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CONTAMINATION OF SOIL BY TANNERY WASTE EFFLUENT

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ABSTRACT

Most of the industrial effluents are disposed into land contains a variety of combination of chemicals that may bring in considerable changes in the geotechnical properties of soils. The tannery effluent is one such effluent characterized by high BOD and COD, high dissolved solids, high or low pH, presence of heavy metals, calcium salts, chlorides, sulfides, fat, liquor and organic dyes. This paper presents the laboratory results to study the effect of tannery effluent on the index and engineering properties of cohesive soil upon contamination. A series of laboratory tests have been carried out to evaluate the index and engineering properties of tannery contaminated clay soils. The virgin characteristic of clay soils is highly swelling clay of CH classification with differential free swell of 66 %. Virgin clay soils have artificially contaminated with varying percentage of tannery effluent collected from Pallavaram in Chennai and tested to evaluate various properties of soils. The results had shown an increase in Atterberg's limits as well as the shear strength with varying percentage of tannery effluent. The nature of the pore fluid has also found to significantly affect the index properties and shear strength.

Keywords: tannery effluent, clayey soil, swelling, shrinkage and shear strength.

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1. INTRODUCTION

India is a leading producer of leather in the world. There are numerous tannery industries located in India. These industries are releasing tons of waste including toxic contents and heavy metals into the adjacent land and water sources. Already, thousands of hectares of land and many valuable water resources have been contaminated with tannery effluent. The soil properties get modified when they mix with these effluents, especially in the case of clay (Rao and Chittaranjan 2012b). The modification in soil properties may lead to changes in the engineering behavior of the soil. The contamination of soil has a potential to affect the high swelling clay (CH). The effects of tannery on clay soil and its changes in liquid limit, plastic limit, plasticity index, shrinkage limit, differential free swell and shear strength were studied.

Experimental studies carried out by earlier researchers had shown that the free swell index, liquid limit and plastic limit values of clay soil reduces upon contamination with tannery effluent whereas the UCC strength reduces upon contamination (Rao et al., 2012a and 2012c; Muthukkumaran, 2010). However, the effect of tannery effluent on soil is different and engineering behavior of soils are to be varied depending upon the chemical composition of the stability of the structure resting upon it. Also, the stability of slopes, foundations and piles has a tendency to get affected when the soil surrounding them gets contaminated

2. MATERIALS USED

Natural clay soil, collected from Velacherry, Chennai, was used for the study. The clay was black in color and quite stiff. It was then dried, crushed and sieved in IS sieves and then its properties were determined as given in Table 1.

Property	Value
Grain size distribution	
Gravel (%)	3
Sand (%)	10
Silt (%)	17
Clay (%)	70
Atterberg's limit	
Liquid Limit (%)	73
Plastic Limit (%)	26
Plasticity Index (%)	46
Shrinkage limit (%)	14
UnUnconfined compressive strength (k((kN /m^2) at 23% water content.	196

Table 1 Properties of the virgin clay soil

The tannery effluent used in the study was collected from Pallavaram. It was black in colour with high viscosity and was generated during the finishing and dyeing process of leather. The properties of the effluent are given in Table 2.

Table 2 Properties of the tannery effluent

Parameter	Value
Colour	Blue
Form	Liquid
pH	3.1
Hexavalant chromium as Cr^{6+}	Below detectable level
Chroumium as Cr	9985 mg/litre
Sulphates as So4	112752 mg/litre
Chlorides as Cl	112484 mg/litre
Sodium as Na	116728 mg/litre
Calcium as Ca	5561 mg/litre
Total Dissolved Solids	59810 mg/ litre

3. METHODOLOGY

The various laboratory tests conducted were framed in two series. In the first series of tests, soil was mixed with effluent directly in place of water and mixed soil was not allowed to dry. This was achieved by storing the effluent mixed soil in air tight plastic bags. Then, various laboratory tests were performed on the prepared soil samples immediately after mixing as well as giving some time period of contamination after mixing of 7 days, 14 days and 28 days. It was assumed to simulate the condition that only tannery effluent alone presence within the voids of soils. In the second series of tests, soils were mixed with the effluent and then, allowed to dry in the open atmosphere after mixing for various contamination periods of 7 days, 14 days and 28 days as followed in the previous case. At the time of testing, the contaminated soil was crushed, sieved and then added with water for various tests. The various laboratory tests were performed on contaminated clay soils with varying consistency. In this type of soil mixing, the pore fluid was only the presence of water alone.

The liquid limit of the clay soil was determined by incrementally adding tannery effluent to the soil at various percentages. In this case, the pore fluid was effluent as it was tested immediately after mixing. It can be seen from Fig.1 that the liquid limit values are increased from 73% to 84% with increase in tannery effluent.

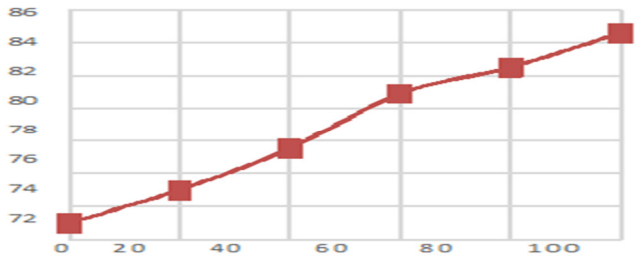

Figure 1 Liquid limit of soil with varying percentage of tannery effluent

4. RESULTS AND DISCUSSION

4.1. Effect on liquid limit

In order to understand the effect of contamination period on the clay soil, samples were prepared by mixing clay soils with the effluent and stored in an air tight bag for a period of 7,

14 and 28 days. Then, liquid limit tests were conducted at the end of each contamination period. It was observed that the period of contamination not showing any effect on the liquid limit of clay sample. The liquid limit, at the end of 28 days of contamination period is the same as that when tested immediately after mixing as shown in Fig. 2.

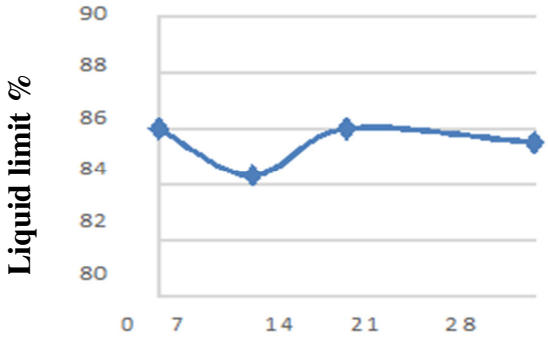

Figure 2 Liquid limit of soil with contamination period

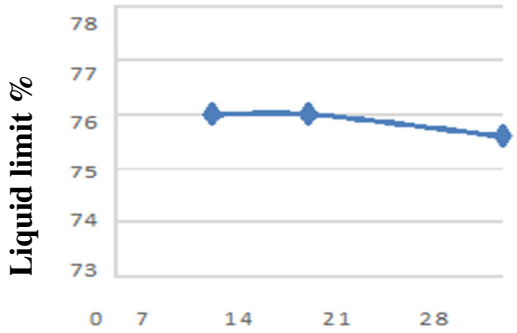

Figure 3 Liquid limit of dried contaminated clay with water as pore fluid

The liquid limits of the soils were also determined by testing the specimens after drying the contaminated effluent. In this case, soil samples were contaminated, but the pore fluid as water in place of effluent. It was observed that a slight increase in liquid limit from 73% to 76 % with contamination period but not showing any influence with respect to the contamination period. It can be seen from Fig. 3 that the effect of contamination period upon the liquid limit is almost nil.

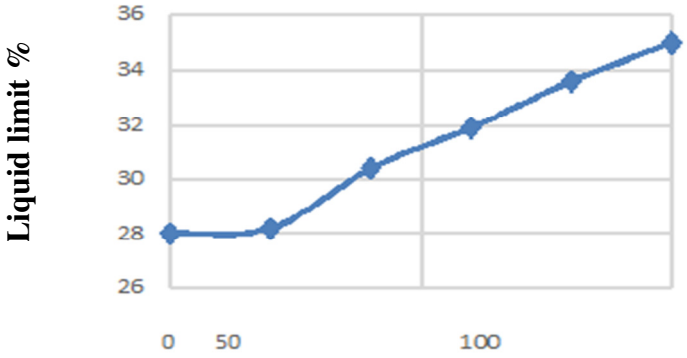

Figure 4 Plastic limit of soil with varying percentage of tannery effluent

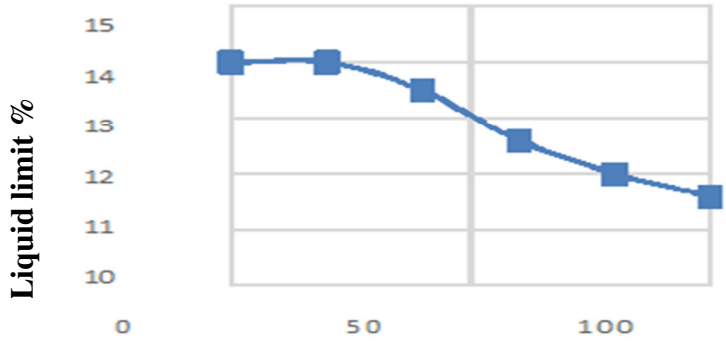

Figure 5 Shrinkage limit of soil with varying percentage of tannery effluent

4.2. Effect on Plastic and Shrinkage Limit

Similar trends were observed for plastic limit and shrinkage limit. The magnitude of change in plastic and shrinkage limit of contaminated clay soil was more with an increase in percentage of contamination. But the time period of contamination not showing any change as compared to the immediate response. However, the plastic limit increased from 28 % to 35 % as seen from Fig. 4 whereas the shrinkage limit decreased from 14 % to 11.5 % as observed from Fig. 5 when the pore fluid was effluent. When the contaminated sample was dried and mixed with water, the plastic limit was 33 % while there was no change in the shrinkage limit as it remained in 14%.

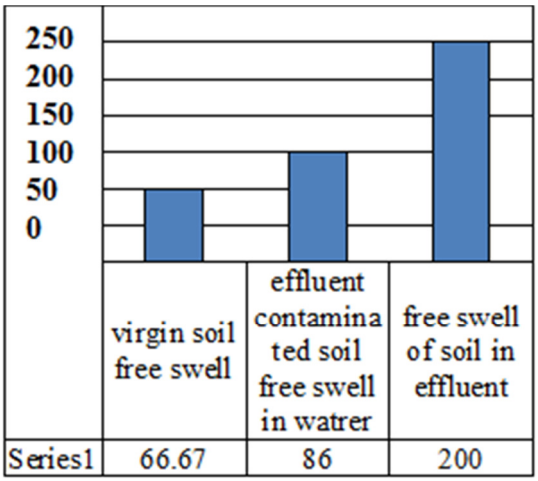

Fig. 6 Differential free swell of contaminated soil in water and in effluent

4.3 Effect on Differential free swells

Differential free swell tests were carried out on the contaminated clay sample after dried. The differential free swell values of contaminated soil were increased from 66 % to 86 % with contamination. In order to understand the swelling nature of clay, free swell tests were carried out on the contaminated clay with pore fluid inside as an effluent.

It can be seen from Fig. 6 that the free swell of contaminated soil with pore fluid as effluent shown a higher increase in free swell up to about 200 %. It indicates the effect of tannery effluent is very severe on the swelling characteristics of clay.

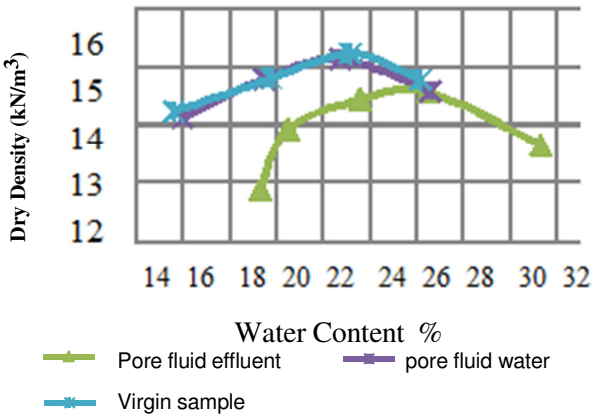

Figure 7 Dry Density – water content relationship curves for the virgin and contaminated soil samples

4.4. Dry Density of contaminated samples

The maximum dry density of the contaminated clay samples and the virgin clay were evaluated by conducting the standard Proctor compaction test. The maximum dry density of virgin clay was found to 15.2 kN/m^3 and an optimum moisture content of 23%. The contaminated samples with water as pore fluid has shown a maximum dry density of 15.1 kN/m^3 at 22.7% water content. It can be seen from Fig.7 that the contaminated samples with effluent as the pore fluid has shown a maximum dry density of 14.55 kN/m^3 at 25.5 % moisture content.

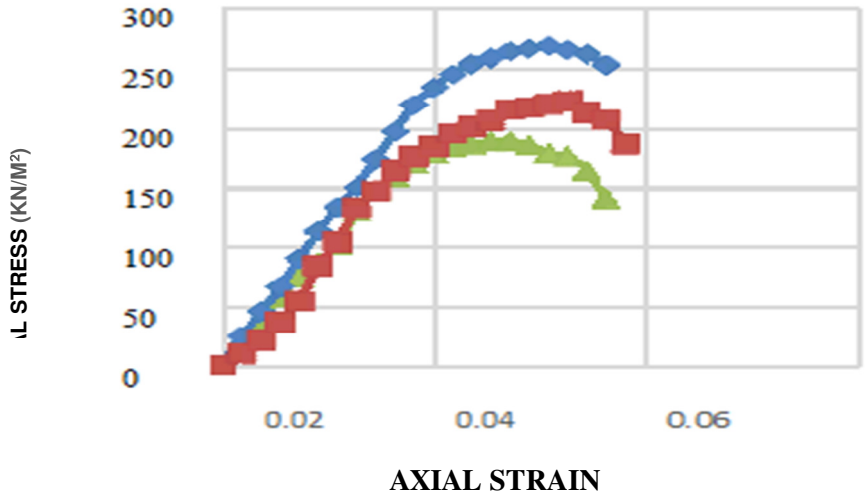

Figure 8 Stress-strain curves for contaminated samples with effluent and water as pore fluid

Virgin soil
Pore fluid effluent
Pore fluid water

4.5 Unconfined compressive strength of contaminated soil

The unconfined compressive strength of tannery effluent contaminated clay soil samples were determined by conducting UCC test on samples prepared at an optimum moisture content of 23%. The stress-strain curves for the virgin sample and the contaminated samples with pore fluid effluent as well as water were plotted. It is seen from Fig. 8 that the UCC values increased for both the cases as compared to that of the virgin soil. However, The UCC strength value is more in case of the contaminated clay samples with effluent as the pore

fluid than that of the contaminated samples with water as a pore fluid. Also, it is observed that the effect of contamination period has not shown any influence on the UCC value of contaminated clay.

5. CONCLUSIONS

This paper has presented laboratory test results to study the effect of tannery effluent on clayey soil. The following conclusions can be drawn from the study**;**

1. Liquid limit and plastic limit of soil increases with increase in contamination while, the shrinkage limit reduces with increase in contamination.
2. The shear strength of the clay increases when the clay is contaminated with the tannery effluent.
3. The presence of tannery effluent in pores slightly reduces the maximum dry density of the clay and increases the optimum moisture content. This may be due to the viscous nature of effluent.
4. The tannery effluent effect is more for contaminated clay with the pore fluid as an effluent than with the pore fluid as water.
5. The results presented in the paper are pertaining to the Pallavaram tannery. However, a change in characteristics of contaminated clay by tannery is mainly depending on the type of tannery effluent. This mainly depends upon the nature and composition of the effluent. Therefore, for general conclusion, it needs to study in details with different types of tanneries on the change in characteristics of clay.

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