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EFFECT OF CERTAIN INDUSTRIAL EFFLUENTS ON COMPACTION CHARACTERISTICS OF AN EXPANSIVE SOIL–A COMPARATIVE STUDY

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Abstract:—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 the three benefits of safe disposal of effluent, using as a stabilizer and return of income on it. If there is degradation of engineering behaviour of soil then solution for decontamination is to be obtained. 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. The Swelling nature of soil causes lot of damages to civil engineering structures which are constructed over them. Hence in this paper the effect of certain industrial effluents on compaction behaviour has been presented. The soil used in this investigation is classified as "SC" as per I.S.Classification system. It is highly expansive nature as the Differential Free Swell Index is about 255%.The Proctor's compaction tests are conducted on the soil treated with Textile, Tannery and Battery effluents at different percentages from 20 to 100% in increment of 20%.In order to compare the results of admixed soil, tests are also conducted on untreated soil. There is a decrease in Optimum Moisture Content values and increase in Maximum Dry Unit Weight of soil is treated with Tannery effluent and whereas increase in Optimum Moisture Content values and decrease in Maximum Dry Unit weight of soil with Textile and Battery effluent.

Keywords:—Expansive Soil, Textile Effluent, Tannery Effluent, Battery Effluent, Optimum Pore fluid Content, Maximum Dry Unit weight.

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. Results of some studies indicate that the detrimental effect of seepage of acids and bases into sub soil can cause severe foundation failures.

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 minimized.

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-aluminum 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. In practice foundation layers, subgrade layer of pavement and also most of the laboratory experiments are conducted at Optimum moisture content and Maximum Dry Unit weight of soil. 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 compaction characteristics of an Expansive Soil.

EXPERIMENTAL INVESTIGATIONS

2.1.Materials used

2.1.1. 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: 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 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.2: 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. 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

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

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 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.

I. TESTS CONDUCTED ON TREATED SOIL

4.1. Standard Proctor Test

The compaction parameters, Optimum pore fluid Content and Maximum Dry Unit Weight play a vital role in changing the strength characteristics of an Expansive soil. But these two parameters are strongly influenced by pore fluid chemistry. Hence in this investigation Standard Proctor's compaction tests are carried out on expansive soil treated with Textile effluent, Tannery effluent, Battery effluent at various percentages of 0%, 20%, 40%, 60%, 80% and 100% by dry weight of the soil.

II. RESULTS AND DISCUSSIONS

5.1. Compaction Parameters-Textile Effluent

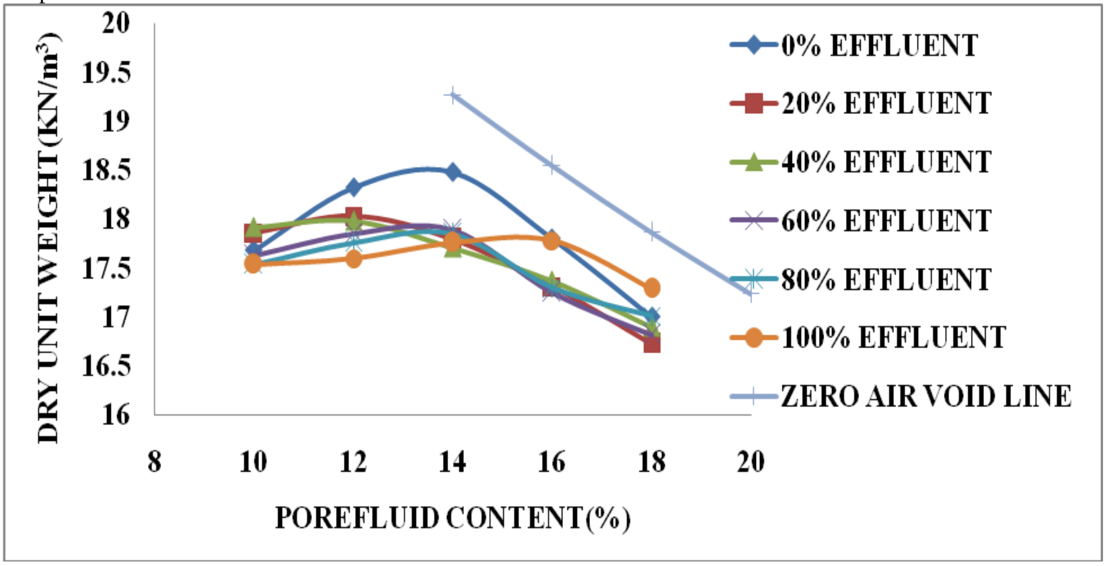

Fig.1: Variation of Dry Unit Weight with per cent Pore fluid content

The results of the Standard Proctor's compaction tests, conducted at different percentages of Textile effluent are reported in Fig.1. From these curves, it is observed that the peak points are shifted towards right with per cent increase of effluents.

5.2. Compaction Parameters-Tannery effluent`

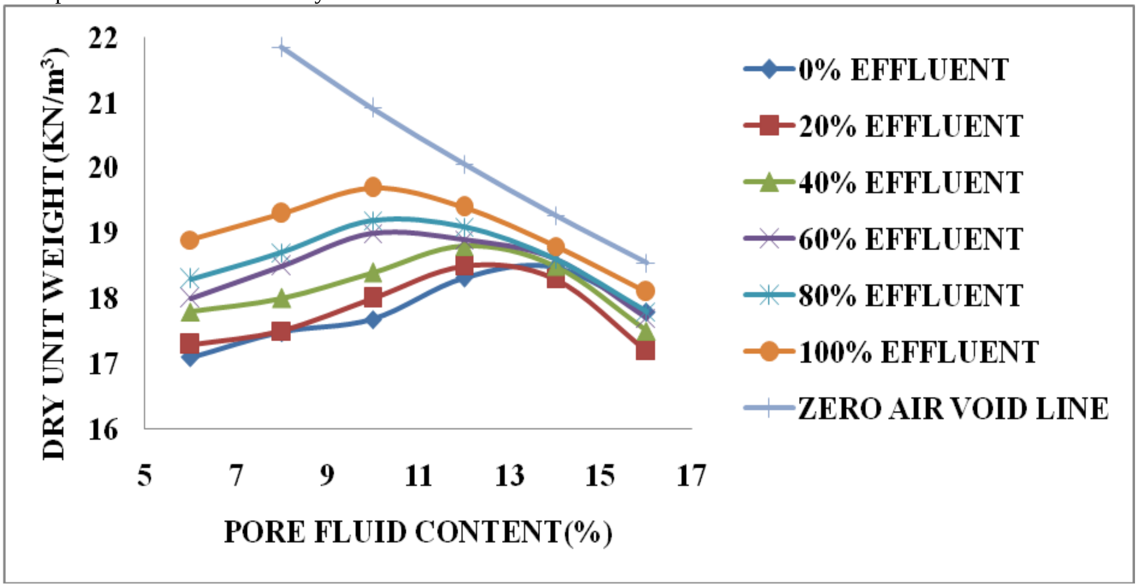

Fig.2: Variation of Dry Unit Weight with per cent Pore fluid content

The results of the Standard Proctor's compaction tests, conducted at different percentages of Tannery effluent are reported in Fig.2.The Top most curve corresponds to 100% of Tannery effluent followed by 80 %, 60 %, 40 %, 20 % and 0% respectively. From these curves, it is observed that the peak points are shifted towards left with per cent increase of Tannery effluent.

5.2.3. Compaction Parameters-Battery effluent

The results of the Standard Proctor's compaction tests, conducted at different percentages of Battery effluent are reported in Fig 3.The Top most curve corresponds to 0% of Battery effluent followed by 20 %, 40 %, 60 %, 80 % and 100% respectively.

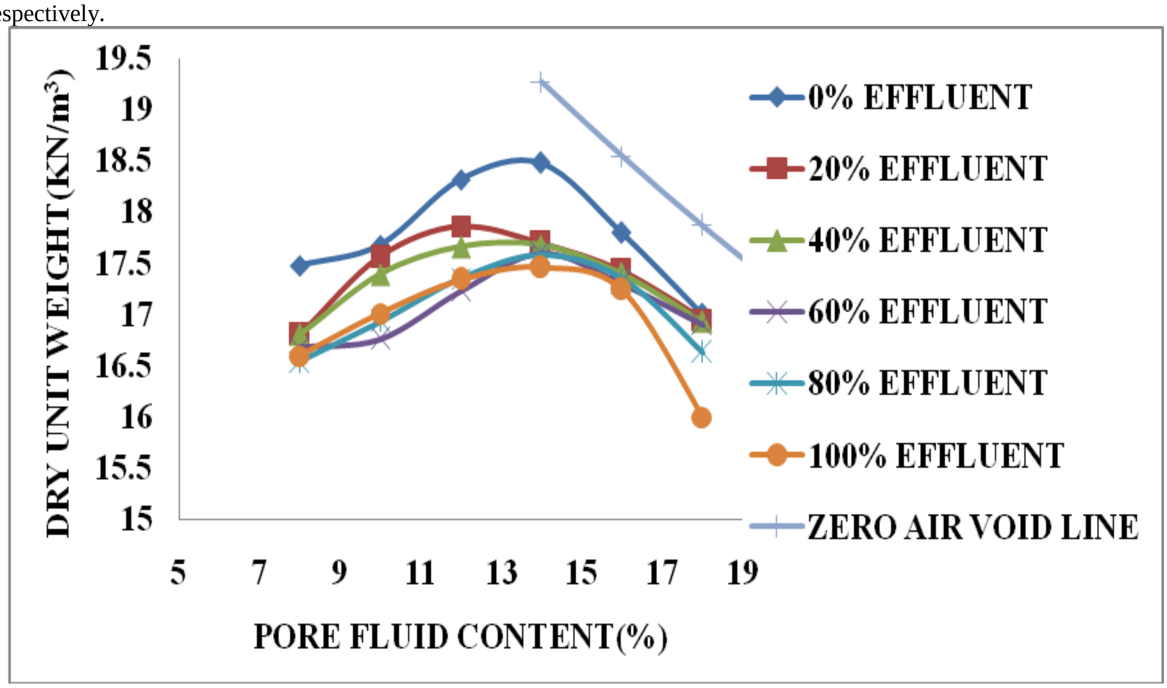

Fig.3.Variation of Dry Unit Weight with per cent Pore fluid content

III. OPTIMUM PORE FLUID CONTENT (O.P.C) -COMPARATIVE STUDY

The variation of the optimum pore fluid content at different percentages of Textile, Tannery and battery effluents are shown in Table.5. The percentage increase/decrease in pore fluid content at different percentages of effluents is shown in Table.6. From the table it is observed that the maximum percentage increase in optimum pore fluid content for 100% Textile effluent is about 24% where as 100% Battery effluent it is about 14%.It is found that the maximum percentage decrease in optimum pore fluid content for 100% Tannery effluent is about 11%.

Table: 5: Optimum Pore fluid (OPC) Content at different Percentages of effluents

Effluent(%):Water(%)%)	**O.P.C (%)**		
	Textile	**Tannery**	**Battery**
0:100	**12.4**	**12.4**	**12.4**
20:80	**12.6**	**12.1**	**13.5**
40:60	**12.9**	**11.9**	**13.6**
60:40	**13.4**	**11.6**	**13.7**
80:20	**14.4**	**11.3**	**13.9**
100:0	**15.4**	**11.1**	**14.1**

Table: 6: Percent increase/decrease in Optimum Pore fluid Content at different Percentages of effluents

Effluent(%):Water(%)%)	**Percent increase/decrease in O.P.C**		
	Textile	**Tannery**	**Battery**
0:100	**-**	**-**	**-**
20:80	**1.61**	**-2.41**	**8.87**
40:60	**4.03**	**-4.03**	**9.67**
60:40	**8.06**	**-6.45**	**10.48**
80:20	**16.12**	**-8.87**	**12.09**
100:0	**24.19**	**-10.48**	**13.71**

The variation of optimum pore fluid content at different percentages of effluents is shown in Fig .4. From the figure it is observed that the Optimum Pore fluid Content increases with per cent increase of Textile and Battery effluents where as it decreases in the case of Tannery effluent. The maximum percentage increase or decrease in Optimum Pore fluid Content occurs at 100% effluent in all the three cases in the tested range.

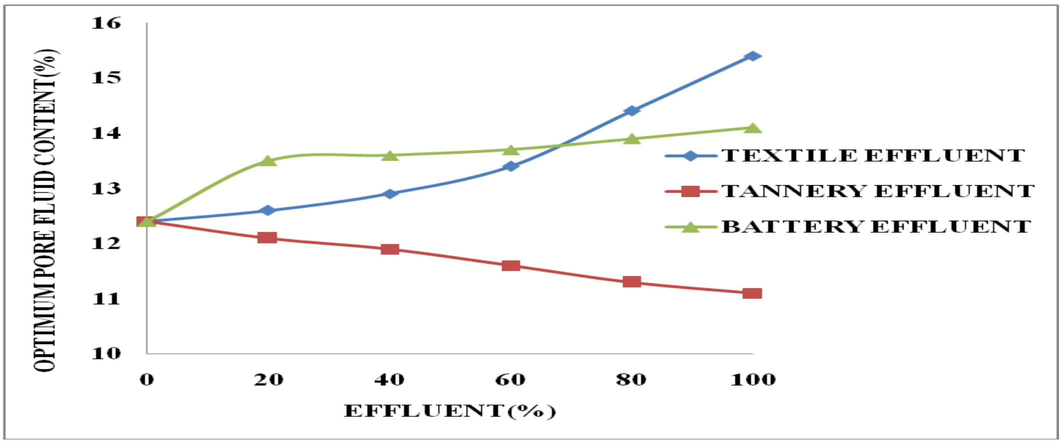

Fig.4: Variation of Optimum Pore fluid Content with percentages of effluents

IV. MAXIMUM DRY UNIT WEIGHT (M.D.U) - COMPARATIVE STUDY

The variation of the Maximum Dry Unit Weight at different percentages of Textile, Tannery and Battery effluents are shown in Table.7.The Percent increase/decrease in maximum dry unit weight at different effluent percentages are also shown in Table.8. From the table it is observed that the maximum percentage decrease in maximum dry Unit Weight for 100% Textile effluent is about 1.5% and for 100% Battery effluent it is about 6.0%.It is found that the maximum percentage increase in Maximum Dry Unit Weight for 100% Tannery effluent is about 8%

Table.7.Variation of Maximum Dry Unit Weight (M.DU) at different Percentages of effluents

Effluent(%):Water(%)	**M.D.U (kN/m^3)**		
	Textile	**Tannery**	**Battery**
0:100	**18.30**	**18.3**	**18.30**
20:80	**18.27**	**18.6**	**17.71**
40:60	**18.22**	**18.8**	**17.51**
60:40	**18.14**	**19.1**	**17.41**
80:20	**18.09**	**19.5**	**17.37**
100:0	**18.03**	**19.8**	**17.2**

Table: 8. Percent increase/decrease in Maximum Dry Unit Weight (M.D.U) at different effluent percentages

Effluent (%): Water (%)	**Maximum Dry Unit Weight (kN/m^3)**		
	Textile	**Tannery**	**Battery**
0:100	**-**	**-**	**-**
20:80	**-0.16**	**1.64**	**-3.22**
40:60	**-0.43**	**2.73**	**-4.31**
60:40	**-0.87**	**4.37**	**-4.86**
80:20	**-1.14**	**6.55**	**-5.08**
100:0	**-1.47**	**8.20**	**-6.01**

The variation of Maximum Dry Unit Weight with different percentages of the three effluents are shown in Fig.5.From the figure it is observed that the Maximum Dry Unit Weight decreases with per cent increase of Textile and Battery effluents where as it increases in the case of Tannery effluent. The maximum percentage increase or decrease occurs at 100% effluent in all the three cases.

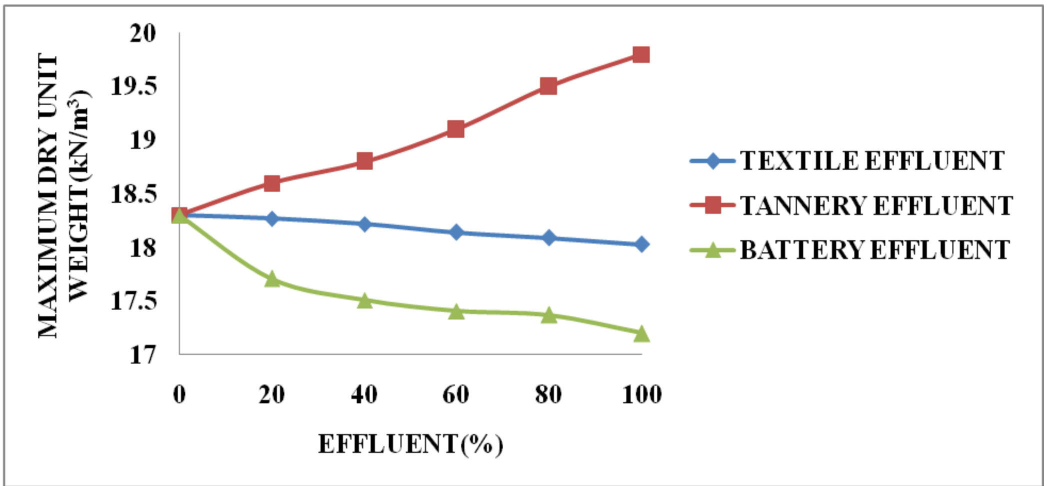

Fig.5: Variation of Maximum Dry Unit Weight at different percentages of effluents

V. MECHANISM INVOLVED IN MODIFICATION OF COMPACTION PARAMETERS

In the case of Expansive soils the Engineering behavior of the soil is governed by thickness of diffused double layer. The thickness of double layer in turn affected by pore fluid chemistry such as Dielectric Constant, Electrolyte Concentration, Ion valency, and hydrated ion radius etc., When Soil interacts with Industrial effluents; the interaction changes the pore fluid chemistry and subsequently the thickness of diffused double layer. These changes are likely to be reflected by variation in compaction characteristics and also engineering properties of soil.

When soil is mixed with Textile effluent the dry density decreases and Optimum Pore fluid Content increases. This could be attributed to ion exchange at the surface of clay particle. The chlorides in the additives reacted with the lower valence metallic ions in the clay microstructure and causes decrease in double layer thickness. The decrease in double layer thickness causes increase in attractive forces and decrease in repulsive forces leading to flocculated structure. Hence Dry density decreases. Due to retaining of water within the voids of flocculated structure water holding capacity of soil increases hence optimum moisture content also increases.

When soil is mixed with Tannery effluent the dry density increases and Optimum Pore fluid Content decreases. This is attributed due to adsorption of Chromium CrO_4 ions on to the clay particles present in the Tannery effluent. Due to its higher valence adsorption of chromium decreases the double layer thickness. The reduction of the double layer thickness brings the particles closer and hence the maximum dry density increases. Therefore using the same amount of compaction energy, the particles pack better together and the dry density increases. Consequent on particles becoming closer and decreased water holding capacity the optimum water content decreases.

When soil is mixed with Battery effluent the dry density decreases and Optimum Pore fluid Content increases. This is attributed due to adsorption of sulphates on to the clay particles present in the Battery effluent. Adsorption of divalent negative sulphate ions causes entire clay particles to be negatively charged. If the entire clay particle becomes negatively charged it increases the activity of clay mineral the absorbed water surrounding which has considerable volume leads to increase in optimum moisture content. The increase in the double layer thickness may cause increase in repulsive forces and dispersion of clay particles. Hence it offers more resistance to pack better together leading to decrease in Maximum Dry Density.

VI. SUMMARY AND CONCLUSIONS

Industrial activity is necessary for socio-economic progress of a country but at the same time it generates large amounts 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 other hand if it causes degradation of soil properties then the solution for decontamination of soil is to be obtaine

In this investigation, an attempt has been made to study the effect of certain industrial effluents such as Textile, Tannery and Battery effluents on Compaction characteristics of expansive clayey sand. From the results presented in this investigation, the following conclusions are drawn.

- An Expansive clay considered in this investigation is sensitive when it is treated with Industrial effluents.

- When soil is treated with Textile and Battery effluents separately an increase in Optimum moisture content and decrease in maximum dry density is observed. But when it is treated with Tannery effluent opposite trend is observed.

Hence the Strength Characteristics such as California Bearing Ratio, Unconfined Compressive Strength, Triaxial shear Strength Parameters which are obtained at Optimum Pore fluid Content and Maximum Dry Unit Weight are strongly influenced by these three industrial effluents.

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