

Expansive soil stabilization with coir waste and lime for flexible pavement subgrade

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Abstract. Expansive soil properties can be improved by various methods to make it suitable for construction of flexible pavement. The coir pith is the by-product (bio-waste) generated from coir industry during extraction of coir fiber from coconut husk. Openly disposed coir pith can make the surrounding areas unhygienic. This bio-waste can be one of the potential materials to stabilize the expansive soils. In the present study coir pith and lime are used as stabilizers. Different combinations of coir pith contents (1%, 2% and 3%) and lime contents (2%, 3% and 4%) are used to study the behavior of expansive soil. Unconfined compressive strength (UCS) of unstabilized and stabilized soils was determined. Optimum content of coir pith and lime are determined based on UCS of the soil. California bearing ratio of soil determined at optimum contents of coir pith and lime. Flexible pavement layer compositions for two levels of traffic using stabilized soil subgrade.

1. Introduction

These Design and construction of pavements over the expansive and soft soil subgrades has always been a challenging task. As the soil possess low bearing capacity and high swelling behaviour many sites need the improvement in soil properties to make it eligible for pavement construction. There are many alternate methods available to handle the problem of expansive soils that include complete or part replacement of subgrade soil, in-place mechanical modification of soil with better soil, treatment with chemical or cementitious or polymeric stabilisers, providing geotextiles and recently mixing with synthetic fibres. However one of the world wide popular methods is to treat the soil with lime to reduce swelling and plasticity and improve the strength.

Coir pith a by-product generated in the process of fiber extraction from coconut husk in coir manufacturing industry. India is the largest coir producing country in the world. And the fact is that for every ton of fiber extracted, about two tons of coir waste is produced. Disposal of this bio-hazardous material into the environment create unhygienic conditions nearby open places of coir industries and posing a serious threat to the sustainable development of coir industry. Most of the subgrade soils need improvement because of its poor strength and expansive nature in the region (coastal India) where coir pith is produced. Engineered utilisation of coir pith can reduce the disposal problem and environmental pollution. Researchers have investigated potential use of coir pith in subgrade soil with marginal improvement in subgrade strength [6, 12, 16], however there are no studies to investigate the potential use of coir pith in combination with lime. In the present study a combination of selected coir pith content with selected lime content are used to improve the expansive soil to use it in flexible pavement subgrade.



2. Literature review

Successful trails reported [14] on the use of coir geotextiles to stabilise and reinforce flexible pavements with poor subgrades. Also the use of coir geotextile found to be very effective for erosion control and even under sea water for mud wall protection [15]. Many studies available in the literature on random reinforcement and change in expansion behaviour of the soil using coir pith [1, 2, 3, 6, 11 and 13]. Coir pith found to be effective in controlling swell pressure and improving strength properties [7, 8 and 9]. There is no provision in the practicing MORD rural road manual [10] to incorporate coir pith into the flexible pavement subgrade.

Specifications for road and bridge works of Indian Road Congress specifies not to have a soil neither in embankment nor in subgrade if it has a free swell index exceeding 50%. Flexible pavement design guidelines are available for soil subgrades with minimum CBR of 2% and above for low volume rural roads (IRC SP 72 2007) and for highways 3% and above. The subgrade shall have a minimum CBR of 8% for the soil to be used in the highway pavement with a traffic of 450 commercial vehicles per day and above (IRC 37 2012). In the present study a combination of lime and coir pith in different proportions mixed with expansive soil to understand the combined effect of stabilization and reinforcement. An effort is made to make the soil eligible to use in subgrade for flexible pavement construction.

3. Experimental work

3.1. Soil

Sample of soil is collected from nearby site and is prepared for the tests following the preparation procedure as per IS 2720 part 1 and appropriate representative quantity of soil for each test is taken. Table 1 presents the characteristic properties of the soil with the reference code followed to perform the test.

Table 1 Properties of un-stabilised soil sample

S.No.	Property	Value	Reference IS code
1	Specific gravity	2.566	2720 Part 3
2	Plastic limit	33%	2720 Part 5
3	Liquid limit	56%	
4	Plasticity index	23%	
5	Free swell index	50%	2720 Part 40
6	Grain size analysis		2720 Part 4
	Clay and silt content	75.3 %	
	Sand content	24.7 %	
7	Optimum water content (OMC)	19%	2720 Part 8
	Maximum dry density (MDD)	1.780 g/cc	
8	pH	8.2	2720 Part 26
9	Unconfined compressive strength	160.8 kPa	2720 Part 10
10	California Bearing Ratio (CBR)	1.04 %	2720 Part 16

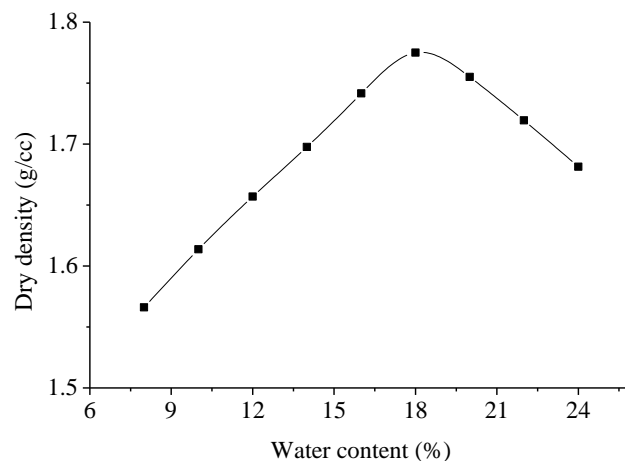


Figure 1 Variation of dry density with water content of untreated soil

3.2 Coir pith

Coir pith is generated after removal of useful fibres from the coconut husk collected from the local market and is air dried for 48 hours to remove the moisture. Figure 2 shows the photograph of the coir pith sample passing 4.75 mm IS sieve used in the study.



Figure 2 Photograph of the coir pith sample passing 4.75mm IS sieve after air drying

3.3 Lime

Slaked lime procured from local market with 98% passing through 75microm IS sieve is used in this study.

3.4 Scheme of Tests

From the experiments conducted by [6] concluded that for an expansive soil optimum coir pith content is in the range of 1.5% to 2% to increase the CBR. Table 2 presents the scheme of compaction tests and UCS test to be conducted with different contents of coir pith and lime in combination with expansive soil. The combinations are selected based on literature review [12] and experience.

Table 2 scheme of tests with different combinations of lime and coir pith

Test ID	Coir Pith quantity, %	Lime quantity, %
1	0	0
2	1.5	2.0
3	1.5	3.0
4	1.5	4.0
5	1.0	3.0
6	2.0	3.0
7	3.0	3.0

4. Results and discussion

The relation between moisture content and density determined following standard Proctor procedure IS 2720 P8. The variation of density with water content for different contents of coir pith at fixed content of lime 3% is plotted in the figure 3. The figure shows that increase in coir pith content reduces the density and increases the optimum water content. Spongy and moisture absorbing nature of coir pith with its lower specific gravity causes significant reduction in the dry density i.e. from 1.780 g/cc to 1.550 g/cc and increase in optimum water content i.e. from 19% to 24% at a fixed lime content. Figure 4 shows the variation of dry density and optimum water content with change in lime content at 1.5% of coir pith content. It is observed that the increase in the lime content reduces the dry density and increases the optimum water content when the coir pith content was kept constant and the trend is very similar to the soil lime mix.

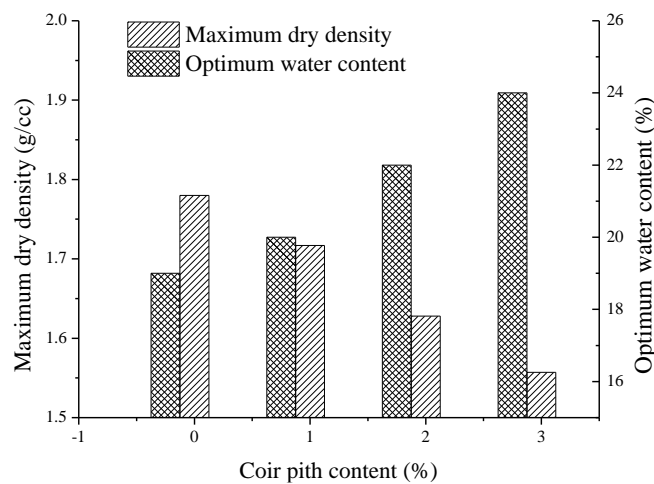


Figure 3 Variation of MDD and OMC with different contents of coir pith at 3% lime

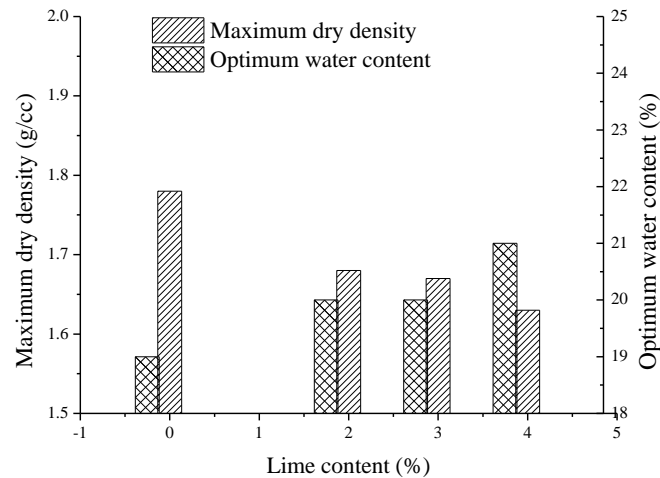


Figure 4 Variation of MDD and OMC with different lime contents at 1.5% coir pith

4.1 Variation of Unconfined Compressive Strength

Unconfined compressive strength (UCS) is defined as the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. The specimen of 38mm diameter and 76mm long were prepared corresponding to optimum moisture content and maximum dry unit weight values for each combination. Cured specimens tested in strain controlled mode at a deformation rate of 1mm per minute, figure 5 shows the photograph of tested specimen. Addition of coir pith and lime to the expansive soil increased the UCS from 160 kPa to a maximum of 570 kPa at a coir pith content of 2% and lime of 3% after 7 days curing. Variation of 3 days and 7 days cured specimen UCS with coir pith content at a fixed 3% lime content is shown in figure 6. With the increase in coir pith content at a fixed lime content of 3% the UCS of soil increases to some extent and then decreases in both the cases of 3 days and 7 days curing and the same trend is observed by [7]. The reason for the reduction in UCS at higher coir pith contents could be the reduced interaction between soil particles. Figure 7 shows the variation of the UCS of 3 days and 7 days cured specimen at a fixed coir pith content of 1.5% and different lime contents (2%, 3% and 4%). Increase in lime content causes increase in UCS. There is an increase in UCS of 40% to 80% from 3 days to 7 days curing period.



Figure 5 Failed specimens after UCS test showing shear failure

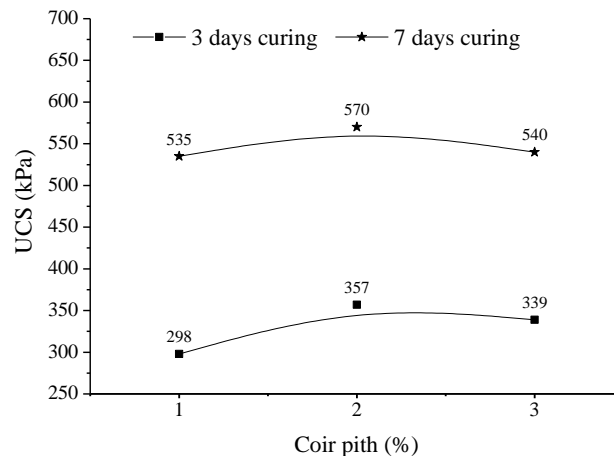


Figure 6 Variation of UCS with different coir pith contents, 3% lime after 3 days and 7 days curing

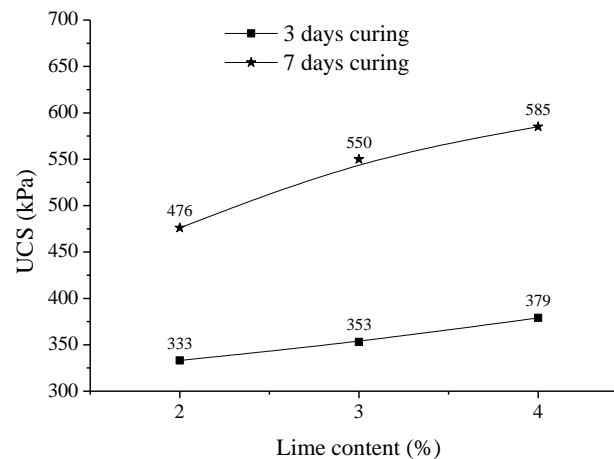


Figure 7 Variation of UCS with lime content at 1.5% coir pith after 3 days and 7 days curing

4.2 California bearing ratio (CBR) of subgrade soil

The pH value of the 3% and 4% lime treated soil found to be 12.1, hence the soil is treated with 3% lime and mixed with 1.5% and 2% coir pith to determine CBR value of treated soil. The CBR specimen prepared at their corresponding optimum water content and maximum dry density to determine 4 days soaked CBR following the dynamic compaction procedure as per IS 2720 P16. Figure 8 shows the plot of variation of load with penetration for treated and untreated soil specimen. CBR of the treated soil found to be 7% and 9% for 1.5% coir pith content with 3% lime and 2% coir pith content with 3% lime respectively.

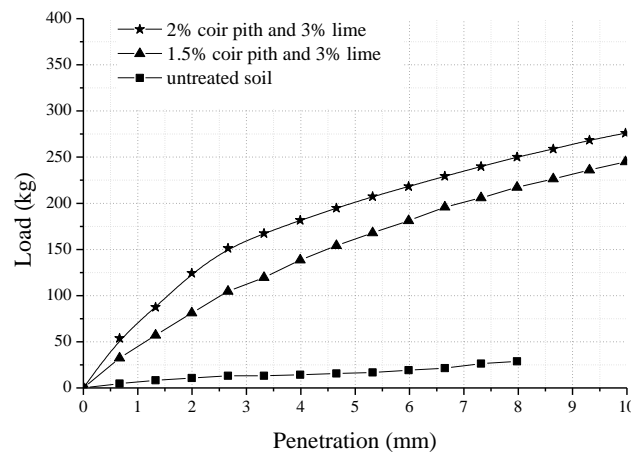


Figure 8 Plot of penetration with load for untreated and treated soil

4.3 flexible pavement design

Flexible pavement structure designed using Indian Road Congress guidelines (IRC 37 2012) for two different traffic levels viz, 10 MSA and 50 MSA. Improved subgrade soil CBR of 7% and 9% is considered in the design. Table 3 summarises the pavement composition above the treated subgrade of thickness 500mm for selected traffic levels and subgrade CBR.

Table 3 summary of pavement composition design for different traffic

S.NO.	Subgrade CBR, %	Traffic level, MSA	Pavement composition	
			Layer type	Thickness, mm
1	7	10	Bituminous Concrete	40
			Dense Bitumen Macadam	60
			Wet Mix Macadam	250
			Granular Sub-base	230
2		50	Bituminous Concrete	40
			Dense Bitumen Macadam	100
			Wet Mix Macadam	250
			Granular Sub-base	230
3	9&10	10	Bituminous Concrete	40
			Dense Bitumen Macadam	50
			Wet Mix Macadam	250
			Granular Sub-base	200
4		50	Bituminous Concrete	40
			Dense Bitumen Macadam	95
			Wet Mix Macadam	250
			Granular Sub-base	200

5. Conclusions

After completion of the experimental work and result analysis on the expansive soil treated with coir pith and lime following conclusions are drawn

- Increase in coir pith content causes the reduction in density and increase in optimum water content
- Addition of lime to expansive soil reduces the swell index and makes the soil to be eligible for use in subgrade
- Unconfined compressive strength of the modified soil (expansive soil + lime + coir pith) is in the range of 300 kPa to 380 kPa after 3 days curing, and after 7 days curing it is in the range of 470 kPa to 570 kPa
- Combined effect of lime and coir pith inclusion in to the soil causes significant increase in CBR from 1.04% to 9%.
- It is a potential technique that can improve the quality of soil from very poor and unsuitable condition to fair and suitable for use in subgrade and reduce the disposal problem of coir pith
- After modification with lime and coir pith the soil can be utilised as subgrade for highways with improved CBR of 8% and above.

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