IJIRSET 2319 – 8753

International Journal of Innovative Research in Science, Engineering and Technology
Vol. 1, Issue 1, November 2012

UNDRAINED SHEAR STRENGTH CHARACTERISTICS OF AN EXPANSIVE SOIL TREATED WITH CERTAIN INDUSTRIAL EFFLUENTS AT DIFFERENT PORE FLUID CONTENT RATIOS

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Abstract: India has a large network of industries located in different parts of the country and many more are planned for the near future. Several million metric tons industrial effluents are produced in these establishments. Disposal of different effluents produced from different industries pose land contamination in nearby locality. Land contamination causes modification of index and engineering properties of soils. Modification of soil properties from industrial wastes causes foundation failures, structural damage in light industrial buildings on soil contaminated by various industrial effluents have been reported. Hence safe disposal of wastes becomes a challenging task for geotechnical engineers in general and environmental engineers in particular. On the other hand in many situations, soils in its natural state do not present adequate geotechnical properties to be used as foundation layers and road service layers. These soils cause many problems in structures that come into their contact or constructed out of them. In order to suit their geotechnical parameters to meet the requirements of technical specifications of construction industry, studying soil stabilization is more emphasized. Earlier investigations reported that some industrial effluents improve the soil properties and they can be used as soil stabilisers. Hence Soil industrial effluent interaction causes improvement in soil properties or degradation of soil properties. Hence, in this paper the effect of certain industrial effluents on the strength characteristics of an expansive soil has been presented. The effect of pore fluid content on Undrained shear strength is studied separately on treated soil. In order to compare the results of treated soil, tests are also carried out on untreated soil.

Key words: Expansive Soil –Undrained Shear Strength-Textile Effluent-Tannery Effluent-Battery Effluent- Pore fluid Content ratio

I. INTRODUCTION

Industrial activity is necessary for socio-economic progress of a country but at the same time it generates large amount of solid and liquid wastes. Disposal of solid or liquid effluents, waste by-products over the land and or accidental spillage of chemicals during the course of industrial process and operations causes alterations of the physical and mechanical properties of the ground in the vicinity of industrial plants. Modification of soil properties from industrial wastes causes foundation failures, structural damage in light industrial buildings on soil contaminated by various industrial effluents have been reported. Hence safe disposal of wastes becomes a challenging task for geotechnical engineers in general and environmental engineers in particular.

Extensive cracking damage to the floors, pavement and foundations of light industrial buildings in a fertilizer plant in Kerala state was reported by Sridharan (1981).Severe damage occurred to interconnecting pipe of a phosphoric acid storage tank in particular and also to the adjacent buildings due to differential movements between pump and acid tank foundations of fertilizer plant in Calgary, Canada was reported by Joshi (1994). A similar case of accidental spillage of highly concentrated caustic soda solution as a result of spillage from cracked drains in an industrial establishment in Tema, Ghana caused considerable structural damage to a light industrial buildings in the factory, in addition to localized subsidence of the affected area has been reported by Kumapley (1985).

Therefore, it is a better to start ground monitoring from the beginning of a project instead of waiting for complete failure of the ground to support human activities and then start remedial actions.

In many situations, soils in natural state do not present adequate geotechnical properties to be used as road service layers, foundation layers and as a construction material. In order to adjust their geotechnical parameters to meet the requirements of technical specifications of construction industry, studying soil stabilization is more emphasized. Hence an attempt has been made by researchers to use industrial wastes as soil stabilizers so that there is a value addition to the industrial wastes and at the same time environmental pollution can also minimised.

Shirsavkar (2010) have been made experimental investigations to study the suitability of molasses to improve some properties of soil. He observed that the value of CBR is found to increase by the addition of molasses. Kamon Masashi (2001) reported that the durability of pavement is improved when stabilized with ferrum lime-aluminium sludge. Ekes Kalkan (2006) investigated and concluded that cement–red mud waste can be successfully used for the stabilization of clay liners in geotechnical applications.

Hence an attempt is made in this investigation to study the effect of certain Industrial effluents such as Textile effluent, Tannery effluent and Battery effluent on the Undrained shear strength values of an expansive Soil at different pore fluid content ratios.

II. EXPERIMENTAL INVESTIGATIONS

A) Materials used

1) Soil:

The soil used for this investigation is obtained from CRS near Renigunta, Tirupati. The dried and pulverized material passing through I.S.4.75 mm sieve is taken for the study. The properties of the soil are given in Table.1. The soil is classified as “SC” as per I.S. Classification (IS 1498:1970) indicating that it is clayey sand. It is highly expansive in nature as the Differential Free Swell Index (DFSI) is about 255%.

TABLE:I Properties of Untreated soil

Sl.No.	Property	Value
1.	Grain size distribution	
	(a)Gravel (%)	3
	(b)Sand (%)	65
	(c)Silt +Clay (%)	32
2.	Atterberg Limits	
	(a)Liquid Limit (%)	77
	(b)Plastic Limit (%)	29
	(c)Plasticity Index (%)	48
3.	Differential Free Swell Index (%)	255
4.	Swelling Pressure (kN/m^2)	210
5.	Specific Gravity	2.71
6.	pH Value	9.20
7.	Compaction characteristics	
	(a) Maximum Dry Unit Weight (kN/m^3)	18.3
	(b) Optimum Moisture Content (%)	12.4
8.	California Bearing Ratio Value (%) at	
	(a)2.5mm Penetration	9.98
	(b) 5.0mm Penetration	9.39
9.	Unconfined compressive Strength(kN/m^2)	173.2

2.1.2 Industrial Effluents

2.1.2.1 *Textile effluent*

Textile effluent is a coloured liquid and soluble in water. The chemical properties of the effluent are shown in Table 2.

2.1.2.2 *Tannery effluent*

Tannery industry effluent is dark coloured Liquid and soluble in water. The chemical composition of Tannery effluent is given in Table.3

2.1.2.3. Battery *effluent*

Battery effluent is a colourless liquid and soluble in water. The chemical properties of the effluent are shown in Table .4

TABLE.II: Chemical Composition of Textile Effluent

Sl.No	Parameter	Value
1.	Colour	Yellow
2.	PH	9.83
3.	Chlorides	380mg/l
4.	Alkalinity	2400mg/l
5.	Suspended solids	1500gm
6.	Total solids	13.50
7.	BOD	150mg/l
8.	COD	6200mg/l

TABLE.III: Chemical Composition of Tannery Effluent

S.No.	PARAMETER	VALUE
1.	Color	Black
2.	pH	3.15
3.	Chromium	250 mg/l
4.	Chlorides	200 mg/l
5.	Sulphates	52.8 mg/l
6.	Total Hardness	520 mg/l
7.	BOD	120 mg/lit
8.	COD	450 mg/lit
9.	Suspended Solids	1200

TABLE.IV: Chemical Composition of Battery Effluent

S.No.	PARAMETER	VALUE
1.	Color	White
2.	pH	8.45
3.	Sulphates	250 mg/l
4.	Chlorides	30 mg/l
5.	Lead Sulfate	63.08%
6.	Free Lead	7.44%
7.	Total Lead	75.42%
8.	BOD	110 mg/l
9.	COD	320 mg/l

III.PROCEDURE FOR MIXING

The soil from the site is dried and hand sorted to remove the pebbles and vegetative matter if any. It is further dried and pulverized and sieved through a sieve of 4.75mm to eliminate gravel fraction if any. The dried and sieved soil is stored in air tight containers and ready to use for mixing with effluents. The soil mixed with water of chosen moisture content and stored of a day for uniform distribution of water in different containers.

The soil sample so prepared is then mixed with solutions of different concentrations of Textile, Tannery and Battery effluent. The percentage varied from 20 to 100% in increment of 20%.The soil - effluent mixtures are mixed thoroughly before testing.

IV.TESTS CONDUCTED ON TREATED SOIL

A. *Unconfined compressive strength test*

This is a special case of Triaxial Compression Test; the confining pressure being zero. A cylindrical soil specimen, usually of the same size as that for the Triaxial compression test, is loaded axially by a compressive force until failure takes =place. Since the specimen is laterally unconfined, the test is known as ‘Unconfined Compressive Strength Test’. No rubber membrane is necessary to encase the specimen. The axial or vertical compressive stress is major principal stress and the other two principal stresses are zero. Undrained cohesion/shear strength is estimated as half of the Unconfined Compressive Strength

In this investigation, the effect of pore fluid content on the strength behaviour of the soil treated with different percentages of effluents is studied. Five different pore fluid contents are chosen for the study namely optimum pore fluid content, two on the dry side of optimum and two on the wet side of optimum. A parameter namely pore fluid content ratio (PCR) is introduced in order to compare and analyse the results the more effectively. PCR is defined as the ratio of pore fluid content to the optimum pore fluid content of the treated soil.

In all cases of pore fluid content ratios effluents are varied from 20% to 100% in increment of 20%. In order to compare the results of treated soil, tests are also conducted on untreated soil.

V.RESULTS AND DISCUSSION

A. Effect of pore fluid content on Undrained shear strength of treated soil

1) *Textile effluent*

The variation of Undrained shear strength with different percentages of Textile effluent for both dry side of optimum and wet side of optimum are shown in Fig.1.For the purpose of comparison, the variation of Undrained shear strength with different percentages of Textile effluent for Optimum pore fluid content is also plotted in Fig.1.The top most curve in the figure corresponds to pore fluid content ratio of 0.9, followed by 0.95, 1.00, 1.05 and 1.10. Hence, it indicates that the strength achieved on the dry side of optimum is higher when compared to the strength achieved at optimum pore fluid content irrespective of per cent Textile effluent, whereas the strength achieved on the wet side of optimum is lower than that of the strength achieved at optimum pore fluid content irrespective of per cent textile effluent.

The Undrained shear strength of soil samples treated with Textile effluent increases with increase in percentage of Textile effluent irrespective of pore fluid content ratio. These results are agreeing with that of Oriola et al (1996) who studied the effect of Textile effluent waste water on the behaviour of Lateritic soil Obtained in Kano Local Government Area of Kano State.

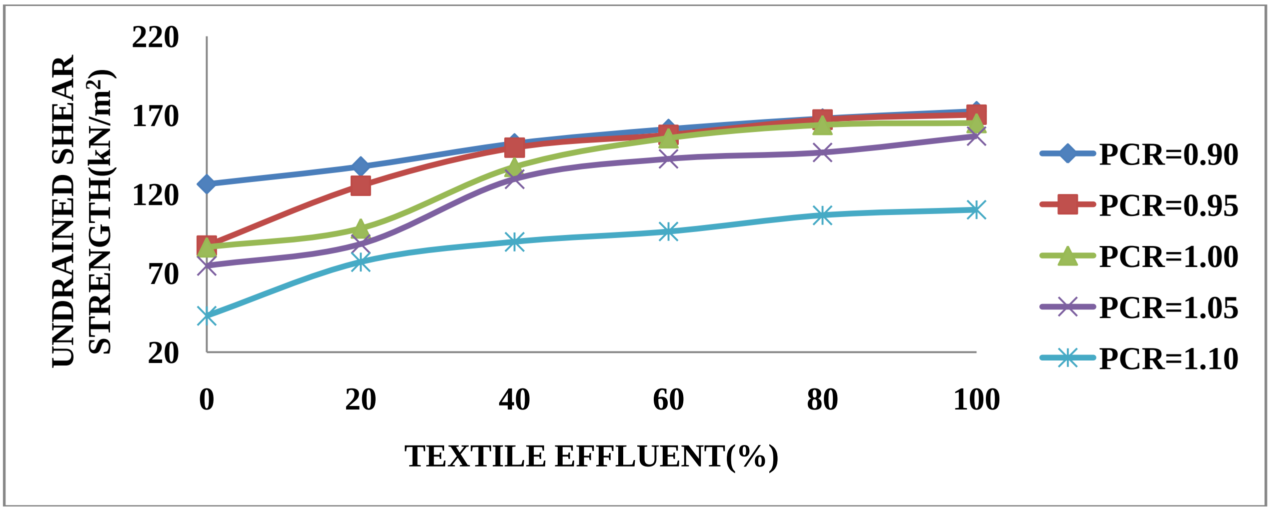

Fig.1: Variation of Undrained Shear Strength of Soil treated with different percentages of Textile Effluent for various Pore fluid Content Ratios

2) *Tannery effluent*

The variation of Undrained shear strength with different percentages of Tannery effluent for both dry side of optimum and wet side of optimum are shown in Fig.2. For the purpose of comparison, the variation of Undrained shear strength with different percentages of Tannery effluent for optimum pore fluid content is also plotted in Fig.2.The top most curve in the figure corresponds to pore fluid content ratio of 0.9, followed by 0.95, 1.00, 1.05 and 1.10. Hence, it indicates that the strength achieved on the dry side of optimum is higher when compared to the strength achieved at optimum pore fluid content irrespective of per cent Tannery effluent, whereas the strength achieved on the wet side of optimum is lower than that of the strength achieved at optimum pore fluid content irrespective of per cent Tannery effluent.

The Undrained shear strength of soil samples treated with Tannery effluent decreases with increase in percentage of Tannery effluent irrespective of pore fluid content ratio. These results are agreeing with that of Stalin et al (2000) who studied the effect of Tannery waste on the behaviour of two natural soil samples collected from Madras City.

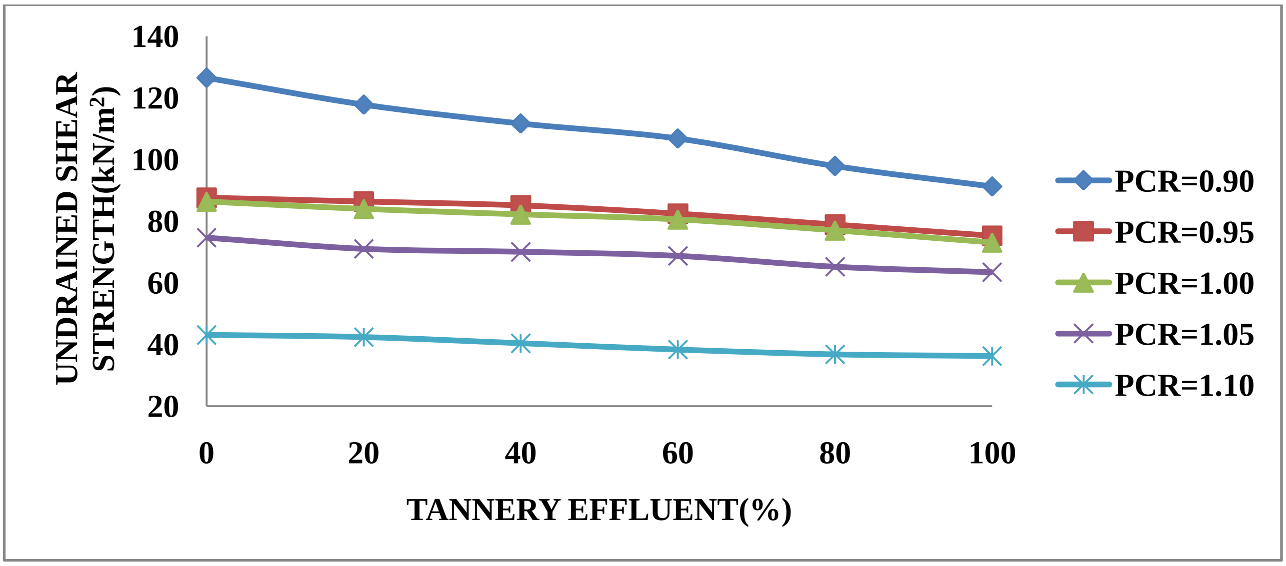

Fig.2: Variation of Undrained Shear Strength of Soil treated with different percentages of Tannery Effluent for various Pore fluid Content Ratios

3) Battery effluent

The variation of Undrained shear strength with different percentages of Battery effluent for both dry side of optimum and wet side of optimum are shown in Fig.3. For the purpose of comparison, the variation of Undrained shear strength with different percentages of Battery effluent for optimum pore fluid content is also plotted in Fig.3.Hence, it indicates that the strength achieved on the dry side of optimum is higher when compared to the strength achieved at optimum pore fluid content irrespective of per cent Battery effluent, whereas the strength achieved on the wet side of optimum is lower than that of the strength achieved at optimum pore fluid content irrespective of per cent Battery effluent. The undrained shear strength of soil samples treated with Battery effluent decreases with increase percentage Battery effluent irrespective of pore fluid content ratio.

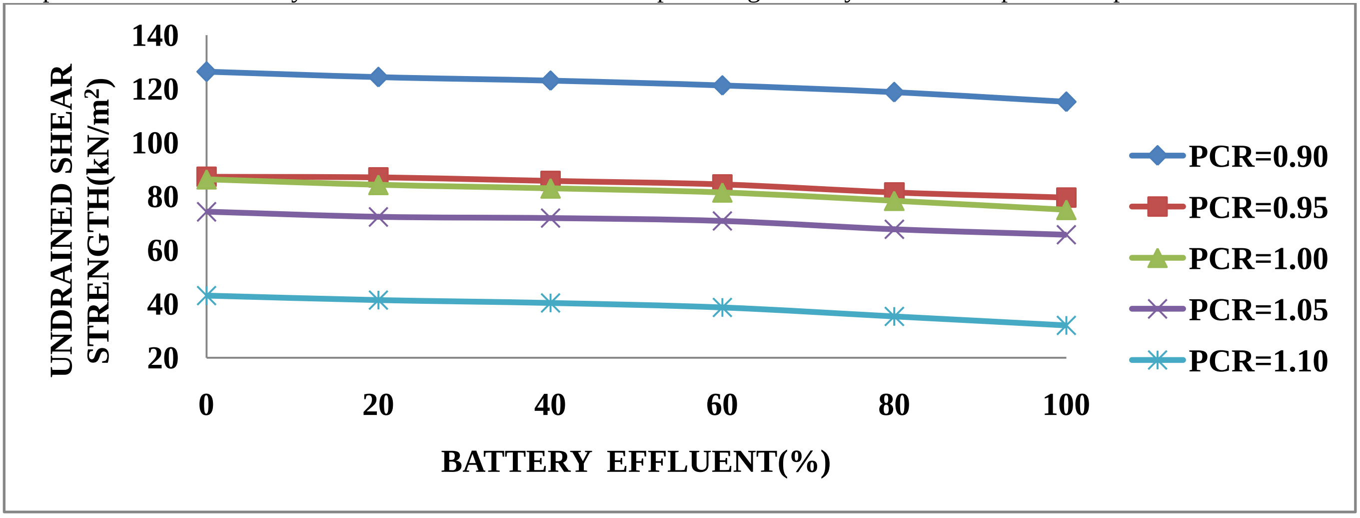

Fig.3: Variation of Undrained Shear Strength of Soil treated with different percentages of Battery Effluent for various Pore fluid Content Ratios

VI.MECHANISM INVOLVED IN MODIFICATION OF UNDRAINED SHEAR STRENGTH

A. Effect of industrial effluent

In general the shear strength of a soil can be considered to have three components viz: cohesion, friction and dilatancy. Cohesion in general is considered as a part of the shear strength that can be mobilized due to forces arising at particle level and is independent of the effective stress and hence, is regarded as a physico-chemical component of the shear strength. Undrained cohesion is estimated as half of the Unconfined Compressive Strength.

. Basically, two mechanisms control the undrained strength in clays, namely (a) cohesion or undrained strength is due to the net attractive forces and the mode of particle arrangement as governed by the interparticle forces, or (b) cohesion is due to the viscous shear resistance of the double layer water (Sridharan, 2002). The Undrained shear strength behaviour of kaolinitic soils is shown to be quite opposite to that observed for montmorillonitic soils under different physico-chemical environments. Concept (a) operates primarily for kaolinitic soil, and concept (b) dominates primarily for montmorillonitic soils. In general fine grained soils consist of different clay minerals with different exchangeable cations and varying ion concentration in the pore water and varying non clay size fraction. In view of this while both concepts (a) and (b) can coexist and operate simultaneously, or one of the mechanisms dominates.

In the case of Textile effluent the increase in UCS values could be attributed to covalent linkages between clay particles and dyes present in Textile effluent. Textile effluent is capable of forming covalent linkages with cellulose, amino, thiol and hydroxyl groups (Srimurali, 2001).Also Textile effluent do contain Cl^- or $O\text{-}So_3$ as leaving group enabling the dyes to form covalent bonds with fibre (Srimurali, 2001).The Clay minerals do contain hydroxyls groups at the surface and possibly a bonding takes place between hydroxyls in the clay minerals and dyes or $O\text{-}So_3Na$ of dyes. This Chemical bonding may be responsible for increase in Undrained cohesion between the soil particles when it is treated with Textile effluent.

In the case of Tannery effluent reduction in UCS value could be attributed to absorption of chromium ions present in the effluent. Due to its higher valence chromium ions causes decrease in double layer thickness which in turn reduces the viscous resistance for the same water content under undrained condition (Sridharan, 2002).

In the case of Battery effluent reduction in UCS Value could be attributed due to absorption of sulphates on to the clay surface causes increase in net negative charge of the clay particles which in turn increases thickness of diffused double layer around the clay particles. This issue results in increase in distance between soil particles which in turn decreases the Electrostatic and Electromagnetic attractive forces between clay particles, consequently increase in antiparticle repulsion and decrease in Undrained shear strength (Seed et al 1959).

B. Effect of variation in pore fluid content ratio on Undrained shear strength

Basically clay structure controls the Undrained shear strength of soil. Based upon the interaction of clay mineral and accompanying diffuse double layer different types of soil structures are formed. The thickness of diffused double layer depends on chemical concentration of pore fluid. When chemical concentration increases, the double layer thickness decreases (Guoy-Chapman theory) theoretically resulting reduced repulsive forces and increase in attraction. This will result in formation of flocculated structure. A flocculated “Card house” arrangement of clay particles suggests higher stiffness, brittle mode of deformation, and higher permeability due to an open fabric. On the other hand the pore fluid interaction and decrease in chemical concentration causes replacement of cations and decrease in double layer thickness. As a result the interparticle repulsion increases the particles tend to move apart leading to dispersed structure. A dispersed “parallel” arrangement of particles suggests lower stiffness, ductile mode of formation, and lower permeability. As the double layer thickness increases the soil loose their cohesion and behaves like silt. Thus foundations especially with design incorporating cohesion factors will be unsafe.

On dry side of optimum due to deficiency of pore water the thickness of diffused double layer water around the particle may be compressed. This may cause increase in Electrostatic and Electromagnetic attractive forces between clay particles leading to development of flocculated structure. The flocculated structure causes increase in undrained shear strength of soil on dry side of optimum when it is contaminated with different effluents.

On wet side of optimum due to excess of pore water the thickness of diffused double layer water around the particle may be expanded. This may cause increase in distance between individual soil grains which in turn decreases the Electrostatic and Electromagnetic attractive forces between clay particles leading to development of dispersed structure. The dispersed structure causes decrease in undrained shear strength of soil on wet side of optimum when it is contaminated with different effluents.

VII. CONCLUSIONS

The rapid growth in population and industrialization cause generation of large quantities of effluents. The bulk effluents generated from industrial activities are discharged either treated or untreated over the soil leading to changes in soil properties causing improvement or degradation of engineering behaviour of soil. If there is an improvement in engineering behaviour of soil, there is a value addition to the industrial wastes serving three benefits of safe disposal of effluents, using as a stabiliser and return of income on it. If there is degradation of engineering behaviour of soil then solution for decontamination is to be obtained. In this investigation an attempt has been made to study the effect of certain industrial effluents such as Textile, Tannery, and Battery effluents on Undrained shear strength characteristics of an Expansive soil. From the results presented in this investigation, the following conclusions are drawn:

- Expansive clay considered in this investigation is sensitive when it is treated with industrial effluents.
- The Undrained Shear Strength of the soil decreases with increase in percentage of Tannery effluent, Battery effluent irrespective of pore fluid content ratio, whereas it increases with increase in percentage of Textile effluent.
- In all the three cases the Undrained shear strength achieved on the dry side of optimum is higher when compared to the strength achieved at optimum pore fluid content irrespective of per cent effluent.
- In all the three cases the undrained shear strength achieved on the wet side of optimum is lower than that of the strength achieved at optimum pore fluid content irrespective of per cent effluent.

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Biography

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