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A LABORATORY STUDY ON THE EFFICACY OF MARBLE DUST FOR IMPROVING THE STRENGTH CHARACTERISTICS OF KAKINADA MARINE CLAY

D. Koteswara Rao[1], T.Geethika Pushpanjali[2]

[1]*Professor of Civil Engineering & Director, Faculty Development Centre, JNTUK Kakinada, A.P, India,*
[2]*PG Student, Department of Civil Engineering, JNTUK Kakinada, Andhra Pradesh, India,*

Abstract: India is a peninsular country which has a very long coastal line, with a length of 6400 km along Gujarat on the west coast to West Bengal on the east coast it is covered by highly compressed and soft marine clays. With the advent of urbanization, resulting search for more and more habitable land, it was essential that the large tracts of marine clays, which are considered inhabitable earlier, had to be retrieved and developed. These marine clays which are well known for its poor shear strength and high compressibility, posed numerous problems to the builders. The present study deals with the engineering properties of the marine clay collected from Kakinada Sea Port Ltd, Kakinada, A.P, India, and the performance of marble dust as an admixture and calcium chloride as an additive for improving the strength characteristics of the marine clay.

Keywords - Kakinada marine clay; Stabilization; Marble powder; Calcium chloride; Compaction test; CBR test

I. INTRODUCTION

Marine soils are one of the soils that are found in the ocean bed. It is also located onshore as well. The properties of marine soil mainly depend on its initial conditions. As clay is an impermeable soil, it holds water; rather permeable soil allows water to rapidly drain, like in gravel or sand. The shrink and swell behaviour are due to change in the moisture content of the soil. Providing a uniform moisture content of the soil under and next to foundation is the best way to moderate the damaging properties of clayey soil.

Marble industries producing a huge quantity of powdered marble waste, which is produced during cutting and grinding of marble. This is very fine but non-plastic and well graded as well. The particle size of this powdered marble waste depends on the marble strength, the type of the grinder or cutter and the pressure applied during cutting and grinding. Hard marble with low cutting pressure produces finer particles and vice-versa.

A broad review of literature indicates the amount of work related to determination of engineering properties and behavior of marine soils that has been carried out worldwide since last 50 years. Amongst, these investigations on physical, chemical and mineralogical properties of marine clay conducted by Eden *et al.* (1957), Noorani (1984), Shridharan *et al.* (1989), Mathew *et al.* (1997) and Chew *et al.* (2004) are worthy. Significant research on strength and stiffness characteristics was performed by Koutsoftas *et al.* (1987) and Zhou *et al.* (2005); Zhuge *et al.*, 2007; Ameta, 2007; Basack *et al.*, 2009; Kamruzzaman *et al.*, 2009 and Fairfax Country, Virginia, 2010). Marine clay deposits of Kakinada sea port ltd is used to investigate its strength characteristics and load bearing capacity and further make suitable for foundation constructions over it.

II. OBJECTIVES

- To study the properties of Marine clay collected at Kakinada sea port Ltd. Kakinada.
- To study the affect of Marble powder on improving the strength characteristics marine clay and further on adding of $cacl_2$.

III. MATERIALS USED

3.1 Soil:
Soil was collected from Kakinada seaport Ltd. Kakinada, Andhra Pradesh, India.
The expansiveness of the soil is very high. The properties of the soil were listed in Table-1. Hence there is a need for improvement of the soil for the development of infrastructural facility in these areas.

3.2 Marble powder:

The marble dust was collected from Astrra chemicals Pvt ltd, Chennai.

Marble is a metamorphic rock that consists predominantly of calcite and/or dolomite. Marble may be considered as metamorphosed limestone (i.e. limestone which has been fully re-crystallized and hardened under hydrothermal conditions). Marble is defined as the metamorphic rock which fully re-crystallized and hardened under hydrothermal conditions (Coats 1996). Marbles dust produced from cutting and grinding of marble has very fine particle size, non plastic and almost well graded. The physical and chemical properties of the marble dust are given table 2 and 3.

3.3 Calcium Chloride:

The ionic compound of calcium and chloride is calcium carbonate. It is a salt that behaves as a typical ionic halide, being solid at room temperature and highly soluble in water. Because of its hygroscopic nature, anhydrous calcium chloride must be kept in tightly sealed, airtight containers. It is used for numerous purposes at different concentrations depending on its use. The properties of calcium chloride ($CaCl_2$) are given in Table 4.

Table 1 Properties of the Marine clay

SI. NO	Property	Marine clay	
1	Gravel (%)	1.103	
2	Sand (%)	9.92	
3	Fines (%)	silt	24.65
		clay	65.33
4	Liquid limit (%)	76	
5	Plastic limit (%)	34.33	
6	Plastic index (%)	41.67	
7	Soil classification	CH	
8	Specific gravity	2.42	
9	D.F.S (%)	110	
10	O.M.C	37.32	
11	M.D.D (gm/cc)	1.47	
12	Cohesion (kn/m^2)	109	
13	Angle of internal friction(ϕ)	5.71^o	
14	CBR (%)	1.792	

Table 2 chemical properties of Marble Dust

S. No	Constituent Elements	Content (%)
1	Silica (SiO2)	11.38%
2	Alumina (Al2O3)	0. 23%
3	Ferric Oxide (Fe2O3)	0. 09%
4	Calcium Oxide (CaO)	45.18%
5	Calcium Carbonate(CaCO3)	88.5%
6	Magnesium Oxide (MgO)	0. 20%
7	Magnesium Carbonate (MgCO3)	0. 42%
8	Sulphur (SO3)	0. 008%
9	Phosphorus (P2O5)	0. 009%
10	Loss on Ignition	43.60%

Table 3 physical properties of Marble Dust

Physical State	Fine Powder
Odour	Odourless
Appearance	Free Flowing
Color	Natural Pure White
Pack Density	1.100 G/Ml
Ph (5% Solution)	6. 0
Specific Gravity	2. 6% Max.
Moisture	Below 0.5%
Oil Obsorption Ml/100gm	18. 20
Particle Size	325 Mesh

Table 4 Property of Calcium Chloride:

Property	value
Molar mass	110.99 $g.mol^{-1}$
Appearance	White powder
Minimum assay	95%
Maximum limits of impurities Iron (Fe)	0.002%
Heavy metals(as Pb)	0.002%
Sulfate (SO4)	0.05%
Loss on drying	10%
Boiling point	1935^0C

IV. LABORATORY STUDIES

The laboratory studies were carried out on the samples of Marine c1ay, Marine clay+20% Marble Dust and Marine clay+20%M.D+1.75% $cacl_2$.

4.1 Liquid limit

Liquid limit test was conductecl on Marine c1ay, Marine clay+20% Marble Dust and Marine clay+20%M.D+1.75% $cacl_2$, using Casagrande's liquid limit apparatus as per the procedures in IS: 2720 part 4 (1970).

4.2 Plastic limit

Plastic limit test was conducted Marine c1ay, Marine clay+20% Marble Dust and Marine clay+20%M.D+1.75% $cacl_2$., as per the specifications laid clown in IS: 2720 part (1970).

4.3 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 l0g is taken into a l00cc capacity graduated cylinder containing water, and the other sample of 10g is taken into a l00cc capacity graduated cylinder containing kerosene oil.

Differential Free Swell (%) = $\frac{Vd-Vk}{Vk} * 100$

Where,
V_d = volume of soil specimen read from the graduated cylinder containing distilled water.
V_k = volume of soil specimen read from 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- l980) gives degree of expansion of a soil depending upon its differential free swell as under.

Table 5 Differential Free Swell

S. No	Differential Free Swell	DFS
1	Low	<20%
2	Moderate	20-35%
3	High	35-50%
4	Very High	>50%

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

4.5 Specific Gravity Test:
Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature. The specific gravity of a 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).

4.6 California bearing ratio test
The California bearing ratio test was conducted on the soil sample with 6 varying percentages of marble dust. Marble dust were added to soil in varying percentages (10,15,18,20,23,25%) respectively. The test results were depicted in the Table 2.CBR value increases up to 20 % addition of marble dust and then decreases. The maximum value of CBR for 20 % addition of marble dust was obtained as 4.92%. The CBR value showed an

Increase from 1.79% to 4.92% at 20% addition of marble dust. Further on addition of 1.75% $cacl_2$ to soil and 20% marble dust the CBR increased from 4.92% to 8.067%. The test was conducted under a constant strain rate of 1.25mm/min. The proving ring 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. The samples were tested in soaked condition. The tests were conducted at time interval of curing for 4 days at optimum moisture content.

V. RESULT AND DISCUSSIONS

The Index & Engineering properties marine Clay, marine clay treated with marble dust and clay with optimum marble dust and $cacl_2$ are determined as per IS code of practice and presented in Table 6

Table 6 Properties of untreated and treated marine clay

S. no	Property	Untreated marine clay	Soil+20 %M.D	Soil+20% M.D+1.75 %$cacl_2$
1	Liquid limit (%)	76	48	32
2	Plastic limit (%)	34.33	25.51	21.32
3	Plastic index (%)	41.67	22.49	14.68
4	Soil classification	CH	CI	CL
5	Specific gravity	2.42	2.63	2.72
6	D.F.S (%)	110	61.70	30
7	O.M.C	37.32	25.5	22.7
8	M.D.D (gm/cc)	1.47	1.576	1.792
9	Cohesion (kn/m^2)	109	60	36
10	Angle of internal friction(ϕ)	5.71^o	16^o	24^o
11	CBR (%)	1.792	4.92	8.067

5.1: OMC & MDD values of the Marine clay treated with percentage variation of Marble Dust

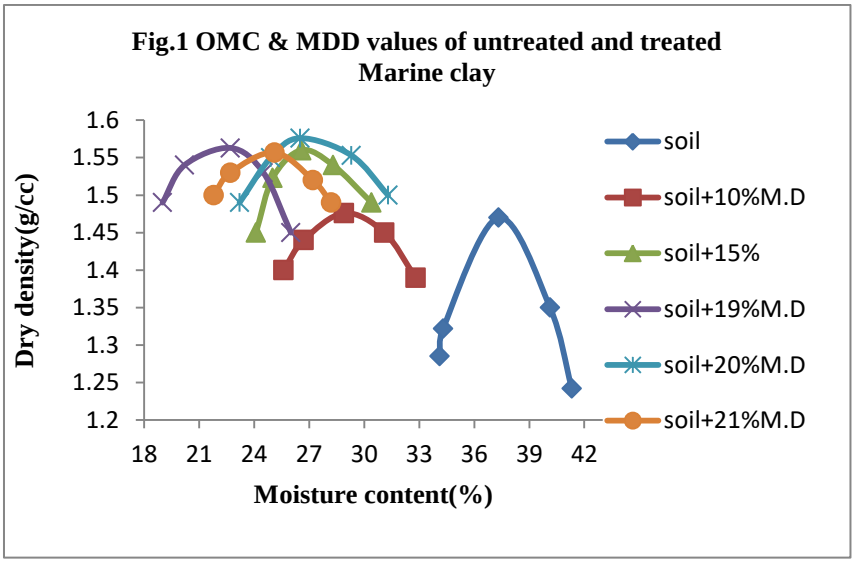
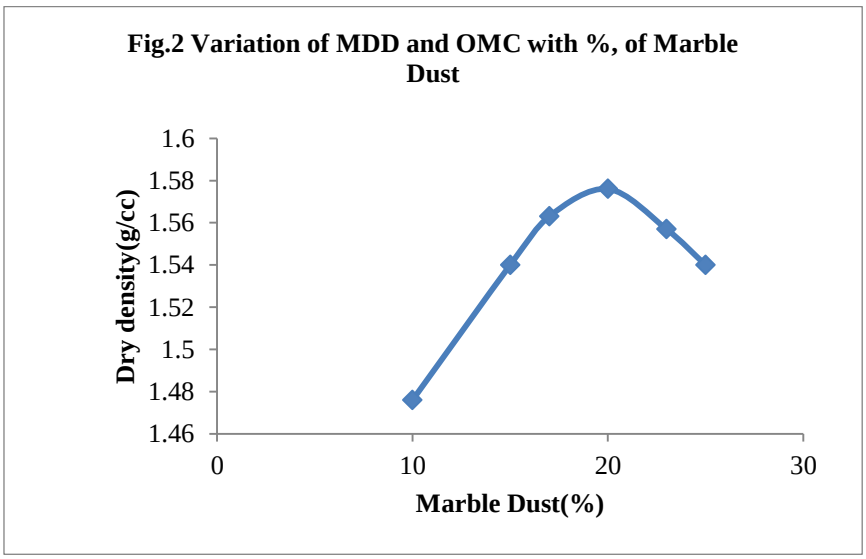


Table 7: Variation of MDD and OMC with %, of Marble Dust

Mix proportion	MDD(g/cc)	OMC (%)
Soil	1.47	37.32
Soil+10%MD	1.476	28.9
Soil+15%MD	1.56	26.57
Soil+19%MD	1.563	23.71
Soil+20%MD	**1.576**	**25.5**
Soil+21%MD	1.557	25.13
Soil+25%MD	1.55	26.16



5.2: CBR values of Marine clay and Marine clay treated with various percentages of marble dust

The soaked CBR values of various mixes of Marine Clay and Marble Powder using OMC obtained from compaction are determined. The soaked CBR after immersing in water for four days, that is when full saturation is likely to occur, is also determined. Variation of CBR with % variation in Marble Powder is presented.

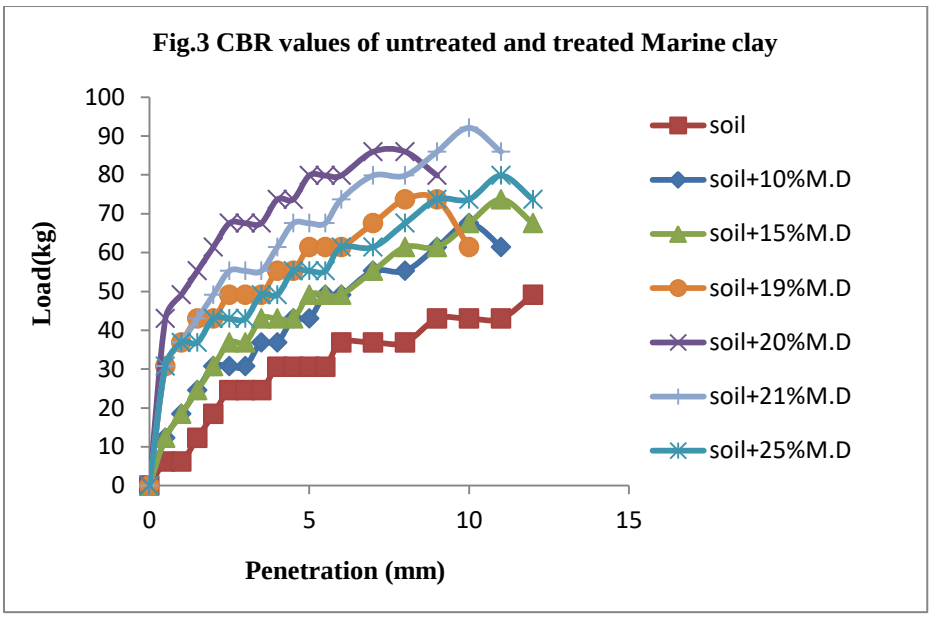
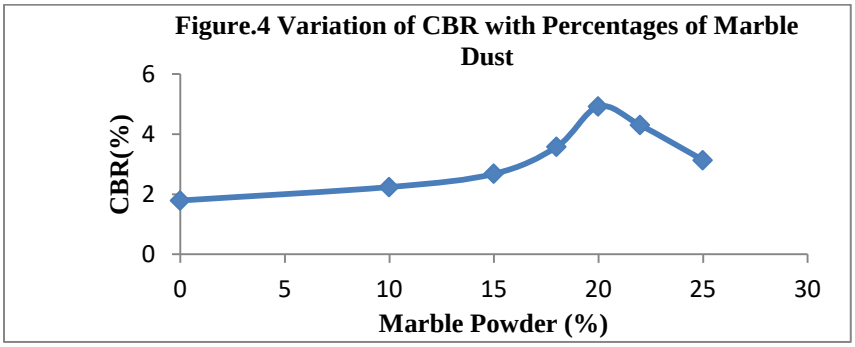


Table 8: Variation of CBR values with Marble Dust

Mix Proportion	Soaked CBR (%)
Soil	1.792
Soil+10%MP	2.24
Soil+!5%MP	2.68
Soil+19%MP	3.58
Soil+20%MP	**4.92**
Soil+21%MP	4.30
Soil+25%MP	3.137



5.3: OMC & MDD values of Marble dust treated Marine soil with various percentages of Calcium Chloride ($cacl_2$)

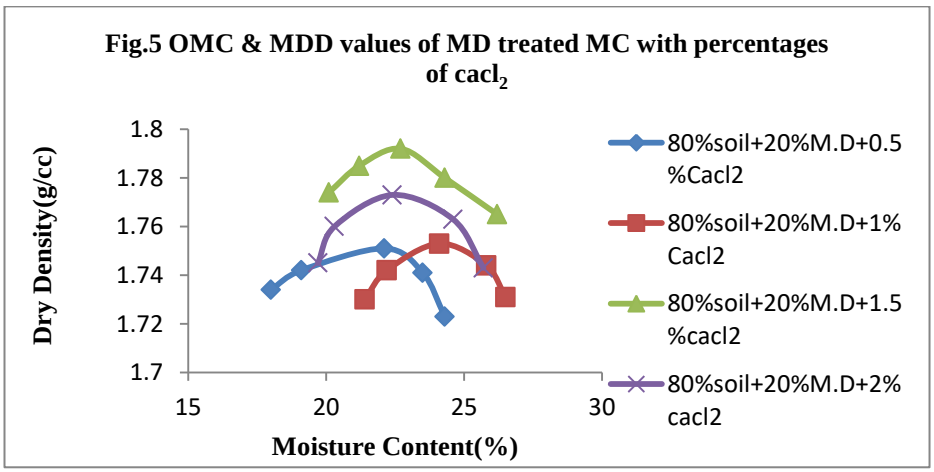
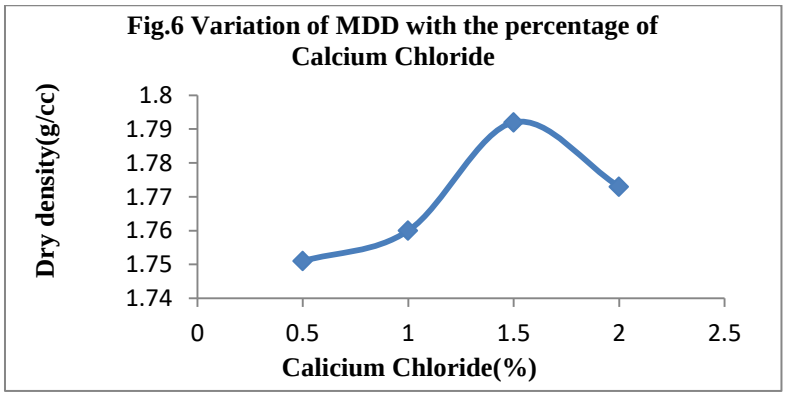


Table9: MDD and OMC values of Marble Dust treated Marine clay with various percentages of Calcium Chloride.

Mix Proportion 80%Soil+20%MD+	MDD(g/cc)	OMC (%)
0.5%$CaCl_2$	1.751	18.96
1%$CaCl_2$	1.753	20.54
1.5$CaCl_2$	**1.792**	**22.45**
2%$CaCl_2$	1.773	25.63



5.4: CBR values of Marble dust treated Marine soil with various percentages of Calcium Chloride (cacl2)

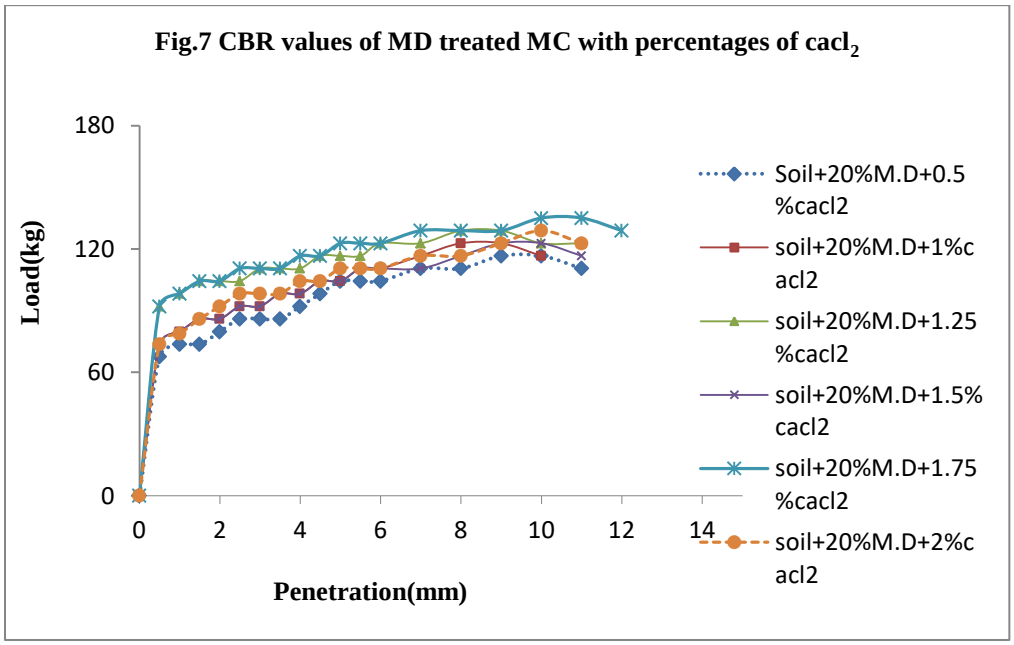
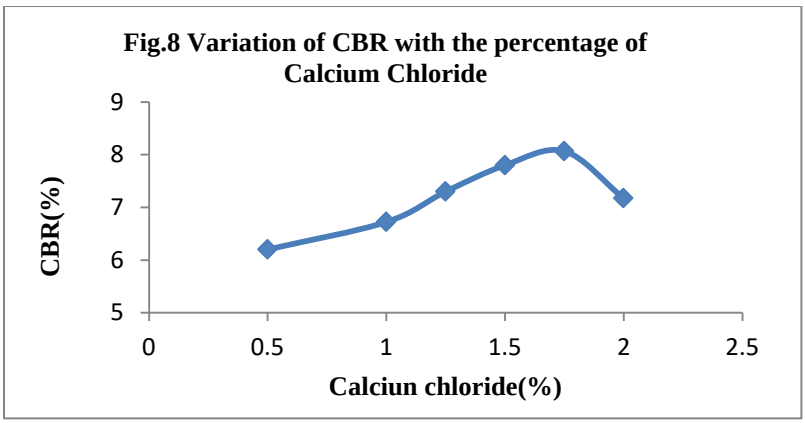


Table10: CBR values of Marble Dust treated Marine Clay with various percentages of Calcium Chloride.

Mix Proportion 80%Soil+20%MP+	**CBR (%)**
0.5%CaCl2	6.27
1%CaCl2	6.722
1.25%CaCl2	7.618
1.5%CaCl2	7.618
1.75%CaCl2	**8.0671**
2%CaCl2	7.171



VI. CONCLUSIONS

- It is observed that the liquid limit of Marine Clay has been decreased by 36.84% on addition of 20% Marble Dust and it has been further decreased by 57.89% when 1.75% $CaCl_2$ added.
- It is noticed that the plastic limit of the Marine clay has been decreased by 23.46% on addition of 20% Marble Dust and it has been further decreased by 37.89% when 1.75% $CaCl_2$ is added.
- It is observed that the plasticity index of the clay has been decreased by 67.02 %into on addition of 20%Marble Dust and it has been further decreased by 64.77% when 1.75% $CaCl_2$ is added.
- It is noticed that the cohesion of Marine Clay has been decreased by 45.4% on addition of 20% Marble Dust and it has been further decreased by 67.27% when 1.75% $CaCl_2$ added.
- It is noticed that the angle internal friction of Clay has been improved by 49.07% on addition of 20% Marble Dust and it has been further improved by 167% when 1.75% $CaCl_2$ added.
- It is found that the O.M.C of the Marine clay has been decreased by 31.6% on addition of 20% Marble Dust and it has been further decreased by 39.17% when 1.75% $CaCl_2$ is added.
- It is found that the M.D.D of the Marine clay has been improved by 19.4% on addition of 20%, Marble Dust and it has been improved by 21.90% when 1.75% $CaCl_2$ is added.
- It is observed that the CBR value of the Marine clay has been increased by 174% on addition of 20% Marble Powder and it has been further improved by 324% when 1.75% $CaCl_2$ is added.
- It is observed that the DFS value of the clay, has been decreased by 43.90% on addition of 20% Marble Dust and it has been further decreased by 72.7% when 1.75% $CaCl_2$ is added.

The soaked CBR of the soil on stabilizing is found to be 8.0671, according to IRC 2001 the CBR value should be in between 5- 6, to be used for Subgrade, and is satisfying. Thus the addition of 20% of Marble Dust and 1.75% of Calcium Chloride improved the properties of the air dried Marine Clay to the desirable extent, making it useful to be used in foundations.

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VII.BIOGRAPHIES

Dr. D. Koteswara Rao Professor of Civil Engineering, University College of Engineering, JNTUK KAKINADA, East Godavari District, Andhra Pradesh, India.

T.Geethika Pushpanjali PG student in SM&FE , Department of Civil Engineering , University College of Engineering, JNTUK KAKINADA, East Godavari District-533003, Andhra Pradesh, India.