TEST Engineering & Management

May – June 2020
ISSN: 0193-4120 Page No. 9950 - 9954

Clay Soil Stabilization using Coconut Fiber, Kernel Powder, Stone Quarry Waste & Cement

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Article Info
Volume 83
Page Number: 9950 - 9954
Publication Issue:
May - June 2020

Article History
Article Received*: 19 November 2019*
Revised*: 27 January 2020*
Accepted*: 24 February 2020*
Publication*: 18 May 2020*

Abstract:
Black cotton soil deposits occupy 20% of the area of India. Being a clay with expansive nature it comes with inherent problems of swelling and shrinkage, loss of shear strength in presence of water etc. so to use such a soil as a construction material is difficult. The alternative to BC soil in form of moorum or sandy soil may not be available everywhere hence the cost of procurement may be higher therefore to make use of black cotton soil fill material or sub grade material should be a priority. With rapid increase in construction activity it becomes imperative that quarrying of basalt rock for aggregate is on the rise. It leads to approximate 25% wastage in form of stone quarry waste. A natural fibre such as coconut coir is a waste material produced out of commercial production of coconut oil and is increasing in quantity day by day. Disposal of huge volume of coconut coir by burning leads to pollution. Heaps of coir piled up as lead to leaching of phenols into the groundwater in state of Kerala. At the same time coconut coir has an advantage of high lignin percentage leading to its stability to retain its strength even after periods as large as two years. This paper envisages to combine the challenges thus posed into an opportunity of better utilization of waste and problematic soil type such as clay soil, into a viable and cheaper engineering solution. After preliminary investigations, conducted on the soil, stone quarry waste, & coconut coir, this study consist of CBR and UCS test with different curing periods conducted after selecting a suitable clay, stone quarry waste combination with variation in coir and cement percentages.

Keywords: *Black cotton soil, Clay, Cement, CBR, Coconut Coir, Kernel, Stone quarry waste, Stress Strain Curve*

Introduction

Soil, in general are broadly categorized in two main groups viz. coarse grained soil and fine grained soil. The fine grained soils which comprise silt size and clay size particles form a very large proportion of natural ground deposit. Also the clay soils which are cohesive in nature occur over the large proportion of the earth surface. [8]Among all the other types of soil, Black Cotton soil is considered to be most problematic soil for constructions because of its behaviour from geotechnical perspective. Black cotton soils are inorganic clays of medium to high compressibility and form a major soil group in India. They are characterized by high shrinkage and swelling properties. Because of its high swelling and shrinkage characteristics, the Black cotton soils (BC soils) have been a challenge to the civil engineers. These soils are very hard when dry, but lose its strength completely when in wet condition. It is observed that after drying, the black cotton soil develops cracks of varying depth. As a result of wetting, upward vertical movement, termed as swelling or upheaval takes place in the soil mass. During drying reverse process takes place. All these movements lead to failure of the structure in the form of settlement, heavy depression, cracking and unevenness.Because of the presence of electrochemical activity in such clays they exhibit distinctly different characteristics depending on the clay mineral structure of the particles. The clays which contain Montmorillionite clay mineral are generally termed as expansive soil[4]. From point of view of economics it is advisable to insitu modify rather than replace.The process of improving the engineering properties of soil and thus making it more stable is called as soil stabilization.

Materials Used for Stabilization

With more emphasis now being placed on civil engineering for sustainable development, there is real need to try various practical applications for

May – June 2020
ISSN: 0193-4120 Page No. 9950 - 9954

waste materials and pass the practical applications to the designers.[1]Coconut coir, kernel are being produced in millions of tons as unwanted byproducts in the manufacturing of coconut oil every year in India as well as all over the world. It is estimated that in Kerala alone ,at present , there is an accumulated stock of 1x10^7 tons of coir waste. Most of this waste is left unutilized and are posing environmental hazard by polluting the soil, water and air. Conventional disposal of this waste such as burning is not environmental friendly. Stabilization of soil using cement[7] or lime is well established. But very few researchers have tried the stone quarry waste ,a wasteful product of stone crusher units, in combination with coconut coir and kernel powder for this purpose. It is found to be very useful for the purpose and also it is beneficial to the environment by putting a waste to good use as well as reducing the carbon foot print by not using cement. The current research conceives to estimate how the use of coconut coir and kernel powder ,in combination with stone quarry waste and cement to improve the geotechnical properties of the black cotton soil including compaction property, California bearing ratio , unconfined compressive strength test. The main objective of this study is to do experimental investigations to know the effect of coconut coir and kernel in powdered form, along with stone quarry waste on black cotton soil with small percentages of cement.

Thus, the main objective of the study undertaken in this dissertation work may be summarized as under:

(i) To evaluate basic physical parameters of the stone quarry waste and coconut coir and kernel powder.

(ii) To compare the effect of both the waste products on various properties of the black cotton soil

(iii) To study and quantify beneficial effect of cement as an additive to both coconut coir and kernel powder and stone quarry waste ,when cement is added in small quantity.

The optimal mixture of black cotton soil with stone quarry waste and coconut coir and kernel powder selected among experiments under consideration and cement was tried in three percentages namely 0%, 2%, 4% to find the effect on various properties of black cotton soil.

Experimental Results & Discussions

In an attempt to observe the effect of the coir and cement on the clay and query mix, UCS and CBR tests have been performed on a sample of 75% clay and 25% Query mixed with different percentage of coir and cement which were 0.5%, 1%, 1.5% and 0, 2 and 4% respectively. In the initial phase of the study basic geotechnical tests were performed on the sample which are summarised below.

Preliminary Characteristics of clay:

Specific Gravity

In the present study specific gravity of the clay soil had been observed experimentally using Pycnometer. It was observed that the specific gravity of clay used clay sample is 2.63.

Liquid limit

Liquid limit of the clay sample was obtained from Casagrande's Liquid limit test. Finding of the test was that the liquid limit of clay is 56.80%.

Plastic limit test

It was observed that the plastic limit of the sample is 34.53%.Plasticity Index of the sample is (56.80-34.53=22.27%) 22.27% which is much higher than 17%. Thus the soil is highly plastic in nature.

Standard Proctor test

Standard proctor test was conducted and obtained values are OMC = 22.09%, MDD = 1.582gm/cc

Methodology:

The strength parameters were tested using UCS and CBR tests on various sample percentages.

Main Test Program:

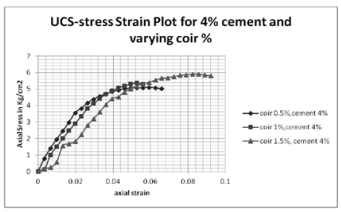
Unconfined Compression Test

In the current study the coir, cement and query has been used to stabilize the clay thus remoulded samples were prepared and UCS test was performed.

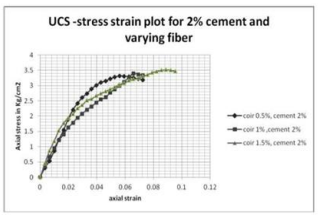
Stress-Strain curve

Stress-strain curve curves are summarized below to show the behaviour of the mix tested on 14th day.

c) 4% cement and varying coir content



b) 2% cement and varying coir content



a) 0% cement and varying coir content

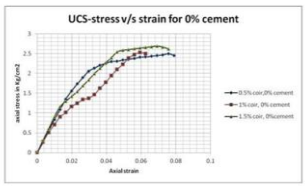


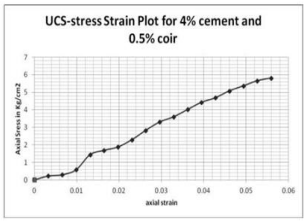
Fig. 1: Stress strain curves for 0%, 2% and 4% cement with varying coir content

TEST Engineering & Management

May – June 2020
ISSN: 0193-4120 Page No. 9950 - 9954

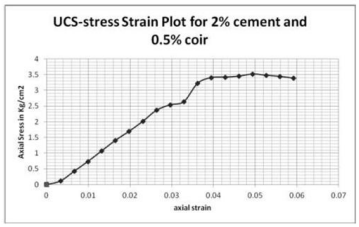
Typical test results of UCS

d) 75% clay+25% query+0.5% coir +4 % cement at curing period of 28 days

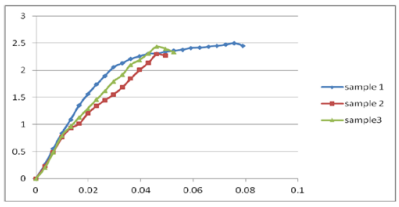


In order to obtain the shear strength of the soil with the mix several UCS tests have been conducted among which few of the typical test results have been shown below.

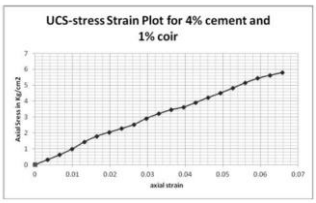
b) 75% clay+25% query+0.5% coir +2 % cement at curing period of 28 days



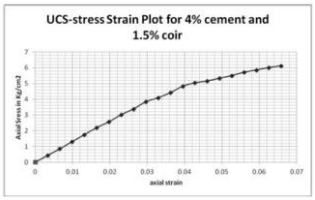
a) 75% clay+25% query+0.5% coir +0% cement at curing period of 14 days



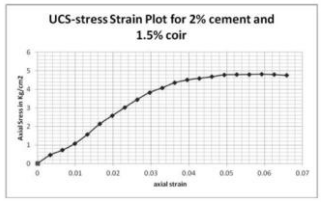
g) 75% clay+25% query+1% coir +4 % cement at curing period of 28 days



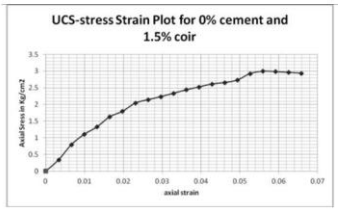
j) 75% clay+25% query+1.5% coir +4 % cement at curing period of 28 days



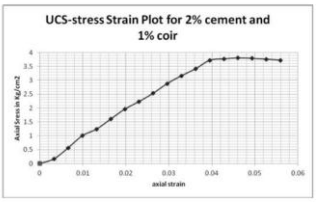
i) 75% clay+25% query+1.5% coir +2 % cement at curing period of 28 days



h) 75% clay+25% query+1.5% coir +0 % cement at curing period of 28 days



f) 75% clay+25% query+1% coir +2 % cement at curing period of 28 days



e) 75% clay+25% query+1% coir +0 % cement at curing period of 28 days

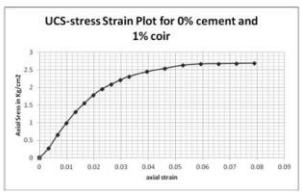


Fig. 2: Stress strain curves with different compositions of querry, coir and cement

Summary of UCS test results and conclusion

Unconfined compression test outcomes with Cement content, Coir content and time as variables are summarised below.

Table 1:UCS test on 75% clay+25% query+0.5% coir +varying cement content

	0.5% Coir,0% cement and mix of 75% clay and 25% query	0.5% Coir,2% cement and mix of 75% clay and 25% query	0.5% Coir,4% cement and mix of 75% clay and 25% query
14 days sample	2.41	3.32	5.06
28 days sample	2.56	3.64	5.88

Table 2: UCS test on 75% clay+25% query+1% coir +varying cement content

	1% Coir,0% cement and mix of 75% clay and 25% query	1% Coir,2% cement and mix of 75% clay and 25% query	1% Coir,4% cement and mix of 75% clay and 25% query
14 days sample	2.51	3.41	5.34
28 days sample	2.69	3.81	6.05

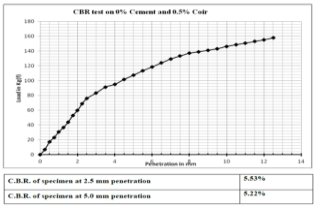
Table 3: UCS test on 75% clay+25% query+1.5% coir +varying cement content

	1.5% Coir,0% cement and mix of 75% clay and 25% query	1.5% Coir,2% cement and mix of 75% clay and 25% query	1.5% Coir,4% cement and mix of 75% clay and 25% query
14 days sample	2.72	3.48	5.86
28 days sample	2.9	4.92	6.35

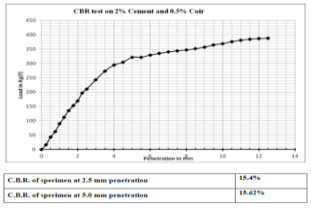
It is observed from the above results that the unconfined compressive strength is increasing with the increase in cement content, i.e. for 0.5% Coir and increasing the amount of cement from 0, 2 to 4% the UCS strength varies from 2.41, 3.32, 5.06 kg/cm2 respectively for 14 days sample. Similar behaviour is observed for other Coir content, i.e. 1% and 1.5%. if we keep the content of cement as a constant and keep on increasing the coir content then also the UCS strength keeps on increasing. But a notable thing is the rate at which it increases is much slower than changing the cement content. As cement achieves its full strength with time, it can be observed that the strength at 28 days for any given sample is higher than the strength at 14 days. These findings are consistent for all the mentioned samples.

3.2.2 Typical test results of California Bearing Ratio (CBR test)

a) CBR test on 75% clay+25% query+0.5% coir +0% cement



b) CBR test on 75% clay+25% query+0.5% coir +2% cement



TEST Engineering & Management

May – June 2020
ISSN: 0193-4120 Page No. 9950 - 9954

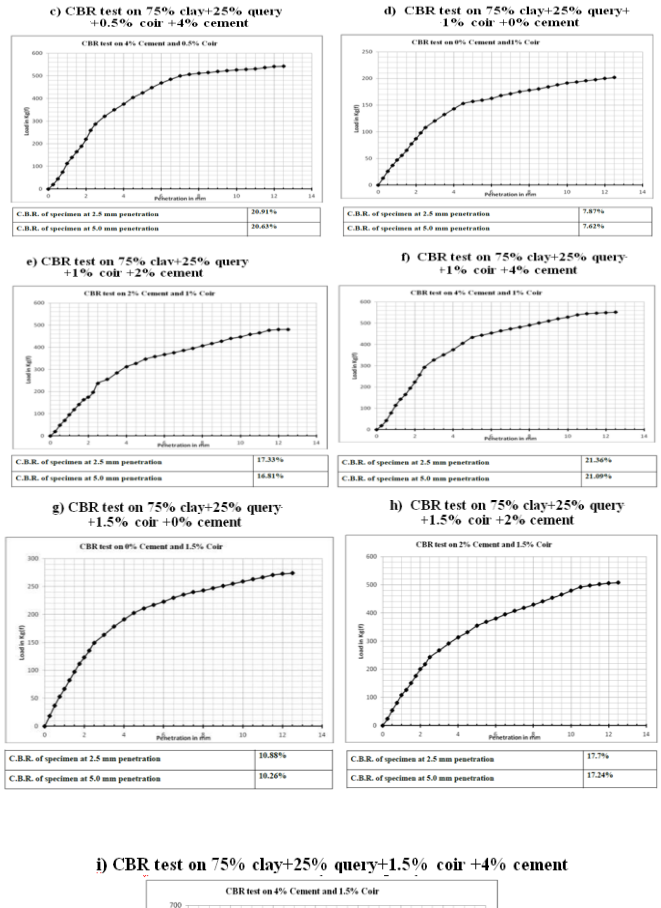


Fig. 3: CBR test results for different compositions of querry, coir and cement

Summary of CBR test results and conclusion

CBR test outcomes with Cement content, Coir content and time as variables are summarised below.

Table 4:CBR test on 75% clay+25% query+0.5% coir +varying cement content

	0.5% Coir,0% cement and mix of 75% clay and 25% query	0.5% Coir,2% cement and mix of 75% clay and 25% query	0.5% Coir,4% cement and mix of 75% clay and 25% query
14 days sample	4.43	14.3	20.1
28 days sample	5.6	15.7	20.97

Table 5: CBR test on 75% clay+25% query+1% coir +varying cement content

	1% Coir,0% cement and mix of 75% clay and 25% query	1% Coir,2% cement and mix of 75% clay and 25% query	1% Coir,4% cement and mix of 75% clay and 25% query
14 days sample	6.56	15.2	20.7
28 days sample	7.8	17.2	21.4

Table 6: CBR test on 75% clay+25% query+1.5% coir +varying cement content

	1.5% Coir,0% cement and mix of 75% clay and 25% query	1.5% Coir,2% cement and mix of 75% clay and 25% query	1.5% Coir,4% cement and mix of 75% clay and 25% query
14 days sample	8.97	16.7	21.9
28 days sample	10.94	17.8	22.84

It is observed from the above that the CBR value is increasing with the increase in cement content. For 1% Coir and variable the amount of cement from i.e. 0, 2 to 4% the CBR value varies from 7.8%, 17.2%, 21.4% respectively for 28 days sample. Similar behaviour is observed for other Coir content, i.e. 0.5% and 1.5%. if we keep the content of cement as a constant and keep on increasing the coir content then also the UCS strength keeps on increasing but the rate of increment is much slower than what we observed while changing the cement content.As cement achieves its full strength with time, it can be observed that the strength at 28 days for any given sample is higher than the strength at 14 days. These findings are consistent for all the mentioned samples. Thus it is clear that both coir and cement are really good materials to improved the compressive strength of clay soil.

Results & Conclusions

Few of the notables are mentioned below

[1] Shear strength (qu) is increased with the inclusion of coir (natural Fiber) and cement.

[2] The increase in UCS value after 14 days of curing due to addition of coir is 12.5% with coir percent increase from 0.5% to 1.5% for a mix where cement was not introduced i.e. (0% cement).

[3] The increase in UCS value after 28 days of curing due to addition of coir is 13.7% with coir percent increase from 0.5% to 1.5% for a mix where cement was not introduced i.e. (0% cement).

[4] The increase in UCS value after 14 days of curing due to addition of coir is 110% to 115% with cement percent increment of 0% to 4% and coir % increment from 0.5% to 1.5% (14 day curing)

[5] Corresponding increase due to cement addition (0% to 4%) varies from 118% ,130%, 164% for coir % of 1.5%,0.5%,1%

[6] The increase in CBR value after 14 days of curing with no cement was noted down to be in the range of 4.43% to 8.97% with an increase in coir from 0.5% to 1.5%.

[7] The increase in CBR value after 28 days of curing with no cement was noted down to be in the range

May – June 2020
ISSN: 0193-4120 Page No. 9950 - 9954

of 5.6% to 10.94% with an increase in coir from 0.5% to 1.5%.

[8] The increase in CBR value after 14 days of curing with increase in cement from 0% to 4% was noted down to be in the range of 4.43 % to 20.1 % where coir percent is kept constant at 0.5%.

[9] The increase in CBR value after 28 days of curing with increase in cement from 0% to 4% was noted down to be in the range of 4.43 % to 20.1 % where coir percent is kept constant at 0.5%.

[10] The increase in CBR value after 14 days of curing with increase in coir percent from 0.5% to 1.5% was noted down to be in the range of 4.43 % to 8.97% while keeping the cement percent fixed to 0.

[11] The increase in CBR value after 14 days of curing with increase in coir percent from 0.5% to 1.5% was noted down to be in the range of 5.6 % to 10.94% while keeping the cement percent fixed to 0.

[12] It can be observed that coir alone can increase the strength of the clay but with in inclusion of the cement the rate of increment of strength is really improved.

[13] The present study concludes that query, cement and coir can be used to improve the quality of the present clay soil.

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