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EFFECT OF CALCIUM EXCHANGE CAPACITY ON THE PROPERTIES OF BLACK COTTON SOIL

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Abstract:
The research work presents the efficacy of Calcium chloride and fly ash as an additive in improving the engineering properties of Black cotton soil which is expansive soil. Calcium chloride of 1%, 2% and 3% were mixed with black cotton soil used in the laboratory experiments. The fly ash percentages of 20% and 30% were used for compare the results obtained with calcium chloride percentages. The effectiveness of the calcium chloride and fly ash tested by conducting unconfined compressive strength and swelling pressure testThe unconfined compressive test has done for curing period of 7, 14, and 28 days to compare the results with 0 days unconfined compressive strength. This study indicates that plasticity index, free swell index, pH, and cation exchange capacity, are decreasing with the addition of flyash and total soluble solids, calcium carbonate content are increasing with the addition of flyash

1.0 Introduction

Many civil engineering structures fail due to failure of soil underlying the structure for e.g. construction of buildings, dam, bridges, etc. Building foundations need to be on stable and strong soils. Expansive soils pose several problems to civil engineers and to geotechnical engineers. Expansive soils such as black cotton soil have the tendency to increase in volume when water is available and to decrease in volume if water is removed. Black cotton soil contains the clay mineral montmorillonite which is responsible for the excessive shrinkage and swelling characteristics of soil. These volume changes in swelling soils are the cause of many problems in structures that come into their contact or constructed out of them. A large part of India is covered with black cotton soil. Black cotton soils are residual deposits formed from basalt. And are highly clayey soils and grayish to blackish in colour.

Black cotton soil:

Expansive soil commonly known as black cotton soil because of their color and their suitability for growing cotton Design and construction of civil engineering structures on and with expansive soil is a challenging task for geotechnical and civil engineers. Expansive soil is considered as most problematic soil as compare to other type of soils .due their behavior of change in

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volume with the variation in moisture content elastic deformation takes place .i.e. cause damage to the structure due swelling in rainy season and shrinkage in summer : building cracks, canal lining slide, beds of canal heave , roads get rutted etc.

Soil:

Soil is normally considered as the fine earthwhich covers land surfaces as a result of the insitu weathering of rock materials or the accumulation of mineral matter transported by water wind, or ice. The distinctive feature of soil is thatto this weathered mineral material is added or-ganic material. This organic material may beboth living and dead. The dead organic matterwill include little altered and freshly added deadplant roots and leaf and other plant litter, deadfauna, and organic material in various stages ofdecomposition from little modified relativelyfresh materials to the complex decomposed material called humus.

Characteristics of soil:

There are three characteristics of soil that are important for plant growth and productivity: physical, biological, and chemical. A change in one characteristic is likely to affect another. Physical The aspects of the soil that you can see and touch. Physical characteristics include: soil texture, soil colour, soil depth, soil structure, porosity (spaces between particles) and stone content. The role physical properties play in soil health are:

- To supply water and air to plant roots and allow adequate water and air movement into and through the soil profile.
- To store water for plant growth.
- To support machine and animal traffic.

The ability to keep clay aggregates chemically stable which impacts on soil structure. Biological The ability to support a healthy microbial population for organic matter breakdown nutrient cycling and the growth of nitrogen fixing bacteria.

Scope of the work:

Calcium chloride is a strong electrolyte and different proportions of calcium chloride is used in the present study and determined behavior of the black cotton soil subjected to wet and dry cycling. The reference solution is used is deionized water

2.0 literature review

Jasbeer Saini (2013)was studied stabilization of expansive soil using calcium chloride. They used different proportions calcium chloride and found out the strength and durability propertied of soil. They were added 0.5, 1,2and 2.5% calcium chloride to the soil and found the consistency limits, unconfined compressive strength and swelling behavior of the soil. **A.V. Narsimha Rao et al. (2014)**due to the contamination of various acids in soils leads to changes of geotechnical properties of soil. Compaction characteristics of the black cotton soil treated with alkali studied and it was found that the density of the soil has improved and optimum moisture content has decreased and also strength propertied of the soil has been improved.

Sujit Kawade, Mahendra Shreedhar Sharanappa(2014) presented combined effect of lime and geo-grid on Black Cotton soil. They conducted test on soil specimen of size (200mm x 100mm

x100mm) reinforced with and without geo-grid. On conducting test it was found that compressive strength increases as lime content increases. Lime and geo-grid has considerably improves the properties of Black Cotton soil.

Chandrasekhar et al. (2001) presented the results of laboratory and field investigations to understand the characteristics of expansive soil with stabilizing agents like sodium silicate and calcium chloride in comparison with RHA-lime stabilization. The RHA-lime stabilization resulted in maximum improvement in strength compared to other treatments.

3.0 materials and methodology

Soil is the essential component of this nature and road development industry knows the significance of it for pavement work. India is confronted with the colossal test of protecting and upgrading the transportation framework to meet the constantly expanding hassles because of heavier burdens delivering layers to the hidden soil. Roads running through expansive soil regions are subjected to severe distress resulting in poor performance and increased maintenance cost. An imperative step is being taken by this study to accomplish monetary utilization of development materials by endeavoring to keep the wastage of soil material through the change of its properties to meet the prerequisites of pavement configuration from its planned utilization.

Black Cottonsoil

Soil used in the experiments has been collected from a village near located in Ujjain. The soil is classified as highly compressible clay, CH, as per IS: 1498 (1970). In the present research, expansive black cotton soil obtained from the geologist, The black cotton soil was obtained after removing 0.5 m depth top soil by the method of disturbed sampling and transported in sacks to the laboratory. The sample is carefully transported to the laboratory without losing the moisture content to determine moisture content of the soil. The soil is dried and grinded to 4.75 mm sieve to carry out laboratory experiments. The various geotechnical properties shown below

Calcium Chloride:

The calcium chloride for this present investigation bought from the Rourkela chemical shop.it has molecular weight 110.47 grams. It is in white crystalline powder form. And also observed that when it is mixed with water it generated heat and also water looks like densified liquid. In the present investigation different proportions of calcium chloride mixed with water and found out the behavior of the soil. Normally expansive soil swells due to the formation of double layer of water in the soil, when we mix with calcium chloride to the soil, it has high affinity to take cation exchange compared with the water.

Fly ash:

Fly ash is a byproduct from the thermal coal power plants. It is waste material formed due to the combustion of bituminous coal. It is separated from the outlets by the electrostatic precipitators before the flue gases reach the chimneys of coal fired power plants. Normally the fly ash removed with the bottom ash from the bottom of the furnace jointly known as coal ash.

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Figure: fly ash

To evaluate the effect of soil/calcium ration and soil/fly ash ratio of swelling pressure and mechanical strength. Three different types of calcium chloride and two different fly ash ratios were used. The calcium ratios were 1%, 2% and 3% and two different proportions of fly ash uses in the present study. The soil and fly ash were mixed thoroughly before the experimental programs conducted. All the tests were conducted according to the IS code method. The following experiments were conducted in the laboratory.

Plastic Limit:

The plastic limit is defined as the water content at which soil crumble into the 4.5mm threads. The plastic limit is the lower water content of plastic stage. The plastic limit test is easy to determine and is determined by continuous rollings of soil mass by hand on a ground glass plat. The procedure for plastic limit was followed according to ASTM. to determine the maximum dry density of the soil. In this method first weight the empty mould of base plate attach collar to the plate. Then apply thin layer of grease to the mould. Then take 2.4 kg of the soil and add the water up to 10% of the weight of the soil, Then mix the soil thoroughly. Keep the soil under covered 20 to 30 seconds to allow the soil for full maturation.

Figure Sample preparation for proctor test

Procedure

The mixed sample was placed in previously weighted mould (m1 kg) of capacity 1000cc in three layers. Each layer was given 25 blows with a 2.6 kg rammer with free fall of height 310mm.After compacting three successive layers collars was removed and excess soil was trimmed off. The weight of mould with soil was taken (m2 kg). This process was repeated for other water content also until there was a decrease in m2 value. For each trial a portion of soil was taken for moisture content determination.

Table: UCS at different percentage of calcium chloride

NO cycles	BCS	BCS+1%$CaCl_2$	BCS+2%$CaCl_2$	BCS+3%$CaCl_2$	BCS+20%FA	BCS+30%FA
0	26.58	27.25	29.21	30.59	28.46	29.31
1	26.98	28.69	30.42	30.79	27.78	30.95
2	27.54	31.05	32.8	34.29	28.99	30.88
3	27.25	32.72	34.55	36.38	29.1	31.48
4	27.25	35.07	37.74	39.52	29.47	31.67
5	27.37	37.43	41.05	42.69	29.73	31.93

Apparatus used

Strain controlled tri-axial test was used to conduct unconfined compression tests to determine shear strength and deformation

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characteristics of untreated soil and soil treated with different dosages of Terrasil. For conduction of unconfined compression test, tri-axial cell is not filled with water so that there is no confining pressure, axial stress applied to fail the specimen. Following apparatus required for determining unconfined compressive strength:

Strain controlled tri-axial test apparatusStrain controlled mechanism consisting of strain setting lever and turret lever for inducing axial strains in the sample at rates varying from0 .02mm/min to 1.00mm/min.

For measurement of compressive stress taken by the sample, 250 kg capacity proving ring with proving ring coefficient of 0.15 kg/division.

1. Load gauge installed in proving ring with a least count of 0.002mm.
2. For measurement of vertical deflection in the sample, dial gauge with a least count of 0.01mm.

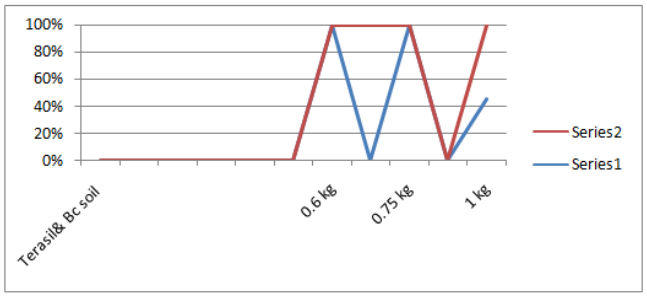
The remolded sample was placed on the pedestal of triaxial cell with non- pervious disc at top and bottom. A loading plate was placed at top which was connected through loading piston to the proving ring. The sample arrangement was brought in contact on deformation dial gauge. The axial strain was chosen as 1.00mm/min by appropriate setting of turret lever and strain setting lever. The compressive stress taken by the sample was recorded at various strain levels. At failure, peak compressive stress was noted as unconfined compressive strength and failure strain was recorded.

4.0 RESULTS

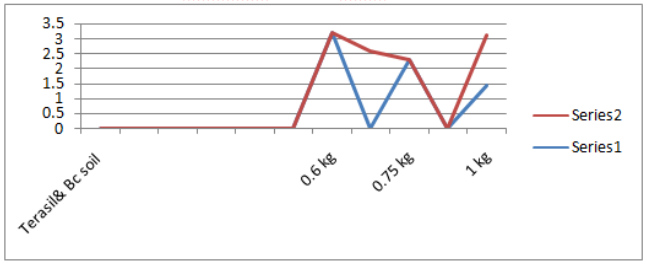
The objective of the present study is to investigate the strength characteristics of Black cotton soil treated with different dosages of Terrasil. This has been done to make the black cotton soil suitable for the construction of structure and safeguard the structures form the hazards of expansive soil. Shear strength of soil treated with different dosages of chemical is analyzed by unconfined compression tests. A series of unconfined compressive strength test is carried out after air curing of 7 days of sample preparation to study the effect of Terrasil on strength properties with passage of time. The results of these tests have been analyzed under following heading.

Table: Summary of Test results pertaining to Clay stabilised with TS and Bc Soil

Terasil&Bc soil	CBR Test Results			
	Unsoaked	Soaked7days	Soaked 14days	Soaked 28days
0.6 kg	6.31	3.2	3.4	3.72
0.75 kg	6.13	2.31	2.57	2.83
1 kg	5.51	1.42	1.68	1.94



Graph: Terasil&Bc soil un soked result variations



Graph: clay stabilized with TS and BC soil in 7 days soaked condition

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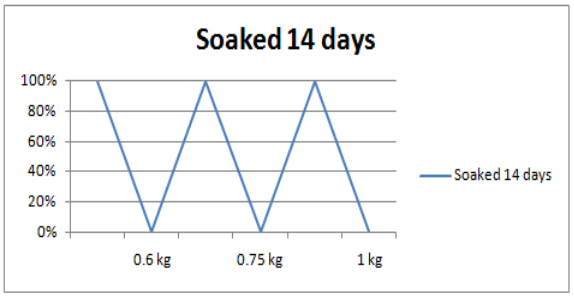
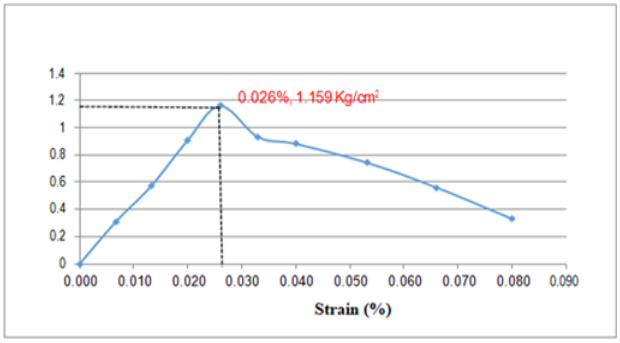
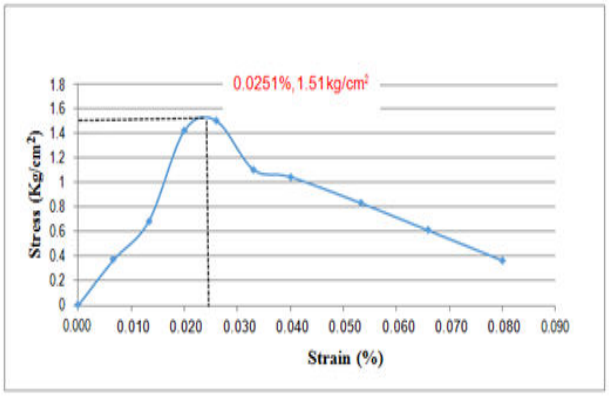


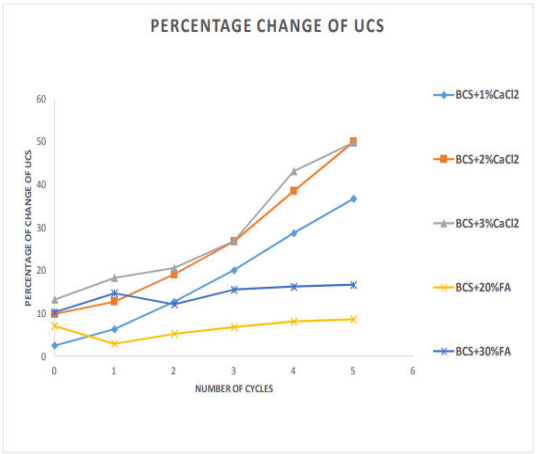
Graph: clay stabilized with TS and BC soil in 14 days soaked condition

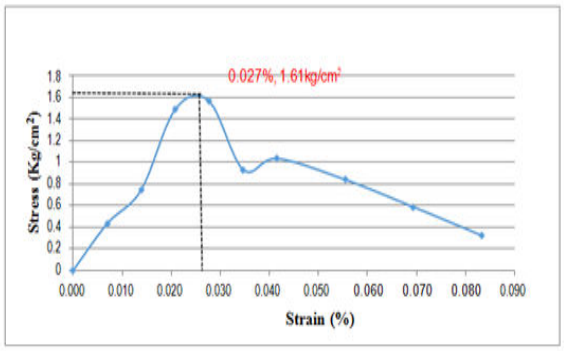


Test results of UCS test for soil treated with CALCIUM

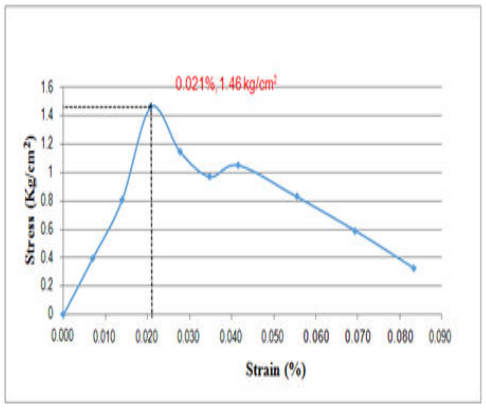


Test results of UCS test for soil treated with CALCIUM 10%





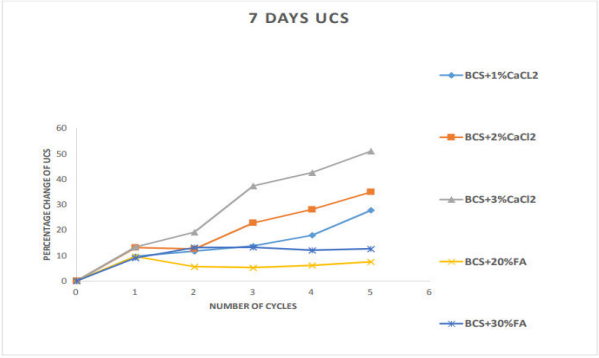
Test results of UCS test for soil treated with CALCIUM 20%



Test results of UCS test for soil treated with CALCIUM 30%

Graph: different proportions of calcium chloride and black cotton soil at 0 days

Above graph is drawn for the percentage of change of UCS with number of wet and dry cycles. It has been observed that with increase of wet and dry cycles the percentage of change of unconfined compressive strength has increased



Graph: different proportions of calcium chloride and black cotton soil at 7 days

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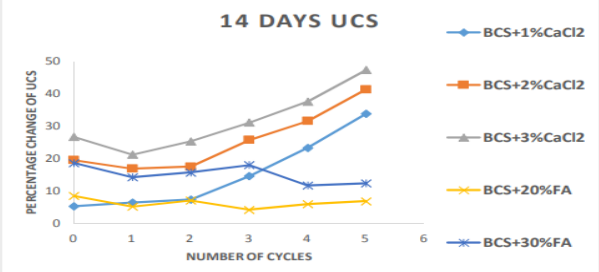
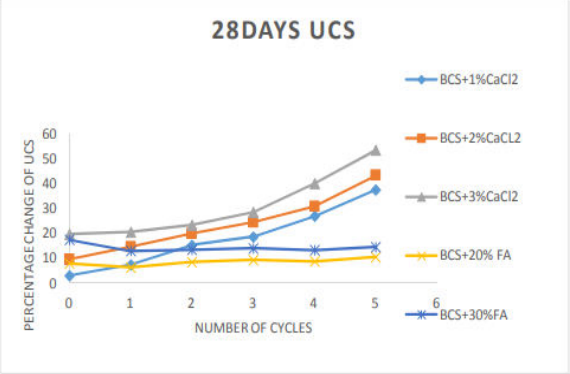
Percentage of change of unconfined compressive strength has been drawn for number of wet and dry cycles. It has been observed that as the number of wet and dry cycled increases 7 days strength of UCS Increases. When the black cotton soil mixed with fly ash the change percentage of unconfined compressive strength constant



Graph: different proportions of calcium chloride and black cotton soil at 14 days



Graph: different proportions of calcium chloride and black cotton soil at 28 days

Black cotton soil is spread in various part of world including India and has highly expansive nature due to the presence of montmorillonite clay mineral. The presence of montmorillonite in Black Cotton soil imparts high moisture content, low shrinkage limit & high optimum moisture content to it, thus these soil get very hard when dry but lose strength completely when gets wet. Soil stabilization is the alteration of properties of a soil to improve its response to engineering problems, like improvement in bearing capacity, stability, shear strength, swelling characteristics, shrinkage property. There are various forms of soil stabilization, commonly the conventional soil stabilization are achieved by chemical and mechanical stabilization techniques. The additives used for stabilization are termed as stabilizers. Many stabilizers such as fly ash, bitumen, lime, cement, and various chemicals are used for stabilization

Conclusions:

Based on the experimental study and analysis of results following conclusions are made.

- Liquid limit of the soil decreases with change of calcium chloride percentage. Thus with increase in calcium chloride Cation exchange of the soil increases
- Liquid limit also decreases with number of wet and dry cycles so we can conclude full cation exchange capacity does not takes place instantly after adding to the soil.
- Plastic limit of the soil increases with change of calcium chloride percentage so we can conclude that plasticity index of the soil decreases, so the swelling characteristics also decrease.
- UCS value of the soil increases with increases of calcium chloride. The UCS results of 3% CaCl2 and black cotton soil slightly above the results of 2% CaCl2 and black cotton soil. So economically 2% calcium chloride has been recommended for stabilization of soil.

- UCS values increases with increase of number of days of curing. And also increases with increases of wet and dry cycles.
- The swelling pressure value of the soil decreases with increases of calcium chloride. The swelling pressure results of 3% CaCl2 and black cotton soil slightly lower than the results of 2% CaCl2 and black cotton soil So economically 2% calcium chloride has been recommended for stabilization of soil

Future scope:

To obtain less cost material for the cation exchange in the place of calcium chloride.

- Field application of this method by the suitable technology
- Use of other chemical their effect on the cation exchange of the black cotton soil.
- Application of this calcium chloride for other highly expansive soil materials

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