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Effect of Textile Effluent on Geotechnical Properties of Expansive Soil for Flexible Pavements

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Abstract - **Soil stabilization can be done in a number of ways. Chemical stabilization methods are highly effective when compared with mechanical stabilization. But the cost of the chemicals makes the process to be a costly one. The present experimental work studies the feasibility of using textile effluent for the stabilization of black cotton soil. Soil sample taken for the study is highly plastic and requires stabilization. Textile effluent from the local industries is to be disposed after several stages of treatment to minimize the environmental risk. Textile effluent is found to be alkaline and also has the cations that can be utilized in chemical stabilization of clayey soil. Different percentages of textile effluent are added to the soil sample and observations are made for the changes in the properties of soil such as plasticity index, swell index, Unconfined Compressive Strength and California Bearing Ratio. The swelling, plasticity and strength characteristics are considerably increased with addition of effluent. From the observation of geotechnical properties 100% of effluent is observed to be optimum for use in practical purposes. Treatment with effluent is recommended for the improvement of clayey sub grade.**

Index Terms— **California Bearing Ratio , Expansive soil,; Plasticity index, Textile effluent ,Unconfined Compressive Strength.**

I. INTRODUCTION

Black cotton soils are inorganic clays of medium to high compressibility and forms a major soil group in India. This Black cotton soil is available in the central and western parts and covers approximately 20% of the total area of India. It has a high proportion of clay, which is principally montmorillonite in structure and black or blackish grey in color. These soils show a very high affinity towards water, which may be recognized to their small grain size and positive ions present in the particles. Black cotton soil undergoes a severe volume change when it comes in contact with excess water content. These soils swell and shrink with increase and decrease in water content respectively. In the rainy season, the expansive clay minerals attract water molecules and water enters into the inter-plane space between the minerals that lead to an increase in volume. The loss of water from soil minerals results in the reduction in volume which causes the shrinkage of soil and desiccation cracks. The location of free water table and its seasonal variation affects the swelling potential of the soil to a large extent. Uneven swelling and contraction do cause decrease in serviceability, appearance of hairline cracks and many a times differential settlements with severe cracks in structures which can even lead to total failure.

Due to the very low bearing capacity and high swelling and shrinkage characteristics the black cotton soil forms a very poor foundation material for pavement construction. The soil is very hard when dry, but loses its strength completely in wet condition. It is observed that on drying, the black cotton soil develops cracks of varying depth. CBR values of black cotton soils are generally found in the range of 2 to 4%. As per IRC 37, soil with CBR less than 4% is very poor. Due to very low CBR values of black cotton soil, too much pavement thickness is required for designing for flexible pavement. Hence objectionable characteristics are to be modified using a appropriate stabilization technique to get better its engineering performance.

The mechanical and physical techniques of soil stabilization are based on decreasing the void rate by compacting or physically changing the grain size factions involving the adjustment of the particle size composition of soil. The chemical technique is also a common soil stabilization approach, since it produces a better quality soil with advanced strength and durability than mechanical and physical techniques. The chemical techniques are dependent on reaction between chemical additives and soil particles which then produce a strong network that binds the soil grains. Lime has been widely used either as a modifier for clayey soil or as a binder. When clayey soils with high plasticity are treated with lime, the plasticity index is decreased and soil becomes friable and easy to be pulverized, having less affinity with water. Lime also imports some binding action. But usage of lime invites profound cost.

A lot of research work has been carried out in the materials used for soil stabilization.Baglari and Dash had studied the effect of combined application of lime and geo synthetic reinforcement on expansive soil. Addition of lime to expansive soil brings major changes in compaction and strength behaviour of expansive soil [1]. Phani Kumar Vaddi and Balaji Tilak [2] investigated the effect of textile effluent on swell index of expansive soil. The treated soil is less prone to heaving and shrinkage at 100% Textile effluent. BabuShemy et al. concluded from experimental investigation that sub grade characteristics of clayey soil can be improved by the addition of waste sand from EICL [3]. Venkateswarlu and Prasad conducted test on expansive soil treated with quarry dust and from the experimental analysis addition of 10% quarry dust to expansive soil is the optimum percentage [4].

Naman Agarwal [5] carried out tests such as compaction, specific gravity and CBR in the laboratory on expansive clays with different proportions of stone dust and concluded that the

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optimum value is 50%. Ramadas and Kumar suggested from the experimental work that when fly ash and stone dust is added to the expansive soil the Atterbergs limits are decreased and maximum Dry Density, Unconfined compressive strength and CBR values are increased [6]. Akanbi and Job have carried out research on suitability of stabilized black cotton soils with cement and quarry dust for road sub base and foundations [7]. Olaniyan and Okeyinka [8] performed laboratory activity with a general idea of optimizing the mix proportion for mineral polymerization technique such as soil to sand ratio and sodium hydroxide percentage.

The textile effluent is the colored fluid collected from the dyeing industry. The solution before treatment is highly alkaline and has cations like Na+ and Ca2+. In the present investigation, textile effluent is added to the black cotton soil in different percentages and the strength and swelling properties are studied for various concentrations. The main objective of stabilization is to increase the strength or stability of soil and to lessen the construction cost by making best use of the locally available materials. The construction cost can be considerably decreased by using locally available materials for soil stabilization.

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II. MATERIALS AND METHODS

The different materials used for the experimental investigation are Black cotton soil and Textile Effluent.

A. Black Cotton Soil

Expansive Soil (Black cotton soil) investigated in this project is collected from our college campus in Kariapatti village, Virudhunagar, Tamil Nadu, India. The collected sample is dried and crushed to get the soil sample for conducting the soil tests. The index properties and engineering properties of the soil were found from the soil tests in accordance with the procedure mentioned in IS 2270 and are presented in Table 1.Sieve analysis is conducted to observe the grain size distribution of the soil. The grain size distribution curve is plotted and the effective size of soil, Uniformity co-efficient (C_u) and Co-efficient of Curvature (C_c) are found. Specific gravity is defined as the ratio of the unit weight of soil solids to that of water. By conducting the Pycnometer test, the specific gravity of the soil is determined.

The Atterberg limits are a basic measure of the critical water contents of a fine-grained soil, such as its shrinkage limit, plastic limit, and liquid limit. The objective of finding Atterberg Limits is to determine the shrinkage and settlement characteristics of soil. The tests are carried out to find the variation of Liquid Limit, Plastic limit and Plasticity index with different percentage of effluent. The optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density is determined experimentally by Proctor compaction test.

The unconfined compressive strength is obtained by testing a cylinder of soil without lateral support in simple compression, at a constant rate of strain. The compressive load per unit area required to fail the specimen as called Unconfined Compressive Strength of the Soil. The California bearing ratio (CBR) is a penetration test for evaluation of the mechanical strength of natural ground, sub grades and base courses beneath new carriageway construction. The basic site test is performed by measuring the pressure required to penetrate soil with a plunger of standard area. The measured pressure is then divided by the pressure required to achieve an equal penetration on a standard crushed rock material.

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Table 1. Properties of Soil

S.No.	Properties	Value
1.	Grain size distribution	
	a) Gravel	4.1%
	b) Sand	82.1%
	c) Silt + clay	13.8%
	Uniformly Co-efficient (C_u)	4.42
2.	Co-efficient of Curvature (C_c)	0.66
3.	Atterberg limits	
	a) Liquid Limit	62%
	b) Plastic Limit	17.65%
	c) Plasticity Index	44.35%
4.	Unconfined compressive strength	1.055kg/cm^2
5.	Compaction characteristics	
	a) Maximum dry unit weight	1.784g/cc
	b) Optimum moisture content	14%
6.	Flow Index	20.85
7.	Specific Gravity (G)	2.74
8.	Differential free swell index	70%
9.	pH value	7.73
10.	CBR value	3.49%

B. Textile Effluent

Textile effluent used in this process is obtained from local dyeing industry. The waste effluent is collected before treatment. The collected effluent is tested for its chemical composition and the results are presented in Table 2. It was observed that the effluent is highly alkaline. Chloride content in the collected effluent is calculated by titration against standard solutions. Sulphate content in the collected effluent is calculated by using turbidity meter.

. Table 2. Properties of Textile Effluent

S.No.	Properties	Value
1.	Color	Greyish black
2.	pH	9.97
3.	Chlorides	5776.26mg/L
4.	Sulphates	20mg/L
5.	Alkalinity	2150mg/L
6.	Acidity	0

III. EXPERIMENTAL INVESTIGATION

Expansive clayey soil is collected, dried, grinded and stored in containers. Samples are prepared by adding different percentages of textile effluent from 0% to 100% to the soil and storing them in airtight containers for at least a day. Liquid Limit and Plastic Limit of the untreated and treated expansive soil were determined by following standard procedures as per IS: 2720 Part V [9]. Specific Gravity was determined by using pycnometer bottle method as per IS : 2720 Part III [10]. The swelling characteristics of untreated and treated expansive soil with various percentages of textile effluent were determined in the laboratory by following standard test procedure of IS: 2720 Part XL [11]. Unconfined Compressive Strength test was carried out on soil samples with various percentages of textile effluent as per recommendations in IS:2720 Part X [12].In present investigation California Bearing Ratio test was carried out on prepared soil samples of untreated expansive soil and treated expansive soil with various percentages of textile effluent under soaked condition as per recommendations in IS 2720 Part XVI [13].

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IV. RESULTS AND DISCUSSION

A. *Plasticity Characteristics*

To study the effect of textile effluent on Liquid limit, Plastic limit and Plasticity index ,the soil with different percentages of effluent are tested and it was observed that the Plasticity index decreases with increase in the percentage of effluent and reaches a minimum of 14.67% at 100% effluent. The variation of Liquid limit, Plastic limit and Plasticity index with percentage of Textile effluent is shown in Fig.1.

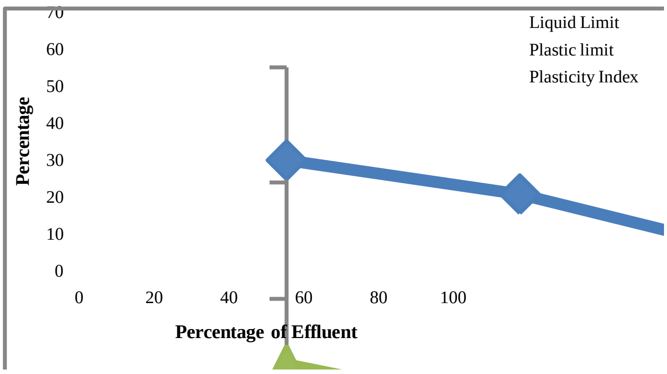

Fig.1. Plasticity Characteristics

B. *Differential Free Swell Index*

Free swell index reveals the swelling characteristics of soil. The variation of differential free swell index with percentage of textile effluent is shown in Fig.2. The differential free swell index value decreases with increase in the percentage of effluent. As a result the swelling potential of soil decreases to 10%.

C. *Unconfined Compressive Strength (UCS)*

The variation of Unconfined Compressive Strength with percentage of textile effluent is shown in Fig..3. There is an increase in unconfined compressive strength as the percentage of textile effluent increases. The unconfined compressive strength of soil increases gradually with an increase in textile effluent. The unconfined compressive strength of the expansive soil can be improved up to 2.493 kg/cm^2.

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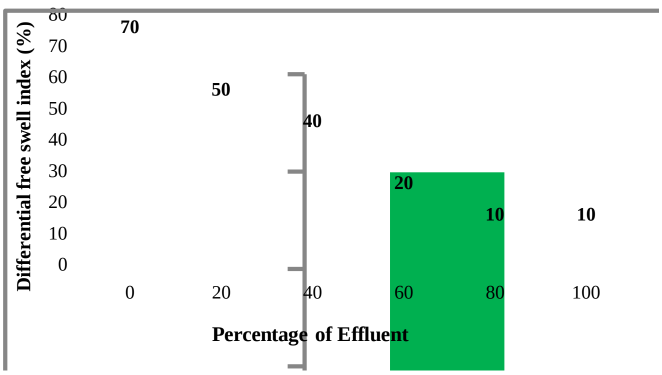

Fig. 2. Variation of differential free swell index with percentage of effluent

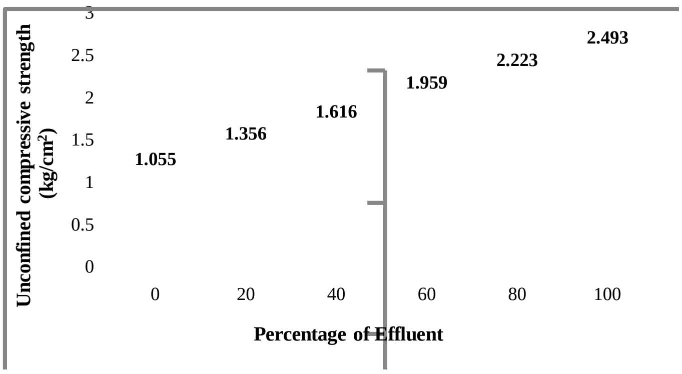

Fig.3. Unconfined Compressive Strength

D. *California Bearing Ratio(CBR)*

Unsoaked CBR of soil is found for soil with various percentage of effluent and the variation of CBR with percentage textile effluent is shown in Fig..4. CBR value increases with the addition of Textile effluent. The maximum California Bearing Ratio value is 5.4% at 100% addition of textile effluent. Improvement of CBR value will help in increasing the suitability of soil for pavement.

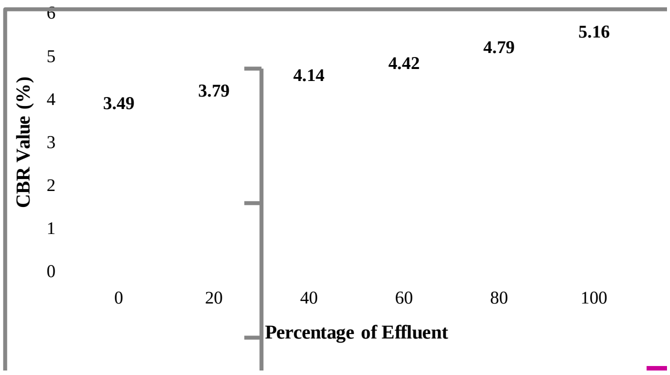

Fig.4. CBR Value Vs Percentage of effluent

V. DESIGN OF FLEXIBLE PAVEMENT

Indian roads congress has specified the procedures for the design of flexible pavements based on CBR values. The flexible pavement has been modeled as a three layer structure. Based on the performance of existing designs and using analytical approach, simple design charts and a catalogue of pavement designs are added in the code. The pavement designs are given for sub grade CBR values ranging from 2% to 10% and design traffic ranging from 1 msa to 150 msa for an average annual pavement temperature of 35°C. Using the simple input parameters, appropriate designs could be chosen for the given traffic and soil strength.

Initial traffic is determined in terms of Commercial Vehicles Per Day (CVPD). For the structural design of the pavement only commercial vehicles are considered assuming laden weight of three tonnes or more and their axle loading will be considered. Estimate of the initial daily average traffic flow for any road should normally be based on 7-day 24-hour classified traffic counts (ADT). In case of new roads, traffic estimates can be made on the basis of potential land use and traffic on existing routes in the area. Traffic growth rates can be estimated (i) by studying the past trends of traffic growth, and (ii) by establishing econometric models. If adequate data is not available, it is recommended that an average annual growth rate of 7.5 percent may be adopted.

For the purpose of the pavement design, the design life is defined in terms of the cumulative number of standard axles that can be carried before strengthening of the pavement is necessary. It is recommended that pavements for arterial roads like NH, SH should be designed for a life of 15 years, EH and urban roads for 20 years and other categories of roads for 10 to 15 years.

A two lane carriage way for our college campus is designed for the improved CBR value based on IRC: 37 2012 [2] for flexible pavement design. The following are the parameters considered for the design of flexible pavement:

- Two lane carriage way
- Initial traffic in the year of completion =400 CVPD
- Traffic growth rate =7.5%
- Design life =15 years
- Vehicle damage factor =2.5
- CBR of untreated soil =3%
- CBR of treated soil =5%

Pavement composition for Untreated sub grade:

Bituminous surfacing =35mm Semi Dense Bituminous Concrete (SDBC) + 75mm DBM (Dense Bitiminous Macadam)
Base = 250mm Water Bound Macadam (WBM)
Sub base = 355mm granular material of CBR not less than 30%

Pavement composition for Treated sub grade:

Bituminous surfacing =35mm Semi Dense Bituminous Concrete (SDBC) + 65mm DBM (Dense Bitiminous Macadam)
Base = 250mm Water Bound Macadam (WBM)
Sub base = 275mm granular material of CBR not less than 30%

In the design of flexible pavements, thickness of different layers obtained for untreated soil and treated soil with textile effluent is shown in Fig.5. When treated with textile effluent, the thickness of dense bituminous macadam and sub base decreases as compared with untreated soil.

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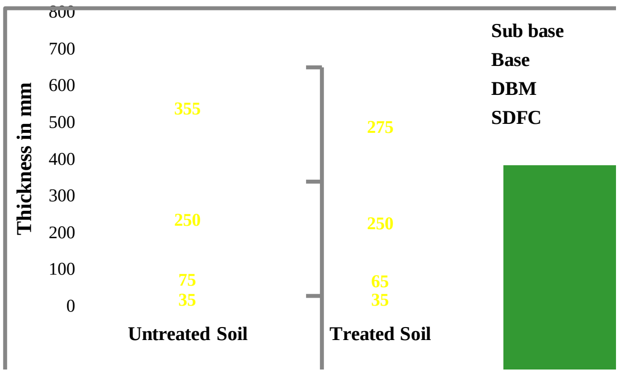

Fig. 5. Comparison of Pavement Composition

VI. CONCLUSION

Black cotton soil is a major soil group in India, covering about 200,000 square miles. Due to its unusual characteristics, it forms a very poor foundation material for road construction. Due to very low CBR values of Black cotton soil excessive pavement thickness is required for designing flexible pavement. Textile industry is one of the largest industries in the world and different fibers such as cotton, silk, wool as well as synthetic fibers are all pretreated, processed, colored and after treated using large amounts of water and a variety of chemicals, there is a need for the safe disposal of the textile effluents. Hence, in this investigation the effect of addition of Textile effluent on plasticity, swelling and strength properties of soil are studied. From the experimental investigation carried out, the following conclusions are arrived at:

- The Plasticity index of expansive soil treated with textile effluent decreases with increase in percentage of effluent.
- The addition of Textile effluent increases the pH of the soil.
- Differential free Swell index of the treated soil decreases with increase in the percentage of textile effluent.
- UCS and CBR values of soil are found to be increasing with increase in percentage of textile effluent.
- Improvement in the properties of soil is highly effective in soil treated with 100% of textile effluent.
- Thickness of the pavement required for flexible pavement is reduced from 715mm to 625mm after treatment

Hence subgrade characteristics of clayey soil can be improved by the addition of Textile effluent.

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