Subgrade Soil Improvement Using Coir Geotextiles and Geocells

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***Abstract*— For the design of pavement structure the subgrade soil and its properties are important as it gives adequate support to the pavement. To increase the life of pavement the subgrade must be able to support loads transmitted from pavement structure without excessive deformation under adverse climatic and traffic conditions. For using the soil as a good quality pavement material, it is a well known fact that all soils do not possess all the desirable qualities. The subgrade performance of such soils should be increased by several modification techniques, when such soils cannot be replaced. Among that providing reinforcement to improve subgrade soil nowadays is widely adopted. Nowadays many reinforcing techniques are used to reinforce the soil, among that coir geotextile is most widely used. As it is a natural geotextile it needs treatment to improve the durability. In this study woven coir geotextile and coir geocells are used as soil reinforcement to improve the subgrade soil and NaOH is used to treat the geotextiles. The improvement in CBR value when coir geotextile placed at different depth in CBR mould is studied. The coir geocells with an aspect ratio of 0.75, 1 and 1.33 is used. The maximum improvement in CBR value is obtained when geotextile is placed at 1/3H. The CBR value improved when treated coir geotextile is used and the percentage improvement is 66.8% for coir geotextiles placed 1/3H and the percentage increase for treated coir geocells when placed at 1/3H is 37.5% . The optimum height of coir geocells is obtained at an aspect ratio of 1.**

Keywords—CBR, geotextile, geocell

I. INTRODUCTION

The transportation infrastructure should be developed for the overall development of a country. To achieve this the quality of level of service provided by roads should improve. In our country, a well connected road network is the basic infrastructures which play a vital role for the fast and comfortable movement of inter regional traffic.

For a rigid or flexible pavement subgrade is the lowermost layer. It acts as the foundation for the pavement which transfers load to the soil beneath. For the design and construction of pavement subgrade is very important, the stronger it is the lesser the thickness of other layers (i.e. base, subbase and surfacing) laid on it, the longer the useful life of the pavement and the lesser the cost and frequency of maintenance.

If roads are built on poor subgrade soils, deformations can occur, thus which increase maintenance cost and lead to interruption of traffic service. It is important to explore alternative construction methods with longer service life and cost effective as the material and construction costs are increasing. For this different ground improvement methods are used.

Most commonly used ground improvement method is reinforcing the soil. Geotextiles are commonly used for reinforcing the soil. The strength of geotextile is derived from a substantial amount of settlement of the structure which, though acceptable in unpaved roads, may not be suitable for paved roads or any kind of structure where large settlement causes severe damage to the structure. This necessitates the use of high-modulus geotextiles or any confinement technique like geocell or geoweb.

Geocells completely encase the soil and provide all-around confinement, thus preventing the lateral spreading of the infill material. The stiffness and the load-deformation behaviour of soil layers will increase due to the confinement of the soil geocell layers and thereby reduces the deformation of the soil. The vertical traffic loads will distribute over a larger area of the subgrade soil by acting the soil geocell layer as a stiff mat.

Abdul et al., (2015) found that the use of coir geotextiles as subgrade reinforcement increased the subgrade strength and reduced the settlement. The coir geotextile significantly decreased the permanent vertical deformation over the loaded area of the pavement under repeated loading by restraining the lateral spreading of base material. Rajkumar et al., (2012) studied the performance of woven and nonwoven geotextile, interfaced between soft subgrade and unbound gravel in an unpaved flexible pavement system is carried out experimentally, utilizing the California Bearing Ratio (CBR) testing arrangement. And found that woven geotextiles give better performance compared to non woven geotextiles.

Bindu et al., (2015) conducted plate load tests on soft clay bed using coir geocell mattresses with varying height. They concluded that the optimum height of geocell in chevron pattern with vertical strips at the joints is equal to width of the loading plate. Further increase in height had no significant effects in improving bearing capacity.

Nowadays coir geotextiles are most commonly used as it is easily available and economical. In this study coir geotextiles and geocells were used for reinforcing the soil. A series of soaked and unsoaked CBR tests are conducted to determine the improvement of poor subgrade soil.

II. MATERIALS AND METHODOLOGY

The soil used is kaoline clay collected from English India Clay Limited, Trivandrum and coir geotextile collected from Alappuzha. The initial properties of soil are determined and the physical properties of coir geotextile are obtained from the manufacturer.

The initial properties of kaoline clay are given in the Table I and the physical properties of coir geotextile are shown in table II. The particle size distribution of soil is given in figure1

In the present study treated and untreated coir geotextile and geocells placed at different depths, 1/3H, 1/2H and 2/3H of CBR mould (H is the distance from top of the mould) and CBR value is found out by conducting soaked and unsoaked CBR tests as per IS 2720: 1987 (Part 16). The CBR tests are conducted by taking about 5kg of soil mixed with optimum moisture content and filled in five layers in the mould and compacted by providing 56 blows for each layer using a rammer weighing 4.89kg dropping from 450mm height. After filling the mould with soil the collar is removed and the mould is taken to the CBR apparatus and load is applied. The CBR value corresponding to 2.5mm and 5mm penetration is noted. For reinforced soil samples the geotextile is placed at required layer. The soil samples are tested after 4 days of soaking in water. The coir geotextile is treated by using NaOH at 0.1M. The coir geocells are made by cutting the coir geotextiles into strips of required length and heights and then sides are stitched. Coir geocells are made in chevron pattern as it gives better performance over diamond pattern [3]. Diameters of geocells are kept constant as 0.8D throughout (D, width of footing). The heights of geocells are varied and three different aspect ratios are used 0.75, 1 and 1.33.

TABLE I. INITIAL PROPERTIES OF KAOLINE CLAY

Properties	Values
Liquid limit (%)	32
Plastic limit (%)	22.6
Plasticity index (%)	11.7
Shrinkage limit(%)	15.7
Specific gravity	2.6
Maximum dry density (g/cc)	1.56
Optimum moisture content (%)	24.2
Is classification	CL
Unconfined compressive strength (kN/m^2)	70
Particle size distribution	
• Percentage of sand (%)	4
• Percentage of silt (%)	45
• Percentage of clay (%)	51

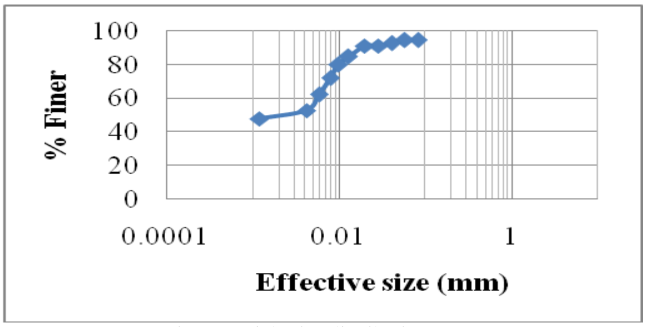

Fig 1. Particle size distribution curve

TABLE II. PHYSICAL PROPERTIES OF COIR GEOTEXTILE

CHARACTERISTICS	VALUES
Mass (gms/m^2)	900
Thickness at 20kPa(mm)	6.5
Ends(Warp) (coir yarn of appropriate twist and strength made from coir fibres of specified length and diameter)	210
Picks(weft) (coir yarn of appropriate twist and strength made from coir fibres of specified length and diameter)	250
Trapezoidal Tear Strength (cross machine direction)	0.15N
Trapezoidal Tear Strength (machine direction)	0.50N
Break Load for Dry Coir (minimum) (machine direction)	15kN/m
Break Load for Dry Coir (cross machine direction)	8kN/m
Break load for wet Coir (minimum) (machine direction)	12.5kN/m
Break load for wet Coir (minimum) (cross machine direction)	5kN/m
Aperture size (mm)	4.2×5.2
Initial tangent modulus at 5mm deformation	65-75 kN/m

III. RESULTS AND DISCUSSIONS

The CBR values of soaked and unsoaked soil with and without coir geotextiles and unsoaked CBR values of coir geocells are determined in the laboratory. The geotextile is placed at 1/3H, 1/2H and 2/3H (H, height of mould from top) in the mould and CBR values are determined. The maximum improvement in CBR value is 4.7%, obtained when the geotextile is placed at 1/3H as explained by Gopichand et al., (2016). Because when it is placed at 1/3H it is within the pressure bulb. When the geotextile is placed at 1/2H as it is nearer to the pressure bulb the CBR value is increased and the value is 4.26%. There is not much increase in CBR value when it is placed at 2/3H because it is at a greater depth from pressure bulb. The CBR value of treated coir geotextile for soaked and unsoaked condition is also found out and the improvement in CBR value is noted. The increase in CBR value for treated reinforcement is 7.99% when it is placed at 1/2H.

For soaked soil samples the CBR value is increased compared to unreinforced soil samples. The maximum value is obtained when the reinforcement is placed at 1/H and the maximum value is 3.99% for untreated soil samples and 4.79% for treated soil samples. The values are shown in table III.

When coir geocells are used the CBR value is increased. By increasing the height of geocell the CBR value is increased but after an aspect ratio 1 the increase is not much significant [2]. The maximum increase in CBR value is obtained when the coir geocell is placed at 1/3H. The CBR values of treated coir geocells also increased and the value is increased upto 11.98%. The CBR values of soil samples with treated and untreated coir geocells with an aspect ratio 0.75, 1, 1.33 are given in table IV, V, VI respectively.

TABLE III CBR VALUES OF TREATED AND UNTREATED COIR GEOTEXTILES

Test condition	CBR value of unreinforced soil samples	CBR value of soil samples when coir geotextile placed at			CBR value of soil samples when treated coir geotextile placed at		
		1/3H	1/2H	2/3 H	1/3 H	1/2 H	2/3H
Unsoaked	2.39%	4.79%	4.26 %	3.99 %	7.99 %	7.19 %	6.39 %
Soaked	1.59%	3.99%	3..19 %	2.39 %	4.79 %	3.99 %	3.19 %

TABLE IV CBR VALUE OF COIR GEOCELLS WITH AN ASPECT RATIO 0.75

Test condition	CBR value of unreinforced soil samples	CBR value of soil samples when coir geocell placed at			CBR value of soil samples when treated geocell placed at		
		1/3H	1/2H	2/3 H	1/3 H	1/2 H	2/3H
Unsoaked	2.39%	7.99%	7.19 %	6.39 %	14.38%	13.58%	11.98 %

TABLE V CBR VALUE OF COIR GEOCELLS WITH AN ASPECT RATIO 1

Test condition	CBR value of unreinforced soil samples	CBR value of soil samples when coir geocell placed at			CBR value of soil samples when treated geocell placed at		
		1/3H	1/2H	2/3 H	1/3 H	1/2 H	2/3H
Unsoaked	2.39%	12.78 %	11.98 %	11.1 %	17.58%	15.98%	14.38 %

TABLE VI CBR VALUE OF COIR GEOCELLS WITH AN ASPECT RATIO 1.33

Test condition	CBR value of unreinforced soil samples	CBR value of soil samples when coir geocell placed at			CBR value of soil samples when treated geocell placed at		
		1/3H	1/2H	2/3 H	1/3 H	1/2 H	2/3H
Unsoaked	2.39%	13.58 %	12.78 %	11.98%	19.18%	16.78%	15.18 %

IV. CONCLUSIONS

The subgrade soil improves when soil is reinforced with geotextiles. The geocell reinforcement gives better performance compared to geotextiles. The major conclusions obtained from the study are

- The CBR value of reinforced soil is increased compared to unreinforced soil. Thus by providing coir geotextiles and geocells the weak soil can be used for pavement construction.
- The maximum improvement in CBR value is obtained when the geotextile is placed at 1/3H.
- Sodium hydroxide treated coir geotextiles gives better performance compared to untreated geotextiles. Hence treatment of coir geotextile is beneficial for improving the CBR value and the percentage improvement in CBR value is 66.8% when it is placed at 2/3H.
- The soaked CBR value also improved when coir geotextiles are used.
- The geocell reinforcement gives better performance than geotextiles. The maximum value of CBR when coir geocell placed at 1/3H is 13.58% and for untreated coir geotextiles the maximum CBR value is 4.79%. The optimum height of coir geocell is equal to the width of footing.
- By using the treated coir geocells the CBR value improved upto 19.18% when placed at 1/3H.

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