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CONSOLIDATION CHARACTERISTICS OF EXPANSIVE SOIL TREATED WITH SILICA FUME AND VARIOUS CHEMICALS

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ABSTRACT- Constructions on expansive soil are challenging and thus prone to some problems and litigation. The engineers make extensive use of local experience and empirical procedures to address these problems. Although there has been extensive study of expansive soils and foundations on expansive soil, data related to performance of residential structures are limited in general and limited in the phoenix area, in the particular. In this study an over view of the phoenix areas in India, mostly found in western and north western portions of the Andhra Pradesh. Consolidation of soil in an effective method for improvement of soil properties and the foundations and pavement system performance. Plasticity index is one of the improvement properties of soil to determine the behavior of soil in presence of water. Now days, soil stabilization is done using the waste material like silica fume, slags, rice husk ash.etc. In geotechnical engineering has been recommended from environmental point of view. The main objective of this study is to evaluate the feasibility of using silica fume as soil stabilization material. In this investigation of silica fume on engineering properties of expansive clay were studied with varying silica fume content from 5% to 20%. $CaCl_2$ $Ca(OH)_2$ and $AlCl_3$ (0.5 %,1.0%, and 1.5%) by weight of the dry soil, the experimental results showed a significant increase in CBR, and co-efficient of consolidation (Cv) compressive index (Cc) are decreased. The differential free swell of the clay is reduced from 110% to 30%. The proctor compaction result showed a small decrease in maximum dry content from this investigation was concluded that the silica fumehasas potential to improve the characteristics of black cotton soil.

KEYWORDS- Expansive Soil, Silica Fume, ($CaCl_2$), ($Ca(OH)_2$), ($AlCl_3$), Coefficient of Consolidation, Coefficient of Compression, Rate of Consolidation.

I. INTRODUCTION

Providing good performance of facilities constructed on expansive soil is challenging as such structures have been proven to be prone to certain problems and litigation. They exhibit large volumetric changes like shrinkage and swelling behavior if the moisture content changed. Due to this nature this type of soil is susceptible to damage to the structures and pavements. Black cotton soil is an expansive soil. It extends nearly one fifth of our country, mainly in the state of Maharashtra, Gujarat, Madhya Pradesh, southern UttarPradesh, Eastern Rajasthan, Karnataka and parts of Telangana, Andhra Pradesh and Tamil Nadu. Considerable amount of work has already been done in understanding the behavior of expansive soils. The parent materials associated with expansive soil s are either basic igneous rocks or sedimentary rocks. In basic igneous rocks, it is formed by decomposition of feldspar and pyroxene and in sedimentary rocks; it is a constituent of rock itself. In any case most expansive soils are rich in montmorillonite clay mineral. Structures constructed in areas of soft or week soils have need of improvement using additives. Consolidation techniques are used to improve shear strength, CBR, reducing expansive characteristic etc. Silica fume also referred as micro-silica and it is extremely fine grey, white in coloured powder particle size less than 0.1micron and specific surface area is about 20,000m²/kg. Silica fume is used as an artificial pozzolanic admixture in concrete. As far as the production of silica fume is concerned nearly 1, 00, 000 ton-micro silica is produced each year worldwide. Steel Authority of India has provided necessary facilities to produce more than 3000 tone of silica fume annually.
Many waste materials are used to modify the properties of soft soils. Generally soils are stabilized by using lime, cement, and different chemicals. In this study an attempts has been made to find the influence of silica fume on engineering properties of black cotton soil.

II. REVIEW OF LITERATURE

Several researches have been made to improve the strength of the expansive soils. From various contributions, the investigations on strength characteristics of expansive soil conducted by S. Narasimha Rao et al (1986, 1987), Sridharan et. Al (1989), Mathew et al (1997), G. Rajashekaram et al (2002), Kate J.M (2005), Ali. M. Abd-Allah (2009), Dr. Koteswara Rao. D et al (2011), Timani K.L, Patel R.M (2015), Prof. R.D.Babu et al. (2015) and several others have conducted experimental studies to improve the properties of the expansive soils using different admixtures and the tests yielded better results. The characteristics that are of concern to the design engineers are permeability, compressibility and durability. The effect of the additives and the optimum amount of additives to be used are dependent mainly on the mineralogical composition of the soils.

III. OBJECTIVES

The objectives of the present experimental study are

- To determine the properties of the expansive soil and silica fume.
- To evaluate the performance of expansive soil when stabilized with silica fume as an admixture and its suitability for foundation beds.
- To evaluate the performance of stabilized expansive soil with an optimum of silica fume $CaCl_2$, $Ca(OH)_2$, $AlCl_3$ and consolidation characteristics.

IV.MATERIALS USED

A.Expansive Soil-The expansive soil used for this study was collected form Allavaram mandal (Devaguptam village) near Amalapuram, East Godavari District, and A.P India. The expansive soil was collected at a depth of 1.5m below the ground level. The index and engineering properties of expansive soil were determined as per IS code of practice and presented in the table below.

TABLE 1
Geotechnical properties of the untreated Expansive soil

S.No	Property	Expansive soil
1	Gravel (%)	5
2	Sand(%)	12
3	Silt Fines (%) Clay (%)	24 59
4	Liquid limit (%)	61.56
5	Plastic limit (%)	25.13
6	Plastic index (%)	36.43
7	Soil classification	CH
8	Specific gravity	2.56
9	D.F.S (%)	110
10	O.M.C	29.23
11	M.D.D (g/cc)	1.45
12	CBR (%)	1.79

B. Silica Fume-Silica fume is a byproduct from the smelting process in the silicon and Ferro –silicon industry. Which is a mineral admixture, composed of submicron particles with more than 95% of particles finer than the 1 micro meter of amorphous silicon dioxide. SF powder with premium of white or Grey color? The silica fume was used in this investigation brought from Astra Chemicals, Chennai, Tamilnadu, India. The SF mainly consisting of 92.68% of silicon oxide (SiO_2) and small amount of iron, calcium,. Magnesium, and alkali oxides was used in the investigation. The quantity of SF varies from 5% to 20% by dry weight of soil.

TABLE 2
Chemical composition of silica fume

S.NO	Constituent Elements	Content (%)
1	Silicon oxide (SiO_2)	92.68
2	Aluminum Oxide (Al_2O_3)	0.69
3	Potassium oxide (K_2O)	0.26
4	Calcium oxide (CaO)	0.2-0.8
5	Magnesium oxide (MgO)	0.2-0.8
6	Sodium oxide (Na_2O)	0.35
7	Moisture	0.78
8	Loss of ignition (LOI)	41.84

(Courtesy to Sandvik, Gjorv)

TABLE 3
Physical properties of silica fume

Physical state	Value
Colour	White or grey
Specific gravity	2.2
Particle size	<1m
Bulk density	
As produced (kg/m^3)	130-430
Slurry (Kg/m^3)	1320-1440
Densified (Kg/m^3)	480-720

(Courtesy to Sandvik, Gjorv)

Calcium Chloride, Calcium Hydroxide and Aluminum Chloride used for this study were collected from SRI SCIENTIFIC & AQUA. Temple street , opp.Lane Dhana Lakshmi Bank ,Kakinada

C. Calcium Chloride ($CaCl_2$)-Commercial grade calcium choloride was used in this study. The quantity of chemical varied from 0.5% to1.5% with an increment of 0.5%.

D. Calcium Hydroxide ($Ca(OH)_2$)-Commercial grade calcium hydroxide was used in this study. The quantity of chemical varied from 0.5% to1.5% with an increment of 0.5%.

E. Aluminum Chloride ($AlCl_3$)-Commercial grade aluminum Chloride was used in this study. The quantity of chemical varied from 0.5% to 1.5% with an increment of 0.5%.

V. LABORATORY STUDIES

The laboratory studies were carried out on the sample of Expansive soil, expansive soil with silica fume, silica fume treated expansive soil with different % additives such as $CaCl_2$, $Ca(OH)_2$, $AlCl_3$.

A. Liquid limit-Liquid limit test was conducted on Expansive soil, Expansive soil with 15%silica fume , and expansive soil with 15% silica fume with 1% $CaCl_2$ using casagrande's liquid limit apparatus as per the porcedute laid down in IS:2720 part 4(1970).

B .Plastic limit-Plastic limit test was conducted on Expansive soil, expansive soil with15% silica fume, Expansive soil with 15% silica fume with 1% $CaCl_2$, expansive soil with15% silica fume with 1% $Ca(OH)_2$, Expansive soil with 15% of silica fume with1% $AlCl_2$ as per the specification laid down in IS 2720 part 4 (1970).

C. Differential free swell-Differential free swell (DFS) is a parameter used for the identification of the expansiveness of the soil.

To determine the free swell of a soil, 20g of oven dry soil passing through 425μ size sieve is taken. One sample of 10g is taken into 100cc capacity graduated cylinder containing water, and the other sample of 10g is taken in to a 100cc capacity graduated cylinder containing kerosene oil.

Differential free swell (%) $=\frac{vd-vk}{vk} * 100$

When

Vd=volume of soil specimen read from the graduated cylinder containing distilled water.

Vk= volume of soil specimen read form the graduated cylinder containing kerosene. Because kerosene is a non-polar liquid, it does not cause any swell of the soil IS: 2720 (part III 0 1980) gives degree of expansion of a soil depending upon its differential free swell as under.

D. Proctor's standard compaction Test-Preparation of soil sample for proctor's compaction test was done as per IS: 2720 part -6 (1974).

E .Specific gravity Test-Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature of the mass of the same volume of gas-free distilled water at a stated temperature. The specific gravity of soil is used in the phase relationship of air, water, and solids in a given volume of the soil. Specific gravity test was carried out by pycnometer as per IS 2720 part 3 (1980).

F. California bearing ratio test-The California bearing ratio test was conducted on the soil sample with 6 varying percentages of silica fume. Silica fume were added 0 % of soil in varying percentage of silica fume .silica fume were added to soil in varying percentages (3,4,5,10,15,20%)respectively. CBR value increases up to 5% addition of silica fume and then decreases. The maximum value of CBR for 5% addition of silica fume was obtained as 3.0% the CBR value showed an increase from 1.79% to 3.0% at 5% addition of silica fume. The test was conducted under a constant strain rate of 1.25mm/min. the proving rings reading is noted for 50 divisions, and loading was continued. Until 3 or more readings are decreasing (or) constant. The test was conducted at optimum moisture content. IS 2720 part 16 (1987).

VI RESULTS AND DISCUSSIONS

The Index and Engineering properties of expansive soil, Expansive clay treated with silica fume and clay with optimum expansive soil are determined as per IS code of practice and presented in the below table

TABLE 4
Physical properties of stabilized Expansive soil with an optimum of 5% silica fume

S.No	Property (%)	Untreated Expansive Soil	ES+ 15%SF SF	ES+15%SF+ 1% $CaCl_2$	ES+15%SF+ 1% $Ca(OH)_2$	ES+15%SF+ 1% $AlCl_3$
1	Liquid limit (%)	61.56	54.0	52.0	49.5	42.945
2	Plastic limit (%)	25.13	28.16	19.90	32.25	17.271
3	Plasticity index (%)	36.43	25.84	19.90	25.81	25.61
4	Soil classification	CH	CH	CH	CH	CH
5	Specific gravity	2.56	2.65	2.60	2.72	2.50
6	D.F.S (%)	110	30	28	29	27
7	O.M.C	39.90	24.5	22.5	25.7	16.0
8	M.D.D(g/cc)	1.45	1.63	1.76	1.69	1.71
9	C.B.R	1.79	3.0	7.08	10.25	5.81

TABLE 5
Free swell index DFS Values of Expansive soil with % variation of silica fume

S.NO	Silica Fume Mix	DFS (%)
1	ES with 2%SF	62.5
2	ES with 3%SF	44.44
3	ES with 4%SF	40
4	ES with 5%SF	30
5	ES with 10%SF	0

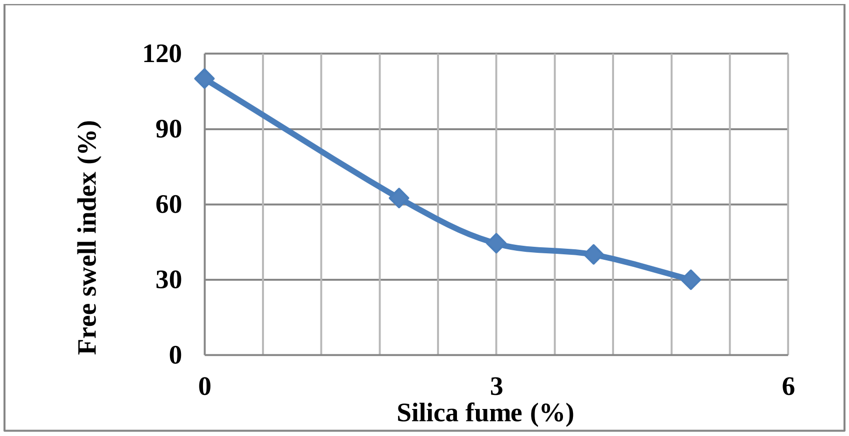

Fig.1 DFS values of Expansive soil with % variation of silica fume

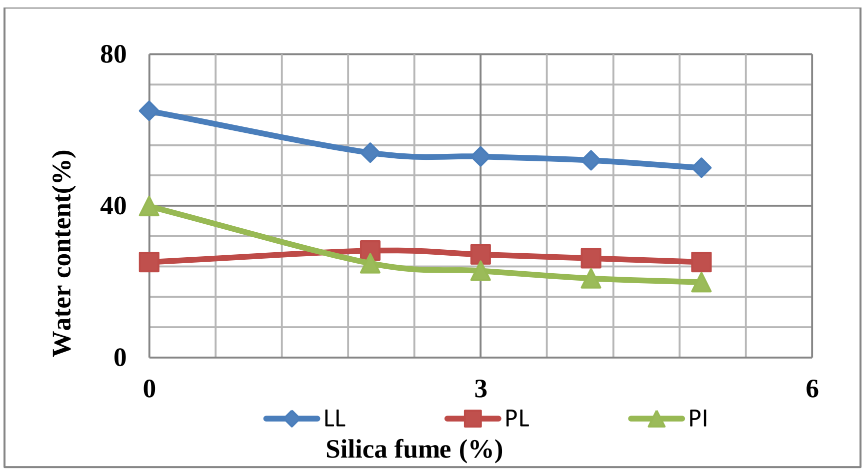

Fig.2 LL, PL, PI Values of Expansive soil with % variation of Silica Fume

TABLE 6
OMC & MDD values of Treated and Untreated Expansive Soil with % Variation of Silica Fume

Mix proportion	MDD (g/cc)	OMC(%)
Untreated Soil	1.450	29.23
Soil with 3% SF	1.541	23.94
Soil with 4% SF	1.595	23.45
Soil with 5% SF	1.608	25.56
Soil with 10% SF	1.635	24.71
Soil with 15% SF	1.638	24.51
Soil with 20% SF	1.586	24.18

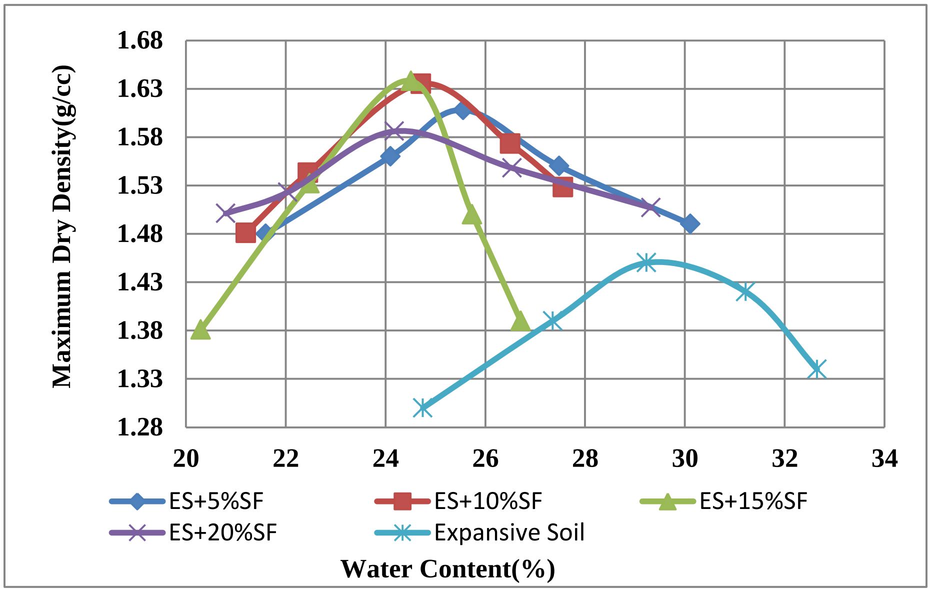

Fig.3 OMC & MDD Values of Various Percentage of silica fume treated with Expansive soil

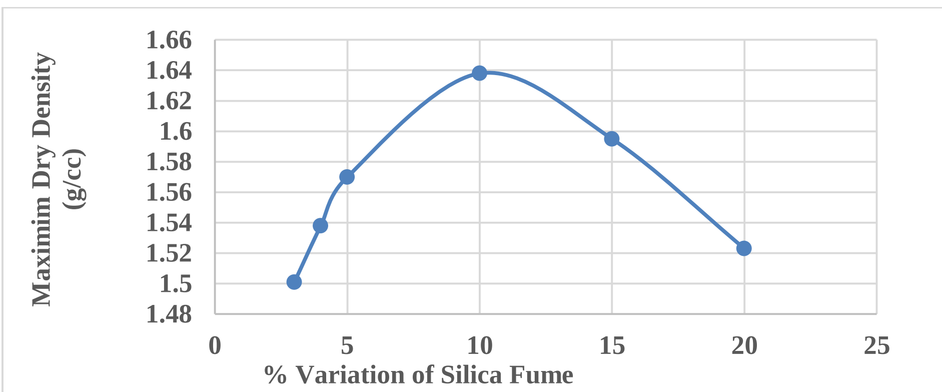

Fig.4 MDD Values of Expansive Soil with % Variation of Silica Fume

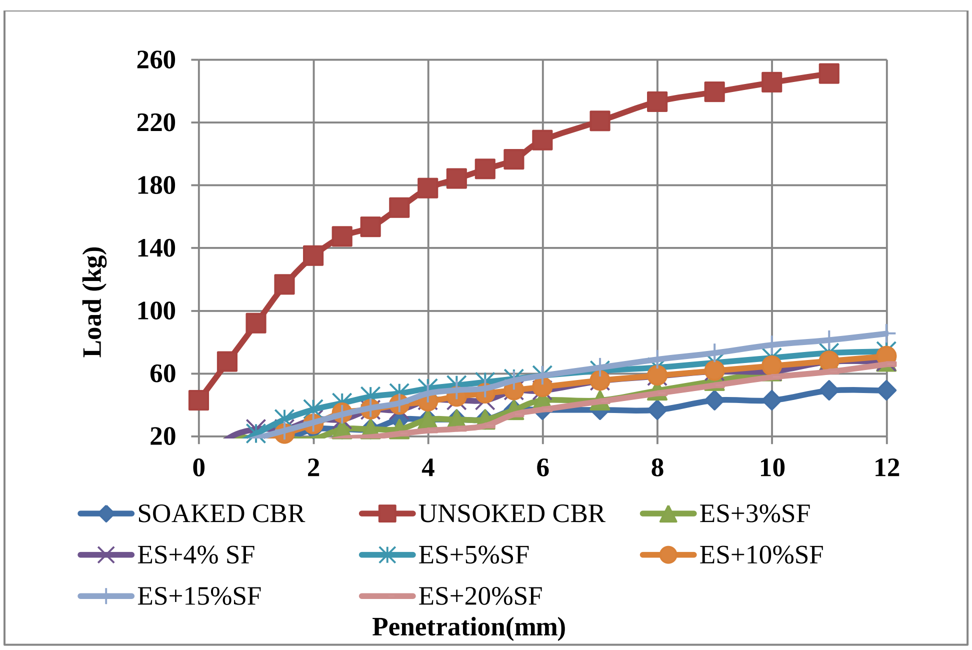

Fig 5 CBR Values of Expansive soil treated with Percentage Variation of Silica fume

TABLE 7
CBR values of Expansive soil Treated with % variation of silica fume

Mix proportion	Soaked CBR (%)
Untreated Soil	1.79
Soil with 3%SF	1.80
Soil with 4%SF	2.24
Soil with 5%SF	3.0
Soil with 10%SF	2.55
Soil with 15%SF	2.18
Soil with 20%SF	1.35

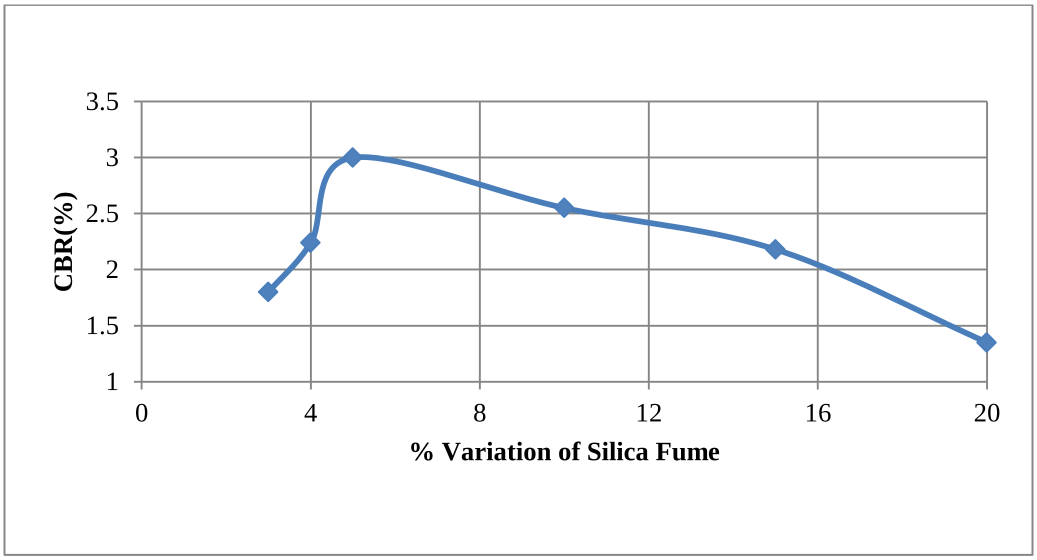

Fig. 6 % of CBR Varying with % of Silica Fume with Expansive Soil

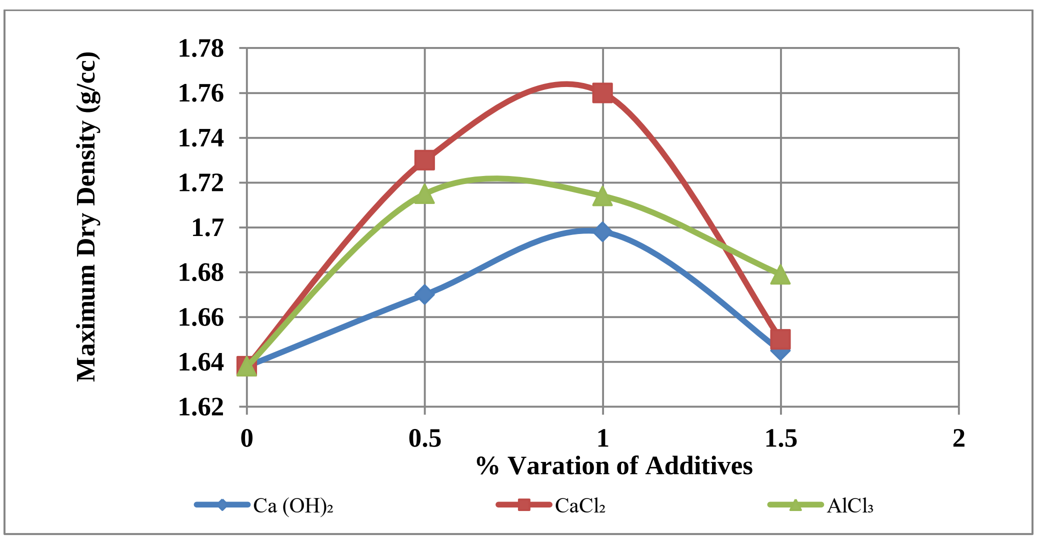

Fig 7 OMC&MDD Values of Expansive soil with % Variation of Additives

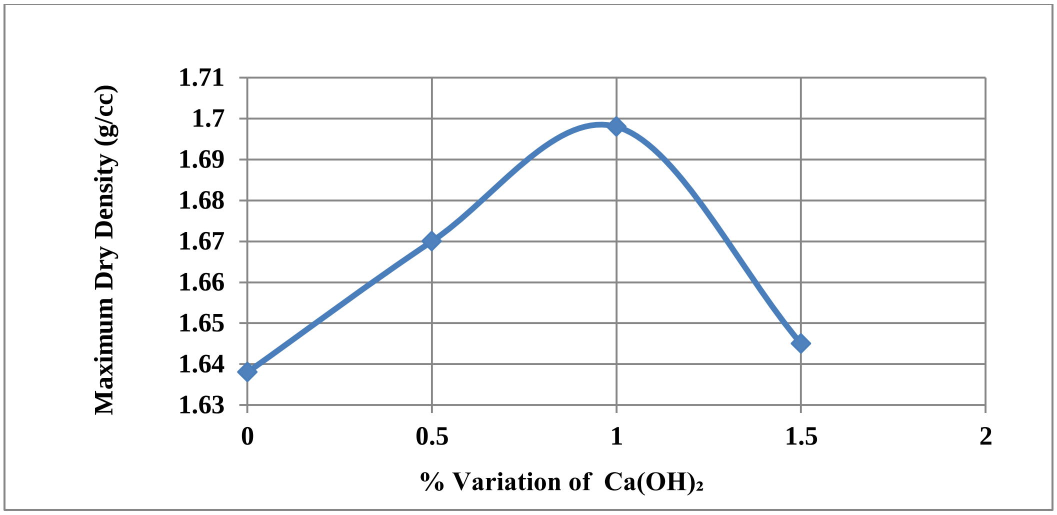

Fig 8 MDD Values of Expansive soil treated with silica fume and % variation of $Ca(OH)_2$

TABLE 8

% Of Mix proportion $Ca(OH)_2$	OMC (%)	MDD (g/cc)
0	24.51	1.638
0.5	18.985	1.67
1.0	**25.7**	**1.698**
1.5	45.417	1.645

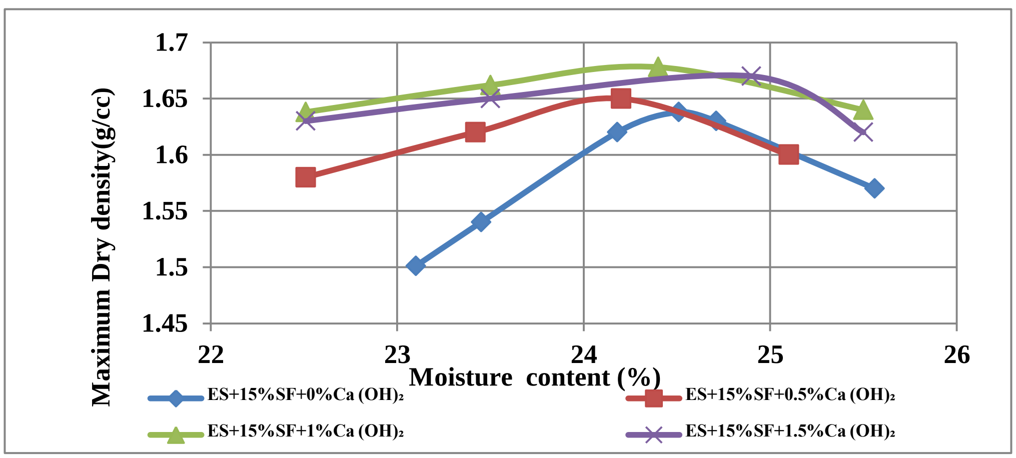

Fig 9 OMC and MDD Values of Silica Fume treated Expansive Soil stabilized with % Variation of $Ca(OH)_2$

TABLE 9

% of mix proportion $CaCl_2$	OMC (%)	MDD (g/cc)
0	24.51	1.638
0.5	21.715	1.730
1.0	**22.5**	**1.760**
1.5	39.0	1.650

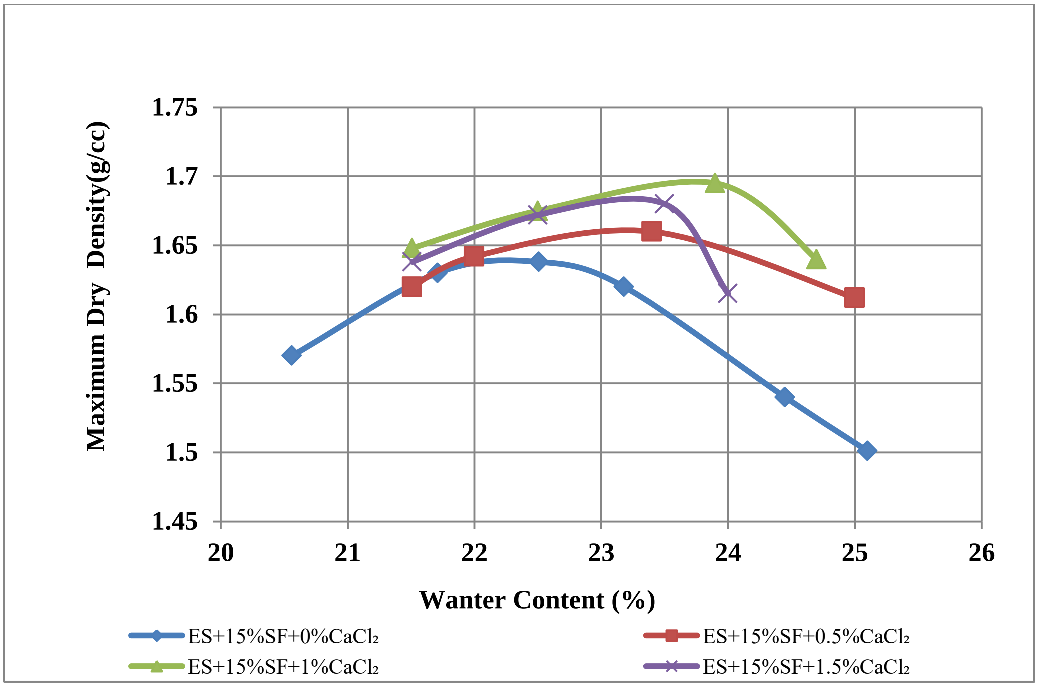

Fig 11 OMC and MDD Values of treated Expansive Soil treated with silica fume with % Variation of $CaCl_2$

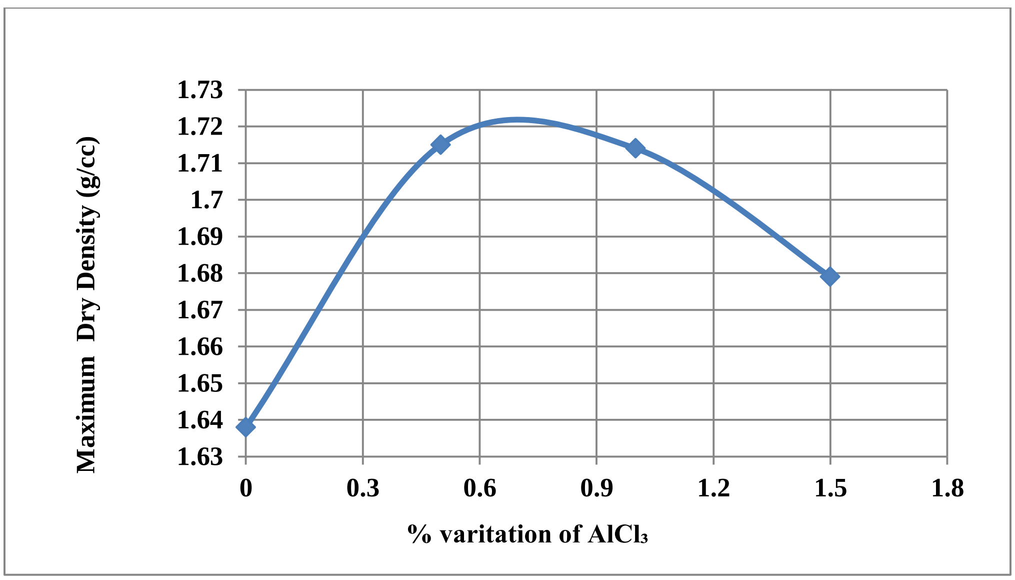

Fig 12 OMC&MDD Values of Expansive soil treated with silica fume and with % variation of $AlCl_3$

TABLE 10

% of mix proportion $AlCl_3$	OMC(%)	MDD (g/cc)
0	24.51	1.638
0.5	14.0	1.714
1.0	**16.0**	**1.715**
1.5	19.98	1.679

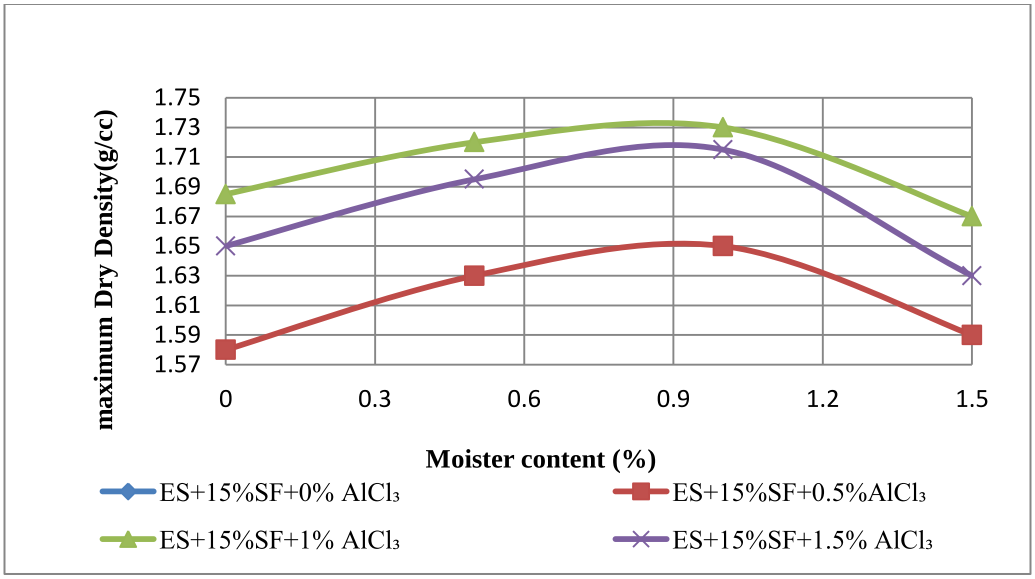

Fig 13 OMC and MDD values of treated Expansive soil trated with silica fume with % Variation of $AlCl_3$

Consolidation tests-Consolidation tests were conducted on the remoulded Expansive soil in a convectional Odometer of diameter 75mm and thickness 25mm.The specimens used for the test are Expansive soil, Expansive soil + 15% SF, ES + 15 % SF+ 1%,$Ca(OH)_2$,ES+ 1% $CaCl_2$,ES +15%SF + 1% $AlCl_3$, are prepared as per IS 2720 part 5 (1979). The setting load is allowed to stand till there is no change in the dial gauge readings for 24 hours and the final dial gauge reading is taken under the initial setting load. After initial the load is increased, is increased to apply a pressure of 20 Kpa and the step is repeated to record the dial gauge reading as started above. Likewise the load is increased to apply pressure of 50, 100,200,400,and 800Kpa and the corresponding dial gauge readings are recorded. However, when the load increment is applied to increase the pressure from 200 to 400 kPa, the dial gauge readings are recorded at 0.0, 0.5, 1.0, 4.0, 9.0, 16.0, 25.0, 36.0, 49.0, 64.0, 81.0, 100.0, 121.0, 144.0, 169.0, 196.0, 400.0, 1440.00, minutes. On completion of the final loading stage, the specimen is unloaded by pressure decrements. which decrease the load to half of the last load. Dial gauge readings are taken during each stage of unloading. And plot the test results.

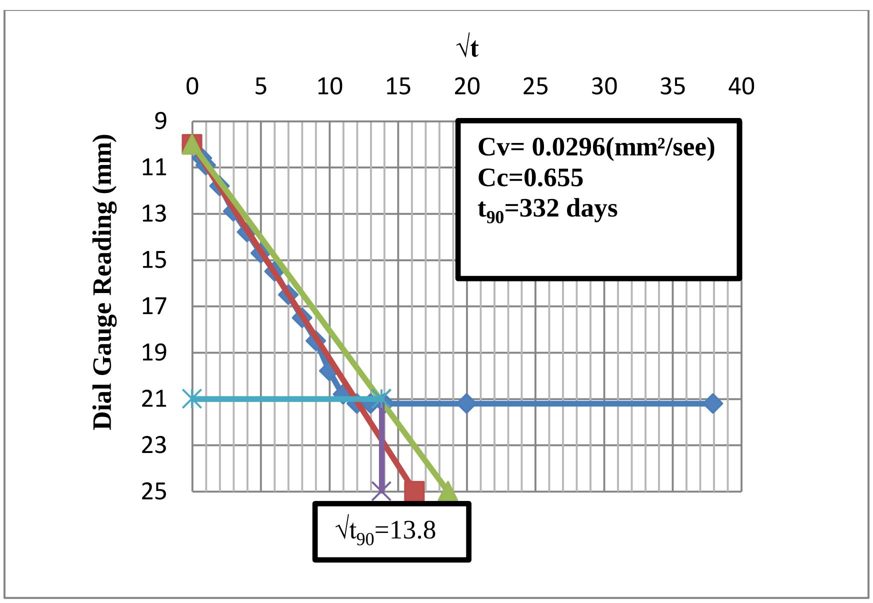

Fig 14 Consolidation characteristics of untreated expansive soil

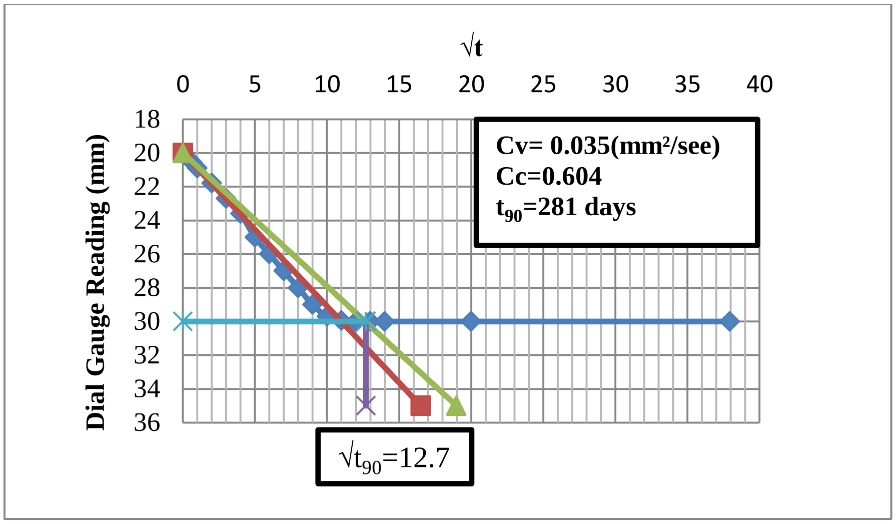

Fig 15 Consolidation characteristics of expansive soil treated with optimum percentage of silica fume

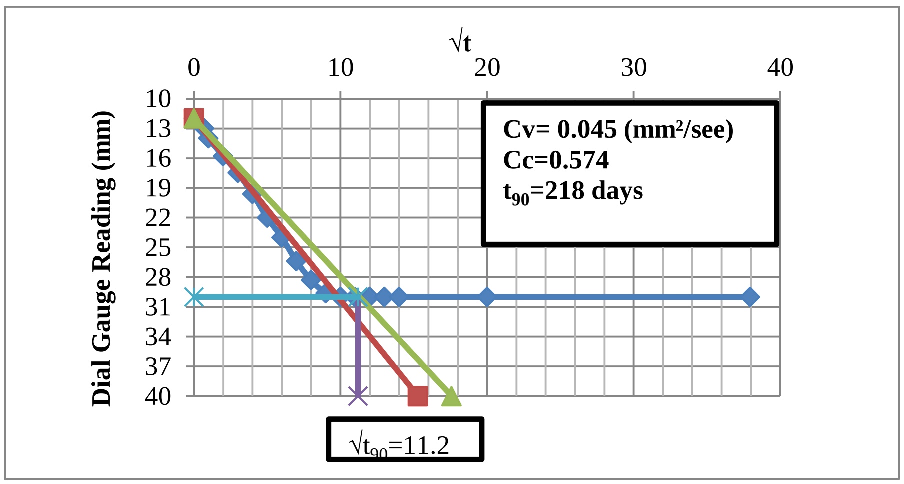

Fig 16 Consolidation characteristics of expansive soil treated with optimum percentage of silica fume and $CaCl_2$

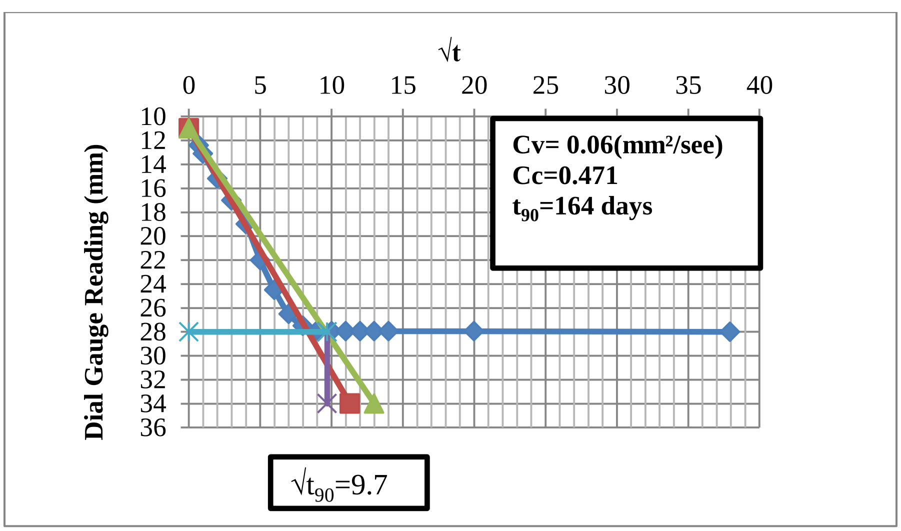

Fig 17 Consolidation characteristics of expansive soil treated with optimum percentage of silica fume and $Ca(OH)_2$

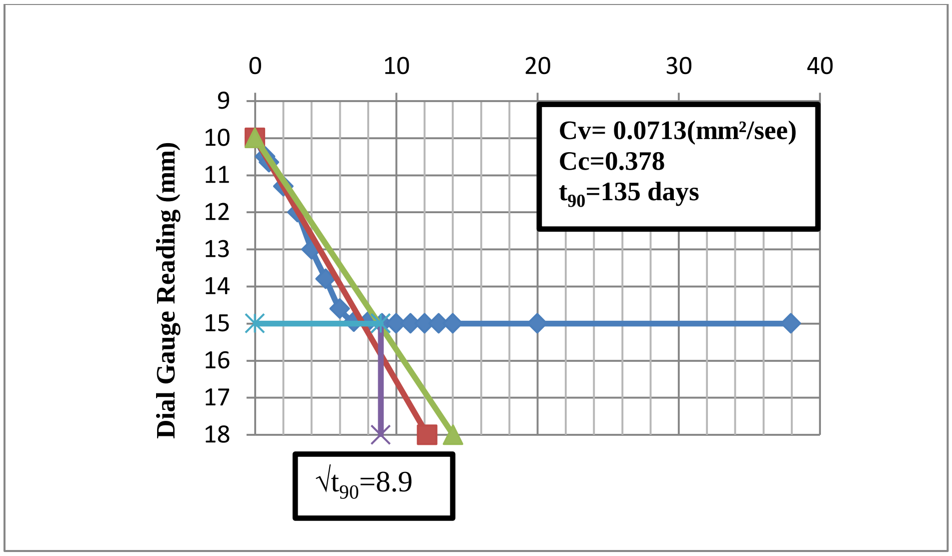

Fig 18 Consolidation characteristics of expansive soil treated with optimum percentage of silica fume and $AlCl_3$

TABLE 11
Coefficient of Consolidation, Compression Index, Rate of Consolidation of Untreated and Treated Marine Clay

S.No	Mix proportion	Coefficient of Consolidation (Cv)	Compression Index (Cc)	Rate of Consolidation (days)
1	Expansive soil	0.0296	0.655	332
2	Expansive soil with 15% silica fume	0.035	0.604	281
3	E.S with 15% S.F with 1% $CaCl_2$	0.045	0.574	218
4	E.S with15%S.F with1% $Ca(OH)_2$	0.06	0.471	164
5	E.S with 15%S.F with 1% $AlCl_3$	0.0713	0.378	135

VII CONCLUSIONS

Conclusions of the various results from the laboratory studies were presented.

I. It was observed from the laboratory investigation that the liquid limit of Expansive soil has been improved by 12.28%, 15.52%, 19.59%, 30.23% with the addition of 15%SF, 15%SF+1%$CaCl_2$, 15%SF+1%$Ca(OH)_2$, 15%SF+1%$AlCl_3$ respectively when compared with the untreated Expansive Soil.

II. It was observed from the laboratory investigation that the plastic limit of Expansive soil has been improved by 12.05%, 20.81%, 28.33%, 31.27% with the addition of 15%SF, 15%SF+1%$CaCl_2$, 15%SF+1%$Ca(OH)_2$, 15%SF+1% $AlCl_3$ respectively when compared with the untreated Expansive Soil.

III. It was observed from the laboratory investigation that the plasticity index of Expansive Soil has been improved by 29.06%, 45.37%, 29.15%, 29.7% with the addition of 15%SF, 15%SF+1%$CaCl_2$, 15%SF+1%$Ca(OH)_2$, 15%SF+1%$AlCl_3$ respectively when compared with the untreated Expansive Soil.

IV. It was observed that the DFS of Expansive soil has been decreased by 72.72%, 74.545%, 73.63%, 75.45% with the addition of 15%SF, 15%SF+1%$CaCl_2$, 15%SF+1%$Ca(OH)_2$, 15%SF+1% $AlCl_3$ respectively when compared with the untreated Expansive Soil.

V. It is found that the O.M.C of the Expansive Soil has been decreased by 16.14%, 43.6%, 35.58%, 59.89% with the addition of 15%SF, 15%SF+1%$CaCl_2$, 15%SF+1%$Ca(OH)_2$, 15%SF+1% $AlCl_3$ respectively when compared with the untreated Expansive Soil.

VI. It was found that the M.D.D of the Expansive Soil has been improved by 12.96%, 21.37%, 17.10%, 18.27% with the addition of 15%SF, 15%SF+1%$CaCl_2$, 15%SF+1%$Ca(OH)_2$, 15%SF+1% $AlCl_3$ respectively when compared with the untreated Expansive Soil.

VII. It was noticed from the laboratory investigations that the C.B.R value of the Expansive Soil has been improved by 67.41%, 295.08%, 147.98%, 224.21% with the addition of 15%SF, 15%SF+1%$CaCl_2$, 15%SF+1%$Ca(OH)_2$, 15%SF+1% $AlCl_3$ respectively when compared with the untreated Expansive Soil.

VIII. It was noticed from the laboratory investigations that the coefficient of consolidation of Expansive Soil has been improved by 27.97%, 67.1%, 127.53%, 227.53% with the addition of 15%SF, 15%SF+1%$CaCl_2$, 15%SF+1%$Ca(OH)_2$, 15%SF+1% $AlCl_3$ respectively when compared with the untreated Expansive Soil.

IX. It was concluded from the laboratory investigations that the coefficient of compression of Expansive Soil has been improved by 7.78%, 12.366%, 28.09%, 42.29% with the addition of 15%SF, 15%SF+1%$CaCl_2$, 15%SF+1%$Ca(OH)_2$, 15%SF+1% $AlCl_3$ respectively when compared with the untreated Expansive Soil.

X. It was noticed from the laboratory investigations that the rate of consolidation of Expansive Soil has been improved by 21.855%, 40.154%, 56.05%, 69.46% with the addition of 15%SF, 15%SF+1%$CaCl_2$, 15%SF+1%$Ca(OH)_2$, 15%SF+1% $AlCl_3$ respectively when compared with the untreated Expansive Soil.

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