Effect of Lead and Iron Contamination on High Plasticity Clay

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***Abstract*— Large amount of hazardous chemicals, metals and several thousand tonnes of wastes are ultimately dumped on the land as municipal or industrial wastes and are responsible for pollution of soil and ground water. Among these, heavy metals constitute a major portion of industrial wastes. For the containment of these wastes or as landfill liners, locally available natural clays are commonly used or commercially available clays may be mixed with local soils to form amended soil liners. Therefore the geotechnical characteristics of clays are to be evaluated in laboratories by artificially contaminating the soil. The present work deals with an attempt to study the effect of lead and iron contamination on the liquid limit, plastic limit, free swell and strength properties of high plasticity clay. The experimental results indicated that the properties of clays were significantly affected by the lead contamination that may influences the clay liner performances.**

Keywords*— *Liquid limit, shear strength, heavy metal, contamination, clay

I. INTRODUCTION

One of the major challenges faced by developing countries like India is the efficient management of municipal solid waste and industrial wastes. Lack of inefficient treatment and dumping methods leads to leaching of heavy metals and leachates into the soil and causes severe soil and ground water contamination.

Considering the industrial wastes, heavy metals usually constitutes its major portion. Metals such as copper (Cu), zinc (Zn), nickel (Ni), lead (Pb) and chromium (Cr) are commonly found in storm water run-off and landfill leachate are considered toxic to human health (Yong, et al, 1993). The present work focus on lead contamination in clays. Where the lead can come from many sources including flaking paints, decades of leaded gasoline use, mining operations, smelter and industrial emissions, waste incineration, and application of pesticides. It is highly toxic for human and animals, hence recognizing and characterizing its behavior in soils are essential. EPA defines a soil lead hazard as 400ppm and 1200ppm in the residential and industrialized areas, respectively.

Therefore the waste containments or landfill liners should be designed so as to prevent leachate from migrating to the surrounding environment. Normally, low permeability compacted clays are used for this purpose. For this reason, the geotechnical characteristics of clays are to be evaluated in laboratories using distilled water as well as by artificially contaminating the soil. So that evidences regarding the effect of contamination on properties of clay barriers which could affect the long-term performance of these liners can be analyzed.

In the present study, effect of lead and iron contamination on high plasticity commercial clays was experimentally investigated. The work deals with an attempt to study the effect on the liquid limit, plastic limit, free swell and strength properties of clays.

II. MATERIALS AND METHODS

A. Clay

Metakaolin was purchased from English Indian Clay Limited, Trivandrum. The soil samples so collected were tested for index properties as per IS 2720: 1991. The results are presented in Table 1.

TABLE 1. PROPERTIES OF CLAY

Index Properties	**METAKAOLIN**
Liquid Limit (%)	85
Plastic Limit (%)	33
Plasticity index	52
	IS Classification :**CH**
Shrinkage Limit (%)	22
Specific Gravity	2.6
GSD clay (%)	62
silt (%)	36
sand (%)	2
OMC (%)	75.50
Maximum dry density (kN/m^3)	10.5
UCC (kN/m^2)	87.1
Shear strength (kN/m^2)	43.5
	Type : Medium soft soil

B. Heavy metal Solution

Inthis investigation, lead Acetate [(CH3COO)2Pb.3H2O] salt and Ferric chloride (FeCl3) salt of analytical reagent grade was used for preparing different concentrations of lead and iron solutions for artificially contaminating the soil.

1) Liquid limit and plastic limit test

The liquid limit and plastic limit were determined as per IS 2720 (Part V). Salt solutions for the tests were prepared in 0.01M, 0.1M, 0.2M and 0.3M concentrations by dissolving powdered salts in distilled water. Tests specimens were prepared by mixing an air-dried clay mass (passing the 425-μm)with each salt solution.

2) Free swell test

Free swell was determined as per ASTM D 5890-02 standard. To perform the tests, a 2g sample of dried and finely powdered bentonite is dispersed into a 100 ml graduated cylinder in 0.1g increments over a period of 30 minutes. The sample is then kept for a period of 24 hours and the swell volume is noted. The free swell is expressed in ml/2g of clay. Lead and iron solutions of different concentrations were used in free swell experiments.

3) Tests on Unconfined Compressive Strength

Unconfined compressive strength (UCS) tests as per IS specification, were carried out on contaminated and uncontaminated soil specimens. The water content was maintained at OMC.

III. RESULTS AND DISCUSSION

In the following sections, the effects of lead contamination at varying concentrations on the liquid limit and UCC strength of clays are presented.

A. Effect of heavy metal solutions on the liquid limit

1) Effect of lead solution

The variation in the liquid limit with the concentration of the lead solutions obtained from the tests is given in Fig 1.

TABLE 2: VARIATION OF LIQUID LIMIT

Concentration (M)	0	0.01	0.1	0.2	0.3
Liquid Limit (%)	85	98	96	84.1	79.5

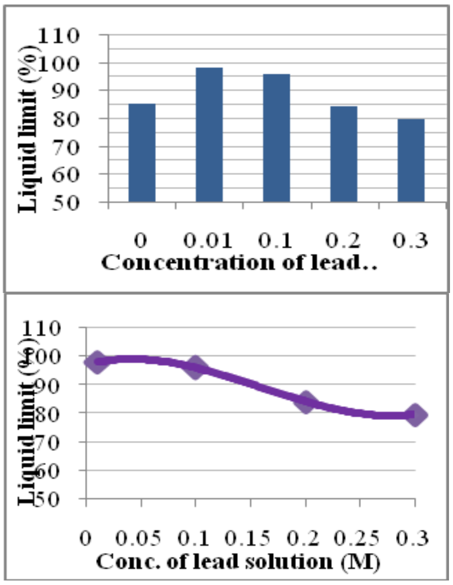

Fig.1. Liquid limit variation for different concentration of lead

Correlation connecting liquid limit and concentration of lead

$$LL = 3015C^3 - 1444C^2 + 103.1C + 97.11 \ (R^2 = 1)$$

The experimental results indicated that, for all concentration of lead solutions used in the tests, the liquid limit generally decreases when the concentration of solution added is increased.

2) Effect of iron solutions on the liquid limit

The variation in the liquid limit with the concentration of the iron solutions obtained from the tests is given in Fig 2.

TABLE 3: VARIATION OF LIQUID LIMIT

Concentration (M)	0	0.01	0.1	0.2	0.3
Liquid Limit (%)	85	83.8	76.2	78.6	79.6

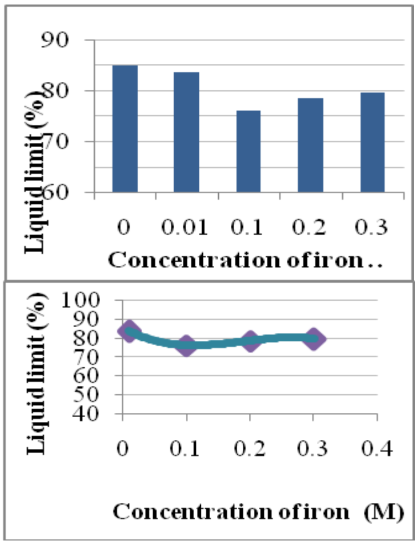

Fig.2. Variation in liquid limit with change in concentration of iron

Correlation connecting liquid limit and concentration of iron

$$LL = -2209C^3 - 1255C^2 + 198C + 85.65 \ (R^2 = 1)$$

Contamination results in decrease of liquid limit. Iron solutions at low concentrations causes more effect on CH soil.

Similar to the findings of the present study, several researchers have reported that chemical solutions at low concentrations are more effective than at high concentrations for CH clays (Gleason et al.,1997; Alawaji, 1999). Similarly, some researchers have also indicated that the liquid limit decreased with increasing salt concentration for CH clays (Gleason et al., 1997; Schmitz et al., 2004). This effect may be because of the tendency of salt solutions to reduce the thickness of the Diffuse Double Layer and flocculate the CH clay particles, resulting in a reduction in the liquid limit of CH clay for increased concentration.

B. Effect of heavy metal solutions on plastic limit

1) Effect of lead solution

The variation in the plastic limit with the concentration of the lead solutions obtained from the tests is given in Fig 3.

TABLE 4: VARIATION OF PLASTIC LIMIT

Concentration (M)	0	0.01	0.1	0.2	0.3
Plastic Limit (%)	33	39.7	55.2	50	46.7

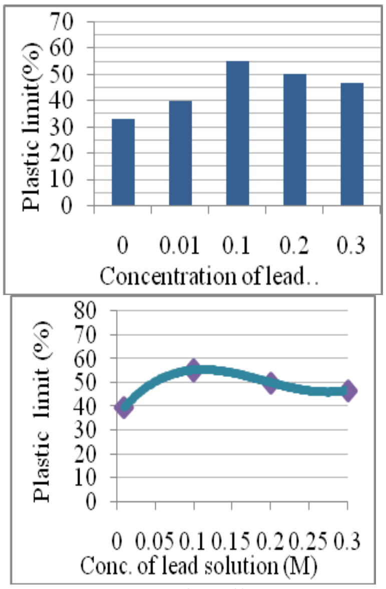

Fig.3. Plastic limit variation for different concentration of lead

Correlation connecting plastic limit and concentration of lead

$$PL= 4397C^3 - 2543^2 + 403.1C + 35.91\ (R^2 = 1)$$

Plastic limit increased with increase in lead concentration initially, but starts decreasing at 0.2 M conc.

2) Effect of iron solution

The variation in the plastic limit with the concentration of the iron solutions obtained from the tests is given in Fig 4.

TABLE 5: VARIATION OF PLASTIC LIMIT

Concentration (M)	0	0.01	0.1	0.2	0.3
Plastic Limit (%)	33	47.4	53.8	51.8	49

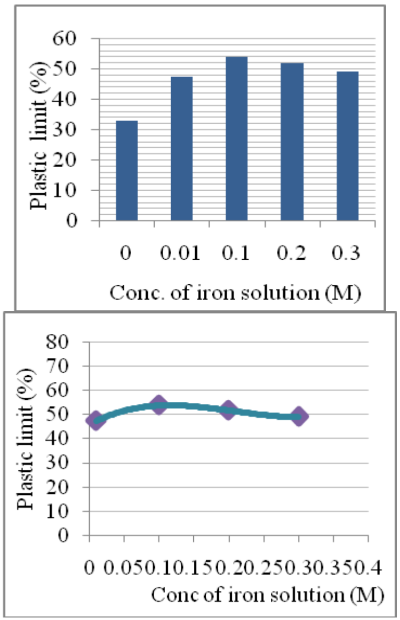

Fig.4. Plastic limit variation for different concentration of iron

Correlation connecting plastic limit and concentration of lead

$$PL= 1515C^3 - 949.3^2 + 158.7C + 35.91\ (R^2 = 1)$$

Plastic limit increased with increase in iron concentration initially, but starts decreasing at 0.2 M concentration.

C. Effect of heavy metal solution on Unconfined Compressive Strength

1) Effect of lead solution

The effect on UCC strength upon variation in concentration in lead solution on CH is summarized in Table.6

TABLE 6. VARIATION IN UCC FOR CH CLAY

Concentration (M)	0	0.01	0.1	0.2	0.3
UCC (kN/m²)	87.1	55.23	71.25	108.56	129.09

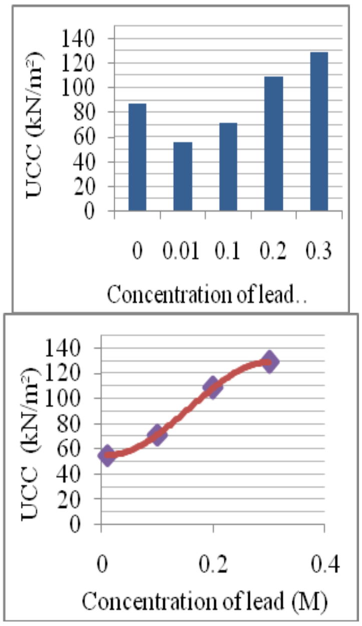

Fig.5. Variation in UCC for different concentration of lead

Correlation connecting UCC and concentration of lead

$$Qu= -6433C^3 + 3021C^2 - 82.93C + 55.76\ (R^2 = 1)$$

Lead contamination results in decrease of UCC strength but starts increasing at 0.2M. Lead solutions at low concentrations causes more effect on CH soil.

2) Effect of iron solution

The effect on UCC strength upon variation in concentration in iron solution on CH is summarized in Table.7

TABLE 7: VARIATION OF UCC

Concentration(M)	0	0.01	0.1	0.2	0.3
UCC (kN/m²)	87.1	93.55	113.26	62.51	44.97

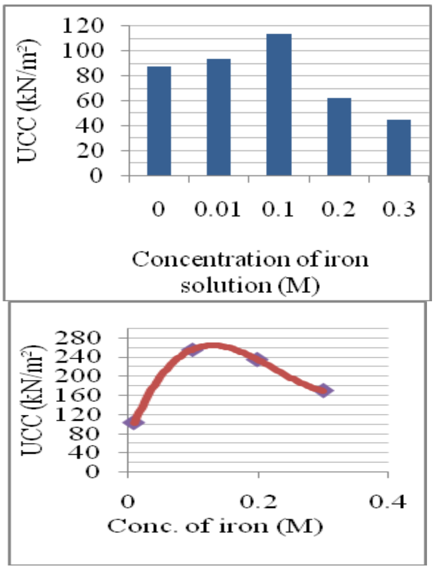

Fig.6. Variation in UCC for different concentration of iron solution

Correlation connecting UCC and concentration of lead

$$Qu= 27472C^3 - 18621C^2 + 3446C + 69.98\ (R^2 = 1)$$

Contrasts to the findings for lead, the UCC value increased with increasing iron concentration but starts decreasing at 0.2M concentration.

As per literatures the effect of lead on UCC for CH soils is that the salt solutions tends to reduce the thickness of the diffuse double layer and flocculate the CH soil particles resulting in a reduction of UCC value.

D. Effect of heavy metal solutions on free swell

The effect of free swell on variation in concentration of lead and iron solution on CH is summarized in Table.7

TABLE 8: VARIATION OF FREE SWELL

Concentration (M)		**0**	**0.01**	**0.1**	**0.2**	**0.3**
Free swell (mL/2g)	**Lead**	3	6	5	4	4.5
	Iron	3	5	6	5	4

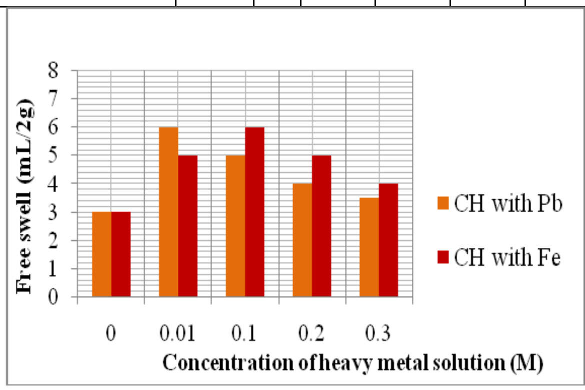

Fig.7. Free swell variation for different concentration of heavy metals

Free swell value is more for CH clays at low concentration. Effect of lead and iron on free swell is found to be almost same.

IV. CONCLUSION

The effect of lead and iron contamination on the liquid limit, plastic limit, shear strength and free swell properties of high plasticity clayey soil was studied. Tests were conducted for soils contaminated with different concentrations of lead and iron. From the results, it may be concluded that engineering properties of soils are getting affected by adsorption of lead and iron and most variations are found to be contrasting for lead and iron. The effect is due to variation occurring in the diffuse double layer or in the inter particle attraction and property also depends on the variation of the valency of the heavy metal that contaminate the soil.

From the study, since the geotechnical property variation is not much affecting due to lead contamination and shear strength is increasing at higher concentration, the CH soil is suitable for using as liner or containment of waste having high lead content.

In case of iron contamination also this CH soil is suitable as liner since it shows good strength and other properties upto 0.2M concentration. The soil shows problem in properties only at very high concentration. In field cases the concentration of iron is not found generally at this much very high concentrations.

Hence the clay studied in the work is suitable for containing lead and iron containing industrial wastes.

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