EFFECT OF METAKAOLIN AND CALCIUM CHLORIDE TO IMPROVE THE STRENGTH PROPERTIES OF EXPANSIVE SOIL

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ABSTRACT:

Expansive clay soils are extensively distributed worldwide and are a source of great damage to infrastructure and buildings. These soils can cause heavy economic losses, as well as being a source of risk to the population. This article presents an experimental study on the stabilization of an expansive soil by reducing its swelling capacity and improving its strength characteristics by addition of Metakaolin (M) and Calcium Chloride ($CaCl_2$).

Keywords: Expansive Soil, Metakaolin (M), Calcium Chloride ($CaCl_2$), OMC, MDD, CBR

I.INTRODUCTION

Expansive soils are found in arid and semiarid regions in the world. In India, it is known as the Black Cotton soil. Black cotton soil is one of the major soil deposits found in India covering about 20% of the area of country. Expansive soils are commonly found in the states of Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra and Tamilnadu.

Characteristics of Black Cotton Soil: Black Cotton soils are inorganic clays of medium to high compressibility and form the major soil group in India. Black Cotton soil has a high percentage of clay, which is predominantly composed of the mineral montmorillonite which is blackish grey in color. Because of its high swelling and shrinkage characteristics, the Black Cotton soil is a challenge to geotechnical and highway engineers. The soil becomes very hard when dry and loses strength when in wet condition. As studied by Balasubramaniam, et. al, 1989 because of its cyclic volumetric change with seasonal moisture fluctuation is accompanied by the loss of strength with increase in moisture content. Because of alternate swelling and shrinkage behavior, there is considerable damage caused to the structures like Cracking and break-up of pavements, railway and highway embankments, roadways, building foundations, slab-on-grade members, irrigation systems, water lines, sewer lines, canal and reservoir linings. These can be identified as the threats posed by expansive soils. (Gromko, 1974; Wayne et al., 1984; Mowafy and Yousry, 1985; Kehew, 1995). By using stabilization process problematic soils such as (Expansive soil, Soft soil, Contaminated soils etc), can be treated by using various chemical stabilizers such as lime and cement. This is well known technique in the field of geotechnical engineering. Hence by using Metakaolin, properties of Expansive soil can be improved for using the soil as a barrier system for the containment of municipal solid waste (Umar et.al., 2015).

II. OBJECTIVES

- To study the effect of laboratory laboratory investigation and to determine the properties of the expansive soil and Metakaolin.
- To evaluate the performance of expansive soil when treated with Metakaolin as an admixture
- To analyze the variation of basic Engineering Properties like, OMC, MDD with the addition of Metakaolin and $CaCl_2$ at different percentages

III. MATERIALS USED

EXPANSIVE SOIL (ES): The soil used in this study is expansive soil, obtained from Innavalli, Amalapuram East Godavari District Andhra Pradesh at a depth of 1.5m from ground level. The Index an Engineering properties of the expansive soil are determined as per IS code of practice.

METAKAOLIN (M): is a pozzolanic material. It's obtained by calcinations of kaolinite clay at temperatures from 700°c to 800°c. Kaolin chemical composition is basically aluminous silicates hydrates associated with mn, fe, ca, k, na. Its crystal has a lattice structure of tetrahedral and octahedral layers with interplanar distance of 7.2 å. The soil used in the present study can be classified according to the unified soil classification system as clay with high plasticity (CH).

CALCIUM CHLORIDE ($CaCl_2$): is an inorganic compound, a salt with the chemical formula $CaCl_2$. It is a colorless crystalline solid at room temperature, highly soluble in water and the efficacy of calcium chloride helps in improving swell and strength properties of Black Cotton Soil.

Table1: Physical Properties of Untreated Expansive soil

S.NO	PROPERTY	SYMBOL	UNTREATED EXPANSIVE SOIL
1.	**Liquid Limit (%)**	**W_L**	*76*
2	**Plastic Limit (%)**	**W_P**	*33.59*
3.	**Plasticity Index (%)**	**I_P**	*42.41*
4.	**Soil Classification**	**--**	*CH*
5.	**Specific Gravity**	**G**	*2.63*
6.	**Free Swell (%)**	**FS**	*120*
7.	**Optimum Moisture Content (%)**	**OMC**	*28.119*
8.	**Maximum Dry Density (g/cc)**	**MDD**	*1.504*
9.	**CBR (%)**	**--**	*2.240*
10.	**Natural Moisture Content (%)**	**--**	*6.769*

Table2: Physical properties of Metakaolin:

SI. NO	METAKAOLIN PHYSICAL COMPOSITION	CONTENT
1	**SPECIFIC GRAVITY**	*2.50g/cm^3*
2	**COLOUR**	*WHITE*
3	**PHYSICAL FORM**	*POWDER*
4	**+325MESS(45 µm) RESIDUE**	*< 1.0%*
5	**AVERAGE PARTICAL SIZE**	*< 2.5 µm*

Table3: Chemical composition of Metakaolin:

SI. NO	METAKAOLIN CHEMICAL COMPOSITION	CONTENT (%)
1	**SIO_2+AL_2O_3+FE_2O_3**	*> 97.0*
2	**SULPHUR TRIOXIDE(SO_3)**	*< 0.50*
3	**ALKALIES(NA_2O,K_2O)**	*< 0.50*
4	**LOSS ON IGNITION**	*< 1.00*
5	**MOISTURE CONTENT**	*< 1.00*

Table4: Properties of $CaCl_2$:

SI.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**	*772-775°C*
6	**Boiling Point**	*1935°C*

IV. LABORATORY STUDIES

The laboratory studies were carried out on the samples of Expansive soil, Expansive soil+10% Metakaolin and Expansive soil+10%M+1.5% $CaCl_2$.

ATTERBERG LIMITS:

The Atterberg Limits of the soil were determined in accordance with IS 2720 (Part 5)-1985. The Atterberg Limits gave the Liquid Limit and Plastic Limit of the soil, from which the Plasticity Index was determined. In that Liquid Limit and Plastic Limit had been conducted on Expansive soil, Expansive soil+10% Met kaolin and Expansive soil+10%M+1.5% $CaCl_2$, using Casagrande's liquid limit and Plastic limit test was conducted on Expansive soil, Expansive soil+10% Metakaolin and ES+10%M+1.5% $CaCl_2$.

Differential Free Swell:

To determine the free swell index of soil, differential free swell test was carried out according to IS 2720 (Part XL) - 1977) from which the degree of expansiveness of soil is determined as per IS 2911 (Part 3)-1980.
To determine the free swell index of a soil, 20g of oven dried soil passing through 425µ size sieve is taken. One sample of l0g is taken in a l00cc capacity graduated cylinder containing water and the other sample of 10g is taken in 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 the degree of expansion of the soil depending upon its differential free swell as shown below.

Table5: Differential Free Swell:

S. NO	DIFFERENTIAL FREE SWELL	DFS (%)
1	**Low**	*<20%*
2	**Moderate**	*20-35%*
3	**High**	*35-50%*
4	**Very High**	*>50%*

MODIFIED PROCTOR COMPACTION TEST:

Modified Proctor compaction test is carried to assess the amount of compaction and the water content required in the field. This test is done on the soil in accordance with IS 2720 (Part VII) - 1980. The water content at which the maximum dry density is attained is obtained from the relationships provided by the test data.

SPECIFIC GRAVITY TEST:

Specific gravity can be determined either by using pycnometer, 500ml flask or 50ml density bottle. Density bottle can be used for the testing of both fine grained and coarse grained soil. Whereas flask and pycnometer is suitable for testing of coarse grained soil Specific gravity test was carried out using Pycnometer as per IS 2720 Part 3 (1980).

CALIFORNIA BEARING RATIO TEST:

The CBR value of a soil is an index which is related to the strength of the soil. The test is conducted in accordance with IS 2720 (Part 16)-1987. Metakaolin is added to soil in varying percentages (6%, 8%, 10%, 12%) respectively. CBR value increases up to 10% addition of Metakaolin and then decreases. The maximum value of CBR for 10 % addition of Metakaolin was obtained as 4.481%. The CBR value showed an Increase from 2.240% to 4.481% at 10% addition of Metakaolin. On further addition of 1.5% $CaCl_2$ to soil and 10% Met kaolin, the CBR increased from 4.481% to 8.515%. The test was conducted at 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 is conducted at Optimum moisture content. The samples were tested in soaked condition.

TRIAXIAL SHEAR TEST:

Triaxial shear test is carried out under the guidelines of triaxial shear test-UU (IS-2720-PART-11). It is used to determine shear parameters of the given soil sample by conducting unconsolidated undrained (UU) triaxial shear test. This test is considered to be the most conveniently available conditions to suit the field situations.

V. RESULTS AND DISCUSSIONS

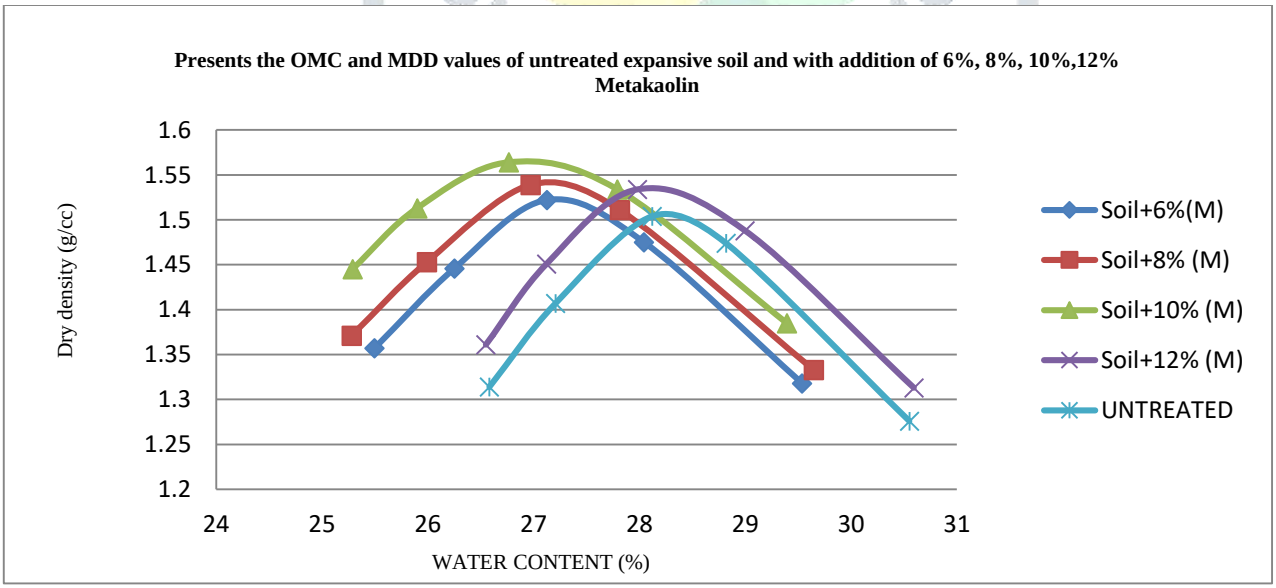
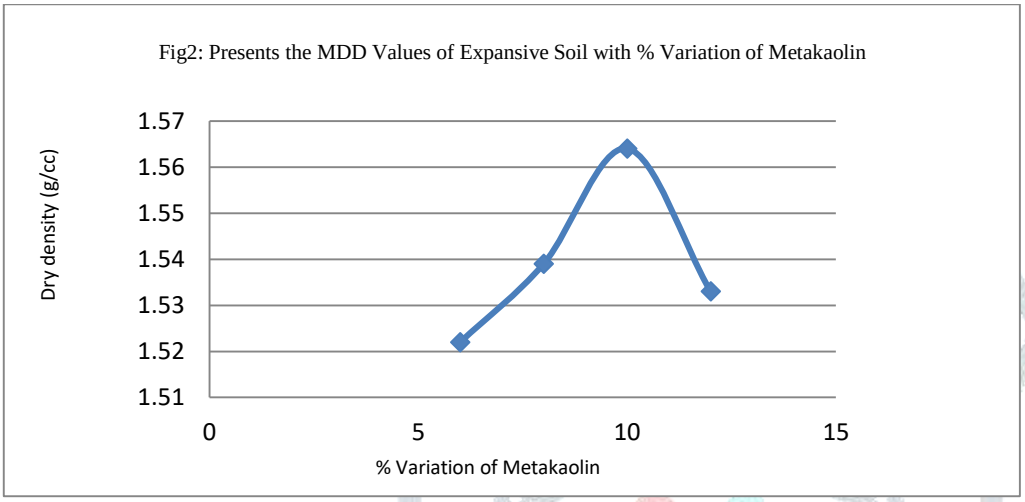


Fig1: Proctor Modified Compaction Results of Untreated Expansive Soil and Treated With Various Percentages of Metakaolin

Table6: OMC & MDD Values of Expansive Soil Treated With % Variation of Metakaolin

SI. NO	MIX PROPORTION	OMC (%)	MDD (g/cc)

1	**Soil**	*28.119*	*1.504*
2	**Soil+0.5% (M)**	*27.114*	*1.52*
3	**Soil+1% (M)**	*26.969*	*1.539*
4	**Soil+1.5% (M)**	***26.764***	***1.564***
5	**Soil+2% (M)**	*27.987*	*1.535*



The soaked CBR values of Different proportions of Expansive Soil and Metakaolin using OMC values obtained from compaction. The soaked CBR values are taken after immersing in water for four days Variation of CBR with % variation in Metakaolin.

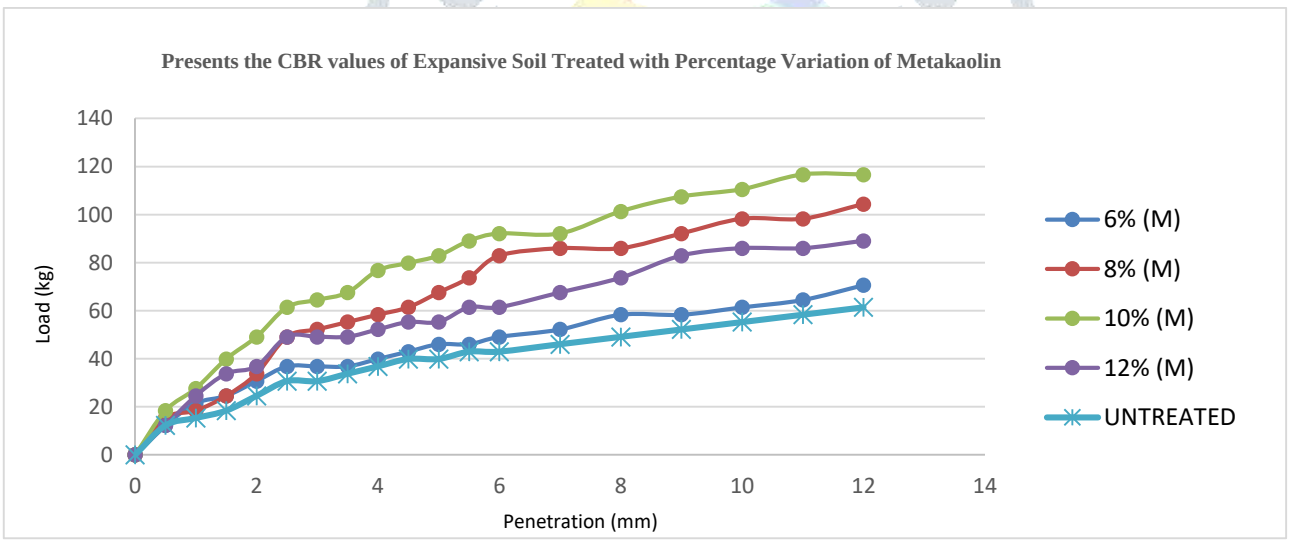
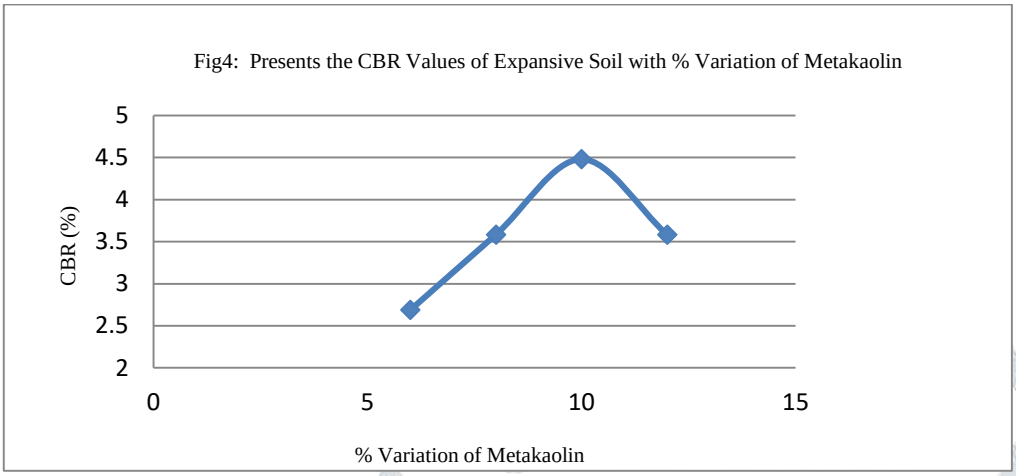


Fig3: CBR Test Results for Expansive Soil Treated With Various Percentages of Metakaolin:

Table7: CBR Values of Expansive Soil Treated With % Variation of Metakaolin

SI. NO	MIX PROPORTION	SOAKED CBR (%)
1	**Soil**	*2.240*
2	**Soil+6% (M)**	*2.689*

3	**Soil+8%(M)**	*3.585*
4	**Soil+10%(M)**	***4.481***
5	**Soil+12%(M)**	*3.585*



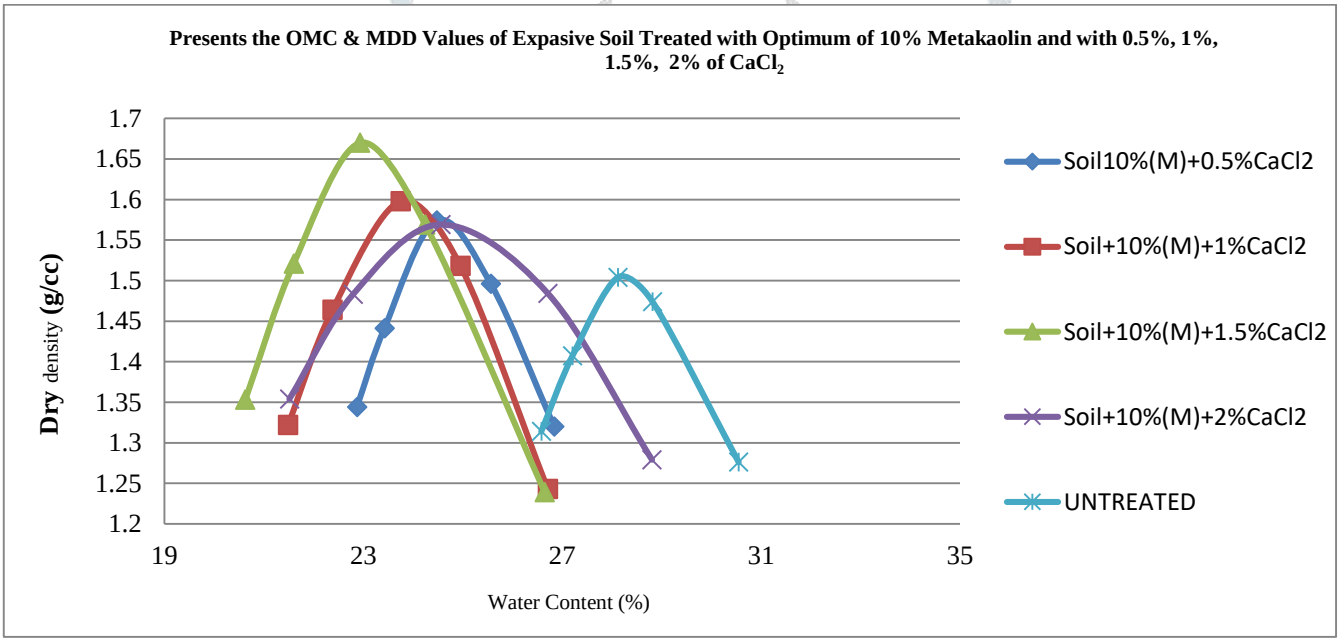
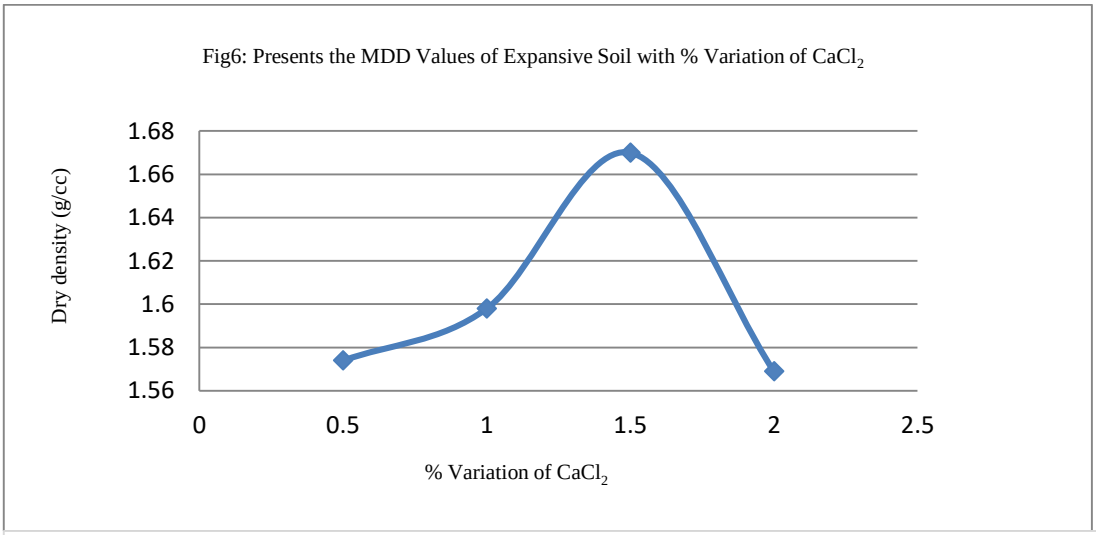


Fig5: Proctor Modified Compaction Results for Optimum 10% Metakaolin Treated Expansive Soil with % Variation of $CaCl_2$

Table8: Variation of MDD and OMC of Metakaolin Treated Expansive Soil with % Variations of $CaCl_2$

SI. NO	MIX PROPORTION	OMC (%)	MDD(g/cc)
1	**Soil+10%M+0.5% $CaCl_2$**	*24.476*	*1.574*
2	**Soil+10% M+1% $CaCl_2$**	*23.753*	*1.598*
3	**Soil+10%M+1.5% $CaCl_2$**	***22.93***	***1.67***

4	**Soil+10% M+2% $CaCl_2$**	*24.562*	*1.569*



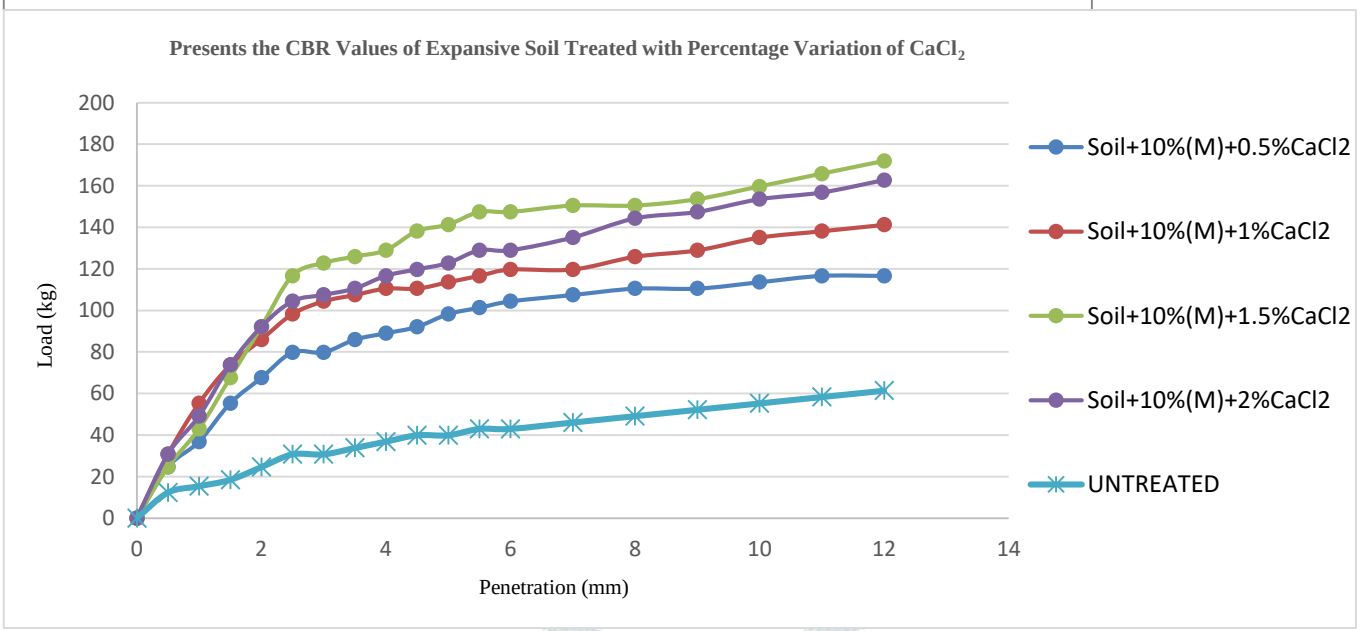


Fig7: CBR Test Results for Optimum of Metakaolin Treated Expansive Soil with Various Percentages of $CaCl_2$

Table9: Variation of CBR values of Metakaolin treated Expansive Soil with various percentages of $CaCl_2$

SI. NO	MIX PROPORTION	CBR (%)
1	**Soil+10% M+0.5% $CaCl_2$**	*5.826*
2	**Soil+10% M+1% $CaCl_2$**	*7.17*
3	**Soil+10% M+1.5% $CaCl_2$**	***8.515***
4	**Soil+10% M+2% $CaCl_2$**	*7.618*

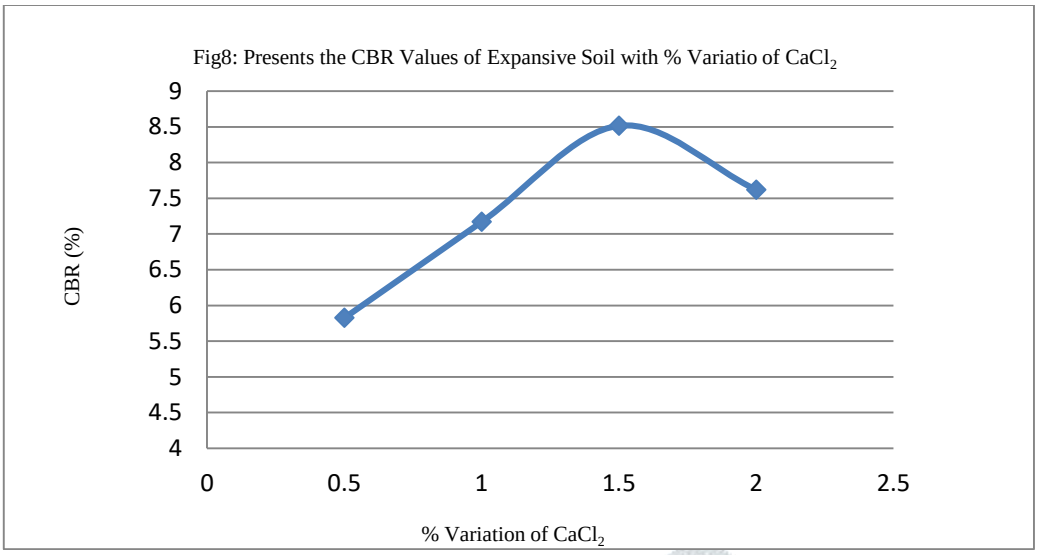


Table10: Properties of the Stabilized Expansive soil with an optimum of 10% Metakaolin and 1.5% CaCl2

SI NO	PROPERTY	SYMBOL	UNTREATED EXPANSIVE SOIL	SOIL+ 10%(M)	SOIL+ 10%(M) + 1.5%$CaCl_2$
1	**Liquid limit (%)**	W_L	*76*	*44*	*27.80*
2	**Plastic limit (%)**	W_P	*33.59*	*23.5*	*18.3*
3	**Plastic index (%)**	I_P	*42.41*	*19.43*	*9.5*
4	**Soil classification**	---	*CH*	*CI*	*CL*
5	**Specific gravity**	**G**	*2.63*	*2.75*	*2.8*
6	**Free swell index (%)**	**DFSI**	*120*	*65*	*40*
7	**Optimum moisture content (%)**	**OMC**	*28.119*	*26.76*	*22.96*
8	**Maximum Dry Density (gm/cc)**	**M.D.D**	*1.504*	*1.564*	*1.67*
9	**CBR (%)**	---	2.240	4.481	8.51
10	**Cohesion (kg/cm2)**	---	0.65	0.45	0.22
11	**Angle of shear resistance(ϕ)**	---	16^0	22.1^0	31.6^0

VI.CONCLUSIONS

- It is observed that the liquid limit of Expansive Soil has been decreased by 42.105% on addition of 10% Metakaolin and it has been further decreased by 63.42% when 1.5% $CaCl_2$ added.
- It is noticed that the plastic limit of the Expansive Soil has been decreased by 30.03% on addition of 10% Metakaolin and it has been decreased by 45.10% when 1.5% $CaCl_2$ is added.
- It is observed that the plasticity index of the Expansive Soil has been decreased by 54.18% into on addition of 10% Metakaolin and it has been further decreased by 77.59% when 1.5% $CaCl_2$ is added.
- It is noticed that the cohesion of Expansive Soil has been decreased by 30.76% on addition of 10% Metakaolin and it has been further decreased by 43.076% when1.5% $CaCl_2$ added.
- It is noticed that the angle internal friction of Expansive Soil has been improved by 38.12% on addition of 10% Metakaolin and it has been further improved by 97.5% when 1.5% $CaCl_2$ added.
- It is found that the O.M.C of the Expansive Soil has been decreased by4.81 % on addition of 10% Metakaolin and it has been further decreased by 18.34% when 1.5% $CaCl_2$ is added.
- It is found that the M.D.D of the Expansive Soil has been increased by 3.989% on addition of 10% Metakaolin and it has been increased by 11.037 % when 1.5% $CaCl_2$ is added.
- It is observed that the C.B.R value of the Expansive Soil has been increased by 100.04% on addition of 10% Metakaolin and it has been further improved by 279.91% when 10% $CaCl_2$ is added.
- It is observed that the DFS value of the Expansive Soil, has been decreased by 45.83% on addition of 10% Metakaolin and it has been further decreased by 66.66% when 1.5% $CaCl_2$ is added.
- The soaked CBR of the soil on stabilizing is found to be 8.51%, but 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 10% of Metakaolin and 1.5% of $CaCl_2$ improved the properties of the air dried Expansive Soil to the desirable extent, making it useful to be used in pavements.

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