Journal of Gateway to sustainable Research
February 2026, Vol. 1, Issue No. 1, pp: 11-14

An Experimental Study On Clayey Soil Stabilization By Using Surkhi And Plastic Bottle Strips

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Abstract: The expansive clay soils are very problematic in geotechnical engineering because they are very compressible, swell, and low shear strength. The paper explores the stabilization of clayey soil by the application of surkhi (powdered burnt brick) and waste plastic bottle strips as sustainable stabilizers. Laboratory tests were carried out to assess the change of the index properties, compaction properties, California Bearing Ratio (CBR), and Unconfined Compressive Strength (UCS). Surkhi was added in ratios of 10 to 40 percent whereas plastic strips were added in 1 to 5 percent mass of dry soil. The findings suggest that surkhi has a significant positive impact on strength and negative effect on plasticity whereas plastic strips have a great effect in increasing ductile and changing the behavior of compaction. They showed the optimum performance of 10 percent surkhi to gain strength and 1 percent plastic strips to enhance strengthening effect. The paper illustrates that the use of locally available wastes in improving the ground sustainably is practical.

Keywords: Clayey soil, Surkhi, Plastic bottle strips, Soil stabilization, CBR, UCS

1. Introduction: A large part of India is faced with clayey soils and especially in the Kadapa region of Andhra Pradesh. These soils are defined by a fine particle size, a great plasticity and a strong capability of swelling and poor shear strength. The clayey soils due to their potential to change in volume when the moisture content is changed tend to inflict structural distress in the pavements, embankments, and shallow foundations. Differential settlement, cracking, and loss of bearing capacity are some of the problems that are normally related to expansive clay deposits.

The concept of soil stabilization has been embraced as one of the methods of ground improvement to improve the engineering characteristics of weak soils. The stabilization techniques can be either mechanical, or chemical and a mixture of both. There has been an increased desire in the use of waste and locally available materials in the past years in order to stabilize the soil following the environment and economic factors.

Surkhi is a finely ground burnt brick that was traditionally used in construction of lime mortar and has pozzolanic properties and may help to enhance soil strength and plasticity. Meanwhile, plastic waste materials particularly, plastic bottle strips have their reinforcement possibilities when placed in the soil mass randomly. Plastic strips can be used to increase the ductility, tensile resistance and crack management in the soil structures. The current research examines the ability of surkhi and plastic bottle strips to enhance geotechnical characteristics of clayey soil by conducting systematic lab work.

The stabilization of clayey soils with industrial by-products and waste materials have been investigated by a number of researchers. Kanav Mehta et al. [1] tested fiber-reinforced mixtures of brick kiln dust (surkhi) and cement-stabilized mixtures of clay. Their observations showed that addition of surkhi strongly enhanced soaked and unsoaked CBR values that exhibited enhanced subgrade performance. E. The authors [2] used surkhi and granite dust in stabilizing compressible soils. They found a decrease of plasticity index and significant rises of UCS and CBR values with the rise in surkhi content. Rachit Mishra et al. [3] investigated the surkhi and polypropylene fibers combined with expansive soil. The experiment indicated an improvement in the shear strength parameters and compaction properties, especially with the best replacement percentages. Rebecca Belay Kassa et al. [4] examined the application of waste plastic strips on clayey soils. Their finding indicated high progressions in shear strength and decrease in swelling conduct at low plastic material. S. Peddaiah et al. [5] determined the effect of plastic bottle strips on silty sand. They said that optimum plastic content increased maximum dry density and CBR values, but high addition of plastic decreased the compaction efficiency. The study by A.K. Choudhary et al. [6] has indicated that reinforcement with waste plastics enhances the CBR values and secant modulus in pavement subgrades, while flexible pavement is concerned. Dr. Significant enhancement of unconfined compressive strength under fly ash and rice husk ash stabilization was reported by Robert M. Brooks and the role of pozzolanic reaction in soil modification is emphasized. Ankit Singh Negi and Mohammed Faizan underlined the efficiency of lime stabilization to decrease plasticity index and enhance bearing capacity of highly active soils. Nurhayat Degirmenci studied the stabilization of phosphogypsum and fly ash and found out that plasticity decreased and compaction properties altered. Juan M. Manso et al. proved that swelling of clay soils is minimized by slag and lime mixtures, and compressive strength is enhanced.

Based on the above researches, it can be observed that pozzolanic materials and reinforcement components can be very useful in enhancing the expansive soil properties. Nevertheless, there is not much literature on the joint impact of surkhi and plastic bottle strips, and it is the subject of the current research.

2. Materials:

2.1 Clayey Soil: The soil used in this study was collected from Chapadu village near Proddatur. The soil was air-dried and sieved through a 425 µm sieve before testing.

Basic properties of natural soil:

- Liquid Limit = 48%
- Plastic Limit = 23.33%
- Plasticity Index = 24.67%
- Free Swell Index = 57.69%
- Specific Gravity = 2.16
- OMC = 15.8%
- MDD = 1.47 g/cc

The high plasticity and swelling index confirm that the soil belongs to inorganic clay of intermediate compressibility.

2.2 Surkhi: Surkhi is a finely powdered burnt brick material possessing pozzolanic properties. It was added to soil in proportions of 10%, 20%, 30%, and 40% by dry weight.

Figure 1: Surkhi

2.3 Plastic Bottle Strips: Plastic strips were cut from waste drinking water bottles. The dimensions of strips were 14 mm × 7 mm. Plastic was added in proportions of 1%, 3%, and 5% by weight of dry soil.

Figure 2: Plastic bottle strips

3. Methodology: The experimental program consisted of the following laboratory tests:

- Sieve analysis
- Atterberg limits (LL and PL)
- Free swell index
- Specific gravity
- Standard Proctor compaction test
- California Bearing Ratio (CBR) test
- Unconfined Compressive Strength (UCS) test

The tests were conducted in three phases:

- Testing of untreated soil.
- Testing of soil mixed with varying percentages of surkhi.
- Testing of soil mixed with plastic bottle strips.

Each test was conducted as per relevant IS codes.

4. Results and Discussion:

4.1 Effect of Surkhi on Atterberg Limits: The addition of surkhi caused noticeable variation in liquid limit and plasticity index. At 20% and 30% surkhi content, a significant reduction in plasticity index was observed. The reduction can be attributed to flocculation and agglomeration of clay particles due to pozzolanic interaction between surkhi and soil minerals. The formation of cementitious compounds reduces the activity of clay particles and limits their ability to absorb water. However, beyond optimum content, irregular trends were observed, likely due to excess non-cohesive particles interrupting soil bonding.

4.2 Effect on Free Swelling Index: Free swelling index decreased at some percentage of surkhi especially around 30%. This decrease is a sign of stabilization of the expansive clay minerals. Surkhi fillers occupy any empty spaces and limit swelling, thus providing controlled swelling. But at 40 percent surkhi, the swelling got a bit higher and this indicates that the excessive replacement does not favour the soil structure.

4.3 Compaction Characteristics: The outcomes of the compaction test results show that the maximum dry density increases at first with the addition of surkhi. This is because of the enhanced rearrangement of particles and enhanced gradation. Optimum moisture content was also different with surkhi percent as more water is needed to react with pozzolana and also to lubricate particles. In the case of plastic strips, there was a slight decrease in MDD proportionate to the growth of plastic content. This is so due to the fact that plastic is less dense than soil. The reinforcement effect however enhances ductility although there is slight decrease in dry density.

4.4 California Bearing Ratio (CBR): CBR outcomes of surkhi-stabilized soil were found to be improved especially with 40 percent surkhi. The CBR value has gone up indicating better load bearing capacity. The creation of cementitious ties enhances rigidity and resistance to penetration. Conversely, when plastic strip inclusion was used, the CBR decreased with increased percentage. Although plastic strengthens the tensile strength, too much incorporation decreases the contact area with the soil and interferes with compaction.

4.5 Unconfined Compressive Strength (UCS): The results of UCS demonstrate that the shear strength was high at 10% surkhi that was 41.5 kN/m 2 in comparison to 21.9 kN/m 2 of untreated soil. This is a great advancement that proves that surkhi is efficient in providing cohesion and inter-particle adhesion. Strength behavior was also affected by plastic strips. At lesser percentages (1%), strength rose a little because of reinforcement effect. Nevertheless, in larger percentages, UCS reduced since too much plastic disrupts soil continuity. In general, the research proves that surkhi is prevalent in the enhancement of compressive strength and lessening plasticity whereas plastic strips are effective in supporting reinforcement and plasticity when incorporated in moderated doses.

5. Conclusion: In the current research, surkhi and plastic bottle strips which are used as a stabilizing agent of clayey soil were studied by a carefully designed laboratory testing program. The natural soil had high plasticity, high swelling capacity, low maximum dry density and low strength and this proved that it could not directly be used in pavement subgrades or foundation layers without being treated.

Surkhi added created a significant enhancement in the engineering behavior of the soil. A significant loss of plasticity index and free swell index was found that means a reduction in the activity of clay and enhanced dimensional stability. Compaction properties exhibited an improvement in the maximum dry density at some of the replacement levels indicating an improvement in particle packing and gradation. Above all the values of unconfined compressive strength and CBR greatly enhanced at the optimum surkhi content indicating higher load-bearing capability and stiffness as a result of pozzolanic reaction and better inter-particle bonding. Out of the proportion tested, 10% surkhi recorded the maximum strength gain in terms of UCS, and the high percentages performed with mixed results based on the parameter under consideration.

The behavior of the soil was affected differently when plastic bottle strips were added. Even though too much content of plastics decreased maximum dry density and CBR values due to low density and disruption in soil compaction, a low percentage (approximately 1) was associated with increased ductility and slight increase in strength. The plastic strips were used as discrete reinforcing elements, serving to control the crack, as well as enhance deformation under load resistance. Nevertheless, increased plastic content affected soil continuity and its strength in general.

All in all, the research confirms the idea that surkhi can be used as a stabilizing agent to enhance the strength of clayey soil and lower the plasticity of it, and plastic bottle strips may be used as the additional reinforcement in a limited amount. The integrated use of the materials offers a geotechnical engineering solution that is cost effective and environmentally friendly in terms of soil stabilization thereby encouraging reuse of waste materials in construction of geotechnical engineering structures.

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