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Study on Improvement of Permeability of Agricultural Land by using Egg Shell Powder and Rice Husk Ash

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Abstract
The permeability of agricultural land plays a very important role in water infiltration, drainage, and overall crop productivity. This study aims to enhance the permeability of agricultural soil by incorporating eggshell powder (ESP) and rice husk ash (RHA) as additives at varying proportions of 0%, 5%, and 10% to the soil. Soil samples were collected from two distinct agricultural regions of *Assam, India*: *Khetri* agricultural fields and *Palasbari* riverside, both representative of loamy soil types. The Falling Head Permeability Test (IS 2720-17, 1986) was used to find the permeability of the soil as the soils had loamy to slightly clayey properties.

The results demonstrate contrasting effects of the two additives on the soil samples. ESP increased soil permeability, with a pronounced effect observed at 5% addition. Whereas, RHA decreased permeability, with a drastic reduction at 5% incorporation. The findings suggest that ESP can be utilized to improve drainage in waterlogged soils, while RHA can enhance water retention in soils with high permeability. This study provides valuable insights into the utilization of agricultural waste materials as soil conditioners. Thus, it contributes to sustainable and efficient water management in agriculture.

Keywords
Egg Shell Powder (ESP), Rice Husk Ash (RHA), Permeability, Optimum Moisture Content (OMC), Maximum Dry Density (MDD), Proctor test, Permeability co-efficient, Agriculture, Irrigation.

1. INTRODUCTION

1.1 Importance of Agriculture

India is primarily an agricultural country with agriculture being an important pillar of India's economy, contributing to about 17% of its GDP and employing 60% of the country's workforce. In 2021, according to *Statista*, India's agricultural land was over 1.78 million square km, and according to *Assam State Rural Livelihood Mission (ASRLM)*, Assam occupies a geographical area of 7.8 million hectares of which the total cropped area is 4.0 million hectares large part of the country as well as the state of Assam are predominantly occupied by agricultural land. There are many factors like climate, rainfall intensity, soil quality, etc that affect crop productivity. Out of all factors, soil is the most important and one of the predominant factors affecting agriculture.

1.2 Agricultural Soil

There are different types of agricultural soil such as loamy soil, silty soil, sandy soil, alluvial soil, peaty soil, etc. Out of these *Assam* is rich in Alluvial soil due to the presence of the mighty river *Brahmaputra* and hence, rice cultivation is primary here. The alluvial soil is a mixture of silt and clay. The cultivation of crops is affected by an important engineering property of soil, i.e., permeability of the soil or hydraulic conductivity.

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1.3 Permeability

The property of soil that permits a liquid to flow through its void is called soil permeability. It is the ease with which water can flow through the soil. It is to be noted that, the larger the soil particles, the larger the volume of voids and the better the connectivity of voids. Hence, a larger amount of water flows through the soil mass resulting in high permeability and vice-versa for smaller soil particles. Soil has different values of permeability for different liquids. Permeability is influenced by soil texture, structure, and organic matter content. In agricultural lands, optimal permeability ensures efficient water management, root aeration, and nutrient absorption. High permeability is preferred for well-drained soils, while low permeability is beneficial for water retention in arid regions or for crops like rice that require to be flooded with water.

1.4 Objective

This Study adopts its primary objective as the investigation and improvement of agricultural soil permeability using eggshell powder (ESP) and rice husk ash (RHA) as additives at 0%, 5%, and 10% addition. The study aims to determine the optimal dosage of these additives to achieve the desired soil permeability for improved agricultural practices.

1.5 Selection of Additives

The selection of additives was based on certain criteria such as cost or economic aspect, availability, and sustainability. Eggshell powder (ESP) and rice husk ash (RHA) were chosen as they are environment-friendly, sustainable, and biodegradable. They also act as a natural fertilizer and have the potential to modify soil properties. RHA is readily available near agricultural sites as agricultural waste, while ESP can be found as household waste. Both are waste products and hence are cost-effective too.

1.6 Relationship between Duty, Delta, and Permeability

Permeability can affect Duty and delta and hence ultimately affect the irrigation requirements in the field. Duty can be defined as the area of land that can be irrigated with a unit volume of water whereas delta refers to the depth of water required to saturate the soil. Soils with high permeability would require more water irrigating larger areas resulting in a higher delta and duty. In the case of low permeability soils water retention would be longer, reducing the need for frequent irrigation.

2. LITERATURE REVIEW

2.1 Overview

According to recent studies, research has been conducted on the use of organic and natural amendments, such as rice husk ash (RHA) and eggshell powder (ESP) to improve soil properties. These materials are cost-effective as well as promote environmental sustainability. Hence, they offer sustainable solutions for soil management (*Kumar et al., 2014; Sanchez et al., 2018*).

2.2 Problem Statement

Despite existing research on soil amendments, there is a lack of specific understanding about the effects of rice husk ash (RHA) and eggshell powder (ESP) on the permeability of agricultural soil, specifically loamy soil. This study aims to fill this gap by assessing the impact of these additives on soil permeability in the agricultural soil of *Assam.*

2.3 Impact of Rice Husk Ash on Soil Permeability

Studies have shown that RHA can significantly reduce soil permeability by filling pore spaces and enhancing soil stability (Kumar & Singh, 2014; Rahman et al., 2015). The silica content in RHA binds soil particles, reducing water movement and improving soil structure (Kumar & Singh, 2014).

2.4 Impact of Egg Shell Powder on Soil Permeability

ESP has been found to increase soil permeability by improving soil aggregation and creating larger pore spaces (Sanchez et al., 2018; Ravindran et al., 2019). The calcium carbonate in ESP enhances soil structure, making it more suitable for crops requiring well-drained soils (Sorum and Kalita, 2020).

2.5 Conclusion Derived from Previous Works

The literature suggested that RHA and ESP can be helpful in modifying soil permeability. It is indicated that RHA is a permeability-reducing additive and ESP a permeability-increasing additive. These findings provide a foundation for further research on the application of these additives. In this study, we focus on the effect of these additives on loamy agricultural soils.

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3. METHODOLOGY

3.1 Collection of Soil Samples

Soil Samples were collected from two different locations viz. *Khetri* agricultural fields and *Palasbari* riverside, Assam. As they were collected in the monsoon season, samples were first air-dried for at least 2 weeks and then oven-dried at 105°C for 24 hours to remove moisture (IS 2720-2, 1980).

3.2 Processing of Raw Materials

The Raw materials were processed first to perform the Proctor test and permeability test.

- Soil Processing: After airdrying of the soil, any unwanted things like roots, twigs, or garbage were removed manually and then oven-dried at 105°C for 24 hours to remove moisture (IS 2720-2, 1980). The soil was crushed to remove lumps and sieved through a 4.75 mm sieve to ensure uniform particle size (IS 2720-7, 1980).

- Egg Shell Powder (ESP): The collected Eggshells were washed thoroughly with water, dried properly, and then converted into a fine powder using a grinder. The powder obtained was sieved through a 75-micron sieve.

- Rice Husk Ash (RHA): Rice husk, collected from the agricultural produce of *Udalguri* district, was burnt and ground into a fine powder passing through a 75-micron sieve.

Fig 1: Eggshell powder (ESP)

Fig 2:Rice Husk Ash (RHA) during the burning process

3.3 Tests done

The Proctor test (IS: 2720-Part 7) was performed to determine the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC). Both the OMC and MDD were used to prepare the permeability soil samples for test. They were taken to reduce the need for large numbers of samples as in the agricultural field in natural conditions each point would have different permeability and also since the permeability would be least in this condition, it would generally follow the same trend with higher permeability in the field as in the agricultural field the soil would not be in MDD and OMC condition. The falling head permeability test (IS: 2720-Part 17) measured the permeability of the soils at 0%, 5%, and 10% additive.

4. RESULTS AND ANALYSIS

4.1 Proctor Test Results

The control soil sample from the *Khetri* region (sample 1) had an MDD of 2.01 g/cc and an OMC of 17.15%. Due to the addition of 5% ESP, the MDD was reduced to 1.724 g/cc and OMC to 15.5%, while the 10% ESP addition further reduced MDD to 1.622 g/cc and increased OMC to 18.6%. On the contrary, 5% RHA reduced MDD to 1.58 g/cc and OMC to 11.5% and 10% RHA maintained similar MDD but increased OMC to 19%.

For the *Palasbari* region sample (sample 2), the control MDD was 1.55 g/cc and the OMC was 22%. Due to the addition of 5% ESP, the MDD increased to 1.6 g/cc and the OMC reduced to 19.85%. 10% ESP addition resulted in a MDD of 1.5 g/cc and an OMC of 23%. The addition of 5% RHA resulted in an MDD of 1.58 g/cc and OMC of 19%, while 10% RHA led to an MDD of 1.6 g/cc and OMC of 28%.

The graphical analysis of the proctor test results is shown in the form of line graphs for sample 1 (Refer *Fig. 3.1* to *Fig. 3.5*) as well as for sample 2 (Refer *Fig. 4.1* to *Fig..4.2*). Refer to *Table no.1* for comparative proctor test results.

Table no. 1: Comparative proctor test results:

Sample no.	Percentage of sample mixture	OMC (%)	MDD (g/cc)
Sample no. 1	Only soil	17	2
	5% egg shell powder	15.5	1.724
	5% rice husk ash powder	11.5	1.580
	10% egg shell powder	18.6	1.622
	10% rice husk ash powder	19	1.580
Sample no. 2	Only soil	22	1.55
	5% egg shell powder	19.845	1.6
	5% rice husk ash powder	22.6	1.451
	10% egg shell powder	23	1.5
	10% rice husk ash powder	28	1.6

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Proctor test graphs:

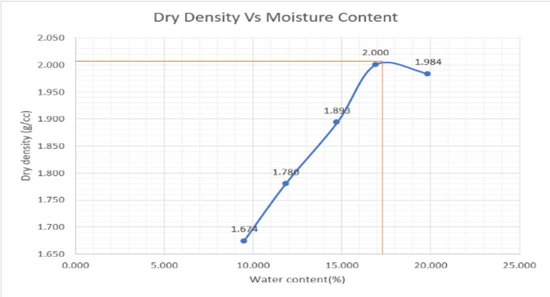

Fig 3.1: Pure soil (0% additive)

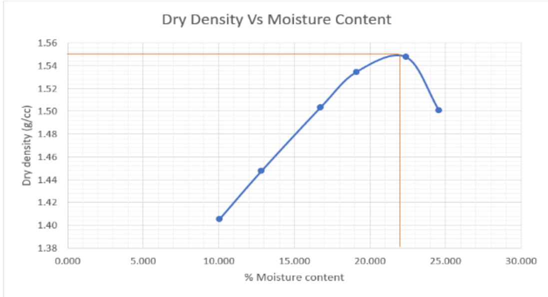

Fig 4.1: Pure soil (0% additive)

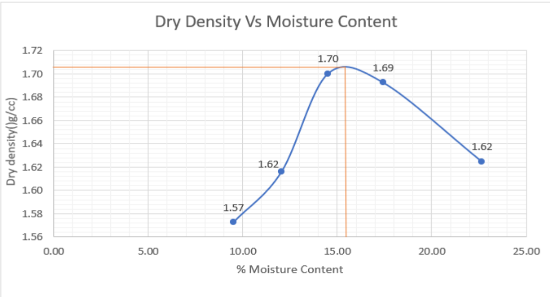

Fig 3.2: 5% ESP added soil sample

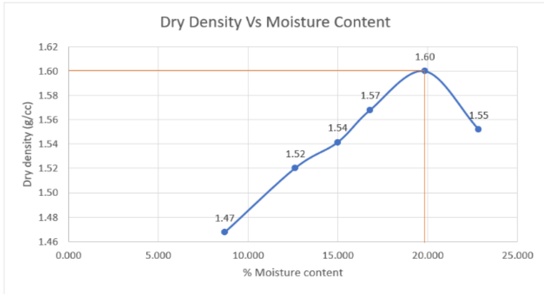

Fig 4.2: 5% ESP added soil sample

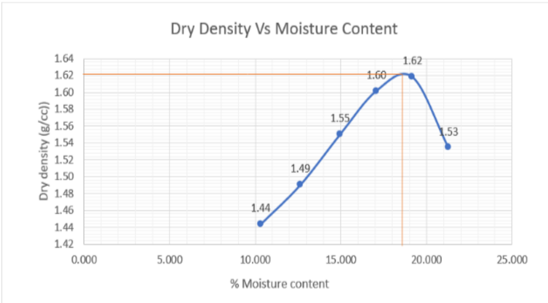

Fig 3.3: 10% ESP added soil sample

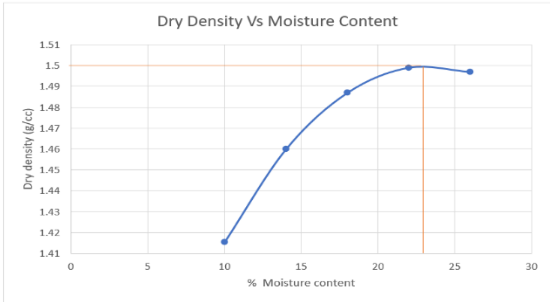

Fig 4.3: 10% ESP added soil sample

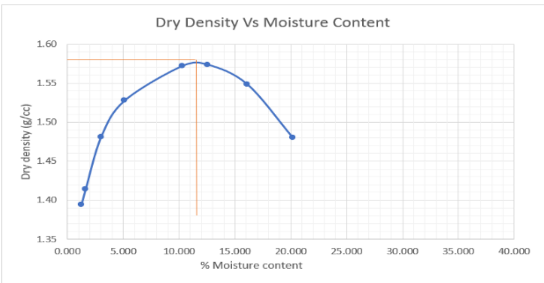

Fig 3.4: 5% RHA added soil sample

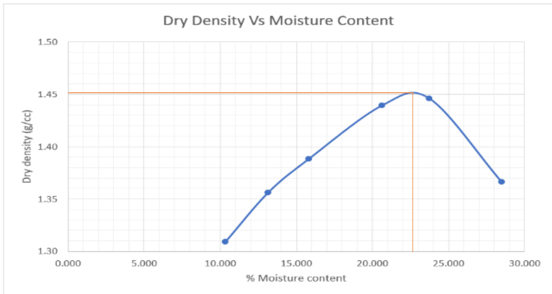

Fig 4.4: 5% RHA added soil sample

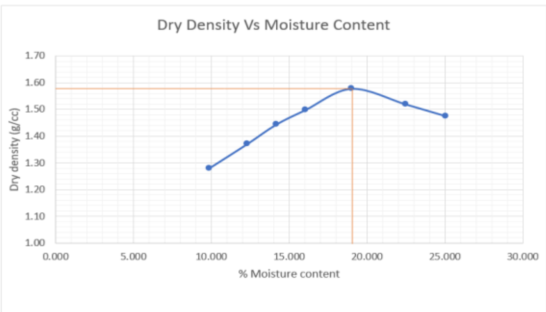

Fig 3.5: 10% RHA added soil sample

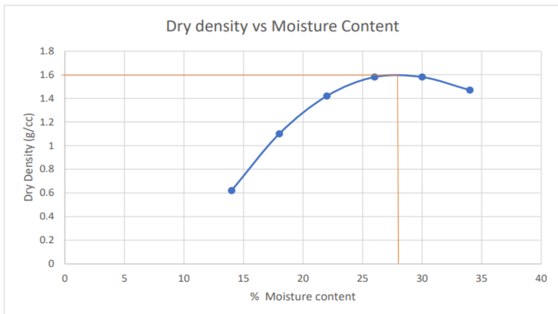

Fig45 10% RHA added soil sample

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4.2 Permeability Test Results

The control soil from the Khetri sample had an initial permeability coefficient (k) of 9.67×10^{-6} cm/s. Due to the addition of 5% ESP permeability increased to 113×10^{-6} cm/s, while 10% ESP further increased it to 145×10^{-6} cm/s. Conversely, 5% RHA decreased permeability to 6.37×10^{-6} cm/s, while 10% RHA further decreased the permeability to 5.8×10^{-6} cm/s. The control soil from the Palasbari sample had an initial permeability coefficient of 8.9×10^{-6} cm/s. After the addition of 5% ESP, the permeability increased to 110×10^{-6} cm/s, and the addition of 10% ESP increased the permeability to 130×10^{-6} cm/s. The addition of 5% RHA decreased the permeability to 6.1×10^{-6} cm/s, while 10% RHA further decreased the permeability to 5.4×10^{-6} cm/s.

The graphical analysis of the permeability test results is shown in the form of line graphs (Refer Fig. 5 to Fig. 8). Refer to Table no.2 for comparative permeability test results.

Permeability test graphs:

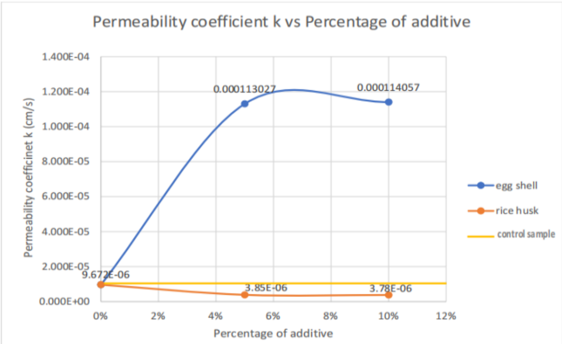

Fig.5.Sample 1, permeability vs percentage of additive graph

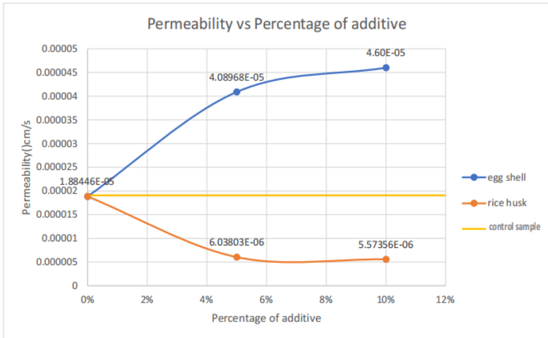

Fig.6. Sample 2, permeability vs percentage of additive graph

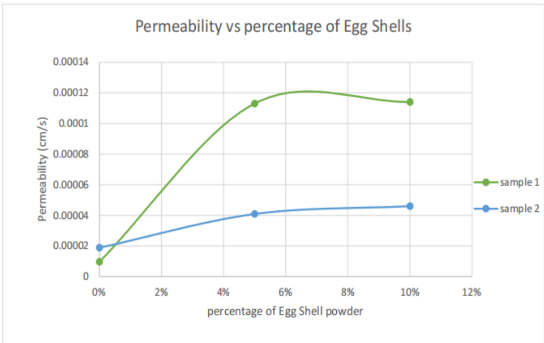

Fig.7. Permeability comparison graph of samples 1 and 2 on the addition of Egg Shell Powder (ESP) at 5% and 10%.

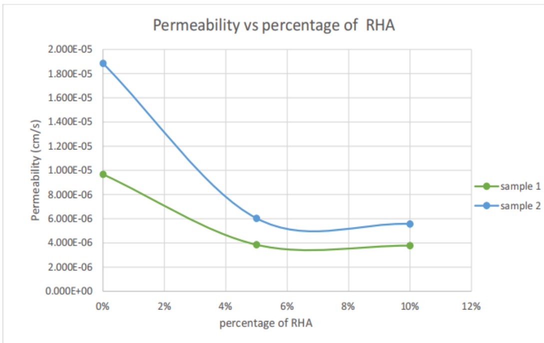

Fig.8. Permeability comparison graph of samples 1 and 2 on the addition of Rice Husk Ash (RHA) at 5% and 10%.

Table no. 2: Comparative permeability test results:

1	ESP	0%	5%	10%
	sample 1	9.67×10^{-6}	113.027×10^{-6}	114.057×10^{-6}
	sample 2	18.84×10^{-6}	40.89×10^{-6}	46.0×10^{-6}
2	RHA	0%	5%	10%
	sample 1	9.67×10^{-6}	3.85×10^{-6}	3.78×10^{-6}
	sample 2	18.84×10^{-6}	6.038×10^{-6}	5.573×10^{-6}

5. CONCLUSION

5.1 Effect of Egg Shell Powder and Rice Husk Ash on MDD and OMC of Agricultural Soil

In the above study, ESP decreases MDD at all doses, making the soil less compact, while the trend in OMC shows that it enhances permeability at lower doses and moisture retention at higher doses. RHA decreases MDD, making the soil less dense, while increasing OMC irrespective of the additive percentage, indicating higher moisture retention.

5.2 Effect of Egg Shell Powder and Rice Husk Ash on Permeability of Agricultural Soil

From the study, it can be concluded that ESP as an additive would significantly increase the permeability of the soil. On the contrary, RHA as an additive would decrease the permeability of soil. The optimum concentration in which the additives work best was determined to be 5%. The changes observed at higher than 5% concentrations were minimal. These conclusions were drawn after testing two control samples from agricultural land in Assam, India, and the soil was silty alluvial in nature with high organic matter content. The samples were prepared and tested in a highly regulated environment to minimize errors.

5.3 Practical Applications in Agriculture

Both additives can be used as per requirement to change the permeability of the soil to suit the needs of the crops to be cultivated. ESP can be used for improving drainage in waterlogged soils, especially for crops requiring well-drained soils, whereas, RHA can be used for retaining moisture in arid regions or for water-sensitive crops like paddy. RHA and ESP are two locally available abundant waste materials making them a cheap alternative to expensive additives.

5.4 Limitations and Future Research

All the data and conclusions found in the study can be generalized for alluvial soil in Assam hence it is geographically constrained. For a different soil type, similar experiments can be conducted to arrive at an optimum amount of RHA and ESP required for agriculture for that soil type. A trend analysis can be made with more samples and the data can be used to improve soil quality and convert barren land into agriculturally viable land.

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