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Influence of Magnesium Chloride on Plasticity Characteristics and Engineering Properties of Black Cotton Soil

Mohankumar S R[1], P.G Rakaraddy[2]

[1]*Assistant Professor, VIF College of Engineering, Hyderabad, Telangana, India.*
[2]*Associate Professor, Basaweshwara Engineering College Bagalkot , Karnataka ,India.*

Abstract - *Expansive soils such as black cotton soil has high tendency to swell and shrink due to moisture variations and susceptible to detrimental volumetric changes. In India these soils are extensive and it is virtually impossible to avoid construction activities. Recently chemical stabilization has become most popular and through various investigations many researchers revealed that common salts like NaCl, $AlCl_2$, KCl, $CaCl_2$, $MgCl_2$, Na_2SO_4,$MgSO_4$, $NaHCO_3$, $CaSO_4$ and $CaCO_3$ can be used as they have ability to dissolve easily in water and in addition to this they adequately supply the cations.*

The aim of present investigation to understand the effect of magnesium chloride on the geotechnical properties of the black cotton soil. The addition of magnesium chloride into soil with different concentration such as 0.5N, 1.0N, 2.0N and 4N for black cotton soil. From the present experimental investigation it is observed that by increasing the concentration there is improvement in consistency limits, compaction characteristics and unconfined compression strength of black cotton soil.

Key Words: **Magnesium Chloride, Black Cotton Soil, Consistency Limit, MDD, OMC, UCS.**

1. INTRODUCTION

Expansive soils are highly problematic in nature by virtue of their inherent capacity to undergo volumetric changes corresponding to changes in moisture regime. They swell when they absorb water and shrink when water evaporates from them. As expansive soils are rich in mineral mont-morillonite which has an expanding lattice structure, swelling occurs when water is absorbed by these soils[1]. The building blocks of the expanding lattice structure of the mineral get separated when water enters them. Thus, swelling takes place in expansive soils. So expansive soil undergoes swelling during rainy seasons and shrinkage during summers. Hence, lightly loaded civil engineering infrastructure such as residential buildings and road pavements are subjected to severe distress and develop unsightly cracking. Hence, there is a need to improve expansive clays. Based on the recent investigations on chemical stabilization many researchers revealed that strong electrolytes such as chlorides of sodium, magnesium, calcium, ferric etc can be used in place of conventionally used lime due to their ready dissolvability in water and supply of adequate cations to stabilize the soil[2]. Such chlorides as specified earlier are directly responsible for reaction to take place with soil which improves the properties of such an expansive soil. When dissolved in water, the chlorides undergo hydrolysis and gives off heat in an exothermic reaction. Such a solution will result in flocculation of the soil particles and there by increases the density of the soil.

2. MATERIALS

2.1 BLACK COTTON SOIL

The soil sampling is carried at kiresur village (Naragund taluk ,Dist -Dharwad , State- Karnataka) which was dark in colour. The soil samples were collected from an open excavation, at a depth of 1m to 1.5m below the natural ground surface .The Soil used in this study is a blackish grey inorganic clayey soil of high plasticity and belongs to OH group. All geotechnical tests were performed according to IS: 2720.

Table -1: Geotechnical properties of the untreated black cotton soil

Sl No	Properties	Value
1	Specific gravity	2.4
2	Grain size distribution (%) Gravel and sand Silt	 0 32
3	Liquid limit (%)	63.5
4	Plastic limit (%)	24.0
5	Plasticity index (%)	39.5
6	Free swell index (%)	52
7	IS classification of soil	OH
8	Proctor Compaction Test Maximum dry density (g/cc) Optimum moisture content(%)	 1.32 34
9	Unconfined compressive strength (kPa)	24

2.2 STABILIZER

In the present investigation the stabilization of black cotton is done using magnesium chloride. and their properties as below,

- Molar mass : 95.211 g/mol (anhydrous)
- Appearance: White or colourless crystalline solid.
- Boiling point: 1685 K.
- Density: 2.32.5 g/cc.
- Solubility in water: 52.3 g/100ml.

The chemical is introduced into the soil in the form of solution as a pore fluid and it was prepared with various concentrations in terms of normalities such as 0.5 N, 1.0 N, 2.0 N and 4.0 N for black cotton soil.

Table -2: Preparation of Magnesium chloride solution

Concentration of chemical solution in Normality (N)	Crystals of chemical used in grams per 1000 ml of distilled water
0.1	10.166
0.5	50.828
1.0	101.655
2.0	203.310
4.0	406.620

3. EXPERIMENTAL PROGRAM

The experimental program for black cotton soil treated with magnesium chloride (Table 3.)

Table -3 : Tests conducted on Black Cotton soil treated with magnesium chloride

Concentration of chemical used in(N)	Type of tests conducted		
0.5	Specific gravity Consistency limits Standard proctor compaction		
1			
2			
4			
Concentration of chemical used in(N)	**Curing period in days**	**Type of test conducted**	**Test condition**
0.5	3	UCS	Unsoaked
1			
2	7		
4	14		

4. RESULTS AND DISCUSSIONS

The effect of magnesium chloride on the various geotechnical properties of black cotton soil such as consistency limits, compaction characteristics and unconfined compressive strength.

4.1. CONSISTENCY LIMITS

The results of consistency limit for various concentration of the pore fluid is tabulated in(Table 4) and clearly observed that the treated soil has followed a trend of continuous reduction in the liquid limit with increase in the concentration of the pore fluid . This is because of the resistance offered by the pore fluid against liquidity of the treated soil that has reduced its liquid limit. On the other hand the reduction in thickness of the double layer resulted in the reduction of liquid limit with the increase in concentration of pore fluid.The variation of plastic limit for various concentration of the pore fluid is observed that the plastic limit of the treated soil was increases continuously throughout the trend ,because this is depressed double layer thickness due to cation exchange and increased electrolyte concentration as chemical is completely soluble in water [3]. In the same way the variation of plasticity index for various concentration of the pore fluid is observed that the reduction of plasticity index of the treated soil because of the increase in plastic limit and decrease in liquid limit causes a net reduction in plasticity index.(Chart-1),(Chart-2).

TABLE -4: Consistency limits of Black cotton soil treated by magnesium chloride

Concentration of chemical solution in Normalities	Atterberg's Limits		
	W_L	W_P	I_P
0	63.50	24.00	39.50
0.5	56.10	26.5	29.60
1	52.90	28.0	24.90
2	48.20	29.80	18.40
4	45.10	31.10	14.00

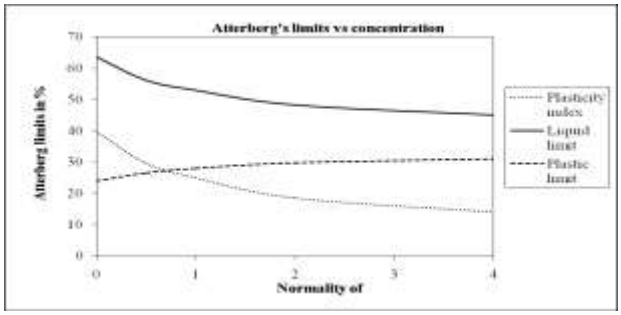

Chart -1: Effects on Consistency limits of BC soil treated by magnesium chloride

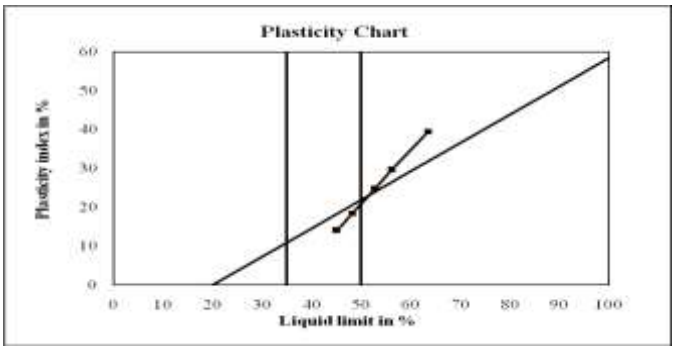

Chart -2: Plasticity chart for stabilized soil

4.2. Compaction characteristics

The compaction characteristics of black cotton soil were carried out with a aid of standard proctor compaction test. The maximum dry density and optimum moisture content of the black cotton soil treated with different concentrations are shown in the (Table 5).

The variation of dry density and moisture content for different concentration of magnesium chloride is observed that maximum dry density increases from 1.320g/cc to 1.430g/cc and optimum moisture content decreases from 34% to 28% with increases to 4N(Chart-3) ,(Chart-4). Because the soil structure (before compaction) tends to change from edge-to-face type of flocculation to face-to-face flocculation with the increase in salt concentration . Consequently under the influence of dynamic compaction, the clay particles become more oriented and the compacted dry unit weight increases with the increase in salt content.

The decrease in the optimum moisture content as the salt content increased may be explained due to the higher the face-to-face flocculation the lower is the amount of water required for lubrication[4].

TABLE -5: Compaction characteristics of Black cotton treated by magnesium chloride

Concentration of chemical solution in (N)	Compaction Characteristics	
	MDD in g/cc	OMC in %
0	1.32	34.00
0.5	1.35	32.5
1	1.38	30.1
2	1.41	29.10
4	1.43	28

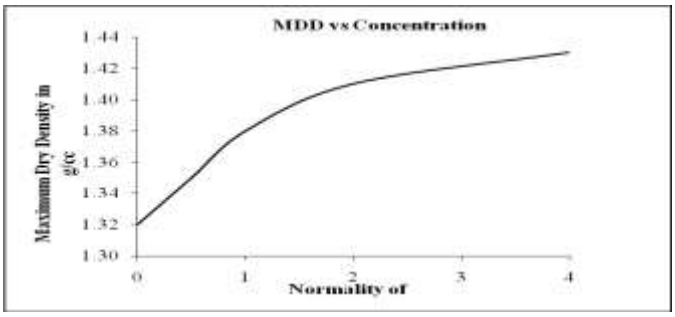

Chart-3: Variation of MDD for different concentrations of magnesium chloride

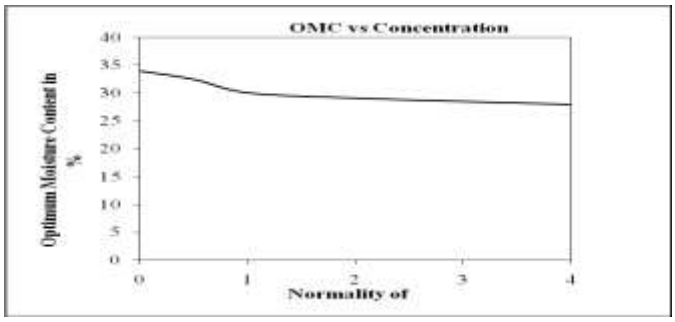

Chart-4: Variation of OMC for different concentrations of magnesium chloride

4.3. Unconfined compression strength test

The Unconfined compression strength test is carried out on untreated and treated black cotton soil. The prepared magnesium chloride solution is mixed in to the soil at different concentrations such as 0.5N, 0.1N, 0.2N and0.4N with no of curing days as 0, 3, 7, 14 and 21. The results of unconfined compressive strength test are shown in the (Table-6). The increase in concentration of the pore fluid led to increase in the UCS, due to the reduction of double layer thickness to a greater extent (Chart-5). When the pore fluid added to the soil it undergoes reaction which forms a cluster that holds the soil particles together [5]. It results in reduction of repulsion force and increased attraction force at inter particle zone that has raised the cohesion of the treated soil[6].

TABLE -6: Experimental program for tests conducted on Black Cotton soil treated with magnesium chloride

Concentration of Chemical solution in normalities	Unconfined compression strength in kPa			
	3 DAYS	7 DAYS	14 DAYS	21 DAYS
0.5	50	102	161.0	240
1	80.5	130.6	215.1	350
2	129.1	260.9	385	502
4	170	295	483.5	603.5

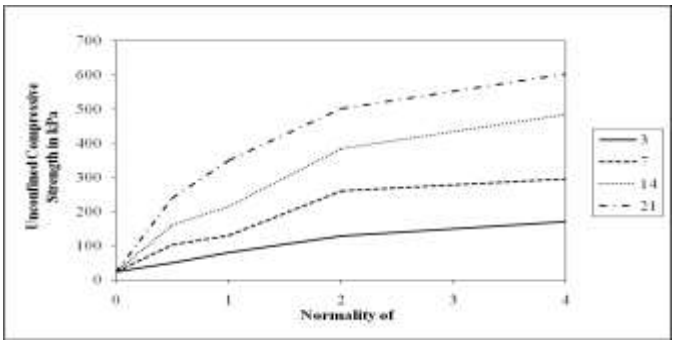

Chart-5: Influence of magnesium chloride on UCS for BC soil

3. CONCLUSIONS

- For B.C soil, it was observed that liquid limit and plasticity index have been decreased by 28.97% and 64.52 % respectively, and plastic limit increased by 22.82% with increase in concentration from 0.5N to 4N of $MgCl_2$.
- For B.C soil, it was observed that MDD has been increased from 1.32 g/cc to 1.43g/cc, and OMC decreased from 34% to 28% with increase in concentration from 0.5N to 4N of $MgCl_2$.
- For B.C soil, it was observed that UCS has been increased from 24 kPa to 603.5 kPa with increases concentration from 0.5N to 4N of $MgCl_2$ for 28 days of curing.

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