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Effectiveness of Agricultural Waste–Based Cement Admixtures for Strength Improvement of Organic Soils

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Abstract: A study has been conducted to enhance the soil in the Siro village, Arunachal Pradesh, utilizing cement and rice husk ash (RHA) as an eco-friendly method for disposal to mitigate the geotechnical challenges associated with peat. Various quantities of cement and RHA were incorporated into the peat soil in the laboratory; cement was introduced in proportions of 5% to 15%, while RHA was added in amounts of 6%, 8%, and 12% depending on the weight of the soil.
The dry density increases with an increase in cement content, while the optimal water content decreases. Conversely, as the RHA level increases, the optimum moisture content (OMC) increases, but the maximum dry density (MDD) reduces.
Microstructural analytical tools such as FESEM and XRD facilitated an extensive analysis of the cement-peat-RHA reaction.
Unconfined compressive strength (UCS) tests were carried out on the samples after 0, 7, 14, and 28 days of curing to evaluate their strength behavior.

Keywords: Peat soil, cement, rice husk ash, OMC & MDD.

Introduction

The demand for soils, even those with subpar geotechnical qualities, is increasing due to urbanization, a shortage of land, and population growth. Peat is defined as a highly organic soil that contains a substantial amount of decomposing plant or animal matter, which accumulates over time in an anaerobic environment. Peatland cover may be utilized in semi-liquid and powdered forms, according to recent studies [3]. Significant strength growth requires the production of calcium silicate hydrates (CSH), calcium aluminates (CAH), and calcium aluminum silicate hydrates (CASH), which are produced when cement is hydrated in soil-cement treatment [21]. Soils rich in organic matter exhibited a much slower strength gain compared to those with lower organic content. Additionally, they noted that the addition of cement caused cementitious materials to form and negated the impact of roughly 4.23 million km² globally, whereas the Indian Council of Agricultural Research estimates that India spans a total geographical area of about 88,756 km² [12]. However, only some areas of India—the southwestern, eastern, and northern regions—have seen the completion of surveys pertaining to peat.

There has not been any research on peat in Arunachal Pradesh yet, but Abhinaba Paul and Monowar Hussain's study concentrated on peat from three northeastern Indian states: Assam, Tripura, and Manipur. Peat can be treated in several ways, but the most effective ones include chemical binders like fly ash, cement, and lime [10]. For example cement is known to enhance the geotechnical characteristics of soil and is commonly applied as a binding agent in ground improvement practices. The UCS value increased as a result of cement, which is organic matter in the soil [17].
When rice husks are burned to produce electricity, a byproduct known as rice husk ash (RHA) is created. It is regarded as an agricultural and industrial waste. Disposing of rice husks is difficult due to their rough texture, woody character, high silica content, and abrasiveness [4]. According to a study, burning rice husk instead of coal to generate one megajoule of energy has a 34-fold lower impact on global warming [19]. India ranks second only to China in rice husk production, generating roughly 20 million tons each year [9]. A significant amount of RHA can pose environmental risks if not managed properly [11]. One practical and economical solution, especially given growing environmental concerns, is to burn rice husk for power generation with no net carbon emissions [9]. Rice husk ash, which remains after the combustion process, is rich in amorphous silica—making up more than 90–95% of its weight [4].

When it comes to stabilizing peat soil, cement plays a vital role in improving its difficult engineering properties. Acting as the primary stabilizer, cement significantly boosts the soil's strength and load-bearing capacity. By creating a stable matrix within the soil, its strong binding and adhesive properties reduce compressibility and improve overall structural integrity [21]. Cement also helps control volumetric changes caused by moisture variations, minimizing the soil's tendency to swell or shrink. Through hydration reactions, it creates strong compounds that make the treated soil more durable over time. Beyond these mechanical advantages, cement provides a dependable foundation for construction on peat soils, which are far more challenging to work with than conventional soils.

This study addresses the challenge of stabilizing peat soil in Ziro Valley for use in construction projects. The work is driven by the absence of previous research focusing on the stabilization of peat soils in this specific region for building purposes. To achieve cost-effective solutions, insights from earlier literature and results from trial-and-error experimentation have been considered and applied to meet the targeted objectives.

2. Materials and methods

2.1 Test materials

2.1.1 Peats

To obtain a representative profile of the soil conditions in the area, samples were extracted from a depth of one meter. This choice of location and depth enabled a detailed understanding of the soil's geotechnical characteristics and its behavior within the context of the study.



Fig. 1a: Open pit excavation

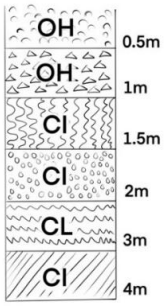


Fig. 1b: Soil profile

The soil sample was obtained using the open pit method, involving the excavation of a 2 m × 2 m pit to a depth of 4 m, followed by a detailed examination of the soil profile. Excavation was carried out in January, during which the groundwater table was observed at a depth of 2 m. For sample preparation, the soil was oven-dried; however, the elevated temperatures used in this process can alter the composition of organic matter, potentially affecting the soil's natural structure and properties. Such changes may include the loss of volatile components and structural modifications such as shrinkage or collapse, which could influence the accuracy of density measurements and mechanical property assessments. While oven drying is a widely accepted procedure, these limitations highlight the importance of cautious interpretation of results and the potential value of alternative drying methods or in-situ testing to better capture the true characteristics of peat soil. Any twigs or big chunks were taken out to ensure we had a clean sample. Unless otherwise specified by standards, ordinary water was used throughout the investigation.

Table 1: General properties of the parent soil

Property	Result
Water Content	67.3%
Specific Gravity	1.33
Sieve analysis	
i. Gravel size (> 4.75mm)	0%
ii. Sand size (0.075mm - 4.75mm)	16.47%
iii. Silt (0.075 mm - 0.002 mm)	4.94%
iv. Clay (<0.002mm)	78.59%
IS Classification of soil	OH (peat)
Liquid limit	52.08%
Plastic limit	37.13%
Plasticity Index	Medium plastic
OMC	29.88%
MDD	13. KN/m²
Organic content	35.76%

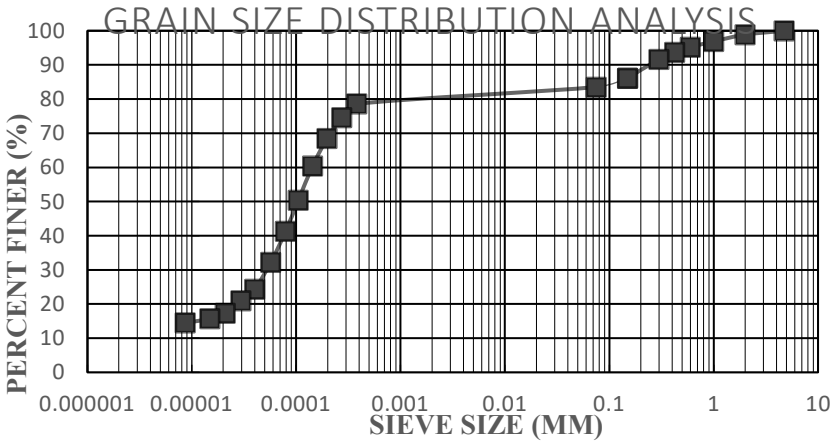


Fig. 2: Grain size distribution curve of Parent soil

2.1.2 Binders

2.1.2.1 Rice husk ash

In this study, we got rice husk ash (RHA) by burning rice husks collected from local sources. The burning took place in a muffle furnace for an hour at a consistent temperature of 600°C. When we analyzed it with energy dispersive X-ray diffractometry (EDX), we found out that silicon dioxide makes up most of the ash's chemical composition.

2.1.3 Cement

Ordinary Portland Cement (OPC) of grade 53 was used in the study, meeting the requirements of IS:12269-1987 specified by the Bureau of Indian Standards (BIS). This grade is characterized by its high compressive strength and durability, making it appropriate for diverse construction purposes. All test specimens were carefully prepared and subjected to a standardized curing process using ordinary water, in line with industry practices, thereby avoiding the need for distilled or specialized water. The use of BIS-compliant OPC of grade 53 ensured uniform cement quality and maintained consistency throughout the experimental program.

2.2 Methodology

2.2.1 Sample preparation

The study systematically incorporated different proportions of RHA specifically, 6%, 8%, and 12% by weight of the soil—into the soil samples. In addition, varying percentages of cement, including 5%, 10% and 15% depending on the weight of the soil, were introduced.

2.2.2 Compaction Tests

The compaction characteristics were determined using the Standard Proctor test on both untreated and treated peat samples in accordance with IS 2720 (Part VII)-1992. The aim was to evaluate how cement and rice husk ash (RHA) influence the strength characteristics of peat soil. For the treated specimens, cement was added in proportions of 5%, 10%, 15% by weight of oven-dried soil, while RHA was incorporated at 6%, 8%, and 12% by weight. Each mix was carefully blended to ensure uniform distribution of the stabilizing agents. This controlled testing procedure allowed for a detailed assessment of how varying amounts of cement and RHA affect the engineering behavior and strength development of peat soil.

2.2.3 Unconfined Compressive Strength Tests

The strength behavior of both untreated peat and samples stabilized with different proportions of cement and rice husk ash was examined through unconfined compressive strength (UCS) testing. This testing was conducted following the guidelines of IS 2720 (Part 10)–1991 (Reaffirmed 2006). Undisturbed soil cores, about 38 mm in diameter and 76 mm in height, were extracted and carefully trimmed to achieve smooth surfaces. Each core was placed in a cylindrical steel mold made to the specified test dimensions. Static loading was used for compaction to avoid disturbances that dynamic methods might cause. Once compacted, the specimens were cured to allow hydration and strength gain.

Tests were carried out after curing periods of 0, 7, and 28 days. Curing was done in a controlled environment using a desiccator to maintain uniform conditions. For each curing duration and mix proportion, three specimens were tested to account for natural variability in results. Following the curing period, the specimens were subjected to axial loading until failure occurred, and the UCS was determined by dividing the maximum load by the specimen’s cross-sectional area. The mean of the three readings for each mix was reported as the representative value, providing a reliable indication of the material’s performance at each curing stage.

3. Results and discussion

3.1 Effect of cement with peat on Compaction

The parent peat soil's OMC and MDD in the subsequent Standard Proctor Compaction test were 29.88 percent and 13.47 kN/m³, respectively. Figure 3 shows that the MDD drops and the OMC rises when 5% cement is added to blends that contain 6% and 8% RHA. We observe the same feature when we mix 10 and 15 percent cement with 6 and 8 percent RHA. The RHA's high porosity likely caused the increase in OMC [24] by improving its capacity to absorb water compared to other materials. Typically, when dry density goes up, it suggests that the soil is getting better. However, adding cement and RHA tends to lower the dry density. This drop happens because of the specific gravity and particle size of the peat, along with the type of stabilizer being used. RHA acts as a pozzolan, reacting with calcium hydroxide that forms when cement hydrates. This reaction leads to the creation of extra cement-like compounds, like calcium silicate hydrates (C-S-H), that help bind and densify the mix.

As a consequence, the increased pozzolanic activity can lead to a reduction in the void spaces within the soil-cement-RHA matrix, enhancing the overall compactness. [20]

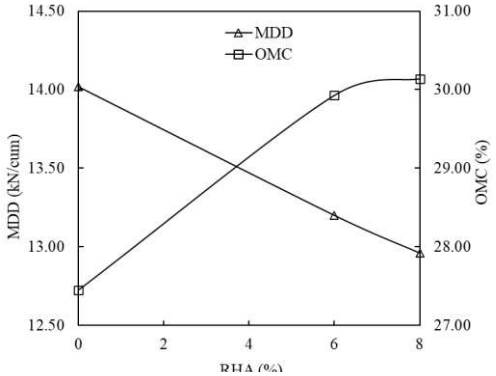


Fig. 3a Trend of MDD and OMC for S+5C+different % RHA

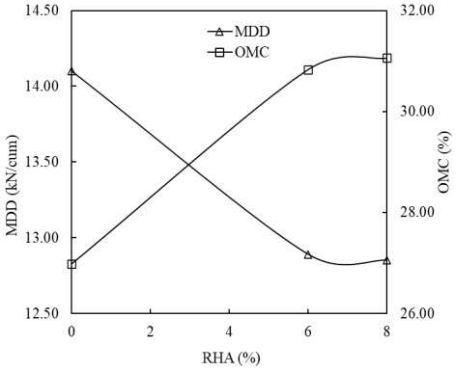


Fig. 3b Trend of MDD and OMC for S+10C+different % RHA

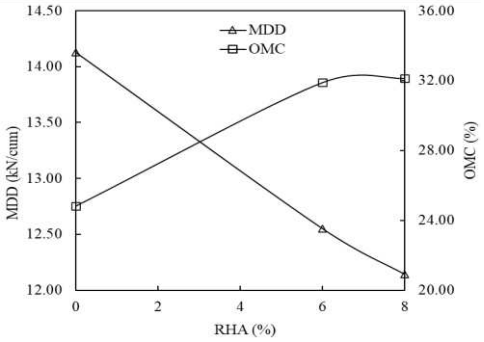


Fig. 3c Trend of MDD and OMC for S+15C+different % RHA

3.2 Effect of cement with peat on unconfined compressive strength

Table 3 shows the unconfined compressive strength (UCS) values and failure strains of the peat-cement mixes as determined by the UCS tests.After a 28-day curing period, the parent soil's UCS value was found to be 189 kPa. However, adding various amounts of cement (5%, 10% and 15%) led to a range of UCS values after zero days of curing, with values of 113 kPa, 155 kPa and 264 kPa, respectively.

UCS readings showed a significant improvement after 28 days of cure. For the aforementioned cement percentages, the UCS values climbed to 189 kPa, 378 kPa and 528 kPa. These findings show that the strength of the parent soil-cement mixtures significantly increased during the curing process. As the curing duration increases, the cementitious materials within the soil matrix undergo further reactions, contributing to improved cohesion and interparticle bonding. This enhanced cohesion tends to increase the CBR values by strengthening the treated soil structure. Longer curing periods provide more time for the formation and maturation of cementitious bonds, resulting in higher CBR values.

The findings clearly show that, both with and without curing, the cement component added to the peat soil significantly increased the UCS values. The curing process further enhanced the strength qualities of the soil-cement mixes, as evidenced by the higher UCS values achieved after the 28-day curing period.

For various percentages of cement at a 28-day curing interval, Figure 4 demonstrates the experimental values of the unconfined compressive strength (UCS) and their related failure stresses. The statistics clearly demonstrate an increase in the failure strain as the cement percentage increases. Additionally, soil samples treated with a higher cement content show a rise in UCS [17].

As shown by the rise in strength with longer curing times across all mix proportions, the curing period is also observed to affect the soil's strength [16]. This demonstrates that soil strength depends not only on the amount of cement present but also on the duration of the curing process.

Figure 5 provides a thorough visual representation of the interaction between these variables by presenting the fluctuations of UCS concerning cement concentration and curing times. These graphs show how the concentration of cement and the curing time affect the strength of the treated soil. The rearrangement of soil and aggregate particles made possible by cement's presence is the mechanism underpinning cement stabilization [8]. Both hydration reactions and pozzolanic reactions are essential to this process [13]. When water is provided, hydration mechanisms involving calcium, silica, and water occur. These reactions lead to the production of calcium hydroxide and calcium silicate hydrate (C-S-H) (CH). Thereafter, pozzolanic reactions occur and more C-S-H, or calcium aluminate hydrate, is produced (C-A-H). The total increase in soil strength after cement treatment is a result of these responses. Therefore, the combined impacts of hydration and pozzolanic processes between the soil and cement content can be used to explain the rise in unconfined compressive strength (UCS). These processes make it easier for soil particles to be restructured and bound together, which ultimately strengthens the stabilized soil's physical properties.

Table 2. UCS and strain values of peat-cement mixes

Mix proportion	Curing period							
	0		7		14		28	
	UCS kPa	Strain (%)	UCS kPa	Strain (%)	UCS kPa	Strain (%)	UCS kPa	Strain (%)
S	78	3.52	92	3.64	154	3.82	189	3.84
S+5C	113	3.64	134	3.71	196	3.84	235	3.98
S+10C	155	3.73	256	3.82	375	3.89	432	4.21
S+15C	264	3.96	349	4.14	462	4.34	528	4.81

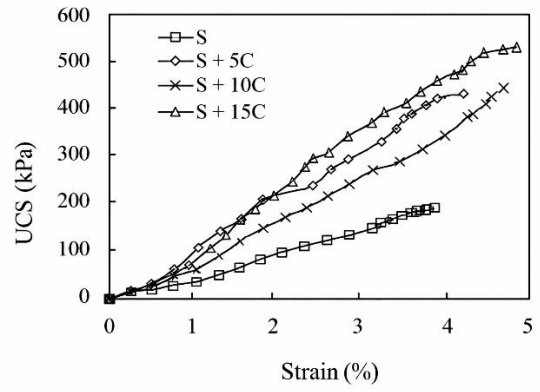


Fig.4: Stress-strain curve for peat-cement mixes of 28days curing

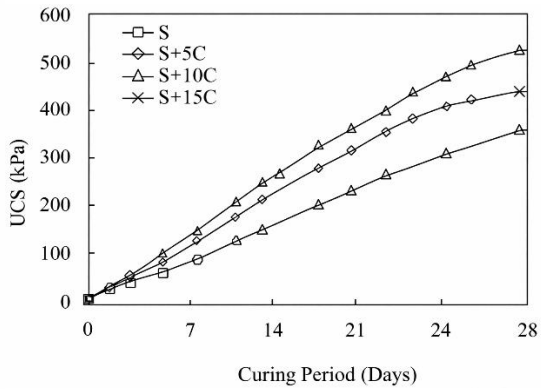


Fig. 5: Trend of UCS for peat-cement mixes



Fig. 6: UCS failure pattern of peat soil
For a 28-day curing period



Fig. 7: UCS failure pattern of S+15C
for 28-day curing period

Table 2 shows the strength development in the parent peat soil over time; this is due to the aging effect, a process involving gradual changes in the soil's physical and chemical characteristics. In peat soils, which are often highly organic and water-saturated, aging results in the rearrangement of organic particles, dissipation of excess pore water, and ongoing biochemical and mineralogical reactions. As aging progresses, the soil structure evolves, leading to improved interparticle bonding and increased cohesion. The breakdown of organic matter, reduction in void spaces, and the development of more stable soil aggregates contribute to enhanced strength properties. The aging effect is especially crucial in peat soils due to their initial low strength and high compressibility. [17]

Figures 6 and 7 illustrate how adding cement and allowing for 28 days of curing can change the failure behavior from ductile to brittle in the unconfined compressive strength (UCS) test of a material. This shift is something we often see in specific soil types or clay-rich materials when treated with cement and cured.

At first, when soil is mixed with cement and let to cure, it goes through a process called cementitious hydration. This process creates compounds like calcium silicate hydrates (C-S-H) and calcium hydroxide (CH), which help strengthen and develop stiffness in the soil-cement mix. In the early curing stages, the material usually behaves in a ductile way. The cement boosts the mixture's cohesion and stiffness, which means it can bear heavier loads and resist deformation better. You might see the material handle more strain and show plastic characteristics under load, letting it deform without a big drop in strength. But as curing continues, more chemical reactions take place, leading to changes in the material's structure. Over time, the hydration process can result in stiffer, more brittle compounds forming within the soil-cement blend. Consequently, the material's failure pattern shifts from ductile to brittle. The transition from a ductile to a brittle failure pattern is influenced by various factors, including cement content, curing conditions, soil type, and specific characteristics of the soil-cement mixture. It is crucial to carefully consider these factors and conduct appropriate testing and analysis to assess the behavior and performance of the soil-cement mixture over time.

3.3 UCS behaviour of peat-RHA mixes

Table 3 summarizes the unconfined compressive strength (UCS) and failure strains from the UCS test on peat-RHA mixes after curing for 28 days. The Unconfined Compressive Strength (UCS) of the parent soil after 28-day curing was 189 kPa. But how will they behave in different percentages of RHA content (6%, 8%, and 12%) mixed with no curing? The peat-RHA mixtures of UCS in curing for 28 days revealed increases: 198 kPa, 212 kPa, and 238.37 kPa. However, these improvements were less significant when compared to cement-peat mixes. Consequently, the combination of RHA and peat soil would enhance the amount of organic matter content.
Figure 8 shows that the variations in Unconfined Compressive Strength (UCS) values observed in this study can be attributed to the chemical reactions and interactions between Rice Husk Ash (RHA) and peat soil. RHA, known for its pozzolanic properties, undergoes chemical reactions with the peat soil during the curing process. These

reactions contribute to the formation of additional cementitious compounds, which can enhance the strength of the soil.

Rice husk ash (RHA) is recognized for its silica content, which can engage in pozzolanic reactions when combined with calcium hydroxide ($Ca(OH)_2$) in the presence of water. These pozzolanic reactions entail the creation of calcium silicate hydrates (C-S-H), playing a role in enhancing the strength and durability of materials with concrete-like properties.

Table 3. UCS and strain values of peat-RHA mixes

Mix proportion	Curing period							
	0		7		14		28	
	UCS kPa	Strain (%)	UCS kPa	Strain (%)	UCS kPa	Strain (%)	UCS kPa	Strain (%)
S	78	3.52	92	3.64	154	3.82	189	3.84
S+6RHA	93	3.67	121	3.49	165	4.18	198	4.21
S+8RHA	112	3.94	154	4.24	170	4.46	212	4.58
S+12RHA	141	4.72	174	4.76	195.79	4.81	238.37	5

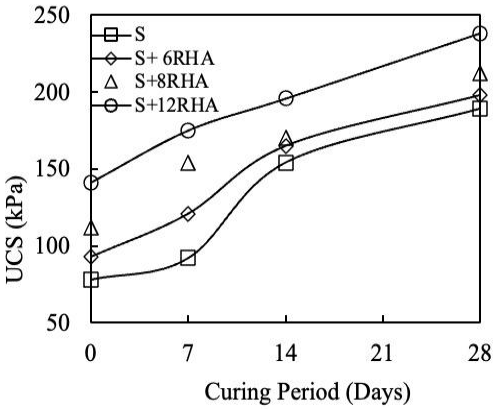


Fig. 8: Trend of UCS forpeat-RHA mixes

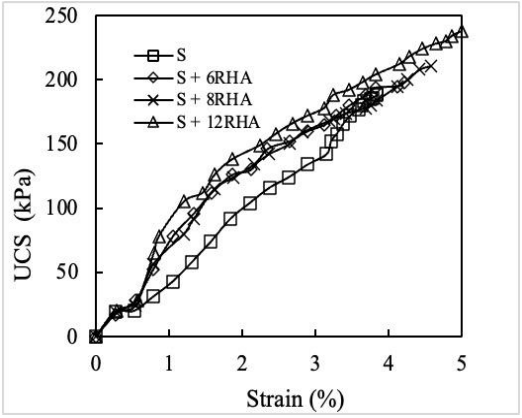


Fig.9: Stress-strain curve for peat-RHA mixes of 28days curing



Fig. 10: UCS failure pattern of Peat soil for a 28-day curing period



Fig. 11: UCS pattern of S+12RHA for The curing period lasts for 28 days.

For the unconfined compressive strength (UCS) test by modifying natural pozzolan with 6% of rice husk ash (RHA) and curing at 28 days, the failure mode has been changed from ductile to brittle, as present in Figures 10 and 11. Initially, the addition of RHA further facilitates cementitious compounds under curing. RHA is rich in silica (SiO_2) that can react with the calcium hydroxide (CH) liberated from cement hydration to form more calcium silicate hydrates (C-S-H). These fillers increase the rigidity and strength of the material. In fact, early in the curing process, it can exhibit ductile behavior.

Over time, ongoing chemical reactions influence the development of the material's microstructure. The pozzolanic activity of RHA, together with its particle size and amorphous silica content, plays a key role in these changes. These factors, along with the specific curing conditions, determine the extent to which cohesion, stiffness, and deformation resistance are improved.

3.3 Studies on UCS behavior of peat-RHA-cement mixes:

After 28 days of curing, Figure 12 presents the experimental results for the unconfined compressive strength (UCS) and corresponding failure strain of peat–cement–rice husk ash (RHA) mixtures. The findings show that the combined application of cement and RHA produces a substantial improvement in UCS compared with using either stabilizer alone. The figure provides a detailed comparison of UCS and failure strain for the S + 5% C + 12% RHA, S + 10% C + 12% RHA, and S + 15% C + 12% RHA mixtures, highlighting the performance differences among these proportions. The findings indicate that increasing the percentages of cement and RHA from 5 to 15 and 6 to 12, respectively, leads to an enhancement in the UCS value. Following a 28-day curing period, the UCS values for the S+5% C+12% RHA, S+10% C+12% RHA, and S+15% C+12% RHA mixtures were 586 kPa, 672 kPa, and 819 kPa, respectively, as seen in tables 4a, 4b, and 4c. This illustrates the significant impact of RHA on the strength properties of the peat-cement-RHA mixture.

Table 4a. UCS and strain values of peat-cement-RHA mixes

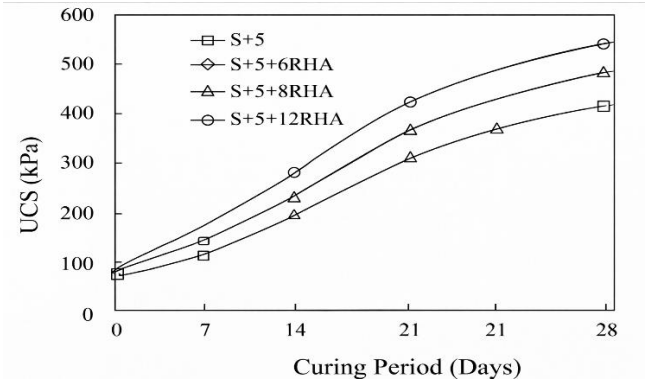
Mix proportion	Curing period							
	0		7		14		28	
	UCS kPa	Strain (%)	UCS kPa	Strain (%)	UCS kPa	Strain (%)	UCS kPa	Strain (%)
S+5C	155	3.73	256	3.82	375	3.89	432	4.21
S+5C+6RHA	238	4.12	349	4.28	426	4.43	525	4.71
S+5C+8RHA	296	4.39	369	4.39	473	4.78	562	5
S+5C+12RHA	367	4.41	412	4.63	568	4.82	586	5.12

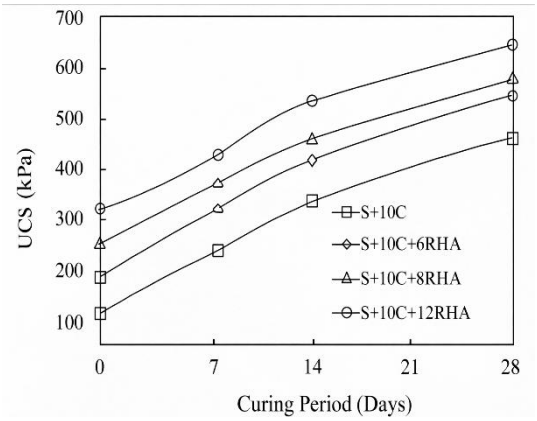
Table 4b. UCS and strain values of peat-cement-RHA mixes

Mix proportion	Curing period							
	0		7		14		28	
	UCS kPa	Strain (%)	UCS kPa	Strain (%)	UCS kPa	Strain (%)	UCS kPa	Strain (%)
S+10C	188	3.84	296	3.97	396	4.22	445	4.63
S+10C+6RHA	312	4.22	378	4.39	468	4.56	554	4.94
S+10C+8RHA	398	4.47	433	4.69	492	5.12	582	5.26
S+10C+12RHA	416	4.72	532	5.15	613	5.28	672	5.41

Table 4c. UCS and strain values of peat-cement-RHA mixes

Mix proportion	Curing period							
	0		7		14		28	
	UCS kPa	Strain (%)	UCS kPa	Strain (%)	UCS kPa	Strain (%)	UCS kPa	Strain (%)
S+15C	264	3.96	349	3.90	462	3.88	528	3.85
S+15C+6RHA	422	4.43	546	4.41	618	4.38	734	4.32
S+15C+8RHA	494	4.74	581	4.67	622	4.54	789	4.51
S+15C+12RHA	541	5.16	642	5.22	768	5.12	819	5.06





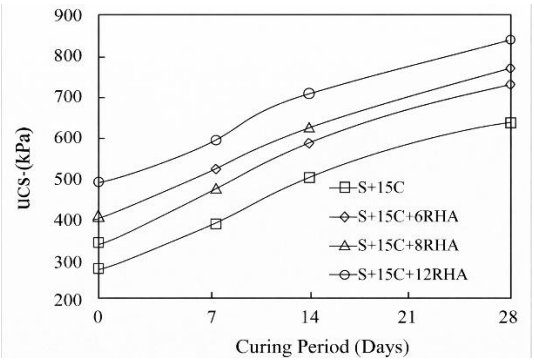


Fig. 12: Trend of UCS for Peat-Cement- RHA mixes

Figure 12 shows how the curing time affects the unconfined compressive strength (UCS) failure pattern of a mixture with cement (C) and peat soil. The UCS test results for 0-day curing show a slight amount of ductile

behavior, but not any more ductile than the UCS of pure peat soil. However, after 28 days of curing and the addition of 15% cement and 12% rice husk ash (RHA), the UCS failure pattern tends to become more brittle.

When the 15 percent cement and peat soil mixture is tested right away after preparation and before any curing time has passed, it exhibits a modest amount of ductile behavior. Cement increases cohesion and rigidity, increasing the mixture's ability to support loads. When compared to pure peat soil, the ductility is not significantly increased by the addition of 15% cement.

The cement in the mixture goes through hydration after 28 days of curing, creating a sturdy cementitious matrix. The material also experiences further reactions and changes in its microstructure with the addition of 12% RHA. The inclusion of RHA can cause behavior to become more brittle depending on its specific properties, such as its particle size, amorphous content, and pozzolanic activity.

As a result, after 28 days of curing, the UCS failure pattern of the combination consisting of 15% C + 12% RHA and peat soil begins to show brittle behavior. The material shows reduced plastic deformation and enhanced vulnerability to abrupt, catastrophic failure, both characteristics of brittle failure as shown in fig. 13.

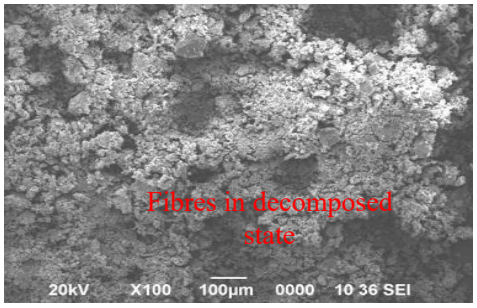


Fig. 13: UCS failure pattern for S+15C+12RHA for a 28-day curing period.

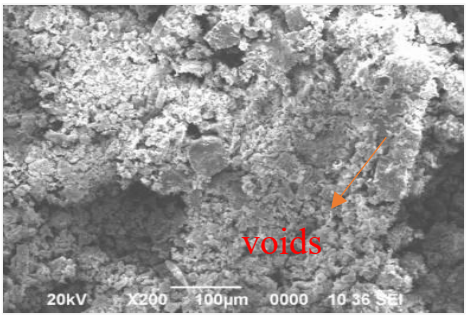
3.4 Microstructure Analysis:

3.4.1 Scanning electron microscope for Peat

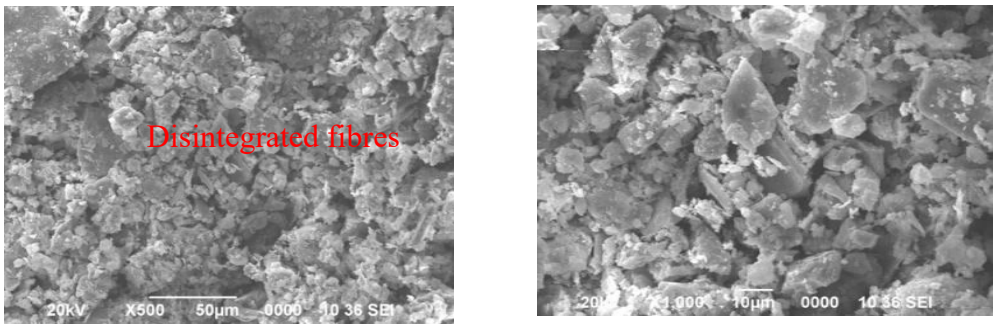
Examining the overall microstructure of a material significantly enhances the comprehension of its constituent parts, especially for a composite like peat soil. In this instance, we looked at the microstructure of peat from Arunachal Pradesh using a scanning electron microscope (SEM), and we captured the findings as SEM micrographs. The micrographs, which are presented as figures 14a, 14b, 14c, and 14d, illustrate the physical characteristics of the peat soil.



(A)



(B)



(c) (d)

Fig. 14: SEM images of untreated peat

A close-up look at the peat sample in Figure 14a reveals the presence of degraded fibers. With the fibers appearing to be in a condition of decomposition, the fibrous nature of peat is clearly visible. This finding indicates that the peat has significantly degraded and changed over time.

Figures 14b and 14c highlight the presence of discernible cavities within the peat microstructure. The organic makeup of peat, which is mostly made up of plant waste and organic materials, is responsible for these spaces or pores. We can link the production of voids to the breakdown and degradation processes that occur within the peat soil.

We can see the internal structure of the peat soil by looking at the SEM analysis of the dry, uncured sample. The micrographs reveal the complex arrangement of fibers, the presence of spaces, and how porous the peat really is. Understanding the geotechnical behavior and potential engineering uses of peat soil requires such information. It is crucial to remember that the SEM study was done on untreated peat samples, giving a foundational understanding of the microstructure of the peat. Additional research, including SEM analysis of treated or stabilized peat samples, may shed more light on the effects of different treatments or additives on the microstructure and general stability of peat soil.

3.4.2 X-Ray Diffraction Test for Peat

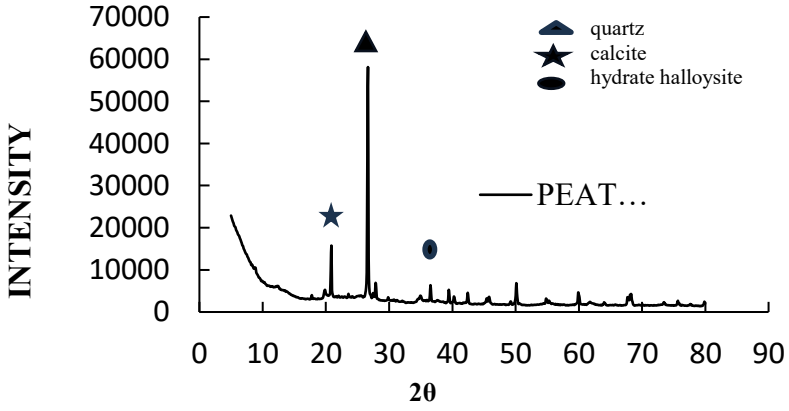


Fig. 15: X-Ray diffraction of Peat soil

When it comes to peat soil, XRD analysis can provide important details on the kinds and relative concentrations of minerals present in the sample. Fig. 15 depicts that peat soil primarily consists of organic matter derived from partially decomposed plant material. The main minerals present in the natural state are calcite, quartz, halloysite hydrate, feldspar, and clay. Among all these, quartz is found to be the most regular mineral. However, XRD can

still detect and identify any minerals present as impurities or due to mineral-rich sedimentation within the peat deposit.
XRD provides insights into the crystal structure of the identified minerals. This information aids in understanding the stability, reactivity, and physical properties of the minerals within the peat soil. Peat soil frequently contains amorphous or imperfectly crystalline components that are difficult to distinguish using XRD. The results of the XRD test may reveal the presence of amorphous content and offer a projection of its percentage in the sample.

3.4.3 Scanning electron microscopy for RHA.

Scanning electron microscopy (SEM) was performed to examine the microstructure of rice husk ash (RHA), and the resulting micrographs are displayed in Figures 16a, 16b, 16c, and 16d. The SEM images offer important details about the morphology and composition of RHA.

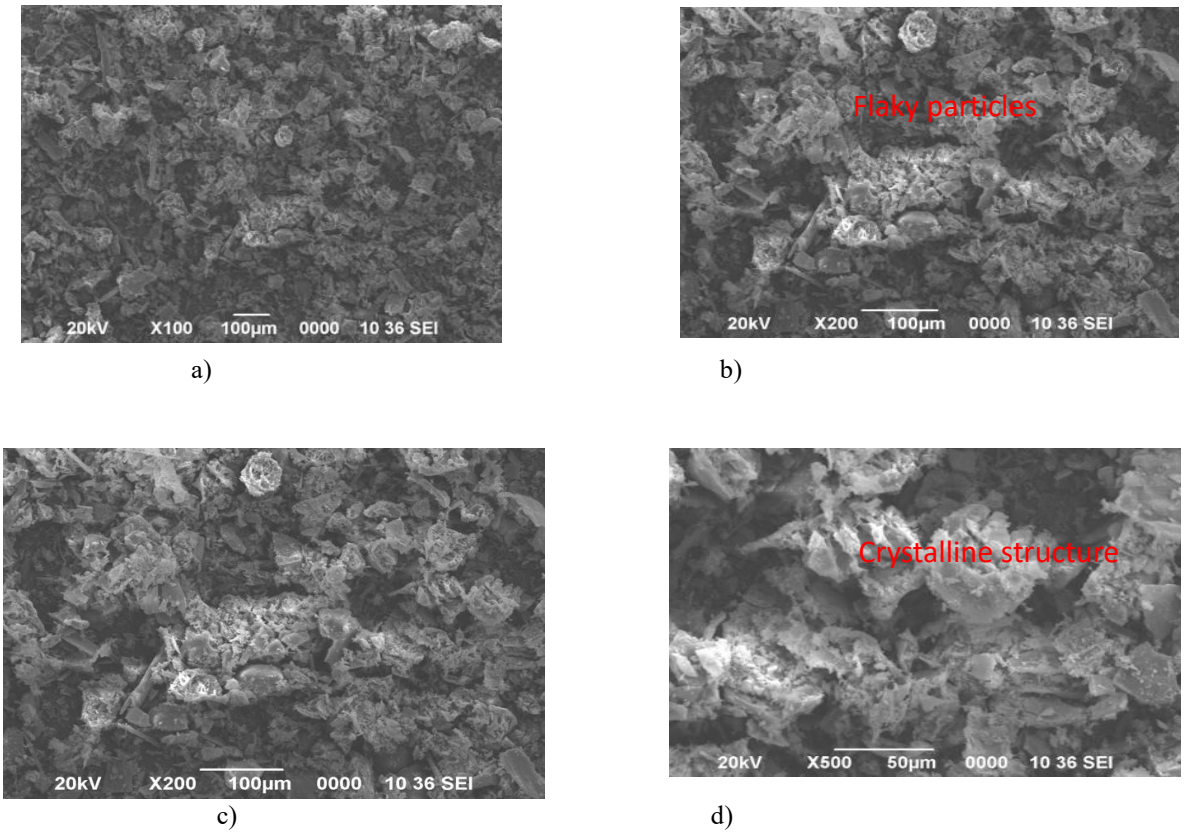


Fig. 16: SEM images of RHA

Figure 16a reveals the presence of crystalline particles within the RHA microstructure. These crystalline particles exhibit distinct shapes and sizes, suggesting the presence of various mineral phases. The crystalline nature of these particles indicates the presence of silica, which is the main component of RHA. In addition to the crystalline particles, flaky particles can be observed in Figures 16b, 16c, and 16d. These flaky particles have a layered structure and contribute to the overall texture of RHA. The presence of these flaky particles further supports the identification of silica in the ash. The microstructural analysis of RHA using SEM confirms the existence of both crystalline and flaky particles, which are characteristic of rice husk ash. These particles predominantly consist of silica, as indicated by their morphology and composition. Understanding the microstructure of RHA is essential for evaluating its properties and potential applications. The unique morphology of RHA particles, including their crystalline and flaky nature, can influence the behavior and performance of RHA when incorporated into various materials.

X-Ray Diffraction Test

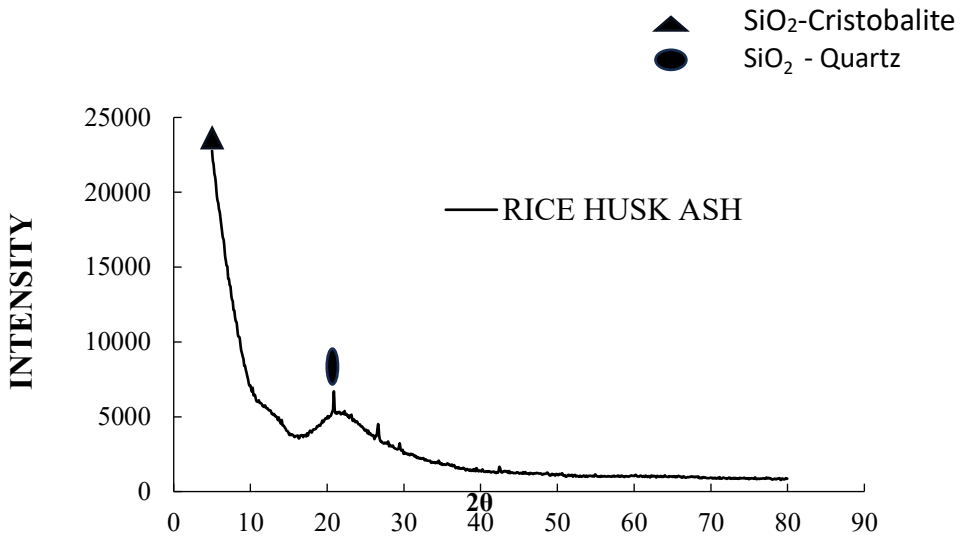


Fig. 17: X-ray diffraction of rice husk ash.

Fig. 17 shows the Peaks that match the mineral phases found in the sample are frequently visible on the XRD test graph for rice husk ash (RHA). Regarding the crystalline components of RHA, the XRD examination yields important information. The XRD graph shows distinct peaks at specific angles (2θ) that indicate the presence of different crystalline phases. These peaks are typically labeled or indexed according to their corresponding mineral phases.

Conspicuous peaks on the XRD graph represent the principal mineral phases identified in RHA. Other possible phases in RHA include calcite ($CaCO_3$), hematite (Fe_2O_3), and mullite. Common mineral phases in RHA include silica (SiO_2) in the form of cristobalite or quartz ($Al_6Si_2O_{13}$).

The RHA contains components that are amorphous or imperfectly crystalline, according to XRD examination. Broad humps or the absence of clearly defined peaks in the XRD graph are frequently used to identify these amorphous phases since they do not form distinct peaks.

Conclusion

The research presented an effective solution for stabilizing peat soil in the Ziro Valley, which will benefit future construction projects in regions with similar geotechnical challenges. The combination of cement and rice husk ash demonstrated its potential as a cost-effective and environmentally responsible approach for improving soil properties and ensuring the long-term durability of construction projects in peat-rich areas.

1. Rice husk ash, a by-product of the rice industry, is also a sustainable alternative that has proven to make peat soil stabilization. It pointed to the possible environmental advantages of using rice husk ash, including minimizing pollution and developing eco-friendly technology.
2. The increase in peat-cement blends' cement concentration results in lower OMC, while MDD increases.
3. In peat-RHA blends, OMC value increases as RHA percentage rises, while MDD decreases as RHA % rises.
4. When the cement content in peat-cement mixes increased, the CBR value increased for both the soaked and unsoaked circumstances. The parent soil under unsoaked and soaked conditions was significantly enhanced by the CBR value of the S+15C mix, going from 2.60% and 1.08% to 3.12% and 4.98%, respectively; this represents a 361.11% percentage increase in CBR.

5. Studies indicate that the CBR value of peat-cement-RHA composites increases with the percentage of RHA added. An increase of 8% RHA within peat-cement mixtures raises the CBR values to acceptable values for design. It was noticed that the mixture with S+15C%+8%RHA was the most effective. This mixture led to a CBR improvement of 124.82% over the parent peat soil, significantly enhancing the unsterilized samples' unsoaked and soaked CBR values of 2.608% and 1.084% to 5.36% and 5.88%, respectively.

6. It is possible to suggest using S+15%C and S+15%C+8%RHA to treat the subgrade.
7. Depending on the project specification and soil conditions, an acceptable quantity of RHA can be determined to achieve the minimum strength requirement. In this example, the combination S+15%C+12RHA showed the highest UCS values among all mixtures.

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The Author, Dr. Ajanta Kalita, an associate professor, played a significant role in completing the investigation in every manner.
The Author, Dr. Ajay Bharti helped in experimental tests that has been carried out.
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