Effects of Sugarcane Bagasse Ash on the Strength Characteristics of Bentonite Clay

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***Abstract*: The economic development of a region depends on the infrastructure that the region has. As every structure stands on the soil therefore, it must be strong enough to bear the stresses caused by it. But sometimes the soil of interest is not of desirable strength. Hence, engineering techniques have to be applied in order to make it useful. On the other hand, our eco-system is being damaged continuously and resources being depleted for the sake of economic development. Thus, to overcome this problem, a solution is required that would help the infrastructure of a country to grow without depleting its resources and without damaging the environment. One of the solutions is to utilize the agricultural waste products such as Sugarcane Bagasse Ash (SCBA) for soil improvements. This study is focused on SCBA; a waste product of sugar mills and utilization of such material for the improvisation of strength characteristics (CBR and UCS) of Bentonite Clay. Different proportions of SCBA i.e. 5%, 10%, 15% and 20% by dry weight of soil are mixed with the soil to observe the changes in strength characteristics of soil. The results showed that with the addition of SCBA, the MDD decreased and the OMC increased. Furthermore, it has been observed that CBR (Soaked) increases with the addition of SCBA and reaches a maximum value on the dosage of 5% of SCBA. Also, CBR (Unsoaked) and UCS tests shows decrease with the addition of SCBA in the bentonite clay.**

***Keywords*: Sugarcane Bagasse Ash, Bentonite Clay, Infrastructure, Economic Development.**

I. INTRODUCTION

The increasing demand for facilities is resulting in the rapid development of civil engineering infrastructures. As the base of every structure lies on the soil, therefore, superior quality of the soil is required for the long life and durability of the structure but sometimes engineers come across a problem that is the soil at a location is not of the quality that satisfies the engineering requirements. The conventional way to solve this problem was either to replace the poor soil with soil of good quality or to abandon such land but as the world leads to constructing convincing infrastructures, such measures which have been taken in the past are not suitable since the lands with good quality of soil have been almost used and it is profligate to replace the poor soil with good soil. To compete in this modernized era and to fulfill the infrastructure needs; the land where the soil of inferior quality is present has also to be utilized by applying certain techniques to make the soil suitable for use.The recent solutions to use the inferior quality of soil for a particular purpose is by stabilizing that soil with different techniques.

One among them is to use geo-synthetics (products that are manufactured to strengthen the soil) but such method was limited to the developed countries due to the increased operational costs. The innovative solution to such a problem that is economically and environmentally acceptable is to improve the quality of soil by using waste materials for the stabilization of poor soil. As Pakistan is 5th largest sugarcane producer having an annual production of 63,800 TMT (Thousand Metric Tons) (Source: www.worldatlas.com). The agro-industrial waste of sugar mills i.e. Sugarcane Bagasse Ash (SCBA) is present in huge quantities. Disposing off the SCBA is a huge problem and its improper disposal can cause a disease known as Bagassosis. Hence the use of such material in stabilization will not only improve the strength characteristics of soil but will also help in getting rid of the environmental pollution and would prove to be an economical practice.

II. MATERIALS & METHODS

A. Base Soil

The soil chosen for the research is Bentonite Clay. It is commercially available in the market. Since the soil excavated from the field has varying properties at different sections of the field. So, in that case manufactured Bentonite which has identical physical and chemical properties has been bought. The variant of Bentonite Clay; "Sodium Bentonite" which is commercially available as "Hi-Gel Optimum" have been selected for the purpose of study, bought from "Ahmad Saeed & Company (PVT.)

Fig. 1: Bentonite Clay

LTD." located in Lahore, Punjab. It is a highly swelling clay and available as fine powder. The Bentonite clay has been shown in Fig. 1.

Following tests have been conducted on base soil and the results are shown in Table I.

Table I: Tests conducted on Bentonite Clay

Tests	Standards	Results
Moisture Content (Oven-Dry)	ASTM D2216 – 10	7.24%
Specific Gravity (Pycnometer)	ASTM D854 – 14	2.54
Atterberg's Limits (LL & PL)	ASTM D4318 - 17e1	LL= 205% PL= 49%
Compaction (Standard Proctor)	ASTM D698 - 12e2	OMC = 28.6% MDD=1.417 g/cc
Unsoaked CBR	ASTM D1883 – 16	11.294%
Soaked CBR		1.18%
Unconfined Compressive Strength (UCS)	ASTM D2166 / D2166M – 16	297.41 kN/m^2

B. Sugarcane Bagasse Ash

In Sugar mills, after the extraction of sugar from the sugarcane, the leftover residue known as "Bagasse Fiber" is used to generate electricity by burning through boilers which results in an agro-industrial waste known as "Sugarcane Bagasse Ash" (SCBA). SCBA in small quantity is used as a fertilizer but an excessive quantity of it is dumped into landfills which disturbs the environment and can cause several diseases. As SCBA is rich in silica and also poses threat to the environment thus, its potential to be used as a soil stabilizer has been assessed. For this purpose, SCBA has been acquired from "Matiari Sugar Mills" located in Matiari, Sindh. The SCBA obtained has been shown in Fig. 2.

Fig. 2: Sugarcane Bagasse Ash

The SCBA has been passed through sieve #4, #10, #40, #100 and #200 and it was observed that a major portion of ash passed through #45 sieve. In this study, particles of SCBA that are finer than 325μm have been used for the purpose of stabilization of soil. The specific gravity of SCBA is found out to be 1.9. The particle size distribution (PSD) curve can be seen in Fig. 3.

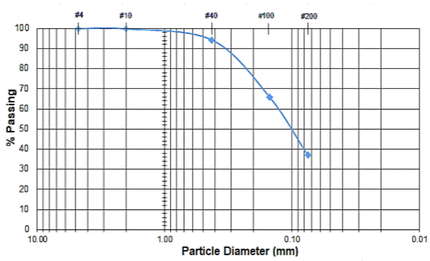

Fig. 3: Particle Size Distribution Curve of SCBA

C. Experimental Study

To achieve the objectives of this research, SCBA has been set as a control parameter. Oven dried SCBA has been passed through #45 sieve and added in proportions of 0%, 5%, 10%, 15% and 20% to the base soil. The standard proctor compaction tests are conducted on the untreated and SCBA treated soil samples according to the standard ASTM D698. The samples are compacted and rammed in three layers with a 25.5 N rammer in a mold having an internal diameter of 101.6 mm and height of 116.4 mm, producing the total energy of 600 kN-m. CBR tests under un-soaked and soaked conditions are conducted as per ASTM D1883-07. For the achievement of the desired density, the samples have been compacted in the CBR mold having 152.4 mm diameter and 177.8 mm height. The compaction process was carried out by placing the sample in three layers and ramming it 56 times (on each layer) with a 25.5 N rammer which was dropped from a height of 305 mm.

The UCS tests are performed as per ASTM D2166. The samples are compacted at the gathered optimum moisture content (OMC) and maximum dry densities (MDD) obtained from standard Proctor test, for the achievement of UCS. A strain-controlled compression machine has been used for the judgment of the stress-strain behavior of the untreated and treated soil specimens.

III. RESULTS

A. *Standard Compaction Test*

Standard proctor test has been conducted on base soil and Sugarcane Bagasse Ash treated soil. The relation between two parameters of compaction graph i.e. dry density and moisture content can be observed in Fig. 4(a). It is seen that as SCBA content increases, the maximum dry density (MDD) decreases. The reason of decrease in dry unit weight of SCBA stabilized bentonite can be essentially ascribed to the replacement of high-density soil solids (i.e. SG = 2.54)) with low-density ash (i.e. SG = 1.90). Secondly, the reason of decrease in dry unit weight can be the disturbance of the original soil structure which increases the void ratio of the combination of the two.

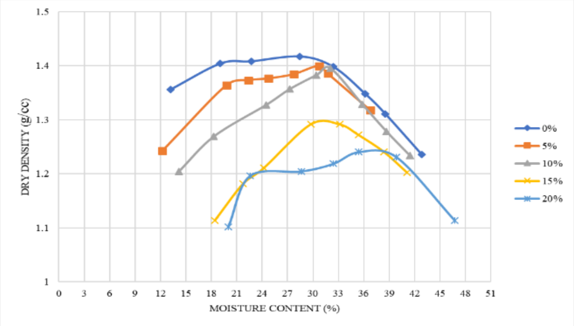

Fig. 4(a): Moisture-Density Relationship

The graph in Fig. 4(b) illustrates a regular trend i.e. the MDD decreases with the increase of the ash content. It can be seen the MDD for the parent soil is 1.417 g/cm^3 which then decreases to 1.24 g/cm^3 on the inclusion of 20% of SCBA. The decrease in the dry density is about 12.5%. The relation between the OMC and SCBA content can be seen in Fig. 4(c). Standard compaction test reveals that OMC increases as the SCBA content increases.

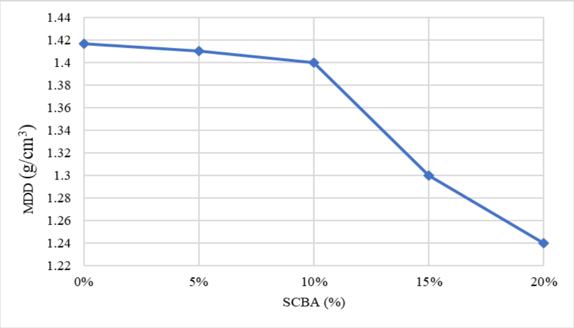

Fig. 4(b): SCBA vs MDD

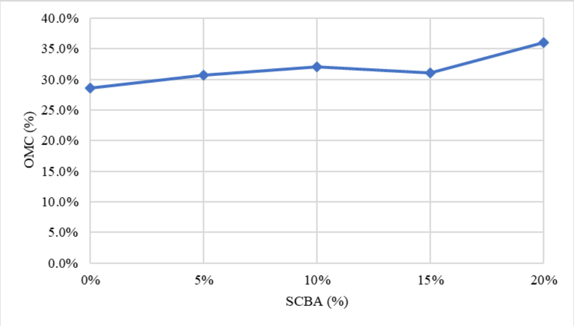

Fig. 4(c): SCBA vs OMC

B. *California Bearing Ratio Test*

1) *Unsoaked CBR*

CBR test on untreated and soil treated with 5%, 10%, 15% and 20% of SCBA have been conducted. The load vs penetration graphs of the tests have been shown in Fig. 5(a). From Fig. 5(b), it is seen that as the SCBA is added with increasing percentages, the CBR values follows no regular trend. Moreover, there is slight decrease in CBR values with the addition of

SCBA. The CBR of parent soil is 11.29 and it decreases to the value of 9.295 for 15% which is a percentage decrease of 17%. The value further increases to 10.752 for 20% but it is 4% less than that of the parent soil.

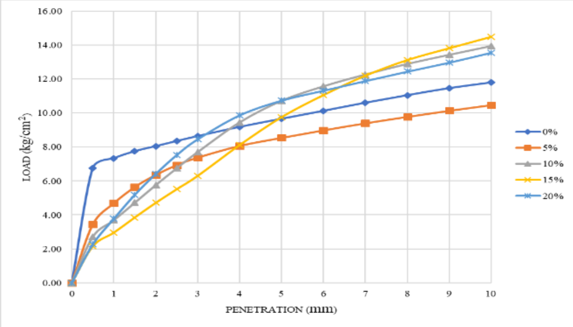

Fig. 5(a): Load vs Penetration for Unsoaked CBR

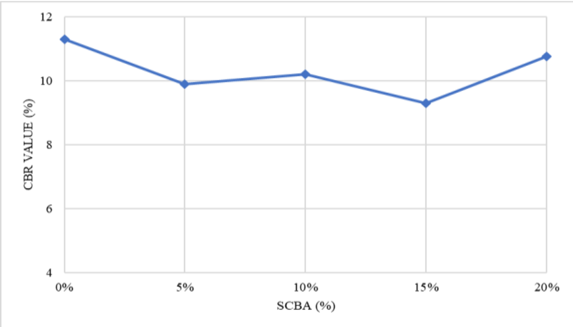

Fig. 5(b): SCBA vs Unsoaked CBR Value

2) Soaked CBR

Soaked CBR test on untreated and soil treated with 5%, 10%, 15% and 20% of SCBA have been conducted. The load vs penetration graphs of the soaked CBR have been shown in Fig. 6(a). In Fig. 6(b), it can be seen that the CBR increases to a value of 1.385 from 1.18 (that of parent soil) on the dosage of 5% of SCBA. It slightly decreases to the value of 1.291 for 10%, then there is a substantial decrease to a value of 0.785 for 15% and then the CBR value increases to 1.261 for 20%. It may be noted that maximum CBR value has been obtained on the dosage of 5%. This may be explained from the fact that as the CBR molds were soaked, the curing activated the cementitious properties of SCBA which in turn strengthened the soil.

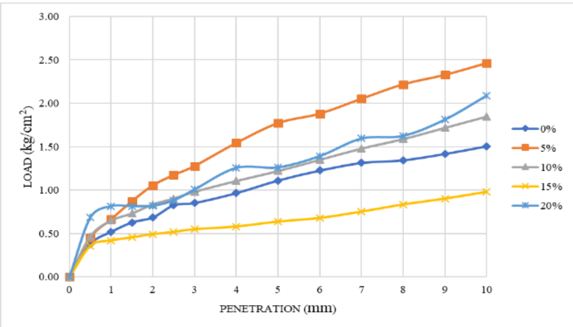

Fig. 6(a): Load vs Penetration for Soaked CBR

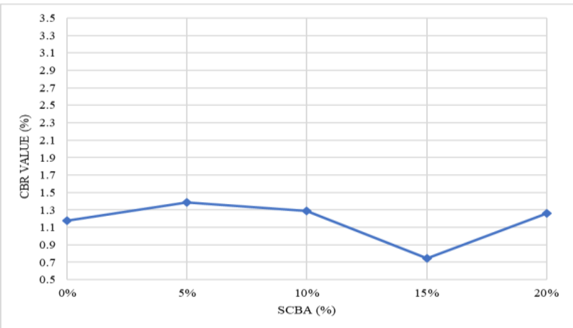

Fig. 6(b): SCBA vs Soaked CBR Value

C. *Unconfined Compressive Strength*

The stress-strain relationships obtained from the UCS for the untreated as well as treated soils have been shown in the Fig.7(a). It can be noted that on the inclusion of SCBA, the UCS variably decreases. The decrease in the UCS value might be due to the fact that the silica content of bentonite is more than that of SCBA. Thus, the SCBA could not induce the cementing properties in bentonite.

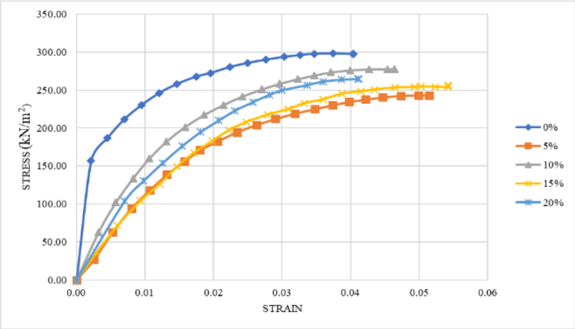

Fig.7(a): Stress-Strain Relationship

Fig. 7(b) shows that the UCS of clay for parent soil is 297.4 kN/m^2 and it decreases by 18% (242.97 kN/m^2) on the inclusion of 5% SCBA content. On the addition of 10%, 15% and 20%, the UCS is greater than that of 5% but still less than that of the parent soil.

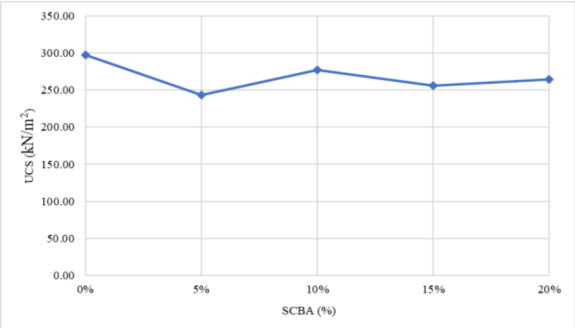

Fig.7(b): UCS vs SCBA

IV. CONCLUSIONS

It is concluded from this research that the maximum dry density (MDD) of the soil decreases upon the addition of SCBA and the optimum moisture content (OMC) increases on the addition of SCBA. The CBR in soaked condition increases with the addition of SCBA and reaches a maximum value on the addition of 5% of SCBA. The CBR in Unsoaked condition decreases with the addition of SCBA and the UCS decreases with the addition of SCBA.

V. RECOMMENDATIONS

Based on the results of the study, following recommendations are made to further explore the effects of SCBA as stabilizer.

1. Further studies maybe undertaken to assess the strength characteristics of soil by using SCBA along with other stabilizers such as lime.
2. This study has assessed the effects of SCBA on clay containing the mineral Montmorillonite. Further studies could be undertaken on the use of SCBA on other minerals such as; Kaolinite and Illite.

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