STABILIZATION OF SOFT SOIL USING INDUSTRIAL WASTE

A Project Report

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to the University of Petroleum & Energy Studies, for the award of the degree of BACHELOR OF TECHNOLOGY in Civil Engineering is a bonafide record of project work carried out by him/her/them under my/our supervision and guidance. The content of the thesis, in full or parts have not been submitted to any other Institute or University for the award of any other degree or diploma.

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ABSTRACT

The main objective of this study is to investigate the use of waste materials in geotechnical applications and to evaluate the effects of waste on permeability, compaction and strength of soil. The results obtained are compared for the two samples and inferences are drawn towards the usability and effectiveness of soil reinforcement as a replacement for deep foundation or raft foundation, as a cost effective approach.

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CHAPTER – 1

INTRODUCTION

For any land-based structure, the foundation is very important and has to be strong to support the entire structure. In order for the foundation to be strong, the soil around it plays a very critical role. So, to work with soils, we need to have proper knowledge about their properties and factors which affect their behavior. The process of soil stabilization helps to achieve the required properties in a soil needed for the construction work.

From the beginning of construction work, the necessity of enhancing soil properties has come to the light. Ancient civilizations of the Chinese, Romans and Incas utilized various methods to improve soil strength etc., some of these methods were so effective that their buildings and roads still exist.

In India, the modern era of soil stabilization began in early 1970's, with a general shortage of petroleum and aggregates, it became necessary for the engineers to look at means to improve soil other than replacing the poor soil at the building site. Soil stabilization was used but due to the use of obsolete methods and also due to the absence of proper technique, soil stabilization lost favor.

Here, in this project, soil stabilization has been done with the help of randomly distributed polypropylene fibers obtained from waste materials.

CHAPTER- 2

LITERATURE REVIEW

2.1 Soil Stabilization

2.1.1 Definition

Soil stabilization is the process of altering some soil properties by different methods, mechanical or chemical in order to produce an improved soil material which has all the desired engineering properties.

Soils are generally stabilized to increase their strength and durability or to prevent erosion and dust formation in soils. The main aim is the creation of a soil material or system that will hold under the design use conditions and for the designed life of the engineering project. The properties of soil vary a great deal at different places or in certain cases even at one place; the success of soil stabilization depends on soil testing. Various methods are employed to stabilize soil and the method should be verified in the lab with the soil material before applying it on the field.

Principles of Soil Stabilization:

- Evaluating the soil properties of the area under consideration.
- Deciding the property of soil which needs to be altered to get the design value and choose the effective and economical method for stabilization.
- Designing the Stabilized soil mix sample and testing it in the lab for intended

stability and durability values.

2.1.2 Needs & Advantages

Soil properties vary a great deal and construction of structures depends a lot on the bearing capacity of the soil, hence, we need to stabilize the soil which makes it easier to predict the load bearing capacity of the soil and even improve the load bearing capacity. The gradation of the soil is also a very important property to keep in mind while working with soils. The soils may be well-graded which is desirable as it has less number of voids or uniformly graded which though sounds stable but has more voids. Thus, it is better to mix different types of soils together to improve the soil strength properties. It is very expensive to replace the inferior soil entirely soil and hence, soil stabilization is the thing to look for in these cases. [9]

- It improves the strength of the soil, thus, increasing the soil bearing capacity.
- It is more economical both in terms of cost and energy to increase the bearing capacity of the soil rather than going for deep foundation or raft foundation.
- It is also used to provide more stability to the soil in slopes or other such places.
- Sometimes soil stabilization is also used to prevent soil erosion or formation of dust, which is very useful especially in dry and arid weather.
- Stabilization is also done for soil water-proofing; this prevents water from entering into the soil and hence helps the soil from losing its strength.
- It helps in reducing the soil volume change due to change in temperature or moisture content.
- Stabilization improves the workability and the durability of the soil.

“The need for soil stabilization, April 9, 2011 by Ana [online] Available at: < http://www.contracostalandscaping.com/the-need-for-soil-stabilization/>”

- - Online refrence

2.1.3 Methods

- Mechanical method of Stabilization

  In this procedure, soils of different gradations are mixed together to obtain the desired property in the soil. This may be done at the site or at some other place from where it can be transported easily. The final mixture is then compacted by the usual methods to get the required density.

- Additive method of stabilization

  It refers to the addition of manufactured products into the soil, which in proper quantities enhances the quality of the soil. Materials such as cement, lime, bitumen, fly ash etc. are used as chemical additives. Sometimes different fibers are also used as reinforcements in the soil. The addition of these fibers takes place by two methods;

  a) Oriented fiber reinforcement-

  The fibers are arranged in some order and all the fibers are placed in the same orientation. The fibers are laid layer by layer in this type of orientation. Continuous fibers in the form of sheets, strips or bars etc. are used systematically in this type of arrangement.

  b) Random fiber reinforcement-

This arrangement has discrete fibers distributed randomly in the soil mass. The mixing is done until the soil and the reinforcement form a more or less homogeneous mixture. Materials used in this type of reinforcements are generally derived from paper, nylon, metals or other materials having varied physical properties.

Randomly distributed fibers have some advantages over the systematically distributed fibers. Somehow this way of reinforcement is similar to addition of admixtures such as cement, lime etc. Besides being easy to add and mix, this method also offers strength isotropy, decreases chance of potential weak planes which occur in the other case and provides ductility to the soil.

"Methods of soil stabilization, December 24, 2010 [online] Available at: < http://www.engineeringtraining.tpub.com/14070/css/14070_424.htm"

- Online refrence

2.2 Soil properties

2.2.1 Atterberg's Limits

1) Shrinkage Limit:

   This limit is achieved when further loss of water from the soil does not reduce the volume of the soil. It can be more accurately defined as the lowest water content at which the soil can still be completely saturated. It is denoted by *ws*.

2) Plastic Limit:

   This limit lies between the plastic and semi-solid state of the soil. It is determined by rolling out a thread of the soil on a flat surface which is non-porous. It is the minimum water content at which the soil just begins to crumble while rolling into a thread of approximately 3mm diameter. Plastic limit is denoted by w_P.

3) Liquid Limit:

It is the water content of the soil between the liquid state and plastic state of the soil. It can be defined as the minimum water content at which the soil, though in liquid state, shows small shearing strength against flowing. It is measured by the Casagrande's apparatus and is denoted by w_L.

2.3 PERMEABILITY-

The falling head permeability test is a common laboratory testing method used to determine the permeability of fine grained soils with intermediate and low permeability such as silts and clays. This testing method can be applied to an undisturbed sample.

2.4 TRIAXIAL SHEAR STRENGTH-

Triaxial test involves subjecting a cylindrical soil sample to radial stresses (confining pressure) and controlled increases in axial stresses or axial displacements. The cylindrical soil specimen is usually of the dimension of 100 mm diameter and 200 mm height. The specimen in vertically enclosed in a thin rubber membrane. The specimen preparation depends on the type of the soil. Samples of cohesive soils are often prepared directly from saturated compacted samples, either undisturbed or remolded. For cohesion-less soils, however, the specimen is prepared with the help of a mold that maintains the required shape of the specimen.

2.5 COMPACTION-

The Proctor compaction test is a laboratory geotechnical testing method used to determine the soil compaction properties, specifically, to determine the optimal water content at which soil can reach its maximum dry density. The original test is often reffered to as Standard Proctor Test, which was later modified and reffered to as Modified Proctor Test . The difference between the two tests lies mainly in the compaction enegry.

“IS 2720(VII):1980 Methods of Test for Soils, Determination of water content dry density relation using light compaction.”

CHAPTER-3

EXPERIMENTAL INVESTIGATIONS

3.1 Scope of work

The experimental work consists of the following steps:

1. Preparation of sample.
2. Determination of the maximum dry density (MDD) and the corresponding optimum moisture content (OMC) of the soil by Proctor compaction test(IS 2720 PART-7).
3. Determination of permeability of soil.(IS 2720 PART 17)
4. Determination of shear strength by Triaxial Test.(IS 2720 PART-11)

3.2 Preparation of samples

Following steps are carried out while mixing the waste to the soil-

- All the soil samples are compacted at their respective maximum dry density (MDD) and optimum moisture content (OMC), corresponding to the standard proctor compaction tests.
- Content of waste in the soils is herein decided by the following equation:

$$\rho_f = \frac{W_f}{W}$$

Where, ρf= ratio of waste content

W_f = weight of the waste

W = weight of the air-dried soil

- The different values adopted in the present study for the percentage of reinforcement are 0, 0.05, 0.15, and 0.25.
- In the preparation of samples, if waste is not used then, the air-dried soil was mixed with an amount of water that depends on the OMC of the soil.

3.3 Brief steps involved in the experiments

3.3.1 Proctor compaction test

This experiment gives a clear relationship between the dry density of the soil and the moisture content of the soil. The experimental setup consists of (i) cylindrical metal mould (internal diameter- 10.15 cm and internal height-11.7 cm), (ii) detachable base plate, (iii) collar (5 cm effective height), (iv) rammer (2.5 kg). Compaction process helps in increasing the bulk density by driving out the air from the voids. The theory used in the experiment is that for any compactive effort, the dry density depends upon the moisture content in the soil. The maximum dry density (MDD) is achieved when the soil is compacted at relatively high moisture content and almost all the air is driven out, this moisture content is called optimum moisture content (OMC). After plotting the data from the experiment with water content as the abscissa and dry density as the ordinate, we can obtain the OMC and MDD.

$$\text{Wet density} = \frac{\text{weight of wet soil in mould gms}}{\text{volume of mould cc}}$$

$$\text{Moisture content \%} = \frac{\text{weight of water gms}}{} \times 100$$

weight of dry soil gms

$$\text{Dry density } \gamma d \text{ (gm/cc)} = \frac{\text{wet density}}{1+\frac{\text{moisture content}}{100}}$$

3.3.2 PERMEABILITY-

The falling head permeability test involves flow of water through a relatively short soil sample connected to a standpipe which provides the water head and also allows measuring the volume of water passing through the sample. The diameter of the standpipe depends on the permeability of the tested soil. The test can be carried out in a Falling Head permeability cell or in an oedometer cell.

Before starting the flow measurements, the soil sample is saturated and the standpipes are filled with de-aired water to a given level. The test then starts by allowing water to flow through the sample until the water in the standpipe reaches a given lower limit. The time required for the water in the standpipe to to drop from the upper to the lower level is recorderd. Often, the standpipe is refilled and the test is repeated for couple of times. The recorded time should be the same for each test within an allowable variation of about 10% (Head 1982) otherwise the test is failed.

On the basis of the test results, the permeability of the sample can be calculated as

$K=[2.3\, a.L / (A.\Delta t)].\mathrm{Log}(h_U / h_L)$

in which we have

L: the height of the soil sample column
A: the sample cross section
a: the cross section of the standpipe
Δt: the recorded time for the water column to flow though the sample

h_U and h_L : the upper and lower water level in the standpipe measured using the same water head reference

3.3.3 TRIAXIAL TEST-

In triaxial consolidated drain tests can be performed on all types of soils. Drainage is allowed in both phases of triaxial testing; isotropic consolidation & shearing. Soil is consolidated under a chosen confining pressure; and after completion of consolidation it is tested for shear by applying deviator stress gradually at slow strain rate while allowing full drainage. It takes more time to complete a test as compared to CU test, and commonly known as "slow" test, which is seldom conducted except for research interest.

Chapter-4

RESULT AND DISCUSSION

4.1 PROCTOR TEST

SAMPLE 1-ONLY SOIL

Test No.	**1**	**2**
Weight of empty mould(Wm) gms	2059	2059
Internal diameter of mould (d) cm	10	10
Height of mould (h) cm	13	13
Volume of mould (V)=(π/4) d^2h cc	1000	1000
Weight of Base plate (Wb) gms	2065	2065
Weight of empty mould + base plate (W') gms	4124	4124
Weight of mould + compacted soil + Base plate (W1) gms	6089	6179
Weight of Compacted Soil (W1-W') gms	1965	2055
Container no.	20.15	21.15
Weight of Container (X1) gms	20.19	21.14
Weight of Container + Wet Soil (X2) gms	84.81	124.16
Weight of Container + dry soil	79.59	114.24

(X3) gms		
Weight of dry soil (X3-X1) gms	59.4	93.1
Weight of water (X2-X3) gms	5.22	9.92
Water content W%= X2-X3/X3-X1	15.79	15.65
Dry density ϒd= Vt/1 + (W/100) gm/cc	1.81	1.79

SAMPLE 2- SOIL WITH CEMENT AND WOOD

Test No.	**1**	**2**
Weight of empty mould(Wm) gms	2059	2059
Internal diameter of mould (d) cm	10	10
Height of mould (h) cm	13	13
Volume of mould (V)=(π/4) d^2h cc	1000	1000
Weight of Base plate (Wb) gms	2065	2065
Weight of empty mould + base plate (W') gms	4124	4124
Weight of mould + compacted soil + Base plate (W1) gms	5963	5987
Weight of Compacted Soil (W1-W') gms	1839	1863
Container no.	20.15	21.15
Weight of Container (X1) gms	20.19	21.14
Weight of Container + Wet Soil (X2) gms	80.81	92.60

Weight of Container + dry soil (X3) gms	70.62	85.24
Weight of dry soil (X3-X1) gms	50.43	64.10
Weight of water (X2-X3) gms	10.19	7.36
Water content W%= X2-X3/X3-X1	20.21	18.42
Dry density Ɣd= Vt/1 + (W/100) gm/cc	1.61	1.65

4.2 PERMEABILITY TEST(FALLING HEAD METHOD)

SAMPLE 1-ONLY SOIL

Area of Standpipe Readings, a :	568.32cm^2			
Area of Sample, A :	81.07cm^2			
Height of travel thru Sample, L :	20.45cm			
Height of Initial Head, h_1 (cm):	52.50	52.50	52.50	52.50
Height of Final Head, h_2 (cm):	52.10	52.10	52.10	52.10
Time, t (seconds):	600.0	550.0	625.0	650.0
Permeability, k (cm/s) =	1.83 E-03	1.99 E-03	1.75 E-03	1.69 E-03
k = (a x L) / (A x t) x LN (h_1 / h_2)				
Average Permeability, k (cm/s) =	**1.82 E-03**			

SAMPLE 2- SOIL WITH CEMENT

Area of Standpipe Readings, a :	568.32cm^2			
Area of Sample, A :	74.38cm^2			
Height of travel thru Sample, L :	20.45cm			
Height of Initial Head, h_1 (cm):	52.50	52.50	52.50	52.50
Height of Final Head, h_2 (cm):	52.10	52.10	52.10	52.10
Time, t (seconds):	751.0	710.0	805.0	745.0
Permeability, k (cm/s) =	1.59 E-03	1.68 E-03	1.48 E-03	1.60 E-03
k = (a x L) / (A x t) x LN (h_1 / h_2)				
Average Permeability, k (cm/s) =	**1.59 E-03**			

SAMPLE 3-SOIL WITH CEMENT AND WOOD MIXTURE

Area of Standpipe Readings, a :	568.32cm^2			
Area of Sample, A :	81.50cm^2			
Height of travel thru Sample, L :	20.45cm			

Height of Initial Head, h_1 (cm):	52.50	52.50	52.50	52.50
Height of Final Head, h_2 (cm):	52.10	52.10	52.10	52.10
Time, t (seconds):	440	425	390	460
Permeability, k (cm/s) =	2.48 E-03	2.47 E-03	2.57 E-03	2.37 E-03
$k = (a \times L) / (A \times t) \times LN(h_1 / h_2)$				
Average Permeability, k (cm/s) =	**2.47 E-03**			

4.3 TRIAXIAL TEST-

SAMPLE 1-ONLY SOIL

- Soil Sample properties
  - Length = 76mm
  - Diameter = 38.1mm
  - Vertical deformation = 7mm

- Test Results

	Cell pressure (kPa)	**Additional axial load at failure (N)**
Test 1	50	55
Test 2	100	80
Test 3	150	100

- Volume of Sample= 88,647 mm3
- CSA at failure = 1,256 mm2
- Cohesion = 10 kPa
- $\phi = 9^{o}$

	Cell pressure (kPa)	Deviator stress (kPa)	Major Princ.stress (kPa)
Test 1	50	43.8	93.8
Test 2	100	63.7	163.7
Test 3	150	79.6	229.6

SAMPLE 2-SOIL WITH CEMENT AND WOOD

Soil sample properties-

- Length = 76mm
- Diameter = 38.1mm
- Vertical deformation = 9mm

- Test Results

	Cell pressure (kPa)	Additional axial load at failure (N)
Test 1	50	154
Test 2	100	212
Test 3	150	332

- Volume of Sample= 88,647 mm3
- CSA at failure = 1,563 mm2
- Cohesion = 13.4kPa
- phi =12.6º

	Cell pressure (kPa)	Deviator stress (kPa)	Major Princ.stress (kPa)
Test 1	50	382.9	432.9
Test 2	100	552.4	652.4
Test 3	150	822.5	972.5

COMPARISION

- The change in properties and results obtained from the research paper on- **Stabilization of Soil using Cement Waste by Y. KEERTHI, P. DIVYA KANTHI, N. TEJASWI, K. SHYAM CHAMBERLIN, B. SATYANARAYANA** *Department of Civil Engineering, K L University, Guntur, Andhra Pradesh, India*

SOIL SAMPLE 1- ONLY SOIL

Strain (micron)	Stress (kPa)	Deformation (mm)	Load (kg)	Dry Density g/cm	Moisture content (%)
99	464	1.398	185	1.864	6.62
96	583	1.358	232	1.864	6.62
107	598	1.509	236	1.898	8.12
89	638	1.26	252	1.898	8.12
82	685	1.158	272	1.925	9.62
89	691	1.254	275	1.925	9.62
89	640	1.258	255	1.892	11.13
86	662	1.206	262	1.892	11.13

SOIL SAMPLE 2- SOIL WITH CEMENT

Strain (micron)	Stress (kPa)	Deformation (mm)	Load (kg)	Dry Density g/cm	Moisture content (%)
101	2638	1.425	1044	1.665	10.64
85	2554	1.206	1012	1.665	10.64
82	3068	1.156	1209	1.69	12.58
89	3279	1.26	1290	1.69	12.58
82	3399	1.159	1340	1.724	14.56
79	3706	1.11	1459	1.728	14.56
135	2332	1.911	924	1.712	16.58
125	2272	1.758	898	1.712	16.58

COMPARISION

The change in properties and results obtained from tests performed are-

SOIL SAMPLE 1- ONLY SOIL

Strain (micron)	Stress (kPa)	Deformation (mm)	Load (kg)	Dry Density g/cm	Moisture content (%)
83	163.7	1.256	186	1.81	15.79
74	93.8	1.115	195	1.79	15.65
93	229.6	1.321	179	1.83	15.82

SOIL SAMPLE 2-SOIL WITH CEMENT AND WOOD WASTE

Strain (micron)	Stress (kPa)	Deformation (mm)	Load (kg)	Dry Density g/cm	Moisture content (%)
87	432.9	1..245	1115	1.65	20.12
81	652.4	1.119	996	1.59	21.50
96	972.5	1.117	1250	1.70	23.24

CONCLUSIONS

On the basis of experimental study done, the following conclusions are drawn:

1. The mixture of wood waste and cement can be used to increase the bearing capacity of soft soil.

2. Wherever the water table is high , the wood waste cannot be used to stabilize the soil.

3. There is a significant increase in shear strength of soil on addition of wood and cement waste mixture.

4. In case of cement and wood waste mixture the permeability of soil increases while in case of cement the permeability decreases. Hence the stabilized soil may be used depending on water table.

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