# STABILIZATION OF SOFT SUBGRADE AND EMBANKMENT SOIL BY USING ALKALINE SOLUTION AND REINFORCING WITH SISAL FIBER

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**Abstract**

Soft soils (Clay soils / Cohesive soils) often exhibit undesirable engineering properties such as low strength, swelling and shrinkage characteristics etc., to improve these properties the common method followed is stabilization. In this paper an attempt was made to assess the effectiveness of Soft soil blended with Alkaline compound for soil stabilization. It gives solution for proper utilization Alkaline compound and also provides good subgrade material for pavement construction. In fact NaOH here is used as an Alkaline compound along with Flyash as filler material. Use of natural fiber in civil engineering for improving soil properties is advantageous because they are cheap, locally available and eco-friendly. The natural fiber reinforcement causes significant improvement in shear strength , Load bearing capacity and other engineering properties of the soil. Over the last decade the use of randomly distributed natural, artificial and synthetic fiber has recorded a tremendous increase. Keeping this in view an experimental study was conducted on locally available soil, reinforced with Sisal fiber. In this study the soil samples were prepared at its maximum dry density corresponding to its optimum moisture content in the CBR mould with and without reinforcement. The percentage of Sisal fiber by dry weight of soil was taken as 0.25%, 0.5%, 0.75%,1%, 3%, 5% etc. In the present investigation the length of fiber was taken as 30 mm. The laboratory CBR values of soil reinforced with Sisal fiber and chemical compound at different percentages were determined. The effects of percentage of fiber and chemical on CBR value, UCC and Shear values of soil were also investigated separately to the normal soil. As we know that Sisal fiber is a biodegradable product. Hence to improve its durability it is necessary to apply an agent such as either turpentine oil or linseed oil.

Finally this paper giving a notation on the optimum percentage of fiber and Chemical compound to attain the good results and also the behaviour of stress - strain of soil before and after adding the chemical and fiber to the normal soil and chemically stabilized and reinforced soil.

**Key words : Alkaline solution/compound; Sisal fiber ; CBR ; Turpentine oil.**

  

## 1. INTRODUCTION

Soil stabilization is the modification of one or more soil properties by either means to produce an improved soil system that will remain in place under the design use conditions throughout the design life of the project. Soil varies throughout the world and their engineering properties are equally variable. Highway construction on cohesive/clayey soils has been a challenge to engineers and designers because of its high swelling and shrinkage characteristics due to presence of inorganic clays of medium to high compressibility, which results in cracks in the pavement structure. Well established mechanical and chemical stabilization techniques are often used to improve its engineering properties along with soil reinforcement. To change the properties of soil that is to minimize the expansion of soil particles it is required to break the cohesion between soil particles. For that Alkaline solution used here along with filler material. Flyash is used here as filler material. Stabilization can be possible by adding equalent amount of Alkaline solution at certain Normality and at certain percentage along with filler material. After mixing soil with chemical and filler material the properties of soil will vary along with the time. That means the cohesive properties of soil or softness of soil will get reduced by increasing time.

Soil has been used as a construction material from time immortal. Being poor in mechanical properties, it has been putting challenges to civil engineers to improve its properties depending upon the requirement which varies from site to site. During last 25 years, much work has been done on strength deformation behaviour of fiber reinforced soil and it has been established beyond doubt that addition of fibre in soil improves the overall engineering performance of soil. Among the notable properties that improved are greater extensibility, small loss of post peak strength, isotropy in strength and absence of planes of weakness. Fiber reinforced soil has been used in many countries in the recent past and further research is in progress for many hidden aspects of it. Fiber reinforced soil is effective in all types of soils (i.e. sand, silt and clay). Use of natural material such as Jute, coir, sisal and bamboo, as reinforcing materials in soil is prevalent for a long time and they are abundantly used in many countries like India, Philippines, Bangladesh etc. The main advantages of these materials are they are locally available and are very cheap. They are biodegradable and hence do not create disposal problem in environment. Processing of these materials into a usable form is an employment generation activity in rural areas of these countries. If these materials are used effectively, the rural economy can get uplift and also the cost of construction can be reduced, if the material use leads to beneficial effects in engineering construction. Due to the presence of high tensile strength of Fibers it may give much more resisting strength to soil. Among all the Natural fibers Sisal fiber has a good values of tensile properties. That's why the soil is reinforced with Natural sisal fiber. Linseed oil used here to minimize the biodegradable nature of fiber in soil.

Here in this project, NaOH optimum content and optimum percentage of fiber founded individually. Free swelling index value used here to find the optimum content of Alkaline solution, CBR results are used here to find the optimum value of fiber content. After finding the optimum contents , CBR values founded at minimum percentage of fiber at optimum percentage of Alkaline solution. In this way this paper presenting a through usage of Chemical especially Alkaline solution along with Filler material and fiber reinforcement in soft soil, located at road construction site. CBR, UCC & Direct shear test results are used here to give the final conclusions.



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## 2. LITERATURE REVIEW

***Abtahi M, Allaie H, Hejazi M*** proved that good properties of soil had found when the percentage of chemical varied along with NaOH i.e. from the nominal percentage of 0.25% and varied to 1.5 by this, an optimum content had found and after that fiber content varied to the optimum soil mix. By this the overall behaviour of soil have found.

***Jamellodin (2012)*** found that a significant improvement in the failure deviator stress and shear strength parameters (C and U) of the soft soil reinforced with palm fibers can be achieved. It is observed that the fibers act to interlock particles and group of particles in a unitary coherent matrix thus the strength properties of the soil can be increased.

***Jessie C et al. Oldham, Royce,C. Eaves, and Dewey W. White, Jr*** given a final report for the US Army Corps of Engineers' Waterways Experiment Station, this report documents the results of approximately 30 years worth of testing. The program was initiated by the military to explore the use of chemical soil stabilizers. The stabilizers tested include acids, asphalt, cement, lime, resins, salts, silicate, and other materials.

- Calcium acrylate was one of the stabilizers evaluated in this report, but similar to what is mentioned in Section 2 – Historical Perspective, while calcium acrylate gave great results initially, the performance dropped upon wetting in the field test.
- The authors concluded that quicklime was the best stabilizer for clay soils. In addition to the use of quicklime alone, magnesium sulphate was found to improve the ability of quicklime as a stabilizer in all instances of its use as an additive.
- Sodium hydroxide was analyzed as an additive to cement as a stabilizer. While sodium hydroxide was found to be beneficial to cement stabilization, it is a caustic, which means that it is a strong alkaline chemical, and extremely corrosive to many materials and human tissue.

At the present time, there is a greater awareness that landfills are filling up, resources are being used up, the planet is being polluted and that non-renewable resources will not last forever. So, there is a need to more environmentally friendly materials. That is why there have been many experimental investigations and a great deal of interest has been created worldwide on potential applications of natural fibers for soil reinforcement in recent years. The term ''eco-composite'' shows the importance role of natural fibers in the modern industry ***( Ling, I., Leshchinsky, D., and Tatsuoka, F 2012***). Mainly, what part of the plant the fiber came from, the age of the plant; and how the fiber was isolated, are some of the factors which affect the performance of natural fibers in a natural fiber reinforced soil. It is necessary to mention that natural fibers have been used for a long time in many developing countries in cement composites and earth blocks because of their availability and low cost.

Unconfined compression strength (UCS), California Bearing Ratio (CBR) and compaction tests were performed on neat and coir fiber reinforced soil samples by ***Marandi (2011).*** They reported that at a constant palm fiber length, with increase in fiber inclusion (from 0% to 1%), the maximum and residual strengths were increased, while the difference between the residual and maximum strengths was decreased. A similar trend was observed for constant coir fiber inclusion and increase in palm fiber length (from 20 mm to40 mm).

***Prabakar and Siridihar*** used 0.25%, 0.5%, 0.75% and 1% of sisal fibers by weight of raw soil with four different lengths of 10, 15, 20 and 25 mm to reinforce a local problematic soil. They concluded that sisal fibers reduce the dry density of the soil. The increase in the fiber length and fiber content also reduces the dry density of the soil. As well it was found that the shear stress is increased non-linearly with increase in length of fiber up

  

to 20 mm and beyond, where an increase in length reduces the shear stress. The percentage of fiber content also improves the shear strength. But beyond 0.75% fiber content, the shear stress reduces with increase in fiber content.

Nearly 4000 structures have been built in more than 37 countries so far using the concept of earth reinforcement. Firstly, polyester filaments before staple fibers entered to the geotechnical engineering market under the traditional brand of ‘‘Texsol’’. This product was used in retaining walls and for slope protections. However, randomly distributed fiber-reinforced soils, known as short fiber soil composites, have recently attracted increasing attention in many geotechnical engineering applications, not only in scientific research environment, but also at executive real field . Synthetic staple fibers have been used in soil since the late 2011, when the initial studies using polymeric fibers were conducted ( ***Vidal 2011***). At final, it can be concluded that the concept of reinforcing soil with natural fibers was originated in ancient times. However, short natural and synthetic fiber soil composites have recently attracted increasing attention in geotechnical engineering for the second time. Therefore, they are still a relatively new technique in geotechnical projects.

## 3. EXPERIMENTAL INVESTIGATION

### 3.1 Soil

Soil was collected from the nearest road site location which contain very soft soil. Later required tests are performed on the soil sample to find the properties of soil. Those are tabulated below.

**Table 1 : Properties of Normal soil (Without adding NaOH)**

| S.No | Test | Result | Remarks |
|---|---|---|---|
| 1 | Free Swelling Index | 101.83% | Degree of Severity is Critical As Per IS 1498-1972 , IS 2720-40 (1977) |
| 2 | Liquid Limit | 54% | Degree of Severity is Critical As Per IS 1498-1972 |
| 3 | Plasticity Index | 25.43% | Degree of Severity is Critical As Per IS 1498-1972 |
| 4 | Optimum Moisture content | 11.9% | Very less value of dry density |
| | Maximum Dry density | 1.979 gm/cc | |
| 5 | CBR | 2.136 | Poor value |
| 6 | UCC ( Shear stress) | 1.064 kg/mm$^2$ | - |

### 3.2 Fly ash

Fly ash is used here as a filler material which may increase the cohesion between stabilized particles and also plays a major role in the soil stabilization, especially in the decrement of Expansion of Soil.



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**Table 2 : Chemical Composition of Fly ash which is used in the project**

| Constituents | Percentage | Constituents | Percentage |
|---|---|---|---|
| MgO | 0.57 | $Fe_2O_3$ | - |
| $Al_2O_3$ | 24.12 | $Na_2O$ | - |
| $SiO_2$ | 52.55 | MnO | - |
| $K_2O$ | 0.965 | $TiO_2$ | - |
| $P_2O_5$ | 0.72 | $SO_3$ | - |
| CaO | 2.65 | Loss of Ignition | 18.18 |

*Source : Krishnapatnam Power generation corporation and Private Limited

### 3.3 Fiber

As we know that Natural fiber is a good ductile , disintegrable material which is having a very good amount of Tensile stress values. Sisal Fiber assumed here as a fiber material , which is used as a reinforcing agent of soil. The Properties of Sisal fiber are listed below.

**Table 3 : Properties of Sisal Fiber**

| | |
|---|---|
| Cellulose | 70% |
| Diameter of sisal fiber | 0.2mm |
| Density | 1.450gm/cm3 |
| Tensile strength | 540Mpa |
| Elongation | 4.3% |
| length assumed | 30mm |

*Source : Sri Balaji Fiber Industries, Guntur, AP.

### 3.4 NaOH

Sodium Hydroxide pellets were collected from Delta Engineering chemical suppliers, Vijayawada, Andhrapradesh. Here initially the project started with 3N,3% later it increased to optimum percentage.

## 4. OPTIMUM CONTENT OF NaOH AND FIBER TO STABILIZE SOIL

### 4.1 Calculation of optimum content of chemical at optimum content of flyash

- Here the optimum content of flyash is a fixed value and this was a founded value (20 - 30% of soil by weight) .
- Now the optimum content of Chemical has to found.

  

- Since it is very difficult to find the optimum content of chemical for the soil sample by conducting all the soil tests. Hence wastage of chemical may increase.
- By considering above difficulties one of the best solution is finding the Free swelling index value of the soil sample.
- For this the normality of the liquid was adopted from 3N to 15N such as 3N, 6N, 9N, 12N,15N and the percentage of solution also varied from 3% to 15% such as 3% , 6% ,9%, 12% ,15%.
- The procedure for preparation of soil is clearly mentioned below.
- Soil has to sieve from 425µ IS sieve and for the preparation of 1N Alkaline NaOH solution it is necessary to add 40gms of NaOH pellets to distilled water. Based on this the pellets will add to water for the required Normality.
- Take 50gms of soil in a bowl and add 12.5gms of Flyash ( since 20% of Soil i.e. by weight) to the soil, mix the complex thoroughly.
- Add the chemical to the soil matrix presented in bowl and here the chemical content have to vary from 3% to 15% as discussed above.
- After mixing the soil sample allow the soil for maturity , that can done by packing the soil in a water tight polythene cover and keeping in desicator for atleast 2 weeks.
- After one week remove the soil packets from Desicator and conduct swelling test for the soil which is presented in polythene covers.
- The overall optimum content of chemical can find by the following calculations.

**Table 4 : Swelling Index Results at Different Normalities and Different Percentages**

| S.No | Normality | Percentage of NaOH added to Soil | | | | |
|---|---|---|---|---|---|---|
| | | **3%** | **6%** | **9%** | **12%** | **15%** |
| 1 | 3 | 80 | 72.4 | 66.67 | 42.4 | 66.1 |
| 2 | 6 | 52.23 | 42.44 | 42.44 | 40.23 | 52 |
| 3 | 9 | 41.43 | 40.26 | 42.1 | 52 | 50 |
| 4 | **12** | 7.4 | 7.6 | **6.6** | 12.5 | 12.5 |
| 5 | 15 | 14 | 10 | 11.4 | 12.4 | 6.3 |

From tabular column we can say that the optimum percentage of NaOH is 9%, 12N.

The following reaction will takes place in case of this stabilization.

In earliest period the following reaction will takes place,

$$SiO_2 + Al_2O_3 + CaO + NaOH + H_2O \longrightarrow CaSiO_3 + NaAlO_2 + Al(OH)_3$$

Where $CaSiO_3$ is a compound which helps for the Stabilization and also for formation of cohesive less nature.

When time increasing $CaSiO_3$ , further reacts with Moisture in the atmosphere and will forms Calcium Silicate Hydrate, which helps to form a pure cohesive less matrix. The following reaction will give a clear notation about the formation of Calcium Silicate Hydrate.



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$$CaSiO_3 + H_2O \longrightarrow CaH_2O_4Si$$

**Table 5: Properties of stabilized soil**

| S.No | Test | Result | Remarks |
|---|---|---|---|
| 1 | Free Swelling Index | 6.6% | Degree of Severity is Non-Critical As Per IS 1498-1972 , IS 2720-40 (1977) |
| 2 | Liquid Limit | 24% | Degree of Severity is Non-Critical As Per IS 1498-1972 |
| 3 | Plasticity Index | 8.6% | Degree of Severity is Non-Critical As Per IS 1498-1972 |
| 4 | Optimum Moisture content | 9.3% | Very less value of dry density |
| | Maximum Dry density | 2.08 gm/cc | |
| 5 | CBR | 6.1 | Good value |

### 4.2 Calculation of optimum content of percentage of sisal fiber for normal soil

The optimum percentage of fiber for normal soil is calculated based on the results obtained from CBR test at different percentages of fiber. Calculated values are tabulated below.

**Table 6: CBR values at different percentage of Sisal fiber content**

| % Of fiber | CBR value | % Of fiber | CBR value | % of fiber | CBR value |
|---|---|---|---|---|---|
| 0.2 | 3.124 | 1.8 | 8.24 | 13 | 17.24 |
| 0.4 | 3.203 | 2 | 10.68 | | |
| 0.6 | 3.28 | 3 | 11.06 | | |
| 0.8 | 3.73 | 4 | 11.74 | | |
| 1 | 5.03 | 5 | 12.2 | | |
| 1.2 | 6.1 | 7 | 13.73 | | |
| 1.4 | 7.32 | 9 | 16.9 | | |
| 1.6 | 8 | 11 | 19.6 | | |

### 4.3 For the mixture of chemical and reinforced soil

  

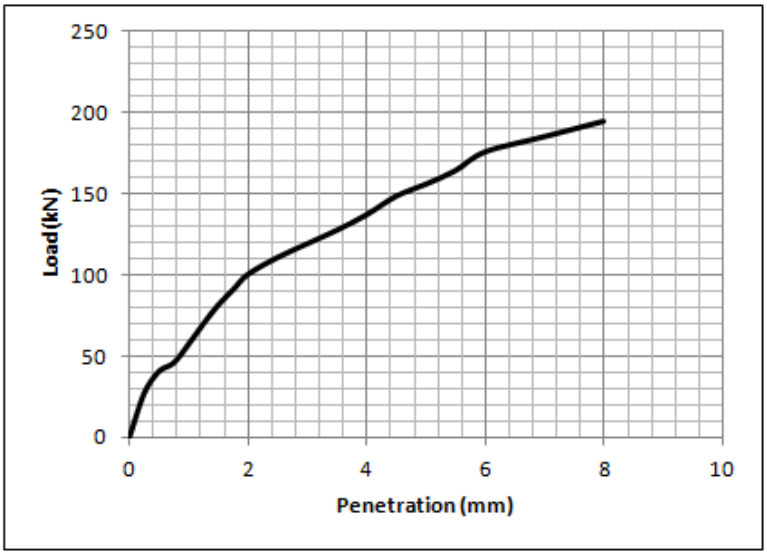


**Fig 1 . CBR graph for NaOH 12N,9% and 0.2% of fiber**

Here from this we can say that by stabilization of soil with Alkaline solution and reinforcing with Sisal fiber will give a good result when compared with normal soil properties at very low amount of fiber.

## 5.CONCLUSION

From the above Project work we can say that at a minimum cost and time duration we can stabilize the sensitive soils, which are having great critical expansion values. By checking the results of final soil matrix we can strongly say that the stabilization of sensitive soil by the help of alkaline solution and with the help of reinforcement we can get the maximum amount of CBR values. That means the Normal soil matrix giving the maximum amount CBR values at nearly 11% of fiber content but due to this stabilization technique we can attain the maximum amount of CBR values at less amount of fiber content i.e. at 0.2%. Here stabilized soil giving Very good CBR values directly. If at any case more CBR values required, Reinforcement is a good and effective method to achieve the results for pavement. Here Sisal fiber used as reinforcing agent, because of its high tensile nature and good young's Modulus values. Here this project was just ended with 0.2% of fiber reinforcement for chemical stabilized soil, because the CBR value here attained is having a value greater than 8, and we know that if CBR value greater than 8 that represents Stone strata. For pavements CBR value 8 is enough for that this project ended with a CBR value 8.

Finally from the above report we can say that for soft soils especially for soft Subgrade and Embankment soils this Stabilization of Alkaline technique is a better technique and also we can say that results can expand by soil reinforcement.



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