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Soil Stabilization using Fly Ash and Cotton Fiber

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ABSTRACT

Mixing of fiber for ground improvement has been practiced for recent years. Many researches has shown the expected results. This paper mainly deals with the ground improvement technique using both Fly Ash and cotton fiber. The combination of them gives a satisfactory value of its practical application. Both Fly Ash and Cotton fiber are treated as waste materials in our country in spite of having its engineering significances. Here all the tests were performed accepting the Fly Ash percent is 10 for maximum bearing capacity of soil. Three types of sample were prepared as per 0.3%, 0.5%, 0.7% of cotton fiber. For instances, it deliberately increases the Dry Density of soil up to 48.05 KN/m3 where as normal unreinforced soil sample gives about 22 KN/m3. The Ultimate bearing capacity increases up to 80.65 Kpa whereas the unreinforced soil sample gives for 35 Kpa. The result of California Bearing Ratio (CBR) test gives desired value (23%) than unreinforced soil (17%). The CBR test is performed only for 0.7% of cotton fiber where maximum stress is found. The most significant part in this study is to show the variation on cotton fiber for ground improvement technique at different ratio. This paper shows the gradual increase in Deviator stress for UCS tests for the increase in the percent of cotton fiber mixing with Fly Ash. This research may meet the need of ground having low strength at important sites.

Keywords: *Soil stabilization, Fly Ash, Cotton fiber, Optimum Moisture Content, Maximum Dry Density, Unconfined Compressive Strength, California Bearing Ratio*

1. Introduction

Structures need a stable foundation for their proper construction and lifelong durability. Foundation needs to rest on soil ultimately, transferring whole load to the soil. If weak soil base is used for construction, with passage of time it compacts and consolidates, which results in differential settlement of structure. It may result in cracks at structure which can have catastrophic affect. To avoid these future problems with weak soil, stabilized soil should be considered (Tiwari et al., 2014).

Soil stabilization is the process of the alteration of the geotechnical properties to satisfy the engineering requirements (Attoh-Okine, 1995). Geotechnically soil improvement could either be by modification or stabilization or both (Kassim et al., 2005).

Soil modification is addition of a modifier (cement, lime, RHA, Fly Ash, pond Ash, sand) to a soil to change index properties where soil stabilization is the treatment of soils to enable their strength and durability to improve such that they become totally suitable for construction beyond their original classification(Chakraborty et al., 1996).

Over the years, number of methods has been developed for soil stabilization in particular and ground improvement in general. Recently, soil reinforcement with short, discrete, randomly oriented fibers is getting more attention from many researches around the world (Pradhan et. al., 2012).

There are many fiber e.g. Cotton, Coconut (coir), Sisal, palm, Jute, barley straw etc., are in use for soil stabilization. These natural fibers are locally available, cheaper, can make composites with cement/

Fly Ash/ RHA/ Pond Ash / Lime etc., biodegradable and environmental friendly (Fatnani et al., 1999, Aggarwal et al., 2010, Sharma, 2012.

The process of improving the engineering properties of weak soil by using various stabilizing agents is called soil stabilization. Stabilization makes soil more stable by reduction permeability, compressibility and with increase in shear strength, it makes the soil more stable thus enhancing bearing capacity of soil (Consoli et al., 2003)

The stabilizatiopn of soil mainly involves the combination of soil in such a way that when it is compacted under specified condition and to specified extent would undergo material change in its properties and may remain in its stable compacted state without any change under the effect of exposure.

2. Materials And Methods

2.1 Collection of samples

The soil sample was collected from the nearby side of Durbar bangla. KUET. The Fly Ash was collected from Doulatpur bazar, Khulna and the cotton fiber was collected from the Fulbarigate bazar.

2.2 Fly Ash

Fly ash is the by-product of coal fired electric power generating plants (Gümüşer et al., 2014). Fly ash has a high amount of silica and alumina. It is increase the soil strength to control the swell characteristics caused by moisture changes. Improvement of soil strength by using this waste material in geotechnical engineering has widely recommended from environmental point of view. The waste product produced on combustion of pulverized coal at high temperatures in power plants is known as fly ash (Tiwari et al., 1014). Fly ash increase strength and bearing capacity of soil, increase durability of soil and increase the resistance to erosion, weathering or traffic loading, used to control the swell-shrink characteristics caused by moisture changes and used to reduce the pavement thickness as well as cost (Dhariwal et al., 2013).

Figure 1: Fly Ash

2.3 Cotton Fiber

Cotton fiber is a cellulosic fiber. It has worldwide popularity for its variety of use. Cotton fiber is the most used fibers for producing various types of fabric through all over the world. It is consider as reinforceing materials and used for ground improvement.

Table.1 Properties of cotton fiber

Particulars	Value
Length (mm)	15 – 55
Diameter (mm)	0.01 –0.03
Color	Depends upon climatic conditions
Polymer system	Linear, cellulose polymer

Figure 2: Cotton fiber

2.4 Preparation of sample

The collected samples were brought to the laboratory and spraded it over the floor to get air dry soil samples. After drying the soil was broken and grinding by using wooden hammer as fine as possible without applying unnecessary force.

The soil powder was passed through #40 standard sieves (Bashar, 2002). Air dry soil powder free from foreign materials. The water content of soil sample is predetermined.

In this study the percent of Fly Ash was previously determined as 10%. The percentage of cotton fiber is used as a variety of 0.3%, 0.5% and 0.7% respectively.

Slurry technique was used in sample preparation. Details of soil slurry and test specimen preparation can be obtained in Alamgir et al. (2006).

2.5 Methodology

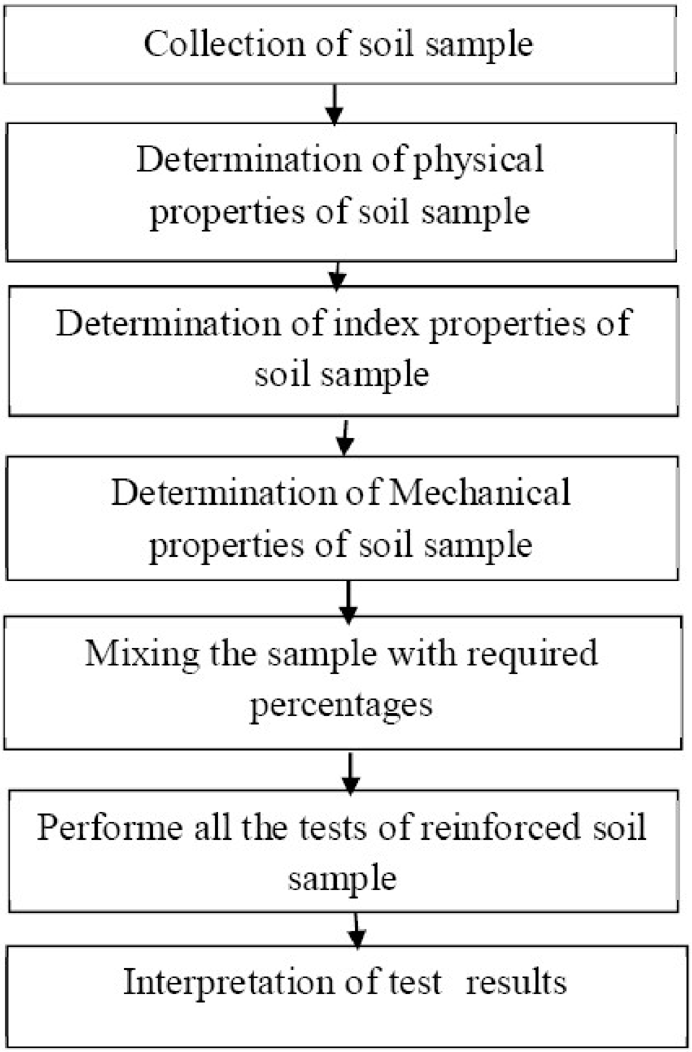

Figure 3: Flow diagram of laboratory investigation.

3 Experimental Details

3.1 Test Performed

- Specific Gravity(Gs) (ASTM 854-14)
- Liquid Limit(LL) (ASTM D 4318)
- Plastic Limit(PL) (ASTM D 4318 10e1)
- Shrinkage Limit(SL) (ASTM D 4318 05)
- Grain Size Distribution (ASTM E112/E1382)
- Unconfined Compression Test (ASTM D2166)
- Compaction Test (AASHTO T99)
- California Bearing Ratio (CBR) Test. (D1883)

3.2 Test Procedure

3.2.1 Water content

- 100gm weight sample were kept to be measured.
- Then it should be placed it oven at 600C.
- Dry sample was measured.
- According to ASTM D 2216-90, water content was computed

3.2.2 Specific Gravity

- 100gm of sample was taken in a flask.
- A clear flask (500mL) with 50% distilled water was taken and heated for de-aeration for 30 minute
- The flask was filled with water up to volume rank. The Weight was then measured.
- The flask was kept for cooking and soil particles wighted seperately. Then it was dried and the weight was measured again.
- The flask was filled with two-thirds of full de-aerated water. The water was recorded.
- The temperature was also recorded.

3.2.3 Atterberg Limit Test

- At first the required ingridents as per the per designated soil-Ash-fiber specimen have been weighted and kept seperated from each other.
- The optimum water content is added of taken soil sample is added to the soil sample.
- The spacer disc was used to determine the shrinkage limit.
- All the 3 tests were performed according to ASTM standard.

3.2.4 Compaction Test

- In this study, standard proctor test was performed for compaction test.
- At first the required ingridents as per the per designated soil-Ash-Fiber specimen have been weighted and kept seperated from each other.
- Saving the Fly Ash percent as 10 and cotton fiber percent were varied from as described before.
- The test was performed according ASTM standard.

- This test was performed both unreinforced and reinforced soil sample.

3.2.5 Unconfined compression

- Test At first the required ingridents as per the per designated soil-Ash-fiber specimen have been weighted and kept seperated from each other.
- In the uniform mixture soil, Fly Ash and cotton fiber were added.
- Different sizes of mold were developed for the test.
- Then by the UC test machine was introduced to the mold.
- The data was recorded for calculations.
- This test was also performed according to ASTM standard

3.2.6 California Bearing Ratio (CBR) Test

- The samples were prepared for the CBR test for the percent of maximum bearing capacity (for 0.7% of cotton fiber).
- The tests were performed according to ASTM standard.

4. Results and Discussions

4.1. Physical and index properties

It is including the Specific Gravity, moisture content, Atterberg limit (liquid limit, plastic limit, Shrinkage limit), Grain size distribution.

Table 2 : The physical and index properties of soil sample

	Properties	Values
1	Specific Gravity	2.52
2	Liquid Limit	31.6%
3	Plastic Limit	22.0%
4	Shrinkage limit	3.50%
5	Grain size distribution	Sand = 39% Silt = 28% Clay = 33%

4.2 Grain Size Distribution

It expresses the type of soil with the % of clay marticles, sand, silt, gravel etc.

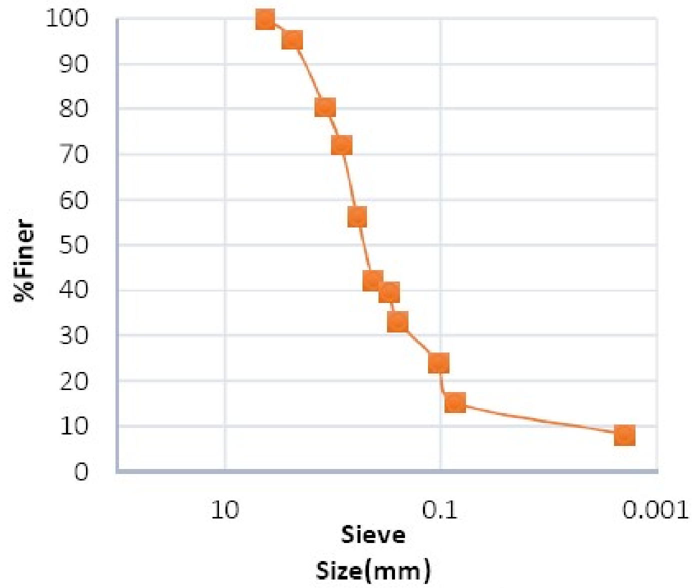

Figure 4: Grain size distribution

From the graph we found the following results

- D_{10}= 0.009
- D_{30}= 0.3
- D_{60}= 0.8
- C_u= 88.89
- C_c= 41.67

4.3 Compaction Test

Compaction is the process of densification of soil by reducing air voids. This test was done to determine the maximum dry density (MDD) and optimum moisture content (OMC) of both unreinforced and reinforced soil.

4.3.1 For Unreinforced soil

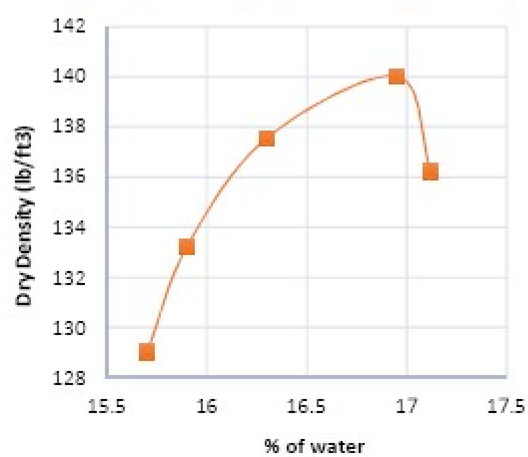

Figure 5: Compaction test for unreinforced soil sample

4.3.2 For Reinforced soil

For reinforced soil sample, Compaction tests were determined only for 10% of Fly Ash with different percent of cotton fiber content (0.3%, 0.5%, 0.7%).

4.3.2.1 For 0.3% cotton fiber

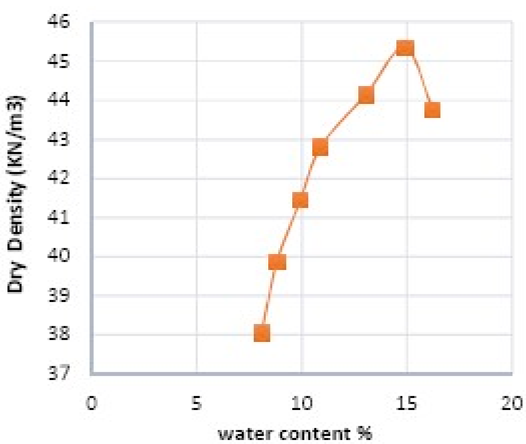

Figure 6: Compaction test for 0.7% cotton fiber content

4.3.2.2 For 0.5% cotton fiber

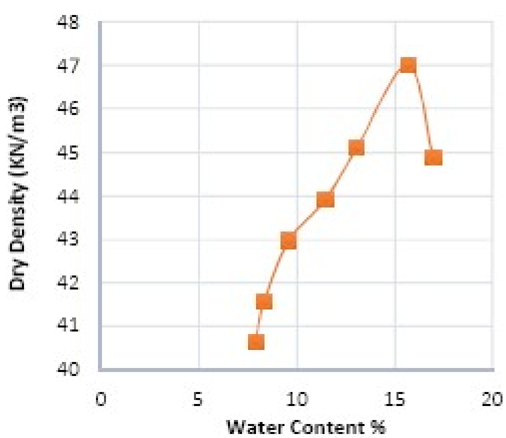

Figure 7: Compaction test for 0.5% cotton fiber content

4.3.2.3 For 0.7% cotton fiber

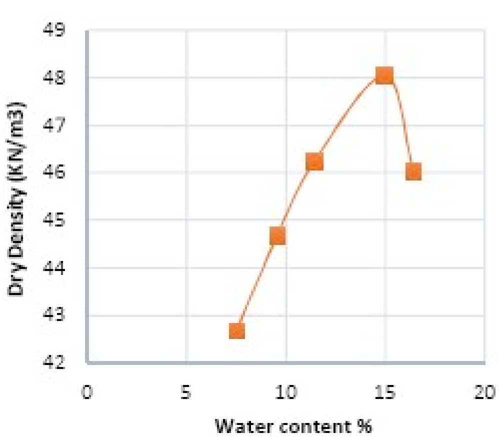

Figure 8: Compaction test for 0.7% cotton fiber content

Here figure 5 is applicable for unreinforced soil sample. The optimum moisture content was found 17% where as the maximum dry density was 140 pcf or 22 KN/m3.

In figure 6, for 10% Fly Ash and 0.3% of cotton fiber reinforced soil sample, the MDD was obtained 45.34 KN/m3 where as the OMC was found as 14.91%. In figure 7, for 10% Fly Ash and 0.5% of cotton fiber reinforced soil sample, the MDD was found as 47.01 KN/m3 where as the OMC was ranges about 15.66%. In figure 8, for 10% Fly Ash and 0.7% of cotton fiber reinforced soil sample, the MDD was found as 48.05 KN/m3 and the OMC was 14.96%.

This is due to initial simultaneous flocculation and agglomeration of clay particles caused by cation exchange with Fly Ash and cotton fiber (Locat et al., 1990; Wild et al., 1996; Mallela et al., 2004; Kassim et al., 2005; Geiman, 2005).

4.4 Unconfined compression Test

Unconfined Compressive Strength (UCS) is the most common and adoptable method of evaluating the strength of stabilized soil sample. It is the main recommendation for the determination of the required amount if cotton fiber that is to be used for the stabilization of the soil sample.

4.4.1 For Unreinforced soil

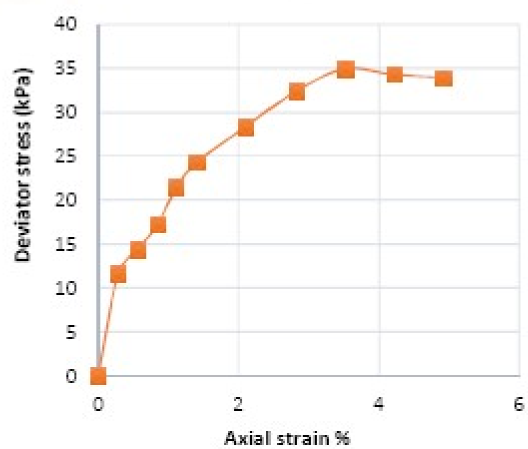

Figure 9: UCS test for unreinforced soil sample

4.4.2 For Reinforced soil

For the reinforced soil sample, UCS tests were determined for 10% of Fly Ash with different percent of cotton fiber content (0.3%, 0.5%, 0.7%).

4.4.2.1 For 0.3% of cotton fiber

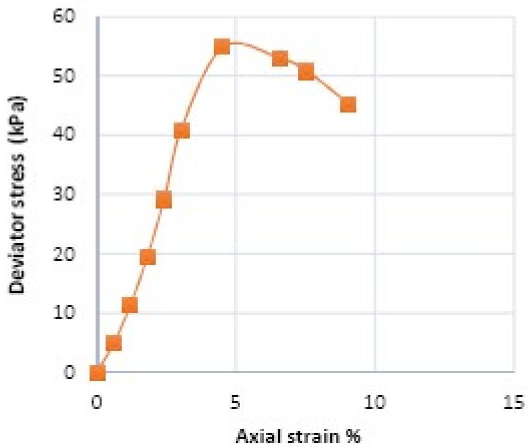

Figure 10: UCS test for 0.3% cotton fiber content

4.4.2.2 For 0.5% of cotton fiber

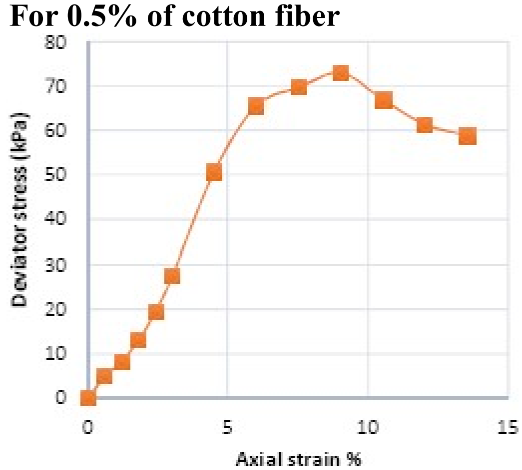

Figure 11: UCS test for 0.5% cotton fiber content

4.4.2.3 For 0.7% of cotton fiber

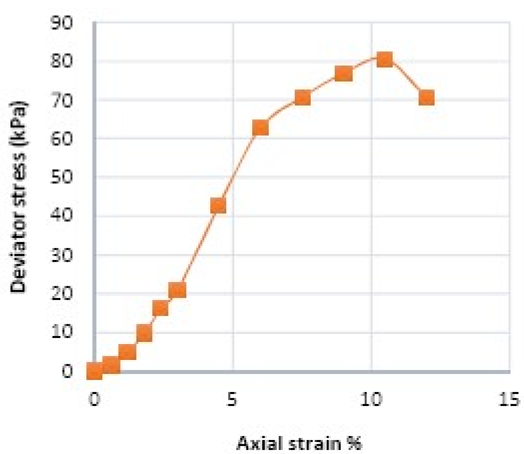

Figure 12: UCS test 0.7% cotton fiber content

From the figure 9, value of Unconfined compressive strength test was found as 35 kpa for unreinforced soil.

For 0.3% of cotton fiber and 10% of fly ash, the UCS value was found as 54.88 kpa. For 0.5% of cotton fiber and 10% of fly ash, the UCS value was found as 72.99 kpa. For 0.7% of cotton fiber and 10% of fly ash, the UCS value was found as 80.65 kpa.

The subsequent increase in the UCS is attributed is the formation of cementitious compounds like cotton fiber and Fly Ash and the pozzolans that is present in Fly Ash.

4.5 California Bearing Ratio (CBR) Test

California Bearing Ratio (CBR) test is a compressive nature penetration test.

The test is specifically used to determine the mechanical strength as well as the potential strength of road subgrades and base courses materials including the recycled material generally used for road and airfield pavements.

CBR value is a percentage comparison with the standard crushed rock from California and thus this test is a comparison test.

4.5.1 For Unreinforced soil

4.5.1.1 Swell Characteristics

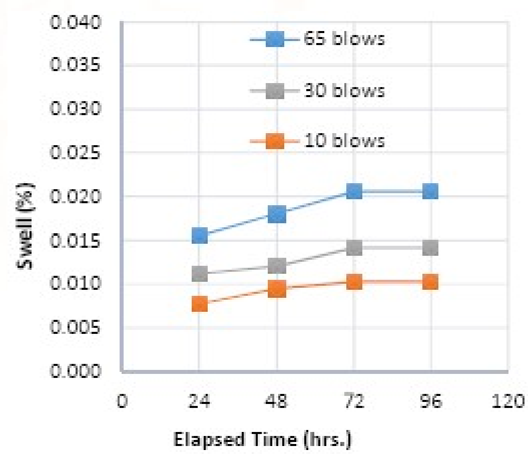

Figure 13: swell characteristics for different blows

4.5.1.2 Penetration Characterstics

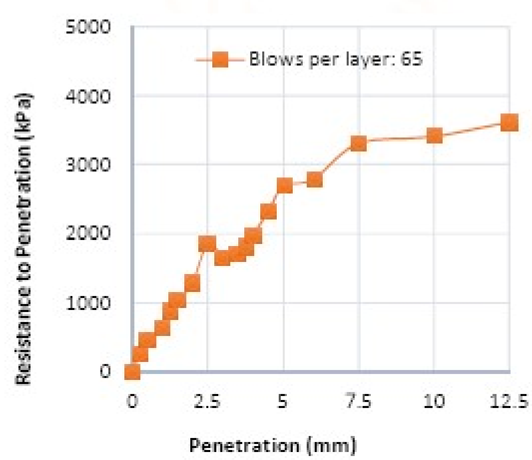

Figure 14: Penetration characteristics for 65 blows

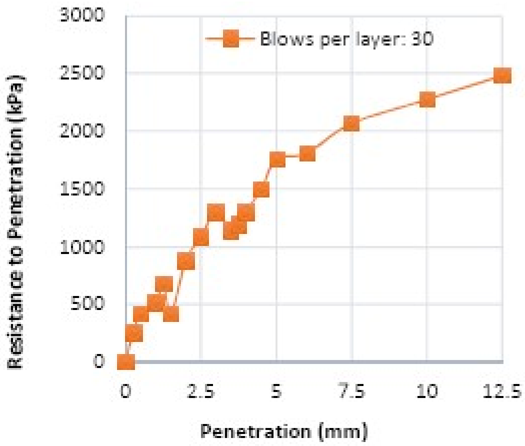

Figure 15: Penetration characteristics for 30 blows

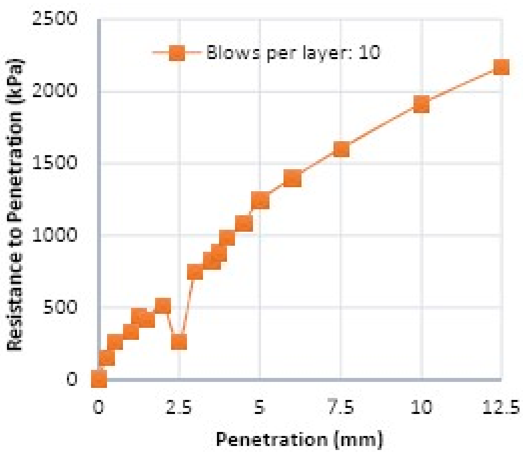

Figure 16: Penetration characteristics for 10 blows

4.5.1.3 Soaked CBR

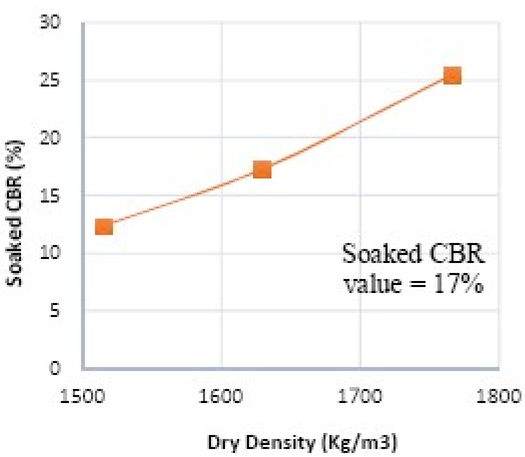

Figure 17: Soaked CBR value for unreinforced soil

4.5.2 For Reinforced soil

As the maximum dry density (MDD) was found 48.05 KN/m^3 for 10% Fly Ash and 0.7% cotton fiber conten so CBR value was determined only for 10% Fly Ash and 0.7% of cotton fiber reinforced soil.

4.5.2.1 Swell Characteristics

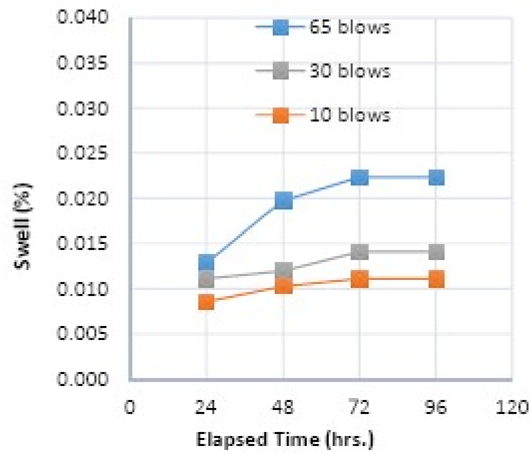

Figure 18: swell characteristics for different blows

4.5.2.2 Penetration Characterstics

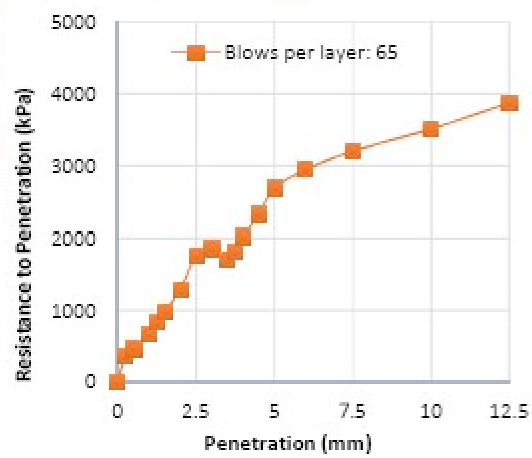

Figure 19: Penetration characteristics for 65 blows

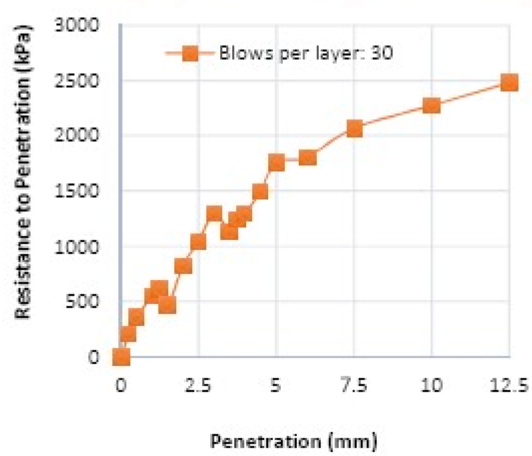

Figure 20: Penetration characteristics for 30 blows

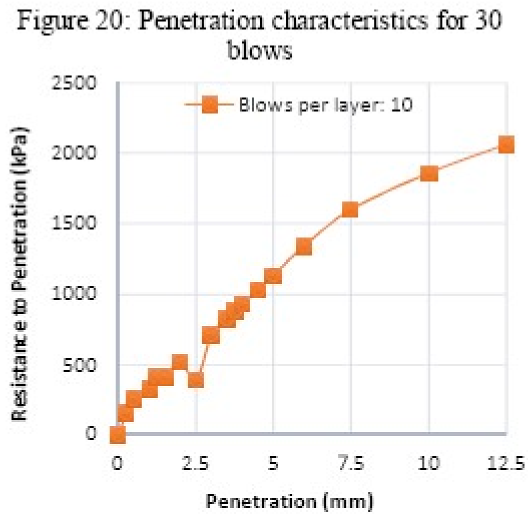

Figure 21: Penetration characteristics for 10 blows

4.5.2.3 Soaked CBR

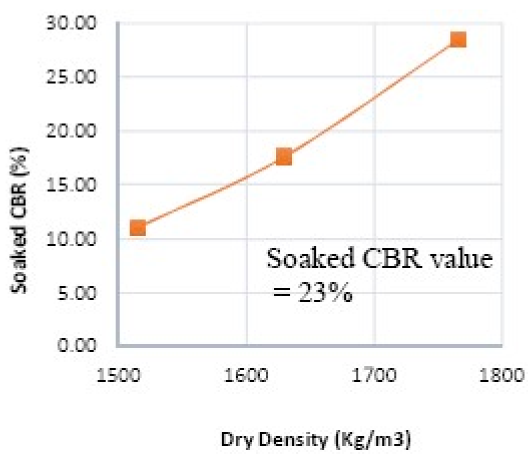

Figure 22: Soaked CBR value for reinforced soil sample

The CBR value for 0.7% of Cotton fiber and 10% Fly Ash was obtained 23%, whereas the CBR value was found for unreinforced soil sample 17%.

CONCLUSION

Based on the results represented in this paper, the following conclusions have made.

- The combination of Fly Ash and cotton fiber have great impact on ground improvement. they can increase the stability properties of normal soil.
- The combined effect of 10% Fly Ash and 0.7% cotton fiber increased the maximum dry density (MDD) and Unconfined compressive strength (UCS) value up to 118.41% and 130.42% respectively.
- The CBR test was performed only for 10% Fly Ash and 0.7% of cotton fiber content and found the CBR value, 35.30% greater than unreinforced soil.

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