Improvement of Engineering Properties of Soil using Fly Ash and coated Jute Fiber

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Abstract : The performance of any type of pavements is more contributed on sub-grade soil strength. Many stabilizing techniques and materials have been used by researchers to increase the strength of sub-grade soil among different natural and artificial reinforcing material. Jute is one of the natural abundant resource materials and many studies have been carried out on jute geo-textile on embankment slope protection and embankment construction and drainage design. Jute and Fly Ash being easily available, the procurement of the material is simple. Therefore, in present study, jute fibers (different proportion and length) and fly ash (varying proportion) are used in order to stabilize the soil sample. On the basis of test results, it is recommended that 27% fly ash along with 0.8% treated jute fibers of length 15 mm to soil gives the optimum results.

***Index Terms*–Soil Stabilization, Jute fiber, Fly ash.**

I. INTRODUCTION

Soil is a complex material whose behavior varies with the natural conditions if not controlled. The soil properties can change in different forms such as with the change of location, depth, availability of water, loading & drainage conditions. However, soil properties are depended on the soil condition under which it exists. Unlike other construction material, soil transportation is not economical as the requirement of quantity of soil is huge when compared with other materials. Therefore, it is not preferred to remove/replace the original available soil and transport the new strengthened soil to the site. In one way or the other, the existing soil has to be reused so that maximum economy is achieved.

The stabilization of the soil is a common practice in modern days as it involves the usage of existing soil while treating the soil with various means such as lime, cement, fly ash etc. soil stabilization simply means to enhance the geotechnical and engineering properties of soil so that it can withstand the applied loads with any kind of failure. Now, this process has been used for many years to enhance the properties of subgrade soil of pavement of roads. As high performance of pavement with stabilized subgrade soil is expected and delivered. There have been emptied methods of soil stabilization. Conventional stabilization of soil with lime and cement has many benefits but these methods are costly and uses raw material. Therefore, many research works have been continued on this topic while using various recycled material such as fly ash, bagasse ash etc. And these research works have been proved beneficial in the area of soil stabilization. The detailed discussion of different types of method of soil stabilization has been carried out in the following section.

The process of modification of the soil engineering properties is called soil stabilization and it is done with different methods with and without admixtures. Compaction and drainage are the methods of soil stabilization without admixtures which is called mechanical methods. And if the admixtures are added in order to enhance the soil, it will improve the engineering properties of soil.

II. MATERIAL TO BE USED

Plain Soil: The soil in current study was selected from subsoil at 'Adarsh Nagar, Bathinda' and was used for various experimental works. The ground level soil was removed in order to collect the soil underneath it.

Figure 1.Plain Soil.

Fly Ash: Fly ash, being the important soil improvement material, was collected from 'LehraBega Thermal Plant'.

Figure 2.Soil containing Fly Ash.

Jute Fibers: Jute twine from local packaging industry/textile industry at Bathinda was procured for the current experimental works and before adding to the soil, the fibers were coated with suitable material prevent the natural biodegradation. The jute was cut into different length of 15mm and 30mm which were used at different proportions of 0.4%, 0.8% and 1.2% in the soil. The jute fibers were treated with two chemicals i.e. Cr2(SO4)3.15H2O and NaHCO3 solution. After the treatment of fibers, they were allowed to dry at room temperature for one day and then utilization in soil was done.

Figure 3.Un-treated Jute Fibers.

III. Laboratory Tests

Test conducted on the above mentioned soil samples are:

i. Specific Gravity (As per IS 2720: Part 3).
ii. Grain Size Analysis (As per IS 2720: Part 4).
iii. Consistency of soil (As per IS 2720: Part 5).
iv. Determination of Maximum dry density and optimum moisture content By Standard Proctor Test (As per IS 2720: part 7)
v. Determination of Stress-Strain behavior by Unconfined compression strength test (As per IS 2720: Part 10)
vi. Determination of Load-penetration Curve by California Bearing Ratio value of Soil (As per IS 2720: Part 16).

Following tests were performed on soil mixed with FA + Jute Fiber.

i. Determination of Maximum dry density and optimum moisture content By Standard Proctor Test (As per IS 2720: part-7)
ii. Determination of Stress-Strain behavior by Unconfined compression strength test (As per IS 2720: Part 10)
iii. Determination of Load-penetration Curve by California Bearing Ratio value of Soil (As per IS 2720: Part 16).

IV. Various Soil Samples

The various soil samples were prepared by using different proportions of Fly ash and Jute fibers in order to perform various laboratory tests for evaluating the behavior of soil. The description of various soil mixes has been mentioned in the table below.

Table: 1. Various Soil Mixes.

S. No.	Proportion of Fly Ash (%)	Proportion of Jute Fiber (%)
Plain Soil	-	-
Soil Mix 1	9	-
Soil Mix 2	18	-
Soil Mix 3	27	-
Soil Mix 4	36	-
Soil Mix 5	27	0.4 (15 mm length treated with CR)
Soil Mix 6	27	0.4 (15 mm length treated with Na)
Soil Mix 7	27	0.4 (30 mm length treated with CR)
Soil Mix 8	27	0.4 (30 mm length treated with Na)
Soil Mix 9	27	0.8 (15 mm length treated with CR)
Soil Mix 10	27	0.8 (15 mm length treated with Na)

Soil Mix 11	27	0.8 (30 mm length treated with CR)
Soil Mix 12	27	0.8 (30 mm length treated with Na)
Soil Mix 13	27	1.2 (15 mm length treated with CR)
Soil Mix 14	27	1.2 (15 mm length treated with Na)
Soil Mix 15	27	1.2 (30 mm length treated with CR)
Soil Mix 16	27	1.2 (30 mm length treated with Na)

Note: 'Na' denotes $NaHCO_3$

Note: 'CR' denotes $Cr_2(SO_4)_3.15H_2O$

V. STANDARD PROCTOR TEST RESULTS

Following are the final results of standard proctor test (OMC and MDD) for all the soil mixes.

Table: 2. Values of MDD and OMC for Plain soil and stabilized soil.

Sr. No.	Soil Type	MDD (γd)g/cc	OMC, (w)%
1.	Plain Soil	1.82	15.20
2.	Soil with 9% FA	1.78	14.30
3.	Soil with 18% FA	1.77	14.80
4.	Soil with 27% FA	1.75	15.10
5.	Soil with 36% FA	1.71	15.50
6.	Soil with 27% FA + 0.4 JF (15 mm length treated with CR)	1.734	15
7.	Soil with 27% FA + 0.4 JF (15 mm length treated with Na)	1.744	15
8.	Soil with 27% FA + 0.4 JF (30 mm length treated with CR)	1.721	14.8
9	Soil with 27% FA + 0.4 JF (30 mm length treated with Na)	1.739	16.1
10	Soil with 27% FA + 0.8 JF (15 mm length treated with CR)	1.719	15.5
11	Soil with 27% FA + 0.8 JF (15 mm length treated with Na)	1.731	16.8
12	Soil with 27% FA + 0.8 JF (30 mm length treated with CR)	1.706	17
13	Soil with 27% FA + 0.8 JF (30 mm length treated with Na)	1.727	15.3
14	Soil with 27% FA + 1.2 JF (15 mm length treated with CR)	1.701	16.1
15	Soil with 27% FA + 1.2 JF (15 mm length treated with Na)	1.724	16.1
16	Soil with 27% FA + 1.2 JF (30 mm length treated with CR)	1.692	15.7
17	Soil with 27% FA + 1.2 JF (30 mm length treated with Na)	1.719	17.3

VI. UCS TEST RESULTS

Following are the final results of unconfined compressive strength test for all the soil mixes.

Table: 3. Values of UCS Test for Plain soil and stabilized soil.

Sr. No.	Soil Type	UCS Value (kg/cm2)
1.	Plain Soil	2.86
2.	Soil with 9% FA	3.01
3.	Soil with 18% FA	3.16
4.	Soil with 27% FA	3.35
5.	Soil with 36% FA	3.06
6.	Soil with 27% FA + 0.4 JF (15 mm length treated with CR)	4.10
7.	Soil with 27% FA + 0.4 JF (15 mm length treated with Na)	3.73
8.	Soil with 27% FA + 0.4 JF (30 mm length treated with CR)	3.88
9	Soil with 27% FA + 0.4 JF (30 mm length treated with Na)	3.46
10	Soil with 27% FA + 0.8 JF (15 mm length treated with CR)	4.71
11	Soil with 27% FA + 0.8 JF (15 mm length treated with Na)	4.52
12	Soil with 27% FA + 0.8 JF (30 mm length treated with CR)	4.48
13	Soil with 27% FA + 0.8 JF (30 mm length treated with Na)	4.30
14	Soil with 27% FA + 1.2 JF (15 mm length treated with CR)	4.15
15	Soil with 27% FA + 1.2 JF (15 mm length treated with Na)	4.04
16	Soil with 27% FA + 1.2 JF (30 mm length treated with CR)	3.92
17	Soil with 27% FA + 1.2 JF (30 mm length treated with Na)	3.81

VII. UCS TEST RESULTS

Following are the final results of California bearing ratio test for all the soil mixes.

Table: 4. Values of CBR for Plain soil and stabilized soil.

Sr. No.	Soil Type	CBR %
1.	Plain Soil	3.65
2.	Soil with 9% FA	4.12
3.	Soil with 18% FA	4.66
4.	Soil with 27% FA	5.73
5.	Soil with 36% FA	4.93
6.	Soil with 27% FA + 0.4 JF (15 mm length treated with CR)	6.72
7.	Soil with 27% FA + 0.4 JF (15 mm length treated with Na)	6.42
8.	Soil with 27% FA + 0.4 JF (30 mm length treated with CR)	6.09
9	Soil with 27% FA + 0.4 JF (30 mm length treated with Na)	5.96
10	Soil with 27% FA + 0.8 JF (15 mm length treated with CR)	8.85
11	Soil with 27% FA + 0.8 JF (15 mm length treated with Na)	9.05
12	Soil with 27% FA + 0.8 JF (30 mm length treated with CR)	7.96
13	Soil with 27% FA + 0.8 JF (30 mm length treated with Na)	7.63
14	Soil with 27% FA + 1.2 JF (15 mm length treated with CR)	7.04
15	Soil with 27% FA + 1.2 JF (15 mm length treated with Na)	6.18
16	Soil with 27% FA + 1.2 JF (30 mm length treated with CR)	6.68
17	Soil with 27% FA + 1.2 JF (30 mm length treated with Na)	5.29

VIII. CONCLUSION

All the laboratory tests have been conducted as per the guidelines of Indian Standards and the results were recorded and used for comparison purpose. The final outcomes were drawn which are represented in the following section.

i. From the results of OMC and MDD for plain soil and soil having fly ash, it can be concluded that the dry density decreases as the percentage of fly ash increases in soil and maximum dry density of soil was attained for plain soil i.e. 1.82 g/cc whereas the MDD for soil having 9% FA, 18% FA, 27% FA and 36% FA is 1.78 g/cc, 1.77 g/cc, 1.75 g/cc and 1.71 g/cc respectively. However, the value of OMC decreases when the fly ash introduced at 9% but after adding 18%, 27% FA and 36% FA, the value of OMC increases almost linearly. OMC for plain soil is 15.20% whereas the OMC for soil having 9% FA, 18% FA, 27% FA and 36% FA is 14.30 %, 14.80 %, 15.10 % and 15.50 % respectively. Therefore, the percentage decrease in MDD of soil after adding 9% FA, 18% FA, 27% FA and 36% FA are 2.2%, 2.75%, 3.85 % and 6.05 % respectively w.r.t plain soil.

ii. From the results of OMC and MDD for soil having fly ash and treated fibers, it can be concluded that the having 15mm length and treated with NaHCO3 reveals maximum MDD from all the Soil type having same proportion of Jute Fibers. But as we increase the proportion of Jute fibers, the MDD starts to decrease. Not drastic change was found. Whereas, the values of OMC showed irregular pattern. Maximum MDD was found out to be 1.744 for soil having 27% FA and 0.4% jute fibers (15 mm in length and treated with NaHCO3) and corresponding OMC value was 15 %. Therefore, the percentage decrease in MDD of soil after adding 0.4% JF, 0.8% JF and 1.2% JF are 5.44%, 6.23% and 7.03% respectively w.r.t plain soil.

iii. From the results of UCS for plain soil and soil having fly ash, it can be concluded that the UCS of plain soil comes out to be 2.86 kg/cm2 but when the fly ash is added, the UCS value of treated soil increases till 27% Fly ash proportion and attains maximum UCS value i.e. 3.35 kg/cm2. Then it tends to decreases for soil having 36% FA i.e. 3.06 kg/cm2. At 27% FA, the UCS value was increased by 17.11% w.r.t plain soil and then UCS value was decreased 8.50% when the proportion of FA was changed from 27% to 36%.

iv. From the results of UCS for soil having fly ash and treated jute fibers, it can be concluded that the maximum UCS of soil having 0.4% JF, 0.8% JF and 1.2% JF comes out to be 4.10 kg/cm2, 4.71 kg/cm2 and 4.15 kg/cm2 respectively. Maximum value of UCS was shown by the soil containing 27% FA and 0.8% jute fibers having length of 15 mm treated with Cr2(SO4)3.15H2O i.e. 4.71 kg/cm2. As the length of jute fiber increases, the UCS value decreases. The percentage increase in UCS value of soil having 0.4% JF, 0.8% JF and 1.2% JF comes out to be 22.47%, 40.54% and 23.81% respectively w.r.t soil having 27% FA only.

v. From the results of CBR for plain soil and soil having fly ash, it can be concluded that the CBR of plain soil comes out to be 3.65 % but when the fly ash is added, the CBR value of treated soil increases till 27% Fly ash and attains maximum CBR value i.e. 5.73 %. Then it tends to decreases for soil having 36% FA i.e. 4.93%. At 27% FA, the CBR value was increased by 57% w.r.t plain soil and then CBR value was decreased 13.89% when the proportion of FA was changed from 27% to 36%.

vi. From the results of CBR for soil having fly ash and treated jute fibers, it can be concluded that the maximum CBR of soil having 0.4% JF, 0.8% JF and 1.2% JF comes out to be 6.72 %, 9.05 % and 7.04 % respectively. Maximum value of CBR was shown by the soil containing 27% FA and 0.8% jute fibers having length of 15 mm and treated with NaHCO3 i.e. 9.05%.. As the length of jute fiber increases, the CBR value decreases. The percentage increase in CBR value of soil having 0.4% JF, 0.8% JF and 1.2% JF comes out to be 17.20%, 57.96% and 22.80% respectively w.r.t soil having 27% FA only.

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