EXPERIMENTAL STUDIES ON INFLUENCE OF ALCCOFINE AND CALCIUM CHLORIDE ON GEOTECHNICAL PROPERTIES OF EXPANSIVE SOIL

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Abstract. Expansive soil deposits occur in the arid and semi-arid regions in the world. They covers a major portion on the geographical area in the world and about one fifth the area of India (approximately 3,00,000 sq km), such soils are popularly perceived as black cotton soils and found extensively in Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra and Tamil Nadu. 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 $Cacl_2$(0.25%, 0.5%, and 1.0%) contents on the FSI, swelling potential, swell pressure, plasticity, compaction, strength, hydraulic conductivity, SEM, XRD, Cation Exchange Capacity(CEC), characteristics of expansive soil. Both admixtures were added independently and blended to the expansive soil. Mixing of both admixtures in to expansive soil results shown that plasticity index, hydraulic conductivity, swelling properties of blends decreased and dry unit weight and unconfined compressive strength is increased in combination of soil+ 6% of alccofine-1203 + 1% $Cacl_2$, but further more addition of alccofine-1203 and $Cacl_2$ leads to decrease in the unconfined compressive strength. It was found that the optimum quantity of material for favorable combination of soil + 6% of alccofine-1203 + 1% $Cacl_2$ was taken for further study in view of its economy due to lower $Cacl_2$ content.

Key words: Expansive soil; Alccofine-1203; Calcium chloride; CEC.

1.0 INTRODUCTION

Expansive soils are known worldwide for their volume change behaviour due to moisture fluctuation because of their intrinsic mineralogical behaviour [1]. These types of soils are found mainly in the arid and semi-arid region [2] such as Australia, Canada, China, India, South Africa, and the United states. In India has extensive track of expansive soils known as black cotton soil covers about twenty percentage of the total land area [3]. Due to its black colour which is a result of high iron and magnesium minerals acquire from basalt [4]. Expansive soils are clayey soils are extensive specific surface area and high cation exchange capacity [5, 6]. Expansive soil contains clayey minerals such as montmorillonite which increases in volume during wetting. This change in volume can exert sufficient stress on a building, side walk, driveways, basement floors, pipelines, and foundations to cause damages. Since the expansive soils are found worldwide, the challenges to the civil engineers in one felt around the globe. If not adequately treated, expansive soils may act as a natural hazards resulting in several damages to structures [7&8]. The annual cost of damages to the civil engineering structures is estimated as 150 million in the U.S and many billions of dollars worldwide [9]. Under the moisture ingress and digress, a building founded on expansive soil undergo differential movements caused by alternate swell/shrink behaviour of soil causing several structural damages. Many reported data are available on the heave profile of soil at the surface, at various depths from the ground surface, and on covered areas [2, 10, 11] it is generally observed that the amplitude of soil movement decreases with depth and there is an increase in time lag with movement at depth compared with that at the surface. To date, distress problems related to this type of soils is quite immense have ensue in the loss of billions of dollars in repairs and rehabilitation [12].

Various innovative techniques such as special foundations that include belled piers, drilled piers, friction piles and moisture barriers have been developed to mitigate the problem posed by the expansive soils [13]. Apart from this techniques stabilization of expansive soils with various additive including flyash, lime, cement, calcium chloride, has also met with considerable success [14-16]. Physic-chemical mechanism of the lime treatment of soil are well established [17] four mechanisms [cation exchange, flocculation, carbonation, pozzolanic reactions] are generally associated with the modification and stabilization of lime treated soils. Further, there has been an increased in the awareness of environmental and ecosystem degradation due to huge production and storage of waste materials is also initiated to stabilize problematic soil, alone or in combination with lime, effectively and economically [18-25]. It has been felt by researchers that strong electrolytes such as potassium chloride, magnesium chloride, zinc chloride, sodium hydroxide, ferric chloride and calcium chloride could be tried instead of lime [26-30] strong electrolytes are readily soluble in water and hence could supply adequate cations for exchange reactions. Industrial by-product material such as flyash [31-33], GGBS [34-35], cement kiln dust [36,37], lime stone dust [38] as additive are becoming more popular due to their relatively low cost additionally CO_2, emission can be reduced significantly by the increased use of such supplementary cementing materials currently wasted in lagoons and landfill sites. The most important feature in the stabilization of clay soils is the ability to stabilizer to provide a sufficient amount of calcium [39]. Granular pile- anchor (GPA) technique has been a recent innovation over the conventional granular pile, modified in to anchors [40]. Stabilization of expansive soil with admixtures controls the potential of soils for a change in volume. In recent years a number a stabilizers from various industries have been developed for the purpose of soil stabilization. Stabilizers can be amended with activators like lime or cement to enhance their cementitious and pozzolanic properties. [41] Improved the unconfined compressive strength of expansive soil by stabilizing them with alccofine. A study by [3] used the different percentages of $Cacl_2$ and RHA mixtures to stabilize clay soil as cushions (CNS) in below footings, pavement slabs and behind canal lining.

The purpose of this study is to investigate the influence of inclusion of alccofine in conjunction with Calcium chloride ($Cacl_2$) in the stabilization of expansive soils. 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 [41,3], while $Cacl_2$ is mainly used to reduce the swelling and increase the shear strength of expansive soil for soil stabilization. The main reason for their underutilization is the lack of pozzolanic reactivity [42]. 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 [42]. On the other hand, $Cacl_2$ 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 [2]. 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 $Cacl_2$ 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 $Cacl_2$ as binder to stabilize expansive soil. The influence of the binder on FSI, swelling potential, swell pressure, plasticity, compaction, strength, hydraulic conductivity, SEM, XRD, Cation exchange capacity(CEC) characteristics of expansive soil have been taken into account for evaluating performance.

2.0 materials and methodology:

2.1. Materials:

Expansive Soil: The expansive clay soil is collected from Kirumambakkam, is located in Puducherry, India. The soil is collected in a dry condition at a depth of 1 meter below the ground level and preserved in the laboratory. Identified the index and engineering properties of expansive soils as shown in Table 1.

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. Chemical composition and physical properties are tested by alccofine micro materials, pissurlem, Goa. Alccofine-1203 properties are given in table 2.

Calcium Chloride: The chemical composition of Calcium chloride is $Cacl_2$. It is a hygroscopic material it also absorbs water from the air and releases heat when it is dissolved in water.

Table: 1 Physical properties of soil.

Properties of soil	Results
Sand (%)	12
Silt (%)	30
Clay (%)	58
Specific gravity	2.60
Liquid limit (W_L)	59%
Plastic limit (W_P)	29%
Shrinkage limit (W_S)	12.5%
Free swell index (FSI)	25%
Water absorption (W_A)	53.69%
Cation exchange capacity (CEC) meq/100g	55
Unified soil classification (USCS)	CH
OMC (%)	18.19
MDD (kn/m^3)	15.73
UCS (kpa)	157
Swell potential (%)	5.29
Swell pressure (kpa)	150
Hydraulic conductivity cm/sec	$1.58x10^{-6}$

Table: 2 Physical and chemical properties of Alccofine-1203.

Properties	Results
Physical properties	
Particle size Distribution	
D10	1.5
D50	4.3
D90	9.0
Specific gravity (g/cc)	2.88
Bulk density (kg/m^3)	680
Chemical properties	
SiO_2	35.6%
Al_2O_3	21.4%
Fe_2O_3	1.3%
CaO	33.6%
SO_3	0.12%
MgO	7.98%

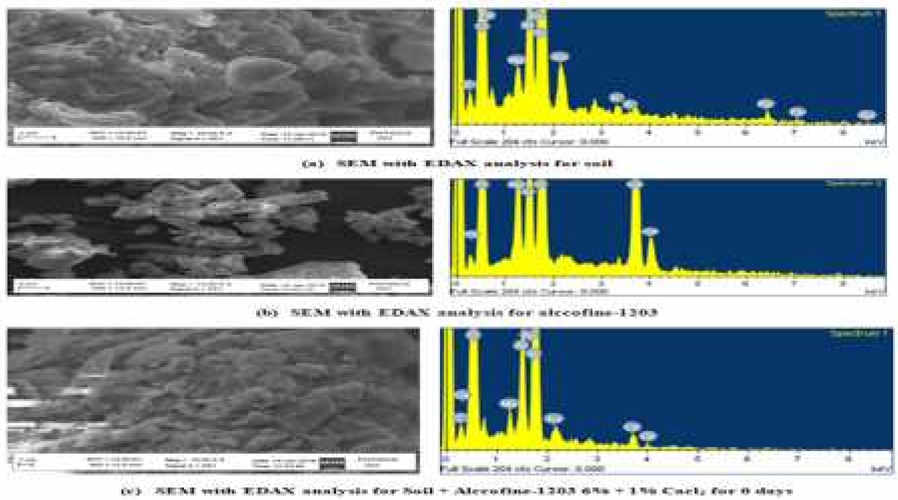


Fig 2. (a) SEM with EDAX analysis for soil; (b) SEM with EDAX analysis for Alccofine1203; (c) SEM with EDAX analysis for soil + Alccofine 1203+ $Cacl_2$ 0 day s.

2.2. Testing methodology:

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 and swell/shrink 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 [44-48].

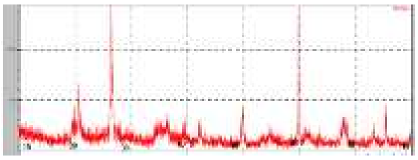
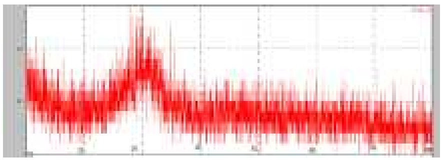
The water absorption (W_A) of the soil mixed with both $Cacl_2$ and alccofine-1203 were added independently and blended to the expansive soil.

A water absorption (W_A) equation is developed and recommended by [49]. Water absorption equation is

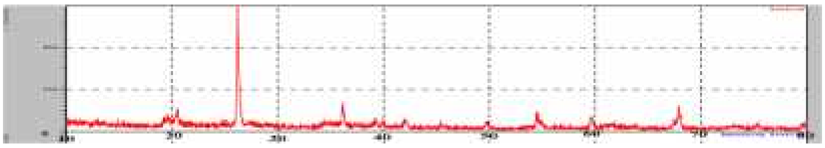
$$W_A = 0.91W_L$$

Where, W_L is liquid limit.

To determine the Specific Surface Area (SSA) of the soil-binders mixtures, a Specific Surface Area is developed and recommended by [51]. The cation exchange capacity (CEC) of the soil soil-admixtures blended samples is determined. The Cation Exchange Capacity (CEC) is developed and recommended by [50]. Finally, detailed micro-analysis (XRD, SEM, and FTIR) have been carried out to elucidate the mechnism of strength variation through change in mineralogy and microstructure, respectively.

(c)soil+6%Alccofine+1%$Cacl_2$ (b) Alccofine-1203



(a) Soil Position (2 theta)

Fig: 3 XRD analysis for (a) soil; (b) Alccofine; (c) soil+6%Alccofine+1%$Cacl_2$.

3.0. Results and discussions:

3.1. Index and compaction characteristics:

The influence of alccofine and $Cacl_2$ on Atterberg limits of expansive soil is shown in Table 3. Results show that liquid limit decreases and plastic limit increases; hence the difference between liquid limit and plastic limit is the plasticity index. Plasticity index is reduced by about 67% when the soil is blended with 6% alccofine + $Cacl_2$ 1%.

The compaction characteristics of untreated and treated soils are shown in Table3. The results of compaction show that the MDD is increases from 15.73 kN/m^3 to 16.92 kN/m^3 and optimum moisture content is reduce from 18.19% to 16.5% with increase of 6% alccofine and 1% $Cacl_2$ binder; that is, for sample which shows maximum strength.

3.2. Unconfined compression strength:

Unconfined compressive strength (UCS) tests were conducted with alccofine-1203 and $Cacl_2$ 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 157 kPa. The percentage of alccofine (3, 6 and 9%) and $Cacl_2$ (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 157 kPa to 418 kPa. Beyond 6% of alccofine with 1% $Cacl_2$ resulted in a slight decreased in UCS values.

3.3 Swell behaviour:

The swell behaviour of soil and mixed with different percentages of alccofine and $Cacl_2$ is presented in Table 3. The maximum swell potential of intrinsic soil is 5.29% and swell pressure is 150 kPa. With addition of various percentages of alccofine and $Cacl_2$, swell of soil decreases gradually and completely brings to halt beyond addition of alccofine 6% with 1% of $Cacl_2$. Beyond alccofine 6% with 1% of $Cacl_2$, complete elimination of swell is due to availability of adequate calcium, not only for cation exchange reaction but also for the formation of pozzolanic reaction compounds.

Cation Exchange Capacity: Exchangeable cataions (i.e.Ca, Mg. Na, and K) determined displacing these from soil colloids with NH_4. This is done by shaking the soil with 1N NH_4OAc adjusted to pH 7.0.

3.2 Mineralogical and Microstructural Analysis:

SEM with EDAX Analysis: SEM and EDAX spectrum analysis for clay soil, alccofine and clay soil + alccofine 6% + $Cacl_2$ 1% are shown in Fig.no. 2a, 2b, 2c. These studies were carried out in order to observe the individually and changes in the soil is blened with admixture of 0 days. Eminent peaks Fe, Au, Al are observed in 2(a) and Fe, Au, Al, Si are observed in clay soil. In alccofine (2b) Ca, Mg, Si, Al eminent peaks are observed. In combination of soil blended with admixture (2c) is observed eminent peaks are Fe, Au, Si, o, Al. The test was performed mainly for the identification of the various cementations compounds on the soil stabilised with 6% alccofine+$Cacl_2$1% binder; that is, for sample which shows maximum strength.

XRD: X-ray diffraction peaks identify for clay soil, alccofine and clay soil + alccofine 6% + $Cacl_2$ 1%. The most important peak traced was related to CH which was identified at 2ϴ =26° to 36° [43].as can be seen from the figure. 3a, 3b, 3c; the addition of alccofine-1203 and $Cacl_2$ in the soil causes CH related peaks to appear at the aforementioned 2ϴ. It has been carried out to confirm the formation of new minerals which can play a significant role of strength improvement behaviour calcium stabilized for soil admixture. The intensity has increased for calcium chloride and alccofine-1203 materials treated when compared with the clay soil, which is all evident from X-ray data.

Table: 3 Effects of soil-admixtures blended on Index and Engineering properties

$Cacl_2$	Alccofin	W_L %	W_P %	W_S %	PI %	MDD kN/m^3	OMC %	UCS (kPa)	S%	S_P kpa	W_A %
0	0	59.0	34.5	12.5	24.5	15.73	18.19	157	5.29	150	53.69
	3	55.0	35.0	13.3	20.0	15.85	17.75	216	3.22	120	50.05
	6	49.0	35.5	16.0	13.5	15.95	17.45	245	1.23	095	44.59
	9	47.0	36.0	22.5	11.0	16.15	17.24	241	0.75	075	42.77
0.25	0	54.0	37.0	14.0	17.0	15.85	18.05	245	2.17	115	49.14
	3	51.0	38.5	15.0	12.5	16.05	17.76	300	1.02	098	46.41
	6	49.0	39.0	19.0	10.0	16.30	17.25	327	0.59	065	44.59
	9	48.0	39.0	24.5	9.0	16.45	17.10	324	0.46	096	43.68
0.5	0	52.5	38.0	14.5	14.5	15.90	17.65	306	1.47	045	47.77
	3	50.4	38.5	16.0	11.9	16.34	17.34	359	0.90	038	45.86
	6	48.0	40.0	18.8	8.0	16.70	16.80	384	0.34	022	43.68

	9	49.0	41.0	24.0	8.0	16.90	16.40	376	0.11	018	44.59
1.0	0	51.0	39.0	18.0	12.0	15.80	17.40	352	0.78	032	45.68
	3	49.0	41.0	21.0	8.0	16.30	16.80	401	0.17	012	44.59
	6	47.0	39.0	22.5	8.0	16.92	16.50	418	0	0	42.77
	9	49.0	42.0	22.8	7.0	16.95	16.24	406	0	0	44.59

Note: W_L = Liquid limit; W_P = Plastic limit; W_S = Shrinkage limit; PI = Plasticity index; MDD = Maximum dry density; OMC = Optimum moisture content; UCS = Unconfined compressive strength; W_A = Absorption water content; S= Swelling potential; S_P= Swell pressure.

Table: 4. Properties Obtained for Optimum Soil-alccofine-$Cacl_2$ Mix.

Properties	**Soil**	**93% soil+1%$Cacl_2$+6% alccofine-1203**
Sand (%)	12	10.3
Silt (%)	30	35.2
Clay (%)	58	54.5
Specific gravity	2.60	2.72
Liquid limit (W_L)	59%	47%
Plastic limit (W_P)	29%	39%
Shrinkage limit (W_S)	12.5%	22.5%
Plasticity Index (PI)	25%	8%
Water absorption (W_A)	53.69%	42.77%
Cation exchange capacity (CEC) meq/100g	55	18
Unified soil classification	CH	CI
OMC (%)	18.19	16.5
MDD (KN/m^3)	15.73	16.92
UCC (kpa)	157	418
Free swell index (FSI)	25%	0
Swell potential (%)	5.29	0
Swell pressure (kpa)	150	0
Hydraulic conductivity cm/sec	$1.58x10^{-6}$	$4.3x10^{-5}$

Conclusion:

In this study, based on the laboratory investigation, a series of test were performed to study the effect of alccofine-1203 and $Cacl_2$ on the swelling properties and strength behaviour of soils. Based on the results presented in this paper, the following conclusions are made:

1. The addition of alccofine-1203 and $Cacl_2$ 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.
2. Unconfined compressive strength (UCS) tests were conducted with alccofine and $Cacl_2$ were added independently and blended to the expansive soil samples. The UCS value for intrinsic soil is 155 kPa. Optimum increase was noticed at 6% alccofine and 1% Cacl2. The UCS strength was increase from 155 kPa to 482 kPa. Beyond 6% of alccofine with 1% $Cacl_2$ resulted in a slight decreased in UCS values.
3. The swell behaviour of soil; swell potential is reduced from 5.29% to 0 and swell pressure is reduced from 150kpa to completely brings to halt beyond addition of alccofine 6% with 1% of $Cacl_2$.

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. The use of cohesive non swelling soils (CNS) cushions below the light weight structures is well accepted. It is to be noted that CNS layer is not present on expansive soil, there is a possibility of differential heave and loss of shear strength at the edges of foundation. In the view of severe scarcity for suitable cohesive non-swelling soils (CNS) at several project sites, an alternative cushion material is proposed to be prepared at the site using the intrinsic soil (expansive soil) by admixing with it 6% Alccofine and 1% $Cacl_2$ by dry weight of the soil. Based on the favourable results obtained, it can be concluded that the expansive soil with alccofine and $Cacl_2$ can be considered as an effective cohesive non-swelling soil (CNS) for pavements, sidewalks, and floorings.

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