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Soil Stabilization Using Waste Fibre Materials

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Abstract

The main objective of this study is to investigate the use of waste fibre materials in geotechnical applications and to evaluate the effects of waste polypropylene fibres on the shear strength of unsaturated soil by carrying out direct shear tests and unconfined compression tests on two different soil samples. The results obtained are compared for the two samples, and inferences are drawn towards the usability and effectiveness of fibre reinforcement as a replacement for deep foundation or raft foundation as a cost-effective approach.

Structures that are constructed on the expansive soil may have occurred several damages due to its hill swell-shrinkage behaviour. So, these type of soil ned to be stabilized in order to increase the shear strength of the soil, the durability of the soil as well, as to prevent from erosion. Various case studies have been carried out for these types of soil to increase the soil properties. In this case study, a raw fibre known as polypropylene fibre has been used to increase the soil properties and interlocking of the soil and have become one of the major practices used in construction work.

Keywords*: - Soil Stabilization, DST, UCS test, Liquid Limit, Plastic Limit.*

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

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factors which affect their behavior. The process of soil stabilization helps to achieve the required properties in the soil needed for the construction work.

From the beginning of construction work, the necessity of enhancing soil properties has come to light. Ancient civilizations of the Chinese, Romans 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 the early 1913s; 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.

In recent times, with the increase in the 696demand for infrastructure, raw materials and fuel, soil stabilization has started to take a new shape. With the availability of better research, materials and equipment, it is emerging as a popular and cost-effective method for soil improvement.

Here, in this project, soil stabilization has been done with the help of randomly distributed polypropylene fibers obtained from waste materials. The improvement in the shear strength parameters has been stressed upon and comparative studies have been carried out using different methods of shear resistance measurement.

SOIL STABILIZATION

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

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.

Needs & Advantages

- 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.

Methods for measuring shear strength

(a) Direct Shear Test (DST)

This is the most common test used to determine the shear strength of the soil. In this experiment the soil is put inside a shear box closed from all sides and force is applied from one until the soil fails. The shear stress is calculated by dividing this force with the area of the soil mass. This test can be performed in three conditions undrained, drained and consolidated undrained depending upon the set-up of the experiment.

b) Unconfined Compression Test (UCS test)

This test is a specific case of tri axial test where the horizontal forces acting are zero. There is no confining pressure in this test and the soil sample tested is subjected to vertical loading only. The specimen used is cylindrical and is loaded till it fails due to shear.

INVESTIGATIONS

Scope of work

The experimental work consists of the following steps:

1. Specific gravity of soil.

2. Determination of soil index properties (Atterberg Limits)

3. Particle size distribution by sieve analysis.

4. Determination of the maximum dry density (MDD) and the corresponding optimum moisture content (OMC) of the soil by Proctor compaction test.

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Materials

Soil sample-1

Location: Behind Shiva Ganga theatre, Gaddiannaram.

Soil sample- 2

Location: Near Sai function hall, Saroornagar.

Preparation of samples

Following steps are carried out while mixing the fiber 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 fiber in the soils is here in decided by the following equation:

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

- The different values adopted in the present study for the percentage of fiber reinforcement are 0, 0.0 5, 0.15, and 0.25.

- In the preparation of samples, if fiber is not used then, the air dried soil was mixed with an amount of water that depends on the OMC of the soil.

- If fiber reinforcement was used, the adopted content of fibers was first mixed into the air dried soil in small increments by hand, making sure that all the fibers were mixed thoroughly, so that a fairly homogenous mixture is obtained, and then the required water was added.

BRIEF STEPS INVOLVED IN THE EXPERIMENTS

Specific Gravity of the Soil

The specific gravity of soil is the ratio between the weight of the soil solids and weight of equal volume of water. It is measured by the help of a volumetric flask in a very simple experimental set up where the volume of the soil is found out and its weight is divided by the weight of equal volume of water Specific Gravity.

$$G = \frac{(w2-w1)}{(W_2-W_1)-(W_3-W_4)}$$

W1-Weight of bottle in gms,
W2-Weight of bottle+ Dry soil in gms,
W3-Weight of bottle + Soil + Water,
W4-Weight of bottle+ water.

Specific gravity is always measured in room temperature and reported to the nearest 0.1.

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Liquid Limit

The Casagrande tool cuts a groove of size 2mm wide at the bottom and 11mm wide at the top and 8mm high. The number of blows used for the two soil samples to come in contact is noted down. Graph is plotted taking number of blows on a logarithmic scale on the abscissa and water content on the ordinate. Liquid limit corresponds to 25 blows from the graph.

Plastic Limit

This is determined by rolling out soil till its diameter reaches approximately 3mm and measuring water content for the soil which crumbles on reaching this diameter. Plasticity index (Ip) was also calculated with the help of liquid limit and plastic limit;

Particle Size Distribution

The results from sieve analysis of the soil when plotted on a semilog graph with particle diameter or the sieve size as the abscissa with logarithmic axis and the percentage passing as the ordinate gives a clear idea about the particle size distribution. From the help of this curve, D_{10} and D_{60} are determined. This D_{10} is the diameter of the soil below which 10% of the soil particles lie. The ratio of, D_{10} and D_{60} gives the uniformity coefficient(C_u) which inturn is a measure of the particle size range.

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,

1) cylindrical metal mould (internal diameter-10.15cm and internal height 11.7cm),
2) detachable base plate,

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. The equations used in this experiment area follow:

Wet density = weight of wet soil in mould(gms)/volume of mould(cc)

Moisture content% = weight of water(gms)/weight of dry soil(gms)

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Moisture content% = weight of water(gms)/weight of dry soil(gms)

Dry densityγ_d (gm/cc) = wet density/ (1+moisture collar content/100)

Direct Shear Test

This test is used to find out the cohesion(c) and the angle of internal friction(φ) of the soil, these are the soil shear strength parameters. The shear strength is one of the most important soil properties and it is required whenever any structure depends on the soil shearing resistance. The test is conducted by putting the soil at OMC and MDD inside the shear box which is made up of two independent parts. A constant normal load(ɐ) is applied to obtain one value of can dφ. Horizontal load (shearing load) is increased at a constant rate and is applied till the failure point is reached. This load when divided with the area gives the shear strength for that particular normal load. The equation goes as follows: τ = c + σ*tan;φJ After repeating the experiment for different normal loads (ɐ) we obtain a plot which is a straight line with slope equal to angle of internal friction(φ) and intercept equal to the cohesion(c). Direct shear test is the easiest and the quickest way to determine the shear strength parameters of a soil sample. The preparation of the sample is also very easy in this experiment.

Unconfined Compression Test

This experiment is used to determine the unconfined compressive strength of the soil sample which in turn is used to calculate the unconsolidated, undrained shear strength of unconfined soil. The unconfined compressive strength (qu) is the compressive stress at which the unconfined cylindrical soil sample fails under simple compressive test. The experimental set up constitutes of the compression device and dial gauges for load and deformation. The load was taken for different readings of strain dial gauge starting from ε= 0.005 and increasing by 0.005 at each step.

RESULTS AND DISCUSSIONS

Standard Proctor Compaction Test

Soil Sample-1

Table 1

Test No.	1	2	3	4	5
Weight of empty mould (Wm) gms	2059	2059	2059	2059	2059
Internal diameter of mould (d)cm	10	10	10	10	10
Height of mould(h) cm	13	13	13	13	13

Volume of mouldîVÖ=îɎ/ИÖd2hcc	1000	1000	1000	1000	1000
Weight of Base plate (Wb)gms	2065	2065	2065	2065	2065
Weight of empty mould + base plate(W') gms	4124	4124	4124	4124	4124
Weight of mould + compacted soil+ Base plate(W1)gms	6089	6179	6271	6086	6080
Weight of Compacted Soil(W1-W')gms	1965	2055	2147	2108	2102
Container No.	20.15	21.1	19.47	21.49	21.12
Weight of Container(X1) gms	20.19	521.1	19.48	21.55	21.14
Weight of Container + Wet Soil(X2) gms	84.81	124.14	89.93	154	113
Weight of Container + dry soil (X3) gms	79.59	6114.2	82.05	138.1	100.5
Weight of dry soil (X3-X1) gms	59.4	4 93.	62.57	3116.5	79.36
Weight of water(X2-X3) gms	5.22	19.9	7.88	815.87	12.5
Water content W%= X2-X3/X3-1	8.79	10.62	12.59	13.61	15.75
Dry density ϒd = Vt/1+ (W/100)gm/cc	1.81	51.8	1.91	1.85	1.82

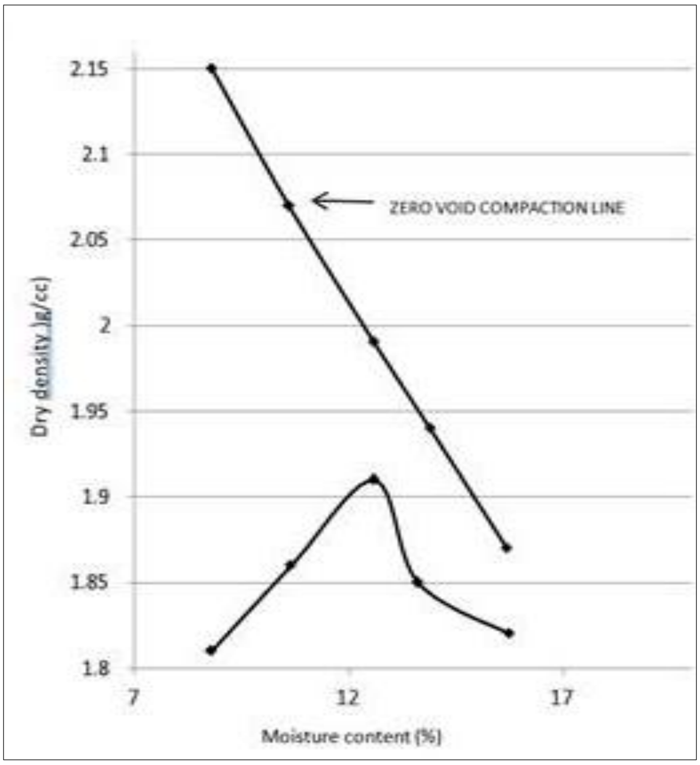

Figure 1

From the figure on the left side, it is evident that,

Optimum moisture content (OMC)=12.6%

Maximum Dry Density (MDD)=1.99g/cc

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Soil Sample-2

Table 2

Test No.	1	2	3	4	5
Weight of empty mould (Wm)gms	2062	2062	2062	2062	2062
Internal diameter of mould (d)cm	10	10	10	10	10
Height of mould(h) cm	13	13	13	13	13
Volume of mouldîVÖ=îϒ/ИÖd´hcc	1000	1000	1000	1000	1000
Weight of Base plate(Wb)gms	2071	2071	2071	2071	2071
Weight of empty mould + base plate(W') gms	4133	4133	4133	4133	4133
Weight of mould + compacted soil+plate Base	6174	6261	6427	6347	6348
(WeightW1)gms of Compacted Soil(W1-W')gms	2041	2128	2294	2214	2215
Container no.	19.47	21.15	21.12	20.15	21.49
Weight of Container (X1)gms	19.49	21.6	21.14	20.19	21.55
Weight of Container + Wet Soil (X2)gms	90.21	122.57	113.12	125.00	119.28
Weight of Container + dry soil (X3)gms	82.51	110.04	99.74	108.94	102.32
Weight of dry soil(X3-X1) gms	63.02	88.87	78.6	88.75	80.77
Weight of water(X2-X3)gms	7.7	12.53	13.38	16.06	16.96
Water content W%=X2-X3/X3-X1	12.18	14.4	17.02	18.1	21
Dry density ϒd=ϒt/(1+ (W/100))gm/cc	1.79	1.86	1.96	1.875	1.83

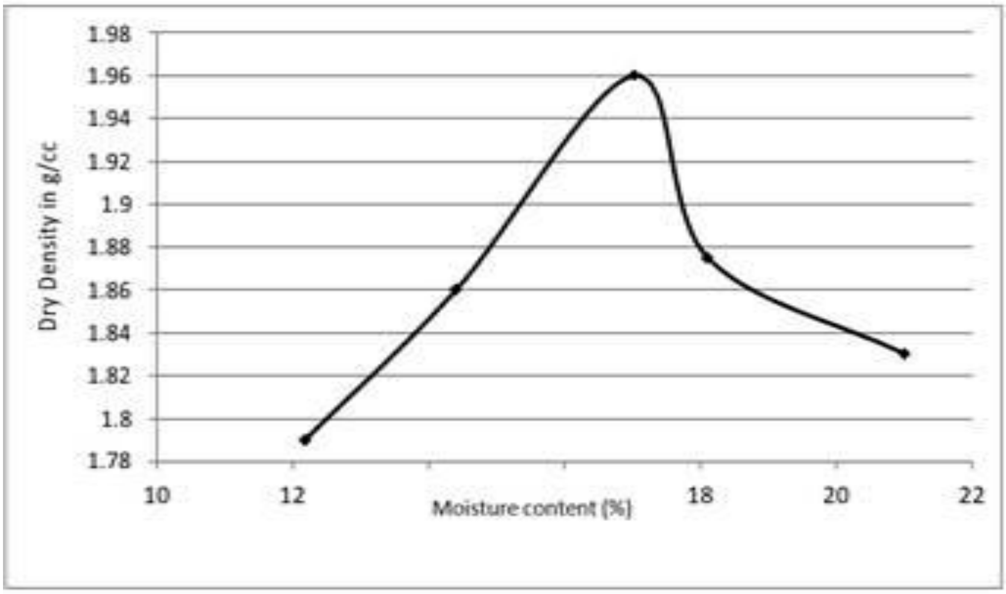

Figure 2

From the figure on the left side it is evident that,

Optimum Moisture Content (OMC) = 17.02%

Maximum Dry Density (MDD) = 1.96g/cc.

Inferences from Direct Shear Test

Soil sample- 1

- Cohesion value increases from 0.325 kg/cm^2 to 0.3887 kg/cm^2, a net **19.6%.**
- The increment graph shows a gradual decline in slope.
- The angle of internal friction increases from 47.72 to 48.483 degrees, a net **1.59%.**
- The increment in shear strength of soil due to reinforcement is marginal.

Soil sample- 2

- Cohesion value increases from 0.3513 kg/cm^2 to 0.5375 kg/cm^2, a net **53.0%.**
- The increment graph for cohesion shows a gradual decline in slope.
- The angle of internal friction increases from 27.82 to 32 degrees, a net **15.02%.**
- The increment graph for φ shows a variation in slope-alternate rise and fall.
- The increment in shear strength of soil due to reinforcement is **substantial**.

Inferences from Unconfined Compression Test

Soil Sample-1

- UCS value increases from 0.0643 Mpa to 0.0562MPa, a net**14.4%.**
- The slope of increment graph is continuously decreasing with an initially steep slope.

Soil sample- 2

- UCS value increases from 0.0692 Mpa to 0.1037MPa, a net **49.8%.**
- The slope of the increment graph varies with alternate rise and fall.

CONCLUSION

1) Based on Specific gravity of a soil- With mixing of 0.5% fibers (PPF) specific gravity of the soil increases by 0.3%. (From table no 3 and 4) Strength of the soil is directly proportional to specific gravity, more is the specific gravity more will be the strength of soil.

2) Based on liquid limit of a soil - Soil without reinforcement and with reinforcement have liquid limit difference of 18.18%.

3) Based on plastic limit of a soil - As similar to liquid limit the plastic limit of soil is also reduces. It reduces from 29.35% to 25.8%. % decrease in plastic limit is 12% (From table no 7 and 8), this result shows increase in shear strength, Cohesiveness and consistency of soil mass.

4) Based on liquid limit of a soil - The value of the shrinkage limit in reinforced soil is less than that of unreinforced soil. Hence with the use of polypropylene fiber shrinkage reduces.

5) The value of shrinkage limit is used for understanding the swelling and shrinkage properties of cohesive soil. Lesser is the shrinkage more will the suitability of material for foundation, road and embankment as more will be the strength.

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