

Utilization of Recron Fibers for Improving Subgrade Stability of Expansive Soils

G. Anil Kumar^{1,*}, G. Prasanna Kumar², Krupasindhu Biswal³

Abstract

The major interest in the utilization of synthetic fibers is used as reinforcing material for developing reinforcing effect into the entire soil composition laid below the structures where as construction works are going on. Various articles are published on soil reinforcement, yet some of them fibers used are prepared by using with synthetic materials, one type of synthetic fibers were Recron fiber it is used as a reinforcing element to advance the soil mechanical and elastic properties. Std proctor test was performed based on IS Light weight compaction method and strength of subgrade of soil was calibrated based on CBR Test performed on different soil samples prepared with various fiber contents of 0%, 1%, 2%, 3%, 4%, 5% and 6% by weight of soil dry weight and on plain soil sample. Experimental study was demonstrated that optimal water content (OMC), ultimate dry density (MDD) and subgrade strength of soil increased with inclusion of fibrous material to the plain soil. ultimate dry density and plastic deformation of soil may decrease with increase fiber inclusion. Moreover, the subgrade strength of soil increases upon fibers addition with all different compositions in soaked and unsoaked conditions. California bearing ratio index results also presented here to show the effect of reinforcement performance on plain soil samples. Optimum fiber dosage obtained to be 5% for all the type of tests performed here. CBRI was resulting based on CBR test results, it was shown the maximum CBRI value was obtained 3.9 and 6.5 respectively for unsoaked and soaked conditions based on these results Reinforcement worked effectively in soaked condition then compared with unsoaked condition. The applications of recron fibers utilization improves the mechanical behaviour of expansive soil and it has more durable compare to the natural fiber reinforcement in the soil composition, performance of soil reinforcement effect has long period due to synthetic fiber addition to soil.

Keywords: Expansive soil, Recron fibers, light weight compaction, CBR (Soaked and unsoaked), CBRI.

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INTRODUCTION

Expansive soil is a very problematic soil because of their critical mineral properties, it has more moisture susceptible when contact with water because of it causes volumetric changes and less subgrade strength. Many of the roads deteriorate because of their extreme soil properties and less subgrade strength. Construction cost and maintenance cost also increased by lack of stability and strength in subgrade. The stability and strength may improve by different stabilization methods, the most important stabilization method is used in this present study was soil reinforcement. From the previous studies researchers can observed many investigative works over soil reinforcement with different natural fibrous materials, synthetic fibrous materials and geosynthetic materials etc. among all

over those studies on expansive soil strength and strength properties are enhanced due to inclusion of fibers as well as geosynthetics. Some disadvantages are observed with natural fibrous material like durable aspects with time. That's why in this investigation synthetic fibers are selected and utilized for better improvement of expansive soil properties. optimal water content and ultimate dry density variation observed based on addition of fibers to plain soil and conduct investigation on CBR value for various amount of fiber addition.

Researcher investigated utilization of some of the natural fibers like Fan Palm (F.P), Date Palm (D.P) trees, and Phragmites Australis (Ph.A) stems in soil for enhance strength characteristics of bare soils with addition of fibers with different dosages like 0.5, 1, 1.5, and 2 percentage by weight of dry plain soil [1]. From the study researchers identified Fiber inclusion leads to improve OMC and ductility and reduce MDD and brittleness of soil matrix [1]. Investigation conducted on stabilization of sandy soils by using OPS (organic polymer stabilizer) and PF (polypropylene) fibers by which enhance stability to sand and improve strength properties. Here OPS are used with different proportions of 1, 2, 3 and 4% and PF with 0.2, 0.4, 0.6 and 0.8% were used for different tests, after that SEM are utilized to analyse mechanism developed between sand, OPS polymer and PF fibers. OPS-PF developed great bonding ability among sand particles was developed stable structure in soil matrix [2]. Rresearcher covers some studies relevant to natural fibers utilized as composite materials for treatments, fabrication methods, various properties and applications [3]. academician studied two various subgrade soils are stabilized with ashes and different fibers like bottom ash, F-class fly-ash, nylon fibers, and polypropylene fibers. Those selected soils are investigated at Various test conditions and material dosages, four dosages of various stabilizers and two compaction moisture contents with 14 days curing period was provided then after samples was tested. Different volumetric examinations are carried out on individual ash treated and combine ash-fiber treated soil samples then calibrate volumetric free swell, swell pressure and shrinkage strain. Ashes are improved in soil characteristics in reducing swelling, plasticity and shrinkage characteristics, in ash-fiber treatment, F-class fly-ash added with nylon fibers get effective results on both subgrade samples [4]. Plant fibers improve their surface by surface modification technique using different chemicals and also discussed about many studies relevant to surface modification [5]. Researchers was studied on expansive soil stabilization with recycled waste materials produced from industries like fly ash and PP fibers. Fly ash-PP fiber blended soils are enhancing strength and decline shrinkage strain, fly ash stabilized soil decrease plasticity and swell characteristics. Recycled material utilization in construction reduces the landfill cost and improve recycling effort [6]. Investigators studied about physical, durable and engineering properties of soil blocks prepared with soil blended with different agricultural fiber wastes. Here two unlike soil types are used for soil block preparation and these soils are reinforced and improved with three various fiber material with a dosage of 0.25-1% by dry weight and perform different tests regarding compactness, compressive & tensile strength, water absorption, erosion, shrinkage and wearing among all tests 0.5% fiber content and more amount clayey soil has got effective results [7].

Investigator studied on examine of expansive soil stabilization with combine alkali binder material and chemical treated fibers, from this they observed some improvement in various strength characteristics like compressive shear, flexural and tensile strength. AAB (Alkali Activated Binder), THF and TCF are used for improvement of soil by this material addition in to soil leads to reduction in swelling potential and enhance tensile strength. Soil-AAB-TCF mix has high interlocking and develop interfacial bonding which improves various strengths and crack resistance [8]. Investigator explained about classification of fibers and elaborately classified on natural fibers and synthetic fibers. Experimental work was conducted on natural bark fibers for determination of stress – strain relationship [9]. physical, mechanical and thermal properties of processed abaca fiber with polymer matrix, also discussed on its benefits and different applications [10]. Another researcher was studied on utilization of natural fiber and nanocellulose for different biocomposite applications [11]. Researchers studied about soil improvement based on inclusion of fiber and cement in the bare soil and prepare 8-shaped samples with a moisture content of OMC and MDD then after put in various curing periods at 7, 14 and 28 days.

These specimens are to be verified for direct tensile properties including stress strain curve, tensile strength and energy absorption along with crack propagation in sample also studied. Low cement content and better curing period sample reinforced sample are significantly improved [12].

MATERIALS AND EXPERIMENTAL METHODS:

Materials

Soil

Expansive soil incorporated in the present experimental investigation work was collected from Peddasana village near Tekkali in Srikakulam district, India. After collecting the soil, it was placed in oven for drying at a temperature of 105°C for 24 hrs and then tested index properties of soil. The index properties are specific gravity, particle size distribution and consistency indices etc. The key properties of expansive soil were measured in accordance with IS 2720 that is BIS standards, and it was presented in Table 1. The soil is high compressible clay according to results evaluated from Atterberg limits and plasticity chart. Figure 1 showed particle size distribution curve of the investigated soil.

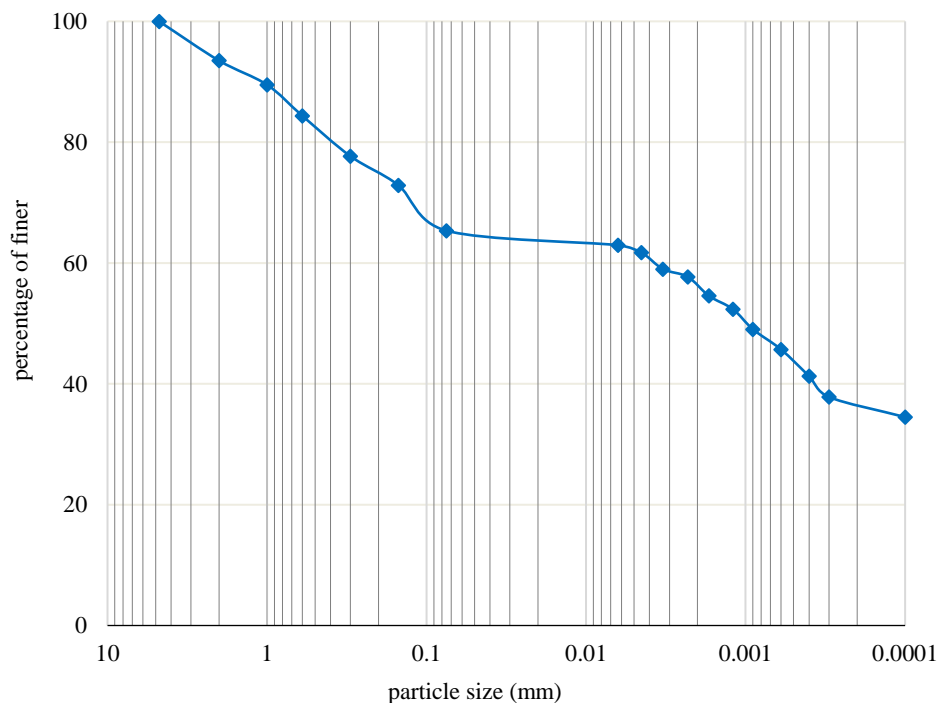


Figure 1. Grain size distribution curve of expansive soil.

Table 1. Expansive soil geotechnical properties.

Specific Gravity	G _s	2.74
Liquid Limit	W _L	54.75%
Plastic Limit	W _P	26.45%
Plasticity Index	PI	28.3
Classification of Soil		CH
OMC For Is Light Weight Compaction	OMC (%)	18.98%
MDD For Is Light Weight Compaction	γ _d (kN/m ³)	1.64 g/cc

Recron Fiber

For the better improvement in the mechanical properties of soil, recron fibers was used as a reinforcement material in this experimental investigation. Recron fibers were used with varying dosages of 1, 2, 3, 4, 5 and 6% by oven dry weight of soil and photograph was showed in Figure 2. Recron fibers was purchased from Reliance Industries, the properties are mentioned bellow in Table 2.

Table 2. Recron fiber properties.

S.N.	Parameter	Value
1	Appearance	Short cut small pieces (12 mm length)
2	Diameter	35-40 microns
3	Viscosity	Not applicable
4	Ignition temperature	>450°C
5	Melting point	162-167°C
6	Flash point	>329°C
7	Relative density	0.89–0.97 gm/cm ³
8	Colour	White

**Figure 2.** Recron fiber used in the present investigation.

Experimental Testing Methods

The laboratory experimental examinations were conducted over the recron fibers added expansive soils for improvement of strength properties in soils. Engineering strength properties of soil can be evaluated before and after addition of geosynthetic reinforcement along with recycled aggregates are enhanced sustainable load bearing layer for all transportation foundation layers [13]. Engineering strength properties of soil can be estimated before and after addition of reinforcement to the soil and compare both results for reinforcement efficiency. In this research investigation tests can be carried out on bare soil alone and similar tests are performed on reinforced soil also. Initially soil index properties are calibrated and then some of engineering properties also estimated by performing laboratory tests on bare soil along with reinforced soil for different fiber dosages of 1%, 2%, 3%, 4%, 5% and 6% by their dry weight.

Firstly, bare soil was dried in oven then after used for various tests, initial soil properties that is specific gravity, Atterberg limits and sieve analysis was performed based on IS 2720 Part 3, 4 & 5. Then, IS Light weight compaction test are conducted on oven dry sample as per IS 2720 part7, as per the test OMC and MDD was calibrated. Compaction test are performed on bare soil and recron fiber reinforced soil matrix samples, mainly reinforced soil sample preparation is an important aspect to eliminate error in estimation in OMC and MDD due to lack of uniform spreading of fibers in soil composition it achieves by proper preparation methods as follows. firstly, Dried soil was blended with

recron fibers with different fiber contents. After that water was mixed progressively and steadily mixed up to a uniform mix composition obtained for test sample preparation for different experimental investigations, tests are performed according to IS 2720 part-7 for calibration of fiber reinforced soil OMC and MDD and IS 2720 Part 16 was used to calibrate CBR for bear and reinforced soil samples.

California bearing ratio index values has calibrating based on CBR test results, from those all experimental results have been identify better reinforcement effect among all the various fiber compositions.

EXPERIMENTAL RESULTS AND DISCUSSION

Compaction Test

The standard proctor tests are used to analyze performance of bare soil samples and reinforced soil samples separately, these test results are displayed in Figure 3, it was displayed how the OMC varies with MDD (compaction characteristics) values with the various fiber composition. Compaction effort enhance the expansive soil dry unit weight from 1.55 g/cm³ for loosest state to 1.693 g/cm³ for densest state for bare soil. From the experimental investigation it was observed that OMC increased and substantially MDD decreased with incorporation of recron fibers into bare soil for all type of samples. The investigated results of the compaction are demonstrated in Figure 3 for the various composition of reinforced soil samples. OMC and MDD trends for different fiber dosages are investigated and the results are displayed in Figure 4. These results are showed in Table. 3.

Table 3. OMC and MDD values with different fiber dosages.

Compaction Data (OMC& MDD)		
% Fibers	OMC (%)	MDD(g/cc)
Plain soil	15.8	1.693
1%	23.45	1.61
2%	23.82	1.557
3%	24.45	1.459
4%	25.96	1.523
5%	26.5	1.445
6%	26.12	1.427

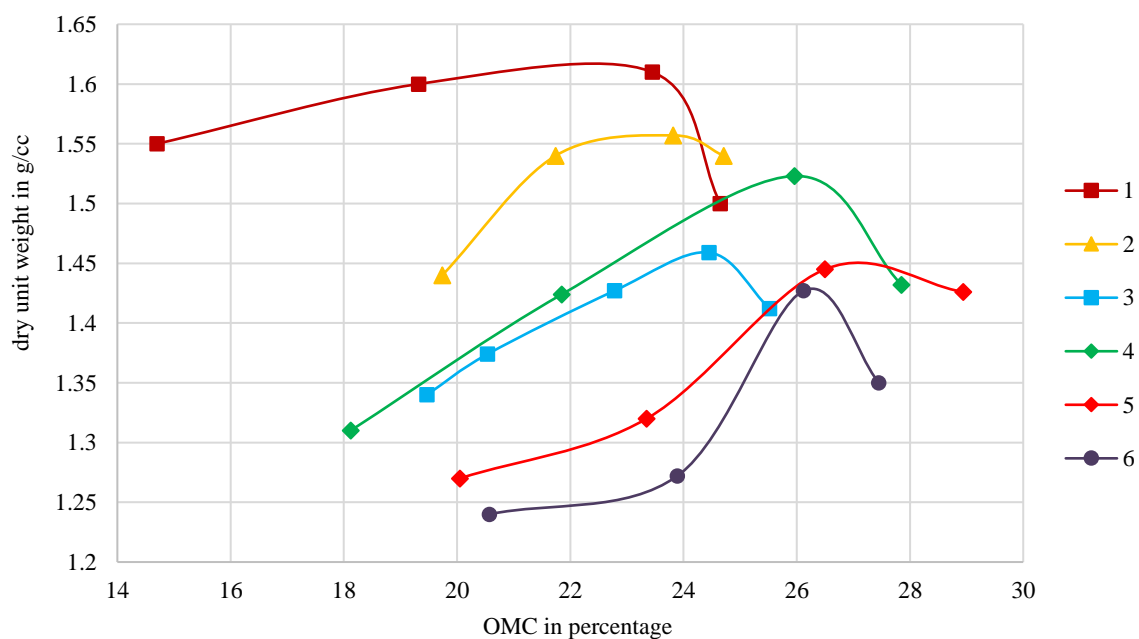


Figure 3. Compaction curves for different composition of Recron fiber reinforced soil samples.

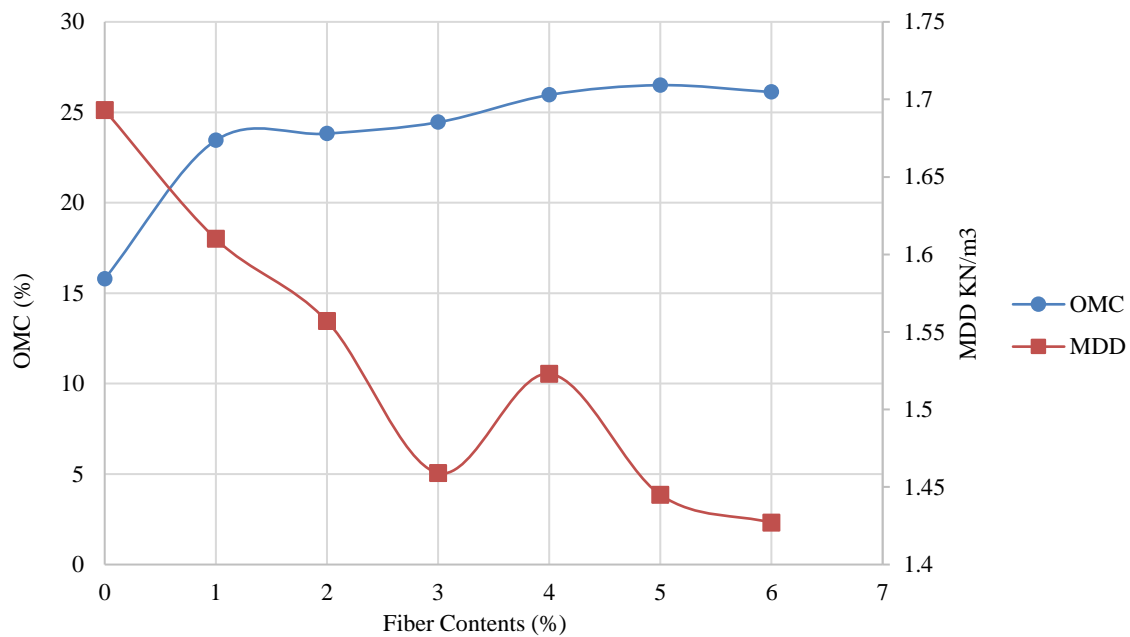


Figure 4. Trend of OMC and MDD with different fiber contents.

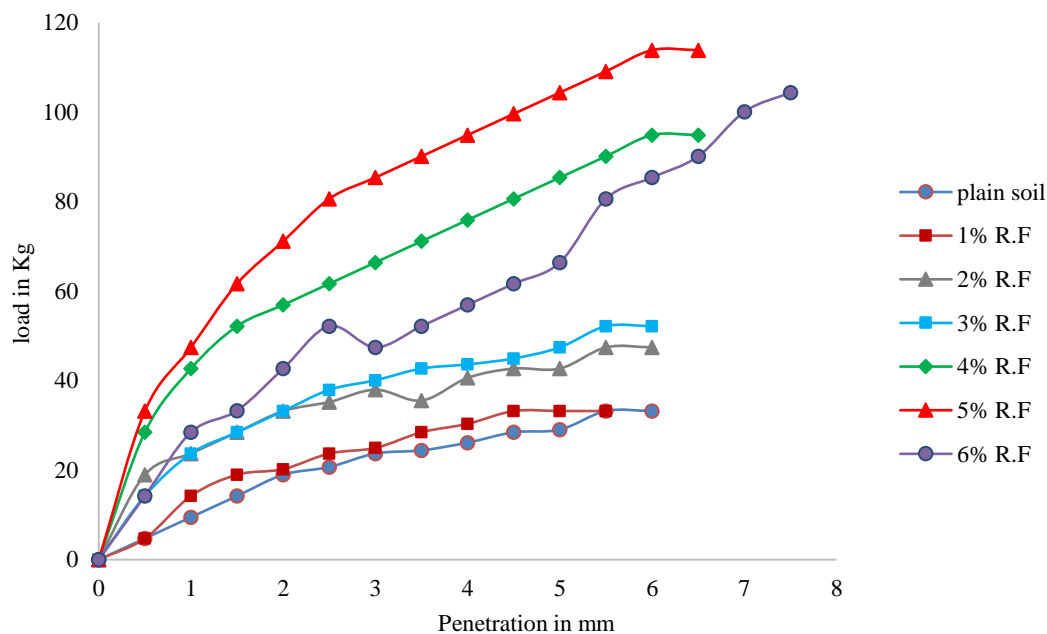


Figure 5. CBR values for different composition of Recron fiber reinforced soil samples in unsoaked condition.

Subgrade Strength

The influence of inclusion of recron fibers in soil on subgrade strength characteristics for any constructions works carried out on expansive soils are discussed in this article. Shear strength parameters of expansive soils are enhanced due to inclusion of jute fibers with various percentage with different lengths [14]. The fiber inclusion enhances the CBR values in all different dosages of fiber added samples and it was perceived in Figure 5 and Figure 6. There is increase in fiber content from 0 to 6% resulted enhancement in CBR values but up to 5% fiber gradual improvement takes place after that some reduction was observed in both soaked and unsoaked conditions. Utilization of recron fibers for expansive soil improvement has a better choice, reinforcement effect ultimately improves strength and stability to the subgrade.

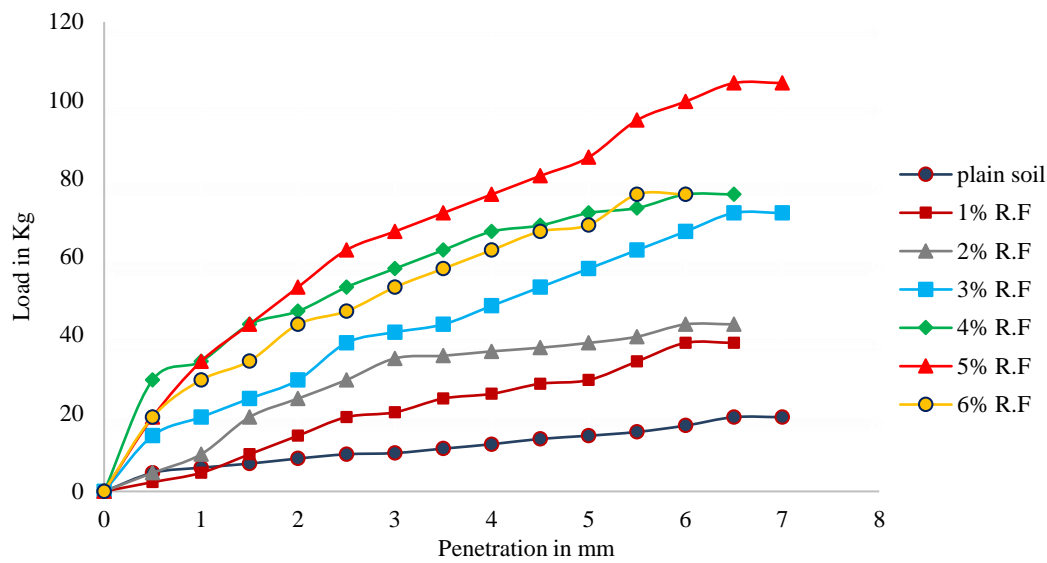


Figure 6. CBR values for different composition of Recron fiber reinforced soil samples in soaked condition.

Table 4. CBR and Improvement of CBR with different fiber dosages for unsoaked condition.

Soil sample type	CBR%	% variation in CBR
0%R. F+S	1.511	0.00
1% R. F+S	1.731	14.56
2% R. F+S	2.57	70.09
3% R. F+S	2.77	83.32
4% R. F+S	4.501	197.88
5% R. F+S	5.886	289.54
6% R. F+S	3.809	152.08

Table 5. CBR and Improvement of CBR with different fiber dosages for soaked condition.

Soil sample type	CBR%	% Improvement in CBR compared with plain soil
0%R. F+S	0.692	0.00
1% R. F+S	1.385	100.14
2% R. F+S	2.077	200.14
3% R. F+S	2.77	300.29
4% R. F+S	3.809	450.43
5% R. F+S	4.501	550.43
6% R. F+S	3.361	385.69

Unsoaked CBR value improvement observed when there is a increment in fiber dosage from 1% to 5% with respect to plain soil is 14.56%, 70.09%, 83.32%, 197.88% and 289.54% respectively, after that reinforcement effort may reduce further increment in fiber dosage beyond 5%. Unsoaked CBR value improvement reduction may occur at 6% fiber dosage is 152.08%, it was reduced from 289.54% at fiber dosage of 5%. These values are tabulated in Table 4. In the similar manner-soaked values are listed in Table 5. based on the results displayed in Table 3, 4 gives better understanding regarding CBR improvement in both soaked and unsoaked conditions. CBR improvement was observed higher in soaked condition with compared to unsoaked condition it was obtained maximum at fiber dosage of 5% is 550.43% it is much higher with compare to unsoaked condition it was only 289.54% with 5% fiber reinforcement.

California Bearing Ratio Index

CBR index is used as a measure of efficiency of reinforcement in reinforced soil matrix CBR with compare to plain soil CBR, CBRI is estimated based on ratio of subgrade strength of reinforced soil matrix to subgrade strength of bare soil composition. It gives indication of how soil subgrade strength are improved with addition of recron fibers into plain soil. CBRI data was displayed in Table 6 for both soaked and unsoaked conditions, CBRI variation with dosage of fiber addition into plain soil graphical representation for both soaked and unsoaked conditions was showed in Figure 7.

Table 6. CBRI values variation with fiber content for both soaked and unsoaked condition.

Fibre addition in %	CBRI for Unsoaked samples	CBRI for soaked samples
0	1.00	1.00
1	1.15	2.00
2	1.70	3.00
3	1.83	4.00
4	2.98	5.50
5	3.90	6.50
6	2.52	4.86

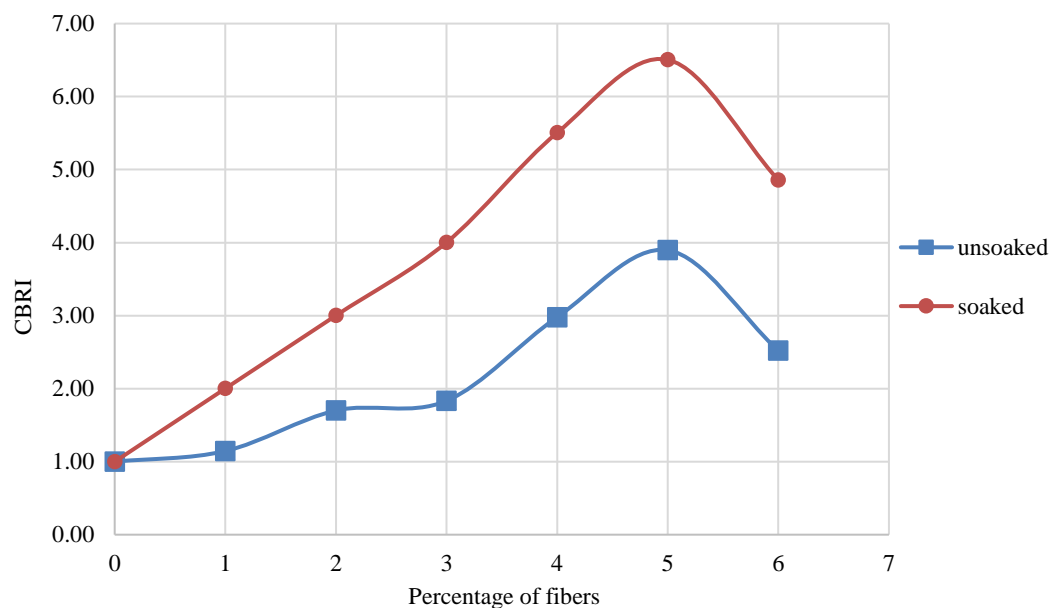


Figure 7. CBRI variation with fiber percentages for soaked and unsoaked conditions.

CONCLUSION

This research article widely examines the influence of randomly distributed recron fibers on the subgrade strength properties of reinforced soil. Experimental investigation gave the valuable conclusions are listed as follows.

- By addition of synthetic fibers, the optimum moisture content (OMC) increased while Maximum dry density (MDD) decreased, this variation was observed up to 5% of Recron fibers after that OMC and MDD both are decreased with increase in fiber content. These results are displayed in Table 3. There is a difference in OMC and MDD values in natural and synthetic fiber inclusion, natural fibers (coir) are not much influenced due to fiber inclusion but strength properties are improved by 50% higher then unreinforced soil [15].
- Investigation results are demonstrated that the Recron fibers effectively improves the subgrade strength of expansive soil. The CBR test results are showed better result for both soaked and unsoaked conditions.

- Reinforcement effect improves upto 5% of fiber addition to plain soil, beyond 5% fiber inclusion in the soil gives the reduction in CBR improvement. Up to 5% fiber dosage the reinforcement effect increased by 289.54% and 550.43% respectively for unsoaked and soaked conditions with compared to plain soil CBR value.

As per the conclusion stated above, it was clearly mentioned that the Recron fiber utilization as highly advanced reinforced material for various expansive soils, enhance geotechnical properties for various types construction works.

REFERENCES

1. Alhakim G, Jaber L, Baalbaki O, Barraaj F. Utilization of Fan Palm, Date Palm, and Phragmites Australis fibers for improving the mechanical behavior of sandy soil. *Geomechanics for Energy and the Environment*. 2023 Mar 1;33:100427.
2. Liu J, Bai Y, Feng Q, Song Z, Wei J, Sun S, Kanungo DP. Strength properties of sand reinforced with a mixture of organic polymer stabilizer and polypropylene fiber. *Journal of Materials in Civil Engineering*. 2018 Dec 1;30(12):04018330.
3. Mylsamy B, Shanmugam SK, Aruchamy K, Palanisamy S, Nagarajan R, Ayrilmis N. A review on natural fiber composites: Polymer matrices, fiber surface treatments, fabrication methods, properties, and applications. *Polymer Engineering & Science*. 2024 Mar 19.
4. Punthutaecha K, Puppala AJ, Vanapalli SK, Inyang H. Volume change behaviors of expansive soils stabilized with recycled ashes and fibers. *Journal of materials in Civil Engineering*. 2006 Apr;18(2):295-306.
5. Karthik A, Bhuvaneshwaran M, Senthil Kumar MS, Palanisamy S, Palaniappan M, Ayrilmis N. A Review on Surface Modification of Plant Fibers for Enhancing Properties of Biocomposites. *ChemistrySelect*. 2024 Jun 4;9(21):e202400650.
6. Puppala A, Hoyos L, Viyanant C, Musenda C. Fiber and fly ash stabilization methods to treat soft expansive soils. In *Soft ground technology 2001* (pp. 136-145).
7. Danso H, Martinson DB, Ali M, Williams JB. Physical, mechanical and durability properties of soil building blocks reinforced with natural fibres. *Construction and Building Materials*. 2015 Dec 30;101:797-809.
8. Syed M, GuhaRay A. Effect of natural fiber reinforcement on strength response of alkali activated binder treated expansive soil: Experimental investigation and reliability analysis. *Construction and Building Materials*. 2021 Mar 1;273:121743.
9. Palanisamy S, Kalimuthu M, Nagarajan R, Fernandes Marlet JM, Santulli C. Physical, chemical, and mechanical characterization of natural bark fibers (NBFs) reinforced polymer composites: a bibliographic review. *Fibers*. 2023 Jan 28;11(2):13.
10. Kurien RA, Selvaraj DP, Sekar M, Koshy CP, Paul C, Palanisamy S, Santulli C, Kumar P. A comprehensive review on the mechanical, physical, and thermal properties of abaca fibre for their introduction into structural polymer composites. *Cellulose*. 2023 Sep;30(14):8643-64.
11. Palanisamy S, Murugesan TM, Palaniappan M, Santulli C, Ayrilmis N, Alavudeen A. Selection and Processing of Natural Fibers and Nanocellulose for Biocomposite Applications: A Brief Review. *BioResources*. 2024 Jan 1;19(1).
12. Tran KQ, Satomi T, Takahashi H. Tensile behaviors of natural fiber and cement reinforced soil subjected to direct tensile test. *Journal of Building Engineering*. 2019 Jul 1;24:100748.
13. Han J, Thakur JK. Sustainable roadway construction using recycled aggregates with geosynthetics. *Sustainable Cities and Society*. 2015 Feb 1;14:342-50.
14. Yixian W, Panpan G, Shengbiao S, Haiping Y, Binxiang Y. Study on strength influence mechanism of fiber-reinforced expansive soil using jute. *Geotechnical and Geological Engineering*. 2016 Aug;34:1079-88.
15. Menezes LC, Sousa DB, Fucale S, Ferreira SR. Analysis of the physical-mechanical behavior of clayey sand soil improved with coir fiber. *Soils and Rocks*. 2019 Jan;42(1):31-42.