A LABORATORY STUDY ON THE STABLIZATION OF EXPANSIVE SOIL USING MARBLE POWDER AND CALCIUM CHLORIDE

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Abstract*-This paper deals with the enhancing the engineering properties of expansive soil by treating it with marble powder and calcium chloride. Expansive soils generally swell significantly when come in contact with moisture and shrink when the moisture squeezes out. Because of this alternative swelling and shrinkage, lightly loaded civil engineering structures like residential buildings, pavements and canal linings are severely damaged. It is, therefore, necessary to mitigate the problems posed by expansive soils and prevent cracking of structures. Many innovative foundation techniques have been revised as a solution to the problem of expansive soils. The chief among them are sand cushion technique, cohesive non-swelling (CNS) layer technique and under reamed piles. Stabilization of expansive clays with various additives has also attained lot of success. In this study, geotechnical properties of expansive clay i.e. OMC & MDD, CBR, Atterberg limits, DFS and strength characteristics have determined before and after treatment by using marble powder, and calcium chloride ($CaCl_2$).The result obtained from this study is considerable improvement in the strength characteristics of the expansive soil.

***Index words*- MDD, OMC, CBR, Marble Powder, $CaCl_2$**

I. INTRODUCTION

Expansive soil is one among the problematic soils that has a high potential for shrinking or swelling due to change of moisture content. Expansive soils can be found on almost all the continents on the Earth. Destructive results caused by this type of soils have been reported in many countries. In India, large tracts are covered by expansive soils known as black cotton soils. The major area of their occurrence is the south Vindhyachal range covering almost the entire Deccan Plateau. These soils cover an area of about 2,00,000 square miles and thus form about 20% of the total area of India. The primary problem that arises with regard to expansive soils is that deformations are significantly greater than the elastic deformations and they cannot be predicted by the classical elastic or plastic theory. Movement is usually in an uneven pattern and of such a magnitude to cause extensive damage to the structures resting on them. Proper remedial measures are to be adopted to modify the soil or to reduce its detrimental effects if expansive soils are identified in a project. The remedial measures can be different for planning and designing stages and post construction stages. Many stabilization techniques are in practice for improving the expansive soils in which the characteristics of the soils are altered or the problematic soils are removed and replaced, which can be used alone or in conjunction with specific design alternatives. Additives such as lime, cement, calcium chloride, rice husk, fly ahs etc. are also used to alter the characteristics of the expansive soils. The characteristics that are of concern to the design engineers are permeability, compressibility of soils and durability of the structures. The effect of the additives and the optimum amount of additives to be used are dependent mainly on the mineralogical composition of the soils.

II. OBJECTIVES

The Objectives of the present experimental study are

- To determine the properties of the Expansive soil.
- To evaluate the properties of expansive soil when treated with different percentage of marble powder as an admixture.
- To evaluate the properties of optimum percentage of marble powder treated with expansive soil.
- To evaluate the properties of optimum percentage of marble powder treated with expansive soil along with the addition calcium chloride ($CaCl_2$).

III. MATERIALS USED

3.1 Clay

The expansive soil for the study has been collected at a depth of 1.2m below ground level from Amalapuram, East Godavari District, Andhra Pradesh state, India. The Index & Engineering properties expansive clay soil are determined as per IS code of practice and determined & presented in Table 5.

3.2 Calcium Chloride

Laboratory grade calcium chloride consisting of 98% $CaCl_2$ was used in this work. The amount of calcium chloride used was between 0 to 4% by dry weight of soil**.**

3.3 Marble Powder

Dolomite is a natural calcium magnesium carbonate which is a form of marble powder with high degree of purity and whiteness. Dolomite (dolomite powder) is rock forming mineral which is noted for its remarkable wettability and dispensability as well as its moderate oil and plasticizers absorption. Dolomite has got increased weathering resistance capacity. 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 graded. The marble powder is collected from Aastra Chemicals group Chennai.

Table 1. Chemical Composition of Marble Powder

S. No	Constituent Elements	Content (%)
1	Silica (SiO_2)	11.38%
2	Alumina (Al_2O_3)	0. 23%
3	Ferric Oxide (Fe_2O_3)	0. 09%
4	Calcium Oxide (CaO)	45.18%
5	Calcium Carbonate ($CaCO_3$)	88.5%
6	Magnesium Oxide (MgO)	0. 20%
7	Magnesium Carbonate ($MgCO_3$)	0. 42%
8	Sulphur (SO_3)	0. 008%
9	Phosphorus (P_2O_5)	0. 009%
10	Loss on Ignition	43.60%

Table 2. Physical Properties of Marble Powder

S.No	Property	Value
1	Physical State	Fine Powder
2	Odour	Odourless
3	Colour	Natural Pure White
4	Density	1.100 g/ml
5	PH (5% Solution)	6.0
6	Specific Gravity	2.6
7	Moisture	Below 0.5%
8	Oil Obsorption (ml/100gm)	18.20

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 upto775°C
6	Boiling Point	1935°C

IV. LABORATORY TESTS

The laboratory studies were carried out on the samples of expansive clay, expansive clay+ Marble Powder, Expansive clay, Marble Powder and Calcium Chloride ($CaCl_2$) mixes.

4.1 Liquid limit

Liquid limit test was conducted on expansive clay. Expansive clay+15% Marble Powder, Expansive clay+15% Marble Powder+ 1.5% $CaCl_2$ using Casagrande's liquid limit apparatus as per the procedures laid down in IS: 2720 part 4 (1970).

4.2 Plastic Limit

Plastic limit test was conducted on Expansive Clay. Expansive Clay+15% Marble Powder, Expansive clay+15% Marble Powder+ 1.5% $CaCl_2$ as per the specifications laid clown in IS: 2720 part4 (1970).

4.3 Differential Free Swell

Differential Free Swell (DFS) is a parameter used for the identification of the expansive soil.For the determination of the differential free swell of a soil. 20g of dry soil passing through a 425µ size sieve is taken. One sample of l0g is poured into a l00cc capacity, graduated cylinder containing water, and the other sample of 10g is poured into a l00cc capacity graduated cylinder containing kerosene oil.

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

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 4. 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+15% Marble Powder. Expansive Clay, Marble 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. RESULTS AND DISCUSSIONS

The Index & Engineering properties Expansive Clay 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%
5	Plastic Limit	W_P	29.29%
6	Plasticity Index	I_P	30.71
7	Soil Classification	-	CH
8	Differential Free Swell	DFS	110%
9	Specific Gravity	G	2.673
10	Optimum Moisture Content	OMC	28.29%
11	Maximum Dry Density (g/cc)	MDD	1.49
12	Cohesion (kg/cm^2)	c	1.22
13	Angle of Internal Friction (°)	ϕ	2
14	Soaked California Bearing Ratio (%)	CBR	1.792

5.1 Proctor compaction results for expansive clay treated with various percentages of marble powder

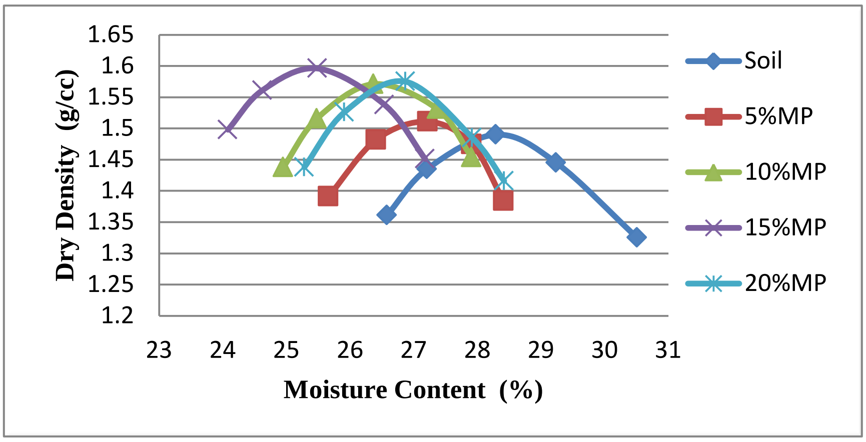

Fig 1. Moisture Content-Dry Density Relationship with the addition of 0%,5%,10%,15% and 20% marble powder

Table 6. Variation of MDD and OMC with %, of marble powder

Mix Proportions	MDD (g/cc)	OMC (%)
Soil	1.49	28.29
Soil+5%MP	1.511	27.22
Soil+10%MP	1.571	26.37
Soil+15%MP	**1.596**	**25.49**
Soil+20%MP	1.575	26.87

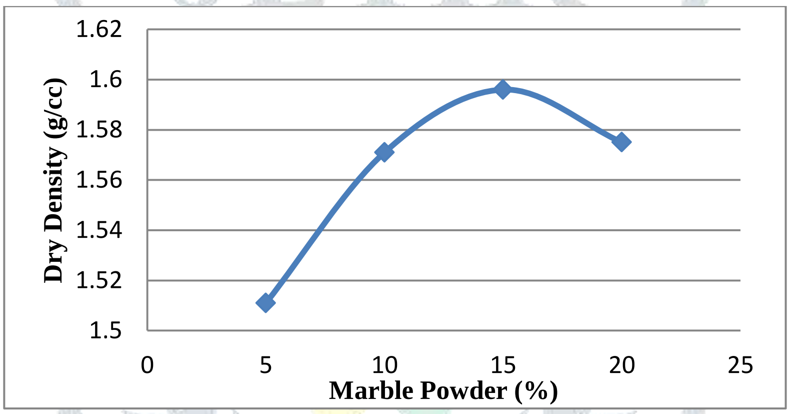

Fig 2. Variation of MDD with Percentage of marble powder

5.2 CBR test results for expansive clay treated with various percentages of marble powder

The soaked CBR values of various mixes of Expansive 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.

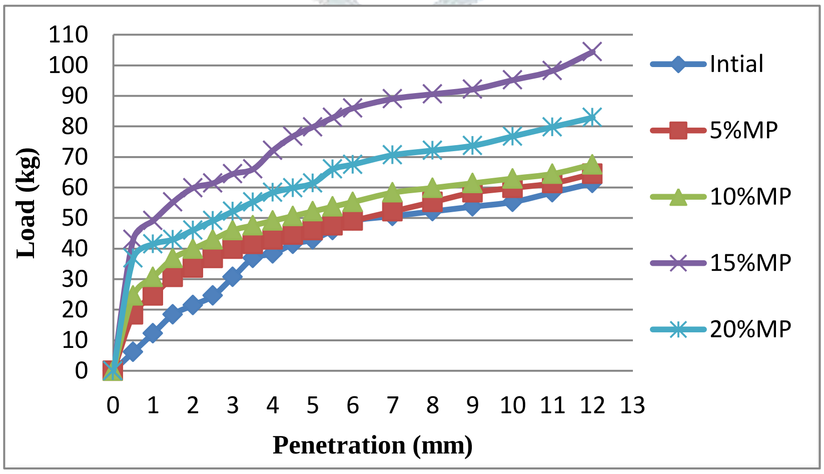

Fig 3. Influence of various percentage of marble powder on soaked CBR values of expansive soil

Table 7. Variation of Soaked CBR values with marble powder

Mix Proportions	Soaked CBR (%)
Soil	1.792
Soil+5%MP	2.689
Soil+10%MP	3.137
Soil+15%MP	**4.48**
Soil+20%MP	3.58

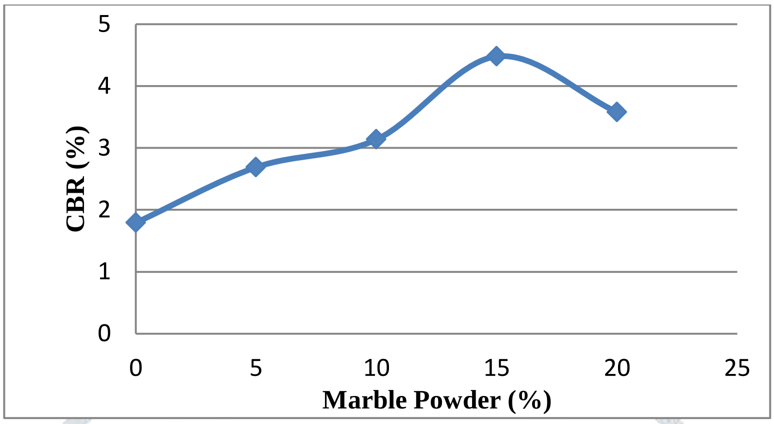

Fig 4. Variation of CBR with Percentages of marble powder

5.3 Proctor Compaction results for marble powder treated expansive soil with various percentages of calcium chloride ($CaCl_2$)

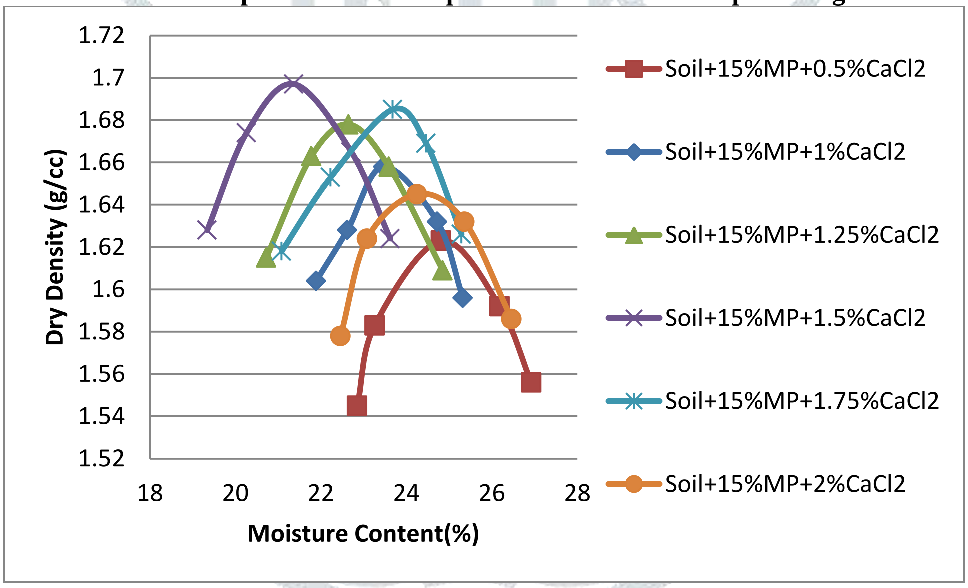

Fig 5. Moisture Content-Dry Density relationship for marble powder treated expansive soil with various percentages of calcium chloride

Table 8. Variation of MDD and OMC of marble powder treated expansive clay with various percentages of calcium chloride

Mix Proportions	MDD (g/cc)	OMC (%)
Soil+15%MP+0.5%$CaCl_2$	1.623	24.81
Soil+15%MP+1%$CaCl_2$	1.658	23.46
Soil+15%MP+1.25%$CaCl_2$	1.678	22.65
Soil+15%MP+1.5%$CaCl_2$	**1.697**	**21.37**
Soil+15%MP+1.75%$CaCl_2$	1.685	23.68
Soil+15%MP+2%$CaCl_2$	1.645	24.25

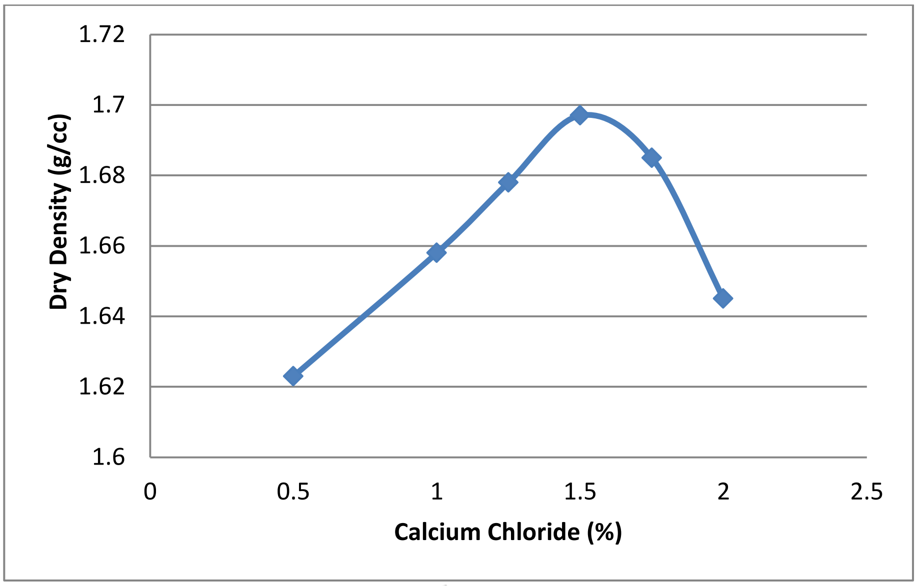

Fig 6. Variation of MDD with the percentage of calcium chloride

5.4 CBR results for marble powder treated expansive soil with various percentages of calcium chloride ($CaCl_2$)

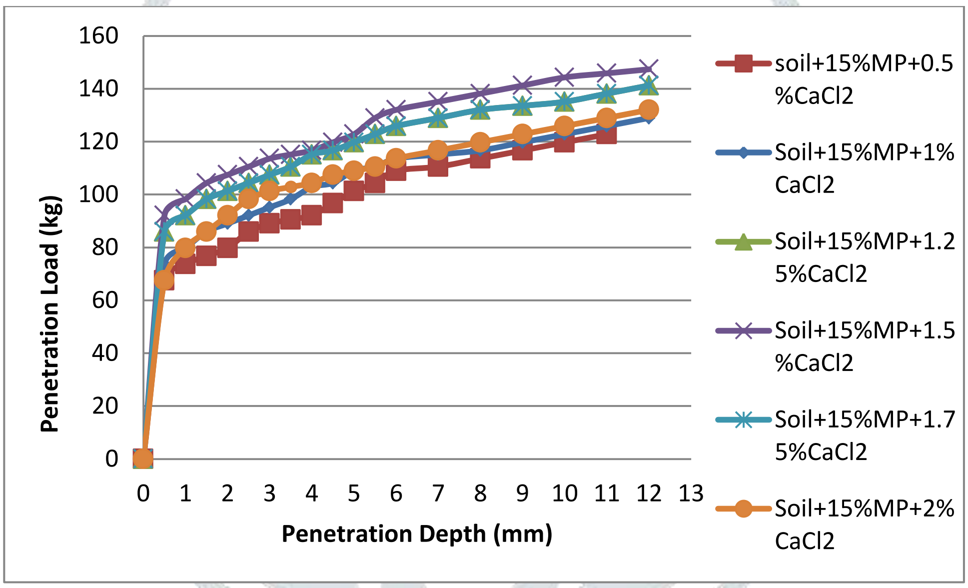

Fig 7. Influence of various percentage of calcium chloride with the marble powder and expansive clay of CBR values

Table 9. Variation of CBR values of marble powder treated expansive clay with various percentages of calcium chloride

Mix Proportions	CBR (%)
Soil+15%MP+0.5%$CaCl_2$	6.27
Soil+15%MP+1%$CaCl_2$	6.722
Soil+15%MP+1.25%$CaCl_2$	7.618
Soil+15%MP+1.5%$CaCl_2$	**8.06**
Soil+15%MP+1.75%$CaCl_2$	7.618
Soil+15%MP+2%$CaCl_2$	7.171

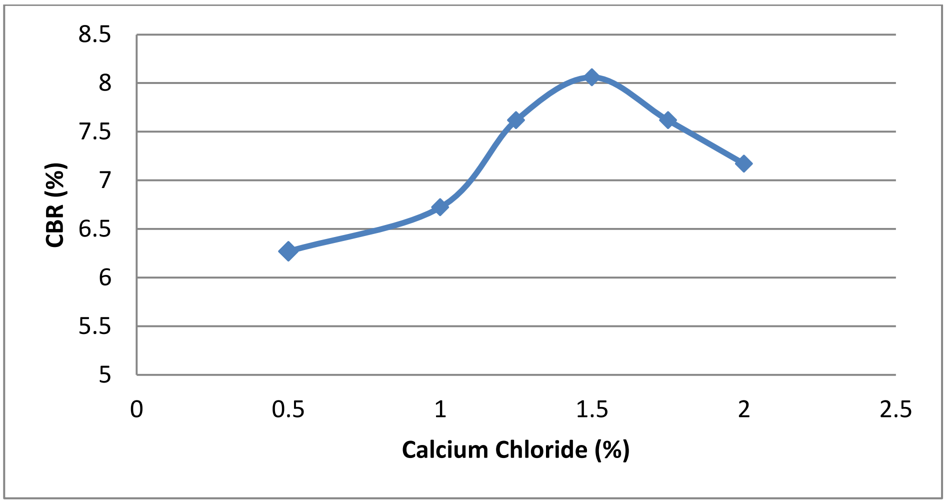

Fig 8. Variation of CBR with the percentage of Calcium Chloride

Table 10. Properties of the Stabilized Expansive Soil with an optimum of 15% Marble Powder and 1.5%$CaCl_2$

S.No	Property	Expansive Clay	EC+15 %MP	EC+15 %MP+1.5 %$CaCl_2$
1	Liquid Limit (W_L)	60%	47%	36.80%
2	Plastic Limit (W_P)	29.29%	23.57%	19.30%
3	Plasticity Index (IP)	31.71	23.43	17.5
4	Specific Gravity (G)	2.673	2.753	2.889
5	Soil Classification	CH	CI	CL
6	Optimum Moisture Content (OMC)	28.29%	25.49%	21.37%
7	Maximum Dry Density (g/cc)	1.49	1.596	1.697
8	CBR (%)	1.792	4.481	8.06
9	Cohesion (kg/cm^2)	1.22	0.923	0.745
10	Angle of Internal Friction (ϕ)	2°	8°	11°
11	Differential Free Swell (DFS)	110%	50%	40%

VI. CONCLUSIONS

- It is noticed that the Liquid Limit of expansive clay has been decreased by 21.66% on addition of 15% marble powder and it has been further decreased by 38.66% when 1.5% $CaCl_2$ is added.
- It is observed that the Plastic Limit of the expansive clay has been decreased by 19.52% on addition of l5% marble powder and it has been further decreased by 34.10% when 1.5% $CaCl_2$ is added.
- It is observed that the Plasticity Index of the clay has been decreased by 26.11%into on addition of l5% marble powder and it has been further decreased by 44.81% when 1.5% $CaCl_2$ is added.
- It is noticed that the Cohesion of expansive Clay has been decreased by 24.34% on addition of 15% marble powder and it has been further decreased by 38.93% when 1.5% $CaCl_2$ added.
- It is noticed that the Angle Internal Friction of expansive clay has been improved by 300% on addition of 15% marble powder and it has been further improved by 450% when 1.5% $CaCl_2$ added.
- It is found that the OMC of the expansive clay has been decreased by 9.89% on addition of l5% marble powder and it has been further decreased by 24.37% when 1.5% $CaCl_2$ is added.
- It is found that the MDD of the expansive clay has been improved by 7.11% on addition of l5%, marble powder and it has been improved by 13.89% when 1.5% $CaCl_2$ is added.
- It is observed that the CBR value of the expansive clay has been increased by 150% on addition of 15% marble powder and it has been further improved by 349.7% when 1.5% $CaCl_2$ is added.
- It is observed that the DFS value of the expansive clay, has been decreased by 54.54% on addition of 15% marble powder and it has been further decreased by 63.63% when 1.5% $CaCl_2$ is added.

The soaked CBR of the soil on stabilizing is found to be 8.06%and is satisfying standard specifications. So finally, it is concluded from the above results marble powder can potentially stabilize the expansive soil solely (or) mixed with $CaCl_2$. The utilization of industrial wastes like marble powder is an alternative to reduce the construction cost of roads particularly in the rural areas of developing countries.

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