Analysis of Geotechnical Properties of Expansive Soil from Sucre (Colombia) Area Mixed with Sawdust Fiber Treated in Alkaline Condition

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Abstracts

Sawdust is a biodegradable material produced by the timber industry and is abundant worldwide. Inadequate final disposal of waste has adverse environmental effects. The random addition of fibers to soils is primarily inspired by the natural phenomenon of grass and/or plants that can enhance the stability of a slope when they grow on it. Although not novel, this concept has gained popularity in recent years in the field of geotechnical engineering. It has been observed that its addition can improve some of its mechanical properties by increasing the bond between the soil grains, owing to the increase in friction between the fibers and the soil matrix. This study analyzes the impact of the addition of variable doses of oak sawdust (Tabebuia Rosea) on the engineering properties of clayey soil from the Department of Sucre (Colombia) with respect to its shear strength parameters (cohesion and angle of internal friction). The fibers used were divided into three different sizes (less than 2.0 mm, between 2.0 mm and 9.52 mm and greater than 9.52 mm). The fibers were previously subjected to the mercerization process (alkaline treatment with sodium hydroxide) at concentrations and times of 3.0, 5.0 and 8.0 N and 15, 45, and 60 min, respectively, and added in percentages of 2.0, 4.0, and 8.0% in relation to the dry weight of soil. The results indicate that the addition of small amounts of sawdust can positively affect the engineering properties of soils with appreciable clay contents. In this study, it was observed that the optimal results were obtained with the addition of 6% fibers with respect to the dry weight of the soil, improving its density by 7.4%, its unconfined compressive strength by 19.3%, and its cohesion by 24%.

Keywords: clay soils, soil reinforcement, natural fibers, sawdust, mercerization.

1. Introduction

The rapid growth of the global population and the necessity for new infrastructure development have led to a common engineering challenge: constructing soils that are inadequate for supporting intended loads [1,2]. Among the most troublesome construction materials are expansive soils, which undergo significant volume changes due to moisture content fluctuations, expanding when wet, and shrinking when dry [3,4]. These volume alterations cause substantial damage and increase expenses in construction projects built on such soils [5,6]. Consequently, geotechnical engineers must enhance soil engineering properties to ensure the structural integrity of buildings [7]. Various soil improvement methods exist depending on the soil type and characteristics, including soil compaction techniques (such as densification or preloading), hydraulic modifications (such as dewatering or electroosmosis), stabilization using additives (mechanical, chemical, and biological), and reinforcement with geosynthetics or structural elements [3].

Presently, the most widely adopted methods for stabilizing expansive soils involve the use of binding agents, such as cement and lime, which have significant economic and environmental consequences [8]. In particular, cement accounts for approximately 42% of construction costs, and its demand has risen dramatically worldwide. The annual global cement production exceeds 5 billion tons, with approximately 400 kg of carbon dioxide (CO_2) released for every 600 kg of cement produced, contributing to environmental harm [9].

Sawdust has emerged as a promising material for enhancing soil properties, drawing significant interest from geotechnical researchers owing to its versatility, cost-effectiveness, and sustainability [10]. This material offers a potential solution to the growing issues of industrial waste production and inadequate disposal practices. The wood industry generates substantial amounts of waste annually, with the United States, Germany, the United Kingdom, and Australia producing approximately 64, 8.8, 4.6, and 4.5 million tons per year, respectively. Notably, over 40% of this waste remains unrecycled [9].

Utilizing waste materials such as sawdust as binding agents could decrease reliance on conventional stabilizers such as lime or cement. This approach aligns with the circular economy concept and seeks economical and environmentally friendly alternatives for soil improvement [2,10]. While research on the application of sawdust in enhancing soil engineering properties is limited [11], studies exist on its use in the development of other products [12].

Recent investigations into the role of sawdust in improving soil engineering properties have primarily focused on its application in calcined residues and dust forms [1,13]. This preference stems from two main factors: 1) the biodegradability of raw fibers and 2) the high specific surface area of the material in these states, which significantly enhances its interaction with the treated soil matrix. The drawback of biodegradability can be mitigated through the mercerizing process, an alkaline surface treatment that reduces the hydrophilic nature of the fibers and increases the surface roughness, thereby improving friction and interaction with soil particles [14].

Currently, there is a growing need to explore innovative methods that combine circular economy principles with the United's sustainable development goals to enhance soil engineering properties in an environmentally conscious manner. This study examines the potential of utilizing sawdust as a secondary resource and evaluates the effects of incorporating varying amounts of oak sawdust fibers (Tabebuia Rosea) on the engineering characteristics of clay soil, offering a possible solution for repurposing byproducts of the wood industry.

2. Materials and Methods

2.1 Materials

The limited availability of appropriate land for buildings has prompted geotechnical researchers to focus on enhancing the engineering quality of existing soil. Concurrently, environmental engineers concentrate on waste management, recycling, and repurposing industrial by-products. This study explored the potential application of sawdust, a waste material, to enhance the physical and mechanical characteristics of soils that exhibit expansive properties.

2.1.1 Soil

Expansive soils (ES) are primarily composed of clay particles smaller than 0.002 µm, predominantly consisting of hydrophilic materials formed through natural geological processes. These soils are distinct from typical clays because of their significant expansion, contraction, and deformation properties when the moisture content fluctuates. ES is prevalent in numerous regions worldwide [4].

For this study, clay soil was obtained from a quarry in Sincelejo (Sucre-Colombia), where a company extracts materials for manufacturing ceramic construction elements. The soil underwent laboratory testing to characterize its properties and determine specific mechanical attributes in accordance with ASTM standards. A summary of clay soil characteristics and particle size distributions is presented in Table 1.

Table 1. Characteristics of Clay Soil

Property	Value*
Liquid limit (%)	64.04
Plastic limit (%)	24.04
Plasticity index (%)	40.0
Contraction limit	13.5
Specific gravity	2.62
Natural moisture content (%)	6.5
Maximum dry unit weight (KN/m^3)	17.65
Optimum moisture content (%)	10.2
Unconfined compressive strength (KN/m^2)	13.346
Cohesion (KN/m^2)	6.673
Angle of internal friction (φ)	47.29º
Particle size distribution	
Sand (%)	8.25
Silt (%)	61.25
Clay (%)	30.5
Unified soil Classification	CH
AASHTO Classification	A-7-6(40)

*Average of 3 samples

Examination of the particle size distribution revealed that the material was classified as fine soil, with 91.75% passing through No.200 sieve (particles smaller than 0.075 mm). The Casagrande plasticity chart categorizes soil as a highly plastic inorganic clay based on its plasticity characteristics. Furthermore, utilizing both granulometry and plasticity data, the soil was designated as A-7-6 with a group index of 40 according to the American Association of State

Highway and Transportation Officials (AASHTO) classification system. The Unified Soil Classification System (USCS) identifies soil as CH.

Laboratory tests were conducted to determine the distribution of coarse and fine soil particles using sieving and hydrometry. The resulting data were used to construct a soil granulometric distribution curve, as shown in Figure 1.

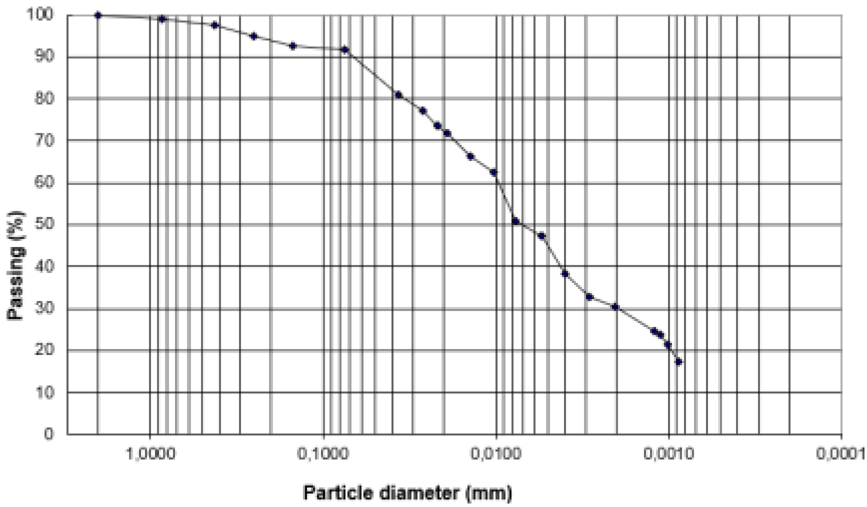

Figure 1. Particle size distribution of soil

XRD analysis was employed to determine the properties and mineral composition of the soil samples. Table 2 displays the results of this analysis and the chemical and mineral constituents of the soils.

Table 2. Mineralogical and Chemical Composition of the clay Soil

		Values
Chemical Composition (%)	SiO_2	55.75
	Al_2O_3	18.17
	Fe_2O_3	9.15
	CaO	10.24
	MgO	1.43
	K_2O	2.07
	Na_2O	1.17
	LOI	2.02
Mineralogical Composition (%)	Kaolinite	27.5
	Quartz	23.6
	Mica	42.1
	Rutile	4.5
	Hematite	2.3

Table 2 shows that the soil is mainly composed of Mica, Kaolinite and Quartz. Soil consists mainly of silica (SiO_2), alumina (Al_2O_3), Calcium Oxide (CaO), and Iron Oxide (Fe_2O_3). The percentages of oxides such as K_2O, MgO, and Na_2O are not very representative.

2.1.2 Sawdust fiber

Sawdust (SD) and wood shavings are byproducts or residues derived from various woodworking processes, including sawing, milling, drilling, sanding, and furniture production. The characteristics of these residues can differ in form and dimensions based on the wood-cutting mechanism, ranging from tiny chips and cut fibers to fine wood particles or even burned material (ASHES) [1,10].

The SD used in this study was from the Tabebuia Rosea species, acquired from a sawmill in Sampués, a municipality in Sucre, Colombia. This particular fiber was selected because of its widespread use in this area. The wood species employed in this study and the distribution of their particle sizes are shown in Figure 2.

Before utilization, the SD was cleaned with fresh water to eliminate contaminants, such as dust and debris. Subsequently, it was thoroughly sun-dried until a stable weight was reached. The dried sawdust was then categorized into three size groups before being incorporated into the soil: particles smaller than 2.0 mm (No. 10 sieve), particles between 2.0 mm (No.10 sieve) and 9.52 mm (3/8" sieve), and particles exceeding 9.52 mm. Following ASTM standards, the SD was subjected to a series of laboratory tests for characterization purposes.

Figure 2. Oak Tree (Tabebuia Rosea), Oak sawdust and particle size distribution of SD

Table 3. Physical properties of Oak SD

Items	SD-a	SD-b	SD-e
Particle size	< 2.0 mm	9.52 mm < x < 2.0mm	> 9.52 mm
Bulk density (g/cm^3)	0.22	0.19	0.17
Specific gravity	1.15	1.09	1.05
Natural moisture content (%)		8.25	
Colour		Light brown	

The physical properties of oak sawdust, categorized into three size groups in this study, are presented in Table 3. The data revealed an inverse relationship between the particle size, bulk density, and specific gravity of the samples. As the particle size increased, these two properties exhibited a corresponding decreased.

2.1.3 Mercerizing of natural fibers

Mercerization is a chemical process that enhances the physical and chemical attributes of fibers by submerging them in sodium hydroxide (NaOH) solution. This technique, patented by John Mercer in 1851, aims to alter the characteristics of cotton fabric, thread, or fibers through treatment with a concentrated alkaline metal hydroxide solution, typically sodium hydroxide (caustic soda) at 32% w/v. Research has shown that the effects on cotton properties remain permanent after washing with water and neutralizing with acid, even after the alkali is removed [15].

Various samples were exposed to NaOH solutions with concentrations of 3, 5, and 8N for 15, 45, and 60 min. Subsequently, the fibers were immersed in 3% acetic acid solution by volume for neutralization. They were then rinsed with distilled water to eliminate any residual chemicals and were sun-dried until they reached a constant mass. The mercerization process for sawdust fibers is illustrated in Figure 3.

Figure 3. Mercerization process of Oak SD

2.2 Test methods

The collected soil was air-dried to a stable weight, then ground and sifted through a 0.25 mm (No. 60) sieve analysis to remove larger particles. A range of tests was conducted in the laboratory to examine the characteristics and performance of both untreated soil and soil mixed with sawdust. These tests were performed in two phases. Initially, experiments were conducted to assess the index and engineering properties of the untreated soil. Following this, sawdust was introduced as a stabilizing agent and mixed with the soil in varying amounts (2.0, 4.0, and 8.0%) based on the soil's dry weight.

The study employed a comprehensive factorial design with four input variables: two related to the natural fibers (size and percentage added) and two associated with the alkaline treatment of fibers using NaOH solution (concentration and exposure duration). Additionally, two response variables were considered: the cohesion and internal friction angle. Table 4 provides an overview of the experimental models used in this study.

Table 4. Experimental research design

INPUT VARIABLES			LEVELS			RESPONSE VARIABLES
Sawdust	%Addition	3	2%	4%	8%	Unconfined compression,
Fiber	Size	3	>9.52 mm	9.52mm<x<2.0mm	<2.0 mm	Cohesion, Compaction
Sodium	Concentration	3	3N	5N	8N	
Hydroxide	Exposure time	3	15 min	45 min	60 min	

In accordance with the experimental protocol, soil specimens were reconstructed with various fiber inclusions, considering the optimal moisture level determined through the modified Proctor test. A total of 81 soil samples were fabricated for both unconfined and direct shear testing procedures.

2.3 Statistical Analysis

One-way ANOVA statistical analysis was conducted to investigate how the addition of sawdust affected the geotechnical properties of clayey soil. This approach was chosen because the study focused on four variables as the sole factors influencing the geotechnical characteristics of the material: two related to sawdust (size and percentage added) and two associated with the alkaline treatment of fibers (solution concentration and duration of exposure).

3. Results and discussions

3.1 Effect of mercerization on the chemical component's Sawdust fiber

To investigate the potential impact of mercerization on sawdust fibers, researchers analyzed the chemical composition of three oak sawdust samples. The first sample consisted of untreated oak sawdust, while the second and third samples underwent mercerization at concentrations of 3 and 5N for 15 and 60 min, respectively.

The findings are presented in Table 5, which illustrates the changes in the cellulose, hemicellulose, and lignin content of the examined fibers.

Table 5. Chemical Components of the Oak Sawdust before and after mercerization

Component	SD raw	SD Mercerized (3N, 15 min)	SD Mercerized (8N, 60 min)
Cellulose (%)	49.38	55.13	56.65
Hemicellulose (%)	9.11	8.88	8.73
Lignin (%)	29.10	26.10	23.71
Ash (%)	1.18	10.72	11.15

3.1.1 Variation in Cellulose content

The mercerization process resulted in an observable increase in the percentage of cellulose within the natural fibers. This occurs primarily because of the reduction in lignin and other components, leading to a higher proportion of cellulose. However, mercerization also induces structural modifications in cellulose, including: 1) cellulose crystallization, which affects the physical and chemical characteristics of the fiber; 2) realignment of cellulose molecules, impacting fiber strength and flexibility; and 3) cellulose hydration, which influences moisture retention and absorption capabilities.

Overall, the elevated cellulose percentage resulting from mercerization can enhance fiber properties, such as durability, smoothness, and luster. Nevertheless, careful control of the process parameters is crucial for preventing undesirable alterations in the cellulose structure.

The experimental results showed that mercerization at a concentration of 3N for 15 min yielded an 11.64% increase in the fiber cellulose content. When the concentration was increased to 8N and the exposure time was extended to 30 min, an increase of 14.72% was observed.

3.1.2 Variation in Hemicellulose content

Mercerization can lead to substantial alterations in hemicellulose, which typically results in its reduction. This is primarily because hemicellulose exhibits greater solubility in alkaline solutions than cellulose. During mercerization, hemicellulose may undergo two main processes: 1) dissolution, in which a portion of the hemicellulose separates from the fiber by dissolving in the alkaline solution, and 2) hydrolysis, in which the alkaline environment causes the breakdown of chemical bonds, forming simpler compounds that are subsequently removed. The extent of this reduction was influenced by specific process parameters, including the concentration of the alkaline solution, duration of treatment, and temperature.

The decrease in hemicellulose content during mercerization can impact various fiber properties, such as 1) diminished water absorption capacity, 2) enhanced tensile strength and flexibility, and 3) alterations in fiber texture and softness. Given the crucial role of hemicellulose in the fiber structure and properties, it is essential to regulate its reduction during mercerization to prevent undesirable changes in the fiber.

Experimental observations revealed that the fiber hemicellulose content decreased by 2.52% when subjected to mercerization at a concentration of 3N for 15 min. Furthermore, a 4.17% reduction was observed when mercerization was conducted at 8N concentration for 30 min.

3.1.3 Variation in Lignin content

Lignin, a component found in plant cell walls, is particularly prevalent in wood and plant fibers. The mercerization process reduces lignin content in natural fibers for several reasons: 1) lignin's partial solubility in alkaline solutions, such as the sodium hydroxide used in mercerization, allows it to dissolve and separate from the fiber; 2) the alkaline solution can cause lignin to undergo hydrolysis, breaking its chemical bonds and forming simpler compounds that are removed; and 3) the mechanical treatment during mercerization, including stretching and rolling, aids in extracting lignin from the fiber. This reduction in lignin content offers numerous advantages, including enhanced fiber flexibility and tensile strength, increased fiber brightness and softness, improved dyeing and finishing capabilities, and improved resistance to ultraviolet light and chemical degradation.

During mercerization, the hemicellulose content of the fiber decreased by 10.3% when treated with a 3N concentration for 15 min, and a further 18.52% reduction was observed with an 8N concentration for 30 min.

It is worth noting that the extent of lignin reduction depends on the specific mercerization conditions, including the alkaline solution concentration, treatment duration, and temperature.

3.1.4 Variation in Ash content

The SD mercerization process results in an elevated ash content, primarily attributed to the absorption of NaOH solution by the fibers and the development of inorganic compounds such as carbonates or silicates on their surface. When these mercerized fibers undergo combustion for ash content determination, the inorganic materials remain unburned and transform into ash, leading to a higher ash percentage than that of untreated fibers.

Fibers mercerized at a 3N concentration for 15 min exhibited an ash percentage 9.1 times greater than that of raw fibers. In contrast, the fibers treated at 8N concentration for 30 min showed a 9.5-fold increase in ash content relative to their original value.

The enhanced ash percentage observed in mercerized sawdust fibers stems from the absorption of chemical agents and the formation of inorganic compounds during the mercerization process.

3.2 Effect of Sawdust on the Cohesion of the Soils (unconfined compression strength)

This experiment aimed to evaluate the shear strength cohesion of clay by varying the sawdust addition (2.0, 4.0, and 8.0%). The test involved applying an axial load to cylindrical specimens measuring 76.2 mm in diameter, with a height-to-diameter ratio of 2:1.

Figure 4 illustrates the results from the 81 tested samples based on the experimental design, along with the mean value for the control samples without sawdust (13.346 KN/m^2). These findings are in contrast to the average value plus or minus the standard deviation of the collected data.

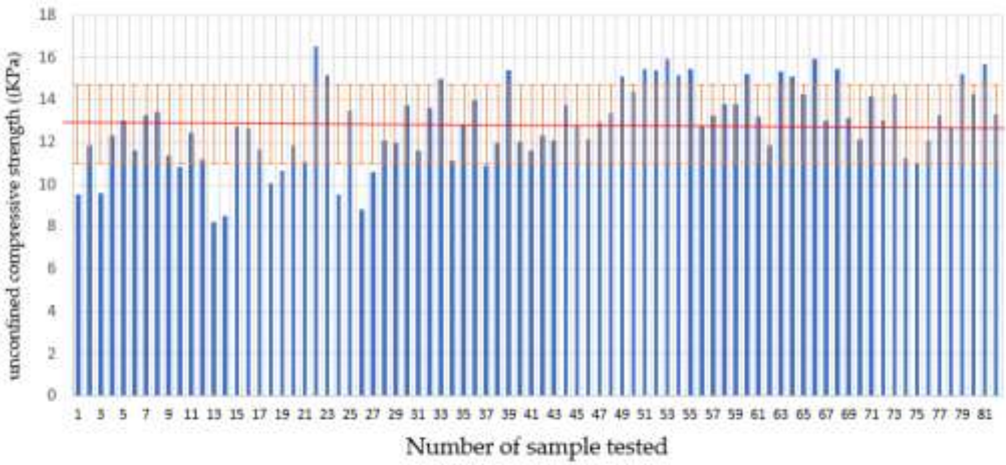

Figure 4. Effect of the percentage of sawdust addition on cohesion

Analysis of the data revealed that approximately 21% (17 specimens) of the specimens exhibited unconfined compression strength (UCS) values exceeding the mean plus one standard deviation. Utilizing the response optimization feature in Minitab's statistical analysis software, 7 out of 8 requested values in the multiple response prediction were found among the 17 data points corresponding to the highest UCS values obtained.

Examination of the data with peak values indicates that the most significant factors influencing unconfined compression strength are the fiber size and the interaction between the alkaline agent solution concentration and fiber exposure time. This relationship is illustrated in Figure 5.

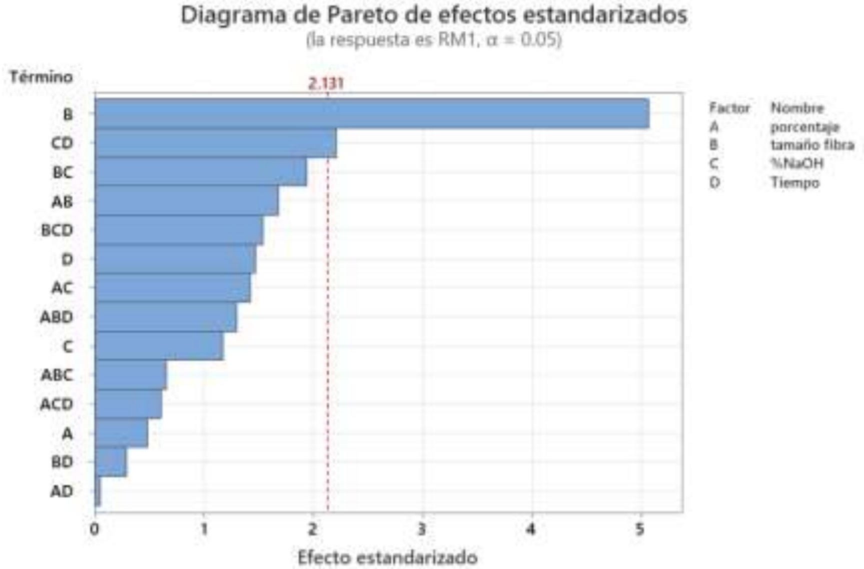

Figure 5. Variables with the highest incidence in the unconfined compressive strength

Specimens prepared with fibers exceeding 9.52 mm (larger than the 3/8” sieve) accounted for 47% of the highest Unconfined Compressive Strength (UCS) values. Furthermore, a significant portion of the maximum UCS values was obtained for the samples in which the incorporated fibers underwent mercerization in a 5 N solution for 15 min. The data indicated that this process resulted in an approximately 19.3% enhancement in the UCS values.

3.3 Effect of Sawdust on the friction angle of the Soil (Direct shear strength)

Shear strength tests were conducted on both unaltered soil samples and samples mixed with varying amounts of sawdust (2.0, 4.0, and 8.0% of the dry weight of natural soil).

Figure 6 displays the results from the 81 tested samples based on the experimental design, along with the mean internal friction angle for the samples without additives (47.29°). These findings are contrasted with the average value plus or minus the standard deviation of the collected data.

Analysis of the data revealed that approximately 17% (14 samples) of the samples exhibited internal friction angle values exceeding the mean plus one standard deviation. The majority of these specimens were fabricated using fibers with dimensions ranging from 2.0 mm to 9.52 mm.

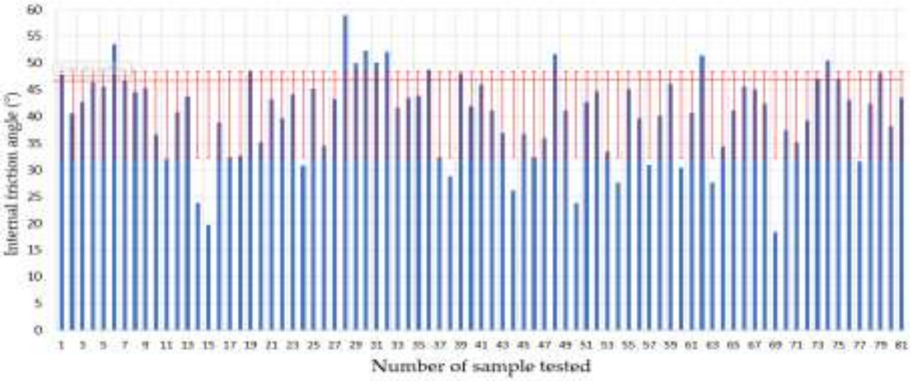

Figure 6. Effect of the percentage of sawdust addition on internal friction angle (φ)

The Minitab statistical analysis program was used to examine the data with the maximum values. The results indicate that the angle of internal friction is most significantly influenced by two factors: the concentration of the NaOH solution applied to the fibers and the interplay between fiber size and alkaline agent solution concentration. This relationship is illustrated in Figure 7.

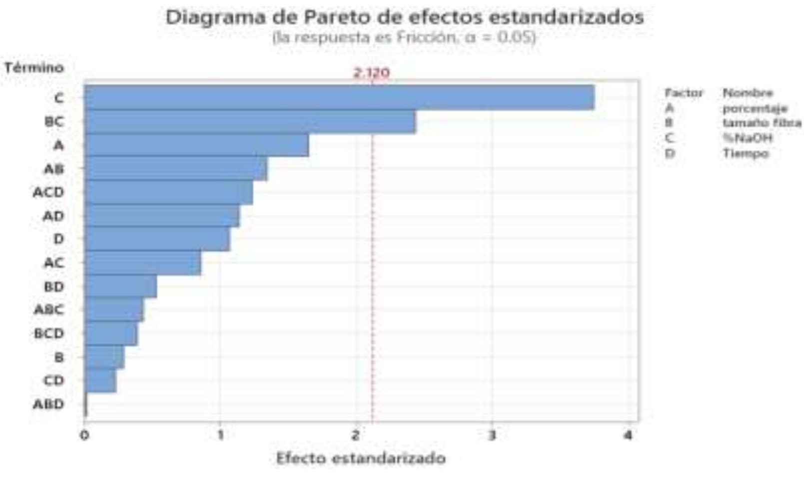

Figure 7. Variables with the highest incidence in the internal friction angle

The Minitab statistical analysis program's response optimization feature was utilized to analyze the eight requested values in the multiple-response prediction. Results showed that 6 out of 8 specimens (75%) were fibers ranging from 2.0 mm to 9.52 mm in size and treated with a 3N sodium hydroxide solution. Among these samples, specimen 28 exhibited the most significant increase in the internal friction angle, reaching approximately 24%.

3.4 Effect of Sawdust on the Modified Proctor Test

To assess the impact of various SD fiber percentages on soil behavior during compaction, experiments were conducted using soil samples with 2.0, 4.0, and 8.0% fiber additions relative to the soil's dry weight. The results were then compared with those of the control sample without any fiber addition.

The fibers used to create the different specimens were larger than the 3/8” (9.52 mm) sieve and underwent mercerization at a 5N concentration for 15 min. This selection was based on the observation that these materials yielded the most significant results in the unconfined compression test for this particular type of material. Table 6 presents the results of the mixed-sample tests.

Table 6. MDD and OMC values for soil and sawdust mixtures for 5N mercerization, 15 min

Test specimen	Dry unit weight (KN/m^3)	Optimus moisture content (%)
Clay soil	17.65	10.20
Soil + SD (2%)	18.25	10.35
Soil + SD (4%)	18.96	10.55
Soil + SD (8%)	18.65	10.75

Soil samples containing varying amounts of sawdust (0.0%, 2.0%, 4.0%, and 8.0%) exhibited maximum dry unit weight values of 17.65 KN/m³, 18.25 KN/m³, 18.96 KN/m³, and 18.65 KN/m³, respectively. This indicates an increase in soil density as sawdust content increases, except for the 8% mixture, which shows a decline in the maximum dry unit weight. The overall increase in maximum dry unit weight was 7.4%.

Figure 8 illustrates the effect of the addition of sawdust fibers on the maximum dry unit weight of the specimens. The graph suggests that the optimal percentage of sawdust fiber addition is approximately 6%, which aligns with previous findings [11].

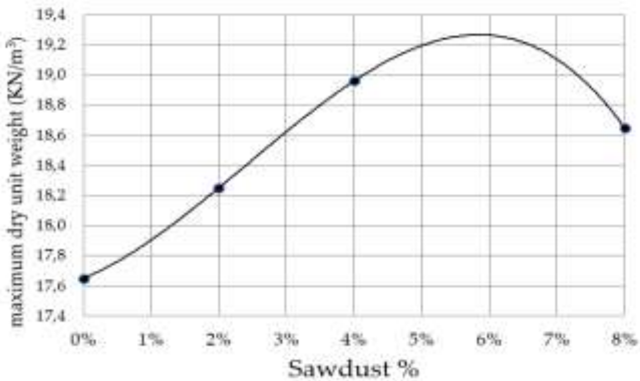

Figure 8. Effect of the percentage of SD addition on MDUW

The modified Proctor test results for the soil samples, with and without sawdust fiber addition, are illustrated in Figure 9. The resulting curves demonstrate subtle upward and rightward shifts.

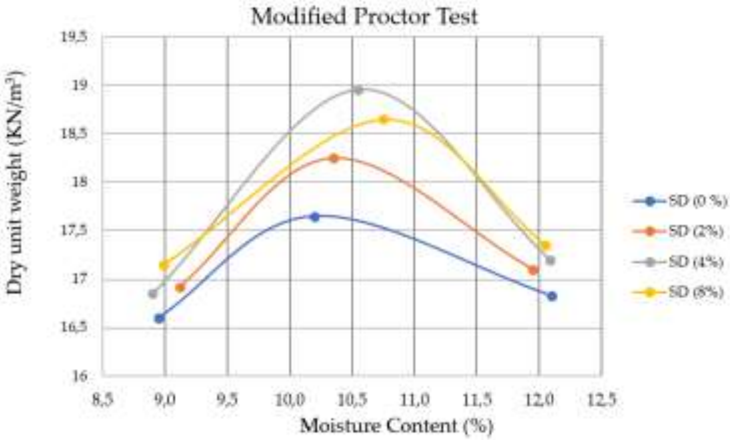

Figure 9. Effect of the percentage of SD addition on MDD y OMC

The elevated Proctor curves observed in soils with additives compared to those without additives can be attributed to enhanced material compaction resulting from the additions. This effect peaked at 6%. The rightward shift of these curves indicates an increase in the Optimum Moisture Content (OMC) required for compacting soil with sawdust fiber additions. This phenomenon primarily occurs because sawdust fibers possess a greater capacity to absorb and retain water than soil alone. Consequently, more water is required to achieve proper soil moisture during the compaction process when sawdust fibers are incorporated.

4. Conclusions

Although incorporating fibers to enhance soil properties is not a novel concept, research into their potential geotechnical applications has surged in recent decades. It is worth noting that research on sawdust fibers as soil reinforcement is currently limited in Latin America. This presents an opportunity to develop knowledge regarding the study, application, and utilization of these abundant agro-industrial byproducts in developing nations.

The fiber mercerization process was found to significantly alter the chemical composition of the treated fibers, reduce lignin and hemicellulose content, and increase cellulose and ash content. This study analyzed the chemical composition of three sawdust samples: one untreated and two mercerized under different conditions (3N concentration for 15 minutes and 8N concentration for 60 min). The results showed a 14.72% increase in cellulose (from 49.38% to 56.65%), 4.17% decrease in hemicellulose (from 9.11% to 8.73%), 18.52% reduction in lignin (from 29.10% to 23.71%), and 9.4-fold increase in ash content (from 1.18% to 11.15%). Analysis of the unconfined compressive strength revealed that fiber size and the interplay between the alkaline agent concentration and fiber exposure time were the most influential factors. The highest values were observed in remolded specimens using fibers larger than 9.52 mm (3/8" sieve opening) treated with 5 N NaOH for 15 min. This process resulted in a 19.3% increase in the unconfined compressive strength, from 13.346 KN/m^2 in fiber less specimens to 15.916 KN/m^2 in samples containing 8% treated sawdust fibers.

In direct shear testing, the alkaline agent (NaOH) concentration and the interaction between the fiber size and mercerization exposure time were the primary influencing variables. Peak values were noted in remolded specimens with fiber particles ranging from 2.0 mm to 9.52 mm, mercerized with 3N NaOH for 15 minutes. A maximum friction angle of 58.981° was recorded for specimen No. 28, representing a 24.7% increase.

To investigate the effect of fibers on soil compaction, modified Proctor tests were conducted on remolded soil samples containing varying fiber percentages (2.0, 4.0, and 8.0%). These fibers, larger than 9.52 mm, underwent mercerization at a 5N concentration for 15 min. Results show that the maximum dry unit weight increases as fiber content rises, starting from 17.65 KN/m^2 for fiber-free soil, peaking at 18.96 KN/m^2 with 4.0% fiber content, then declining to 18.65 KN/m^2 at 8.0% fiber addition. The samples exhibited a trend of increasing optimal moisture content as the fiber percentage increased. This study suggests an optimal fiber addition of approximately 6% relative to the dry weight of the soil. Although oak sawdust fibers lack inherent cementitious properties, their incorporation in small amounts can enhance soil engineering characteristics. This improvement is primarily attributed to the rough surface texture of the fibers, which, when integrated into the soil matrix, can boost its shear strength. Mercerization tends to reduce the hydrophilic nature and biodegradability of the fibers; further research is recommended to examine how curing time affects strength parameters in soil samples containing sawdust.

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