Experimental Investigation on Effect of Coconut Shell Powder on Index Properties of Lime Treated Black Cotton Soil

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Abstract: *The present paper reports the results of laboratory investigation on effect of Coconut Shell Powder (CSP) on lime treated Black cotton (BC) soil. The soil modified with 2%, 4%, 6%, 8% and 10% of lime is studied to get the optimum content of lime. It is then treated with various different dosages of Coconut Shell Powder (CSP). Atterberg limits, Compaction and Free Swell Index (FSI) tests were conducted. The liquid limit of the soil lime mixture treated with different dosages of CPS decreases with curing period while the plastic limit and shrinkage limit increases with curing period. Further studies on the strength and durability of the mixtures are needed to evaluate for long-term performance.*

Keywords: *Atterberg limits, Black cotton (BC) soil, Compaction, Free Swelling Index (FSI), Lime, Coconut Shell Powder (CPS)*

1. Introduction

Expansive soils occur in semi arid and arid regions of the world. These soils are very well known for their swell-shrink behaviour whenever there is a change in moisture content [4]. Expansive soils are clays of high plasticity. They predominantly contain montmorillonite clay mineral, which is the most unstable clay mineral. Thus the soils have high expansive nature [6]. Expansive soils are problematic because of less strength, low permeability and higher compressibility. Lime is a traditional stabilizer but it has a negative impact on the environment and, thus, its use is discouraged now-a-days [1]. Coconut shell powder (CSP) soil stabilizers are available in powder form and are available by grinding coconut shell [7]. Coconut has its scientific name as Cocosnucifera. Early Spanish explorers called it coco, which means “monkey face” because the three indententations (eyes) on the hairy nut resembles the head and face of a monkey. [9].The addition of lime 4 to 6% of lime substantially improves the engineering properties of BC soil [5]. coconut shell powder is made from coconut shells and is used as a filler in the manufacturing of thermoset moulding powders like bakelite, synthetic resin glues or phenol formaldehyde. Mesh size of 80-100 is suitable for thermoset moulding powder whereas for synthetic resin glues, the size has to be around 230-240 mesh. Product provides substantial value-addition as normally shells are either thrown away or used as a fuel. Coconut shell Powder is mainly used as filler and thus it is an industrial product. [3]. Reactive lime changes the soil properties by cation exchange mechanism rather than the binding action brought by pozzolanic reaction. To improve the engineering properties of soil, it is feasible to add CSP and lime together since both uses the same mechanism of cation exchange [2].

2. Materials and Experimental Programme

The BC soil used in the present research work is obtained from Raichur district, Karnataka State, India. Then the soil is powdered in the ball mill and sieved through 425 micron sieve. The geotechnical properties of BC soil are presented in table 1 .Figure 1 show the BC soil used for the present work

Table 1 Geotechnical properties of BC soil used in present study

Soil property		Value
Distribution of grain size	Percentage of fine sand size	14
	Percentage of silt size	25
	Percentage of clay size	61
Specific gravity of soil solids		2.78
Consistency limits	Percentage of liquid limit	75
	Percentage of plastic limit	31
	Percentage of shrinkage limit	9
Plasticity Index (%)		44
Compaction parameters of IS standards	Percentage of optimum moisture content, OMC	28
	Maximum dry unit weight (MDU) in percentage, (kN/m^3)	14
Free Swell Index (%), FSI		80

Fig. 1 BC soil used in the research work

Coconut Shell Powder is made from coconut shells and is used as filler in the manufacturing of thermoset moulding powders like bakelite, synthetic resin glues or phenol formaldehyde. Mesh size of 80-100 is suitable for thermoset moulding powder whereas for synthetic resin glues, the size has to be around 230-240 mesh. Product provides substantial value-addition as normally shells are either thrown away or used as a fuel. Coconut shell Powder is mainly used as filler and thus it is an industrial product.
It is used in the manufacture of thermoset moulding powders such as phenol formaldehyde moulding powder or bakelite and synthetic resin glues. Powder of different particle size is required for different end-uses. Yet another favorable aspect of Coconut Shell Powder is that it is comparatively cheaper filler and hence preferred for many applications.

3. Experimental Procedure

All tests were conducted according to procedures specified in respective Indian Standard (IS) code. The consistency limits, Compaction and FSI tests on soil modified with 2%, 4%, 6%, 8% and 10% of lime were conducted to find the optimum dosage of lime. Further, optimum dosage of lime-soil mixture is treated with different dosages of CSP.

4. Results and Discussion

4.1 Atterberg limits of BC soil treated with various dosages of lime

The tests were conducted to find the Atterberg limits of soil alone and soil- lime mixture for immediate and 7 –day cured sample. Lime is added to soil at an increment of 2% up to 10%. The results obtained are as shown in table 2

Table 2 Atterberg limits of BC soil treated with lime mixtures for different curing periods

Lime added (%)	Percentage of liquid limit		Percentage of plastic limit		Percentage of shrinkage limit	
	Curing periods		Curing periods		Curing periods	
	Immediate	7- day	Immediate	7- day	Immediate	7- day
0	75	75	31	31	9	9
2	68	70	34	40	15	19
4	59	65	35	45	17	20
6	55	63	35	47	20	27
8	52	60	36	48	21	32
10	50	58	37	48	22	39

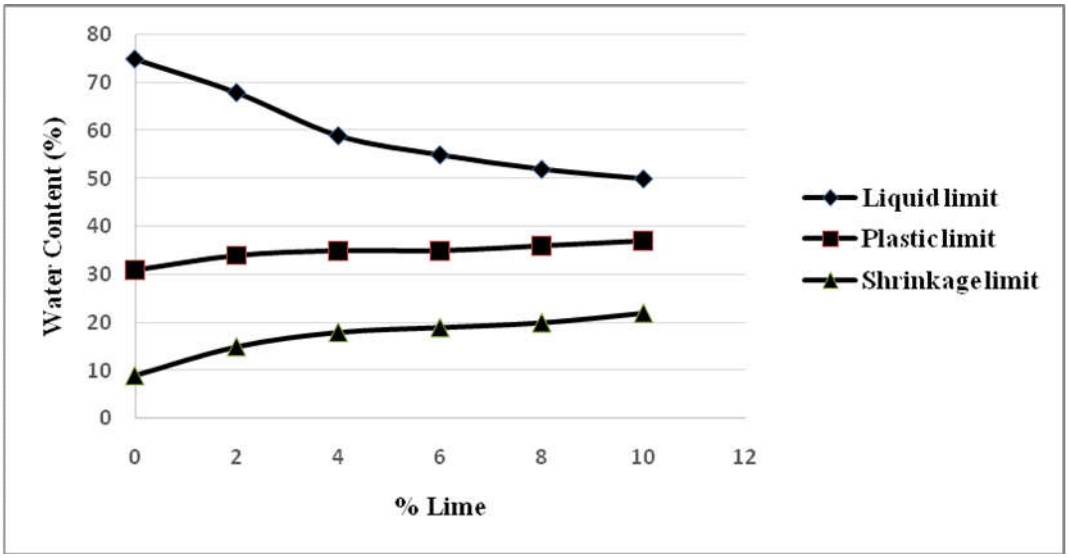

Fig. 2 Variation in Atterberg limits of BC soil treated with various dosages of lime for immediate testing

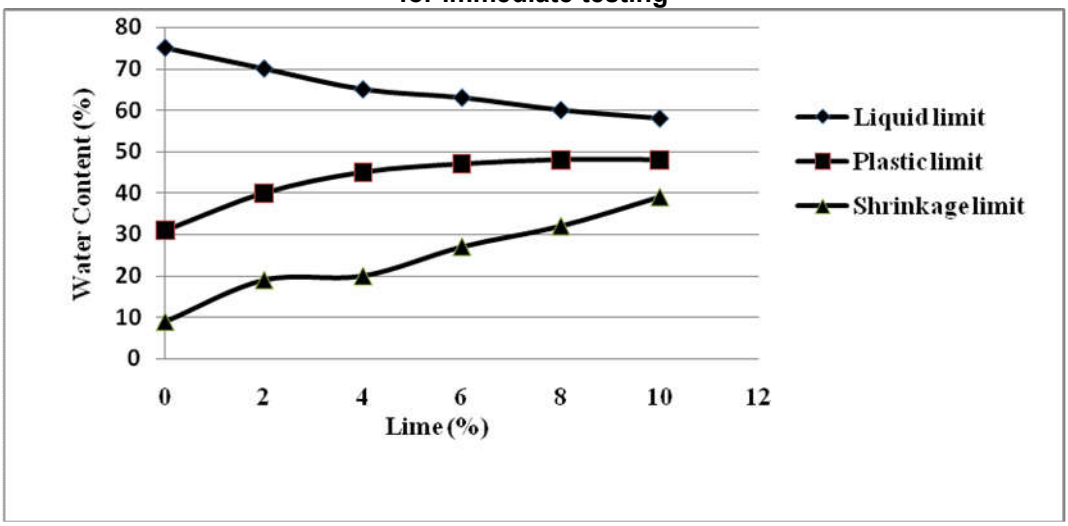

Fig. 3 Variation in Atterberg limits of BC soil treated with different dosages of lime for 7-day curing

Figures 2 and 3 show that, the liquid limit of treated soil marginally decreased with the increase in dosage of lime while the plastic limit and shrinkage limit increased for immediate and 7- day curing. This is due to the reduction in surface area, clay content and improved gradation in soil-lime mixtures.

4.2 Compaction behaviour of lime treated BC soil

The variation in MDU and OMC of BC soil treated with various dosages of lime is as shown in figure 4

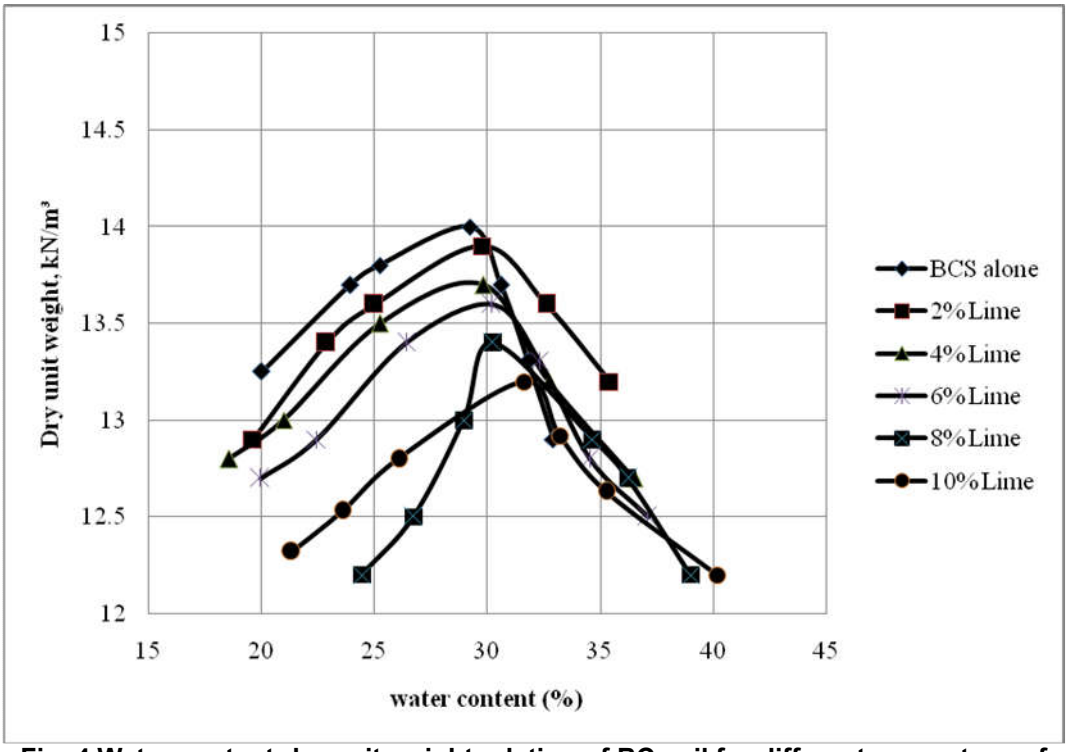

Fig. 4 Water content-dry unit weight relation of BC soil for different percentage of lime

From the figure 4, it was observed that, slight reduction in MDU upto 6% addition of lime and beyond 6%, there is a considerable reduction in MDU. OMC increased slightly upto 6% lime and considerable increase in OMC was observed beyond that point. This is due to the introduction of lime, the soil structure becomes flocculated and water holding capacity increases which results in increasing optimum moisture content

4.3 Swelling behaviour of lime treated BC soil

Free Swelling Index (FSI) is an important property of BC soil and it shows the shrink-swell behaviour of expansive soil. It is the increase in volume of given soil without any external constraint when it is subjected to submergence in water. The variations in FSI for soil treated with different dosages of lime soil mixture are presented in table 3.

Table 3 FSI of BC soil treated with different dosages of lime

Lime content (%)	FSI (%)
0	80
2	67
4	53
6	28
8	20
10	15

With the above results of Index properties and FSI, it can be observed that 6% addition of lime decreased the liquid limit and Plasticity Index. Beyond 6% further increase of lime content does not have the significant effect on the atterbergs limits. Hence, 6% lime (6% L) can be considered as optimum percentage for soil-lime mixture.

Further studies were conducted to find the effect of different dosages of CSP on BC soil treated with optimum content of lime (6%)

4.4 Consistency limits of BC soil + 6% L treated with various dosages of CSP

Based on the above results, 6% lime content is considered as optimum dosage. Further soil-lime mixture is treated with different dosages of CSP to improve the soil properties to a significant scale. Consistency limits of 6% lime - BC soil mixture treated with different dosages of CSP is found for immediate and 7- day curing period. Results obtained are as shown in table 4. Figure 5 and 6 shows Atterberg limits variation of 6% lime - BC soil mixture treated with various dosages of CSP for immediate and 7-day testing

Table4 Consistency limits of (BC Soil+6%Lime) mixture treated with Different dosages of CSP

CSP Content (%)	Liquid limit (%)		Plastic Limit (%)		Shrinkage Limit (%)	
	Curing periods		Curing periods		Curing periods	
	Immediate	7 days	Immediate	7 days	Immediate	7 days
0	59	72	42	38	38	41
3	57	52	37	35	30	36
5	60	56	38	38	26	31
7	64	60	36	40	23	28
9	66	62	39	39	22	25

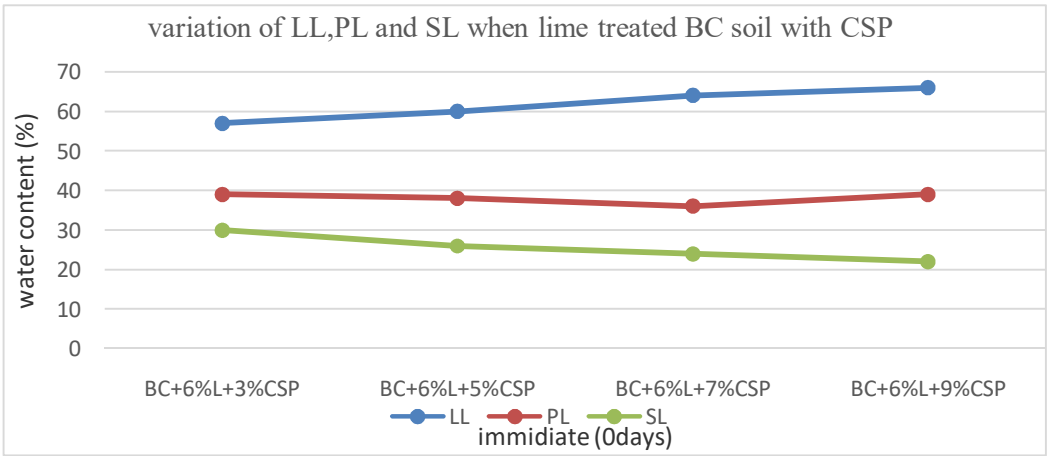

Fig. 5 Variation in Atterberg limits of BC soil – 6% lime mixture treated with various dosages of CSP for immediate testing

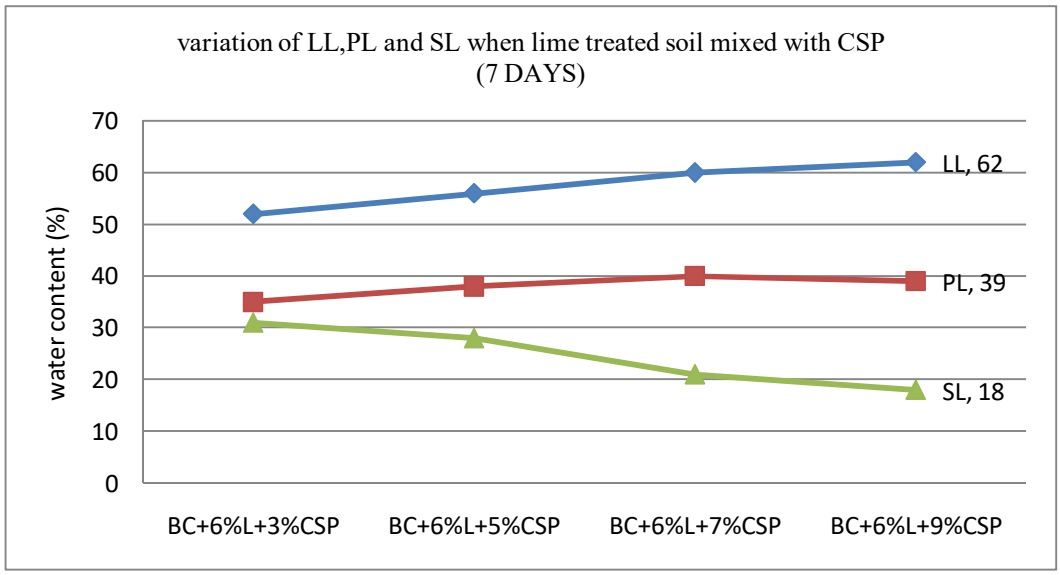

Fig. 6 Variation in Atterberg limits of BC soil – 6% lime mixture treated with various dosages CSP for 7-day testing

From the figures 5 and 6, it was observed that, with increase in percentage of CSP from 3% to 9% the liquid limit of Soil-lime mixture has been increased from 57% to 66% for immediately tested samples and that for 7 days cured sample the liquid limit has been increased from 52% to 62%. This shows that liquid limit increases with increase in lime sludge content. Increase in liquid limit is due to depression of diffused double layer thickness associated with clay particle. From the figure it is also observed that for a given percentage of CSP there is an increase in liquid limit for uncured and 7 days cured samples. With curing Soil structure is converted into flocculated one, water holding capacity as well as shear strength increases and this in turn results in increased value of liquid limit

4.5 Compaction characteristics of BC soil + 6% lime treated with various dosages of TZ

Compaction test were carried out on BC soil- 6% lime (optimum dosage) mixture treated with CSP content varying from 1 to 9 % at an increment of 2%. Figure 7 shows water content-dry unit weight relationship for BC soil - 6%lime mixture treated with CSP

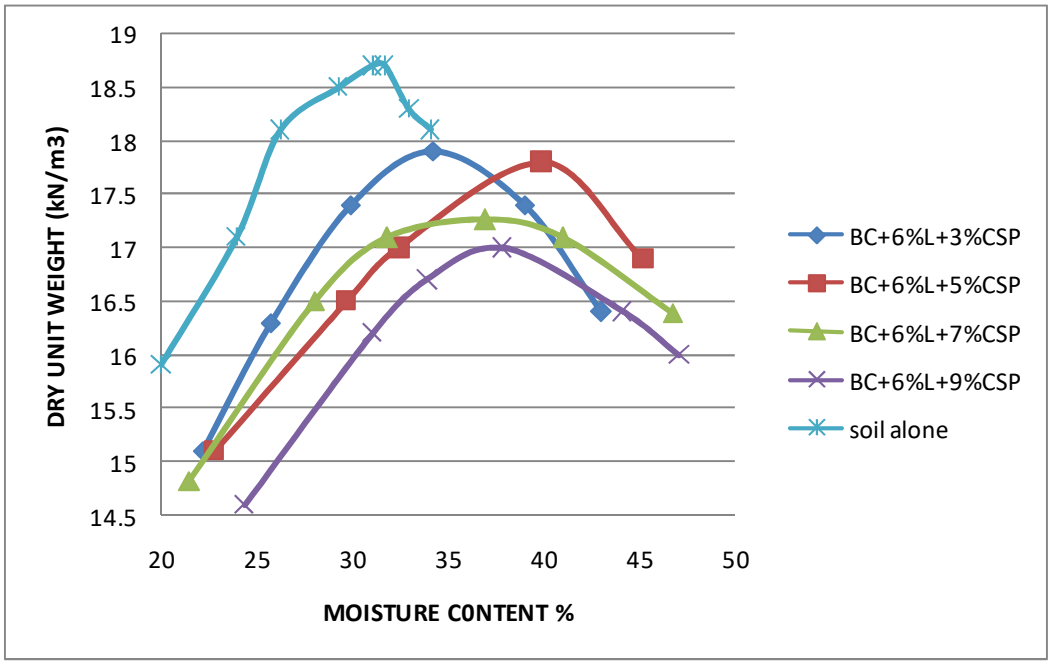

Fig.7 Dry unit weight –water content relationship for BC soil-6%lime mixture treated with CSP

Increase of maximum dry density at 3%CSP and considerable decrement in MDD is observed with further addition of CSP treated (Soil+6%LIME) mixture. Figure 5.8 presents variation in maximum dry density of Soil-lime mixture treated with CSP. From the figure, it can be inferred that maximum dry density increased at 3% CSP then dry density decreased with addition of Lime Sludge. The decrease in maximum dry density is due to flocculation of particles.

4.6 Swelling charecteristics of BC soil + 6% lime treated with different dosages of CSP

In order to reduce the expansive nature of BC soil to a significant scale further it is treated with different dosages of CSP. FSI tests were conducted on BC soil - 6% lime mixture modified with varying dosages of CSP. The variation in swelling for BC soil - 6% lime mixture treated with various dosages of CSP are presented in table 5

Table 5 FSI of BC soil+6% lime mixture treated with different dosages of CSP

CSP Content (%)	Free Swell Index (%)
1% CSP	31
3% CSP	29
5% CSP	22
7% CSP	21
9% CSP	19

5. Conclusions

From the present study the following conclusion can be drawn.

On treating the BC soil with different dosages of lime, the plasticity index decreases and the shrinkage limit increases. This is due to flocculation of particles that suppressed the thickness of diffused double associated with clay particles. On treating expansive black cotton soil with different dosage of CSP, liquid limit and plastic limit have increased. This may be due to the finer particle in CSP consist of higher percentage of carbon compound that leads to increase the liquid limit and plastic limit.

The FSI test results show that the expansive behaviour of the soil reduces with the addition of lime. 6% lime is considered as optimum content since the percentage decrease in swelling is higher as compared to other dosages of lime. Also, the swelling reduced appreciably for the soil-lime mixture with the addition of coconut shell powder. 5% CSP is considered as optimum content since the decrease in swelling is higher as compared to other dosages of CSP.

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6. References

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