Combined Influence of Alccofine And Calcium Chloride In Improving Problematic Expansive Soils

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Abstract- *Expansive soils, also termed as swelling soils or shrink-swell soils pose a major challenge to civil engineers all over the world as they cause severe distress to structures constructed on them. In India, these soils are also called as Black soils or Black cotton soils. Soil stabilization involves addition of a binder to improve mechanical and chemical properties of the soil. Stabilization of expansive soils has been successfully done with various chemicals. Calcium chloride is a hygroscopic material and absorbs water. Chemical stabilization is a technique commonly used to improve the expansive soil properties. In this regard, an attempt has been made to evaluate the influence of Calcium Chloride (CaCl2) stabilizer on the engineering properties of expansive soil. The present study is to elucidate and efficacy of materials as an additive in improving the engineering characteristics of expansive soils. An experimental program has evaluated the effects of alccofine-1203 (3%, 6% and 9%) and Cacl2 (0.25%, 0.5%, and 1.0%) contents on the FSI, plasticity, compaction and strength characteristics of expansive soil. Both admixtures were added independently and blended to the Expansive soil.*

Keywords- Clayey soil, Calcium Chloride (CaCl2), alccofine-1203, plasticity, compaction and strength characteristics

I. INTRODUCTION

Expansive soil deposits occur in the arid and semi-arid regions of the world and are problematic to engineering structures because of their tendency to heave during wet season and shrink during dry season (Mishra et al. 2008). Expansive soils are a worldwide problem that poses several challenges for civil engineers. They are considered a potential natural hazard, which can cause extensive damage to structures if not adequately treated (Al-Rawas, 2002). Expansive soils causes more damage to structures, particularly light buildings and pavements, than any other natural hazard, including earthquakes and floods (Jones and Holtz, 1973). During the last few decades damage due to swelling action hasbeen observed clearly in the semi-arid regions in the form of cracking and breakup of pavements, roadways, building foundations, slab-on-grade members, and channel and reservoir linings, irrigation systems, water lines, and sewer lines (Çokça, 2001).

For centuries mankind was wondering at the instability of earth materials, especially expansive soil. One day they are dry and hard, and the next day wet and soft. Swelling soil always create problem for lightly loaded structure, by consolidating under load and by changing volumetrically along with seasonal moisture variation. As a result the superstructures usually counter excessive settlement and differential movements, resulting in damage to foundation systems, structural elements and architectural features. In a significant number of cases the structure becomes unstable or uninhabitable. Even when efforts are made to improve swelling soil, the lack of appropriate technology sometimes results volumetric change that are responsible for billion dollars damage each year.

Soil is the collection of natural bodies on earth's surface containing living matter and supporting, or capable of supporting plants. Its upper limit is the atmosphere (air) or water, and at its lateral margins it grades to deep water or barren areas of rock and ice. Its lower limit is normally considered to be the lower limit of the common rooting zone (root zone) of the native perennial plants, a boundary that is shallow in the deserts and tundra and deep in the humid tropics. Soil itself is very complex. It would be very wrong to think of soils as just a collection of fine mineral particles. Soil also contains air, water, dead organic matter, and various types of living organisms. The formation of a soil is influenced by organisms, climate, topography, parent material, and time.

Various remedial measures like soil admixture, moisture control, pre-wetting, lime stabilization have been practiced with varying degrees of success. However, these techniques suffer from certain limitations with respect to their adaptability, like longer time periods required for pre-wetting the highly plastic clays, difficulty in constructing the ideal moisture barriers, pulverization and mixing problems in case of lime stabilization and high cost for hauling suitable refill material for soil admixture etc.

Stabilization of expansive soils is an alternative for geotechnical engineers considering the economics of construction with expansive clay soils. Mechanical stabilization, such as compaction, is an option; however many engineers have found it necessary to alter the physicochemical properties of clay soils in order to permanently stabilize them.
In India, an industrial product alccofine material is manufactured by ambuja cement private limited. The majority of this material is utilized in the high performance concrete structures either as a cement replacement or as an additive to improve concrete properties in both fresh and hardened states and soil stabilization purpose while Cacl2 is mainly used to reduce the swelling and increase the shear strength of expansive soil for soil stabilization.

1.2 OBJECTIVES OF THE STUDY

The purpose of this study is to investigate the influence of inclusion of alccofine in conjunction with Calcium chloride (Cacl2) in the stabilization of expansive soils. The main reason for their underutilization is the lack of pozzolanic reactivity .Alccofine is ultrafine ground granulated blast furnace slag (UFGGBS), performs a superior than all other mineral admixtures used in India. It is a micro fine material of particles size (Range 0- 17microns) much finer than other hydraulic materials like cement, lime, fly ash. On the other hand, Cacl2 is the hygroscopic material and hence is pre-eminently suited for stabilization of expansive soils, because it absorbs water from the atmosphere and prevents shrinkage cracks occurring in expansive soils during summer season. The combination of the two materials can be more beneficial when used as a stabilizing agent then using them individual. However, no studies on the joint activation of alccofine and Cacl2 as stabilizing agents for expansive soils have been published to date. An attempt has been made in this study is to utilize mixture of alccofine and Cacl2 as binder to stabilize expansive soil.

II. LITERATUREREVIEW

2.1 PREVIOUS RESEARCH PAPERS AND CONCLUSIONS

Soil stabilization is a procedure where we improve engineering properties of soil with the use of natural or synthesized admixtures. In the past many researchers have carried out their research work for improving the strength of black cotton soil using different types of admixture at different percentages. A brief review of previous studies on black cotton soil is presented in this section and past efforts most closely related to the needs of present work.

Expansive soils pose the greatest hazards that many geotechnical engineers face. Such soils may cause heavy damages in light loaded structures such as water canals, reservoirs, highways, railways and airport runways etc., unless appropriate measures are taken. Various stabilization techniques are in practice for improving expansive soils by reducing its swelling potential and increasing its strength characteristics. Modification of expansive soil by chemical admixture is a common practice for stabilizing the swell-shrink tendency of expansive soil. Advantages of chemical stabilization are that they reduce the swell-shrink tendency of expansive soils and also render the soils less plastic. In this section, the experiences of various investigators concerning chemical stabilization using calcium chloride have been reviewed.

Numerous investigators, have studied the influence of lime, cement, lime-cement, lime-fly ash, and cement–fly ash mixes on soil properties, mostly focusing on the strength and swelling aspects. Among the chemical stabilization methods for expansive soils, lime stabilization is mostly adopted for improving the swell-shrink characteristics of expansive soils. As lime and cement are binding materials, the strength of soil-additive mixtures increases provided the soil is reactive with them. However, for large-scale field use, the problems of soil pulverization and mixing of additives with soil have been reported by several investigators. Calcium chloride is an inorganic salt, which is a by-product of sodium carbonates. The use of calcium chloride in place of lime, as calcium chloride is more easily made into calcium charged supernatant than lime. A recent study indicated that CaCl2 could be an effective alternative to conventional lime used due to its ready dissolvability in water and to supply adequate calcium ions for exchange reactions. Calcium chloride is known to be more easily made into calcium charged supernatant than lime and helps in ready cation exchange reactions. CaCl2 might be effective in soils with expanding lattice clays. The bibliography on stabilization of soil and calcium chloride is giving its wide use in highways.

Hausmann and Shepardhave stated that CaCl2 enjoyed its wide use as dust palliative and frost control of subgrade soil. Calcium chloride has hygroscopic property. This means that calcium chloride attracts and absorbs water. This is a function of relative humidity and temperature. It can easily liquefy in moisture of its own absorption.

Shepard reported that calcium chloride is highly soluble and can be dissolved easily so it can be easily washed away by rain and more than one treatment in a single season may be required to maintain its effectiveness. For the same humidity and temperature, the vapor pressure of calcium chloride is lower than water. Calcium chloride has a higher surface tension and a lower freezing point compared to water.

Shon et al. reported that treatment of soil with calcium chloride increases the density and strength of the compacted soil. They found that calcium chloride increases the surface tension of the retained moisture within the soil matrix, thus increasing the suction pressure of the system. This, in turn, increases the cohesive energy between the particles which result in greater strength.

M Muthu Kumar (2015) studied by waste marble dust which is the byproduct of marble industry, is used for the soil stabilization. Utilization of waste marble powder may reduce the disposal problem and preserve the ecological system. Use the marble powder is used to improve the Engineering property of expansive soil, thus making it more stable and also to stabilize the soil with a very low cost material. The marble powder has very high lime (CaO) content and is reported Many researchers. We have added the marble powder to the expansive soil as 5%, 10% 15%, 20%, 25% and studied the compaction characteristics and strength characteristics. The maximum unconfined compressive strength of the clay is 215kN/m2 at 15% of marble powder. The Marble Powder is added about 15% to the soil as strength. The expansive soil was modified in to low plasticity and silt behavior.

Monica Malhotra (2013) studied by Expansive soils always create problems more for lightly loaded structures than moderately loaded structures. By consolidating under load and changing volumetrically along with seasonal moisture variation, these problems are manifested through swelling, shrinkage and unequal settlement. From the results it is clear that a change of the expansive soil texture takes place. When lime & fly ash are mixed with the expansive soil, the Plastic limit increases by mixing lime and liquid limit decreases by mixing fly ash, which decreases plasticity index. As the amount of fly ash & lime increases there is apparent reduction in modified dry density & free swell index and increase in optimum moisture content. It can be concluded that the mixing lime & fly ash in specific proportion with the expansive soil is an effective way to tackle the problem of shrinkage, swelling and unequal settlement

kshaya Kumar Sabat studied the effect of polypropylene fiber on engineering properties of rice husk ash –lime stabilized expansive soil. He concluded that the addition of Rice Husk and Lime decreases the MDD and increases the OMC of the expansive soil.MDD goes on decreasing and OMC goes increasing with increase in percentage of polypropylene fiber in the rice husk ash –lime stabilized expansive soil. Addition of rice husk ash and lime increases the UCS and soaked CBR of the expansive soil with the addition of polypropylene fiber.

2.2 STABILIZATION

Using rice husk ash, flyash have been more attractive recently due to its promising results compared to other sources. Overview about the methods and the basis of application will be presented in this section. Soil stabilization is the process of improving engineering properties of the soil and thus making it more stable. Soil stabilization means the improvement of the stability or bearing power of the soil by the controlled compaction; proportioning and/or addition of suitable admixture or stabilizers. Soil stabilization is the alteration of soil to enhance their physical properties.

METHODS OF SOIL STABILIZATION

- Mechanical Stabilization.
- Soil Cement Stabilization.
- Soil Lime Stabilization.
- Soil Bitumen Stabilization.
- Thermal Stabilization.
- Chemical Stabilization.

III. METHODOLOGY

The methodology of this project is carried out by collection of brown clayey soil sample from proposed area and various tests on soil have been performed as per IS(2720) on expansive soil with proportion of Calcium Chloride ($CaCl_2$), alccofine-1203. Based on test reports various discussions have been present as per the strength variations criteria.

The various physical properties of soil were assessed using methods below given in different parts of Indian standards (IS 2720). The specific gravity, grain size analysis, atterberg limits and shrinkage limits were derived as per the methods given in IS 2720: part 3(1980), IS 2720: part (1980), IS 2720: part 5(1980),IS 2720: part 6(1972) respectively. Compaction test as per IS 2720: part 7(1980) was performed to determine optimum moisture content and maximum dry density of the soil specimen.

In this chapter, a brief description of the experimental procedures adopted in this investigation and the methodology adopted during the course of study are briefly presented.

MATERIALS USED AND THEIR PROPERTIES

3.1 SOIL

For conducting the study, soil samples were collected from Komarigiripatnam (Odalarevu) in East Godavari District, A.P. The soil excavated from below 3ft depth. The soil sample is free from plant roots and stone pieces and rubbles. The sample is first spread on a flat surface. If more than 50% of the particles are visible to the naked eye, the soil is coarse grained otherwise it is fine grained.The fine grained particles are smaller than 75micron size and are not visible to naked eye.

Table 5.1 Properties of expansive soil

Properties of Expansive Soil		
S. No.	**Property**	**Value**
1	Specific gravity	2.63
2	Differential free swell Index (%)	100
3	Atterberg's Limits	
	i) Liquid limit (%)	57.2
	ii) Plastic limit (%)	34.5
	iii) Plasticity index (%)	22.7
5	Grain Size Distribution	
	i) Sand Size Particles (%)	7
	ii) Silt & Clay Size Particles (%)	41&52
6	IS soil classification	CH
7	Compaction Parameters	
	i) Max. Dry Density (kN/m3)	15.02
	ii) Optimum Moisture Content (%)	18.19
9	Unconfined compressive strength	138

3.2 ALCCOFINE

Alccofine is ultrafine ground granulated blast furnace slag (UFGGBS), performs a superior than all other mineral admixtures used in India. Manufactured by Ambuja cement private limited in India.

Physical properties

Particle size Distribution

D10	1.5
D50	4.3
D90	9.0
Specific gravity (g/cc)	2.88
Bulk density (kg/m3)	680

Chemical properties

SiO2	35.6%
Al2O3	21.4%
Fe2O3	1.3%
CaO	33.6%
SO3	0.12%
MgO	7.98%

3.3 CACL2

The chemical composition of Calcium chloride is Cacl2. It is a hygroscopic material it also absorbs water from the air and releases heat when it is dissolved in water..

IV. LABORATORY EXPERIMENTATION

The soil was initially air dried prior to the testing. The tests were conducted in the laboratory on the marine clay to find the properties of virgin marineclay.

- Grain size distribution
- Specific gravity
- Index properties –liquid limit, plastic limit
- Compaction tests
- Penetration tests-California bearing ratio test.
- Unconfined Compression Test-Triaxial

V. RESULTS AND DISCUSSIONS

5.1GENERAL

In the laboratory, various experiments were conducted by adding different percentages of Alccofine in the expansive soil and also further stabilizing it with CACL2 as a binder. Compaction, Strength and CBR tests were conducted with a view to determine the optimum combination of Alccofine and $CACL_2$ as admixtures in expansive soil.

Different tests can be used to characterize the index and engineering properties of stabilized soils. The present study focuses on evaluating the physical properties, compaction, strength behaviour. Experimental Investigations have been carried out on expansive soil with the addition of varying percentages of calcium chloride (0.25%, 0.50% and 1.0%) and alccofine (3%, 6% and 9%). The specific gravity, Atterberg limits, compaction, unconfined compressive strength (UCS), consolidation and swelling characteristics of clay soil sample was determined according to the Indian Standards.

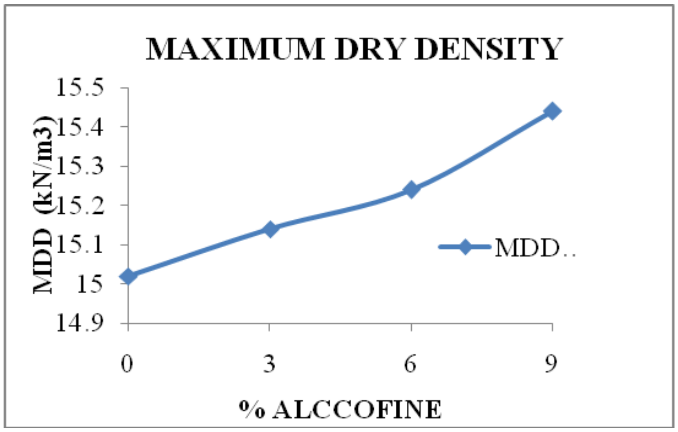

Fig.5.1 Variation of maximum dry density with % of Alccofine as addition of expansive soil for 0% Cacl2.

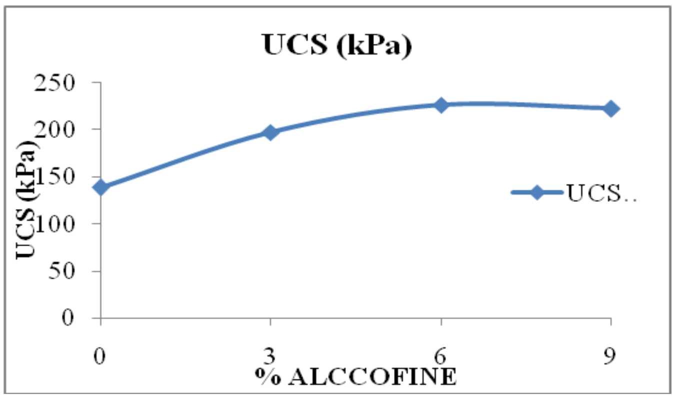

Fig.5.2 Variation of UCS Values with % of Alccofine as addition of expansive soil for 0% Cacl2.

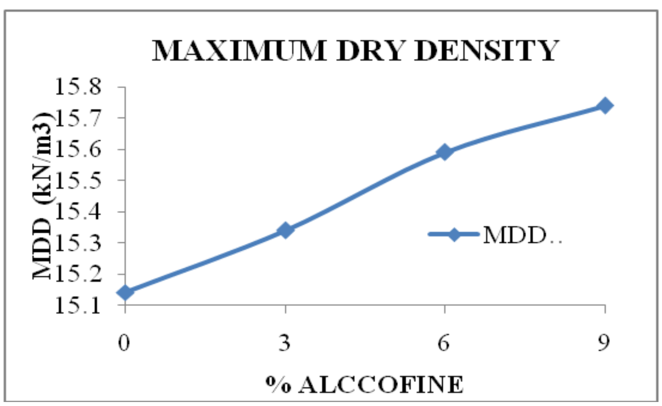

Fig.5.3 Variation of maximum dry density with % of Alccofine as addition of expansive soil for 0.25% Cacl2.

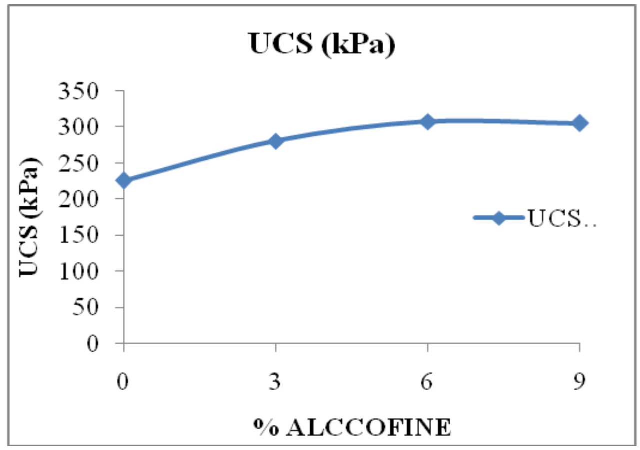

Fig.5.4 Variation of UCS Values with % of Alccofine as addition of expansive soil for 0.25% Cacl2.

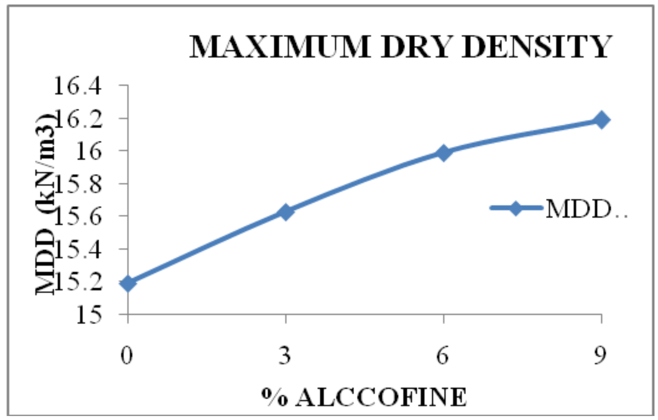

Fig.5.5 Variation of maximum dry density with % of Alccofine as addition of expansive soil for 0.5% Cacl2.

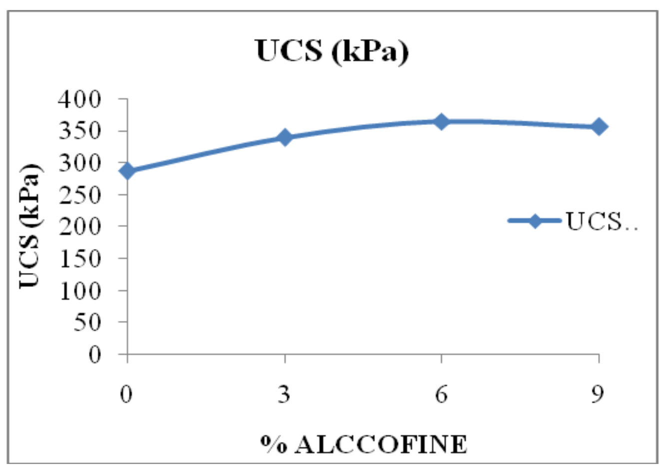

Fig.5.6 Variation of UCS Values with % of Alccofine as addition of expansive soil for 0.5% Cacl2

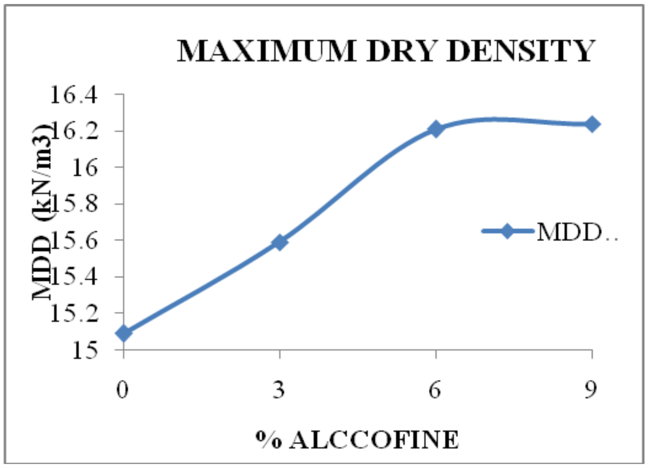

Fig.5.7 Variation of maximum dry density with % of Alccofine as addition of expansive soil for 1% Cacl2.

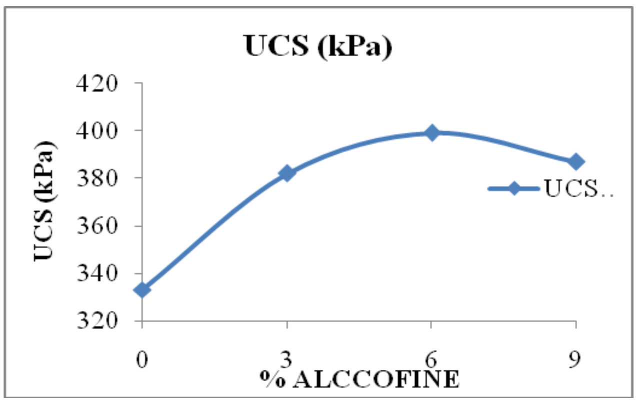

Fig.5.8 Variation of UCS Values with % of Alccofine as addition of expansive soil for 1% Cacl2.

5.2 EFFECT OF ALCCOFINE AND $CACL_2$ ON THE ATTERBERGS LIMIT VALUES OF EXPANSIVE SOIL

Table 6.1, 6.2, 6.3 and 6.4 Figures 6.1, 6.2, 6.6, 6.7, 6.16 and 6.17, shows the variation of Atterbergs limit values for admixture of Alccofine and Cacl2 respectively. The percentage of Alccofine was varied from 0% to 9% with an increment of 3% and $Cacl_2$ was varied from 0% to 1%. All these materials showed an improvement in plasticity characteristics. For all increase in % of admixture of alccofine in virgin soil a good improvement i.e. decrease in Plasticity Index.

5.3 EFFECT OF % ALCCOFINE AS ADMIXTURE AND $CACL_2$ AS AN ADDITIVE ON THE COMPACTION PROPERTIES OF EXPANSIVE SOIL

Table 6.1, 6.2, 6.3 and 6.4 Figures 6.3, 6.4, 6.13, 6.14, 6.18 and 6.19 shows the variation of Compaction properties for admixture of Alccofine and $Cacl_2$ respectively. The percentage of Alccofine was varied from 0% to 9% with an increment of 3%. From the optimum percentage of alccofine percentage addition of $CACL_2$ was varied from 0% to 1%. From the graphs, it was observed that the treatment as individually with 6% alccofine has moderately improved the expansive soil.

The compaction characteristics of untreated and treated soils are shown in Table 6.1, 6.2, 6.3 and 6.4. The results of compaction show that the MDD is increases from 15.02 kN/m3 to 16.24 kN/m3 and optimum moisture content is reduce from 18.19% to 16.24% with increase of 6% alccofine and 1% $Cacl_2$ binder; that is, for sample which shows maximum strength.

5.4 EFFECT OF % ALCCOFINE AS ADMIXTURE AND $CACL_2$ AS AN ADDITIVE ON THE STRENGTH PARAMETERS OF EXPANSIVE SOIL

Table 6.1, 6.2, 6.3 and 6.4 and Figures 6.5, 6.10, 6.15, 6.20 shows the variation of UCS Values for admixture of alccofine and $CACL_2$ respectively. The percentage of Alccofine was varied from 0% to 9% with an increment of 3%. From the optimum percentage of alccofine percentage addition of $Cacl_2$ was varied from 0% to 1%. From the graphs, it was observed that the treatment as individually with 6% alccofine has moderately improved the expansive soil.

Unconfined compressive strength (UCS) tests were conducted with alccofine-1203 and Cacl2 were added independently and blended to the expansive soil samples. UCS test were performed on both intrinsic soil and chemically treated soil. The UCS value for intrinsic soil is 138 kPa. The percentage of alccofine (3, 6 and 9%) and Cacl2 (0.25, 0.5 and 1.0%) were added by dry weight of the soil. The UCS values are shown in Table no. 3. Optimum increase was noticed at 6% alccofine and 1% $Cacl_2$. The UCS strength was increase from 138 kPa to 399 kPa. Beyond 6% of Alccofine with 1% $Cacl_2$ resulted in a slight decreased in UCS values.

Finally from the above discussions, from the above results the Optimum Content of 1.0% $Cacl_2$ + 6% Alccofine as admixture of Expansive Soil. It is clear that there is improvement in the behavior of Expansive soil stabilized with 1.0% $cacl_2$ + 6% alccofine .It is evident that the addition of Alccofine to the virgin Expansive soil showed an improvement in Compaction and Strength characteristics to some extent and on addition of $CACL_2$ shows a prominent results.

This made the problematic expansive soil which if not stabilized is a discarded material, a useful fill material with better properties. The Alccofine admixture in the expansive soil has improved its strength, the strength has further improved and also these materials has imparted friction to the clayey soil. It can be summarized that the materials Alccofine, $CACL_2$ had shown promising influence on the Strength and Penetration properties of expansive soil.

VI. CONCLUSIONS

The following conclusions are made based on the laboratory experiments carried out in this investigation. In this study, based on the laboratory investigation, a series of test were performed to study the effect of alccofine-1203 and Cacl2 on the swelling properties and strength behaviour of soils. Based on the results presented in this paper, the following conclusions are made:

- From the laboratory studies, it is observed that the Expansive Soil chosen was a problematic soil having high swelling, and high plasticity characteristics.
- It was observed that expansive soil treated with Alccofine has moderately improved the expansive soil.
- The addition of alccofine-1203 and Cacl2 to the soil decreased liquid limit and plasticity index while increasing the shrinkage limit. The optimum moisture content (OMC) was found to decrease while the maximum dry dendity (MDD) increased with increasing with binding content.
- Unconfined compressive strength (UCS) tests were conducted with Alccofine and Cacl2 were added independently and blended to the expansive soil samples. The UCS value for intrinsic soil is 138 kPa. Optimum increase was noticed at 6% alccofine and 1% Cacl2. The UCS strength was increase from 138 kPa to 399 kPa. Beyond 6% of alccofine with 1% Cacl2 resulted in a slight decreased in UCS values.
- The results presented that the type and amount of additives play a crucial role in the stabilization process. It is immensely important to select the additive based on different properties, and there chemical composition is the most important among these properties.
- Based on the favourable results obtained, it can be concluded that the expansive soil with alccofine and Cacl2 can be considered as an effective cohesive non-swelling soil (CNS) for pavements, sidewalks, and floorings.

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