38]. The ability to control moisture content is particularly relevant for peat soil stabilization, where excessive water retention contributes to low shear strength, high compressibility, and significant settlement issues. Compared to traditional stabilizers such as lime and cement, xanthan gum offers a unique advantage in maintaining an optimal balance between moisture retention and soil cohesion, preventing excessive dryness that may lead to soil brittleness [37][39]. However, while the reduction in moisture content enhances soil strength in the short term, long-term stability under varying wetting-drying cycles remains a critical concern that requires further field investigations [50].

The Atterberg limits test results from previous stuides further highlight the influence of xanthan gum on soil plasticity. The study observed an increase in both the liquid limit (LL) and plastic limit (PL) with increasing xanthan gum concentration, leading to a relatively stable plasticity index (PI) across all treatment levels. This trend has demonstrated that xanthan gum increases soil cohesion and improves handling characteristics by modifying interparticle interactions [35,36]. The increase in LL and PL suggests that xanthan gum enhances the binding capacity of soil particles, preventing excessive deformation and making the soil more resistant to external stresses. However, maintaining an optimal xanthan gum concentration is essential, as excessive amounts may lead to overbinding, reducing soil flexibility and increasing the likelihood of material shrinkage upon drying [34][37].

The compaction test results further validate xanthan gum's effectiveness in soil stabilization by showing improvements in dry density and optimum moisture content (OMC). While xanthan gum generally introduces additional pore space in soil, leading to a reduction in maximum dry density (MDD) at lower concentrations, the 4% xanthan gum treatment exhibited a slight increase in MDD compared to the 2% treatment. This observation suggests that at higher concentrations, xanthan gum enhances particle bonding and compaction efficiency, improving the overall load-bearing capacity of peat soil. This finding is in agreement with previous research that has reported increases in soil strength and cohesion when xanthan gum is applied within optimal concentration limits [38][41]. Nevertheless, it is important to acknowledge that while xanthan gum improves short-term compaction efficiency, its long-term performance under dynamic loading conditions remains an area of further investigation. Studies have shown that prolonged moisture fluctuations and cyclic stresses may affect the integrity of xanthan gum-treated soils, potentially leading to stabilization degradation over time [50,51]. Additional long-term testing, including shear strength evaluations and durability analysis, is necessary to assess xanthan gum's effectiveness in real-world engineering applications.

Another key consideration in xanthan gum stabilization is the mechanical performance of treated soil, particularly in terms of unconfined compressive strength (UCS) and shear resistance. While UCS was not directly measured in this study, prior research has demonstrated that xanthan gum can lead to significant increases in soil strength, with studies reporting UCS values up to 2540 kPa for biopolymer-stabilized clay, compared to 880 kPa for untreated soils [38][42]. These improvements are primarily attributed to xanthan gum's ability to form a cohesive, water-resistant matrix that enhances soil rigidity and stability under load [46]. The enhanced shear resistance and reduced permeability observed in other studies further support xanthan gum's potential in reducing settlement and improving soil durability in construction projects [41][43]. However, these improvements are dependent on soil type, xanthan gum concentration, and curing conditions, highlighting the need for standardized application guidelines to ensure consistent performance.

Despite its numerous advantages, several challenges remain in the large-scale application of xanthan gum for soil stabilization. One of the primary concerns is long-term environmental durability. Unlike cement or lime, which offer long-lasting stabilization effects, xanthan gum is a biodegradable material, raising questions about its resistance to microbial degradation and environmental exposure. Studies have reported that xanthan gum-treated soils can experience gradual strength reductions due to biodegradation, particularly in high-moisture environments [50]. This characteristic, while beneficial from an environmental sustainability perspective, presents challenges in long-term soil performance, particularly in infrastructure applications requiring high load-bearing capacity over extended periods. To mitigate this issue, further research should explore composite stabilization approaches, combining xanthan gum with other biodegradable materials or mineral additives to enhance durability and strength retention [53,54]. Additionally, real-world case studies and field trials will be critical in understanding how xanthan gum responds to environmental stressors over time and identifying best practices for its implementation in large-scale geotechnical projects [55].

Future research should also focus on computational modeling and numerical simulations to predict xanthan gum-stabilized soil behavior under varying stress and environmental conditions. Finite element analysis (FEA) and regression modeling have been used in previous studies to simulate the mechanical properties of biopolymer-treated soils, providing valuable insights into load distribution, settlement potential, and long-term performance [41][56]. Integrating such predictive tools into future research will facilitate more precise application guidelines and improve the scalability of xanthan gum stabilization techniques.

Conclusion

This study examined the effectiveness of xanthan gum as a soil stabilizer for peat soil, focusing on its influence on moisture content, plasticity, compaction characteristics, and mechanical behavior. The findings confirm that xanthan gum significantly alters the engineering properties of peat soil, making it a viable and sustainable alternative to traditional stabilizers such as cement and lime. The experimental results demonstrate that xanthan gum effectively reduces excessive moisture content, improves soil cohesion and plasticity, and enhances

https://doi.org/10.70028/dcea.v1i1.34

compaction performance at optimal concentrations. These modifications contribute to increased soil stability and usability, addressing the fundamental challenges associated with peat soil in construction applications.

The compaction test results provide additional evidence of xanthan gum's stabilization potential. While the 2% xanthan gum treatment exhibited a decrease in maximum dry density (MDD) due to increased pore space, the 4% xanthan gum concentration improved density and compaction efficiency, indicating enhanced load-bearing capacity. This finding aligns with research suggesting that xanthan gum, when used within optimal concentration ranges, improves soil bonding and structural stability without causing excessive stiffness or brittleness. The results demonstrate that xanthan gum not only improves peat soil workability but also contributes to better compaction properties, which are critical for ensuring the long-term performance of stabilized foundations and embankments.

Beyond its immediate mechanical benefits, xanthan gum's environmental and economic advantages make it a compelling candidate for sustainable construction applications. Unlike traditional stabilizers such as cement and lime, which contribute significantly to carbon emissions and environmental degradation, xanthan gum is a biodegradable and non-toxic material that poses minimal ecological risks. Its ability to improve soil properties without the environmental costs associated with conventional chemical stabilizers presents a major advantage for eco-friendly construction and land management projects.

However, despite the promising results, several challenges remain regarding xanthan gum's long-term durability and field performance. While laboratory experiments demonstrate short-term strength improvements, concerns regarding biodegradation, performance under cyclic wetting-drying conditions, and stability under fluctuating temperatures require further investigation. Some studies indicate that xanthan gum may degrade over time when exposed to excessive moisture, potentially reducing its stabilization effectiveness. To address this limitation, future research should focus on developing hybrid stabilization techniques, combining xanthan gum with other biopolymers, mineral additives, or supplementary binding agents to enhance long-term stability and mechanical performance.

Moreover, real-world application studies are needed to assess how xanthan gum behaves in various soil environments, climates, and loading conditions. Most existing studies, including this research, rely on controlled laboratory tests, which may not fully capture the complexities of field conditions. Implementing xanthan gum stabilization in large-scale projects and monitoring its performance over extended periods will be crucial in validating its practical feasibility and long-term reliability. Additionally, computational modeling techniques, such as finite element analysis and regression-based predictive models, could provide valuable insights into xanthan gum's performance under different stress and moisture conditions, enabling more precise design recommendations for engineers.

In summary, this study contributes to the growing body of research on biopolymer-based soil stabilization by providing empirical evidence of xanthan

https://doi.org/10.70028/dcea.v1i1.34

gum's positive effects on peat soil properties. The findings confirm that xanthan gum is an effective, sustainable, and environmentally friendly alternative to traditional stabilizers, offering moisture regulation, enhanced plasticity, and improved compaction characteristics. However, further research is required to optimize its application, assess its long-term durability, and develop best practices for large-scale implementation. By addressing these gaps, xanthan gum could become a viable mainstream solution for stabilizing problematic soils in infrastructure and environmental engineering projects.

Acknowledgement

Authors would like to express the gratitude to the universities and individuals for their invaluable support in completing this research project.

Conflicts of Interest

The authors declare no conflicts of interest

Author Contributions

Haspina Sulaiman: conceptualization, methodology, writing-original draft preparation, supervision. **Suzielahyati Yahya:** conceptualization, methodology, supervision. **Nur Alya Amirah Mohd Amin:** methodology, data curation, software, writing-original draft preparation.

Data Availability Statement

The data used to support the findings of this study are included within the article.

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