Effect of Polypropylene Fiber on Lime, Fly Ash Stabilized Black Cotton Soil

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Abstract :- *The principle materials used for the stabilization and modifications of highway pavements materials are lime, Fly Ash and Polypropylene Fiber. Whereas lime is manufactured product, Fly Ash is the product of burning of coal in thermal power plant and Polypropylene fiber is produced in the factory. Black Cotton Soil is collected from our college. The form of the lime could be either quicklime (calcium oxide [CaO]), or hydrated lime (calcium hydroxide [$Ca(OH)_2$]). Quicklime hydrates with the soil moisture to become hydrated lime and therefore acts as a better drying agent before providing the calcium to react with the silica and alumina in the clayey soil. The present study is an attempt to estimate how the use of Lime, Fly Ash and Polypropylene fiber could improve the geotechnical properties including consistency limits, compaction properties, elasticity modulus, durability, California bearing ratio (CBR), etc of black cotton soil. The addition of Polypropylene fibers increases the optimum moisture content and decreases maximum dry density. The application of admixture for stabilization of pavement may be taken as positive contribution to economic and resource sustainability because the process could be alternative to all of the by products which are used for the purpose of stabilization.*

Keywords: - *Lime, Fly ash, Polypropylene fiber, soil stabilization.*

1. INTRODUCTION

With the reduction of available land resources, more and more construction of civil engineering structures is carried out over weak or soft soil, which leads to the establishment and development of various ground improvement techniques such as soil stabilization and reinforcement. The soil stabilization means the improvement of stability or bearing power of the soil by the use of controlled compaction, proportioning and/or the addition of suitable admixtures or stabilizers.

Lime stabilization has been extensively applied in practice of civil engineering such as foundations, roadbeds, embankments and piles. When lime is added to soils, it reacts with soil particles, which leads to the improvement in many engineering properties of soils. Some investigators found that the strength behavior of soils was greatly improved after lime treatment.

In order to understand the effect of polypropylene fiber content, lime content and curing time on the strength behavior of a clayey soil investigated, a great number of untreated and treated soil specimens were subjected to unconfined compressive tests and direct shear tests. Moreover, other important engineering properties such as swell percent, shrinkage parameters and failure characteristics were studied. Besides these tests, some specimens after shearing were taken for scanning electronic microscopy (SEM) analysis. On the basis of SEM analysis, the improving mechanisms of polypropylene fiber and lime were discussed and the Observations from tests were explained. The primary objective of this project described treatment material for improving the pertinent engineering properties of a clayey soil, e.g. strength, swelling–shrinkage potential and failure characteristics.

2. EXPERIMENTAL WORK

2.1 Materials Used:

2.1.1 Soil - The soil used in the study was the locally available soil from Priyadarshini College of Engineering Campus. The soil was black cotton soil.

Table 1 Chemical composition of Black Cotton Soil:

Sr. No.	Chemical's Name	Percentage (%)
1.	Na_2O	0.36
2.	MgO	2.42
3.	Al_2O_3	15.17
4.	SiO_2	46.48
5.	P_2O_5	0.09
6.	SO_3	0.02
7.	K_2O	0.96
8.	CaO	7.45
9.	TiO_2	1.56
10.	Cr_2O_3	0.02
11.	MnO	0.29
12.	Fe_2O_3	11.57
13.	CO_3O_4	0.009
14.	NiO	0.01
15.	CuO	0.01
16.	ZnO	0.01
17.	Rb_2O	0.007
18.	SrO	0.01
19.	Y_2O_3	0.004
20.	ZrO_2	0.040
21.	BaO	0.03
22.	PbO	0.006
23.	Nb_2O_5	-
24.	LOI	13.36

2.1.2 Lime - The lime used in the study was the locally available lime (Diamond Brand).

Table 2 Chemical composition of Lime:

Sr. No.	Chemical's Name	Percentage (%)
1.	Na_2O	0.04
2.	MgO	18.31
3.	Al_2O_3	0.56
4.	SiO_2	9.19
5.	P_2O_5	0.005
6.	SO_3	0.01
7.	K_2O	0.03
8.	CaO	30.75
9.	TiO_2	0.03
10.	Cr_2O_3	-
11.	MnO	0.04
12.	Fe_2O_3	0.46
13.	CO_3O_4	-
14.	NiO	-
15.	CuO	-
16.	ZnO	-
17.	Rb_2O	-
18.	SrO	0.004
19.	Y_2O_3	-
20.	ZrO_2	0.054
21.	BaO	-
22.	PbO	-
23.	Nb_2O_5	-
24.	LOI	40.45

2.1.3 Fly-ash - The Fly-ash used in the study was collected from koradi Power Station.

Table 3 Chemical composition of Fly-ash:

Sr. No.	Chemical's Name	Percentage (%)
1.	Na_2O	0.23
2.	MgO	0.59
3.	Al_2O_3	26.4
4.	SiO_2	55.58
5.	P_2O_5	0.25
6.	SO_3	0.32
7.	K_2O	0.85
8.	CaO	6.71
9.	TiO_2	1.54
10.	Cr_2O_3	0.02
11.	MnO	0.05
12.	Fe_2O_3	3.92
13.	CO_3O_4	-
14.	NiO	0.01
15.	CuO	0.01
16.	ZnO	0.009
17.	Rb_2O	0.006
18.	SrO	0.01
19.	Y_2O_3	0.006
20.	ZrO_2	0.056
21.	BaO	0.03
22.	PbO	0.009
23.	Nb_2O_5	0.004
24.	LOI	3.68

2.1.4 Polypropylene Fiber - The Polypropylene fiber used in the study was collected from Bajaj Steel Industries Limited, Nagpur which was of 0.05mm diameter.

3. LABORATORY TESTS

3.1 Preparation of Samples:

The main aim of the present investigation is to study and understand the strength and deformation behavior of soil. For this study Black cotton soil is taken and laboratory tests are conducted to determine the effect of Poly-propylene fiber, Lime, Fly-ash on Black cotton soil. For experimental procedure, we have prepared the soil sample by mixing soil, lime and fly ash in different proportions. we have prepared a mix of soil and fly ash in proportion of 100&0%, 75&25% and 50&50% with which lime have been used as an additive in 3%, 6% & 9%. The polypropylene fiber is added further in 2%. Then the prepared mix has been kept for curing for 7 days and 28 days. After curing this samples are used for carrying out the different index properties of soil.

Table 4 Mix Proportion of Samples for 7 Days and 28 Days Curing:

Sr. No.	Soil	Fly ash	Lime
1.	100	0	+3
2.	100	0	+6
3.	100	0	+9
4.	75	25	+3
5.	75	25	+6
6.	75	25	+9
7.	50	50	+3
8.	50	50	+6
9.	50	50	+9

3.2 Index properties of Soil:

3.2.1 Liquid Limit:

Liquid limit is the water content at which soil passes from zero strength to infinitesimal strength hence the true value of liquid limit cannot be determined. For determination purpose, liquid limit is that water content at which a part of soil, cut by a groove of standard dimension, will flow together for a distance of 1.25cm under an impact of 25 blows in a standard liquid limit apparatus.

Liquid limit is determined in the laboratory with the help of the standard liquid limit apparatus designed by Cassagrande. The apparatus consist of a hard rubber base of B.S. hardness 21-25,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 a 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.The Cassagrande tool cuts a groove of size 2mm wide at the bottom, 11mm wide at the top and 8mm high.

About 120gm of the specimen passing through 425micron sieve is mixed thoroughly with distilled water in the evaporation dish or on a marble plate to form a uniform paste .A portion of the paste is placed in the cup over the spot where the cup rests on the base, squeezed down and spread into position and groove is cut in the soil pat. The handle is rotated at a rate about 2 revolutions per second, and the number of blows are counted until the two parts of the soil sample come into contact at the bottom of the groove along a distance of 10mm.Some soils tend to slide on the surface of the cup instead of flowing. If it occurs, the result should be discarded and the test repeat until flowing does not occur. After recording the number of blows, approximately 10gm of soil from near the closed groove is taken for water content determination. Since it is difficult to adjust the water content precisely equal to the liquid limit when the groove should close in 25 blows, the liquid limit is determined by plotting a graph between number of blows as abscissa on a logarithmic scale and the corresponding water content as ordinate.

3.2.2 Plastic Limit:

The moisture content at which soil has the smallest plasticity is called the plastic limit. For the determination purpose, the plastic limit is defined as the water content at which a soil will just begin to crumble when rolled into a tread of 3mm in diameter.

To determine the plastic limit, the soil specimen, passing 425 micron sieve, is mixed thoroughly with distilled water until the soil mass becomes plastic enough to be easily moulded at fingers. The plastic soil mass should be left for enough time to allow water to permeate through the soil mass. A ball is formed with about 8gm of this plastic soil mass and rolled between the fingers and a glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. When a diameter of 3mm is reached, the soil is remoulded again into a ball. This process of rolling and remoulding is repeated until the thread starts just crumbling at a diameter of 3mm.The crumbled threads are kept for water content determination. This test is repeated twice more with fresh samples. The plastic limit is then taken as the average of these three water contents.

The values of liquid limit and plastic limit are directly used for classifying the fine grained cohesive soils according to Indian Standard on Soil Classification. The values of these limits are also used in calculating the flow index, toughness index and relative plasticity index which are useful in giving an idea about the plasticity, cohesiveness, compressibility, shear strength, permeability, consistency and state of cohesive soils.

3.2.3 Plasticity Index:

The numerical difference between liquid limit and plastic limit is called as plasticity index.

3.2.4 Shrinkage Limit:

Shrinkage limit is the maximum water content at which a reduction in water content does not cause an appreciable decrease in the volume of soil mass. At shrinkage limit, on further reduction in water, air starts to enter into the voids of the soil and keeps the volume of voids constant.

Shrinkage limit, $w_{s.L.}(\%) = [\, w_1 - \frac{(v_1 - v_2)\gamma_w}{w_s} \,] \times 100.$

Where,

w_1 = water content in initial soil sample in saturated stage

v_1 = volume of the soil sample in saturated stage

v_2 = volume of the oven dried sample

w_s = weight of oven dried sample

γ_w = unit weight of water

The value of shrinkage limit is used for understanding the swelling and shrinkage properties of cohesive soils. It is used for calculating the shrinkage factors which help in the design problems of the structures made up of the soils and resting on soil. It gives an idea about the suitability of the soil as an construction material in foundations, roads, embankments and dams. It helps in knowing the state of the given soil. Approximate values of specific gravity of soil grains may also be determined from the data of shrinkage limit test.

3.2.5 Particle Size Distribution:

The soil is sieved through a set of sieves. Sieve are generally made of spun brass and phosphor bronze (or stainless steel) sieve cloth, According to IS 1498-1970. The sieve are designed by the sizes ranging from 80 mm to 75 microns are available. The diameter of sieve is generally between 15 to 20 cm. Dry sieve analysis is suitable for cohesion less soil, with little or no fines. If soil contains a substantial quantity (say more than 5%) of fine particles, a wet sieve analysis is required.

The particle size distribution curve, also known as a gradation curve, represents the distribution of particle of different of sizes in the soil mass. The percentage finer N than a given size in the soil mass. The particle size is plotted as ordinate (on natural scale) and the particle size as abscissa (on log scale).

3.2.6 Specific Gravity:

Specific gravity is the ratio of the mass/ weight in air of a given volume of dry soil solids to the mass/weight of equal volume of distilled water at 4°C.

Specific gravity (Gs) = $\frac{(w_2-w_1)}{\{(w_2-w_1)-(w_3-w_4)\}}$

Where,

w_1 = mass of empty pycnometer

w_2 = mass of pycnometer + soil grain

w_3 = mass of pycnometer +soil grain +water

w_4 = mass of pycnometer + water.

Specific gravity of soil grains is a important property and is used in calculating void ratio, porosity, degree of saturation if density and water content are known. Its value helps up to some extent in indentification and classification of soils. It gives an idea about the suitability of the soil as a construction material; higher value of specific gravity gives more strength for roads and foundations. It is used in computing the soil partical size by means of hydrometer analysis. It is also used in estimating the critical hydraulic gradient in soil when a sand boiling condition is being studied and in zero air-void calculations in the compaction theory of soils.

Coarse Grained Soils	-	2.6 – 2.7
Fined Grained Soils	-	2.7 – 2.8
Organic Soils	-	2.3 – 2.5

3.2.7 Compaction Test:

Compaction is the process of densification of soil mass by reducing air voids. This process should not be confused with consolidation which is also a process of densification of soil mass but by the expulsion of water under the action of continuously acting static load over a long period.

The degree of compaction of a soil is measured in terms of its dry density. The degree of compaction mainly depends upon its moisture content, compaction energy and type of soil. For a given composition energy every soil attains the maximum dry density at a particular water content which is known as optimum moisture content.

Compaction of soils increases their density, shear strength, bearing capacity but reduces their void ratio, porosity, permeability and settlements. The results of this test are useful in the stability of field problems like earthen dams, embankments, roads and airfields. In such constructions, the soils are compacted. The moisture content at which the soils are compacted in the field is controlled by the value of optimum moisture content determined by the laboratory proctor compaction test. The compaction energy to be given by the field compaction unit is also controlled by the maximum dry density determined in the laboratory. In other words, the laboratory compaction tests results are used to write the compaction specification for field compaction of soils.

4. RESULTS AND DISCUSSION

The index properties such as Liquid limit, Plastic limit, Shrinkage limit, Specific gravity, Compaction test, particle size distribution as per Indian Standard test. The value of Particle Size Distribution curve test results has C_c=1.097 and C_u=1.182. Based on this property it can be reported that black cotton soil is uniformly graded soil.

Table 5 Index properties of Black Cotton soil:

Table 6 After 7 Days Curing Results with Lime and Fly-ash:

Samples	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)	O.M.C (%)	M.D.D (KN/M^3)
100% soil+0% fly-ash+3% lime	66.59	34.53	**32.06**	24.01	1.55
100% soil+0% fly-ash+6% lime	59.1	30.17	28.93	20.10	1.54
100% soil+0% fly-ash+9% lime	55.6	30.34	25.26	17.02	1.53
75% soil+25% fly-ash+3% lime	31	26.8	4.2	22.22	1.81
75% soil+25% fly-ash+6% lime	32.45	28.16	4.29	21.51	1.79
75% soil+25% fly-ash+9% lime	30.94	26.91	4.03	20.77	1.6
50% soil+50% fly-ash+3% lime	34.87	32.2	2.67	19.51	1.6
50% soil+50% fly-ash+6% lime	32.38	30.01	2.37	18.52	1.56
50% soil+50% fly-ash+9% lime	32.1	29.53	0.57	18.67	1.52

Table7 After 28 Days Curing Results with Lime and Fly-ash:

Samples	After 7 Days		After 28 Days	
	O.M.C (%)	M.D.D (KN/M^3)	O.M.C (%)	M.D.D (KN/M^3)
100% soil+0% fly-ash+3% lime+2%fiber	28.52	1.42	28.72	1.39
100% soil+0% fly-ash+6% lime+2%fiber	28.88	1.39	29	1.35
100% soil+0% fly-ash+9% lime+2%fiber	29	1.35	29.20	1.32
75% soil+25% fly-ash+3% lime+2%fiber	28.48	1.41	28.56	1.41
75% soil+25% fly-ash+6% lime+2%fiber	28.94	1.40	28.94	1.39
75% soil+25% fly-ash+9% lime+2%fiber	29.01	1.38	29.42	1.38
50% soil+50% fly-ash+3% lime+2%fiber	28.99	1.40	29.01	1.37
50% soil+50% fly-ash+6% lime+2%fiber	29	1.38	29.42	1.32
50% soil+50% fly-ash+9% lime+2%fiber	29.56	1.32	29.56	1.30

Liquid limit	Plastic limit	Plasticity index	Shrinkage limit	Specific gravity	O.M.C (%)	M.D.D (KN/M^3)
71.4%	37.19%	34.31%	12.8%	2.61	28.5	1.44

Table 8 After 7 and Days Curing Results with polypropylene fiber:

Samples	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)	O.M.C (%)	M.D.D (KN/M^3)
100% soil+0% fly-ash+3% lime	52.7	28.97	23.73	24.72	1.71
100% soil+0% fly-ash+6% lime	54.86	29.39	25.47	20.37	1.62
100% soil+0% fly-ash+9% lime	53	30.34	22.66	17.06	1.45
75% soil+25% fly-ash+3% lime	36.11	32.38	3.73	23.23	1.63
75% soil+25% fly-ash+6% lime	36	32.25	5.75	22.57	1.59
75% soil+25% fly-ash+9% lime	35.57	32.29	6.28	22.3	1.56
50% soil+50% fly-ash+3% lime	33.44	30.76	2.68	20.07	1.51
50% soil+50% fly-ash+6% lime	32.01	30.01	3.43	19.15	1.48
50% soil+50% fly-ash+9% lime	31.15	30.65	2.5	17.97	1.45

From the above results it was found that with the increase of percentage of Lime and Fly Ash the value of Liquid limit decreases and Plastic limit increases. The value of Plasticity index decreases and the value of O.M.C and M.D.D also decreases.

The OMC and dry density test results on black cotton soil with different 2% fiber content are reported in table 6. These data indicate that maximum dry density decreases gradually with addition of the fiber content, which is due to lower density of the fiber than the soil particles. An increase in optimum moisture content was observed due to adsorption of water particles on the surface of polypropylene fibers.

5. CONCLUSION

Based on the studies carried out following conclusions are drawn:

1. The soil used in the present study is found to be uniformly graded soil and in its present form it is not suitable for construction and hence needs improvement.

2. Soil is modified by addition of lime and fly-ash in proportion of 100&0%, 75&25% and 50&50% with which lime have been used as an additive in 3%, 6% & 9%. Addition of Lime and Fly Ash decreases the Liquid limit value and increases the Plastic limit value and also decreases the value of Plasticity index due to this the soil becomes more stiffened.

3. With addition of polypropylene fibers in the soil maximum dry density decreases gradually which is due to lower density of the fiber than the soil particles. An increase in optimum moisture content was observed due to adsorption of water particles on the surface of polypropylene fibers.

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