Geotechnical Evaluation of Sawdust-Derived Biochar as a Sustainable Stabilizer for Clayey Soils in Nueva Ecija

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***Abstract*: This research investigates the potential of sawdust-derived biochar as a sustainable soil stabilizer for clayey soils in Nueva Ecija, Philippines. Conventional stabilizers, such as cement and lime, are associated with high carbon emissions, prompting interest in environmentally friendly alternatives. In this study, sawdust—a common agricultural byproduct—was converted into biochar and mixed with clay soil at varying proportions (0%, 5%, 10%, and 12% by weight). Laboratory evaluations included Standard Proctor Compaction, California Bearing Ratio (CBR), and Direct Shear Tests. The 10% biochar content emerged as the most attractive content of biochar for improvement in shear strength and compaction characteristics, while 12% contributed to minimizing the swelling potential. However, even with such improvements, none of the CBR values termed the subgrade suitable, thus indicating biochar is better used as a supplemental stabilizer. It is concluded that sawdust biochar is a promising material for sustainable geotechnical applications, especially when mixed with other stabilizing agents.**

***Keywords*: Biochar, Soil stabilization, Sawdust-derived biochar, Clayey soil, California Bearing Ratio (CBR), Shear strength, Swelling potential, Sustainable engineering, Geotechnical applications, Nueva Ecija.**

1. Introduction

Soil reinforcement is an important topic in geotechnical engineering, especially in infrastructure construction where an attractive balance between safety, economy, and durability can be achieved. Clayey soils, which are widespread in several areas in the Philippines, including Nueva Ecija, generally have low shear strength, high plasticity, and undergo considerable volumetric changes with a change in moisture content. However, these properties can have a detrimental effect on the structural performance of pavements, buildings, and other civil systems if they are not well modified.

Conventional methods of soil stabilization often use chemical stabilizers, such as cement or lime, to enhance soil properties. However, these materials are energy-expensive to process and become a large source of greenhouse gases in the atmosphere. In light of increasing global awareness of sustainable development and climate change mitigation, the quest for environmentally friendly substitutes has become more important.

Biochar is a carbon-rich material produced from biomass pyrolysis in oxygen-limited environments and is of great interest in both agricultural and environmental engineering. Made of agricultural waste such as sawdust, biochar has been reported to possess merits such as great porosity, cation exchange capacity, and the possibility of carbon sequestration. Recent investigations show that biochar can enhance some geotechnical index characteristics of soil, such as shear strength, permeability, and compaction behavior.

In this paper, mahogany sawdust-based biochar as a possible stabilizer for clay-type soils in Nueva Ecija is explored. To be more specific, it analyzes the impact of the change in biochar content (0%, 5%, 10%, and 12% by weight) on the physical and mechanical properties of the soil, according to standard laboratory tests. The objective was to determine if biochar would be a viable alternative or additive to traditional stabilizers on Philippine soils.

2. Review of Related Literature

Soil stabilization has been a concern of geotechnical engineers for a long time, especially in areas with problematic soils that have the potential for expansion or low strength, as these may cause problems for structural stability. Commonly, cement and lime are the conventional materials that are utilized to enhance the strength of the soil and reduce its plasticity. However, these materials suffer from environmental limitations, especially high carbon emissions during manufacture. As reported by Van Nguyen et al. (2019), the production of cement contributes almost 8% of global CO_2 emissions overall, underlining how it is urgently needed to replace non-sustainable materials used in construction [6].

In recent years, biochar has received significant attention as a sustainable soil enhancer, originally in agriculture and now also in geotechnical use. Biochar is made by pyrolyzing organic materials (for example, crop wastes, wood chips, or sawdust). In soil stabilization, its porous structure, high specific surface area, and chemical activity with soil particles provide an opportunity to improve physical strength and reduce water-holding capacity [1].

Research by Kinuthia et al. (2017) has shown that biochar mixed with weak soil can improve compressive strength and decrease swelling potential [2]. Similarly, Latifi et al. (2016) observed that the CBR and UCS of clayey soils increased with the addition of biochar [3]. These enhancements are mainly due to void filling, friction strengthening inter-particle contact, and cooperation with other stabilizers to form cementitious chains made of biochar.

A study by Thomas et al. (2018) studied the sawdust-derived biochar and reported that high lignin content was responsible for the structural integrity of biochar, enabling it to be applied in soil for the long term [5]. Moreover, Mahapatra and Dutta (2021) pointed out that the particle size and application rate of biochar play an important role in the stabilizing efficiency of biochar [4]. The majority of reports indicate maximum stabilization effectiveness at an intermediate biochar application rate, which generally falls between 5% and 12%, with no further increase in mechanical properties or leachate reduction at higher application rates.

In the context of the Philippines, sawdust as a type of agricultural waste is an opportunity for waste utilization in a circular approach. However, indigenous studies of biochar use in geotechnical applications seem to be very scarce. This gap highlights the necessity of region-specific research to investigate the interaction of biochar and native soils in local climate and geological conditions.

This study contributes to this growing body of knowledge by evaluating sawdust-derived biochar's effectiveness as a stabilizer for clayey soil in Nueva Ecija. It draws upon previous international findings while providing context-specific insights that can inform sustainable construction practices in the Philippines.

3. Conceptual Framework

This study is anchored on the principle that soil properties can be enhanced through the incorporation of natural, carbon-based stabilizing agents such as biochar. Soil stabilization involves the modification of soil behavior to improve its engineering performance—particularly its strength, compaction characteristics, and resistance to deformation or moisture-related changes. In this context, biochar functions not only as a physical filler but also as a modifier that interacts with soil particles through physico-chemical processes.

The theoretical foundation of this study is based on soil mechanics and stabilization theory, which suggests that additives with high surface area and porosity can improve inter-particle friction, reduce plasticity, and enhance shear strength. Biochar's porous structure and ability to retain moisture and nutrients make it beneficial in agricultural soils, and these same properties are hypothesized to influence geotechnical behavior when applied to clayey soils.

The framework of the study is further guided by sustainable engineering practices, emphasizing the utilization of agricultural waste (sawdust) to produce value-added materials while reducing environmental impact. Instead of relying solely on traditional stabilizers like cement and lime—which contribute to greenhouse gas emissions—this study promotes the use of biochar as a greener alternative or supplement.

The conceptual relationship among the key variables is illustrated below:

The study hypothesizes that increasing biochar content will result in improvements in soil strength and compaction behavior up to an optimal point, beyond which the benefits may plateau or decrease. The study seeks to provide insight into these relationships and to generate empirical data for sustainable soil stabilization practice, and to advocate for the use of biochar in geotechnical engineering practice in the Philippines.

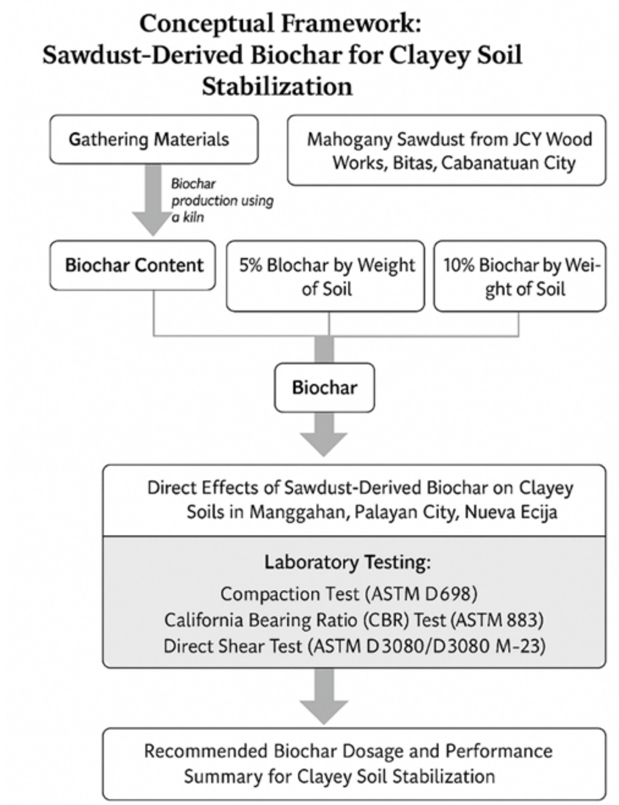

Fig. 1. Conceptual Framework

4. Hypothesis of the Study

This research is premised on the supposition that clayey soil whenever amended with biochar derived from sawdust will enhance its geotechnical characteristics. The hypotheses are proposed as follows:

A. Null Hypothesis (H_0)

There is no significant impact on the compaction properties, bearing capability, shear strength, and swelling tendency of clayey soils in Nueva Ecija as a function of the amount of biochar from sawdust.

B. Alternative Hypothesis (H_1)

Adding biochar produced from carbonization of sawdust proves to effectively enhance the compaction, bearing capacity, shear and the swelling properties of the clayey soils of Nueva Ecija with peak responses observed at an optimum biochar content.

5. Research Problem and Objectives

Clay is commonly encountered in many areas in Nueva Ecija province, Philippines which is difficult to handle in the civil engineering design because of its low strength, high plasticity and high swelling and shrinkage properties. Such properties tend to cause reduced load bearing capacity and structure where moisture is changing. Alternative materials such as cement and lime have long been used for stabilization purposes, but their adverse impact on the environment (namely carbon emissions and resource consumption) have called into question the long-term sustainability of such practices.

Due to the availability of agrowaste in the area like sawdust, biochar from this source may be an environment friendly option. Although the geotechnical effectiveness of sawdust biochar on clayey soils has not been well studied in the local context. It is the objective of this study to investigate the biochar as a potential alternative or supplement to traditional stabilizers and determine the corresponding optimal dosage of biochar.

Hence, the central problem addressed by this study is:

Can sawdust-derived biochar significantly enhance the geotechnical properties of clayey soil in Nueva Ecija, and what application rate yields the most favorable stabilization outcomes?

Objectives of the Study

General Objective:

To assess the potential of sawdust-derived biochar as a sustainable soil stabilizing agent for clayey soils in Nueva Ecija.

Specific Objectives:

To produce biochar from locally sourced sawdust through pyrolysis.

To apply varying biochar dosages (0%, 5%, 10%, and 12% by weight) to clayey soil samples.

To evaluate the effects of biochar on soil compaction (Maximum Dry Density and Optimum Moisture Content), bearing capacity (California Bearing Ratio), and shear strength (Direct Shear Test).

To identify the optimal biochar dosage that yields the best improvement in soil strength and stability.

To analyze the potential of biochar as a supplementary or alternative stabilizer to conventional methods from both geotechnical and sustainability perspectives.

A. Objectives

1. The primary aim of this study is to assess the effectiveness of biochar generated from sawdust as a long-term soil stabilizer. Specifically, the objectives include:
2. To assess the influence of mahogany sawdust-derived biochar on the strength and compaction behavior of soil.
3. To investigate the potential of mahogany sawdust-derived biochar to enhance the water retention capacity of soil.
4. To determine the optimal dosage of mahogany sawdust-derived biochar required to achieve effective soil stabilization.

6. Significance of the Study

This study holds significance in both engineering and environmental contexts, particularly in addressing the dual challenge of problematic clayey soils and the sustainable management of agricultural waste in Nueva Ecija, Philippines.

From a geotechnical engineering perspective, the findings of this research may offer a viable solution to improve the performance of clayey soils using a locally available, cost-effective, and sustainable material. The enhancement of soil strength and stability through the use of sawdust-derived biochar could benefit infrastructure development projects—especially in rural or agricultural areas where soil conditions pose limitations.

From an environmental standpoint, this study supports waste valorization by converting sawdust, a common byproduct of lumber and furniture industries, into a value-added stabilizing material. This approach promotes circular economy principles by reducing waste, minimizing reliance on carbon-intensive stabilizers like cement and lime, and contributing to climate change mitigation.

Beneficiaries of this study include:

Local government units and engineers, who may adopt sustainable soil stabilization methods for roadworks and construction projects.

Environmental planners and researchers, who may use the study as a reference for integrating biochar into land development strategies.

Agricultural and wood-processing industries, which can explore new uses for their waste byproducts.

Future researchers, who may build upon this work to explore biochar blends, long-term performance, or field-scale validation in other soil types.

Ultimately, this study contributes to the growing body of knowledge on sustainable construction practices and promotes environmentally responsible engineering innovations suitable for local application.

7. Scope and Limitation of the Study

A. Scope of the Study

This study focuses on evaluating the effectiveness of biochar derived from sawdust as a soil stabilizing agent for clayey soils found in selected areas of Nueva Ecija, Philippines. The scope is limited to laboratory-scale testing and analysis. Specifically, the study investigates the effects of four biochar dosage levels (0%, 5%, 10%, and 12% by weight of dry soil) on the geotechnical properties of clayey soil.

The following are the main laboratory tests performed:

Standard Proctor Compaction Test – used to calculate Maximum Dry Density (MDD) and Optimum Moisture Content (OMC); the California Bearing Ratio (CBR) Test – to determine bearing capacity;

Shear-box – for determining the shear strength (cohesion and internal friction angle).

Biochar Biochar used in this research is produced from pyrolysing mahogany sawdust in controlled kiln. The local soil samples are collected and graded as per ASTM.

Limitations of the Study

The study is performed on laboratory scale, and field application or long-term durability is not assessed.

The use of only one clay soil and one type of biomass (mahogany sawdust) applied can limit the application of the results to other soils or regions.

External factors (such as rainfall, fluctuation of temperature, and microbial activities) that affect the performance of biochar-treated soil are not, however, considered in the model.

48 The potential effects of combining biochar with other stabilizers (e.g., lime, cement) have not been investigated although suggested for future work.

Notwithstanding these limitations, the study offers indispensable fundamental data on the performance of sawdust based biochar as a means of sustainable stabilizer and could be also utilized guidelines for further research and field validation.

8. Research Design

This paper uses a quantitative experimental research design to evaluate the suitability of sawdust-based biochar as a soil stabilizer for clayey soil. The method harvested controlled setting experiments on soil prepared with different contents of biochar: 0%, 5%, 10% and 12% by weight, to investigate the variations in geotechnical properties.

The biochar content were taken as the independent variable and maximum dry density (MDD), the optimum moisture content (OMC), California Bearing Ratio (CBR) and shear strength parameters from the direct shear test were considered as dependent factors in this study. Each type of biochar-soil blend was treated by a series of standard protocols in order to standardize the process and the results.

The study evaluates the relative benefit of enhanced growth under biochar-treated soils compared to 0% biochar (i.e., the control sample), using a relative-to-control based design. The graphical and statistical methods of analysis were employed in order to follow the shifting of trends and to select the optimal stabilization dose.

This experimental design gave us the advantage of easily performing a well-defined and systematic study of the influence of various amounts of biochar on the physical and mechanical responses of the clayey soil in the laboratory.

9. Locale of the Study

The research took place in Palayan City in the province of Nueva Ecija in the Philippines. The clayey soils used for laboratory measurements were taken from an agricultural area in a rural village (Barangay Manggahan) comprising of vast hectares of agricultural lands and clay-type soil profile. This site was selected because of the frequent occurrence of difficult clayey soils that have often frustrated the construction of robust infrastructure throughout the region.

All of the laboratory tests were conducted in the Soil Mechanics and Materials Testing Laboratory of the Nueva Ecija University of Science and Technology (NEUST) - Sumacab Campus, which is equipped with the required tools for compaction, bearing capacity and shear strength tests. Pyrolysis of the sawdust into biochar was also done at NEUST using an improvised kiln that is suitable for controlled thermal decomposition.

The selection of Nueva Ecija as the study area is significant, as it represents both a source of agricultural waste materials (e.g., sawdust from local wood industries) and a region facing geotechnical challenges with clayey subsoils. Thus, the study not only addresses a local engineering concern but also promotes sustainable resource utilization within the province.

10. Research Instrument

This study utilized standard geotechnical testing equipment and laboratory procedures to assess the physical and mechanical properties of biochar-treated clayey soil. The following instruments and apparatuses served as the primary tools for data collection:

Standard Proctor Compaction Apparatus: Used to determine the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of soil samples in accordance with ASTM D698.

California Bearing Ratio (CBR) Testing Machine: Used to evaluate the bearing capacity of both untreated and treated soil samples following ASTM D1883. CBR values indicate the load-supporting capacity of subgrade soils.

Direct Shear Test Apparatus: Employed for determination of the shear strength (c and φ) of the soil according to ASTM D3080.

Drying Oven and Electronic Weighing Scale: Employed to determine the moisture content and ensure accurate preparation of biochar-soil mixtures.

Pyrolysis Kiln (Locally Fabricated):Utilized to convert mahogany sawdust into biochar under controlled thermal decomposition at low oxygen conditions.

Each instrument was calibrated and operated according to prescribed testing standards to ensure the reliability and accuracy of the data collected. The consistent application of these tools allowed for objective comparison across varying biochar concentrations.

11. Data Gathering Procedure

Data were collected in various stages, from material gathering to pre-treatment, and from laboratory testing of untreated soil and soil treated with the additives. The operations of these procedures were conducted with caution to obtain reproducibility for the measurement under all test conditions.

A. Collection of Materials

- soil samples were collected in Barangay Manggahan, Palayan City, Nueva Ecija. The samples were allowed to air dry, ground, and sifted to remove foreign materials and homogenize particle size.
- Hard wood, specifically Mahogany sawdust, that was obtained from a Nueva Ecija lumberyard was used as the precursor for biochar in this study.

B. Production of Biochar

- Pyrolysis of the sawdust was done in a locally fabricated kiln to low temperature, with inhibition of air supply. The biochar was cooled and then ground to a consistent particle size that could be mixed with soil.

C. Preparation of Soil-Biochar Mixtures

- Four biochar rates were applied to the soil: 0% (control) 5%, 10% and 12% as weight percentage of the dry soil. The agglomerates were homogeneously mixed for each blend to ensure homogeneous distribution of biochar..

D. Laboratory Testing

- Maximum dry density (MDD) and optimum moisture content (OMC) of the all mixtures were obtained using the standard Proctor compaction test.
- The compaction CBR test was conducted to determine the capacity of the treated soils to sustain loads.
- Shear strength properties (cohesion and angle of internal friction) were determined using the Direct Shear Test.

E. Data Recording and Analysis

- For both tests, the test results were written down, keyed and compared to each other, also in the context of different biochar dust concentrations. Graphical and statistical analyses were performed to find the most appropriate dosage by looking at trends.
- All experiments were performed following standardized conditions and procedures to guarantee scientific rigor and reproducibility of the findings according to ASTM recommendations.

12. Data Analysis Technique

Quantitative analysis of data from laboratory tests were carried out to evaluate the influence of different contents of biochar on the geotechnical properties of clayey soil. This was to enable comparison of performance of each biochar-soil mixture that is at 0%, 5%, 10% and 12% in relation to compaction characteristics, bearing capacity and shear strength.

The following techniques and tools were employed:

The following approaches and instruments have been used:

A. Descriptive analysis of the Data

The mean and the standard deviation of the measurements of each sample were calculated for each of the variables: Maximum Dry Density (MDD), Optimum Moisture Content (OMC), California Bearing Ratio (CBR), cohesion (c), and internal friction angle (φ) to evaluate general trends, as well as the variability of the measurements.

B. Graphical Representation

Line graphs and bar charts were used to visually illustrate the relationship between biochar dosage and each geotechnical parameter. These visual tools aided in identifying the optimal percentage of biochar for soil improvement.

C. Comparative Analysis

The performance of biochar-treated samples was directly compared with the control (0% biochar) to evaluate the degree of improvement across the tested parameters.

D. Interpretive Assessment

The results were assessed based on accepted engineering standards and literature benchmarks, particularly the minimum CBR requirements for subgrade suitability. Soil samples failing to meet these thresholds were considered inadequate for use as stabilized subgrade without supplementary treatment.

E. Conclusion Derivation

Based on the statistical and graphical outputs, conclusions were drawn regarding the most effective biochar dosage for enhancing the strength and stability of clayey soil. Recommendations for further research and potential composite stabilization strategies were also formulated.

All analyses were conducted using Microsoft Excel and standard calculation procedures, ensuring accuracy, clarity, and reproducibility of findings.

13. Ethical Consideration

This study was conducted in adherence to the ethical standards of academic research and engineering practice. As the research involved no human or animal subjects, the ethical risks were minimal. However, the following considerations were observed to maintain the integrity, transparency, and social responsibility of the research:

A. Environmental Responsibility

The collection of soil and sawdust samples was done with care to avoid environmental degradation. No chemical pollutants or hazardous substances were introduced during the testing procedures. Biochar production was carried out using a controlled pyrolysis process to minimize emissions.

Table 1
Compaction characteristics

Biochar Content (%)	Maximum Dry Density (kN/m³)	Optimum Moisture Content (%)
0	17.2	19.0
5	17.0	19.5
10	16.8	20.0
12	16.6	20.3

B. Proper Waste Management

All testing materials, including residual soil and biochar mixtures, were disposed of according to laboratory safety and waste management protocols. No harmful substances were released into the environment.

C. Permission and Access

Prior consent was obtained from local authorities for soil collection in Barangay Manggahan, Palayan City. The use of laboratory facilities at NEUST – Sumacab Campus was officially permitted.

D. Academic Integrity

The study strictly followed protocols to avoid plagiarism, data fabrication, or misrepresentation. All references to existing literature, standards (e.g., ASTM), and tools used were properly cited.

E. Transparency of Results

Findings were presented objectively, regardless of whether they supported the expected outcomes. Negative or inconclusive results were documented and discussed to support future research directions.

By following such ethical considerations, the research adds responsibly to the knowledge base in the field of geotechnical engineering and sustainability in through such environmental approaches.

14. Presentation, Analysis, and Interpretation of Data

This chapter gives the results of the experiments for which soil samples have been treated with different rates of sawdust biochar. Parameters considered are compaction, bearing capacity, shear strength and swelling nature of the soil mass. Data were analyzed to determine trends and efficacy of biochar as a soil stabilizer.

As shown in the table above, increasing the biochar content resulted in a gradual decrease in Maximum Dry Density (MDD) and a slight increase in Optimum Moisture Content (OMC). This trend is attributed to the low specific gravity and porous nature of biochar, which reduces overall soil density while increasing its water-holding capacity.

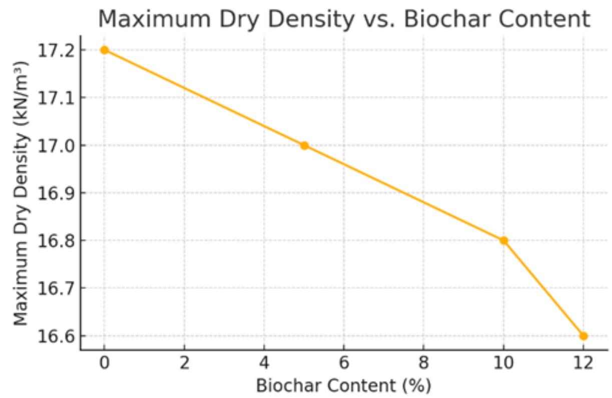

Fig. 2. Maximum Dry Density Vs. Biochar

A. Chart 1: Maximum Dry Density vs. Biochar Content

Table 2

Biochar Content (%)	CBR (%)
0	3.5
5	4.8
10	5.6
12	5.3

The CBR values increased with the addition of biochar up to 10%, peaking at 5.6%, before slightly declining at 12%. Although this improvement demonstrates the potential of biochar to enhance load-bearing capacity, the values remain below the typical minimum CBR requirement (≥8%) for subgrade suitability, indicating that biochar alone may not suffice.

B. Chart 2: CBR vs. Biochar Content

Both cohesion and friction angle showed measurable improvement with increasing biochar content, particularly at 10%, indicating enhanced shear strength. The decline at 12% may be due to excess biochar reducing particle interlocking or creating discontinuities within the soil matrix.

Biochar significantly reduced the swelling potential of clayey soil. The most notable decrease occurred at 12%, showing that biochar is effective in limiting moisture-induced volume changes—critical for expansive soils.

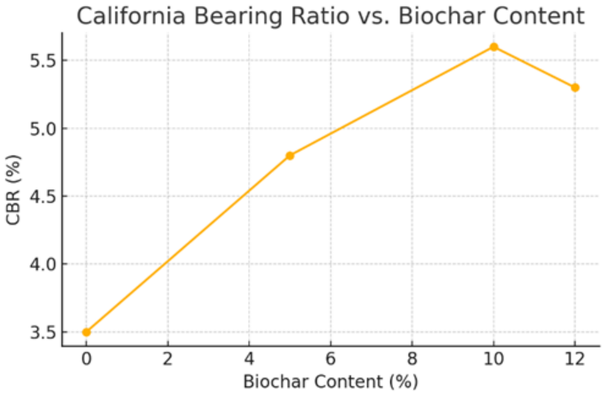

Fig. 3. California Bearing Ratio Vs. Biochar

Table 3

Biochar Content (%)	Cohesion (kPa)	Friction Angle (°)
0	25	22
5	28	24
10	32	26
12	30	25

Table 4

Biochar Content (%)	Swelling Potential (%)
0	12.0
5	9.5
10	7.0
12	5.8

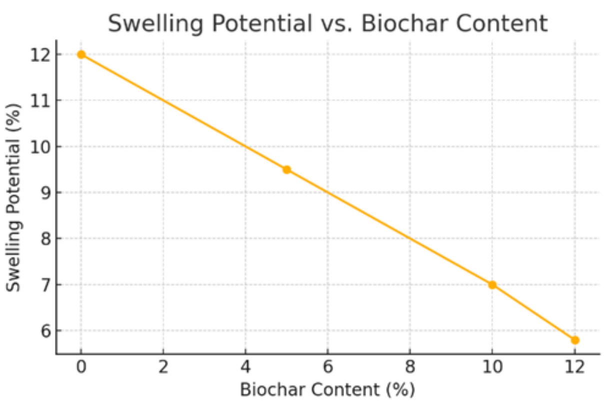

Fig. 4. Swelling Potential Vs. Biochar

C. Chart 3: Swelling Potential vs. Biochar Content

Summary of Findings

The optimum biochar dosage for balanced improvement in strength and moisture sensitivity is 10% by weight.

CBR results, while improved, remain below subgrade suitability thresholds, suggesting the need for composite stabilization with other agents.

Biochar is most effective in reducing swelling potential and moderately improving shear strength and compaction properties.

15. Summary

This study was conducted to assess the effectiveness of sawdust-derived biochar as a sustainable soil stabilizing agent for clayey soils in Nueva Ecija, Philippines. Motivated by the need to find environmentally friendly alternatives to conventional stabilizers like cement and lime, the research focused on utilizing agricultural waste—specifically mahogany sawdust—converted into biochar through pyrolysis.

Soil samples were treated with four different biochar dosages: 0% (control), 5%, 10%, and 12% by weight. Laboratory tests conducted included the Standard Proctor Compaction Test, California Bearing Ratio (CBR) Test, and Direct Shear Test. The study analyzed the following parameters: Maximum Dry Density (MDD), Optimum Moisture Content (OMC), CBR value, shear strength parameters (cohesion and friction angle), and swelling potential.

Key findings revealed:

- A decrease in MDD and an increase in OMC with higher biochar content.
- Improved shear strength at 10% biochar application.
- Peak CBR value also occurred at 10%, though all values remained below typical subgrade requirements.
- Swelling potential was significantly reduced, with the lowest observed at 12% biochar.

16. Conclusions

Based on the results of this experimental investigation, the following conclusions were drawn:

1. Biochar has a significant impact on the geotechnical properties of clayey soil, particularly in enhancing shear strength and reducing swelling potential.
2. The optimum biochar dosage was found to be 10% by weight, which provided the best balance between strength, compaction behavior, and moisture control.
3. Despite these improvements, the CBR values remained below subgrade suitability thresholds, indicating that biochar alone is insufficient as a primary stabilizer in structural applications.
4. Biochar shows promise as a supplementary stabilizer when combined with other conventional binders or when applied in low-load-bearing projects.
5. The use of sawdust-derived biochar aligns with sustainable engineering practices and waste valorization strategies, offering a dual benefit of soil improvement and environmental conservation.

17. Recommendations

In light of the findings and limitations of the study, the following recommendations are proposed:

A. Composite Stabilization Approach

Further research should investigate the performance of biochar when combined with small amounts of cement or lime to meet structural CBR requirements.

B. Field-Scale Validation

Conduct pilot-scale field tests to assess the long-term behavior of biochar-treated soils under actual loading and environmental conditions.

C. Biochar Characterization Studies

Explore how variations in pyrolysis temperature, particle size, and feedstock type affect the stabilizing efficiency of biochar.

D. Cost-Benefit Analysis

Evaluate the economic viability of biochar-based stabilization compared to traditional methods, particularly for LGU-funded or rural infrastructure projects.

E. Promotion of Circular Economy

Encourage the use of biochar from agricultural waste in civil engineering as part of local environmental and waste management policies.

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