Use of Egg Shell Powder and Periwinkle Shell Ash to Strengthen the Engineering Properties of Clayey Soil

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Abstract - *Recently, the stabilization of clayey soil (CS) has drawn the attention of numerous researchers. In the past, Egg Shell Powder (ESP) and Periwinkle Shell Ash (PSA) were individually tested for their ability to stabilize clayey soil. The author has attempted to stabilize the clayey soil by combining the two of them. The goal of the current study was to compare the efficacy of various eggshell powder and periwinkle shell ash concentrations as soil stabilizers. Testing procedures include the California Bearing Ratio (CBR), Atterberg limits, Unconfined Compression Test (UCS), and compaction tests on the mixture of clayey soil, eggshell powder and periwinkle shell ash. In this study, ESP and PSA were used as soil stabilizers. PSA was varied (i.e., 3%, 6%, 9%, 12%) after ESP was fixed at 12% utilizing index properties testing. The current study aims to evaluate the increase in the strength and stability qualities in soft subgrade soil by stabilizing it first with ESP and then reinforcing it with PSA. It was found that curing time, eggshell powder, and periwinkle shell ash concentration all significantly affected the engineering qualities of the stabilized soil. The findings demonstrated that increasing eggshell powder content increased unconfined compression strength and California bearing ratio values up to a certain point and then decreased slightly. On the other hand, the strength attributes described increased as periwinkle shell ash concentration increased. Additionally, it was found that the stabilized soil samples' strength properties had been significantly improved by the curing period.*

Key Words: *Atterberg limits, CBR, Compaction test, Eggshell Powder, Periwinkle Shell Ash*

1.INTRODUCTION

Because of increasing urbanization and industrial expansion, which drives the construction of other weak or inappropriate soils, soil improvement is a key concern in building operations. Soil improvement is the process of using a variety of technologies to improve index and other soil engineering parameters. Soil serves as a versatile construction material across numerous industries, such as road construction, irrigation systems, canal structures, and more. When the soil is weak, it is vital to improve it. The soil must be altered to suit requirements that differ from one place to the next.

Soil reinforcement is one of numerous methods for improving soil quality. Strengthening the soil mass by increasing its carrying capacity and reducing settlement and lateral deformation enhances stability. Strips are regularly inserted using traditional reinforcement procedures. Natural materials such as jute, bamboo, coir, and corn silk have been used for reinforcing purposes in various South Asian countries for a long time. Soil stabilization has been practiced for millennia to improve the soil's engineering properties. Soil stabilization techniques involve adding more strength or binding materials like calcareous, cement, calcium, and fiber to the soil.

Increased soil strength, bearing capacity, ductility, and the prevention of deformations are all benefits of soil strengthening. High-strength metal strips, wire, industrial and agricultural wastes, natural and synthetic fibers with low modulus can all be used to enhance soil. Over the years, significant progress has been made in improving the soil's engineering qualities.

Soil, according to civil engineers, is a complex material. We design and build practical pavement foundations, embankments, and excavations. It is necessary to determine the physical properties of the soil and to be aware of the difficulties. Some issues need the use of improvements in soil properties. Using eggshell powder and periwinkle shell ash, this study seeks to stabilize the soil.

2. Literature Review

Several studies have been conducted independently using eggshell powder (ESP) and periwinkle shell ash (PSA) in soil over the past few decades. The use of ESP and PSA must be considered, and if it is determined to be a viable option for enhancing the engineering qualities of soil, it may result in its employment in geotechnical applications. The behavior of soil combined with ESP and PSA has been the subject of numerous studies, some of which are highlighted in the literature review.

➢ **Arunava Das et al., (2022):** According to the experimental results, the sand's unconfined compressive strength significantly increased and now stands at about 650 kPa. Additionally, the permeability of the sand dramatically decreased, going from 6.3 E3 to 3.2 E5 cm/s, a reduction of two times. When the sand is treated with S. pasteurii and a 0.50 molarity of eggshell cementing chemical, gains in Young's modulus and calcium carbonate content are seen that are the greatest, with improvements of 28.9 MPa and 17.9%, respectively. Scanning electron microscopy (SEM), microstructural examinations, and energy-dispersive X-ray analyses (EDX) are used to further validate the experimental results. This study showed how bio-cementation technology, which uses eggshell as a cementing agent and S. pasteurii bacteria as a cementing agent, can improve the engineering qualities of sand.

➢ **Muhammad Syamsul Imran Zaini et al., (2022):** An potential to lessen the negative environmental effects of the building sector exists with the use of chemical stabilizers in soil stabilization. However, because environmentally harmful materials like cement and lime are expensive, stabilizing soft clay is difficult. This study concentrated on the usage of expanded shale aggregate (ESA) and silica fume (SF) to stabilize kaolin soils (also known as USS). By adding replacements of 2%, 4%, and 6% (based on the weight of dried soft kaolin clay soil) as cement substitutes in kaolin soil (with respect to the weight of dry soft kaolin clay and SF content), the influence of SF and ESA was investigated. The findings showcased several improvements: a decrease in specific gravity (reduced by 4.9%), a reduction in plasticity index (PI) by 48.4%, a lower maximum dry density (MDD) by 5.5%, an enhanced optimum moisture content (OMC) by 8.7%, and an increase in undrained shear strength (USS) by 68.8%. This effective application of SF and ESA as soil stabilization agents increased the soil's strength, particularly that of kaolin soil, opening the door for reasonably priced and ecologically responsible soil stabilization alternatives.

➢ **S.C. Boobalan et al., (2022):** Investigating the effects of diverse natural materials in traditional ground improvement procedures was the main goal of this extensive research investigation. The review article looked at the use of natural materials as soil stabilizers, including eggshell powder, rice husk ash, wheat husk ash, and tamarind kernel. The optimal content of eggshell powder was found to be 5%, resulting in enhanced strength of the dry soil sample when replaced by weight. Rice husk ash demonstrated improved soil qualities at an optimal level of 6-8%, enhancing strength parameters. The soil's liquid limit increased from 67% to 117% with the addition of 10% Tamarind Kernel Powder (TKP). The soil sample's shrinkage limit was lowered to 15.4% and 11.4%, respectively, by adding 2% and 8% TKP. Additionally, the dry density of the soil sample dropped from 17.1 kN/m2 to 14 kN/m2 as a result of the addition of 8% TKP. Additionally, it was shown that combining jaggery with eggshell powder, lime, and Chebula might strengthen the soil.

➢ **Fatemeh Moghimi et al., (2022):** The ideal incineration conditions for SSA were found to be 1 hour at a temperature of 900 °C based on the study's findings and taking energy efficiency and time constraints into consideration. The outcomes showed that SSA has the potential to greatly improve the toughness and longevity of fat clay. At a concentration of 9% SSA, the UCS gain was at its maximum; at higher concentrations, the improvement waned. Notably, the UCS of the SSA-stabilized samples showed a rise with increasing moisture content, in contrast to unstabilized clay. As the SSA content rose, the shear strength metrics similarly showed an upward trend. Microstructural analysis showed that the stabilized samples' structure was significantly impacted by the addition of SSA. A stronger and denser structure was produced as a result of coating the particles and filling the pore gaps. The study's overall conclusions support the use of SSA as a novel additive for soil stabilization, offering a promising strategy to enhance the characteristics of problematic soils.

➢ **Uduak Bassey Ebong et al., (2021):** This study utilized lime and periwinkle shell ash (PSA) stabilization procedures successfully to examine the appropriateness of lateritic soil for pavement layering. SEM and Fourier transformation infrared (FTIR) analysis were used to detect the morphological alterations and functional groupings in the stabilized soil. The soil's consistency limits generally reduced as the percentage of stabilizers increased. Additionally, a rise in OMC resulted with a decline in MDD. For the mixture comprising 8% lime and 8% PSA, the UCS test yielded peak strengths of 895, 1810, and 2670.45 kN/m3 at 7, 14, and 28 days, respectively. Untreated soil had maximum CBRS and CBRU values of 4.3% and 11.5%, respectively, while a mixture of 8% lime and 8% PSA produced enhanced CBRS and CBRU values of 79.3% and 91.2%, respectively. Both the original and stabilized soil samples showed separate functional groups with discrete bands in the FTIR analysis, whereas the stabilized soil showed new microstructural arrangements in the SEM examination. The study's findings led it to the conclusion that enhancing marginal soils with PSA and lime is an affordable option. The stabilizers improve the soil's technical qualities, making it a better material for layering in pavement.

➢ **Muzamir Hasan et al., (2021)**: Due to their high cost and the use of unfriendly materials like concrete and lime, improving kaolin clay soils successfully remains difficult. In order to overcome this difficulty, this study looked into the possibility of stabilizing these delicate soils by mixing silica fume (SF) with expanded shale aggregate (ESA). The study's conclusions showed that adding SF and ESA to kaolin clay soil enhanced its undrained shear strength significantly. Different replacement degrees were looked at, ranging from 3% to 9% of ESA and 2% to 6% of SF (by dry weight of kaolin clay soil).

➢ **David Ufot Ekpo et al., (2021):** In this study, the prospect of enhancing the geotechnical characteristics of lateritic soil in order to increase its usefulness as a pavement layer material was investigated in a lab setting using Portland limestone cement (PLC) and periwinkle shell ash (PSA). PLC (varying from 0% to 8%) and PSA (varying from 0% to 10%), both added in increments of 2%, were used to treat the soil. The earth was compacted using the typical Proctor technique. Microstructural analyses of the soil-PLC-PSA mixtures were performed to identify functional groups, morphological alterations, and mineralogical modifications. These tests made use of Fourier transform infrared (FTIR) and scanning electron microscopy (SEM). The peak UCS of 920 kN/m2 was within the range set by Ingles and Metcalf as the acceptable maximum for sub-base materials. As seen by their unique bands, Fourier transform infrared (FTIR) spectroscopy revealed distinct functional groups in the native soil, cement, PSA, and optimally treated soil.

➢ **Ekpo et al., (2021):** In this study, the geotechnical properties and indices of two soils were evaluated, as well as the effects of cement kiln dust (CKD) and periwinkle shell ash (PSA) on these properties. With an emphasis on their potential for road construction, the study also sought to establish the ideal ratios of CKD and PSA for soil stabilization. From particular locations in Osun State, Nigeria, soil samples with the labels "soil A" and "soil B" were gathered. After being produced by calcining periwinkle shells, PSA was added to the soils at concentrations of 2%, 4%, 6%, 8%, and 10% by dry weight of the soil. The soils also received additions of CKD at rates of 5%, 10%, 15%, and 20% by dry weight of the soil. The soil samples received a combination of CKD and PSA treatment. The LL, PL, PI, MDD, OMC, UCS, CBRu, and CBRs of the amended soils were then calculated. A statistical analysis of the gathered data was used to calculate the ideal percentages of CKD and PSA. Both soils were identified as low plasticity clayey soils by the index properties data. Both soils required stabilization. The greatest benefits were seen in patients with 10% CKD and 8% PSA. Both of the treated soils' soaking CBR values were greater than the required threshold of 30%. Two-way analysis of variance (ANOVA) statistical analysis proved that CKD and PSA had a substantial impact on the index and geotechnical characteristics of the soils. The 10% CKD and 8% PSA ratios were shown to be the best ones for stabilization. The investigation found that the application of CKD and PSA for stabilizing expansive soils is a viable alternative.

➢ **Rodrigo Beck Saldanha et al., (2021):** The results showed that eggshell limes had less of an effect on land occupancy, terrestrial ecotoxicity, and aquatic ecotoxicity than regular limes did. This resulted from the cessation of the processes for improving and quarrying limestone. Eggshell hydrated lime showed a 50% reduction in impact to ecosystem quality compared to quicklime made from limestone, whereas eggshell quicklime showed a 65.1% reduction. Physical-chemical-mineralogical analysis showed that quicklime, which contained 97.0% calcium oxide and 2.0% magnesium oxide, and eggshell lime, which contained 89.6% calcium hydroxide, 2.9% magnesium hydroxide, and 5.0% calcium carbonate, had the qualities needed for hydrated lime applications in soil stabilization.Additionally, both kinds of limes reacted with ground glass, increasing the investigated soil's strength and stiffness. This interaction between the limes and ground glass acted as a pozzolan, contributing to the improvement of soil properties. In summary, the study concluded that eggshell limes exhibited reduced environmental impacts compared to traditional limes. They demonstrated favorable physical-chemical-mineralogical properties for soil stabilization purposes, and their combination with ground glass resulted in improved soil strength and stiffness.

➢ **R.Subalakshmi et al., (2021):** The main goal of this study was to determine whether adding eggshell powder to lime powder could strengthen soil. From 1% to 10% of the dry weight of the soil, eggshell powder and lime powder were added to soil samples in different amounts. In order to evaluate the behavior of the soil after the addition of eggshell powder, index and engineering properties were looked at. The eggshell powder (ESP) and lime powder were discovered to have an impact on the soil's plasticity index. Additionally, tests were run on samples that had been cured for seven days. The soil's strength ratings were increased when ESP and lime powder were used together. This study looked into using eggshell powder along with lime powder as a low-cost supplement to strengthen soil. The findings demonstrated that the combination of ESP and lime powder greatly boosted the soil strength. In order to develop soil, this study underlines the potential of exploiting eggshell waste as a resource, offering a long-term and financially sound soil stabilization alternative.

➢ **Mfon Ekanem Antia et al., (2020):** The goal of this study was to find out how lateritic blocks' ability to absorb water and shrink when mixed with cement and periwinkle shell ash (PSA). To evaluate the water absorption and shrinkage properties, several methods were used, such as sedimentation tests, common proctor tests, Atterberg's limit testing. A 5% cement composition and PSA replacement amounts of 0%, 10%, 20%, 30%, 40%, and 50% were employed to produce blocks. Tests for water absorption and shrinkage were performed on blocks that were molded, dried, and 21 cm by 10 cm by 10 cm in size. The findings demonstrated that when cement replacement with PSA level rose, so did the water absorption. For replacement levels of 0%, 10%, 20%, and 30%, it was discovered that the water absorption percentages were 12%, 16%, 18%, and 19.95%, respectively. Additionally, as cement substitution with PSA varied from 0% to 30%, the linear shrinkage of the blocks rose from 1.5 mm to 2.8 mm.. Therefore, it was recommended to utilize a replacement percentage of up to 30% in lateritic blocks. In summary, the study concluded that incorporating PSA with cement in lateritic blocks influenced their water absorption and shrinkage characteristics. The findings suggested that a replacement level of up to 30% provided acceptable results, ensuring the blocks met the required standards for crack width. These results highlight the potential of using PSA as a supplementary material in the production of lateritic blocks, offering a sustainable and eco-friendly alternative for construction materials.

➢ **Roland Kufre Etim et al., (2019):** The purpose of this study was to assess how well periwinkle shell ash (PSA) suited the needs of road building as a pavement material. PSA was applied to the laterite soil in varied concentrations (up to 12% by dry weight of the soil). For all compaction efforts, the maximum dry density rose as the ideal moisture content fell. Regardless of the amount of compaction energy used, the peak values of unconfined compression strength (UCS) and California bearing ratio (CBR) were reached with a 6% PSA content. A higher PSA content increased resistance to strength loss, according to the durability assessment, although an increase in compaction effort didn't seem to follow any predictable pattern. With an 8% PSA treatment, the British Standard heavy compaction had the highest peak resistance to strength loss of all the compaction energies, at 24.3%. As to the study's findings, PSA can be employed for enhancing the lateritic sub-base of seldom traveled roadways.

➢ **Abiola. M. Dauda et al., (2019):** Periwinkle Shell Powder (PSP), a material that is safe for the environment and can stabilize lateritic soil's engineering features, was explored in this study. The lateritic soil stabilized with varied concentrations of PSP (2%, 4%, 6%, 8%, and 10%) and Ordinary Portland Cement (OPC) was then subjected to engineering tests. The findings demonstrated that the lateritic soil's Maximum Dry Density (MDD) increased gradually as cement was added, rising from 1875 kg/m3 (at 2% OPC) to 2294 kg/m3 (at 10% OPC). Comparing this to the unstabilized state, MDD increased by 22%. The MDD of the soil treated with PSP, on the other hand, increased by 5.3% from its unstabilized form and peaked at 6% PSP (1974 kg/m3). For both stabilizing agents, the Optimal Moisture Content (OMC) increased as well. Cement produced a 34% rise in California Bearing Ratio (CBR) readings, while PSP exhibited a 5.6% increase. This implies that PSP has potential as a lateritic or clayey material stabilizer.

➢ **Nnochiri et al., (2017):** This study looked at how periwinkle shell ash (PSA) affected soil that had been stabilized with lime. The first step entailed classifying and identifying a natural soil sample with the designation A-7-5. The soil sample was subsequently treated with varied amounts of lime, including 2%, 4%, 6%, 8%, and 10%. The ideal lime concentration, as determined by Atterberg limit testing, was discovered to be 10% since it produced the lowest plasticity index value. The soil sample that had been treated with lime was then subsequently amended with PSA at various concentrations ranging from 2% to 10%. The outcomes showed a notable rise in CBR and UCS values for the lime-stabilized soil samples that included PSA. Improved strength properties are shown by this. Additionally, the study came to the conclusion that PSA can replace lime for soil stabilization at a lower cost. Soil stabilized with lime revealed good benefits from the addition of periwinkle shell ash (PSA), resulting in improved strength qualities. The results indicate that PSA can be used as a practical and more affordable alternative to lime in soil stabilization procedures.

Research Gap

According to the examination of the literature, eggshell powder and periwinkle shell ash have both been used individually to enhance soil, but their combined usage has not received as much attention. This topic has been covered in the current study project.

To better understand how expanding soil functions over time, the study will combine eggshell powder with periwinkle shell ash. Therefore, using eggshell powder and periwinkle shell ash to change the soil's characteristics is justified in this investigation.

3. Materials And Methodology

3.1 Materials Used

The various materials include:

1. Clayey soil

2. Egg shell powder

3. Periwinkle shell ash

3.1.1 Expansive Soil

Soil (from Jammu): The soil sample utilized in this study was obtained from the fields located in RS PURA (JAMMU DISTRICT), J&K.

Since the top 1.5 meters of soil are likely to include organic materials and other foreign objects, the necessary amount of dirt is removed from the area at that depth. To confirm the general homogeneity of the soil sample, it was carefully checked. According to the IS Code, fundamental testing is performed on this soil. The site's gathered soil was broken into smaller pieces with a wooden hammer before being allowed to air dry in a covered area. Then it was completely blended after being sieved with a 2.35 mm IS sieve. A certain amount of soil was removed from Polythene bags for each test and dried in an oven at 105°C/5°C for 24 hours. At room temperature, the soil was allowed to cool.

Figure 3.1: Clayey Soil Sample

Table 3.1: Properties of Clayey Soil

PROPERTIES	Value
Specific gravity	2.86
Liquid Limit LL (%)	39
Plastic Limit PL (%)	23.5
Plasticity Index PI (%)	15.5
Optimum Moisture Content (%)	18.45
Maximum Dry Density (kN/m^3)	16.15
C.B.R (%) (soaked)	3.87
C.B.R (%) (unsoaked)	6.21
U.C.S (kN/m^2) (7 days)	66
U.C.S (kN/m^2) (14 days)	78
Indian Soil Classification	CI

Table 3.2: Chemical Composition of Expansive Soil

(source: Internet)

Mineral	Value
Alumina	10 %
Iron Oxide	(9 – 10) %
Lime And Magnesium Carbonates	(6 –8) %
Potash	< 0.5 %
Phosphate, Nitrogen, Humus	Low

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3.1.2 Egg Shell Powder

The eggshell was gathered from Bhargav Hotel (Samba), and a fast-food restaurant. The eggshell was manually cracked, allowed to air dry, and then ground into a powder that was collected in polythene bags and kept at room temperature. In the end, the eggshell powder was sieved.

Fig 3.2: Egg Shells **Fig3.3: Egg Shell Powder**

Table 3.3 Chemical Composition of Egg Shell Powder

Mineral	Composition %
Calcium Oxide	62.35%
Sulphur Trioxide	1.32%
Iron Oxide	0.63%
Silicon Dioxide	0.61%
Magnesium Oxide	0.36%
Potassium Oxide	0.22%
Aluminium Oxide	0.07%

3.1.3 Periwinkle Shell Ash

The periwinkle shells are sun-dried to reduce moisture before being calcined in an electric muffle in a lab at 1000oC. This calcined product is crushed and sieved using an IS sieve (75 microns) to obtain fine ash.

Fig 3.4: Periwinkle Shells **Fig 3.5: Periwinkle Shell Ash**

Table 3.4 Chemical Composition of Periwinkle Shell Ash

Composition by weight	PSA (%)
Al2O3	9.75
CaO	43.00
SiO2	31.52
K2O	0.4
SO3	0.07
Fe2O3	9.68
Na2O	0.28
MnO	0.01
MgO	0.75
TIO2	0.024
ZnO	0.01
LOI	4.3

3.2 Methodology Adopted

1) To assess the various characteristics indicated in the objectives, the following experiments will be performed on virgin soil as well as soil having varied proportions of eggshell powder and periwinkle shell ash:

2) Calculation of soil index characteristics - Atterberg's limits (IS: 2720 Part-V)

    a. Liquid limit test

    b. Plastic limit test

3) Specific Gravity (IS: 2720 Part-III)

4) The Proctor compaction test (IS: 2720 Part-VII) is used to determine the maximum dry density (MDD) and associated optimum moisture content (OMC) of soil.

5) Calculation of strength metrics, such as

    a. CBR value (IS: 2720, Part-X)

    b. Unconfined Compressive Strength (UCS) (IS: 2720 Part-VI)

4. Results

After the soil was oven dried, following basic tests were performed on it:

- Atterberg's limit analysis (IS: 2720 Part V-1985)
- Specific Gravity Test (Pycnometer test) (IS: 2720 Part III-Section I/II-1980)
- Standard proctor test (IS: 2720 Part VII-1980)
- California bearing ratio test (IS: 2720 Part XVI-1987)
- Unconfined compressive strength test (IS: 2720 Part X-1991)

4.1 Standard Proctor Test

Table 4.1: Results of MDD & OMC value for clayey soil sample.

SOIL: ESP: PSA	MDD (kN/m³)	OMC (%)
100:0:0	16.15	18.45
85:12:03	18.13	19.41
82:12:06	17.79	19.69
79:12:09	17.11	20.12
76:12:12	16.53	20.67

4.1.1 Untreated Soil And Esp Mix

Table 4.2: Results of OMC and MDD for Soil, ESP and PSA mixes

SOIL: ESP	MDD (kN/m³)	OMC (%)
100:0	16.15	18.45
96:04	15.75	18.92
92:08	15.10	19.43
88:12	14.67	19.81
84:16	15.23	18.90

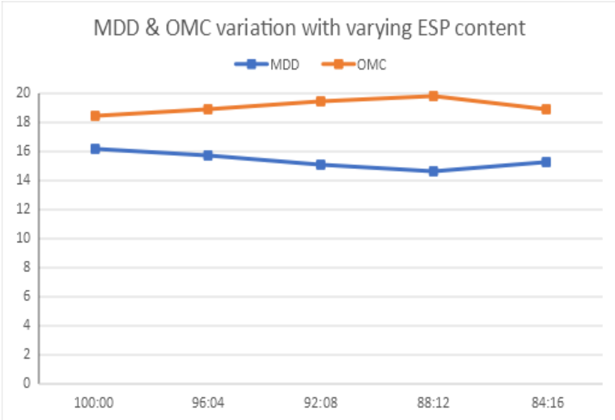

Fig 4.1: Variations b/w MDD and OMC of untreated soil & ESP mix

4.1.2 Clayey Soil, ESP and PSA Mixes

Table 4.3: Results of OMC and MDD for Soil, ESP and PSA mixes

Clayey soil	MDD (kN/m³)	OMC (%)
100:0	16.15	18.45

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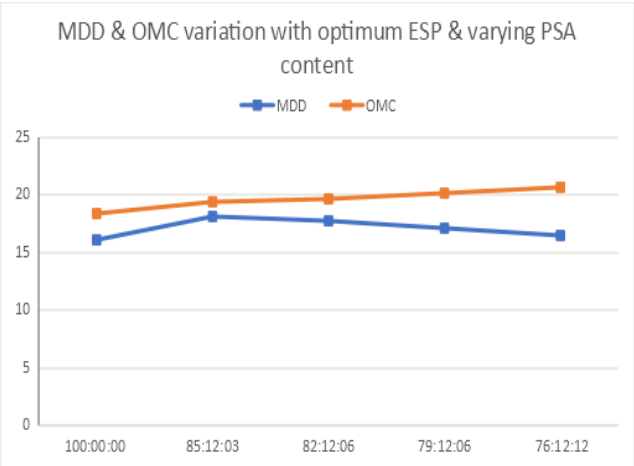

Fig 4.2.: Variations b/w MDD and OMC of treated soil, optimum ESP & varying PSA

4.2 California Bearing Ratio Test

Table 4.4: Results of CBR value for clayey soil sample.

Clayey soil	CBR(soaked) (%)	CBR (unsoaked) (%)
100:00:00	3.87	6.21

4.2.1 Clayey Soil and ESP Mixes

Table 4.5: Results of CBR for Soil and ESP mixes

Soil: ESP	CBR (soaked) (%)	CBR (unsoaked) (%)
100:00	3.87	6.21
96:04	4.20	6.88
92:08	5.14	7.10
88:12	6.68	8.90
84:16	5.92	8.20

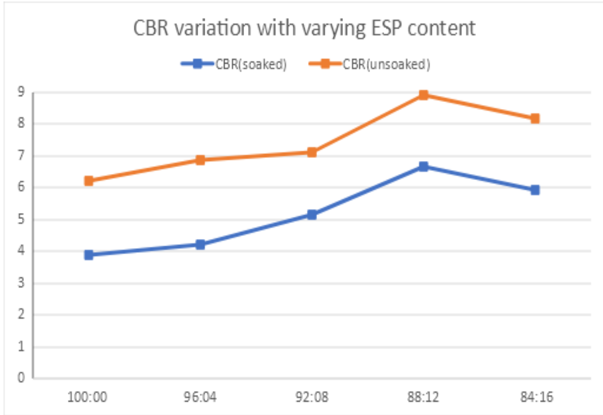

Fig 4.3: CBR variations of untreated soil & ESP mix

4.2.2 Clayey Soil, Esp And Psa Mixes

Table 4.6: Results of CBR for Soil, ESP and PSA mixes

Soil: ESP: PSA	CBR (soaked) (%)	CBR (unsoaked) (%)
100:00:00	3.87	6.21
85:12:03	6.42	7.7
82:12:06	6.92	8.3
79:12:09	7.43	8.9
76:12:12	7.84	9.1

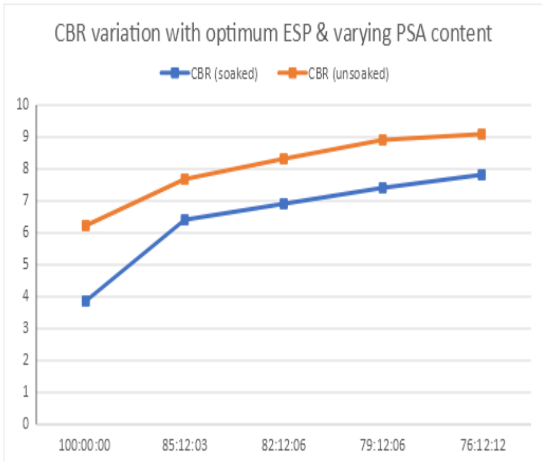

Fig 4.4: CBR variations of treated soil, optimum ESP & varying PSA

4.3 Unconfined Compression Strength (UCS) Test

Table 4.7: Results of UCS Test for clayey soil sample

Clayey Soil	Curing Period(Days)	UCS (kN/m^2)
100:00:00	7	65.51
	14	78

4.3.1 Clayey Soil And Esp Mixes

Table 4.8: Results of UCS for Soil and ESP mixes

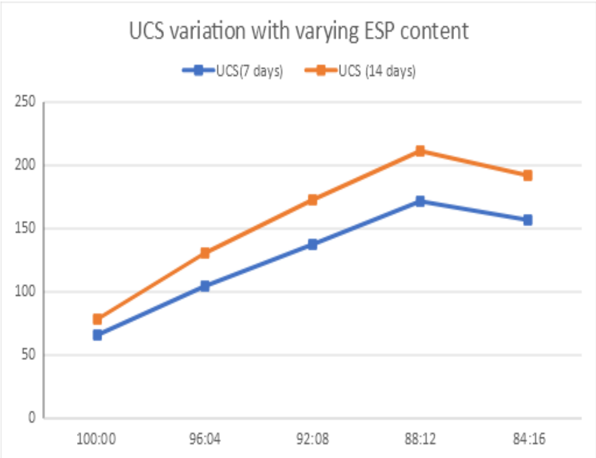

Fig: 4.5: UCS variations of untreated soil & ESP mix

4.3.2 Clayey Soil, ESP and PSA Mixes

Table 4.9: Results of UCS for Soil, ESP and PSA mixes

Soil: ESP: PSA	UCS (kN/m^2) (7 days)	UCS (kN/m^2) (14 days)
100:00:00	66	78
85:12:03	197	292
82:12:06	313	390
79:12:09	382	463
76:12:12	457	536

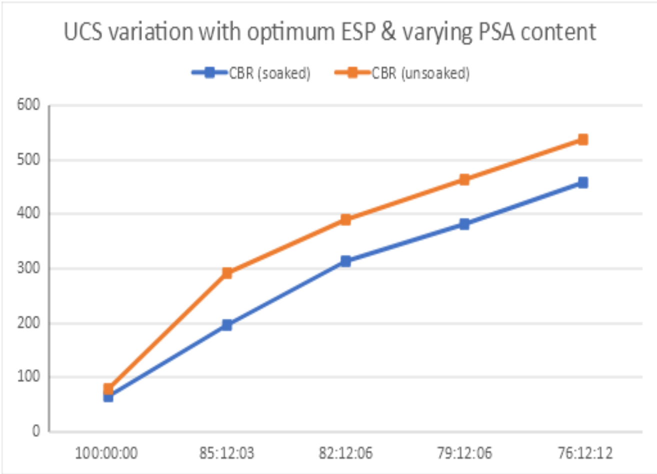

Fig:4.6: UCS variations of treated soil, optimum ESP & varying PSA

Soil: ESP: PSA	UCS (kN/m^2) (7 days)	UCS (kN/m^2) (14 days)
100:00:00	66	78
85:12:03	197	292
82:12:06	313	390
79:12:09	382	463
76:12:12	457	536

5. Discussions

5.1 Compaction Test

The goal of the current study was to examine soil compaction characteristics using various ESP percentages. The findings showed that the Maximum Dry Density (MDD) decreased as the amount of ESP rose. Due of ESP's lower

specific gravity than soil, this decline can be explained. The Optimal Moisture Content (OMC) increased as the amount of ESP increased. This is a result of the pozzolanic reaction between ESP and the soil, which necessitates more water in order to promote the cation exchange process. Additionally, given the enormous surface area of ESP, moisture is required to provide adequate soil wetting and packing.

The figures below illustrate the variations in MDD and OMC with respect to thepercentage of ESP.

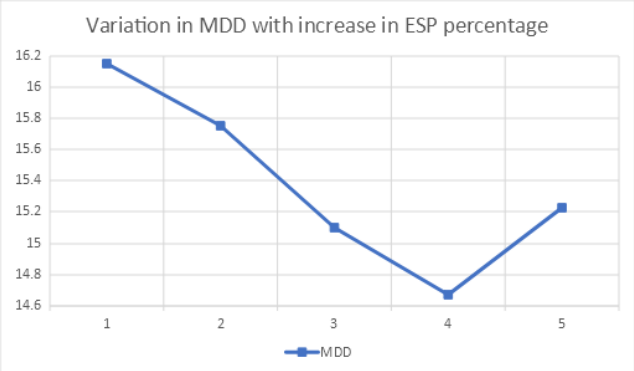

Fig 5.1: Variation in MDD with increase in ESP content

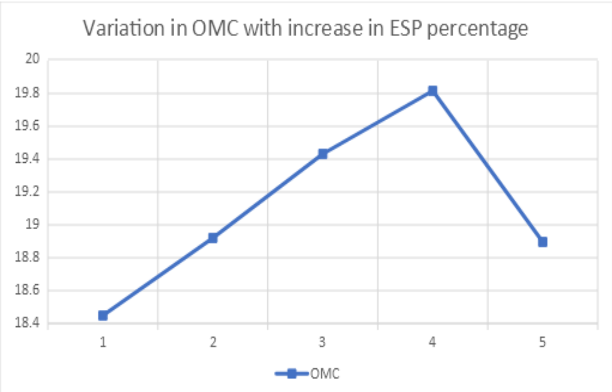

Fig 5.2: Variation in OMC with increase in ESP content

The Maximum Dry Density (MDD) of the soil-ESP combination increases when the PSA (periwinkle shell ash) content increases when the right amount of ESP is added. This is as a result of PSA's smaller weight, which adds more void spaces to the combination and increases MDD. However, when the amount of PSA grows, the soil-ESP mixture's Optimum Moisture Content (OMC) rises. The reason for this is that PSA has a substantial absorption capacity, requiring more moisture to compress to the required level.

The figures presented below illustrate the variations in MDD with increasing ESP content and the variations in OMC with increasing PSA content

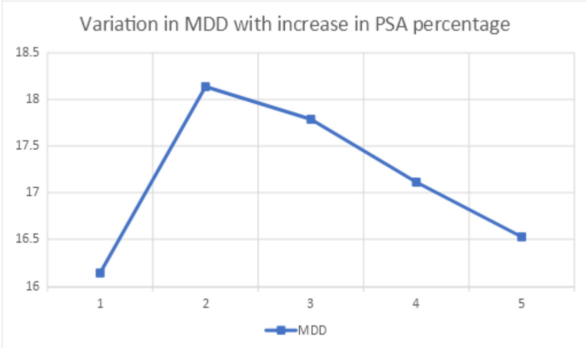

Fig 5.3: Variation in MDD with increase in PSA content

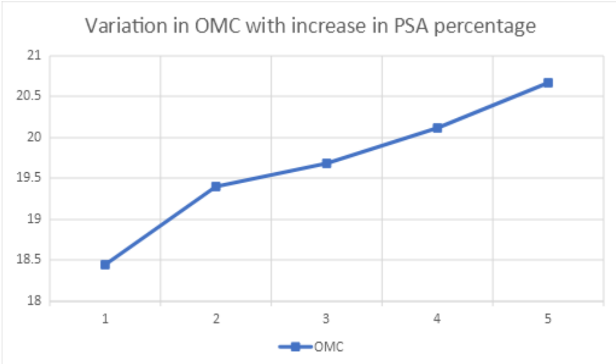

Fig 5.4: Variation in OMC with increase in PSA content

5.2 California Bearing Ratio Test

Both soaked and unsoaked CBR (California Bearing Ratio) measurements marginally improved when ESP (eggshell powder) was added to soil samples. The soaked CBR value climbed from 3.87% to 6.68% and the unsoaked CBR value increased from 6.21% to 8.9% when the content of ESP and PSA (periwinkle shell ash) increased. The reaction between the pozzolanic compounds of ESP and the soil's content of CaOH (calcium hydroxide) resulted in the creation of cementitious compounds, which is what caused the increase in CBR value.

The appropriate quantity of 12% ESP was added, and this increased both CBR (wet) and CBR (unsoaked) by up to 6.68% and 8.9%, respectively. Additionally, the inclusion of various PSA dosages led to an even greater increase the CBR values.

5.3 Unconfined Compression Strength (UCS)Test

The virgin soil's Unconfined Compressive Strength (UCS) values significantly increase with the addition of ESP (eggshell powder) and PSA (periwinkle shell ash).

The UCS values rise from 66 kN/m2 to 157 kN/m2 after a 7-day curing time and from 78 kN/m2 to 192 kN/m2 after a 14-day curing period when ESP and PSA are added. When ESP and PSA come into touch with water during the curing process, pozzolanic reactions take place, which is what is responsible for this improvement.

The creation of cementitious compounds as a result of these pozzolanic reactions helps to strengthen the soil's strength. As a result, the UCS values exhibit a considerable improvement after ESP and PSA, demonstrating their beneficial effects on the soil's strength characteristics.

Conclusion

Following conclusions can be inferred on the basis of the experiments performed:

1. ESP, as a waste product, exhibits cementitious qualities that effectively contribute to soil stabilization and improve soil strength.
2. The addition of PSA in small quantities can bring about significant changes in the strength properties of soil.
3. Based on the current study, the optimal percentage of ESP is determined to be 12%, as it yields the optimal values for MDD, OMC, CBR, and UCS when added to the soil.
4. Due to the finer nature of ESP, there is a decrease in MDD and an increase in OMC as the amount of ESP additive increases.
5. When PSA is increased while keeping the ESP amount constant, the CBR value shows an upward trend. The soaked CBR value increases by approximately 1.7 times, and the unsoaked CBR value increases by around 1.43 times compared to the untreated soil.
6. The soil's unconfined compressive strength (UCS) increases with an increase in PSA while maintaining a constant ESP level. After ESP and PSA have been added together, the UCS value is 2.3 times higher after 7 days and 2.4 times higher after 14 days when compared to the untreated soil.

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