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Stabilization of Black Cotton Soil Using Waste Pet Bottles

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Abstract

Soil is a most essential component of the earth's ecosystem. But now a day's the soil is getting polluted due to disposal of waste plastic materials by human beings. For engineering consideration's, black cotton soil is one of the challenging material for construction purpose, which will not easily get stabilized due to its high potential of shrinking and swelling as an effect of change in moisture content. It will minimize the stability and shear strength of black cotton soil when compared to other types of soil. This paper explains stabilization of black cotton soil through application of PET **(**Polyethylene Terephthalate**)** bottles which is efficiently used to come across the challenges of society, to reduce the quantities of plastic wastes, to improve the physical properties of soil, such as shear strength, bearing capacity through controlled compaction. PET **(**Polyethylene Terephthalate**)** bottles are used in different proportion (3%, 5%, and 7%) in size is less than 0.5 mm. Then index Properties test, Standard Proctor, Unconfined Compressive, Moisture Content and California Bearing Ratio are conducted to find the properties of soil which will increases the bearing capacity of soil.

Keywords-soil stabilization, black cotton soil, plastic wastes, PET bottles.

INTRODUCTION

In nature, soil will deposit and occur in an erratic manner, thus turn out an infinite variety of possible combination which will affect the strength of the soil. For years' research personnel have tried to improve the mechanical properties of soil to suit the requirements of engineering structures. Since new techniques are either available or constantly emerging. Now a day's sites which have been deemed unsuitable, are being put to use for the construction of new challenging structures. The buildings which are constructed in cohesive soils may tend to easy settlement of the structure. In order to withstand the load of the structure, it is essential to improve the shear strength, bearing capacity and behavior of the soil. Soil stabilization means the improvement of stability or bearing power of the soil by the use of proportioning and the addition of suitable admixture or stabilizer's and controlled compaction. Over the last few years there has been a considerable rise in the use of plastic products which caused a proportionate increase in the plastic waste. But only a lesser quantity of such materials are recycled and reused and rest of them are stored or thrown to the disposal. The disposed or stored plastic waste pollutes the soil mass and causes health problems. These plastic materials are used in lesser quantity for engineering purpose. Several studies have shown that the addition of plastic waste in soil will cause a development in the strength characteristics of soil.

PHYSICAL & ENGINEERING PROPERTIES OF MATERIAL

***Clay soil* -** Clay soil will have poor aeration compared to sandy soil. But it holds water much better than sand, however is susceptible to water logging which results in settlement to structures.

***PET bot*tles -** PET bottles are semi rigid to rigid, and it is lightweight. It was a fair moisture and good gas barrier and barrier to alcohol and solvents. It is impact-resistant and strong. PET becomes white when exposed to chloroform and other chemicals such as toluene.

***Wate*r -** This is the important ingredients of soil. The water, makes the soil strength and it should be clean and free from harmful impurities such as alkali, oil, acid etc. In general, the water, which is fit for drinking, should be used.

***Sample collection* -**The samples are taken from the location as per procedure. In each location three points are fixed at an interval of 5m. Then at finally the samples are mixed well and used for the experiments.

Table 1: shows sample details and location of sample

S.No	Sample	Location
1	Black Cotton Soil	Thondamuthur (Coimbatore)

Laboratory model test

The laboratory test is to improve bearing capacity of soil by using Waste PET bottles. Initially the preliminary tests are carried out only with clay soil in order to determine the Properties of soil. The Experimental laboratory test results includes Atterbergs limit, Oven dry method, sieve analysis, Hydrometer analysis, Standard Proctor tests, Unconfined compressive test and California Bearing Ratio test.

1. Determination of strength properties of soil

Experimental test is carried out by standard proctor compaction test to determine the optimum moisture content of the clay soil, Unconfined Compressive test to determine the strength of the clay soil and California Bearing Ratio test to determine the Mechanical strength of the clay soil by adding varies percentage of Waste PET bottles.

Figure 2: shows black cotton soil with waste PET bottles

2. LABORATORY MODEL TESTS

2.1 Atterbergs limits

2.1.1 liquid limit test

Table 2.1.1 Liquid Limit for soil.

S.NO	Weight of dry soil (g)	Quantity of water added (ml)	Percentage of water added (%)	No. of blows
1	100	38	38	34
2	100	40	40	26
3	100	42	42	22
4	100	44	44	16

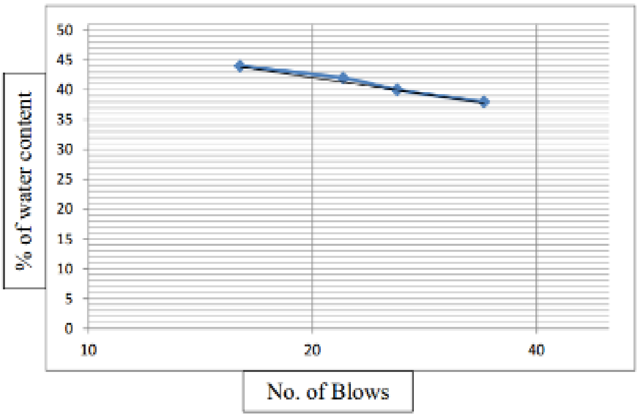


Figure 2.1.1. show that for every Percentage of water added how much blows have been attained.

The results for liquid limit from graph is

1. Liquid limit = 40.5%
2. Flow Index = 14.5%

2.1.2 Plastic limit test

$$Plastic\ limit = \frac{(w_2 - w_3)}{(w_2 - w_1)} * 100$$

Table 2.1.2: shows Plastic Limit for soil

Weight of empty container	(W1) = 20g
Weight of container + Sample before drying	(W2) = 46g
Weight of container + Sample after drying	(W3) = 40g

$$= \frac{(46-40)}{(46-20)} * 100$$

Plastic limit = 30%
Plasticity Index = Liquid limit – Plastic limit
= 40.5 – 30
= 10.5%

3.1.3 shrinkage limit

Mass of Empty Shrinkage Dish (M_1) =40g

Mass of Shrinkage Dish + Wet Soil (M_2) = 80g

Mass of Shrinkage Dish + Dry Soil (M_3) = 68g

Mass of Dry Soil (M_d)= (M_{3-} M_1) =28g

Mass of Water = (M_{2-} M_3) = 12g

Moisture Content in soil in percentage =

(12/28) *100 = 42.85%

Mass of Mercury + Shrinkage dish (M_4) = 356g

Mass of Mercury in shrinkage dish (M_5) = (M_{4-} M_1) =316g

Volume of wet soil (V) = M_5/13.6=23.24

Mass of mercury Displaced by dry Soil + Porcelain Dish (M_6) =458g

Mass of Mercury Displaced by dry (M_7) =458-248=210g

Volume of Dry Soil (V_d)=M_7/13.6=15.44

$$Shrinkage\ limit \left(W - \frac{(V - V_D)}{(M_D)} \right) * 100 = 15\%$$

Shrinkage ratio = M_D / V_D=1.813

Volumetric Shrinkage = (42.85 – 15) × 1.813== 50.13%

Result- Shrinkage limit value -15%

EXPERIMENTAL TESTS

***3.1 standard* proctor compaction test**

OBSERVATION

Diameter of mould (d)=11cm

weight of the mould with base plate=4696g

Depth of mould (h)=12.5cm

Volume of mould (V)= 1187.5cm

Table 3.1: shows *standard* proctor compaction test

s.no (1)	% Of water added Cc (2)	Volume of water added Cc (3)	Weight of mould with base plate (g) (4)	Weight of compacted soil + mould + base plate (g) (5)			Weight of compacted soil (6)		
				SPT 3%	SPT 5%	SPT 7%	SPT 3%	SPT 5%	SPT 7%
1	10	250	4696	6252	6674	6290	1556	1978	1594
2	12	300	4696	6506	6700	6436	1810	2004	1740
3	14	350	4696	6656	6850	6588	1960	2154	1892
4	16	400	4696	6760	6980	6640	2064	2284	1944
5	18	450	4696	6668	6762	6680	1072	2066	1912

Wet unit weight (g/cc) (7)			Dry unit weight (g/cc) (8)		
SPT 3%	SPT 5%	SPT 7%	SPT 3%	SPT 5%	SPT 7%
1.30	1.665	1.341	1.18	1.5	1.219
1.52	1.68	1.464	1.357	1.513	1.307
1.64	1.80	1.592	1.446	1.59	1.396
1.73	1.922	1.636	1.49	1.656	1.410
1.65	1.739	1.609	1.40	1.47	1.363

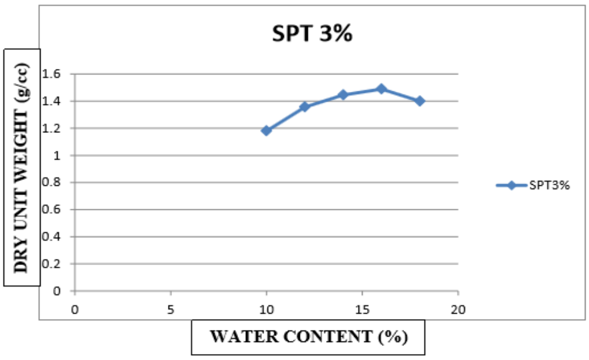


Fig 3.1.1 Compaction curve for 3% PET bottles

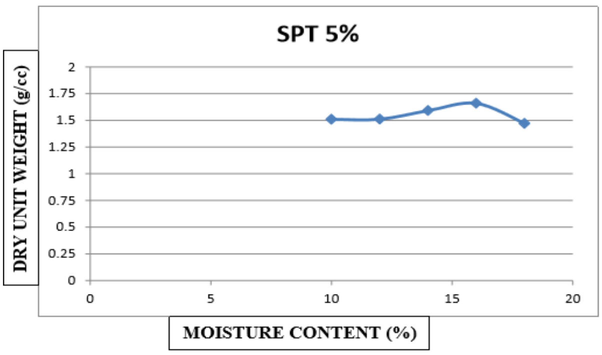


Fig 3.1.3 Compaction curve for 7% PET bottles

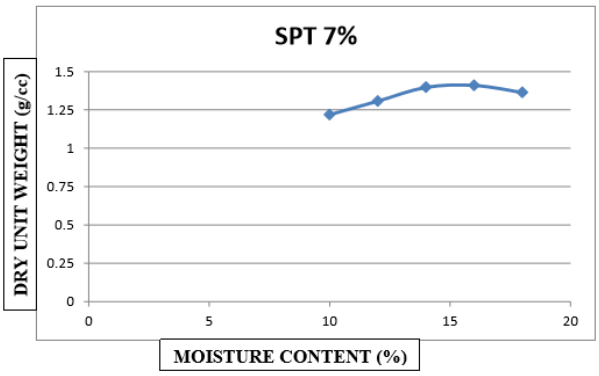


Fig 3.1.2 Compaction curve for 5% PET bottles

3.2 Hydrometer test

Table 3.2 percentage finer tabulation by hydrometer test

Time (min)	Actual reading	Composite correction	Corrected reading RH=RH'+CM	Hydrometer reading (RH)	Height (H)	Effective height (H_e)	Particle size(mm)	%finer 50g N'%	%finer 100g N %
0.5	1.019	0.004	1.015	15	5.7	13.58	0.06	47.75	32.94
1	1.0185	0.004	1.0145	14.5	5.85	13.73	0.04	46.11	31.81
2	1.017	0.004	1.013	13	6.2	14.08	0.031	41.34	28.52
4	1.0165	0.004	1.0125	12.5	6.5	14.38	0.02	39.75	27.42
8	1.015	0.004	1.011	11	7	14.88	0.016	34.98	24.13
15	1.015	0.004	1.011	11	7	14.88	0.011	34.98	24.13
30	1.015	0.004	1.011	11	7	14.88	0.0084	34.98	24.13
60	1.099	0.004	1.095	9.5	7.6	15.48	0.006	30.21	20.84
120	1.012	0.004	1.008	8	8.2	16.08	0.0043	25.44	17.55
240	1.079	0.004	1.075	7.5	8.5	16.39	0,0031	23.85	16.45
480	1.011	0.004	1.007	7	9	16.88	0.0022	22.26	15.35
720	1.011	0.004	1.007	7	9	16.88	0.0018	22.26	15.35
1440	1.059	0.004	1.055	5.5	11.5	19.38	0.0013	17.49	12.06

3.3 OVEN DRY METHOD

To clean, non-corrosive container is weighed (W_1) =20g. A small quantity of soil sample is placed in the container and weighed (W_2) =72g. The container is kept in the oven at a temperature of 1100℃ for 24hours. The container is removed and allowed to cool. The weight of the container with dry soil is taken as (W_3) =66g.

$$Moisture\ Content = \frac{(w_2 - w_3)}{(w_2 - w_1)} * 100$$

$$Moisture\ content = 13.04\%$$

3.4 SPECIFIC GRAVITY OF THE SOIL SOLIDS

The Specific gravity of the black cotton soil is determined using pycnometer as per IS 2720 (PART III/Sec I) 1980.

Weigh a clean and dry pycnometer with lid (W_1) =630g. Fill about one third of the bottle with oven dry soil and find the weight (W_2) =910g. Fill the jar with water, ensure that air bubbles are trapped and weigh it (W_3) =1700g. Empty the container and clean the bottle thoroughly. Fill the bottle completely with water and find its weight (W_4) =1494g.

$$\frac{w_2 - w_1}{(w_4 - w_1) - (w_3 - w_2)} = 2.69$$

3.5 Unconfined compressive strength of cohesive soil

Initial diameter D=40mm, initial length L=98mm, initial area A_0=1256.63sq .mm

Table 3.5 Unconfined compressive strength of cohesive soil

s.no	Deformation dial reading (mm)	Proving ring reading	Force P (N)	Strain E= Δ l/l 10^{-3}	Area A=A_0/(1-E) sq.mm	stress N/mm^2 ϭ =P/A 10^{-2}
1	0	0	0	0	1256.33	0
2	0.5	1	2.33	5.1	1262.43	0.185
3	1	2	4.66	10	1268	0.37
4	1.5	3	6.99	15	1275	0.51
5	2	5	11.65	20	1281	0.90
6	2.5	7	16.31	25.5	1288.9	1.265
7	3	9	20.97	30.6	1295	1.665
8	3.5	10	23.3	35.7	1301	1.79
9	4	13	30.29	48	1310	2.31
10	4.5	19	44.26	49.5	1321	3.35
11	5	22	51.27	51	1323	3.87
12	5.5	24	55.92	56.1	1330	4.2
13	6	26	60.58	61	1337	4.525
14	6.5	27	62.9	66.3	1340	4.69

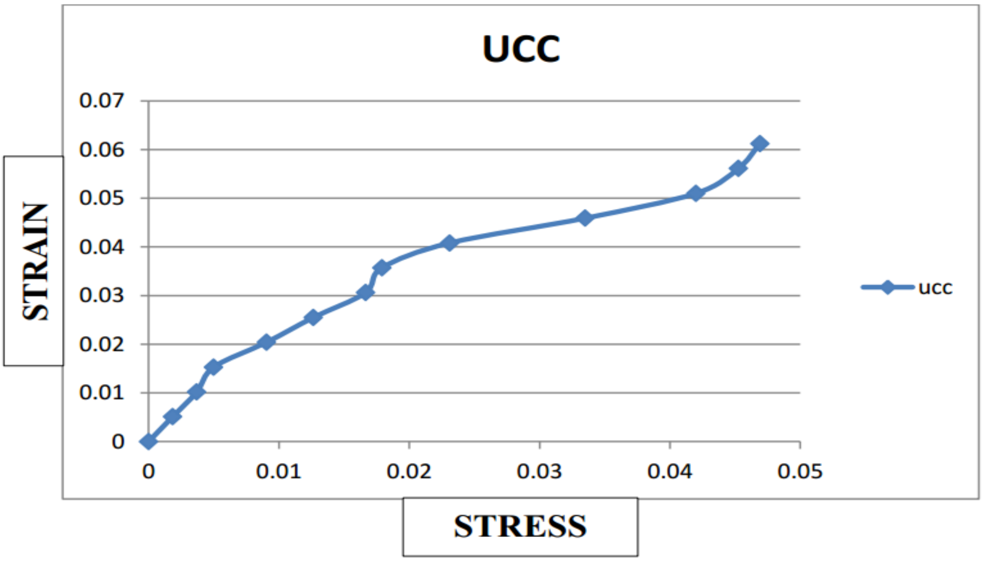


Fig 3.5 . Stress-strain curve for 0% PET bottles

The Unconfined Compressive Strength = 0.0469 N/ mm^2

Shear strength = 0.02345 N/ mm^2

3.6 CALIFORNIA BEARING RATIO

S.NO	Dial gauge reading	Penetration (mm) ✕ 0.01	Proving ring reading			Load in (kg) ✕ 1.08			Penetration resistance (kg/sq.mm)		
			3%	5%	7%	3%	5%	7%	3%	5%	7%
1	50	0.5	26	27	26	12.96	29.16	28.08	0.66	1.485	1.43
2	100	1	38	40	38	37.8	43.2	41.04	1.925	2.2	2.09
3	150	1.5	47	54	47	50.76	58.3	50.76	2.585	2.965	2.585
4	200	2	55	65	55	59.4	70.2	59.4	3.025	3.75	3.025
5	250	2.5	62	74	62	69.88	79.7	66.96	3.35	4.07	3.41
6	300	3	68	80	68	72.36	86.4	73.44	3.685	4.4	3.735
7	350	3.5	73	86	73	78.8	92.85	78.84	4.015	4.73	4.01
8	400	4	77	92	77	82.08	99.35	83.16	4.175	5.06	4.235
9	450	4.5	82	96	82	86.4	103.68	88.56	4.4	5.28	4.511
10	500	5	86	100	86	87.48	108	92.88	4.45	5.5	4.73
11	600	6	89	102	89	92.85	110.15	96.12	4.73	5.61	4.895
12	700	7	92	108	92	97.2	116.6	99.35	4.95	5.931	5.061
13	800	8	96	111	95	97.2	119.9	102.6	4.95	6.105	5.225
14	900	9	99	114	97	99.35	123.1	104.95	5.06	6.27	5.345
15	1000	10	100	115	100	103.68	124.2	108	5.28	6.325	5.5
16	1100	11	101	118	102	106.9	127.4	110.16	5.445	6.49	5.61
17	1200	12	92	121	105	108	130.68	113.4	5.5	6.655	5.775
18	1250	12.5	96	124	107	109.05	133.9	115.56	5.55	5.61	5.885

For 3% of waste PET bottles

C.B.R. at 2.5mm penetration = actual load taken by soil/standard load at 2.5mm penetration

= (3.35/70) *100= 4.75%

C.B.R. at 5mm penetration = actual load taken by soil/standard load at 5mm penetration

= (4.45/105) *100= 4.2%

For 5% of waste PET bottles

C.B.R. at 2.5mm penetration = (4.07/70) *100 = 5.814%

C.B.R. at 5mm penetration = (5.5/105) *100 = 5.239%

For 7% of waste PET bottles

C.B.R. at 2.5mm penetration = (3.41/70) *100= 4.85%

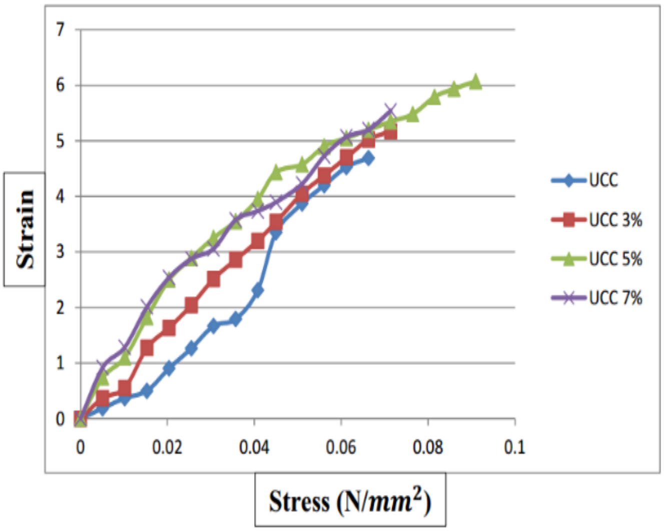
C.B.R. at 5mm penetration = (4.73/105) *100= 4.5%

RESULTS AND DISCUSSIONS

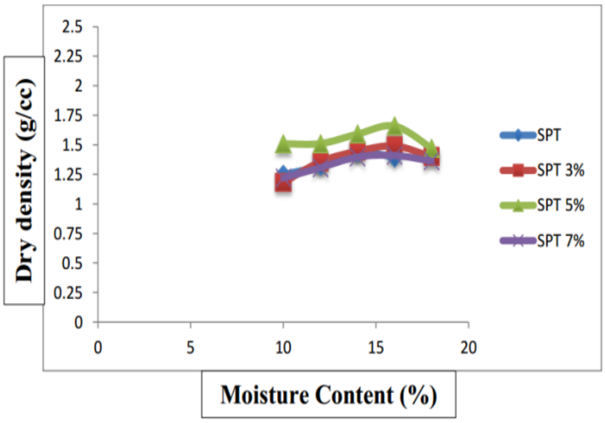
From the test results, it has been found that the maximum values are obtained when 5% of Waste PET bottles of size less than 1mm is added into the soil. Additions of waste PET bottles as stabilizer will economically stabiles the Black cotton soil compared to other stabilizers. It also reduces the cost of disposing PET bottles and acts as a method for plastic waste management.

Results for admixed soil

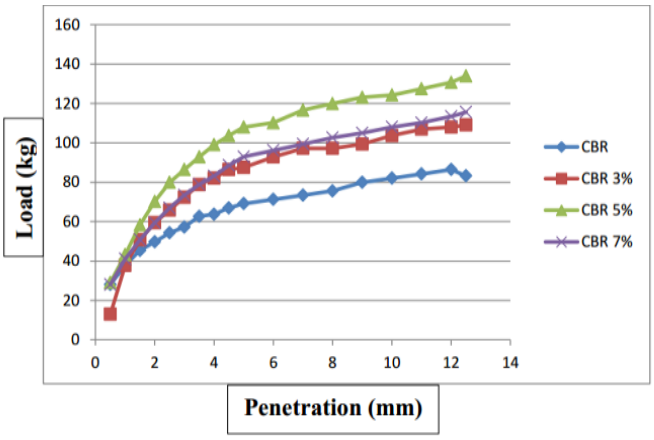
% of PET bottles	Optimum moisture content%	Maximum dry density	Unconfined Compressive Strength (N/mm^2)	CBR value%
0	14	1.439	0.0469	3.95
3	16	1.49	0.0517	4.75
5	16	1.656	0.0607	5.81
7	16	1.410	0.0554	4.85



Graph 1(a) Results of stress-strain curve



Graph 1(b) Results of Compaction Curve



Graph 1(c) Results of CBR curve

CONCLUSIONS

Based on the results of the present study, the following conclusion can be drawn:

1. The model Unconfined Compressive Strength test was conducted for improvement of bearing capacity of foundation by using waste PET bottles.
2. It was observed that the load carrying capacity of the soil was found to increase with addition of waste PET bottles.
3. Hence, it is suggested to provide PET bottles with the soil to improve its strength.
4. 4.Therefore it is recommended that the waste PET bottles used for improving the strength of foundation will also act as earthquake resistant material.
5. End of use plastics are waste materials that can be cost effective when used in foundation along with clay soil.
6. Hence, it can be concluded on the whole that, by utilizing these types of industrial by-product as a strengthening material by effective proportioning, we can reduce the cost of construction and also reduce the environmental impact.

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