Influence of Textile Polyester Waste Fiber on Strength and Sub grade Properties of High to Low Plastic Clay

Dr. Pratima A. Patel[1], Yati R. Tank[2]

[1,] Faculty of Civil Engineering, SCET, Surat – 395007, Gujarat, India
[2,] Applied Mechanics Department, SVNIT, Surat – 395007, Gujarat, India

pratima.patel@scet.ac.in, yatitank93@gmail.com

Abstract: In India, a major portion of total land area is covered by high to low plastic clayey soil. Of this, a large proportion is expansive soil. Structures constructed over this expansive soil may be severely damaged due to its high swell-shrinkage behavior. So, such soils need to be improved its strength, durability and to prevent erosion. Various studies have been carried out on expansive soils to improve its properties. Soil stabilization is one of the promising techniques used to improve the geotechnical properties of soil and has become the major practice in construction engineering. This study work to evaluate the improvements in properties of CH – CI soil of south region of Surat by adding textile polyester waste fiber. For improvement of engineering properties this fibers are used as reinforcement by varying percentage of 1%, 2%, and 3%. The soil parameters such as Shear Strength, Sub grade characteristics tested under UCS and CBR. These values are compared to that of a control specimen. Author critically remarked as CH soil has different characteristics as compared to CI soil under this test. Experiments results show this fact that using textile polyester waste fibers leads to increasing shear strength, dry density, CBR value and reduction in plasticity index and free swell index in CI soil as compare to CH soil. Analysis of result obtained from experiments may be proving the effectiveness of this product to construction site having this both type of soil. The expansive soil can be successfully stabilized by the combined action of fibers with soil.

Keywords: Stabilization, Textile polyester waste fibers, UCS, CBR, Free swell index.

1 Introduction

1.1 Preface

Urbanization leads to non- availability of good ground condition for construction of new infrastructure throughout the world. This thrust on ground improvement of the existing soil in both developed and under developing countries, the ground improvement is becoming the integral part of the infrastructure development. Expansive soil is considered as most problematic soil as it shows the increase and decrease in volume in presence and in absence of water respectively. The major problem associated with the consulting geotechnical engineer in the last few decades is to design a foundation on expansive soil which threat to public safety and the potential damage to property.

Expansive soil can exert the force and cause the movement to a heavily loaded structure that can be more than those experienced from the ordinary soil. Along with this, cost incorporates in development of expansive soil site is very much high compared to non-expansive soil site. In contrast with normal soil site, expansive soilrequiresmoreextensivetestingandanalysesduringthesiteinvestigationanddesignphase, and also the construction phase needs continuous supervision and observation as compared to normal available soil. Additionally, the cost associated with the reconstruction of a structure damaged by expansive soil may be restrictive because the cost of reconstruction is often more than the original cost (initially estimated cost) of the structure.

It can be concluded that estimated lost cause by expansive soils may be more than the annual damage from the earthquake, floods, hurricanes, and tornados (column of air which is rotated rapidly, extend from the thunderstorm to ground).

In dry state expansive soil has the consistency of stiff clay and have the excellent shear strength which diminished significantly with the ingress of water. High swelling and shrinkage characteristics of the expansive soil are due to the presence of a clay mineral known as montmorillonite, Illite, Kaolinite, etc.

Expansive soil deposits and the problem caused by this soil is reported from all six continents except Antarctica and more than 40 countries worldwide (Nelson et al. 2015). The mentioned below countries in which expansive soil have been reported are Argentina, Australia, Burma, Canada, Cuba, Ethiopia, Ghana, India, Israel, Iran, Mexico, Morocco, Rhodesia, South Africa, Spain, Turkey, U.S.A., Venezuela (Chen 1975). So, the problem of expansive soil is worldwide. Expansive soils are in abundance where the annual evapotranspiration exceedstheprecipitation.Thisfollowsthetheorythatinsemi-aridzones, the lack of leaching has aided the formation of montmorillonite (Steinberg 1999). The above-mentioned countries belong to the semi-arid area only.

The problem of expansive soil is not only related to economy of infrastructure but also with environmental perspective of living being. Expansive soil exerts great uplift pressure on the structure built on it when it is in contact with water which results in excessive heaving, cracking of the structural and non-structural members of the building and destruction of the road pavements, underground pipeline system, lined and unlined canals and airfields. These are the major area where expansive soil deposits required great care in all phases of construction.

1.2 Problem Summary:

In this project work purpose of addition of waste textile fiber to improve penetration resistance and shear characteristics.

In this present study the stabilization of two types of soil i.e. CH and CI with the artificial fiber i.e. Polyester which is in the form as a waste product from textile industries has been carried out. This polyester fiber is to be mixed with both the type of soil by partial replacement of soil by weight in 1%, 2%, 3%. The soil is naturally available from the ongoing site from Vesu, situated at South- West zone of Surat city. This fiber increases the dry density of soil and thus increases the shear strength and load bearing capacity of soil by conducting Unconfined Compressive Strength , California Bearing Ratio and Compaction Tests. CH soil has different characteristics as compared to CI soil. The varying dry density, shear strength and load bearing capacity give the variation in Strength& Sub grade properties.

Study shows the effect of Textile waste recycled polyester fiber on soil engineering properties by conducting Standard Proctor Test, Unconfined Compression Strength and California Bearing Ratio Test.

1.3 Aim & Objective of Present Study Work:

In our study an attempt is made to stabilize expansive soil with addition of textile fibres. The strength parameters like CBR, UCS are determined to know the suitability of materials.

In the process of soil stabilization and modification emphasis is given for maximum utilization of local material so that cost of construction may be minimized to the minimum extent

Soil stabilization is the treatment done on the soils to improve their properties so that it becomes suitable for construction.

The aim of proposed study is to assess and evaluate all basic properties of CH and CI soil before adding the Artificial Fiber i.e. Textile waste recycled polyester fiber. Evaluated properties of untreated soil with the artificial fiber with adding 1%, 2%, and 3% by weight as per test schedule and make comparison of results with all variations. By gradual increase in the percentage of fiber in the CH and CI soil, the increment in strength, dry density and penetration capacity of soil is to be determined. Mainly modified compaction test, UCS and CBR tests will be conducted on treated soil sample at laboratory in control volume. Results of all tests were compared with untreated soil sample.

1.4 Problem Specifications and Background:

Soil stabilization have evolved innovative techniques of utilizing locally available environmental and industrial waste material for the modification and stabilization of deficient soil.

Surat city is known for its textile business, so plenty of textile polyester fibers waste available. In this study stabilization of clayey soil using Textile waste recycled polyester fiber for improvement of engineering properties as Strength and Sub grade. This fiber is used as a non-traditional reinforcement. The influence of randomly oriented polyester fiber on the engineering behavior of soil has not been reported to some extent. Ease of application and reduction in cost are making this treatment more popular. Polyester fiber is not 100% prone to restrict the water therefore it absorbs a very small amount of water. Maybe a little water could be on the surface of the fiber to make it wet, it doesn't necessarily need to absorb.

2 Contribution of Researchers:

Avoiding the site is not a better solution when site is located in urban area as scarcity of land. Adopting Raft and Pile foundation is very much costly affairs for light weight structures. So, soil stabilization as a ground improvement is better solution for light weight structure on high to low expansive soils

The identification of expansive soil can be done through the understanding of its micro scale aspects and macro scale aspects. The micro scale aspects of the expansive soil include mineral composition, morphology, caution exchange capacity, and specific surface area. The macro scale aspects include Atterberg properties, compressibility characteristics, swelling properties and strength characteristics.

The stabilization of expansive soil is most effective while it is carried out using the addition of traditional and non-traditional additives. The traditional additives include lime and cement whereas non-traditional additives include majorly available industrial wastes such as fibers, fly ash, Ground granulated blast furnace slag (GGBS), copper slag, cement kiln dust (CKD), Rise husk ash(RHA),etc. Literature study is highlighted only the review of soil stabilization using non-traditional additives.

A.R. Estabragh, Ranjbari, Javadi [1] Properties of clay soil and soil cement reinforced with polypropylene fibers. Arvind Kumar, Baljit Singh Walia, Asheet Bajaj [2] Influence of fly ash, lime, and polyester fibers on compaction and strength properties of expansive soil. Avinash Bhardwaj, B. S. Walia [3] Influence of cement and polyester fibres on compaction and CBR value of clayey soil. Babak Amini Behbahani, Hadi Sedaghatnezhad, Foad Changizi [4] Engineering properties of soils reinforced by recycled polyester fiber. C. M. Sathya Priya, S. Archana, A. Bichu Albert, A. D. Deeraj [5] Stabilization of clayey soil using polypropylene fiber. Kalpana Maheshwari, Dr. Chandresh H Solanki, Atul K Desai [8] Effect of polyester fibers on strength properties of clayey soil of high plasticity. Saikrishnamacharyulu, Vinodh Kumar, K. Bhanuji Rao, G. Himala Kumari [10] Experimental study on soil stabilization using waste fibre materials.

3 Experimental Investigation:

3.1 Test Material used as Expansive Soil (CH & CI), Water, Textile Polyester Waste Fiber

Expansive Soil (CH&CI):

The soil is classified as CH & CI soil as per IS: 1498-1970 and have a high to low free swell Index (30 % to 45 %) according to the classification. The black cotton soil is mixed with textile polyester fiber in both the type of soil by partial replacement by weight in 1%, 2%, 3%to increase the reliability of experiments results and thereby achieving the intended purpose of the study. (i.e. effect of fibers on Strength & Sub grade properties of expansive soil).

These different proportions of mixtures (black cotton soil and fibers) are examined by a series of tests (UCS, CBR) to decide one suitable proportion for future investigation.

The soil used in this study is obtained at a depth of 1 m from the site Surat Multi-specialty Hospital under construction near Shanti Niketan Appt., Vesu, (South -west Zone of Surat City for investigation.

Two types of expansive soil (CH&CI) sample was collected as consideration for the study work for evaluation of behavior of various proportion of fibers with this soil.

Fig. 1. CH Soil Sample

Fig. 2. CI Soil Sample

Fig. 3. Textile Polyester Waste Fiber

Water:

Water used for mixing and curing shall be clean and free from injurious amounts of oils, salts, acids, alkalis, sugar, organic materials or other deleterious materials. The pH value of water shallbenotlessthan6.Potablewater or distil water is generally considered satisfactory for mixing.

Textile Polyester Waste Fibers:

Source: Shree Balaji Textile, Navjivan Circle Bhatar, Surat. Amanufacturedfiber-inwhichthefiberformingsubstanceisanylong-chainsyntheticpolymer composed of at least 85% by weight of an ester of a substituted aromatic carboxylic acid, including but not restricted to substituted terephthalic units, p(-R-O-CO- C6H4-CO-O-)x and Para substituted hydroxy-benzoate units,p(-R-O-CO-C6H4-O-)x.

Characteristics of Polyester Fiber: Strong, Resistant to stretching and shrinking, Resistant to most chemicals, Quick drying, Crisp and resilient when wet or dry, Wrinkle resistant, Mildew resistant, Abrasion resistant, Retains heat-set pleats and crease, Easily washed.

Cut Length: Cut lengths available are 32, 38, 44, 51 and 64 mm for cotton type spinning and a blend of 76, 88 and 102 mm-average cut length of 88m for worst ed-spinning. The most common cut length is 38 mm.

These fibers are generally used on worsted system and 1.4 D for knitting.

Tensile Properties: usually in 2.0 / 3.0 D for suiting endues with tenacities of 3.0 to 3.5 GPD (grams per denier).

3.2 Experimental Programme:

Test schedule of untreated soil sample of CH&CI as: Grain size analysis, Liquid limit and plastic limit test, Shrinkage limit. Specific gravity, Standard Compaction test, California Bearing Ratio, Unconfined Compressive Strength as per I.S. codes specifications.

4 Results and Discussion

Test results as follows: (Without addition of Fibers)

The clay concentration is high in both the soil sample from the study site of Vesu, Surat. (from Sieve analysis)

Table 1. Various Index Properties of CH and CI Soil Sample

Index Properties Assessed	For CH Soil	For CI Soil
Liquid Limit	60.49 %	44.33 %
Plastic Limit	20.04 %	17.08 %
Plasticity Index	40.45 %	27.25 %
Free Swell Index	45.45 %	30 %
Specific Gravity	2.33	2.51
Shrinkage Limit	12.13%	23.65 %
OMC	23%	20.60 %
MDD	1.54 g/cc	1.66 g/cc

The CH soil has high expansive property and CI soil has moderate expansive property. From the test results, properties of CH and CI are justified as per their classification.

Table 1 shows all index properties of CI and CH soil. This all properties verified and confirmed with IS specification

Results of Compaction test, CBR test and UCS test (CH &CI Soil with fibers & without fibers)

Table 2. Comparative Result of all Tests

Soil	Mix Type	Sample Name	MDD (g/cc)	OMC (%)	UCS (kg/cm^2)	CBR (2.5mm) (%)	CBR (5 mm) (%)
CH	Untreated	CH (U)	1.54	23.00	1.50	1.87	1.58
	CH + 1% Fiber	CH (1%)	1.55	21.20	2.34	1.75	1.85
	CH + 2% Fiber	CH (2%)	1.54	21.40	2.18	1.69	2.04
	CH + 3% Fiber	CH (3%)	1.46	26.80	1.64	3.70	3.23
CI	Untreated	CI (U)	1.66	20.60	3.04	3.73	4.57
	CI+ 1% Fiber	CI (1%)	1.59	22.00	2.82	6.37	6.90
	CI+ 2% Fiber	CI (2%)	1.54	22.50	4.50	6.96	7.16
	CI+ 3% Fiber	CI (3%)	1.49	22.80	4.52	4.73	7.03

Table 2 highlight test result of compaction CBR and UCS, which shows variation in each values with compare to untreated soil samples.

Remark of Compaction Test:

Experimental results on compaction test shows that Maximum Dry Density decreases and Optimum Moisture Content increases with the increase in Polyester fiber content.

The decrease in MDD is due to the results of the fiber having less specific gravity in comparison with the soil grains and fibers prevent the soil particles to approach each other. The increase in OMC is due to result of fibers having greater water absorption capacity than the surrounding soil.

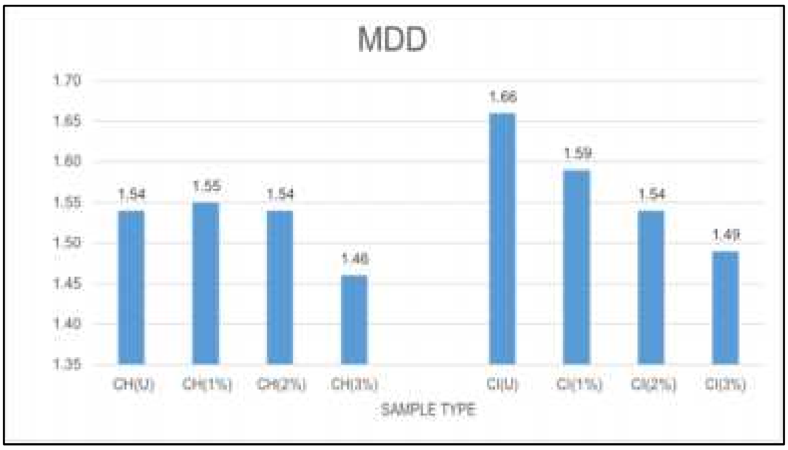

Fig. 4. Comparative Result Graph of MDD

Figure 4 shows with constant value of MDD of untreated soil, addition of fiber MDD value decreases.

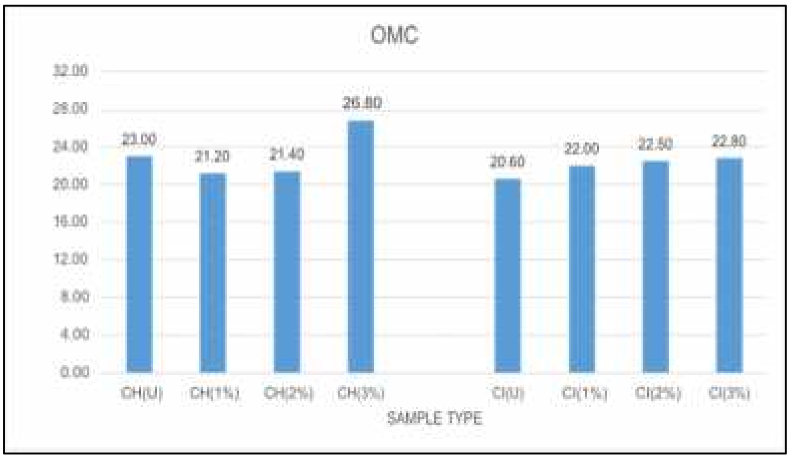

Fig. 5. Comparative result Graph of OMC

Figure 5 shows with constant value of OMC of untreated soil, addition of fiber OMC value increases.

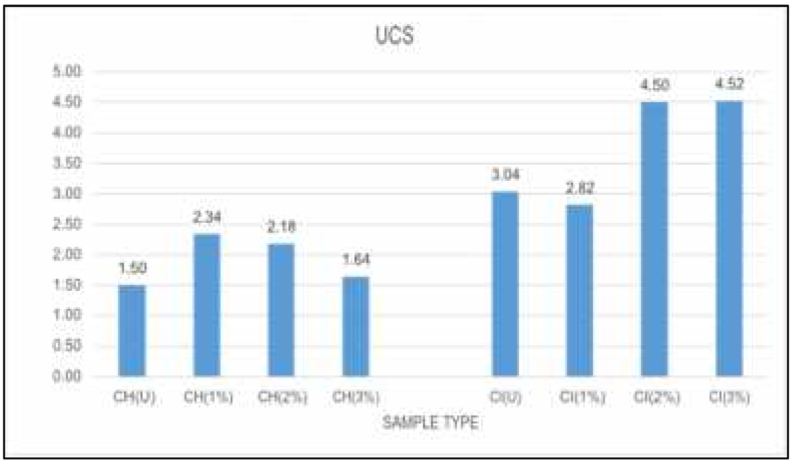

Fig. 6. Comparative Result Graph of UCS Test

Figure 6 shows UCS result improve in low plastic soil than high plastic soil.

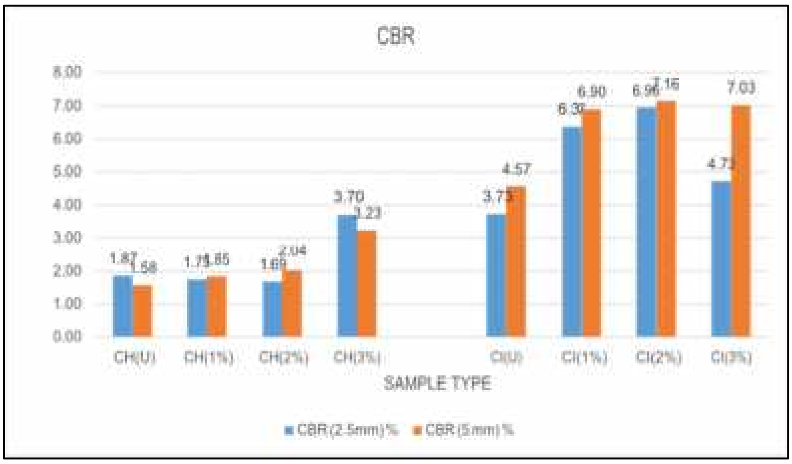

Fig. 7. Comparative Result Graph of CBR Test

Figure 7 shows with addition 3 % of fibre CH soil give maximum CBR value at 2.5 mm penetration but CI. This value is increase at 5 mm penetration.

5 Concluding Remarks

Detailed conclusions as results of the study have been discussed. The variations of the results are shown in tabular form. Also, these variations are related to only percentage of addition of fibers with both soils.

- Hence, these variation shows that CI soil is equal useful in construction. (without ignoring its important properties)
- Due to mineral composition of CI soil, it gives best results as compared to CH soil. CI soil can be used for Pavements, Soil Stabilization and Bearing Capacity. By gradually increasing percentage of fiber, the strength behavior of CI soil also increases. CH soil is highly plastic soil due to high value of plastic limit and liquid limit & high free swell Index, which affects the desire properties of soil.
- As during the soil exploration, CH soil is to be found generally in the upper crust and CI soil is at deeper depth is been ignored, but here the results shows that CI soil has good strength behavior as compared to CH. So, the CI soil is preferable for construction purposes.

References

1. A. R. Estabragh, S. Ranjbari, and A. A. Javadi,"Properties of Clay Soil and Soil Cement Reinforced With Polypropylene Fibers", Materials Journals, Vol. 114, Issue 2, Pages195-205.

2. Arvind Kumar, Baljit Singh Walia, Asheet Bajaj, "Influence of Fly Ash, Lime, Polyester Fibers on Compaction and Strength Properties of Expansive Soil", Journal of Materials in Civil Engineering(ASCE).
3. Avinash Bhardwaj, B.S. Walia, "Influence of Cement and Polyester Fibers on Compaction and CBR Value of Clayey Soil", Indian Geotechnical Conference 2017, IIT Guwahati,I ndia.
4. Babak Amini Behbahani, Hadi Sedaghatnezhad, Foad Changizi, "Engineering Properties of Soil Reinforced by Recycled Polyester Fiber," Journal of Mechanical and Civil Engineering, Vol. 13, Issue 2, Ver. III, ISSN 2278- 1684.
5. C. M. Sathya Priya, S. Archana, A. Bichu Albert, A. D. Deeraj, "Stabilization of Clayey Soil using Polypropylene Fiber", International Research Journal of Engineering and Technology (IRJET), Vol. 4, Issue 4, ISSN2395-0056.
6. Chen, Fu Hua. (1975)" Foundations on Expansive Soils." Elsevier Scientific Publishing Company.
7. Giang Nguyen, Eva Hrubešová, Adam Voltr, "Soil Improvement using Polyester Fibers", XXIV R-S-P Seminar, Theoretical Foundation of Civil Engineering.
8. Kalpana Maheshwari, Dr. Chandresh H Solanki, Dr. Atul K Desai, "Effects of Polyester Fiber on Strength Properties of Clayey Soil of High Plasticity", International Journal of Scientific & Engineering Research, Vol.4, Issue 6, ISSN 2229-5518.
9. Nelson, John D., Kuo Chieh Chao, Daniel D. Overton, and Erilk J. Nelson (2015)." Foundation Engineering for Expansive Soils". John Wiley & Sons, Inc., Hoboken, New Jersey.
10. Saikrishnamacharyulu I., Vinodh Kumar, K. Bhanuji Rao, G. Himala Kumari(2017) "Experimental study on soil stabilization using waste fiber materials". International Journal Technological Research in Engineering, Vol.4, Issue 10, ISSN 2647-4718.
11. Steinberg, Malcolm. (1999) "Geomembranes and the Control of Expansive Soil in Construction" McGraw-Hill.
12. Tank Y. R., Parmar J. P., (2014), "Experimental Study of Compressive Strength of Recycled Aggregate Concrete", International Journal of Engineering Research & Technology (IJERT), Vol. 3 Issue 4, ISSN: 2278-0181, April – 2014.