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Effect of Zinc Contamination on Some Geotechnical Properties of Clayey Soils

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Abstract:

A study was conducted to determine the effect of metal contamination on different clayey soils. The metal contaminant used was zinc. The variation of geotechnical properties of the clayey soils were studied by conducting liquid limit and plastic limit test using different molarities of contaminant. The variations at molarities 0.05M, 0.1M, 0.2M, 0.4M, 0.8M, 1M. Variations in liquid limit and plastic limits were observed with increase in concentration of contaminants.

Keywords **—contamination, bentonite, kaolinite, zinc**

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I. INTRODUCTION

Soil contamination due to heavy metals is a very serious problem today. Increased industrial activities and over use of pesticides and chemicals for agriculture are the main reasons for soil contamination by metals. Heavy metals are natural constituents of the earth crust. A number of these elements are biologically essential and are introduced into aquatic enrichments by various anthropogenic activities. The chemical composition of soil, particularly its metal content is environmentally important, because toxic metals concentration can reduce soil fertility, can increase input to food chain, which leads to accumulate toxic metals in food stuffs, and ultimately can endanger human health. These contaminants may bring in considerable changes in the geotechnical properties of soils. Lee et al., (2005) also investigated the effect of CaCl2 solutions with concentration of 5, 10, 20, 50, 100, 500 mM on the liquid limits of GCL's. Similar studies were carried out by van Paassen (2002) and Schmitz et al. (2004), they determined a reduction in liquid limits of bentonite and colclay (i.e., an industrial smectite clay) when NaCl, KCl and CaCl2 solutions at different concentrations were added. Therefore, it could be said that the salt solutions tended to reduce the thickness of the DDL and flocculate the CH clay particles, resulting in a reduction of liquid limit of CH clay. Shackelford et al. (2000) indicated that the thinnest double layer and the smallest swell were obtained with trivalent cations, while monovalent cations had little effect on the thickness of the double layer and the swelling.This paper investigates the effect of zinc contamination on the liquid limit and plastic limit in sodium bentonite and kaolinite at different molarities.

II. MATERIALS

A. Soil

Two types of soils were used in the study. The first one was high plastic clay (CH) i.e., sodium bentonite and the second one was low plastic clay (CL) i.e., Kaolinite. The image of the soil sample is given in fig 1 and fig 2 respectively. The index properties are also shown in table 1 and table 2 respectively.

Fig.1. Bentonite

Table 1
Properties of Bentonite

SOIL PROPERTIES	VALUES
Specific gravity	2.59
Liquid limit (%)	336
Plastic limit (%)	47
Shrinkage limit (%)	12.4
Plasticity index (%)	289
IS classification	CH
Percentage clay (%)	82
UCS (KPa)	45.9
OMC (%)	38
Dry density (KN/m^3)	12.65
Coefficient Of Permeability(m/s)	$3.2x10^{-10}$

Fig.2. Kaolinite

Table 2
Properties of kaolinite

SOIL PROPERTIES	VALUES
Specific gravity	2.6
Liquid limit (%)	34
Plastic limit (%)	23
Shrinkage limit (%)	14.1
IS classification	CL
UCS (KPa)	63
OMC (%)	20
Dry density (g/cc)	1.357
Percentage of clay (%)	66
Percentage of silt (%)	23
Percentage of sand (%)	11

B. Contaminant used

In the present study the metal contaminant used was zinc. For artificially contaminating the soil samples zinc acetate was used. Detail of the contaminant used is given in table 3.

Table 3
Details of contaminant used

Parameters	Constituent salt used	Chemical formula	Molecular weight (g/mol)
Zinc	Zinc Acetate	$Zn(CH_2COO)_2.H_2O$	219.49

C. Test procedure

In this study the soil was contaminated using zinc acetate. The soils was contaminated using different molarities of contaminants i.e., 0.05M, 0.1M, 0.2M, 0.4M, 0.8M, 1M. The liquid limit and plastic limit tests were carried out as per IS 2720 PART 5.

III. RESULTS AND DISCUSSIONS

A. Variation of liquid limit in bentonite and kaolinite due to zinc contamination.

Table 4
Variation of liquid limit in bentonite and kaolinite

Molarity(M)	Liquid limit (%)	
	Sodium bentonite	Kaolinite
0	336	34
0.05	310	33.5
0.1	260	33
0.2	236	33.2
0.4	184	32
0.8	160	30
1	156	28

The decrease in liquid limit with increase in concentration of Zinc in bentonite and kaolinite was due to the decrease in the negative charge. The reduction in the charge reduces the immobilized water; this is because water is attracted to the surface of the clay by electrical forces of various kinds including electrostatic attraction (Michaels, 1959). The thickness of the diffused double layer decreasesand the clays loses its water holding capacity leading to reduction in liquid limit (Shackelford et al., 2015).

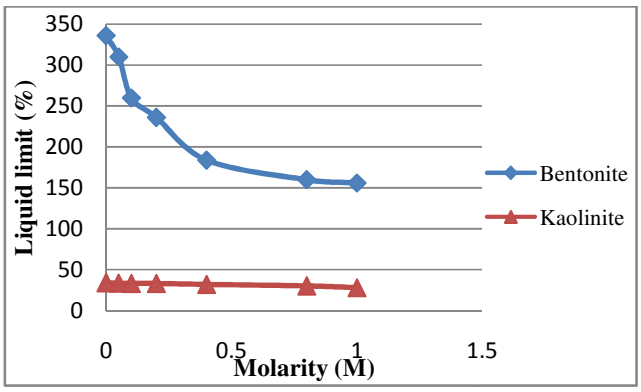

Fig.3. Variation of liquid limit in bentonite and kaolinite

B. Variation of plastic limit in bentonite and kaolinite due to zinc contamination.

Table 5
Variation of plastic limit in bentonite and kaolinite

Molarity(M)	Plastic limit (%)	
	Sodium bentonite	Kaolinite
0	47	23
0.1	37	22.6
0.1	34	21.8
0.2	34	20.6
0.4	34	19.3
0.8	33	18.9
1	32	18.3

A decrease in plastic limit in bentonite was observed with increase in concentration of zinc. This decrease was due to the decrease in the negative charge. The reduction in the charge reduces the immobilized water; this is because water is attracted to the surface of the clay by electrical forces of various kinds including electrostatic attraction (Michaels, 1959). The thickness of the diffused double layer thickness decreases (Shackelford et al., 2015) and the clays lose its water holding capacity leading to reduction in liquid limit. The plastic limit decreases in kaolinite with increase in concentration of zinc and this is due to reduction in thickness of diffused double layer (Shackelford et al., 2015)

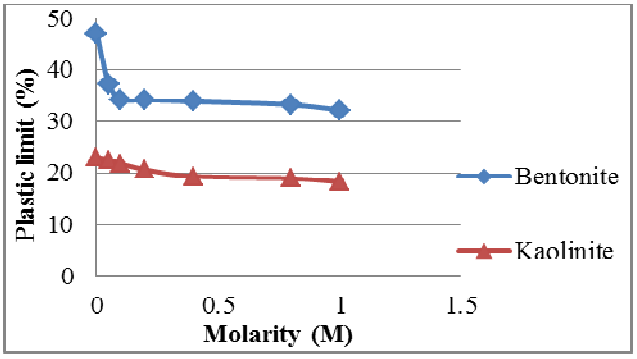

Fig.4. Variation of plastic limit in bentonite and kaolinite

IV. CONCLUSIONS

The study was conducted to investigate the variation of geotechnical properties like liquid limit and plastic limit in bentonite and kaolinite on zinc contamination. The conclusions made from the study include:

- In bentonite the liquid limit reduced to about 53% due to zinc contamination.
- Plastic limit increased to about 32% due to bentonite.
- Plastic limit increased to about 17% in bentonite due to zinc contamination.
- Plastic limit increased to about 20.4% due to zinc contamination in kaolinite.
- The reduction in negative charge and also the reduction in diffused double layer are the main reasons for the variation in the geotechnical properties in bentonite and kaolinite.

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