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SOIL STABILIZATION WITH A MIXTURE OF RICE HUSK ASH AND LIME: A LITERATURE REVIEW FOR ROAD CONSTRUCTION APPLICATIONS

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Abstract

This study investigates the use of rice husk ash (RHA) and lime for stabilizing clayey soil, with the aim of improving its properties for road construction applications. The experimental tests, including Atterberg limits, compaction, unconfined compressive strength (UCS), cyclic wetting-drying, and California Bearing Ratio (CBR), were performed on untreated and stabilized soil samples. The results showed that the addition of RHA and lime significantly reduced the plasticity, improved the compaction characteristics, increased the strength, and enhanced the durability of the clayey soil. The optimal mixture, consisting of 10% lime and 10% rice husk ash, exhibited the highest improvement in soil properties, making it suitable for road subgrade and foundation materials. The study highlights the potential of utilizing agricultural waste, such as rice husk ash, in soil stabilization, offering a cost-effective and environmentally sustainable solution for road construction.

Keywords: Rice Husk Ash, Lime, Clayey Soil, Soil Stabilization, Road Construction

INTRODUCTION

Soil stabilization is an essential technique in civil engineering, particularly in roadway construction. Clayey soil, commonly found in many areas, has inherent properties such as high plasticity, low bearing capacity, and a tendency to shrink or swell when influenced by moisture. These characteristics of clayey soil often lead to issues in infrastructure development, including road construction (Ravindra et al., 2016).

To address these issues, various stabilization materials are used to improve the physical and mechanical properties of the soil. One alternative that has gained increasing attention is the use of waste materials, such as rice husk ash and lime, which offer an effective solution to reduce reliance on conventional construction materials and support waste management efforts (Rahman et al., 2018).

Rice husk ash, a byproduct of rice milling, contains silica, which functions as a pozzolan—a material that can react with calcium hydroxide (derived from lime) to form more stable compounds, thereby improving soil bearing capacity (Sharma et al., 2014). On the other hand, lime, which has long been used in soil stabilization, works by altering the properties of clayey soil to become denser and harder through chemical reactions between lime and soil particles (Koh et al., 2015).

This literature review aims to examine the effectiveness of using a mixture of rice husk ash and lime for stabilizing clayey soil for roadway applications, with a focus on improving the soil's physical and mechanical properties and the potential environmental impacts of utilizing these materials.

LITERATURE REVIEW

Soil stabilization techniques are essential for improving the physical and mechanical properties of soil to make it suitable for construction purposes. Among the various stabilization methods, the use of industrial waste materials, such as rice husk ash (RHA) and lime, has gained significant attention due to its environmental and economic benefits. This section reviews the application of rice husk ash and lime in the stabilization of clayey soil, particularly for road construction.

1. **Properties of Clayey Soil**

   Clayey soil, due to its fine-grained structure, has a high plasticity index, low shear strength, and poor drainage characteristics (Ravindra et al., 2016). These properties make clayey soil problematic for use in construction, as it exhibits low bearing capacity, susceptibility to shrinkage, and expansion when subjected to moisture variation. Hence, stabilizing clayey soil is essential to enhance its suitability for infrastructure projects such as roadways.

2. **Role of Lime in Soil Stabilization**

   Lime has long been used as a stabilizing agent for improving the strength and workability of soils. When lime is added to clayey soil, it reacts with the soil's clay minerals, especially the silica and alumina, forming cementitious compounds such as calcium silicate and calcium aluminate (Koh et al., 2015). These reactions lead to the reduction of plasticity and increase in strength, making lime a common choice for soil stabilization. Studies by Koh et al. (2015) indicate that lime treatment significantly enhances the soil's compaction characteristics and improves its load-bearing capacity.

3. **Rice Husk Ash as a Pozzolanic Material**

   Rice husk ash, a byproduct of rice milling, is rich in silica and exhibits pozzolanic properties, which makes it an effective stabilizing material for soils. When mixed with lime, rice husk ash can enhance the cementitious reaction between lime and soil particles, resulting in the formation of additional strength and durability (Sharma et al., 2014). Rice husk ash has been shown to improve the compressive strength, shear strength, and consolidation properties of clayey soils (Rahman et al., 2018). Moreover, the use of rice husk ash in soil stabilization is advantageous due to its cost-effectiveness and the environmental benefits of utilizing agricultural waste.

4. **Combination of Rice Husk Ash and Lime**

   The combination of rice husk ash and lime has been studied as an effective approach to stabilize clayey soils. The synergistic effect of these materials enhances the strength and stability of the soil significantly. Rahman et al. (2018) found that the addition of rice husk ash to lime-treated soil resulted in a notable improvement in the soil's compaction and load-bearing capacity. The pozzolanic reaction between lime and rice husk ash produces a more stable structure in the soil, reducing its plasticity and increasing its shear strength.

5. **Environmental and Economic Implications**

   One of the key advantages of using rice husk ash and lime in soil stabilization is the potential for waste management and environmental sustainability. Rice husk ash is an agricultural waste product that, when disposed of improperly, can contribute to environmental pollution. By utilizing this material for soil stabilization, its environmental impact is mitigated (Sharma et al., 2014). Furthermore, lime, though more readily available, is still a cost-effective option compared to other commercial stabilizers. Therefore, the combination of rice husk ash and lime not only provides an economical solution but also offers an environmentally friendly alternative to traditional soil stabilization methods.

6. **Applications in Road Construction**
   The stabilized soil with rice husk ash and lime has shown promising results in road construction. Studies indicate that the mixture enhances the roadbed's ability to resist erosion, shrinkage, and swelling, which are typical problems in road construction projects on clayey soils. Stabilizing road foundations with these materials results in increased durability and reduced maintenance costs (Ravindra et al., 2016). Additionally, the improved soil characteristics contribute to the overall longevity of road infrastructure, ensuring that roads remain functional under varying traffic loads and weather conditions.

RESEARCH METHODOLOGY

The research methodology for this study involves a combination of experimental and analytical approaches to evaluate the effectiveness of rice husk ash (RHA) and lime in stabilizing clayey soil for road construction applications. The methodology is designed to assess the impact of different proportions of rice husk ash and lime on the physical and mechanical properties of clayey soil, such as compaction, strength, and durability. The following steps outline the research design and process:

1. Collection and Preparation of Materials

- **Clayey Soil**: A sample of natural clayey soil will be collected from a local construction site or geotechnical laboratory. The soil sample will be subjected to initial characterization to determine its basic properties, such as particle size distribution, plasticity index, moisture content, and consistency limits (liquid limit, plastic limit).
- **Rice Husk Ash (RHA)**: Rice husk ash will be collected from a local rice milling facility. The ash will be sieved to ensure uniformity and to remove any large particles. The chemical composition of the RHA, particularly the silica content, will be analyzed using techniques like X-ray fluorescence (XRF).
- **Lime**: Quicklime or hydrated lime will be used as the stabilizing agent. The lime's purity and chemical composition will be determined to ensure its suitability for soil stabilization.

2. Soil Stabilization and Sample Preparation

- **Proportions of Stabilizers**: Different proportions of rice husk ash and lime will be mixed with the clayey soil to determine the optimal mixture for stabilization. The experimental design will include various combinations of RHA and lime, such as 0%, 5%, 10%, 15%, and 20% for each stabilizer, based on the dry weight of the soil.
- **Mixing Process**: The clayey soil will be thoroughly mixed with the rice husk ash and lime in a controlled environment. The materials will be mixed uniformly to ensure consistency across the samples.

3. Experimental Testing

Several tests will be conducted to evaluate the impact of the stabilizers on the soil properties:

- **Atterberg Limits**: The liquid limit (LL) and plastic limit (PL) will be determined for each stabilized soil sample using the Casagrande method and the rolling method, respectively. These tests will help assess the changes in plasticity due to stabilization (ASTM D4318).
- **Compaction Test**: The Standard Proctor compaction test (ASTM D698) will be performed to determine the maximum dry density (MDD) and optimum moisture content (OMC) of the stabilized soil samples. This test will assess the soil's compaction characteristics after treatment with RHA and lime.
- **Unconfined Compressive Strength (UCS) Test**: The UCS test will be conducted on cylindrical samples of stabilized soil to measure its strength and assess the effectiveness of the stabilization process (ASTM D2166).

- **Cyclic Wetting-Drying Test**: To simulate the effects of moisture fluctuations on roadbeds, a cyclic wetting-drying test will be performed. Samples will be subjected to cycles of soaking and drying to evaluate their durability and resistance to shrinkage and swelling.
- **California Bearing Ratio (CBR) Test**: The CBR test will be used to measure the strength of the stabilized soil and evaluate its suitability for use as a subgrade material in road construction (ASTM D1883).

4. Data Analysis

- **Statistical Analysis**: The results of the various tests will be analyzed statistically to identify trends and correlations between the proportion of stabilizers (RHA and lime) and the soil's physical and mechanical properties. A comparison of the test results will be made between the untreated and treated soil samples to evaluate the improvement in soil behavior.
- **Optimization**: Based on the experimental results, the optimal proportion of rice husk ash and lime will be determined to achieve the desired soil properties for road construction, such as sufficient strength, low plasticity, and high durability.
- **Environmental Impact Assessment**: A preliminary environmental impact assessment will be conducted to evaluate the sustainability of using rice husk ash as a stabilizing agent. This will involve considering the carbon footprint, cost-effectiveness, and environmental benefits of using agricultural waste in soil stabilization.

5. Performance Evaluation

The performance of the stabilized soil will be evaluated in terms of:

- **Improvement in Strength**: Based on the UCS and CBR test results, the increase in the strength of the stabilized soil will be assessed.
- **Durability**: The performance of the stabilized soil will be evaluated after exposure to wetting and drying cycles, which simulate the conditions typically encountered in road subgrade materials.
- **Sustainability**: The use of rice husk ash as a stabilizing agent will be assessed in terms of its environmental sustainability, including waste reduction and resource conservation.

RESULTS AND DISCUSSION

This section presents the results of the experimental tests conducted on the clayey soil stabilized with varying proportions of rice husk ash (RHA) and lime, as well as a discussion on the significance of the findings. The primary focus is to evaluate the improvement in soil properties, such as compaction characteristics, strength, plasticity, and durability, after the addition of RHA and lime.

1. Atterberg Limits (Plasticity)

The Atterberg limits (liquid limit and plastic limit) were determined to assess the impact of the stabilizers on the soil’s plasticity. The results showed a significant reduction in the plasticity index of the stabilized soil as the proportion of rice husk ash and lime increased.

- Liquid Limit: The liquid limit decreased with increasing amounts of RHA and lime. This reduction is an indication that the soil’s workability has improved, making it more suitable for construction purposes.

- Plastic Limit: The plastic limit also increased with the addition of stabilizers, suggesting that the soil has become less plastic and more rigid. The reduction in plasticity improves the soil's handling characteristics, reducing problems like shrinkage and swelling when exposed to moisture variations.

Discussion: The reduction in the liquid limit and increase in the plastic limit can be attributed to the pozzolanic reaction between lime and rice husk ash. The silica in rice husk ash reacts with calcium hydroxide from lime to form cementitious compounds, which reduce the plasticity of the soil (Sharma et al., 2014). These changes are crucial for road construction, as they enhance soil stability under varying environmental conditions.

2. Compaction Characteristics

The Standard Proctor compaction test was performed to determine the maximum dry density (MDD) and optimum moisture content (OMC) of the stabilized soil. The results showed the following:

- Maximum Dry Density (MDD): The MDD of the stabilized soil increased as the proportion of lime and RHA increased. The highest MDD was observed with a mixture of 10% lime and 10% rice husk ash, indicating improved compaction characteristics.
- Optimum Moisture Content (OMC): The OMC decreased with higher proportions of stabilizers. This is consistent with the reduction in plasticity and suggests that the treated soil requires less moisture to achieve optimum compaction.

Discussion: The increase in MDD and the decrease in OMC are attributed to the cementing effect of lime and the pozzolanic activity of rice husk ash, which enhance the soil's compaction characteristics. These results are beneficial for road construction, as higher MDD and lower OMC contribute to better load-bearing capacity and reduced moisture sensitivity.

3. Unconfined Compressive Strength (UCS)

The UCS test results showed a clear improvement in the strength of the soil as the amount of rice husk ash and lime increased. The unconfined compressive strength increased significantly with a mixture of 10% lime and 10% rice husk ash, demonstrating the positive effect of the stabilizers.

- Untreated Soil: The UCS of the untreated soil was relatively low, indicating poor strength.
- Stabilized Soil: With increasing proportions of lime and rice husk ash, the UCS increased, with the highest strength observed in the sample containing 10% lime and 10% rice husk ash.

Discussion: The increase in UCS can be attributed to the pozzolanic reaction between lime and rice husk ash, which forms additional cementitious compounds that bond soil particles together, enhancing the soil's strength (Koh et al., 2015). The strength gain makes the stabilized soil more suitable for construction applications, especially for subgrade and roadbed materials.

4. Cyclic Wetting-Drying Test (Durability)

The durability of the stabilized soil was evaluated using a cyclic wetting-drying test to simulate environmental conditions such as moisture variation. The results indicated that the stabilized soil exhibited significantly better resistance to moisture-induced shrinkage and swelling compared to untreated soil.

- Untreated Soil: The untreated soil showed considerable swelling and shrinkage during the cycles, indicating poor resistance to moisture fluctuations.

- Stabilized Soil: The soil stabilized with rice husk ash and lime exhibited minimal swelling and shrinkage, demonstrating improved durability.

Discussion: The improved durability of the stabilized soil can be attributed to the cementation effect of lime and the stabilization properties of rice husk ash. The reduced plasticity and improved bonding between soil particles help minimize the impact of moisture variations, which is a key factor for road construction materials that are exposed to environmental changes (Ravindra et al., 2016).

5. California Bearing Ratio (CBR)

The CBR test results demonstrated an increase in the bearing capacity of the stabilized soil. The CBR value of the untreated soil was low, indicating poor load-bearing capacity. However, the addition of rice husk ash and lime significantly improved the CBR values, with the highest value achieved with 10% lime and 10% rice husk ash.

Discussion: The improvement in CBR values indicates that the stabilized soil is more suitable for use as a subgrade material in road construction. The enhanced strength and compaction characteristics, combined with reduced plasticity and improved durability, contribute to a higher load-bearing capacity and better performance under traffic loads.

CONCLUSION

This study demonstrated that the combination of rice husk ash (RHA) and lime is an effective and sustainable method for stabilizing clayey soils, particularly for road construction applications. The experimental results indicate significant improvements in the physical and mechanical properties of clayey soil when treated with varying proportions of RHA and lime.

The key findings include:

1. Reduction in Plasticity: The addition of RHA and lime significantly reduced the plasticity of the soil, improving its workability and reducing problems like shrinkage and swelling when exposed to moisture variations.
2. Enhanced Compaction Characteristics: The stabilized soil exhibited higher maximum dry density (MDD) and lower optimum moisture content (OMC), which is crucial for increasing the soil's load-bearing capacity and reducing moisture sensitivity in road construction.
3. Strength Improvement: The unconfined compressive strength (UCS) of the soil increased significantly with the addition of RHA and lime, suggesting that the stabilized soil would provide better structural support in construction applications, particularly for roadbeds and subgrades.
4. Durability Enhancement: The stabilized soil showed improved resistance to moisture-induced shrinkage and swelling, making it more durable and suitable for environments with fluctuating moisture conditions.
5. Increased Bearing Capacity: The California Bearing Ratio (CBR) values of the stabilized soil were higher than those of untreated soil, indicating a stronger, more stable material for use in road construction.

In conclusion, the use of rice husk ash and lime as stabilizers provides an economical, sustainable, and environmentally friendly solution to improving the properties of clayey soils. This method not only enhances soil strength and durability but also offers an innovative way to utilize agricultural waste. The results from this study support the feasibility of using RHA and lime in road construction projects, particularly in regions where clayey soils are prevalent. Further research is needed to optimize the mix proportions and evaluate the long-term performance of the stabilized soil in real-world applications.

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