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Influence of Microstructural and Geotechnical Behaviour of Expansive soil Using Ultra-Fine Slag and Calcium Chloride

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Abstract. The present study is to elucidate and efficacy of ultra-fine slag and $CaCl_2$ in ameliorating the engineering properties of expansive soils. An experimental program has evaluated the effects of ultra-fine slag (4%, 8%, & 12%) and $CaCl_2$ (0.5% & 1%) contents on the FSI, plasticity, compaction, unconfined compressive strength, and microstructural (SEM & XRD) tests of expansive soil. Both admixtures were added independently and blended to the expansive soil. Mixing of admixtures into expansive soil results shown that plasticity index, swelling behavior blends decreased and dry unit weight and unconfined compressive strength is increased in a combination of soil with micro-fine slag up to 8% mixing and Calcium Chloride 1%, however furthermore addition of micro-fine slag and $CaCl_2$ leads to decrease in the UCS test. It was found that the optimum quantity of material for favorable combination of soil +8% micro-fine slag +1% $CaCl_2$was taken for further study in view of its economy also it is well suited for sustainable development purposes..

Keywords: Expansive soil; Ultra-fine slag; Calcium Chloride; CEC.

1 Introduction

The expansive soil problems were the first investigated by U.S. Bureau of Reclamation (USBR) in 1938 (1). Expansive soils occur above water table; they swell with an increase in moisture content and shrink with a decrease in moisture content (2). These types of soils are known worldwide for their volume change behaviour due to moisture fluctuation because of their intrinsic mineralogical behaviour (3). Expansive soils are in arid and semi-arid regions in the world 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 (4-5). The swelling phenomenon is attributed predominantly to the presence of montmorillonite clay mineral in the soil. The montmorillonite is hydrated Aluminium silicates with 3 layered lattice structures in which intra particle space when occupied by layers of water molecules give rise to swelling and related phenomena. The change in volume in montmorillonite clay can exert sufficient stress on a building, side walk, driveways, basement floors, pipelines, and foundations to cause damages. While it is true that swelling soils are probably responsible for most of the cracking and movement of lightly loaded structure, other aspects of foundation movement cannot and should not be ignored (6). 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 natural hazards resulting in damages to structures (7-10).

2 Materials and Methods

2.1 Materials

Expansive soil

The expansive clay soil is collected from Ariyankuppam, 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.

Ultra-fine slag

Alccofine is a ultra-fine slag it performs a superior than all other mineral admixtures used in India. It is a micro fine material of particles size much finer than other hydraulic materials like cement, lime, fly ash etc. manufactured by Ambuja cement private limited in India. Alccofine-1203 and Alccofine-1101 are two types with low calcium silicate and high calcium silicate respectively. Alccofine-1203 has the lime content 34% and average particle size 4 microns (Range 0-17microns). Alccofine has almost same binding characteristics as silica fume. It controls high reactivity because of controlled granulation and it also improves workability by reducing the water demand. Chemical composition and physical properties are tested by alccofine micro materials, pissurlem, Goa. Alccofine-1203 properties are given in table 2.

Calcium chloride

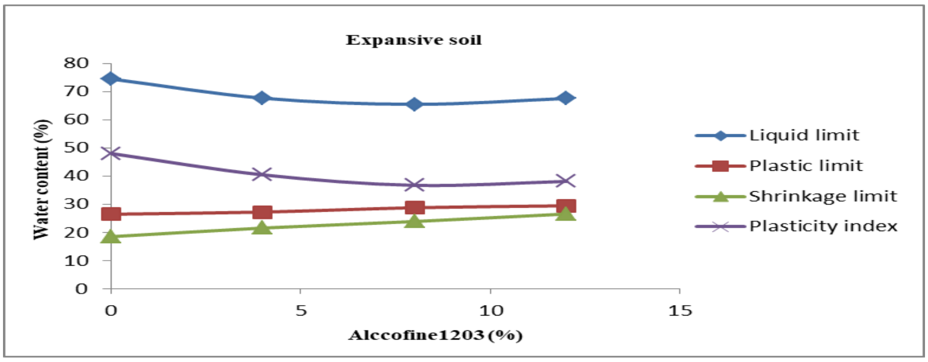
Commercially grade $CaCl_2$ having the composition of 50% $CaCl_2$ and 50% $MgCl_2$.

Table 1. Physical properties of soil

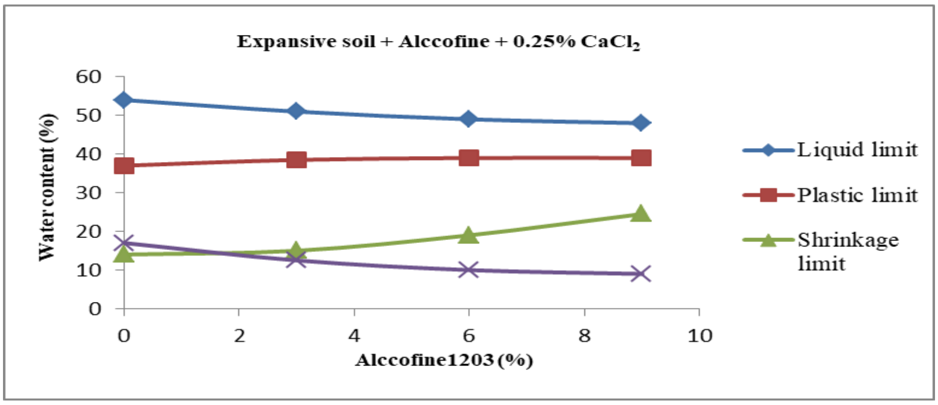
Properties of soil	Results
Specific gravity	2.65
Liquid limit (W_L)	74.48%
Plastic limit (W_P)	26.45%
Shrinkage limit (W_S)	18.5%
Free swell index (FSI)	90%
Water absorption (W_A)	68.92%
Cation exchange capacity (CEC) meq/100g	50.96
Unified soil classification (USCS)	CH
OMC (%)	20.19
MDD (kN/m^3)	16.55
UCS (kpa)	104
Swell potential (%)	36.86
Swell pressure (kPa)	256

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

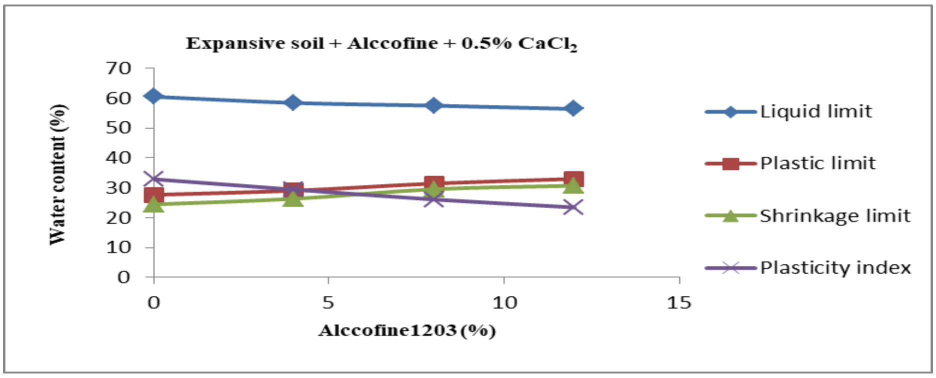
Properties	Results
Physical properties	
Particle size Distribution (mm)	
D10	1.5
D50	4.3
D90	9.0
Specific gravity (g/cc)	2.88
Bulk density (kg/m^3)	680
Chemical properties	
SiO_2	35.6%
Al_2O_3	21.4%
Fe_2O_3	1.3%
CaO	33.6%
SO_3	0.12%
MgO	7.98%



(a) Soil + Alccofine

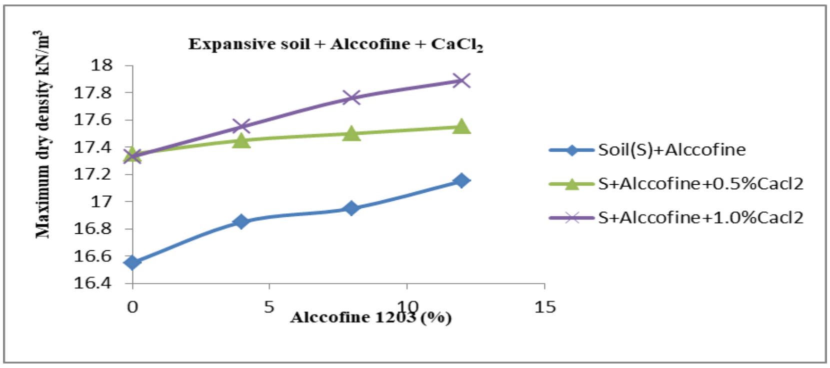


(b) Soil + Alccofine + 0.5% $CaCl_2$

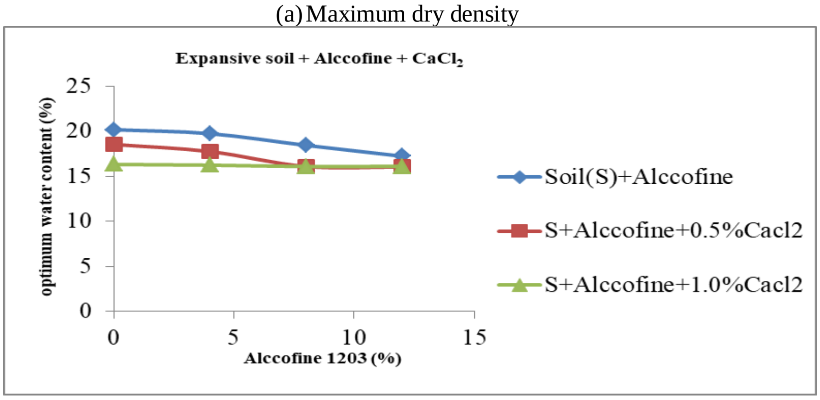


(c) Soil + Alccofine + 1% $CaCl_2$

Fig. 1. Atterberg limits: (a) Soil + Alccofine; (b) Soil + Alccofine + 0.5% $CaCl_2$; (c) Soil + Alccofine + 1% $CaCl_2$



(a) Maximum dry density



(b) Optimum moisture content

Fig. 2. (a) Maximum dry density; (b) Optimum moisture content

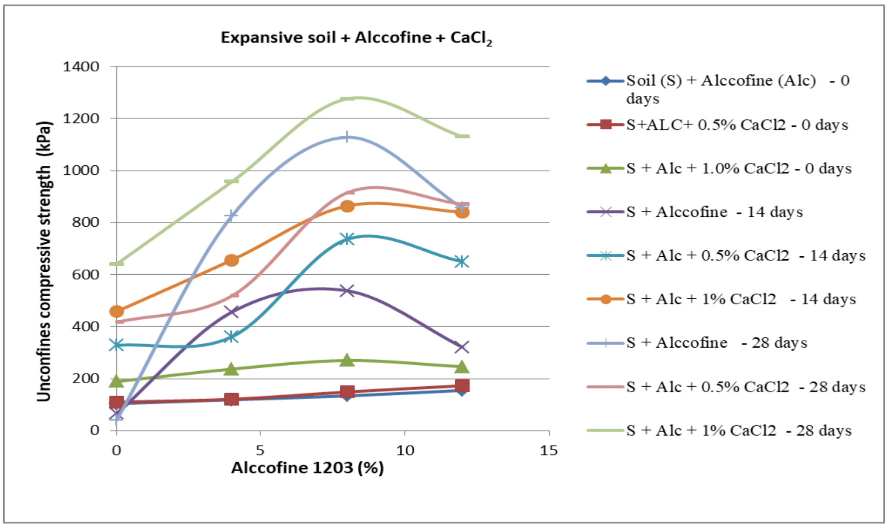
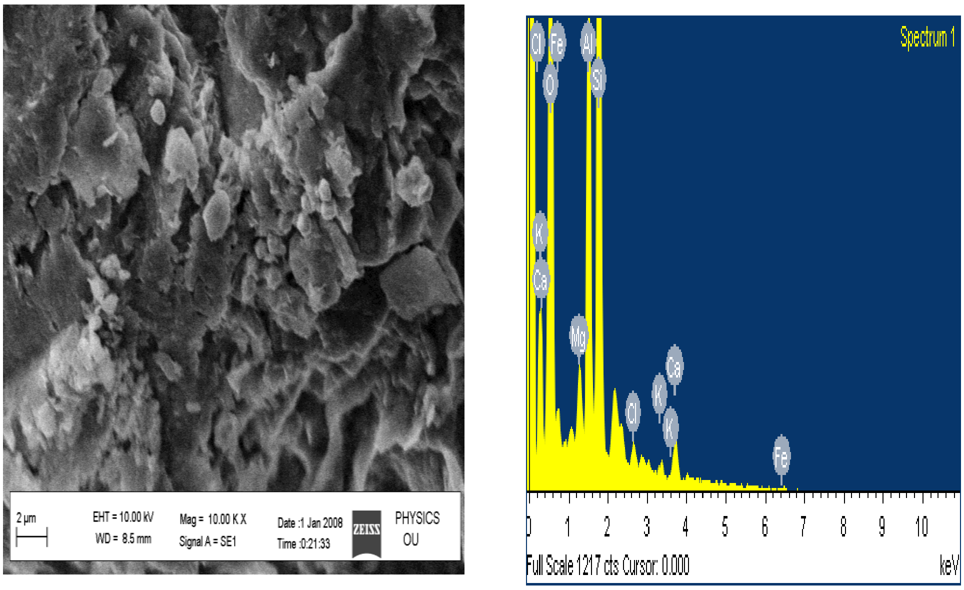
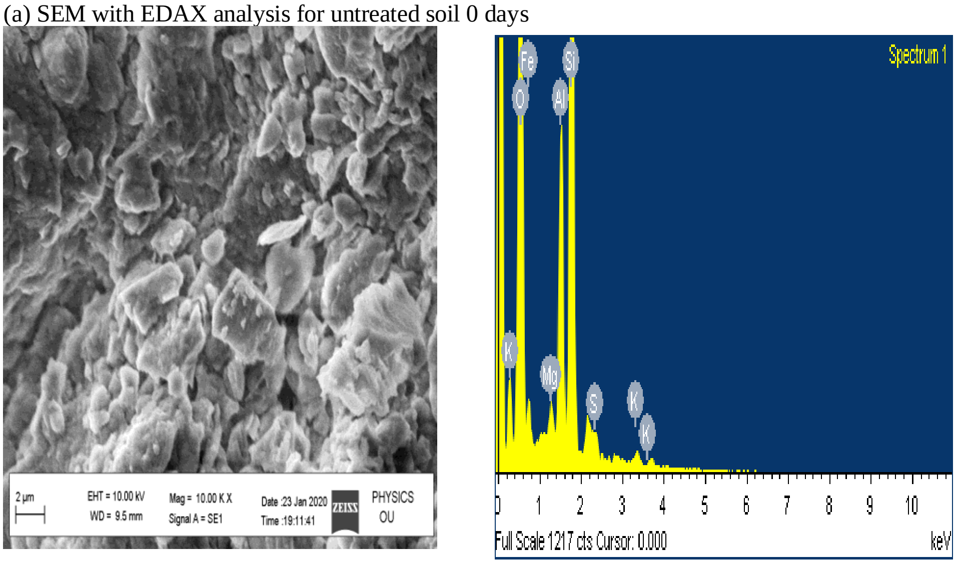


Fig. 3. Variation of UCS with Soil + Alccofine + $CaCl_2$

SEM Analysis

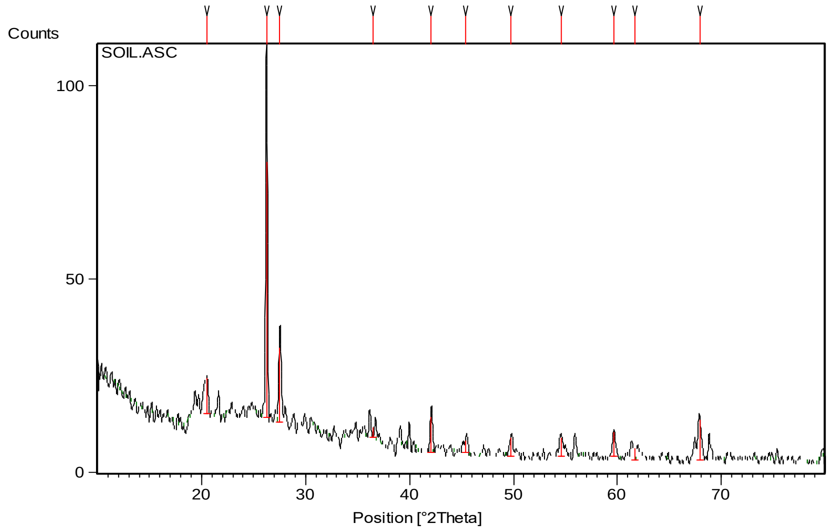


(a) SEM with EDAX analysis for untreated soil 0 days

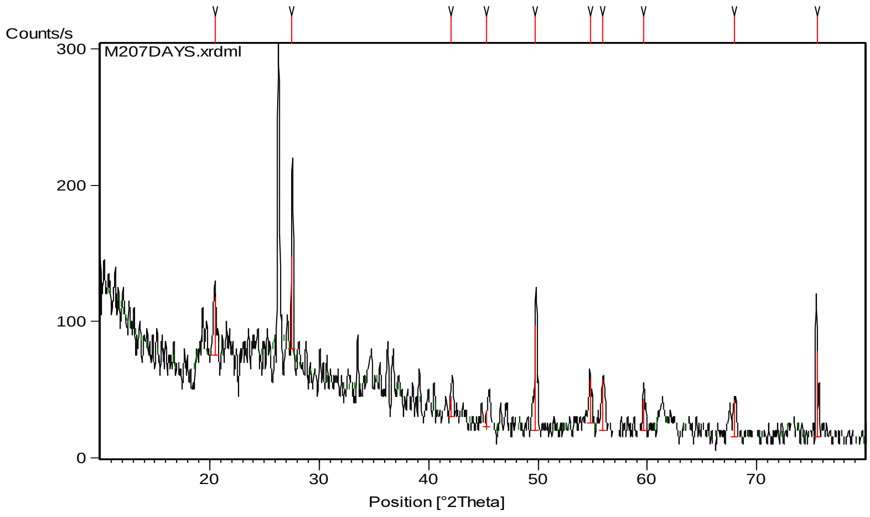


(b) SEM with EDAX analysis for treated soil (soil + 8%alccofine+1%$CaCl_2$) for 28 days of curing.

Fig 4. (a) SEM with EDAX analysis for soil; (b)SEM with EDAX analysis for soil + 8% Alccofine-1203+ 1.0% $CaCl_2$ 28 days.



(a) Expansive soil



(b) Soil+8%Alccofine+ 1.0%$CaCl_2$

Fig. 5. XRD analysis for (a) soil; (b) Soil + 8%Alccofine+1.0%$CaCl_2$

3 Results and Discussion

3.1. Index and compaction characteristics

The influence of alccofine and $CaCl_2$ on Atterberg limits (liquid limit, plastic limit, and shrinkage limit) 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 from 48.03% to 16.45% when the soil is blended with 8% alccofine + $CaCl_2$ 1%.

The compaction characteristics of untreated and treated soils are shown in Table. 3. The results of compaction show that the maximum dry density is increases from 16.55 kN/m^3 to 17.76 kN/m^3 and optimum moisture content is reduce from 20.19% to 16.10% with increase of 8% 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 104 kPa. The percentage of alccofine (4, 8 and 12%) and $CaCl_2$ (0.5, 1.0%, 1.5% & 2.0%) were added by dry weight of the soil. The UCS values are shown in Table. 3. Optimum increase was noticed at 8% alccofine and 1% $CaCl_2$. The UCS strength was increase from 104 kPa to 1270 kPa. Beyond 8% of alccofine with 1% $CaCl_2$ resulted in a slight decreased in UCS values.

3.4 SEM Analysis

SEM and EDAX spectrum analysis for clay soil, alccofine-1203 and clay soil + alccofine-1203 8% + $CaCl_2$ 1% are shown in Fig.no. 4a and 4b . These studies were carried out in order to observe the individually and changes in the soil is blended with admixture of 0 days. Eminent peaks Fe, Si, Al are observed in 4(a) and Fe, Si and Al are observed in clay soil. (1b) is observed eminent peaks are Fe, Au, Si, o, Mg, Ca and Al. The test was performed mainly for the identification of the various cementations compounds on the soil stabilised with 8% alccofine + $CaCl_2$ 1% binder; that is, for sample which shows maximum strength.

3.5 XRD

X-ray diffraction peaks identify for clay soil, alccofine-1203 and clay soil + alccofine-1203 8% + $CaCl_2$ 1%. The most important peak traced were related to CH which were identified at $2\Theta = 26°$ to $36°$ as can be seen from the figure. 5a, 5b; 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.

4 Conclusions

1. The addition of alccofine-1203 and $CaCl_2$ to the soil decreased liquid limit and plasticity index while increasing the shrinkage limit. It is found that the addition of binders causes flocculation of clay.
2. Particles and increases the number of coarse particles which help in reducing the Atterberg limits.
3. The optimum moisture content (OMC) was found to decrease 20.19% to 16.10% while the maximum dry density (MDD) increases f rom 16.55kN/m^3 to 17.76 kN/m^3 with binding content.
4. 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 104 kPa. The percentage of alccofine (4, 8 and 12%) and $CaCl_2$ (0, 0.5 and 1.0%) were added by dry weight of the soil. Optimum increase was noticed at 8% alccofine and 1% $CaCl_2$. The UCS strength was increase from 104 kPa to 1270 kPa. Beyond 8% of alccofine with 1% $CaCl_2$ resulted in a slight decreased in UCS values.

5. SEM, XRD studies confirm the formation of reaction products such as Ca, Mg and Si to contribute to strength significantly. In XRD the addition of alccofine-1203 and $CaCl_2$ in the soil causes CH related peaks to appear at the aforementioned 2ϴ.

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