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Soil Stabilization using Plastics and Gypsum

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Abstract*: Infrastructure is a major sector that propels overall development of Indian economy. The foundation is very important For any structure and it has to be strong enough to support the entire structure. For foundation to be strong the soil around it plays a very important role. Expansive soils like black cotton soil always create problems in foundation. The problems are swelling, shrinkage and low bearing capacity. Plastic consumption is increasing day by day due to rapid growth in population and urbanization, recycling of these plastics is very less compared to its production and a large quantity of plastics is dumped into landfills as waste resulting in various environmental concerns. The use of plastic as a stabilizing agent reduces the problem of plastic disposal as well as helps in stabilizing the soil in an economical way. In this project in order to address strength problem of black cotton soil, shredded plastic fibers were mixed and in order to address volumetric changes of the soil, Gypsum is added. Plastic fibers were added in varying proportions by dry weight and standard proctor test was used to determine the optimum percentage of plastic. Gypsum was mixed in different proportions by dry weight and tests such as Free Swell Index, Atterbergs limit tests were used to determine the optimum percentage of gypsum. The optimum percentages of shredded plastic and gypsum were then added with clay and the effectiveness of stabilization was determined using California bearing Ratio Test.

***Keywords*: expansive soils, foundation problems, gypsum, plastics, stabilization.**

1. Introduction

Engineers are often faced with the problem of constructing facilities on or with soils, which do not possess sufficient strength to support the loads imposed upon them either during construction or during the service life of the structure. Many areas of India consist of soils with high silt contents, low strengths and poor bearing capacities. Due to rapid growth in population and development activities suitable ground for constructions are depleting day by day. This situation leads to take unsuitable ground for construction. The poor engineering performance of such soils has forced Engineers to attempt to improve the engineering properties of poor quality soils. There are various methods that could be used to improve the performance of poor quality soils. The choice of a particular method depends mainly on the type of soil to be improved, its characteristics and the type and degree of improvement desired in a particular application. Soil deposits in nature exist in an extremely erratic manner. About 20% of India's Land area is covered by Clayey Soil. Black Cotton soil is a type of expansive clayey soil which is very fertile and suitable for agriculture but not good for construction of Civil Engineering Structures. Expansive soils contain minerals that are capable of absorbing water. They undergo severe volume changes corresponding to changes in moisture content. They swell or increase in their volume when they imbibe water and shrink or reduce in their volume on evaporation of water. Because of their alternate swelling and shrinkage, they result in detrimental cracking of lightly loaded civil engineering structures such as foundations, retaining walls, pavements, airports, side -walks, canal beds and linings. Due to these reasons expansive soils are generally poor material for construction. With the rapid Industrialization, bursting population and decrease of available land, Transportation Sector has to expand out on available Black Cotton soils which is having poor shear strength. The stability and performance of pavements are greatly influenced by the subgrade as they serve as foundations for pavements. Roads on black cotton soils pose challenges in selecting suitable soil modification technique. The quality of a pavement depends on the strength of its sub-grade. Soil stabilization is one of the best methods to improve the properties of soil. The objectives of any stabilization technique used are to increase the strength, durability, erosion control, improve workability and constructability of the soil.

2. Methodology

Methods of Soil Stabilization: There are different materials in utilization for the stabilization of black cotton soils. Depending on the internal factor which describes the bonding between the soil and the stabilizer utilized, the methods are broadly classified into two types. They are, Mechanical Stabilization: It is based on the principle of friction i.e., when the admixtures are added to soil and compacted the strength is enhanced due to the friction between the soil and the material added. Examples for the materials which increase the strength by this principle are sand, plastic, geo textiles etc.

Chemical Stabilization: It is based on the chemical reaction between the material added and the minerals in soil. Examples for this type of stabilizers are lime, fly ash, bituminous materials, cement etc. Inclusion of plastic waste strips comes in the category of Mechanical Stabilization of soil. Addition of Gypsum comes under chemical stabilization of soil. Gypsum can help stabilize aggregate structure in some soils. Plastic solves the problem of low Bearing Capacity of Black cotton soil. But the other major issue of Black cotton soil is its

Shrinking and Swelling characteristics, which leads to formation of cracks, which has not been addressed by the use of mechanical stabilization. So, to address this issue, we has chemical stabilization as the solution. Addition of Gypsum was chosen over lime because of reasons: Ca Ion of gypsum replaces Na/K/Mg ions which results in flocculation and Calcium silicates/aluminates formed helps in bonding. Gypsum is a naturally occurring mineral that is made up of calcium sulphate and water ($CaSO_4+2H_2O$) that is sometimes called hydrous calcium sulphate. It is the mineral calcium sulphate with two water molecules attached. By weight it is 79% calcium sulphate and 21% water. Gypsum is mined and made into many products like drywall used in construction, agriculture and industry. It is also a by-product of many industrial processes.

3. Properties of natural clay

A. *Specific gravity*

Specific Gravity = (w2-w1)/ ((w2-w1)-(w3-w4))
Where, w1 = Weight of Volumetric Flask (g)
w2 = Weight of flask + soil (g)
w3= Weight of flask + soil + water (g)
w4= Weight of flask + water (g)
w1: 197.98g; w2 : 397.83g; w3 : 813.35g ; w4 :694.78g
Specific Gravity of the sample: 2.46

B. *Particle size distribution analysis*

About 200grams of the soil sample (dry) shall be taken and sieved through 4.75mm sieve and 2mm sieve. The weight of material retained in each sieve was determined and the percentage of material passing through 4.75mm sieve and 2mm sieve are determined. 50 grams of material (dry) passing through 2mm sieve shall be taken in a container and to this 100ml of solution containing 8grams of sodium oxalate per liter was added. The mixer was well stirred with a glass rod and allowed to stand overnight. Next day, the suspension was then washed through 0.075mm sieve, number of times till the wash water was clear. Soil suspension passing through the sieve was carefully collected and transferred to the measuring cylinder and made up to 1000ml with distilled water. The material retained in sieve no 75 microns was dried in oven, cooled, weighed and used for sieve analysis. The material retained in 0.075mm sieve shall be sieved through the sieves of 1mm, 0.425mm, 0.212mm, 0.075mm. The weight retained in all these sieves were measured and recorded separately and calculations were made.

1) *Dry sieve analysis*

- Weight of material taken for test (Wo) = 200 gm
- Weight retained on 4.75mm sieve (W1) = 0 gm
- Weight retained on 2.00mm sieve (W2) = 0 gm
- Weight retained in 0.075mm sieve after washing (g) = 11.21 gm

Percentage passing through 4.75 mm sieve = 100 x (W0–W1)/W0 = 100%
Percentage passing through 2.00 mm sieve = 100 x (W0– (W1 + W2))/W0 = 100%
Weight of material passing through 2mm sieve taken for mechanical analysis = 50 gm

Table 1
Observation of Sieve Analysis

Sieve	Weight retained (gm)	Total weight retained (gm)	Total weight passing (gm)	%Passing (2mm basis)	%Passing (total basis)
1mm	1.38	1.38	48.62	97.24	97.24
425µ	2.5	3.88	46.12	92.24	92.24
212µ	3	6.88	43.12	86.24	86.24
75µ	4.33	11.21	38.79	77.58	77.58

C. *Hydrometer analysis*

Particles passing through 75 micron IS sieve along with water collected and put into a 1000 ml jar for hydrometer analysis. More water if required is added to make the soil water suspension just 1000ml. The suspension in the jar is vigorously shaken horizontally by keeping the jar in between the palms of two hands. The jar is put on the table. A graduated hydrometer is carefully inserted into the suspension with minimum disturbance. At different time intervals, the density of the suspension at c.g of the hydrometer is noted by seeing the depth of dinking of the stem. The temperature of suspension is noted for each recording of the hydrometer reading. Hydrometer reading is taken at a time of 0.5, 1.0, 2.0, 4.0, 8.0, 15.0, 30.0, 60.0, 120.0, 180.0, minutes and 24 hours. By using the monogram, the diameter of the particles of different hydrometer reading is found out. After completing the mechanical and hydrometer analysis the results are plotted on a semi-log graph with particle size as abscissa (log scale) and the percentage smaller than specified diameter as ordinate.

1) *Correction of Hydrometer reading*

- *Meniscus correction (Cm):* Since the suspensions are opaque, the true readings of the hydrometer at the bottom of the meniscus of liquid cannot be obtained. In order to read the hydrometer at the top of the meniscus, a meniscus correction must be made. The meniscus correction is positive and added to the hydrometer reading.
- *Temperature correction (Mt):* Hydrometers are usually calibrated at 20 degree C and if the suspension is not at this temperature, correction is necessary for the change in density of liquid. The correction is added if the temperature is above standard temperature and subtracted if below.
- *Dispersing agent correction (Cd):* The addition of dispersing agent raises the specific gravity of the liquid and therefore this correction has to be subtracted. For standard concentration, the correction is 0.8

The corrected hydrometer reading 'R' is given by
R = Rh + Cm – Cd+ Mt
Correction of height of fall

The concentration is due to rise in level of suspension in the hydrometer jar due to immersion of hydrometer

- Coarse Gravel (20mm-80mm) -0%
- Fine Gravel (4.75mm-20mm) -0%
- Coarse Sand (2mm-4.75mm) -0%
- Medium Sand (.425mm-2mm) -8%
- Fine Sand (.075mm-.425mm) -14%
- Silt (.002mm-.075mm) -75%
- Clay (<.002mm) -3%

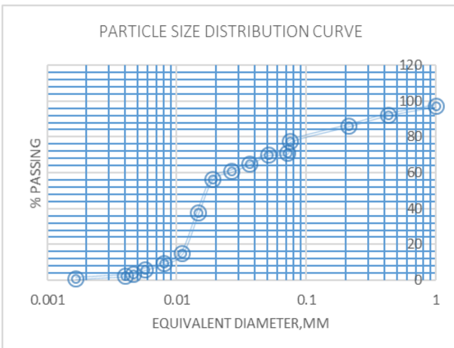

Fig. 1. Particle size distribution curve

D. *Shrinkage limit*

100 gm. of soil sample from a thoroughly mixed portion of the material passing through 425 micron IS sieve was taken. About 30 gm. of above soil sample was placed in the evaporating dish and thoroughly mixed with distilled water to make a paste. The weight of the clean empty shrinkage dish was recorded. The dish was filled in three layers by placing approximately 1/3rd of the amount of wet soil with the help of spatula. Then the dish with wet soil was weighed and recorded immediately. The wet soil cake was air dried until the color of the pat turns from dark to light. Then it was oven dried at a temperature of 1050 C to 1100 C. The weight of the dish with dry sample was determined and recorded. Then the weight of oven dry soil pat was calculated (W0). The oven dried soil pat was placed on the surface of the mercury in the cup and pressed by means of the glass plate with prongs, the displaced mercury being collected in the evaporating dish. The mercury so displaced by the dry soil pat was weighed and its volume (Vo) was calculated by dividing this weight by unit weight of mercury.

Shrinkage Limit = [W-((V-V0)/W0)]*100

Where W is the moisture content of the soil.

E. *Maximum dry density*

About 3kg of dried soil passing through 4.75mm IS Sieve was taken and thoroughly mixed with suitable amount of water to start. The moist soil was compacted exactly in 3 layers. Each layer was compacted with 25 blows, the rammer being dropped through the specified height and the blows being delivered uniformly over the surface of each layer. After compacting the three layers, the collar was removed and the excess soil was struck off to the top of the mould by means of a straight edge.

Table 2
Observation of Shrinkage limit

	Observation	Trial 1	Trial 2	Trial 3
1	Shrinkage dish no	1	2	3
2	Wt of empty shrinkage dish, g	12.5	13	12
3	Volume of dish=volume of wet soil pat, cc	25.11	24.15	23.83
4	Wt of dish & wet soil pat, g	54.04	51.9	51.44
5	Wt of wet soil pat, g	41.54	38.9	39.44
6	Wt of shrinkage dish & dry soil pat, g	39.58	38.5	37.77
7	Wt of oven dried soil pat, g	27.08	25.5	25.77
8	Water content of wet soil pat,%	53.39	52.55	53.05
9	Wt of mercury displaced by dry soil pat+ wt of evaporating dish, g	212.44	201.78	202.65
10	Wt of evaporating dish, g	42.44	42.44	42.44
11	Wt of mercury displaced by dry soil pat, g	170	159.34	160.21
12	Volume of dry soil pat, cc	12.5	11.72	11.78

Shrinkage Limit of Clay : 5.64%

The weight of the mould and the compacted soil was noted; the compacted soil was then extracted from the mould, cut in the middle and a representative soil specimen was taken for moisture content determination. The experiment was repeated with increased moisture content. Thus was continued until there was a substantial decrease in the weight of the compacted soil.

- Diameter of mould : 10.2cm.
- Height of mould : 11.8cm
- Volume : 964.21cm^3

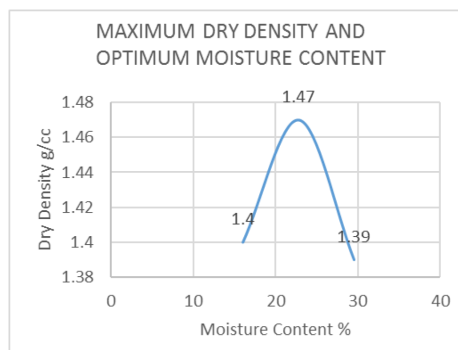

Fig. 2. Maximum Dry density and optimum moisture content of clay.

From the graph,
Maximum Dry Density of clay - 1.47g/cc
Optimum Moisture Content - 22.2%

F. *California bearing ratio (CBR)*

7Kg of sample passing 4.75mm IS Sieve was taken. It was thoroughly mixed by adding water equal to optimum moisture content of the sample. The moist soil was compacted in three layers with each layer being compacted by 60 blows from a standard rammer of 50mm diameter. After compacting the three layers, the collar was removed and the excess soil was struck off to the top of the mould by means of a straight edge. The mould was placed in the soaking tank for 4 days (this step was ignored in the case of unsoaked CBR). After 4 days, the mould was taken and the surface was dried with a cloth. The surcharge weight was placed on the top of the specimen in the mould and the assembly was placed under the plunger of the loading frame. Load was applied on the sample by a standard plunger at the rate of 1.25 mm/min. A load penetration curve was drawn.

CBR= (Load carried by the specimen at a penetration)/ (Load carried by the standard specimen at the same penetration)

Surcharge weight - 4.5Kg

Proving Ring capacity - 293 divisions=3000kg; 1divison= 10.24kg

Table 3
Determination of Moisture Content

Trial no	Can No	Empty wt of can(g)	Wt of can+wet soil(g)	Wt of can+dry soil(g)	Wt of dry soil(g)	Wt of water (g)	Moisture content (%)
1	33	11.85	31.7	28.95	17.1	2.75	16.08
2	13	13.85	26.91	24.81	10.96	2.1	19.16
3	18	14.76	27.45	25.09	10.33	2.36	22.85
4	14	13.88	33.76	29.71	15.83	4.05	25.58
5	1	13.88	33.37	28.93	15.05	4.44	29.5

Table 4
Determination of Dry Density of clay

Trial no	Wt of mould+ compacted soil(g)	Wt of empty mould without collar(g)	Wt of compacted soil (g)	Wet Density (g/cc)	Moisture content (%)	Dry Density (g/cc)
1	4051	2482	1569	1.63	16.08	1.40
2	4161	2482	1679	1.74	19.16	1.46
3	4218	2482	1736	1.8	22.85	1.47
4	4267	2482	1785	1.85	25.58	1.47
5	4225	2482	1743	1.81	29.5	1.39

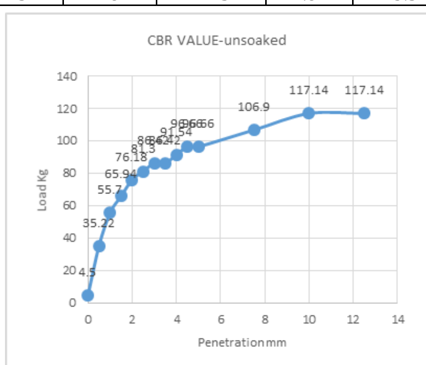

Fig. 3. CBR Curve- unsoaked condition

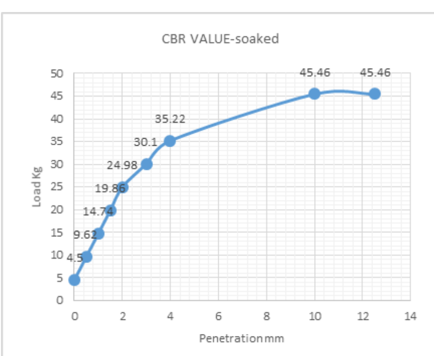

Fig. 4. CBR Curve- soaked condition

Table 5
Observation for Unsoaked condition

Penetration (mm)	**Load (Divisions)**	**Load (Kg)**
0	0	4.5
.5	3	35.22
1	5	55.7
1.5	6	65.94
2	7	76.18
2.5	7.5	81.3
3	8	86.42
3.5	8	86.42
4	8.5	91.54
4.5	9	96.66
5	9	96.66
7.5	10	106.9
10	11	117.14
12.5	11	117.14

Load for 2.5 mm penetration =81 Kg;
CBR for 2.5mm penetration =5.9%
Load for 5mm penetration =98.5Kg;
CBR for 5 mm penetration =4.8%

California Bearing Ratio of the clay sample in unsoaked condition: 5.9%. Since CBR value lies between 4 and 7, the clay was categorized as poor soil.

Table 6
CBR Observation-soaked

Penetration (mm)	**Load (Divisions)**	**Load (Kg)**
0	0	4.5
.5	0.5	9.62
1	1	14.74
1.5	1.5	19.86
2	2	24.98
2.5	2	24.98
3	2.5	30.1
3.5	2.5	30.1
4	3	35.22
4.5	3	35.22
5	3	35.22
7.5	3.5	40.34
10	4	45.46
12.5	4	45.46

Load for 2.5 mm penetration =28 Kg;
CBR for 2.5mm penetration =2.04%
Load for 5mm penetration =37 Kg;
CBR for 5 mm penetration =1.8%

California Bearing Ratio of the clay sample in soaked condition: 2.04%. Since CBR value lies between 2 and 4, the clay was categorized as very poor soil.

4. Effect of gypsum and plastic in soil stabilization

A. Determination of optimum percentage of gypsum

Keeping in mind the purpose for addition of gypsum, Free Swell Index Test was used to determine the optimum percentage of gypsum.

1) Addition of 2% gypsum by dry weight of sample

It can be seen that; Free Swell Index value tends to be the least (30%) upon addition of 4% of Gypsum. Free swell Index

Table 7
Table title comes here

Properties of clay	Experiment	Value
Liquid Limit (LL)	LL & PL Test	54%
Plastic Limit (PL)	LL & PL Test	25%
Plasticity Index (PI)	Difference of LL & PL	29%
Specific Gravity	Volumetric Flask	2.46
Maximum Dry Density	Standard Proctor Test	1.47g/cc
Optimum Moisture content	Standard Proctor Test	22.2%
California Bearing Ratio	California Bearing Ratio Test	5.9%(Poor Soil)
CBR-Soaked condition	California Bearing Ratio Test	2.04%(Very Poor Soil)

Addition of 2% gypsum by dry weight of sample:

Table 8
Free Swell Index for 2% Gypsum

Volume in Kerosene, V_d (cc)	**Volume in Water, V_k (cc)**	**Free Swell Index (%)**
9	12	33.33

Addition of 4% gypsum by dry weight of sample:

Table 9
Free Swell Index for 4% Gypsum

Volume in Kerosene, V_d (cc)	**Volume in Water, V_k (cc)**	**Free Swell Index (%)**
10	13	30

Addition of 6% gypsum by dry weight of sample:

Table 10
Free Swell Index for 6% Gypsum

Volume in Kerosene, V_d (cc)	**Volume in Water, V_k (cc)**	**Free Swell Index (%)**
9	14	55.56

of Natural Clay was 100% which has been reduced to 30% when 4% gypsum was added. Reduction in Free Swell Index indicated reduction in volumetric changes. Thus, Optimum Percentage of Gypsum was identified to be 4%.

B. Effect of addition of optimum percentage of gypsum

Since Gypsum reacts with clay chemically, Properties of clay such as Liquid Limit, Plastic Limit and Shrinkage Limit were determined for clay mixed with 4% Gypsum.

1) Liquid limit & plastic limit

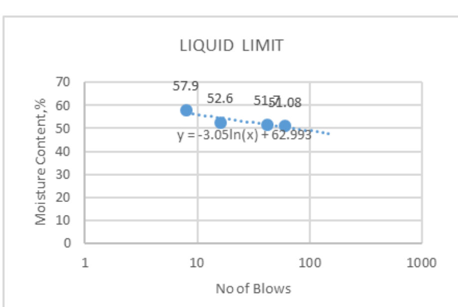

Fig. 5. Liquid Limit and Plastic Limit of clay+4% Gypsum

Liquid Limit, upon addition of gypsum, has decreased; thus, compressibility decreases. Plastic Limit has increased when gypsum was added. Thus, Plasticity Index has decreased.

Table 11
Liquid Limit and Plastic Limit of clay+4% Gypsum

	Liquid limit				**Plastic limit**
Number of blows	8	16	42	60	-
Container Number	36	28	3	13	8
Weight of container(g)	11.52	11.45	11.15	13.85	10.56
Wt of container + Wet soil(g)	25.23	24.33	27.58	27.04	43
Wt of Container + oven dried soil(g)	20.2	19.89	21.98	22.58	36.02
Weight of oven dried soil(g)	8.68	8.44	10.83	8.73	25.46
Weight of Water(g)	5.03	4.44	5.6	4.46	6.98
Moisture Content (%)	57.9	52.6	51.7	51.08	27.42

C. Shrinkage limit

Table 12
Shrinkage Limit of clay+4% Gypsum

	Observation	Trial 1	Trial 2	Trial 3
1	Shrinkage dish no	1	2	3
2	Wt of empty shrinkage dish,g	12.5	13	12
3	Volume of dish=volume of wet soil pat,cc	25.11	24.15	23.83
4	Wt of dish & wet soil pat,g	52.98	51.4	51.24
5	Wt of wet soil pat,g	40.48	38.4	39.24
6	Wt of shrinkage dish & dry soil pat,g	39.20	38.01	37.82
7	Wt of oven dried soil pat,g	26.7	25.01	25.82
8	Water content of wet soil pat,%	51.6	53.54	51.97
9	Wt of mercury displaced by dry soil pat+ wt of evaporating dish,g	227.37	208.56	216.40
10	Wt of evaporating dish,g	42.44	42.44	42.44
11	Wt of mercury displaced by dry soil pat,g	184.93	166.12	173.96
12	Volume of dry soil pat,cc	13.59	12.21	12.79

Shrinkage limit of clay+4% Gypsum: 7.76%

Thus, upon adding 4% gypsum, the shrinkage limit increases.

The lower the shrinkage limit, the greater is the possible volume change corresponding to a given variation in the moisture content of the soil.

Increase in Shrinkage limit is therefore beneficial.

1) Standard proctor test

Though the purpose of adding gypsum doesn't tend to increase the strength of the soil directly, this experiment was performed to see the influence of gypsum on the soil.

Diameter of mould : 10.2cm
Height of mould : 11.8cm
Volume : 964.21 cc

Table 13
Determination of Moisture content

Trial no	Can No	Empty wt of can (g)	Wt of can+wet soil (g)	Wt of can+dry soil (g)	Wt of dry soil (g)	Wt of water (g)	Moisture content (%)
1	3	11.15	28.87	27.34	16.19	1.53	9.45
2	16	10.56	28.52	26.53	15.97	1.99	12.46
3	24	13.24	26.85	24.98	11.74	1.87	15.93
4	34	11.32	26.2	23.98	12.66	2.22	17.54
5	11	10.86	29.2	26.13	15.27	3.07	20.1

Table 14
Determination of Dry Density

Trial no	Wt of mould+ compacted soil(g)	Wt of empty mould without collar(g)	Wt of compacted soil(g)	Wet Density (g/cc)	Moisture content (%)	Dry Density (g/cc)
1	4052	2482	1570	1.63	9.45	1.49
2	4096	2482	1614	1.67	12.46	1.49
3	4230	2482	1748	1.81	15.93	1.56
4	4284	2482	1802	1.87	17.54	1.59
5	4265	2482	1783	1.85	20.1	1.54

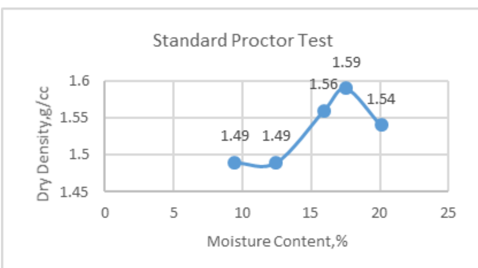

Fig. 6. Maximum Dry Density and optimum Moisture Content for clay+4% Gypsum

From the Graph,
Maximum Dry Density : 1.59 g/cc
Optimum Moisture Content : 17.5%
Maximum dry density of clay mixed with 4% gypsum is higher relative to the maximum dry density of clay (1.47 g/cc).

D. Determination of optimum size of plastic

Keeping in mind the purpose of addition of Plastic,

Standard Proctor Test was used to determine the optimum size of plastic to be used. 0.3% of each size of Plastic by the dry weight of the sample was used in the test and the size which yields the maximum dry density was to be finalized as the optimum size.

Three sizes of Plastic were taken into consideration,

- Plastic passing 1.18mm Sieve
- Plastic passing 2.36mm Sieve
- Plastic passing 4.75mm Sieve

1) Addition of plastic passing 1.18mm sieve

- Diameter of mould : 10.2cm;
- Height of mould : 11.8cm
- Volume : 964.21cm^3.

Table 15
Determination of Moisture Content

Trial no	Can No	Empty wt of can(g)	Wt of can+wet soil(g)	Wt of can+dry soil(g)	Wt of dry soil(g)	Wt of water (g)	Moisture content (%)
1	28	11.45	26.94	24.27	12.82	2.67	20.83
2	2	14.32	27.43	24.82	10.5	2.61	24.86
3	3	11.15	27.19	23.84	12.69	3.35	26.39
4	12	11.10	26.64	23.22	12.12	3.42	28.22

Table 16
Determination of Dry Density

Trial no	Wt of mould+ compacted soil(g)	Wt of empty mould without collar(g)	Wt of compacted soil(g)	Wet Density (g/cc)	Moisture content (%)	Dry Density (g/cc)
1	4150	2482	1668	1.73	20.83	1.43
2	4230	2482	1748	1.81	24.86	1.45
3	4225	2482	1743	1.81	26.39	1.43
4	4198	2482	1716	1.78	28.22	1.38

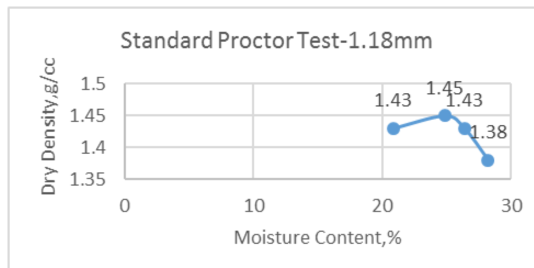

Fig. 7. Standard Proctor test curve for clay + 0.3% plastic passing 1.18mm Sieve

From the Graph,
Maximum Dry Density : 1.45 g/cc
Optimum Moisture Content : 25%
Maximum Dry Density had decreased relative to that of untreated clay and optimum Moisture content had increased.

E. Addition of plastic passing 2.36mm sieve

Table 17
Determination of Moisture Content

Trial no	Can No	Empty wt of can(g)	Wt of can+wet soil(g)	Wt of can+dry soil(g)	Wt of dry soil(g)	Wt of water (g)	Moisture content (%)
1	27	10.52	29.99	27.96	17.44	2.03	11.64
2	6	10.58	29.52	26.8	16.22	2.72	16.77
3	31	11.33	26.2	23.74	12.41	2.46	19.82
4	23	12.37	29.02	26.24	13.87	2.78	20.04
5	2	14.32	29.23	26.05	11.73	3.18	27.11
6	24	13.23	29.01	25.42	12.18	3.59	29.47

Table 18
Determination of Dry Density

Trial no	Wt of mould+ compacted soil(g)	Wt of empty mould without collar(g)	Wt of compacted soil(g)	Wet Density (g/cc)	Moisture content (%)	Dry Density (g/cc)
1	3952	2482	1470	1.52	11.64	1.36
2	4025	2482	1543	1.6	16.77	1.37
3	4175	2482	1693	1.76	19.82	1.47
4	4228	2482	1746	1.81	20.04	1.51
5	4260	2482	1778	1.84	27.11	1.45
6	4225	2482	1743	1.81	29.47	1.39

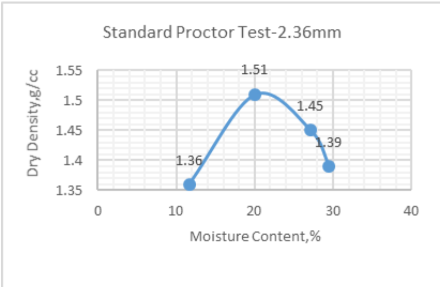

Fig. 8. Standard Proctor curve for clay + 0.3% of Plastic passing 2.36mm Sieve.

From the Graph,

Maximum Dry Density : 1.512 g/cc

Optimum Moisture Content : 21%

Maximum Dry Density had increased relative to that of untreated clay and optimum Moisture content had decreased.

F. Addition of plastic passing 4.75mm sieve

Table 19
Determination of Moisture Content

Trial no	Can No	Empty wt of can(g)	Wt of can+wet soil(g)	Wt of can+dry soil(g)	Wt of dry soil(g)	Wt of water (g)	Moisture content (%)
1	14	13.88	25.6	23.61	9.73	1.99	20.45
2	1	13.88	27.47	24.96	11.08	2.51	22.65
3	7	14.30	25.45	23.21	8.91	2.24	25.14
4	11	10.86	26.17	22.90	12.04	3.27	27.16

Table 20
Determination of Dry Density

Trial no	Wt of mould+ compacted soil(g)	Wt of empty mould without collar(g)	Wt of compacted soil(g)	Wet Density (g/cc)	Moisture content (%)	Dry Density (g/cc)
1	4105	2482	1623	1.68	20.45	1.39
2	4224	2482	1742	1.81	22.65	1.48
3	4232	2482	1750	1.81	25.14	1.45
4	4191	2482	1709	1.77	27.16	1.39

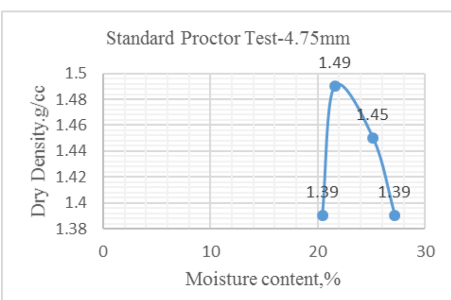

Fig. 9. Standard Proctor curve for clay + 0.3% of Plastic passing 4.75mm Sieve

From the Graph,

Maximum Dry Density : 1.492 g/cc

Optimum Moisture Content : 22%

Maximum Dry Density had increased relative to that of untreated clay and optimum Moisture content had decreased.

Out of the three sizes considered,

Plastic passing 2.36mm Sieve had the highest Maximum Dry density and least optimum moisture content for the same 0.3% of plastic added. Thus, Plastic Passing 2.36mm Sieve was chosen as the optimum Size.

G. Determination of optimum percentage of plastic

Standard Proctor Test which was used for determining the optimum size of Plastic, was again used for determining the optimum percentage of plastic passing 2.36mm sieve. There were three percentages of plastic considered for addition,

- 0.3% by the dry weight of sample
- 0.5% by the dry weight of sample
- 0.7% by the dry weight of sample

1) Addition of 0.3% of plastic passing 2.36mm sieve

As addition of 0.3% of plastic passing 2.36mm Sieve was used to determine the optimum size of plastic, its effect was explained in detail in the previous chapter.

Maximum Dry Density : 1.512 g/cc

Optimum Moisture Content : 21%

2) Addition of 0.5% of plastic passing 2.36mm sieve

Table 21
Determination of Moisture Content

Trial no	Can No	Empty wt of can(g)	Wt of can+wet soil(g)	Wt of can+dry soil(g)	Wt of dry soil(g)	Wt of water (g)	Moisture content (%)
1	28	11.45	26.65	24.42	12.97	2.23	17.19
2	7	14.30	27.15	25.05	10.75	2.1	19.53
3	33	11.85	26.85	24.28	12.43	2.57	20.68
4	14	13.88	26.53	24.03	10.15	2.5	24.63

Table 22
Determination of Dry Density

Trial no	Wt of mould+ compacted soil(g)	Wt of empty mould without collar(g)	Wt of compacted soil(g)	Wet Density (g/cc)	Moisture content (%)	Dry Density (g/cc)
1	4079	2482	1597	1.66	17.19	1.42
2	4133	2482	1651	1.71	19.53	1.43
3	4240	2482	1760	1.83	20.68	1.52
4	4204	2482	1722	1.79	24.63	1.44

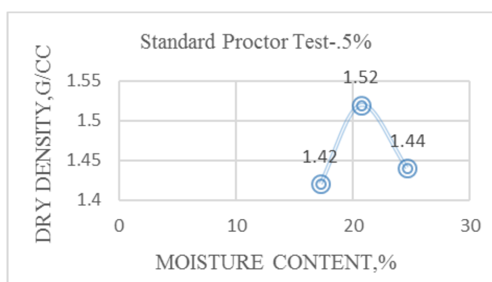

Fig. 10. Standard Proctor curve for clay + 0.5% of Plastic passing 2.36mm Sieve

From the graph,

Maximum Dry Density : 1.52 g/cc

Optimum Moisture Content: 20.7%

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H. Addition of 0.7% of plastic passing 2.36mm sieve

Table 23
Determination of Moisture Content

Trial no	Can No	Empty wt of can(g)	Wt of can+wet soil(g)	Wt of can+dry soil(g)	Wt of dry soil(g)	Wt of water (g)	Moisture content (%)
1	35	10.44	26.85	23.99	13.55	2.86	21.11
2	29	10.44	26.86	23.87	13.43	2.99	22.26
3	31	11.33	26.18	23.13	11.8	3.05	25.85
4	7	14.30	27.19	24.48	10.18	2.71	26.62

Table 24
Determination of Dry Density

Trial no	Wt of mould+ compacted soil(g)	Wt of empty mould without collar(g)	Wt of compacted soil(g)	Wet Density (g/cc)	Moisture content (%)	Dry Density (g/cc)
1	4182	2482	1700	1.76	21.11	1.45
2	4239	2482	1757	1.82	22.26	1.49
3	4235	2482	1753	1.82	25.85	1.45
4	4180	2482	1698	1.76	26.62	1.39

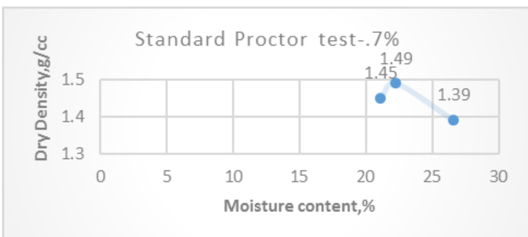

Fig. 11. Standard Proctor curve for clay + 0.5% of Plastic passing 2.36mm Sieve.

From the graph,
Maximum Dry Density : 1.492 g/cc
Optimum Moisture Content : 22%

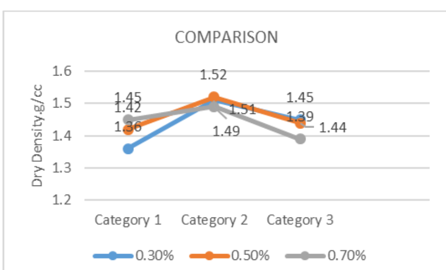

Fig. 12. Comparison of Different % of Plastic based on Dry Strength

Out of the three percentages considered,

Addition of 0.5% of Plastic passing 2.36mm Sieve had the highest Maximum Dry density and least optimum moisture content.

Thus, 0.5% of Plastic Passing 2.36mm Sieve was chosen as the optimum Percentage.

I. Effect of addition of optimum percentages of gypsum and plastic

Maximum dry density, optimum moisture content, Soaked and unsoaked CBR- are determined to explain the effect of addition of optimum percentages of plastic and gypsum.

- Diameter of mould: 10.2cm;
- Height of mould : 11.8cm
- Volume : 964.21cm^3.

1) Standard proctor test

Table 25
Determination of Moisture Content

Trial no	Can No	Empty wt of can(g)	Wt of can+wet soil(g)	Wt of can+dry soil(g)	Wt of dry soil(g)	Wt of water (g)	Moisture content (%)
1	7	14.30	26.58	24.89	10.59	1.69	15.95
2	29	10.44	26.84	24.38	13.94	2.46	17.65
3	31	11.33	27.03	24.45	13.12	2.58	19.66
4	35	10.44	26.46	23.64	13.2	2.82	21.36

Table 26
Determination of Dry Density

Trial no	Wt of mould+ compacted soil(g)	Wt of empty mould without collar(g)	Wt of compacted soil(g)	Wet Density (g/cc)	Moisture content (%)	Dry Density (g/cc)
1	4072	2482	1590	1.65	15.95	1.42
2	4152	2482	1670	1.73	17.65	1.47
3	4237	2482	1755	1.82	19.66	1.52
4	4183	2482	1701	1.76	21.36	1.45

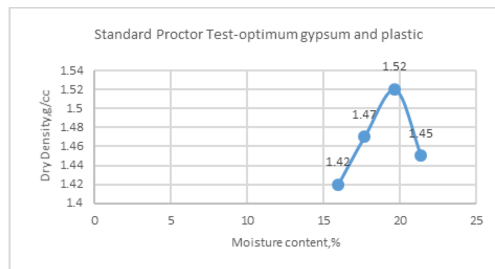

Fig. 13. Standard Proctor curve for clay + optimum percentages of plastic and gypsum

From the graph,
Maximum Dry Density : 1.52 g/cc
Optimum Moisture Content :19.7%

Maximum Dry Density had increased relative to that of untreated clay and optimum Moisture content had decreased.

2) California bearing ratio test

Surcharge weight - 4.5Kg
Proving Ring capacity - 293 divisions=3000kg;
1divison= 10.24kg

J. Unsoaked condition

Table 27
CBR Observation-Unsoaked stabilized clay

Penetration (mm)	Load (Divisions)	Load (Kg)
0	0	4.5
.5	3	45.46
1	5	55.7
1.5	6	76.18
2	7	86.42
2.5	7.5	96.66
3	8	96.66
3.5	8	101.78
4	8.5	101.78
4.5	9	106.9
5	9	112.02
7.5	10	127.38
10	11	137.62
12.5	11	158.1

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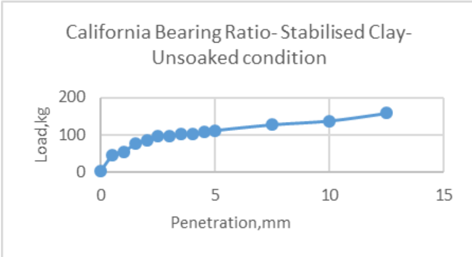

Fig. 14. California Bearing Ratio curve for the stabilized clay in unsoaked condition

Load for 2.5 mm penetration = 97 Kg;
CBR for 2.5mm penetration =7.1%
Load for 5mm penetration =112 Kg;
CBR for 5 mm penetration =5.5%

California Bearing Ratio of the Stabilized clay in unsoaked condition: 7.1%. Since CBR value lies between 7 and 15, the Stabilized clay in unsoaked condition was categorized as a fair soil.

K. Soaked condition

Table 28
CBR Observation-soaked stabilized clay

Penetration (mm)	Load (Divisions)	Load (Kg)
0	0	4.5
.5	0.5	9.62
1	1	14.74
1.5	1	14.74
2	1	14.74
2.5	1.5	19.86
3	1.5	19.86
3.5	2	24.98
4	2	24.98
4.5	2	24.98
5	2	24.98
7.5	2.25	27.54
10	2.25	27.54
12.5	2.5	30.1

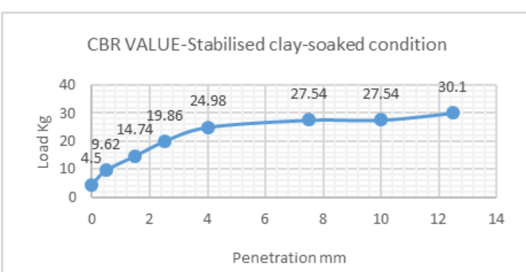

Fig. 15. California Bearing Ratio curve for the stabilized clay in soaked condition.

Load for 2.5 mm penetration = 20 Kg;
CBR for 2.5mm penetration =1.46%
Load for 5mm penetration =26 Kg;
CBR for 5 mm penetration =1.27%

California Bearing Ratio of the stabilized clay in soaked condition: 1.46%. CBR in soaked condition of Stabilized clay comes out to be less than that of normal clay.

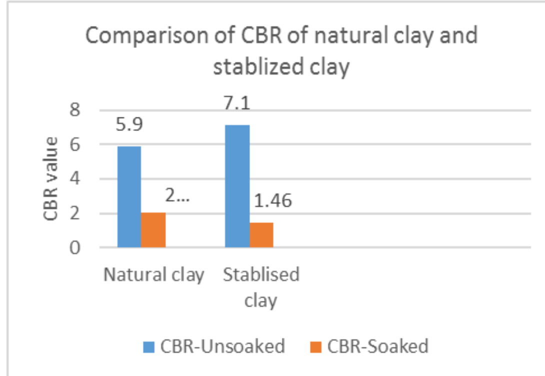

Fig. 16. Comparison of CBR values of natural clay and that of Stabilized clay

5. Conclusion

The project is focused on the performance of Plastic fiber and Gypsum as soil stabilization material. There are many natural wastes being sent out to environment, plastic waste is one such waste. Being produced in large quantities, the cost towards the application is very less. Use of plastic products such as waste plastic bag strips is increasing day by day the disposal of plastic waste without causing ecological hazards challenge to the present society. Thus using plastic strips is an economical and gainful utilization since there is scarcity of good quality soil for embankment fills. As far as plastic is considered, the Maximum dry density was obtained for a percentage of 0.5 plastic fibers passing through 2.36mm Sieve. There is an increase in the maximum dry density which in turn indicates an increase in the bearing capacity of black cotton soil.

In order to address the swelling and shrinkage properties, Gypsum was used. It was found to be effective when a percentage of 4% was used through free swell Index test. The effectiveness was further confirmed by the decrease in liquid limit, decrease in plasticity index, and increase in shrinkage limit.The CBR value of clay mixed with optimum percentages of plastic and gypsum (stabilized clay) was higher than that of natural clay in un-soaked condition. The soil was improved from poor soil to fair soil upon stabilization in un-soaked condition.But, upon performing CBR test in soaked condition, the results weren't positive. The CBR value of natural clay was higher than that of stabilized clay upon soaking. Plastic tends to serve its purpose as a stabilizer meant for increasing the strength and Gypsum tends to serve its purpose of reducing the volumetric change separately, thus, they are effective stabilizers. Also, they are economical options of stabilization. So, it can be concluded that these two materials could be effectively utilized separately or in combination with other admixtures or with each other in a percentage obtained from a wider range and just that these can't be mixed with each other for the purpose of subgrade stabilization.

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