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Strength Behavior of Lime Stabilised Soil Reinforced with Waste Plastic Strips

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Abstract. Plastic which is a waste after its usage can be useful for improving the ground properties. Black cotton soils which are problematic for construction can be utilized safely by stabilizing it with lime and reinforcing it with waste plastic. The present study deals with the strength behavior of stabilized swelling soil. Unconfined compression, triaxial and CBR tests have been conducted on the soil which is stabilized with 12% lime and mixing it with different (0.25%, 0.5%, 0.75% & 1%) proportions of plastic waste. Plastic waste used in the study is thrown plastic bottles. These plastic bottles are made into small strips and mixed with lime stabilized soil. The strength characteristics of the stabilized soil are improved enormously after mixing it with plastic waste. This method is an economical method since plastic waste which is cheap and easily available is used as a reinforcement material instead of steel stirrups, plates, geosynthetics etc.,

.**Keywords:** Plastic Waste, Black Cotton Soil, Lime.

1 Introduction

Increasing population and developmental activities force people to convert agricultural fields to roadways and railways. As most of the cultivating fields comprise of highly compressible soils, there is need to improve the properties of soils. There are many methods to improve soil, one of the best methods is soil stabilization. The main problem with highly compressible soils is their high swelling and shrinkage property. Lime can be effectively used for reducing the swelling and shrinkage property of highly compressible / expansive soils.

Because of developmental activities the problem is not only with the availability of soils but also with the waste plastics present in the landfills. Plastic products have wide range of applications. These are used as carriage bags, garbage bags, fluid containers, clothing, toys, films, wrapping materials, household and industrial products, and building materials with its more advantageous characteristics like less weight, less cost and more load carrying capacity and are used by all types of age groups of people. The usage of plastic in Geotechnical Engineering applications is one of the better methods to improve the engineering properties of soil and to control the percentage of plastic waste in environment. In the present study, an attempt is made to

use this plastic waste for improving the engineering properties of lime stabilized soil by adding plastic waste strips as reinforcement.

2 Materials and Methodology

2.1 Materials used

Soils. The soil used for the study is highly compressible soil and is abundantly available in and around Kallur, Tirupati, A.P. The soil properties are shown in Table 2.1.

Table 1. Geotechnical properties of soil

Parameters		Values
Coarse Grained fraction (%)	Gravel	4
	Sand	21
Fine Grained fraction (%)	Silt	20
	Clay	55
Specific Gravity		2.52
Liquid Limit (%)		78
Plastic Limit (%)		22
Shrinkage Limit (%)		17
Plasticity Index PI (%)		56
Classification		CH
Maximum dry density, MDD(g/mm^3)		1.56
Optimum moisture content, OMC (%)		18
Unconfined Compressive Strength(kg/cm^2)		3.09
Cohesion (kg/cm^2)		1.545
CBR % (Unsoaked sample)		9.54
CBR % (Soaked sample)		2.18
Free Swell Index (%)		80
Cohesion(kg/cm^2)		9
ϕ (Degrees)		0

Lime. Quick lime is used in the present study. For obtaining optimum lime content, P^H meter test had performed. The P^H values of various soil and lime composition. The PH values of 12.4 is taken as optimum percentage of lime if 12.4 value is not attained. So, in successive highest values of P^H the lowest percentage is taken.

Plastics. Plastic waste used in the study is thrown Kinley bottles, collected from various places in and around Tirupati. These plastic bottles are made into small strips with aspect ratio 3 and mixed with lime stabilized soil. The properties of the plastic strips and the picture of the plastic strips are given in Table 2.2 and Figure 2.1 respectively.

Table 2. Basic properties of the plastic strips

Parameters	Properties
Resin type	Polypropylene
Aspect ratio	3
Thickness	200μ
Specific Gravity	0.91
Length × Breadth(UCS& Triaxial), mm	5 × 15
Length × Breadth(CBR), mm	8 × 24

Fig.1. Water bottle and strips of plastic bottles

2.2 Soil composition indications

For easy identification of soil samples, soil composition indications are given in the Table 2.3. For obtaining optimum lime content, P^H meter test had performed. The P^H values of various soil and lime composition. The P^H values of 12.4 is taken as optimum percentage of lime if 12.4 value is not attained. Successive highest values of P^H the lowest percentage is taken.

Table 3. Soil composition indications

Soil composition	Symbol
Soil	S1
Soil + 12% Lime	S2
Soil + 12% lime +0.25% Plastic strips	S3
Soil + 12% lime +0.5% Plastic strips	S4
Soil + 12% lime +0.75% Plastic strips	S5
Soil + 12% lime +1% Plastic strips	S6

2.3 Methodology

Plastic waste strips are mixed at different percentages i.e., 0.25%, 0.5%, 0.75% and 1.0% to the dry weight of soil. Unconfined Compression test and California Bearing Ratio test are conducted to determine the strength and CBR values of soil and lime stabilized soil. Mixing of plastic strips in soil should be done carefully such that these strips are distributed uniformly in the soil. The mixing is done manually and proper care is taken to prepare a homogeneous mixture.

Unconfined compression test

The unconfined compression test gives the undrained shear strength of the soil in a simple and quick way and is determined at which the cylindrical specimen fails in compression or at 15% of strain. $q_u = P/A$

where q_u = Unconfined Compression Strength
P = Load at which the specimen fails in compression, kg
A = Corrected area of the specimen, cm^2.

Fig.2. (a) Plastic waste strips mixed soil (b) Sample prepared with plastic waste mixed soil

Figures 2.2(a) and (b) are showing soil mixed with plastic waste strips and the sample prepared. The load at which these samples fail under compression gives Unconfined Compression Strength. The UCS tests are conducted in accordance with the ASTM D5102-09 [ASTM 2009b].

Triaxial compression test

Triaxial compression test on soil measures the shear parameters of the soil. In this test, soil sample is subjected to stress all around the sample. The test is most widely used and is suitable for all types of soils. The Unconsolidated Undrained tests are conducted in accordance with the ASTM D2850-03 [ASTM 2007a].

$$S = c + \sigma \tan \Phi$$

California bearing ratio test

The California Bearing Ratio test is conducted for evaluating the suitability of the subgrade and materials used in sub-base and base course of a flexible pavement. CBR is defined as the ratio of force per unit area required to penetrate a soil mass with a circular plunger of 50mm diameter at the rate of 1.25mm/min to that required for corresponding penetration of a standard material. The specimens are prepared in a cylindrical mould of 150 mm-diameter and 175-mm height and compacted in three layers at its MDD and OMC based on the standard Proctor compaction. The tests were conducted in accordance with ASTM D1883-07 (ASTM 2007). The mould is kept under CBR testing machine and the load corresponding to the 2.5mm and 5.0mm are taken from load-penetration curve to determine the CBR Values.

$$\text{CBR Value} = (\text{Test load}/\text{Standard load}) \times 100$$

Soaked CBR tests are also conducted for examining the performance of plastic waste mixed soil when it is in its worst condition. After compacting the plastic waste mixed soil in CBR mould, the set up is kept submerged in water for about 4 days. The specimen is covered with surcharge mass to simulate the effect of overlying material. After 96 hours of submergence, it is taken out and tested to determine the soaked CBR Value.

3 Results and Discussions

The results obtained from the Unconfined Compression tests, Tri-axial tests and California Bearing Ratio tests performed on plastic waste reinforced lime stabilized soils are discussed below.

3.1 Lime stabilized soil

Plasticity of clay is changed on addition of lime and the values are tabulated under Table 3.1.

Table 4. Properties of the lime stabilized soil

Parameters	Values
Liquid Limit (%)	45
Plastic Limit (%)	18
Shrinkage Limit (%)	10
Plasticity Index PI (%)	27
Classification	CL
Maximum dry density, MDD(g/mm^3)	1.6
Optimum moisture content, OMC (%)	22
Unconfined Compressive Strength(kg/cm^2)	7.69
Cohesion (kg/cm^2)	3.84
CBR % (Unsoaked sample)	15.33
CBR % (Soaked sample)	6.32
Cohesion(kg/cm^2)	13
ϕ (Degrees)	4

3.2 Unconfined compression test

Soil samples are tested for Unconsolidated Undrained compressive strength. Variation of compressive strength with percentage of plastic strips is shown in figure 3.1 and this indicates that Unconfined Compression strength of lime stabilized soil is increased due to addition of different percentages of plastic waste.

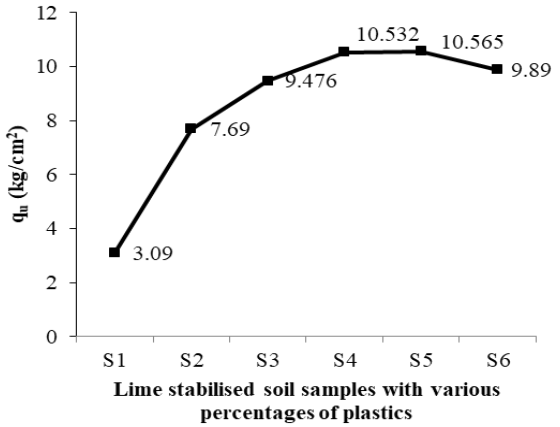

Fig.3. Variation of compressive strength with percentage of plastic strips

The increase in Unconfined Compressive strength of lime stabilized soil is due to

developed friction between soil and plastics. And also the plastic strips not allow the soil to expand by arresting the movement of the particles. Lime decreases the swelling and shrinkage characteristics and increases the size of the particle of black cotton soils thereby improves the strength. Whereas plastic strips act as additional support to increase the stability, resist the soil movement and improves the strength.

3.3 Triaxial test

The results of Tri-axial tests indicate that there is appreciable increase in C and ϕ values when lime stabilized soil is reinforced with plastic strips. Variations of shear parameters with addition of plastic strips are shown in the figures 3.2 and 3.3.
There is appreciable improvement in cohesion parameter of the soil and little variation in the angle of internal friction is observed from the given results. This is due to improvement in the bond force that is developed between the plastic strips and soil.

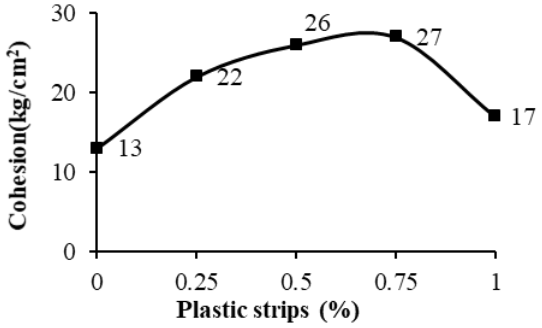

Fig.4. Increase of cohesion with increase in percentage of plastic strips

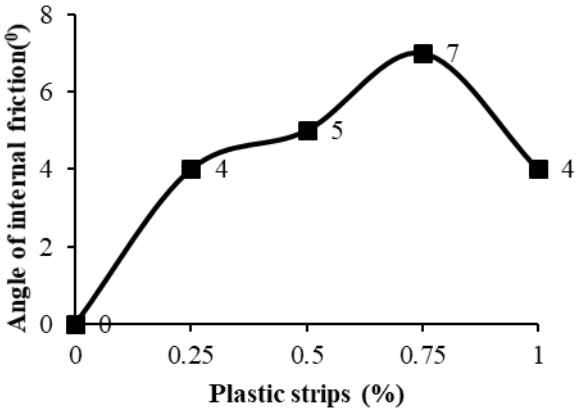

Fig.5. Variation of angle of internal friction with the increase in the plastic strips

In both UCS and triaxial compression tests there is decrease in strength, it is due to the loss of integrity between soil and plastic waste strips. This loss of integrity is due to addition of a large amount of the fiber. Addition of large amount of fibers will cause a slippage and decrease the friction between soil and fiber.

3.4 California bearing ratio tests

Unsoaked CBR test

In unsoaked CBR test, the specimens are prepared by mixing different percentages of plastic waste strips and then they are kept under CBR testing machine to determine the CBR values. CBR values of the tested specimens are represented in Figure 3.4.

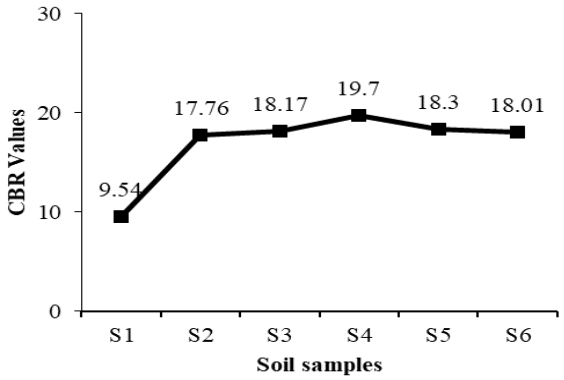

Fig.6. Variation CBR values for different soil compositions

Soaked CBR test

In soaked CBR test, after preparing the specimens, the specimens are immersed in water and soaked for 4 days to simulate the worst condition of soil. After soaking period is completed, the specimens are tested using CBR testing machine.

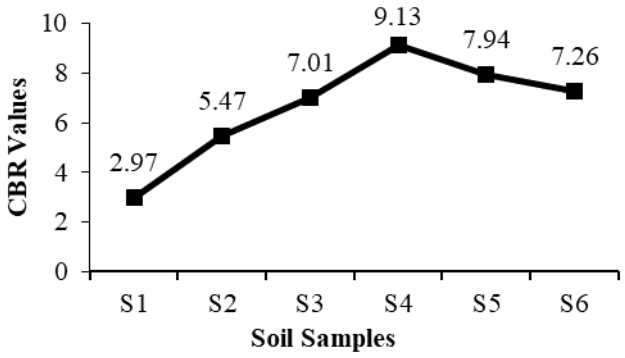

Fig.7. Variation of soaked CBR values with different soil compositions.

The CBR values of lime stabilized soils are increased with the increase in plastic waste content. This increase in CBR values are attributed to the resistance offered by the strips present in the soil. Generally, the plunger penetrates into the soil when the specimen is subjected to loading. But in case of plastic waste reinforced soil, the strips present in soil do not allow the plunger to penetrate into the soil so that the fiber reinforced soil can take more load than plain soil. The penetration resistance of the soil is increased due to the inclusion of plastic waste strips and also due to confinement effect of the mould which is not there in Unconfined Compression test.

4 Conclusions

A series of UCS tests, Tri-axial tests and CBR tests are conducted on soil stabilized with lime and reinforced with different percentages of plastic strips. The conclusions made from the present study are given below

1. Unconfined Compressive Strength of lime stabilized soil is increased to 2.48 times of unstabilised soil. And it is further increased to 1.34 times when it is reinforced with plastic waste strips.
2. Shear strength of the lime stabilized soil is increased by inclusion of waste plastic strips. Angle of internal friction is increased from 0^0 to 7^0 and cohesion from 19 kg/cm^2 to 27 kg/cm^2.
3. California Bearing Ratio values are increasing with increase in percentage of plastic waste strips for lime stabilized soils in both soaked and unsoaked conditions. The values increased from 9.54 to 19.70 for unsoaked condition and from 2.97 to 9.13 for soaked condition.
4. Thickness of flexible pavement will be reduced with inclusion of waste plastic strips in lime stabilized soil. Reduction in thickness of pavement saves significant cost of its construction.

This study has given a scope to reutilization of plastic waste in improving the geotechnical properties of soils and there by safe disposal of plastic waste. Further studies have to be carried out using different additives to make expansive soils as suitable subgrade

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