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Analysis of Clay Soil Stabilization Comparison Using Rice Husk Ash and Cement Additives on Standard Compaction: Implications for Sustainable Construction

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Abstract
This study aims to compare the properties of clay soil stabilized with rice husk ash and cement. The main focus is to evaluate how these materials affect compaction, maximum dry density, and optimum moisture content, and their role in sustainable construction. By considering the economic and environmental benefits of using RHA as a waste material, this research hopes to support the development of more sustainable construction methods. This study employs a qualitative approach with a comparative analysis method to examine the stabilization of clay soil using rice husk ash (RHA) and cement. Rice husk ash increases maximum dry density and reduces optimum moisture content, with variations influenced by soil conditions and testing methods. Cement, however, consistently reduces moisture content and increases dry density, improving soil structure and compaction. These materials have important implications for sustainable construction, with rice husk ash offering an eco-friendly option and cement providing stable, reliable results. The choice of material should consider project needs, soil conditions, and sustainability goals.

Keywords: *Rice Husk Ash (RHA), Cement, Integration of Rice Husk Ash (RHA) and Cement in Clay Soil Stabilization*

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I. INTRODUCTION

Clay soil, as one of the most commonly encountered soil types at construction sites, presents specific challenges due to its high plasticity, significant moisture retention, and expansive behavior, which can affect the stability and strength of structures [17]. When exposed to water, clay soil tends to swell, while it shrinks during drying, potentially causing damage to overlying structures [5,7]. Furthermore, the bearing capacity of clay soil is typically low, as evidenced by California Bearing Ratio (CBR) values that often fall below construction standards [24]. Therefore, soil stabilization efforts are necessary to improve its mechanical properties and ensure safe and durable construction.

Soil stabilization through the addition of external materials such as Rice Husk Ash (RHA) and cement has become a common solution. Rice Husk Ash (RHA) is recognized as an effective pozzolanic material for improving soil properties. As an agricultural waste, RHA not only enhances the mechanical parameters of soil, such as maximum dry density, California Bearing Ratio (CBR), and unconfined compressive strength (UCS), but also serves as an environmentally friendly material that supports sustainability in construction [13,3].

In addition, cement is often used as a stabilizing agent capable of increasing soil strength and bearing capacity through the hydration process, though its use should take into account the environmental impact of cement production, which generates high carbon emissions [16]. The combination of RHA and cement has proven to have a synergistic effect in improving problematic soils such as clay and peat, resulting in significant enhancements in bearing capacity and soil stability parameters [9].

This study aims to analyze the comparative mechanical properties of clay soil stabilized with rice husk ash and cement. The primary focus of the research is to evaluate the effects of these two materials on compaction parameters, maximum dry density, and optimum moisture content, as well as their implications for sustainable construction. By considering the economic and environmental benefits of using RHA as a waste material, this research is expected to contribute to the development of more sustainable construction methods.

1.1.1 Rice Husk Ash (RHA)

Rice Husk Ash (RHA) is an effective additive for enhancing the properties of clay soil, offering benefits in soil stabilization, nutrient enrichment, and acidity correction. As a byproduct of rice milling, RHA has gained recognition for its potential applications in both agricultural and construction sectors. In soil stabilization, RHA significantly improves the mechanical properties of soil, such as unconfined compressive strength (UCS) and California Bearing Ratio (CBR). The combination of RHA with cement has been proven to reduce soil plasticity and enhance shear strength, making it suitable for construction applications such as road bases and sub-bases [8,18]. The pozzolanic activity of RHA, produced through controlled combustion, allows this material to act as a soil stabilizer, particularly for clay soils, when used in specific proportions (3–20%) [15].

Although RHA offers numerous benefits in improving clay soil, its effectiveness may vary depending on the soil type, application rate, and environmental conditions [15].

1.1.2 Cement

Cement is widely recognized as an effective binding material for stabilizing clay soil, primarily due to its ability to enhance the mechanical properties and durability of soil. The stabilization process involves chemical reactions that improve the geotechnical characteristics of the soil, making it more suitable for various construction and engineering applications.

One of the key contributions of cement in soil stabilization is the improvement of the soil's microstructure. This process creates a dense network that fills soil voids and enhances strength parameters. For instance, cement-stabilized loess has shown increased unconfined compressive strength (UCS) and flexural tensile strength, particularly with higher cement content and extended curing periods ("Microstructure and Strength Parameter of Cement Stabilized Loess," 2023; [4]). The hydration and pozzolanic reactions in cement produce new cementitious materials, such as calcium silicate hydrate (C-S-H) and ettringite, which significantly improve the soil's mechanical properties [14].

1.1.3 Integration of Rice Husk Ash (RHA) and Cement in Clay Soil Stabilization

The integration of rice husk ash (RHA) and cement in clay soil stabilization offers a promising approach to sustainable construction. This method not only enhances the mechanical properties of clay soil but also provides environmental benefits through the utilization of waste materials. The combination of RHA and cement improves soil stability, reduces plasticity, and increases load-bearing capacity, making it an effective alternative to traditional soil stabilization methods.

Beyond improving soil properties, the RHA-cement combination also delivers environmental and economic advantages. The utilization of RHA, a byproduct of rice milling, helps reduce environmental pollution and minimizes the amount of waste sent to landfills. Moreover, incorporating RHA decreases reliance on cement, thereby lowering greenhouse gas emissions associated with cement production [10]. From an economic perspective, RHA is a low-cost material that can significantly reduce overall construction project expenses [12].

1.2 Research Methodology

This study employs a qualitative approach with a comparative analysis method to examine the stabilization of clay soil using rice husk ash (RHA) and cement. The qualitative approach was chosen because it generates descriptive data in the form of written or spoken words from observable data and results [11]. Secondary data were utilized in this research, sourced from various relevant references such as scientific journals, theses, dissertations, and conference publications.

1.2.1 Data Collection

Data were collected by identifying previous studies that explored the stabilization of clay soil using RHA and cement. The selected studies had to meet specific criteria, including clear methodologies, reliable results, and a focus on analyzing the physical and mechanical properties of clay soil after stabilization. The data extracted included relevant parameters such as maximum dry density and optimum moisture content.

1.2.2 Data Analysis

The analysis was conducted using a comparative analysis technique based on the interactive approach by Miles and Huberman. This technique consists of three main components: data reduction, data presentation, and conclusion drawing/verification [2,1,21,11]. The analysis stages are as follows:

(i) Data Reduction

In this stage, the collected data were processed and categorized based on the type of stabilization used, namely RHA and cement. The parameters measured in each study were recorded, along with the corresponding results.

(ii) Data Presentation

The reduced data were analyzed by comparing the two stabilization methods based on the recorded parameters. The comparison results were presented in tables and graphs to facilitate the visualization of the effectiveness of each stabilization method.

(iii) Data Verification

Conclusions were drawn based on the findings from the data analysis. Additionally, this study provides recommendations for future research to further explore the effectiveness of the two stabilization methods under specific soil conditions and parameters.

Through these steps, this study aims to provide an in-depth understanding of the effectiveness of clay soil stabilization using RHA and cement. This approach also establishes a robust foundation for developing more efficient soil stabilization methods and contributing to sustainable construction practices.

II. RESULT AND DISCUSSION

The results obtained are as discussed below

2.1.1 Characteristics of Clay Soil with the Addition of Rice Husk Ash Based on Standard Proctor Test Values

According to data obtained from [19] in the study *Analysis of Clay Soil Stabilization Using a Rice Husk Ash Mixture on Soil Shear Strength Values*, various percentages of rice husk ash as a stabilizing agent for clay soil exhibited different behaviors in terms of maximum dry density and optimum moisture content. Each percentage of rice husk ash mixture resulted in changes in characteristics that reflect varying stabilization effects.

Table 1. Standard Proctor Test Results for Native Soil and Soil Mixed with Rice Husk Ash

Sample Type	Dry Density	Optimum Moisture Content
	(Kg/cm^2)	(%)
Native Soil	1.45	25
Native Soil + ASP 5%	1.47	23
Native Soil + ASP 10%	1.49	22
Native Soil + ASP 15%	1.52	21
Native Soil + ASP 20%	1.54	20

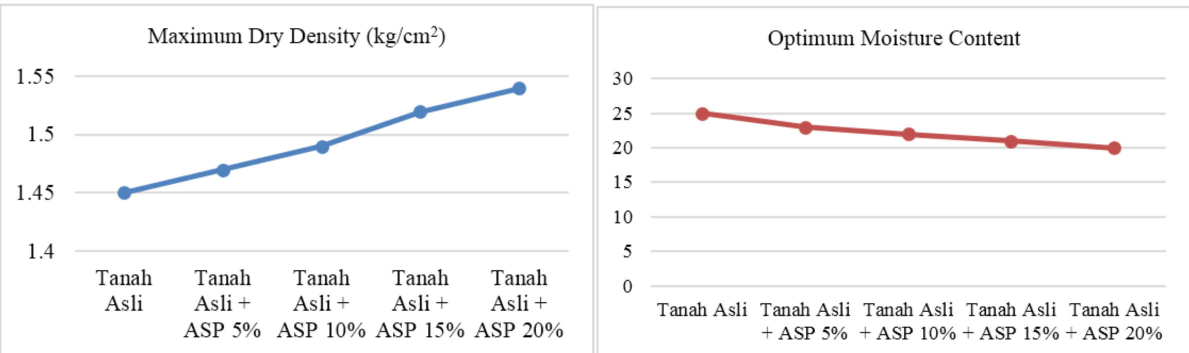
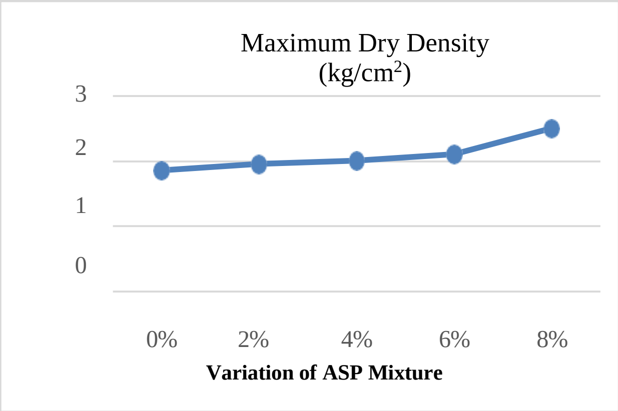


Figure 1. Graph of Maximum Dry Density and Optimum Moisture Content against Rice Husk Ash

The analysis of both graphs indicates that the native soil and soil mixed with rice husk ash at variations of 0%, 5%, 10%, 15%, and 20% show significant differences in dry density and optimum moisture content. The highest dry density value was observed in the mixture with 20% rice husk ash, reaching 1.54 g/cm³. Conversely, the lowest dry density value was recorded for the native soil at 1.45 g/cm³. Regarding optimum moisture content, the highest value was found in the native soil at 25%, while the lowest value occurred in the soil mixture with 20% rice husk ash, which was only 20%.



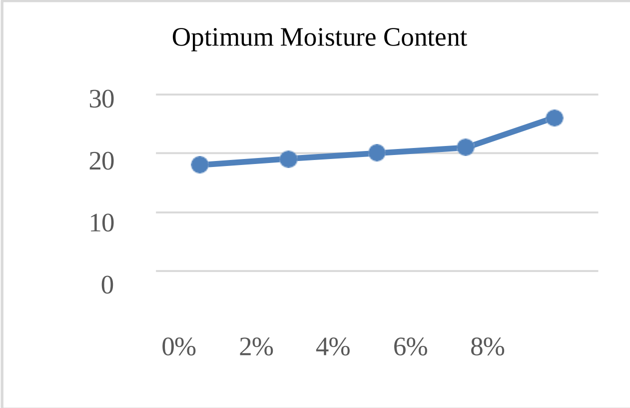


Figure 2. Graph of Maximum Dry Density and Optimum Moisture Content versus Rice Husk Ash

Meanwhile, data from Tanjung et al. (2023) in the study *The Effect of Unconfined Compressive Strength on the Addition of Rice Husk Ash to Clay Soil* demonstrate a similar trend, where the addition of rice husk ash affects both optimum moisture content and maximum dry density in specific mixtures [23].

The graph of maximum dry density shows that the dry density values for each variation of rice husk ash mixture tend to decrease with the increasing addition of the material to the native soil. However, some variations exhibit an increase. For example, the addition of 2% rice husk ash resulted in a 0.1% increase in dry density. At a 4% mixture, the increase was 0.05%, while at 6%, the dry density rose again by 0.1%. The most significant increase occurred with an 8% mixture, leading to a 0.4% rise in dry density.

In contrast, the graph for optimum moisture content indicates that the addition of rice husk ash to the soil consistently increased the optimum moisture content due to the inclusion of the material. For native soil, the optimum moisture content was recorded at 18.00%. After stabilization with mixtures up to 8%, the optimum moisture content increased to 26.00%.

Based on data from Shidiq et al. (2024), the variation in rice husk ash percentage as a clay soil stabilizing material shows a consistent trend of increasing maximum dry density with higher proportions of rice husk ash. Conversely, the optimum moisture content in this study tends to decrease with the addition of rice husk ash. This suggests that the use of rice husk ash in clay soil not only enhances soil density but also reduces the water demand required to achieve maximum density [20].

However, differing results are observed in the data from Tanjung et al. (2023). Although maximum dry density still exhibits an increasing trend with the addition of rice husk ash, the optimum moisture content shows a rise instead. This discrepancy could reflect differences in the properties of the native soil, the characteristics of the rice husk ash used, or the testing methods applied in each study. The increase in optimum moisture content in Tanjung et al. (2023) might be attributed to structural changes in the soil that require more water to achieve optimal density [23].

4.2. Characteristics of Clay Soil with the Addition of Cement Based on Standard Proctor Test Values

According to data from Syahrul (2023) in the study *The Effectiveness of Cement Addition on the Stability of Local Samarinda Soil*, variations in cement percentage as a stabilizing material for clay soil exhibit diverse responses in terms of maximum dry density and optimum moisture content. Each composition of the cement mixture induces different soil characteristics, reflecting varying levels of stabilization effectiveness [22].

Table 2. Standard Compaction of Cement Stabilization

Cement Content (%)	*w opt* (%)	*d*(gr/ml)
0	19,54	1,436
5	12,69	1,973
10	7,54	2,198
15	7,30	2,210

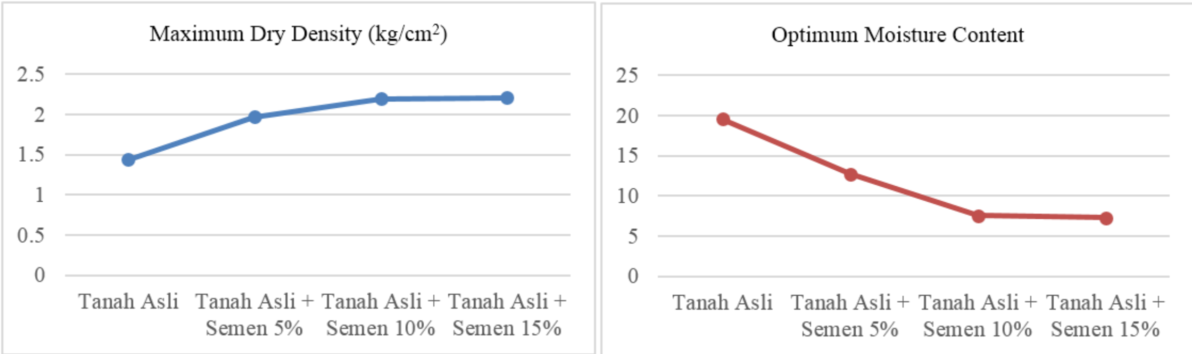


Figure 3. Graph of Maximum Dry Density and Optimum Moisture Content versus Cement

The data in the table and graph illustrate the effect of varying cement content on the optimum moisture content (w_o□□) and maximum dry density (γmax) of clay soil. For native soil without cement (0%), the optimum moisture content was recorded at 19.54%, with a maximum dry density of 1.436 g/ml. Gradual additions of cement resulted in a decrease in optimum moisture content and an increase in maximum dry density.

At 5% cement content, the optimum moisture content decreased to 12.69%, while the maximum dry density increased to 1.973 g/ml. The decrease in optimum moisture content became more significant at 10% cement content, reducing to 7.54%, with the maximum dry density rising to 2.198 g/ml. At 15% cement content, the optimum moisture content slightly decreased further to 7.30%, while the maximum dry density reached its highest value of 2.210 g/ml.

This trend indicates that the gradual addition of cement increases soil density and reduces water requirements, resulting in a more stable and compact soil structure.

Cement (%)	Optimum Moisture Content (%)	Maximum Dry Density (gr/cm^2)
0	19,08	1,261
5	19,9	1,279
10	18,90	1,303
15	18,57	1,319

Based on data from Haris (2023) in the study *The Effect of Cement Addition on Clay Soil Stabilization: A Case Study in Lanang Hamlet, Lampasio Village, Tolitoli Regency*, the addition of cement percentages to clay soil shows a decreasing trend in optimum moisture content (w_o□□) and an increasing trend in maximum dry density

(γ_{eiax}) [6]. The optimum moisture content exhibited slight fluctuations, with the highest value recorded at 5% cement content (19.9%) and the lowest value at 15% cement content (18.57%).

Meanwhile, the maximum dry density consistently increased from 1.261 g/cm³ for native soil (0% cement) to 1.319 g/cm³ at 15% cement content.

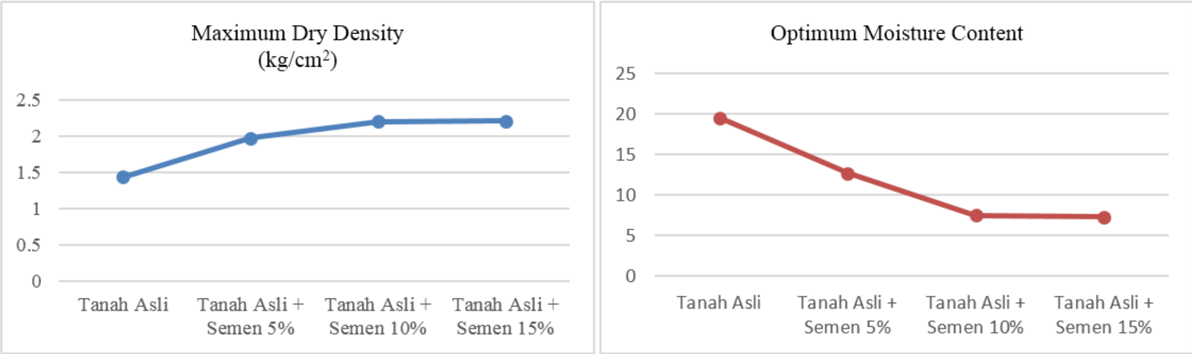


Figure 4. Graph of Maximum Dry Density and Optimum Moisture Content versus Cement

III. CONCLUSION

Based on data from the two stabilizing materials, rice husk ash and cement, it can be concluded that clay soil stabilization with these additives exhibits distinct characteristics in influencing optimum moisture content and maximum dry density. The addition of rice husk ash increases the maximum dry density while decreasing the optimum moisture content. Differences in optimum moisture content values suggest that the properties of rice husk ash are influenced by the native soil conditions and the testing methods used.

On the other hand, stabilization with cement shows a more consistent pattern, characterized by a reduction in optimum moisture content and an increase in maximum dry density. This effect reflects the ability of cement to improve soil structure, reduce water demand, and enhance soil compaction.

These stabilization materials have significant implications for sustainable construction. Rice husk ash offers an eco-friendly alternative material, while cement provides more uniform and stable results for soil strength improvement. The selection of appropriate materials should consider specific project requirements, soil conditions, and sustainability goals in construction.

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