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Stabilization of Black Cotton Soil Using Sodium Chloride

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Abstract: Stabilization is the process of physical and chemical alteration of soils to enhance their engineering properties and thus improving the load bearing capacity of a sub-grade or a sub-base to support pavements and foundations. Sodium chloride has been used for many years as a stabilizing admixture in selected base course materials. Sodium chloride added to raw soil were found to have negligible effects on soil plasticity while increasing compacted density and decreasing optimum moisture content. In this project, the stability of soil is found out by adding Sodium chloride (NaCl) and thus compared with the stability of soil without adding Sodium chloride (NaCl) followed by different laboratory tests.

Keywords: Soil Stabilization, Black Cotton Soil, Sodium Chloride, Admixture, Bearing Capacity.

I. INTRODUCTION

Mainly in economically backward countries, the economies lead by the construction field for the development of the country, and it also depends on the durability aspect of construction. In this regard, one step for strengthening the rural economy is based on by providing all weather resistant roads have been emphasized. In countries like India, the biggest handicap is to provide a complete network of road system with the limited finances available to build the road by conventional methods. Therefore there is a need to resort one of the suitable methods of low cost road construction. The construction cost can be considerably decreased by local materials including local soils for the construction of the lower layers of the pavement such as the sub-base course.

The layers of the pavement may comprise of different types of soils. One of them is black cotton soil and it is highly weak because of the large changes in volume due to fluctuations in the moisture content. In monsoon seasons, water which is absorbed by soil results in swelling, and also in the reduction of bearing capacity. In dry seasons, these soils shrink or reduce in volume due to evaporation of water and they become harder. For effective treatment of soil, one of the methods is by adding the quantity of Sodium chloride to develop increased strength varies with the type of clay mineral present.

Regarding the strength of clay soils, air drying in a humid environment produces a hard and strong mass. In the extreme, banking at elevated temperatures converts clay to brick. For most practical purposes the strength of soil has less importance than its resistance to deformation under load. Not all low strengths are associated with increased moisture content. In India Black Cotton soil also known as "Regurs" are found in extensive regions of Deccan Trap. They have variable thickness and are underlain by sticky material locally known as "Kali Mitti". In terms of geotechnical engineering, the Black Cotton soil is one which was associated as engineering structure and in presence of water it will show a tendency to swell or shrink causing the structure to experience moments which are largely unrelated to the direct effect of loading by the structure. The black cotton soil is not suitable for the construction work on account of its volumetric changes. It swells and shrinks excessively with a change of water content. Such tendency of soil is due to the presence of fine clay particles which swell when they come in contact with water and also resulting in alternate swelling and shrinking of soil due to which differential settlement of structure takes place. To change or modify the soil properties by some means to suit the requirements is known as "stabilization". Stabilization in a broad sense incorporates the various methods employed for modifying the properties of a soil to improve its engineering performance. The main objective is to increase the strength or stability of soil and to reduce the cost by making the best use of the locally available materials.

The chief properties of a soil with which the construction engineer is concerned are volume, stability, strength, permeability, and durability. Stabilization is not only in terms of corrective treatment but also as a preventive measure against adverse conditions. The stabilization converts the soil to a rigid mass to resist the internal swelling pressure of clays and retards moisture movement within the soil. For example for blocking pores to improve soil strength and also volume stability, stabilization is necessary. Mechanical properties of a soil can readily be improved or maintained at some constant design condition by stabilization. Problems of soil permeability can generally be corrected by stabilization. The problem of poor durability of soil can be avoided. Out of the many methods of stabilization techniques, sodium chloride stabilization suits best to the black cotton soil.

Sodium chloride stabilization is achieved with calcium hydroxide. The soils to be stabilized are first mixed with, predetermined sodium chloride at which the maximum strength occurs. Thus the corresponding optimum water content is also added and compacted to the maximum dry density. However, the performances of these compacted soils are inadequate for the traffic conditions. Keeping in view, the variation pattern of the dry density with water content both for pure soils and soils-sodium chloride mixes, it may be thought that the OMC (Optimum Moisture Content) for MDD (Maximum Dry Density) may not be OMC for strength parameters.

So the stabilization has done for the black cotton soil which was done in this project work by using sodium chloride as an admixture. If the requirements of these soils are not sufficient, then either the soils are to be totally replaced by a better one or modify the properties as required. The former process is very costly and generally, the latter is preferred.

This project deals with studying such variation of strength parameter CBR with water content, of a sodium chloride stabilized soil. A locally available soil is selected for this purpose. The OMC of the soil sodium chloride mixes at different percentages of sodium chloride are determined. The soil with sodium chloride content is mixed with corresponding OMC and MDD and its strength parameters are noted. The optimum sodium chloride content at which maximum strength occurs is noted as sodium chloride Modified optimum, (for CBR). It is assumed that the Ratio of strength at OMC & corresponding MDD and respective maximum strength for any sodium chloride content remains constant. Also, it is assumed that the variation between maximum strength at any sodium chloride content and the strength at OMC & corresponding MDD is a straight line. The sodium chloride is added to the soil at different proportions and the variation of strength parameters (CBR) is noted. The experiments are done for two compactive efforts vis. Standard proctor compactive effort and Modified proctor compactive effort. The stabilization is done for the following reasons. Soil stabilization is widely used in connection with road, pavement and foundation construction. It improves the engineering properties of the soil,

- Strength - to increase the strength and bearing capacity
- Volume stability - to control the swell-shrink characteristics caused by moisture changes
- Durability - to increase the resistance to erosion, weathering or traffic loading.
- To reduce the pavement thickness as well as cost.

A. Soil Stabilization

Natural soil is both complex and variable material because of its universal availability and its low cost, it offers a great opportunity for skilful use as an engineering material. If the soil at any particular locality is unsuited for the construction, a basic decision is made whether to

- Accept the site material as it is, the design is made to meet the restrictions imposed by its existing quality.
- Remove the site material, and replace with superior material.
- Altering the properties of the existing soils so as to create a new site material capable of better, meeting the requirements of the task at hand.

The soil stabilization is used to

- Increase or decrease the strength or reduce the sensitivity of soil to environmental changes, especially moisture changes.
- Increase or decrease the permeability.
- Reduce compressibility.
- Reduce frost susceptibility.

The properties of a soil may be altered in many ways among which were included chemical, thermal, mechanical and another mean. While stabilization, it is most often thought in the context of road construction, it may also be used from highways to deep excavation, from dust prevention to tough reinforcement. Stabilization is useful for slope protection and erosion control. The chief properties of soil are volume, stability, strength, permeability, and durability. Inadequate control over any of these properties can have serious consequences like road distress, slope failures, piping failures of earth dams, deep erosions. It is a preventive measure against adverse conditions developing either in the course of construction or throughout the life of the structure. The classification of soil stabilization techniques are based on the treatment given to soil (Ex: dewatering, compaction etc.), the process involved (Ex: Thermal, electrical etc.) and on additives employed (Ex: Lime, cement etc.

B. Objectives

- To increase the shear strength of soil.
- To improve the soil strength using sodium chloride solution.
- To compare the test results of normal soil and sodium chloride solution added to the soil.

II. MATERIALS

A. Black Cotton Soil

The most important characteristic of the soil is, when dry, it shrinks and is hard like stone and has the very high bearing capacity. Large cracks are formed in the bulk of the soil. The whole area splits up and cracks up to 150 mm wide is formed up to a depth of 3.0 to 3.5 metre. But when the soil is moist it expands, becomes very soft and loses bearing capacity. Due to its expansive character, it increases in volume to the extent of 20% to 30% of original volume and exerts pressure. The upward pressure exerted becomes so high that it tends to lift the foundation upwards. This reverse pressure in the foundation causes cracks in the wall above. The cracks are narrow at the bottom and are wider as they go up.

The unusual characteristics of the soil make it difficult to construct a foundation in such soil. A special method of construction of foundation is needed in such soil.

Setbacks with Black Cotton soil:

- High compressibility
- Low strength

Hence an experimental program is planned to improve the engineering properties of black cotton soils using lime separately and lime rice husk ash combinations for the stabilization. For this experimental program, clay samples are collected from Chittipalem, near Bandar Kota, BANDAR Mandal.

The identification tests were conducted on these collected soil samples to confirm whether it is a black cotton soil or not and to know the properties of the collected soil samples.

After identifying the various properties (viz… plastic limit, liquid limit, plasticity index, California bearing ratio test, unconfined compressive strength test etc) we are concluded that it is necessary for stabilization of soil.

Table.1 Physical Characteristics of Black Cotton Soil

Parameter	Component	Test value
Specific Gravity	B.S.C	28
Soil Classification	B.S.C	CH
Free Swell Index	B.S.C	45
Grain Size Analysis	%of gravel	1.5
	%of sand particles	16.5
	%of silt size particles	41
	%of clay size particles	40
Atterberg's Limits	Liquid limit %	45
	Plastic limit %	22
	Plasticity index	23
Compaction Characteristics	Max. dry density(KN/m3)	1.61
	Optimum moisture content % (OMC)	24

B. Sodium Chloride

Sodium chloride is also known as salt or halite, is an ionic compound with the chemical formula NaCl, representing a 1:1 ratio of sodium and chloride ions. With molar masses of 22.99 and 35.45 g·mol−1, respectively, 100 g of NaCl contain 39.34 g Na and 60.66 g Cl. Sodium chloride is the salt most responsible for the salinity of seawater and of the extracellular fluid of many multi cellular organisms. In the form of edible or table salt, it is commonly used as a condiment and food preservative. Large quantities of sodium chloride are used in many industrial processes, and it is a major source of sodium and chlorine compounds used as feed stocks for further chemical syntheses. A second major application of sodium chloride is de-icing of roadways in sub-freezing weather.

Table.2 Composition and Characteristics of Sodium Chloride

Melting point	8010c
Boiling Point (hpa)	14610c (1013)
Vapour Pressure (8650c)	1.3hpa
Specific Gravity	2.165
Solubility in Water	358g/l (200c)
Sulphate	<0.2%
Calcium	<0.01%
Iron	<0.001%
Arsenic	<0.00005%
Insoluble matter	<0.03%
Magnesium	<0.01%
Copper	<0.0002%
Cadmium	<0.00002%
Lead	<0.0001%
Mercury	<0.000005%
Molecular weight	58.44

III. METHODS

SOIL-SODIUM CHLORIDE STABILIZATION

The potential of sodium chloride as a stabilizing agent for highway construction has been investigated. The results of laboratory tests with mixtures of several soils and a gravel with a commercial montmorillonite clay stabilized with rock salt and brine are presented. Soils treated with sodium chloride fall into two broad groups, as does the usage of the material.

1. Sodium chloride treatment is aimed at modifying the soil properties by reducing plasticity, improving workability, increasing grain size etc., the criteria for mechanically stabilized mixture are applied.
2. Sodium chloride treatment is limited to pavements and substantial stabilization of a soil, then the criteria are based on strength bearing capacity etc., in a similar manner to that developed for cement stabilized soils.

IV. RESULTS AND DISCUSSIONS

The tests are conducted on a locally available black cotton soil, collected in the disturbed state. The soil is powdered and the various tests are conducted on the fraction passing through a 425µ sieve. The various tests conducted on soil and soil-lime mixes are as follows:

The following tests are conducted on black cotton soil

- Atterberg limits
- Liquid limit
- Plastic limit
- Swelling
- Water content and dry density relations
- CBR.

The following results are obtained by conducting laboratory soil tests and given in the table.3

Table.3 Experimental Values for Black Cotton Soil With Sodium Chloride

Name of The Experiment	**Raw Soil**	**Soil + 2% NaCl**	**Soil + 4% NaCl**	**Soil + 6% NaCl**	**Soil + 8% NaCl**	**Soil + 10% NaCl**
Liquid Limit (%)	45	40	40	39	35	36
Plastic Limit (%)	22	20	18	18	16.5	17
Swelling (%)	45	41	34	31	25.4	28
OMC (%)	24	21.16	19.46	17	16	16.5
Max Dry Density (G/Cc)	16.1	16.4	16.8	17.1	17.6	17.4
CBR Values (Soaked) (%)	1.82	2.13	2.3	2.55	3.1	3.05
Strength{C- Kg/Cm^2}	1	1	1.1	1.4	1.4	1.1
Φ	16^0	17^0	12^0	14^0	18^0	18^0

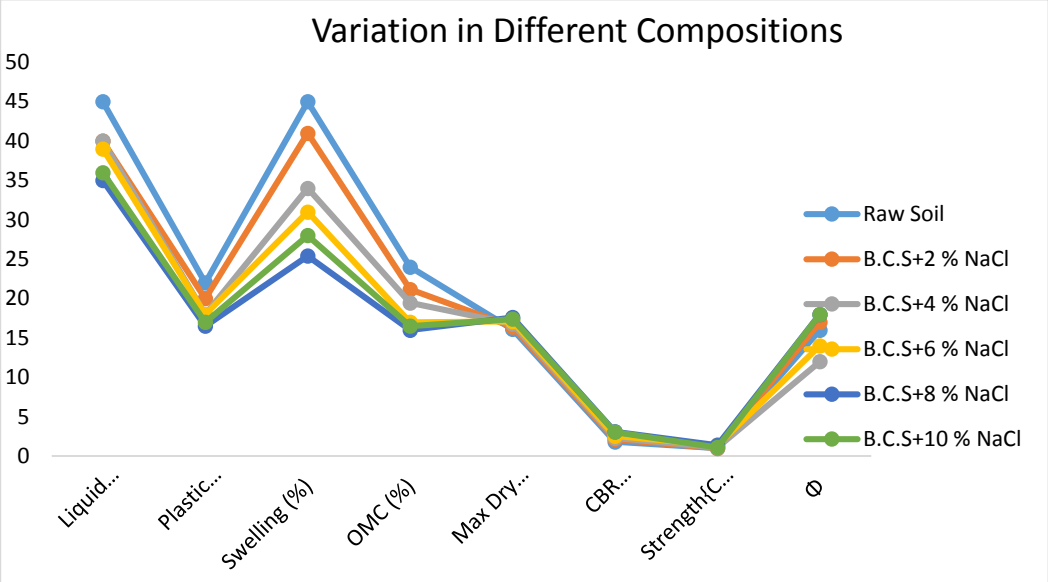

Fig.1 Black Cotton Soil Stabilisation with Calcium Chloride at Different Compositions

V. CONCLUSIONS

- As a percentage of sodium chloride increases liquid limit decreases plastic limit and shrinkage limit increases and plasticity and plasticity index decreases.
- As percentages of sodium chloride increases, OMC increases, MDD decreases for a compaction energy.
- The soil strength parameter CBR increases and the swelling and shrinkage decreases with increases in sodium chloride up to certain extent (5%) and then decreases
- With the increases in the compactive effort, the OMC for maximum strength further reduces.
- For the percentage of sodium chloride 8%, the CBR value is found to be 6.1% which is enough for the construction of pavements.

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