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A Study on the Effect of Salt Solutions on Certain Geotechnical Properties of Two Clays

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ABSTRACT

For assessing the suitability of foundation soil for engineering purpose and to initiate appropriate measures to make it fit for construction, studies on the soil-pollutant interactions are essential. Previous studies have reported that salt solutions can cause significant changes in the geotechnical properties of soil. Salts may occur in the soils through precipitation, irrigation, fertilization, leachate from landfills etc. Salinity causes costly damage to urban infrastructure every year. Thus in this study the effect of certain salt solutions on geotechnical properties of soil like liquid limit, plastic limit and free swell are determined. The salt solutions used are Sodium Chloride, Magnesium Chloride and Calcium Chloride. Two types of clayey soil belonging to CL and CH classifications were used for the study. The experimental results indicated considerable changes in the properties of soil.

Keywords: Kaolinite, Metakaolin, Salt Solutions, Liquid Limit, Plastic Limit, Free Swell.

I. INTRODUCTION

One of the major issues that world is facing today is soil contamination. Soil pollution can occur mainly from pesticides, insecticides, fertilizers, industrial waste etc. Behavior of any chemical or contaminant in the soil depends upon its properties and its interactivity with soil [6]. Results of some studies indicate that the detrimental effect of seepage of acids and bases into subsoil can cause severe foundation failures [6]. Likewise, the prevention of environmental risks due to individual activities is one of the most important subjects in the geo-environmental problems [4].

Many researches in Geotechnical engineering have found that the changes in pore fluid distribution generally exert a significant influence on the behaviour of clays. In the present investigation, an attempt has been made to determine these influences by using different salt solutions. The process of increasing the salt content is known as salinization. Salination can be caused by natural processes such as mineral weathering, gradual withdrawal of an ocean or by artificial processes such as irrigation.

In the soil solution, salts predominantly comprises of a positively charged cation (such as Na^+, Mg^{2+}, Ca^{2+}, K^+ etc) and a chloride anion (Cl^-). The Cl^- anion does not form complexes readily, and shows little affinity in its adsorption to soil components. Thus, Cl^- movement within the soil is largely determined by water flows. This study deals with the effect of adding different salt solutions like NaCl, $MgCl_2$ and $CaCl_2$, in various percentages to study the variation in the properties of soil.

II. MATERIALS AND METHODS

Clay soils are highly susceptible to environmental changes. Therefore they are selected for most of the studies. Two different samples of commercially available clay are used for the present study. The basic properties of the samples obtained through experimental investigations are presented in subsequent section.

A. Kaolinite

Kaolinite is a clay mineral with the chemical composition $Al_2Si_2O_5(OH)_4$. For the purpose of the study commercially available Kaolinite clay was

collected from English Indian clay limited, Trivandrum. The properties of Kaolinite are given in Table I.

TABLE I
PROPERTIES OF KAOLINITE

Soil property	Value
Specific Gravity	2.6
Liquid limit (%)	34
Plastic limit (%)	22
Shrinkage limit (%)	18
Plasticity Index (%)	12
IS Classification	CL
OMC (%)	30.25
Dry density (g/cc)	1.424
% Clay	65
% Silt	29
% Sand	6

B. Metakaolin

Metakaolin is a dehydroxylated form of the clay mineral kaolinite. The particle size of metakaolin is smaller than cement particles, but not as fine as silica fume. Metakaolin used for the present study was also obtained from English Indian Clays Limited, Trivandrum. The properties of metakaolin are presented in Table II.

TABLE III
PROPERTIES OF METAKAOLIN

Soil Property	Value
Specific Gravity	2.6
Liquid limit (%)	85
Plastic limit (%)	33
Shrinkage limit (%)	30
Plasticity Index (%)	52
IS Classification	CH
OMC (%)	64.8
Dry density (g/cc)	1.117
% Clay	65
% Silt	32
% Sand	3

C. Salt solutions

Three different salt solutions namely Sodium chloride (NaCl), Magnesium chloride ($MgCl_2$) and Calcium chloride ($CaCl_2$) are used for the present study. The different salt solutions were added at varying percentages (2%, 4%, 6% 8% and 10%) to the soil samples to study the variation in geotechnical properties.

D. Preparation of the specimen

The salts used were dissolved in water and then mixed with soil. After mixing the soil, the resulting thick homogenous paste, was cured for at least 24 hours at constant room temperature. The liquid limits of soil were determined using cone penetration method. The liquid limits and plastic limits of soils were determined as per IS 2720 (Part 5) – 1985 [5]. Free swell of the soil was determined as per ASTM D 5890-02 [3].

III. RESULTS AND DISCUSSION

A. Effect of salt solutions on the liquid limit of clays

Effect of salt solutions on the liquid limit was studied on CL and CH clays using NaCl, $MgCl_2$ and $CaCl_2$ by varying percentages. The results obtained are presented in Fig. 1, Fig. 2 and Fig. 3 respectively.

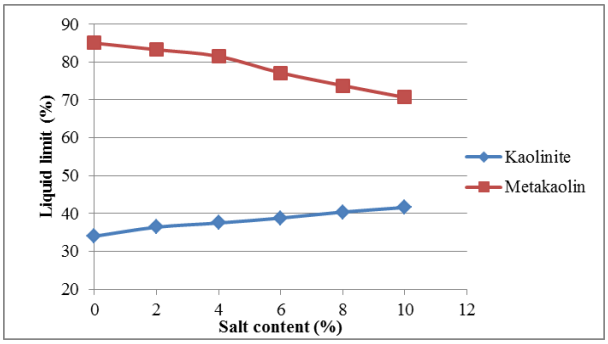

Fig. 1: Variation of Liquid limit with NaCl

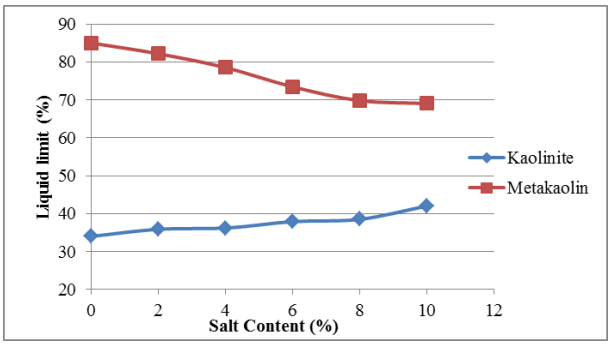

Fig. 2: Variation of Liquid limit with $MgCl_2$

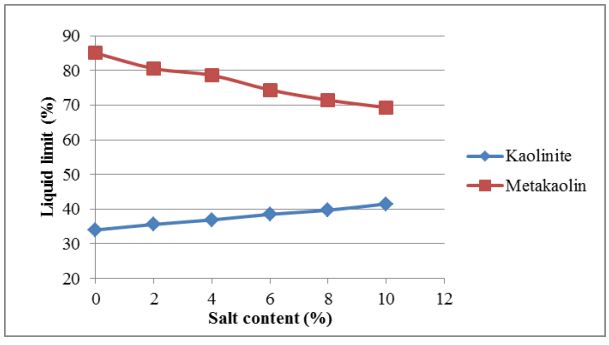

Fig. 3: Variation of Liquid limit with $CaCl_2$

The liquid limit increases with increasing salt content for low plasticity clay and decreases with increasing salt content for high plasticity clay. The salt solutions tended to increase the thickness of the Diffused double layer and disperse the clay particles, resulting in increased liquid limit of low plasticity clay. However the salt solutions tended to reduce the thickness of Diffused double layer and flocculate the clay particles, resulting in reduction of liquid limit of high plasticity clay [2].

B. Effect of salt solutions on the plastic limit of clays

Effect of salt solution on the plastic limit was studied on CL and CH clays using NaCl, $MgCl_2$ and $CaCl_2$ by varying percentages. The results obtained are presented in Fig. 4, Fig. 5 and Fig. 6 respectively.

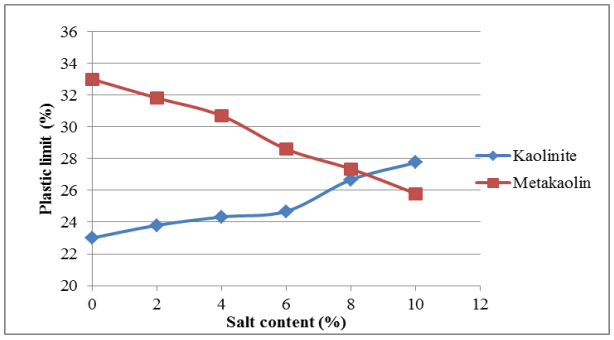

Fig. 4: Variation of Plastic limit with NaCl

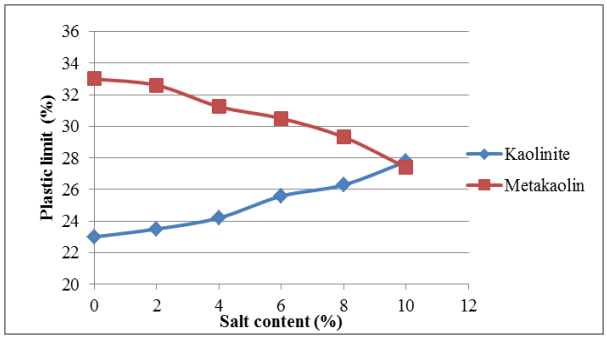

Fig. 5: Variation of Plastic limit with $MgCl_2$

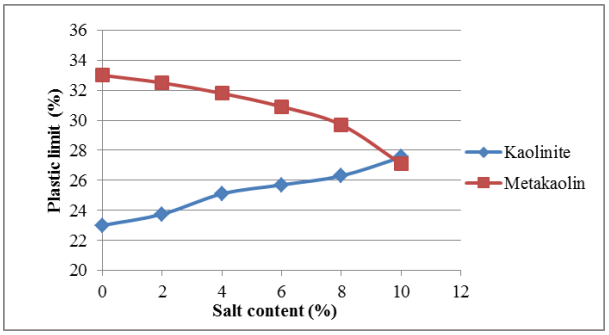

Fig. 6: Variation of Plastic limit with $CaCl_2$

The plastic limit increases with increasing salt content for low plasticity clay and it decreases with increasing salt content for high plasticity clay. The increased plastic limit of low plasticity clay could be due to the increase in thickness of the Diffused double layer and thereby the dispersion of the clay particles. Whereas 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 plastic limit [2].

C. Effect of salt solutions on the free swell of clays

Effect of salt solutions on the swelling characteristics of both the clays was studied using the salt solutions at different percentages i.e., 2%, 4%, 6%, 8% and 10% and the results are presented below. The test was conducted as per ASTM D 5890-02. Fig. 7, Fig. 8 and Fig. 9 show the variation in free swell index due to NaCl, $MgCl_2$ and $CaCl_2$ respectively.

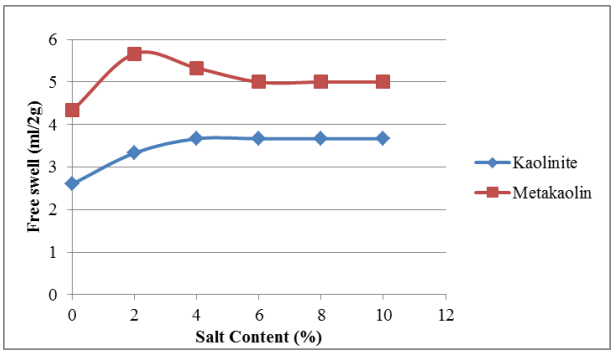

Fig. 7: Variation of Free swell index with NaCl

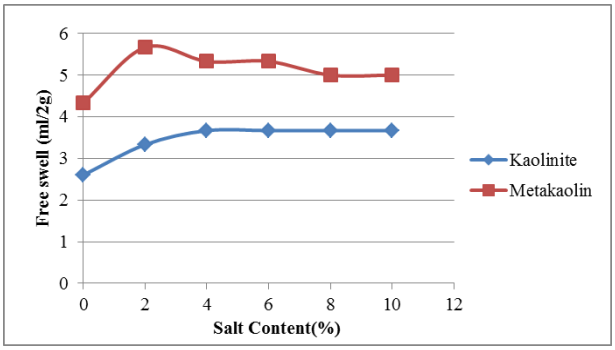

Fig. 8: Variation of Free swell index with $MgCl_2$

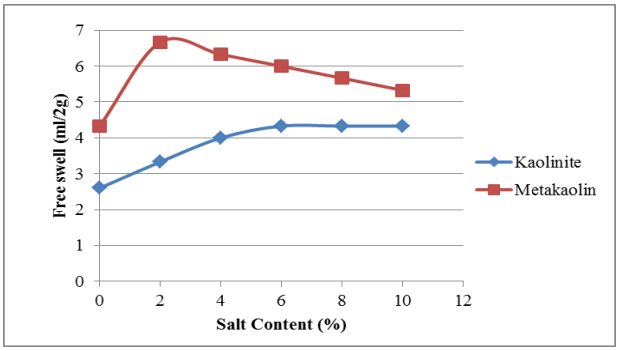

Fig. 9: Variation of Free swell index with $CaCl_2$

The results of the experiments indicated that increase in salt content increased the swell index of low plasticity clays. Whereas in high plasticity clays, the swell index initially increased at 2% of salt solution using all the three solutions but thereafter it decreased. The increase in the swelling index of low plasticity clays could be attributed to dispersion of clay particles and the decrease in the swelling index of high plasticity clays may be due to flocculation of clay particles when the respective clays were contaminated with salt solutions [1].

IV. CONCLUSION

A study was conducted to analyse the effect of three salt solutions (i.e. Sodium Chloride (NaCl), Magnesium Chloride ($MgCl_2$) and Calcium Chloride ($CaCl_2$). Liquid limit, plastic limit and free swell tests were conducted on two types of commercial clay namely kaolinite and metakaolin belonging to low plasticity (CL class) and high plasticity (CH clay) classifications. Tests were performed using both distilled water and the salt solutions at five varying concentrations between 2 and 10%.

The conclusions derived from the study are:

1. The liquid limit of low plasticity clay increased with increase in salt content. Whereas the liquid limit of high plasticity clay decreased with the increase in salt content.
2. The plastic limit of low plasticity clay increased with the increase in salt content. Whereas the plastic limit of high plasticity clay decreased with the increase in salt content.
3. The free swell index of low plasticity clay slightly increased with the increase in salt content, whereas the free swell index of high plasticity clay initially increased at about 2% of salt content and thereafter it decreased with the increase in salt content.

From the test results, it can be seen that the presence of salt has significant influence upon the liquid limit, plastic limit and free swell of clays. Thus it is one of the factors which has an impact on clay behaviour and needs to be studied in detail.

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