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REINFORCEMENT OF BLACK COTTON SUBGRADE SOIL USING COIR GEOTEXTILE AND ANALYSIS OF RUT DEPTH BY LWT

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ABSTRACT

Considerable length of roads planned to be constructed in India under various programmes is constructed over poor sub grade soil. This study is to Increase the strength of sub grade soil by adding chemical admixtures and to assess the effects of geotextile inclusion and its placement location on the accumulation of permanent deformation. Loaded wheel tester (LWT) is employed in this study to investigate the effect of coir geotextile reinforcement on pavement model of 30 cm × 30 cm × 20cm height mould representing T1 Traffic category (10,000 – 30,000) ESAL designated by IRC. Effects of fly ash, cement and coir geotextile are evaluated in this study by conducting various laboratory tests, including basic tests on soil, compaction and California Bearing Ratio (CBR) tests .The rut depth and wheel repetitions obtained is utilised for predicting the design life of unpaved roads in terms of number of loads repetitions.

Keywords : *Black cotton soil, fly ash, cement, wheel tracking apparatus.*

I. INTRODUCTION

The Expansive soil is a worldwide problem that causes extensive damage to civil engineering structures. Certain areas in India are susceptible to damage from expansive soils than other areas, especially those areas that have large surface deposits of clay and climates characterized by alternating periods of rainfall and drought. Areas with these conditions include most of the parts in southern India .The primary reason expansive soils cause such significant damage is because of their swell and shrink behaviour. For example, a shallow slab-on-grade foundation may heave during the rainy season and then settle during the dry season. Cyclic upward and downward movement of the foundation can cause cracking and fatigue to the structure.

Field measurements of this cyclic upward and downward movement have been recorded. One of the main problems faced by the highway engineers is the instability of subgrade. It is often impossible to build a stable base course over soft sub grade and hence a ground improvement method has to be resorted to. There are many methods of ground improvement such as cement stabilization, lime stabilization, chemical stabilization etc. Several research works are being carried out all over the world to improve its mechanical or engineering properties. Among these researches, major development is the reinforced soil. Reinforced soil is formed by association of frictional soil and tension resistant element in the form of sheets, strips, nets or mats of metal, synthetic or fibre reinforced plastic, coir, jute, etc. Though many published works are available on the study of strength characteristics of stabilized soil, rut analysis is still under research. This paper discusses the strength of subgrade in terms of rutting behaviour of plain soil (unreinforced) and to compare it with that of soil stabilized with fly ash and coir geotextile using Wheel Tracking Apparatus and to placement of geotextile at appropriate depth (h/2, h/3, h/4) to determine the strength of reinforced pavement model of 30 ×30×20 cm height for T1 traffic. T1 means 10,000 to 30,000 (Equivalent single axle load) ESAL

II. OBJECTIVES

The roads laid on BC soil bases develop undulations at the road surface due to loss of strength of the sub-grade through softening during monsoon. BC soil is a highly expansive clayey soil and problem for highway engineers. In dry state it shrinks and becomes so hard that the clods cannot be easily pulverized for treatment for its use in roads Construction. However, chemical stabilization is applied to alter the strength of black cotton soil as they

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reduce the swell shrink tendency of expansive soils and make soil less plastic. One third part of the country roads on black cotton soils are known for bad condition and unpredictable behaviour. Stabilization of problematic black cotton soil with chemical agents like cement or lime is neither economical nor eco-friendly and increases carbon footprints. This work aims at studying the rut behaviour of subgrade soil or unpaved roads reinforced with coir geotextiles and also stabilized with fly ash in place of ordinary Portland cement to reduce the environment hazards factors.

III. MATERIALS USED

The materials used in the study are subgrade soil, fly ash, ordinary Portland cement and coir geotextile.

Subgrade Soil: The subgrade soil selected was black cotton soil from a lake deposit beside NIT Warangal. The engineering properties of the soil were studied in detail and the soil was classified. The properties of the soil are summarized in Table 1. The soil was found to have a very low CBR value of less than 2% (soaked) which shows weak subgrade hence require reinforcement. The properties of the subbase soil for the demonstration of pavement model shown in Table2 .

Table 1 Physical properties of the Subgrade soil

Property	Subgrade soil
Specific gravity	2.62
Sieve analysis gravel (%) sand (%) fines (%)	 0 37.4 62.6
Liquid limit (%)	62
Plastic limit (%)	27
Plasticity index	35
Maximum dry density (kN/m3)%	19
Optimum moisture content (%) (High compaction)	14
CBR value (%) (unsoaked)	5.4
Free swell Index (%)	62
Cohesion C (MPa)	0.11
IS Classification	CH

Table 2 Physical properties of the Sub base soil

Test	Result
Sieve analysis . % gravel % sand % fines	 15 81 4
OMC(high compaction)%	10
Max dry density (g/cc)	1.82

Fly Ash: The fly ash used was supplied from s.v. fly ash brick industry, Warangal selected for stabilization of the subgrade and its properties are listed in Table 3.

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Table 3 Properties of Fly ash

Properties	Value
Specific Gravity	1.9
Sieve analysis	
Fine sand	27
Silt	68
Clay	5
Maximum dry density (g/cc)	1.36
OMC (%)	24
CBR value(Unsoaked)	3.60

Coir Geotextile: Coir Geotextile supplied by the Kerala State Coir Corporation Ltd was used for the study. The properties of the geotextile selected are listed in Table4

Table 4 Properties of Coir Geotextile: H2M8

Properties	Value
Material	100 % natural coir fibre
Construction	Plain weave
Weight (g/m2)	700 (H2M8)
Maximum length (m)	50
Width (cm)	120 to 300
Ends / dm	11.00
Picks / dm	7.00
Thickness (mm)	6.34
Aperture size (mm)	7 x 10
Breaking Load (kN/m)	
-Machine direction	20.34 (Dry); 20 (Wet)
-Cross direction	9.52 (Dry); 8.5 (Wet)

IV. METHODOLOGY

The methodology adopted for the study is detailed as follows.
a) Characterization of the materials for the study
b) Proper mixing of the soil and anchoring of geotextile
c) Selection of possible combination of subgrade.
d) Determination of Compaction & CBR of soil under different conditions of Fly ash content and/or geotextile.
e) Conduct of field simulation tests on subgrade soil systems using Wheel Tracking Apparatus
f) Comparison of rut deformations with CBR

Field Simulation Using Wheel Tracking Apparatus:
Rut analysis was performed on stabilized soil with the help of "Single Wheel Tracking Test Assembly".

Repetitive loads were applied to different types of subgrade samples with different combination of sub base to find the suitable height of geotextile and then different types of subgrade samples only , mixed with fly ash and cement resulting in rut deformation are measured which will help in developing a design methodology for flexible pavements. As per IRC 37-2001, the permissible rut depth is 20 mm. Researchers reported that nearly 50 percent of the total rut formed is attributed to the subgrade beneath and the remaining to the pavement layer over it. Thus by limiting the rut depth to the permissible value for the subgrade the design repetitions can be estimated through a field simulation study using Wheel Tracking Apparatus. Wheel Tracking Test Apparatus consists of a single wheel (test wheel) on which a pan is mounted to keep weights simulating vehicular loads. The test wheel is driven by means of 3 phase, 2 HP electric motor and the load repetitions are counted by means of a digital counter. With the help of the wheel tracking apparatus, wheel loads giving a contact pressure of 0.5-0.7 MPa are applied repeatedly to form rut on the subgrade. Then the rut depth is measured using a Vernier depth gauge (least count = 0.02 mm) at different intervals of load repetitions at different locations of the rut produced.

V. RESULTS AND DISCUSSION

The black cotton soil collected was characterized and its strength parameters were studied in detail. It was found that the CBR value of the soil comes to about 5 percent only which indicates a weak subgrade. The free swell index and expansion ratio indicates that the soil can absorb water heavily, swell, become soft, loose strength, be susceptible to compression and with a tendency to heave during wet condition. They are expansive and can undergo volumetric changes leading to pavement distortion. The properties like CBR and rut depth of the black cotton soil were found to vary with the introduction of marginal materials such as fly ash, cement and geotextile. Anchoring Geotextile at respective heights and then testing under wheel tracking apparatus helps us to know the strength of the pavement model .variations with the depth can be easily seen in figure 1

Table5 variation in depth of geotextile performed in 20 cm mould.

Combinations	Number of wheel repetitions
BC + 10 cm moorum + coir geotextile	255
BC + 15 cm moorum + coir geotextile	492
BC + 5 cm moorum + coir geotextile	985

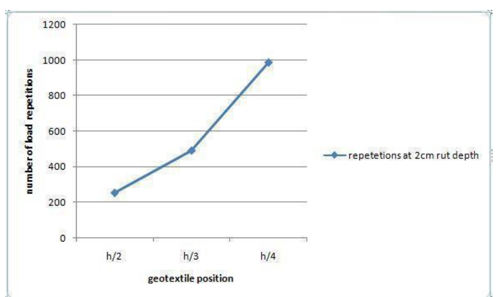

Figure 1: graph showing geotextile position Vs number of load repetitions

Mould is placed on the wheel tracking machine as shown in figure2 and rutting is allowed till 2cm i.e. permissible limit by IRC. It is observed that sample will be failed across its side resembling replica of general shear failure as shown in figure3. Corresponding readings are noted down by anchoring geotextiles at appropriate depth by varying the depth of subbase and subgrade correspondingly is well shown in table 5.

Figure 2: Apparatus setup

Figure3: Sample failure at 2cm rut depth

Table6: Variation in properties with introduction of marginal materials in subgrade soil (Black cotton)

Sl No.	CBR value		Average rut at 1000no. of repetitions	
	Value	%increase	Value (mm)	% increase
1. Soil(BC)	5.4	-	10.4	-
2. Soil +Geotextile	9.6	76.8	9.2	12
3. Soil +5%Flyash +3%Cement	17.5	224	7.1	32
4. Soil + 5%Flyash + 3%Cement +Geotextile	25	362	6.2	41

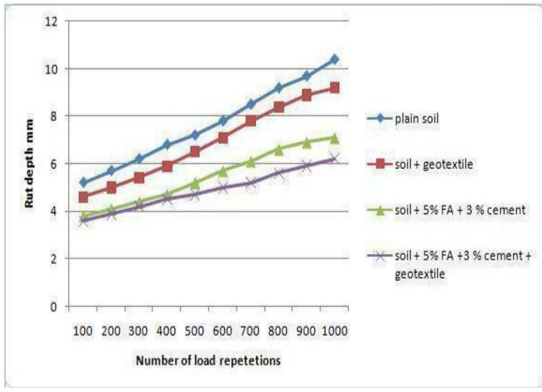

Figure4: Graph showing variation of rut depth with number of load repetitions for different combinations.

Fly ash as a Stabilizing Agent

In order to find out the optimum fly ash content giving the maximum strength, the fly ash content was varied and the different properties were studied. At about 5 percent fly ash content, the CBR was found to increase by 62 percent. Also, with the addition of 3 percent cement along with 5 percent fly ash, the CBR was further increased and the following observations were made.

The CBR value gets increased to 17.5 percent, i.e. an increase of about 224 percent The rut depth has decreased from 10.4mm to 7.1mm at 1000 load repetitions giving a percentage decrease of 32 percent.

Geotextile as Reinforcement

The soil was stabilized with coir geotextile (H2M8). For performing the CBR test, the geotextile was placed at a mid depth of the mould while compacting. In the field simulation test for the measurement of rut depth, a layer of geotextile was provided at a depth of 15cm and above that the soil was compacted in layers to form the subgrade. Variation in CBR and average rut depth with the improvement of subbase and reinforcing with geotextile is shown in Table 6. Distinction of rut depth with number of load repetitions for different combinations of soil with fly ash, cement and geotextile is shown in figure 4. The following inferences were drawn from the experiments conducted on soil reinforced with geotextile:

CBR of soil reinforced with geotextile is increased to 9.6 percent, i.e. about 76.8 percent increase CBR of soil stabilized with 5 percent fly ash and 3 percent cement and reinforced with geotextile is found to be excellent and comes to 25 percent, i.e. an increase of 362 percent. Maximum rut depth in soil stabilized with 5 percent fly ash and 3 percent cement and reinforced with geotextile at 1000 number of repetitions is 6.2mm.

Environmental concerns of Flyash:

Fly ash is a fine powder which is a byproduct from burning pulverized coal in electric generation power plants. Fly ash includes substantial amounts of silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and calcium oxide (CaO). There are about 88 power plants in India, which form the major source of fly ash in the country producing around 131.09 million tons of annually. With the commissioning of new power plants and with the increasing use of low grade coal of high ash content makes the necessity of reuse of fly ash. Since coal contains trace levels of trace elements (like e.g. arsenic, barium, beryllium, boron, cadmium, chromium, thallium, selenium, molybdenum and mercury), fly ash obtained after combustion of this coal contains enhanced concentrations of these elements. The presence of Fine particles and heavy metals in fly ash may lead to substantial amount of air pollution and Groundwater pollution respectively. These environmental problems due to the fly ash makes the necessity of reuse of fly ash. The reusing methods like inclusion in making of bricks, soil stabilization etc.

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VI. CONCLUSIONS

The strength characteristics of the selected subgrade soil in terms of CBR and rut depth along with the appropriate position of Geotextile were studied in detail through various experiments. Measures were adopted to improve the strength by the introduction of marginal materials. The following conclusions were arrived at from the experiments:

i. Wheel Tracking Apparatus can be effectively used for studying the rut failure of pavements simulating the field conditions.
ii. The results of rut analysis found to correlate with the CBR values obtained.
iii. The placement of geotextile at one –fourth in 20 cm mould yields the best results. Most of the stress is taken by the geotextile itself.
iv. Stabilization of black cotton soil with flyash and cement increases its CBR by 224percent and decreases the rut depth by 32percent.
v. Reinforcing the soil with geotextile can improve the strength characteristics of the soil. It can increase the CBR by 76.8percent and decrease the rut depth by 12percent.
vi. The highest performing subgrade was obtained with the application of fly ash, cement and coir geotextile at one fourth distance of total depth from top.

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