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STABILIZATION OF CLAY USING POLYPROPYLENE FIBER AND BLAST FURNANCE SLAG

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ABSTRACT

In design and construction of any structure, the role of soil is very crucial. Since the soil is in direct contact with the structure, it acts as a medium of load transfer. The bearing capacity and rate of settlement greatly depend upon the type of subsoil present beneath the structure. Clay soil often causes difficulties in construction with its low strength and stiffness. This has caused serious problems in geotechnical engineering because weak soil may cause damage to the foundation of buildings and cracks along the road pavement. Clay soils are commonly stiff in dry state but lose their stiffness when comes in contact with water This research set out to improve the engineering quality of clayey soil obtained from the village Pammal using waste materials. The selected waste materials are Blast furnace slag (BFS) and Poly-propylene fibre (PPF), they are a by-product from iron making industry and oil refining industry respectively. These waste materials are disposed and generally have no economic value. Thus, the effectiveness of using Blast furnace slag (BFS) and Poly-propylene fibre (PPF) in stabilizing fine-grained clayey soil (CI) was investigated in the laboratory. The soil samples taken in natural state and when mixed with varying percentages of Blast furnace slag (BFS)and Poly-propylene fibre (PPF) were used for the laboratory tests, that included atterberg limits tests, standard Proctor compaction tests, unconfined compression tests and California bearing ratio tests. The results showed significant changes in the optimum moisture content and maximum dry density of clayey soil with increasing percentage content of BFS and PPF. The results of the unconfined compressive strength (UCS) and California bearing ratio (CBR) tests show that, the addition of BFS and PPF caused an increase in the value of UCS & CBR for 4% BFS+ 1%PPF and 13% BFS+1% PPF respectively, thereafter the values of UCS and CBR decreased

***KEYWORDS**: Stabilization, Clay, Polypropylene, Fiber, Blast , Furnance Slag*

I. INTRODUCTION

Any load Bearing Structure Transfer the load to Soil through its Foundation. The bearing capacity and rate of settlement greatly depend upon the type of subsoil present beneath the structure. As all the load of structure goes directly to the soil under the structure, hence for analysis of forces and design and stability of structure, one has to consider the stress distribution through soil through study of soil properties, which makes Geotechnical study of soil a very essential step at the planning stage. The clayey soil has the swelling and shrinkage properties under different moisture conditions. Under dry state, the clay has very good strength, but when it makes contact with water, it exhibit Swelling & Shrinkage Characteristics. To minimize its Expansive Nature, Stabilization of Available soil with waste material is a good option slightly than changing the site. Stabilization of soil can be done by using different types of Stabilizers like cement, bitumen and lime etc. With Advancement of Research Methods & Materials, soil Stabilization emerges out as a popular and economical mean for betterment of poor soil. The present study deals with the Stabilization of clayey soil using Blast furnace slag (B.F.S.) and poly-propylene fibre (P.P.F.).

II. OBJECTIVES

- To calculate the compaction characteristics of clay on addition of B.F.S. and P.P.F. in a variety of percentages.
- To calculate the unconfined compressive strength value of clay on addition of B.F.S. and P.P.F. in a variety of percentages.
- To calculate the C.B.R. value of clay on addition of B.F.S. and P.P.F. in a variety of percentages

III. LITRATURE REVIEW

Dayakar et al (2018) checked the improvement of C.B.R. strength, M.D.D, compressive strength of clay mixed with P.P.F. in different ratios of 0.25%, 0.50%, 0.75% & 1%. With increased addition of P.P.F, the O.M.C. decreased by 3% and compressive strength increased by 0.96% with 1% P.P.F. They found increment of 50% & 20% in C.B.R. with 1% & 0.50% P.P.F. respectively.

Mohammadia et al (2017) checked the effect of B.F.S. on black cotton soil. They added B.F.S. in 0, 10, 20, 30 and 40 percent in the soil and performed Atterberg limits test, compaction test, direct shear test and C.B.R. test. With increase in B.F.S. content the Atterberg limits decreases making soil less plastic. The M.D.D. value increases and O.M.C. decreases with increase in B.F.S. content and optimum content comes out at 20%. With increase in B.F.S. content, cohesion decreases and angle of internal friction increases considerably and make the soil more resistant to shear stresses. C.B.R. value increases with more addition of B.F.S. and reaches optimum value at 20%.

Priya et al (2017) checked the effect of P.P.F. in varying percentages of 0.5, 1.0 and 1.5% for unconfined compressive strength and compaction test. They observed that there was increase in M.D.D. and U.C.S. with the addition of P.P.F. content up to 1% and after that it decreased.

Ayothiraman and Singh (2017) checked improvement of clay soil properties using basalt fibre and P.P.F. varying from 0 to 1.5%. The M.D.D. decreased marginally and O.M.C. increased with addition of fibre content. The U.C.S. value increased from 178.2 kPa to 234.9 kPa with 1% P.P.F. and increased from 178.2 kPa to 208.1 kPa with 1.5% basalt fibre.

Teja (2016) checked the effect of addition of P.P.F. on U.C.S. on 2 soil sample named sample- 1 & sample-2. The U.C.S. test result from sample-1 showed that for optimum addition of 0.05% P.P.F., the increase in strength from the virgin soil was 11.68%. The U.C.S. test result from sample-2, showed 49.8% increase in strength from the initial value 0.0692 Mpa to 0.1037 Mpa.

IV. MATERIALS AND METHODS

1.To find the properties of virgin expansive soil.

S. No.	Soil Parameters	Tests
1	Liquid limit & plastic limit	Casagrande Test and Thread test
2	Specific Gravity	Pycnometer test
3	M.D.D. & O.M.C.	Standard proctor Test
4	Strength Characteristic	U.C.S. & C.B.R. value

a. To find out effect of addition of varying % of B.F.S. on soil parameters.

Soil: B.F.S.	Soil parameters	Tests
92:6	M.D.D. & O.M.C.	Standard proctor Test
	Strength characteristic	U.C.S.
		C.B.R. value
88:11	M.D.D. & O.M.C.	Standard proctor Test
	Strength characteristic	U.C.S.
		C.B.R. value
89:13	M.D.D. & O.M.C.	Standard proctor Test
	Strength characteristic	U.C.S.
		C.B.R. value
79:21	M.D.D. & O.M.C.	Standard proctor Test
	Strength characteristic	U.C.S.
		C.B.R. value

b. To find out the effect of addition of different % of P.P.F. using optimum value of B.F.S.

% of P.P.F.	Soil parameters to be evaluated for different % of P.P.F. using optimum value of B.F.S.
0.7%	M.D.D. & O.M.C.
1.3%	U.C.S.
1.7%	C.B.R. value (Unsoaked)
2.3%	

Using above Methodology, Optimum mix of B.F.S. and P.P.F. will be obtained.

MATERIAL

a. Clay soil

The clay soil used in research was taken from village Baddowal, Ludhiana. The sample was taken at depth 1 to 2 meter from Natural Ground Level (N.G.L.) .The various properties of the clay soil is as under

Sr. No.	Property	Value
1	Atterberg Limits Liquid limit w_L % Plastic limit w_p % Plasticity Index I_p %	 43 23 20
2	Soil classification	CI
3	Specific gravity	2.44
4	UCS	93.63kN/m^2
5	Dry density	18.32kN/m^3
6	OMC %	15.9

b.Blast furnace slag

Blast Furnace Slag is a Granulated Sand - type slag waste material. The B.F.S used in Research was Procured from IND SYNERGY LIMITED, Raigarh, Chhattisgarh. The granular Blast Furnace Slag is passing 4.75 mm sieve.

Sample was taken for the Research Purpose. B.F.S was added in soil by 7%, 13%, 19% and 23% of totalweight. The specific gravity of B.F.S is found to be 1.89.

c.Polypropylene fibre

The P.P.F. were procured from Jindal Fibres Pvt Ltd, Ludhiana. The polypropylene fibres of length 14 mm were used in various percentages (0.9, 1.3 and 1.7%). The properties of the P.P.F. are shown in following table

Table 3-5 Properties of fibres

Length (mm)	14
Elongation (%)	53
Diameter (mm)	0.03
Melting point (ºC)	165
Relative density	89%
Softening point (ºC)	140

PROCESSING OF MATERIAL

The soil taken from the village Baddowal in natural state in lumps. The lumps & bits of soil were conked out and the soil was oven dried for 24hours to remove the moisture, then passed through 4.75mm sieve.

TEST CONDUCTED IN THE LABORATORY

Soil particles passing 4.75mm sieve were oven dried at temperature of 105-110^{o}C for 24 hours. Then B.F.S & P.P.F with varying percentage of (7%,13%,19%,23%) & (0.9%,1.3%,1.7%) of total weight were added. To obtain the listed objectives following tests were performed in lab for virgin soil and then with addition of B.F.S & P.P.F in the above mentioned percentage by weight of soil mass.

1. Pycnometer/Specific Gravity Test
2. Liquid Limit Test
3. Plastic Limit Test
4. Standard Proctor Test
5. U.C.S.
6. C.B.R. Test

a. Pycnometer test

Equipment- Pycnometer (1 litre capacity), weighing balance, glass rod

Formula Used- $G = (W_2-W_1)/\{(W_2-W_1)-(W_3-W_4)\}$

W_1 = weight of empty pycnometer.

W_2 = weight of pycnometer and dry soil.

W_3 = weight of pycnometer, soil & water.

W_4 = weight of pycnometer with water only.

Procedure- Take clean & dry Pycnometer and weight it (W_1). Open the pycnometer and take 200 g of soil (oven dried) & weight it (W_2). Open the pycnometer and fill with water to the Pycnometer & weight it (W_3). Empty the same and clean it and wipe it dry. Fill the Pycnometer with water only & take its weight (W_4).

Using the above mentioned formula, find specific gravity of soil sample.

Figure - Pycnometer

b.Liquid limit test

Equipment- Casagrande's device, grooving tools, evaporating dish, spatula, 425 micron sieve, weighing balance, wash bottle.

Procedure- Take 120g of the soil sample (air dried) after passing it through 425 micron IS sieve. Add water to the sample and mixed it thoroughly to make a uniform paste. Take a small amount of prepared paste and place it in the cup. Cut a groove on the paste with help of the grooving tool. Start turning the handle of the device (2 revolutions per second) & count the number of blows (N) required for the grooved parts of the soil specimen to come in contact. Repeat the above procedure at different water contents (w).

With the help of flow curve (log N v/s w), determine the liquid limit (when N=25).

Figure - Casagrande's device

c.Plastic limit test

Equipment- Clean glass plate, metallic rod of 0.3cm dia, wash bottle.

Procedure- Take 30g of the soil sample (air dried) after passing it through 425 micron IS sieve. Add water to the sample and mixed it thoroughly on the glass plate until it has enough plasticity to attain shape of small ball and note down the water content. From this ball take 10gm of soil mass and roll it on the glass plate with help of hand to form a thread of roughly 3 mm diameter. Note down the water content at which the soil mass is not plastic enough to rolled into thread of 3 mm diameter.

d.Standard proctor test

Equipment- Weighing balance, oven, mould for compaction 895 cc, collar, 2.6kg hammer, spatula, graduated jar.

Formula Used- Dry Density = $\frac{M/V}{(1+w)}$

M = mass of soil

V = volume of mould & w = water content

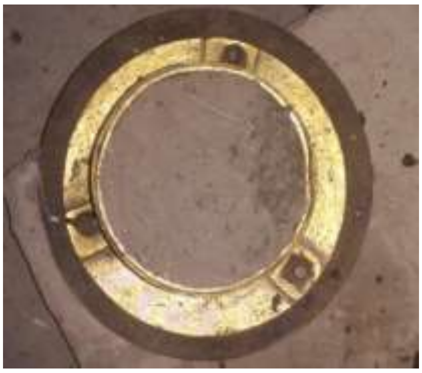

Figure - Standard Proctor test Mou

compaction of final layer collar is removed and extra soil is trimmed off with help of straight edge. Take its weight. After this remove the soil mass from the mould. Increase the percentage of water by 2% and repeat the procedure for different water content.

e.Unconfined compressive strength test

Equipment- Weighing balance, oven, U.C.S. apparatus, knife, sample extractor.

Formula Used- $q_u = P/A$

P is load at failure & A= corrected area = $A_0/(1-E)$, A_0= area of specimen initially and E is axial strain.

Procedure- Prepare the soil sample at required water content and place it inside the sampling tube. Coat the split mould with grease. Extract this soil sample from the sampling tube and place the same into the split mould with the help of sample extractor and the knife. Then remove the sample from the mould by splitting this mould into 2 parts. Note down the length and diameter .Place the specimen in the compression machine and bring the upper plate downwards to hold the specimen. Adjust the gauges on the machine to zero. Now apply the compressive load to cause an axial strain (½% to 2% per minute). Note down the gauge reading. Continue to increase load until failure of specimen did not occur.

Figure - Split sampler

f. C.B.R. Test

Equipment- C.B.R. machine, cylindrical moulds, 4.89 kg hammer, surcharge weight, IS sieve 20mm, weighing balance.

Procedure- Take about 5 kg of soil sample after passing it through 20mm sieve. Add water equal to optimum moisture content found out in lab or field moisture content found out in field. Mix this mass thoroughly. This prepared soil specimen is filled in mould in 5 equal layers and each layer is given 56 uniformly distributed blows from 4.89 kg hammer. Same process is repeated for all subsequent layers. After 5^{th} layer, collar is removed and extra soil is struck off with the help of straight edge. Base plate is removed and the mould is rotated and clamped to the base plate. Surcharge weight (2.5kg) is placed on specimen and this mold is placed in compression testing machine. A seating load of 4 kg is applied with penetration plunger. Adjust the gauges on the machine to zero. Application of Load is started on the specimen at penetration rate of 1.25mm per minute. Value of dial gauge is noted at various penetrations and C.B.R. value is obtained at penetration of 2.5& 5mm.

Figure - CBR mould

V.RESULTS AND DISCUSSIONS

To find index properties of virgin soil, we conducted the following lab tests like- L.L., P.L., pycnometer test, standard proctor test, U.C.S. test and C.B.R. test.

a. Pycnometer test (virgin soil)

Specific Gravity (G) =2.47

b. L.L. test & P.L. (virgin soil)

Sr. No.	Water Content	Number of Blows
1	35%	40
2	37%	37
3	41%	32
4	44%	27
5	48%	22
6	51%	17

From the graph on next page, we get w_L = 43% w_P = 23% & I_p = 43-23=20%

According to A-line, I_p = 0.73x(42-20)=16.06%

As soil is above A line and liquid limit is between 35% to 50% soil is classified as CI.

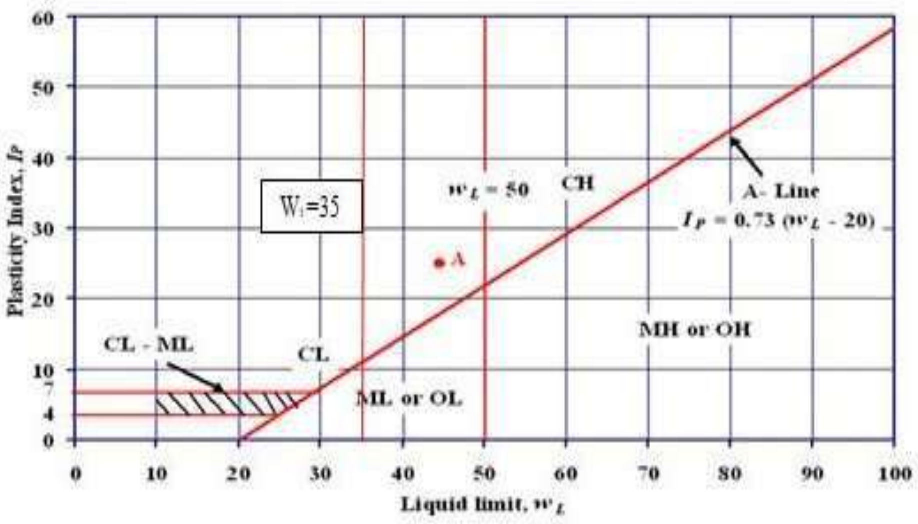

Figure -A-line graph

c.Standard proctor test (virgin soil)

From the graph below, we found M.D.D. = 18.32kN/m^3 & O.M.C. = 15.09%

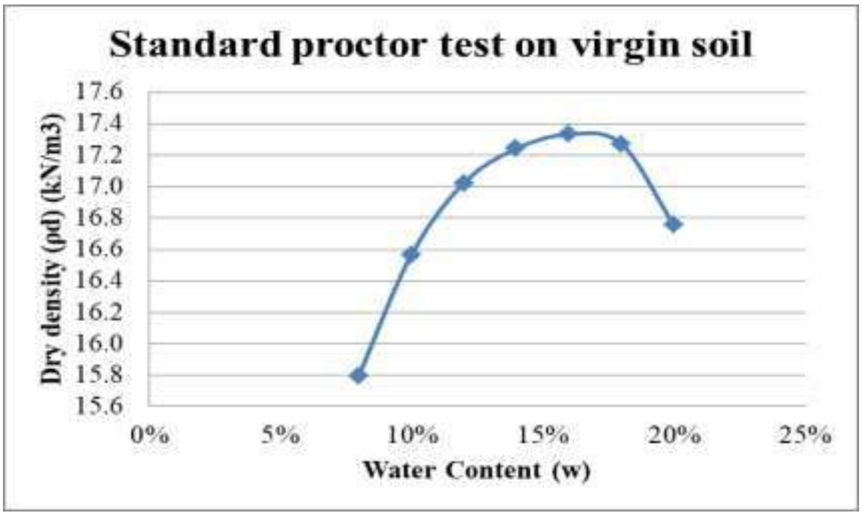

Figure - M.D.D. & O.M.C. graph for virgin soil

d.U.C.S. test (virgin soil)

From U.C.S. test, $q_u = 94.36$ kN/m^2.

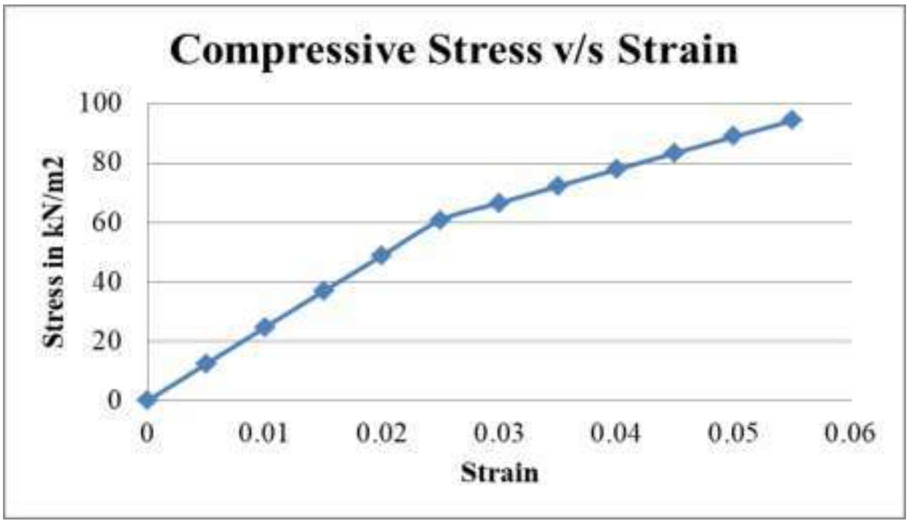

Figure 4-3 U.C.S.-strain graph of virgin soil

e. C.B.R. Test

C.B.R.value at 2.5 mm penetration = (60/1370)x100 = 4.38
C.B.R.value at 5.0 mm penetration = (85/2055)x100 = 4.14

C.B.R. of virgin soil = 4.38

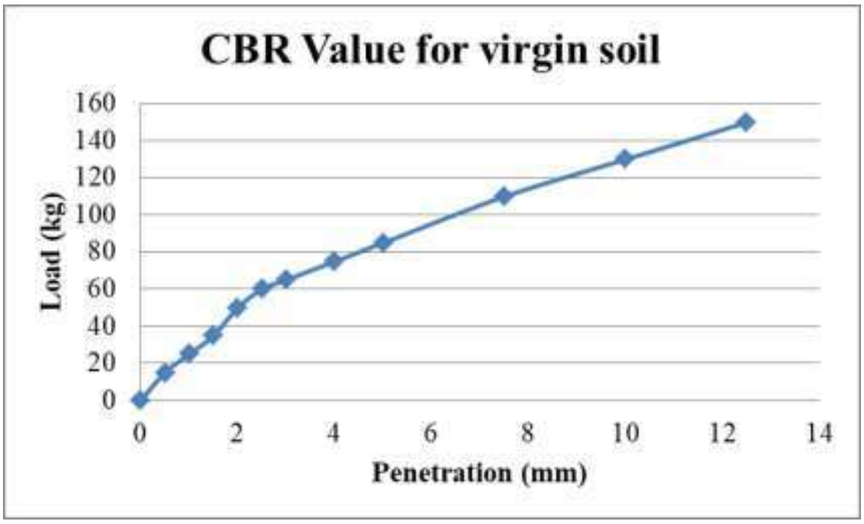

Figure - Load-Penetration (C.B.R.) graph of virgin soil

VI. CONCLUSION

The study investigated the strength behaviour of clayey soil on addition of B.F.S. & P.P.F. The effect of addition of material is studied after performing series of compaction test, unconfined compression test & California bearing ratio test with varying percentages. Following are the main conclusions of this research study.

Compaction test-

1. With addition of B.F.S, the M.D.D. value increases and O.M.C. decreases. Optimum value for B.F.S. comes out to be 14.6%, at which M.D.D. increases by 6.11% and at which O.M.C. value decreases by 14.13%. The main reason for increase in compactibility is the replacement of soil particles by BFS particles (which are heavier than soil particles) increasing the unit weight of soil mass. Also BFS particles react chemically with clay grains and create a layer around them, reducing their water intake.
2. With addition of P.P.F, the M.D.D. decreases and O.M.C. increases. Optimum value for P.P.F. comes out to be 1.3%, at which M.D.D. value decreases by 1.7% and O.M.C. value increases by 5.57%.The main reason for decrease in compactibility is the replacement of soil particles by PPF particles (which are lighter than soil particles) decreasing the density of soil mass. Also PPF particles absorb water due to their large surface area, which in turn increases the O.M.C.
3. By addition of optimum value of P.P.F. and varying percentages of B.F.S., the M.D.D. value increases and O.M.C. decreases. At 14.09% B.F.S. & 1.3% P.P.F, M.D.D. value increases by 7.19% and O.M.C. decreases by 9.49%. The net increase in M.D.D. can be attributed to the fact that with addition of both B.F.S. & P.P.F. the clay particle are replaced and Pozzolanic compounds are made, which brings soil particles togetherwhereas the P.P.F. fibre acts as a reinforcement holding this dense soil mass together.

Unconfined compression test-

1. With addition of B.F.S., the value of compressive stress increases. Optimum value for B.F.S. comes out to be 4.91%, at which compressive stress increases by 41.32%.
2. With addition of P.P.F., the value of compressive stress increases. Optimum value for P.P.F. comes out to be 1.4%, at which compressive stress increases by 27.68%.
3. With addition of optimum value of P.P.F. and B.F.S., the value of compressive stressincreases. At 5.1% B.F.S. & 1% P.P.F., compressive stress increases by 74.20%.

California bearing ratio test-

1. With addition of 21% B.F.S. & 1.3% P.P.F., the C.B.R. value increases by 110.33%.

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