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# Stabilization Of Soil Using Eggshell Powder

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***Abstract*** The study focuses on improving the engineering properties of clay soil a commonly used but moisture-sensitive material in construction by using eggshell powder, an industrial waste, as a stabilizer. Eggshell powder was mixed with clay soil in varying proportions to evaluate changes in index properties, compaction, and shear strength. The aim was to enhance soil strength while promoting environmental sustainability by reusing waste materials, thus reducing disposal issues and environmental hazards. Experimental results were compared to untreated soil to assess effectiveness.

**KEYWORDS:-Stabilization, Soil, Eggshell powder.**

## I. INTRODUCTION

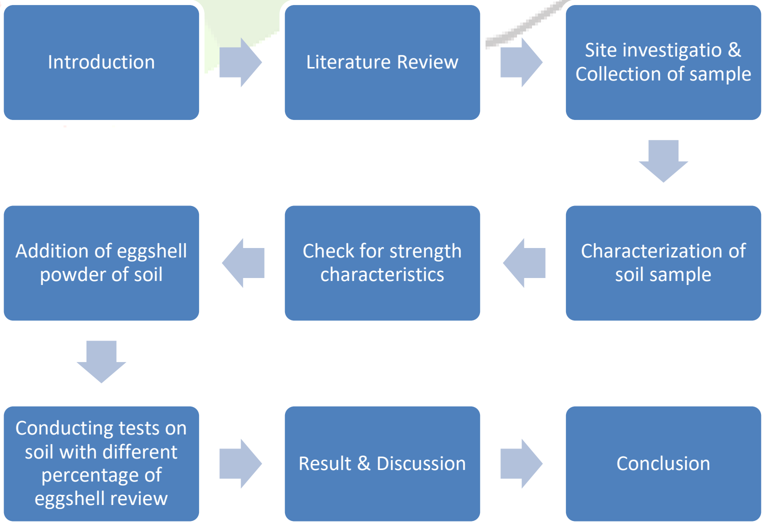
The behavior of the soil greatly affects the structure above it. Soil as a building material is spread from borrowed areas collected as embankment material, which are generally clay soils. Clay behavior that is very sensitive to increasing water content and high shrinkage. The conditions of the soil where shrinkage occurs can also affect the bearing capacity of the soil. Eggshell powder (ESP), which is a waste from the food industry, was considered as a clay mixture material to increase the bearing capacity of soil and the strength parameter of clay. Overall, previous ESP studies have found that this improves soil strength. With a proper mixing method, the good properties of and ESP are expected to increase the use of ESP in clay stabilization. The main objective of this research aims to lessen shrinkage and swelling, increase soil strength, workability, shear strength, and permeability. Eggshell Powder (ESP) has not been in use as a stabilizing material and it could be a good replacement for industrial lime, since its chemical composition is similar to that of lime. Chicken eggshell is a waste material from domestic sources such as poultries, hatcheries, homes and fast-food centers. This amounts to environmental pollution. Eggshell waste falls within the category of waste food, they are materials from the preparation of foods and drinks, if subjected to adequate scrutiny, and they could be suitable for soil stabilization. The use of lime for stabilization is becoming expensive, requiring an economical replacement. Soil stabilization is a vital technique in construction and geotechnical engineering aimed at improving the engineering properties of soil, making it more suitable for infrastructure development. Weak or unstable soil poses a challenge for building foundations, roads, and embankments, as it can lead to structural issues such as settlement and cracking. Stabilizing the soil involves modifying its characteristics to increase load-bearing capacity, reduce shrinkage and swell potential, and improve resistance to water and erosion. Conventional stabilization methods rely on chemical additives like cement, lime, and bitumen. However, these traditional methods often come with environmental and economic downsides, including high energy consumption, $CO_2$ emissions, and cost. Consequently, there is a growing interest in sustainable alternatives, such as using industrial by-products and waste materials, with eggshell powder emerging as a promising option.

Eggshells, a common food waste by-product, are generated in vast quantities globally. Rich in calcium carbonate ($CaCO_3$) similar to the lime used in traditional stabilization eggshells have properties conducive to soil improvement. Calcium carbonate is known to increase soil strength, reduce plasticity, and enhance the durability of soils, especially clay and sandy types. By processing eggshells into a fine powder, it can be blended into the soil as a stabilizing agent.

Research has shown that eggshell powder can enhance the compaction properties of soil, improve cohesion, and reduce soil permeability. This can make the soil more resistant to structural deformation, erosion, and weather-related issues, making it a suitable base for roads, buildings, and embankments. Using eggshell powder for soil stabilization addresses both environmental and engineering concerns. From an environmental perspective, eggshell waste can be a pollutant, contributing to landfill overload and waste management issues. Recycling eggshells not only reduces waste but also conserves resources that would otherwise be used to produce traditional stabilizers. Economically, eggshell powder offers a low-cost alternative to traditional stabilizing agents, potentially reducing construction costs, especially in regions where eggshell waste is abundant and commercial stabilizers are costly or scarce. The effectiveness of eggshell powder as a soil stabilizer has been studied in various settings, often with positive results. When mixed with soil in specific proportions, eggshell powder can significantly increase compressive strength and reduce swelling properties. For clay soils, which are particularly problematic due to high plasticity and tendency to retain water, eggshell powder can reduce the plasticity index and increase the soil's load-bearing capability. Studies suggest that, in certain applications, eggshell powder alone can achieve stabilization results comparable to lime or cement, while in others, it can be used in combination with these agents to improve performance further. Moreover, the use of eggshell powder for soil stabilization supports the broader goals of sustainable development by reducing reliance on industrially manufactured stabilizers, thus lowering carbon emissions and promoting waste-to-resource

approaches in construction. However, while research has shown promising results, additional studies are necessary to optimize the mix design, understand long-term performance, and address potential limitations such as local availability and variability in eggshell composition. Overall, the use of eggshell powder for soil stabilization presents a practical, eco-friendly, and economical solution that aligns well with modern construction and environmental goals.

## II. RESEARCH METHODOLOGY




## III. Results and Discussion

The outcomes of the experiments done on the original soil and soil treated with 2%, 3%, 5%, 8%, 10%, 12% and tests, 15% eggshell powder. The basic geotechnical inquiry used in the experimental investigations has assisted in understanding the clay soil. Standard Proctor Test, Direct shear test, Liquid & Plastic Limit, Specific Gravity Test are among the tests done on the various combinations. A pictorial graph is used to help visualize the outcomes of each experimental research of a certain combination profile after a table is used for test reading. From the experiments conducted with optimum percentage of ESP and the obtained results were shown below

**1.Specific Gravity Test**

**Table no 1. Specific Gravity Test**

| **Observation** | **Sample 1** |
|---|---|
| Weight of pycnometer (W1 g) | 616 |
| Weight of pycnometer + fine aggregate (W2 g) | 1120 |
| Weight of pycnometer + water + fine aggregate (W3 g) | 1794 |
| Weight of pycnometer + water (W4 g) | 1513 |
| Specific Gravity | 2.26 |

**2. Liquid Limit Test**

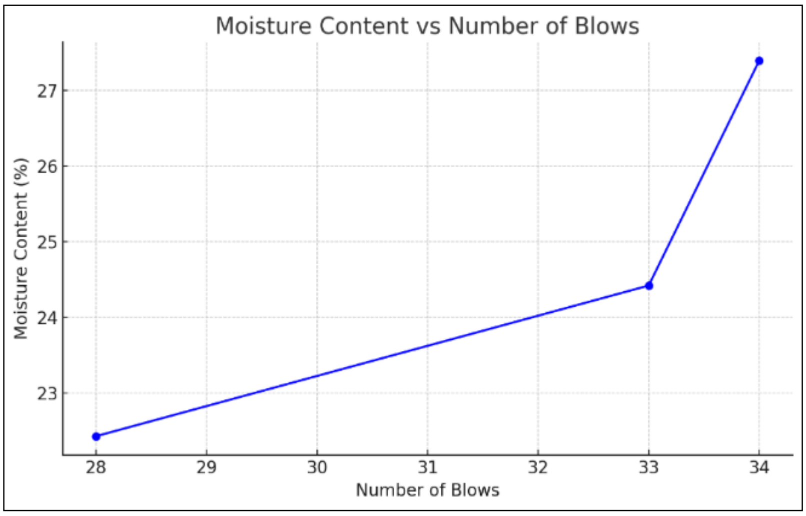
**Table No. 2 Liquid Limit Test**

| **Parameters** | **Sample 1** | **Sample 2** | **Sample 3** |
|---|---|---|---|
| Container no. | 1 | 2 | 3 |
| Weight of empty can + lid (g) | 12.23 | 13.31 | 11.87 |
| Weight of can + lid + moist soil (g) | 18.56 | 19.27 | 15.73 |
| Weight of can + lid + dry soil (g) | 17.4 | 18.10 | 14.9 |
| Weight of dry soil (g) | 5.17 | 4.79 | 3.03 |
| No. of blows | 28 | 33 | 34 |
| Moisture content (%) | 22.43 | 24.42 | 27.39 |
| Average moisture content (%) | 25.5% | | |

**RESULT:-**

The Liquid limit of Black Cotton Soil is 25.5%

**GRAPH: -**



### 3. Plastic Limit Test

**Table No. 3 Plastic Limit Test**

| Parameters | Sample 1 | Sample 2 | Sample 3 |
|---|---|---|---|
| Container no. | 1 | 2 | 3 |
| Weight of empty can + lid (g) | 9.78 | 9.83 | 11.16 |
| Weight of can + lid + moist soil (g) | 16.39 | 19.43 | 22.23 |
| Weight of can + lid + dry soil (g) | 15.28 | 17.69 | 20.43 |
| Weight of dry soil (g) | 5.5 | 7.86 | 9.27 |
| Moisture content (%) | 20.18 | 22.13 | 19.41 |
| Average moisture content (%) | 20.57% | | |

### 4. Standard Proctor Test

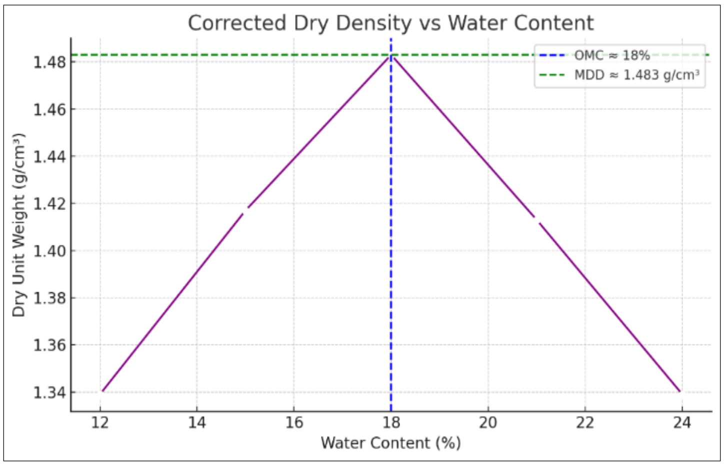
**Table No. 4 Standard Proctor Test**

| Parameters | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 |
|---|---|---|---|---|---|
| Weight of empty mould + base plate (kg) | 4.612 | 4.612 | 4.612 | 4.612 | 4.612 |
| Weight of compacted soil + base plate (kg) | 1.492 | 1.548 | 1.658 | 1.623 | 1.573 |
| Bulk unit weight of compacted soil | 1.5 | 1.63 | 1.75 | 1.71 | 1.66 |
| Water content (%) | 12 | 15 | 18 | 21 | 24 |
| Dry unit weight of soil | 1.339 | 1.417 | 1.483 | 1.413 | 1.339 |

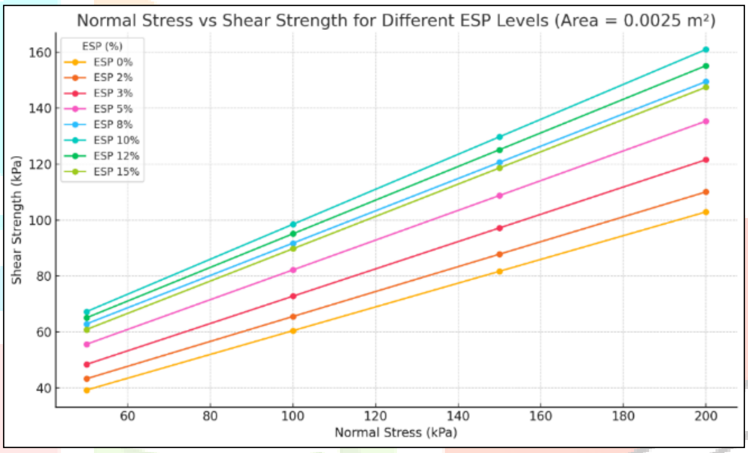
**RESULT:-**

1) Maximum dry density (MDD) = 1.483
2) Optimum moisture content (OMC) = 18%

GRAPH: -




**5. Direct Shear Test**




**Explanation:**

- The Mohr-Coulomb equation:

$$\tau = c + \sigma \cdot \tan(\phi)$$

was fitted to the data of normal stress vs. shear stress.
- The intercept of the regression line gives cohesion (c).
- The slope corresponds to tan(ϕ) from which we compute the angle of internal friction φ in degrees.

**Table No 5 Direct Shear Test**

| ESP (%) | Cohesion (kPa) | Angle of Friction (°) |
|---|---|---|
| 0 | 18 | 23 |
| 2 | 21 | 24 |
| 3 | 24 | 26 |
| 5 | 29 | 28 |
| 8 | 34 | 30 |
| 10 | 36 | 32 |
| 12 | 35 | 31 |
| 15 | 32 | 30 |

**Result and Discussion: -**

1. **Cohesion (c):**
   - Increases with ESP content up to about 10%.
   - $CaCO_3$ reacts with soil particles, forming cementitious compounds that bind particles together, increasing cohesion.
   - Beyond 10–12%, the cohesion may decline slightly due to excess fines causing particle separation or brittleness.
2. **Angle of Internal Friction (ϕ):**
   - Improves steadily with ESP up to 10% due to better particle interlock, reduction in plasticity, increase in dry density.
   - After 10–12%, φ may plateau or slightly drop due to smoother $CaCO_3$ particles reducing interparticle friction.

## IV. CONCLUSION

- In conclusion, the stabilization of black cotton soil using eggshells has shown promising results as an eco-friendly and cost-effective method for improving its engineering properties. The addition of eggshell powder enhances the soil's strength, reduces its plasticity, and improves its compaction characteristics, which are essential for construction and roadwork. This sustainable approach not only helps in utilizing a waste material but also offers an environmentally friendly solution for soil stabilization. Further research, however, could explore the long-term effects and optimal dosage of eggshell powder to fine-tune the stabilization process for various soil conditions and engineering applications.

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