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Stabilization of soil using sisal, polypropylene and hybrid fibers

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ABSTRACT

Geotechnical engineers face various problems while designing foundation because of clayey soil due to poor bearing capacity and excessive settlement. So, we rectify that with various engineering works but in this project we choose fibers for improving soil parameters, this method is cost-effective and eco-friendly one. The clay sample was collected from Devakottai, Tamil Nadu, and India. Sisal, polypropylene, and hybrid of these two fibers were used for soil stabilization. The sisal fiber was mixed 0 .1%, 0.2%, 0.3% and 0.4% by weight of the soil samples. Similarly, polypropylene fiber was mixed 0.5%, 1%, 1.5% and 2% by weight of the soil samples and hybrid fiber mixed soil samples randomly distributed. The effect of fiber addition on soil stabilization was evaluated by conducting tests such as Atterberg's limits, Standard Proctor compaction test, Unconfined Compressive strength test, Specific gravity test, and California bearing ratio test.

Keywords— *Soil stabilization, Sisal fiber, Polypropylene fiber, Hybrid fibers, Shear strength, Unconfined compressive strength, Bearing capacity*

1. INTRODUCTION

The foundation soil is very important in the Civil Engineering field to support the structure and resist the entire load. Therefore, a foundation should be strong enough to increase the service life of any structure. Some soils are not suitable for foundation work so these soils are stabilized to achieve the required properties needed for construction work. Various methods are involving soil stabilization by mechanical and additive methods. But, here we choose one of the additive methods that are the cost-effective and eco-friendly one. Soil reinforcement by fiber material is considered an effective ground improvement method because of its cost effectiveness, easy adaptability, reproducibility. The use of random flexible fibers gives the possibility of improving the strength and the stability of near-surface soil layers. The use of natural fibers as soil stabilizers is a good method because of their biodegradable property. There are many advantages where using sisal fibers (e.g. resistance to fungi, excellent insulation against temperature and sound, tough and durable). Here in this project, soil stabilization has been finished the help of at randomly distributed of sisal fiber, polypropylene fiber and hybrid of these two fibers.

From the previous researches, the increase in fiber length and fiber content reduce the dry density and optimum moisture content [9].

Increase in fiber content caused an increase in strength and shrinkage potential but brought on the reduction of swelling potential. An increase in curing duration improved the unconfined compressive strength and shear strength parameters of the stabilized soil significantly [8].

Increase in fiber content causes a significant improvement in the shear strength parameters (c and φ) [6].

Increase in sisal fiber introduces a reduction in the maximum dry density and the optimum moisture content of the soil. It also indicated an improvement in the CBR value and unconfined compressive strength of soil due to the addition of sisal fiber [7].

For a certain percentage of fiber contents in the compaction tests, the maximum dry density of stabilized soil increased and optimum moisture content decreased [10].

Hence, in this project, The various proportion of sisal fiber (0.1%,0.2%,0.3%,0.4%) is used with natural soil and also use the various proportion of polypropylene fiber (0.5%, 1%,1.5%, 2%) with natural soil to know its strength and CBR value. After getting the optimum result of these two, then the soil will be stabilized using the hybrid fibers while taking any one of the

fiber as a constant percentage and another one is mixing with a various percentage to know its strength behaviour.

2. MATERIALS AND METHODOLOGY

2.1 Methodology

Clay soil mixed with sisal fiber in the percentage of 0.1%, 0.2%, 0.3% and 0.4% corresponding soil weights. Clay soil mixed with polypropylene fiber in the percentage of 0.5%, 1%, 1.5% and 2% corresponding soil weights. Clay soil mixed with hybrid fiber, the sisal fiber percentage is 0.3% because it gives maximum increasing strength rate but 0.4% gives maximum strength but workability property will be affected so, we choose 0.3% percentage for sisal fiber , that percentage will constant and polypropylene fiber percentage will vary with 0.1%, 0.2%, 0.3% and 0.4% corresponding the soil weights.

2.2 Experiments

- The specific gravity of soil
- Determination of soil index properties(Atterberg's Limits)
- Liquid limit by Casagrande's apparatus
- Plastic limit
- Determination of the maximum dry density (γ_{dmax}) and the corresponding content (OMC) of the soil by Standard Proctor compaction test.
- Preparation of reinforced soil samples.
- Soil sample with sisal fiber (Natural Fiber)
- Soil sample with poly propylene fiber (Synthetic Fiber)
- Soil sample with a combination of both fibers (Hybrid Fiber)
- Unconfined compression test for cohesive soil
- CBR test

2.3 Materials

2.3.1 Soil sample: Clayey soil clay is a finely grained natural rock or soil material that combines one or more clay minerals with possible traces of quartz (SiO_2), metal oxides (Al_2O_3, MgO etc.) and organic matter. For this study, the sample I was collected on Devakottai at Sivaganga district.

Table 1: Properties of soil sample

Properties of soil	Values
Specific gravity	2.382
Liquid limit	40.6
Plastic limit	18.1
Plasticity index	22.7
Optimum Moisture Content	15.6 %
Max Dry Density	1.705 kg/cm³
Unconfined compressive strength	10.984 /cm²

2.3.2 Natural fiber: Sisal is a species of Agave native to Southern Mexico but widely cultivated and naturalized in many other countries. Traditionally, sisal has been the leading material for agricultural twine because of its strength, durability, and ability to stretch.

Table 2: chemical composition of sisal fiber

Chemical Composition	Percentage
Cellulose	65%
Hemicelluloses	12%
Lignin	9.90%
Waxes	2%

Table 3: Physical properties of Sisal Fiber

Properties	Values
Density	1.33 - 1.5 g/cm³
Tensile strength	400- 700 MPa
Young' modulus	9000-38000 MPa

Table 4: Physical Properties of Polypropylene Fiber

Properties	Values
Density	0.895 - 0.92 g/cm³.
Tensile strength	350 to 700 MPa
Young' modulus	1300 3500 MPa

3. RESULT AND DISCUSSION

3.1 Specific gravity

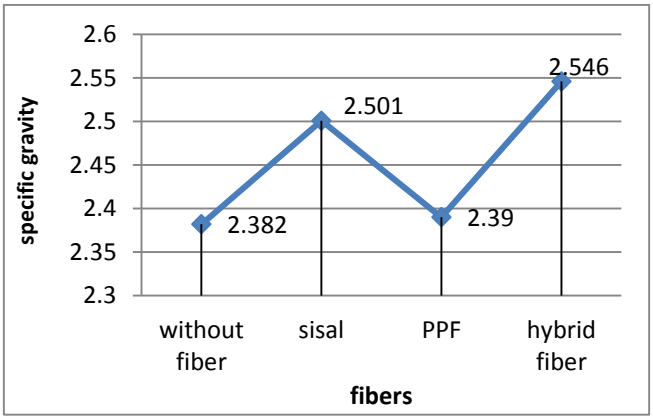

Fig. 1: Comparison of Specific Gravity

The specific gravity of the control specimen of the soil sample is 2.382 which can be classified as the soil is Organic Clay Soil**.** The specific gravity of the clayey soil will increase by using sisal fiber. At the same time, polypropylene cannot change the specific gravity of the soil. Hybrid of these fibers gives the maximum specific gravity when compared with mixing of sisal & PPF separately. Hybrid fibers will increase it from 2.382 to 2.546. Sisal has a higher density when compared with water for the reason of increasing. The density of PPF is nearer to the density of water for the reason of unchanged.

3.2 Atterberg's limits

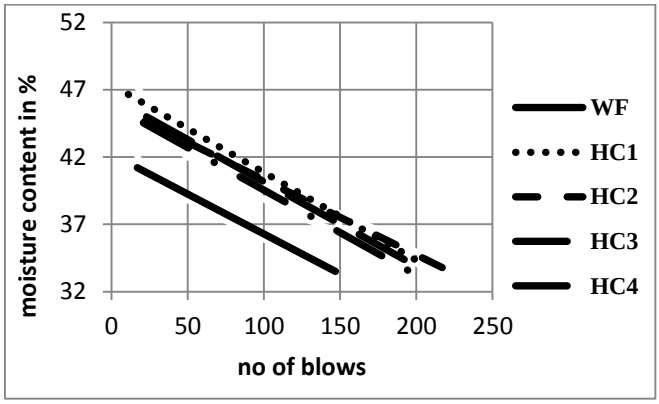

Fig. 2: Comparison of Atterberg's limit

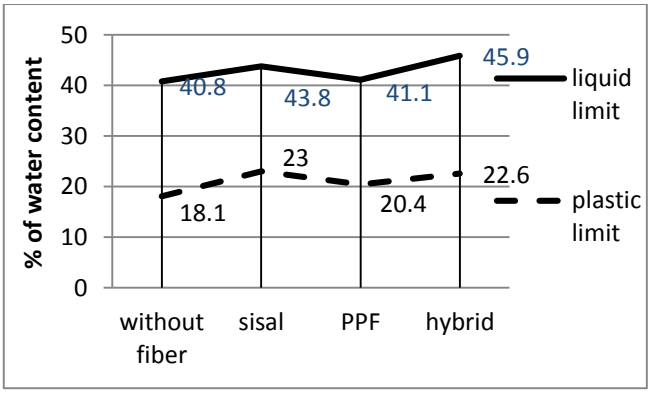

Fig. 3: Comparison of Atterberg's limit

Plasticity index of the soil is greater than the 0.73 (W_L-20), and the liquid limit of the soil is lies between the 35 and 50. According to the 'A' line curve, the soil is classified as medium Compressibility Soil (CI). From figure 3, the liquid limit of the soil increases when the sisal fiber is used for the stabilization because of its water absorption capacity. But the polypropylene does not increase the liquid limit. So the natural fibers absorb some amount of water but the synthetic fibers cannot do that. Hybrid Fibers can increase the 12.5% of liquid limit from the controlled specimen.

3.3 Maximum dry density

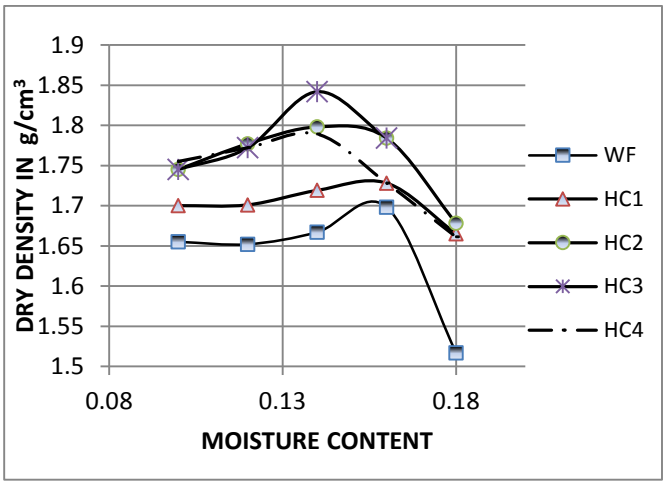

Fig. 4: γdmax Vs OMC for hybrid fibers

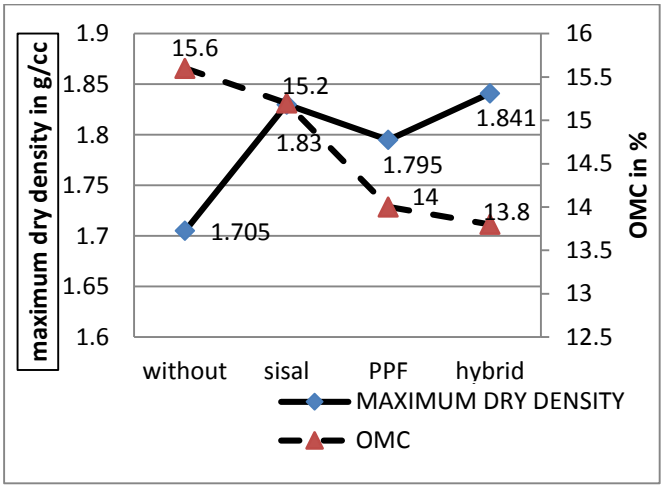

Fig. 5: Comparison of γdmax Vs OMC

Figure 5 show the increasing of the maximum dry density when the natural, synthetic and hybrid fibers were mixed randomly. But the OMC of the soil when mixing with these fibers were decreased up to 14% water content the maximum $\gamma_{d,\,max}$ can be achieved at the soil by the mixer of 0.3%of sisal 0.3% PP fibers. In controlled specimen, porous of the soil can be filled with water. But using the sisal fiber voids are filled by the fibers. It increases the $\gamma_{d,\,max}$ of the soil. The water absorption capacity of sisal fiber reduces the decreasing percentage of OMC.

3.4 The Un-Confined Compressive strength (UCC)

The figure 7 indicates that the hybrid fibers increase the un confined compressive strength of soil tremendously when compared to the other singular fibers. Sisal and PPF can only increase the UCC of soil upto double times of its initial strength. But the small percentage of the hybrid fibers can increase the UCC of soil upto three times of their initial strength.

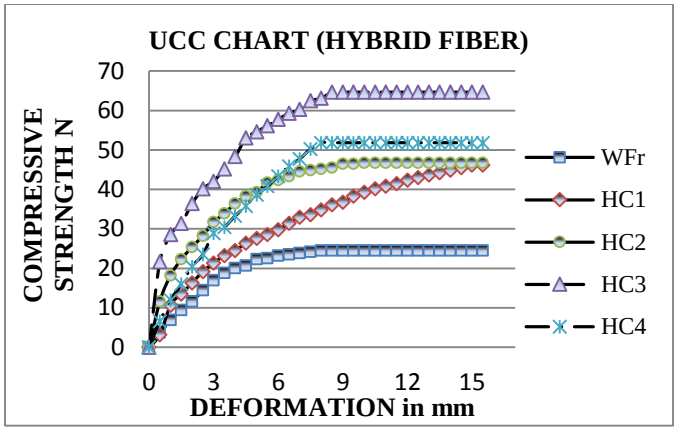

Fig. 6: UCC test result for hybrid fibers

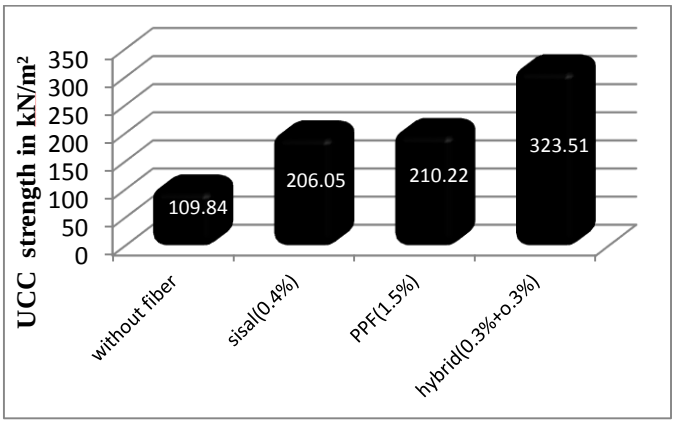

Fig. 7: Comparison of UCC test

3.5 California Bearing Ratio(CBR)

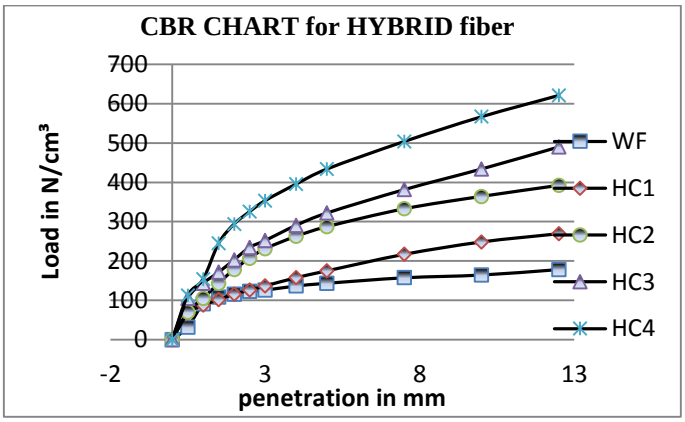

Fig. 8: CBR test result for hybrid fibers

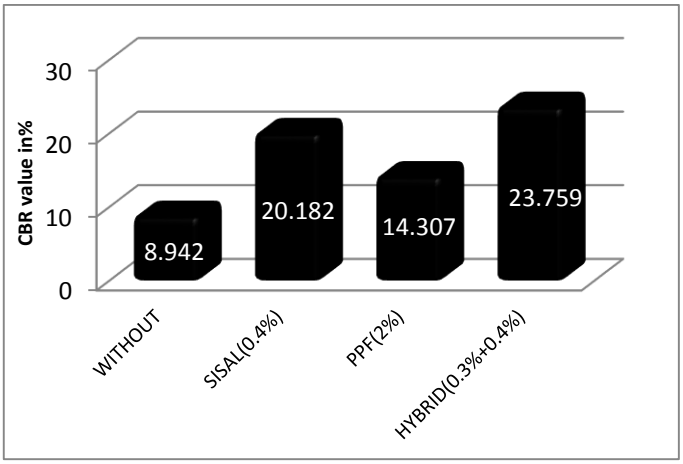

Fig. 9: Comparison of the CBR test

The CBR value of the soil can increase upto three times its initial value while using hybrid fibers. Reason for the increasing of CBR value is the total external loads have been transferred soil to fibers. Fibers have high tensile strength and it resists the penetration. So the CBR value gets increased**.** The increase in CBR value was attributable to the fact that fibers contributed significantly to enhance the bearing capacity of the stabilized soil. [10]

4. CONCLUSION

On the basis of a present experimental study, the following conclusions are drawn

- Liquid limit of the soil is slightly increasing when the soil is stabilizing with sisal fiber. But the polypropylene fiber does not any change in the liquid limit of the soil. Because Sisal fibers absorb some amount of water but polypropylene cannot do that.
- When compared to the unstabilized soil sample, the Optimum Moisture Content is decreasing and the maximum dry density is increasing when the soil sample is admixed with Sisal, Polypropylene and Hybrid fibers. The soil sample admixed with hybrid fiber (0.3% sisal+0.3% PPF) attains the maximum dry density ($\gamma_{d,\ max}$). The reason for decreasing OMC is the admixed fibers were fill the voids and also the reason for increasing maximum dry density is the density of fibers were greater than the density of water. [1],[2],[4],[5],[11]
- An increasing percentage of UCC Strength is 87.6%, 91.4% and 194.5% from unstabilized clay soil when it mixing with Sisal, Polypropylene and Hybrid fibers respectively. Reason for the increasing of strength is Sisal fibers have changed the nature of soil brittle behaviour to ductile behaviour. The fiber can confine the soil particles and increase global stability of the soil mass. [2],[3],[4],[5],[8],[10]
- An increasing percentage of CBR value is 125.7%, 60% and 165.7% from unstabilized clay soil where the using of Sisal, Polypropylene and Hybrid fibers respectively. Reason for increasing of CBR value is the all external loads have taken by fibers from the soil. Since the Fibers have high tensile strength and resistance against penetration. [2],[7]
- Hence we obtained the optimum percentage of hybrid fiber is randomly mixing of 0.3% of sisal and 0.3% polypropylene fiber for soil stabilization.
- Finally, we concluded that reinforcement of soil using hybrid fiber (0.3% of sisal and 0.3% polypropylene fiber) can be considered to be an excellent ground improvement technique. It can be applied easily than the other stabilization methods in the field of Geotechnical Engineering.

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