Effect Of Certain Industrial Effluents On Undrained Shear Strength Behaviour Of An Expansive Soil– A Comparative Study

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ABSTRACT

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. If soil-waste interaction causes improvement in soil properties then the industrial wastes can be used as soil stabilizers. On the other hand if industrial wastes cause degradation of soil properties then the solution of decontamination is to be thought of.

Expansive soils are mostly found in the arid and semi-arid regions of the world. In India expansive soils are called black cotton soils because of their colour and cotton growing potential. Expansive soils undergo swelling when they come into contact with water and shrink when water is squeezed out. The typical swelling/shrinkage behaviour is due to the basic mineral composition of the montmorillonite. These volume changes in swelling soils are the cause of many problems in structures that come into their contact or constructed over these soils.

Hence, in this paper the effect of certain industrial effluents on Undrained Shear Strength characteristics of an expansive soil has been presented. The soil used in this investigation classified as 'SC' as per I.S. Classification system. It is found to be highly expansive in nature as the Differential Free Swell Index is around 255%.The effect of curing on Undrained Shear Strength is studied separately on treated soil. In order 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, Curing Period.

1. Introduction

The Index and Engineering properties of the ground gets modified in the vicinity of the industrial plants mainly as a result of contamination by the industrial wastes disposed. The major sources of surface and subsurface contamination are the disposal of industrial wastes and accidental spillage of chemicals during the course of industrial operations. The leakage of industrial effluent into subsoil directly affects the use and stability of the supported structure.

Extensive damage to the floors, pavement and foundations of a 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 Kumaply and Ishola (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 environment pollution is 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 be increased by the addition of molasses. Kamon Masashi, (2001) reported that the durability of pavement is improved when stabilized with ferrum lime-aluminium sludge. Ekrem 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 Undrained Shear Strength of an Expansive soil.

2. Experimental investigations

2.1. Materials used

2.1.1Soil

Table: 1 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	18.3
	(b) Optimum Moisture	12.4
8	California Bearing Ratio	
	(a)2.5mm Penetration	9.98
	(b) 5.0mm Penetration	9.39
9	Undrained Cohesion (kN/m^2)	86.4

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%.

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.

Table 2: Chemical Composition of Textile Effluent

S.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
1.	Colour	Yellow

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.

Table 3: 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 mg/lit

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 .4: 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

3. 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 pulverised and sieved through a sieve of 4.75mm to eliminate gravel fraction if any. The dried and sieved soil is sorted in air tight containers ready for 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 concentrate solutions of Textile, Tannery and Battery effluents. The percentage weight varied from 20 to 100% in increment of 20%.The soil effluent mixtures are mixed thoroughly before testing.

4. Tests on treated soil

4.1. Unconfined Compression Test

Undrained shear strength is estimated as half of the Unconfined Compressive Strength. Hence Unconfined Compressive Strength is conducted on the treated and untreated soil. 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 Compression 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.

In this investigation, Unconfined Compressive Strength test is , carried out to study the strength behaviour of soil treated with different percentages of effluents are critically discussed. The effect of curing on the strength behaviour of soil treated with different percentages of effluents is also studied. Five different curing periods are considered for the study namely 0 day, 1day, 3 days, 7 days and 15 days. The tests are conducted at the optimum pore fluid content. The 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.

5. Results and Discussion

5.1. Effect of curing period on Undrained Shear Strength of Soil

5.1.1. Textile Effluent

The variation in Undrained Shear Strength or Cohesion with respect to different percentages of Textile effluent for various curing periods is shown in Fig .1. From the figure, it is observed that the strength of the soil increases with increase in percentage of Textile effluent irrespective of curing period.

The variation of Undrained Cohesion with respect to different curing periods for various percentages of Textile effluent is shown in Fig.2. From the figure it is observed that the strength of the soil increases with increase in curing period irrespective of per cent Textile effluent. The maximum improvement in Undrained Cohesion occurs on the soil specimens treated with 100% Textile effluent and cured for 15 days.

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.

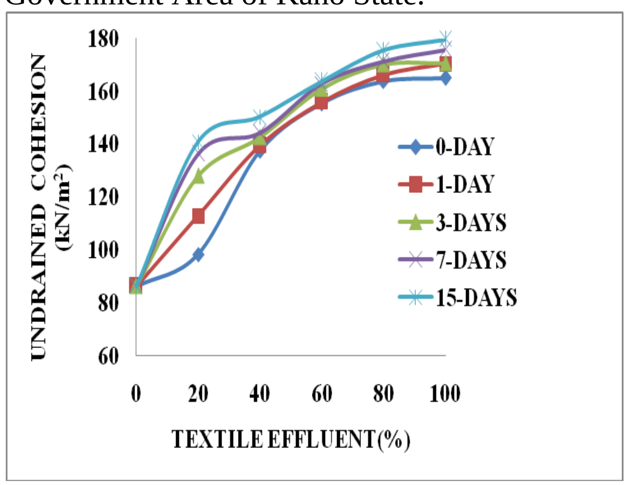

Fig.1: Variation of Undrained Cohesion with Per cent Textile Effluent for different

Curing Periods.

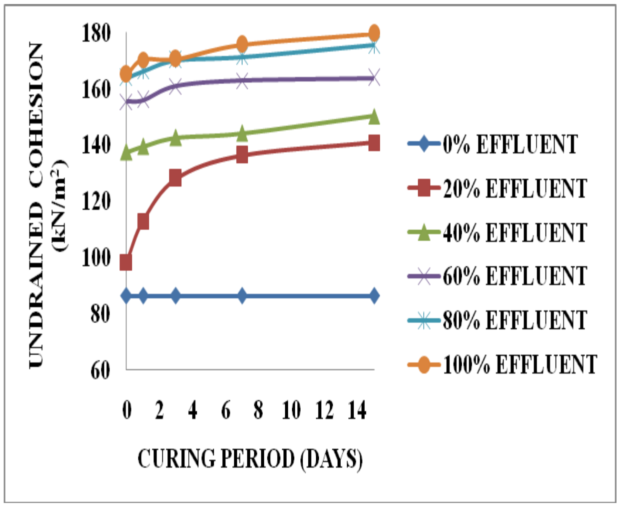

Fig.2: Variation of Undrained Cohesion with curing period for different percentages of Textile Effluent.

5.1.2. Tannery Effluent

The variation in Undrained Cohesion with respect to different percentages of Tannery effluent for various curing periods is shown in Fig.3.From the figure, it is observed that the strength of the soil decreases with increase in percentage of Tannery effluent irrespective of curing period.

The variation in Undrained Cohesion with respect to different curing periods for various percentages of Tannery effluent is shown in Fig.4.From the figure it is observed that the strength of the soil decreases with increase in curing period irrespective of per cent Tannery effluent. The maximum reduction in Undrained Cohesion occurs on the soil samples treated with 100% Tannery effluent and cured for 15 days.

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.

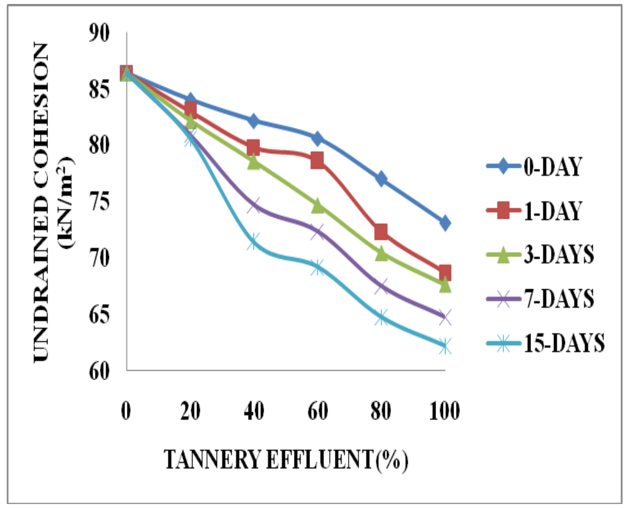

Fig.3: Variation of Undrained Cohesion with Per cent Tannery Effluent for Different curing periods.

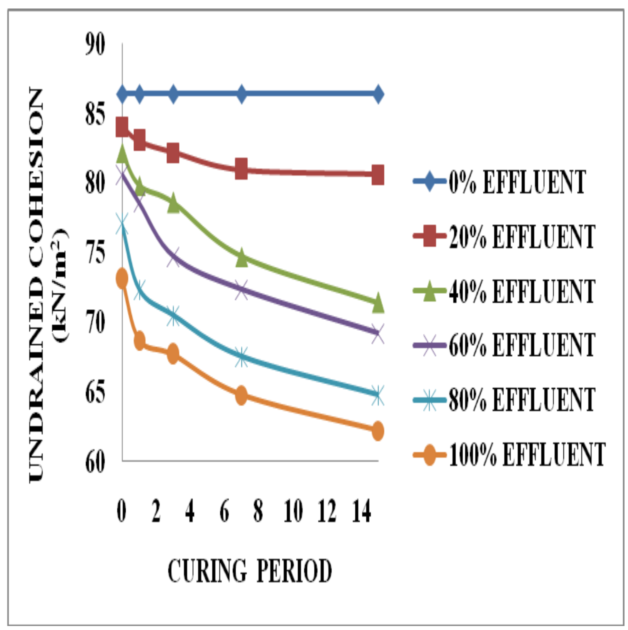

Fig.4: Variation of Undrained Cohesion with curing period for different percentages of Tannery Effluent

5.1.3. Battery Effluent

The variation of Undrained Cohesion with respect to different percentages of Battery effluent for various curing periods is shown in Fig.5. From the figure, it is observed that the strength of the soil decreases with increase in percentage of Battery effluent irrespective of curing period.

The variation in Undrained Cohesion with respect to different curing periods for various percentages of battery effluent is shown in Fig.6. From the figure it is observed that the strength of the soil decreases with increase in curing period irrespective of per cent Battery effluent. The maximum reduction in Undrained Cohesion occurs on the soil samples treated with 100% Battery effluent and cured for 15 days.

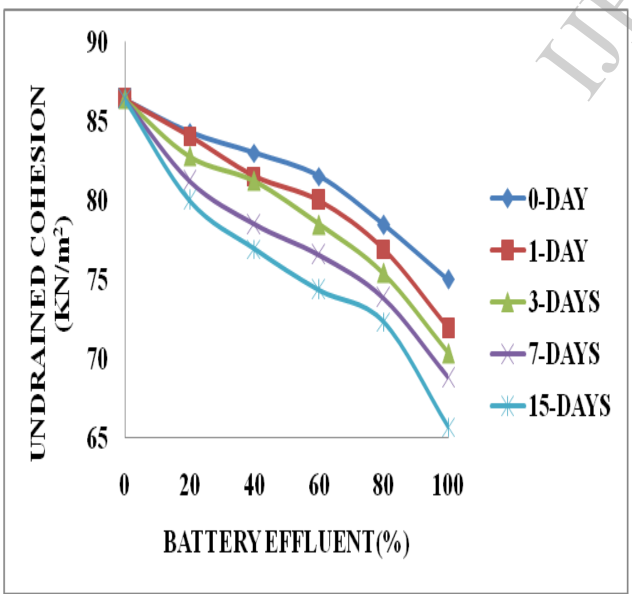

Fig.6: Variation of Undrained Cohesion with Per cent Battery Effluent for different Curing Periods.

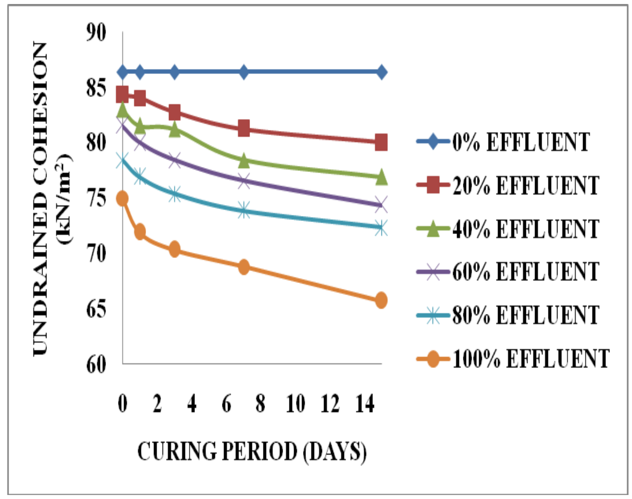

Fig.5: Variation of Undrained Cohesion with Curing period for different percentages of Battery Effluent

There is a two fold increase in Undrained Cohesion of soil samples treated with 100% Textile effluent and cured for 15 days when compared to untreated soil specimens. In case of Tannery and Battery effluents the maximum reduction in Undrained Cohesion of soil specimens takes place at 100% effluent and cured for 15 days when compared to untreated soil samples and the percentage reduction in soil samples are 28% and 24% respectively.

6.Mechanism involved in modification of Undrained Cohesion of treated soil with increase in curing period.

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 Undrained Cohesion 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-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-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. The gain in strength of specimens with age was due primarily to the long-term hydration reaction that resulted in the formation of newer compounds due to the presence of chlorides which are known to be stabilizing agents.

In the case of Tannery effluent reduction in Undrained Cohesion 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). The reduction in strength of specimens with age was due to the long-term interaction between clay particles and effluent and predominant role of chromium ions in decreasing double layer thickness and viscous resistance.

In the case of Battery effluent reduction in Undrained Cohesion 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 and consequently increases in antiparticle repulsion and decrease in undrained shear strength (Seed et al 1959). The reduction in strength of specimens with age was due to the long-term interaction between clay particles and effluent and adsorption of sulphates on clay surfaces results in decrease in strength due decrease in cementation ability.

7. Summary and 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 behavior 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 strength characteristics of an Expansive soil. From the results presented in this investigation, the following conclusions are drawn:

- The Undrained Cohesion of the soil decreases with increase in percentage of Tannery Effluent, Battery effluent irrespective of curing period whereas it increases with increase in percentage of Textile effluent.
- The Undrained Cohesion (UC) of the soil increases with increase in curing period irrespective of per cent Textile effluent whereas it decreases with increase in curing period irrespective of per cent Tannery effluent or Battery effluent.
- The maximum improvement in UC occurs at 100% Textile effluent for the specimens cured at 15-days whereas the maximum reduction in UC Occurs at 100% Tannery effluent or Battery effluent for the specimens cured at 15-days.
- For lesser curing periods more quantity of Textile effluent is required to achieve the same Undrained Cohesion.
- Textile effluents raise the hope of value addition to the industrial wastes where as Battery effluent and Tannery effluents can be treated as contaminant.

References

1. Ekrem Kalkan "Utilization of red mud as a Stabilization material for the preparation of clay Liners "Engineering, Geology, Volume 87, Issues,3- 4, 3 November 2006, Pages 220-229.

2. F.O.P.Oriola and A.Saminu "Influence of Textile Effluent Waste Water on Compacted Lateritic Soil "EJGE Journal 17, Bund.B, 167-1778 (2012)

3. I.S. 1498-1970 (First Revision), Classification of soils for General Engineering purposes

4. Joshi,R.C.,Pan,X.andLohita,P(1994),"Volume Change in Calcareous Soils due to Phosphoric Contamination", Proc.of the XIII ICSMFE, New Delhi, Vol.4.pp.1569- 1574.

5. Kamon Masashi GU Huanda' Masahiro "Improvement of mechanical properties of ferrum lime Stabilized soil with the addition of aluminum Sludge "Materials Science research international, ISSN1341-1683, 2001 vol. 7, pp. 47-53

6. Kumapley, N.K., and Ishola,A.(1985),"The Effect of Chemical Contamination on Soil Strength"Proc.of the XI ICSMFE, Sanfrancisco, Vol.3, pp.1199-1201.

7. Seed, H.B., and Chan, C.K. "Structure and Strength Characteristic of Compacted Clays."J. of Soil Mechanics and Foundation Engg.Vol.85, No.SM 5, ASCE. 87 –128. (1959).

8. Sridharan, Asuri and El-Shafei, Ahmed and Miura,Norihiko "Mechanisms controlling the Undrained,Strength behavior of remolded Ariake marine clays".in: Marine Georesources & Geotechnology, 20 (1). 21-50. (2002).

9.Sridharan,A,Nagraj,T.S.,andSivapullaiah,P.V. (1981) Heaving of soil Due to Acid Contamination"Proc.of the X ICSMFE, Stockholm, Vol.2, pp.383-386.

10.Srimurali,M (2001)"Removal of Colour from Dye wastes By Chemical Coagulations Ph.D.Thesis, Submitted to Dept. of. Civil.Engg. S.V.University, India (2001).

11.S.Shirsavkar,Prof.S.S.Koranne(2010)"Innovation in Road Construction Using Natural Polymer", EJJE, Journal, Vol.15, Bund.O, pp.1614-1624.

12.Stalin,V.K.Muthukumaran,K.and artikeyan,A, Effect of Liquid waste on the index and Engineeringbehaviour of soils "Indian Geotechnical Conference- 2000 (Millennium Conference)". 229-230. (2000).