

A LABORATORY STUDY ON THE CONSOLIDATION CHARACTERISTICS OF MARINE CLAY TREATED WITH SILICA FUME AND ADDITIVES

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Abstract - Marine clay is highly deformable soil in nature, available along the coastal corridor. Marine clays are highly compressible and possess moderate swelling behaviour. Marine clays are moderate in expansive nature due to the presence of chlorite, illite, kaolinite and montmorillonite. The natural water content of the marine clay is always greater than its liquid limit. The properties of marine clay differ significantly in moist and dry conditions. Due to the poor engineering characteristics of these marine clay soil deposits causes several problems in pavement design and has potential to destroy building foundations in almost all the countries. Many of these areas covered with thick soft marine clay deposit, with very low shear strength and high compressibility. In this present study the consolidation characteristics i.e., coefficient of consolidation, compression index and rate of consolidation of untreated and treated marine clay were determined by adding Silica Fume as admixture and also with chemicals i.e. ammonium chloride, potassium chloride and ferric chloride.

Key words - Marine clay, chemical stabilisation, Silica Fume, NH_4Cl , KCl , FeCl_3 , Consolidation Characteristics.

I. INTRODUCTION

The soil formed in the ocean bed as well as located on shore can be classified as marine clay. The properties of saturated marine clay may vary considerably from moist soil to dry soil. Marine clay is microcrystalline in nature, it contains clay minerals like chlorite, illite, kaolinite and non-clay minerals like quartz and feldspar are present in marine soil. Marine clay imposes great problems in pavement design due to uncertainty associated with their performance. Marine clays tend to swell when wetted and may shrink when dried. These volume changes may create problems in structures that come in to their contact. Marine clay deposits of Kakinada were used for the testing with the aim to investigate its consolidation and strength characteristics and further make suitable for foundation constructions or sub-grades over it. The soil was collected at 0.5m, depth from the Kakinada Sea Ports limited, Kakinada, A.P, India and used for the study.

II. REVIEW OF LITERATURE

The comprehensive review of literature, carried out worldwide since last five decades shows that a considerable amount of work is related for the determination of consolidation characteristics, deformation characteristics and strength characteristics of the marine clay. From the various investigations carried out on consolidation characteristics and strength characteristics of marine clay conducted by Narasimha Rao et.al (1987,1996), Shridharan et.al (1989), Mathew et.al (1997) and Wong et al., (2014) reported that when marine Clay treated with Calcium chloride-Cement mixture the bearing capacity of the Marine Clay improved greatly. Nor Zurairahetty Mohd Yunus et al., (2015) presented the efficiency of lime for improving the strength and compressibility behaviour of the marine clay (Iskandar Malaysian Region), Int.J.of GEOMATE. J. Sangeetha et al., (2016) reported that Marine Clay treated with percentage variation of jero fix the CBR value and MDD values. An accountable study on engineering properties of marine clay was performed by Dr. D. Koteswar Rao (2006, 2011, 2012, 2013, 2014,2018). Dr. D. Koteswara Rao and Y. Saieswar (2018) presented the efficiency of Calcium Carbide and other chemicals for improving the consolidation characteristics of marine clay.

III. OBJECTIVES OF STUDY

- To determine the properties of marine clay.
- To evaluate performance of marine clay treated with Silica Fume, NH_4Cl , KCl and FeCl_3 .
- To evaluate the consolidation characteristics of marine clay treated with Silica Fume, NH_4Cl , KCl , and FeCl_3 .

IV. MATERIALS USED

A. Marine Clay (MC)

The soil used for the study was collected at a depth of 0.5 to 1m below the bed level in Kakinada Sea Port Limited, Kakinada. The Index & Engineering properties of marine clay are determined as per IS code of practice.

B. Silica Fume

Silica fume, also known as microsilica, is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete. Silica Fume was varied in percentages of 5%, 10%, 15% and 20% by weight of marine clay throughout the experiments.

C. Ammonium Chloride (NH_4Cl)

Commercial grade Ammonium Chloride (NH_4Cl) was used in this study. Ammonium Chloride (NH_4Cl) in varying percentages of 0.4%, 0.6%, 0.8%, 1.0% & 1.2% is added to the marine clay. The quantity of Ammonium Chloride (NH_4Cl) was varied from 0 to 1.2% to the dry weight of soil.

D. Potassium Chloride (KCl)

Commercial grade Potassium Chloride (KCl) was used in this study. Potassium Chloride (KCl) in varying percentages of 0.6%, 0.8%, 1.0%, 1.2% & 1.4% is added to the marine clay. The quantity of Potassium Chloride (KCl) was varied from 0.6% to 1.4% to the dry weight of soil.

E. Ferric Chloride ($FeCl_3$)

Commercial grade Ferric Chloride ($FeCl_3$) was used in this study. Ferric Chloride ($FeCl_3$) in varying percentages of 0.6%, 0.8%, 1.0%, 1.2% & 1.4% is added to the marine clay. The quantity of Ferric Chloride ($FeCl_3$) was varied from 0.6% to 1.4% to the dry weight of soil.

V. LABORATORY INVESTIGATION

The Physical Properties of marine clay and particle size distribution of marine clay were presented in tables-1 below. The tests are conducted as per IS 2720 codes of practice.

TABLE I
Physical properties of Untreated Marine Clay

S.no	Property		Values
1.	Gravel (%)		0.0
2.	Sand (%)		6.0
3.	Fines	Silt (%)	24.65
		Clay (%)	69.35
4.	Liquid Limit (%)	W_L	76
5.	Plastic Limit (%)	W_P	34.33
6.	Plasticity Index (%)	I_p	41.67
7.	Soil Classification	--	CH
8.	Specific Gravity	G	2.4
9.	Free Swell (%)	FS	80
10.	Optimum Moisture Content (%)	OMC	37.32
11.	Maximum Dry Density (g/cc)	MDD	1.47
12.	CBR (%)	--	1.792
13.	Natural Moisture Content (%)	--	82

Compaction Test:

The tests were conducted as per IS 2720 Part – VII. OMC & MDD of air dried untreated and treated Marine clay with Silica Fume, NH_4Cl , KCl & $FeCl_3$ are presented in the tables II, III, IV, V, VI & Figures below.

TABLE II
OMC & MDD Values of Untreated Marine Clay

S.no	Water Content (%)	Dry Density(g/cc)
1.	33.12	1.423
2.	34.61	1.448
3.	37.32	1.470
4.	38.67	1.435
5.	39.41	1.419

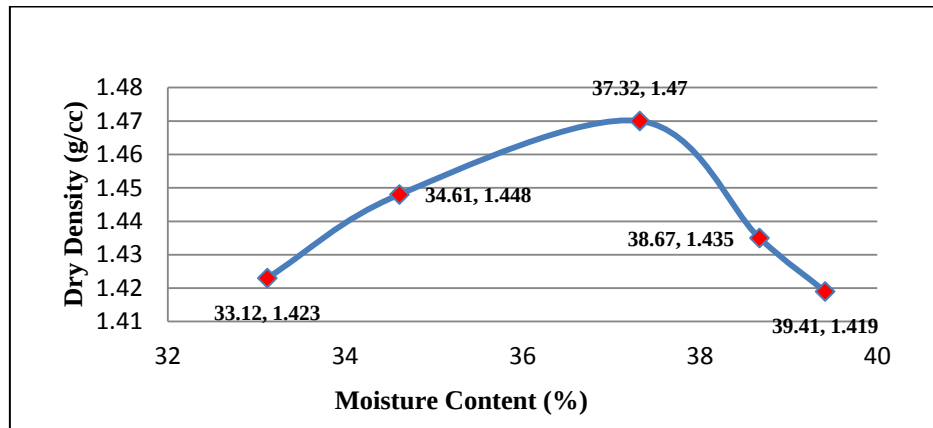


Fig.1 OMC & MDD Values of Untreated Marine Clay.

TABLE III
OMC & MDD Values of Marine Clay treated with % Variation of Silica Fume

Marine clay treated with % variation of Silica Fume	Water Content (%)	Dry Density(g/cc)
0	37.32	1.470
5	34.56	1.482
10	35.24	1.546
15	35.96	1.507
20	36.42	1.452

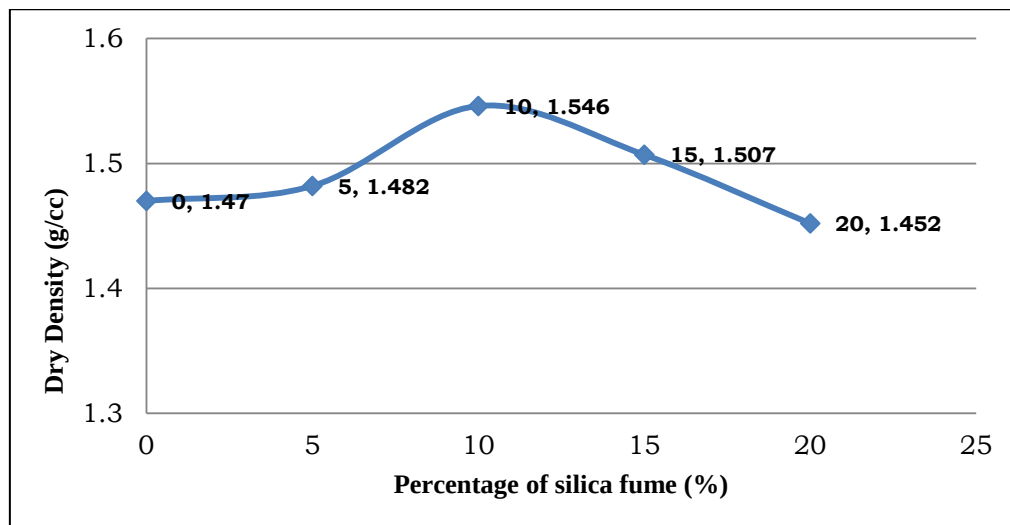


Fig. 2 OMC & MDD Values of Marine Clay treated with Silica Fume

It is observed from the above Table III and Fig.2, the treated Marine clay has exhibited the MDD value of 1.546 g/cc on addition 10% Silica Fume.

TABLE IV

OMC & MDD Values of Marine Clay treated with 10% Silica Fume along with percentage variation of NH_4Cl

Silica Fume treated marine clay with % variation of NH_4Cl	Water Content (%)	Dry Density(g/cc)
0.4	27.25	1.528
0.6	28.72	1.582
0.8	29.34	1.613
1.0	29.92	1.591
1.2	30.42	1.512

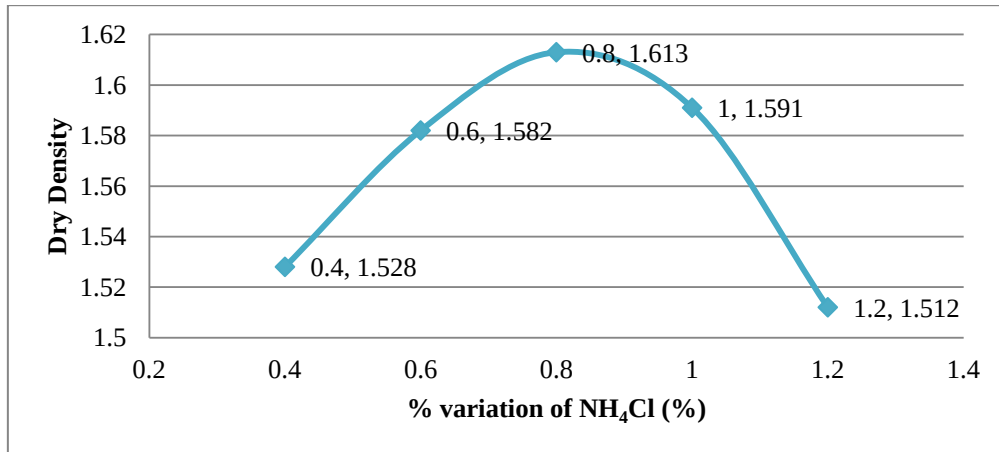


Fig. 3 OMC & MDD Values of Marine Clay treated with 10% Silica Fume along with percentage variation of NH_4Cl
It is observed from the above Table IV and Fig.3, the treated Marine clay has exhibited the MDD value of 1.613 g/cc on addition 10% Silica Fume and 0.8% of NH_4Cl

TABLE V

OMC & MDD Values of Marine Clay with optimum percentage of Silica Fume and mixed with percentage variation of KCl

Silica Fume treated marine clay with % variation of KCl	Water Content (%)	Dry Density(g/cc)
0.6	25.14	1.582
0.8	26.54	1.613
1.0	27.23	1.694
1.2	28.92	1.643
1.4	29.50	1.598

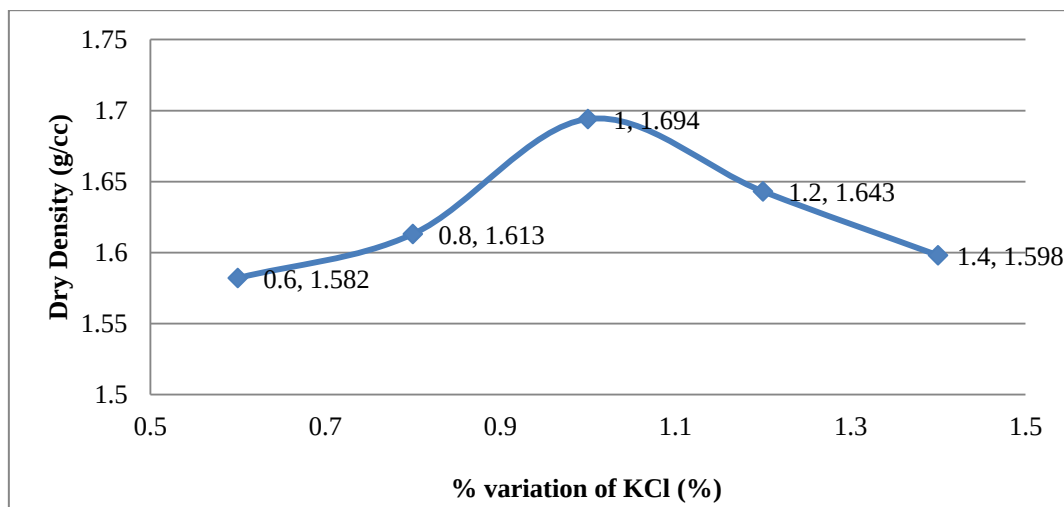


Fig. 4 OMC & MDD Values of Marine Clay with 10% of Silica Fume and mixed with percentage variation of KCl
It is observed from the above Table V and Fig.4, the treated Marine clay has exhibited the MDD value of 1.68 g/cc on addition of 10% Silica Fume and 1% KCl.

TABLE VI

OMC & MDD Values of Marine Clay with optimum percentage of Silica Fume and mixed with percentage variation of FeCl_3

Silica Fume treated marine clay with % variation of FeCl_3	Water Content (%)	Dry Density(g/cc)
0.6	22.62	1.632
0.8	23.15	1.689
1	23.86	1.723
1.2	24.32	1.691
1.4	24.91	1.641

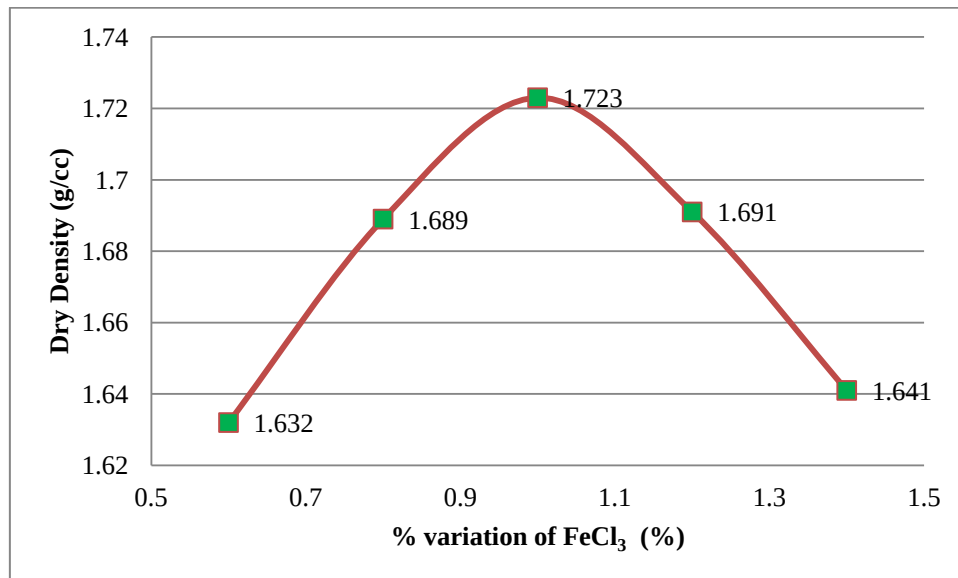


Fig.5: OMC & MDD Values of Marine Clay with optimum percentage of Silica Fume and mixed with percentage variation of FeCl_3

It is observed from the above Table VI and Fig.5, the treated Marine clay has exhibited the MDD value of 1.723 g/cc on addition of 10% Silica Fume and 1% FeCl_3 .

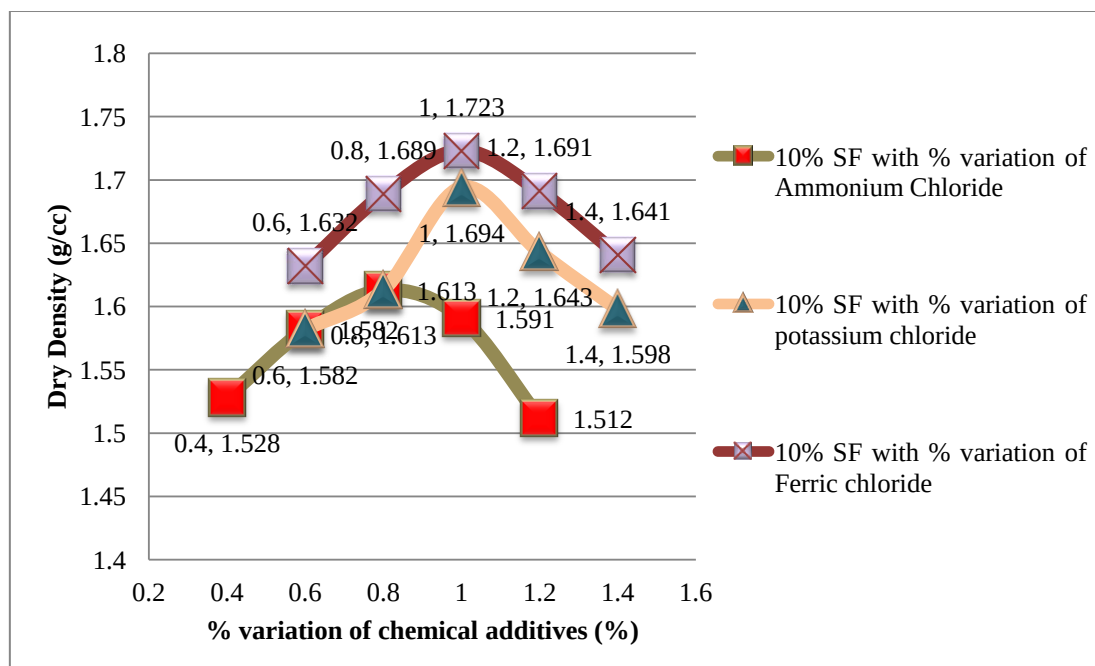


Fig. 6 Chart showing all the optimum values of chemicals added to the optimum Silica Fume

CONSOLIDATION TEST:

The test was carried out in accordance with IS – 2720 part 15 codes of practice. The calculations of consolidation was carried out by using square root of time method. Which is one of the curve fitting methods as per the codes of practice.

Consolidation characteristics:

The time required for the 90% consolidation, coefficient of consolidation & compression index of untreated and treated marine clay by using a standard method and were presented in table VII & Fig. 7 to 11.

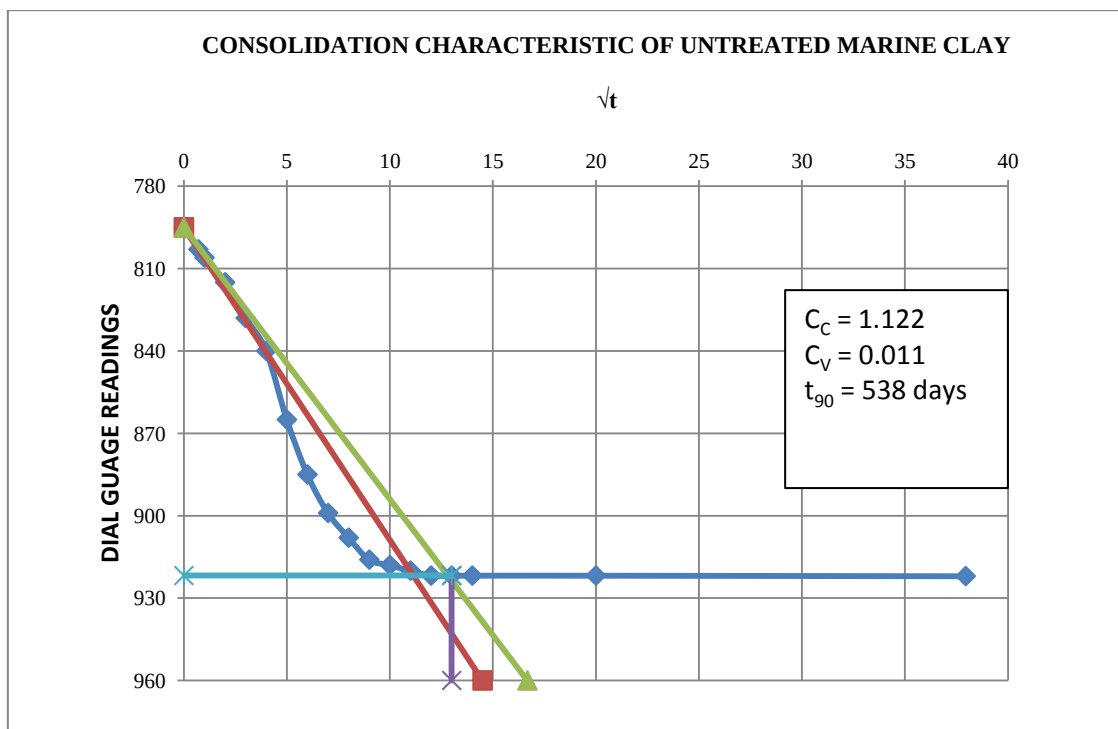


Fig.7 Consolidation Characteristic Of Untreated Marine Clay @3.2Kg/Cm

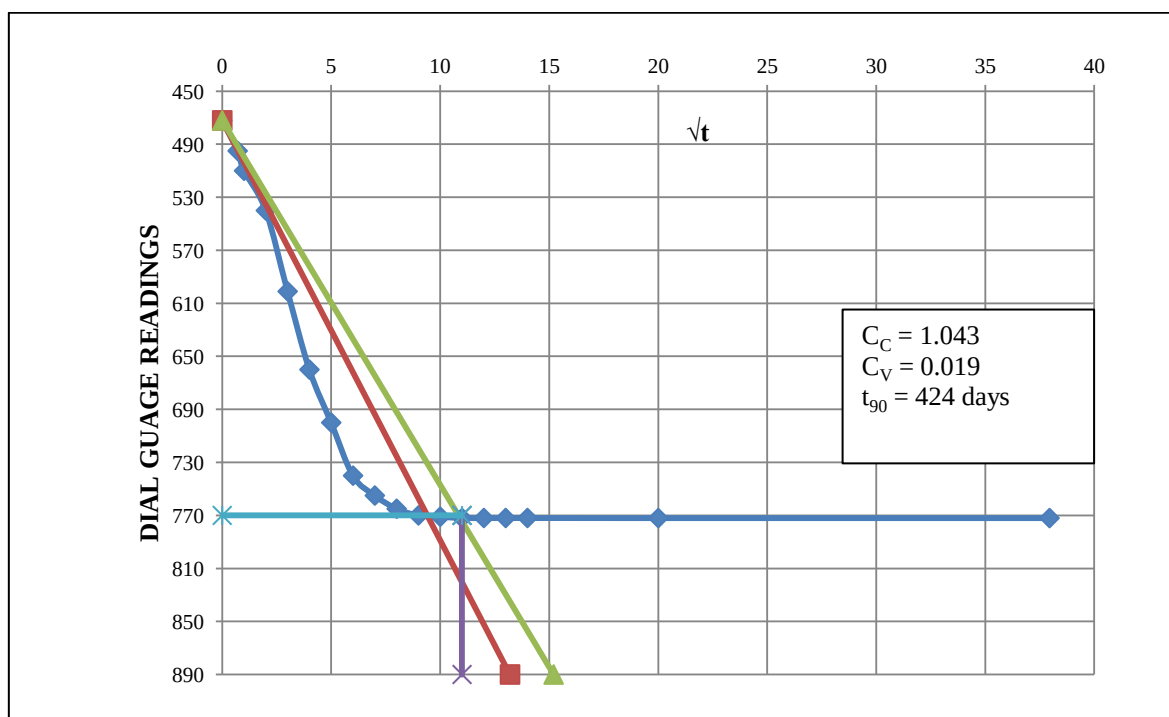


Fig. 8 Consolidation Characteristics of Marine Clay treated with 10% of Silica Fume

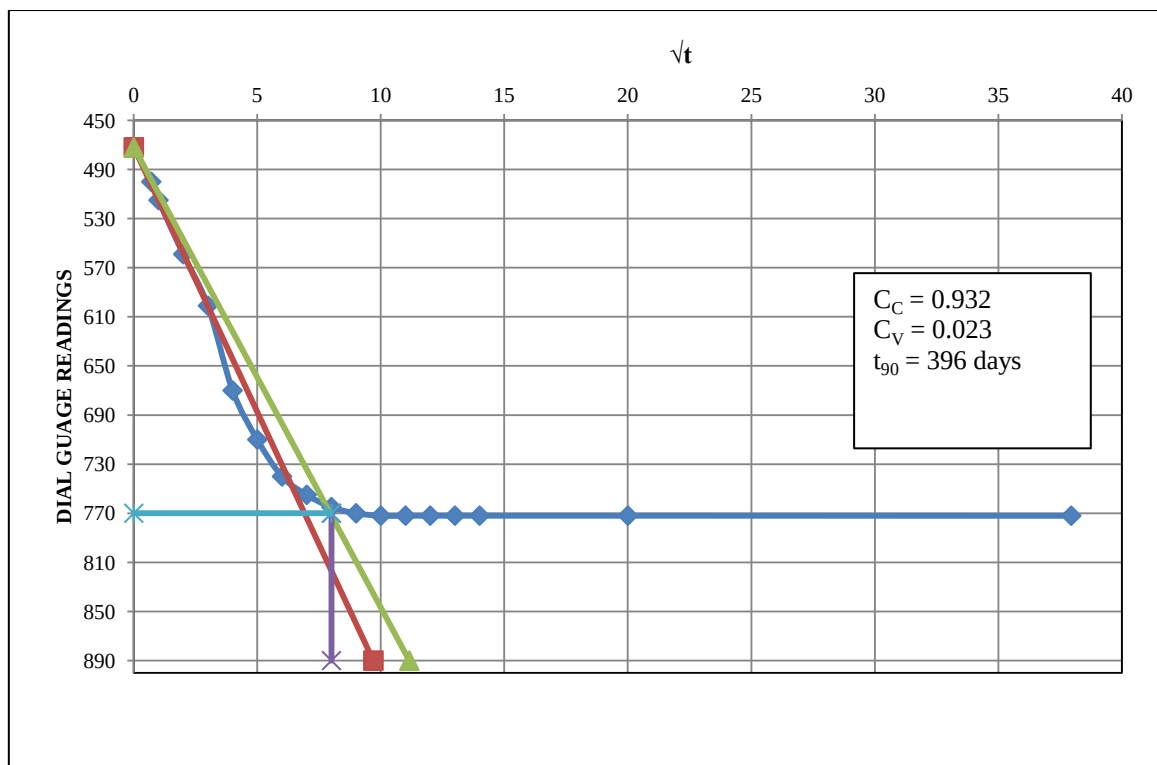


Fig. 9 Consolidation Characteristics of Marine Clay treated with optimum percentage i.e., 10% SF and 0.8% NH_4Cl

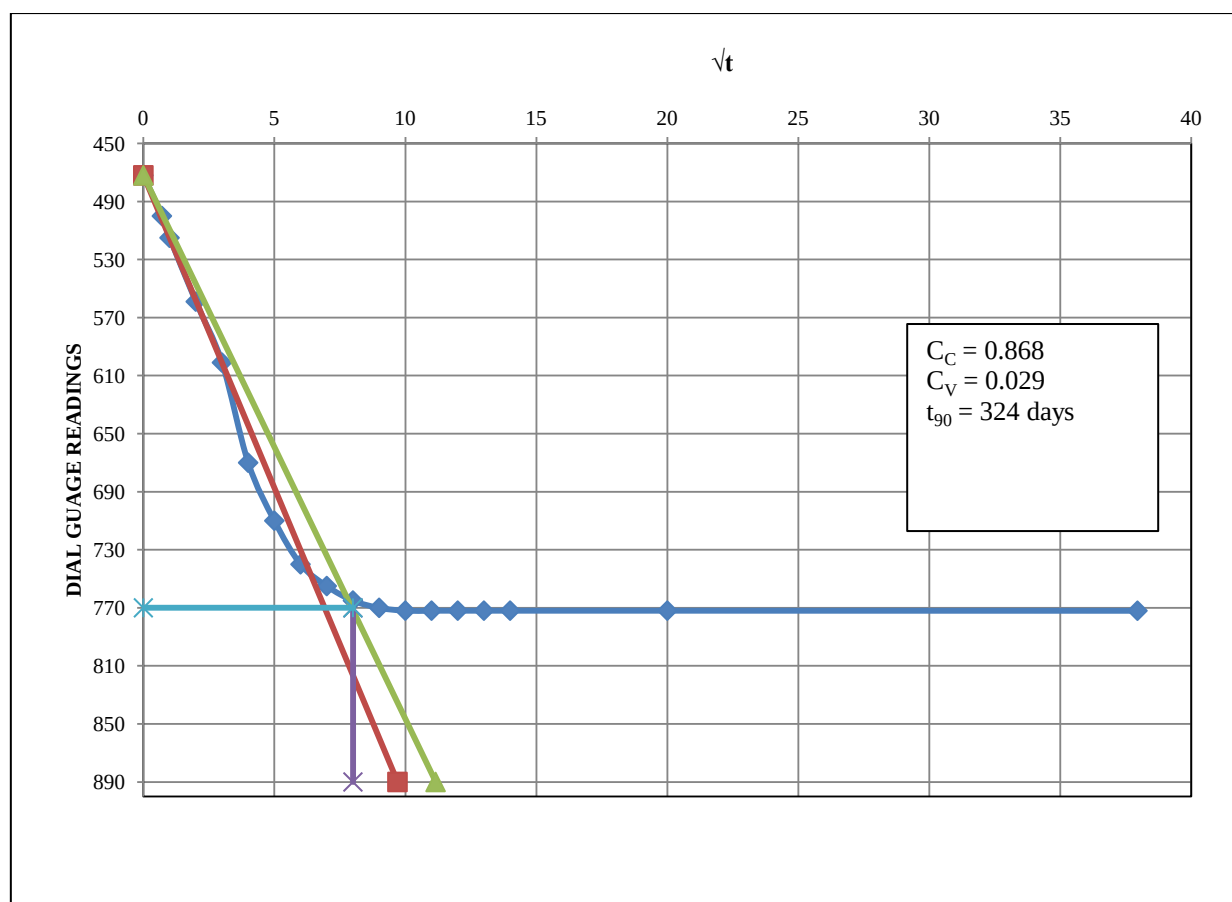


Fig. 10 Consolidation Characteristics of Marine Clay treated with optimum percentage i.e., 10% SF and 1% KCl

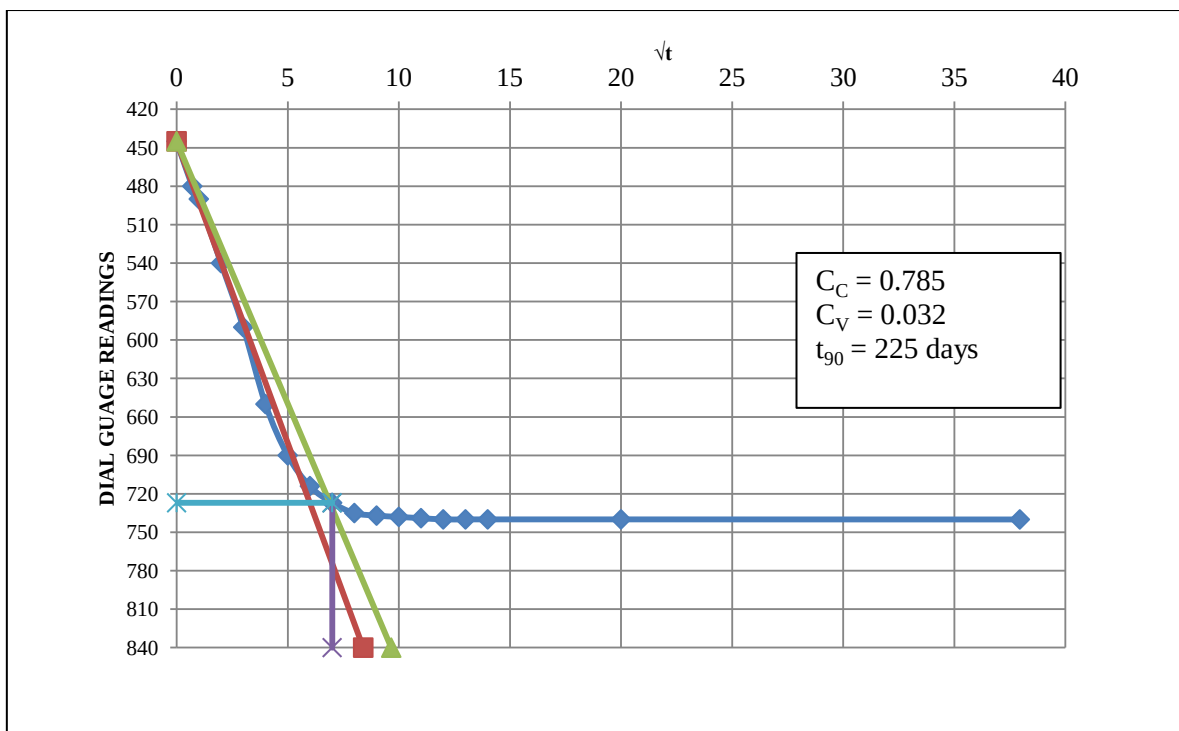


Fig. 11 Consolidation Characteristics of Marine Clay treated with optimum percentage i.e., 10% SF and 1% FeCl₃

TABLE VII

Coefficient Of Consolidation, Compression Index, Rate Of Consolidation Of Untreated And Treated Marine Clay

Description	Coefficient of consolidation C_v (cm / sec)	Compression index C_c	Rate of consolidation (days)
Untreated Marine Clay	0.011	1.122	538
Marine Clay treated with 10% SF	0.019	1.043	424
Marine Clay treated with 10% SF and 0.8% NH ₄ Cl	0.023	0.932	396
Marine Clay treated with 10% SF and 1% KCl	0.029	0.868	324
Marine Clay treated with 10% SF and 1% FeCl ₃	0.032	0.785	225

TABLE VIII

Represent the properties of Untreated Marine Clay, Marine Clay treated with 10% SILICA FUME, 0.8% NH_4Cl , 1% KCl and 1% FeCl_3

S.No	Property	MC	MC treated with 10% Silica Fume	MC treated with 10% Silica Fume & 0.8% NH_4Cl	MC treated with 10% Silica Fume & 1% KCl	MC treated with 10% Silica Fume & 1% FeCl_3
1	Liquid limit (%) W_L	76	65.2	55	43.2	38
2	Plastic Limit (%) W_p	34.33	30	25.8	24.3	21
3	Plasticity Index (%) I_p	41.67	35.2	29.2	18.9	17
4	Soil classification	CH	CH	CH	CH	CH
5	Specific Gravity G	2.4	2.55	2.62	2.68	2.71
6	Optimum Moisture Content (%) O.M.C	37.32	35.24	29.34	27.23	23.86
7	Maximum Dry Density (g/cc) M.D.D	1.47	1.546	1.613	1.694	1.723
8	CBR Value (%)	1.792	5.86	6.8	7.72	8.15
9	Free Swell DFSI	80	55	45	35	30

VI. CONCLUSION

1. The optimum percentage of chemicals and admixtures, observed during the laboratory investigation are summarized and presented in the following table.

S. no	Additive	Optimum percentage
1	Silica Fume	10%
2	NH_4Cl	0.8%
3	KCl	1%
4	FeCl_3	1%

2. Conclusions of the various results from the laboratory studies were presented.
 - i) It was observed from the laboratory investigations that the liquid limit and the plasticity index of marine clay has been improved by 14.2%, 15.52%; 27.63%, 29.92%; 43.15%, 54.64%; 50%, 59.2% with the addition of 10% SF; 10% SF + 0.8% NH_4Cl ; 10% SF + 1% KCl; 10% SF + 1% FeCl_3 respectively when compared with the untreated marine clay.
 - ii) Future it was noticed from the laboratory investigations that the coefficient of consolidation of marine clay has been improved by 39.82%; 87.42%; 62.57%; 108.98% with the addition of 10% SF; 10% SF + 0.8% NH_4Cl ; 10% SF + 1% KCl; 10% SF + 1% FeCl_3 respectively when compared with the untreated marine clay.

- iii) It was concluded from the laboratory investigations that the coefficient of compression has been improved by 366.4%; 160%; 154%; 165.68% with the addition of 10% SF; 10% SF + 0.8% NH_4Cl ; 10% SF + 1% KCl ; 10% SF + 1% FeCl_3 respectively when compared with the untreated marine clay.
- iv) It was perceived from the laboratory investigation that the rate of consolidation of marine clay has been improved by 28.32%; 46.41%; 38.56%; 51.87% with the addition of 10% SF; 10% SF + 0.8% NH_4Cl ; 10% SF + 1% KCl ; 10% SF + 1% FeCl_3 respectively when compared with the untreated marine clay.

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