Shear Strength and Permeability Study of Clay Stabilized with Coir Waste

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ABSTRACT: Clayey soils pose great challenges to geotechnical engineers and consultants, as structures on soft compressible clays create number of problems. Construction without soil improvement is usually impractical due to anticipated large settlements. Coir waste, consisting of coir pith and coir fibre, is a waste material generated during the extraction of coir fibre. Effective use of these materials uplifts the rural economy and its use in engineering construction reduces the construction cost. Coir pith and coir fibre were added to the clayey soil as 0 – 3% and 0 – 1% respectively by dry weight of soil. The main objective of the present investigation is to assess the impact of coir waste inclusion on the shear strength and permeability characteristics of Cochin Marine clay. The testing program includes a series of UCS tests, triaxial tests and permeability tests. This study also evaluates the long term effect on the shear strength of clay treated with coir waste.

1 INTRODUCTION

Clayey soils pose great challenges to geotechnical engineers and consultants, as structures on soft compressible clays create number of problems. Construction without soil improvement is usually impractical due to anticipated large settlements and long coastline covered with thick soft clay deposit. In view of the increased industrial activities along the coastline, it has become necessary to utilize these areas, after suitably improving the ground, so that various structures can be safely supported.

The use of natural materials such as jute, cotton, coir, sisal etc. as reinforcing materials in soil started in the early nineties. The main advantage of these materials is that they are locally available with practically little cost. They are biodegradable and hence will not create environmental problems.

Coir waste is a spongy, peat like residue obtained from the processing of coconut husk for coir fibre. Coir waste strongly absorbs liquids and gases. This property is due to the honeycomb like structure.

2 LITERATURE REVIEW

The process of randomly mixing discrete fibres into the soil has become a proven technology to improve the strength of the soil as pointed out by various researchers. The fibers increase the cohesion among the soil particles.

Several studies have been reported on the influence of both natural and synthetic fibres on different strength aspects of soft soils. Addition of randomly distributed natural fibres increases optimum moisture content and decreases maximum dry density. This is due to the fact that inclusion of materials with low specific gravity and unit weight replaces the soil mass and also due to the rearrangement of soil particles with reinforcing particles. Bindhu et al. (2011) reported that the inclusion of coir fibers in marine clay increases the shear strength. As compared to the unreinforced soil sample, shear strength of soil sample reinforced with coir fibers is 300%. Among the natural fibres, coir is having the highest lignin content (46%) which provides the highest durability for coir fibre. Balan (1995) reported that the shear strength parameters of a granular soil are improved because of coir fiber inclusion; it is a function of percentage of coir fiber content and length of fibre.

Thus, it is seen that, there exists very little data in literature concerning the shear strength property of soils treated with coir waste and also the long term curing effect of soil treated with coir waste. This work aims at understanding the shear strength characteristics of clayey soil treated with coir waste. A better understanding of these properties will enhance the usage of the material in geotechnical engineering works in places where they are plenty.

3 MATERIALS AND METHODS

3.1. Materials

The materials used for the study are Cochin marine clay and coir waste. The soil used was sun dried and then powdered to a fraction passing through 4.75 mm sieve. The coir waste was in a soaked state and it was then sun dried to reduce the water content to 0%. The coir waste was separated into coir fibres and coir pith by sieving the waste through 4.75 mm sieve. The fraction which is passing through 4.75 mm sieve is designated as coir pith and that retained as coir fibre in this paper mm sieve is designated as coir pith and that retained as coir fibre in this paper.

3.2. Methods

The engineering and index properties such as specific gravity, Atterberg's limits, unconfined compressive strength, compaction characteristics etc. of the particular soil selected for this study were determined in the laboratory. The properties of the soil are given in Table 1. The soil used has 74% and 20% of silt and clay content respectively. Light compaction tests were conducted as per IS 2720 Part 7 .

Table 1. Property of Cochin Marine Clay

Property of soil	Marine Clay
Specific gravity	2.16
Liquid limit (%)	52
Plastic limit (%)	28
Plasticity index (%)	24
Shrinkage limit (%)	12
Max dry density (g/cc)	1.683
OMC(%)	31.70
UCS (kPa)	4.2

4 RESULTS AND DISCUSSIONS

4.1. Compaction Characteristics

The optimum moisture content and dry density of soil with various percentage of coir pith (0%, 0.5%, 1.0%, 1.5%, 2.0%, 2.5% and 3.0% of dry weight of soil) and of coir fibre (0%, 0.2%, 0.4%, 0.6%, 0.8% and 1.0% of dry weight of soil) were determined by performing the Standard Proctor test as per IS 2720 Part VII (1980) .

When pith content increases dry density decreases which is in line with the study conducted by Jayasree *et al.* (2013). When pith content increases, OMC decreases in the beginning and thereafter increases. Jayasree *et al.,* (2013) has reported that OMC increases with the addition of pith. Least OMC corresponds to a pith content of 1.5% and is about 22%. So optimum pith content is arbitrarily taken as 1.5%.

As fibre content increases, it has been observed that the dry density decreases. The behaviour observed in previous study conducted by Jayasree *et al.* (2013) was that there is a nominal increase in dry density as fibre content increases. OMC found to decrease with fibre content till 0.8% fibre and thereafter an increase in trend. Hence, optimum fibre content is arbitrarily taken as 0.8%.

4.2 Shear strength characteristics

UCC tests were conducted by varying coir pith content in the range of 0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0% and coir fibre content by 0, 0.2, 0.4, 0.6, 0.8, 1.0 % of dry weight of soil as per IS 2720 part 10(1973) . Tests were conducted at maximum dry density and optimum moisture content. Unconfined compressive strength (UCS) ratio is the ratio of unconfined compressive strength of the treated soil to that of the plain soil.

Addition of both fibre and pith in isolation will increase the UCS value of clayey soil till the pith and fibre contents are 0.5% and 0.8% respectively, thereafter it decreases. The increase in strength was found to be 5.98 times and 7.71 times that of plain soil for pith and fibre mixing respectively. The variation of UCS ratio with varying percentages of coir pith and coir fibre is shown in Fig. 1.

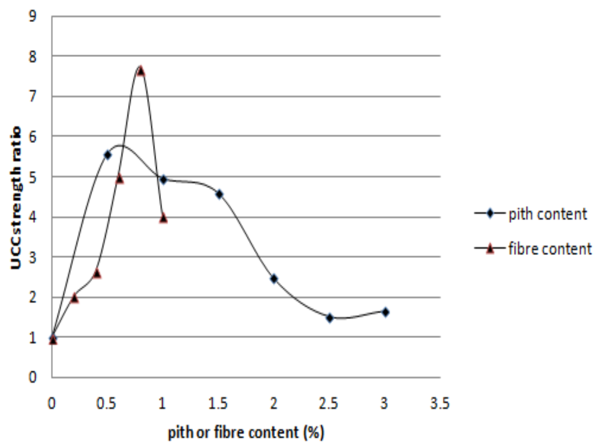

Fig. 1 Variation of UCS ratio with pith and fibre content

4.3 *Effect of curing on shear strength of soil*

Samples were prepared at maximum dry density and optimum moisture content and kept in air tight bags and dipped in water for conducting UCC tests by treating it with coir pith and coir fibre. Prepared specimens were tested after a curing period of 1 week, 2 weeks, 3 weeks, 6 weeks and 12 weeks respectively.

Addition of both fibre and pith in isolation and curing the specimen for one week will increase the UCS value of clayey soil till the pith and fibre contents are 1% and 0.8% respectively, thereafter it decreases. Uncured specimen treated with pith has shown a peak UCS at 0.5%, whereas with fibre, curing doesn't influenced the percent content and it remained at 0.8%. Experiments were repeated at 2nd , 3rd ,6th and 12th week of curing and the same trend was observed. The maximum UCS strength ratio for different curing period is summarized in Table 2. Peak UCS ratio for varying percentages of pith and fibre is shown in Table 3.

Table 2. Variation of peak UCS ratio with curing

Curing period (weeks)	Peak UCS ratio at		Peak UCS ratio value	
	% pith	% fibre	% pith	% fibre
0	0.5	0.8	5.97	7.71
1	1	0.8	6.44	8.73
2	1	0.8	6.80	9.10
3	1	0.8	7.2	9.55
6	1	0.8	6.27	8.84
12	1	0.8	5.79	8.16

Table 3. Peak UCS ratio for varying percentages of pith and fibre

Combinations	Curing period corresponds to peak UCS strength ratio (weeks)	Peak UCS strength ratio
1% pith+99% soil	3	7.2
1.5%pith+98.5% soil	3	6.76
2% pith+98% soil	3	6
3% pith+97% soil	6	4.47
0.2%fibre+99.8% soil	3	6.95
0.4%fibre+99.6% soil	3	7.97
0.6%fibre+99.4% soil	3	8.34
0.8%fibre+99.2% soil	3	9.55
1% fibre+99% soil	2	6.75
1.5% pith + 0.8% fibre+97.7% soil	2	5.71

The variation of UCC strength ratio with pith content and fibre content at different curing period is shown in Figs. 2 and 3 respectively.

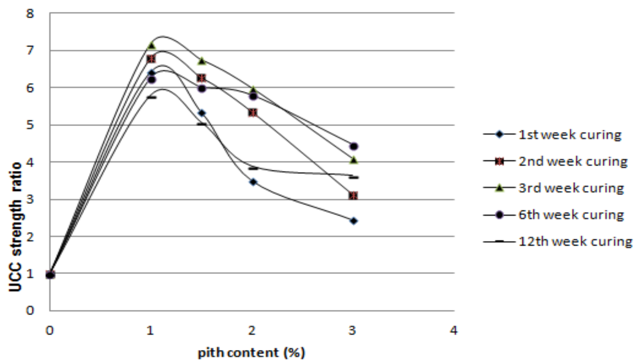

Fig. 2 Variation of UCS ratio with pith content at different curing.

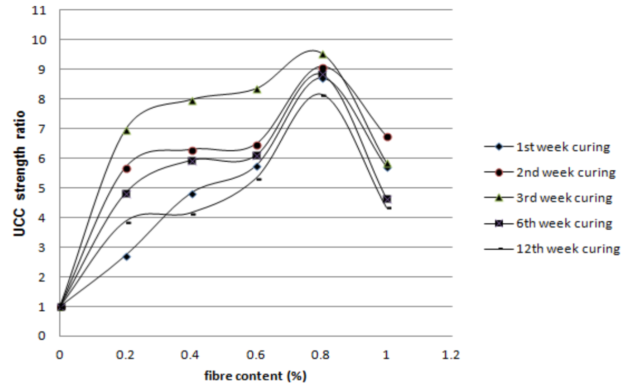

Fig. 3 Variation of UCS ratio with fibre content at different curing.

It can be observed that for the mix (1.5% pith + 0.8% fibre), peak UCS value is at 2nd week of curing. Curing of soil with varying percentages of pith content alone shows a peak UCS value at 3rd week of curing, except 3%, which has shown a peak at 6th week of curing. Similarly, the cured samples with varying percentages of fibre content alone shows a peak UCS value at 3rd week of curing, except 1%, which has shown a peak at 2nd week of curing.

The optimum percentage of pith was found to be 1.5% pith content from compaction and 1% as optimum from the curing results. The optimum percentage of fibre was found to be 0.8% from the compaction results and also from curing results.

4.4 Triaxial tests

Unconsolidated Undrained triaxial tests were conducted at 1% pith, 1.5% pith, 0.8% fibre , a mix of 1% pith & 0.8% fibre and also a mix of 1.5% pith & 0.8% fibre. Tests were conducted on three identical specimens at confining pressures 50 kPa, 100 kPa and 150 kPa. Test results for the optimum percentages of coir pith and coir fibre is given in the Table 4.

Table 4. Triaxial test results for the optimum percentages of coir pith and short coir fibre.

Values	Plain soil	1% pith	1.5 % pith	0.8 % fibre	1.5% pith &0.8 % fibre	1% pith & 0.8 % fibre
Cohesion, C(kPa)	12.5	19.5	17.5	25	6.5	8.4
Angle of friction, ϕ	4.6º	8.5º	5.4º	12º	24.5º	27º

When the soil is treated with optimum pith contents, it was found that the cohesion value and the angle of friction increases. The same trend has been observed for the soil treated with optimum fibre. When the soil is treated with the combination mix of pith and fibre, it was observed that the cohesion value decreases and the angle of friction increases.

4.3 Permeability characteristics

Variable head permeability tests were conducted by varying coir pith content and coir fibre content. The permeability test results for soil with varying percentages of coir pith and coir fibre is shown in Table 5

Table 5.. Coefficient of Permeability for varying percentages of coir pith and coir fibre

Combinations	Coefficient of Permeability (cm/s)
0.5% pith + 99.5% Soil	$1.2755 * 10^{-5}$
1% pith + 99% Soil	$1.4153 * 10^{-5}$
1.5% pith + 98.5% Soil	$2.093 * 10^{-5}$
2% pith + 98% Soil	$2.385 * 10^{-5}$
2.5% pith + 97.5% Soil	$2.648* 10^{-5}$
3% pith + 97% Soil	$4.92 * 10^{-5}$
0.2% fibre + 99.8% Soil	$1.32 * 10^{-5}$
0.4% fibre+ 99.6% Soil	$2.517 * 10^{-5}$
0.6% fibre + 99.4% Soil	$2.8 * 10^{-5}$
0.8% fibre + 99.2% Soil	$3.442 * 10^{-5}$
1% fibre + 99% Soil	$2.15 * 10^{-5}$

It can be observed that the coefficient of permeability increases with the pith content. With the addition of coir fibre, coefficient of permeability increases upto 0.8% fibre and then decreases.

5 CONCLUSIONS

In the present study, the suitability of coir waste to improve the geotechnical characteristics is studied. According to the test results, the following outcomes can besummarized.

Dry density of the clay is decreasing with increase in pith and fibre content. Shear strength in terms of UCS was found to increase and reaches a peak at 0.5% pith and 0.8% fibre, thereafter it decreases with further treatment. As the pith and fibre absorbs water and also there is a possibility of chemical action with clay, the time dependent strength shown a peak value at 21st day of curing for varying percentages of pith and fibre content, except for 3% pith and 1% fibre, which has shown a peak at 42nd day and 14th day respectively. When the soil is treated with the optimum pith content , it has been found that the cohesion value and the angle of friction increases. The same trend has been observed when the soil is treated with optimum fibre content. When the soil is treated with the combination of pith and fibre, it has been found that the cohesion value decreases and the angle of friction increases. With the addition of coir fibre, coefficient of permeability increases upto 0.8% fibre and then decreases.

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