Amendments in Soil using Biochar

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Abstract - Biochar is a carbon rich compound produced through pyrolysis of organic matter. This study investigates the effects of locally produced biochar amendment on mechanical properties of clay. A set of mechanical tests, including compaction and unconfined compressive strength will be performed on untreated and treated clay with biochar. Biochar can be used as an eco-friendly construction material for problematic soil improvement. The optimum of biochar using UCS was found as 10%. The compaction tests showed a recalcitrant behaviour of lowering maximum dry density and increasing optimum moisture content with increase in percentage of biochar.

Keywords— Stabilization, Biochar, UCS Compaction, Direct shear

1. INTRODUCTION

Soil stabilization is widely used in connection with road, pavement and foundation construction. It improves the engineering properties of soil such as strength, volume, stability, durability, to reduce the pavement thickness as well as cost. Soil is a construction material which is available in abundance. Earth has been used for the construction of monuments, tombs, dwellings, etc. The study of engineering behavior of different types of soils is extremely important because all civil engineering structures will have to be rested and founded on soil. The purpose of soil stabilization is to increase bearing capacity and reduce settlement and deformation.

The presence of problematic soils often requires the use of soil improvement technologies to enhance the exiting ground or fill materials. Depending on the needs these technologies may be temporary or permanent, using a variety of techniques including mechanical, biological, physical, and chemical treatments (Latifi et al. 2017; Ivanov and Chu 2008; Indraratna, Chu, and Rujikiatkamjorn 2015).

Biochar is a carbon rich material that is produced by thermochemical conversion of biomass (Garcia-Perez et al. 2010). This biomass can be produced from a variety of sources including: agricultural waste, logging residues, wood production waste, urban wood-waste, and other biological sources (Garcia-Perez et al. 2010). Biochar has been attractive for recent research efforts due to its presence as a byproduct of gasification and energy production (Grebner and Khanal 2015). The produced biochar has been used in agricultural and environmental remediation projects as a type of carbon capture technology for quite some time (Hansen et al. 2015, Xie et al. 2015a, 2015b). However, civil engineering application outside of environmental remediation had not been well explored. Recently, several authors have looked into the effects of biochar on mechanical properties of soil (Lu et al. 2014, Reddy et al. 2015, Yargicoglu and Reddy 2017) as well as possible applications as a construction material (Gupta and Kua 2017). However, it should be noted that the type of feedstock and production process used have significant impacts on the properties and quality of biochar (International Biochar Initiative 2015). In addition, previous studies indicated that the soil properties and microbial and atmospheric conditions will also affect the benefit of amending soils with biochar (Latifi et al. 2015; Latifi et al. 2016).

2. MATERIALS

2.1 Kaolinite Soil

The soil used in the present study is kaolinite clay of low plasticity. It has been collected from Thonnakkal. On visual examination it was found to be white in colour. The soil obtained from the site is processed and powdered for testing purposes. The properties of the soil are studied using standard procedures and the results are tabulated in Table 1.

2.2 Biochar

The stabilizing agent used in the investigation is biochar. For studying the effect of biochar in soils, different tests were conducted and were added in different concentrations i.e., various percentages. (Table 2)

Table 1 Properties of Kaolinite clay

Properties	Result
Specific Gravity	2.63
Liquid limit (%)	32
Plastic limit (%)	20
Shrinkage limit (%)	17.25
Plasticity index (%)	12
Natural moisture content (%)	26
Optimum moisture content (%)	23.5
Maximum dry Density (g/cm^3)	1.5
Percentage of clay	68
Percentage of silts	21.93
Percentage of sand	10.07
UCC strength (kPa)	50.32
Classification of soil	CL

Table 2 Properties of Biochar

Properties	Specifications
Optimum moisture content (%)	0.94
Total moisture content (%)	4.08
Particle size (mm)	4.75 passing
Total ash (%)	1.77
Fixed carbon (%)	66.37
Volatile matter (%)	30.92
Colour	Black

3. METHODOLOGY

The index properties of soil were determined as per the respective IS Codes. Basic geotechnical laboratory testing was performed to establish the initial properties of the untreated clay used for the study. Basic geotechnical properties testing such as Atterberg limits, specific gravity, grain size distribution, unconfined compressive strength and compaction test were conducted to assess the behavior of the soil used in this study.

The effect of biocharcoal on the geotechnical properties of clay, the soil is mixed with biocharcoal by percentages 2%,4%,6%,8%, 10%and 12% of dry weight and various tests are done.

The study focuses on studying the effect of biochar on the soil strength improvement and further applications of biochar stabilized clay.

4. RESULTS AND DISCUSSIONS

4.1 Atterberg Limit

From Figure 1, one can conclude that the addition of 10% biochar leads to a reduction in liquid limit from 36% to 26.8%, compared with the natural clay, indicating a reduction in liquid limit of 16% at a biochar dosage of 12% The decrease in liquid limit due to absorbtion of water content by biochar in soil. Decrease in liquid limit is due compounds possessing cementitious properties and flocculation. The decrease in liquid limit also account with decrease in Diffused Double Layer (DDL) (Muntohar and Hantoro (2000)).

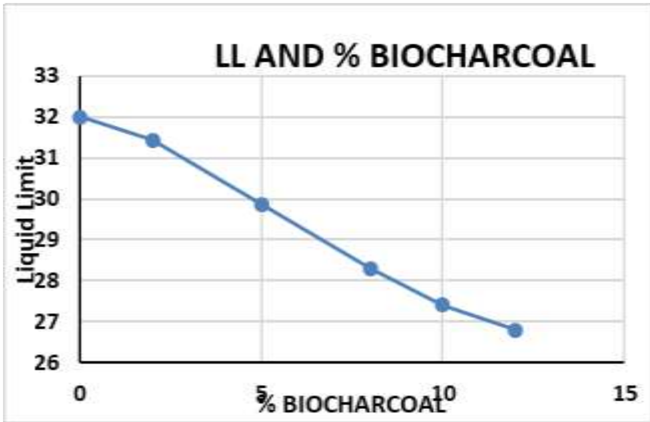

Chart -1: **Variation of liquid limit with biochar**

The results of the plastic limit test on clay with added biochar are shown in Figure 2. The figure indicates that an increase in biochar content leads to an increase in the plastic limit of stabilized. clay. Compared with the natural clay plastic limit increases with increase in percentage of biocharcoal and the percentage increase is about 14% for 12% of biocharcoal.

The PI is the difference between the liquid limit and the plastic limit of soil. From Figure 3, one can conclude that an increase in biochar content leads to a reduction in the PI of stabilised clay due to increase in plastic limit and decrease in liquid limit.

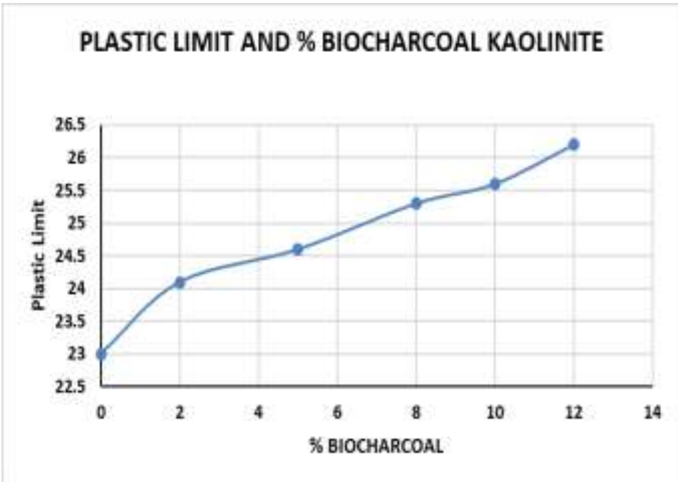

Chart -2: **Variation of plastic limit with addition of biochar**

4.2 Compaction Test

The strength of soil can be altered by the addition of biochar in varying percentages. In the present investigation a series of compaction tests were carried out by varying biochar content. The data from the test indicates that the optimum moisture content of stabilized soil are less than that of the raw soil.

The OMC value increased with increase in biocharcoal content. The increase percentage of OMC with increase upto 12% of biocharcoal is about 14%. Exceeding water absorption by biochar as a result of its porous properties causes this increase of OMC (Zhang et al (1996)).

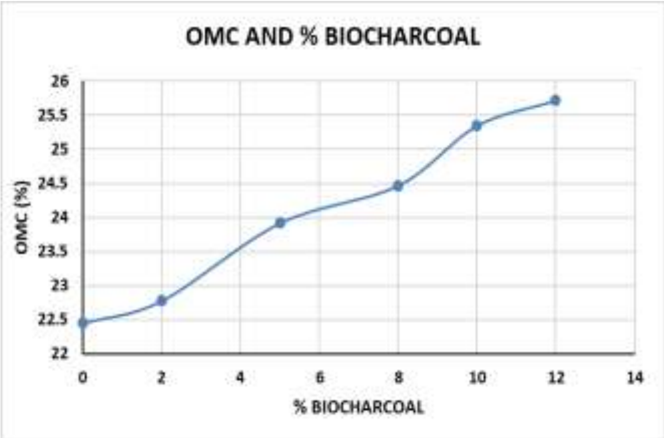

Chart -3 Variation of optimum moisture content with addition of biochar

Figure 4 shows the results of the maximum dry unit weight and of soil stabilised with biochar obtained compaction tests. The figure indicates that an increase in biochar content contributes to a decrease in the maximum dry unit weight.

A range of maximum dry unit weights varying from 1.357 to 1.005 g/cc was achieved for soils depending on the biochar content. The observed changes are attributed to the replaced air between the soil grains by biochar and the effect of moisture absorbed by the biochar. Also, occupies pores between clay particles, which results in a reduction in the void ratio of the soil mass, contributing to the decrease in the maximum dry unit weight of stabilised soil. An increase in biochar above the optimum limit may possibly result in agglomeration of biochar particles, which in turn causes an increase in the void ratio and then a decrease in density. The MDD decreased with increase in biocharcoal concentration occurs because of both particles size and specific gravity of the soil and stabilizer. Decreasing dry density indicates that it need only low compactive energy (CE) to attain its MDD. As a result, the cost of compaction becomes economical (Basha E A et al (2004)).

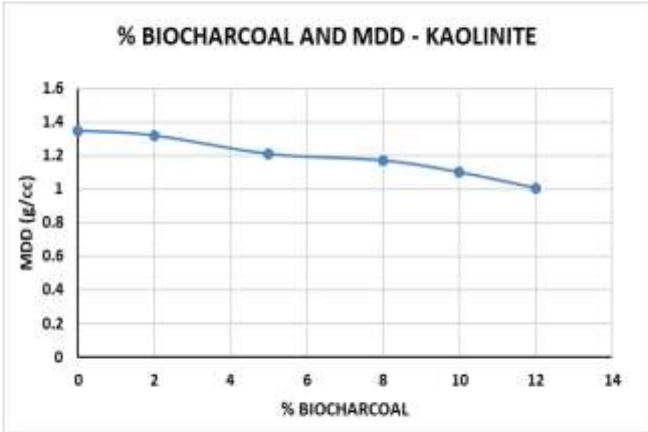

Chart -4: Variation of maximum dry density with addition of biochar.

4.3 Unconfined Compressive Strength

The figure 5 indicates that, with increasing biochar content, the peak UCS of stabilised clay increases, The UCS increases with an increase in biochar content up to 10%, beyond which it decreases. Thus, the optimum biochar content is 10%. At constant moisture content, due to the absorption of water by biochar, the clay became less compressible, which was worsened with increasing biochar content. This may be the reason for the reduction in the peak strength of stabilised clay with 12% biochar in comparison with clay stabilised with10% biochar. It is clear from Figure 5 that the increase in the UCS of stabilised clay occurs at lower strain in all specimens compared with the natural clay.

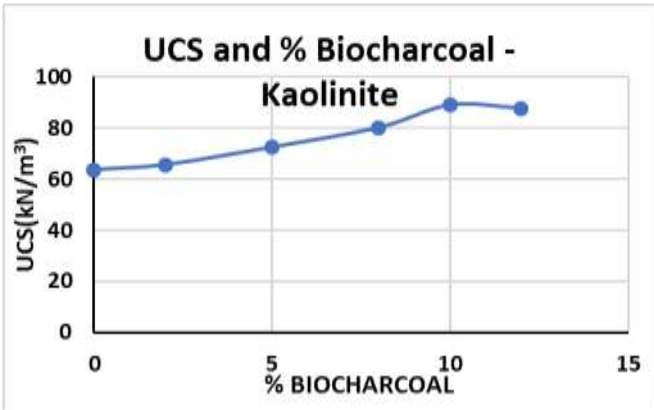

Chart -5: Variation of UCS with addition of biochar

5. CONCLUSIONS

From the test results it was noted that:

- Liqiud limit decreases and plastic limit increases. Thereby the plasticity index decreases. A further increase in additive percentage beyond optimum causes reduction in overall rate of PI of stabilised soil.

- Addition of biochar leads to an increase in water absorption and a reduction in pores between clay particles, resulting in a decrease in the maximum dry unit weight and increase in optimum moisture content of soil.
- The biochar has a positive influence on the stiffness of treated specimens. The addition of biochar to clay causes a reduction in failure strain of the specimens compared with untreated clay.
- At the optimum level of 10%, the biochar provides a stiff particle network to carry applied stresses while the clay particles fill void spaces and hold the specimen together.
- Increasing past this optimum percentage heighten the risk of void space between biochar material while reducing the effectiveness of the soil's cohesive properties, resulting in weaker, brittle mixtures.

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