International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 04 | Apr 2020 www.irjet.net p-ISSN: 2395-0072

Study on the Effect of Salt Solution on Geotechnical Properties of Clayey Soil

Shanu Joseph[1], Nirmal John Joy[2]

[1]*PG Student, Geomechanics and Structures, Dept. of Civil Engineering, Saintgits College of Engineering, Kottayam, Kerala, India*
[2]*Assistant Professor, Dept. of Civil Engineering, Saintgits College of Engineering, Kottayam, Kerala, India*

Abstract – *Studies on soil- pollutant interactions are essential in the field of geoenvironmental engineering due to increase in soil contamination problems. Soil pollutant interaction changes soil behavior and also can lead to various geotechnical problems. In the present study effect of salt solution on geotechnical properties like consistency limit, compaction test, unconfined compressive strength and CBR were determined. Salt solution used is sodium chloride with different concentrations deionized water. Clayey soil belonging to CH classification was used for the study. Experimental results shows considerable changes in the properties.*

Key Words: **Clay, Salt solution, Consistency limit, Compaction, UCS, CBR**

1. INTRODUCTION

At present, as economy develops rapidly and industrialization pushes on world, soil pollution is getting more and more serious. Major sources which cause ground contamination can be of disposal of oil field brines, hazardous chemical waste, land fill leaching, sea water intrusion, surface impoundments etc. All type contamination have direct or indirect effect on various soil properties. Modification of soil properties can lead to several geotechnical engineering problems such as landslides, ground subsidence and settlement, structural instability of substructures, corrosion and durability of foundation problems.

Based on geotechnical researches pore properties of the fluid have a direct impact on behavior of clay like fabric and the bonding mechanism. In this investigation influence of these parameters by salt solution is determined. The term 'salinity' represents the soluble salts total concentration in the soil. Increase in salt content leads to salinization. Salinity in pore water influence on the behavior of clay particles as a result to the chemical interaction that may occur between the soil particles and the ions in the pore water. Salt mainly consists of positively charged cation and a negatively charged anion (ie, mainly Cl^- anion). The Cl^- anion shows little affinity in its adsorption to soil components. Thus, Cl^- movement within the soil is largely determined by water flows. The current study deals with the effect of adding salt solution like NaCl in various concentrations to study the variation in the properties of soil.

1.1 Scope

- Understand the soil response to salt contamination and find available methods to control them.
- Give attention to mineralogical changes caused due to the behavior of soil interacted with contaminants.

2. LITERATURE SURVEY

Recently a number of studies have been performed to look into the effect of the chemistry of pore water and its impacts on the geotechnical characteristics of soil. The salinity of the water has been shown to effects on the geotechnical properties of fine soils used in Korchay dam core had been studied Ajalloeian, et al.[10]. Several soil measurments as Atterberg limits, compaction, consolidation, direct shear and dispersion have been carried out by the use of waters of different salt concentrations like distilled, half saline and saline waters. The charges in the geotechnical properties of the soil were neglected. Results revealed the values of the Atterberg limits, compression index and swelling index decrease and consolidation coefficient and shear strength parameters increase as the amount of pore water salinity increases. When comparing those results with other tests carried out using water that has been desalinized, the effect of water salinity on consolidation under high pressures is not consideration. The sea water effects on consistency limits and compressibility properties of clayey soils of low and high plasticity were examined by Aksoy, et al. [12]. The results shows that sea water impacts were almost negligible on the tested consistency limits and compressibility characteristics of soils when they have liquid limits up to 110%. The sea water effect is mostly noticed on the consistency limits and compressibility of Na-bentonites. Influence of NaCl and $CaCl_2$ at various concentrations on compressibility of mixtures of basalt soil and bentonite was examined by Mazzieri et al. [2]. Along with this impact of distilled water and calcium chloride in a modified bentonite on hydraulic conductivity and effect of NaCl on hydraulic properties of Bentonite and Bentonite – palygorskite mixture were studied. It can be concluded that the compressibility of the soil mixture was reduced with increasing salt concentration of the pore fluid. In the case of hydraulic conductivity it is increased

from 1.16 x 10^{-11} m/s in distilled water to 7.06 x 10^{-11} m/s in 5 molar $CaCl_2$. The increase in hydraulic conductivity was also attributed to the invasion of pore space by Ca^{2+} cations. Finally the Na-bentonite palygorskite mixture serves as an effective absorber of both water and saline solutions up to a concentration of 10% (1.80 M) of NaCl without increasing the hydraulic conductivity. Again the influence of NaCl and $CaCl_2$ at various concentrations on permeability of mixtures of basalt soil and bentonite has studied by Misra et al. [1]. Experimental study concluded that comparison of hydraulic conductivity (k) for different salt solutions shows that the divalent cations have more effect than monovalent cation. Comparison of different salt concentrations for a particular salt on a particular soil mixture show that the k decreases with decreasing salt concentration. This decrease can be attributed to an increase in diffuse double layer thickness. A change in salt concentration from 0 (deionized water) to 0.01 mol/L did not produce any significant effect on the k for the basalt soil-bentonite mixture of proportion 100:20.

3. MATERIALS USED AND METHODS

3.1 Soil Sample

In this investigation, clay sample collected from Pandarakulam, Alappuzha district at a 1.5m depth was used. Figure 1 shows the clay sample.

Fig-1: Clay sample

Grain-size distribution tests were carried out according to the IS soil classification and soil classified in CH. The properties of clay are given in Table 1.

Table -1: Properties of clay

Sl No	Properties	Clay
1	Water Content %	63
2	Specific Gravity	2.4
3	% of Clay	69
4	% of Silt	23
5	% of Sand	8
6	Liquid Limit (LL) %	85
7	Plastic Limit (PL) %	47
8	Plasticity Index (I_p) %	38
9	Maximum Dry Density (g/cc)	1.3
10	Optimum Moisture Content (%)	37.8
11	Compressive Strength (kPa)	10.3

3.2 Salt Solution

Four different salt level solutions (2%, 4%. 6% and 8 % NaCl solutions) were used in this study and deionized water is indicated as 0% salt solution. Commercial NaCl crystals were used to prepare the different saline pore fluids. The pore fluid salinity depends on the mass of the NaCl in the solution i.e., 2% NaCl concentration represents 2 g of NaCl in 100 ml of deionized water. Salt solutions were prepared by adding NaCl to deionized water and it was thoroughly mixed to form a uniform solution.

3.3 Specimen Preparation

The sample used for the study was air dried, and sieved through 4.75 mm sieve to eliminate gravel fraction. This sample was stored in airtight containers. The soil sample kept was mixed with NaCl solutions of varying concentrations to find its effect on clay properties. The liquid limit, plastic limit and shrinkage limit tests were conducted as per IS: 2720, Part V, VI [5, 6]. The standard proctor compaction tests were conducted as per IS: 2720, Part VII [7] on clay. Unconfined compressive strength was determined as per IS 2720 Part X [8]. Test was conducted after 7 days curing period. Finally CBR at unsoaked condition was examined as per IS 2720 Part 16.

4. RESULTS AND DISCUSSIONS

4.1 Effect on Consistency Limits

Effect of salt solutions on the liquid limit, plastic limit and shrinkage limit was studied on CH clay using NaCl by varying percentages. The result obtained is presented in chart-1 respectively.

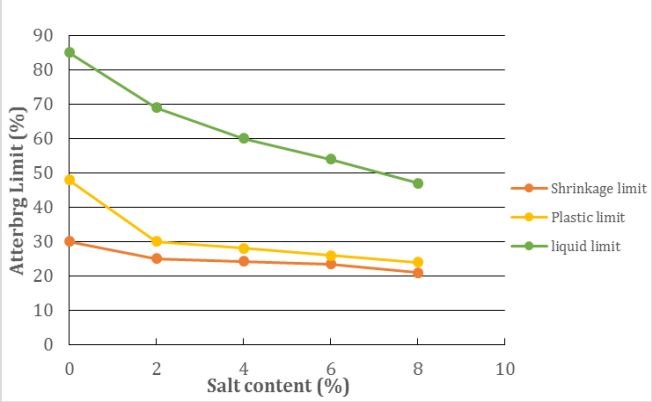

Chart -1: Variation of Consistency Limit with Salt Content

The results shows that the liquid limit of soil when mixed with deionized water is 85% and it goes on decreases with increase in salt content. Plastic limit shows the similar variation. ie, it drops progressively from 47% to 24.9%.Shrinkage limit also shows a decreasing trend. In case of plasticity index it is further decreased to 38%, 36.9%, 32%, 27.5%, 21.9% respectively when the water having increase in salt content. It is attributed to the fact that the thickness of the double diffused layer around the particle decreased with the increase in the salt content in water added to the clay. These observations were in agreement with the studies reported by Arasan and Yetimoglu [12] as in high plasticity clay the salt solutions tended to reduce the thickness of diffused double layer and flocculate the clay particles, resulting in reduction of consistency limit.

4.2 Variation of Compaction Characteristics with Salinity

Compaction tests were conducted on the clay and the variation of the dry density and the optimum moisture content with the salt solution is shown in chart-2. The study of chart reveals that the maximum dry density for the clay was 1.3g/cc which increased to 1.34, 1.38, 1.42 and 1.45g/cc, respectively with the addition of salt content of 2, 4, 6 and 8% in the water added to the clay.

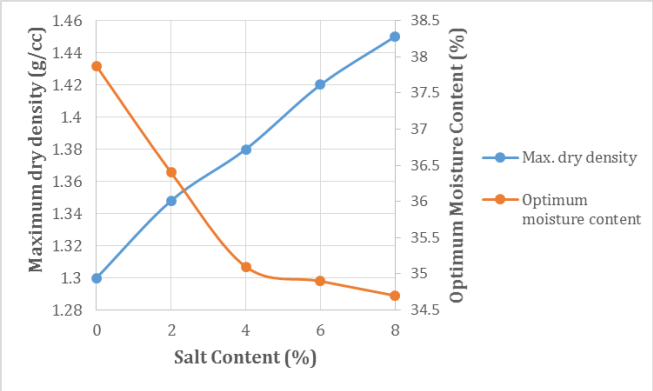

Chart -2: Variation of Dry Density and Optimum Moisture Content with Salt Content

Further study reveals that the optimum moisture content of the clay was 37.8% which decreased to 36.4%, 35.1%, 34.9% and 34.7% with the addition of water having salt content respectively. The decrease in the optimum moisture content with the increase in the salt content in water added to the clay was attributed to the fact that higher the face-to-face contact among clay particles in flocculation, the lower was the amount of water required for lubrication. These observations were in agreement with the earlier studies [3, 4, 10 and 14]. Also the decrease of the diffuse double layer's thickness is the source of this trend.

4.3 Effect of Salinity on Unconfined Compressive Strength of the Clay

Unconfined compression tests were conducted on the clay and its variation with the varying salt content in water added to the clay was shown in chart-3.

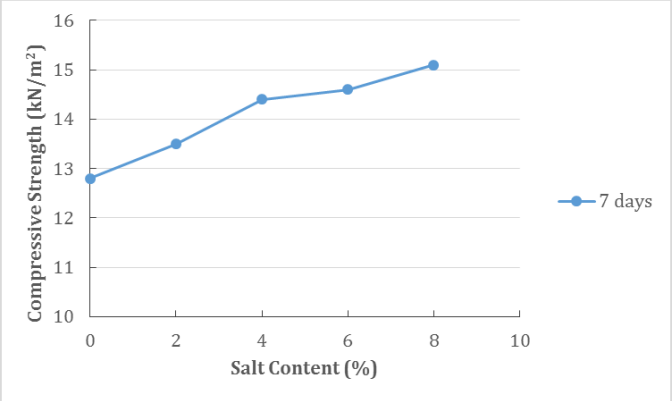

Chart -3: Variation of Unconfined Compressive Strength with Salt Content.

The studies shows that the unconfined compressive strength of the clay specimen compacted at optimum moisture content was 12.8 kN/m². At a curing period of 7 day, this unconfined compressive strength of clay mixed with water having salt content of 2% was increased to 13.5 kN/m². The unconfined compressive strength at the same curing period further increased to 14.4, 14.6, 15.1kN/m², respectively corresponding to 4, 6 and 8% of salt content in water added to the clay. The increase in unconfined compressive strength with the increase in salt content in water added to the clay was attributed to the increase in the dry unit weight. Similar observation was reported by Ismeik et al. [9] where fine grained soils were mixed with sea water having varying salinity and tested for unconfined compressive strength.

4.4 Effect of Salinity on California Bearing Ratio of Clayey Soil

Soil CBR is an important index to be determined for usage as the road base or sub-base material. This gives an indication of the soil strength and/or stiffness and bearing

capacity, under controlled density and moisture conditions. Effect of salt solutions on the CBR value of clay was studied using the NaCl solutions at different percentages i.e., 2%, 4%, 6% and 8% and the results are presented in chart- 4 below.

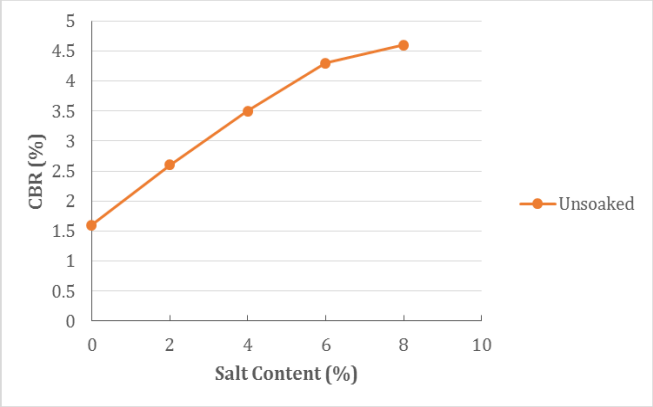

Chart -4: Variation of CBR with Salt Content.

The unsoaked CBR test results indicates that the value of CBR without salinity is 1.6%. When salinity increases the value raises to 2.6%, 3.5%, 4.3% and 4.6% respectively. At salinity of 6% and 8%, CBR value shows only a slight increment ie, 4.3% to 4.6%. The main reason of these changes has been attributed to an increase of attractive force between soil particles, establishment of bonding between them and formation of salt crystals in pores of soil and role of the cement.

5. CONCLUSIONS

An experimental study is carried out to investigate the effect of varying NaCl in water added to the clay on the index and engineering properties such as consistency limits, compaction, unconfined compressive strength and california bearing ratio of clay. The study brings forth the following conclusions.

1. There was a drastic decrease in the liquid limit, plastic limit, shrinkage limit and plasticity index and free swell index when salinity of 2% was added to the clay. These decrease was marginal beyond 2% salinity.

2. The maximum dry unit weight increased and the optimum moisture content decreased with the increase in the salinity of the clay.

3. The unconfined compressive strength of clay increased with the increase in NaCl solution. The increase in the unconfined compressive strength was marginal beyond a 2% NaCl solution added to the clay.

4. California bearing ratio also increases with increase in salinity of clay.

From the test results, it can be seen that the presence of salinity has significant influence upon the consistency limits, compaction, unconfined compressive strength and CBR of clay. Thus it is one of the factors which has an impact on clay behavior and needs to be studied.

REFERENCES

[1] A. K. Misra, M. Ohtsubo, Lorretta and H. Takahiro, “Effect of salt concentration on the permeability and compressibility of soil and bentonite mixture”, department of bioresource and environmental science, Kyushu university, fukuoka, July 26, 2005.

[2] F. Mazzieri, G. D. Emidio and P. O.Van, “Diffusion of calcium chloride in a modified bentonite: Impact on osmotic efficiency and hydraulic conductivity”, Clays and Clay Minerals, Vol. 58, No. 3, 2010, 351–363.

[3] G. Anandhanarayanan, V. Murugaiyan, “Effect of salt solutions and sea water on the geotechnical properties of soil – A review”, Int J Eng Res Technol. 2014; 3(3): 1819–1824p.

[4] I. H. Alainachi, G. A. Alobaidy, “The effects of Basra gulf salt water on the proctor compaction and CBR test results of soil samples at Baniyas City, Abu Dhabi, UAE” Electron J Geotech Eng. 2010; 15: 1–16p.

[5] IS: 2720, Part V, Determination of liquid and plastic limit. Indian Standard methods of test for soils, Bureau of Indian Standards. 1985, New Delhi, 1–16.

[6] IS: 2720, Part VI, Determination of shrinkage factors, Indian Standard methods of test for soils, Bureau of Indian Standards. 1972, New Delhi, 1–12.

[7] IS: 2720, Part VII, Laboratory determination of water content-dry density relation using light compaction. Indian Standard methods of test for soils, Bureau of Indian Standards. 1980, New Delhi, 1–9.

[8] IS: 2720, Part X, Determination of unconfined compressive strength. Indian Standard methods of test for soils. Bureau of Indian Standards. 1991, New Delhi, 1–4.

[9] M. Ismeik, A. M. Ashteyat, K. Z. Ramadan, “Stabilisation of fine-grained soils with saline water”, Eur J Environ Civil Eng. 2013; 17(1): 32–45p.

[10] M. R. Emami Azadi, “The effects of urmieh lake salt water on the proctor compaction and CBR test results of well graded gravel-sand mixed with clay (GSCW) soil samples”, Electron J Geotech Eng. 2008; 13.

[11] R. Ajalloeian, H. Mansouri and A.H. Sadeghpour,” Effect of saline water on geotechnical properties of fine-grained soil”, Electron J Geotech Eng. 2013, 18, 1419–1435p.

[12] S. Arasan and T. Yetimoglu, “Effect of inorganic salt solutions on the consistency limits of two clays”, Turkish Journal of Engineering and Enivironmental science, 2008, Vol.32, pp. 107-115.

[13] Y.Y.Aksoy, A.Kaya, A.H. Oren, "Seawater effect on consistency limits and compressibility characteristics of clays", Engineering Geology, 102, 2008 54–61.

[14] Z.M. Mansour, M.R. Taha, Z. Chik, "Fresh - brine water effect on the basic engineering properties of lisan marl-dead sea" Jordan. J Appl Sci. 2008; 8: 3603–3611p.