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Minimisation of Subgrade Thickness Using Natural and Synthetic Additives in Roads

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Abstract: *This study aims to have an experimental investigation to check the enhancement in the properties of highly compressible or expansive clay soil reinforced with randomly oriented natural and synthetic fibers such as coir fiber and nylon tyre-cords respectively. The area chosen for investigation was village roads of Thanjavur district. Consistency limits identified were used in classification of soil as per IS standards. The Engineering properties of soil sample collected were investigated by treating it with these fibers as additives in the percentage of 0.1%, 0.2%, 0.3% and 0.4%. The Engineering properties includes maximum dry density, unconfined compressive strength and California bearing ratio were determined in the laboratory for both soil treated with and without fibers. In addition to the optimum mix of traditional fiber the expansive clays were also treated with non-traditional Bio-enzyme stabilizer. The pavement subgrade thickness was designed based on the CBR value as per IRC recommendations.*

Keywords: *Bio-Enzymes, Consistency, Subgrade, Tyre cords, Unconfined Compressive strength*

I. Introduction

The demand for transportation leads to increase in roadways, railways, airways and waterways. Except waterways the other means of transports requires good pavement with high subgrade strength. In place of highly compressible or highly expansive soil the achievement of good subgrade strength is the challenging task. In order to improve the strength of the soil various methods have been adopted. The ground improvement by additives is the evolution of recent researches, which includes both natural [1] and manmade synthetic materials [2]. Also reduction of dump wastes is also essential for the eco-friendly environment. Waste dump material found in abundant and also can be used as an additive for the stabilization of expansive soil includes quarry dust, ceramic dust, flyash, reinforcement concept by various fibers [3] in various proportions. Of which the soil reinforcement by natural or synthetic fibers are the findings of recent research.

The present study includes the utilization of Coir fiber, Tyre cord fiber and Bio enzyme in the stabilization of expansive soil thereby enhancing the subgrade strength by improving the geotechnical properties and economization by reducing the thickness of subgrade. The area chosen for the study includes the village roads of Budalur (Sample A) and Orathur (Sample B) of Thanjavur districts. The reason behind the selection of these area was due to its high expansive or compressible in nature. The main aim of this experimental study is to enhance the geotechnical properties of these sites by soil reinforcement through randomly oriented fibers and designing the reduced thickness of the subgrade.

II. Materials

The materials for this study includes the soil sample collected from the two village roads of Thanjavur District, soil reinforcement by Coir fibers from coconut and Nylon tyre cord fibers [4]extracted from the waste tyres. Nontraditional stabilizer Bio enzyme was also used as an additive for stabilization. The index properties of the soil was identified in the laboratory which is shown in the table 2.1 were the main source of classification of the soil. The additive materials are shown in figure 2.1 and 2.2 whereas the properties are tabulated in the table 2.2 and 2.3. The Enzyme properties were listed in the table 2.4.

2.1 Bio-Enzyme

One commercially available Bio-enzyme has been used in the present investigation. It is available as a concentrated liquid and is to be diluted with water in specified proportion before mixing with the soil. The manufacturer's information available for this product is presented in Table 2.4. According to the literature, when mixed with water and applied, the enzyme solution combines the inorganic and organic material in the soil through a catalytic bonding process, producing a "cementation" action. Soil stabilization using enzymes is a relatively new approach to soil improvement.

Fig 2.1 Coir Fiber

Fig 2.2 Nylon Tyre Cord fiber

Enzyme promotes the development of cementitious compounds using the following, general reaction. The organic cation also reduces the thickness of the electrical double layer. This allows the enzyme treated soils to be compacted more tightly together.

$$H_2O + Clay + Enzymes \longrightarrow H_2CaO_4Si$$

(Calcium Silicate Hydrates)

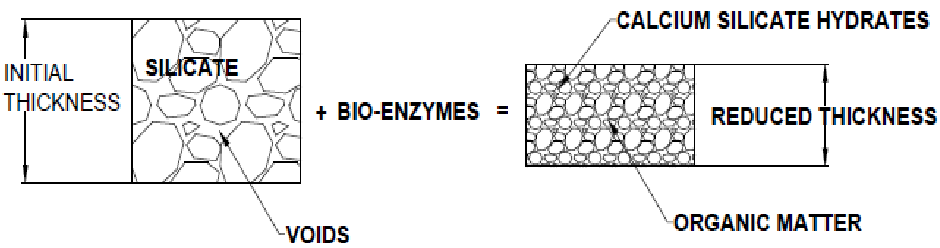

Fig 2.3 Enzyme Reaction

Table2.1: Properties of Soil

S.No	Properties	Sample A	Sample B
1	Specific Gravity (G)	2.51	2.60
2	Liquid Limit, LL (%)	54.1	77.10
3	Plastic Limit, PL (%)	39.3	52.5
4	Free Swell Index	87.5%	91%

Table 2.2 Properties of Coir

Properties	Values
Physical Properties	
Length in inches	6-8
Density (g/cc)	1.40
Tenacity(g/Tex)	10.0
Breaking Elongation%	30%
Diameter in mm	0.1 to 0.5
Rigidity of Modulus	1.8924 dyne/cm^2
Chemical Properties	

Lignin	45.84%
Cellulose	43.44%
Hemi –Cellulose	0.25%
Pectin's and related compound	3.0%
Water soluble	5.25%
Ash	2.22%

Table 2.3 Properties of Nylon Tyre Cord

Properties	Values
Tensile Strength	95-180 N/mm^2
Impact Strength	6.0-12.0 Kj/m^2
Melting point	200-300^{0}C
Density	1.12-1.30g/cm^3

Table 2.4 Enzyme Properties

Physical/Chemical Characteristics	
Boiling Point	212^{0}F
Specific Gravity	1.05
Evaporation rate	Same as water
Solubility in Water	Complete
Appearance/Odor	Brown liquid, Non-obnoxious

2.2 Enzyme Dosage

The enzyme dosage varies from 200 ml/3m^3 to 200 ml/1m^3 of the soil, and it depends upon soil properties [15]. In this experimental investigation enzyme dosage of 200ml for 1m^3 of soil is considered to study the variation in geotechnical properties of the selected soil.

III. Methods of Experiments

The experimental work was categorized into three phases. The phase I includes the determination of index properties, second phase comprising the determination of Engineering properties and last phase involves the designing of subgrade pavement thickness.

3.1 Index Properties

Index properties tests were carried out mainly aiming at classification of soil and the tests done are specific gravity (G_s), Liquid limit (w_L), Plastic limit (w_P), differential free swell index.

3.2 Engineering Properties

Identification of geotechnical properties plays a vital role in evaluation of shear strength, settlement, permeability etc., undrained shear strength or Cohesion c_u and angle of shearing resistance φ are the basic shear strength parameters to be determined from the Engineering properties tests. The tests carried out in this experimental study include the Standard proctor compaction test to identify the maximum dry density for the corresponding optimum moisture content, unconfined compression test and California Bearing Ratio test [5].

3.3 Design of subgrade thickness

IRC method [9] (as per IRC 37-2001)

$$\mathbf{A} = \mathbf{P}\ (\mathbf{1}+\mathbf{r})x \qquad \ldots\ldots\ldots\ldots(1)$$

Where,
A = Initial Traffic in the year of completion of construction in terms of the number of commercial vehicles per day.
P = number of commercial vehicles as per last count = 1050
r = annual growth rate of commercial vehicles = 5% (i.e 0.05)
x = number of years between last count and the year of completion of Construction = 2 years
A = 1050 (1+0.05)2
A = 1157.6

Design Traffic in terms of the cumulative number of standard axles

$$\mathbf{N}=\mathbf{365} \times[(\mathbf{1}+\mathbf{r})\mathbf{n}-\mathbf{1}]\mathbf{r} \times\mathbf{A}\times\mathbf{D}\times\mathbf{F} \ \ldots\ldots(2)$$

Here,
r = 0.05

n = design life in years = 12 for Village Road
(10-15 years)
D = Lane distribution factor
= 50% (i.e.0.50) for single lane carriage way
F = Vehicle damage factor = 3.5 for traffic volume of 150 – 1500
Commercial Vehicle Design (CVD)

$$N = \mathbf{365} \times [(\mathbf{1}+\mathbf{0.05})^{\mathbf{12}}-\mathbf{1}]/\mathbf{0.05} \times \mathbf{1157.6} \times \mathbf{0.50} \times \mathbf{3.5}$$
= 11.76 msa

IV. Experimental Programme

The results of the experimental study obtained by conducting various tests in the laboratory for determining the enhancement in the geotechnical properties using fibers in different proportions were tabulated and shown in figures.

4.1 Standard Proctor Test

The relevant calculations were carried out and the compaction curve was plotted for the dry density corresponding to moisture content. The maximum dry density is finally obtained from the maximum point of the compaction curve and its corresponding water content, also known as the optimal moisture content.The results obtained for trials with no fibers added, coir fibers and tyre cord fibers in different percentages were shown graphically in figure 4.1.

4.2 Unconfined Compression Test

Shear strength properties of purely cohesive soil (φ=0) is determined in the laboratory quickly and easily by using unconfined compression test.The test was conducted for various percentages of coir fiber and tyre cord fiber and these results were compared with unconfined compressive strength of sample without fiber. The test results were shown graphically in figure 4.4

4.3 California Bearing Ratio Test

It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material.

C.B.R. = {Test load/Standard load} ×100 ……(3)

The test may be performed on undisturbed specimens and on remolded specimens which may be compacted either statically or dynamically. By Conducting a load penetration test in the laboratory the CBR value was determined. The CBR value obtained for both Sample A and B by adding fibers with different percentages were compared with the samples without fiber. The results obtained were shown graphically in figure 4.6.

Fig 4.1 Proctor Compaction Mould

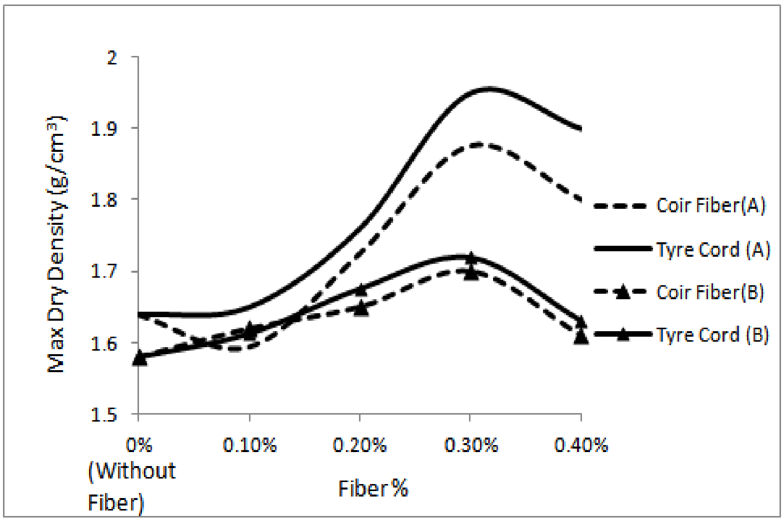

Fig 4.2 Standard Proctor test results

Fig 4.3 Unconfined Compression Strength Test

4.4 Design of Subgrade Thickness

The subgrade thickness was calculated as per IRC recommendation (IRC 37-2001). The length of the road was assumed to be 1km and width of the lane as per recommendation.

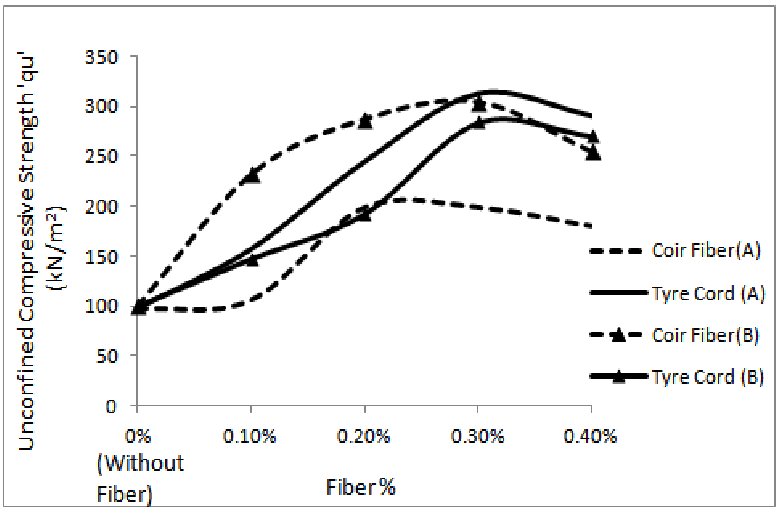

Fig 4.4 UCC Test Results

Fig 4.5 CBR Test setup

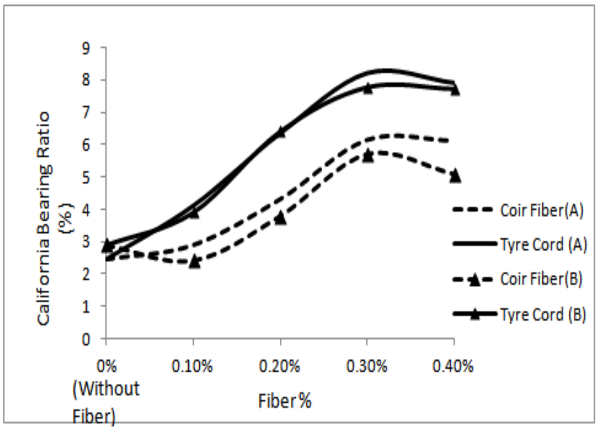

Fig 4.6 CBR Test Results

V. Observations

- The consistency test reveals that the soil was highly expansive or compressible. Based on the plasticity chart recommended by BIS classification the soil is classified as highly compressible Clayey soil and it is proven by differential free swell index.
- Among the two samples, sample B is found to be more swelling than sample A.

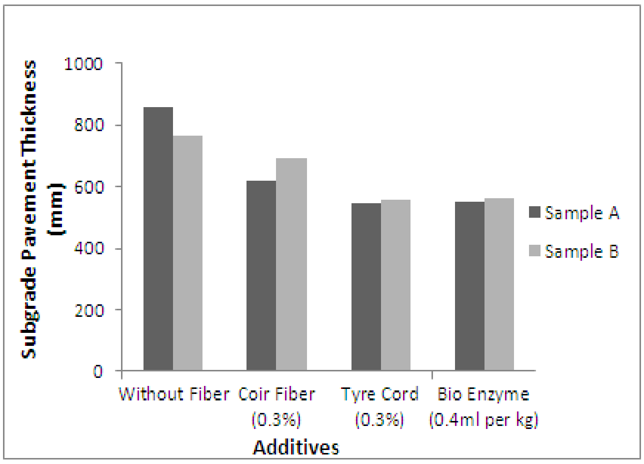

Fig 4.7 Sub grade Thickness

- From the standard proctor test it is observed that maximum dry density achieved for samples with fiber is higher than for the samples without fiber. Among the samples containing fiber the tyre cord fiber mix samples achieved higher maximum dry densities than the coir fiber mixed samples.

- Greater value of unconfined strength is achieved for sample B than Sample A. The coir fiber samples yield higher strength than the tyre cord fiber sample and sample without fibers.
- Similar to the standard proctor compaction test the CBR value was found to be more for tyre cord fiber samples.
- From all the tests it was observed that the 0.3% addition of fiber yields higher value and it can be considered to be the optimum mix for the sample A and B.
- The 0.4ml of Bio-Enzymes added to the soil and tested after a curing period of a week gives an equivalent strength of Nylon tyre cord fiber mix soil.
- It is to be noted that the thickness of pavement reduced by the addition of Bioenzyme was coherent to the Tyre cord fiber added soil.

VI. Conclusion

- Thus the study was carried out in three phases and in all three phases the results obtained using the fiber mix and enzyme mix in different percentages showed improved results when compared with the soil without additives.
- Based on the tests conducted for the enhancement in the shear strength properties of soil the subgrade thickness was designed.
- Also the study showed significant results in the reduction of pavement thickness which greatly minimized the requirement of quantity of soil.
- Since it reduces the quantity of soil required by addition of low cost fibers and natural enzymes, the project was proved to be an economic and also ecofriendly by greatly minimizing and reusing the harmful waste at the dumpsites.

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