Effect of Iron on Some Geotechnical Properties of Clays

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Abstract – *Urbanization and industrial development has led to an increase in risk of environmental pollution. Heavy metal contamination is a very serious threat faced by the environment currently. Most of the heavy metals are toxic in nature but are required in trace amounts by humans, animals and plants. Iron is one such heavy metal which is essential but at the same time in excess can cause contamination. This paper studies the effect of iron on the liquid limit, plastic limit and hydraulic conductivities of two soils. The results show that iron tended to reduce the permeability of the soils. The liquid limit and plastic limit was found to increase for CL clay whereas for CH clay both the limits initially decreased and then showed an increasing trend.*

Key Words: **Contamination, heavy metal, iron, hydraulic conductivity, liquid limit, plastic limit**

1. INTRODUCTION

The accelerated development of industries and urbanization has led to an exponential increase in the generation of waste and pollutants. The lack of proper disposal facilities as well as the careless attitude of man has led to the release and accumulation of pollutants into the environment. These wastes may comprise of both hazardous and non-hazardous wastes. Out of the hazardous wastes, majority of it is constituted by heavy metals which mostly are toxic and carcinogenic in nature.

Iron is one among the oldest heavy metals existing on earth. It is a heavy metal which is essential for the environment as a hole. It is required by plants, animals and humans for their bodily metabolism and growth. A deficiency of iron can cause anaemia whereas excess iron can cause various health problems including gastrointestinal irritations and even cancer. Excess iron can also cause soil as well as underground water contamination. The presence of iron in soil can also result in the alteration of soil properties. Therefore, it is important that the effect of this heavy metal on soils be studied.

This paper deals with the study of how iron can alter the liquid limit, plastic limit and hydraulic conductivities of two soils; one of low plasticity (CL) and another of high plasticity (CH).

2. METHODOLOGY

2.1 Materials used

Two soils were used in this study. One was a high plastic clay (CH) acquired from a quarry in Coimbatore and the second was of low plasticity (CL) obtained from Thonnakkal, Trivandrum. The images of the soils used are shown in fig 1 and fig 2 and its index properties are given in table 1 and table 2.

In order to artificially contaminate these soils, anhydrous ferric chloride was used. It was greenish black in appearance with a molecular mass of 162.21 g/mol. The contaminant is shown in fig 3.

Table -1: Properties of CH soil

Properties	Values
Specific gravity	2.24
pH	8.8
Permeability (cm/sec)	4.704×10^{-7}
Liquid limit (%)	127
Plastic limit (%)	41.66
Plasticity index (%)	85.34
IS classification	CH
Optimum moisture content (%)	18.3
Dry density (g/cc)	1.31
% clay	60
% silt	40
UCC strength (kN/m^2)	50.717

Table -2: Properties of CL soil

Properties	Values
Specific gravity	2.64
pH	6.5
Permeability (cm/sec)	5.88×10^{-7}
Liquid limit (%)	33.5
Plastic limit (%)	21.8
Plasticity index (%)	11.7
IS classification	CL
Optimum moisture content (%)	23

Dry density (g/cc)	1.591
% clay	59.2
% silt	29.1
% sand	11.7
UCC strength (kN/m²)	63.274

Fig -1: CH soil

Fig -2: CL soil

Fig -3: Anhydrous ferric chloride

2.2 Test procedure

The soils were contaminated with various molarities of ferric chloride solutions; 0.05M, 0.1M, 0.2M, 0.3M, 0.4M and 0.5M. The liquid limit and plastic limit tests were carried out as per the procedure specified in IS 2720 PART 5. The hydraulic conductivity test was performed according to IS 2720 PART 17.

2.3 Results and Discussions

Table 3 shows the results of the liquid limit test upon the addition of ferric chloride and chart 1 represents the variation.

Table -3: Liquid limit variation

MOLARITY	CH	CL
0	127	33.5
0.05	64.6	36
0.1	57.6	37.5
0.2	56.2	41.5
0.3	75.4	42.12
0.4	76.8	44.8
0.5	79.6	47.25

Liquid limit generally increases for CL clay with increase in concentration of ferric chloride. This is in accordance with the findings of Arasan and Yetimoglu (2007). The increase in liquid limit is due to dispersion of the clay particles when permeated with ferric chloride solution. Also, the salt solution must have caused the formation of new swelling compounds which may have increased the liquid limit.

The liquid limit for CH clay decreased up to 0.2M, and then increased with increase in concentration of solution. The solution tended to decrease the double layer thickness and flocculate the clay particle, thus reducing the liquid limit.

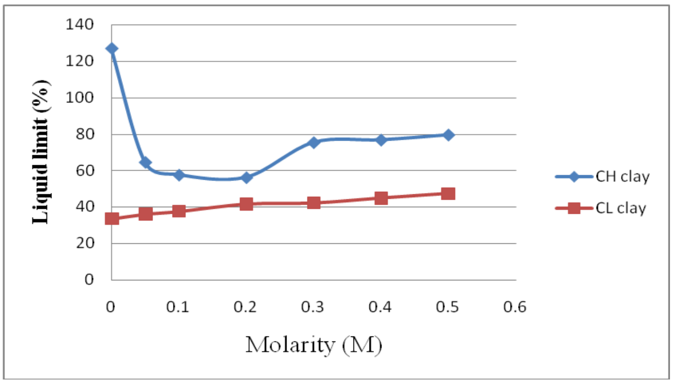

Chart -1: Liquid limit variation of both soils

Table 4 shows the plastic limit variaton of the soils after being contaminated with ferric chloride. The representation of the above results is given by chart 2.

Table -4: Plastic limit variation

MOLARITY	CH	CL
0	41.66	21.8
0.05	37.84	23.5
0.1	36.6	24.35

0.2	31.97	32.8
0.3	27.127	36.26
0.4	28.22	37.5
0.5	30.722	40.437

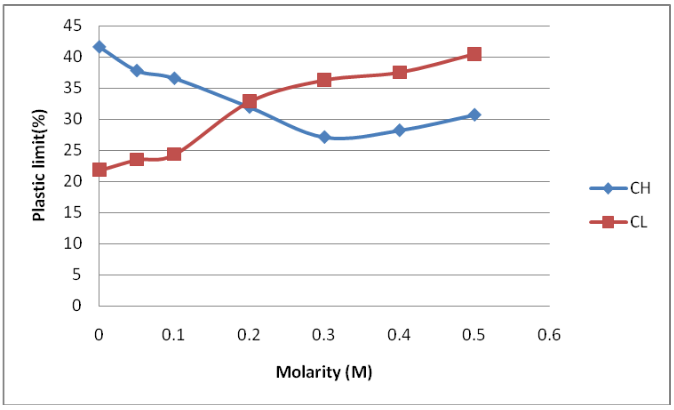

Chart -2: Plastic limit variation of both soils

The plastic limit increases with increase in concentration of ferric chloride solution, which is in agreement with the findings of Arasan and Yetimoglu (2007). The increase can be as a result of dispersion of clay particle and formation of new swelling compounds when the solution is added to it.

For CH clay, the plastic limit decreased initially and then increased with increase in concentration of solution. The reason for this trend can be explained by the flocculation of clay particles due to reduction in double layer thickness.

Table 5 shows the variation in hydraulic conductivity with the addition of the contaminant.

Table -5: Variation in hydraulic conductivity

MOLARITY	CH ($x10^{-8}$ cm/sec)	CL ($x10^{-8}$ cm/sec)
0	47.04	58.8
0.05	0.6439	0.276
0.1	0.865	0.801
0.2	1.799	1.56
0.3	1.196	2.21
0.4	1.2	2.385
0.5	1.241	2.46

The permeability of soil decreased by two orders, i.e., from 10^{-7} to 10^{-9}, when iron was added. But with increasing concentration of ferric chloride, a slight increase in permeability is observed. The increase in hydraulic conductivity when the concentration of the salt solution was increased can be attributed to the decrease in the thickness of DDL, resulting in flocculation of the clay particles and consequently high void ratio. This is in agreement with the study conducted by Arasan (2010).

3. CONCLUSIONS

Iron is a heavy metal which is very essential for humans, plants and animals. But in excess, it can cause soil as well as water contamination. When it comes to the case of soils, it can also lead to the alteration of soil properties. The variation in liquid limit, plastic limit and hydraulic conductivity was studied and the conclusions drawn are:

- ✓ An increase in liquid limit of 41% was observed for CL clay and a decrease by 50% for CH clay.
- ✓ The plastic limit decreased by 35% for CH clay and increased by almost 85% for CL clay.
- ✓ Permeability decreased by two orders, i.e., from 10^{-7} to 10^{-9} cm/sec on the addition of the contaminant, then as the concentration of contaminant increased, a slight increase in permeability was observed, but still lower than that of virgin soil.

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