An Experimental Investigation On Soil Stabilization By Waste Materials

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Abstract—*The main objective of this study is to investigate the use of organic waste materials in geotechnical applications and to evaluate the effects of wastes coconut fibre, eggshell powder, rice husk, on shear strength of unsaturated soil by carrying out unconfined compression test on two different soil samples. The results obtained are compared for the two samples and inferences are drawn towards the usability and effectiveness of fiber reinforcement as a replacement for deep foundation or raft foundation, as a cost effective approach.*

Keywords— ***coconut fiber, eggshell powder and rice husk.***

I. Introduction

Soil Stabilization

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.

EXPERIMENTAL WORK

The wetting and drying process of a subgrade layer composed of black cotton (BC) and clay soil result into failure of pavements in form of settlement and cracking. Therefore, prior to construction of a road on such subgrade, it is important either to remove the existing soil and replace it with a non-expansive soil or to improve the engineering properties of the existing soil by stabilization. Replacing the existing soil might not be a feasible option, therefore, the best available approach is to stabilize the soil with suitable stabilizers. Various types of soil stabilizers (i.e.,fly ash, cement kiln dust, lime) and locally available materials (i.e., slate dust, rice husk ash) are being used for stabilization of soil. However, the selection of a particular type of stabilizer depends upon the type of subgrade soil and availability of stabilizers.The clay soil which is under experiment is taken near bysingampunari, kalapurin sivagangai district. Egg shell is obtained from restaurants.Rice husk is obtained from natham Rice mill. coconutfibre is obtained from mk coir factory . Due to construction of pavement on these soils, the pavement experiences many problems such as unequal setting due to huge cracks are formed on the surface of the pavement. Black cotton soil also has a huge clay content due to which it will not allow water to drain causing water logging of the pavement. Due to alternate heating and cooling, the cracks widens due to which the needsstabilization.Stabilization can be carried out by adding eggshell, coconut fibre and rice husk during the construction of the pavement.

RICE HUSK :

Rice milling generates a by-product known as husk. This surrounds the paddy grain. During milling of paddy about 78% of weight is received as rice, broken rice and bran. Rest 22% of the weight of paddy is received as husk. This husk is used as fuel in the rice mills to generate steam for the boiling process. This husk containsabout 75% organic volatile matter and the remaining 25% of the weight of this husk is converted into ash during the firing process, known as Rice Husk Ash (RHA). This RHA in turn contains around 85% - 90% amorphous silica. So for every 1000 kg of paddy milled, about 220 kg (22%) of husk is produced, and when this husk is burnt in the boilers, about 55 kg (25%) of RHA is generated. India is a major rice producing country and the husk generated during milling is mostly used as a fuel in the boilers for processing paddy, producing energy through direct combustion and/ or by gasification. About 20 million tonnes of RHA is produced annually. This RHA is a great environmental threat causing damage to the land and the surrounding area in which it is dumped.Lots of ways are being thought for disposing it by making commercial use of RHA.

EGGSHELL POWDER

Chicken eggshell is a waste material from domestic sources.such as poultries, hatcheries, homes and fast food restaurants.Eggshells were spread on the ground and air dried for 2 days. to facilitate easy milling. After air drying the eggshells weremanually broken and milled into powdery forms which werecollected in polythene bags. The eggshell powder was finallysieved through 425μ sieve. Eggshell powder contains 99.83%of CaO and remaining consists of Al_2O_3, SiO_2, Cl, Cr_2O_3, MnOand CuO.

COCONUT FIBRE

- Coconut fibre has been categorized as pozzolana, with about 67-70% silica and, approximately 4.9 and 0.95% of aluminum and iron oxides, erespectively
- ***Chemical Composition*:** The quantitative analysis of the percentage composition of silica oxide and other chemical compound such as SO_3, K_2O, MnO, Fe_2O_3 and so on, were carried out on the coconut husk

TEST PROCEDURES:

SIEVE ANALYSIS:

In the BS and ASTM standards, the sieve sizes are given in terms of the number of the inch. The complete sieve analysis can be divided into two parts-the coarse analysis and fine analysis. Since black cotton soil is an expansive soil we are using wet sieve analysis to classify the soil. It is advisable to wash the soil portion passing through 4.75mm sieve over 75 micron sieve so that silt and clay particles sticking to the sand particles may be dislodged. Washing should be continued until the water passing through 75 microns sieve is substantially clean. The fraction retained on 75microns sieve is dried in the oven. The dried portion is sieved through various sieves.

Sieving is performed by arranging the various sieves one over the other in the order of their mesh openings. The largest aperture sieve being kept at the top and smallest aperture sieve kept at the bottom. The soil sample is put on the top sieve and the whole assembly is fitted on a sieve shaking machine. The amount of shaking depends upon the shape and the number of particles. At least 10min of shaking is desirable for soils with small particles. The portion of soil sample retained on each sieve is weighed. The percentage of soil retained on each sieve is calculated on the basis of the total mass of soil.

SPECIFIC GRAVITY TEST (G):

Specific gravity test is defined as the ratio of weight of given volume of soil soilds at a given temperature to the weight of an equal volume of distilled water at that temperature both weights being taken in air.

The specific gravity is determined by a 500ml flask, the mass M1 of the empty dry bottle is first taken. The sample is put on the bottle and the mass M2 is taken. The bottle is then filled with water and the entrapped air is removed by applying vacuum. The mass M3 of the bottle soil and water is taken. Finally, the bottle is emptied completely and thoroughly washed, and clean water is filled to top, and the mass M4 is taken.

The specific gravity can be computed as G=(M2-M1) /((M2-M1)-(M3-M4))

ATTERBERG LIMITS:

LIQUID LIMIT(W_L):

The liquid limit is determined with the standard liquid limit apparatus. The apparatus consists of a hard rubber base over which a brass cup drops through a desired height. The brass cup can be raised and lowered to fall on the rubber base with the help of a cam operated by handle. The height of fall of the cup can be adjusted with the help of adjusting screws. Before starting the test the height of fall of the cup is adjusted to 1cm.

About 120 gram of the specimen passing through 425 micron sieve is mixed with water. The portion of the paste is placed in the cup over the spot where cup rests on the base, squeezed down and spread into position and the groove is cut in the soil pat. The handle is rotated at the rate about to revolutions per second, and the numbers of blows are counted until the two parts the soil come into contact. The liquid limit is determined by plotting a graph between number of blows on the abscissa on the logarithmic scale and the corresponding water content as ordinate.

PLASTIC LIMIT(W_P):

Soil specimen passing through 425 micron sieve is taken and mixed with water. The plastic soil mass is left for enough time to allow water to permeate through the soil mass. A ball is formed with about 8gm of plastic soil mass and rolled between the fingers and the glass plate with sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. When a diameter of 3mm is reached, the remould again into a ball. The process of rolling and remoulding is repeated until the thread starts crumbling at a diameter of 3mm.The crumbled threads of kept for water content determination. The plastic limit W_P is then taken as the average of three water content.

Plasticity Index:

The plasticity index is calculated from the relation, $I_P = W_L - W_P$

STANDARD PROCTOR COMPACTION TEST:

About 3 kg of air dried and pulverized soil, passing a 4.75mm sieve, is mixed thoroughly with the small quantity of water. The mixture is covered with wet cloth, and left for the maturing time of about 5 to 30 minutes(or more for clayey soils) to permit proper absorption of water. The quantity of water to be added for the first step depends upon the probable water content for the soil. The initial water content may be taken as 4% for coarse grained soils, and 10% for fine grained soils. The empty mould attached to the base plate is weighed without collar. The collar is then attached to the mould. The mixed and matured soil is placed in the mould and compacted by giving 25 blows of the rammer uniformly distributed over the surface such that the compacted height of the soil is about 1/3 of the layer being given 25 blows. The collar is removed and the excess soil is trimmed off to make it level with the top of the mould. The weight of the mould, base plate and the compacted soil is taken. The bulk density? and the compacted dry density ? For the compacted soil are calculated from the following relation:

D=M/V(g/cc); d=?/(1+w)(g/cc)

Where

M = Mass of the wet compacted specimen (g)

W = Water content (Ratio)

V =Volume of the mould.

The test is repeated with increasing water contents on the soil, and the corresponding dry density? d obtained is then determined .A compaction curve is plotted between the water contents as the abscissa and the corresponding dry densities as the ordinates. The dry density goes on increasing as the water content is increased, till maximum dry density is reached. The water content corresponding to the maximum dry density is called the optimum water content Wo.31

PERMEABILITY TEST

The object of the experiment is to determine coefficient of permeability of the soil using a variable head permeameter.

The following procedure is adopted:

- The permeametermould should be filled with assigned soil sample in a manner specified by the instructor. The weight of the soil filling the mould
- Keep the permetermould assembly in the bottom tank.
- Connect the water inlet nozzle of the mould to the standpipe filled with water .Permit water to flow for some time till steady state of flow is reached.
- Note down the time required for the water level in the standpipe to fall from some convenient initial value(h1) to some final value(h2)
- Repeat the above step at least three steps times and determine the time for the water

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 setup 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. The corrected cross-sectional area was calculated by dividing the area by (1- ε) and then the compressive stress for each step was calculated by dividing the load with the corrected area.

qu= load/corrected area (A')

qu- compressive stress

A'= cross-sectional area/ (1- ε)

RESULTS AND DISCUSSIONS

SIEVE ANALYSIS:

S. NO	IS sieve	Mass retained	% of mass retained	% of cumulative mass retained	% of finer
1	4.75	0.043	4.3	4.3	95.7
2	2.36	0.053	5.3	9.6	90.4
3	1.18	0.079	7.9	17.5	82.5
4	600	0.055	5.5	23	77
5	300	0.05	5	28	72
6	150	0.032	3.2	31.2	69.8
7	75	0.006	0.6	31.8	68.2

Grain size distribution of clay

Result :

% of gravel=4.2%

% of coarse sand=8.0%

% of medium sand=12.4%

% of fine sand=7.20%

% of clay & silt=68.2%

SPECIFIC GRAVITY TEST:

Specific Gravity (G) is defined as the ratio of the weight of the given volume of the soil solids at a given temperature to the weight of an Equal volume of Distilled water at that Temperature, both weights being taken in air. The IS specifies 27 Celsius as the standard temperature for reporting the specific gravity.

Specific gravity is determined by the pycnometer

Materials	Specific Gravity
Clay	2.45
Eggshell powder	1.37
Rice Husk	1.68
Coconut fibre	1.35

Specific gravity results for various Materials

SPECIFIC GRAVITY CALCULATION

Observations and tabulation:

SI.no	DESCRIPTION	WEIGHT IN GRAMS	WEIGHT IN GRAMS
1.	Weight of pycnometer (W1) gm	645	645
2.	Weight of pycnometer + dry soil (W2) gm	865	865
3.	Weight of pycnometer + soil + water (W3) gm	1442	1442
4.	Weight of pycnometer + water (W4) gm	1857	1857
5.	Specific gravity (G)	2.45	2.45

Result

Specific gravity G = 2.45

LIQUID LIMIT CALCULATION

Observation and tabulation:

S.No	Water added in ml	No. of blows
1.	20	45
2.	30	26
3.	40	18

4.	50	10

I_f =45.92 ml
Plasticity index in % = 45.92 - 12
Plasticity index in % = 32.92%
Liquid limit is directly found from the graph (corresponding to 25 number of blows)

Graph for liquid limit of the soil:
X-axis water added in ml, Y- axis number of blows

liquid limit of the soil

Result:
Liquid limit of the soil = 45.92 %
Plasticity index in % = 33.92%

PLASTIC LIMIT CALCULATION
Plastic limit of the soil = 12%
Plastic intex = 45.92 – 12 = 33.92 %

STANDARD PROCTOR COMPACTION TEST

Tabulation:

SI.No	**Description**	**Trial - I**	**Trial-II**	**Trial-III**
1.	Empty weight of the mould (W1) gm	7295	7295	7295
2.	Weight of mould + soil (W2) gm	9688	9704	9752
3.	Weight of compacted soil (W3=W2-W1) gm	2393	2409	2457
4.	Bulk density (ρ = W3/V)g/cm^3	2.03	1.129	2.08
5.	Water content (w) (%)	5%	12%	14%
6.	Dry density =ρ_d = [ρ / (1+w)] g/cm^3	1.845	1.026	1.890

5.7.FALLING HEAD PERMEABILITY TEST

Tabulation :

SI. No	**Description**	**Unit**	**Trial-I**	**Trial -II**	**Trial – III**
1.	Area of stand pipe (dia 2cm)	Cm^2	3.14	3.14	3.14
2.	Cross sectional area of the soil specimen (A) (Diameter = 10cm)	Cm^2	78.54	78.54	78.54
3.	Length of the specimen	L	12.5	12.5	12.5
4.	Initial reading of the stand pipe (h_1)	Cm	80	80	80
5.	Final reading of the stand pipe (h_2)	Cm	70	70	70
6.	Time taken	t sec	2.39	1.81	1.53
7.	Coefficient of permeability K = 2.303al $\log_{10}(h_1/h_2)$ / (A.t)	Cm /s	0.027	0.036	0.044
			0.0362		

Result:
The Coefficient of permeability of the soil = 0.0362cm/sec

UNCONFINED COMPRESSION TEST

Tabulation:

SI.No	**Deformation dial reading 1 div = 0.01mm**	**Deformation Δlµm**	**Proving ring dial reading (cm)**	**Axial load(p) kg**	**Strain ϵ =Δl/l**	**Area A =A₀/(1-ϵ) cm²**	**Stress =P/A kg/cm²**
1	20	0.20	0.2	0.6	0.033	16.44	0.020
2	40	0.40	0.4	1.32	0.066	17.02	0.040
3	60	0.60	0.6	1.98	0.100	17.66	0.080
4	80	0.80	0.8	2.64	0.130	16.10	0.110
5	100	1.00	1.0	3.30	0.160	18.92	0.150
6	120	1.20	1.2	3.96	0.200	19.87	0.170
7	140	1.40	1.4	4.62	0.230	20.64	0.200
8	160	1.60	1.6	5.28	0.260	21.48	0.230
9	180	1.80	1.8	5.94	0.300	22.71	0.245
10	200	2.00	2.0	6.6	0.330	23.73	0.260

Strain (ϵ) = Deformation / Height of the specimen
= 0.20 / 7.5
= 0.026
Corrected area = Area of the specimen / (1-ϵ)
= 15.90/ (1-0.026)
=16.32cm^2
Stress = load / corrected area of the specimen
= 0.13 / 16.32
= 0.0079kg/cm^2
Axial load = proving ring x calibrating factor
= (0.2x 10) x (0.026)
p = 0.052kg
Unconfined compressive strength (q_u) = maximum stress from graph
= 0.179kg/cm^2
Shear strength =q_u / 2
= 0.179 / 2
= 0.0895kg/cm^2

Graph:
Draw a graph between stress (X axis) and strain (Y axis)

Result:
Unconfined Compressive Strength (q_u) = 0.179kg/cm^2
Shear strength = 0.089kg/cm^2

EXPERIMENTAL INVESTIGATONS LABORATORY TESTS WITH USING WASTE MATERIALS

LIQUID LIMIT CALCULATION

Observation and tabulation:
(ADDING 5% OF WASTE MATERIALS)

S.No	Water added in ml	No. of blows
1.	20	51
2.	30	33
3.	40	21
4.	50	10

CALCULATIONS:
Flow index (I_f) = (W4 – W1) / log (N_1/N_4)
W4 =50, W1 =20, N_1= 51, N_4= 10
I_f = (50 – 20) / log (51/10)
I_f =42.39 ml
Plasticity index in % = 42.39 – 18.55
Plasticity index in % = 23.84%
Liquid limit is directly found from the graph (corresponding to 25 number of blows)

Graph for liquid limit of the soil:
X-axis water added in ml, Y- axis number of blows
liquid limit of the soil

Result:
Liquid limit of the soil = 42.39 %
Plasticity index in % = 23.84%

Observation and tabulation:
(ADDING 10% OF WASTE MATERIALS)

S.No	Water added in ml	No. of blows
1.	20	55
2.	30	45
3.	40	35
4.	50	22

CALCULATIONS:
Flow index (I_f) = (W4 – W1) / log (N_1/N_4)
W4 =50, W1 =20, N_1= 55, N_4= 22
I_f = (50 – 20) / log (55/22)
I_f =35.58 ml
Plasticity index in % = 35.58 – 27.77
Plasticity index in % = 7.8%
Liquid limit is directly found from the graph (corresponding to 25 number of blows)

Graph for liquid limit of the soil:
X-axis water added in ml, Y- axis number of blows
liquid limit of the soil

Result:
Liquid limit of the soil = 35.58 %
Plasticity index in % = 7.8%

PLASTIC LIMIT CALCULATION
(ADDING 5% WASTE MATERIALS)

Observations :
1. Empty weight of the container (W_0) = 9 gm
2. Weight of the container + wet soil (W1) = 38 gm
3. Weight of the container + dry soil (W2) = 36 gm
4. Weight of water (W1-W2) gm = 2 gm
5. Weight of the wet soil (W1-W_0) gm = 29 gm
6. Weight of the dry soil (W2-W_0) gm= 27gm

Calculations:
Plastic limit =(weight of water / weight of dry soil) x 100
= (2 /27) x100 =18.55%

Result:
Plastic limit of the soil = 18.55%
Plastic intex = 42.39 – 18.55 = 23.84 %

PLASTIC LIMIT CALCULATION
(ADDING 10% WASTE MATERIALS)

Observations :

1. Empty weight of the container (W_0) = 9 gm
2. Weight of the container + wet soil (W1) = 32 gm
3. Weight of the container + dry soil (W2) = 27 gm
4. Weight of water (W1-W2) gm = 5 gm
5. Weight of the wet soil (W1-W_0) gm = 23 gm
6. Weight of the dry soil (W2-W_0) gm= 18gm

Calculations:

Plastic limit =(weight of water / weight of dry soil) x 100
= (5 /18) x100
Plastic limit = 27.77%

Result:
Plastic limit of the soil = 27.77%
Plastic intex = 35.55 – 27.77 = 7.84 %

STANDARD PROCTORS COMPACTION TEST
(ADDIND 4.5% AND 6% WASTE MATERIALS)

Observation:

Diameter of the mould (d) = 10 cm
Height of the mould (h) = 12.73 cm
Weight of the mould(W1) in gms = 5640g
Volume of the mould = 999.812 cm^3

Tabulation:

SI.No	Description	Trial-I	Trial-II
1.	Empty weight of the mould (W1) gm	7295	7295
2.	Weight of mould + soil (W2) gm	9620	9586
3.	Weight of compacted soil (W3=W2-W1) gm	2325	2291
4.	Bulk density (ρ = W3/V)g/cm^3	1.97	1.94
5.	Wastes added	4.5	6
6.	Water content (w) (%)	5%	12%
7.	Dry density =ρ_d = [ρ / (1+w)] g/cm^3	1.758	1.732

Model calculations:

Trial I

Empty weight of the mould (W1) = 7295 gm
Weight of the mould + soil (W2) = 9620 gm
Weight of the compacted soil (W3) = (W2-W1) g = 2325 gm
Bulk density (ρ = W3/V) g/cc =2325/1178.09
=1.97 g/cc
Water content (w) (%) =12%
Dry density =ρ_d= [ρ /(1+w)] g/cc =1.97 / (1+0.12)
= 1.73 g/cc

Result :
Maximum dry density of the soil = 1.73 g/cc

FALLING HEAD PERMEABILITY TEST
(ADDING 5% AND 10% WASTE MATERIALS)

Observation:

Diameter of the stand pipe (d) = 2cm
Area of the stand pipe (a) = 3.14 cm^2
Diameter of the soil specimen (D) = 10 cm
Area of the soil specimen (A) = 78.54cm^2
Length of the stand pipe (L) = 100cm

Formula Used:

$K = 2.303 a l \log_{10}(h_1/h_2) / At$
h_1= Initial head
h_2= Final head

Tabulation :

SI. No	Description	Unit	Trial-I	Trial –II	Trial – III
1.	Area of stand pipe (dia 2cm)	Cm^2	3.14	3.14	3.14
2.	Cross sectional area of the soil specimen (A) (Diameter = 10cm)	Cm^2	78.54	78.54	78.54
3.	Length of the specimen	L	12.5	12.5	12.5
4.	Initial reading of the stand pipe (h_1)	Cm	100	100	100

5.	Final reading of the stand pipe (h_2)	Cm	80	60	40
6.	Time taken	t sec	43.5	100	177
7.	Coefficient of permeability $K = 2.303al \log_{10}(h_1/h_2) / (A.t)$	Cm /s	1.38 $X10^{-3}$	1.479 $X10^{-3}$	1.698 $X10^{-3}$
			1.519		

Model Calculations:

$K = 2.303al \log_{10}(h_1/h_2) / (A.t)$

$= 2.303 \times 3.14 \times 12.5 \times (\log_{10}(100/80) / (78.54 \times 2.39)$

$K = 1.38X10^{-3}$

Result:

The Coefficient of permeability of the soil = $1.519X10^{-3}$

CONCLUSION

The study has been successfully conducted to assess the geotechnical properties of expansive soils improved with RHA, coconut fiber, egg shell .RHA, CF,EG altered the texture of clay soil by reducing the fine particles. EG, CF and RHA reduce the liquid limits while the plastics limits increased. As a result, the plasticity indices reduced. Swelling potential of expansive soil diminished with the addition of admixtures. The compressibility of soil reduces with blend of lime and RHA. In terms of compaction, the OMC moves to wet side, and MDD enhanced marginally.

- It indicates that the additives, especially Rice husk imbibe much water to attain the MDD.
- The plastic index of each sample reduced with the addition of various percentages of Cf.
- We can utilize the eggshell waste as a useful soil stabilizing material. By using the eggshell powder as a soil stabilizer, we can minimize the waste disposal problem of eggshell.

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