IMPROVISING RED SOIL'S GEOTECHNICAL PERFORMANCE WITH POLYPROPYLENE AND GYPSUM

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Abstract - *In civil engineering, the foundation plays a vital role in ensuring the stability and safety of any structure, as it must safely transfer all imposed loads to the ground without failure. However, in many regions, natural soils possess inadequate strength and require improvement through stabilization techniques. Soil stabilization becomes essential in such cases to enhance properties like strength, durability, and load-bearing capacity. Red soil, which covers approximately 10.6% of India's geographical area, is characterized by its reddish color due to the high iron oxide content. In this study, red soil has been selected to evaluate its engineering behavior and improve its properties using additives. The soil sample was collected from Rath district in Uttar Pradesh and transported to the laboratory for testing. Polypropylene fibers were added in varying proportions of 1%, 1.5%, and 2%, along with a constant 5% gypsum content, to study their combined effect on soil properties. Various geotechnical tests such as compaction, California Bearing Ratio (CBR), and strength tests were conducted to assess improvements in performance. The study aims to evaluate the effectiveness of these additives in enhancing soil stability, reducing plasticity, and improving its suitability for construction applications such as subgrade and pavement layers.*

***Key Words*: Soil stabilization, red soil, polypropylene, Gypsum, CBR etc.**

1. INTRODUCTION

Soil stabilization is a process that alters and improves the engineering properties of the soil in order to make it more suitable for building. Soil stabilization is a civil engineering technique for refining and improving soil engineering properties including mechanical strength, permeability, compressibility, hardness, and plasticity. The base soil serves as the foundation for any construction project, for a house, a road, or an airport. Furthermore, soil is an essential building material to stand any structure. As a result, soil should have properties that enable it to form a solid base.Soil stabilization is a common practice in the construction of airfields, parking lots, landfills, embankments, highways and foundations, waterway maintenance, agriculture, and mining sites.

Soil stabilization is a critical component of various civil engineering projects. Without removing the entire soil, the most effective technique is to use appropriate accessible. methods and materials to enhance the soil qualities. As a result, soil stabilization is thought to be the best strategy for improving soil geotechnical parameters. Chemical additives, thermal energy, compaction, and plant-based or synthetic fiber reinforcing are all common stabilization approaches. Straw, coir, palm, sisal, and jute are examples of plant-based fiber reinforcement materials that are inexpensive. Synthetic fiber reinforcing materials, such as polypropylene, nylon, rubber, or plastic, can also help reduce waste. Research into the use of waste materials to stabilize soil is currently a global trend, as surplus waste materials pose public safety and logistical issues in terms of disposal.

2. MATERIAL USED

In this study, the following materials were used:

i) Red Soil

ii) Polypropylene

iii) Gypsum

2.1 RED SOIL

The soil sample for this study was taken in the district of Rath in Uttar Pradesh. The earth is a bright crimson color. Red soil is a type of soil that forms in warm temperatures and is common in damp climates with deciduous or mixed woods. The red soil's texture ranges from sandy to clay, with loam accounting for the majority of it.

Table -1: Geotechnical properties of red soil

Specific Gravity	2.64
Liquid Limit	31.03%
Plastic limit	20.77%
Plasticity Index	10.16%
Max Dry Density	1.9 gm/cc
Optimum Moisture content	14.2%

CBR (2.5mm penetration)	6.64
Cohesion (C)	0.72kg/cm^2
Angle of internal friction (Φ)	14°

2.2 POLYPROPLYENE

Polypropylene's starting material is nonnumeric C_3H_6, a completely hydrocarbon compound. Polypropylene fibers have particularly beneficial qualities due to their form of polymerization, high molecular weight, and the way they are processed into fibers. Polypropylene fiber is a single fiber with a diameter of 0.034mm and comes in lengths of 6mm, 12mm, and 20mm.

Table - 2: Characteristics of Polypropylene

Length	6mm
Diameter	0.034mm
Specific Gravity	0.91
Moisture absorption	0% to 0.05%
Relative Density	0.91
Tensile Strength	550-700 MPa
Percentage Elongation at failure	21%
Modulus of Elasticity (E)	3.5-6.8 GN/m^2
Thermal Conductivity	6(with air as 1)
Melting Point	165°C
Softening Point	140°C
Alkali Resistance	Low

2.3 Gypsum

Gypsum powder is chemically known as calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$), meaning it contains calcium, sulfur, oxygen, and water molecules. Gypsum is a widely used building material that comprises 70% CaSO4 and can be utilized in the construction of buildings. In terms of chemistry, gypsum is a calcium sulphate that contains two molecules of water, or CaSO4, $2H_20$. It is a crystalline material that dissolves in weak hydrochloric acid and water with very little difficulty, but not in sulfuric acid. It is made up of 20.9% water and 79.1% calcium sulphate.

3. Literature Review

T.N Dave et.al (2020)

The use of polypropylene fires (PPF) for the stabilization of expansive soil obtained from Dedicated Freight Corridor (DFC) project site Bhestan near Surat. In this research. PPF has been mixed with soil in proportions of 0.75%, 1.5%, 2.0%, 2.25%, and 2.5%.

Tharini et.al (2020)

The laboratory conducted for study the performance on Black cotton soil reinforced with polypropylene fiber mixed at 0.2%, 0.3%, 0.4%, and 0.5%. The soil was gathered near PSNA College of Engineering and Technology, Dindigul, Tamil Naidu, India Petry & Little (2002).

Thomas M. Petry and Dallas N. Little (2022)

Reviewed 60 years of research on expansive clay soils. These soils swell and shrink with moisture changes, causing structural damage. The paper summarizes key advances, current stabilization practices, and future research directions.

Amiri, Kalantari & Porhonar (2023):

Mohammad Amiri, Behzad Kalantari, and Fatemeh Porhonar (2023) studied how heating red soil (100–900 °C) changes its structure and strength. New minerals like mullite and anorthite formed, increasing strength up to 20 times, showing thermal treatment improves soil properties for construction.

Singh & Kumar (2023)

Gypsum-Stabilized Low Plasticity Soils In their 2023 study, Singh & Kumar investigated the influence of gypsum stabilization on low plasticity soils, including red soils with similar properties. They found that the addition of gypsum led to a reduction in Atterberg limits, indicating reduced plasticity and improved workability. The chemical interaction between calcium from gypsum and the soil particles resulted in enhanced aggregation and slightly increased strength values in Compaction and California Bearing Ratio (CBR) tests. While the effect was more pronounced in soils with higher clay content, the study demonstrated that gypsum is a promising stabilizer for soils exhibiting poor engineering behavior, particularly in regions where traditional stabilizers like lime or cement are expensive or unavailable.

Ahmed & Islam (2024)

Combined Effects of Fibers and Chemical Stabilizers Ahmed and Islam (2024) conducted a comparative study on the combined effects of polymeric fibers and chemical stabilizers (including gypsum and lime) on expansive soils. They reported that when polymer fibers were used together with gypsum, there was a significant improvement in strength, stiffness, and resilience to moisture changes compared to using either additive alone. The fibers provided mechanical reinforcement, while gypsum improved particle bonding and reduced swelling potential. The combined stabilization technique showed improved performance in swelling potential tests, suggesting that composite stabilization can effectively address both strength and volumetric instability problems in problematic soils similar to red soils.

Purohit et al. (2025)

Red Soil Stabilization Using Waste Plastic Additives Purohit et al. (2025) investigated the use of waste plastic materials (including polypropylene waste strips) in the stabilization of red soils, with an emphasis on environmental sustainability. Their work demonstrated that inclusion of waste plastic improved tensile strength and ductility and reduced the formation of cracks during drying and wetting cycles. In addition to benefits in mechanical behavior, the use of waste plastic helped reduce the environmental burden of plastic disposal. Coupled with gypsum treatment, the composite approach was found to enhance soil performance significantly more than either additive used alone. This study provides important evidence for environmentally conscious stabilization techniques suitable for regions with abundant red soil.

4. METHODOLOGY AND EXPERIMENTAL INVESTIGATION

There was some procedure which was taken into the use of the materials for the investigation is listed below. 1.Sieve Analysis. 2.Specific Gravity. 3.Free swell test. 4.OMC-MDD. 5.CBR consideration during the undertaking of the project. The process

4.1 SIEVE ANALYSIS

A representative oven-dried soil sample of suitable mass was taken based on the maximum particle size, and all sieves along with the bottom pan were cleaned and weighed. The sieves were arranged in descending order, and the soil sample was placed in the top sieve and subjected to mechanical shaking for about 10 minutes. After shaking, each sieve with the retained soil was weighed, and the mass of soil retained on each sieve was determined, ensuring the total mass was approximately equal to the initial sample. The percentage retained, cumulative percentage retained, and percentage finer were then calculated. Finally, the grain size distribution curve was plotted with sieve size on a logarithmic scale and percentage finer on a normal scale.

4.2 SPECIFIC GRAVITY

The pycnometer (density bottle) was first washed, dried, and weighed. Approximately 200 g of dry soil sample was then placed in the bottle and weighed. De-aired water was added to cover the soil, and the bottle was connected to a vacuum pump to remove entrapped air. After removing air, the bottle was filled with water up to the calibration mark, cleaned externally, and weighed again. The bottle was then emptied, cleaned, refilled with distilled water up to the mark, and weighed. The entire procedure was repeated three times to ensure accuracy

Table – 3: SPECIFIC GRAVITY

EXPERIMENT NO	VALUES (gm)
MASS OF DENSITY BOTTLE, W_1	434
MASS OF DENSITY +DRY SOIL, W_2	611
MASS OF DENSITY +SOIL+WATER, W_3	1475
MASS OF DENSITY+WATER, W_4	1360

SPECIFIC GRAVITY= $(W_2\text{-}W_1)/(W_2\text{-}W_1)$ - $(W_3\text{-}W_4)$

= (611-434)/ (1362-434) -(1475-611)

Specific Gravity of given Sand is=2.76

4.3 COMPACTION TEST

The maximum dry density and optimum moisture content were determined by conducting standard proctor compaction test. In this test, the soil was compacted using a test mould and a rammer at different water contents until the wet density started decreasing. Moisture content of the soil at different water additions was obtained, and the dry density for each compaction level was graphed with its respective water content. The peak of the curve provided the maximum dry density that the soil can be compacted to, with the optimum moisture content that can yield the maximum compaction. how dry density can be calculated, where is dry density, wet density and water content.

Table – 4: COMPACTION VALUE

TEST NO.	1	2	3	4	5
WATER CONTENT%	14.5	16.5	17.2	21.8	24.2
DRY DENSITY(g/cc)	1.5	1.7	1.78	1.6	1.56

RESULT MDD =1.72 g/cc OMC= 16.35%

4.4 CBR (CALIFORNIA BEARING RATIO)

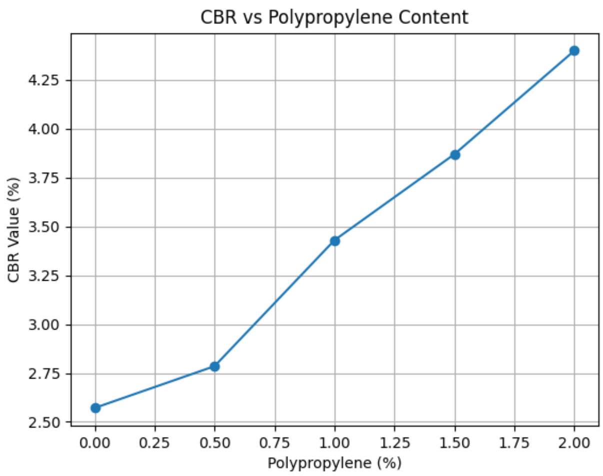
The test specimen was prepared as per IS 2720 (Part 10), and swelling was conducted if required before performing the penetration test. The mould with the specimen and base plate was placed in the testing machine, and appropriate surcharge weights were applied to simulate field conditions. A seating load of 4 kg was applied to ensure proper contact between the plunger and soil surface, and the gauges were set to zero. Load was then applied at a constant penetration rate of about 1.25 mm/min, and readings were recorded at specified penetration intervals. Moisture content was determined from the top layer of the specimen, and a load–penetration curve was plotted with corrections if necessary. Finally, the CBR value was calculated and reported to one decimal place.

Table – 5: CBR MEASURMENT

POLYPROPYLENE (%)	CBR VALUE (%)
0	2.571
0.5	2.785
1	3.43
1.5	3.87
2	4.4

5. RESULTS AND DISCUSSIONS

For the soil sample the Free swell value is 73.6 % For the soil sample the Specific Gravity value is 2.76 For the soil sample the Optimum moisture content (OMC)value is 16.35% For the soil sample the CBR value is 4.3%.



6. CONCLUSION

- The results of the study concluded that insertion of plastic waste material in clayey soils would be productive for ground improvement and soil stabilization in geotechnical engineering.
- In the present study, different content of plastic waste in % by weight varying from 0% to 2% were added into the soil.
- The optimum moisture content (16.35%) and in the maximum dry density (1.72g/cc) results respectively.
- The swelling of the soil was reduced significantly at high percentages of plastic content because of replacement in an equal mass of expansive soil by non-expansive plastic
- Reduction in swelling.
- Properties of soil can be improved by using waste plastic as stabilizer: - CBR value (4.3%) and increase the strength of soil. Reduction in consolidation settlement.

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