ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

# 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 solution for soil stabilization. It gives solution for proper utilization Alkaline solution and also provides good subgrade material for pavement construction.

Use of natural fiber in civil engineering for improving soil properties is advantageous because they are cheap, locally available and eco-friendly. 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 0.2%, 0.4%, 0.6%, 0.8%,1.0%, 1.2%, 1.4%, 1.6%,1.8%, 2.0%,3%,4,5%,7% etc and it increased to the optimum value. In the present investigation the length of fiber was taken as 30 mm. This length value found and decided by testing. 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. 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 comparison between normal soil, reinforced soil, chemically stabilized soil and chemically stabilized and reinforced soil also giving a brief notation of the behavior of stress of soil before and after adding the chemical and fiber.

## 1.INTRODUCTION

Soil Stabilization is only one of several techniques available to the geotechnical engineer and its choice for any situation should be made only after a comparison with other techniques indicates it to be the best solution to the problem. It is a well known fact that, every structure must rest upon soil or be made of soil. It would be ideal to find a soil at a particular site to be satisfactory for the intended use as it exists in nature, but unfortunately, such a thing is of rare occurrence. The alternatives available to a geotechnical engineer, when an unsatisfactory soil is met with, are (*i*) to bypass the bad soil (*e.g.*, use of piles), (*ii*) to remove bad soil and replace with good one (*e.g.*, removal of peat at a site and replacement with selected material), (*iii*) redesign the structure (*e.g.*, floating foundation on a compressible layer), and (*iv*) to treat the soil to improve its properties. The last alternative is termed soil stabilization. Although certain techniques of stabilization are of a relatively recent origin, the art itself is very old. The original objective of soil stabilization, was, as the name implies, to increase the strength or stability of soil. However, techniques have now been developed to alter almost every engineering property of soil. The primary aim may be to alter the strength and/or to reduce its sensitivity to moisture changes.

### Classification of the methods of stabilization

A completely consistent classification of soil stabilization techniques is difficult. Classifications may be based on the treatment given to soil, on additives used, or on the process involved.

Broadly speaking, soil stabilization procedures may be brought under the following two heads:
I. Stabilization without additives
II. Stabilization with additives

## SOIL REINFORCEMENT

### Reinforced earth

Majorly Soil reinforcement may done by using Metallic mesh or Geosynthetics. The idea of retaining earth behind a metallic facing element connected to anchor or tieback elements, which may be thin metal strips, or strips of wire mesh, is of relatively recent origin. The resulting structure is known as ‘‘reinforced earth’’. The facing element is restrained by the mobilization of friction and or cohesion to ‘grip’ the anchor or tieback; the latter are extended into the backfill zone. A layer of these strips is placed at one elevation and backfilling is carried out; the entire process is repeated to the next higher elevation until the desired height is obtained. Typical spacings between the reinforcing ties are 0.3 to 1.0 m in the vertical direction and 0.60 to 1.50 m in the horizontal direction. Metal strips of 5 to 12 m width and 1.5 mm thickness may be used. If welded wire mesh is used it can be 1 cm diameter in grids of 15 cm × 60 cm. Strips as well as mesh must be galvanized to prevent corrosion. In highly corrosive environments like marine areas, even this may not ensure durability for the anticipated lifetime of the structure. Backfill soils of free-draining type such as sands and gravels are preferred; of course, 5 to 10% of material passing No. 75-μ IS sieve will be helpful for achieving good compaction.

### Fiber Reinforcement

The standard fiber-reinforced soil is defined as a soil mass that contains randomly distributed, discrete elements, i.e. fibers, which provide an improvement in the mechanical behavior of the soil composite . Fiber reinforced soil behaves as a composite material in which fibers of relatively high tensile strength are embedded in a matrix of soil. Shear stresses in the soil mobilize tensile resistance in the fibers, which in turn imparts greater strength to the soil . Mainly, the use of random discrete flexible fibers mimics the behavior of plant roots and contributes to the stability of soil mass by adding strength to the near-surface soils in which the effective stress is low.

## SCOPE AND OBJECTIVE

In this way both Chemical/Admixture stabilization and soil reinforcement are advanced treatments to increase the efficiency of soil. In this project the both words were adopted to attain very good results. Where in this project NaOH assumed as a chemical stabilizer, Flyash assumed as cementing material and Sisal Fiber assumed as reinforcing material.

In the present study, an attempt is made to study how NaOH, Flyash and Sisal fibers may be effectively utilized in combination with locally available soil to get an improved quality of composite material which may be used in various Subgrades and Embankments. The soil used in investigation was obtained from Musunuru village near to Kavali in Nellore district of A.P. NaOH Pellets from Simhapuri chemicals, Nellore(A.P), Flyash from locally available market and Sisal fiber also from locally available market. This research aims at investigation of various technical properties like CBR, Stress strain behavior and compaction characteristic of soil . The objective of present work is to study the most appropriate combination of soil, Chemical compound i.e. NaOH with an optimum % of flyash and optimum % of Sisal fiber at the optimum moisture content and maximum dry density.

## 2. LITERATURE REVIEW

***Abtahi M, Allaie H, Hejazi M* [1]*(2013)*** 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* [2] *(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

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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* [3] *(2011)*** 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.

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* [4] *(2012*)**.

Unconfined compression strength (UCS), California Bearing Ratio (CBR) and compaction tests were performed on neat and coir fiber reinforced soil samples by ***Marandi* [5] *(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* [6]** 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.

## 3. EXPERIMENTAL INVESTIGATION

It deals with the study of various properties of materials used in the preparation of or stabilization of soft subgrade and embankment soil by using NaOH , fly ash and reinforcing with Sisal fiber.

Behavior of Soft subgrade soil, particularly this type of soil depends on many parameters like materials used, sequence of mixing the materials, mixing procedure, dosage of chemical, flyash and sisal fiber etc. It is essential to have a reliable data base, so that the field engineers or researchers can work towards the further developments. It has already been said that most of the soil reinforcement with sisal fiber have no information with regard to either the behaviour of sisal in soil matrix. The main objective of the present investigation is, thus to obtain specific experimental data, which helps to understand the matrix behaviour in the presence of natural fiber (sisal fiber) after attaining the stabilization .

The present investigations carried out are mainly directed towards obtaining specific information regarding the CBR value, MDD and OMC , Shear behaviour with natural fiber apart from their behaviour in soil matrix. The natural fiber considered here is Sisal fiber.

## STUDIES ON MATERIALS:

### SOIL

The clay soil ( Expansive / Soft soil) available in the Musunuru village had used in this project . the soil used here in the project contain no any other organic matter and it is free from other industrial chemicals. The soil was tested for physical requirements in accordance with IS 1498-1972 and IS: 2720 all parts.

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## ALKALINE SOLUTION

Strong Base solution has selected here the whole preparation of Solution have done based on the chemical mixing guide lines that is the solution had prepared based on normality and its considerations on the other hand 40gms of NaOH pellets added for 1liter of Distilled water to prepare 1N NaOH solution.

## FLYASH

The flyash using in the stabilization process should consist a good values of Ca composition and that is used as a filler material. Class F flyash used here as a filler agent because of presence of good value of Calcium percentage.

## SISAL FIBER

SCIENTIFIC CLASSIFICATION

Kingdom : Plantae
Order : Asparagales
Family : Asparagaceae
Subfamily : Agavoideae
Genus : Agave
Species : A. Sisal fiberana
Binomial name: Agave sisal fiberana

**Sisal fiber** (*Agave sisal fiberana*) is an agave that yields a stiff fiber traditionally used in making twine rope and also dartboards . The term may refer either to the plant or the fiber , depending on context. It is sometimes incorrectly referred to as *sisal fiber hemp* because hemp was for centuries a major source for fiber, so other fibers were sometimes named after it.

Fig 1 : Sisal plant

The Sisal fiber plants consist of a rosette of sword-shaped leaves about 1.5 to 2 meters tall. Young leaves may have a few minute teeth along their margins, but lose them as they mature. The sisal fiber plant has a 7–10 year life-span and typically produces 200–250 commercially usable leaves. Each leaf contains an average of around 1000 fibers. The fibers account for only about 4% of the plant by weight. Sisal fiber is considered a plant of the tropics and subtropics, since production benefits from temperatures above 25 degrees Celsius and sunshine.

**Fiber extraction**

Fig 2: Fiber extraction

Fiber is extracted by a process known as Decortication, where leaves are crushed and beaten by a rotating wheel set with blunt knives, so that only fibers remain. In India, where production is typically on large estates, the leaves are transported to a central decortication plant, where water is used to wash away the waste parts of the leaf. The fiber is then dried, brushed and baled for export. Superior quality sisal fiber is found in East Africa. Proper drying is important as fiber quality depends largely on moisture content. Artificial drying has been found to result in generally better grades of fiber than sun drying.

## TURPENTINE OIL

A product which is useful to minimize the decay of wood and wood resigns. Here also this turpentine oil used to minimize the natural decay of fiber in soil matrix. Turpentine oil bought from the local market.

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Sisal fiber initially dipped in the oil and later seasoning has done to it. This may reduce the decay of fiber in soil.

Fig 3: Turpentine oil

Fig 4: Fiber seasoning

## 4.MATERIALS USED AND THEIR PROPERTIES

This is Deals with the physical and chemical properties of various materials used in the stabilization of the soft subgrade soil/Embankment soil by using Alkaline solution, Flyash and reinforcing with Sisal fiber.

## SOIL

### FREE SWELL INDEX TEST:

Initially Free Swell Index test conducted to the soil sample, based on this selling index value the value of optimum chemical value can find easily. IS: 2720 Part(40) - 1970

**Formulas to be used**

Free swell index = $[V_d - V_k] / V_k$ x 100%

Where, $V_d$ = Volume of soil specimen read from the graduated cylinder containing distilled water.

$V_k$ = Volume of soil specimen read from the graduated cylinder containing kerosene.

**Result ( for Normal soil)**

$V_d$ = Volume of soil specimen read from the graduated cylinder containing distilled water = 22

$V_k$ = Volume of soil specimen read from the graduated cylinder containing kerosene = 10.9

Free Swell Index value = {( 22-10.9)/10.9}X100 = 101.83%

Therefore , FSI value for Normal soil = 101.83%

( Since, From Table 1 - Degree of severity is High)

## ATTERBERG'S LIMITS

All the tests are conducted based on IS: 2720 Part(V) - 1965.

### LIQUID LIMIT TEST:

**Results**

Table 2 : Liquid limit test results for normal soil

| S.NO | Weight of soil taken (gms) | Water added (%) | No. of blows |
|---|---|---|---|
| 1 | 120 | 30 | 56 |
| 2 | 120 | 35 | 49 |
| 3 | 120 | 40 | 42 |
| 4 | 120 | 45 | 35 |
| 5 | 120 | 50 | 32 |
| 6 | 120 | 55 | 23 |

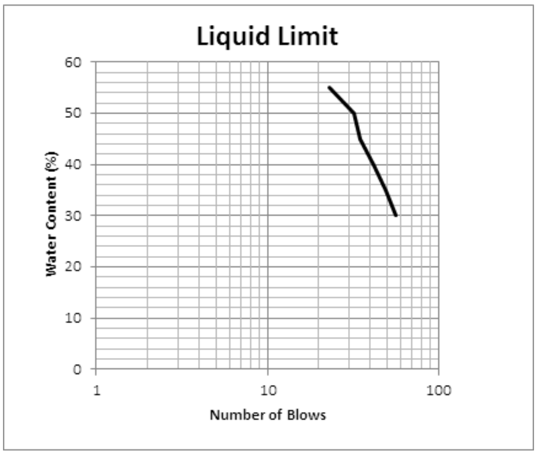


Fig 5: Water content Vs Number of blows

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International Journal & Magazine of Engineering, Technology, Management and Research
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From the graph we can get the liquid limit value as 54% .

Hence, $W_L$ = 54% .

But, as per Indian Standards , IS 1498-1972 the soil sample contains **High degree of severity.**

## PLASTIC LIMIT:

### FORMULAS TO BE USED:

Plastic Limit $W_p = M_w/M_s$

Where Mw= Mass of water added

Ms= Mass of dry soil

**Plastic limit** for normal soil

* Weight of empty container(W1)= 15 gms
* Weight of empty container + wet soil(W2)= 60 gms
* Weight of empty container + dry soil(W3)=50 gms
* Water content = ( W2- W3)/( W3- W1) * 100
  = (60-50)/(50-15) * 100
  = 28.57 %
* Plastic limit $W_P$ = 28.57 %

**Plasticity Index**

* I.P = L.L - P.L = 54 – 28.57

*Plasticity Index $W_P$ = 25.43%

As per Indian Standards , IS 1498-1972 the soil sample contains **High degree of severity**

## STANDARD PROCTOR TEST

Test is conducted based on IS: 2720 Part(IX) -1971

### FORMULAS TO BE USED

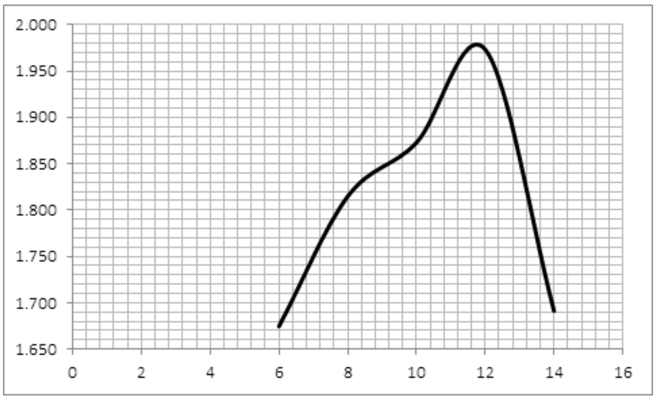
Bulk density ρ= M/V

Where M= Mass of soil V= Volume of soil

Dry density $\rho_d = \rho/(1+W)$

Where W= Water content added

### RESULTS




From Graph

Maximum Dry Density = 1.979 gm/cc

Optimum Moisture Content = 11.9%

## CALIFORNIA BEARING RATIO TEST:

Test is conducted based on IS: 2720 Part(XVI) -1965

### FORMULAS TO BE USED

Bulk density ρ = M/V

Where M = Mass of soil

V = Volume of soil

Dry density ρd = ρ/(1+w)

Where w = Water content added

CBR at 2.5mm & 5.0mm penetration = (Test value / Standard value) X 100

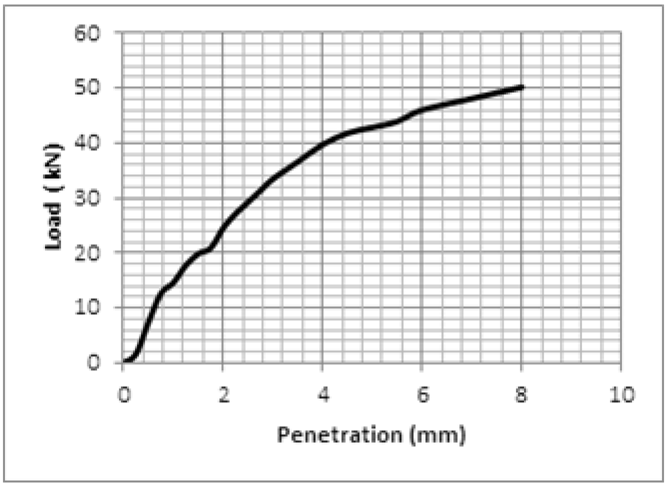
Where, Test value = From the graph between load & penetration

Standard value = From standard values table

| Penetration of plunger(mm) | 2.5 | 5.0 | 7.5 | 10.0 | 12.5 |
|---|---|---|---|---|---|
| Standard load(kg) | 1370 | 2055 | 2630 | 3180 | 3600 |

Table 4 : CBR standard load

### RESULTS




From Graph CBR value

@ 2.5mm Penetration = 2.136

@ 5.5mm Penetration = 2.085

CBR value of the Soil is taken as 2.136.

Table 6: IRC considerations for Subgrade soil

| S.No | CBR value | Nature |
|---|---|---|
| 1 | 1-3 | Poor |
| 2 | 3-5 | Good |
| 3 | 5-8 | Very good |
| 4 | >8 | Strong (as like rocky strata) |

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International Journal & Magazine of Engineering, Technology, Management and Research
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As per IRC considerations the CBR value is less than 3, hence it contain very poor properties as subgrade layer.

### UNCONFINED COMPRESSION TEST:

Test is conducted based on IS: 2720 Part(X) -1973

### FORMULAS TO BE USED

Compressive stress qu = P/Ac

Where P = k X Load

K = spring constant= 0.594

Ac = Area after load application

Compressed specimen area Ac= Ao/(1+ Ɛ)

Where Ao = Initial area of the soil specimen

Ɛ = Axial strain of soil specimen

Cohesion = qu/2; if the sample is fully saturated

qu/(2 tanα); if the sample is partially saturated

Where α = 45+φ/2

φ = Angle of internal friction value of soil

### RESULTS

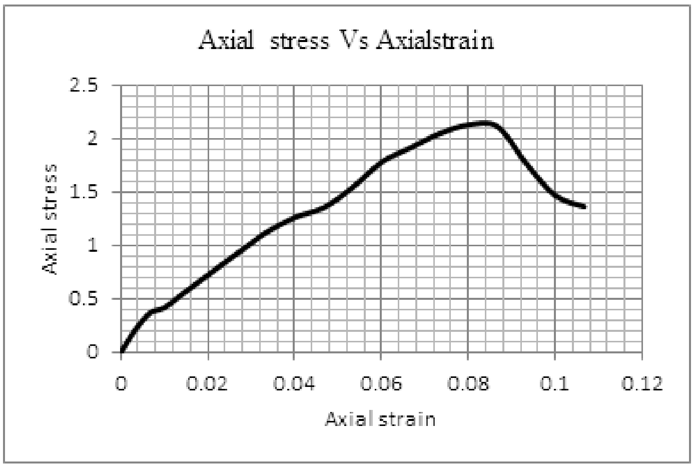


Fig 7: Axial stress Vs Axial strain

Maximum Axial stress $q_u$ = 2.128 $kg/mm^2$

Maximum shear stress of Normal soil = ($q_u$ / 2) = 2.128 / 2 = 1.064 kg $/mm^2$

### ALKALINE SOLUTION

1. A strong base solution like NaOH assumed here.
2. For 1N solution it is necessary to add 40gms of NaOH pellets to One liter of Distilled water.
3. Based on this, different normality of solutions are prepared

### FLY ASH

Table 8 : Chemical composition of Flyash

| 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 |

### SISAL FIBER

| | |
|---|---|
| Cellulose | 70% |
| Diameter of sisal fiber | 0.2mm |
| Density | 1.450gm/cm3 |
| Tensile strength | 540Mpa |
| Elongation | 4.30% |
| length assumed | 30mm |

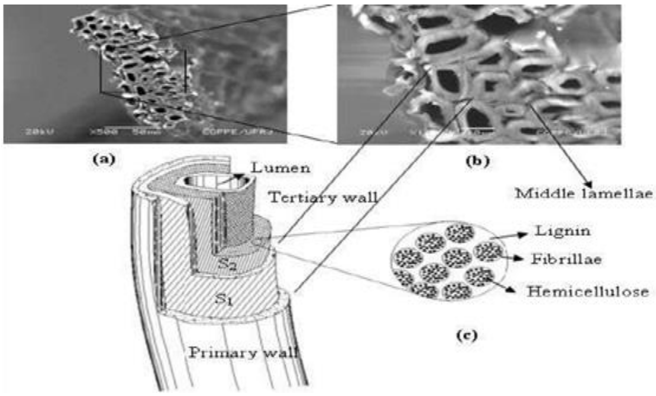


Fig 8 : Fiber-cell microstructure : a) A cross section showing the fiber cells, lumens and middle lamellae, b) Magnification of the cross section
c) A schematic drawing showing the differ

### MSTURE CONTENT OF THE FIBERS

Cellulosic fibers are hydrophilic and absorb moisture. The moisture content of the fibers can vary between 5 and 10%. This can lead to dimensional variations in composites and also affects the mechanical properties of the composites. During processing of composites based on thermoplastics, the moisture content can lead to poor process ability and porous products. Treatment of natural fibers with chemicals or grafting of vinyl monomers can reduce the moisture gain and to increase the durability of sisal fiber it is necessary to add linseed or turpentine oil.

## 5.OPTIMUM CONTENT OF NaOH AND FIBER TO STABILIZE SOFT SOIL

This is Deals with the optimum dosages of NaOH solution, Flyash and Sisal fiber. The optimum dosage of fly ash here is fixed as 20% by weight of soil, since the stabilization had already done by the flyash for the same soil sample by my colleagues. Here in this session the optimum content of fly ash , Sisal fiber was find separately.

### CALCULATION OF OPTIMUM CONTENT OF NaOH ( for 20% of Fly ash by weight of soil )

1. Here the optimum content of flyash is a fixed value and this was a founded value.
2. Now the optimum content of Chemical has to found.
3. 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.
4. By considering above difficulties one of the best solution is finding the Free swelling index value of the soil sample.
5. 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%.
6. The procedure for preparation of soil is clearly mentioned below

### PREPARATION OF SOIL TO FIND THE SWELLING INDEX

### Apparatus required

a. 425µ IS Sieve
b. Balance
c. Measuring jars
d. Sodium Hydroxide pellets
e. Distilled water
f. Pipette

Fig 9 : Keeping soil in Desiccator for maturity

### Mixing procedure

i) 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.

ii) 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.

iii) 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.

iv) 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.

v) After one week remove the soil packets from Desicator and conduct swelling test for the soil which is presented in polythene covers

vi) The overall optimum content of chemical can find by the following calculations

### CALCULATION OF SWELLING INDEX VALUE FOR SOIL SAMPLE

**<u>For 3N solution</u>**

**i) 3N/3%**

Volume change in kerosene = 11.95
Volume change in Water = 21.5
Free Swelling index value (FSI) = 80%

**ii) 3N/6%**

Volume change in kerosene = 12.3
Volume change in Water = 21.2
Free Swelling index value (FSI) = 72.4%

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
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**iii) 3N/9%**

Volume change in kerosene = 12
Volume change in Water = 20
Free Swelling index value (FSI) = 66.67%

**iv) 3N/12%**

Volume change in kerosene = 13.76
Volume change in Water = 19.6
Free Swelling index value (FSI) = 42.4%

**v) 3N/15%**

Volume change in kerosene = 11.8
Volume change in Water = 19.6
Free Swelling index value (FSI) = 66.1%

Similarly based on above calculation the swelling index values for all the remaining percentages and Normalities are tabulated below

| S.No | Normality | Percentage of chemical 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 |

Table 9 : FSI for NaOH mixed soil at different Normality and Percentage

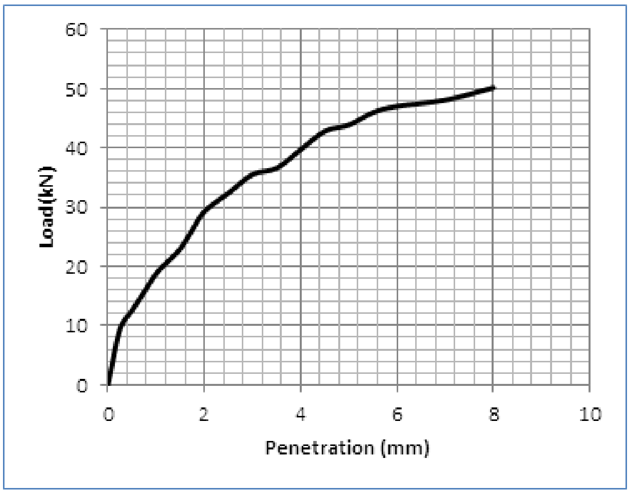
## CALCULATION OF OPTIMUM CONTENT OF % OF SISAL FIBER

1. Here the optimum length of Fiber was first to be found.
2. For that, the length of fiber assumed as 0.5mm at 0.2% of weight of soil, and CBR value found.
3. Next for 1.0mm length and next 1.5mm,2.0mm,2.5mm and 3.0mm found. Percentage of fiber here also assumed as 0.2% (by weight of soil).
4. Based on all the results optimum length found.
5. After finding the optimum resultant length , the percentage varied from 0.4% in such a way that 0.6%,0.8%,1.0% , 2 , 3 etc.
6. From the test readings CBR value @ 0.2% is calculated and tabulated below. This may useful for calculating the optimum length of fiber.

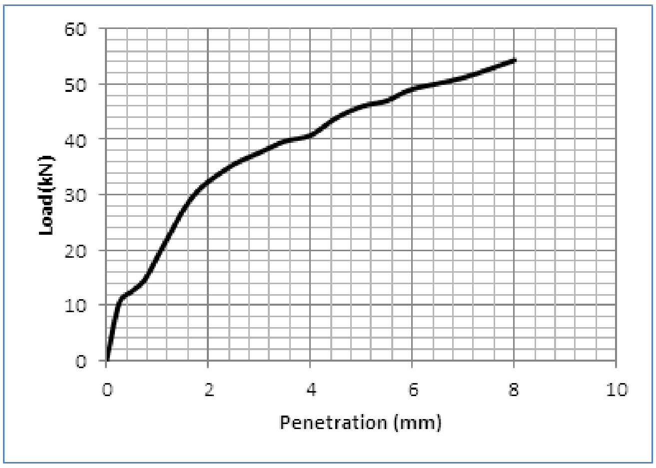
| S.No | Length of fiber (cm) | CBR value |
|---|---|---|
| 1 | 0.5 | 2.365 |
| 2 | 1 | 2.593 |
| 3 | 1.5 | 2.670 |
| 4 | 2 | 2.746 |
| 5 | 2.5 | 2.822 |
| 6 | 3 | 3.124 |

Table 10 : CBR Results at Different length of Fiber at 0.2% fiber content

**A) 0.5cm length of fiber**




**B) For 1.0cm length of fiber**



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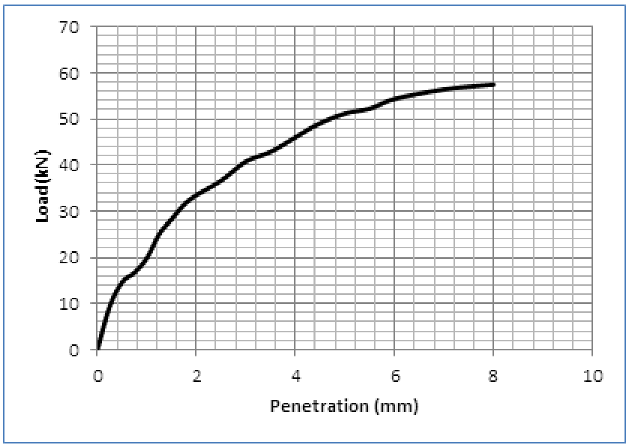
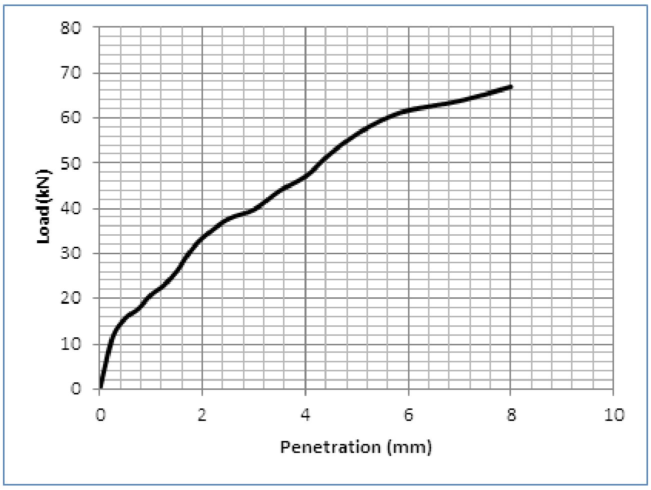
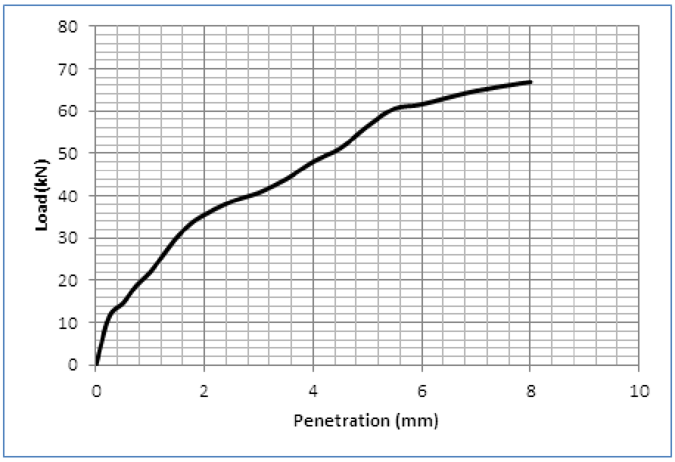
**C) For 1.5cm length of fiber**



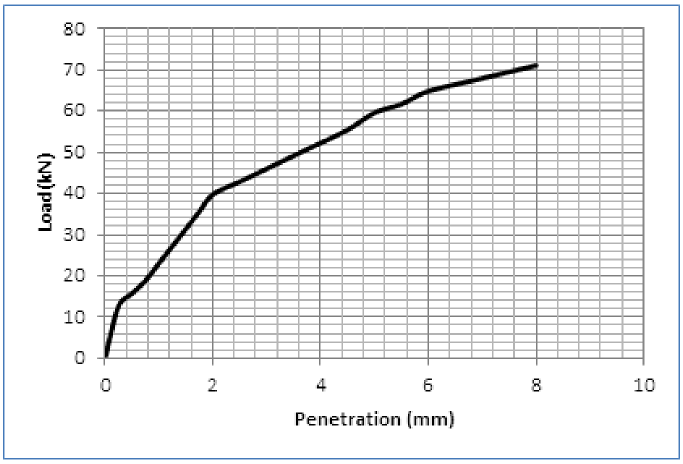

**D) 2.0cm Length of fiber**




**E) For 2.5 cm length of fiber**




**F) For 3.0cm Length of Fiber**




***By considering all the results length of fiber is fixed as 3.0cm**

## 6.EXPERIMENTAL RESULTS AND DISCUSSION

This session gives about the experimental results of both Chemically stabilized soil and Sisal fiber reinforced soil individually and also it gives the results oh Final soil sample that is both Chemically stabilized and Fiber reinforced soil.

## SOIL MIXED WITH NaOH

For 12N, 9% of Chemical content and 20% of Flyash percent added to soil to form the good and stabilized results. After mixing the soil with both chemical and Flyash it is required to kept the soil for maturity atleast a period of one week. After maturity soil tests will conduct to find the properties. The results are shown in below articles. After soil mixing it should be required to allow for maturity that is shown below.

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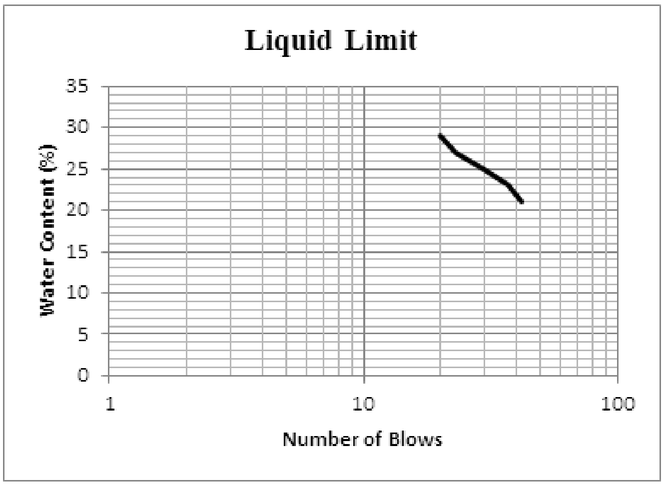
After getting maturity ( one week ) soil has allowed for testing. Those results are listed below.

## FREE SWELLING INDEX

Volume of Soil in
Kerosene = 6.1
Water = 6.5
Free swelling index of chemically stabilized soil = 6.6
As per IS 1498-1972,
FSI value 6.6 represents Degree of Expansion value is Low and Degree of severity is Non-Critical.

## ATTERBERG LIMITS



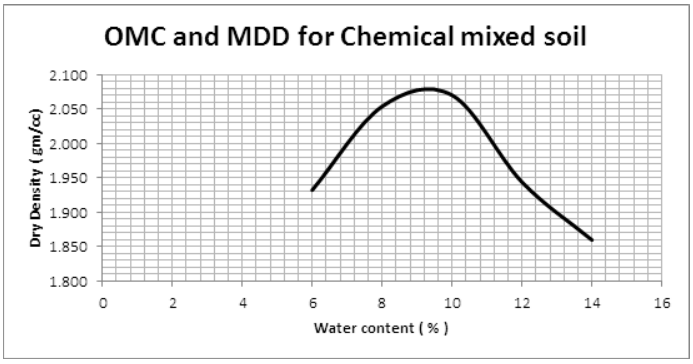

## LIQUID LIMIT

From Graph,
Liquid Limit $W_L$ = 26%
$W_L$ = 26% represents Degree of Expansion value is Low and Degree of severity is Non-Critical.

## PLASTICITY INDEX

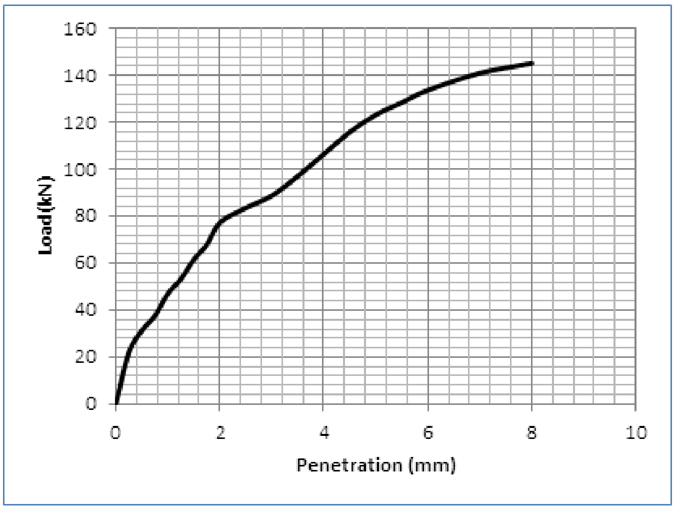
Plastic limit for normal soil
Weight of empty container(W1) = 15 gms
Weight of empty container + wet soil(W2)= 42 gms
Weight of empty container + dry soil(W3)= 38 gms
Water content = ( W2- W3)/( W3- W1) * 100
= (42-38)/(38-15) * 100
= 17.4%
Plastic limit $W_P$ = 17.4 %
Plasticity Index
I.P = L.L - P.L = 26 – 17.4 = 8.6
PI = 8.6 that is < 12 represents Degree of Expansion value is Low and Degree of severity is Non-Critical.

## STANDARD PROCTOR TEST



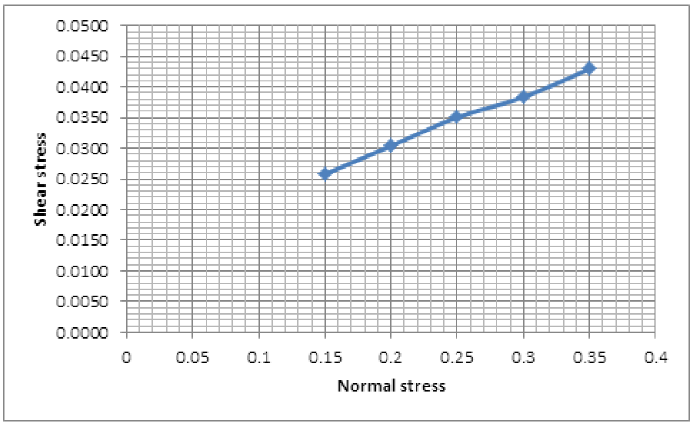

From Graph,
Maximum dry density of soil is 2.08 gm/cc
Optimum Moisture Content is 9.3%

## CALIFORNIA BEARING RATIO (CBR)




CBR value
@ 2.5 mm Penetration = 6.102 @ 5.0mm Penetration = 6.01

## DIRECT SHEAR



**From graph,**

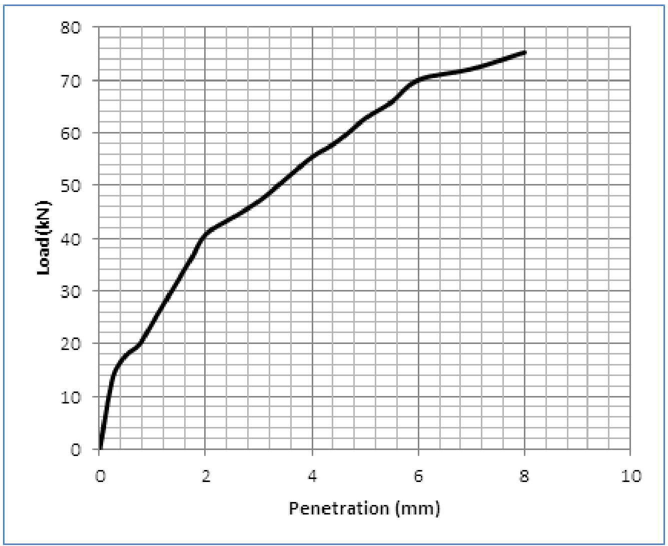
Cohesion value C = 0.128

Angle of Internal friction = $38.7^0$

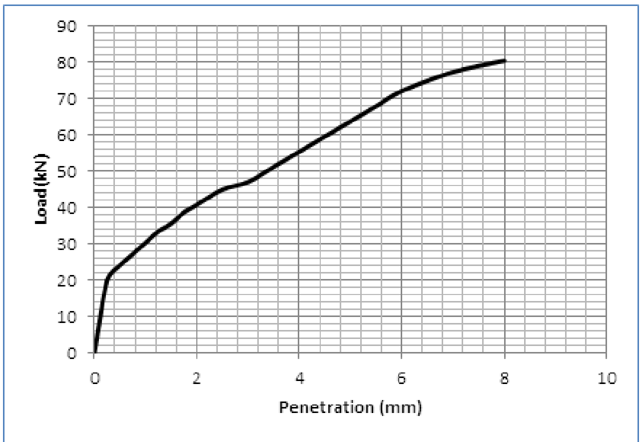
### REINFORCED SOIL

Initially soil is tested with 0.2% fiber content and the CBR value calculated and now the testing for the samples are done from 0.4%, 0.6%, 0.8%, 1.0%, 1.2%, 1.4%, 1.6%, 1.8%, 2.0%, 3.0%, 4.0%, 5.0%, 7% ,9% ,11% and 13% of fiber content is not getting possible because the fiber content in the mould increasing and due to that adding soil content in the mould value is decreasing. Test results for the fiber contents are listed in tabular columns. That are shown below.

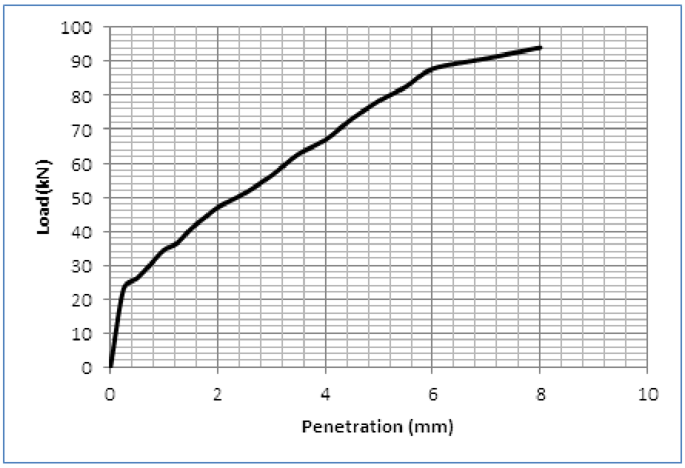
### FOR FIBER HAVING 0.4% OF SOIL



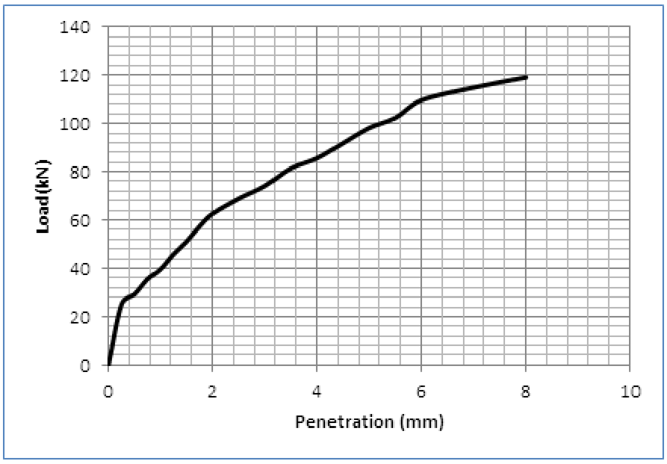

### FOR FIBER HAVING 0.6% OF SOIL



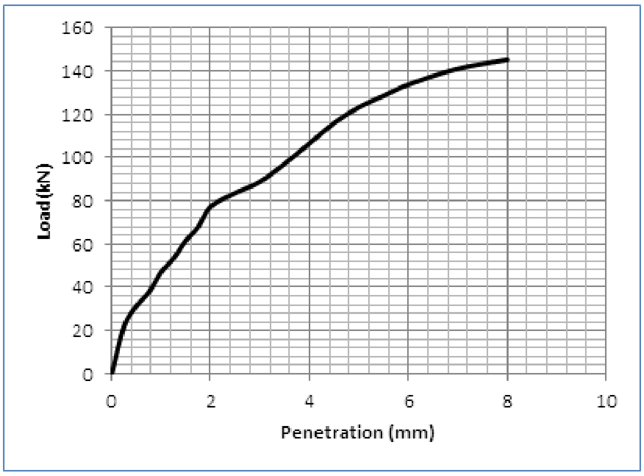

### FOR FIBER HAVING 0.8% OF SOIL



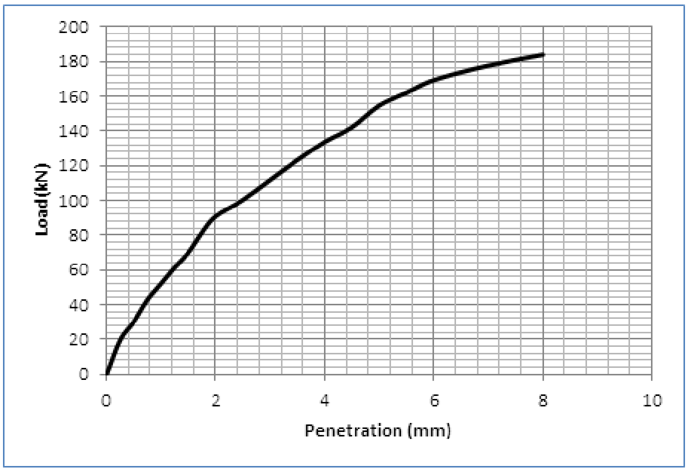

### FOR FIBER HAVING 1.0% OF SOIL



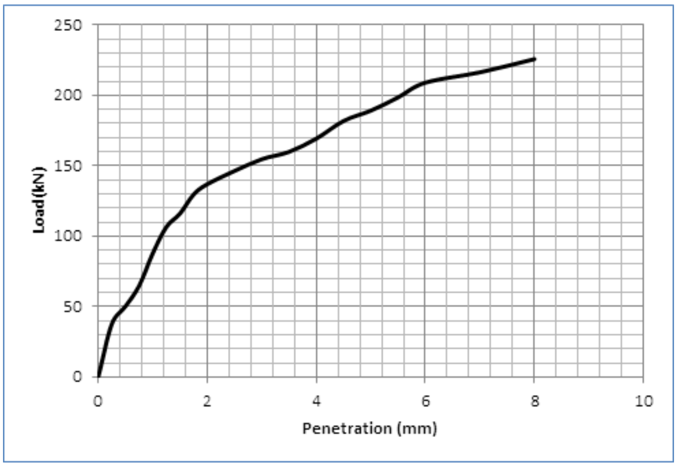

### FOR FIBER HAVING 1.2% OF SOIL



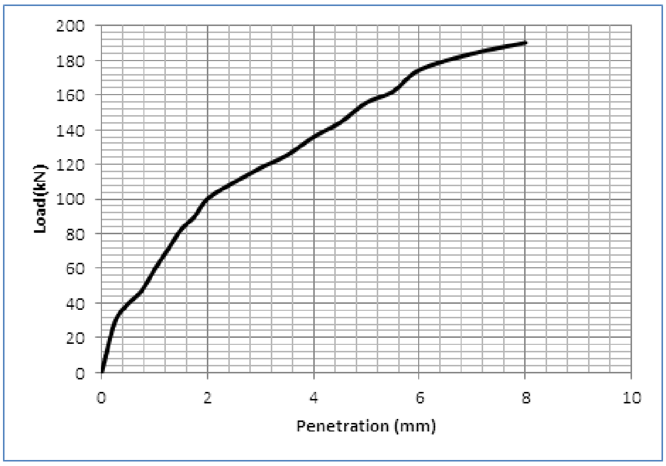
FOR FIBER HAVING 1.4% OF SOIL



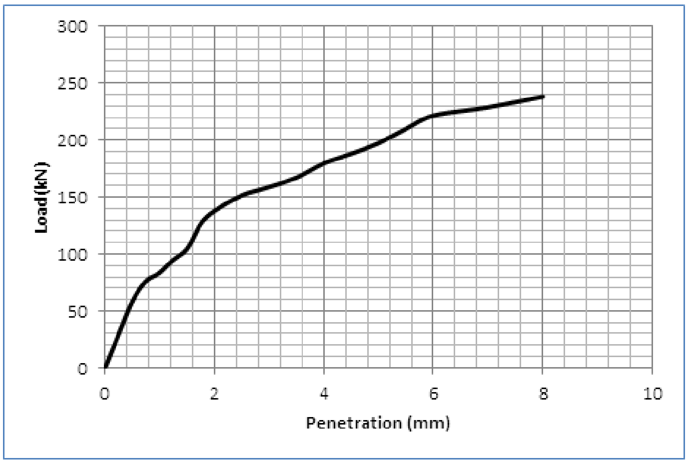

FOR FIBER HAVING 2.0% OF SOIL



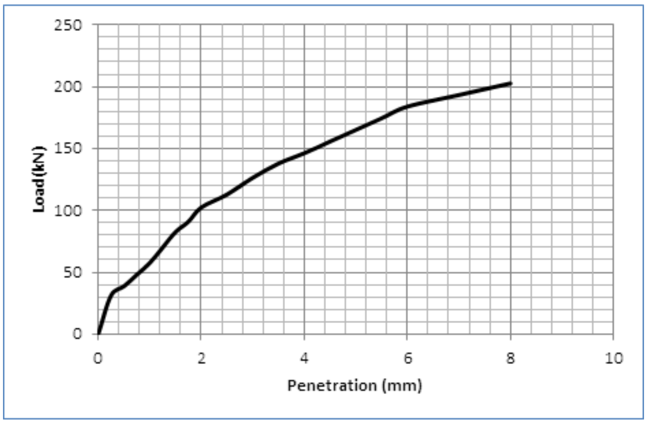

FOR FIBER HAVING 1.6% OF SOIL



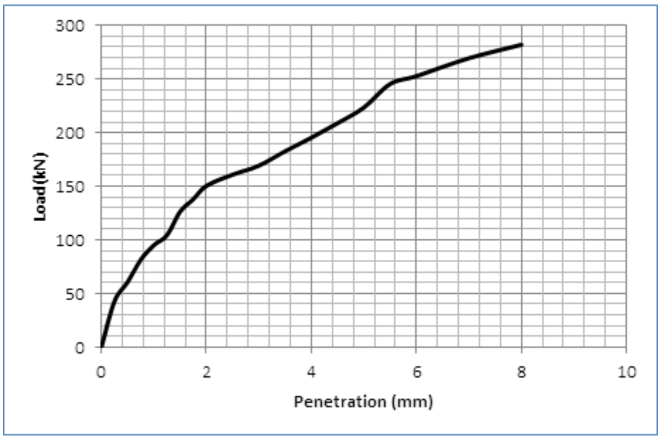

FOR FIBER HAVING 3.0% OF SOIL




FOR FIBER HAVING 1.8% OF SOIL




FOR FIBER HAVING 4.0% OF SOIL



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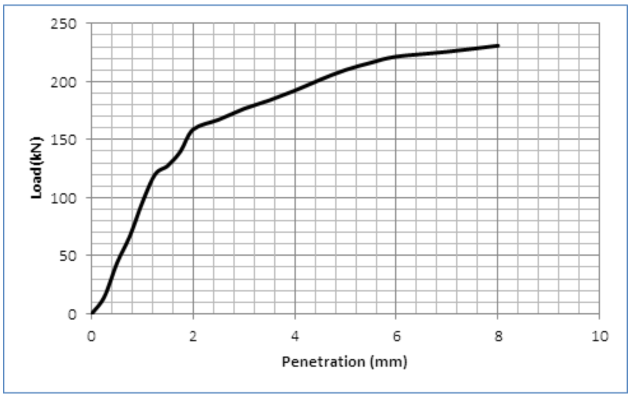
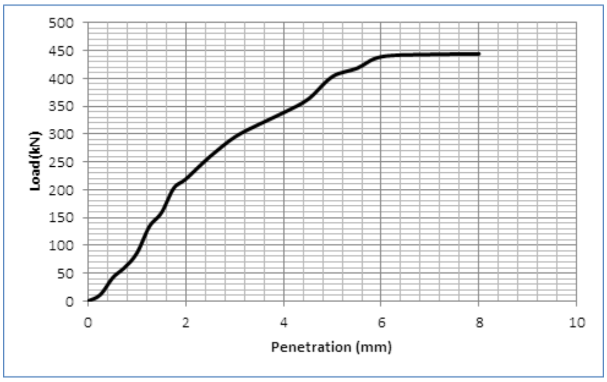
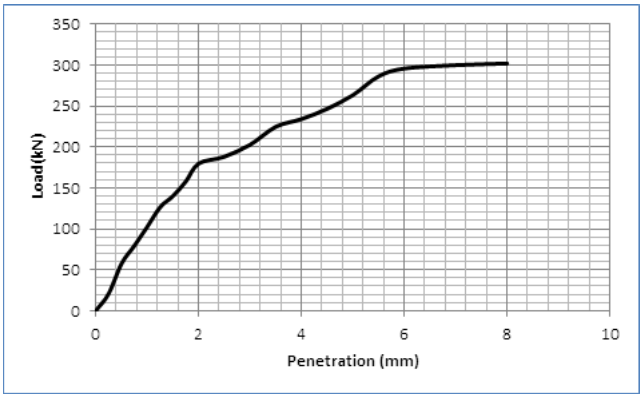
**FOR FIBER HAVING 5.0% OF SOIL**



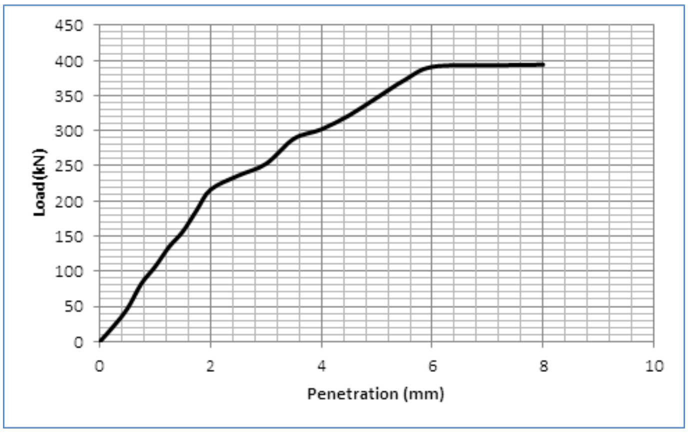

**FOR FIBER HAVING 11.0% OF SOIL**



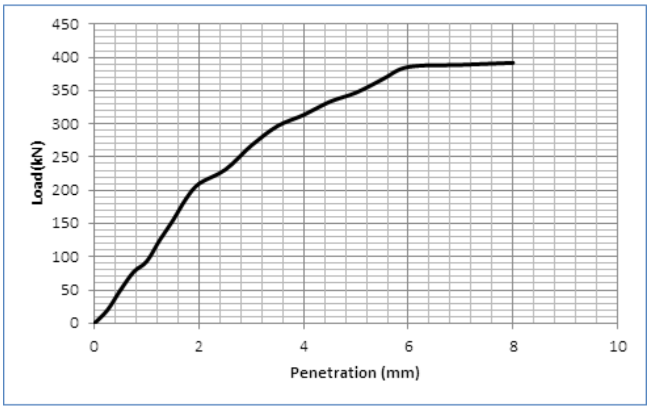

**FOR FIBER HAVING 7.0% OF SOIL**




**FOR FIBER HAVING 13.0% OF SOIL**



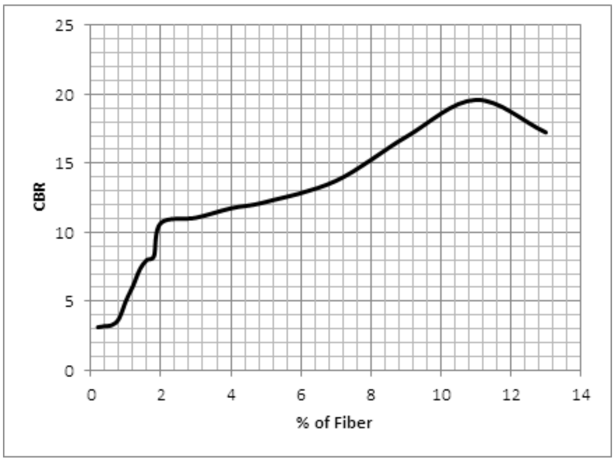

**FOR FIBER HAVING 9.0% OF SOIL**




CBR results of all percentages of fiber is shown below.

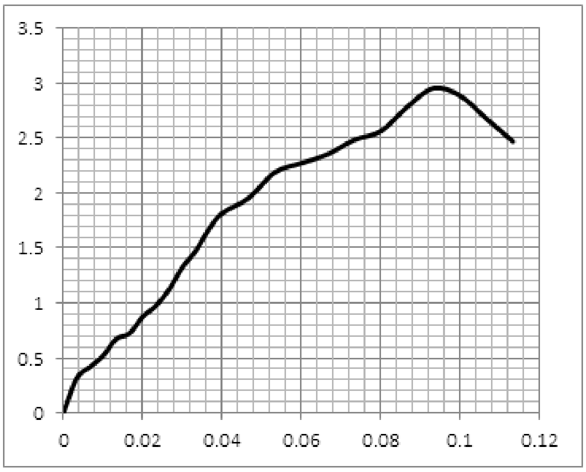
Table : CBR for different % of fiber

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




From graph we can say that the maximum amount of fiber content value to attain maximum percentage of CBR value is 11%.

## UNCONFINED COMPRESSIVE STRESS @ 11% OF FIBER CONTENT




**From Graph,**

The maximum value of Axial stress $q_u$ = 2.955 kg/mm$^2$

The maximum value of Shear stress = $q_u/2$ = 1.4775 kg/mm$^2$

Which is greater than the Normal soil shear stress value.

## FOR THE MIXTURE OF CHEMICAL AND REINFORCED SOIL

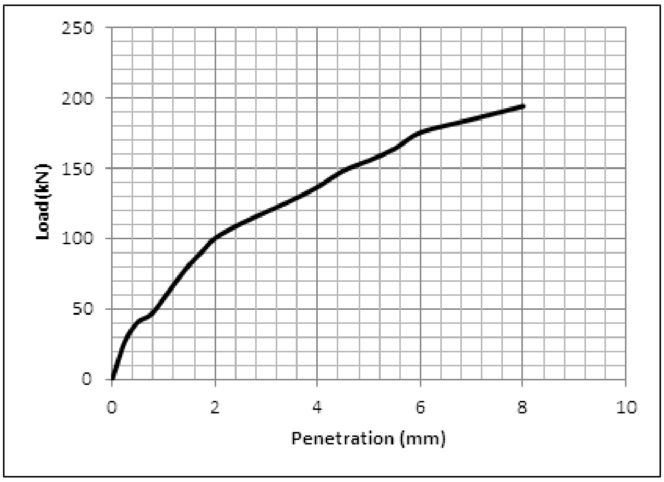
## CBR FOR 0.2% OF FIBER

CBR value of soil matrix

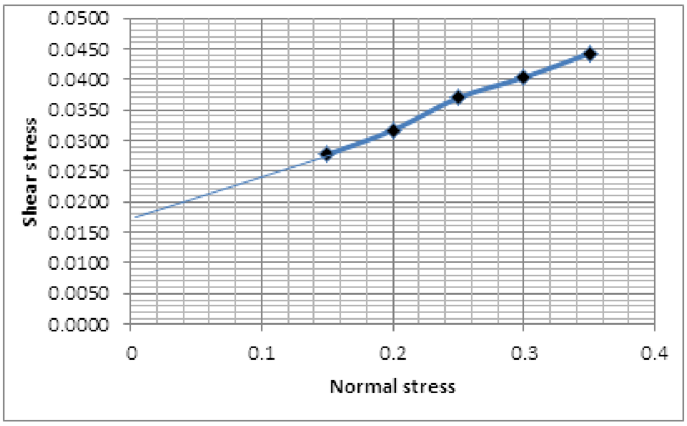
@ 2.5mm penetration = 8.085

@ 5.0mm Penetration = 7.55

*CBR value of soil matrix is 8.085




## DIRECT SHEAR 0.2% OF FIBER




**From graph**

Cohesion of soil contain reinforcement = 0.017

Angle of internal friction Ø = 40.4$^0$

## Comparison between Results

## For Normal soil

| 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$^2$ | - |

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## For 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% | Good value of dry density |
| | Maximum Dry density | 2.08 gm/cc | |
| 5 | CBR | 6.1 | Good value |

## 7.DISCUSSION

### FREE SWELL INDEX

1. Initially Free Swell Index value found for the normal soil, the founded value of FSI for normal soil is 101.83% and Degree of Severity is Critical As Per IS 1498-1972 , IS 2720-40 (1977).
2. After finding the value of FSI for normal soil, NaOH solution added to the soil along with having 20% of Flyash as filler material.
3. This added NaOH contains different Normality and different percentage values.
4. Initially soil mixed with 3N/3% along with flyash and later continued till 15%, finally the mixing values ended with 15N/15% , after mixing with NaOH soil allowed for maturity.
5. After one week FSI value calculated for the stabilized soil, based on the results ( shown in Table: 9) the optimum value of NaOH is 12N/9%, because the FSI value here is too much less and efficient i.e. FSI at 12N/9% is 6.6%, Degree of Severity is Non-Critical as per IS 1498-1972.

### ATTERBERG LIMITS

### LIQUID LIMIT

1. Initially liquid limit value found to the normal soil, the value obtained here is 54% , but as per IS 1498-1972 Degree of Severity is Critical.
2. Later soil mixed with 12N/9% NaOH and allowed for maturity.
3. After one week soil tested and the result obtained is 24%, Degree of Severity is Non-Critical as per IS 1498-1972.

### PLASTICITY INDEX

1. Initially Plasticity value found to the normal soil, the value obtained here is 25.43% , but as per IS 1498-1972 Degree of Severity is Critical.
2. Later soil mixed with 12N/9% NaOH and allowed for maturity.
3. After one week soil tested and the result obtained is 8.6%, Degree of Severity is Non-Critical as per IS 1498-1972.
4. In this way Plasticity values are reduced, simultaneously Plastic limit values are also decreased.

### OPTIMUM MOISTURE CONTENT AND MAXIMUM DRY DENSITY

1. Initially OMC and MDD values found for normal soil that are 11.9% and 1.979 gm/cc respectively.
2. After stabilized with NaOH solution the values are changed to 9.3% and 2.08gm/cc.
3. This is because of the end product in the reaction i.e. due to Calcium Silicate Hydrate ($CaH_2O_4Si$) , the expansion nature has decreased. That's why the OMC value decreased and simultaneously MDD value increased.

### CBR

1. Due to the stabilization CBR value has increased from 2.136 to 6.10 .
2. In fact we know that 2.136 is a very poor CBR value for subgrade and it won't preferable as a subgrade layer, but this overcame by the stabilization that CBR value has increased to 6.10 after stabilization. As we know that 6.10 is an exceptionally very good value for the pavement construction.
3. Hence we can consider 12N , 9% value of NaOH concentration as an optimum content.
4. To increase the CBR value of soil matrix reinforcement is a good technique.

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5. Sisal fiber is used here as the Reinforcing agent, 1.2% fiber content required to get CBR value of 6.1.
6. But after stabilization, that percentage value decreased to 0.2%.

## 8. COST ANALYSIS

In this session Audit of the project listed.

1. For the project , Soil brought from Musunuru

Transportation charges per One Quintal = Rs. 100.00/-

2. Fly ash bought from Krishnapatnam Power Generation Corporation and Private Limited, Krishnapatnam , Nellore, Andhrapradesh.
   Cost of fly ash per One Quintal = Rs. 100.00/-
3. NaOH pellets bought from Delta Engineering chemical suppliers, Vijayawada, Andhrapradesh.
   Cost of NaOH pellets per 1 kg = Rs. 500/-
4. Fiber bought from Sri Balaji fiber industries , Guntur
   Cost fiber per one Quintal= Rs. 500/-

5. Turpentine oil bought from local market,

Cost turpentine oil per 10 lit = Rs. 400/-

**Expenses required to take stabilize one kilogram soil,**

Soil transportation charges = Rs. 1.00/-
Cost of fly ash ( 200gms) = Rs. 0.20/-
Cost of NaOH pellets ( 43.2gms) = Rs. 21.60 /-
Lump sum = Rs. 3.40/-
Total = Rs. 25.00/-

**Expenses after adding fiber to soil ( bring 8.085 CBR value for one kilogram of stabilized soil)**

Cost of fiber ( 0.002gms) = Rs. 0.01/-
Cost of Turpentine oil ( 500 ml) = Rs. 20.00/- ( Lump sum)
Total = Rs. 20.01/-
Lump sum = Rs. 4.99/-
Total = Rs. 25.00/-

Therefore, Total cost required to bring 8.085 CBR value of the stabilized reinforced soil

= 25.00+25.00 = **Rs. 50.00/-**

## 9.CONCLUSION

1. By using NaOH as an admixture we can stabilize the soft soil. It gives strength to the soil.
2. Engineering & Index properties of soft soil will improved while using NaOH as an admixture at 12N, 9% for the subgrade construction purposes.
3. As a civil engineer it is our duty to convert the useless construction materials in to useful materials and we have to choose the better ways based on the economic considerations also.
4. We have to control the environmental pollution using the pollution creating agents as the admixtures for the stabilization of materials or to increase strength of the building materials that's why Flyash here used as a filler material. In fact there are so many filler materials in the nature. But fly ash used here because of it is a great pollutant.
5. Improvement of engineering properties is the main criteria for the civil engineers for an economic purpose in the site. 20-30% by weight of fly ash is suited for the little stabilization of soft soil. That is why 20% assumed as a filler material content.
6. After mixing the soil with NaOH and Fly ash , the CBR value increased to 6.1 (After Maturity) from 2.136
7. Also Atterberg limits also get good values that is $W_L$ changed from 54% to 24% and $I_P$ changed from 25.43% to 8.6% .
8. OMC value also changed from 11.9% to 9.3%. Simultaneously MDD value also increased from 1.979gm/cc to 2.08gm/cc.
9. In this way the soil can stabilize effectively at a minimum cost.

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