International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 4, Issue 08, August-2018

A LABORATORY STUDY ON THE CONSOLIDATION CHARACTERISTICS OF MARINE CLAY TREATED WITH CALCIUM CARBIDE POWDER AND ADDITIVES

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Abstract*— Rapid Population growth results in scarcity of land for housing, commercial, industrial, transportation and infrastructure purpose. This necessitated the use of land, which has weak strata, where the geotechnical engineers are challenged by the presence of problematic soils with varied engineering properties. One of such soil is marine clay. Marine Clays are problematic soils all around the world and especially in the regions where climate is arid or semi-arid. These soils are highly compressible soils suffering from low shear strength and high compressibility associated with movements of pavements and foundations may result in cracking and breaking of structures. Several methods are used to improve the engineering properties of marine clay. Among those methods, chemical stabilization is widely used. 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 Calcium Carbide Powder as admixture and also with chemicals i.e. ammonium chloride, potassium chloride and ferric chloride.

Key words*— Marine clay, chemical stabilisation, Calcium Carbide Powder, NH_4Cl, KCl, $FeCl_3$, Consolidation Characteristics.

I. INTRODUCTION

The soil found in the ocean bed is classified as marine clay. It can even be located onshore as well. The marine clay is available at fully saturated condition in the costal corridors. Marine clay is microcrystalline in nature and clay minerals like chlorite, Kaolinite and Illite and non-clay minerals like quartz and feldspar are moderately present in the soil. The soils have higher proportion of organic matters that acts as a cementing agent. The natural moisture content of the marine clays is always greater than its liquid limit. The particles can self-assemble in to various configurations, each with totally different properties. Marine clay has low shear strength and high compressibility. Hence, it is becoming a great challenge for the Civil Engineers to design suitable pavements and foundation for the structures in these regions. The problems posed by marine clay can be minimised by various ground improvement techniques.

Methods to Improve the Marine clay : Different measures have been proposed and methodologies adopted for overcoming problems associated with these kinds of soils. The methodologies used worldwide are like pre-wetting, surcharge loading, admixture and chemical stabilization, reinforcement techniques, sand drains etc., Among these, one of the most widely used methods are using admixture, chemical and reinforcement techniques for improving the load caring capacity of the soft soils. In this experimental investigative, marine clay is stabilised with the percentage variation of calcium carbide powder as an admixture along with chemicals viz ammonium chloride, potassium chloride and ferric chloride which are added separately at optimum percentages and the consolidation characteristics are noted.

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 G.Rajasekaran et.al (2002) are worthy to be noted. Improving the strength of marine clay by the stabilisation technique was performed by Nontanandh et.al (2004) and an accountable study on engineering properties of marine clay was performed by Dr. D. Koteswar Rao (2006,2011,2012,2013, 2014).

III. OBJECTIVES OF STUDY

- To determine the properties of marine clay.

- To evaluate performance of marine clay treated with Calcium Carbide Powder, NH_4Cl, KCl and $FeCl_3$.
- To evaluate the consolidation characteristics of marine clay treated with Calcium Carbide Powder, 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. Calcium Carbide Powder *(CaC_2)*

Calcium Carbide Powder (CCP) is a by-product from the acetylene gas production. This gas is used around the world for welding, lighting, metal cutting and to ripen fruits.

$CaC_2 + 2H2O \longrightarrow C_2H_2 + Ca(OH)_2$.

Calcium hydroxide rich material used to produce moderately high strength. Three basic reactions, which are cation exchange, aggregation and flocculation which attributed the engineering properties of rich material stabilized clay. The influences of these three are primarily responsible for the change in plasticity and shrinkage. The quantity of Calcium Carbide Powder (CaC_2) was varied from 4 to12% to the dry weight of soil.

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 to1.2% 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% to1.4% 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% to1.4% 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 calcium carbide powder, 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

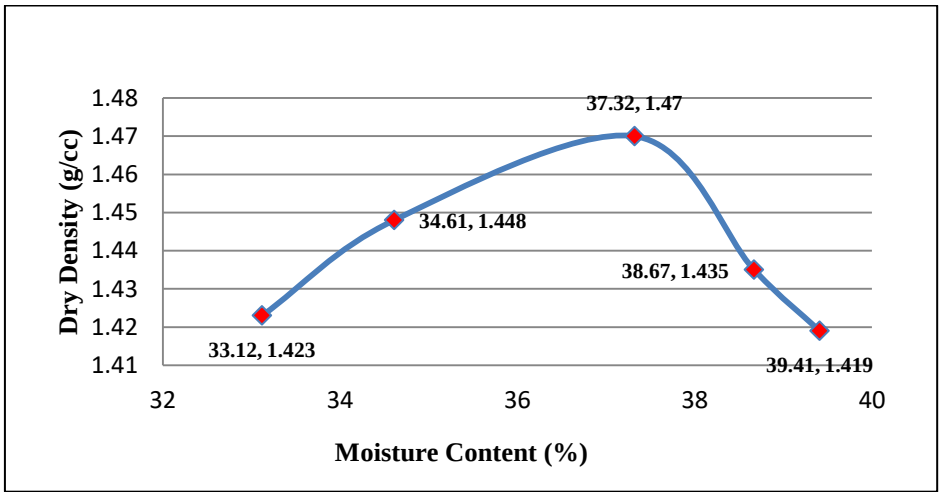

Fig.1 OMC & MDD Values of Untreated Marine Clay.

TABLE III
OMC & MDD Values of Marine Clay treated with % Variation of Calcium Carbide Powder

Marine clay treated with % variation of CCP	Water Content (%)	Dry Density(g/cc)
4	27.12	1.42
8	27.85	1.48
12	**28.13**	**1.53**
16	28.92	1.49
20	29.52	1.43

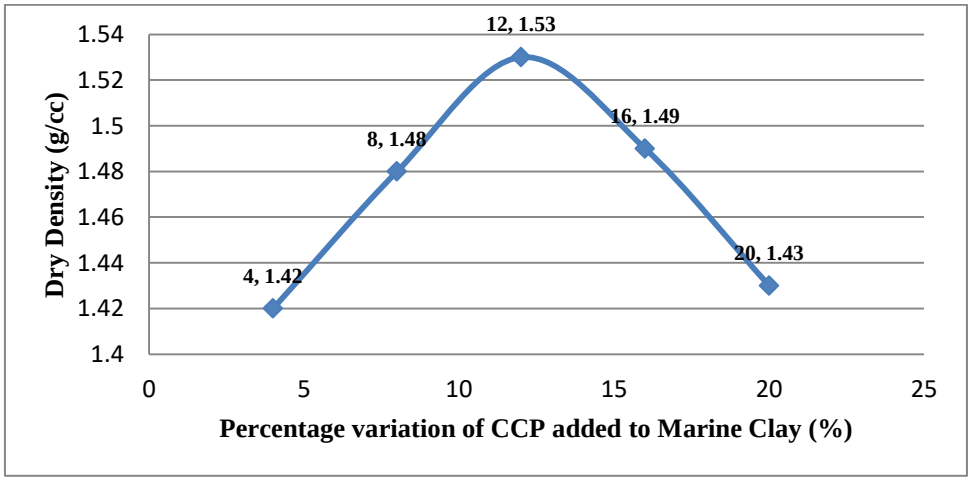

Fig. 2 OMC & MDD Values of Marine Clay treated with Calcium Carbide Powder

It is observed form the above Table III and Fig.2, the treated Marine clay has exhibited the MDD value of 1.53 g/cc on addition 12% CCP.

TABLE IV
OMC & MDD Values of Marine Clay treated with 12% CCP along with percentage variation of NH_4Cl

CCP treated marine clay with % variation of NH_4Cl	Water Content (%)	Dry Density(g/cc)
0.4	24.14	1.54
0.6	24.84	1.59
0.8	**25.23**	**1.65**
1.0	25.92	1.59
1.2	26.30	1.52

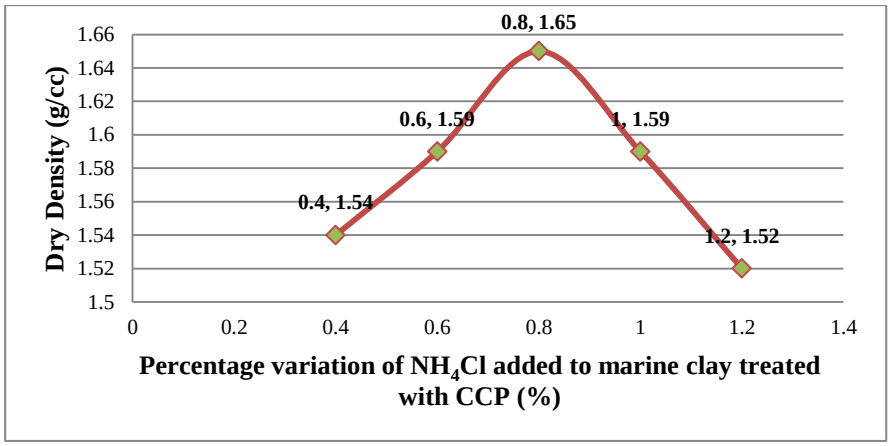

Fig. 3 OMC & MDD Values of Marine Clay treated with 12% CCP along with percentage variation of NH_4Cl

It is observed form the above Table IV and Fig.3, the treated Marine clay has exhibited the MDD value of 1.650 g/cc on addition 12% CCP and 0.80% of NH_4Cl

TABLE V
OMC & MDD Values of Marine Clay with optimum percentage of CCP and mixed with percentage variation of KCl

CCP treated marine clay with % variation of KCl	Water Content (%)	Dry Density(g/cc)
0.6	23.23	1.58
0.8	23.92	1.63
1.0	**24.38**	**1.68**
1.2	24.86	1.62
1.4	25.37	1.58

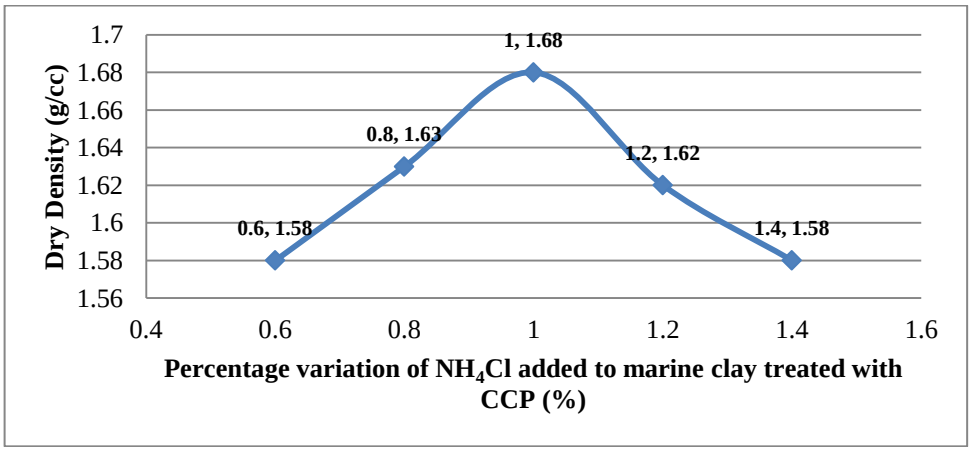

*Fig. 4 **OMC & MDD Values of Marine Clay with 12% of CCP and mixed with percentage variation of KCl***

It is observed form the above Table V and Fig.4, the treated Marine clay has exhibited the MDD value of 1.68 g/cc on addition of 12% CCP and 1% KCl.

TABLE VI
OMC & MDD Values of Marine Clay with optimum percentage of CCP and mixed with percentage variation of $FeCl_3$

CCP treated marine clay with % variation of $FeCl_3$	Water Content (%)	Dry Density(g/cc)
0.6	21.15	1.69
0.8	21.92	1.74
1.0	**22.55**	**1.79**
1.2	23.06	1.72
1.4	23.86	1.68

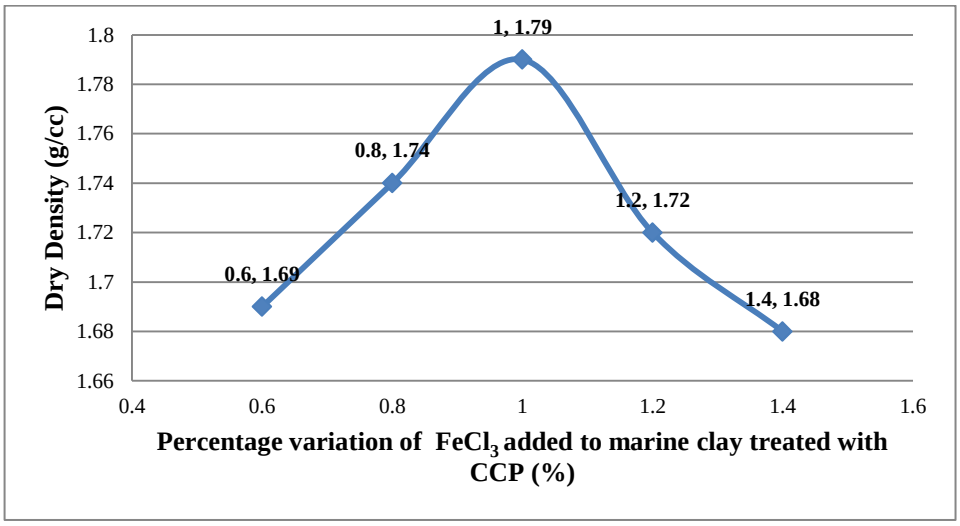

Fig.5: OMC & MDD Values of Marine Clay with optimum percentage of CCP and mixed with percentage variation of $FeCl_3$

It is observed form the above Table VI and Fig.5, the treated Marine clay has exhibited the MDD value of 1.79 g/cc on addition of 12% CCP and 1% $FeCl_3$.

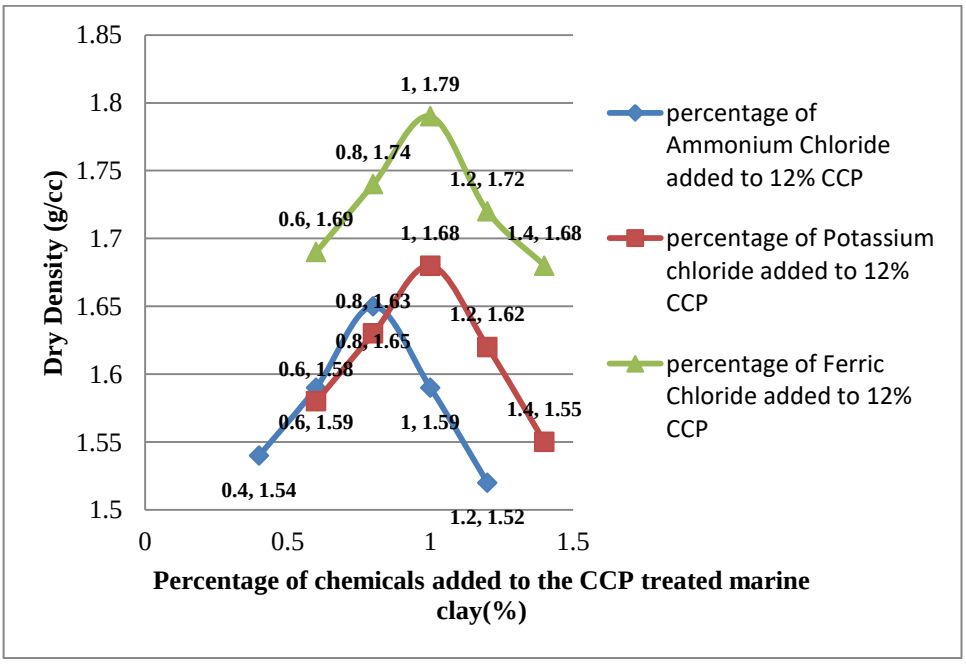

Fig. 6 Chart showing all the optimum values of chemicals added to the optimum Calcium Carbide Powder

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.

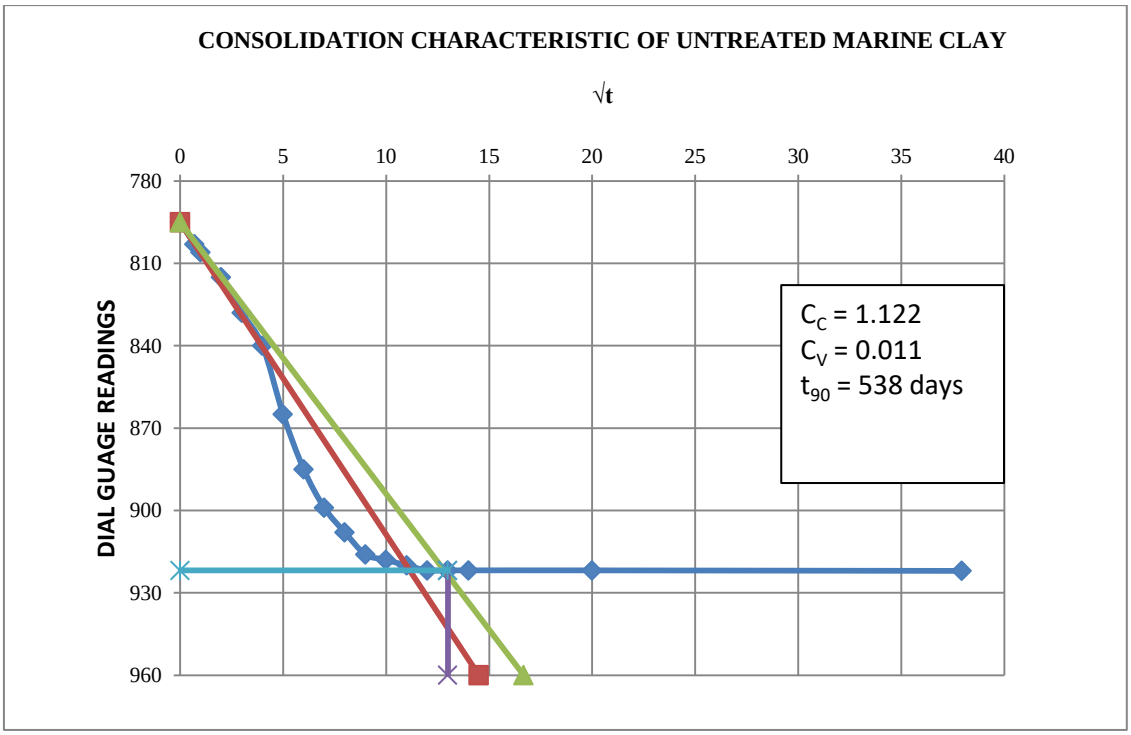

Fig.7 Consolidation Characteristic Of Untreated Marine Clay @3.2Kg/Cm

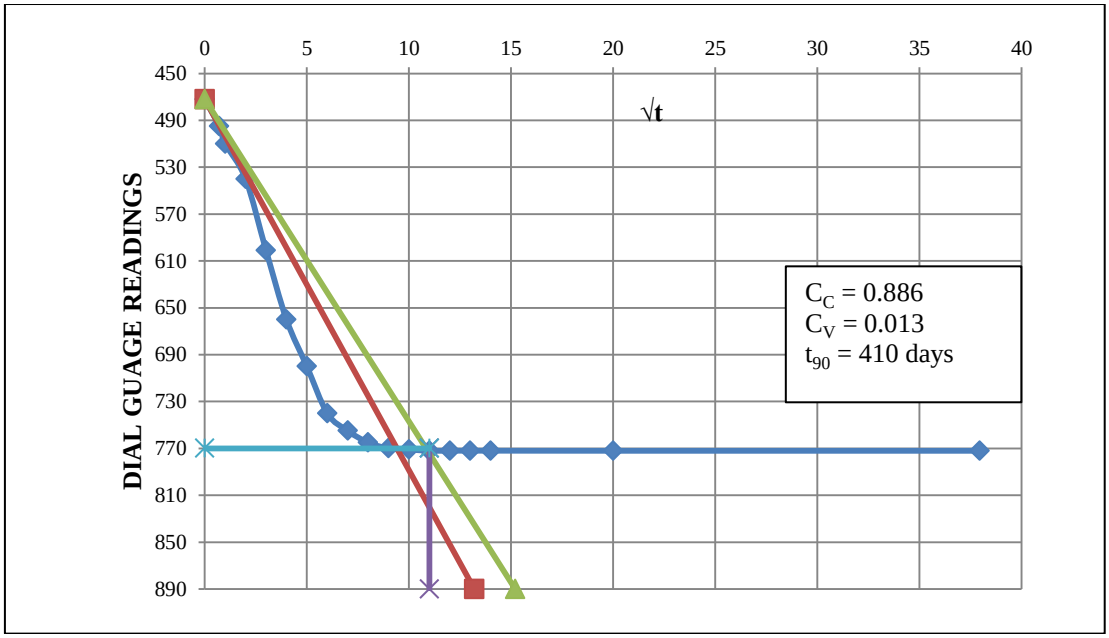

Fig. 8 ***Consolidation Characterisrics of Marine Clay treated with 12% of Calcium Carbide Powder***

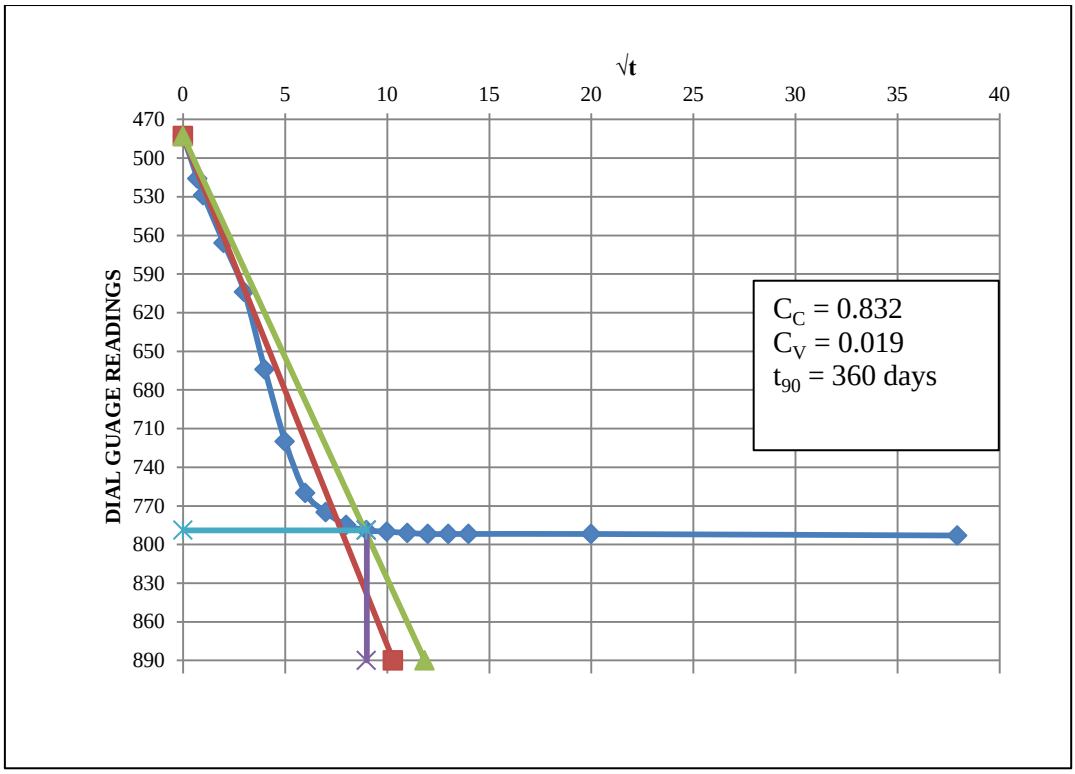

Fig. 9 ***Consolidation Characterisrics of Marine Clay treated with optimum percentage i.e., 12% CaC_2 and 0.8% NH_4Cl***

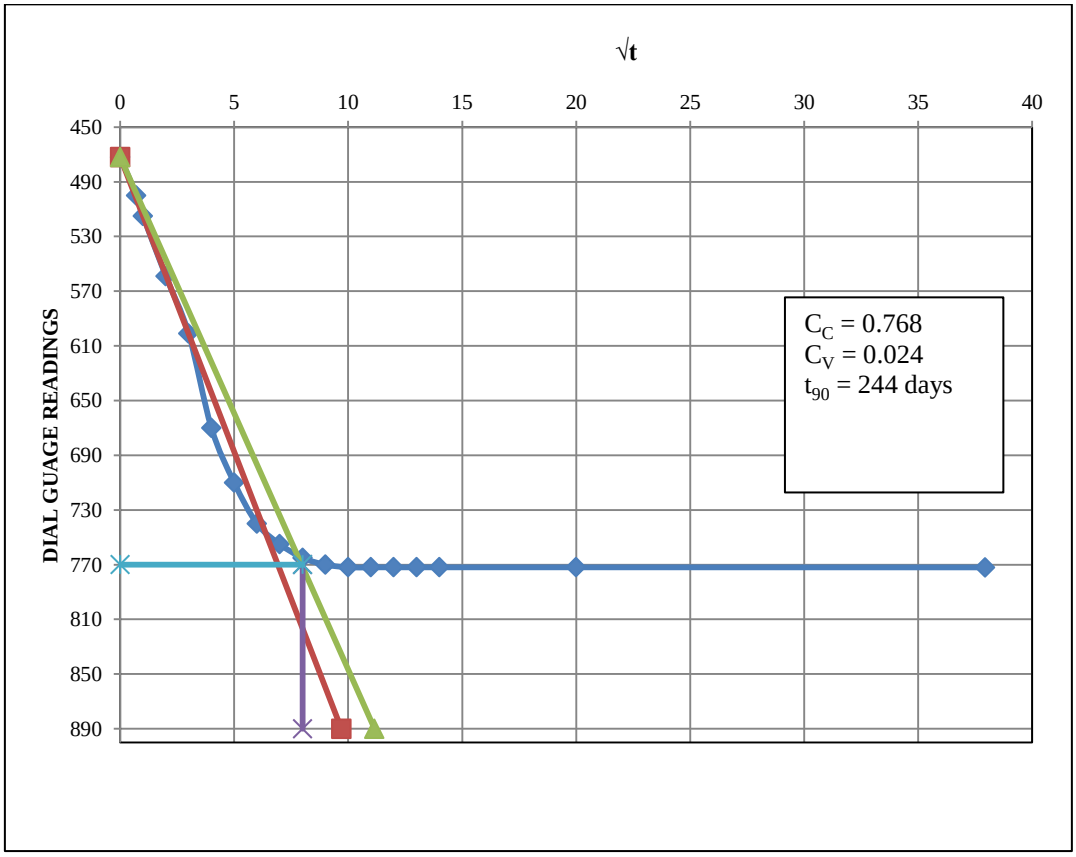

Fig. 10 ***Consolidation Characterisrics of Marine Clay treated with optimum percentage i.e., 12% CaC_2 and 1% KCl***

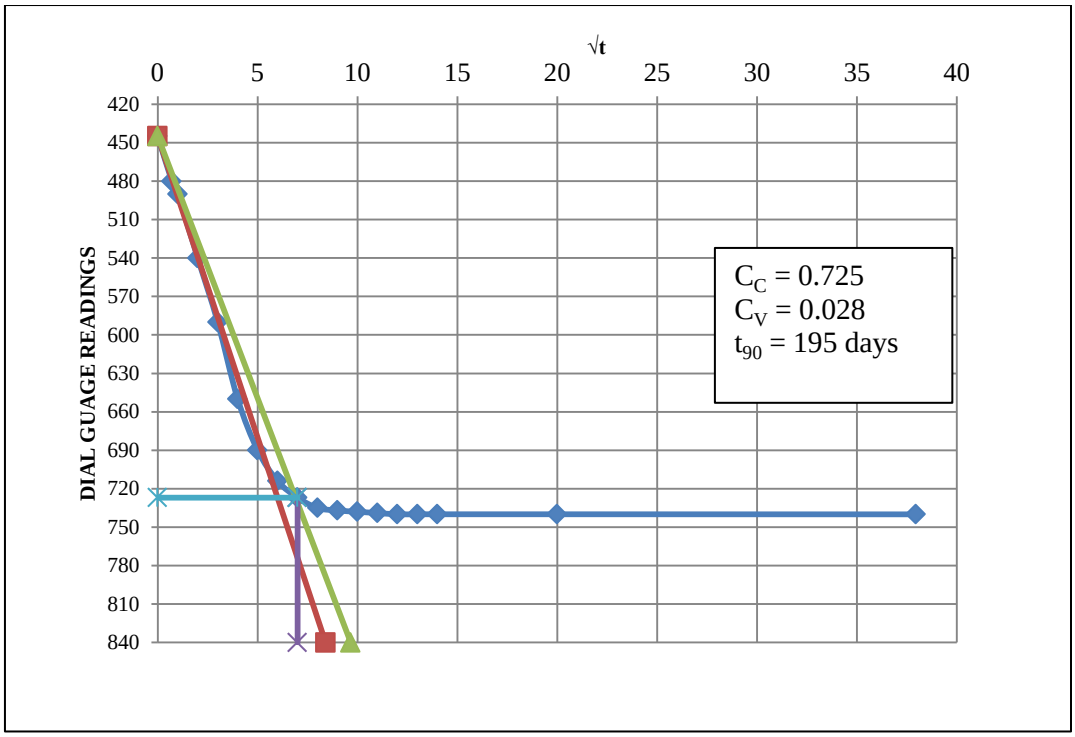

Fig. 11 ***Consolidation Characterisrics of Marine Clay treated with optimum percentage i.e., 12% CaC_2 and 1% $FeCl_3$***

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

Description	**Coefficient of consolidation C_V (cm^2 / sec)**	**Compression index C_C**	**Rate of consolidation (days)**
MC	0.011	1.122	538
MC treated with 12% CaC_2	0.013	0.886	410
MC treated with 12% $CaC_2$and 0.8% NH_4Cl	0.019	0.832	360
MC treated with 12% CaC_2 and 1% KCl	0.024	0.768	244
MC treated with 12% CaC_2 and 1% $FeCl_3$	0.028	0.725	195

TABLE VIII

Represent the properties of Untreated Marine Clay, Marine Clay treated with 12% CCP, 0.8% NH_4Cl, 1% KCl and 1% $FeCl_3$

S.No	Property	MC	MC treated with 12% CCP	MC treated with 12% CCP & 0.8% NH_4Cl	MC treated with 12% CCP & 1% KCl	MC treated with 12% CCP & 1% $FeCl_3$
1	Liquid limit (%) W_L	76	58.3	54.3	45.6	38
2	Plastic Limit (%) W_P	34.3	22.9	22.3	21.6	23
3	Plasticity Index (%) I_P	41.6	35.4	32	24	15
4	Soil classification	CH	CH	CH	CI	CI
5	Specific Gravity G	2.4	2.62	2.64	2.68	2.73
6	Optimum Moisture Content (%) O.M.C	37.3	28.13	25.23	24.38	22.55
7	Maximum Dry Density (g/cc) M.D.D	1.47	1.53	1.65	1.68	1.79
8	CBR Value (%)	1.7	6.82	7.8	8.4	8.6
9	Free Swell DFSI	80	45	35	30	25

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	CaC_2	12%
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 23.26%, 15.04%; 28.55%, 23.2%; 40%,42.4%; 50%, 64% with the addition of 12% CaC_2; 12% CaC_2 + 0.8% NH_4Cl; 12% CaC_2 + 1% KCl; 12% CaC_2 + 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%; 106.58%; 163.47%; 245.2% with the addition of 12% CaC_2; 12% CaC_2 + 0.8% NH_4Cl; 12% CaC_2 + 1% KCl; 12% CaC_2 + 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%; 424%; 383.2%; 359% with the addition of 12% CaC_2; 12% CaC_2 + 0.8% NH_4Cl; 12% CaC_2 + 1% KCl; 12% CaC_2 + 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%; 51.2%; 61.7%; 70.98% with the addition of 12% CaC_2; 12% CaC_2 + 0.8% NH_4Cl; 12% CaC_2 + 1% KCl; 12% CaC_2 + 1% $FeCl_3$ respectively when compared with the untreated marine clay.

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