

Experimental Study on Stabilization of Clayey Soil Using Eggshell Powder and Ceramic Waste Powder

Faiqa Fatima, Anoop Sharma

U.G. Student, Department of Civil Engineering, SSCET, Pathankot, Punjab, India

Assistant Professor, Department of Civil Engineering, SSCET, Pathankot, Punjab, India

Abstract - Without proper treatment, clayey soils are undesirable for construction because they frequently show low strength, significant plasticity, and poor load-bearing ability. The goal of this project is to employ waste materials, specifically eggshell powder and ceramic waste powder to improve the engineering qualities of clayey soil. The application of these materials encourages sustainable waste management in addition to improving soil performance. In this study, different proportions of ceramic waste powder and eggshell powder were added to soil samples. The results indicate that the addition of eggshell powder, rich in calcium content, contributes to improved bonding and strength through chemical reactions, while ceramic waste powder enhances particle interlocking and reduces plasticity. An optimum mix proportion was identified where maximum strength and stability were achieved with reduced permeability. Overall, the study concludes that eggshell powder and ceramic waste powder can be effectively utilized as eco-friendly stabilizing agents for clayey soils, offering both technical and environmental benefits. The index and engineering properties were carried out to access the behavior of soil with the addition of eggshell powder. The soil's plasticity index can be regulated by the ESP. The optimum moisture content (OMC) and maximum dry density (MDD) values were obtained using the conventional proctor test. For the ideal dosages of ESP and CWP, the UCS and CBR test was carried out. The inclusion of ESP and CWP significantly raised the strength value. Clayey soil was treated with ESP in four different percentage amounts (5%, 10%, 15%, and 20%) as part of an experimental inquiry. Following that the CWP was mixed with the soil and 15% ESP mixed soil at rates of 5%, 15%, 25%, and 35%. The effects of CWP and ESP on Atterberg limits, C.B.R., U.C.S., O.M.C., and M.D.D. were investigated.

Key Words: Compaction test, CBR, UCS, ESP, Ceramic waste powder

INTRODUCTION

Projects involving civil engineering are invariably built into the earth. Any structure must therefore have a foundation with adequate bearing capacity. The idea of "soil improvement" dates back to antiquity and the Renaissance, and it is still used today to expand existing techniques and create new ones, particularly in emerging nations with growing populations and pressing economic issues. These soils are adversely affected by moisture, which makes them especially harmful to buildings built on top of them, such foundations and light constructions. Expansive soil is one of these challenging types of soil. Large portions of the country's regions were covered with expansive soil. Expansive soil is a challenging soil that requires upgrading. When a certain amount of load is applied to soil, it usually deforms in the direction of the load application. The soil determines the kind and extent of deformation. To obtain enough bearing capacity and strength to support the load applied to them, such soils must either be replaced with suitable soil or treated with an appropriate mechanism. Tiny particles are present in significant amounts in expansive soil soils, such as silty and clayey soils with high moisture content, peat foundations, and loose sand deposits close to or below the water table (Indraratna, Chu, & Cholachat, 2015). Low strength, high sensitivity, and high compressibility are characteristics of expansive soils (Huang et al., 2020; Indraratna et al., 2015). In general, expansive soils are associated with serious difficulties. These soils have poor shear strength and are prone to deformation, which can result in structural damage during construction. Additionally, the dual swelling shrinkage nature of expansive soil makes it difficult to build structures like pavements and multistory buildings. When it rains, the expansive soil subgrade swells and the structure experiences shear failure. The expansive soil's swelling pressure and heave phenomena were

lessened using a variety of mechanical and chemical techniques. The earliest and most conventional techniques for enhancing the engineering qualities of expansive soils are mechanical and chemical stabilization. Nevertheless, these approaches are costly and time-consuming. This study examines some of the mechanical characteristics of expansive soil after adding waste materials from the environment, such as powdered egg shells. To obtain enough bearing capacity and strength to support the applied load, such soils must either be replaced with appropriate soil or treated using an appropriate technique.

Eggshell powder (ESP), a ceramic waste powder, is employed in this study to stabilize expansive soil while preventing the consumption of natural limestone. Because ESP and limestone components share some chemical similarities, ESP can be utilized in place of limestone. In recent years, the usage of stabilizing technology has increased dramatically, particularly when development sites are often located on undeveloped soil.

2. Literature Review

Fordjour et al (2024)

Predicting the compressive strength of environmentally friendly lateritic modified with eggshell and plastic powder was the goal of this investigation. In order to do this, the surrigate model was utilized to optimize the muilt conditions of plastic and eggshell as stabilizers. For paired generation, Latin hypercube sampling was utilized, and a batching ratio of 1:4 with a water-to-cement ratio of 0.4 was used. The results showed that adding both ESP (eggshell powder) and PW (plastic waste) significantly improved the engineering properties of the clayey soil. ESP, PW ingredients, and curing time all affect these positive effects. The stabilized soil samples' engineering properties were greatly enhanced during the curing period. It was determined that the eggshell significantly affected the maximum dry density (MDD), optimum moisture content (OMC), and California bearing ratio (CBR) under all circumstances. For ID number 19, the estimated variances of the optimal and experimental values were determined to be 1.70%, 7.74%, and 0.52% for the CBR, OMC, and MDD, respectively. The CBR, OMC, and MDD variances

for ID number 58 were determined to be 9.0%, 5.34%, and 1.38%, respectively. Similar variances for the CBR, OMC, and MDD in ID number 63 were discovered to be 7.5%, 8.13%, and 1.74%, respectively.

Sadek Deboucha et al (2024)

For the sub-base layer of roadways, this study looks at cement and ceramic waste (CW). The hazards connected with inappropriate industrial waste disposal can be eliminated with this novel approach. Several ratios of cement and CW, ranging from 1.5 to 2% and 5% to 15%, respectively, were used to accomplish this goal. The study's objective was to investigate how CW and ordinary Portland cement (OPC) affected the microstructures, permeability, consolidation, and unconfined compressive strength (UCS) of both treated and untreated road sub-base layer soil. The laboratory and in-situ experiments analyzed included the Guelph permeameter, UCS, permeability, and one-dimensional consolidation; SEM, infrared (IR), and mercury intrusion porosimetry (MIP) were used to characterize the microstructures. The results showed that our road suffered damage shortly after construction due to the natural soil's high permeability. Permeability was reduced by almost 100% and settling by around 43% when 5 to 15% CW was applied. Additionally, combining CW and OPC with soil increased UCS by around 182% and 20 times, respectively, in wet and submerged circumstances. This study showed that CW and OPC coupled with soil might be used as a road sub-base layer material by improving its geotechnical qualities.

Sai Ram et al (2023)

In this experiment, we use eggshell powder and quarry dust to improve the soil's qualities. The tests were conducted using different percentages of quarry dust, such as 8%, 16%, 24%, and 32%, to replace the soil, and where the maximum density value was obtained, eggshell powder was added to the soil's weight at varying percentages of 4%, 8%, 12%, and 16%. In order to stabilize black cotton soil and red soil for construction, the best percentage of eggshell powder addition and quarry dust replacement was found. Researchers and engineers working in the subject of soil stabilization might learn a lot from this experimental study. A number of laboratory experiments, including sieve

analysis, Atterberg limits, compaction, unconfined compressive strength, and California bearing ratio (CBR) tests, were used to conduct the study.

Nidhya Rathinavel et al (2023)

To the greatest extent feasible, the construction sector can lessen its environmental impact by implementing appropriate waste management technology to decrease the production of new materials. In this work, fly ash (FA), a waste from burning coal, and eggshell powder (ESP), a waste from the poultry industry, were used as precursors to make geopolymers and to replace traditional cement-based building materials. To create lightweight geopolymer panels, three distinct weight percentage ratios of precursors—90FA:10ESP, 80FA:20ESP, and 70FA:30ESP—were reinforced with two distinct weight percentages of paddy straw—15 and 30 wt%—in the presence of appropriate sodium hydroxide and silicate combinations.

The results of various analytical tests, including density, water absorption, compressive strength, and flexural strength, indicate that the use of ESP significantly improves the geopolymer products' performance. The experimental sample manufactured with 70FA:30ESP without paddy straw reinforcement has a greater compressive strength value (15.64MPa) than panels reinforced with paddy straw. The flexural behavior of paddy straw reinforcement was found to exhibit the opposite tendency, with 15 weight percent having a greater value than the panel (70FA:30ESP) manufactured without reinforcement.

Poonam Shekhawat et al (2023)

This work focuses on employing flyash-based geopolymer, such as eggshell powder, to stabilize illite and kaolin-based clay at room temperature. Flyash and eggshell powder are both waste resources, and using them as green building materials can solve a number of disposal-related issues. Additionally, the calcium-rich eggshell powder can improve the clayey or soft soil's strength qualities. A thorough testing program that included compaction, compressive strength, tensile strength, California bearing ratio, and microstructure analysis was carried out with the aforementioned considerations in mind. The findings showed that the strength qualities of clayey soil were improved to a level equivalent to that of clayey soil without any treatment when flyash-eggshell powder geopolymer was partially or completely replaced. The microstructure analysis confirms that the portion of

the various calcium-based geopolymer gel produced in small amounts from the activation of eggshell powder within the flyash-based geopolymer is primarily associated with short-term strength development, even though the novel geopolymers precursor material, eggshell powder, contains CaO in the crystalline phase.

The primary findings show that a 30% concentration of geopolymer in clay greatly improved the material's tensile strength, California bearing ratio, and compressive strength. Lastly, as sustainable building materials made from household and industrial waste, the geopolymer-treated clay mixes discovered throughout the experiment may find use in pavements and embankments.

Dr. K. Harish et al (2023)

Given the millions of tonnes of waste produced nationwide each year, which not only presents disposal challenges but also increases environmental contamination and health risks, the use of such refuse, industrial wastes, and their subsidiary products as alternatives to building materials may effectively contribute to environmental preservation and minimize their negative effects on the environment. In the current study, the index features, compaction, and shear strength of clay soil were investigated at different mixed proportions using eggshell powder as a waste to mix with soil. Next, experimental specimens that had been mixed with different ratios of eggshell powder were compared to the shear strength of previously examined soils.

Sreerema Prasad .S (2022)

The investigation came to the conclusion that adding waste additives improves clayey soil's engineering qualities. Waste products like ESP and CFF have the potential to seriously harm the environment. These solutions are cost-effective and the greatest option for long-term environmental preservation when used as soil stabilizers.

Saber, S. A. et al (2022)

Had investigated a type of clay soil's geotechnical characteristics following the addition of ceramic dust in percentages of 0%, 5%, and 10%. The results demonstrated that adding ceramic dust to clay soil reduced the specific gravity values. In the Atterberg limit, ceramic dust usage up to 10% reduced both the liquid and plastic limits. The PI value only minimally

increased since just 5% of CD was used; nevertheless, if 10% of CD was used, the PI value declined; CD had little effect on the PI's tendency to increase. The study also concentrated on the Proctor test, which revealed that the percentages of ceramic dust permanently raised the maximum dry density (MDD) value while lowering the optimum moisture content (OMC) value. Unsoaked California bearing ratio (UCBR) is another test utilized in research. It was evident from the data values and curves that the addition of CD to the clay soil was successful in raising the CBR values.

Saya Abdullah Saber et al (2021)

Natural resource consumption can be reduced, and new emissions and environmental burdens can be avoided. Three local clay soil samples from Erbil, North Iraq, were collected for this purpose, and the effects of adding waste ceramic dust on these samples' mechanical properties were experimentally investigated in two different grading sizes. Particle sizes of ceramic dust that passed through sieves No. 40 and No. 10 in percentages of 0, 5, and 10% were utilized. The investigation demonstrated that the ideal moisture content of the clay declined as the percentages of ceramic dust, liquid limit, plastic limit, and plasticity index increased. Conversely, the California bearing ratio, maximum dry density, and unconfined compressive strength all rose. According to the study, adding ceramic dust of No. 10 gradation produces a greater benefit than adding the same amount of No. 40 size ceramic dust. According to the current research, soil stabilized with the proper kind and proportion of ceramic dust may be appropriate for a sustainable highway construction subgrade by lowering the design thickness and possibly being more cost-effective.

Prasad Gajanan Sonar et al (2021)

Another wave of biological waste disposal crises would result from the growing need for PPE suits and masks in a world full of crises. Throwaway waste disposal is a major problem since most of the waste is not biodegradable and cannot be burned. By using appropriate compaction and additional materials like concrete and lime, soil stabilization improves the weak soil's engineering qualities. However, these materials are getting more and more expensive, so

plastic made from egg shell powder could improve the qualities and serve as a sustainable substitute for concrete, lime, and other stabilizers. It has been demonstrated via extensive experimental research that plastic and egg shell powder may be utilized as an efficient solution for stabilizing weak soil and as an effective stabilizer when dealing with waste disposal issues. These PPE stripes and shredding are renowned for their great strength, affordability, and considerably lower environmental risk. The engineering qualities of soil can be improved by combining egg shell powder with PPE stripes or shredding.

Rajit Sharma et al (2021)

Pavement embankments are composed primarily of dirt and other earthy materials. When the strength or other design requirements of the soil are not reached, we can improve the soil up to the intended limitations by adding anything to it. Currently, research is being done on the use of waste materials, such as egg shells and recorn, which can only be added to something because they cannot be disposed of. By adding the aforementioned materials, this study seeks to improve the soil's characteristics in comparison to observations of virgin soil. The load is transferred from the upper to the lower layers of embankments. Every material must achieve the intended design strengths. Utilizing waste materials as stabilizers benefits both the environment and the strength of the soil.

Sourav et al (2021)

Soil stabilization has long been a focus of research, and diverse techniques and additives like fly ash, lime, and asphalt have been employed to achieve this goal. Eggshell powder and coir fiber, two sustainable waste materials, were utilized to create soil with a substantial soil holding capacity in order to contribute to the study of soil stabilization. Eggshell powder (5%, 10%, and 15%) and coir fiber (1%, 2%, and 3%) were combined. The CBR was used to access load penetration, the direct shear strength test was used to assess shear strength, and the standard proctor test was used to test the soil for basic and fundamental soil parameters such as OMC-MDD. For the weight of soil masses, we found that 15% eggshell powder and 2% coir fiber produced the best and most optimal results. Additionally, the other combination yields satisfactory outcomes. Comparative charts were

used to assess various data, and it was discovered that one parameter was associated with other soil parameters.

Sadegh Ghavami et al (2021)

The findings showed that the ideal addition level of activators used to improve the geotechnical capabilities of the ESP-treated soil was 1% nano-silica and 15% silica fume by dry soil weight, respectively. Additionally, ESP-treated soil was the most sustainable blend, according to the sustainability assessment. Considering the sustainability benefits, adding less than 2% of nano-silica and silica fume to the ESP-stabilized soil can result in treated soil that is significantly more sustainable than cement. It is important to emphasize that the sustainability of stabilized soils containing nano-silica was significantly lower than that of ESP-treated soils containing silica fume.

A Iravanian et al (2020)

Determining the utilization of ceramic wastes as a raw material for soil structures and road pavement subgrade construction is the aim of this review study. Over 22 billion tons of ceramic waste powder (CWP) are produced worldwide during the last stage of ceramic tile polishing. The use of (CWP) in landfills may result in significant problems for the climate, water, and soil. According to calculations, the ceramic sector wastes almost thirty percent of its daily growth. Depending on the quantities we can utilize, we can minimize the usage of natural goods, lower the amount of money spent, and improve land conditions by attempting to diminish this material. Because they cannot be handled in any way, these wastes cause problems with disposal and loss to the industry. Because of its strength, durability, and resistance to all types of diminishing powers, ceramic waste can be used in place of replacements. We will get diverse outcomes and attributes of soil constructions in varied California bearing ratios, dry unit weight, unconfined soil density, and ideal water content using different amounts of ceramic waste.

Aneesh P.C et.al (2020)

In order to achieve the ideal percentage of each additive, three different amounts of ESP (2%, 5%, and 8%) and plastic wastes (0.25%, 0.5%, 0.75%, and 1%) were applied in this experimental

investigation on stabilizing cochin clay using egg shell powder (ESP) and shredded LPDE. The obtained sample is classified as silt clay (53.3%), and the Unified Soil Classification System (USCS) places our clay sample under CH based on the plasticity index.

Mahmud et al. (2020)

It was shown that when cement and CWP increased, the maximum dry densities (MDD) decreased and the optimum moisture content (OMC) decreased in the same sequence. For a given cement addition, the unconfined compressive strength (UCS) rose with increasing CWP up to a maximum of 30% CWP, after which the values were seen to decline. Therefore, the ideal CWP needed for maximal UCS strength is 30% CWP. After 90 days of curing, a maximum of 2700 kN/m² was measured at 6% cement and 30% CWP. The requirement that a stabilized material be utilized as base course material for heavily traveled roads was met by this maximum value. A notable rise in UCS was also noted as the number of curing days increased, indicating the presence of a Pozzolanic reaction in the combination. Thus, cement-stabilized clay soil can be effectively stabilized using 30% CWP.

Alzaidy.M.N.J (2019)

This study examines the impact of combining egg shell powder and plastic waste strips on a number of clayey soil engineering properties, including compaction characteristics, swelling potential, unconfined compressive strength, California bearing ratio test, and shear strength parameters. The purpose of this work is to examine how the strength behavior of clayey soil is affected by eggshell powder contents, plastic trash, and curing time. Unconfined compressive strength rises with an increase in ESP concentration. After adding both ESP and PWS, a notable net improvement in the clayey soil's engineering properties was observed. ESP, PWS contents, and the length of curing time all affect these positive effects.

Ajay Upadhyay et al (2016)

When a soil lacks characteristics necessary for the desired structure, it must be stabilized. Therefore, it is essential to use appropriate materials and techniques in order to enhance the engineering

features of such soil. The characteristics of the soil, the style of building, cost, and environmental factors all influence the choice of specific material and technique. Examining the many industrial waste materials that are produced in enormous amounts is necessary. One such technique that can be utilized to enhance the geotechnical characteristics of soil is soil stabilization utilizing leftover ceramic dust. Clayey soils have a limited bearing capacity and poor shearing strength. Such soil is difficult to work with because it lacks the strength to sustain the weight that is placed on it. The characteristics of such soil must be improved for the construction placed on it to work satisfactorily. To get better results, the ceramic waste might be combined with other waste products.

3. Materials

3.1 Expansive soil The expansive dirt utilized in this study was gathered locally. The soil was transported to the lab in bags, dried in an oven for a day, and then ground into a powder. The soil was ground up such that it could pass through a 4.75 mm sieve, and it was then stored so that the soil had very little possibility of absorbing moisture. Soil was classified using sieve analysis tests, and the results showed that the soil could be classified as CH (Highly compressible Expansive soil).

Table no. 1 Properties of soil used in the study

S No.	Properties	Results
1	Specific gravity	2.67
3	Liquid Limit (%)	64
4	Plastic Limit (%)	31.7
5	Plasticity index (%)	32.3
6	Classification of soil	CH
7	Maximum Dry Density (kN/m ³)	18.5
8	Optimum Moisture Content (%)	14
9.	UCS	165
10.	CBR	10.40 (Soaked)
		10.75(unsoaked)

3.2 CERAMIC WASTE POWDER

When finely crushed ceramic powder demonstrates pozzolanic properties, it can be used to stabilize soil. Ceramic waste is crushed, ground into a fine powder, and sieved through a 75 µm sieve before being mixed with soil for use in laboratories. The fine particles create a denser soil structure by filling in the spaces between the clay particles and improving the soil's gradation. In general, adding waste ceramic powder improves the strength and bearing capacity of stabilized soils while decreasing soil flexibility and increasing dry density.

Table 2: Chemical Properties of CWP

Sr.No.	Properties	Value
1	SiO ₂	64.04%
2	Al ₂ O ₃	21%
3	CaO	1.29%
4	Na ₂ O	2.07%

5	Fe ₂ O ₃	6.51%
6	SO ₃	0.11%
7	LoI	1.1%

Table 3. Physical Properties of CWP

Sr.No.	Properties	Value
1	Moisture Content (%)	0.2
2	Specific density(kg/m ³)	2540
3	Specific surface area (m ² /kg)	554

3.3 EGG SHELL POWDER

The calcium carbonate found in egg shells will break down into carbon dioxide and calcium oxide when they are burned to ash. The ESA's specific gravity was 2.14. Eggshells were collected from the market, cleaned with water, and then dried in an air oven at 110 degrees Celsius for 12 hours as part of the experimental program. then ground the egg shells into a powder.

Table 4 Chemical Properties ESP

Constituent	% by weight
CaCO ₃	47.49
SiO ₂	0.11
MgO	nil
K ₂ SO ₄	5.9
CaSO ₄	5.2

Al ₂ O ₃	nil
Fe ₂ O ₃	traces

4. EXPERIMENTAL RESULTS

The different experiments that were conducted in this chapter are described in depth in this chapter. It also gives specifics about how the different resources are used and processed in this study. Additionally, it provides the mix proportion ratios. The most lucrative viewpoint in this portion is that it also includes the results of many testing. Compaction, O.M.C., M.D.D., UCS, and CBR test results were among the outcomes.

4.1 Mix Proportion Used

Table 5 various mix proportion

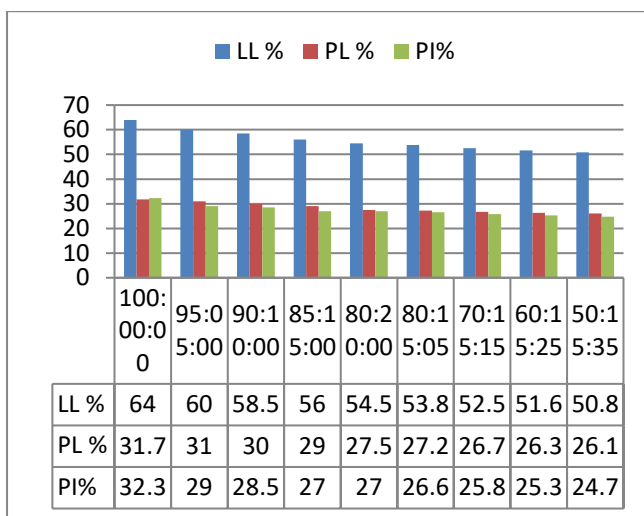
Sr. No.	Designation (CS:ESP:CWP)
1.	100:0:0
2.	95:05:0
3	90:10:0
4.	85:15:0
5.	80:20:0
6.	80:15:05
7.	70:15:15
8.	60:15:25
9.	50:15:35

6. Atterberg's limits

Sr. No.	(CS:ESP:CWP)	LL %	PL %	PI%
1.	100:0:0	64	31.7	32.3
2.	95:05:0	60	31	29
3	90:10:0	58.5	30	28.5

4.	85:15:0	56	29	27
5.	80:20:0	54.5	27.5	27
6.	80:15:05	53.8	27.2	26.6
7.	70:15:15	52.5	26.7	25.8
8	60:15:25	51.6	26.3	25.3
9.	50:15:35	50.8	26.1	24.7

Graph 1: Graph showing Atterberg's limit of various mixes



Graph:-2 OMC and MDD of Expansive soil with ESP mix

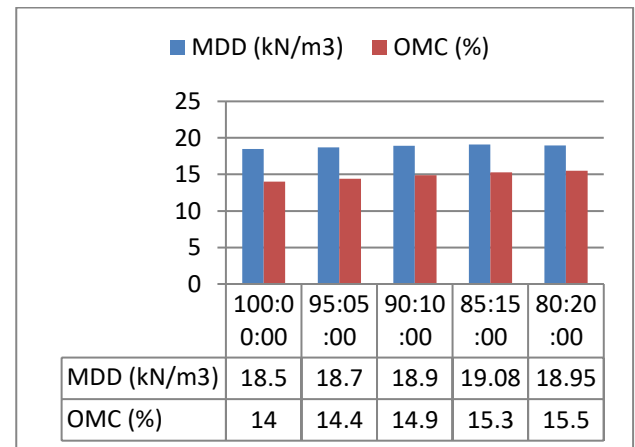


Table 8 OMC and MDD Results of Expansive soil and ESP and CWP

CS : ESP:CWP	M.D.D(g/cm ³)	O.M.C %
80:15:05	19.20	15.9
70:15:15	19.65	16.05
60:15:25	19.95	16
50:15:35	19.8	16.10

4.1 STANDARD PROCTOR TEST

Table no. 7: compaction test results for Expansive Soil and ESP

S No.	[CS:ESP:CWP]	MDD (kN/m ³)	OMC (%)
1.	100:0:0	18.5	14
2.	95:05:0	18.70	14.4
3	90:10:0	18.90	14.9
4.	85:15:0	19.08	15.3
5.	80:20:0	18.95	15.5

Graph 3: Graph of MDD and OMC for Soil, ESP and CWP

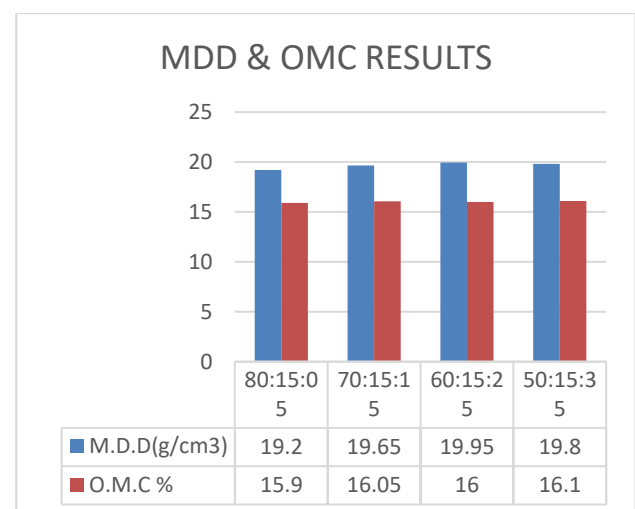


Table 9: UCS values of various mixes together

CS: ESP:CWP	UCS (kPa)	UCS (kPa)	UCS (kPa)	UCS (kPa)
	0 day	7 days	14 days	28 days
100:0:0	60	95	135	165
95:05:0	75	120	150	195
90:10:0	80	140	185	210
85:15:0	88	180	215	240
80:20:0	85	170	200	225
80:15:05	93	195	225	245
70:15:15	112	215	250	260
60:15:25	119	235	267	280
50:15:35	117	220	255	270

Graph:-4 Graph showing values of SOIL, ESP and CWP

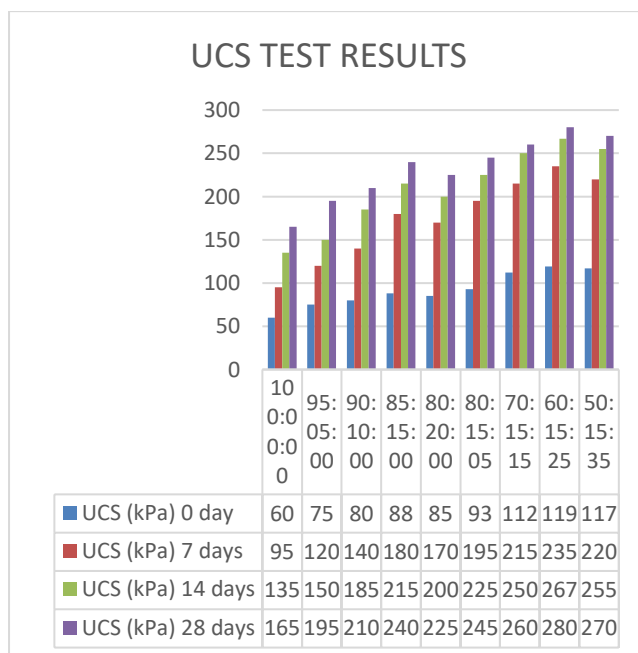
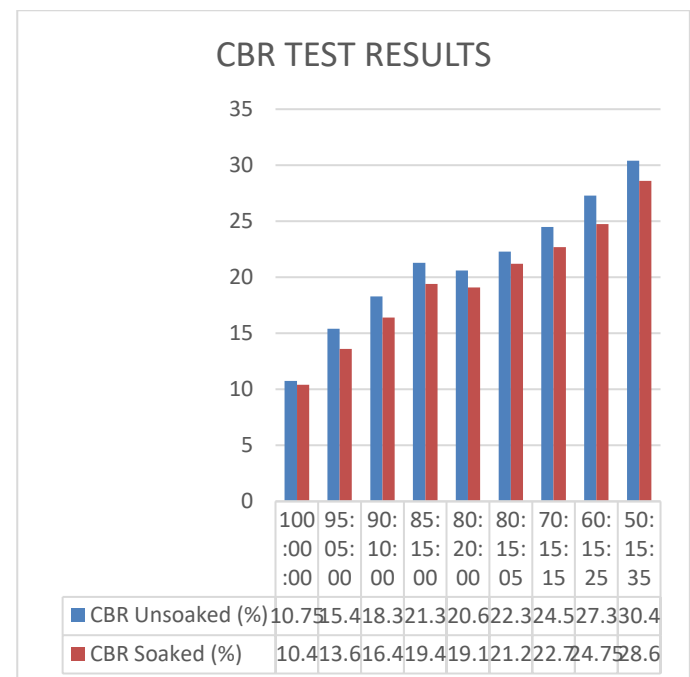


TABLE 10: CALIFORNIA BEARING RATIO (UNSOAKED and SOAKED) TESTS RESULTS FOR SOIL, ESP and CWP

Mix Type	CBR Unsoaked (%)	CBR Soaked (%)
100:0:0	10.75	10.40
95:05:0	15.40	13.60
90:10:0	18.30	16.40
85:15:0	21.30	19.40
80:20:0	20.60	19.10
80:15:05	22.30	21.20
70:15:15	24.50	22.70
60:15:25	27.30	24.75
50:15:35	30.40	28.60

Graph:-5 Graphs representing the curves that are obtained from California bearing ratio test for SOIL, ESP and CWP mixture



5. DISCUSSIONS

STANDARD PROCTOR TEST:

- When the percentages of ESP employed were 5, 10, 15, and 20%, respectively, and with different percentages of CWP, a rise in OMC from 14% to 16.10% and an increase in MDD from 18.5kN/m³ to 20.10kN/m³ were seen.
- The hydration process between cement and water, which produced calcium hydroxide Ca (OH)₂ and calcium silicate hydrate gel (C-S-H), was the cause of this increase in MDD. The strength rose as a result of the gel's ability to bind the expansive soil particles.

UCS TEST

- When 25% CWP and 15% ESP were added to the clay soil, the UCS strength increased. The Pozzolanic reaction between the CWP and calcium hydroxide produced as a byproduct of the ESP reaction upon the addition of water is confirmed by the rise in UCS strength with an increase in CWP composition and curing days in the presence of ESP. For a soil material to be used as base course material for heavily traveled road bases, the maximum UCS strength of 280kN/m² observed at 15% ESP and 25% CWP is sufficient.

CBR TEST

The addition of eggshell powder (ESP) and ceramic waste powder (CWP) significantly improved the strength qualities of the stabilized soil, according to the California Bearing Ratio (CBR) test findings. The best mix proportion among all the combinations assessed was determined to be 15% ESP and 25% CWP. At this composition, the stabilized soil's soaking CBR value rose significantly from 10.75% for the untreated natural soil to 30.40%. This significant improvement in CBR shows that the load-bearing capacity and resistance to clayey soil penetration are successfully improved by the combined application of ESP and CWP. The stabilizing elements' filler effects and pozzolanic reactions, which aid in the creation of a denser and more robust soil matrix, are responsible for the improvement. According to our results, the best combination of ESP and CWP may significantly enhance subgrade performance in pavement construction while encouraging the

sustainable use of waste materials from industry and agriculture.

6. CONCLUSIONS

On the basis of experimentation, the following conclusions have been drawn:

- When percentage ESP increases in soil there is increase in MDD and increase in OMC for some values.
- With the increase in quantity of CWP the value of O.M.C. And MDD increases.
- Based on the test results achieved from UCS after the curing periods of 7, 14 and 28 days, the optimum mixing stabilizing agent for clay soil is 15% of ESP and at 25% of CWP.
- Based on the unconfined compression test it is found that the combination of these two additives gives best compressive characteristics in the proportion of 25% CWP and 15% ESP. The maximum compressive strength obtained at 7, 14 and 28 days 220kN/m², 255kN/m² and 270kN/m²
- The best ratio obtained was 60% soil: 15% ESP: 25CWP.
- For virgin soil, the unsoaked CBR value rises from 10.75% to 30.40% for the ideal mix ratio, while the soaked CBR value rises from 10.40% to 28.60% for the ideal mix ratio.

References

- 1) Alexander Fordjour, Augustine Korli Lawer, Frank Owusu Adjei (2024) "Multi-Condition Optimization of Plastic and Eggshell as Stabilizer via Surrogate Model". The Journal of Engineering 2024, Wiley.
- 2) Sadek Deboucha, Hocine Ziani, Abderrachid Amriou (2024) "Influence of Ceramic Waste And Cement On The Mechanical And Hydraulic Properties, And Microstructure Of The Road Sub-Base Layer". The Baltic Journal Of Road And Bridge Engineering 2024/19(3). ISSN 1822-427X/eISSN 1822-4288 2024

- Volume 19 Issue 3: 132–157
<https://doi.org/10.7250/bjrbe.2024-19.645>.
- 3) A V V Sai Ram, P. Mushraf Khan (2023) “An Experimental Study On Stabilization Of Soil By Using Quarry Dust And Egg Shell Powder”. International Research Journal Of Engineering And Technology (IRJET). Volume: 10 Issue: 03 | Mar 2023.
 - 4) Nidhya Rathinavel, Kavikumaran Kannadasan (2023) “Impact of Eggshell Powder on the Mechanical and Thermal Properties of Lightweight Geopolymer”. Hindawi Advances in Civil Engineering Volume 2023, Article ID 6655921, 11 pages
<https://doi.org/10.1155/2023/6655921>.
 - 5) Poonam Shekhawat, Gunwant Sharma (2023) “Strength characteristics of hazardous wastes flyash and eggshell powder-based geopolymer-stabilized soft soil cured at ambient Temperature”. Arabian Journal of Geosciences (2023) 16:127 <https://doi.org/10.1007/s12517-023-11234-2> © Saudi Society for Geosciences and Springer Nature Switzerland AG 2023.
 - 6) Dr. K. Harish, Ch.Sandeep Reddy (2023) “A Study On Stabilization of Soils by Using Egg Shell Powder”. International Journal of Innovative Research in Engineering & Management (IJIREM) ISSN: 2350-0557, Volume-10, Issue-2, April 2023
<https://doi.org/10.55524/ijirem.2023.10.2.17> Article ID IJIR2357, Pages 96-98.
 - 7) Saya Abdullah Saber, Anoosheh Iravanian (2021) “Using Waste Ceramic Dust In Stabilization Of Clay Soils”. International Journal Of Sustainable Construction Engineering And Technology Vol. 13 No. 1 (2022) 68-80, Ijscet. Issn : 2180-3242 E-Issn : 2600-7959. Doi: <https://doi.org/10.30880/Ijscet.2022.13.01.007>.
 - 8) Prasad Gajanan Sonar, Shejwal Neha Sanjay, Dorkhe Suraj Bhaskar (2021) “Stabilization of Soil by the Composition of Eggshell Powder and Shredded PPE Kit”. International Journal of Scientific Research in Science, Engineering and Technology Print ISSN: 2395-1990 | Online ISSN: 2394-4099 (www.ijrsrset.com) doi: <https://doi.org/10.32628/IJSRSET218455>.
 - 9) Rajit Sharma¹, Er. Neeraj Kumar (2021) “Study On Subgrade Soil with Addition of Egg-Shell Powder and Recron-3s Fibres”. International Research Journal of Engineering And Technology (IRJET). Volume: 08 Issue: 03 | Mar 2021.
 - 10) Sourav, Vinod Kumar Sonthwal (2021) “Soil Stabilization Using Eggshell Powder And Coir Fiber”. International Research Journal of Modernization in Engineering Technology and Science. Volume: 03/Issue: 03/March-2021. E-ISSN: 2582-5208.
 - 11) A Iravanian, and S A Saber (2020) “Using Ceramic Wastes in Stabilization and Improving Soil Structures”. ICECAE 2020 IOP Conf. Series: Earth and Environmental Science 614 (2020) 012081 IOP Publishing, doi:10.1088/1755-1315/614/1/012081.
 - 12) Ajay Upadhyay, Suneet Kaur (2016) “Review On Soil Stabilization Using Ceramic Waste”. International Research Journal of Engineering and Technology (IRJET). Volume: 03 Issue: 07 | July 2016.
 - 13) Eberemu, Adrian O. “Evaluation of Bagasse Ash Treated Lateritic Soil as a Potential Barrier Material in Waste Containment Application.” Acta Geotechnica 8, no. 4 (2013): 407–21. doi:10.1007/s11440-012-0204-5.
 - 14) Reddy, N. Gangadhara, Janardhan Tahasildar, and B. Hanumantha Rao. “Evaluating the Influence of Additives on Swelling Characteristics of Expansive Soils.” International Journal of Geosynthetics and Ground Engineering 1, no. 1 (2015). doi:10.1007/s40891-015-0010-x.
 - 15) Mishra, Sudhashru, S. N. Sachdeva, and Rakesh Manocha. “Subgrade Soil Stabilization Using Stone Dust and Coarse Aggregate: A Cost Effective Approach.” International Journal of Geosynthetics and Ground Engineering 5, no. 3 (2019). doi:10.1007/s40891-019-0171-0.
 - 16) Choobbasti, A. J., H. Ghodrati, M. J. Vahdatirad, S. Firouzian, A. Barari, M. Torabi, and A. Bagherian. “Influence of Using Rice Husk Ash in Soil Stabilization

- Method with Lime.” *Frontiers of Earth Science in China* 4, no. 4 (2010): 471–80. doi:10.1007/s11707-010-0138-x.
- 17) Dang, Liet Chi, Hayder Hasan, Behzad Fatahi, Robert Jones, and Hadi Khabbaz. "Enhancing the engineering properties of expansive soil using bagasse ash and hydrated lime." *International journal of GEOMATE* 11, no. 25 (2016): 2447-2454.
- 18) Amadi, Agapitus Ahamefule, and Shagba Lubem. "Assessing Stabilization Effectiveness of Combined Cement Kiln Dust and Quarry Fines on Pavement Subgrades Dominated by Black Cotton Soil." *Geotechnical and Geological Engineering* 32, no. 5 (2014): 1231–38. doi:10.1007/s10706-014-9793-0.
- 19) Mudgal, Ankur, Raju Sarkar, and A. K. Sahu. "Effect of Lime and Stone Dust in the Geotechnical Properties of Black Cotton Soil." *International Journal of GEOMATE* 7, no. 2 (2014): 1033–39. doi:10.21660/2014.14.140402.
- 20) Gyanen. Takhelmayum, Savitha.A.L, Krishna Gudi(2013) — Laboratory study on soil stabilization using Bagasse Ash mixtures, *International Journal of Engineering Science and Innovative Technology (IJESIT)* Volume 2, Issue 1.
- 21) ASTM International. "Standard Test Methods for Laboratory Compaction Characteristics of Soil Using." ASTM Standard Guide. West Conshohocken, PA: ASTM International, (2003).
- 22) Davis, Tim. "Geotechnical Testing, Observation, and Documentation" (September 2008): 25. doi:10.1061/9780784409497.
- 23) ASTM International. Standard Test Methods for Laboratory Compaction Characteristics of Soil Using. ASTM Standard Guide. Vol. 3. West Conshohocken, PA: D698-12e2, (2003).
- 24) ASTM International. Standard Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted. Methods. Vol. i. West Conshohocken, PA: D1883-16, (2005).
- 25) MRD (2001). PMGSY Scheme and Guidelines: Programme Objectives. Ministry of Rural Development, Government of India, No. P-12025/8/2001-RC.
- 26) A.P.W.R.D. Schedule of Rates for Rural Roads for All Divisions under PWRD, Assam. Commissioner and Special Secretary Public Works Roads Department, Assam Dispur, Guwahati India, 2017-2018. Available online: <https://pwardroads.assam.gov.in/information-services/schedule-of-rates> (accessed on May 2021).
- 27) Caraşca, Oana. "Soil Improvement by Mixing: Techniques and Performances." *Energy Procedia* 85 (2016): 85–92. doi:10.1016/j.egypro.2015.12.277.
- 28) ASTM D4318, ASTM D 4318-10, and ASTM D4318-05. Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils. Report. Vol. 04. West Conshohocken, PA: ASTM International, (2005).
- 29) ASTM. Standard Test Method for Specific Gravity of Soil Solids by Gas Pycnometer, ASTM International, D5550-14, West Conshohocken, PA, (2014).
- 30) ASTM D6913-04R2009. "Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis." ASTM International, West Conshohocken, PA, 04, no. Reapproved 2009 (2004): 1–35.