

# Experimental Investigation on the Synergistic Stabilization of Expansive Soil Using Calcium Chloride and Shredded Rubber Mulch

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**Abstract-** *Expansive soils, commonly referred to as black cotton soils in India, present significant geotechnical challenges because they undergo swelling when they absorb moisture and shrink upon drying. This repeated cycle of expansion and contraction can lead to considerable damage to the foundations of structures constructed on such soils. Therefore, understanding the engineering behaviour of expansive soils and implementing suitable stabilization techniques has become an important area of study for geotechnical engineers.*

*Considerable research has been undertaken to identify effective methods for minimizing the expansive characteristics of these soils. Among the various ground improvement techniques, the use of electrolytes has emerged as a promising approach for enhancing the engineering properties of expansive soils.*

*In the present study, a systematic laboratory investigation was carried out to evaluate the effects of an electrolyte and an industrial waste by-product, namely shredded rubber mulch, together with calcium chloride, on the engineering properties of expansive soil. The experimental program was conducted under carefully controlled laboratory conditions following a structured testing methodology to assess the effectiveness of these stabilizing materials.*

**Keywords-** swell and shrinkage, Shredded Rubber Mulch, calcium chloride.

## I. INTRODUCTION

### 1.0. General

Expansive soils are considered one of the most challenging soil types in geotechnical engineering because they undergo considerable swelling when moisture content increases and shrinkage when moisture is lost. These volume changes can cause severe problems for engineering structures. Such soils are found across many regions of the world, and their damaging effects on civil infrastructure have been widely reported. In India, expansive soils are commonly known as black cotton soils and occupy extensive areas, particularly south of the Vindhya ranges, covering most of the Deccan Plateau. They extend over approximately 200,000 square miles, accounting for nearly 20% of the country's total land area.

The major Engineering concern associated with

expansive soils is that the resulting deformations are much greater than normal elastic deformations and cannot be accurately predicted using conventional elastic or plastic theories. The swelling and shrinkage occur in an irregular manner, producing differential ground movements that can lead to significant damage to buildings, pavements, foundations, and other structures supported on these soils.

## II. REVIEW OF LITERATURE

Derriche and Iguechtal (2000) investigated structural distress in light residential buildings, such as studio apartments supported on pad foundations, and reported that swelling clay soils were the primary cause of foundation movement and subsequent structural damage. Similarly, Osama and Ahmed (2002) presented a case study of a single-storey reinforced concrete building in Rigid City, Jordan, where severe cracking developed as a result of the expansive clay underlying the structure.

Zhuge et al. (2004) reported widespread cracking and structural failures in masonry houses constructed on expansive soils across various regions of Australia. Their study demonstrated that differential ground movements caused by moisture-induced volume changes significantly affected the performance of residential buildings. Abdullah et al. (2006) also observed extensive damage to low-rise buildings in Tabuk, Saudi Arabia, where expansive clay soils were identified as the principal factor responsible for foundation distress and structural cracking.

Lucian (2006) examined the geotechnical problems associated with construction on expansive soils in Kibaha, Tanzania. The study emphasized the influence of expansive clay on foundation performance and highlighted the importance of adopting appropriate site investigation, design, and soil stabilization techniques to minimize structural damage.

Cabalar (2011) blended GTR with sands from two geologic formations, Leighton Buzzard Sand (LBS) and Ceyhan Sand (CS). These sands were selected for their differences in structure and engineering properties. LBS is coarse with sub angular particles, and CS is fine with angular particles. The rubber particle size was not listed but the particles were described as “flaky.” Rubber was blended with each type of sand at 5, 10, 20, and 50% by weight. Each blend was subjected to direct shear tests and observed that

the shear stress and internal friction angle of the two mixtures decreased at about 10% rubber concentration and then leveled off. He concluded that the blends were useful as lightweight embankment fill on weak foundation soils and retaining wall backfill material since the sand rubber mixtures were significantly lighter than 100% sand mixtures.

Ventappa and Dutta (2016) performed a study with objective of determining compressibility and strength characteristics of sand and tire mixtures for suitability of sand tire chip mixture for embankment. they concluded that upto 20% compressibility of sand-tire mixture was 1% i.e. intolerance limit for 10m height of embankment and produced cohesion between 7-17.5 KPa and also internal frictional angle increased from 38 to 40 degree.

### III.METHODOLOGY

#### Shredded Rubber Mulch

Rubber tyre was collected and cutted into small strips, tyre absorbs almost no water. The gas and water vapor permeability (only polar gases) is lower than for most plastics; carbons, oxygens. PE can become brittle when exposed to sunlight, carbon black is usually used as a UV stabilizer. rubber is a good electrical insulator. It offers good tracking resistance; however, it becomes easily electrostatically charged (which rubber can be reduced by additions of graphite, carbon black or antistatic agents) is of low strength, hardness and rigidity, but has a high ductility and impact strength as well as low friction. It shows strong creep under persistent force, which can be reduced by addition of short fibers. It feels waxy when touched. The scrap tires in Algeria are estimated at approximately 25,918 tones/year. Waste tires need a larger storage space than other waste due to their large volume and fixed shape. They are unlikely to be decomposed, as burying the waste tires would shorten the service life of the burial ground and have low economic benefit; In addition, buried waste tires often emerge from the burial ground surface or destroy the anti-leakage cover of the burial ground and the exposed waste tires accumulate water that may breed bacteria, molds, insects or mice. In case of fire, waste tires generate toxic gases, such as dioxin, that could result in severe pollution problems.

#### Properties of shredded Rubber Mulch

Density 0.82

Size 80  $\mu$ m – 1.5 mm Elongation

(%) 420 Rate of steel fiber 0%

Shredded rubber tyre was cut into different sizes ranges from 1mm to 25mm (Width) and 3mm to 50mm (Length). Added amount of rubber tyre had been varied in proportions of 1%, 2%, 3% and 4%.

#### Properties of Rubber Mulch

Page | 23

S.NO	properties	values
1	Hardness	40-90
2	Elongation	300-700%
3	SBR	48%
4	Carbon black	47%
5	Extender oil	1.9%
6	Zinc oxide	1.1%
7	Stearic acid	0.5
8	Sulphur	0.8
9	Accelerator	0.7

#### Sample Preparation

Both treated and untreated samples were prepared by compacting different mixes to the maximum dry density of the soil. The initial moisture content for these samples was maintained at optimum moisture content of the untreated soil. The amount of chemical/material to be added to the amount of water was arrived at based on the optimum moisture content of the natural soil and the chemical solution was prepared. This solution was added to the dry soil and the mixture was thoroughly mixed.

#### Unconfined Compressive Strength

The various mixes of soil and additives in different proportions are fixed at water content corresponding to OMC values of each mix and the samples are prepared for conducting Unconfined Compressive Strength test for each proportion in the constant volume mould. These samples are cured for 1 day, 7 days and 14 days. After the period of curing, these samples are tested for unconfined compressive strength test as per IS code of practice (IS : 2720,1664).

### IV.DISCUSSION ON TEST RESULTS

#### Laboratory Test Results on Chemical and Mechanical Stabilization

The effect of adding different chemicals to the expansive soil on Atterberg limits, DFS and Strength Properties are discussed in the following sections

Material	Percentages of material added to the soil	Index properties of soil			
		W <sub>L</sub> (%)	W <sub>P</sub> (%)	I <sub>P</sub> (%)	W <sub>S</sub> (%)
Shredded Rubber Mulch	0	85	39	46	12
	0.5	79	39	40	12.6
	1	73	39	34	13.6
	1.5	69	40	29	15.1
CaCl <sub>2</sub>	0	85	39	46	12
	0.5	76	40	36	12.9
	1	67	40	27	14.4
	1.5	65	41	24	15.4

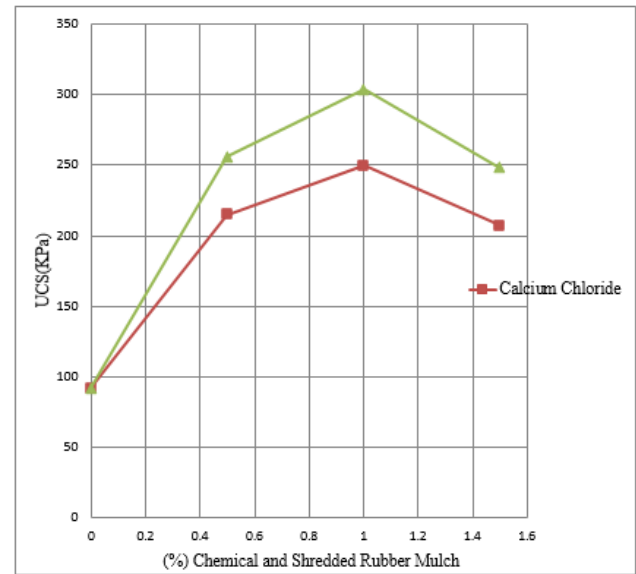


Fig.4.i: Variation of UCS for 14 days curing

The unconfined compressive strength of the remoulded samples prepared at MDD and optimum moisture content with addition of 0.5%, 1% and 1.5 % of chemical CaCl<sub>2</sub> & Shredded Rubber Mulch, to the expansive soil are presented in the table 4.6. The prepared samples are tested after 1day, 7 days and 14 days. As expected, the unconfined compressive strength is increasing with time may be due chemical reaction. It is observed that the unconfined compressive strength of the stabilized expansive soil is increasing with increase in percentage of chemical added to the soil. The unconfined compressive strength of stabilized expansive clay is increased by 171% & 230% when treated with 1% chemical, of CaCl<sub>2</sub> and Shredded Rubber Mulch respectively. The increase in the strength with addition of chemicals may be attributed to the cation exchange of CaCl<sub>2</sub> & Shredded Rubber Mulch between mineral layers and due to the formation of silicate gel. The reduction in strength beyond 1% each of CaCl<sub>2</sub> & Shredded Rubber Mulch may be due to the absorption of more moisture at higher CaCl<sub>2</sub> & Shredded Rubber Mulch.

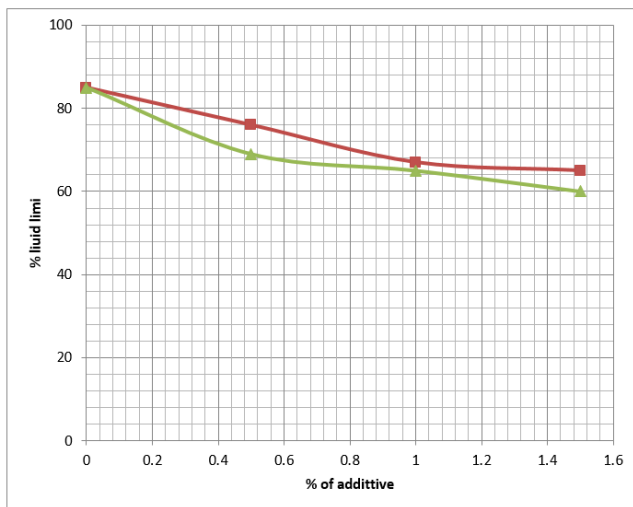


Fig.4.a: Variation of liquid limit with addition of percentage additive

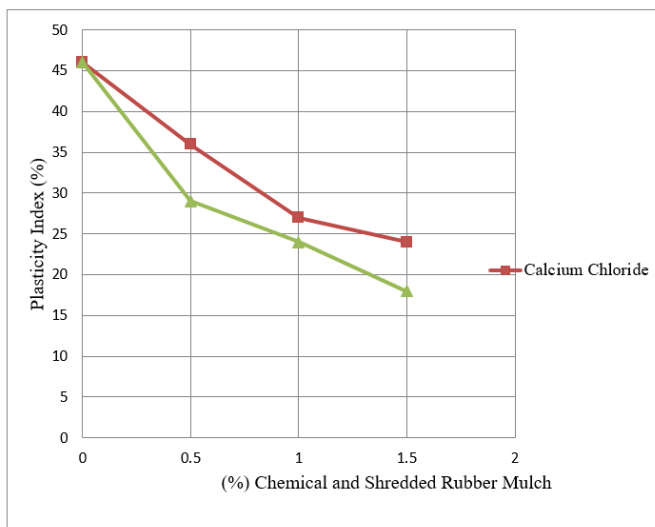


Fig.4.c: Variation of plasticity index with addition of percentage chemical and Shredded Rubber Mulch

### V. CONCLUSIONS

- Based on the laboratory investigations conducted in this study, the following conclusions are drawn:
- The liquid limit of the expansive soil decreased significantly with the addition of stabilizing agents. A reduction of approximately 63% and 70% was observed with the addition of 1% calcium chloride (CaCl<sub>2</sub>) and 1% shredded rubber mulch, respectively.
- The plastic limit showed a marginal increase after the incorporation of calcium chloride and shredded rubber mulch, indicating an improvement in the workability

characteristics of the expansive soil.

- The plasticity index decreased with the addition of both stabilizing materials, demonstrating a reduction in the plastic nature and swelling tendency of the expansive soil.
- The shrinkage limit increased with increasing stabilizer content up to 1.5%. The shrinkage limit improved from 12% for untreated soil to 15.4% and 16.0% for soils treated with calcium chloride and shredded rubber mulch, respectively.
- The Differential Free Swell (DFS) values decreased considerably after stabilization. Reductions of 43% and 47% were recorded for soils treated with 1% calcium chloride and 1% shredded rubber mulch, respectively, indicating a substantial decrease in swelling potential.
- The California Bearing Ratio (CBR) values increased significantly following stabilization. Improvements of 103% and 116% were achieved with 1% calcium chloride and 1% shredded rubber mulch, respectively, demonstrating enhanced load-bearing capacity of the expansive soil.
- The shear strength characteristics of the stabilized soil showed noticeable improvement. A significant increase in undrained cohesion was observed, while only a marginal variation occurred in the angle of internal friction with the addition of calcium chloride and shredded rubber mulch.

The Unconfined Compressive Strength (UCS) increased substantially after stabilization and curing. For a curing period of 14 days, the UCS values increased by 171% and 230% for soils treated with 1% calcium chloride and 1% shredded rubber mulch, respectively, indicating that shredded rubber mulch provided greater strength improvement than calcium chloride under the investigated conditions.

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