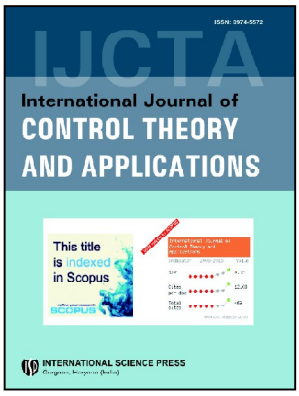

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Effect of a Chemical Contamination on Geotechnical Properties of Black Cotton Soil

P. Ramesh[1] and T. Srikanth[2]

[1] *Department of Civil Engineering, Sree Vidyanikethan Engineering College, A. Rangampet, Andhra Pradesh, India*
E-mail: rameshparlapalli65@gmail.com
[2] *Department of Civil Engineering, Sree Vidyanikethan Engineering College, A. Rangampet, Andhra Pradesh, India*
E-mail- tangudusrikanth513@gmail.com

Abstract: Contamination of the ground forms one of the major topics of environmental geotechnology. This contamination leading to the alteration of the characteristic properties of the ground in the vicinity of the industrial plants occurs mainly as the result of contamination by the industrial wastes disposed. The effect of sodium chloride on geotechnical properties of black cotton soil has been presented in this paper. The soil used falls under "CH" group as per IS classification and its Differential Free Swell Index is 50% indicating high degree of expansiveness. Chemically pure sodium chloride is used as the contaminant. The geotechnical properties considered are plasticity characteristics, swelling characteristics, compaction characteristics and strength characteristics. The concentrations of sodium chloride are varied from 2.5 to 20 per cent in increment of 2.5%. In order to compare the test results of contaminated soil, the uncontaminated soil is taken as the reference soil. The plasticity characteristics are reduced marginally when the soil is contaminated with sodium chloride. The pH value of the uncontaminated soil decreases with the contamination of the sodium chloride. Both the Differential Free Swell Index and Swelling pressure decrease with increase in concentration of sodium chloride. There is a slight reduction in optimum pore fluid content where as a slight increase in maximum dry unit weight of soil contaminated at different concentrations of sodium chloride when compared to uncontaminated soil. The California Bearing Ratio Values are reduced when the soil is contaminated with sodium chloride. The strength of contaminated soil samples tested immediately decrease with increase in concentration of sodium chloride. There is improvement in strength with curing. The strength of contaminated soil decreases when the pore fluid content passes from dry side of optimum to wet side of optimum irrespective of the per cent concentration of sodium chloride.

Keywords: Chemical contamination, Properties of Black Cotton Soil, Sodium Chloride, DFSI, Swell Pressure, California Baring Ratio Value and UCC.

I. INTRODUCTION

The modification of the physical, chemical and mechanical properties of the soil in the vicinity of industrial plants occurs mainly as a result of their pollution or contamination by the industrial effluents. The pollution of industrial effluent into sub soil directly or indirectly affects the soil properties and stability of the supported structure.

Sridharan *et al* [14] (1981) have reported the extensive damage to the floors, pavements and foundations of a light industrial building in a fertilizer plant in Kerala. Joshi *et al*[4] (1994) has reported the Severe damage occurred to the interconnecting pipe of a phosphoric acid storage tank in particular and also to the adjacent buildings due to differential movements between pump and acid tank foundations of fertilizer plant in Calgary, Canada. Kumapley and Ishola[8] (1985) have reported a similar case of accidental spillage of highly concentrated caustic soda solution as a result of spillage from cracked drains in an industrial establishment in Tema, Ghana caused considerable structural damage to a light industrial building in the factory, in addition to localized subsidence of the affected area. Yaji *et al*[16] (1996) has investigated the influence of contaminants like waste engine lubricating oil, coconut oil and caustic soda on the behaviour of Shedi soil. They found that these contaminants modify the geotechnical properties of shedi soil. Sivapullaiah *et al* (2000) [13] have reported the effect of sulphate on strength behavior of black cotton soil. Laredj *et al* (2008) [9] has reported the effect of chemical solutes concentration changes on deformation behavior of expansive soil. Ramesh *et al* (2008) [11] have reported the effect of sulphuric acid on the compaction and strength properties of black cotton soil. Grzegorz Jozefaciuk and Grzegorz Bowanko. (2002) [1] reported the effect of acid attack on the crystal structures of alumina silicate minerals.

Therefore, it is better to start ground monitoring from the beginning of a project instead of waiting for complete failure of the ground to support human activities and then start the remedial actions.

Black cotton Soils have high shrinkage and swelling characteristics. In general, these soils are very much sensitive to changes in environment. The environment includes the stress system, the chemistry of pore water in the system, the seasonal variations in ground water table and temperature variations.

In the present paper, an attempt is made in this investigation to study the effect of sodium chloride on geotechnical properties of a black cotton soil.

II. EXPERIMENTAL INVESTIGATIONS

In this investigation, an attempt has been made to study the effect of sodium chloride on geotechnical properties of a black cotton soil. The contamination has been done in the laboratory. Importance has been accorded to qualitative magnitude of impact of contamination rather than to study the mechanism due to which this happens in this presentation.

III. MATERIALS USED

3.1. Soil

Soil for the present investigation is collected from Auto Nagar area, Tirupati. The soil is of high swelling type with Differential Free Swell Index of 50%. Its swelling pressure under no-volume change condition is 338.2 kN/m^2. It is classified as 'CH' group as per IS classification[(1)] (1970). The properties of the soil are given in Table 1.

3.2. Sodium Chloride

Sodium chloride is a crystal form and white in colour. It is hygroscopic and deliquescent. It lowers the vapour pressure of water. It also reduces or prevents frost heave in soil by lowering the temperature of water. It checks the formation of shrinkage cracks. Sodium chloride is extensively used in many chemical industries and also metal treating, water softing etc,. The chemical composition of sodium chloride is NaCl.

3.3. Procedure for Contamination

The soil from the site is dried and the pebbles, organic matter if any are separated by manually. It is further the soil sample is allowed to dried and pulverized and sieved with 4.75 mm sieve size to removal of gravel fraction,

Table 1
Properties of the Soil

Sl. No.	*Properties of the soil*	*Details*
1.	Grain size distribution:	
	(a) Gravel	2%
	(b) Sand	6%
	(c) Silt + Clay	92%
2.	Atterberg limits:	
	(a) Liquid Limit	58%
	(b) Plastic Limit	27%
	(c) Plasticity Index	31%
3.	Differential Free Swell Index	50%
4.	Swelling pressure (under no volume condition)	338.2 kN/m2
5.	Specific gravity	2.72
6.	pH value 8.40	
7.	Compaction characteristics:	
	(a) Maximum dry unit weight	15.85 kN/m3
	(b) Optimum moisture content	20%
8.	California Baring Ratio value	13.03%
9.	Unconfined Compressive Strength at optimum moisture content	215.6 kN/m2

if any. This dried and prepared soil sample is kept in air-tight containers for further contamination. The prepared soil sample kept for contamination is mixed with sodium chloride solutions of varying concentrations, prepared are 0, 2.5, 5.0, 7.5, 10.0, 12.5, 15.0 and 20.0%.

IV. TESTS CONDUCTED

The experiments were conducted to determine the:

1) Liquid limit tests, 2) Plastic limit tests, 3) pH tests, 4) Differential Free Swell Index tests, 5) Swelling pressure tests, 6) Compaction tests, 7) California Bearing Ratio tests and 8) Strength tests.

The pH of the soil specimen was determined by the electrometric method as per IS: 2720 (part 26)-1987. Atterberg's limits of the soil specimen was determined as per IS: 2720 (part 5) – 1985, The Standard proctor compaction characteristics of the soil sample was determined as per the Indian Standard specification IS: 2720 (part 7)-1980. The unconfined compression test of the soil specimen was determined as per the Indian Standard specification IS 2720 (Part 10)-1991 (Reaffirmed 1995). The CBR value of the soil specimen was determined as per the Indian Standard specification IS 2720 (Part 16)-1987. All the reported results are the average results of three tests.

Two series of strength tests are conducted on black cotton soil contaminated with different concentrations of sodium chloride. In the first series the effect of curing is studied. The curing times considered are 0, 1, 3, 5, 7 and 15 days. In this series, all the tests are conducted at the optimum pore fluid content. In the second series the effect of pore fluid content is studied.

V. RESULTS AND DISCUSSION

The variation of liquid limit, plastic limit and plasticity index with per cent concentration of sodium chloride is shown in Fig.1. From the figure, it is observed that the liquid limit, plastic limit and plasticity index values of the

contaminated soil decrease with per cent increase in concentration of sodium chloride. The intervention of foreign electrolyte (sodium chloride dissolved in distilled water) would result in change in the ion exchange capacity, a reduction in liquid limit, plastic limit and plasticity index values is generally due to increase in electrolyte concentration of the pore fluid and consequent decrease in the thickness of double layer developed and also indicates an increase in the frictional resistance and decrease in cohesion in soil. The ion concentration reduces the repulsive forces and increases the effective stress leading to flocculation of clay particles. Flocculation reduces the plasticity.

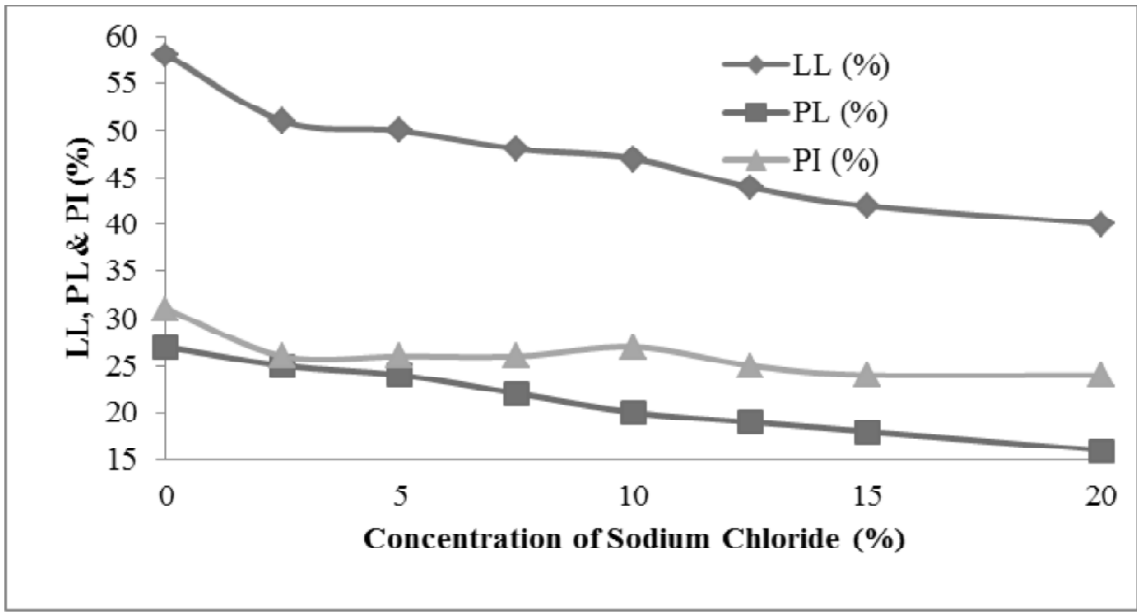

Figure 1: Variation of Liquid Limit, Plastic Limit and Plasticity Index with Concentration of Sodium Chloride

Fig. 2 depicts the variation of pH with per cent concentration of sodium chloride. The pH value of uncontaminated soil is 8.40, which decreases with increase in per cent concentration of sodium chloride. The

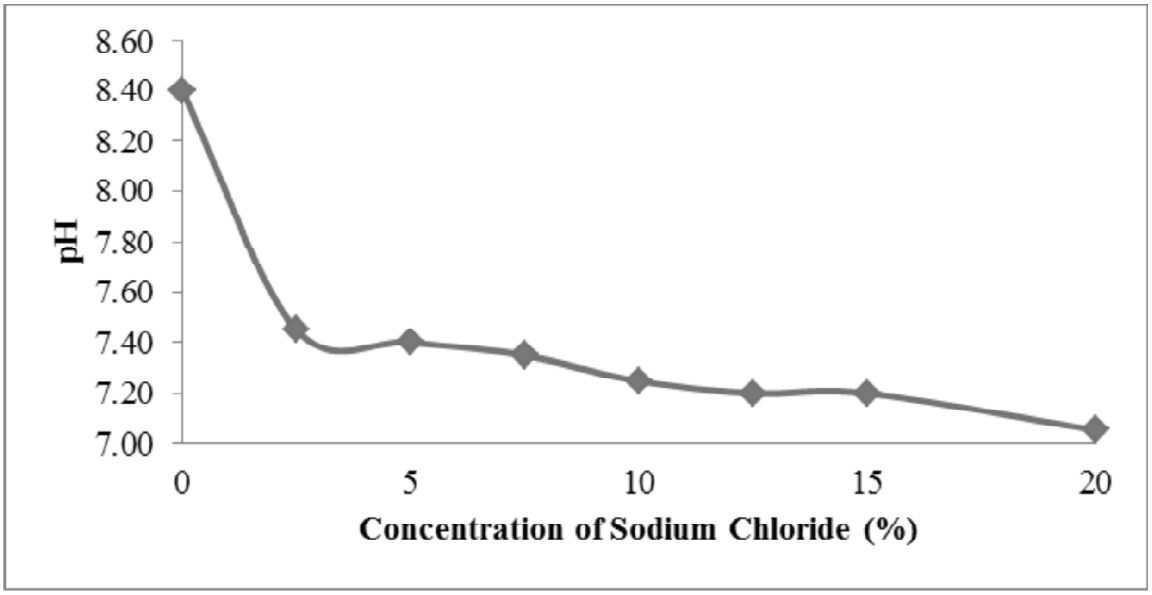

Figure 2: Variation of pH with Concentration of Sodium Chloride

reduction in the pH of soil may also be due to the leaching of cat-ions and the adsorption of H+ ions due to the ion exchange reaction [10]. The pH plays a very important role in the behaviour of clay suspensions. A low pH promotes a positive edge to negative surface attraction, often leading to flocculation from suspension. Stable suspensions or dispersions of clay particles often require high pH condition [3]. The stability of clay particles is affected by low pH because sodium chloride attacks clay particles at edges and releases Al ions [6]. There will be marked changes due to sodium chloride attack in the crystal structures of aluminosilicate minerals because of dissolution of structural ions and/or rearrangement of the structure [1].

Fig. 3 shows the variation of both Differential Free Swell Index and Swelling pressure with per cent concentration of sodium chloride. From the figure, it is found that both Differential Free Swell Index and Swelling pressure decrease with per cent increase in concentration of sodium chloride. These changes in swelling characteristics are due to alterations in crystal structure of expansive clay with addition of sodium chloride.

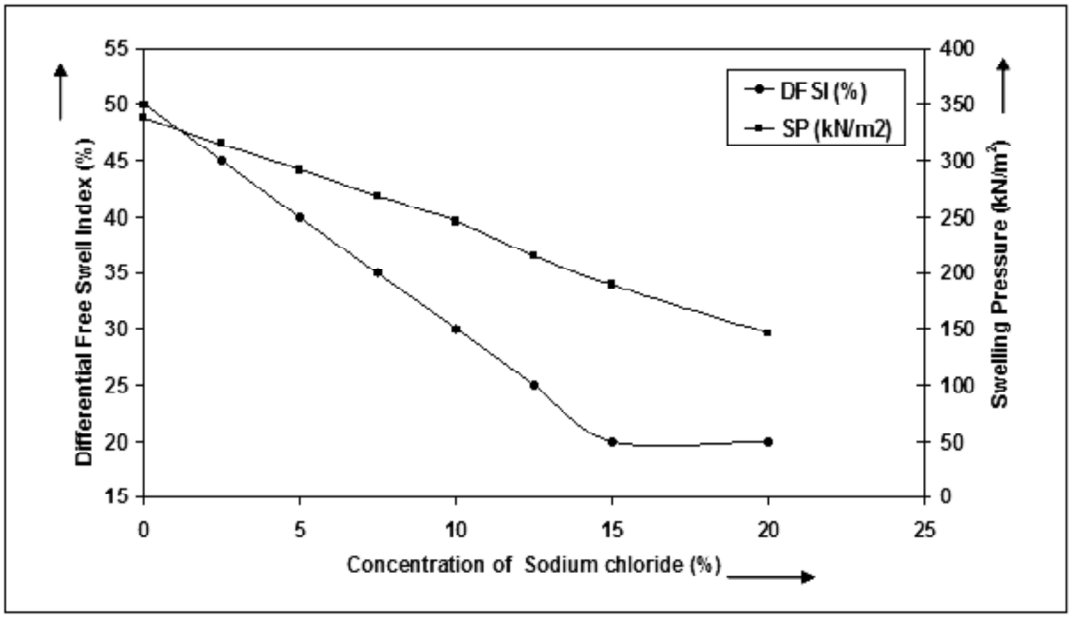

Figure 3: Variation of Both Differential Free Swell Index and Swelling Pressure with Concentration of Sodium Chloride

The variation of optimum pore fluid content and maximum dry unit weight is presented in Fig. 4. From the Figure, it is observed that there is a slight reduction in optimum pore fluid content with per cent increase in concentration of sodium chloride. It is also observed that the maximum dry unit weight increases slightly with increase in concentration of sodium chloride. The increase itself is almost identical to the quantity of the sodium chloride added. The reduction in optimum moisture content at higher concentration of sodium chloride (NaCl) indicates that the soil has got less affinity which leads to increase in the electrolyte concentration in pore fluid. And also the sodium chloride salt will fill up the voids and increasing the density of soil.

The variation of California Bearing Ratio value with per cent concentration of sodium chloride is plotted in Fig.5. From this figure, it is observed that the California Bearing Ratio value of the uncontaminated soil decreases with increase in percent concentration of sodium chloride.

The variation of Unconfined Compressive Strength of contaminated soil with different concentrations of sodium chloride for 0, 1, 3, 5, 7 and 15 days curing is shown in Fig.6. Sodium chloride acts as soil flocculent. It increases the electrical force of attraction between the adjacent particles without providing cementing effect. It is observed that the Unconfined Compressive Strength of soil samples tested immediately decrease with increase

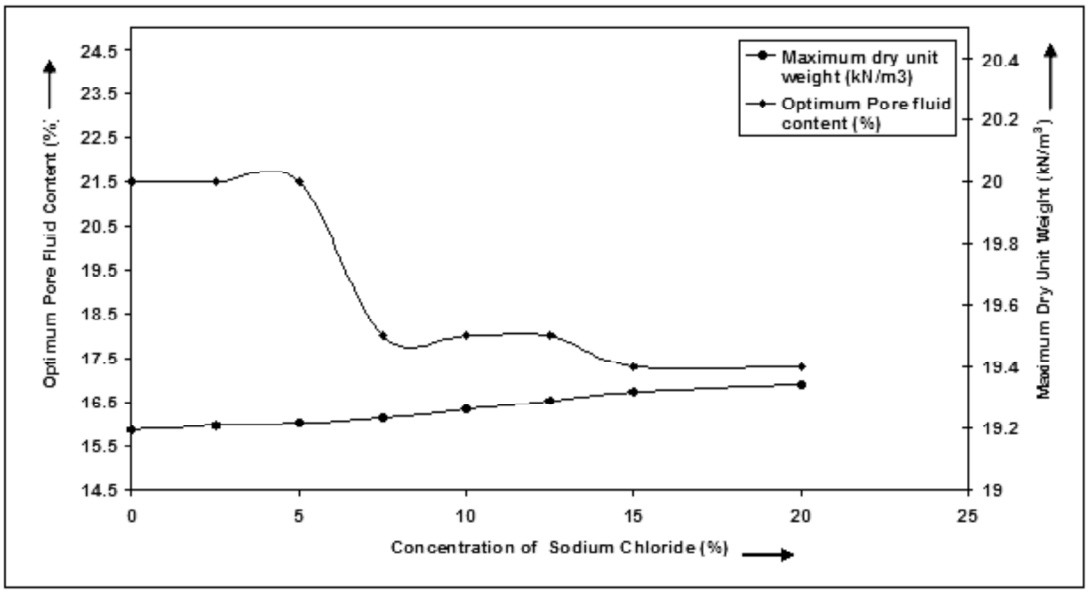

Figure 4: Variation of Optimum Pore Fluid Content and Maximum Dry Unit Weight with Concentration of Sodium Chloride

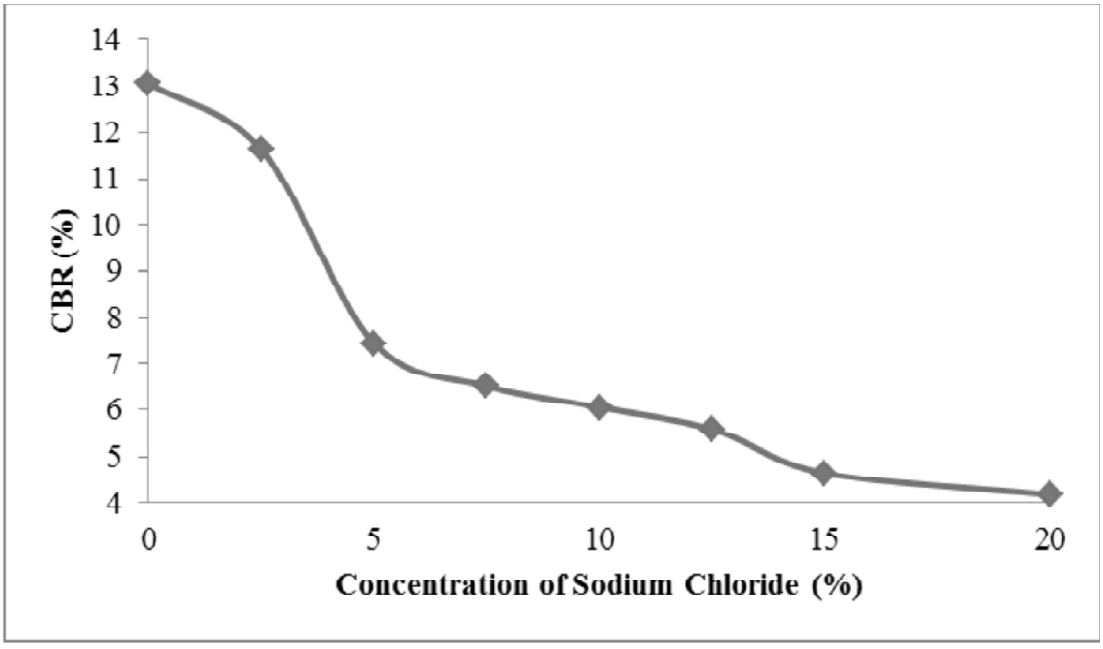

Figure 5: Variation of California Bearing Ratio with Concentration of Sodium Chloride

in per cent concentration of sodium chloride. Cementing action comes into play as time elapses. Hence, with curing there is improvement in the strength. It is also observed that the Unconfined Compressive Strength of contaminated soil at 2.5% concentration of sodium chloride for 15 days curing time is 1.6 times of the Unconfined Compressive Strength of the uncontaminated soil. The decrease in strength due to contamination is attributed to possible breakage of bonds internally. Thus strength of soil is reduced due to the effect of sodium chloride in the pore fluid.

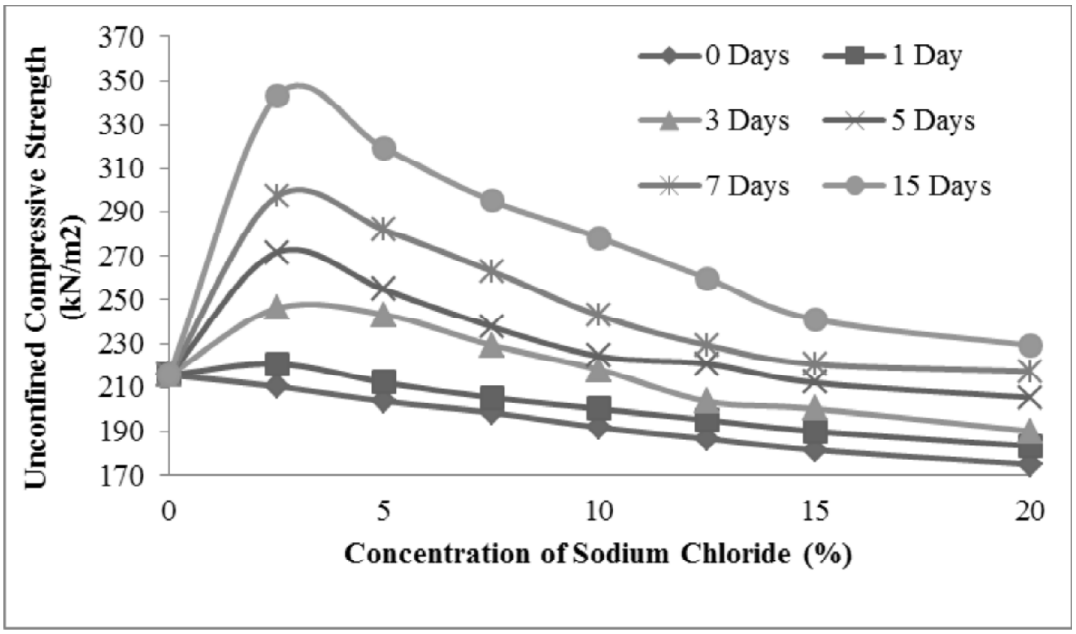

Figure 6: Variation of Unconfined Compressive Strength with Concentration of Sodium Chloride for Different Curring Periods

The variation of Unconfined Compressive Strength with different concentrations of sodium chloride with different pore fluid content ratios is shown in Fig. 7. The Pore fluid Content Ratio (PCR) is defined as the ratio of pore fluid content of the contaminated soil to the optimum pore fluid content of the contaminated soil. The strength of the contaminated soil decreases when the pore fluid content passes from dry side of optimum to wet side of optimum irrespective of the per cent concentration of sodium chloride.

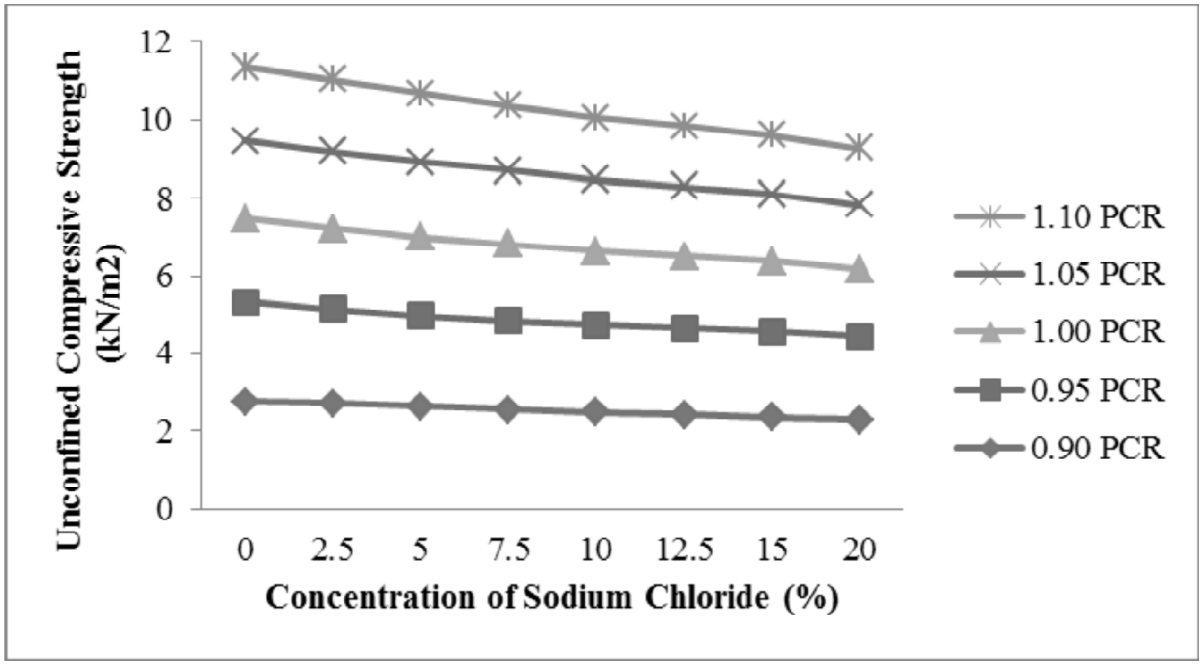

Figure 7: Variation of Unconfined Compressive Strength with Concentration of Sodium Chloridefor Different Pore Fluid Content Ratio

VI. CONCLUSION

The following conclusions have been drawn from this investigation.

- The plasticity characteristics are reduced marginally when the soil is contaminated with sodium chloride.
- The pH value of the uncontaminated soil decreases with the contamination of sodium chloride.
- The swelling characteristics decrease with increase in contamination of sodium chloride.
- There is a slight reduction in optimum pore fluid content where as a slight increase in maximum dry unit weight of soil contaminated at different concentrations of sodium chloride when compared to uncontaminated soil.
- The California Bearing Ratio values are reduced when the soil is contaminated with sodium chloride.
- The strength of contaminated soil samples tested immediately decrease with increase in concentration of sodium chloride.
- There is improvement in the strength with curing.
- The strength of contaminated soil decreases when pore fluid content passes from dry side of optimum to wet side of optimum irrespective of the per cent concentration of sodium chloride.

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