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A LABORATORY STUDY ON THE STABILIZATION OF EXPANSIVE SOIL BY USING CERAMIC WASTE POWDER AND CALCIUM CHLORIDE

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ABSTRACT

This paper deals with enhancing the engineering properties of expansive soil by treating it with ceramic waste powder with calcium chloride as binder. Expansive soil generally swell significantly when come in contact with moisture and shrink when the moisture squeezes out, and this type of soil will have low bearing capacity. Therefore it is necessary to stabilize expansive soil, thus improving the load bearing capacity of a sub grade to support pavement and foundation. The expansive soil is collected locally and mixed with varying percentage of ceramic waste powder with calcium chloride as binder, Liquid Limit Test, Plastic Limit Test, Standard Proctor Test, California Bearing Ratio Test (CBR), and DFS were conducted on soil sample and checked the improvement in engineering properties of soil.

KEY WORDS: Expansive Soil, OMC, MDD, CBR, Ceramic Waste Powder, $CaCl_2$.

I. INTRODUCTION

Expansive clay is one of the most abundant problems faced soil in geotechnical engineering applications. With lattice clay minerals, such as Montmorillonite, exhibit the most profound swelling properties. The deposits of expansive soils occupy about 20% of the India's surface area. In India these soils are predominant in the states of Gujarat, Madhya Pradesh, Andhra Pradesh, Karnataka and Tamilnadu. Expansive soils are frequently overlooked as a major problem because they take years to cause extensive damage. Expansive soils cause heavy damages in structures, especially in Water conveyance canals, lined reservoirs, highways, and airport runways etc., unless appropriate measures are taken. This behavior is attributed to the present of clay minerals with expanding lattice structure. Among them Montmorillonite clay mineral is very popular and absorbs water significantly. The soil is hard as long as it is dry but loses its strength (stability) almost completely on wetting. On drying, the soil cracks very badly and in worst cases, the width of cracks is almost 150mm and travel down to 3m belowground level. Indian black cotton soils are found to be formed by weathering of Basalts and traps of Deccan plateau. However, their occurrence on limestone gneiss, shale's, sandstones, slates and limestone is also recognized. These soils are usually found near the surface with the layer thickness varying from 0.5m to about 3m. The distinct black color of this soil is due to the presence of Titanium in small quantity and cotton grows in these soils commonly. Several researches have made to improve the strength characteristics of expansive soils. The findings wove published by Akshaya Kumar(2012); Bell, F.G.,(1993); Gosavi, M.Patil, K.A.Mittal and Saran (1991),(1983);Muntohar, A.S (2006);Nelson ,J.D. and Miller ,D.J.,(1992); Setty, K.R. Narayana swamy and Anantha Krishna Murthy,A.T(1990).

II. OBJECTIVES OF THE STUDY

- To study the physical properties of expansive soil.
- To evaluate the performance of expansive soil when stabilization with ceramic waste powder and calcium chloride.
- To evaluate the performance of the stabilized expansive soil with an optimum of ceramic waste powder and calcium chloride.

III. MATERIALS USED

3.1 Expansive Soil

The Expansive Soil for this study has been collected from Amalapuram, East Godavari District, at a depth of 1.2m below the ground level. The Index & Engineering properties of Expansive soil are determined as per IS code.

3.2 Ceramic Waste Powder

Ceramic tile wastes are generated as a waste during the process of dressing and polishing. Ceramic waste can be used as a partial replacement of cement or as a partial replacement of fine aggregate sand as a supplementary addition to achieve different properties of concrete. Ceramic waste is collected from RAK ceramics.

3.3 Calcium Chloride

Laboratory grade Calcium Chloride consisting of 98% $cacl_2$ was used in this work. The amount of calcium chloride was used between 0 to 3% by dry weight of soil.

Table 1.Chemical composition of ceramic waste powder

S. No	Constituent	Content (%)
1	Silica (SiO_2)	49.52
2	Alumina (Al_2O_3)	14.70
3	Calcium (CaO)	1.40
4	Iron (Fe_2O_3)	0.40
5	Magnesium Oxide (MgO)	2.45
6	Sodium (Na_2O)	2.71
7	Potassium (K_2O)	2.69
8	Phosphorus (P_2O_5)	0.05
9	Loss on ignition	26.08

Table 2.Physical properties of ceramic waste powder

S. No	Properties	Values
1	Specific Gravity	2.48
	Grain Size Distribution	
2	Coarse Sand (%)	0
3	Medium Sand (%)	1.52
4	Fine Sand (%)	97.34
5	Silt & Clay (%)	1.14
	Compaction Properties	
6	Optimum Moisture Content (%)	19.2
7	Maximum Dry Density (g/cc)	1.59
8	Atterberg's Limits	NP

Table 3.Properties of Calcium Chloride

S. No	Property	Value
1	Molar Mass	110.98g.mol^{-1}
2	Appearance	White Powder
3	Odour	Odourless
4	Density	2.15g/cm^3
5	Melting Point	772 Upto 775°C
6	Boiling Point	1935°C

IV. LABORATORY TESTS

The laboratory studies were carried out on the samples of Expansive soil+ Ceramic waste, Expansive soil + Ceramic waste + Calcium chloride mixes.

4.1 Liquid Limit

Liquid Limit Tests was conducted on expansive soil. Expansive soil+20% Ceramic waste, Expansive soil+20% Ceramic waste + 2% Calcium chloride using Casagrande's liquid limit apparatus as per the procedures laid down in IS:2720 part 4(1970)

4.2 Plastic Limit

Plastic Limit Tests was conducted on expansive soil. Expansive soil+ 20% Ceramic waste, Expansive soil + 20% Ceramic waste +2% calcium chloride as per the specifications laid clown in IS:2720 part 4 (1970).

4.3 Differential Free Swell

Differential Free Swell Test was conducted on expansive soil carried out as per IS: 2720(Part III- 1980).

Table4. 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 Specific Gravity Test

Specific gravity test was carried out by pycnometer as per IS: 2720 part 3 (1980).

4.5 Proctor's Standard Compaction Test

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

4.6 California Bearing Ratio Test

The California Bearing Ratio tests are conducted Expansive Clay. Expansive Clay+ 20% ceramic waste Powder. Expansive Clay, ceramic waste powder, Calcium Chloride mixtures as per IS 2720 part l6 (1979). 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 expansive soil are determined as per IS code of practice and presented in Table 5

Table 5.The Properties of Expansive Clay

S.No	Property	Symbol	Value
1	Gravel		0.61%
2	Sand		12.29%
3	Fines	Silt	38.57%
		Clay	48.53%
4	Liquid Limit	W_L	60.8%
5	Plastic Limit	W_P	30.27%
6	Plasticity Index	I_P	30.53%
7	Soil Classification		CH
8	Differential Free Swell	DFS	110%
9	Specific Gravity	G	2.61
10	Optimum Moisture Content	OMC	28.29%
11	Maximum Dry Density (g/cc)	MDD	1.49
12	Cohesion (kg/cm^2)	C	0.55
13	Angle of Internal Friction	Φ	17^0
14	Soaked CBR (%)	CBR	2.24

5.1: Proctor Compaction Results for Expansive Clay Treated With Various Percentages of Ceramic Waste Powder

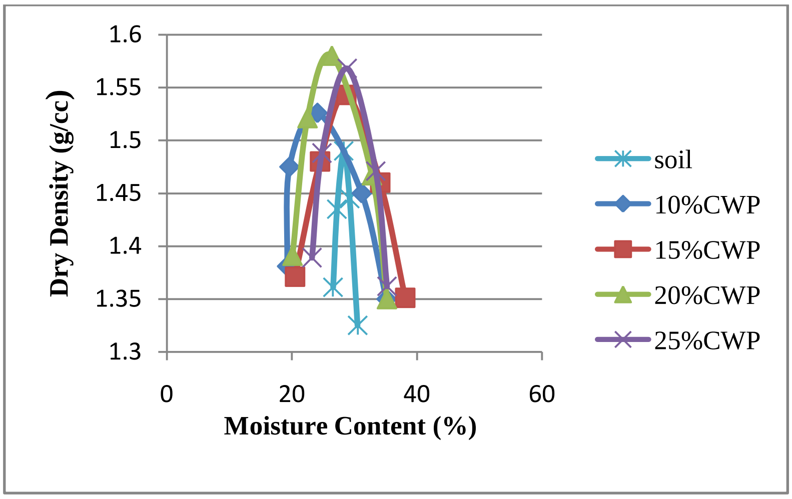

Figure1: Moisture Content-Dry Density Relationship with the addition of 0%, 10%, 15%, 20% and 25% Ceramic waste powder.

Table 6.Variation of MDD and OMC with % of Ceramic Waste Powder

Mix Proportions	OMC (%)	MDD (g/cc)
Soil	28.29	1.49
Soil+10%CWP	24.07	1.52
Soil+15%CWP	28.69	1.54
Soil+20%CWP	**26.4**	**1.58**
Soil+25%CWP	28.8	1.56

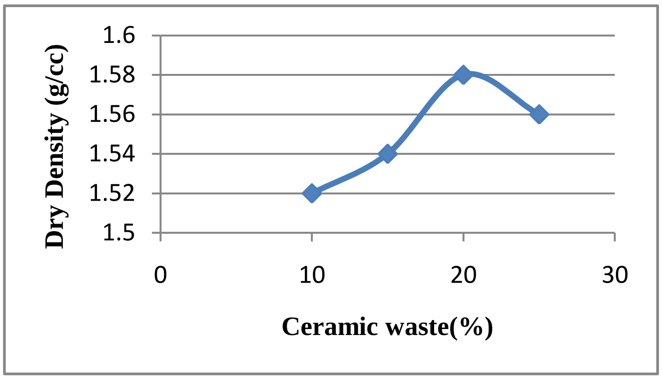

Figure2: Variation of MDD with Percentage of Ceramic waste powder

5.2: CBR Test Results for Expansive Clay Treated With Various Percentages of Ceramic Waste

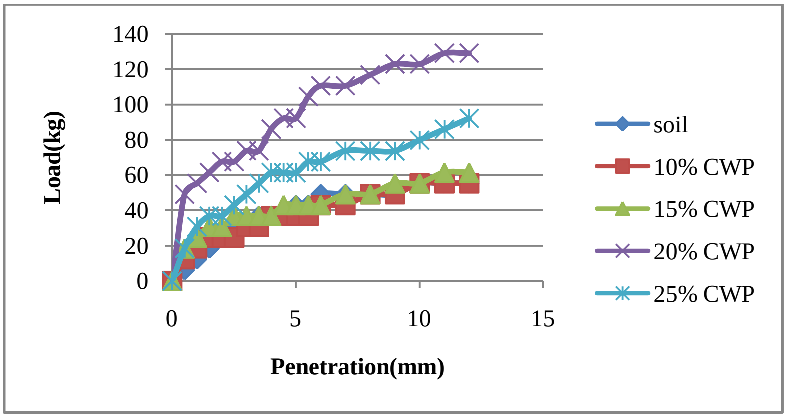

Figure3: Influence of various percentage of Ceramic waste on soaked CBR values of Expansive soil

Table7.Variation of Soaked CBR values with Ceramic waste

Mix Proportion	Soaked CBR (%)
Soil	2.24
Soil+10%CWP	2.68
Soil+15%CWP	3.13
Soil+20%CWP	**4.92**
Soil+25%CWP	4.03

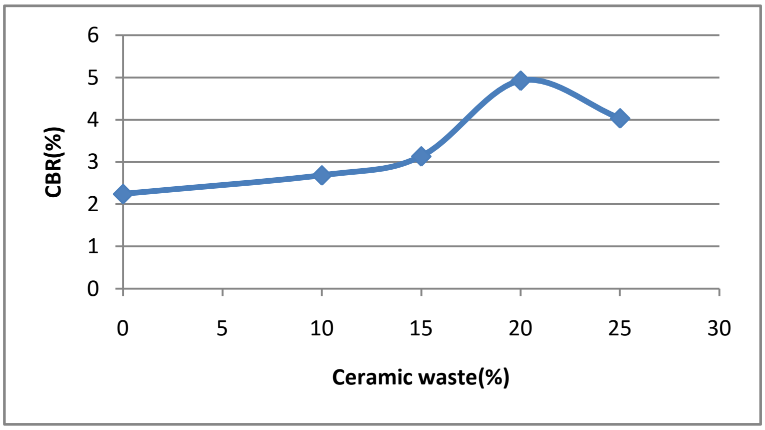

Figure4: Variation of CBR with Percentages of Ceramic Waste

5.3: Proctor Compaction Results for Ceramic Waste Powder Treated Expansive Soil with Various Percentages of Calcium Chloride

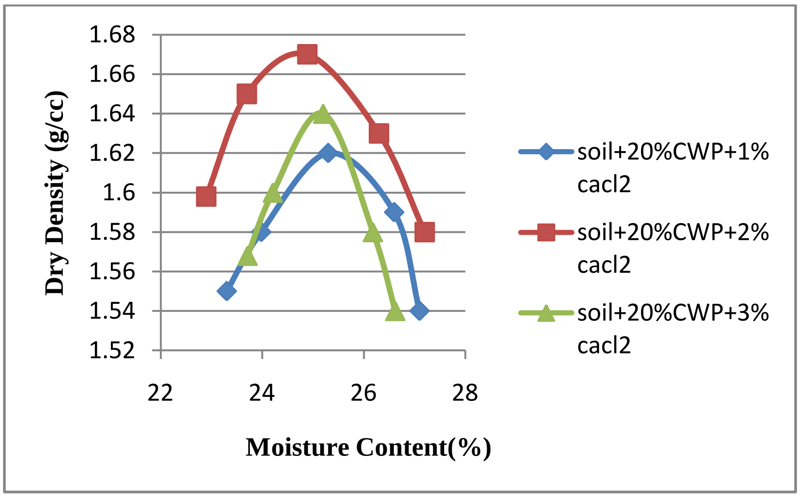

Figure5: Moisture content-Dry Density Relationship for ceramic waste treated Expansive soil with various percentages of Calcium Chloride.

Table8. Variation of MDD and OMC of Ceramic waste treated expansive soil with various percentages of Calcium Chloride.

Mix proportion soil+20%CWP+$CaCl_2$	**MDD(g/cc)**	**OMC(%)**
1% $CaCl_2$	1.62	25.34
2% $CaCl_2$	**1.67**	**24.89**
3% $CaCl_2$	1.64	25.22

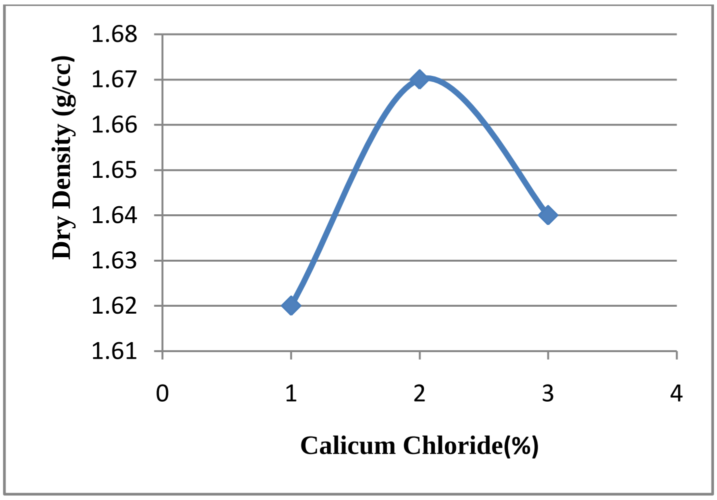

Figure6: Variation of MDD with the percentage of Calcium Chloride

5.4: CBR Result for Ceramic Waste Treated Expansive Soil with Various Percentages of Calcium Chloride ($CaCl_2$)

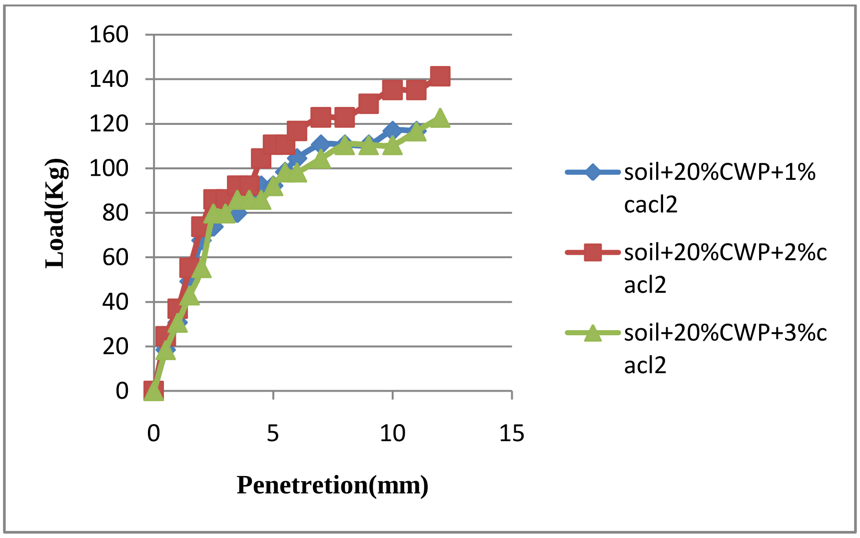

Figure7: Influence of various percentages of Calcium Chloride with the Ceramic waste and expansive soil of CBR values.

Table9. Variation of CBR values of Ceramic waste treated expansive soil with various percentages of Calcium Chloride.

Mix proportion soil+20%CWP+$CaCl_2$	**CBR (%)**
1% $CaCl_2$	5.37
2% $CaCl_2$	**6.14**
3% $CaCl_2$	5.8

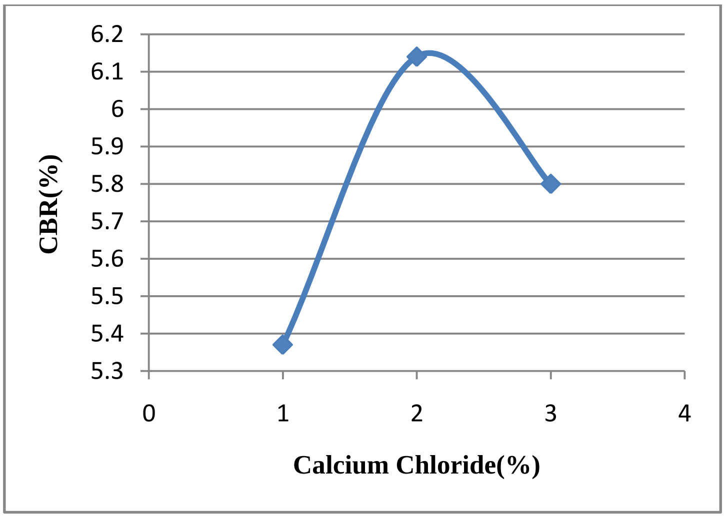

Figure8: Variation of CBR with the percentage of Calcium Chloride

Table10. Properties of the Stabilized Expansive soil with an optimum of 20% Ceramic Waste and 2%$CaCl_2$

S. No	Property	Expansive soil	EC+20% CWP	EC+20% CWP+2% $CaCl_2$
1	Liquid Limit (W_L)	60.8%	47.8%	32.2%
2	Plastic Limit (W_P)	30.27	25.94	19.06
3	Plasticity Index (I_P)	30.53	21.85	13.14
4	Specific Gravity (G)	2.61	2.76	2.94
5	Soil Classification	CH	CI	CL
6	Optimum Moisture Content (OMC)	28.29	26.4	24.89
7	Maximum Dry Density (MDD)	1.49	1.58	1.67
8	CBR (%)	2.24	4.92	6.14
9	Cohesion, c (kg/cm^2)	0.55	0.41	0.29
10	Angle of Internal Friction, Φ	17°	24.5°	37.8°
11	Degree of free swell (%)	110	50	38

VI. CONCLUSIONS

- It is noticed that Liquid Limit of Expansive soil has been decreased by 21.38% on addition of 20% Ceramic Waste and it has been further decreased by 47.03% when 2%$CaCl_2$ added.
- It is observed that the Plastic Limit of the expansive soil has been decreased by 14.30% on addition of 20% Ceramic Waste and it has been further decreased by 37.03% when 2% $CaCl_2$ added.
- It is observed that the Plasticity Index of the Expansive Soil has been decreased by 28.43% into on addition of 20% Ceramic Waste and it has been further decreased by 56.96% when 2% $CaCl_2$ is added.
- It is noticed that Cohesion of Expansive soil has been decreased by 25.45% on addition of 20% Ceramic Waste and it has been further decreased by 47.27% when 2%$CaCl_2$ added.
- It is noticed that Angle of Friction of Expansive soil has been improved by 44.11% on addition of 20% Ceramic Waste and it has been further improved by 122.35% when 2%$CaCl_2$ added.
- It is found that OMC of the Expansive Soil has been decreased by 6.68% on addition of 20% Ceramic Waste and it has been further decreased by 12.01% when 2%CaCl2 is added.
- It is found that MDD of the Expansive Soil has been improved by 6.04% on addition of 20% Ceramic Waste and it has been improved by 12.08% when 2% CaCl2 is added.
- It is observed that the CBR value of the Expansive Soil has been increased by 119%on addition of 20% Ceramic Waste and it has been further improved by 174.1% when 2% CaCl2 is added.
- It is observed that the DFS value of the Expansive Soil, has been decreased by 54.5% on addition of 20% Ceramic Waste and it has been further decreased by 65.45% when 2% CaCl2 is added. The soaked CBR of the soil on stabilizing is found to be 6.14% and is satisfying standard specifications. So finally, it is concluded from the above results ceramic waste can potentially stabilized the expansive soil solely (or) mixed with $CaCl_2$. The utilization of industrial wastes like ceramic waste is an alternative to reduce the construction cost of roads particularly in the rural areas of developing countries.

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