

A STUDY ON RED COTTON SOIL STABILIZATION USING GYPSUM AND BROWN COIR

N. Mounika¹, K. Lakshmana Ravi Kumar¹, D. Naga Sai¹, R. Anand Kumar¹, M. Veera babu¹,

M. Hemanth¹, Ms. Syamala Rani²

¹Undergraduate Students, Department of Civil Engineering, Bonam Venkata Chalamayya Engineering College (Autonomous), Odalarevu, Amalapuram, Andhra Pradesh, India – 533210.

²Assistant Professor (Guide), Department of Civil Engineering, Bonam Venkata Chalamayya Engineering College (Autonomous), Odalarevu, Amalapuram, Andhra Pradesh, India – 533210.

Corresponding author's Email: satyashyamala95.bvce@bvcegroup.in

Abstract: Red cotton soil (expansive soil) changes its volume when moisture content varies, which can cause problems like cracks, settlement, and low load-bearing capacity. So, stabilization of this soil is important for safe construction. In this study, red cotton soil is stabilized using gypsum and brown coir. Gypsum helps to reduce plasticity and improves the soil structure, while brown coir, a natural fiber from coconut husk, increases tensile strength and reduces cracking. Different percentages of gypsum (2%, 4%, 6%, and 8%) and coir (0.5%, 1%, and 1.5%) were mixed with the soil to study their effects. Laboratory tests such as Atterberg limits, Standard Proctor test, Unconfined Compression Test (UCC), and California Bearing Ratio (CBR) test were conducted on untreated and treated soil samples. The results showed that liquid limit and plasticity index decreased, while strength, maximum dry density, and CBR values increased with the addition of gypsum. The use of coir improved flexibility and reduced shrinkage cracks. Overall, the combination of gypsum and coir improves the strength and stability of red cotton soil, making it suitable for use in road construction, embankments, and light foundations.

Keywords: Red cotton soil, expansive soil, soil stabilization, gypsum, brown coir, Atterberg limits, plasticity index, Unconfined Compression Test (UCC), California Bearing Ratio (CBR), maximum dry density, subgrade improvement, and shrinkage cracks.

1. Introduction

Red cotton soil, classified as an expansive soil, is widely known for its high clay content and its tendency to undergo significant swelling and shrinkage due to variations in moisture content. These volume changes often result in serious engineering problems such as surface cracking, differential settlement, and a reduction in the stability and load-bearing capacity of foundations, pavements, and other civil engineering structures. Such challenges make it essential to improve the engineering properties of red cotton soil to ensure safe, durable, and long-lasting construction.

Soil stabilization is one of the most effective techniques used to enhance the strength, durability, and overall performance of weak soils. In recent years, there has been increasing interest in the use of both chemical and natural stabilizing materials for sustainable and cost-effective ground improvement. In this study, gypsum and brown coir are used as stabilizing agents to improve the behavior of red cotton soil. Gypsum acts as a chemical stabilizer that reduces plasticity, enhances soil bonding, and improves the overall structure of the soil. On the other hand, brown coir fibers, which are natural fibers obtained from coconut husk, function as reinforcement material that increases shear strength, improves ductility, and helps control cracking.

To evaluate the effectiveness of these stabilizers, a series of laboratory tests were conducted on both untreated and treated soil samples. The tests include specific gravity, Atterberg limits (liquid limit and plastic limit), compaction test, direct shear test, and core cutter test. The soil was mixed with varying proportions of gypsum and brown coir, typically in percentages such as 0%, 5%, 10%, and 15%, to assess their influence on geotechnical properties. The results obtained from these tests provide valuable insights into the changes in strength, plasticity, and compaction characteristics of the soil.

The main objective of this study is to determine the effectiveness of gypsum and brown coir in stabilizing red cotton soil and to identify the optimum proportion of these materials that yields maximum improvement in soil strength and stability. The findings of this research can be useful for practical applications in road construction, embankments, and foundation works, particularly in regions where red cotton soil is predominant.

2.Literature reviews

J. Mathew (2020) studied soil stabilization using coir fiber and polypropylene fiber. The results showed that fiber addition greatly increases soil strength. The unconfined compressive strength became about five times higher than normal soil. The best performance was observed at 1.5% fiber content with 30 mm length.

Materials and Methodology

P. Upadhyay (2017) investigated the use of coir fiber in expansive soil. The study found that adding coir fiber increases the Optimum Moisture Content (OMC). This indicates that the soil can hold more water and improves its workability.

R. R. Singh (2019) examined the use of coir fiber in subgrade soil for road construction. The study showed improvement in engineering properties of soil. However, it suggested that further field studies are needed before practical application

A. Venkatesh (2019) conducted experiments on expansive soil with coir fiber. The study showed improvement in strength and stiffness of soil. The optimum fiber content was found to be 0.75%.

U. Kumar (2020) studied the effect of different percentages of coir fiber on soil. The results showed that soil stability and strength increase with fiber addition. Coir fiber acts as a good reinforcing material.

K. Sarath Chandra et al. (2021) investigated stabilization of red mud using gypsum. The study showed that gypsum improves strength due to pozzolanic reactions. The treated material can be used in construction works.

P. K. Kolay et al. (2010) studied peat soil stabilized with fly ash and gypsum. The results showed that soil strength increases with curing time. This combination improves soil properties effectively.

B. Ganesh et al. (2016) studied soil stabilization using salts and gypsum. The results showed increased strength and reduced plasticity. This improves soil stability.

H. Purwanto et al. (2020) studied soft clay stabilized with gypsum waste. The results showed significant increase in CBR value. This indicates improved load-bearing capacity.

S. D. Turkane et al. (2021) studied the use of fly ash in embankment soil. The results showed improved stability and safety factor. The optimum percentage of fly ash was found to be 30%.

H. N. Ramesh et al. (2016) studied fly ash with lime and salts in soil. The results showed that strength increases 2 to 4 times due to chemical reactions.

M. R. Vaidya et al. (2018) studied black cotton soil stabilized with fly ash and rice husk. The results showed improvement in soil properties and strength.

D. Shukla et al. (2015) studied coir fiber in expansive soil. The results showed increase in CBR and strength. Soil properties improved significantly.

Subramani and Udayakumar (2016) studied clay soil with coir fiber. The results showed improvement in UCS and CBR values. The optimum fiber content was 0.5%.

Priyanka et al. (2017) studied coir fiber with lime in soil. The results showed that dry density increases initially and then decreases. OMC increases with fiber addition.

Singh and Mittal (2014) studied coir fiber in soil. The results showed increase in UCS and CBR values. This helps in reducing pavement thickness.

Tiwari and Mahiyar (2014) studied fly ash, glass, and coir fiber. The results showed maximum strength at optimum percentages, after which it decreases.

J. K. Choudhary (2022) studied polypropylene fiber waste in soil. The results showed improvement in strength and bearing capacity.

Y. Mishra (2022) studied polypropylene fiber in clay soil. The results showed improvement in strength and density. It is useful for weak soils.

U. Kumar (2022) studied coir fiber in soil. The results showed improvement in MDD, CBR, and UCS values. Best performance was around 0.5%.

A. Manoj (2022) studied glass fiber and epoxy resin in soil. The results showed increase in strength and density.

P. Guruswamy Goud (2021) studied waste fibers in soil. The results showed improved strength and suggested use as an alternative to deep foundation.

J. Jagadeeshwar (2019) studied coir fiber in soil. The results showed improvement in strength and soil properties. A. Roy (2014) studied rice husk ash and cement in soil. The results showed increased strength and CBR, but reduced dry density. Chava and Nagakumar (2014) studied bagasse ash in soil. The results showed reduced plasticity and increased strength. It is an eco-friendly material.

3. Materials

3.1. Red Cotton Soil:

Red cotton soil is a type of clayey expansive soil that contains a high amount of fine particles and minerals. It gets its red color from the presence of iron oxides. This soil is very sensitive to changes in moisture—when it absorbs water, it swells (expands), and when it dries, it shrinks and forms cracks. Because of this swelling and shrinking behavior, red cotton soil is considered problematic for construction, as it can affect the stability of buildings, roads, and foundations.



Figure 1: Red cotton soil sample collected from Allavaram, East Godavari District.

Table 1: Index properties of untreated expansive clay soil

Property	Description
Color	Reddish due to presence of iron oxides
Soil Type	Clayey, expansive soil
Grain Size	Very fine-grained
Clay Content	High
Plasticity	High plasticity (easily moldable when wet)
Swelling & Shrinkage	High (expands when wet and shrinks when dry)
Permeability	Low (water movement is slow)
Bearing Capacity	Low (not suitable for heavy loads without treatment)
Compressibility	High (prone to settlement)
Shear Strength	Low to moderate
Water Retention Capacity	High
Cracking Behavior	Develops cracks during dry conditions

3.2. Gypsum:

Gypsum is a naturally occurring soft mineral composed of calcium sulfate dihydrate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). It is usually white or light grey in color and is commonly found in sedimentary rock formations. Gypsum is widely used in construction and geotechnical engineering due to its beneficial properties. When added to soil, it acts as a stabilizing agent by reducing plasticity, decreasing swelling behavior, and improving the bonding between soil particles, which increases overall strength. It is also used in the manufacture of cement, plaster, and fertilizers. Because of its ability to improve soil structure and stability, gypsum is commonly used in soil stabilization for construction purposes.



Figure2: Gypsum

Table2:Index properties of gypsum

Property	Value / Description
Chemical Formula	CaSO ₄ ·2H ₂ O (Calcium sulfate dihydrate)
Color	White, grey, or colorless
Specific Gravity	2.2 – 2.4
Density	2.3 g/cm ³ (approx.)
Hardness (Mohs scale)	2 (soft mineral)
Solubility in Water	Slightly soluble
pH Value	Neutral to slightly alkaline (6.5 – 8)
Texture	Fine-grained, smooth
Plasticity	Non-plastic
Binding Property	Good (improves soil particle bonding)
Effect on Soil	Reduces plasticity and swelling, increases strength
Water Absorption	Moderate

3.3.Brown Coir:

Brown coir is a natural fiber obtained from the outer husk of mature coconuts. It is coarse, strong, and has a brown color due to the maturity of the coconut from which it is extracted. This fiber is widely available in tropical regions and is considered an eco-friendly and biodegradable material. In engineering and construction, brown coir is used as a reinforcing material in soil stabilization. When mixed with soil, it helps to increase tensile strength, improve ductility, and reduce the formation of cracks caused by shrinkage. Because of its durability, low cost, and natural origin, brown coir is commonly used in geotechnical applications such as road construction, embankments, and erosion control.



Figure3: Brown Coir

Table3:Index properties of Brown Coir

Property	Value / Description
Source	Coconut husk (natural fiber)
Color	Brown
Fiber Type	Coarse, natural lignocellulosic fiber
Density	1.15 – 1.40 g/cm ³
Diameter	0.1 – 0.5 mm (approx.)
Length	Varies (usually 5 – 30 cm for engineering use)
Tensile Strength	100 – 200 MPa
Elongation at Break	15% – 30%
Water Absorption	High
Durability	Good (resistant to salt water and microbial attack)
Biodegradability	Biodegradable and eco-friendly
Flexibility	High
Effect on Soil	Improves strength, reduces cracks, increases ductility

4.Result and Discussion:

4.1.Specific Gravity:

The specific gravity test measures how heavy soil particles are compared to water. Using a pycnometer, the weights of the bottle, dry soil, soil with water, and water alone are recorded. From these values, the specific gravity is calculated. This helps in identifying the soil type and is important for understanding soil behavior in geotechnical works.



Figure4:Specific Gravity

Table4: Specific gravity for different Gypsum-B.C mix proportions

Mix(%)	Specific Gravity(%)
0%	1.81
5%	2.18
10%	2.33
15%	2.76

4.2. Atterberg Limit:

4.2.1. Liquid Limit:

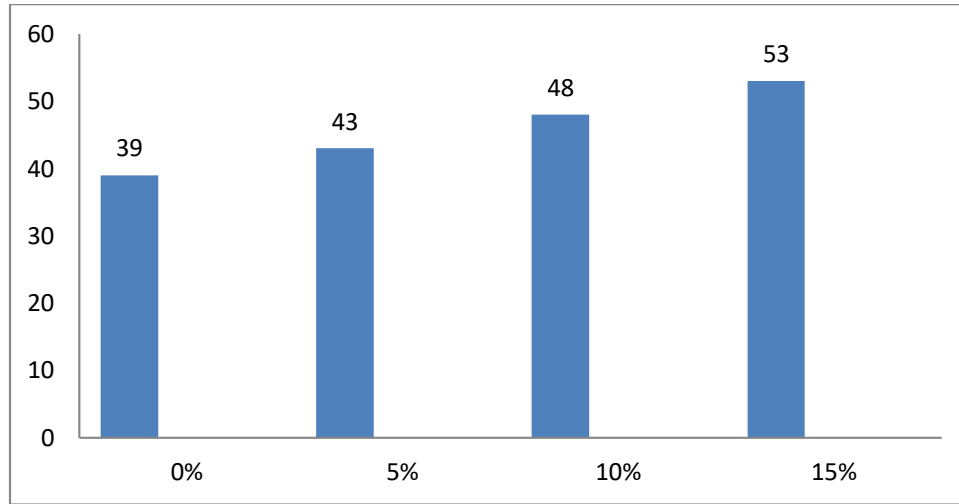
The liquid limit test is conducted to determine the water content at which soil changes from plastic state to liquid state. This test indicates the flow characteristics and compressibility of soil. The test is performed using the Casagrande liquid limit apparatus. In this method, the soil paste is placed in a brass cup and a groove is made at the center using a standard grooving tool. The cup is repeatedly dropped from a standard height until the groove closes for a length of about 12 mm. The number of blows required to close the groove is recorded.



Figure5: Liquid Limit

Table5: Liquid Limit for different Gypsum-B.C mix proportions

Mix(%)	Liquid Limit(%)
0%	39%
5%	43%
10%	48%
15%	53%



4.2.2. Plastic Limit:

The plastic limit test determines the moisture content at which soil starts to crumble when rolled into 3 mm threads. It indicates the soil's plasticity and workability. A lower plastic limit means the soil becomes plastic with less water, while a higher value shows more moisture-holding capacity. This test helps classify soil and assess its shrink–swell behavior for construction use.

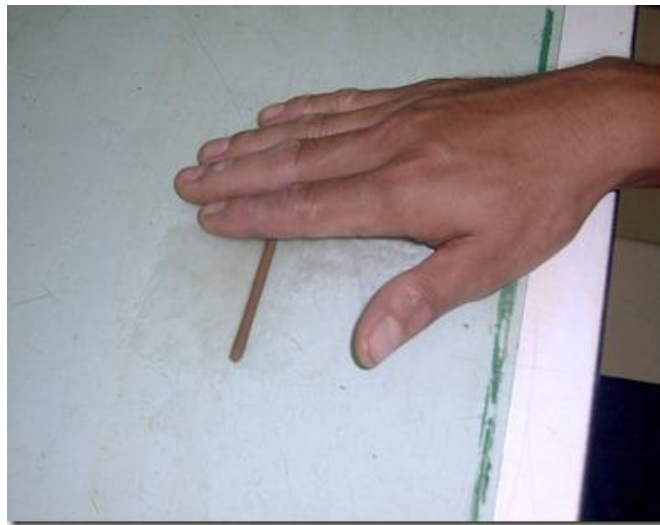
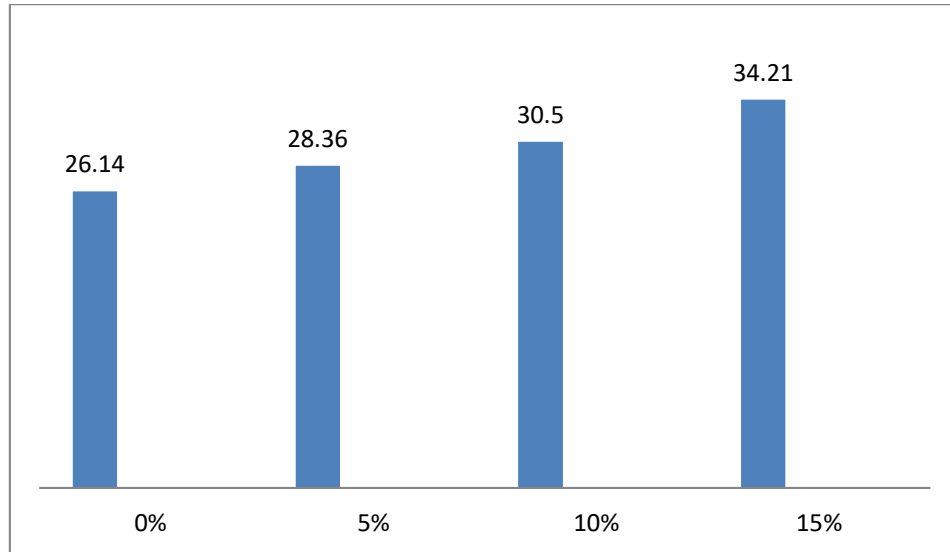


Figure6: Plastic Limit

Table6: Plastic Limit for different Gypsum-B.C mix proportions

Mix(%)	Plastic Limit(%)
0%	26.14%
5%	28.36%
10%	30.50%
15%	34.21%



4.3. Proctor Compaction Test:

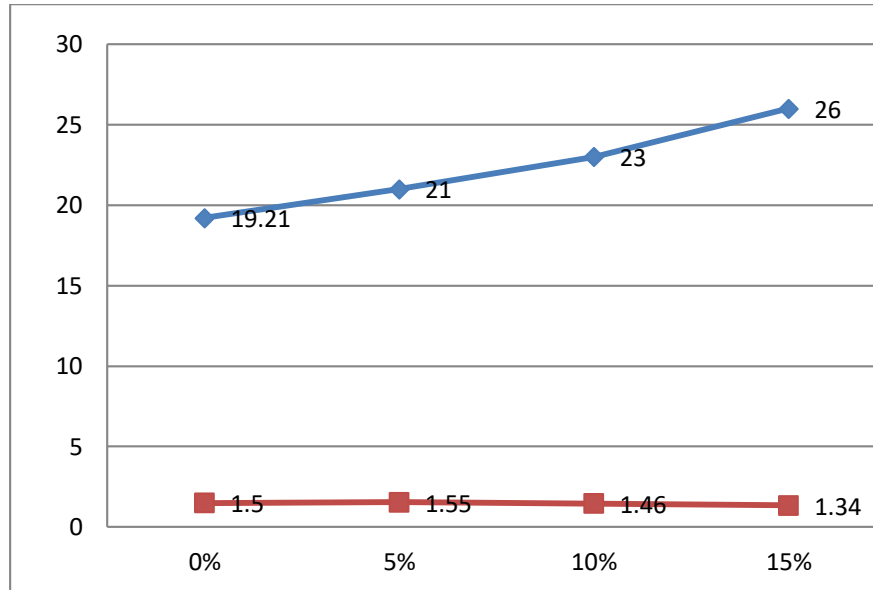
The Compaction Test is conducted to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of soil. Compaction means increasing the soil density by reducing the air voids using mechanical effort. In this test, soil is placed in a mould of known volume and compacted using a rammer. The weight of the compacted soil is measured to calculate wet density, and the water content is determined separately. Using these values, dry density is calculated. This test is important because proper compaction increases soil strength, improves load-bearing capacity, and reduces settlement. It helps in designing stable foundations for roads, embankments, and buildings.



Figure7: Standard Proctor Compaction

Table7: Compaction Characteristics for different Gypsum-B.C mix proportions

Mix(%)	OMC(%)	MDD(g/cc)
0%	19.21%	1.5g/cc
5%	21%	1.55g/cc
10%	23%	1.46g/cc
15%	26%	1.34g/cc



4.4. Core Cutter:

A core cutter is a field testing equipment used in geotechnical engineering to determine the in-situ (natural) bulk density and dry density of soil. It consists of a cylindrical steel cutter with a known volume, along with a rammer and dolly. In this method, the core cutter is driven into the soil using a rammer, and the soil sample inside the cutter is carefully extracted. The weight of the soil is then measured, and since the volume of the cutter is known, the density of the soil can be calculated. This test is commonly used for cohesive soils and helps in evaluating soil compaction and strength in the field.



Figure8: Core Cutter

Table 8: Core Cutter

Weight of soil in core cutter (W)	2.390
Volume of soil (V)	0.001021 m ³
Bulk density (γ)	2341 kg /m ³
Moisture content (W)	18%
Dry density ($\gamma - d$)	1984 kg /m ³

4.5. Direct Shear:

The Direct Shear Test is a laboratory test used in geotechnical engineering to determine the shear strength of soil. It helps to find important parameters like cohesion (c) and angle of internal friction (ϕ), which are essential for analyzing soil stability. In this test, a soil sample is placed in a shear box that is divided into two halves. A normal load is applied vertically on the sample, and then a horizontal force is applied to make one half of the box move relative to the other. This causes the soil to shear along a predetermined horizontal plane. The force required to cause this failure is measured. From the test results, the shear strength of soil is calculated, which is useful in the design of foundations, retaining walls, and slope stability analysis.

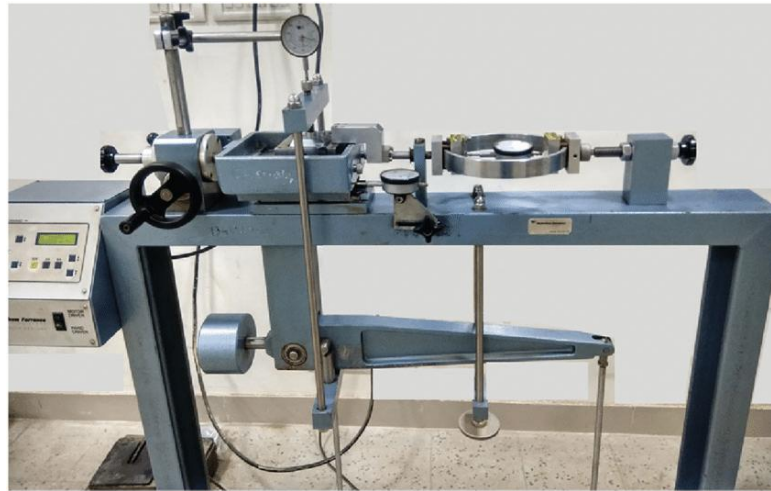
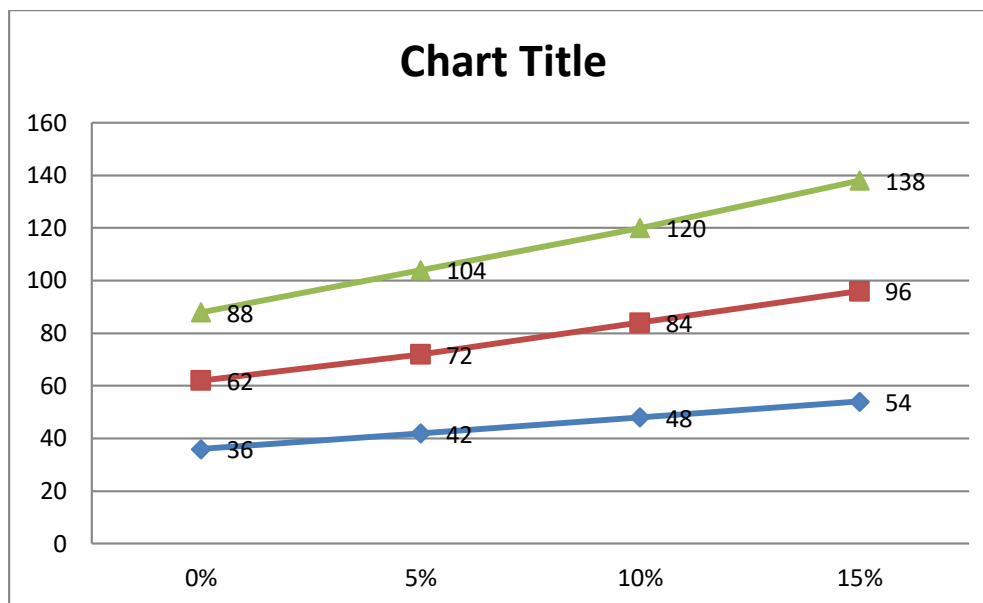


Figure9: Direct Shear

Table 9: Direct Shear

GYP SUM + COIR	50KN/M ²	100KN/M ²	150KN/M ²
0%	36	62	88
5%	42	72	104
10%	48	84	120
15%	54	96	138



5. Conclusion:

This study focuses on improving the properties of red cotton soil by using gypsum and coir fiber as stabilizing materials. Red cotton soil is highly expansive and shows swelling and shrinkage, which affects its performance in construction. The addition of gypsum reduces plasticity and improves workability, while coir fiber increases strength, ductility, and controls cracking. The results show improvements in compaction, strength, and load-bearing capacity, including higher UCS and CBR values. Overall, the combined use of gypsum and coir fiber is an effective, economical, and eco-friendly method for soil stabilization, suitable for applications like road subgrade and foundations, though proper dosage selection is important for best results.

The study focuses on stabilization of red cotton soil using gypsum and coir fiber.

- Red cotton soil is highly expansive and shows swelling and shrinkage, which affects construction.
- Gypsum reduces plasticity by causing flocculation of clay particles.
- Liquid limit and plasticity index decrease, improving soil workability.
- Coir fiber increases tensile strength and ductility of soil.
- It helps in controlling cracks and reduces brittle failure.
- Compaction properties improve with increase in maximum dry density (MDD).
- Optimum moisture content (OMC) decreases up to optimum stabilizer content.
- Unconfined compressive strength (UCS) increases significantly.
- California Bearing Ratio (CBR) values improve, showing better load-bearing capacity.
- Combination of gypsum and coir fiber is more effective than using them separately.
- It is a cost-effective and eco-friendly method using waste materials.
- Suitable for applications like road subgrade, embankments, and light foundations.
- Results are based on laboratory tests, so field performance may vary.
- Proper optimum stabilizer content should be selected for best results.

6. References:

1. Mathew, J. (2020). Comparative study on effect of soft soil stabilization using coir fibers and polypropylene fiber.
2. Upadhyay, P. (2017). Soil stabilization using natural fiber coir.
3. Singh, R.R. (2019). Improvement of local subgrade soil for road construction by the use of coconut coir fiber.
4. Venkatesh, A. (2019). Experimental investigation on expansive soil stabilized using coir fibre.
5. Kumar, U. (2020). Stabilization of soil using coir fibers.
6. Sarath Chandra, K., et al. (2021). Stabilization of red mud using gypsum.
7. Kolay, P.K., et al. (2010). Stabilization of peat soil using fly ash and gypsum.
8. Ganesh, B., et al. (2016). Effect of salts and gypsum on engineering properties of soil.

9. Purwanto, H., et al. (2020). Stabilization of soft clay using gypsum plafond waste.
10. Turkane, S.D., et al. (2021). Slope stability analysis using fly ash in embankment construction.
11. Ramesh, H.N., et al. (2016). Effect of fly ash on lithomargic soil treated with lime and sodium salts.
12. Vaidya, M.R., et al. (2018). Stabilization of black cotton soil using fly ash and rice husk.
13. Shukla, D., Rajan, S., Saxena, A.K., & Jha, A.K. (2015). Soil stabilization using coconut coir fiber.
14. Subramani, T., & Udayakumar, D. (2016). Experimental study on stabilization of clay soil using coir fiber.
15. Priyanka, Kumar, V., & Parkash, V. (2017). Soil stabilization of clayey soil using coir fibre and lime.
16. Singh, B., & Mittal, S. (2014). Improvement of soil properties using coir fiber.
17. Tiwari, N., & Mahiyar, H. (2014). Study on soil stabilization using fly ash, crushed glass and coir fiber.
18. Choudhary, J.K. (2022). Study on stabilization of soil using polypropylene fibre waste.
19. Mishra, Y. (2022). Stabilization of clay soil using polypropylene fibre.
20. Kumar, U. (2022). Stabilization of soil using coir fibre.
21. Manoj, A. (2022). Expansive soil stabilization using glass fibre and epoxy resin.
22. Guruswamy Goud, P. (2021). Soil stabilization using waste fibre materials.
23. Jagadeeshwar, J. (2019). Soil stabilization using coir fibre.
24. Roy, A. (2014). Soil stabilization using rice husk ash and cement.
25. Chava, P., & Nagakumar, M.S. (2014). Studies on soil stabilization using bagasse ash.

Copyright & License:

© Authors retain the copyright of this article. This work is published under the Creative Commons Attribution 4.0 International License (CC BY 4.0), permitting unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.