Improvement in Strength Properties of Black Cotton Soil Using Bottom Ash and Lime

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***Abstract*- The foundation of a building or road is an essential part for effective transmission of load to the subsoil. The type of structure and its design depends upon the quality of soil. The expansive soils or black cotton soil are examples of weak soils, which encountered in foundation. The soil responsible for failure of structure in form of settlement and cracks etc. the waste products available in environment like bottom ash along with lime can be used to modify and improve the properties of black cotton soil. The paper describes the methods followed to find the optimum percentage of bottom ash and lime for soil improvements along with supporting result data. The paper concludes that the optimum percentage of soil mix gives better result with increment in bearing capacity and CBR value.**

Index Terms- soil improvement, lime, bottom ash, black cotton soil, CBR, Direct shear test

I. INTRODUCTION

Available land for construction is very less because of increasing urbanization and modernizations. Now a day construction of structures is being carried on land having weak or soft soil. Stability of any structure depends on the properties of soil on which structure has to be done. Using land having soft soil for construction it is required to improve their properties by various ground improvement techniques. Formerly soil stabilization and soil reinforcement techniques are used to improve. Most of the soil available are such that they have good compressive strength adequate shear strength but weak in tension/ poor tensile strength. Nearly 51.8 million hectares of land area in India are covered with Expansive soil (mainly Black Cotton soil). The property of these expansive soils, in general, is that they are very hard when in dry state, but they lose all of their strength when in wet state. In light of this property of expansive soils, these soils pose problems worldwide that serve as challenge to overcome for the Geotechnical engineers.

Black cotton soil is expansive soil. Expansive soils exhibit generally undesirable engineering properties. They tend to have low shear strengths and to lose shear strength due to wetting or other physical disturbances. They can be plastic and compressible. Cohesive soils can creep over time under constant load. In such situations, soil improvement or modification plays a major role. Soil stabilization is nothing but modifying the properties of soil to improve its engineering performance. As a result of soil stabilization, the bearing capacity of the soil is increased and its strength, resistance to washout, and other properties are improved. In general, Soil stabilization can be achieved by modification of properties of existing soil with compaction or with various additives i.e. cement, lime etc.

The first method of soil stabilization is a costlier one. But in second method we have to use waste material as an additive which is economical. In the past few years, many researches focused on utilization of different types of waste for soil stabilization purposes.

Bottom Ash: During coal combustion, large amounts of ash are created along with carbon dioxide and other gases. The fine particle ash that rises up with the flue gases is known as fly or flue ash while the heavier ash that does not rise is called bottom ash.

In India about 10000 brick kilns are there. It consumes approximate 35 million tonnes of coal in a year. Brick kiln ash is the residue obtained after the burning of various materials in kiln for backing the bricks. These coal wastes have no use and hence it dumped as waste material. Hence such waste are utilize for stabilization of expansive soil etc is justified. In the present study, using bottom ash obtained from Kolhapur area is used for stabilization

of black cotton soil obtained in Kasaba Bawad from Kolhapur is attempted. With various proportions of this additive, an expansive soil is stabilized.

Lime: Lime stone is the main source of the lime production. Lime is vastly used for soil stabilization because of its binding properties. Lime, when comes in contact with water there is chemical reaction which creates a cementing compound. Lime provides more strength to soil and make the soil more durable and hard.

II. LITERATURE REVIEW

Most of the literature discuss about the mixing of lime and fly ash separately in black cotton soil and its related properties and improvements.

The literature review shows that coal bottom ash is a cheap stabilizing agent for clay soil. The optimum percentage for the tests to be conducted are 20,30 and 40%. From the literature, it is observed that the addition of bottom ash to the soil changes its properties. Most of the researchers performed the test like liquid limit, plastic limit, shrinkage limit, standard Proctor compaction, swelling index and unconfined compressive strength. From literature review it shows that addition of coal bottom ash to soil increases the CBR, OMC and UCS whereas decreases the MDD, liquid limit, plastic limit, plasticity index and swelling index of the soil decrease. The optimum percentage is around 40% of soil weight.

Similarly, lime can be treated as one of the best stabilizing materials for clayey soils. A large number of tests determining the liquid limit, plastic limit, free swell, swell pressure, standard Proctor compaction, pH, unconfined compressive strength, tri-axial, direct shear, consolidation, California bearing ratio, were conducted by several researchers on soils stabilized with lime Many researchers concluded that addition of lime decreases plasticity index, free swell, swell pressure, maximum dry density whereas addition of lime increases the optimum moisture content, UCS, CBR, shear strength and pH. The increase in UCS and CBR value is observed only up to certain lime content after which it starts decreasing. The optimum percentage utilization of lime is around 6% of soil weight.

III. OBJECTIVE OF RESEARCH

The proposed research uses bottom ash and lime to enhance the strength properties of black cotton soil w.r.t. following geotechnical engineering properties:
Liquid limit, plastic limit, compaction properties, shear strength

IV. METHODOLOGY

From literature review it is clear that approximately 40% of bottom ash and 6% of lime is sufficient to stabilize the black cotton soil. Hence the mix proportion is considered as below for initial experimentation work.

Table no.1 Soil mix proportion list

Mix. No.	Proportions
1	Clay:100
2	clay: coal ash: 90: 10
3	clay: coal ash: 80: 20
4	clay: coal ash: 70: 30
5	clay: coal ash: 60: 40
6	clay: coal ash: 58: 42
7	clay: coal ash: 55: 45
8	clay: lime: 98: 2
9	clay: lime: 96: 4
10	clay: lime: 94: 6
11	clay: lime: 93.5: 6.5
12	clay: lime: 93: 7

Laboratory tests were conducted according to Indian Standards as shown in table 2.

Table no. 2 Indian Standards for different tests.

Test	Indian standard
Water content	IS 2720-02-1973
Specific gravity	IS 2720-03el-1980
Consistency limits	IS 2720-05-1985
Permeability test	IS 2720-17-1986
Standard Proctor test	IS 2720-07-1980
CBR test	IS 2720-16-1987

The mainly engineering properties are focused on soil mixes. Further finding optimum percentage of bottom ash and lime the mix category is changed to get the final mix proportion and best outcome. The test performed on

The initial tests were carried out on pure black cotton soil. The properties are as below.

Table no. 3 Properties of pure black cotton soil

Sr.	Property	Value
1.	Specific gravity	2.54
2.	Liquid limit (%)	54.14 %

3.	Plastic limit (%)	24.8 %
4.	Plasticity index (%)	29.34 %
5.	Soil classification	CH
6.	Optimum moisture content (%)	22.4
7.	Maximum dry density (g/cm3)	1.61
8.	Differential free swell (%)	42.85%
9.	Unsoaked CBR (%)	2.92

V. RESULT AND DISCUSSION

The various test performed on pure black cotton and soil mix. The results and respective graphs are tabulated as below.

Results of black cotton and bottom ash mixes:

Table no.4 Results for plasticity index of soil + bottom ash mix

Mix	Plasticity Index	% Change
Soil	33	-
90:10	28.1	-14.84
80:20	24.7	-25.15
70:30	22.3	-32.42
60:40	19.1	-42.12
58:42	17.9	-45.75
55:45	19.4	-41.21

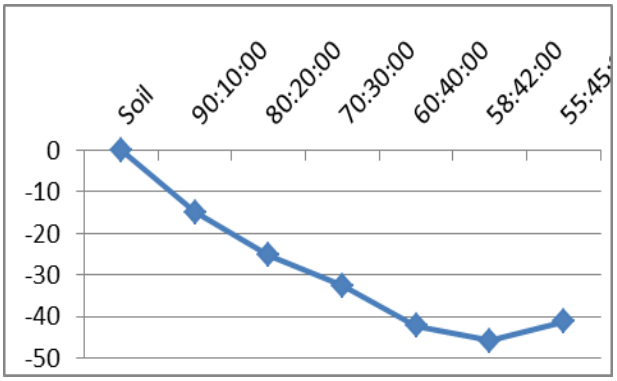

Figure no. 1 Chart of soil mix (soil + bottom ash) versus plasticity index

In initial study optimum swelling index is obtained at 42% of mix proportion. Hence additional mix is considered for plasticity index. The figure no. 1 shows, the plasticity index decreases till 42% then again increases.

Table no. 5 Results for compaction test of soil + bottom ash mix

Mix	OMC	% change in OMC	MDD	% change in MDD
Soil	24	0	1.07	0
90:10	28	16.67	1.32	18.93
80:20	27	12.5	1.38	22.46
70:30	26	8.33	1.45	26.2
60:40	25	4.16	1.56	31.41
58:42	23	4.16	1.63	52.33
55:45	26	8.33	1.48	10.13

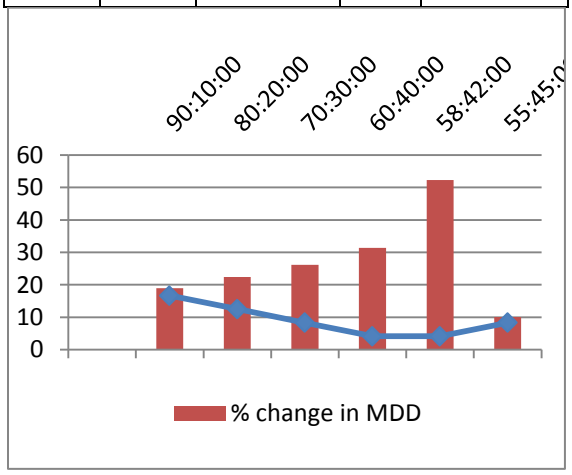

Figure no. 2 Chart of soil mix for percentage change in OMC and MDD

The figure no. 2 shows, the soil mix proportion 58:42 gives lowest OMC and maximum MDD. Hence the mentioned proportion is best for having maximum strength of soil mix.

Results of black cotton and lime mixes:

Table no. 6 Results for compaction test of soil + lime mix

(BC:L)	Plasticity index (Ip)	% change in Ip
Soil	33.1	0
98:02	29.8	-9.96
96:04	28.1	-15.1
94:06	26.3	-20.54
93.5:6.5	24.1	-27.19
93:07	24.8	-5.07

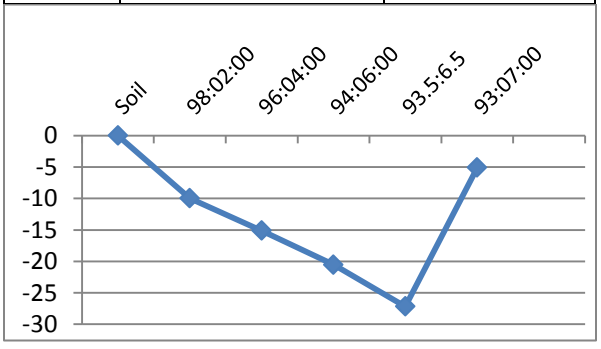

Figure no. 3 Chart of soil mix (soil + lime) versus plasticity index

The figure no. 3 shows, the plasticity index decreases till 6.5% of lime addition then again increases. It indicates that, optimum utilization of lime is around 6.5% when used as only single mix with black cotton soil.

Table no. 7 Results for compaction test of soil + fly ash mix

Mix	OMC	% change in OMC	MDD	% change in MDD
Soil	33.1	0	1.07	0
98:02	27	12.5	1.25	16.82
96:04	26	8.34	1.29	20.56
94:06	25	4.17	1.35	26.16
93.5:6.5	22	-8.34	1.4	30.84
93:07	25	4.17	1.33	24.29

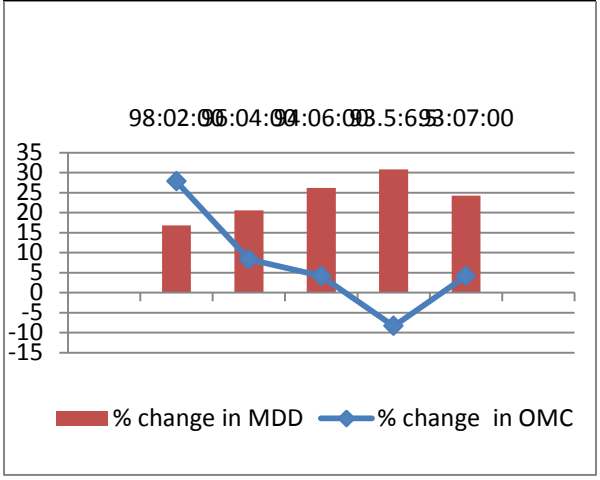

Figure no. 4 Chart of soil mix (soil + lime) for percentage change in OMC and MDD

The figure no. 4 shows, the soil mix proportion 93.5:6.5 gives lowest OMC and maximum MDD. Hence the mentioned proportion is best for having maximum strength of soil mix.

From results of liquid limit, plastic limit, plasticity index and Proctor test, the mix proportion all ingredients are finalized and direct shear test is carried out for determination of cohesion and angle of internal friction (shear strength parameters). Terzaghi's bearing capacity equation is used to find the bearing capacity of soil and tabulated in table no.8. and charts of same is plotted on figure no.5. this shows the proportion 51.5 (black cotton soil) : 42 (bottom ash) : 6.5 (lime) is best suitatble for soil improvement.

Table no.8 bearing capacity from direct shear test results

Mix proportion	Bearing capacity= qu=5.7c+γD
Soil	3.71
54:40:06	3.91
53.5:40:6.5	3.95
53:40:07	3.97
52:42:06	4.01
51.5:42:6.5	4.09
51:42:07	4.08
49:45:06	4.01
48.5:45:6.5	4.03
48:45:07	3.96

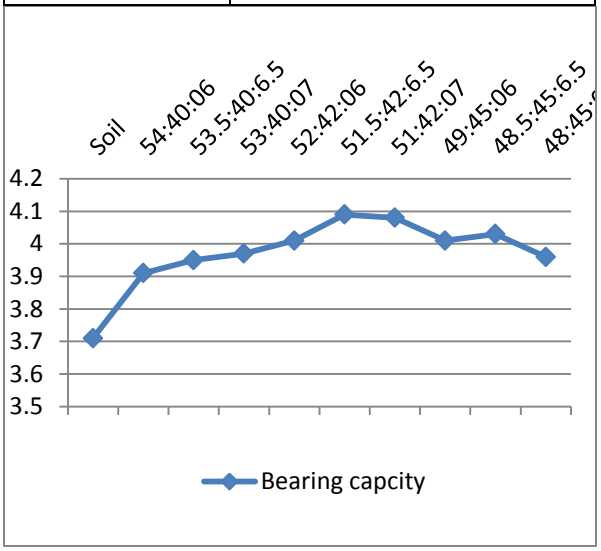

Figure no. 5 Chart of bearing capacity for different soil mix (Soil + BA + Lime) proportions

From results of direct shear test the finalized mix proportion is considered for CBR test and CBR results compared with original only soil condition as below.

- C.B.R. of black cotton soil specimen at 2.5mm penetration =7.82
- C.B.R of black cotton soil specimen at 5mm penetration=7.61
- C.B.R. of Soil Mix (51.5: 42: 6.5) specimen at 2.5mm penetration =33.31
- C.B.R of Soil Mix (51.5: 42: 6.5)specimen at 5mm penetration=23.79
- C.B.R value for soil is 7.82 & for optimum mixture is 33.31, % of increase of C.B.R value is 76.82 %.

VI. CONCLUSION

From the various geotechnical Engineering properties test performed on soil and various soil mix following conclusions are made.

1. For optimum mix of soil + bottom ash + lime, % change in of liquid limit, plastic limit and plasticity index were observed. On the addition of kiln coal ash and lime the plastic limit of soil increases. Therefore soil becomes non plastic. Also plasticity index decreases shows that soil become non-plastic in nature which is important property as it reduces the swelling and shrinkage behavior of clayey soil.
2. The addition of kiln coal ash and lime individually and in combination of kiln coal ash-lime in the clayey soil increases the maximum dry density of mixes. The OMC decreases on addition of kiln coal ash & lime in clay soil. Thus, a compaction characteristic gives the clear idea about optimum content for stabilization of clayey soil.
3. From the results of Direct shear test, bearing capacity calculation shows the bearing capacity increased from 3.71 to 4.09 i.e. by 10.24% for optimum mix.
4. The CBR tests were conducted on soil and optimum mix shows rise of CBR strength by increase of C.B.R value is 76.82 %.

Form these it can be concluded that the proportion 51.5 (black cotton soil) : 42 (bottom ash) : 6.5 (lime) is best optimum for strength improvement in black cotton soil

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