STABILIZATION OF SUBGRADE BY CEMENT WITH NATURAL ADDITIVES

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ABSTRACT

Stabilization of soil refers change or modifies the soil properties by adding suitable additives to it. Stabilization method depends upon number of factors like type of terrain, type of soil, nature of construction methods etc. The subgrade should have a strong nature so that it can carry enough loads. Effective use of additives in laterite soil will increase its strength characteristics. The usage of natural material provides environmental sustainability and they have less toxicity. Natural materials can be used as a cost effective and environmental friendly material for increasing the strength characteristics of the soil. In this study cement, plastic waste in the form of plastic strips (PS), rubber latex (RL), and coir fiber ash (CFA) were used as the stabilizing agents for laterite soil stabilization. Plastic waste in the form of plastic strips was used as the stabilizing agents. Addition of plastic strips causes an increase in strength of soil due to the ductile property of plastic. India is the second largest producer of cement. Cement act as a good binder to soil. When it comes in contact with water the soil-cement becomes harder. It provides brittleness to soil. The usage of CFA helps to reduce the environmental impact due to agricultural waste. Presence of lignin in coir fiber imparts good strength. Coir Fiber is one of the waste produced from agricultural industry. RL preserves the CFA mixed soil and thereby increase the durability of the soil mix. Series of compaction tests were conducted to get the best combination of the above mentioned additives. Apart from compaction test, unconfined compressive strength (UCS) test, California bearing ratio (CBR) test were also conducted. For the test, varying percentage of plastics and cement were added to the soil, varies from 0.4% to 1.2% and 0.5% to 3% respectively. Test results show that 0.8% plastic waste and 1% cement gives the best result. Similarly RL content varied from 5% to 30% and CFA varied from 0.5% to 4%. A combination of 25% RL and 1% CFA showed satisfactory increase in the strength of the soil.

Key-Words: Cement, coir fiber ash, plastic strips, rubber latex, stabilization.

INTRODUCTION

Stabilization of soil refers to changes or modifications brought in the soil properties by adding suitable additives. Since laterite possesses good characteristics it can be used as an engineering construction material. In this study some locally available additives were added to the soil in order to bear heavy loads and make the soil much more stable condition. In fact treated soil is now widely used for almost all types of engineering projects.

8% of cement gives better result in the case of lateritic soil. Lateritic-cement blocks can be modified using natural rubber latex. 8% of cement and 2.5% rubber content considered as optimum percentage by evaluating compressive strength and weathering resistance (Alex & Kasthurba, 2021). Applications of natural latex as additive for soil cement block production was studied by conducting in two types of soil such as laterite and sandy loam. The highest compressive strength was obtained by laterite soil treated with 5% rubber latex (Sudniran, 2021).

Addition of plastic content from 4%, 8% and 12% to the soil at different curing period of 0, 7, 14 days cause an increase in strength behaviour of soil. Optimum result obtained at a plastic content of about 8% at a curing period of 14 days. 8% of powdered plastic waste increased the dry density of soil from 1.73 g/cc to 1.91 g/cc (Thasleema et. al., 2020). To get a better bonding between rubber waste and hardened cement paste, carboxylate styrene butadiene rubber latex were added. Rubber fraction of 0.5mm had negative impact of freeze and thaw cycle. Higher closed porosity and higher durability was obtained for concrete modified with smaller fraction rubber waste (Grinys et al., 2020). Effect of plain and perforated plastic strips in soil stabilization is studied by conducting series of CBR test performed by varying percentage of plastic strips with different lengths and proportion. Optimum amount of plastic were found to be 0.6%. But the CBR value was maximum at 0.4%. Further increase in plastic content reduced the CBR value (Abhinandan et.al., 2020). Strength attained by compacted lateritic soil after adding polypropylene waste strips is studied by conducting at different sizes of polypropylene strips (10, 15, 20 and 30 mm) with varying percentage (0.25% to 2%). After adding plastic strips CBR value of clayey sand increased by 70%, but addition of plastic would not cause any significance change for clayey soil (Marcal et.al., 2020).

Almond leaf ash and cement can be used for subgrade construction (Eme et.al., 2020). For deep soil mixing mostly geopolymer binders are used as a sustainable alternative for cement. Inclusion of fibre helps to avoid the formation of cracks in the soil. Soil treated with geopolymer is mixed with a binder of 30% and it is reinforced with 1% Polypropylene fibre. This combination increased the strength and durability of the soil (Chowdary et al., 2020). Influence of waste tire rubber fibres on swelling behaviour, unconfined compressive strength and ductility of cement stabilized bentonite clay soil has been conducted by (Bekhiti et al., 2019). 2% cement mixed with granular lateritic soil is sufficient for sub-base from compressive strength criteria and 5% is suitable for base layer of the pavements (Biswal et.al., 2018). Cement stabilization enhanced the mechanical properties of laterite soil and cause a reduction of permanent strain. CBR value increased when 8% Cement/ lime and sugar cane fibre ash added on laterite soil (Charles et al., 2018).

MATERIALS AND METHODS

Materials used in the study

The materials used in the investigation are Black Cotton Soil, Sand, Cement and Terrasil chemical.

Black cotton soil

The soil is classified as highly Compressible clay, CH, as per IS: 1498(1970).

Terrasil

Terrasil is a nanotechnology based material. It is made of 100% organo-silane molecules. Terrasil Locally available lateritic soil was used in the present study. The soil is identified as Granular lateritic soil. The properties of soil used in the study were presented in Table 1. Before starting testing procedure, soil samples were oven dried and crushed. Figure 1 shows the particle size distribution curve of soil.

Table 1. Properties of soil.

Properties of soil	Value
Specific gravity	2.58
Liquid limit (%)	56.73
Plastic limit (%)	38.62
Plasticity index (%)	18.72
Shrinkage limit (%)	27.90
Maximum dry density (g/cc)	1.58
OMC (%)	22
UCS (kPa)	66

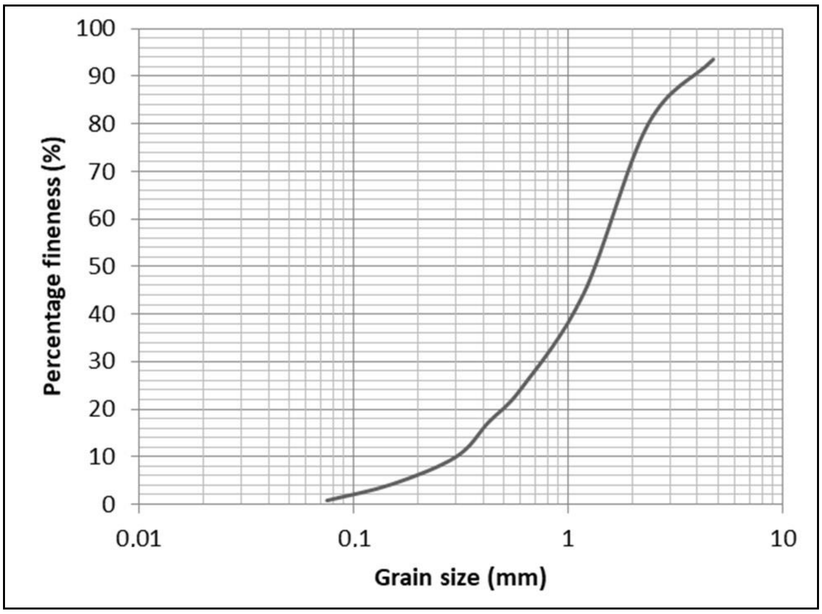

Figure 1. Grain size distribution curve of soil.

Figure 2 shows the additives used in the study. Plastic waste in the form of plastic strips of length 3 cm and width of 1.5 cm is used. RL is easily available inexpensive material. Ammonia content of 3% was added to Rubber Latex to decelerate self-hardening. It shows good resistance against abrasion. Also it forms a strong bond in between the soil particles.

Figure 2. Additives used for the test: plastic strips, rubber latex, coir fiber ash.

Fly ash

In this study, the fly ash Class F is used as the primary and base additive. According to USCS, fly ash is classified as non-plastic fine silt. Fly ash used in the current study was sourced from a local supplier. Coir fiber Ash is 100% natural and doesn't cause any environmental pollution.

Natural soil

Very soft, swelling clay was the natural soil used in this research as a subgrade. It was brought from the excavation from about 2 m deep under the ground's surface (the foundation level, according to a geotechnical report).

Proportioning

Determine the appropriate mix proportions of cement and natural additives based on laboratory testing and analysis of the soil to be stabilized. Proportions may vary depending on factors such as soil type, moisture content, and the desired strength of the stabilized subgrade.

Mixing procedure

Specify the mixing procedure, including the order of adding materials, mixing time, and equipment to be used. Ensure thorough and uniform mixing of cement and natural additives with the soil.

Moisture Content Control

Monitor and control the moisture content of the soil during mixing to achieve optimal compaction and bonding with the additive is shown in Table 2.

Table 2. Moisture content of soil.

Moisture Content (%)	**Dry Unit Weight (kg/m³)**
10	1.810
12	1.890
14	1.920
16	1.945
18	1.964
20	1.925

Soil–fly ash mixtures

To study the effects of other additives on fly ash stabilized soil, different mixtures were made. Class F fly ash was added at 7.5% and 15% to the dry soil and then was moisturised to their respective OMC as obtained by standard compaction test. Before compacting the samples in the mould, they were cured in sealed bags for 24 h to a full moisture equilibrium under room temperature and then well mixed by mechanical mixer before compacting in the mould.

Tests Performed

The testing program consists of preliminary test such as sieve analysis, Specific gravity and Atterberg limit test. The influence of stabilization agents on the properties of the soil were assessed through a series of Standard Proctor tests, Unconfined Compression Tests and California Bearing Ratio tests.

Compaction Test

The optimum percentage of cement and natural additives which gives the maximum dry density was obtained by conducting Standard Proctor Compaction test. Tubber latex was added to the soil at varying percentage of 5, 10, 15, 20, 25, 30 and 35. The percentage of CFA was varied from 0.5, 1, 2, and 4. Similarly PS added to the soil ranging from 0.4%, 0.8% and 1%. By Keeping the optimum value of PS, 0.5%, 1%, 2%, 3% cement were added to the soil and test were repeated is shown in Table 3.

Table 3. CBR mould compaction procedures.

Test Method	Mass of Rammer (kg)	Height of Drop mm	Number of Layers	Blows per Layer
2.5 kg rammer method	3.5	325	4	63
Intermediate compaction	5.5	365	5	60
4.5 kg rammer method	4.5	460	4	69
Vibrating hammer method	-	-	3	72

Unconfined Compressive Strength Test

Samples were prepared as per IS2720-10 (1991) with optimum percentage of additives as follows and UCC tests were performed. This test involves simply compressing a soil into a cylinder without lateral reinforcement until breakdown at a steady rate of strain of the sample as shown in Table 4. Unconfined compressive strength of the soil is the amount of compressive force per unit area needed to cause the test specimen to fail is shown in Table 5.

Series 1 – Soil with optimum percentage of RL (25%)
Series 2 – Soil with RL (25%) + CFA (1%)
Series 3 – Soil with optimum percentage of PS (0.8%)
Series 4 – Soil with PS (0.8%) + Cement (1%)

UCC values have been determined and stress strain graph were plotted for each case.

Table 4: Unconfined test samples.

Sample ID	Height (cm)	Diameter (cm)	Applied Load (kN)
1	13	7	55
2	13	7	62
3	13	7	57

Table 5. Result of UCS Test.

DOSAGE	MDD in g/cc	OMC in %
Parent soil	1.54	31.5 %
Soil+30%Sand+ 3%Cement	1.72	8.3%

California Bearing Ratio Test

To assess the pavement suitability of the stabilized lateritic soil, California Bearing Ratio test were conducted. The test where conducted as per IS 2720, part16 (BIS 1987). About 6 kg samples was prepared by mixing Soil + 30% Sand +3% Cement. Mix the sample properly such that cement and sand should be equally gets distributed. Take the CBR mould apply oil inside the mould properly such that there should no difficulty in removing the sample. Prepare a solution of Terrasil mixed with water, add that solution to the mix sample and mix it properly. Place the sample into the mould in 5 layers each layer being compacted for 56no of blows. Remove the collar and trim the soil sample and make it level. Prepare another solution of Terrasil mixed with water for curing of the surface. The rate of application of Terrasil for curing is 4 kg/m^2. Apply to one surface and make it dry for 45 mins to 60 mins in natural sun light. After that turn the mould and apply solution to another face and keep it in sunlight for same 40 mins to 65 mins. After drying, keep the specimen for 7 days air drying. After 7 days of air drying place the mould into bucket of water and keep it for 4 days. After 4 days remove the mould from bucket and keep it inclined for 30-45 mins. Such that all the water present in the mould comes out. After that place the mould into CBR apparatus and test the sample. Note down the penetration and dial gauge reading for further calculation.

Three series of CBR tests were conducted and are as follows:

Series 1 – Soil with optimum percentage of RL (25%)

Series 2 – Soil with RL (25%) + CFA (1%)

Series 3 – Soil with optimum percentage of PS (0.8%).

Load versus penetration curve were determined for each case and CBR values for 2.5 mm penetration and 5 mm penetration were determined.

Preparation for the mixture

This procedure is for 2.5 kg hammer. Divide the prepared quantity of soil into three portions with a mass equal to within 50 g of each other and seal each portion in an airtight container until required for use. c) Place one portion in the mould and level the surface. Compact to 1/3 the height of the mould in the compression device using suitably marked steel spacer discs to obtain the required depth of sample (127/3 = 42 mm). The mould is then removed from the compression device and the second portion of the material is added. This is then compressed to give a total sample depth to 2/3 the height of the mould (i.e. 85 mm). Finally, the remainder of the sample is 150 ± 0.5 / 50 ± 1 added and the mould is returned to the compression device until the finished sample is just level with the top of the mould. Care should be taken not to damage the press by attempting to crush the steel mould when the sample is level always pay close attention to the load gauge. Except for some dense aggregates the force required for compaction should not be very large. On completion of compaction weigh the mould, soil and base-plate to the nearest 5 g (m3). Unless the sample is to be tested immediately, seal the sample (by screwing on the top plate if appropriate) to prevent loss of moisture. With clay soils or soils in which the air content is less than 5%, allow the sample to stand for at least 24 h before testing to enable excess pore pressures set up during compression to dissipate.

Dry density specification

The mass of soil m1 (in g), required to just fill the CBR mould of volume Vm (in cm^3) is given by the equation

$$m1 = \frac{V1}{100}(100 + W)P_d$$

RESULTS

Effect of cement and natural additives on compaction value

Figure 3 shows the optimum moisture content and dry density relation of soil treated with varying percentage of RL. From the figure, it can be observed that the maximum dry density was obtained at 25% content of rubber latex. Figure 4 gives the compaction curves for Coir Fiber Ash treated with optimum RL content (25%) to the soil. RL treated soil increases the dry density 3.18%. It can be observed that addition of 1% of CFA to 25% RL treated soil increases the dry density by 5.24%. Figure 5 shows the variation of dry density of the soil treated with plastic strips. It can be seen that the dry density is maximum when the percentage plastic strip is 0.8. Further increase in plastic strips reduces the dry density of the soil.

From Figure 6, it can be seen that when cement is added to the optimum content of 0.8% plastic strips, the dry density increases by 11.04% with 1% cement content. It can be summarized that higher dry density of lateritic soil can be achieved with 0.8% plastic strips and 1% cement compared to CFA and RL combination. The optimum moisture content of the bare soil was found to be 22%. When it is treated with RL and CFA, the optimum moisture content was reduced to 16%. Addition of plastic and cement also reduced the optimum moisture content to 18.42%.

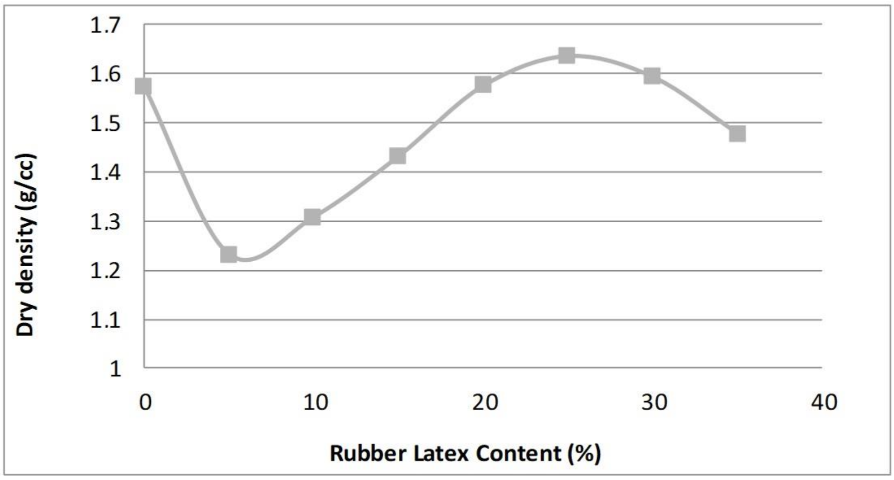

Figure 3. Dry density Vs Rubber latex content in soil.

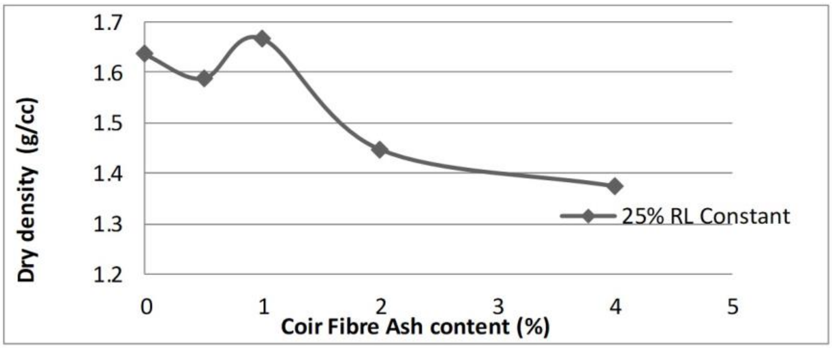

Figure 4. Compaction for constant RL with varying percentage of CFA.

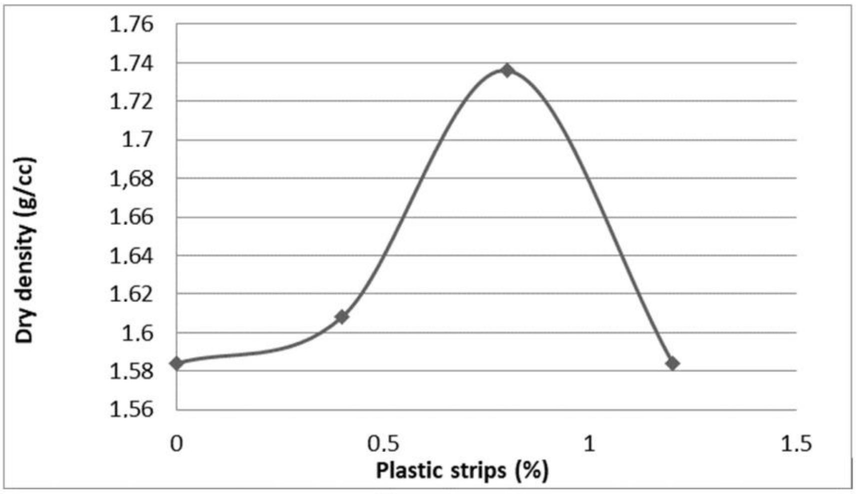

Figure 5. Compaction curves for plastic strip additive.

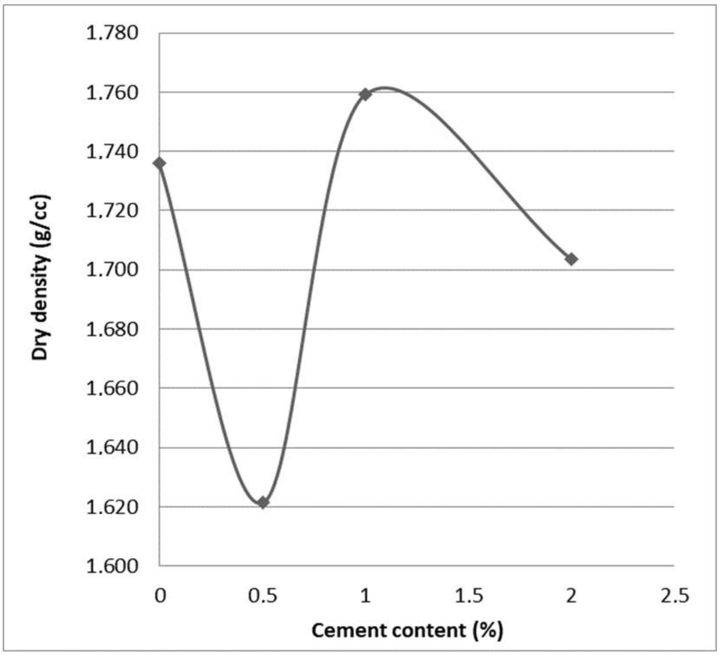

Figure 6. Dry density of soil treated with cement and 0.8% plastic strips.

Effect of cement and natural additives on UCC value

Unconfined compressive strength tests were conducted on three different combinations of soil mixes. The dry density and water content were maintained as that obtained from the standard proctor compaction tests. The unconfined compressive strength of the bare soil was found to be 0.66 kg/cm^2. Figure 7 shows the stress strain graph for different additive treated soil. 25% Rubber Latex addition to the soil increased the unconfined compressive strength by 44%.

Treating the soil with 1% CFA and 25 % RL increased the unconfined compressive strength value by 86% as shown in Figure 8. Addition of 0.8% PS produced an unconfined compressive strength of 1.04 kg/cm^2. Combination of 0.8% plastic strips and 1% Cement provided maximum unconfined compressive strength of 1.43 kg/cm^2 (117%) as shown in Figure 8. From the UCC test result it is seen that plastic strip alone and combination of plastic strip and cement provided a greater unconfined compressive strength than the Rubber Latex and its combination with coir fiber ash.

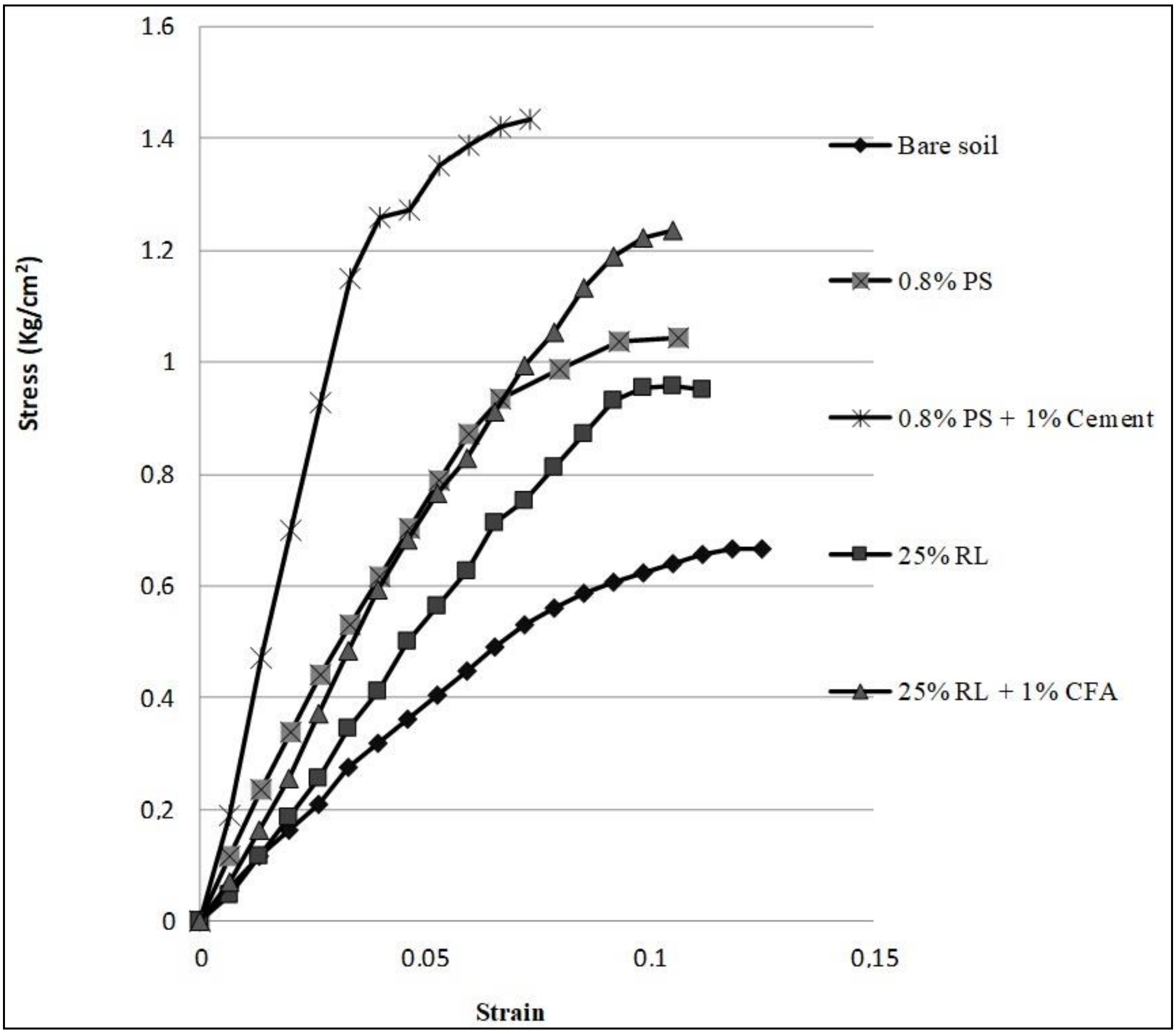

Figure 7. Stress strain graph for varying additives.

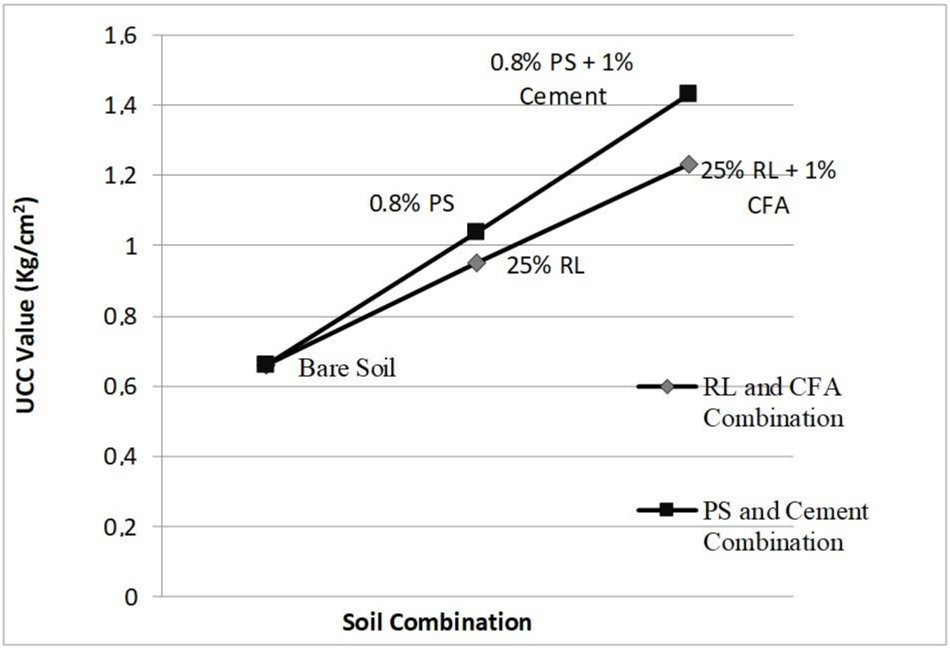

Figure 8. Comparison graph for UCC value versus both combination.

Effect of Cement and Natural Additives on CBR Value

CBR value of the optimum percentage addition of RL, RL and CFA, PS, PS and Cement were conducted. Load penetration graph for various additive combinations are shown in Figure 9. Here the CBR value under unsoaked condition increases with addition of 0.8% plastic strip and 1% Cement. The bare laterite soil possesses an unsoaked CBR value of 5.82%. 25% addition of RL increases the CBR value by 7% and addition of 25% RL and 1% CFA increases it by 15% from bare soil CBR value. A 9% increase in CBR value occurred by the addition of 1% CFA to 25% RL. 0.8% PS addition increases the CBR value by 10% and combination of 0.8% PS and 1% Cement increases it by 17 % from bare soil CBR value. An 8% increase occurred by the addition of 1% cement to 0.8% PS. It is seen that the combination of plastic strips and cement shows a 2% increase in the CBR value rather than the RL and CFA combination. Figure 10 shows combined value for both combinations.

DISCUSSION

Addition of rubber latex improves the compaction characteristics, unconfined compressive strength and also the CBR value of lateritic soil. Stabilization of lateritic soil with rubber latex found to increase the compaction characteristics, UCS and CBR values by about 3.18%, 44.07%, 114.43% respectively. The improvement was due to the binding action of RL with the soil. The optimum content of RL for maximum dry density was found to be 25%.

When laterite soil is stabilized with 25% rubber latex and 1% coir fiber ash, there is further increase in the dry density of the soil, unconfined compressive strength and CBR value by about 5.24%, 84.87% and 264.43% respectively. The increase in properties may be due to the adhesion property of the ash with rubber latex. Stabilization of lateritic soil with plastic strips found to increase the compaction characteristics, UCS and CBR values by about 9.59%, 56.64%,

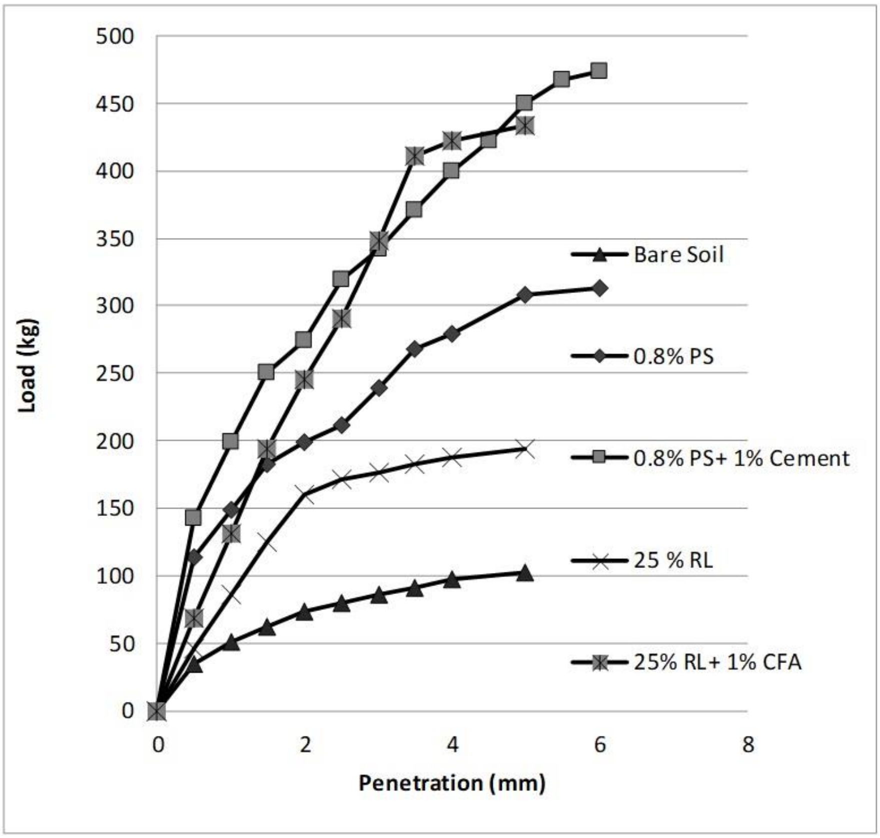

Figure 9. Load penetration curve for varying additives.

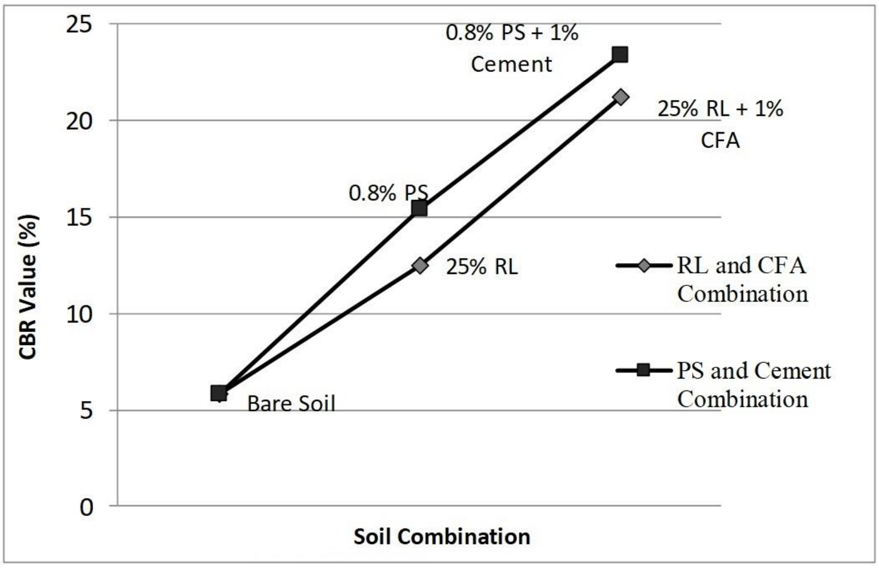

Figure 10. Comparison graph for CBR value versus both combinations.

164.43% respectively. The optimum percentage of plastic strips was found to be 0.8%. Plastic strips acts like filaments in the soil mass and gives more bondage between the soil layers.

Along with 0.8% of plastic strips, if 1% cement is added as stabilizing agent, the above mentioned properties further increases by about 11.04%, 115.52%, 300% respectively. Cement stabilization of lateritic soil combined with the fiber reinforcing action of plastic strips is increasing the property of the stabilized soil.

RL has high binding property considered to other natural polymers. Outcome from this study can be used for soil stabilization researches. Natural additives are abundantly available in nature and cement is needed only in smaller quantities thus this type of stabilization will be more effective than other chemical stabilizations.

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