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Stabilization of Red Soil by Natural and Polymeric Additives

Brightson P[1]*, Ravi Kumar M S[2], Albina A[3], Shannan B A[4] Shreyaan B A[5]
[1]Department of Civil Engineering, PSNEC, Melathediyoor, Tieunelveli, India.
[2]PSNEC, Melathediyoor, Tieunelveli, India.
[3]Aringar Anna College, Aralvaimozhi, Tamilnadu, India.
[4]CHSS, Nagercoil, Tamilnadu, India.
[5]LFNPS, Nagercoil, Tamilnadu, India.
*drbright.sa@gmail.com,

ABSTRACT
Soil reinforcement using short discrete randomly oriented fibers is getting more attention from many researchers around the world. Human hair fiber (HHF) is considered as a natural reinforcing material to enhance the strength characteristics of a weak soil. It is a non-degradable waste material causing environmental problems if not disposed properly. Natural rubber latex is a polymer in the form a milky liquid present in the cells of rubber producing plants. In this study, the effectiveness of using both human hair fibre and natural rubber latex on the stabilization of red soil was analyzed. Human Hair Fibre (HHF) and Natural Rubber Latex (NRL) were added in (0%, 1%, 1.5% and 2%) and 5%, 10%, 15% and 20% by weight of dry soil respectively. Soil samples were tested by performing standard proctor compaction test, unconfined compressive strength tests, California Bearing Ratio (CBR) tests and permeability tests and results are compared with untreated soil. Fibers of average length 2.5 cm were used. The results showed significant strength improvement by the inclusion of 1.5% HHF and 15% NRL in soil.
Keywords: *Red soil, Human hair fibre, Natural Rubber latex, Soil Stabilization*

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INTRODUCTION

Addition of Natural and Polymeric Additives For The Stabilization Of Red Soil

Soil stabilization is the process of improving the engineering properties of the weak soils, thus enhancing the load bearing capacity of a sub grade to support pavements and foundations. The challenge of construction at unsuitable sites comes up to the geotechnical engineers. Numerous researches were carried out to enhance the engineering properties of expansive soil using additives such as lime, fly-ash, cement, synthetic and natural fibers etc. In this study the effectiveness of using natural additives such as human hair fiber and natural rubber latex for stabilizing red soil is evaluated.Tests such as compaction tests, UCS tests, California bearing ratio tests and variable head permeability tests were performed on raw soil, soil treated with rubber latex and soil treated with rubber latex and human hair fibre.

Literature Review

The effects of pvc grid, geo grid, and human hair fiber on the CBR of clayey soil were investigated in a study [1]. As reinforcement, equal parts human hair were mixed into the soil. Next, single and double layers of mats composed of geo synthetic reinforcing materials geo gridand PVC grid were placed at equal intervals. Here CBR increased with increased addition of reinforcing material. When compared to other geo grids, the double layer geo grid produces superior results. [2] examined the effects on shear strength metrics of the coir fiber reinforcement in marginal soil amended with cement and fly ash. The shear strength of the marginal soil increased 1.5 to 2 times when mixed with 2% coir and 10% fly ash, according to the results. [3] conducted studies on the use of natural rubber latex (NRL) for pavement foundation treatments to strengthen cement-stabilized soil. Unconfined Compressive Strength (UCS) was improved up to 30%, 21%, and 18% for 3,5, 7 percentages of cement contents. Flexural strength was increased up to78%, 40%, and 29% for 3%, 5% and 7% cement contents respectively. Soil stabilization using fiber reinforced geo-polymer treated soft clay was reported by [4]. In this case, soft clay was treated by reacting blast furnace slag with 8 M sodium hydroxide as a binder. Reinforcement was provided by approximately 12-mm-long polypropylene (PP) fibers. Superior strength and durability properties are demonstrated by the geopolymer-treated soil mixed with a 30% binder content, 0.75 activator/binder ratio, and 1% PP fiber reinforcement. [5] looked into how well human hair fiber performed as a possible binder in flexible pavements by examining its effect on asphalt strength. The black-top blend's ability to withstand higher weights is enhanced by adding additional human hair debris to it. A 6% increase in human hair in the asphalt mixture resulted in a 30% increase in instability. Regardless of the proportion of additional drug, conditioned samples have lower strength than unconditioned ones. The range for hair additives is between 2% and 6% of the bitumen weight of the binder; any more or less and the mix would become unstable because of insufficient bond. [6] conducted an analysis of the efficacy of stabilizing elements derived from solid waste for improving the properties of expanded soil. The findings indicate that two key factors influencing strength development are the kind of soil used and the industrial waste used. Conditions that might negatively affect clayey soil's hydraulic and mechanical characteristics include swelling, desiccation, cracking, and shrinking. As the cement hardens, the soil's volume changes less and the soil becomes unsuitable. Lime stabilization is the preferable method of stabilization in both wet and dry soil situations. [7] carried out tests on the stabilization of black cotton soil using chicken fur and human hair fiber. In contrast to the initial soil sample and the soil replaced with 1% HHF and 4% of CF, the compressive strength value increased by 6543.84%. Thus this replacement is better for soil stabilization. [8] investigated the results of using human hair fiber to stabilize the soil for black cotton. The results show that the liquid limit value increases at 1.2% of HHF after initially decreasing. The unsoaked CBR achieves its maximum value at 1.2% of HHF. Furthermore, the UCC value increased to 2.3 times that of the soil without reinforcement. Consequently, 1.2% is the optimal quantity to provide noticeable increases in strength. Rice husk ash and coconut coir fiber stabilization was applied to red soil by [9]. Red soil stabilized with 15% rice husk ash and 5% coconut coir fiber had better technical properties.The optimum moisture content (OMC) and maximum dry density (MDD) have both increased to 1.89 g/cc., was reduced to 11.60% at 5% fiber and 15% ash respectively. UCS shows a significant improvement of 142 KN/m^2 and cohesion was about 71 KN/m^2at this optimum percentage addition. Sand was stabilized by employing several forms of short fiber and organic polymer [10]. Here the effectiveness of adding of polypropylene fiber, basalt fiber and fiberglass for stabilization of sand is investigated. Enhancement in compressive and tensile strength in polyurethane (PU) polymer treated sand was about 108.07% and 295.42% when0.8% polypropylene fiber was added. Addition of 0.8% basalt fiber shows 63.91% and 147.06% of compressive and tensile strength respectively. When 0.8% fiberglass added , an increment in 47.92% and 253.08% forcompressive and tensile strength on PU polymer treated sand was obtained.

MATERIAL AND METHODS

Red soil

The soil used in the present study was red soil. It is obtained from a place near Varkala, Thiruvananthapuram district in Kerala at 1m depth below the ground surface. The properties of soil were determined according to standard tests (IS :2720). The particle size distribution of soil is done using hydrometer analysis. The physical properties of soil were shown in Table 1 and gradation curve is shown in Figure 1.

Human Hair Fibre

Human hair fibre is considered as a natural fibre formed by a protein called Keratin which is rich in high sulphur content. Hair keratin is hard, compact and strong and have high tensile strength. A normal hair is composed of 45.68% carbon, 27.9 % oxygen, 6.6% hydrogen, 15.72% Nitrogen, and 5.03% sulphur, (Choudhry and Pandey,2012). After collecting HHF, fibers of approximate equal length were segregated and cut into a length of 2.5 cm. The properties of fibre are studied by [17]and is given in Table 2.

Natural Rubber Latex

Rubber latex is extracted from the bark of the rubber tree called Hevea brasiliensis. The chemical formula for rubber latex is cis-1,4 poly-isoprene. This structure helps to form strong bonding between the soil particles. It consists of predominantly rubber as dispersion phase and dispersion medium water. It was collected from rubber plantation unit near Kilimanoor in Thiruvananthapuram district, Kerala. Ammonia solution is used to prevent the coagulation of latex. About 7 Litres (3.5%) of ammonia is added to 200 Litres of latex to keep it in liquid form. The surface of the rubber particles is surrounded with negative charges. Each rubber particle consists of rubber molecules which are enveloped by protein membrane. If ammonia is added into latex, the hydroxide ions present in the ammonia will neutralize the hydrogen ions from acid produced by the bacteria in latex. The negative charges thus remain on the rubber particles and the coagulation is prevented. Here liquidized rubber latex is used. Properties are shown in Table 3.

METHODOLOGY

This investigation was carried out to find effect of adding both rubber latex and human hair fibre on compaction, unconfined compressive strength (UCS), the California bearing ratio (CBR) resistance and permeability characteristics of red soil compacted at the maximum dry density and OMC.

Different soil compositions such as untreated treated with only rubber latex and treated with both rubber latex and human hair fibre were used for the investigation. Rubber latex was used in four different percentages namely 5%, 10%, 15% and 20% by weight of the dry soil. Human hair fibre was used in different percentages such as 0%, 1%, 1.5% and 2% by weight of the dry soil. In the preparation of specimens, firstly oven dried soil sample is treated with different percentage of rubber latex and found the best percentage addition of latex content by Standard Proctor Compaction test. Keeping this optimum rubber latex content as constant, the same test is carried out in soil with varying percentages of short discrete human hair fibers, in order found the optimum percentage HHF needed to bring noticeable changes for better stabilization. Fibers of approximate length 2.5 cm were used. After finding the optimum percentage of additives, UCS, CBR and permeability tests were carried out with best percentage addition of additives and the results are compared with untreated soil.

Testing Conducted

Standard Proctor Compaction Test

The compaction test is carried out according to IS 2720 Part 7-1983. Here the maximum dry density and optimum moisture content of the untreated and treated sample is found out by treating it with different moisture content.

Unconfined Compressive strength tests

It is the maximum compressive stress which a cylindrical soil sample can carry when its sides are not confined. It is according to IS: 2720 Part (10) - 1991. Cylindrical soil samples of diameter 38mm and height of 76mm was prepared at OMC and maximum dry density obtained from compaction test results. A strain rate of 0.5 to 1 percent per minute was given to the machine.

California Bearing Ratio tests

CBR test was carried out as per IS 2720(Part 16) -1979. It is the ratio of force per unit area needed to penetrate a soil mass with a circular piston at the rate of 1.25mm/min to that needed for the corresponding penetration of the standard material. Here the untreated and treated soil specimen was prepared at maximum dry density and OMC.

Permeability tests

The permeability test is conducted according to IS 2720 part 36-1987. Permeability is the ease with which water can flow through the soil.In this study, the variable head method was used to find the coefficient of permeability (k) of treated and untreated soil.

RESULTS

Effect of Rubber latex on Compaction behaviour of red soil

Fig 2 represents the variation of MDD against varying percentage of rubber latex from 0 to 20%. The soil sample stabilized at 15% RL content gives better results. The maximum dry density was about 1.673g/cc at an optimum moisture content of 15.2%. From the figure 2 it is clear that as the rubber latex content increases MDD also increases, but beyond 15%, there is a decrease in MDD was observed.

OMC of the virgin soil was about 15.6% which decreased to 15.2% when stabilized with 15% RL content (Fig 3).The increase in MDD and decrease in OMC compared to raw soil demonstrates the suitability of soil-RL mixture for use as a subgrade material. From the results, 15% RL content was taken as the optimum.

It has been reported in literature that [6] latex content less than 15% dissolve in laterite soil and latex content of about 25 to 30% has found to have more resistance. In the present study, RL treated with ammonia to keep it in liquid form has been used and found that 15% of rubber latex is optimum which gives higher dry density in compaction. Further increase in latex content decreased the dry density.

Effect of Optimum Rubber latex with varying contents of human hair fiber.

Fig.4 and Fig.5 shows the variation of MDD and OMC when stabilized with 15% RL and varying percentage of HHF. The optimum percentage of rubber latex remains constant throughout this test series.The maximum dry density of treated soil increases with increased addition of HHF which may be due to effective contact area between fibers and adjacent soil and rubber particles. The MDD increased significantly from 1.673 at 0% HHF to 1.894 at 1.5% HHF, i.e., an increase of 13% with respect to RL treated soil and 22% with respect to that of original soil. Further increase in HHF content decreases the MDD. It may be due to increase in fiber-fiber interaction. With increase in fibre content, the fibre may not get properly arranged with soil-RL matrix causing poor dispersion of fibre in soil-RL matrix thus resulted in a lower efficiency.

Likewise, OMC was found to reduce with an increase in HHF up to 1.5% and increased beyond 1.5% of HHF. The OMC of the virgin soil was 15.6 % which is then reduced by 2.6 % when stabilized with 15% RL. When soil was stabilized with 15% RL and 1.5 % HHF, the OMC was reduced to 11.9% showing an increase in strength of 31% compared to original soil. Hence 15% RL and 1.5% HHF is selected as the suitable percentage addition for better red soil stabilization. The increase in MDD and significant decrease in OMC indicates the suitability of soil-RL-HHF mixtures for use as subgrade material and also the soil can be stabilized even at lower water content.

Effect in Unconfined Compressive Strength (UCS).

The stress-strain curves obtained from the unconfined compression test for untreated and samples treated with optimum percentage of additives are shown in Fig 6.

In soils treated with both rubber latex and human hair fiber, the axial stress was found to increase with the additives. The unconfined compressive strength of red soil treated with both rubber latex and HHF was found to be the highest. The UCS value of red soil increased by 62.7% when it is stabilized with 15% RL and when it is treated with 15% RL and 1.5% HHF, it is increased by 117%. This increase can be attributed to proper intergranular packing of fiber with soil-RL particles. It helps in improving ductile nature and increase friction between particles. UCS sample treated with RL and HHF after loading is shown in Fig 7.

Effect in CBR value.

CBR method was used to evaluate strength of subgrade and fot estimating the desired thickness of pavement for a given loading. Figure 8 shows the penetration curves of CBR tests of untreated soil and sample treated with optimum percentage of additives. Figure 9 shows the variation of CBR values stabilized with optimum % of additives. As seen from Fig 9, CBR value of the red soil was increased by 46% when treated with 15% RL and improved by 146% when treated with 15% RL and 1.5% HHF. .ie.,CBR value increased to about 2.5 times compared to that of the virgin soil. Increase in CBR values by the addition of rubber latex and short discrete fibers to red soil may due to increased interfacial adhesion between the soil–rubber particles and the fibre, which causes significant transfer of stress along the soil-RL-fibre matrix interface. Thus it is better for mixing rubber latex and human hair fiber in red soil for the construction of road pavements.

The optimum HHF content reported in literature were either 1.2% for expansive soils like black cotton soil [9],[10],[15] It is of 2% for clayey soil [1], [2], [13]. The UCS value or CBR value has tremendous increase at these optimum percentage content. In the present study, for red soil available in Kerala, the optimum content of HHF was found to be 1.5% when the soil is treated with RL of 15%. This combination gives better improvement in UCS as well as in CBR values of the treated soil.

Effect of rubber latex and human hair fibre on permeability of red soil.

The permeability values of untreated soil and treated with optimum percentage additives were determined using variable head permeability test and are provided in Table 4. From the table it is clear that the permeability of the red soil reduces substantially with the addition of both rubber latex and human hair fiber.The permeability of the untreated soil was about 2.637x 10^{-4}cm/sec.Soil treated with optimum percentage of rubber latex was reported to be lowest than virgin soil, it was about 1.908x 10^{-4}cm/sec (less by 28%). The coefficient of permeability (K) of soil showed a decrement to 1.251x10^{-4} cm/sec when treated optimum percentage of 15% RL and 1.5% HHF (reduced by 53%). The binding of soil particles due to rubber latex and better interlocking provided by human hair fibers results in substantial decrease in the permeability.

Table 1: Properties of soil

Soil Properties	Values
Specific gravity	2.69
Liquid limit	35.5%
Plastic limit	18.6%
Plasticity index	16.9%
Maximum dry density (gm/cc)	1.55
Optimum moisture content (%)	15.6
Sand %	22
Silt (%)	38
Clay (%)	40
UCS (KN/m^2)	60.13
CBR(%)	5.5

Table 2: Properties of human hair fiber

Properties of HHF	Values
Length	2.5 cm
Diameter	50µm
Cross section	Circular
Liner density(gm/cc)	1.25-1.40
Elongation	1.5 x dry weight
Tensile strength	About 400Mpa
Flexural strength (Mpa)	25-30
Chemical reaction	Depends on surface porosity of hair.
Absorption	Depends on surface tension
Friction	Depends on the physical-chemical status of the hair.

Table 3: Properties of Rubber latex

Property	Values
Specific gravity	0.97
pH	10.3
Rubber	30-40%
Protein	1.5%
Resins	1.5 -3%
Mineral matter	0.8%
Carbohydrates	1%/
Water	55-60%
Size	0.02-3µm
Ammonia	0.7-1%

Table 4: Coefficient of Permeability Of The Soil

Samples	Coefficient of permeability, K (x10^{-4} cm/s)
0% of RL + 0% of HHF	2.637
15% of RL + 0% of HHF	1.908
15% of RL + 1.5% of HHF	1.251

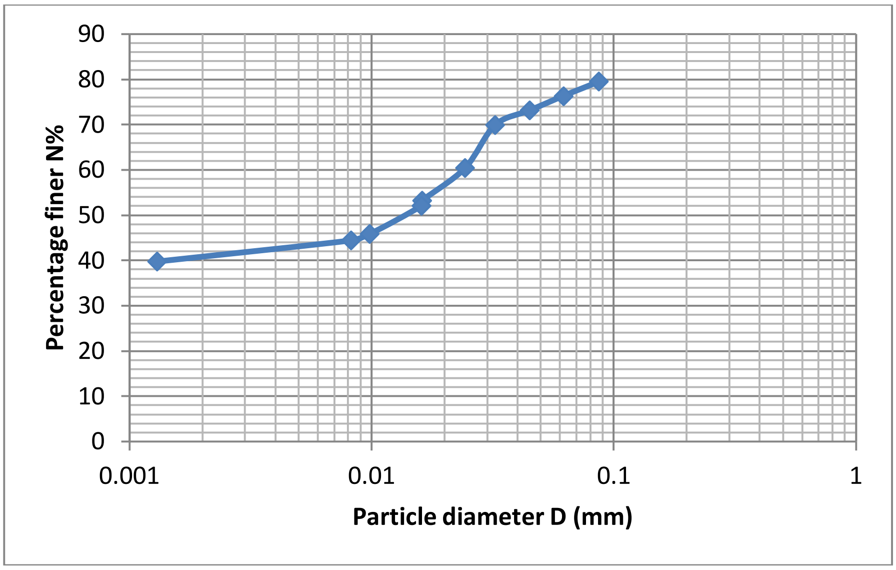

Figure 1: Particle size distribution of the soil

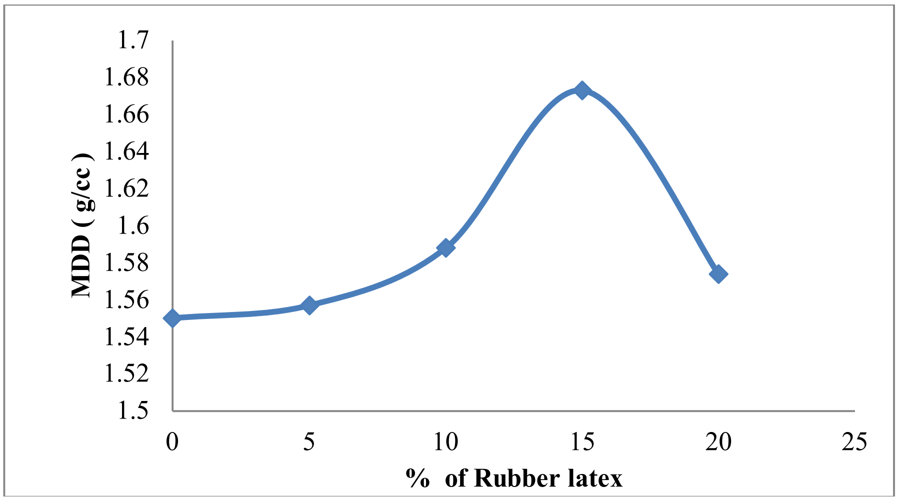

Figure 2: MDD verses percentage of Rubber latex

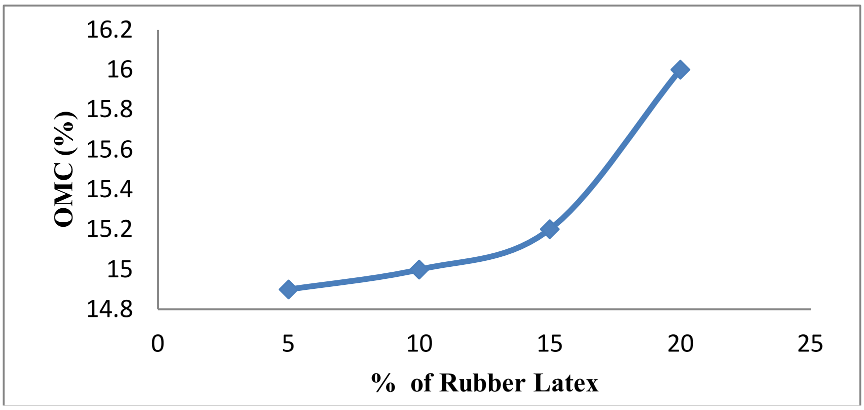

Figure 3: OMC verses % of Rubber latex

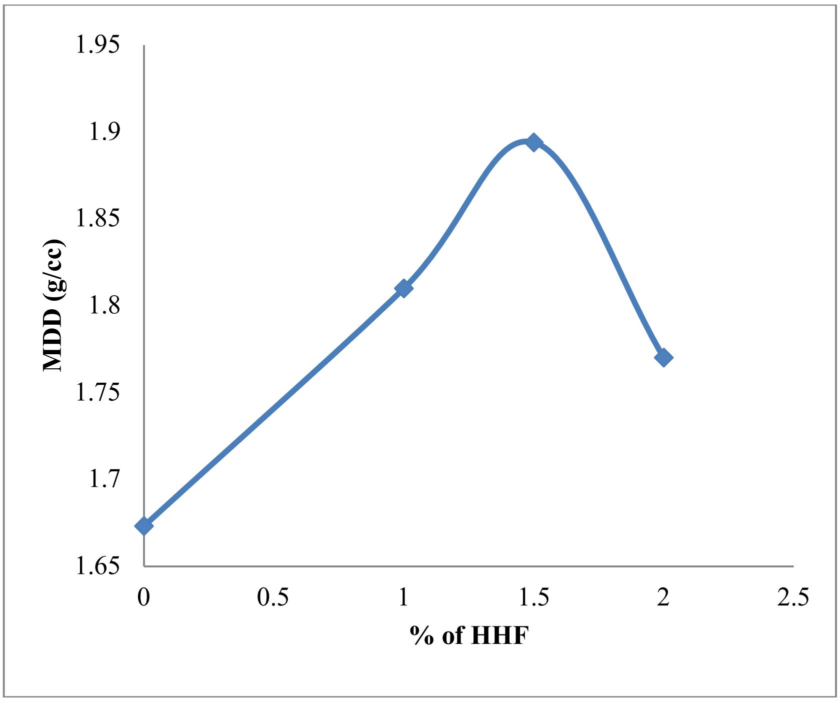

Figure 4: Variation in MDD of 15% RL-HHF stabilised soil samples

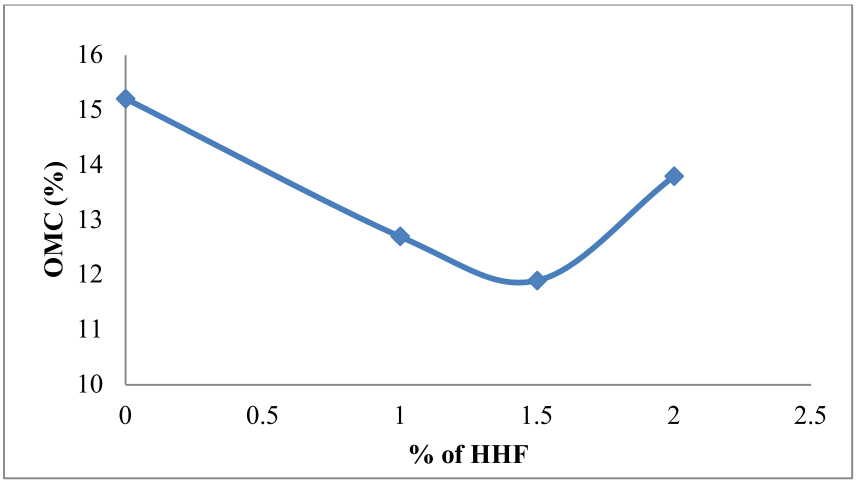

Figure 5: Variation in OMC of 15% RL- HHF stabilised soil samples.

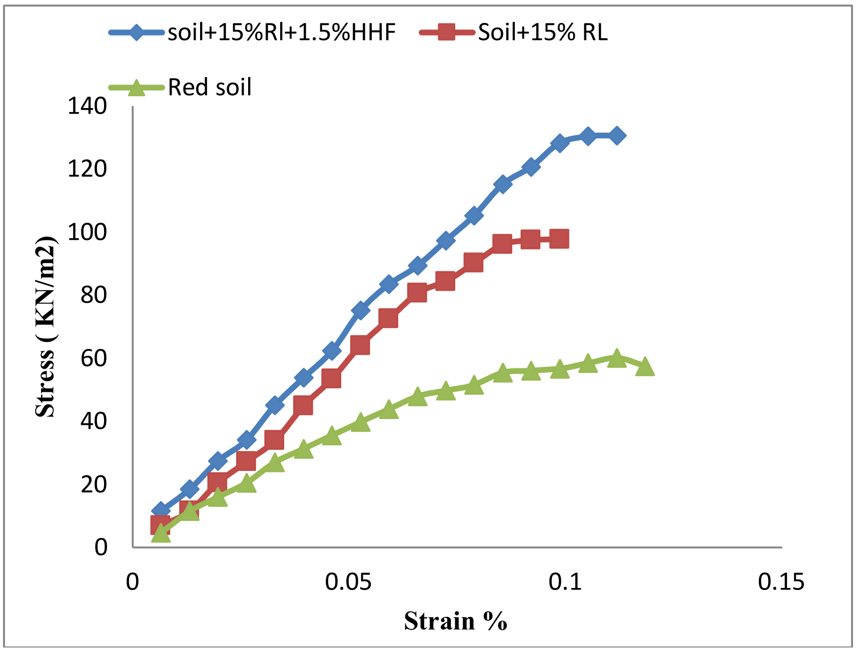

Figure 6: Stress-strain curves from UCC test for the untreated and treated soil

Figure 7: UCS sample of soil-RL-HHF mix

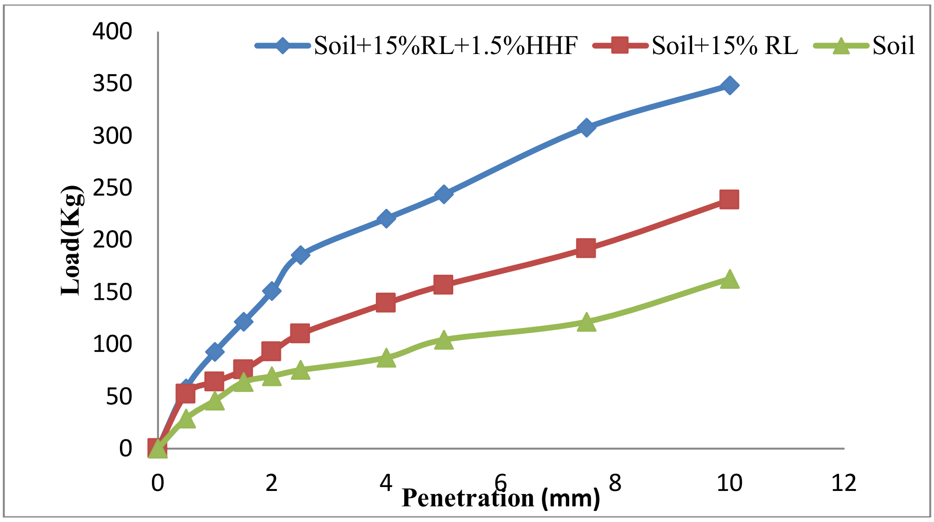

Figure 8: Penetration curves of CBR tests on untreated and samples treated with optimum % of additives.

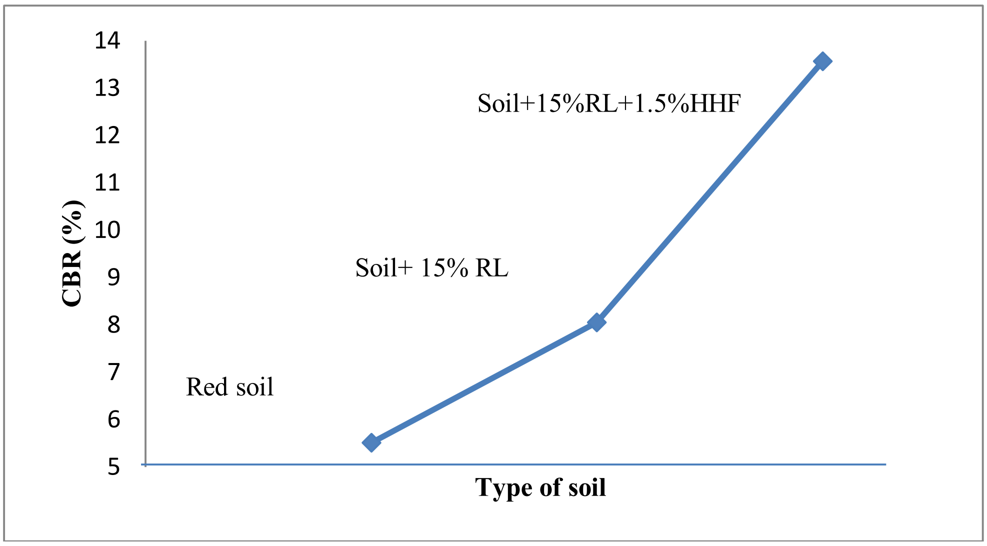

Figure 9: Variation of CBR value stabilized with optimum % of additives.

DISCUSSIONS

The suitability of red soil stabilized using rubber latex and human hair fibre has been reported in this paper. Tests such as compaction tests, unconfined compressive Strength tests, California bearing ratio tests and variable head permeability tests were performed on raw soil, soil treated with rubber latex and soil treated with rubber latex and human hair fibers. Significant improvements in geotechnical properties like increase in MDD and decrease in OMC, increase in unconfined compressive strength and California bearing resistance and a reduction in permeability were observed in soil treated with rubber latex and human hair fibers. Thus it can be concluded that rubber latex and human hair fiber can be used as a better additives for the stabilization of red soil. It is useful for the stability of slopes, reinforcements in flexible pavements and also the subgrade thickness decreases. Dumping of human hair waste in open areas can be reduced to some extend and sustainable development of infrastructures on weak soil is also achieved. From the study the following major conclusions has been obtained.

- From compaction test results, 15% RL and 1.5% HHF was obtained as optimum amount for better stabilization. And other tests were carried out with this optimum percentage of additives.
- The MDD and OMC were 1.894g/cc and 11.9% respectively at 15% RL and 1.5% HHF inclusion.
- UCS value showed a significant increase from 60.13 KN/m^2 to 130.63KN/m^2 showing an increase in strength of 117% compared to that of virgin soil.
- CBR value of the red soil was increased from 5.51% to 8.05% when treated with optimum percentage addition of rubber latex (15%). Significant improvement in CBR of about 13.57% was obtained when

treated with 15%RL & 1.5% HHF addition (ie., showed an increase in strength of 146%).

- The coefficient of permeability (K) of soil showed a decrement to $1.251x10^{-4}$ cm/sec when treated optimum percentage of 15% RL and 1.5% HHF.(less by 53%).

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