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Effect of Waterborne Polymer on Geotechnical Properties of Black Cotton Soil

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Abstract. Soil stabilization is an engineering process which, used to improve the engineering properties & stability of the soil. Improvement and stabilization of soil widely used as an alternative to substitute the lack of suitable material on site. There are so many stabilizers to improve the strength of black cotton soil. Some are traditional stabilizers like lime, cement, fly ash, stone dust, marble dust, etc. but traditional stabilizers require more time & a relatively large quantity of additive for significant strength improvement. On the other side, the use of non-traditional stabilizers in stabilization is growing day by day because it does not require more time & large quantity. In this study, the soil is stabilized with the waterborne acrylic copolymer. The effectiveness of waterborne acrylic copolymer is studied in terms of standard proctor, California bearing ratio, swelling pressure, differential free swelling & unconfined compressive strength tests. For the study of the behavior of black cotton soil, the waterborne acrylic copolymer has been mixed on varied percentages with black cotton soil. The mixture of acrylic co-polymer with black cotton soil improves the properties of black cotton soil. The Atterberg's limit of black cotton soil has improved with the addition of acrylic co-polymer. The significant results were observed when black cotton soil stabilized using a waterborne acrylic copolymer.

Keywords: Waterborne Polymer, Non-Traditional Stabilizer, California Bearing Ratio, Swelling Pressure, Unconfined Compressive Strength.

1 Introduction

Soil stabilization used to improve the wide range of subgrade material from clay to granular material. Many types of traditional & non-traditional stabilizers are used for soil stabilization. Fly ash, cement, bitumen, cement kiln dust, brick dust, marble dust, kota stone slurry, wooden dust, lime, etc. used as a traditional stabilizer while polymer, polymer emulsion, enzymes, acid, etc. used as a non- traditional stabilizer. Black cotton soil is mainly covering western & eastern part of India. Black cotton soil tends to adopt water so it is used for the cultivation of cotton, that's the reason behind it's called black cotton soil. They have high rated swelling & shrinkage properties when contact with moisture. Black cotton soil is a very challenging soil for high load-bearing structures. Many geotechnical engineers work on the stabilization of black cotton soil. This soil has plasticity properties due to that cracks developed on it when it becomes dry. Black cotton soil has a low bearing capacity & strength. When it comes to contact with moisture it changes volume when water percentage change. That's why it is dangerous for construction purposes. A copolymer is a large molecule composed of many repeating subunits. A Polymer is divided into natural polymer & synthetic polymer. Both polymers are used in the daily life of a human. We used a water-based acrylic copolymer as a waterproofing agent in construction work. Acrylic co-polymer used as a binder in construction. Two columns of concrete are bonded by acrylic co-polymer due to its binding properties. An acrylic copolymer is normally available in liquid form. When we used liquid admixture, it's had an advantage of easier access with the soil particle's surface compared to granular admixtures. Synthetic polymer emulsion normally consists with the help of acrylic co-polymer.

2 Literature Review

Naderi et al (2009) [1] presented a "The influence of polymer inclusion and plasticity index on the unconfined strength of clays" in which he mixed clay soil with waterborne polymer with a different percentage of 1, 2, 3, 4 & 5. He conducts various laboratory tests like Atterberg limit, grain size analysis, standard proctor test & unconfined compressive strength test. The UCS value of soil after polymer treatment increased by up to 55 %. He found that when the curing time of polymer mixed soil sample increase, a significant result obtained. In general, results show that when we increase the percentage of polymer in soil, unconfined compressive strength (UCS) is increased.
Naeini et al. (2009) [2] presented an "Effect of polymer on shear strength of silty sand" in which they mixed sand with water & different percentage (0.025, 0.05 & .10 weight % of sand) of the polymer. He found that the peak strength of soil mainly depends on silt content. If silt content increases up to 35 % then shear strength decreases. When polymer mixed with the sand, shear strength increases while the percentage of polymer increased. When 0.10 percentage polymer mixed with sand shear strength increased up to 35 %.

Rajoria et al. (2015) [3] presented an "Effect of polymer stabilizer on the geotechnical properties of black cotton soil" in which they used to a different percentage of cement with the addition of a different percentage of renolith polymer with black cotton soil. They observed that the addition of polymer caused a significant modification in the engineering properties of black cotton soil. They conduct various laboratory tests like atterberg limit, standard proctor test, California bearing ratio, unconfined compressive strength & scanning electron microscopic test. The percentage was decrease observed in liquid limit up to 33.2 % with the addition of polymer. When soil is treated with a higher percentage of polymer maximum 67 % decrease in plasticity index was observed. The maximum percentage increase in CBR value of polymer treated soil is 772 %. The UCS value of normal soil is 672 KPA while UCS value of polymer treated soil is increased from 712 KPA to 2214 KPA.

Nitesh et al. (2015) [4] presented an "A study on strength characteristics of black cotton soil treated with zycosoil" in which they conduct various laboratory test on black cotton soil mixed with a different percentage such as 1%, 2%, 3% & 4% of zycosoil. zycosoil is a water-soluble compound. In zycosoil Si-O-Si bond is present which is the strongest bond and survives for centuries. It helps to maintain shear strength of soil in wet condition. The un-soaked CBR value & soaked CBR values are 33.01 % & 2.48 % with addition of 2% of zycosoil. when a percentage of zycosoil is more than 2 % than CBR value of zycosoil treated soil is reduced due to the transformation of soil structure from flocculent to dispersed.

Kolay et al. 2016) [5] presented an "Effect of Liquid Acrylic co-polymer on Geotechnical Properties of Fine-Grained Soil" in which they conduct various laboratory test on Carbondale soil with the addition of different percentage such as 2%, 3%, 4% & 5% of acrylic co-polymer. Standard Proctor test was conducted to find out OMC & MDD of soil. With the addition of polymer MDD of polymer treated soil is decreased up to 1.8-5.2 % while OMC of polymer treated soil increased 1.5-11.9 %. When the percentage of polymer above 4 %, MDD of polymer treated soil slightly increased while OMC of soil decreased. They conduct California Bearing Ratio (CBR) test under the soaked condition of 7, 14 & 28 days. He observed when the curing period of the sample increased CBR value also increased. Some significant changes were observed in Atterberg's Limit & Unconfined Compressive Strength (UCS) of polymer treated soil samples.

Azhar et al. (2017) [6] presented a "Shear Strength of Stabilized Kaolin Soil Using Liquid Polymer" in which they conduct Unconfined Compressive Strength laboratory test on liquid polymer mixed kaolin soil. they mixed different percentage such as 10%, 15%, 20%, 25%, 30% & 35% of liquid polymer (1-part polymer: 3-Part water) with kaolin soil within curing period of 3, 7, 14 & 28 days. Polymer stabilized kaolin soil show the highest UCS value with 35 % of polymer compare to other percentages of polymers. They found increment in UCS value of 35 % polymer mixed soil which is 45.72 % for 3 Days, 67.57 % for & days, 81.73 % for 14 days & 77.84 % for 28 days of curing period.

3 Materials Used

3.1 Black cotton soil

It is collected from kunhadi area, near nayapura, Kota. The soil oven-dried and sieved as required for laboratory tests.

3.2 Waterborne polymer

The liquid Acrylic co-polymer used for this study which is in liquid form. It was obtained from Ambani Organics Limited. The Engineering properties of acrylic co-polymer are given in table -1.

Table 1. Important properties of Acrylic Co-Polymer

Sr. No.	Properties of Polymer	Value
1	Physical State	Milky Liquid
2	Odor	Slight
3	Density (g/cm^3)	1.11
4	Melting Point	32 °F
5	Flash Point	>200 °F
6	pH	7.5 - 8.5
7	Total Solid % by Weight	55
8	Minimum Film Forming Temperature	8°

4 Experimental Detail

In the present study, black cotton soil has been stabilized using liquid acrylic copolymer. Various Laboratory tests like Atterberg Limits, Standard Proctor Test, Swelling Pressure, California Bearing Ratio (CBR) Test, Unconfined Compression (UCS) test were conducts by changing the percentage of acrylic co-polymer like 2%, 3%, 4%, 5%, 10% & 15% with black cotton soil.

5 Results & Discussions

5.1 Atterberg's limit

Liquid limit & Plastic limit test were conducted on expansive soil with different percentages of acrylic co-polymer, it was observed that the liquid limit & plastic limit decrease with the addition of acrylic co-polymer with expansive soil.

Table 2. Atterberg Limit Results for BCS with different % of ACP

Test Specimen (Polymer %)	Liquid Limit W_L (%)	Plastic Limit W_P (%)	Specimen Classification
0	42.88	21.29	CI
2	42.16	20.67	CI
3	41.13	19.86	CI
4	39.9	18.67	CI
5	37.54	17.60	CL
10	30.49	13.97	CL
15	22.57	10.39	CL

5.2 Standard proctor compaction test

Standard Proctor test is used in geotechnical lab to find out the MDD & OMC of virgin soil & acrylic co-polymer mix specimen. From the experimental results it we got the MDD of black cotton soil is 1.661 kg/cm3 while OMC is 18.57 %. When black cotton soil is mixed with acrylic co-polymer MDD of soil is increased up to 15 % of acrylic co-polymer while OMC is decreased but when % of polymer is increased, MDD of soil increased while OMC is decreased. The variation of proctor test results with the addition of acrylic copolymer is shown in fig. 1.

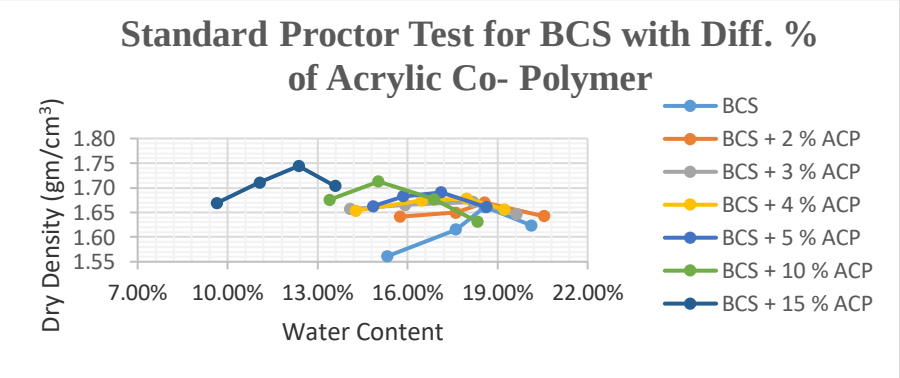

Fig. 1. Standard Proctor Results for BCS with diff. % of Acrylic co-polymer

5.3 Differential free swelling index

To find out the swelling properties of black cotton soil, a differential free swelling test conducted. With the help of differential free swelling identify the potential of black

cotton soil to swell. Variation of DFS with the addition of acrylic co-polymer show in fig 2.

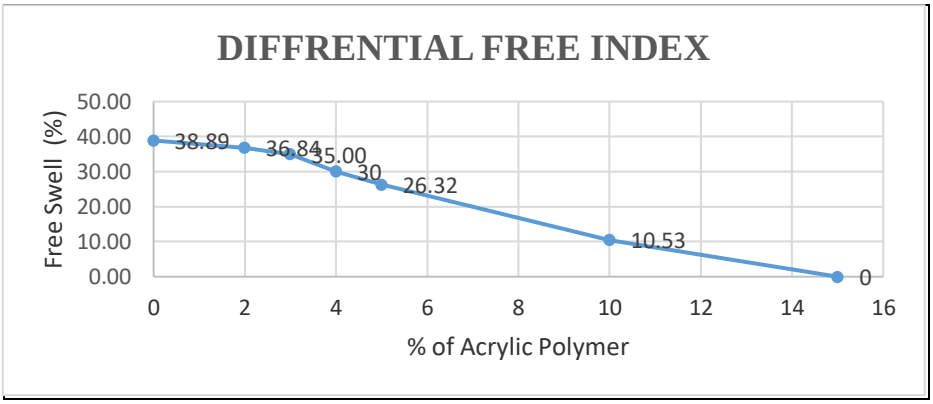

Fig.2. DFS Test for BCS with diff. % of Acrylic co-polymer

5.4 Swelling pressure test

The Swelling pressure of black cotton soil is determined by the consolidometer method. Variation of swelling pressure of black cotton soil with the mixture of acrylic copolymer is shown in fig 3.

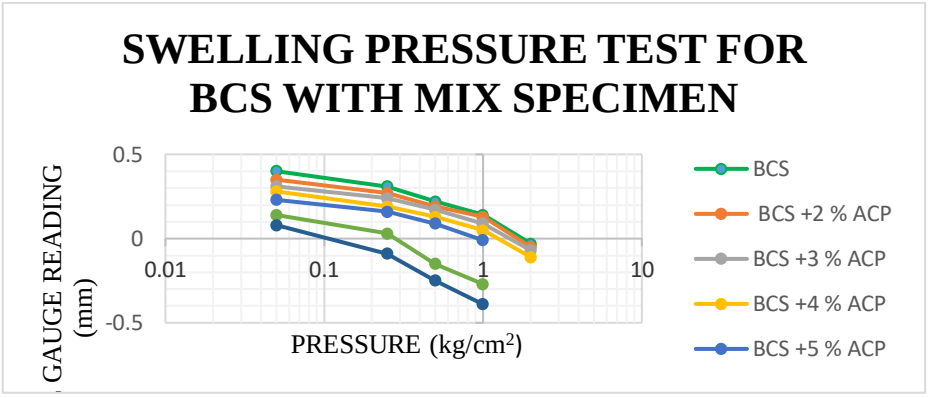

Fig. 3. Variation of Swelling Pressure for BCS with Mix Specimen

5.5 California bearing ratio (CBR) test

California Bearing Ratio Test is conducted in geotechnical laboratory to find out the CBR value of black cotton soil with different % of acrylic co-polymer in soaked conditions for 7 days.

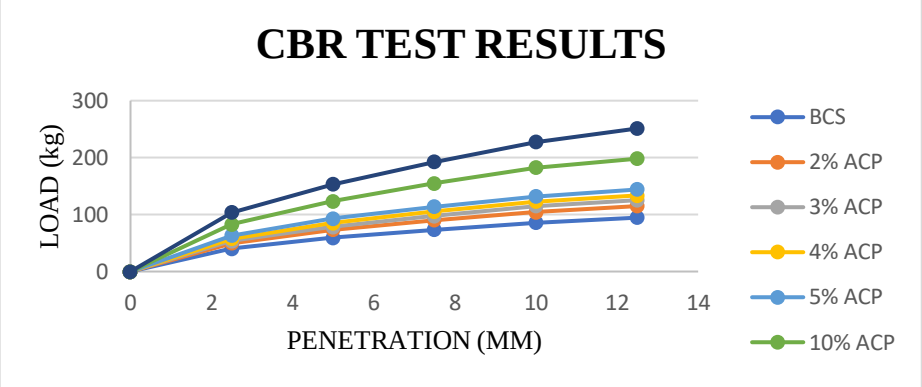

Fig. 4. Variation of CBR Test results for BCS with Mix Specimen

5.6 Unconfined compressive strength (UCS) test

The Unconfined compressive strength (UCS) test is conducted to find out stress & strain value of acrylic copolymer treated soil in a laboratory after 7 days-soaked condition. The graphical representation of unconfined compressive strength results shown in fig 5.

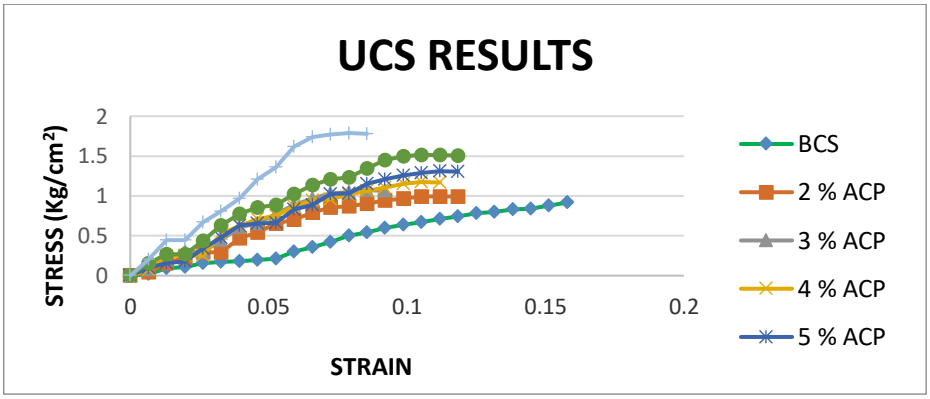

Fig. 5. Variation of UCS Test results for BCS with Mix Specimen

6 Conclusions

1. Atterberg's parameters of black cotton soil decrease with increasing the percentage of acrylic co-polymer. When 15 % of acrylic co-polymer mixed with soil, the mixed specimen has liquid limit, plastic limit, and plasticity index 22.57 %, 10.39 % & 12.18 % respectively.

2. With increasing the percentage of acrylic co-polymer in black cotton soil, soil nature change from CI to CL.
3. With the addition of acrylic co-polymer, the MDD of black cotton soil increases up to while OMC of black cotton soil is decreased. The MDD of natural soil is 1.661 g/cm3 at 18.57 % OMC. When 15 % of acrylic co-polymer mixed with black cotton soil, MDD is increased up to 1.744 g/cm3 at 12.37 % OMC.
4. The differential free swell index decreases with the addition of acrylic co-polymer up to 100 %. The DFS of natural soil is 38.89 % which is decreased up to 0 % with the addition of 15 % acrylic co-polymer.
5. The swelling pressure of black cotton soil is decreased with increases of acrylic co-polymer up to 92.30 %. The swelling pressure of natural black cotton soil is 1.82 kg/cm2 which is decreases up to 0.14 kg/cm2 with the addition of 15 % acrylic co-polymer.
6. The CBR value of black cotton soil is increased by up to 159 % with increasing the percentage of acrylic co-polymer after 7 days-soaked conditions. The CBR value of untreated black cotton soil is 2.92 % in soaked conditions for 7 days. When the percentage of the acrylic copolymer is increased, CBR value of the soil is also increased. At 15 % of acrylic co-polymer, the CBR value of acrylic treated black cotton soil is increased from 2.92 % to 7.59 %
7. The UCS value of natural black cotton soil is 0.916 N/cm2 which is increased up to 1.788 N/cm2 at 15 % acrylic co-polymer addition with black cotton soil. It is observed that when the percentage of the acrylic copolymer is increased, the UCS value of polymer treated black cotton soil is also increased up to 95.23 %.
8. From experimental work, it is observed that if the quantity of acrylic copolymer is increased, the stability of black cotton soil is also increased due to the electrostatic bond which is formed by acrylic copolymer with clay particle.

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