International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 07 | July - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

# A Study on Stabilization of Soils by Using Egg Shell Powder and Basalt Fiber

**Arun Kumar[1], Anoop Sharma[2]**

*[1]PG student, Dept. of Civil Engineering, Sri Sai College of Engineering& Technology, Badhani, Punjab, India*
*[2]Associate Professor, Dept. of Civil Engineering, Sri Sai College Of Engineering& Technology, Badhani, Punjab, India*
*erarun805@gmail.com*
*anoopsharma777r@gmail.com*

---

**Abstract -** One of the most important aspects of building a solid infrastructure is soil stabilization. The weight of the soil not only supports the loads, but also retains the structure's strength, durability, and stiffness. Researchers have long been involved in soil stabilization, and different practices have been used to accomplish this aim, as well as various additives such as asphalt, lime, and Fly Ash. In a manner to contribute the soil stabilization research a sustainable waste material like Eggshell powder and Basalt fiber were used to attain the soil with significant soil bearing capacity. A combination of 5%, 10% and 15% of eggshell powder along with 2%, 3% and 4% of Basalt fiber were used. The standard proctor test was used to test the soil for basic and fundamental parameters such as OMC-MDD, the CBR was used to access load penetration, and the unconfined compression strength test was used to assess the soil's shear strength. The best and optimum results we obtained at 10% of eggshell powder with 3% of Basalt fiber for the weight of soil masses. Satisfactory results are obtained at the other combination also. Different parameters were analyzed using comparative charts and was found out that one parameter is correlated with other soil parameters. Based on these investigations, it has been shown that the UCS increases as the amount of Basalt fiber added to Eggshell powder increases. The highest UCS value is achieved at 10% Eggshell powder and 3% Basalt fiber. The "bridge effect" of fiber reinforcement in soil prevents stress cracks from spreading further, and the intermixing of basalt fiber with the soil serves as a reinforcing element in binding the soil particles.

***Key Words***: Compaction test, CBR, UCS, ESP, Basalt Fiber

## 1. INTRODUCTION

Expansive soils are the soils which have high shrinkage and swelling characteristics and lower strength when it came in contact with water. These soils are very sensitive to variations in water content and show excessive volume changes and has high compressibility. This highly plastic soil may create cracks and damage the construction work done above these types of soils.

In India, expansive soil covers nearly about 20% of the land and includes approximately the entire Deccan Plateau. They are mostly black and reddish brown in colour and are generally found with layer thickness between 0.5 m to 10 m below the surface. Because the expansive soil is prone to volume changes when it came in contact with the water by rain or water table capillary action, it will get expand and may cause lifting of the structures built over it. So, these soils are not suitable for construction works until they are properly stabilized which can increase the low bearing capacity of expansive soils.

In India, nearly 46% of total land is covered by Alluvial soil which is the most important soil type of or country. Other soils such as Black cotton soil, desert soil, laterite soil and marine soil are also the important soil groups of

India. The Alluvial soil and the black cotton soil mainly consists of clay which is very fine soil and it's the main constituent of expansive soils and due to the cohesive nature of clay, these soils absorb large amounts of water and show swelling characteristics which create problems such as bulging of soil, low bearing strength of soil, and can cause cracks in the foundation.

## 2. Literature Review

**Nidhya Rathinavel et al (2023)** Adopting proper waste management technology in the place of the construction industry to the extent possible to lower the production of new materials and intern reduces the environmental impact pertaining to the industry. In this work, eggshell powder (ESP; waste from the poultry industry) and fly ash (FA; waste from combustion of coal) were utilized as precursors for producing geopolymer and to substitute conventional cement-based construction materials. Three different weight percentage ratios of precursors, namely, 90FA:10ESP, 80FA:20ESP, and 70FA:30ESP were reinforced with two different weight percentages, namely, 15 and 30 wt% of paddy straw in the presence of suitable combinations of sodium silicate and sodium hydroxide to obtain lightweight geopolymer panels. Results received from different analytical tests, namely, density, water absorption, compressive strength, and flexural strength infer that the incorporation of ESP enhances the performance of the geopolymer products to a considerable extent. The specimen sample made using 70FA:30ESP in the absence of paddy straw reinforcement possesses a compressive strength value of 15.64MPa, which is higher than that of paddy straw reinforced panels. It was observed that there was a reverse trend noticed in the case of flexural behavior on reinforcement of paddy straw, namely, 15 wt% possesses a higher value than that of the panel (70FA:30ESP) made using in the absence of reinforcement.

**Poonam Shekhawat et al (2023)** This study emphasizes on stabilization of illite and kaolin-based clay at ambient temperature using flyash-based geopolymer, including eggshell powder. Both flyash and eggshell powder are waste materials, and applying these wastes as green building materials can resolve many troubles associated with disposal. Moreover, the calcium-rich eggshell powder can enhance the strength characteristics of clayey or soft soil. Keeping the above in view, a comprehensive experimental program was conducted, including compaction, compressive strength, tensile strength, California bearing ratio, and microstructure analysis. The results indicated that introducing partial to full replacement of flyash-eggshell powder geopolymer enhanced the strength characteristics of clayey soil comparable to those of clayey soil without any treatment. Although the novel geopolymeric precursor material, eggshell powder, contains CaO in the crystalline phase, the microstructure analysis confirms that short term strength development is primarily associated with the part of the various calcium-based geopolymer gel produced in small amounts from the activation of eggshell powder within the flyash-based geopolymer. The main results demonstrate that 30% geopolymer concentration in clay significantly increased compressive strength, tensile strength, and California bearing ratio. Finally, the geopolymer-treated clay mixtures found in the investigation have possible applications in pavements and
Embankments as sustainable building materials prepared from industrial and domestic wastes.

**Dr. K. Harish et al (2023)** The use of such refuse and industrial wastes and their subsidiary products as alternatives to construction materials may effectively contribute to environmental preservation and minimize their negative effects on the Environment, especially in

light of the millions of tonnes of waste produced annually across the nation, which not only poses the problem of disposal but also adds to environmental contamination and health risks. In the current study, eggshell powder was utilized as a waste to mix with soil in order to examine clay soil's index characteristics, compaction, and shear strength at various mixed proportions. The shear strength of soils that had already been tested was then contrasted with experimental specimens that had been combined with various ratios of eggshell powder.

**Kumar et al. (2023)**

The major goal of the study in this work is to improve the geotechnical qualities of soil by the effective usage of stabilization utilizing basalt fiber and ground granulated blast furnace slag (GGBS) in varied quantities. The study used 2%, 3%, and 4% of basalt fiber and 5%, 10%, and 15% of powdered granulated blast furnace slag in three different amounts. Compaction and an unconfined compressive test (UCS) were performed on the reinforced soil. The findings of the trial indicated that the soil's compressive strength and shear strength had been effectively improved.

**Megha S. Mahaladkar et al. (2022)** The main objective of this study is to investigate the effect of index properties of clayey soils when blended with silica fume and basalt fiber. A series of laboratory experiments have been conducted on samples with 0%, 5%, 10%, 15% and 20% of Silica fume and 0.05%, 0.1%, 0.15% and 0.2% of Basalt fiber by weight of dry soil. The test results showed a significant change in consistency limits of samples containing Silica fume and basalt fiber. The investigation showed that the Silica fume is a valuable material to modify the index properties of black cotton soil to make them suitable for different construction activities. The addition of basalt fiber gives a very good compressive strength to the BC soil as compared to silica fume.

**Anju George (2022)** In this paper, the effects of basalt chopped fiber with coir pith on geotechnical properties of clayey soil in varying proportions are discussed. The utilisation of waste material and natural fibers helps to boost soil quality is beneficial, because they are inexpensive, accessible locally and ecological. Basalt fiber is a non - metal inorganic fiber which acts as a reinforcement for soil. It has excellent thermal, chemical, mechanical properties and environmental friendly material. The stabilizing effect of both the fibers on soil properties was observed. Addition of fibers improved the soil properties such as shear strength, and showed significant effects on cohesion, shrinkage characters. Also, it reduces desiccation and cracking.

**Prasad Gajanan Sonar et al (2021)** In the world full of crises, also the rising demand for PPE suits and masks would lead to another wave of biomedical waste disposition crises. The disposal of thrown away wastes causes a serious issue as the waste are most of the time are non- biodegradable and these are also not fit for incineration. Soil stabilization improves the engineering properties of the weak soil, by proper compaction and additional materials such as lime, concrete, but these materials are becoming expensive day by day, hence plastic by the composition of egg shell powder could enhance the properties and can be a sustainable replacement for lime, concrete, etc. as stabilizer. Through much experimental investigation it has been showed that plastic and egg shell powder can be used as an effective stabilizer with encountering waste disposal problem as well, along with the economical solution for

stabilizing weak soil. This PPE stripes/shredding are known for its high strength, low cost, significantly less dangerous for the environment. The combined effect of PPE stripes/shredding along with egg shell powder can enhance engineering properties of soil.

**Rajit Sharma et al (2021)** Embankment of pavements is made up with earthen material mainly used soil. Sometimes soil have not fulfill the desired parameters of strength or other design conditions then we have an option to add something to soil which helps us to upgrade soil up to designed limits. At present study the utilization of waste material i.e. egg shell and recorn in which the disposal of egg shells is not possible which is only done with its addition in something. This study aims to enhance the properties of soil with addition of mentioned materials which compared to virgin soil observations. Upper layers of embankments transmit the load to the lower layers. It is required to all materials that they fulfill the desired design strengths. Use of waste materials as stabilizer it is good for soil strength as well as for good environment.

**P. Kulanthaivel et al (2021)** The current study presents the laboratory investigation on the use of nano-silica (0.2, 0.4, 0.8 and 1.0%) and polypropylene fiber (0.25, 0.50, 0.75 and 1.0%) in problematic clayey soil to enhance the shear strength and compaction characteristics. From the Transmission electron microscopy (TEM) analysis, it is observed that the diameter of nano-particles used in this study was in the range of 10–20 nm. The nano-particles have a spherical shape and amorphous in nature. Extensive laboratory tests such as the standard Proctor compaction test and unconfined compressive strength test have been conducted on untreated and polypropylene fiber along with nano-silica treated clayey soil. The outcomes showed that the addition of polypropylene fiber in poor soil, increase the maximum dry density and reduce the optimum moisture content of the soil. The optimum dosage of polypropylene fiber and nano-silica added to the poor soil was 0.75% and 0.8%, respectively.

**Sourav et al (2021)**

One of the most important aspects of building a solid infrastructure is soil stabilization. The weight of the soil not only supports the loads, but also retains the structure's strength, durability, and stiffness. The primary prerequisite for any project construction is adequate bearing capacity soil. True classification of strength parameters is an important aspect of successful building technique. Researchers have long been involved in soil stabilization, and different practices have been used to accomplish this aim, as well as various additives such as asphalt, lime, and Fly Ash. In a manner to contribute the soil stabilization research a sustainable waste material like Eggshell powder and Coir fiber were used to attain the soil with significant soil bearing capacity. A combination of 5%, 10% and 15% of eggshell powder along with 1%, 2% and 3% of coir fiber were used. The soil was tested for the basic and fundamental soil parameters like OMC-MDD via standard proctor test, Load penetration was accessed by the CBR and shear strength was determined using the direct shear strength test. The best and optimum results we obtained at 15% of eggshell powder with 2% of coir fiber for the weight of soil masses.

**Adla Prathyusha et al. (2020)**

The purpose of this study is to evaluate the suitability of red soil from a nearby source with the addition of basalt fiber for highway building. Basalt fibers are added to the conventional red soil in varying proportions (by weight of the raw soil, 0%, 0.2%, 0.4%, 0.6%, 0.8%, 1%, 1.2%, and 1.4%). Proctor compaction tests and California bearing ratio (CBR) testing were performed on stabilized soil in addition to the preliminary tests.

The experiment's results show that strengthening the soil by adding basalt fiber was greatly enhanced. By adding basalt fiber to subgrade soil at a rate of 0.8% (by soil weight), it is possible to dramatically boost the strength of the soil, which also has a positive impact on the design of highway pavement structures.

## 3. Materials

### 3.1 SOIL

**Source of soil** The soil used for the experiment purpose, which is clay soil (CI) was taken from the local area near Jammu. After bringing the soil to the working area, the lumps and the organic impurities in the soil were removed by using tools like Hoe and Rake. The soil that was got after removing lumps and organic impurities were then passed through the sieve having size 4.75 mm to differentiate the hard large size particles from the soil and to get a uniformly sized soil sample required for the desired purpose. Before making the soil samples of different proportion and with different materials for various experiment purposes, the soil was dried for the whole day at 100 °C. The various properties of untreated soil that is used are:

**Table no. 1 Properties of soil used in the study**

| S.No. | Properties | Result |
|---|---|---|
| 1. | Liquid limit (%) | 35 |
| 2. | Plastic limit (%) | 22 |
| 3. | Plasticity Index (%) | 13 |
| 4. | Specific Gravity | 2.57 |
| 5. | Maximum Dry Density (KN/m³) | 14.10 |
| 6. | Optimum Moisture Content (%) | 18.40 |
| 7. | Soil Classification | CI (Intermediate Compressive Clay) |
| 8. | CBR (%) (soaked) | 4.1 |
| 9. | CBR (%) (Unsoaked) | 5.6 |
| 10. | UCS ($kN/m^{2)}$ | 310 |

### 3.2 EGGSHELL POWDER

Details of the chemical composition of Eggshell Powders can be seen in Table 3.2 which shows calcium content of more than 50% and other organic materials as well as water. Furthermore, explained that egg shells are environmentally friendly, inexpensive, and available in abundance. The egg shells are then cleaned and dried in the sun to dry. Then the egg shells are mashed by pulverizing it into eggshell powder (ESP) which passes the number 200 sieve.

**Table 2: Chemical properties of Eggshell powder**

| Egg Shell Powder (ESP) | |
|---|---|
| **Description** | **Composition** |
| $SiO_2$ | 0.61 % |
| $Al_2O_3$ | 0.07 % |
| $Fe_2O_3$ | 0.63 % |
| CaO | 62.35 % |
| MgO | 0.36 % |
| $SO_3$ | 1.32 % |
| $Na_2O$ | 0.15 % |
| $K_2O$ | 0.06 % |

| | |
|---|---|
| $P_2O_3$ | 0.22 % |

### 3.3 BASALT FIBER

In the test, 6mm Basalt Fiber of various lengths will be used. The basalt fiber is equally distributed throughout the clay soil sample prior to dispersion. The filamentous Basalt Fiber is bought online from Delhi.

**Table 3:- Properties of Basalt Fiber**

| | |
|---|---|
| Density | 2.65g/cm$^3$ |
| Elastic modulus | 85.9Gpa |
| Elongation at break | 3.12% |
| Tensile at strength | 2611Mpa |
| Length | 6mm |

## 4. EXPERIMENTAL RESULTS

### 4.1 STANDARD PROCTOR TEST

**Table no. 4:** MDD and OMC for soil– Eggshell powder – Basalt Fiber mix

| SOIL:ESP:BF | MDD (kN/m³) | OMC (%) |
|---|---|---|
| 100:00:00 | 14.10 | 18.40 |
| 88:10:02 | 16.80 | 17.60 |
| 87.5:10:2.5 | 17.90 | 16.50 |
| 87:10:3.0 | 18.70 | 15.30 |

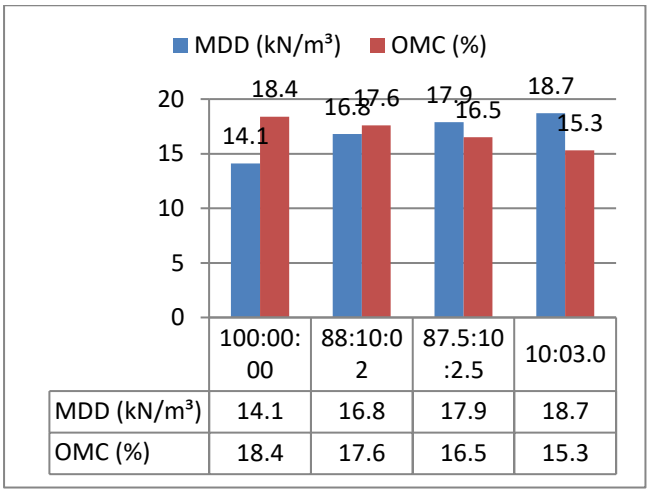



**Fig:-1** Variations b/w MDD and OMC of Eggshell powder, Basalt Fiber & soil with different proportions

**Table 5:** Results of UCS of Eggshell powder and Basalt Fiber Mix with Soil

| SOIL:ESP:BF | Curing Period (Days) | UCS (kN/m$^2$) |
|---|---|---|
| 100:00:00 | 7 | 240 |
| 88:10:02 | 7 | 340 |
| 87.5:10:2.5 | 7 | 410 |
| 87:10:3.0 | 7 | 470 |

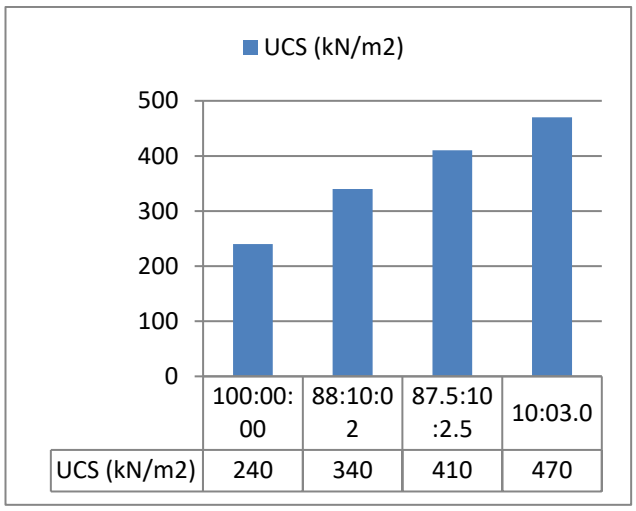



**Fig:-2** Variations b/w UCS Values of Clayey soil, Eggshell powder and Basalt Fiber with different proportions

**Table 6:** Results of CBR of Eggshell powder and Basalt Fiber Mix with Soil

| SOIL:ESP:BF | CBR (%) (Soaked) | CBR (%) (Unsoaked) |
|---|---|---|
| 100:00:00 | 4.1 | 5.6 |
| 88:10:02 | 6.2 | 8.0 |
| 87.5:10:2.5 | 6.9 | 8.9 |
| 87:10:3.0 | 7.8 | 10.14 |

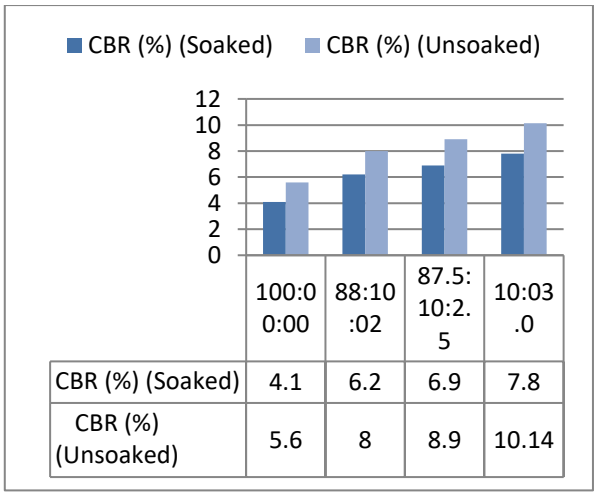



**Fig:-3** Variations b/w CBR Values of Clayey soil, Eggshell powder and Basalt Fiber with different proportions

## 5. DISCUSSIONS

- **5.1 STANDARD PROCTOR TEST:** There is an also decrease of OMC from 18.40 to 15.30% and increase of MDD from 14.10 to 18.70% when the percentages of Basalt Fiber vary from 02, 2.5 and 3% and Eggshell Powder is fixed at 10%.

- There is an increase in MDD of modified soil with increase in percentage of Eggshell Powder, due to the lower specific gravity of Eggshell Powder as compared to the unmodified soil and OMC of modified soil is decrease as the percentages of Eggshell Powder increases, due to the increase in cohesive property of soil.

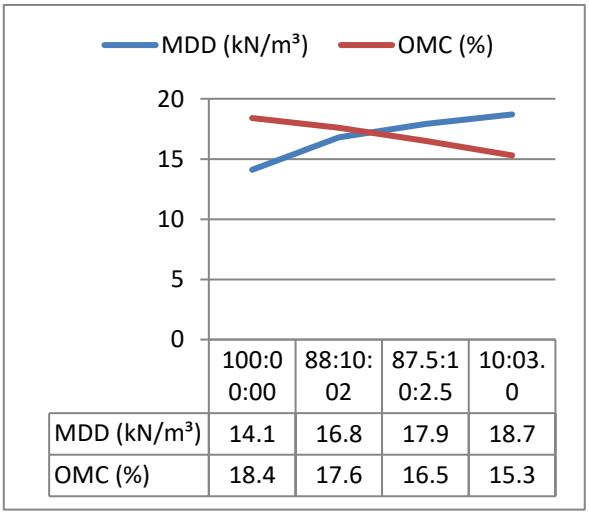
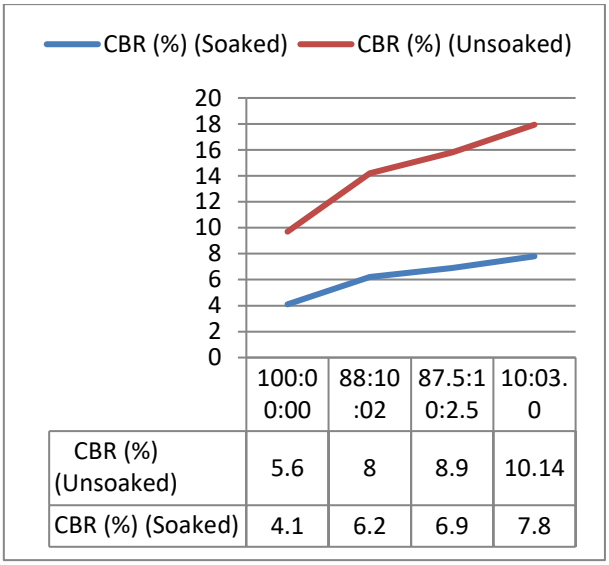



**Fig:-4 Variations b/w MDD and OMC values of Eggshell powder and Basalt Fiber Mix with Soil**

**5.2 CBR TEST:**

- The CBR value of soil is 5.6 and it increases to 1.44 times with addition of 04% Basalt Fiber when observed in soaked conditions.

- The increase in CBR value from 5.6 to 10.14 when Eggshell Powder is fixed at 10% and Basalt Fiber added at different ratios i.e. 02, 2.5,03.
- This enhancement in CBR may be because of the gradual formation of hydration compounds in the soil due to the reaction between the stabilizers and the essentials particle present in the soil.

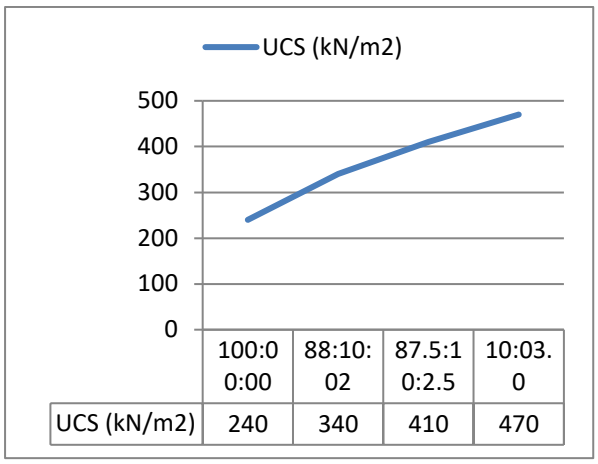



| | 100:00:00 | 88:10:02 | 87.5:10:2.5 | 10:03.0 |
|---|---|---|---|---|
| CBR (%) (Unsoaked) | 5.6 | 8 | 8.9 | 10.14 |
| CBR (%) (Soaked) | 4.1 | 6.2 | 6.9 | 7.8 |

**Fig:-5 Variations b/w CBR Values of Eggshell powder and Basalt Fiber Mix with Soil**

### 5.3 UCS TEST:

- The UCS value of soil also improves considerably with expansion of Eggshell Powder 10% and Basalt Fiber 3.0%. The value increases from 310kN/m² to 660kN/m² with addition of Eggshell Powder and Basalt Fiber.
- The reason behind of this when Eggshell Powder and Basalt Fiber comes in contact with water, Because Eggshell Powder wraps the outer surface of the Fiber and hence form better bond between the soil particles and the Fiber surface which results in improving soil characteristics.




| | 100:00:00 | 88:10:02 | 87.5:10:2.5 | 10:03.0 |
|---|---|---|---|---|
| UCS (kN/m2) | 240 | 340 | 410 | 470 |

**Fig:-6 Variations b/w UCS Values of Eggshell powder and Basalt Fiber Mix with Soil**

## 6. CONCLUSIONS

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

**I.** In this study the series of compaction test, unconfined test and California bearing ratio test were conducted to study the behavior of soil with the addition of basalt fiber and Eggshell Powder in varying proportions.

**II.** Basalt fiber is a non - metal inorganic fiber which acts as a reinforcement for soil. It has excellent thermal, chemical, mechanical properties and environmental friendly material. Fiber is abundant, non - toxic in nature, low density and high degree of water retaining capacity. Finding the optimum percentage of both materials and combining them together make it more economical and vital in soil stabilization.

**III.** Based on the compaction test it is found that OMC decreases and MDD increases. The optimum moisture content is 15.30% and Max dry density is 18.70 (kN/m$^3$).

**IV.** Based on the test results achieved from UCS after the curing periods of 7 days, the optimum mixing stabilizing agent for clay soil is 10% of Eggshell Powder and at 3.0% of Basalt Fiber.

**V.** Based on the unconfined compression test it is found that the combination of these two additives gives best compressive characteristics in the proportion of 3.0% basalt fiber and 10% Eggshell Powder. The maximum compressive strength obtained is (660kN/$m^2$)

**VI.** Thus the optimum ratio of mixture of 87% soil/ 10% ESP/ 3.0% Basalt Fiber are suggested for usage as soil stabilization process.

## References

*1) 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.*

*2) 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.*

*3) 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.*

*4) 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.*

*5) Mrs. Megha S. Mahaladkar, Mrs. Megha Mayuri B G (2022) "Comparison of Soil Stability Using Silica Fume and Basalt Fiber on Black Cotton Soil". International Research Journal of Engineering and Technology (IRJET) Volume: 09 Issue: 07 | July 2022*

*6) P.Kulanthaivel, S. Selvakumar, B. Soundara, V. S. Kayalvizhi · S. Bhuvaneshwari (2021) "Combined effect of nano-silica and randomly distributed fibers on the strength behavior of clay soil". Nanotechnology for Environmental Engineering https://doi.org/10.1007/s41204-021-00176-3. The Author(s), under exclusive licence to Springer Nature Switzerland AG 2021.*

*7) Anuj Tomar, Tarun Sharma, Sandeep Singh (2019) "Strength properties and durability of clay soil treated with mixture of nano silica and Polypropylene fiber". Materials Today: Proceedings journal homepage: www.elsevier.com/locate/matpr*

*8) Faseela M, Jisna sherin K C, Nafla C H, Rahib P (2018) " COMPARATIVE STUDY ON FIBRE AMENDED SOIL". International Research Journal of Engineering and Technology (IRJET) Volume: 05 Issue: 05 | July 2018*

*9) Anjana V. Niranjana K. (2018) "Strength Characteristics of Basalt Fibre Reinforced Soil". JSRD - International Journal for Scientific Research & Development| Vol. 5, Issue 12, 2018 | ISSN (online): 2321-0613*

*10) G. Ramachandran (2019) "experimental study on soil stabilization using basalt fiber and ground granulated blast furnace slag in organic soil". International Journal of advance and Research and innovation. Volume: 06, Issue: 04. ISSN 2347-3258.*

*11) Adla Prathyusha, Harish kumar (2020) "Experimental Study on the Suitability of Basalt Fiber Reinforced Red Soil for Highway Construction". 2020 IJRTI | Volume 5, Issue 1 | ISSN: 2456-3315.*

*12) Kavita Pawar, Ganesh Handibagh (2022) "Influence of steel slag addition on strength characteristics of clayey soil". International Journal for Research in Applied Science & Engineering Technology (IJRASET) ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538, Volume 10 Issue IV Apr 2022.*

*13) R Suresh, V.Murugaiyan (2018) "Improvement of Clay Soil Using Natural Fibers and Nano Silica". Indian J.Sci.Res. 17(2): 252 - 256, 2018, Issn: 0976-2876 (Print).*

*14) P.Bharat Goud (2018) "Stabilization of Black cotton soil with Copper slag and Rice husk ash- An Environment Approach". International Journal of Science and Research(IJSR). ISSN(online) 2319-7064, ICV 79.57.*

*15) Sharana Kumar B.M (2018) "the Use of copper slag and Polypropylene fibre to strengthen the engineering properties of soil". International Research Journal of Engineering and Technology (IRJET), e-ISSN: 2395-0056, Volume: 05, Issue: 06, p-ISSN: 2395-0072*

*16) Pooja Upadhyay, Yatendra singh (2017) "Soil stabilization using natural coir fiber".*
*International Research Journal of Engineering and Technology (IRJET), e-ISSN: 2395-0056, Volume: 04, Issue: 12, p-ISSN: 2395-0072.*

*17) Jheelu Bajaj, Vikash kumar singh (2016) "Performance Evaluation of Block Cotton Soil Stabilized with Sugarcane Bagasse Ash and Randomly Distributed Core Fibres". IJIRST –International Journal for Innovative Research in Science & Technology,Volume 2 , Issue 11 , April 2016 ISSN (online): 2349-6010.*

*18) Anil kumar Sharma, P.V. Sivallaiah (2016) "Ground granulated blast furnace slag amended Bagasse Ash as an expansive soil stabilizer". Soil and Foundations.*

*19) Abhijith R.P. (2015) "Effect of Natural Coir fibers on CBR Strength of Soil Sub grade". International Journal of Scientific and Research Publications, Volume 5, Issue 4, April 2015.*

*20) Ayininuola G.M. and Oladotun P.O. (2016) "Geotechnical Properties of Coconut Coir Fiber Soil Mixture ". Journal of Civil Engineering Research, 6(4), pp.79-85.*

*21) Priyank Goyal, Ashutosh Shankar Trivedi, Manoj Sharma(2015) "Improvement in Properties of Black Cotton Soil with an Addition of Natural Fiber (Coir) Derived from Coconut Covering" International Journal of Engineering Research and Applications (IJERA), Vol:5 Issue No:3, 36-37.*

*22) 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.*

*23) ASTM International. "Standard Test Methods for Laboratory Compaction Characteristics of Soil Using." ASTM Standard Guide. West Conshohocken, PA: ASTM International, (2003).*

*24) Davis, Tim. "Geotechnical Testing, Observation, and Documentation" (September 2008): 25. doi:10.1061/9780784409497.*

*25) ASTM International. Standard Test Methods for Laboratory Compaction Characteristics of Soil Using. ASTM Standard Guide. Vol. 3. West Conshohocken, PA: D698-12e2, (2003).*

*26) ASTM International. Standard Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted. Methods. Vol. i. West Conshohocken, PA: D1883-16, (2005).*

*27) MRD (2001). PMGSY Scheme and Guidelines: Programme Objectives. Ministry of Rural Development, Government of India, No. P-12025/8/2001-RC.*

*28) 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://pwdroads.assam.gov.in/information-services/schedule-of-rates (accessed on May 2021).*

*29) Caraşca, Oana. "Soil Improvement by Mixing: Techniques and Performances." Energy Procedia 85 (2016): 85–92. doi:10.1016/j.egypro.2015.12.277.*

*30) 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).*

*31) ASTM. Standard Test Method for Specific Gravity of Soil Solids by Gas Pycnometer, ASTM International, D5550-14, West Conshohocken, PA, (2014).*

*32) 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.*