Use of Pulverized Agro-Waste Materials For Soil Stabilizers

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***Abstract*— This research investigates the efficacy of utilizing pulverized agro-waste materials alongside cement for soil stabilization purposes. Specifically, the study focuses on rice husk, corn husk, and coconut husk powders as potential alternatives to lime, aiming to enhance both the economic and ecological aspects of soil stabilization processes. Through comprehensive testing, including strength assessments, various mixtures incorporating agro-waste powders at levels of 92% and 96% by weight of soil were evaluated, with lime replacement rates reaching up to 50%. Results demonstrate that all treated mixtures exhibited significantly improved strength compared to untreated soil samples. Remarkably, the substitution of lime with agro-waste powder at a 20.21% rate yielded superior strength properties, indicating its practical viability for widespread adoption. This study underscores the potential of agro-waste materials as sustainable alternatives in soil stabilization applications, offering promising avenues for environmentally friendly construction practices.**

***Keywords*— soil stabilization, agro-waste, sustainable construction, lime replacement, strength properties**

I. Introduction

In the realm of soil mechanics, constructing on soft ground presents a significant problem. Due to the poor tensile strength and high ductility of this soil, several technical difficulties such as landslide hazards, normally provides collapse, or differential settlement might develop either during or after the building phase [1]. Soft soil is often defined as having a low tensile resistance, being very fragile, and having a poor permeability [2]. The soil's tensile resistance is revealed to be less than 40 kPa, and it can be mechanically shaped with light firm pressure. In this formation, the most common construction issues include inadequate ductility, excessive post-construction subsidence, and instability during excavation and embankment formation. In theory, a settlement issue may be characterized as soil deformation caused by applied forces. The geometry of the load bearing system will vary as a consequence of settlement, and if the ground water level is high, a portion of the concrete aggregate will become buoyant, influencing the overall surcharges pressure and the soil's resilience [3] Soil stabilization is a procedure that is used on practically all road developments. All kinds of soil treatment may be broadly divided into two categories: mechanical stabilizing and chemical stabilization. Mechanical stabilizing involves changing the classifications of a soil by blending it with other kinds of soils of varying grades. This allows for the formation of a compacted soil mass. Chemical stabilization, on the other hand, is connected with the alteration of soil characteristics by the addition of chemically active elements. It is critical in soil stabilization to understand the material qualities involved in the combination as well as the result following mixing [4].

Agricultural waste is waste that is produced as a consequence of different agricultural processes. It comprises agricultural trash, land waste, chicken waste, and crop waste. Every year, around 350 million tonnes of agricultural residues are created in India [5]. As a result, agricultural waste control and use become critical in order to alleviate the challenges connected with waste disposal. Waste material may also be used to stabilize the soil. Agricultural wastes such as rice husks, ground nut shell, and others may be utilized to stabilize soil. Agriculture generates a massive amount of garbage from collected harvests [6]. Straws, husks, and bagasse are the most common types of biomass derived from plants or crops. The production of a considerable amount of agricultural waste causes serious environmental difficulties as well as landfill-related challenges [7]. Agricultural waste is often burned for energy production or as a fuel source in factories and mills [8]. Ashes are produced as a byproduct of the combustion of agricultural wastes such as wheat straw, rice straw, rice husk, sugar cane bagasse, sugar cane straw, wood straw, and maize cobs [9]. Misleading practices, such as open dumping of agricultural waste ash (AWA), have severe environmental and health consequences, owing mostly to groundwater pollution. As a result, a considerable amount of agricultural leftovers create tonnes of AWA when burned, causing the previously noted environmental and landfill issues.

In road construction engineering, soil stabilization is the process of strengthening the shear strength parameters of soil and thereby increasing its bearing capacity. A non-burning environmental solution was investigated to see whether it may help to decrease the adverse impact on the environment that burning has. As a result, it was decided to pulverize the agricultural waste and use it to stabilize the soil as a soil conditioner. As the cost of soil stabilization chemicals such as cement and lime rises, the cost of common soil stabilization processes is becoming more expensive. The cost of stabilization may be decreased by substituting agro-wastes such as rice husk, coconut husk, and maize husk for a major amount of the stabilizing agent.

II. Related Works

In general, soil stabilization involves blending and mixing various components to enhance soil qualities, catering to diverse geotechnical applications such as road surfaces. This process aims to improve parameters like dry unit weight, bearing capacities, and volume changes, rendering in situ subsoils and waste materials more suitable for construction purposes [10]. Stabilization methods can be mechanical, chemical, or biological, offering versatile approaches to address soil challenges [11].

The addition of cement or lime to soil stands as a common practice in soil stabilization, augmenting the engineering properties of the stabilized soil and yielding superior construction materials. This includes enhanced soil strength, durability, stiffness, and reduced plasticity and swelling/shrinkage potential [12][13][14][15]16]. Amidst escalating concerns over environmental impact and resource scarcity in conventional construction practices, researchers have explored alternative approaches, among which soil stabilization using various additives emerges prominently. Modern scientific methods offer promising avenues to address these challenges [17].

A study investigating the use of Oil Palm Shell (OPS) as a coarse aggregate for structural concrete blocks underscores the potential of unconventional materials in construction. Similarly, research on sugarcane bagasse ash (SCBA) showcases its effectiveness as a sand replacement in mortar and concrete, exhibiting mechanical performance comparable to conventional materials [18]. Agricultural waste, a byproduct of farming activities, presents both waste management challenges and opportunities for soil modification. Various agricultural residues like rice husk and groundnut shell offer potential for soil stabilization [19].

A recent study examined the use of bagasse ash and lime to stabilize expansive soil, revealing significant improvements in soil properties such as plasticity index and California bearing ratio (CBR) with the addition of these additives [20]. Another investigation focused on the utilization of Rice Husk Ash (RHA) and lime in soil stabilization, assessing their impact on soil characteristics and geotechnical properties. The study revealed that incorporating RHA increased the optimal moisture content (OMC) of the soil, while the addition of lime enhanced parameters like CBR and unconfined compressive strength (UCS), demonstrating the efficacy of soil stabilization using RHA [21].

III. Methods

A. *Preparation of Materials*

The materials utilized in producing soil stabilizers consist of pulverized agro-waste materials, namely rice husk, coconut husk, and corn husk, along with cement and soil. These agro-waste materials were sourced from Cagayan, Philippines. Soil samples were excavated using a shovel to a depth of 1.5 meters below the ground surface, then transferred to the DPWH laboratory and oven-dried at 105°C for 24 hours. Subsequently, the soil was crushed to achieve a finer grain size using a hammer before being ready for testing.

The agro-wastes were collected from nearby fields or plantations and thoroughly cleaned. Rice husk, coconut husk, and corn husk shown in Figure 1, Figure 2, and Figure 3, respectively were sun-dried before undergoing pulverization. Rice husk was pulverized using a specialized machine, while coconut husk and corn husk were pulverized using a blender.

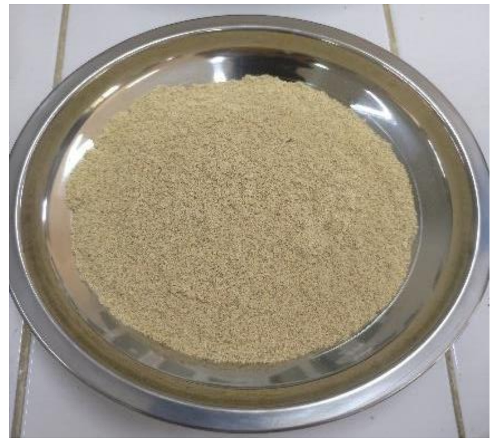

Fig. 1. Pulverized rice husk.

Fig. 2. Pulverized coconut husk.

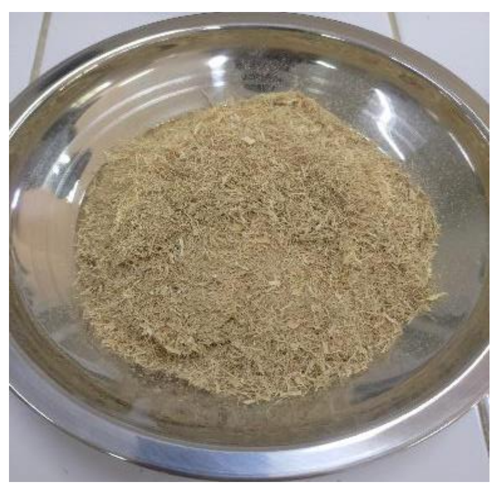

Fig. 3. Pulverized corn husk.

For soil stabilization, soft soils such as silty, clayey peat, or organic soils were primarily used, aiming to enhance engineering properties like compressibility, strength, permeability, and durability through the incorporation of stabilizing agents.

Cement, being a binder, plays a crucial role in construction by binding materials together through setting, hardening, and adherence, making it an essential stabilizing agent or hydraulic binder.

B. Making of Samples

Standard specimen and specimens with rice husk (RH), coconut husk (CoH), and corn husk (CH) admixture were prepared following specific ratios determined based on weight percentages. Cement and soil amounts were fixed, and the mix design details are presented in Table I. The agro-waste materials were mixed to form the soil stabilizers using equipment such as shovels, grinding materials, and a 14 mesh screen.

TABLE I. PROPORTION OF ADMIXTURE IN SOIL SAMPLES

Sample	Pulverized Agro-Waste			Cement (%)	Soil (%)
	Rice Husk (%)	Coconut Husk (%)	Corn Husk (%)		
Control	0	0	0	0	100%
PAW3	1%	1%	1%	1%	96%
PAW6	2%	2%	2%	2%	92%

Soil properties presented in Table II were initially examined for untreated samples, followed by extensive laboratory work to assess the engineering properties of soil samples with RH, CoH, and CH admixtures, guided by AASHTO T-99 guidelines.

TABLE II. SOIL PROPERTIES BEFORE STABILIZATION

Property	Value
Liquid Limit (%)	47.44%
Plastic Limit (%)	15.39%
Plastic Index	32.05%
Group index	N/A
Group Classification	A6 Clay Soil

C. Testing and Evaluation

The California Bearing Ratio (CBR) test using the machine shown in Figure 6 was conducted to measure the pressure required to penetrate a soil sample with a standard plunger area, aiding in the characterization of subgrade strength and pavement bearing capacity. After 96 hours, soil stabilizer specimens were subjected to CBR testing.

The Standard Proctor Test was performed with the aid of the digital compactor shown in Figure 5 and extruder shown in Figure 6 to estimate the maximum load-bearing capacity of the soil and assess compaction characteristics as moisture content varies. The Standard Proctor Test, as described in AASHTO T-99, can be used to establish the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) values.

Fig. 4. California Bearing Ratio Machine

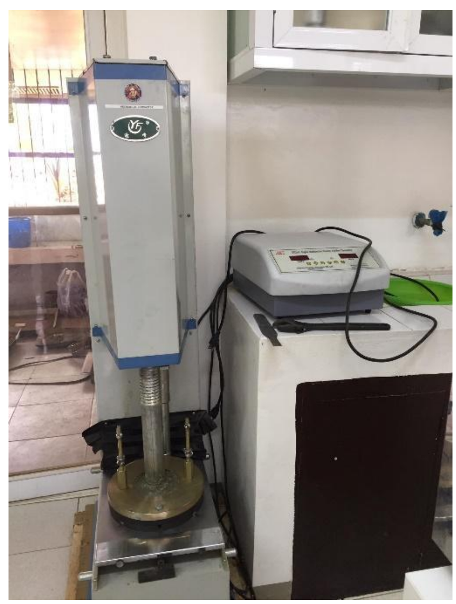

Fig. 5. Digital Compactor Machine

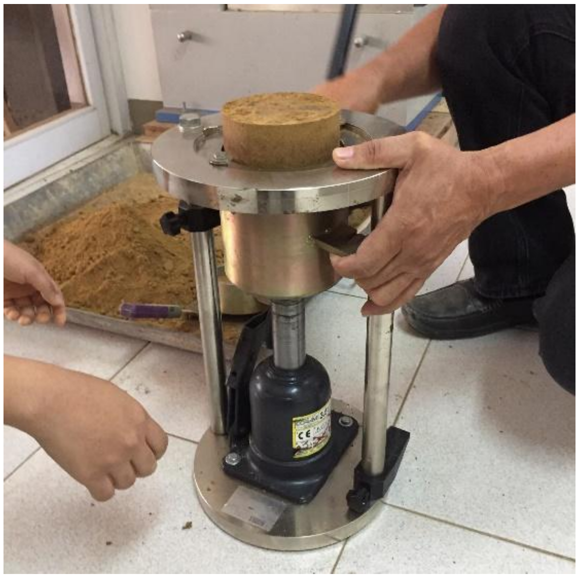

Fig. 6. Extruder Machine

IV. Results and Discussion

The table presents the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) values for different samples, including the control and those treated with pulverized agro-waste (PAW) materials. It's evident that the introduction of PAW materials has influenced the soil's compaction characteristics. Particularly, in comparison to the control sample, both PAW 3 and PAW 6 exhibit comparable OMC values, suggesting similar moisture requirements for optimal compaction. However, noteworthy deviations emerge in terms of MDD. PAW 3 displays a lower MDD compared to the control, indicating a decrease in soil density upon the addition of the agro-waste material. Conversely, PAW 6 exhibits a higher OMC and lower MDD, indicating a potential for improved soil compaction at slightly higher moisture content, albeit with a lower maximum density. These results suggest the varying effects of different concentrations of agro-waste materials on soil compaction properties, highlighting the importance of precise mixture design to achieve desired engineering outcomes in soil stabilization applications.

TABLE III. OMC and MDD Values for Soil Samples

Sample	OMC (%)	MDD(Mg/m^3)
CONTROL	20.20	1.574
PAW 3	20.21	1.409
PAW 6	22.2	1.299

The observed variations in OMC and MDD underscore the intricate interplay between soil composition and the added agro-waste materials. While PAW 3 demonstrates a reduction in maximum dry density, potentially indicating improved workability, PAW 6 presents a nuanced scenario with both higher moisture content requirements and reduced density. These findings necessitate a careful balance between moisture content and density requirements in soil stabilization endeavors. Moreover, they emphasize the need for further investigation into the specific mechanisms underlying the influence of different agro-waste concentrations on soil compaction characteristics. Future research could focus on optimizing mixture compositions to harness the beneficial effects of agro-waste materials while ensuring optimal soil compaction and engineering performance.

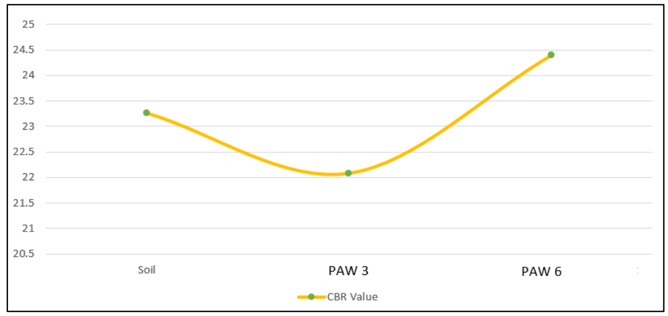

Fig. 7. Comparison of specimen's CBR value

The laboratory determination of the CBR of a compacted specimen was obtained by measuring the forces required to cause a cylindrical plunger of a specified size to penetrate the specimen at a specified rate. Figure 7 shows that PAW6 mixtures attain the maximum CBR value, respectively. This statement is supported by a study which discovered that optimum CBR value achieved at PAW6 of addition of agro-waste in clay soil type [13]. There is another study [14] which conforms to this result as they found that the addition of small amount of cement helps in increasing the pozzolanic reaction that caused higher impact on soil strength. The increase in CBR value corresponds to the increase in cement content. This trend shows that the presence of water (moisture) helps further the cementitious compounds' formation.

V. Conclusion

In conclusion, the findings from this study highlight the potential of pulverized agro-waste materials as additives in soil stabilization processes. The variations observed in Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) among different samples underscore the complex influence of agro-waste concentrations on soil compaction characteristics. Notably, the PAW 6 mixture exhibited the highest attainable California Bearing Ratio (CBR) value, indicating superior strength properties compared to other samples. These results underscore the need for meticulous mixture design to achieve desired engineering outcomes in soil stabilization applications. Overall, the study signifies the promise of utilizing agro-waste materials as sustainable alternatives in soil stabilization, with potential implications for cost-effective and eco-friendly construction practices.

Moving forward, it is recommended to conduct further research to comprehensively assess the long-term performance and environmental impacts of soil stabilized with pulverized agro-waste materials. Additionally, detailed studies should focus on optimizing mixture compositions to maximize the benefits of agro-waste additives while ensuring optimal soil compaction and engineering properties. Moreover, collaborative efforts between researchers, policymakers, and industry stakeholders are crucial to facilitate the adoption of agro-waste-based soil stabilization techniques on a broader scale, thereby promoting sustainable construction practices and mitigating environmental impacts associated with traditional stabilization methods.

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