Stability Evaluation of Black Cotton Soil With Rubber Powder, Sodium Chloride and Calcium Chloride As Admixtures

Mousheen H M
Department of Studies in Civil Engineering
Jain Institute of Technology Davangere,
Karnataka, India

Inchara B S
Department of Studies in Civil Engineering
Jain Institute of Technology Davangere,
Karnataka, India

Abhishek R
Department of Studies in Civil Engineering
Jain Institute of Technology Davangere,
Karnataka, India

Madhushree N
Department of Studies in Civil Engineering
Jain Institute of Technology Davangere,
Karnataka, India

Mithun K N
Department of Studies in Civil Engineering
Jain Institute of Technology Davangere,
Karnataka, India

***Abstract*— Expansive soils are always considered as one of the most problematic soil for civil engineers because of their extreme swelling and shrinkage attributes. The nature of swelling and shrinkage properties is due to moisture content change. And because of this, huge settlements and structural damages take place. To understand the cause of failure, the index properties and engineering behavior of the soil should be understood. Many experimental investigations are done in the past concerned over the stabilization of expansive clay soil. In present study, the waste material like rubber powder is selected as the soil stabilizer for modifying soil properties. The soil collected for the study is blended with the varying percentage of stabilizers along with chemical admixtures and laboratory tests were conducted on the blended soil samples to evaluate the effectiveness of stabilizers in stabilization of black cotton soil. Finally, the stability of black cotton Soil is evaluated and optimum dosage of admixture is suggested.**

Keywords : Black Cotton soil, Admixtures.

1. INTRODUCTION

Soil is one of the most important natural resources, together with air and water. In engineering, soil is referred to as regolith or loose rock materials. Black Cotton Soils are those bedrocks that increase in volume or expand as they get in contact with moisture and shrink as they dry out. Black Cotton soil when companioned with engineering structure and in presence of water will exhibit a trend to swell or shrink causing the structure to encounter moments which are extensively independent to the direct consequences of loading by the structure. The Black Cotton Soil has poor engineering properties for large scale construction and because of this Stabilization of Black Cotton Soil becomes essential. Soil Stabilization is defined as chemical or physical treatment with the adoption of stabilizers and chemical admixtures to increases or maintains the stability of a soil.

1.1 Problem Statement

Fig. 1 Discarded Waste Rubber Tyre

India is one of rapidly developing country in the world because of which there has been expeditious annual increase in the number of automobiles resulting in steady volumetric increase in the waste rubber tyres every year. These discarded tyres are disposed to landfills, stock fills, and is being burned in local industries to generate the heat. Waste rubber tyres release toxic gasses when they are exposed to fire which is dangerous to human health and envioronment in general.

1.2 Solution

Utilization of waste rubber tyre as Soil Stabilizer reduces its impact on environment and health and it is essential for sustainable development. In the present study a secondary raw material in the form of finely pulverized rubber powder which is yielded by Rubber Granulate Processing on mechanical and chemical basis sourced from waste rubber tyres is utilized as

Soil Stabilizer to enhance the engineering attribute of expansive black cotton soil along with chemical admixtures.

2. OBJECTIVE OF THE PROJECT

- To examine the basic attributes of Black Cotton Soil by conducting various tests.
- To study the variation in Maximum Dry Density and OMC of Black Cotton soil by adding Crumb Rubber Powder and Chemical Admixtures
- To investigate the shear strength attributes of Black Cotton soil by adding Rubber Powder and Chemical Admixtures.
- To evaluate the variation in swelling attributes of Black Cotton soil by adding Chemical Admixtures.
- To suggest the optimum dosage of Rubber Powder and chemical admixtures for the present soil.

3. MATERIALS

The following are the materials adopted to evaluate the stability of black cotton soil which include naturally available Black Cotton Soil, Rubber Powder and chemical admixtures.

a. Black Cotton Soil

Fig.2 Black Cotton Soil

Soil sample was collected from Bilichodu village located in Jaglur Taluk Davangere District in the southern state of Karnataka. The topmost layer of the soil was removed along with all the organic debris and other waste substances.

b. Crumb Rubber Powder

Fig.3 Crumb Rubber Powder

Crumb Rubber Powder is a valuable secondary raw material which is in the form of finely pulverized powder yielded by rubber granulate processing on mechanical-chemical basis. Granulate is sourced from used and recycled tyres from both cars and trucks. The crumb rubber powder embody of both natural and artificial rubber granule. This low cost raw material makes the stabilization process more economical.

- *Physical and Chemical Characteristics of Rubber Powder*

Physical and Chemical attributes of Crumb Rubber Powder was determined with the help of various experiments before using it as stabilizer to stabilize the bc soil. The crp from discarded tyres adopted for the study does not contain steel content but contain less than 5% of fabric strands. A microscopic investigation was conducted to determine grain size of rubber powder which concluded that particle size alter from 1.5mm to 0.9mm with an average granular particulate of 1 mm. The average density of the rubber powder is determined to be 0.80. The Crumb Rubber powder has insignificant water absorption rate which is less than 2%.

The tyre is manufactured mainly using rubber. Its composition varies a little between the regular car tyres and heavy vehicle tyres. Rubber from waste tyres consists of a intricate combination of Polyisoprene, Elastomers, zinc oxide (1.8%), extender oil (1.7%) and carbon black (32.0%) are the major constituent of tyres. The extent of steel particles present is usually about 18% to 20%, for this experimental investigation steel particles were removed by adopting magnetic separation.

c. Sodium Chloride Solution (NaCl)

Fig. 4 Sodium Chloride (NaCl)

Sodium chloride is a common salt which readily dissolves in water. The solution is odorless and is hygroscopic in nature. For the present work Sodium Chloride is used in the form of solution of 1 Molar Concentration. The solution for each concentration was prepared using clean portable water. Sodium Chloride attracts and retains moisture which retards further evaporation and also reduces the formation of shrinkage cracks.

d. Calcium Chloride Solution ($CaCl_2$)

Fig.5 Calcium Chloride ($CaCl_2$)

Calcium Chloride is used as a water retentive additive. Being hydroscopic in nature and deliquescent in character, $CaCl_2$ observes moisture content from the atmosphere and retains it. It makes modification in the characteristics of pure water. The vapor pressure gets lowered and the surface tension gets reduced

which results in preclusion of frost heave. Calcium Chloride performs as soil flocculent. It increases the compaction and enhances the density. The Calcium Chloride of equivalent weight 110.98 grams is mixed with 1 liters of portable water to prepare the solution of 1 molar concentration.

4. METHODOLOGY

The aim of the methodology is as follows

1. To evaluate the strength attributes of Black Cotton Soil with different percentages of Rubber Powder, sodium chloride and calcium chloride solution with varying percentage.
2. To enhance the engineering attributes of the BC soil by adding admixtures and make it suitable for construction process.
3. To determine the effects of Rubber powder as stabilizing agents on Black Cotton soil.
4. To determine the swelling attributes of the soil due to effect of NaCl and $CaCl_2$.

4.1 Mix Proportions

Fig.6 Mix Proportions

With reference from the journals and literature review the probable mix proportions of admixtures and soil stabilizers is selected i.e. Rubber Powder (RP), Sodium Chloride (1M Solution) and Calcium Chloride solution (1M Solution)

- 1%, 3%, 5%, 7% and 9% of Crumb Rubber Powder (CRP)
- 0.5%, 0.75%, 1%, 1.25% and 1.50% of NaCl Solution
- 0.5%, 0.75%, 1%, 1.25% and 1.50% of $CaCl_2$ Solution

Table 1

Sl. No.	**Preparation of Specimens**	
	Specimen	***Percentage Variance***
1	Specimen 01	Natural Black Cotton Soil
2	Specimen 02	BC Soil+1% CRP +0.50% NaCl + 0.5% $CaCl_2$
3	Specimen 03	BC Soil+3% CRP +0.75% NaCl + 0.75% $CaCl_2$
4	Specimen 04	BC Soil+5% CRP +1.00% NaCl + 1.00% $CaCl_2$
5	Specimen 05	BC Soil+7% CRP +1.25% NaCl + 1.25% $CaCl_2$
6	Specimen 06	BC Soil+9% CRP +1.50% NaCl + 1.50% $CaCl_2$

4.2 Tests Conducted

The following Table (2) shows the tests that are executed to examine the basic properties of BC Soil confirming to Indian Standard Codes.

Table 2

Sl. No.	**List of tests conducted**	
	Title of the tests	***Reference***
1	Specific Gravity Test	IS 2720 – Part I – 1980
2	Moisture Content Test	IS 2720 – Part II – 1973
3	Grain Size Analysis	IS 2720 – Part IV – 1985
4	Atterberg Limit and Indices	IS 2720 – Part V – 1985

The following tests are executed to determine the Engineering Properties of BC Soil which was collected from study area confirming to Indian Standard Codes.

Table 3

Sl. No.	**List of tests conducted**	
	Title of the tests	***Reference***
1	Standard Proctor Test	IS 2720 – Part VIII – 1983
2	Unconfined Compressive Test	IS 2720 – Part X – 1991
3	Free Swell Index Test	IS 2720 – Part 40 – 1977

5. RESULTS AND DISCUSSIONS

As mentioned in methodology the foremost objective of the work is to determine the basic attributes of Black Cotton Soil. Tests to determine the basic properties of black cotton soil tests were executed for treated and untreated soil sample.

5.1 Basic Attributes of Black Cotton Soil

The following Table (4) shows the results we obtained in relation to the tests conducted.

Table 4

Sl. No.	**List of tests conducted**	
	Title of the tests	***Results***
1	Specific Gravity Test (Pycnometer Method)	2.18
2	Specific Gravity Test (Desity Bottle Method)	2.18
3	Moisture Content Test	9.87%
4	Grain Size Analysis	Well Graded
5	Liquid Limit Test (Cone Penetrometer Method)	43.40%
6	Liquid Limit Test (Casagrande Method)	46.85%
7	Plastic Limit Test	29.59%

Average specific gravity of soil sample was found to be 2.18. The initial moisture presence of the soil sample was 9.87%. Grain size test was conducted on the soil sample and the results indicated that the soil sample is well graded. Atterberg Limit and Indices Tests on the soil sample to determined its liquid limit to be 46.85 and plastic limit to be 29.59%.

5.2 Engineering Attributes of Black Cotton Soil

Tests to determine the engineering attribute of bc soil tests were executed for treated and untreated black cotton soil confirming to Indian Standard Codes.

a. Standard Proctor Test (Light Compaction Test)

Standard compaction of soil is the method of increasing the density of soil by eliminating the void space present in soil mass. The compaction process majorly depends on the moisture present in the soil mass and the energy required for compaction. The Optimum Moisture Content and Maximum Dry Density of soil mass were determined by executing the compaction test. All the compactions were carried out with light compaction test apparatus. For the determination of Optimum Moisture Content and Maximum Dry Density relationship, it involved energy derived from a hammer of 2500 grams mass falling from a height of 305mm in a 1000cc capacity mould. Each layer is compacted in three layers such that each layer enduring 25 impacts. The relation between MDD and OMC for different percentage of admixtures is plotted in the following Fig 7&8.

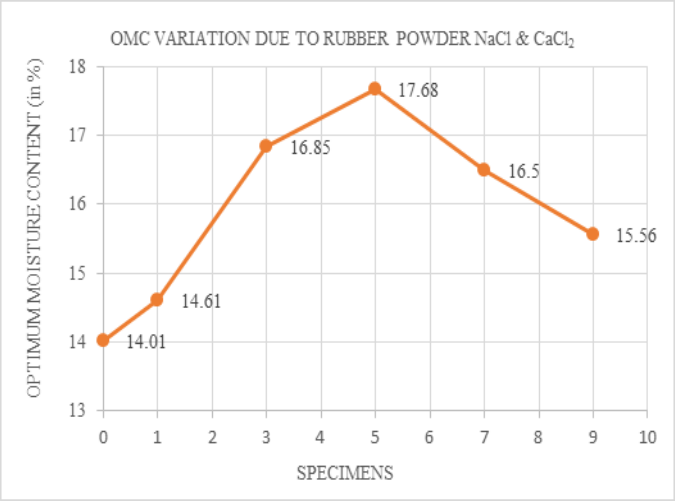

Fig. 7 OMC variation due to Rubber Powder, NaCl & $CaCl_2$

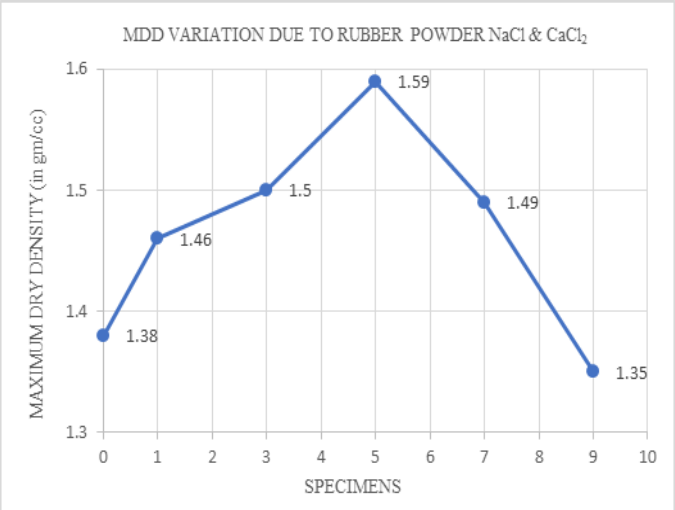

Fig. 8 MDD variation due to Rubber Powder, NaCl & $CaCl_2$

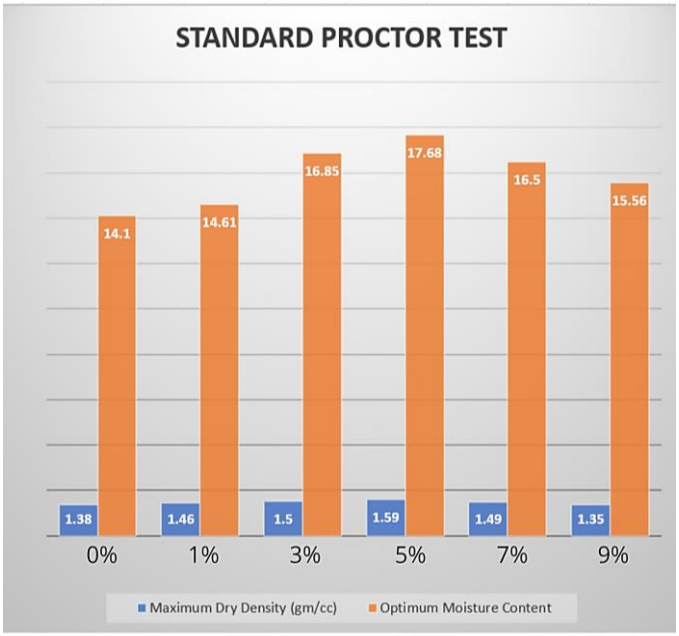

Fig.9 Effect of Rubber Powder NaCl and $CaCl_2$ on OMC & MDD

Table 5

Sl. No.	**OMC and MDD Variation**		
	Mix Proportion	***OMC***	***MDD***
1	Natural Black Cotton Soil	14.01%	1.38 gm/cc
2	BC Soil+1% CRP +0.50% NaCl + 0.5% $CaCl_2$	14.61%	1.46 gm/cc
3	BC Soil+3% CRP +0.75% NaCl + 0.75% $CaCl_2$	16.85%	1.50 gm/cc
4	BC Soil+5% CRP +1.00% NaCl + 1.00% $CaCl_2$	17.68%	1.59 gm/cc
5	BC Soil+7% CRP +1.25% NaCl + 1.25% $CaCl_2$	16.5%	1.49 gm/cc
6	BC Soil+9% CRP +1.50% NaCl + 1.50% $CaCl_2$	15.56%	1.35 gm/cc

Fig. 10 Standard Proctor Test

b. Unconfined Compression Test (UCT)

Unconfined Compression Test (UCT) is a laboratory testing process used to determine the engineering characteristics of rocks and fine grained clay soils. UCT helps to determine the Unconfined Compressive Strength which is used to compute the unconsolidated undrained shear strength and stress-strain properties of the soil.

Fig.11 UCT Test Specimens

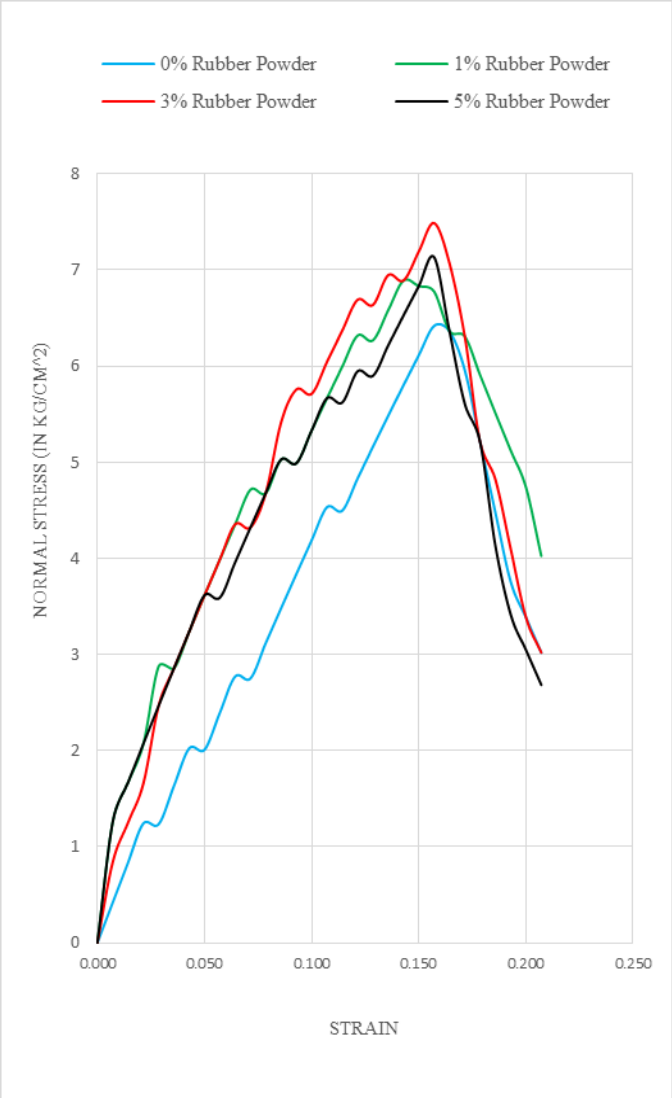

Fig. 12 Normal Stress - Strain variation due admixtures

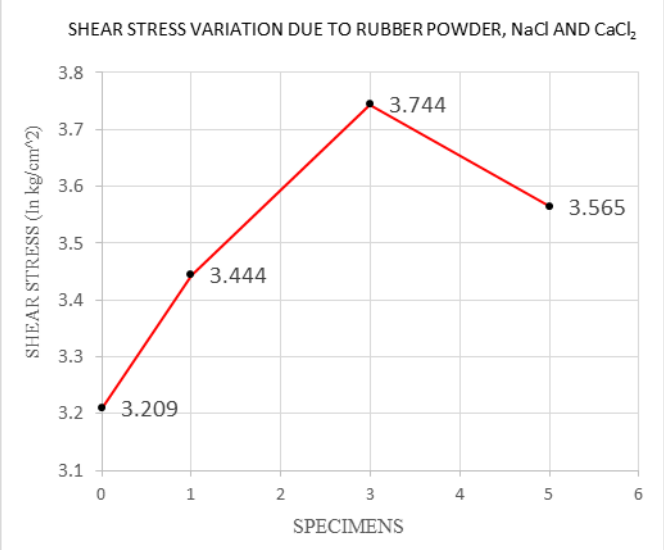

Fig. 13 Shear Stress variation due admixtures

Table 6

Sl. No.	UCT Results		
	Specimen	*Normal Stress*	*Unconfined Compressive Strength*
1	Natural BC Soil	6.418 gm/cc	3.209 gm/cc
2	BC Soil + 1% CRP + 0.5% NaCl + 0.5% $CaCl_2$	6.889 gm/cc	3.444 gm/cc
3	BC Soil + 3% CRP + 0.75% NaCl + 0.75% $CaCl_2$	7.488 gm/cc	3.744 gm/cc
4	BC Soil + 5% CRP + 1% NaCl + 1% $CaCl_2$	7.131 gm/cc	3.565 gm/cc

c. Free Swell Index Test

Free swell is the augment in volume of soil mass, outwardly any exterior repression on immersion in water. The potential of affliction to structures due to swelling character of Black Cotton Soil need be discovered laboratory examination to unmask the undesirable expensive characteristics. For the given clay the free swell index in percent can be compute using the following formula:

$$\text{Free swell index} = (V_d - V_k / V_k) \times 100$$

Table 7

Sl. No.	Free Swell Index Test Results		
	Specimen	$\frac{Vd - Vk}{Vk}$	*Unit*
1	Free Swell index with Distilled Water	68.18	%
2	Free Swell index with 0.5% NaCl	68.31	%
3	Free Swell index with 1.0% NaCl	62.76	%
4	Free Swell index 0.5% $CaCl_2$	73.63	%
5	Free Swell index 0.1% $CaCl_2$	86.81	%

6. CONCLUSIONS

According to the experimental investigation results and analysis, we can conclude that:

- It is noticed that, OMC and MDD is increasing with the addition of 5% rubber powder 1% NaCl and 1% $CaCl_2$ as admixture and decreases with the further addition of admixtures.
- By comparing the results of Unconfined Compressive Strength, it's concluded that the Unconfined Compressive Strength is increasing with the addition of 3% rubber powder 0.75% NaCl and 0.75% $CaCl_2$ as admixture and decreases with the further addition of admixtures.
- The swelling property of soil decreases rapidly with the increase in the concentration of Sodium Chloride solution.
- The swelling property of the soil increases steadily with the increase in the concentration of Calcium Chloride solution.

7. SCOPE FOR FUTURE INVESTIGATION

- The above work has been carried out in laboratory conditions. Practical feasibility at site has to be studied.
- Other than the above admixture used, we can further use different sort of admixtures from different sources to study their effect on stabilization of BC soil.

- The long-term performance of soil stabilizer and chemical admixture with the expansive soil could be further investigated by extensive field studies in real life situation.

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