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A LABORATORY STUDY ON THE INFLUENCE OF CALCIUM CHLORIDE ON THE MARINE CLAY TREATED WITH PHOSPHOGYPSUM

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Abstract— Marine clay is a type of clay found in coastal regions around the world. India being peninsular country has large area coming under coastal region. There are nine states and four union territories forms Indian coastline. Marine clay is one of the poor soils which have low shear strength, highly compressible. The natural moisture content of the marine clay is always greater than its liquid limit. Population growth leads to rapid urbanization requires vast lands for the development of commercial, residential, industrial, infrastructure and transportation but due to lack of availability of lands, ground improvement techniques are required. This necessitated the geotechnical engineers to improve the strength of weak soils viz the marine clay and the expansive soils. The present study deals with the influence of Phosphogypsum and Calcium Chloride on improving the strength characteristics of the marine clays.

Keywords— Marine clay, Phosphogypsum, Calcium Chloride, Cohesion, Angle of internal friction, OMC, MDD, CBR.

I. INTRODUCTION

Origin of the marine clay: The marine clay is found in coastal regions around the world. It is formed by the sedimentation of clayey soils in marine environments. Marine clay expands when water is added and shrinks when it dries. Marine clay is micro crystalline in nature and clay minerals like chlorite, kaolinite, illite and non-clay minerals like quartz and feldspar are present in the soil. These soils are highly saturated, highly deformable, sensitive and normally consolidated. The marine clay pose problems with regard to bearing capacity and stability because of their low shear strength. Several remedial measures like soil replacement, admixture stabilization, chemical stabilization, mechanical stabilization, thermal stabilization and grouting etc., methods have been done for improving the properties of weak soils. From the various contributions, investigations on marine clay conducted by S. Narasimharao et al.,(1987,1996), Mathew et al., (1997), Petry and Armstrong, 1989, DivyaKrishnan.K (2014) , Mishra and Mathur (2004) , K.V.N.MallikarjunaRao and D.Koteswara Rao (2011,2012,2013, 2014) . The results concluded that the load carrying capacity of treated marine clay is suitable as a sub grade material for the pavement construction and also for various types of foundations.

II. OBJECTIVES

- To determine the properties of the Marine Clay.
- To evaluate the properties of Marine Clay stabilized with Phosphogypsum as an admixture.
- To evaluate the properties of Marine Clay treated with optimum % of Phosphogypsum on % variation of Calcium Chloride.

III. MATERIALS USED

A.Marine Clay

The Marine soil used for the present study was collected at a depth of 0.5m to 1m below the bed level in port area of Kakinada sea port limited, Kakinada. This soil is tested in the laboratory to determine the properties as per the IS codes of practice.

B.Phosphogypsum

Phosphogypsum is a byproduct of phosphoric acid obtained by processing the phosphate rock using wet acid method. Table 1 and Table 2 present chemical composition and particle size distribution of Phosphogypsum.

C.Calcium Chloride

Calcium chloride is an inorganic compound, with the chemical formula $CaCl_2$. It is colorless crystalline solid at room temperature, highly soluble in water. Table 3 present chemical properties of $CaCl_2$.

I. TABLE
CHEMICAL COMPOSITION OF PHOSPHOGYPSUM

S. No.	Chemical constituent	Percentage
1	Calcium Oxide	31.2
2	Silicon Dioxide	3.92
3	Sulphur Trioxide	42.3
4	P_2O_5	3.6
5	Mgo	0.49
6	Phosphate, Fluoride	18.49

Courtesy by: Nagarjuna Fertilizers, Samalkot

II. TABLE
PARTICLE SIZE DISTRIBUTION OF THE PHOSPHOGYPSUM

Sieve Size (mm)	% Passing of PG
76.2	100
2.0	100
4.75	95.3
0.425	87.3
0.075	71

III. TABLE
CHEMICAL PROPERTIES OF CALCIUM CHLORIDE

S. No.	Property	Value
1	Molar Mass (g/mol)	110.98
2	Appearance	White Powder
3	Odour	odourless
4	Density (g/cc)	2.15
5	Melting Point (^{0}C)	772-775
6	Boiling Point (^{0}C)	1935

Courtesy by: Andhra laboratory chemicals, Kakinada

IV. LABORATORY TESTING

The laboratory studies were carried out on the samples:
1. Untreated Marine Clay
2. Marine Clay treated with the percentage variation of the Phosphogypsum
3. Marine Clay treated with an optimum % of Phosphogypsum on percentage variation of the Calcium Chloride

1) Properties of Untreated Marine clay

The following properties were observed from visual classification in dry condition.

Colour -- Black in colour
Odour -- Odour of decaying vegetation
Texture – Fine grained
Dry strength -- Medium
Dylatancy -- Less Sluggish
Plasticity --Highly plastic
Classification -- Highly Compressible Clay (CH)

IV. TABLE
PHYSICAL PROPERTIES OF UNTREATED MARINE CLAY

S. No.	Property	Symbol	Value
1	Gravel (%)		0
2	Sand (%)		10.02
3	Fines (%)	Silt	24.65
		Clay	65.33
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	Differential Free Swell	DFS	110
9	Specific Gravity	G	2.42
10	Optimum Moisture Content (%)	O.M.C	37.32

11	Maximum Dry Density (g/cc)	M.D.D	1.47
12	CBR (%)	CBR	1.792
13	Cohesion (kg/cm^2)	C	0.7
14	Angle of Internal Friction(°)	ϕ	5.71

2) Modified Proctor Compaction test results of untreated Marine Clay

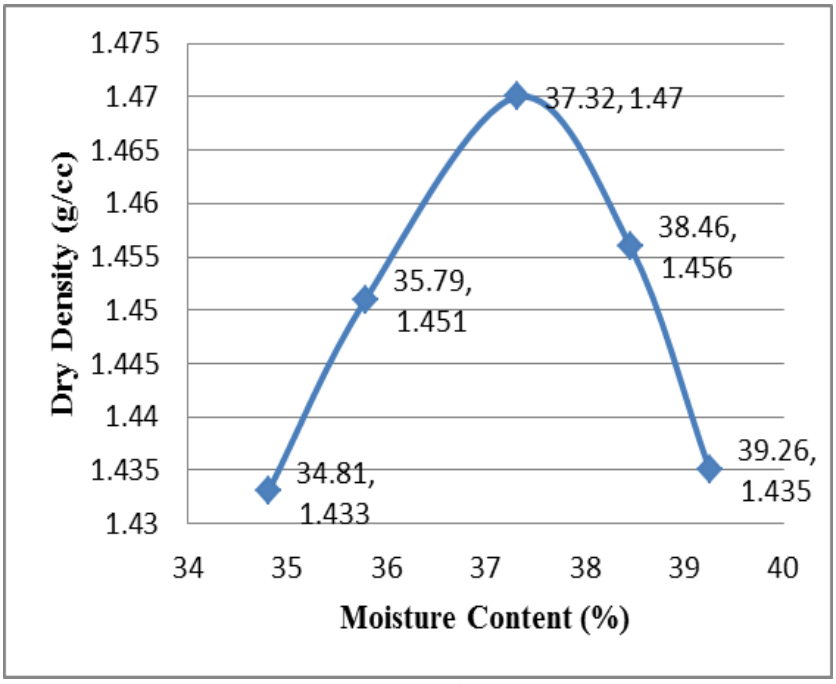

Fig. 1 OMC and MDD values of untreated marine clay

3) CBR values of untreated marine clay

The CBR test was carried out as per the IS code 2720 part 16, 1987. Fig. 2 and Table 6 present the CBR values of untreated Marine Clay and Marine Clay treated with the percentage variation of PG.

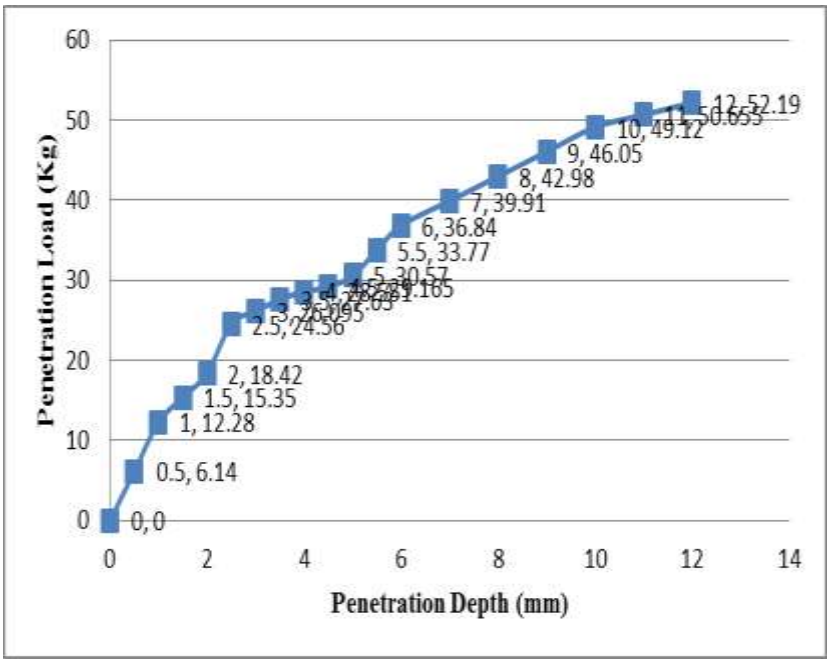

Fig. 2 CBR values of untreated marine clay

4) Modified Proctor Compaction test results for Marine Clay treated with Percentage variation of Phosphogypsum

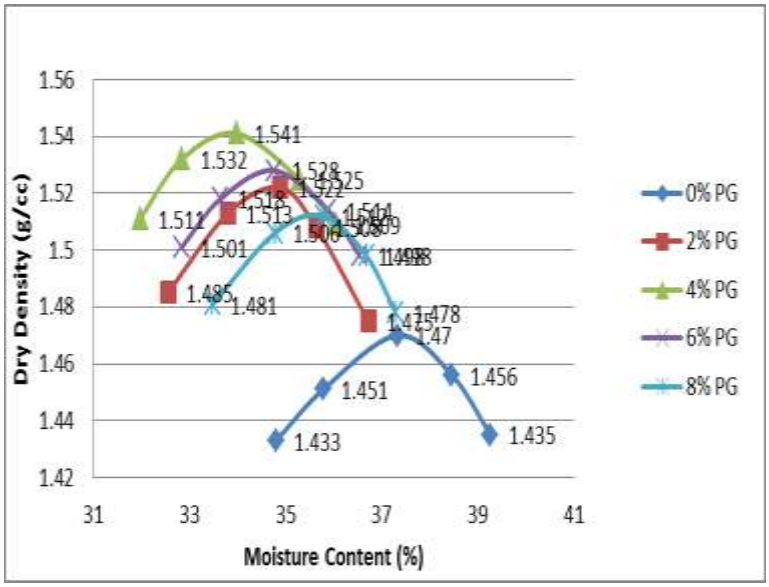

Fig.3 OMC and MDD values for marine clay treated with the percentages variation of Phosphogypsum

V. TABLE

VARIATION OF MDD WITH % OF PHOSPHOGYPSUM

Mix Proportion	MDD
100%MC	1.47
98%MC+2%PG	1.522
96%MC+4%PG	1.541
94%MC+6%PG	1.528
92%MC+8%PG	1.512

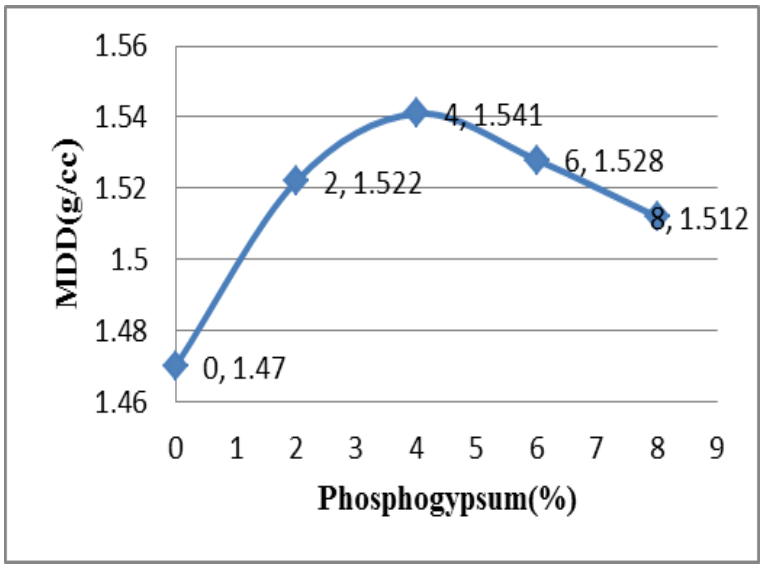

Fig. 4 Variation of MDD with % variation of Phosphogypsum

5) CBR test results for Marine Clay treated with Percentage variation of Phosphogypsum

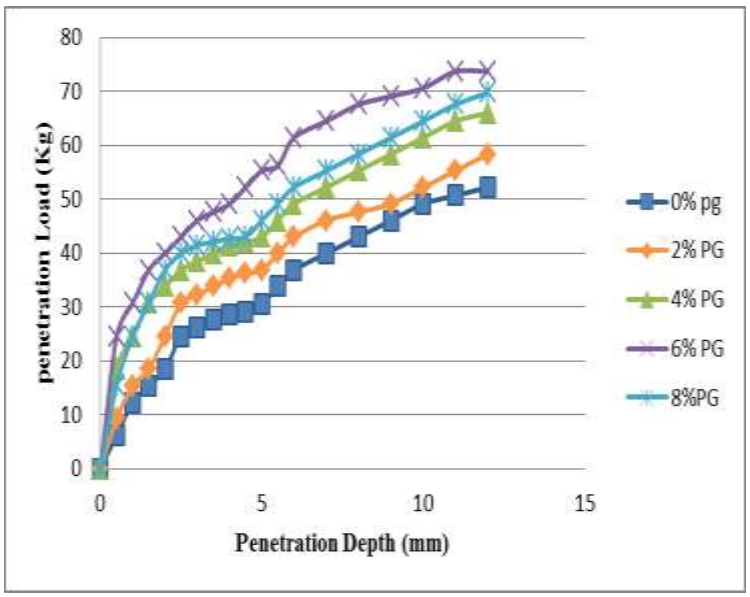

Fig. 5 CBR Values of Marine Clay with % variation of Phosphogypsum

VI. TABLE
VARIATION OF CBR VALUES WITH % VARIATION OF PHOSPHOGYPSUM

Mix Proportion	CBR Value
100% MC	1.792
98%MC+2%PG	2.240
96%MC+4%PG	2.689
94%MC+6%PG	3.137
92%MC+8%PG	2.913

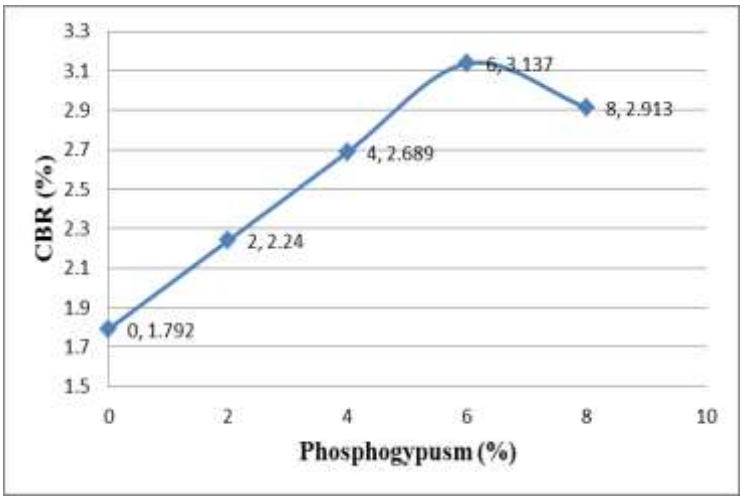

Fig.6 Variation of CBR values with % variation of phosphogypsum

DISCUSSION-1

It was observed from the laboratory test results that the Marine Clay treated with an optimum of 6% of PG has exhibited the CBR value of 3.137% which is less as per IS codes of practice to use this treated Marine Clay as subgrade for flexible pavements. Hence it is essential to improve this treated Marine Clay by making an attempt with the addition of suitable chemical for further improving the CBR value to suit this treated soil as subgrade for flexible pavements as per IS-2720 (Part-16) and IRC:37-2012, pp:10. In the present study Calcium chloride was used for further improvement in CBR value of the Marine Clay treated with an optimum percentage of $CaCl_2$.

6) Modified Proctor Compaction test results for Phosphogypsum treated Marine Clay with Percentage variation of Calcium Chloride ($CaCl_2$)

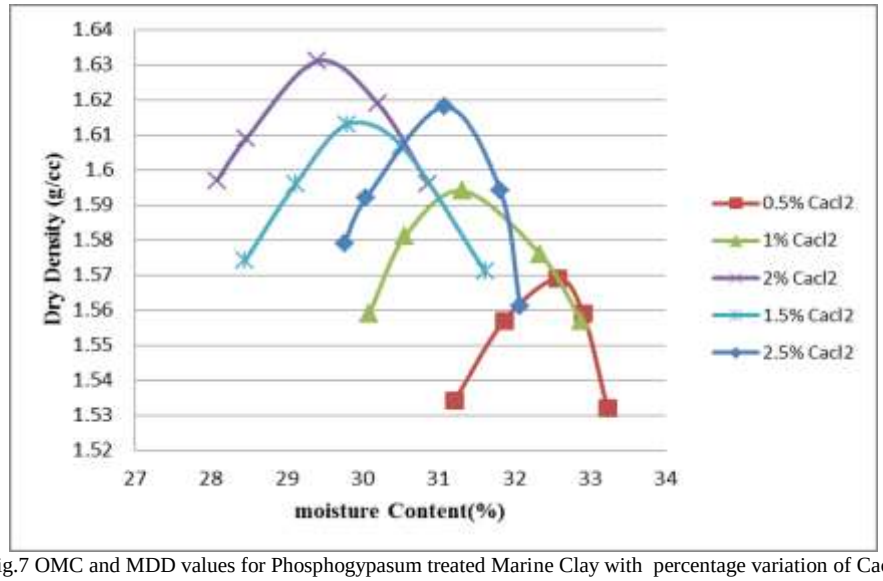

Fig.7 OMC and MDD values for Phosphogypasum treated Marine Clay with percentage variation of $Cacl_2$

VII. Table

Variation of MDD with % of $CaCl_2$

Mix Proportion	MDD
94%MC+6%PG+0.5%$Cacl_2$	1.569
94%MC+6%PG+1%$Cacl_2$	1.594
94%MC+6%PG+1.5%$Cacl_2$	1.618
94%MC+6%PG+2%$Cacl_2$	1.631
94%MC+6%PG+2.5%$Cacl_2$	1.613

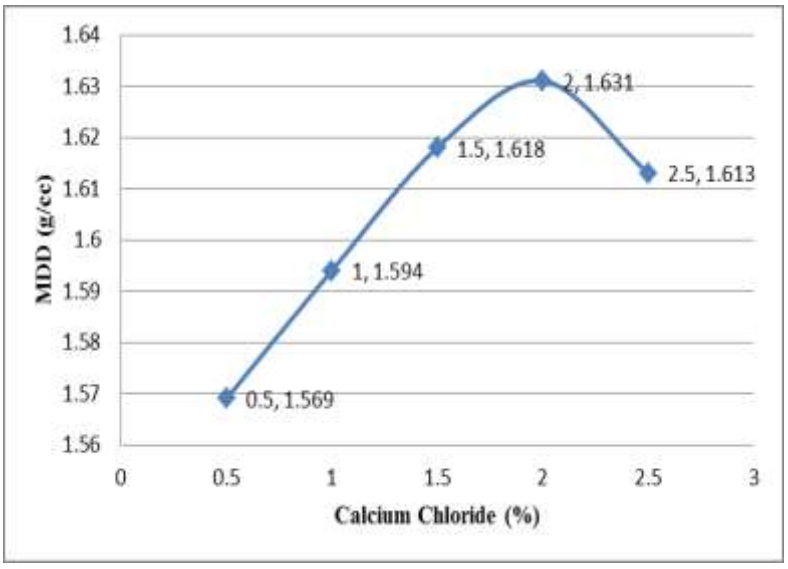

Fig.8 Variation of MDD values with % variation of $CaCl_2$

7) CBR test results for Phosphogypsum treated Marine Clay with Various Percentages of Calcium Chloride ($CaCl_2$)

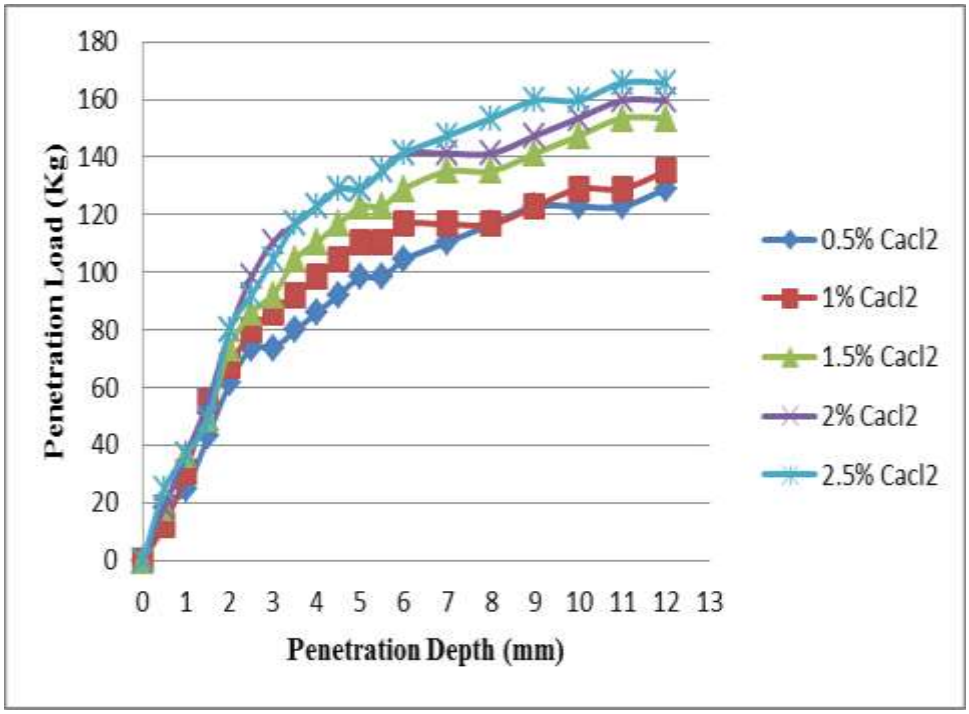

Fig.9 CBR values of phosphogypsum treated Marine Clay with % variation of $Cacl_2$

VIII. Table

Variation of CBR values of Phosphogypsum treated Marine Clay with various percentages of Calcium Chloride

Mix Proportion	CBR (%)
94%MC+6%PG+0.5%$CaCl_2$	5.378
94%MC+6%PG+1%$CaCl_2$	5.82
94%MC+6%PG+1.5%$CaCl_2$	6.274
94%MC+6%PG+2%$CaCl_2$	7.17
94%MC+6%PG+2.5%$CaCl_2$	6.72

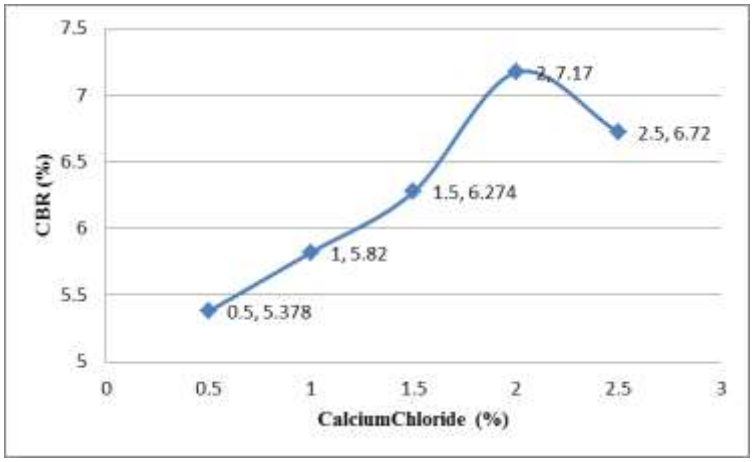

Fig.10 Variation of CBR values with % variation of $CaCl_2$

DISCUSSION-2

It was observed from the laboratory test results that the Marine Clay treated with an optimum percentages of 6% PG and 3% Calcium Chloride has exhibited a CBR value of 7.17% which is accepted as per IS Codes of practice to use this treated Marine Clay as subgrade for flexible pavement. Hence the laboratory tests Liquid limit, Plastic limit, Plasticity Index, Compaction, CBR, Specific gravity, Differential Free Swell, Cohesion, angle of shear resistance were conducted on the marine clay treated with the optimum percentage of PG and Calcium chloride. The results were tabulated in Table 9.

IX. Table

Properties of the Stabilized Marine Clay with an optimum of 6% Phosphogypsum and 3% $CaCl_2$

S.No	Property	Symbol	Marine Clay	94%MC+6 %PG	94%MC+6%PG +2%$CaCl_2$
1	Liquid limit (%)	W_L	76.00	61.4	46.5
2	Plastic Limit (%)	W_P	34.33	28.8	24.6
3	Plasticity Index (%)	I_P	41.67	32.6	21.9
4	Soil Classification		CH	CH	CI
5	Specific Gravity	G	2.42	2.64	2.78
6	Optimum Moisture Content (%)	OMC	37.32	33.98	29.4
7	Maximum Dry Density (g/cc)	MDD	1.47	1.541	1.631
8	CBR (%)		1.792	3.137	7.17
9	Cohesion (kg/cm^2)	C	0.7	0.52	0.36
10	Angle of Internal Friction(°)	ϕ	5.71	8.41	12.36
11	Degree of free swell (%)	DFS	110	60	40

V. CONCLUSIONS

1) It is noticed that the liquid limit of Marine Clay has been decreased by 19.21% on addition of 6% Phosphogypsum and it has been further decreased by 38.81% when 2% $CaCl_2$ added.
2) It is observed that the plastic limit of the Marine Clay has been decreased by 16.1% on addition of 6% Phosphogypsum and it has been further decreased by 28.34% when 2% $CaCl_2$ is added.
3) It is observed that the plasticity index of the Marine clay has been decreased by 21.76 % on addition of 6% Phosphogypsum and it has been further decreased by 47.44% when 2% $CaCl_2$ is added.
4) It is noticed that the cohesion of Marine Clay has been decreased by 25.71% on addition of 6% Phosphogypsum and it has been further decreased by 48.57 % when 2% $CaCl_2$ added.
5) It is noticed that the angle internal friction of Marine Clay has been improved by 47.28 % on addition of 6% Phosphogypsum and it has been further improved by 116.46% when 2% $CaCl_2$ added.
6) It is found that the O.M.C of the Marine Clay has been decreased by 13.74% on addition of 6% Phosphogypsum and it has been further decreased by 21.22% when 2% $CaCl_2$ is added.
7) It is found that the M.D.D of the Marine Clay has been improved by 4.6% on addition of 6% Phosphogypsum and it has been improved by 10.95% when 2% $CaCl_2$ is added.
8) It is observed that the CBR value of the Marine clay has been increased by 75.054% on addition of 6% Phosphogypsum and it has been further improved by 300.11% when 2% $CaCl_2$ is added.
9) It is observed that the DFS value of the Marine Clay, has been decreased by 45.45% on addition of 6% Phosphogypsum and it has been further decreased by 63.63% when 2% $CaCl_2$is added.

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