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Effect of Acidic Silk Dyeing Effluent on the Compaction and Strength Behaviour of Expansive Black Cotton Soil

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Abstract - **In India one of the fastest growing economy in the world, the major employment is from textile industry which is next only to agricultural industry. As most of the textile industry in India is small scale in nature whereas least importance is given by small scale industries for post treatment of effluent i.e., after dyeing the colour to textile yarns. Exceptionally after acidic dyeing to textile yarns, there is no proper treatment for effluent before discharge, leading to soil pollution. Interaction with pollution can affect the engineering properties of the soil. This paper presents the effect of acidic effluents from silk dyeing on compaction and strength behaviour of black cotton soil. From experimental results it indicates that intrusion of acidic effluent has marginally improves the maximum dry density of the soil and reduces the optimum moisture content. The unconfined compressive strength tests were conducted on the soil compacted to their respective maximum dry density at optimum moisture content. The changes vary with concentration of acidity in the effluent. At 60% of acidic effluent (by weight of soil) has shown 1.6 times increase in the strength of soil compared to uncontaminated soil. All the tests were conducted as per I S standards.**

Keywords —Effluent, Matrix, Maximum Dry Density, Percentage Variation.

I. INTRODUCTION

In India, nearly 20% of the land is covered by expansive Black Cotton Soil. Most of the textiles dyeing industries in India are located nearby rivers, lake beds, where discharge of effluent can be easily taken off from the source of its origin. Generally this soil will have organic intrusion/ chemical contamination which change the properties of non expansive soil to expansive soil. As India is developing country, major area of employment is either from agricultural or textile industry. Disposal of effluent from textile industry to such expansive soil alters the engineering properties of soil. Silk dyeing industries use harmful dyes for colouring fabrics in cloths. This colour coated on the fabric has to be rinsed before weaving. This rinsed water contains considerable amount of acidic effluent which is directly discharged into unlined open drains or on to the open land. Soil pollutants interaction can affect properties of most soils. In this paper the silk dyeing acidic effluent from dye industry which is potential contaminant of soil at Vijayapur zone near Bengaluru city, Karnataka state, India, has been taken. Strength of soil is one of the properties of the soil which will have an important bearing on the stability of structures founded on them. The strength of soil depends on the levels of compaction and the water content. Thus in this study the compaction of behaviour of soil with different levels of contamination with acidic effluents and the unconfined compressive strength of soil has been studied. It is well recognised that the liquid limit of soils play a very important

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role in controlling the compaction behaviour and the unconfined compressive strength of soils. Hence to understand the mechanism of effect of acidic effluents on the behaviour of soils tests are also conducted on the liquid limit of soils contaminated with different levels of concentration of acidity in the soil.

II. Review of Literature

Several researchers attempted to study the behaviour of discharged effluent on geotechnical properties of soil. Amulya et al., (2015) has brought out that Black Cotton Soil contaminated with sulphuric acid has shown changes in the mineralogy and micro structure in the soil [1]. Sojil and Rajesh (2015), found that when soil in indented with increasing percentage of acidic effluent, liquid limit increases upto certain percentage of H_2SO_4 indentation, beyond that with increase in the percentage of acidic effluent, the liquid limit decreases[15]. Sojil and Rajesh (2015), has carryout study on index and engineering properties of black cotton soil due to acid contamination. They found that, addition of acid Sulphuric acid (H_2SO_4), Phosphoric acid (H_3PO_4) and Nitric acid (HNO_3) as contaminant agent for black cotton soil, changes the phisico-chemical characteristics of black cotton soil due to Catioan Exchange Capacity process. They found that, with increase in acidic contaminant on black cotton soil optimum moisture content increases while maximum dry density decreases. Similarly unconfined compressive strength results shows that with increase in acid concentrations, shear strength reduces which indicate overall reduction in the strength with acid concentration [16]. Umesh et al., (2012) have studied the adverse effect of acid concentration on geotechnical properties of black cotton soil through increase in the water holding capacity resulting in strength reduction [19]. Shivaraju et al., (2011) found that the optimum moisture content of soil treated with silk dyeing acidic effluent decreases with increase in maximum dry density. The unconfined compressive strength also increases for the soil treated with acidic effluent in comparison with uncontaminated soil [13]. Compaction and strength behavior of lime-coir fiber treated Black Cotton soil has been studied by Ramesh et al. (2010) [12]. Rao and Indiramma (2009) have reported that the textile effluent is found to reduce the liquid limit as well as swelling properties, increase in strength, and alter the compaction characteristics and stability of soil mass due to increase in the textile effluent concentration [10]. Gratchew and Sassa (2009)[4], Gratchew and Towhata (2009)[5], performed systematic studies aimed to determine whether pH can influence the properties of soil that are typically encountered in geotechnical practice. Mallikarjuna et al., (2008) says that structural change in clay due to textile dye waste on clayey soil and affects the engineering properties of soils [7]. Wang and Siu (2006 a,b), soil treated with acidic medium trends to form open flocculated arrangement. This indicates increase in compressibility of the soil [20] and [21]. According to Imai et al. (2006), says that when acid come in contact with naturally consolidated clays it may destroy/dissolve the chemical bond or cementation between the clay particles forming relatively loose structure. This leads to reduction in strength carrying capacity of soil [6]. Similar observations were made by Suarez et al. (2001) that surface area of clayey soil doubled on activation of HCl when compared with the natural mineral [18]. Sridharan and Prakash (1999) noted that the process altering the diffuse double layer would have a significant impact on soils with montmorillonite while charges in particle orientation caused by chemicals should have a dominant effect on the properties of kaolinitic soils [17]. Deknay et al. (1999), says that during acid treatment on clayey soil, clay structure is progressively transformed into amorphous silica-alumina [3]. According to Chrisidis et al. (1997), conclude that due to complex changes of mineral in the acid environment, their surface properties are modified. They found that HCl activation of two bentonites leads to a 5-fold increase of the surface area of raw materials [2]. Masashi et al., (1997) studied the effect of acid rain on physico-chemical and engineering properties of soil and concluded that the unconfined compressive strength has generally increased with soaking duration [8]. Mitchell (1993) [9], Olphen (1991) [11], conducted several tests on clayey soil indented with slightly acidic effluent. They found that when the environment become slightly acidic, hydrogen ion (H^+) engage in the exchange process with the cations from the diffuse double layer of clay particles. Hydrogen ion would likely to replace the commonly found exchanged cations such as Na^+, Ca^{2+}, Al^{3+}, or Fe^{3+}. From this clay colloidal chemistry, it is known that this process would lead to an increase in double layer thickness resulting in a greater compressibility of soil. Olphen (1991) [11] and Mitchell (1993) [9], noted that on extremely high concentrated acidic environment (pH≈1), significantly changes in the mineral structure of soil. Hence this process will have higher impact on compressibility of soil. Thus it is known that the presence of acid, a contaminant as effluent in soil can change the behaviour of soil, though different acids show different trends. Hence in this research work a detailed experimental investigation is carried out to understand the effect of different concentration of silk dyeing acidic effluent on compaction and strength behaviour of black cotton soil.

III. Materials and Methods

Sample preparation

In the existing methodology all the researchers were consider some normality/molarity concentration of either sulphuric

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acid /phosphoric acid and conducted index and engineering property tests. However, in the current methodology, effluent concentration were not altered in order to stimulate actual filed conditions while small scale silk dyeing industry discharging effluent directly into the unlined open drains or on to the open land. But in our research programme, the methodology has been planned in such a that to know the effect of varying percentage of effluent on compaction and strength behaviour of black cotton soil by adding 10% to 100% with an increment of 10% dilution of effluent by volume and addition of effluent to the soil by weight of soil (Shivaraju et al., 2017) [14]. Dried and sieved Black Cotton Soil was soaked in different containers with silk dyeing acidic effluent for a period of four days in order to stimulate field soil contamination condition, as shown in photo 1. Then the soil which is taken from the containers were air dried and oven dried in a thermostatically controlled oven, there after soaked soil samples were taken for carrying out compaction and Unconfined Compressive Strength tests. In the first phase oven dried field soil mixed with tap water to stimulate uncontaminated ground condition. In the second phase, to stimulate varying concentration of acidic effluent in soil, the collected acidic effluent has diluted from 10% to 90% and these diluted effluent preserved in separate cans as shown in photo 2. At each stage of experiment instead of distilled /tap water, diluted effluents which are preserved in respective cans are used for compaction and Unconfined Compressive Strength test. The physical and chemical properties of Black Cotton expansive soil are shown in Table 1 and Table 2. Chemical properties of effluents are shown in Table 3.

Photo 1 Storage of Black Cotton Soil treated (soaked) in Acidic effluent

Photo 2 Storage of Acidic effluents collected from the Industry

Table 1 Physical Properties of Expansive soil

Properties	Values
Natural moisture content (%)	8.5
Liquid Limit (%)	77.0
Plasticity Index (%)	54.0
Gravel (%)	0.40
Sand (%)	23.40
Silt (%)	34.20
Clay (%)	42.00
Classification of soil	CH
Compaction test OMC (%) MDD (kN/m^3)	25.80 15.40
Shear strength parameters C (N/mm^2) Φ (^{o})	4.71 10
Unconfined Compressive Strength at MDD and OMC, (kN/m^2)	230

Table 2 Chemical Properties of Expansive Black Cotton Soil

Parameters	Results
Calcium Oxide as CaO, (% by mass)	2.8
Magnesium Oxide as MgO, (% by mass)	1.2
Silicon Dioxide as SiO_2, (% by mass)	64.1
Iron Oxide as FeO_3, (% by mass)	5.6
Aluminium Trioxide as Al_2O_3, (% by mass)	8.43
Loss on Ignition, by mass at 900^{0}C	8.8
Sodium Oxide as NaO_2, (% by mass)	0.086
Potassium Oxide as K_2O, (% by mass)	0.35
Manganese Oxide as MnO, (% by mass)	0.03

Table 3. Chemical properties of effluent

Properties	100% concentrated Effluent	60% concentrated Effluent	Water (Tap)
Pb (µg/l)	16.83	2.32	0.14
Cd (µg/l)	18.01	3.85	0.02
Al (µg/l)	18.22	3.32	0.06
Na (mg/l)	92.00	58.90	28.00
K (mg/l)	6.00	4.20	1.30
Cr (mg/l)	0.11	0.01	0.01

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IV. PROPOSED WORKING METHODOLOGY-FLOW CHART DIAGRAM

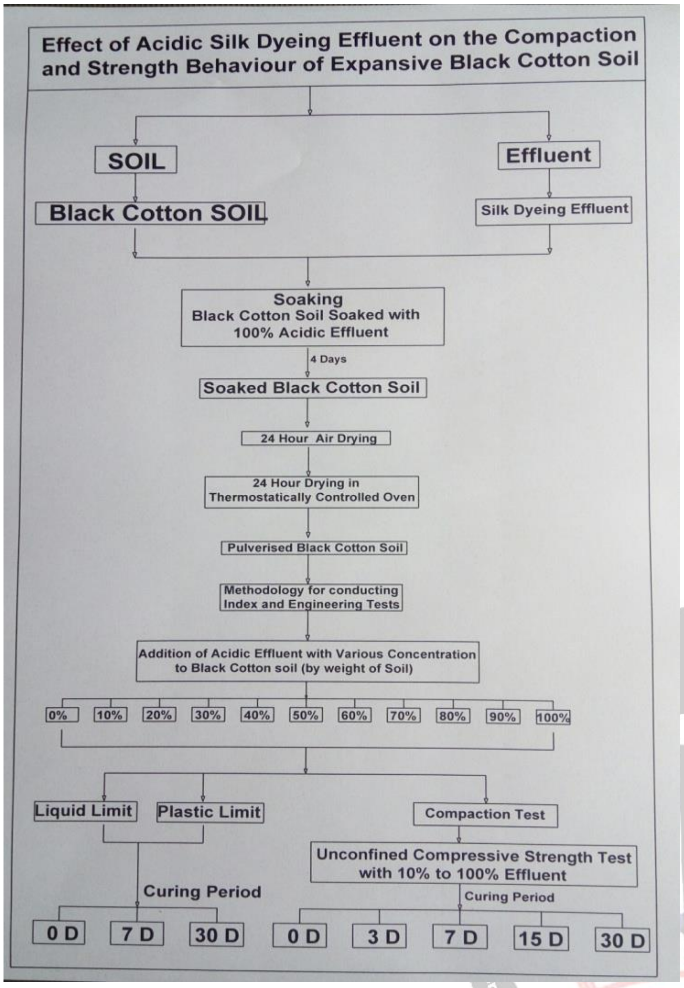

Photo 3. Methodology - Flow Chart Diagram

The black cotton soil is soaked for a period of four days in soaking containers to stimulate site contaminated condition. The soaked soil is air dried for a period of 24 hours and the same is oven dried in a thermostatically controlled oven at 105^0C-110^0C for a period of 24 hours. The soaked and dried soil sieved through 425µ IS sieve has been used for conducting all the tests. On the other hand the similar tests also conducted on black cotton soil with water alone for comparison. The methodology adopted has been shown in Photo 3 flow chart diagram.

V. RESULTS AND DISCUSSION

Effect of acidic effluents on the compaction characteristics of black cotton soil

Figure 1 shows that, Black Cotton Soil treated with varying percentage of acidic effluent increases the maximum dry density and reduces optimum moisture content for all the acidic effluent concentrations. It is also been observed that addition of acidic dyeing effluent shifted compaction curve to the left side of optimum on compared with soil treated with tap water. This may be due to the increase in workability of matrix in presence of acidic effluent.

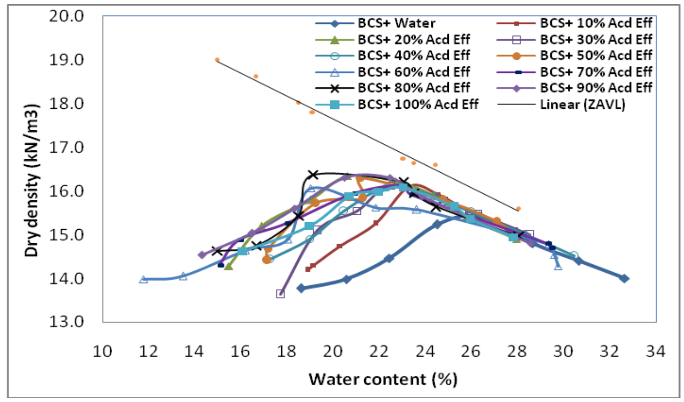

Figure 1 Unit weight – water content relationship of Black Cotton Soil (BCS) treated with varying percentages of acidic effluent concentration

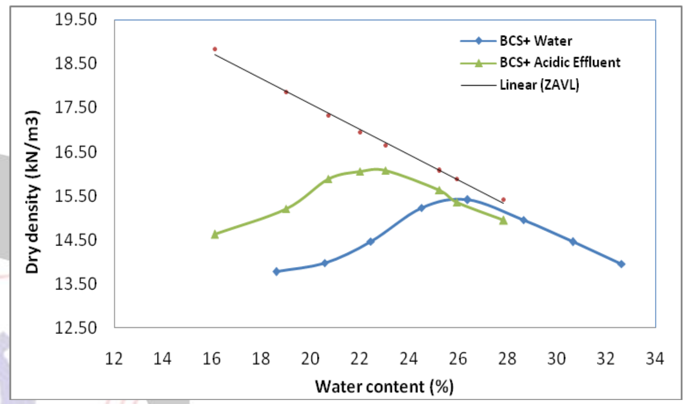

Figure 2 Unit weight –water content of Black Cotton Soil (BCS) treated with water and acidic effluent

Relationship between liquid limit and geotechnical behaviour of contaminated soil

Liquid limit of soil has been correlated with several physic chemical properties of soil. This is because the factors that control liquid limit also control their geotechnical behaviour. Extensive literature is available on them. How they are related to contaminated soil has been studied in this paper. The variation in liquid limit of soils with acidicity of fluid and with curing period is shown in Figure 3. It can be with increase in the acidity of the effluent the liquid limit decreases, optimum moisture decreases and maximum dry density increases.

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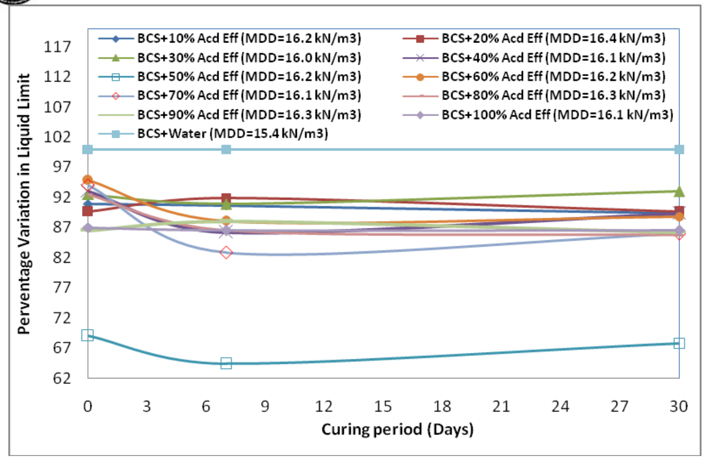

Figure 3 Variation in Liquid Limit with percentages of effluent with curing period

Relationship between Liquid limit and Cation Exchange Capacity of soil and compaction characteristics of contaminated soil

An attempt has been made to relate the liquid limit of the soil with its cation exchange capacity. Relationship between CEC and liquid limit of contaminated soil is shown in Figure 4. It can be seen that both liquid limit and CEC of soil decreases with increasing the concentration of acid contaminated effluent from dye industry.

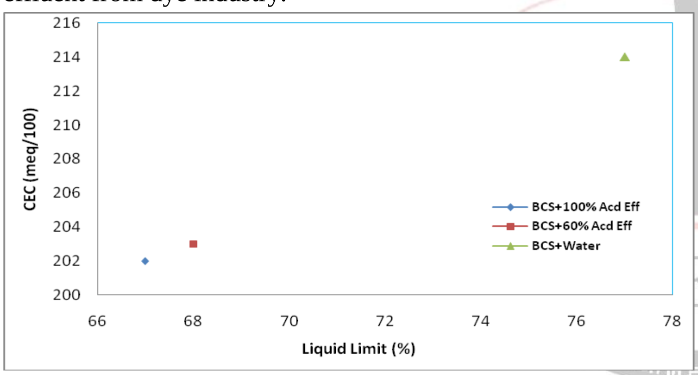

Figure 4 Variation of CEC with Liquid Limit

In the cation exchange capacity of soil soaked with acidic effluent is less than soil with tap water. This might further lead to replacement of existing cations of the soil with silica and aluminium ions leading to effective bonding of cation and reduction in lower surface area and increase in strength. Replacement of ions in the exchangeable complex by aluminium can suppress the double layer expansion. This in fact confirmed by reduction in the OMC of contaminated soil and increase in the MDD as seen from compaction test results. Also the liquid limit of the soil is found to decrease in the activity of the clay. However, Black Cotton Soil treated with 60% acidic effluent (by weight of soil) is found to have higher formation of cluster and strengthening of cluster due to optimal physic-chemical reaction between ions. Hence from 30 days curing, it has been concluded that Black Cotton Soil treated with 60% acidic effluent (by weight of soil) found to be optimum.

It can be seen that as the liquid limit of decreases with increase in the concentration of acidity in the soil which in turn increases the MDD and reduces the OMC of the soil for the same compactive effort (Figure 4 and 5).

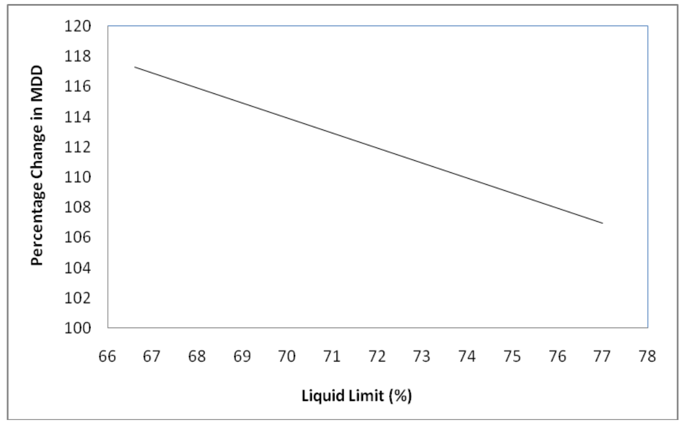

Figure 5 Variation of Maximum Dry Density with Liquid Limit

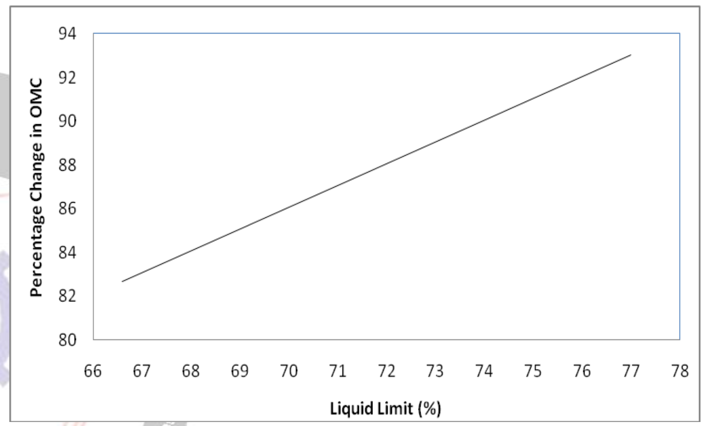

Figure 6 Variation of Optimum Moisture Content (OMC) with Liquid Limit

Effect of Acidic Effluent on Unconfined Compressive Strength of Soil

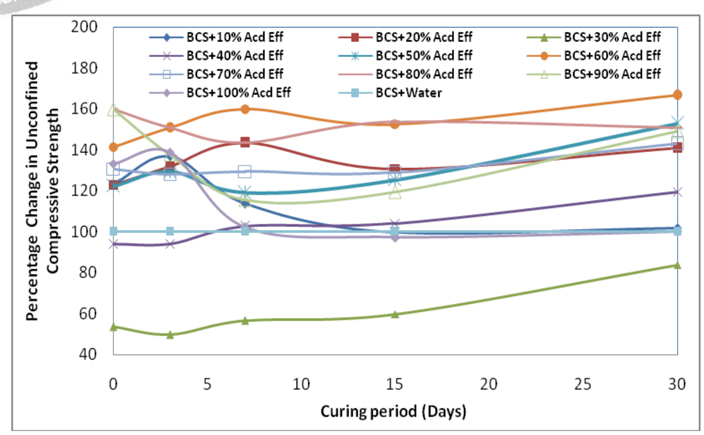

Figure 7 Variation of Unconfined Compressive Strength of Black Cotton Soil treated with water and different percentages of acidic effluent with varying curing period

The results of tests conducted on unconfined compressive strength of soil with different diluted effluents and cured for different periods are presented in Figure 7. From Figure 7 it is

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observed that the unconfined strength of Black Cotton Soil treated with varying percentage of acidic effluent increases for most of the dilutions. The change in strength occurs within one week and remains almost constant with further curing. This may be due to formation of cluster and improvement of cluster with thixotropic effect with curing.

The improvement of unconfined compressive strength of soil treated with acidic effluents can be represented in terms of Percentage Variation as shown below:

$$Percentage\,Variation = \frac{Qa - Qt}{Qt} \times 100$$

Where

Qa = UCS of soil specimen treated with acidic effluent

Qt = UCS of soil specimen treated with tap water

VI. CONCLUSION

Based on the experimental investigation and analysis of investigated results following conclusions were drawn:

Addition of varying percentage of effluent in the pore fluid to the Black Cotton Soil makes the soil more flocculated in nature and thereby with effluent, the compaction curve shifted to left of optima in comparison with soil alone for all combinations for the same compactive effort. From the liquid limit test it is observed that with increase in percentage of effluent the liquid limit and Optimum Moisture Content decreases and Maximum Dry Density increases. This may be because of Black Cotton clayey soil structure originally cemented by calcium carbonate which were partially destroyed by acid as it dissolves the carbonic bond between the clay particles. The results of compressive tests on the indented specimen indicate that these soils with slightly acidic, hydrogen ion engage in the exchange process with cation from the diffused double layer of clay particles. This process affects the behaviour of the soil. Black Cotton Soil soaked with acidic effluent is having lower cation exchange capacity compared with Black Cotton Soil treated with tap water. The Unconfined Compressive Strength test conducted to their respective Optimum Moisture Content and Maximum Dry Density as the Optimum Moisture Content decreases and Maximum Dry Density increases due to formation of cluster during physico-chemical reactions between the ions, strength increases upto 60% acidic effluent by weight of soil for both immediate and with curing. This may be because of strengthening of cluster due to thixotropy of clay and replacement of existing cation of the soil with silica and alumina ions leading to effective bonding of cations and reduction in lower surface area and also increase in the strength. The replacement of ions in the exchangeable capacity by aluminium can suppress the double layer expansion due to reorientation of clayey particles. The strength increases as shown in Percentage Variation Number analysis.

REFERENCES

[1] Amulya M, C R V Prasad, P H P Reddy, G K Kumar, 2015. Effect of sulphuric acid on black cotton soil. *Int. National Journal of Earth Sciences and Engineering*, 196-200.

[2] Christidis G E, Scott P W and Dunham A C, 1997. Acid activation and bleaching capacity of bentonites from the islands of Milos and Chios, Aegean, Greece. *Applied Clay Science*, 12: 329-347.

[3] Dekany I, Turi L, Fonseca A and Nagy J B, 1999. The structure of acid treated sepiolites: small-angle X-ray scattering and multi mass MAS-NMR investigation, *Applied Clay Science*, 14: 141-160.

[4] Gratchev I, Sassa K, 2009. Cyclic behaviour of fine-grained soils at different pH values. *Journal of Geotechnical and Environmental Engineering, ASCE*, 135(2): 271-279.

[5] Gratchev I, Towhata I, 2009. Effects of acidic contamination on the geotechnical properties of marine soils in Japan. Proc ISOPE-2009 Osaka. 19th International Offshore (Ocean) and Polar Clay with Reference to Calcium Carbonate Contents *Journal of ISTM International*, 3:1-9.

[6] Imai G, Komatsu Y, Fukue, 2006. Consolidation yield stress of Osaka-Bay Pleistocene clay with reference to calcium carbonate contents. *Journal of ASTM International*, 3: 1-9.

[7] Mallikarjuna Rao K, V Tirumal Rao, G Reddy Babu, 2008. An interaction of a clayey soil with textile dye waste. *EJGE*. Vol.13 Bund. A: 1-18.

[8] Masashi Kamom, Changyun Ying, Takeshi Katsumi, 1997. Effect of acid rain on physico-chemical and engineering properties of soils. *Soil and Foundation*, Vol. 37 (4), 23-32.

[9] Mitchell J, 1993. Fundamentals of soil behavior. *John Wiley & Sons.*

[10] Narasimha Rao, A V, P Indiramma, 2009. Effect of textile effluent on geotechnical properties of black cotton soil. *Proceedings of Indian Geotechnical Conference*, Guntur, India: IGC, 308-311.

[11] Olphen H, 1991. An introduction to clay colloidal chemistry. *Krieger publishing company.*

[12] Ramesh H N, Manoj Krishna, K.V. Mamatha, H V, 2010. Compaction and strength behavior of lime-coir fiber treated Black Cotton soil, *Geotechnics and Engineering*, Vol. 2 (1), 19-28.

[13] Shivaraju R, B V Ravishankar, H S Nanda, 2011. Engineering properties of soil contaminated with dyeing

 DOI : 10.18231/2454-9150.2017.0053

effluent. *Proceedings of Indian Geotechnical Conference,* 15-17 December 2011, Kochi, India: IGC, 788-790.

[14] Shivaraju R, B V Ravishankar, H S Nanda, Manoj Krishna, 2017. A case study of geological influence for variation in index and engineering behavior of black cotton soil contaminated with acidic effluent through comparative variation number, *IOSR Journal of Applied Geology and Geophysics*, Vol. 5, Issue 6, Ver. I, 01-09.

[15] Sojil Jain and Rajesh Jain, 2015. Change in index properties of black cotton soil due to acid contamination. *International Journal of Engineering Research and Science & Technology*. Vol.4, No.4, 192-196.

[16] Sojil Jain and Rajesh Jain, 2015. Change in engineering properties of black cotton soil due to acid contamination. *International Journal of Engineering Research & Technology*. 192-196. Vol.4, Issue 11, 256-259.

[17] Sridharan A, Prakash K, 1999. Mechanism controlling the undrained strength behavior of clays. *Canadian Geotechnical Journal*, 36: 1030-1038.

[18] Suarez Barrios M, de Santiago Buey C, Garcia Romero E and Martin Pozas J M, 2001. Textural and structural modifications of saponite from Cerro del Aguila by acid treatment. *Clay minerals*, 36: 483-488.

[19] Umesh T S, S V Dinesh, P V Sivapullaiah, 2012. Effect of acids on geotechnical properties of black cotton soil. *International Journal of Geology*, Issue.3 Vol.6, 69-76.

[20] Wang Y, Siu W, 2006 a. Structure characteristic and mechanical properties of kaolinite soils.1. Surface charges and structural characterizations. *Canadian Geotechnical Journal*, 43: 587-600.

[21] Wang Y, Siu W, 2006 b. Structure characteristic and mechanical properties of kaolinite soils.1. Surface charges and structural characterizations. *Canadian Geotechnical Journal*, 43: 601-617.

 DOI : 10.18231/2454-9150.2017.0053