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Enhancing the Engineering Properties of Black Cotton Soil by using Magnesium Chloride

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Abstract. Black cotton soils are fundamentally helpless to hinder the volumetric changes as the moisture content changes. These soils are forming vital issues to the engineering structures. Such soils show excessive volume changes after comprising with water. The black cotton soil has a poor encouraging limit and huge change in volume on varieties of moisture content. Such black cotton soils ought to be improved to make them appropriate for construction exercises. This paper introduces the impact of Magnesium Chloride ($MgCl_2$) on compaction qualities, Atterberg's limit, California bearing proportion, Standard proctor compaction test, unconfined compressive quality parameters and Swelling pressure characteristics. Plastic limit decreases with decrease in the amount of magnesium chloride. The dry density and CBR values of soil stabilized with 8% $MgCl_2$ increased approximately 22% and 223% correspondingly. Coming from the inspection of test outcomes it was discovered that, fluid utmost, versatility list, ideal dampness content diminished and most extreme dry thickness, California bearing proportion and edge of inward grating expanded with an expansion in $MgCl_2$.

Keywords: Black Cotton Soil, Soil Stabilization, Magnesium Chloride, Atterberg's limit, Compaction, UCS value

1 Introduction

Construction on Black cotton soil dependably makes an issue for structural architects due to its swelling behavior for analysis. At the point when the Black cotton soil comes in contact with water then over the top swelling is caused and when water content declines shrinkage happens in the soil. In India, the black cotton soil covers 20-25% land zone and mostly found in areas of Rajasthan, Madhya Pradesh and Andhra Pradesh. The dark cotton soil contains high level of montmorillonite mineral which bestows far reaching nature to it. Construction of different structures on Black cotton soils represents a noteworthy hazard to the structure in view of the expansive level of precariousness in these dark cotton soils. Many researchers are working on different methods to enhance the properties of BC soil. Plastic limit decreases with decrease in amount of magnesium chloride. The effectiveness to cost ratio is better in $MgCl_2$ than

other salts like NaCl and $CaCl_2$. One of the methods is to transfer of Magnesium chloride turning into a stabilizing agent

2 Literature Review

Tamadher et al. (2007) [1] observed the outcome of distinct chloride compound on engineering property of silty clayey soil. The proportion of soil is taken to be 2%, 4%, 6% and 8%. On addition of NaCl solution maximum UCS was found on 4% concentration, while maximum UCS was found at addition of 8% solution of calcium chloride. On the basis of this study $CaCl_2$ solution found to be more effective than NaCl. Radhakrishnan et al. (2014) [2] studied the swelling properties of black cotton soils experimented with chemicals ($MgCl_2$, $AlCl_3$) and fly ash were evaluated as a stabilizer. It was noted that the addition of 1% and 10% of fly ash with $AlCl_3$ was high. The percentage decrement in swell potential is 63%, 68% and swell pressure is 69%, 73% correspondingly. Muthyalu et al. (2012) [3] evaluated the performance of chemically stabilized expansive soil. It was noted that there was a notable variation in consistency limit. When the chemical added to 1% there was a decrease in liquid limit. Nominal increase in plastic limit and CBR was recorded. Due to the reduction of liquid limit and increment in plastic limit, the net reduction in plasticity index occurs. As the percentage of chemical was increased in untreated soil there was a significant increase was observed in the UCS value. Al-Omari et al. (2010) [4] estimated the outcome of potassium chloride on cyclic behavior of expansive clays. The liquid limit and plasticity index were decreased by KCl. The OMC decreases as the MDD increases. The best enhancement of free swell and swelling pressure occur at 5% KCl where they are reduced by 56% and 65% respectively. Mallika and B. Ganesh (2017) [5] observed the influence of chemical stabilizing medium on strength and swelling properties of soil. The liquid limit of soil decreases and plastic limit slightly increases as the chemical content ($CaCl_2$ and $FeCl_3$) was increased. The percentage reduction in the swelling pressure were 26% and 35% for $CaCl_2$ and $FeCl_3$ at an optimum value of chemical content. At 1% of $CaCl_2$ the value of UCS were increased by 177% and 203% and $FeCl_3$. It was noted that $FeCl_3$ was more effective in improving the properties of BC soil. Ajay Raj et al. (2018) [6] examined the stabilization of BC soil by using Sodium Chloride and Fly ash and came up with the results that the liquid limit decreases when the NaCl and fly ash were added. As the value of OMC decreases MDD increases and an improvement in the compaction parameters was seen. As the addition of NaCl (0%, 3%, 6%, 9% & 12%) and fly ash (0%, 5%, 10%, 15%, & 20%) increases the UCS values are also increased. Zumrawi and Eltayeb (2016) [7] concluded that there was a significant decrease in plasticity with increasing percent of calcium chloride. At the addition of 5% $CaCl_2$ the shear strength increases. Kolaventi et al. (2016) [8] obtained the comparative analysis of black cotton soil using NaCl and $CaCl_2$. The findings indicated that the properties are improved at the addition of 8% $CaCl_2$. Also the author gets the better results for calcium chloride as compared to sodium chloride.

Rambabu and Bhavannarayana (2019) [9] investigated the experimental study by using expansive soil with banana fibre (BF) along with magnesium chloride. It was observed that with the addition of 1% BF when compared with expansive soil the free swell index and liquid limit of expansive soil has been decreased. The plastic limit, CBR value and static plate load test results were improved with the addition of BF along with optimum percentage of $MgCl_2$. Srinivas and Prasada (2010) [10] spring up with the findings that swell potential and swell pressure values has been decreased at 1% chemical. The time taken for treated model flexible pavement is nearly two-thirds of the untreated model flexible pavement to attain its maximum heave for Ferric Chloride.

3 Materials Used

3.1 Black cotton soil

It was obtained from the district of Baran, Rajasthan India. The specimen was extracted from a pit of 1.5m beneath ground level with the help of Auger. The soil uprooted contains harmful substances and are in various sizes. The properties of the soil have higher proportion of expansive clay which is more problematic type for medium and high constructions.

Fig. 1. Black Cotton Soil

3.2 Magnesium chloride

The Magnesium Chloride Hexahydrated used in this study was collected from K.S.SCIENTIFICS Chemical Shop Kota, Rajasthan. Bischofite with the chemical name of "Magnesium Chloride Hexahydrate" ($MgCl_2.6H_2O$) is one of the non-traditional stabilizers which have recently been the center of focus for researchers. Magnesium chloride ($MgCl_2$) was used as a dust control and soil stabilizing agent. The hydrated $MgCl_2$ can be extracted from brine or sea water. As the use of magnesium chloride is becoming more regular especially in pavement industry, its potential to

mitigate the swelling potential of expansive soils is getting more attention amongst researchers. The properties of $MgCl_2$ are shown in Table 1.

Table 1. Composition of Magnesium Chloride

Property	Value
Molar Mass	203.30 g/mol
Appearance	White Powder
Minimum assay	99%
Max. Limits of Impurities-	
Sulfate (SO_4)	0.01%
Phosphate (PO_4)	0.004%
Iron (Fe)	0.002%
Calcium (Ca)	0.05%
Density	1.57 g/cm^3
Boiling point	1412^{0}C

Fig. 2. Magnesium Chloride

4 Experimental Program

The $MgCl_2$ was mixed in proportions of 2%, 4%, 6%, and 8% by weight of the dry soil in running water. Atterberg's limit test, Sieve analysis, Standard Procter Test, Unconfined compression test, Swelling Pressure and California bearing ratio test are going to be performed to analyze the behavior of expansive soil with $MgCl_2$. The various properties of BC soil are listed below in Table 2.

Table 2. Physical Properties of BC Soil

S. No.	Property	Value
1	Soil Classification	CH
2	Liquid Limit	63.74%
3	Plastic Limit	26.74%
4	Plasticity Index	37%
5	Max. Dry Density	1.72 kg/cm^3
6	Swelling Pressure	1.45 kg/cm^2
7	O.M.C.	19.7%
8	Free Swell Index	64.71%
9	CBR Value	1.71%
10	UCS Value	1.76 N/cm^2

5 Results and Discussions

5.1 Grain size analysis

Particle size analysis was performed as per IS: 2720 (Part-IV) -1985 and this was used to plot the graph of particle size distribution on semi log curve of the sample. The percentage of sample passing each and the percentage mass retained were determined from the data acquired.

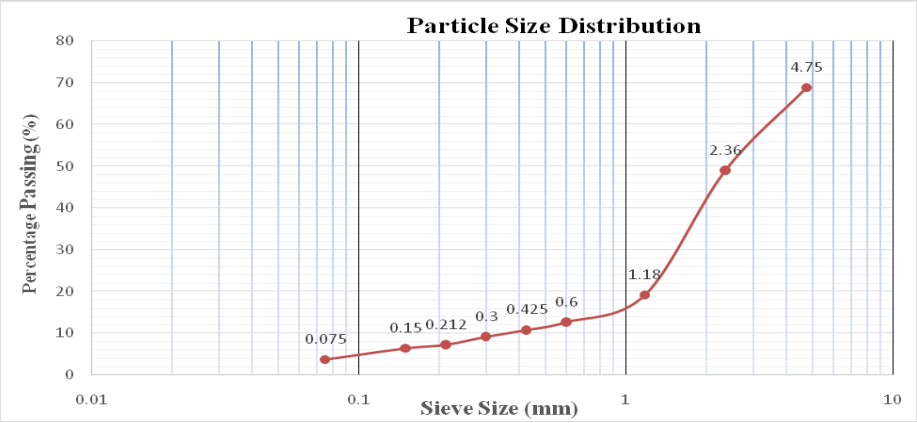

Fig. 3. Particle size distribution curve for BC Soil

5.2 Atterberg's limit

The liquid limit, plastic limit and plasticity index were determined as per IS: 2720(Part 5)-1985. With the addition of $MgCl_2$ the experimental results reveal that the liquid and plastic limit of the soil decreases.

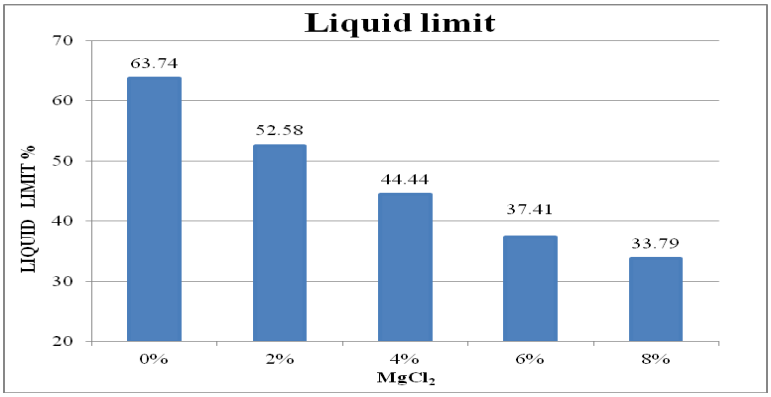

Fig. 4. Liquid limit with $MgCl_2$

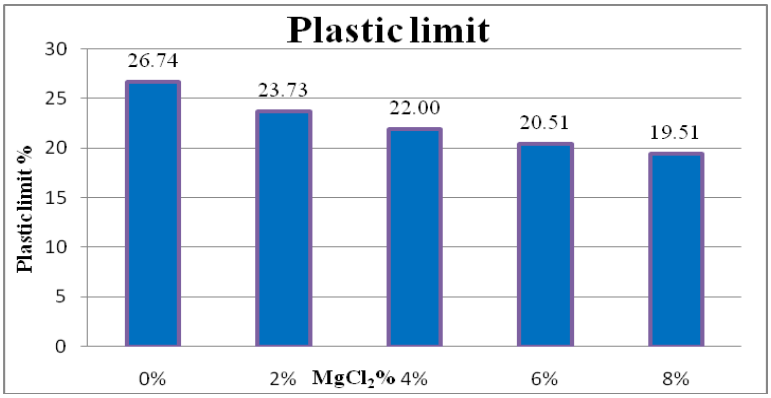

Fig. 5. Plastic limit with $MgCl_2$

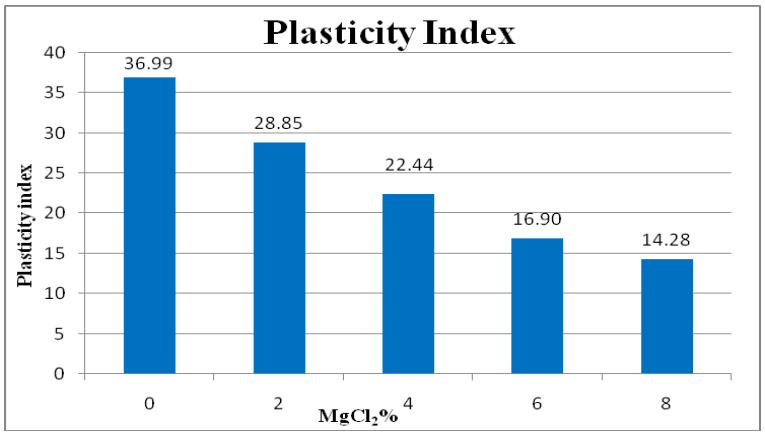

Fig. 6. Plastic index with $MgCl_2$

5.3 Standard proctor compaction test

The Standard Proctor test has been analysed according to IS: 2720(Part 7)-1980 and the curve is plotted between Optimum moisture content (OMC) and Maximum dry density (MDD). The subsequent result is translated by the figure shown. It was found that the maximum density of dry soil is 1.72 kg/cm³. As the soil specimen is mixed with magnesium chloride the value of OMC decreases from 19.7% to 12.5%. On adding 8% $MgCl_2$ the OMC was decreased by 36.55% and the MDD value was increased from 1.72 g/cc to 2.07 g/cc. In other words it can also be said that as compared to untreated black cotton soil maximum dry density value was increased by 22.35%.

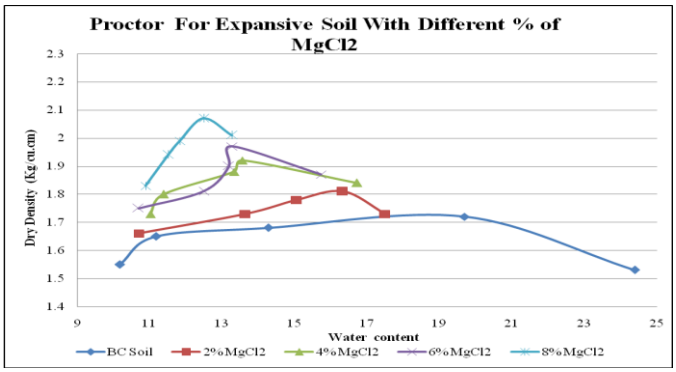

Fig. 7. Compaction test results obtained with various percentage of $MgCl_2$

5.4 Unconfined compression test

The Unconfined compression test (UCS) was executed as per the IS: 2720(Part 10)-1991 and Stress-Strain curve is plotted as shown in Fig. 9. It's clear from the figure that the UCS value was increased from 1.76% to 3.21% at the addition of 8% $MgCl_2$. On comparing the untreated black cotton soil, UCS values are increased by 182.39% in treated black cotton soil with 8% $MgCl_2$.

Fig. 8. UCS testing machine with sample

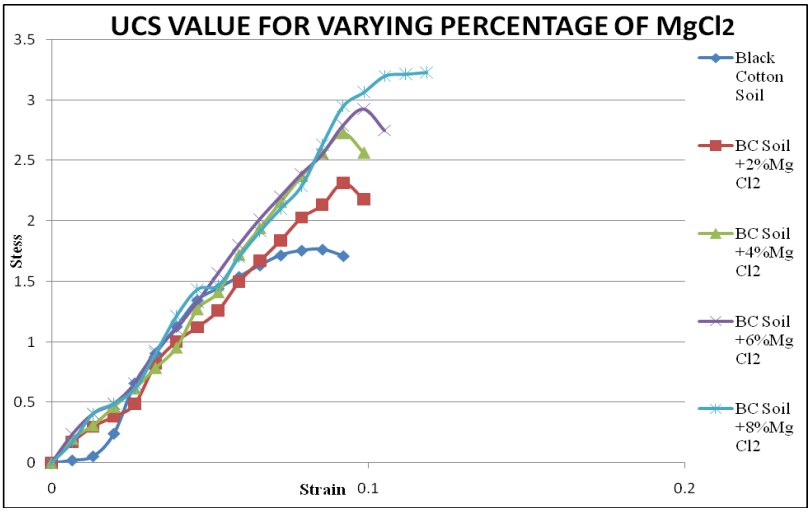

Fig. 9. UCS Test results obtained by black cotton soil with magnesium chloride

5.5 California bearing ratio test

CBR test was performed as per the IS: 2720 (Part 16)-1987. The value of the soaked CBR was increased from 1.71% to 5.54% of the black cotton soil at 8% addition of $MgCl_2$. CBR value is increased by 223.98% on adding 8% $MgCl_2$ on comparing with the untreated soil. Load versus penetration curve is plotted and shown in Fig. 11.

Fig. 10. California Bearing Ratio testing machine

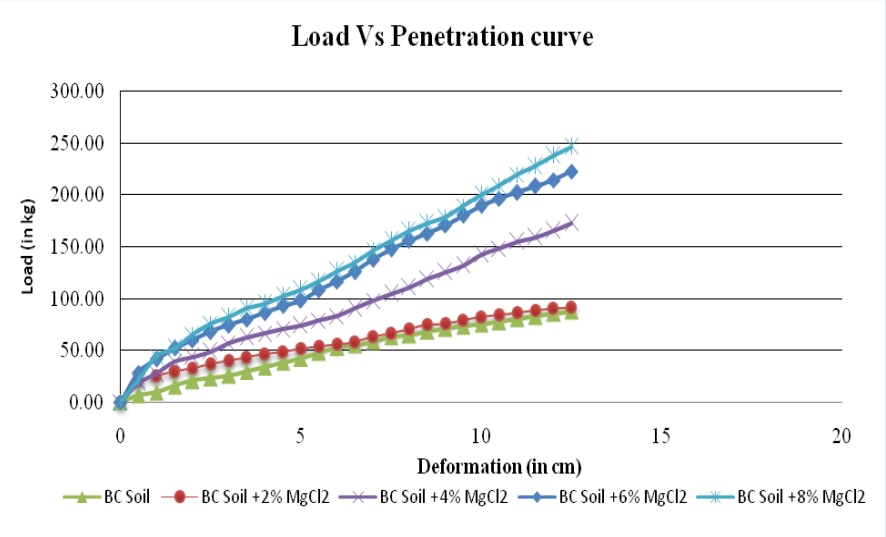

Fig. 11. California Bearing Ratio results

5.6 Swelling pressure test

For the observations of swelling pressure of black cotton soil the Indian Standard guidelines were used as per IS: 2720(Part 41)-1977. It was observed that the swelling pressure test for black cotton soil is 1.45 kg/cm^2. Figure 12 shows the variation of the swelling pressure with BC Soil. The swelling pressure was decreased due to the increase in percentage of $MgCl_2$ in BC Soil.

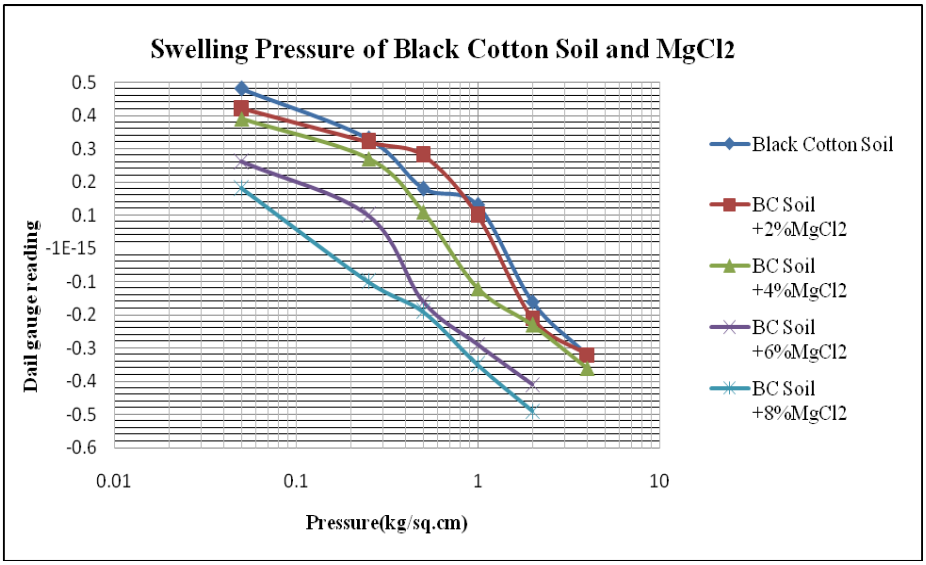

Fig. 12. Swelling Pressure results for black cotton Soil with Magnesium Chloride

6 Conclusions

The following conclusions can be drawn-

1. With the inclusion of $MgCl_2$ into the soil, the values for liquid limit of the samples were decreasing. It was decreased from 63.74% to 33.79% on adding of 0% to 8% $MgCl_2$ with untreated soil.
2. There is significant reduction in the plastic limit values from 26.74% to 19.51%. The maximum decrease in plastic limit was observed to be 27.04% at 8% $MgCl_2$.
3. The OMC value was decreased by 36.55% from 19.7% to 12.5% on addition of 8% magnesium chloride.
4. The MDD value was raised from 1.72g/cc to 2.07g/cc and MDD increased by 22.35% on adding 8% $MgCl_2$ when compared with the untreated BC Soil.
5. At 8% $MgCl_2$ the values were increased from 1.71% to 5.54% of the soaked CBR. As compared to untreated black cotton soil there was an increase of 223.98% in CBR value at 8% $MgCl_2$.
6. At the addition of 8% $MgCl_2$ the UCS value of BC soil was increased from 1.76% to 3.21%.
7. The swelling pressure values are also decreased by 90.95% and 87.67% respectively for 8% of $MgCl_2$ treatment.
8. The properties of the BC soil are enhanced at 8% $MgCl_2$.

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