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Investigation of Permeability Changes in Ultisols Treated with Rice Husk Ash, Bagasse Ash, and Coconut Shell Ash Mixtures

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Abstract:
This thesis delves into the investigation of permeability changes in Ultisols treated with rice husk ash, bagasse ash, and coconut shell ash mixtures. The primary objective was to assess the impact of these ash mixtures on Ultisol permeability, aiming to provide insights into sustainable soil improvement practices. Following a methodological framework encompassing objective identification, material procurement, and testing center selection, the study conducted experiments to analyze the alteration in Ultisol permeability post-treatment with ash mixtures. The results revealed a significant increase in Ultisol permeability with the addition of ash mixtures, particularly noting the effectiveness of a 2.5% addition. Conclusions drawn underscored the viability of ash mixtures in enhancing Ultisols' permeability, offering promising avenues for soil improvement. Recommendations were outlined for further research, urging exploration into higher percentages of ash mixtures, soil replacement equivalents, and assessment of other soil properties. Moreover, geotechnical engineers were advised on the efficacy of ash mixtures in permeability enhancement, while local communities and farmers were encouraged to explore the economic potential of utilizing agricultural waste materials for soil improvement and business endeavors. This thesis contributes to the understanding of sustainable soil management practices and offers practical insights for stakeholders involved in soil improvement initiatives.

Keywords **—Rice Husk Ash, Bagasse Ash, Coconut Shell Ash**

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I. INTRODUCTION

Ultisols are low-base-saturation soils with an increase in clay in the subsoil horizons. They are the most fruitful soils, and with proper management, they can continue to be productive. Ultisols are fundamental to the formation of the terrestrial landscape. Tropical and subtropical areas primarily host these soils, which stand out for their worn, acidic nature. Furthermore, Ultisols form in warm, humid climates where vital weathering processes lead to mineral leaching and clay buildup in the B horizon. According to the USDA Soil Taxonomy, Ultisols are the most prevalent type of soilin the Philippines [1].

When it comes to controlling essential soil functions, permeability is important. Clay makes up a large portion of the subsurface horizons in Ultisols. This feature significantly impacts the soil matrix's nutrient mobility, drainage patterns, and water retention. In comparison to sandy soils, clay soils typically have reduced permeability. The clay particles' small size and dense packing produce a fine-textured soil that impedes water flow. The engineers must consider the possibility of soil swelling and shrinking, particularly in response to soil moisture content variations. To guarantee stability and reduce the chance of settlement, proper foundation design should consider the unique properties of the soil.

Agricultural waste materials include the ashes from rice husks, bagasse, and coconut shells. The potential benefits of these ash mixtures for improved soil and sustainability have received attention. Silica is abundant in rice husk ash. Bagasse ash is a byproduct of sugarcane processing with a high silica content and the ability to improve soil structure. Because silica enhances soil structure, particle arrangement, pore spaces, and water movement, it mainly affects permeability. Ash from coconut shells, a byproduct of processing coconuts, enriches the soil with organic matter and increases fertility. Using these ash mixtures may lessen the problems caused by Ultisols.

Ultisol soil has a low natural fertility due to its extreme weathering. Underneath forest vegetation, soil has formed. The properties of this acidic soil include low pH, high aluminum saturation, poor cation exchange capacity, low basic saturation, low P concentration, low organic matter, high bulk density, sluggish soil permeability, and high erodibility [2]. An amendment to soil is any substance that is applied to improve physical properties such as structure, permeability, water infiltration, drainage, and aeration. Soil amendments enhance the aggregation of clayey soils, augment their porosity and permeability, and enhance aeration, drainage, and rooting depth [3]. In order to blend the ash from rice husk, bagasse, and coconut shell, soil was replaced by weight at 0%, 2.5%, 5%, 7.5%, and 10% [4].

The breakdown of a strong embankment with a well-compacted core was caused by subsequent core cracking from undrained deformations, which decreased the dike's shearing strength [5]. When pore water is unable to exit the soil, the soil is said to be undrained [6]. A trunk road segment of Brazil's Amazonas state's Urucu Oil Basin that degraded after little time of use. In this instance, soil-atmosphere interaction rather than a structural design flaw caused the deterioration. Due to soil swelling during heavy rainstorms, this interaction caused longitudinal fractures in the embankment and transverse cracks in areas where only earthworks were present, which were located slightly above natural soil level [7]. The main cause of soil swelling is the absorption of water by clay particles. Water can permeate and drain more easily in areas with high permeability. This limits the quantity of water that clay particles may absorb, which in turn prevents swelling [8].

1.1 Statement of the Problem

The effectiveness of a combination of rice husk ash, sugarcane bagasse, and coconut shell ash on the permeability of ultisols is assessed by the researchers. It specifically aimed to respond to the following questions:

1. What is Ultisol's permeability?
2. What is the Optimum amount of RHA, BA, and CSA to achieve desired permeability characteristics?
3. Will the permeability of ultisols increase?
4. Will the permeability of ultisols decrease?

1.2 Objectives of the Study

To use the falling head test in accordance with Indian Standard 2720 part 17 to investigate the alteration in ultisol's permeability by mixing Rice Husk Ash, Bagasse Ash, and Coconut Shell Ash.

1. To apply the falling head test to evaluate the samples' permeability.
2. To investigate the effectiveness of 2.5%, 5%, 7.5%, and 10% of ash in ultisol.
3. To determine the optimal percentage of ashes that is added to the soil to achieve the desired permeability.

1.3 Significance of the Study

Researchers. The findings of this study will support the RHA, BA, and CSA's scientific understanding of how they affect soil permeability and soil amendments. The results of this study can be used as a starting point for more research in this area.

Geotechnical Engineers. This research offers an alternative method or resolution for addressing the permeability issues observed in Ultisols.

Local Communities. This research can give the people in the local community a way for their waste materials to have a purpose rather than just being used as fertilizer. It can also give the people in the local community awareness on the problems around their vicinity because of ultisol's problems like erosion.

Farmers and Agricultural Producers. The findings of this research could help the farmers and agricultural producers reduce the waste materials in the community. Also, if the results of this study prove to be positive, it could increase the economic level of the community as the waste materials could be used as a business endeavor.

1.4 Scope and Limitations

This study examines the effects of a combination of rice husk ash (RHA), bagasse ash (BA), and coconut shell ash (CSA) on Ultisol's permeability and is carried out at a testing facility. The study aims to analyze how varying concentrations (2.5%, 5%, 7.5%, and 10%,) of the RHA-BA-CSA mixture affect Ultisol permeability compared to untreated samples. However, certain limitations exist. Financial constraints might limit the scope of testing. A regulation which is ASTM D-5084 that restricts applying these results directly to field scenarios without qualified personnel. Also, the research focuses solely on Ultisols permeability and the specific RHA-BA-CSA mixture. Despite these limitations, the study can provide valuable data on the influence of RHA-BA-CSA mixture on Ultisol permeability within a controlled setting, potentially informing future field-based research.

1.5 Review of the Related Literatures

Ultisol generally exhibits a high toxicity to aluminum, a low organic matter content, inadequate nutrient composition (particularly phosphorous and exchangeable cations such as calcium, magnesium, sodium, and potassium), a high Al content, and a low cation exchange capacity (CEC). It is prone to erosion [9]. Due to the granular clay texture of this type of soil, which consists mainly of sand, the soil's capacity for storing water is minimal [10].

Ultisol is also a soil order found in the U.S. Taxonomy of Soils. They are reddish, clay-rich, acidic soils, and sustain a mixed woodland vegetation before cultivation. Not only are they reliable building materials, but they also make good forestry and agricultural resources when lime and fertilizers are added. They were formed in regions of mountains, hills, and undulating to rolling plateaus. Ultisols, or geologically aged soils, are found in aged, solid, and heavily weathered landscape locations, such as steep highlands, hills, and mountains, because of their high temperatures and regular precipitation [11].

Ultisols, which are considered problem soils due to their severe acidity, poor base saturation, high P retention, and highly leached state, make up a large component of the upland regions. Furthermore, Ultisols are vulnerable to erosion since they are found in highland regions. According to USDA Soil Taxonomy, soils in the Philippines are divided into six (6) Soil Orders (Table I). Ultisols are the most widespread, making up about 124,500 square kilometers, or 41.5 percent of the nation [12]. One of the most remarkable facts regarding Ultisols is that, with proper care, these soils can be beneficial [11].

In southern Chile, ultisols have bulk densities greater than 1.0 Mg m^-3 and limited permeability due to the presence of more than 50% clay in the upper layers [13]. Apart from deficiencies in some nutrients, the upland ultisol soil exhibits low levels of organic matter, high bulk density (BD) of soil, low levels of soil permeability and total pore space, and low levels of available water [14].

All around the world, indigenous soil categories exist. They serve as the foundation for a variety of management techniques, including modifying soil conservation measures and precisely tailoring cropping systems to the site's agricultural potential [15]. Within the fine clayey soil family are the well-drained, shallow to moderately deep Antipolo soils. Light reddish brown, dark reddish brown, strong brown, brown to dark brown, and yellowish red are among them [16]. Using reconnaissance soil investigations, maps of Antipolo clay loam, sandy clay, clay, and undifferentiated clay were created for the provinces of Zambales, Quezon, Rizal, Bataan, Laguna, Zamboanga del Sur, and Lanao [11]. Ultisol costs 0.39 PHP per kilogram [17].

About 750 million tons of rice husks are grown per year, yielding about 160 million tons of rice husk waste that is eventually discarded into the environment, filling up a sizable landfill and contributing to pollution issues. One of the main grains produced globally is rice. About 20% of the milled rice kernel's weight is retained in the rice husk throughout the production of rice. Rice husk is the term for the natural covering of rice kernels. In nations where rice production is substantial, a large amount of agricultural waste is composed of rice husk. When rice husks are burnt, either directly or as a fuel in cogeneration plants, (RHA) is created [18]. RHs are created in large quantities worldwide each year, but they have only been recycled for low value uses. It is challenging to dispose of RHA in open fields or landfills due to the low bulk density, which can have serious negative effects on human health and the environment. Limited space may make it difficult to properly dispose of RHA in garbage dumps, which might pose a serious risk to the environment [19].

A considerable volume of waste and byproducts is generated, among other things, during production, in the service sector, and from urban solid refuse. Consequently, solid waste management has become a prominent environmental concern worldwide [20]. As byproducts of the rice and sugar mills, industrial waste consists of rice husk ash and bagasse ash, accordingly [21]. The ash was acquired by incinerating coconut shells in an open-air environment [22]. The experimentation involved subjecting the materials to varying temperatures of 600° and 700°C while also considering different heating durations, spanning one and two hours each [23]. A 15% RHA addition to the soil raises its permeability to 8.4×10^{-7}, allowing subgrade soil to drain effectively. The permeability of the soil continues to increase as FA and RHA are added [24].

Rice Husk Ash, produced as a result during rice crushing, is rich in silicate and iron oxide [25]. Rice husk ash, a readily available and inexpensive pozzolanic material, can stabilize soil. Ash is produced by burning rice husk at a regulated temperature, and it makes up between 17 and 25 percent of the rice husk's mass [26]. Among the largest users of rice worldwide are the Filipinos. The average Filipino eats roughly 100 kg of rice annually. While rice is grown all throughout the nation, the two main rice-growing regions are Central Luzon and the Cagayan Valley [27]. The cogeneration plants' projected cost per 40-kg bag of RHA trash was 278.01-340.93 PHP [28].

One of the most often grown crops worldwide is sugarcane. Sugarcane bagasse is produced following the extraction of sugarcane juice. Bagasse from sugarcane accounts for about 46 percent of the total weight of sugarcane excluding straws or leaves. Following its utilization as a fuel in cogeneration facilities for the production of sugar, sugarcane bagasse ash (SCBA) is generated. The growing demand for ethanol and sugar has led to a steady increase in the production of SCBA. The amount of SCBA that is being used has increased the strain on landfills. In addition to having little nutritional value, SCBA is unsuitable for use as fertilizer. It is possible for heavy metals to seep into the ground and contaminate soil and groundwater if SCBA is used as fertilizer. This could lead to serious health and societal problems [29].

A considerable quantity of bagasse is either disposed of as waste in open air heaps, which presents an environmental hazard, or incinerated for electricity cogeneration, resulting in substantial CO_2 emissions that contribute to the phenomenon of global warming [30]. A considerable amount of residual bagasse ash is typically deposited in landfills in India, where it is utilized as biomass in the cogeneration furnace [31].

Bagasse is a residual material that is obtained from the grinding of sugarcane, especially the cane fiber. It acts as a holding area for the moisture and leftover liquid during extraction [32].5.78 percent iron oxide (Fe_2O_3), 65.58 percent silicon oxide (SiO_2), and 5.78 percent aluminum oxide (Al_2O_3) are the ingredients found in pozzolana, which makes up bagasse ash [33]. Further observation reveals that the hydraulic conductivity of soil mixed with BA increases from $1.877x10^{-7}$ m/s at no BA content to $1.12x10^{-5}$ m/s at 75% BA content [34].

The most productive area for sugarcane production this quarter was still Western Visayas, with 1.34 million metric tons, or 47.2% of total production. Northern parts of Mindanao and Central Visayas region came next, with outputs of 516.79 thousand metric tons (18.3%) and 355.41 thousand metric tons (12.6%), respectively. 78.1 percent of the sugarcane produced nationwide came from these locations [35]. The cost per 40-kg bag of BA waste from cogeneration facilities was projected to be between 49.23-269.66 PHP [28].

The Philippines cultivated 347 million coconut trees in 2020, from which it harvested 14.7 million kilograms of coconuts. 15.18% of each fruit is composed of endocarp, or coconut shells, which are regarded as a byproduct and amount to 2.2 million tons [36]. Coconuts yield solely beneficial byproducts, namely copra and coconut oil; the remainder, including coconut hulls, are discarded on farms. Due to their lack of economic value, coconut shells, which are an agricultural solid waste, will ultimately be disposed of and linked to the contamination of public spaces. The degradation process of coconut shells in the environment can take up to ten years, contributing to unsightliness in urban settings and serving as breeding grounds for mosquitoes and vectors of disease [37].

The lightweight and weather-resistant nature of coconut shells makes them an exceptional aggregate material for asphalt and concrete. Further, their exceptional water resistance renders them an optimal selection for outdoor structures such as driveways [38]. Using coconut shell ash for soil stabilization will be another way to reduce this waste. Coconut shell ash is a silica-rich waste that, when used with calcium-rich material, will yield a cementing property through a pozzolanic reaction [39, 40].

The output of coconuts (with husk) increased by 1.5% annually to 3.41 million metric tons between April to June 2023, compared to the 3.36 million metric tons generated in the same period of 2022. With a production of 461.07 thousand metric tons, or 13.5 percent share, the Davao Region was the leading producer of coconuts for the quarter. Northern Mindanao and the Zamboanga Peninsula produced 437.60 thousand metric tons (12.8%) and 452.33 thousand metric tons (13.3%) of coconuts, respectively, making them the top three regions with the largest output [41]. In the Philippines, the average cost per kilogram of raw shell charcoal, also known as coconut shell ash, is 11.45 PHP [42].

The ability of soil to transfer liquids, including water, is referred to as permeability. It is an important attribute that has an impact on civil engineering, agriculture, and environmental management [43]. Most soils had a surface permeability that was initially between moderate and moderately quick. In comparison to the untreated plots, the addition of fertilizers and limestone has enhanced the soil's permeability rate [44]. It will take longer for poor permeability soils to solidify. This has an impact on the rates of strength increase and settling, which are critical processes for all earth constructions [45].

Allegheny County's soil frequently exhibits high porosity but low permeability. To improve the soil's ability to absorb water, green infrastructure designers occasionally incorporate materials like sand and compost [46].

The characteristics and behavior of the soil are significantly influenced by the amount, dispersion, and flow of water in the soil. It is important for the engineer to possess knowledge of fluid flow principles, as groundwater situations frequently arise during building projects. Field permeability study data is used to calculate aquifer constants and the pumping capacity required to dewater excavations. This data is essential for the planning of many civil engineering projects, such as the cut-off wall design of earthen dams. The hydraulic conductivity of soils has a major influence on the erodibility of open cuts in water-bearing sand, subgrade drainage, foundation stability, seepage loss via reservoir embankments, and the rate at which water flows into wells [47]. Since identifying, assessing, and appropriately managing drainage issues that arise during the design and construction of structures is one of the main issues facing soil and foundation engineers, soil permeability is a crucial physical attribute [48]. When building an embankment or fill, a variety of soil types may be used, from the highly desirable granular soils (sand and gravel) to the generally less acceptable fine-grained soils (silt and clay), and even rock [49]. The average price of soil used in embankments per kilogram is 1.02 PHP [50].

The Falling Head Test allows the pressure to progressively drop while water seeps into the sample. Generally, falling head operations are restricted to fine-grained soils. A "constant head test" apparatus keeps the head pressure—the height of the water column relative to the sample—constant during the test. Water permeates soil particles at a rate known as soil permeability, also known as hydraulic conductivity. This test works well with specific clay soils and high-flow soil types like sands and gravels. While the constant head test technique is utilized for cohesionless and more permeable soils, the falling head test is frequently employed for cohesive or less permeable soils [51].

Red clay, characterized by its elevated liquid limit and reduced permeability, is considered unsuitable for engineering endeavors in accordance with pertinent Chinese standards. Because red clay is water-sensitive, rainfall may cause landslides to develop along its slopes [52].

Kaolinite is often the predominant clay mineral found in Ultisols [11]. Kaolinite had a significant effect on these parameters since a 5% increase in the proportion of clay resulted in a decrease in permeability [53].

Significant factors influencing the settling and stability of earth embankments are the permeability of the foundation soil and the amount of leaking via earthen dams or storage ponds. The hydraulic conductivity of the subgrade soil affects side drain performance along a transport route as well. Permeability of the soil is crucial. Low permeability soils will take longer to solidify, which has an impact on the two essential characteristics for all earth structures: the rate of strength growth and the rate of settling. The subgrade strength of roads will be significantly impacted by the permeability of the subgrade soil, both during and after construction. Consequently, especially during the constructing stage, a saturated soil strength may be more appropriate for road design [45].

When evaluating an embankment's safety, a precise estimation of the seepage flow through the soil embankment is crucial [54]. An abundance of soft, compressible soils, including marks, peats, organic silts, and clays, can lead to issues with settlement and embankment stability. When embankments are constructed without the proper foundation preparation on weak soils, including soft clays, organic silts, and peats, disagreements may arise [55]. Clay has a lot of potential and, with the right design and preparation, might be used for road embankments [56].

The behavior of the soil with regard to collapse is significantly correlated with the stability of a road or railway subgrade. There is a prevailing belief that water is the primary external determinant, while clay minerals are the primary internal determinant. Maximizing the utilization of the composite material consisting of fully weathered phyllite soil and red clay is critical in order to address the subgrade's constructability issue, decrease the expenses associated with highway and railway maintenance, and enhance economic gains [57].

Ultisols are excellent for construction in a lot of ways. Regarding swelling or shrinking according to water content, they are less picky. They provide strong foundation stability and can withstand stress. Nevertheless, in addition to being challenging to maintain for lawns and gardens, Georgia red clay frequently creates issues with water drainage [58].

1.6 Conceptual Framework

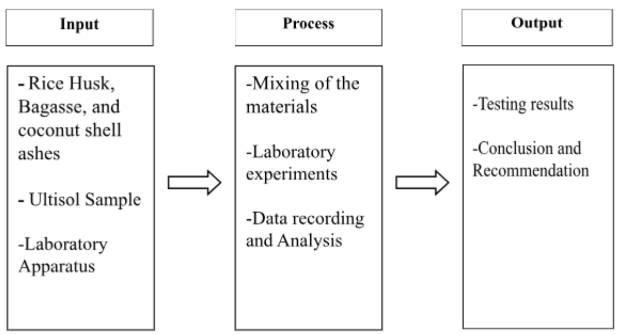


Figure1:Conceptual Framework

1.7 Definition of Terms

Ash - Consists of any non-gaseous, non-aqueous residues remaining after something has burned. In the field of analytical chemistry, ash is the solid, non-gaseous remnant remaining after the complete combustion of chemical samples to determine their metal and mineral content.

Bagasse - It initially denoted the byproduct obtained during the pressing process of palm kernels, olives, and grapes. As time passed, the term began to be applied to the refining of sugarcane and sugar beets, among other plants.

Coconut shells - The most durable component contained in coconut fruit is the coconut shell. In between the coconut inside and the coconut husk is the coconut shell. Typically, the purpose of this shell is to seal the interior of the coconut.

Kaolinite - Kaolinite is regarded as one of the six most abundant minerals in the earth's crust. It is the most common mineral found in clays, particularly in soils with a humid tropical climate.

Permeability - Estimates the capacity of a sediment to let the passage of water. The relationship between soil porosity and permeability is direct; that is, the greater the soil porosity, the greater its permeability.

Rice Husk –It is the outermost coating of the seed or core of rice. Among the stiff materials that make up its structure to protect the seed throughout the growth season are lignin and silica. For every kilogram of milled white rice, about 0.28 kg of rice fiber are created during the milling process.

Ultisols - The taxonomy of the United States Department of Agriculture places this soil, often known as red clay soil, in one of twelve orders. The name "ultisol" is derived from the word "ultimate" because of the belief that it originated from a constantly degrading mineral environment in a humid, temperate climate without depositing glacial soil.

II. METHODOLOGY

2.1 Methodological Framework

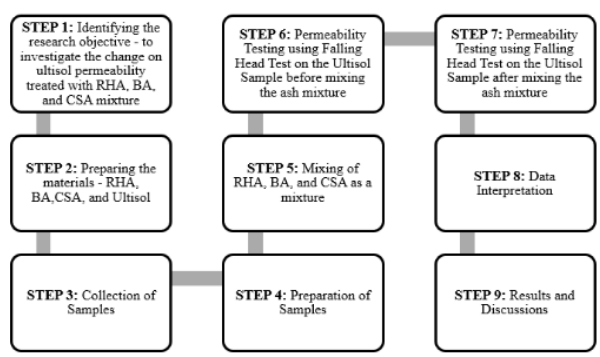


Figure2:Methodological Framework

2.1 Phase 1 – Methodological Framework

2.1.1 Research Design

Research serves as a pivotal tool in uncovering information and facts. The pursuit of this research involves the completion of several tasks. A methodological approach closely aligned with scientific inquiry is termed experimental research. Within this framework is a variable manipulated by the researcher alongside measurable, quantifiable, and comparable variables. Most importantly, experimental research is conducted within a controlled and regulated environment, ensuring careful precision in its implementation.

This study used an experimental research design, where a control variable consisted of a specimen setup consisting of basic components, while other setups had different replacement percentages. Testing trials were used to gather data for the study in order to achieve its goals, which were then carefully examined and assessed [59].

2.1.2 Methods of Testing

A falling head test will be performed on the controlled sample which does not contain the ash mixture and the experimental sample containing the ash mixtures to verify its permeability. The testing follows the IS 2720 part 17.

a. The specimen must be connected to the chosen stand-pipe through the top inlet in order to perform a falling head test configuration.
b. When the bottom outlet is opened, the amount of time needed to measure the drop in water level from a given beginning head to a known ending head at the outlet center will be noted.
c. The test will be repeated until three successive measurements yield a nearly identical interval with the standpipe filled with water.
d.As with the initial determination, the time periods for the head drop are being recorded from the same beginning to end values.

Formula of Hydraulic Conductivity or Permeability:

$$K = \frac{2.30\, aL}{At} \log_{10} \frac{h_1}{h_2}$$

Where:

A = Area of standpipe, cm^2
L = Length of the specimen, cm
A = Area of specimen, cm^2
t = time, s
h_1 = Initial reading of standpipe, cm
h_2= Final reading of standpipe, cm

2.2 Phase 2 - Data Collection

2.3 Research Instrument

This study aims to investigate the effects of RHA, BA, and CSA on the permeability of ultisols, determining whether they have positive or negative impacts. The research involves conducting standardized laboratory tests to measure the permeability of Ultisols with and without the ash mixture. These tests will adhere to the IS (Indian Standards) for accuracy and consistency in measurement.

Observational data collection involves the systematic process of visually observing and carefully documenting the various behaviors, characteristics, or patterns exhibited by the subjects or samples under study. This method requires keen attention to detail and the consistent recording of observations through manual documentation.

2.4 Data Collection Methods

The data can be obtained through laboratory equipment that is used in a falling head test and the testing adheres to the IS 2720 Part 17. The researchers can assess and compare their permeability by performing these tests on pure Ultisol and the mixtures. This data is essential for evaluating how the ash mixture affects the permeability of ultisol.

2.4.1 Materials

The raw materials used in this study to generate the soil samples that include Ultisols soil samples, bagasse ash, rice husk ash, and coconut shell ash are listed below. These samples are crucial for determining how their mixing affects soil permeability. The two waste organic materials which are RH and CS were sourced in the respective communities of the researchers while the BA is sourced out at Central Azucarera de Tarlac and lastly the Ultisol was sourced in Bataan.

Rice husk - It is the outermost coating of the seed or core of rice. Among the stiff materials that make up its structure to protect the seed throughout the growth season are lignin and silica. For every kilogram of milled white rice, about 0.28 kg of rice fiber are created during the milling process.

Figure 3: Rice Husk and Rice Husk Ash

Bagasse - It initially denoted the byproduct obtained during the pressing process of palm kernels, olives, and grapes. As time passed, the term began to be applied to the refining of sugarcane and sugar beets, among other plants.

Figure 4: Sugarcane Bagasse and Sugarcane Bagasse Ash

Coconut shell - The most durable component contained in coconut fruit is the coconut shell. In between the coconut inside and the coconut husk is the coconut shell. Typically, the purpose of this shell is to seal the interior of the coconut.

Figure 5. Coconut Shell and Coconut Shell Ash

Ultisol - Also referred to as red clay soil. "Ultisol" is a term derived from "ultimate" due to the perception that it was formed as the result of perpetual mineral degradation in a humid, temperate environment devoid of glacial soil deposition.

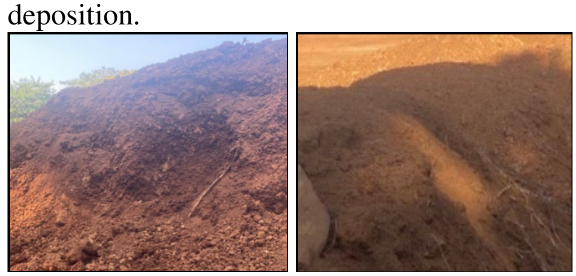


Figure 6: Ultisol

Water - The water's viscosity is influenced by temperature. As the temperature rises, the permeability decreases and the viscosity increases. Permeability can exist at any temperature, however the coefficient of permeability is standardized at 20°C. The permeability at a certain temperature is commonly found in the literature using the traditional temperature calibration formula (TTCF), which is based on the permeability at 20 °C [60].

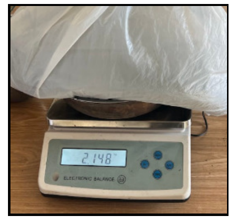
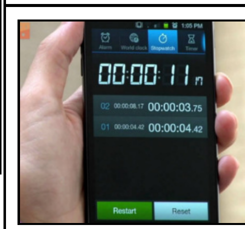
Figure 7: Water

2.4.2 Tools and Equipment

The following list of crucial information was needed for this inquiry, which was conducted using both manual tools and sophisticated equipment for sample processing by the proponent:

2.4.2.1 Tools

Table 1. Tools and Its Definition

Tools	Tool and its Definition
	**Shovel.** A tool used for moving loose, granular materials (soil, gravel, grain, or snow) as well as for excavating.
	**Trowel.** A trowel is one of numerous types of small hand instruments utilized to move, apply, smooth, or excavate small quantities of viscous or particulate matter; common varieties include the float trowel, garden trowel, and masonry trowel.
	**Electronic Weighing Scale.** A device that measures weight or mass. It was employed to calculate the ultisol and ash weights.
	**Sack.** A sturdy fabric, paper, or plastic bag that is sufficiently large to accommodate a significant amount of a particular item.
	**Container.** A container is any enclosure or receptacle used to store or package a product. By virtue of their confinement within the container's structure, objects stored within are safeguarded on multiple fronts.
	**Scoop.** A utensil utilized for scooping up flour, maize and the like, such as a small shovel featuring deep sides and a short handle liquid-dispensing implements consisting of a round basin and a long handle.
	**Small Brush.** A bristle device is commonly designed with filaments arranged in a handle. Its primary functions include sweeping, smoothing, scrubbing, and painting.
	**Timer.** The duration of water percolation through the soil sample is determined using a timer." At a minimum, the timepiece must be precise to within 0.1 seconds.

2.4.2.2 Equipment

Table 2. Equipment and Its Definition

Equipment	Equipment and its Definition
	**Falling Head Test**. In addition to developing new techniques for predicting permeability, it will be utilized to evaluate the sustainability of soils for uses including road construction, landfill lining, and dam foundation.
	**Permeameter.** A permeameter is an apparatus designed to facilitate the passage of water through a soil sample. Glass or stainless steel are instances of nonreactive materials that should be used to construct the permeameter.
	**Sieve Shaker.** An automated machine was employed to vibrate and apply consistent force while shaking the sieve. This equipment played a vital role in conducting the sieve analysis throughout this study.

Table 3. Falling Head Equipment Specification

Diameter of the specimen, cm	6.135
Length of the specimen, cm	4.025
Cross-sectional area of the specimen, cm²	29.56
Volume of the specimen, cm³	118.98
Diameter of the standpipe, cm	in 1.0
Cross-sectional area of the standpipe, cm²	0.79

2.3 Phase 3 - Data Analysis and Evaluation

2.3.1 Data Analysis

Comparative analysis to compare the permeability of the control sample (untreated Ultisol) with the experimental samples treated with 2.5%, 5%, 7.5%, and 10% ash additions, researchers can identify and quantify the changes in permeability due to the treatments. Observing how permeability changes with increasing ash content, identifying any optimal level of addition. Graphical Representation which presents the results of the testing through graphs and figures to illustrate the impact of ash mixtures on ultisol permeability.

2.3.2 RHA-BA-CSA Mixtures

This section provided step-by-step instructions for making the ash mixtures. The procedure was broken down into two primary steps: producing the ash from rice husk, sugarcane bagasse, and coconut shell, and weighing and combining the resulting mixtures.

2.3.2.1 Preparation of Rice Husk, Sugarcane Bagasse, and Coconut Shell

1. During the collecting process, dirt buildup on rice husk, sugarcane bagasse, and coconut shell must be cleaned off.
2. For the burning process, three separate containers were employed. The coconut shell, rice husk, and sugarcane bagasse were regularly processed in this manner until they converted to ash.
3. For the next step, the ashes were then moved to another container with a cover and kept somewhere dry.

2.3.2.2 Weighing and Mixing the Mixtures

1. The RHA, BA, and CSA were then measured in grams to ensure they were exactly equal in weight.
2. The RHA-BA-CSA mixtures were then properly combined to ensure even mixing.

2.3.3 Design Proportion

This research delves into the change of ultisol's permeability treated with RHA, BA, CSA mixtures. The testing will comprise a control group and an experimental group. The control group which is pure Ultisol (0%) and the experimental group will comprise of 4 treatments with increasing dosages of the ash mixture to the ultisol which are 2.5%, 5%, 7.5%, and 10%.

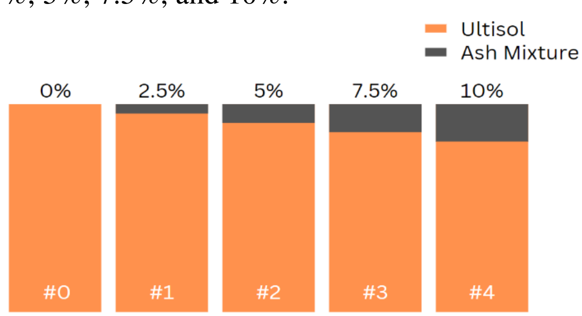


Figure 8: Percentages of Ash Mixtures on the Ultisol

Table 4. Design Mixture of Permeability Samples

Ash Mixtures (grams)	0	5	10	15	20

Materials	Percentages of Materials Per Specimen %				
	#0 (0%)	#1 (2.5%)	#2 (5%)	#3 (7.5%)	#4 (10 %)
Ultisol (grams)	200	200	200	200	200

III. RESULTS AND DISCUSSIONS

3.1 Data Description

Two broad datasets were used in this study: the first dataset was given by the control variable, and the second dataset was provided by the experimental group variable. Chapter 2 goes into great detail about the tools and procedures used to collect the raw data. The permeability test mean value of hydraulic conductivity, obtained from three trials per sample, is utilized to evaluate the impact of the combination on ultisol's permeability. Moreover, the laboratory manager assisted by the proponents computed the results after the laboratory technician in charge of executing the falling head test on the samples finished performing the testing.

3.2 Data Analysis and Findings

The testing facility measured the time and the hydraulic conductivity using this approach during the Falling Head tests that were carried out for this investigation. The equipment utilized for the process produced the following outcomes:

3.2.1 Falling Head Test

A laboratory test called the Falling Head Test is used to measure a porous material or soil's hydraulic conductivity. Permeability measures a porous material's ability to enable fluids to pass through it. It quantifies how easily a fluid can flow through the interconnected void spaces within the material.

Table 5. Falling Head Test Time Result

Sample Identification	Trials	Initial reading of standpipe, h2 (cm)	Final reading of standpipe, h1 (cm)	Time, t (sec)
#0	Trial 1	140.0	110.0	288
	Trial 2	140.0	110.0	292
	Trial 3	140.0	110.0	287
#1	Trial 1	140.0	110.0	4.41
	Trial 2	140.0	110.0	4.07
	Trial 3	140.0	110.0	4.07
#2	Trial 1	140.0	110.0	3.19
	Trial 2	140.0	110.0	3.85
	Trial 3	140.0	110.0	3.49
#3	Trial 1	140.0	110.0	2.96
	Trial 2	140.0	110.0	3.01
	Trial 3	140.0	110.0	2.87
#4	Trial 1	140.0	110.0	2.79
	Trial 2	140.0	110.0	2.82
	Trial 3	140.0	110.0	2.85

The table above shows the results of the falling head test in terms of how much time does the water flow through the ultisol were specified in Table 3. The fluid flow of the control took almost 5 minutes while all the tested ultisol treated with the ash mixtures have not exceeded 5 seconds. All of the tested ultisol with ash mixtures had a significant effect on ultisol permeability.

Figure 9. Falling Head Test

3.2.2 Falling Head Test (Hydraulic Conductivity)

A hydraulic conductivity test, often known as a permeability test, measures the ability of soil materials to transport water. It's an important metric in hydrogeology, geotechnical engineering, and environmental science since it helps us understand how water moves through a porous medium.

3.2.2 Falling Head Test (Hydraulic Conductivity)

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Table 6. Average Permeability Values

Sample Identification	Trials	Hydraulic Conductivity (cm/sec)	Average Hydraulic Conductivity (cm/sec)
#0	Trial 1	$8.955x10^{-5}$	$8.924x10^{-5}$
	Trial 2	$8.832x10^{-5}$	
	Trial 3	$8.986x10^{-5}$	
#1	Trial 1	$5.848x10^{-3}$	$6.17368x10^{-3}$
	Trial 2	$6.3365x10^{-3}$	
	Trial 3	$6.3365x10^{-3}$	
#2	Trial 1	$8.0845x10^{-3}$	$7.39091x10^{-3}$
	Trial 2	$6.6986x10^{-3}$	
	Trial 3	$7.3896x10^{-3}$	
#3	Trial 1	$8.71273x10^{-3}$	$8.75556x10^{-3}$
	Trial 2	$8.5680x10^{-3}$	
	Trial 3	$8.9860x10^{-3}$	
#4	Trial 1	$9.2436x10^{-3}$	$9.14596x10^{-3}$
	Trial 2	$9.1453x10^{-3}$	
	Trial 3	$9.0490x10^{-3}$	

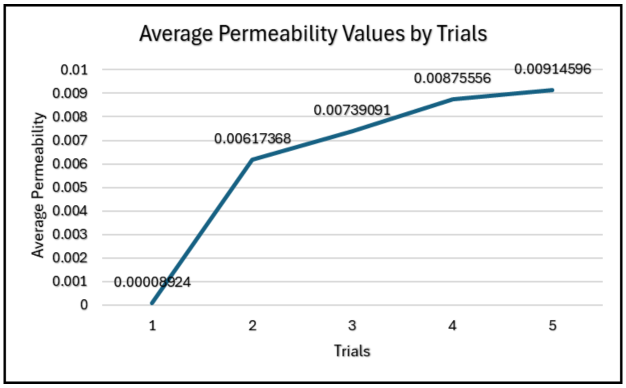

Figure 10. Average Permeability Values

The data showed a drastic increase after the first trial which is the control trial (0%) and it continued to increase steadily up until the fifth trial. Overall, The data tells a promising approach for improving Ultisol Permeability using ash mixtures. However, To completely comprehend the mechanisms at work and the long-term ramifications, more research is necessary.

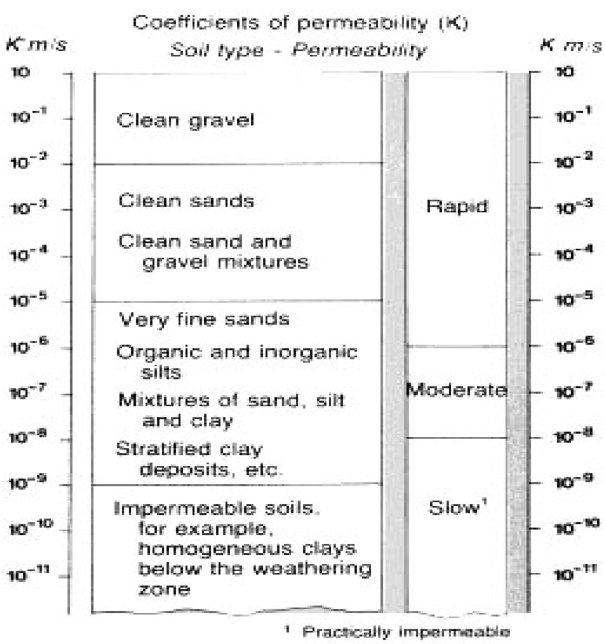

Photo from www.fao.org (https://rb.gy/8qazr3)

Figure 11. Soil Permeability Classes

Based on the result of the samples, the controlled sample (pure ultisol) is classified as a mixture of sand, silt and clay based on figure 11 and its soil permeability degree is moderate to poor. The experimental sample, #1, #2, #3, and #4 has increased its permeability and its soil permeability degree is from rapid to moderate.

IV. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This section provides an overview of the research, "Investigation of Permeability Changes in Ultisols treated with Rice Husk Ash, Bagasse Ash, and Coconut Shell Ash Mixtures," as well as recommendations and conclusions drawn from the data analyzed and summarized in the preceding chapter.

4.1 Summary

As presented in Chapter 1, The study's stated problem is to find out how Ultisol's permeability changes after being treated with a mixture of rice husk ash, bagasse ash, and coconut shell ash. As presented in the preceding chapters and following the methodological framework starting from identifying the research objective followed by the procurement of the materials which are Rice Husk Ash, Bagasse Ash, Coconut Shell Ash and Ultisol to looking for a testing center that will conduct the falling head test. The results of the data shows that the permeability of Ultisol increased with the addition of the ash mixtures.

4.2 Conclusions

Based on the results of the research, the following conclusions can be drawn:

- Using the ash mixture is a practical method of making ultisols more permeable.
- A 2.5% addition of the ash mixture to the ultisol will increase its permeability.
- Agricultural waste organic materials could be used for different purposes but in this study after it has been turned to ash it has been proven to increase the permeability of ultisol.
- Ultisol treated with RHA, BA, and CSA can be used in embankments based on its permeability.

- The experimental samples have a lower cost than the soil usually used for embankments.

4.3 Recommendations

Researchers

- Increase the percentage (%) addition of the ash mixtures.
- Replace a part of the soil in equivalence to the percentage of your choosing.
- Incorporating a different material or a different type of soil.
- Taking into account how the ash mixture affects other soil characteristics.

Geotechnical Engineers

- Using the ash mixture is a practical method of making ultisols more permeable.
- A 2.5% addition of the ash mixture to the ultisol will increase its permeability.

Local Communities

- Their agricultural waste materials could be used as a source of income for the community.
- The use of agricultural waste materials could provide an outlet for managing waste materials.

Farmers and Agricultural Producers

- The ash mixture could be used for agricultural purposes.
- The agricultural waste materials could be used as a business endeavor.

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