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Utilization of Non-Destructive Additives in Highly Cohesive Soil for Stabilization

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***Abstract* - This paper investigates the utilization of non-Destructive Additives in highly cohesive soil to stabilization. Highly cohesive soil stabilized with copper slag that is produced from the process of smelting of copper these slags is mechanically concentrated before smelting contains iron oxides and silicon oxides. The addition of copper slag reduces the shrinkage of the cohesive soil. And further polypropylene fiber is added for the uses of increases the shear strength of the soil. The ratio of each Admixtures were obtained in terms of percentage ranges from (1% to 4%) and the laboratory investigation is performed for the admixture treated soil with 16 difference ratios. The detail observation of swelling and shrinkage behavior of clay soil is assessed in a consecutive manner. Similarly, The variation in the strength; hydraulic conductivity deformation characteristics were also observed. The test results showed that copper slag and polypropylene significantly changes the strength characteristics, swelling and strength properties of the clay soil.**
***Keywords:* Utilization, Non-Destructive Additives, Cohesive Soil, Stabilization**

I. INTRODUCTION

Generally, expansive soil possesses low strength, high potential for swelling and shrinkage. Uneven settlement characteristics make the soil is unsuitable for construction and other pavement works. In this situation, some modification techniques are achieved to induce their strength and made the soil to stabilize. Along this different techniques are used to improve the behavior of clayey soil. In towards, mechanical stabilization is simplest and effective type of stabilization techniques to reduce the moisture absorption and to attain both the maximum compression strength and shear strength. For the stabilization, natural pozzolana and lime are added to the soil within the range of 0-20% and 0-8% at a different manner (Aref al-Swaidani *et al.,* 2016). In past researches, limestone and recycled aggregate are used as stabilization agents to the soil. Then those not having a high crushing strength and density, and it should not results high stability. But copper slag has a high density and may be arises high stability against the external load (Brian *et al.,* 2017)

In this paper for the stabilization, a two different material are used such as Copper Slag& Polypropylene fiber. Both the materials are behaves in two different manner. The fiber would be act as a reinforcement agent to the soil particle. Similarly, copper slag has a size equal to sill. So it will give some adhesion to the Soil particle. Generally, the fiber material has a high resistance to the tensile force i.e. having a high tensile strength. Thus resistance is specifically depends on the aspect ratio of the fiber. Aspect ratio is a representation of the ratio between the length to its diameter (Hanifi Canakci, *et al.,* 2016 and Antonio Correia *et al.,* 2015).

The Shear & Compression strength of stabilized soil were to be formulated by conducting Direct Shear test for Shear strength Unconfined Compressive Strength (UCS) test for Compression Strength. For those strength assessment, the soil to be maintaining constant moisture content equal to the optimum moisture content obtained from the result of Proctor Compaction Test.

Based on these studies, the materials are contributed as per the terms of aspect ratio depending upon their Geometrical properties. The length of Polypropylene fiber is maintain in yield of effective stabilization with corresponding the field conditions, the proportions range is adopted with appropriate aspect ratio of Polypropylene as constant of 1% to 4% by varying the proportions of Copper Slag as 1%, 2%, 3% and 4% (i.e., 1%:1%, 1%:2%, 1%:3%, 1%:4%, 2%:1%, …….. 4%:4%). For every varying aspect ratio, OMC & the Proctor test is done to determine the maximum density to achieve further laboratory test. For this density range, unconfined compression test, Direct Shear Test, Swelling Test are also achieved. Hence, based on the studies, the effect of soil with Non-Destructive additives has been investigated.

II. MATERIALS USED

A. Soil

The soil sample was collected from the specific deposit of clayey minerals. It may be contains organic contents because it could be collected from the agricultural land. The engineering specifications of soil were studied in the laboratory.

B. Polypropylene

Propene undergoes – $[CH_2\text{-}CH]\text{-}_n$ addition Polymerization to produce Poly (Propene), after known as CH_3. Polypropylene is one of the most versatile thermoplastic polymers. We use the Polypropylene fiber with Length of

5mm and Width of 1.5mm. The proportion of the Poly fiber is used in the ascending graduate (i.e., 1%, 2%, 3%, 4%…). It performs as a Reinforcement agent to the soil. It also used as Water absorption to the soil.

Fig. 1 Polypropylene Fiber

C. Copper Slag

Copper slag is granulated cohesionless sandy sized material with the appearance of dark black color. During the extraction of Copper by melting Process, Copper Slag is obtained. This Slag is obtained by Quenching the Molten Metal in Water that produces Angular Granules of the Copper Slag. It is Composed of Oxides of Silicon and Iron. It can be used as a partial replaceable material to the Soil (Ali Behnood *et al.*, 2015). By the Sieve analysis test, the copper slag comes under Silty Sand classification. It exposes the clear representation on the additional friction to the soil particles.
Specific Gravity of Copper Slag = 3.66

Fig. 2 Appearance of Copper Slag used for the Stabilization

III. TEST METHODS

The Engineering and Geotechnical properties of Soil has been Founded in the Laboratory by conducting a various test procedure with reference of Indian Soil Code practice SP 36.

After the studies on properties of Additives, it should be assorted to the clay soil with varying its proportion. The Proctor Compaction Test has to be performed for the above proportions onwards the Direct Shear Test was conducted for those assorted Soil mixed with water content (i.e, Optimum Moisture Content) obtained from the Proctor Compaction Test. Throughout the Shear Test, the Water content and Maximum Density of Soil is maintained at the value results from this Proctor Compaction Test.

From those Test Procedures, the enhanced value of Shear properties of jumbled Soil is formulated and tabulated.

IV. RESULTS AND DISCUSSION

Initially, the geotechnical and engineering properties of soil is to be formulated in the terms of resistance against different criteria with reference to the Indian code practice for testing of soil. Table I shows the results of laboratory investigation on the soil testing. As basis on the laboratory investigation, the soil is said to be Organic Clay with high plasticity (CH). It could be classified as per the specifications of Indian Classification System. A typical particle distribution curve for that soil is expressed in following figure 3.

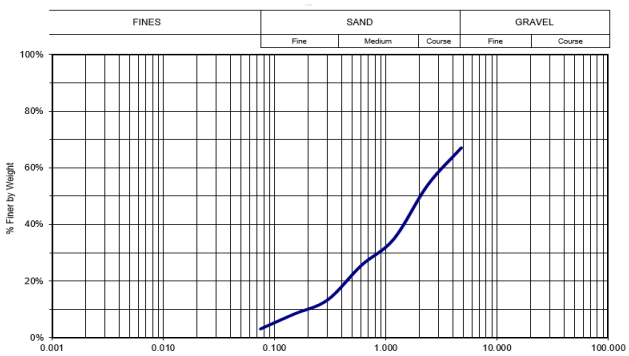

Fig. 3 Particle Size Distribution Curve of Soil

TABLE I ENGINEERING PROPERTIES OF SOIL

Properties	Result	IS code referred
Uniformity coefficient (Cu)	4.848	IS 1498:1970
Coefficient of curvature (Cc)	1.065	IS 1498:1970
Plasticity index (%)	36.5	IS 2720(v):1985
Liquidity index (%)	13.6	IS 2720(v):1985
Consistency index (%)	86.0	IS 2720(v):1985
Free Swell Index (%)	2200	IS 2720(20):1978
Flow index (%)	353	IS 2720(v):1985
Activity of clay	2..6734	IS 2720(v):1985
Bulk density (kg/m^3)	2013	IS 2720(vii):1980
Dry density (kg/m^3)	1780	IS 2720(vii):1980
OMC (%)	13	IS 2720(vii):1980
Permeability (mm/sec)	0.000347	IS 2720(17):1986
Cohesion (kN/m^2)	26	IS 2720(39):1977
Angle of Internal Friction	16°	IS 2720(39):1977
Shear strength (kN/m^2)	41.56	IS 2720(39):1977

The variation in shear strength of soil due to the presence of polypropylene fiber and copper slag is to be assessed in the direct shear test. The fiber reinforced and copper slag mixed

soil is to be mixed with the water that is equal to the optimum moisture content of soil formulated form proctor test. Then it shall be introduced to the shear box having the dimensions of 60 x 60 x 50mm. Further, it shall be allowed to formulate the shear stress corresponding to the different rate of normal stress.

The shear parameters of soil such as cohesion and angle of internal friction were assessed for the different ratio of additives mixed to the soil and tabulated in the following table II. The values of stresses are expressed in unit of N/cm^2.

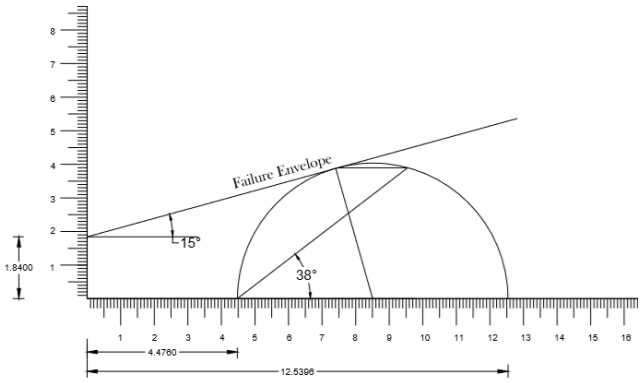

Fig. 4 Graphical Representation of Shear Failure Plane of Soil Results from Direct Shear Test

The shear plane in the soil during a failure is graphically represented as in the above figure.4 and also it shows the variation of shear stress on a plane with respect to the normal stress i.e. Failure envelope. The shear strength of the soil is to be formulated by the expression as follow.

Fig. 5 Failed Sample Obtained from the Direct Shear Test

$\tau = c + \sigma \tan\varphi$

Where, c – the cohesion of the soil
σ – Abnormal stress acting on the shear plane
φ – Angle of repose or internal friction

Figure 5 clearly shows the how the soil sample get failed under shear load in a shear box. Presence of large clay particle, the soil failed with low resistance to the shear and high cohesion between the clay particles.

TABLE II ENGINEERING PROPERTIES OF STABILIZED SOIL

Proportions	Cohesion (kN/m^2)	φ	Shear strength (kN/m^2)
1%P.P+1%C.S	7.70	17	29.40
1%P.P+2%C.S	10.60	19	25.62
1%P.P+3%C.S	12.50	26	45.04
1%P.P+4%C.S	18.40	15	26.50
2%P.P+1%C.S	18.50	25	46.90
2%P.P+2%C.S	8.16	22	27.18
2%P.P+3%C.S	25.30	15	38.69
2%P.P+4%C.S	34.90	11	39.44
3%P.P+1%C.S	20.3	20	37.26
3%P.P+2%C.S	18.5	30	11.70
3%P.P+3%C.S	1.96	26	47.58
3%P.P+4%C.S	22.7	16	32.56
4%P.P+1%C.S	16.5	19	29.70
4%P.P+2%C.S	18.85	20	44.30
4%P.P+3%C.S	19.2	26	50.60
4%P.P+4%C.S	16.93	25	44.50

When introducing a fiber into the soil it may influences on both shear strength and compressive strength of soil. The variations in shear strength is mainly depends on the aspect ratio of single fiber that would be added to the soil. Similarly, the copper slag having sandy size so it may be reduces the cohesion between the clay particles and increases its angle of internal friction. On other words, the angle of internal friction is conventionally depends on the size of particle presented.

V. PERFORMANCE ANALYSIS ON THE ADDITIVES JUMBLED SOIL

A specified additive is to be mixed to the soil at varying proportions. Initially, it would be started with single percentage of fiber and copper slag. Then the fiber content shall be standardized at certain percentage and the copper slag content could be varied.

Similarly, the fiber content standardized at two percentage, the copper slag content should be varied. Table II visualizes the diversification on shear strength due to the presence of polypropylene fiber and copper slag at different proportions.

From the results, the shear strength of soil is enhanced at certain maximum value is clearly can visualized. Mostly, at three percentage of copper slag results the high shear strength with every mixing ratio to the fiber. For the variation studies, graphical representations are mandated in a graphs format. Cohesion is an inhibited property represents the shear strength of cohesive soil, so the desperation for different proportions of agents is expressed in the following figure 6.

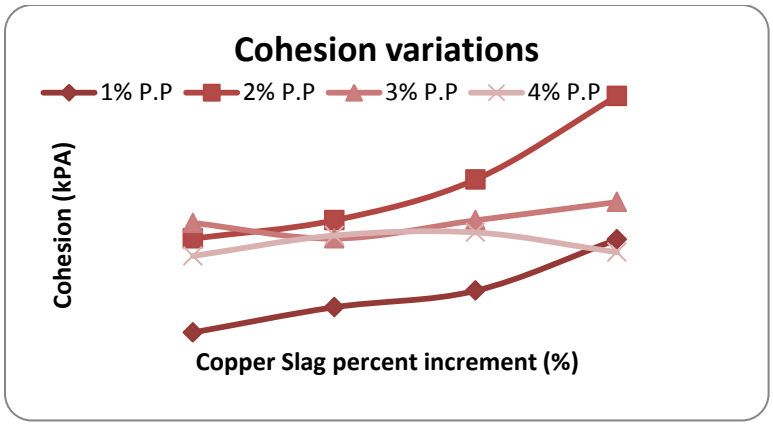

Fig. 6 Cohesion Variations for the Different Proportions of Polypropylene Fiber and Copper Slag

From the discussion it clearly shows the enhance strength in both compressive and shear strength of soil due the presence of polypropylene fiber and copper slag.

VI. CONCLUSION

Finally to conclude with the two consecutive points as prescribed in below

1. If use of polypropylene on the clayey soil may enhances its compressive and shear strength of soil. i.e., to attribute the resistance against the shear strength and act as reinforcement bed to the soil.
2. The utilization of sandy sized particles to the clay mineral soil, it shall be flocculates its clay particle each other. Due to this flocculation, the swelling and shrinkage potential of soil may decrease.

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