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Experimental Study on Black Cotton Soil Stabilized with Human Hair and Recron Fiber

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ABSTRACT
The black cotton soil is known as expansive type of soil which expands suddenly and start swelling when it comes in contact with moisture. Due to this property of soil the strength and other properties of soil are very poor. To improve its properties it is necessary to stabilize he soil by different stabilizers. Expansive type of soil shows unpredictable behavior with different kind of stabilizers. Soil stabilization is a process to treat a soil to maintain, alter or improve the performance of soil. In this study, the potential of Recron fiber and human hair as stabilizing additive to expansive soil is evaluated for the improving engineering properties of expansive soil. The varying proportion of Recron fiber and human hair were added to enhance the strength properties and make them more suitable to use and noted that there will be Change in various soil properties such as plastic limit, liquid limit, Shrinkage limit, Maximum dry density, Optimum Moisture Content and Unconfined Compression Strength, of soil were studied
Keywords: Black cotton soil, recron fiber, Human hair, Stabilization, OMC, MDD.

1. Introduction

For any land-based structure, the foundation is very important and has to be strong to support the entire structure. In order for the foundation to be strong, the soil around it plays a very critical role. So, to work with soils, we need to have proper knowledge about their properties and factors which affect their behavior. The process of soil stabilization helps to achieve the required properties in a soil needed for the construction work. From the beginning of construction work, the necessity of enhancing soil properties has come to the light. Ancient civilizations of the Chinese, Romans and Incas utilized various methods to improve soil strength etc., some of these methods were so effective that their buildings and roads still exist.In India, the modern era of soil stabilization began in early 1970's, with a general shortage of petroleum and aggregates, it became necessary for the engineers to look at means to improve soil other than replacing the poor soil at the building site. Soil stabilization was used but due to the use of obsolete methods and also due to the absence of proper technique, soil stabilization lost favor. In recent times, with the increase in the demand for infrastructure, raw materials and fuel, soil stabilization has started to take a new shape. With the availability of better research, materials and equipment, it is emerging as a popular and cost-effective method for soil improvement.Soil stabilization is used to reduce the permeability and compressibility of the soil mass in the earth structure and to increase its shear strength. Soil stabilization is required to increase the bearing capacity of foundation soil. However, the main use of stabilization is to improve the natural soil for the construction of highway and airfields. The principles of soil stabilization are used for controlling the gradient of soil and aggregate in the construction for base and sub-base for the highways and airfields. Soil stabilization is also used to make an area trafficable within a short period of time for military and other emergency purposes. Sometimes, soil stabilization is used for city and suburban streets to make them more noise-absorbing.

2. Literature Review

Being the major component of structure, many researches have been done on soil to improve its properties in every possible manner to develop a sustainable soil stabilization. Recron fiber and human as stabilizing additive to expansive soil is evaluated for the improving engineering properties of expansive soil. The details of literature review are given below.

An experimental study on stabilization of black cotton soil mistreatment hdpe wastage fibers, stone mud and lime -Arun Patida & Dr. H.K. Mahiyar,2014: during this investigation is run to review the impact of high density synthetic resin fibers, stone dirt and lime on index and engineering properties of the black cotton soil. The properties of stable soil like compaction characteristics unconfined compressive strength and CA bearing relation were evaluated and their variations with content of fibers, stone dirt and lime unit of measurement evaluated. Study on stabilization of black cotton soil by mistreatment stone mud and polypropene fibres - Dhananjay kumar Tiwari,dr. R.K.Dixit, Dr. Subrat Roy,2018 : This paper deals with a usefulness study distributed to hunt out the standard of exploitation waste the strength of black cotton soil is significantly improved by combination with stone mud and plastic fibers as stable materials. Geotech engineers area unit constantly sorting out new and acceptable engineering ways for rising the engineering properties black cotton soil. Our building comes, airports, terminal generates Brobdingnagian quantity of waste materials like stone mud, plastic fibers. Effect of lime and stone mud in the geotechnical properties of black cotton soil -Ankur Mudgal, Raju Sarkar and A.K. Sahu,2014: within the gift study Black Cotton Soil was stable with a mixture of lime and Stone mud. initial associate optimum worth of lime selected the concept of some geotechnical properties of mixture of lime and Black Cotton Soil. The samples were collected in the flesh and procured freshly at the beginning of the study and hold on properly. The collected soil samples were characterized inside the geotechnical laboratory of Delhi Technological University. Effect of quarry mud on engineering properties of black cotton soil - Hindu deity Chansoria,R. K. Yadav,2018 : This analysis paper presents the impact of quarry mud on engineering characteristics of black cotton soil . The check results shows that the California bearing relation (CBR) and compaction parameters of black cotton soil area unit improved with the addition of quarry mud. It is determined that the CMB values area unit exaggerated from one.75% to 7.05%, the optimum wet content has been reduced from twenty one.1% to 12.6% and most dry density square measure exaggerated from one.6 to 1.76gm/cc . it's together found that the expansive behavior of black cotton soil reduced to the great extent. during this experimental study it'll be finished that the expansive behavior of black cotton soil area unit reduced to a considerable extent with utilization of quarry mud. Experimental study on stabilization of black cotton soil with stone mud and fibers - K. Suresh, V. Padmavathi, Apsar Sultana,2009: during this stabilization methodology, primarily involve excavation of the unmoved soil, treatment to the unmoved soil and compacting the treated soil. as a result of the stabilization methodology involves excavation of the unmoved soil, this method is sweet for improvement of soil in shallow depths like pavements. Foundations in expansive soils, popularly referred to as black cotton soils throughout this country, bear alternate swelling and shrinkage upon wetting and drying as a result of seasonal wet fluctuations. Typically, wet and vapor migrates from the nice and cozy temperature zones around the building. the excellence in water contents between the within and so the outside zones of the building causes uplift of the within portion and lands up in mound – fashioned heave of the bottom of the building. This induces hogging moments, that unit of measurement extra detrimental to the protection of the structure than lax moments. Cement stabilized black cotton soil for pavement subgrade construction -Githaiga Esther Nyakarura,2015: The expansive nature decreases the bearing capability of the soil. The black modify Black cotton soil is as a result of the presence of Titania in small concentration. Expansive soils, once associated with academic degree engineering structure, will show a bent to swell or shrink inflicting the structure to experience movements that unit of measurement unrelated to the direct loading of the structure. because of its high swelling and shrinkage characteristics, Black cotton soils square measure a challenge to the most road engineers.

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Objectives

1. To evaluate physical properties of existing soil in laboratory and compare the property of recron fiber with human hair.
2. To determine the properties of soil and soil stabilized with recron and human hair with different percentage individually.
3. To find out the improvements in soil by the addition of optimum dose of Recron fibers and human hair mixes in terms of UCS value.
4. To determine the Effect of recron and human hair fiber on shear parameters of soil.

Scope:

The experimental work consists of the following steps:

1. Specific gravity of soil
2. Determination of soil index properties (Atterberg Limits)

i) Liquid limit by Casagrande's apparatus
ii)Plastic limit

3. Determination of the maximum dry density (MDD) and the corresponding optimum moisture content (OMC) of the soil by Proctor compaction test
4. Determination of the shear strength by:

i) Unconfined compression test (UCS)

3. Materials & Methods

The materials to be used in the present project will be collected from various places and the basic tests were carried out on the procured materials to study the material properties in order to make suit the material for the project.

Black cotton Soil

Black Cotton Soil is soils or soft bedrock that increases in volume or expand as they get wet and shrink as they dry out. In India this Expansive soil is called "Black Cotton Soil". The soil used in this study was collected from Coimbatore city. The sample was thoroughly oven dried, weighted and stored in sacks at room temperature. The general properties of the soil was thoroughly studied in the laboratory. The soil was tested for liquid limit, optimum moisture content, maximum dry density and unconfined compression strength.

Human Hair

The Human Hair was locally purchased. Keratin is a protein that is responsible for the formation of human hair. Length of the Human hair fiber is 4 cm. Diameter is 60-100µm. Human hair creates environmental problems, to minimize that it can be used as reinforcing agent. Addition of hair fiber to the concrete increases the mechanical properties.

Table 1: Physical properties of human hair

Length	40
Diameter	60-100
Plastic modulus(G Pa)	3.5
Linear density(g/cm)	1.32
Yield strength(M Pa)	74.34
Breaking strength(M Pa)	119
Strain at break (%)	29
Tensile strength(M pa)	384.79

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Fig 1 Black cotton soil with human hair

Recron Fiber

Fig 2 Recron Fiber

Recron 3S is a modified polyester synthetic fibre. It is generally utilized as secondary reinforcing material in concrete and soil to increment their performance. Recron 3S sample utilized in experiment was of 12mm length and manufactured by Reliance Industries limited. Utilization of Recron-3S as a reinforcing material is to increment the in sundry applications like cement predicated precast products, filtration fabrics etc. It withal provides resistance to impact, abrasion and greatly ameliorates the quality of construction during substratum, retaining wall design etc. Recron-3S fibre is the most widely used includes laboratory testing of soil reinforcement. Currently Recron-3S fibre is utilized to enhance the soil strength properties, to decrease the shrinkage properties and to surmount chemical and biological degradation.

Mix Details:

For getting a good result all the material should be properly mixed in dry condition and required proportion should be maintain. Recron Fiber and hair mixed with black cotton soil in different proportion. Recron Fiber proportion varying from 0 % to 20. Same way Hair proportions varying from 0% to 10 %. To make experimental work easy and avoid the misinterpretation; fix designation was given to each type of mixes. Various mixes and their designation are given in Table 2.

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Table 2: Various mixes and their designation

Mix Name	Recron Fiber	Hair
Mix-1	0%	0%
Mix-2	1%	0.5%
Mix-3	3%	1.5%
Mix-4	5%	2.5%

4. Experimentation

This chapter presents the details of experimental investigations carried out on the test specimens to study the properties of soil and soil stabilized with recron fiber and human hair with different percentage individually. The experiment is conducted on recron fiber and human hair test specimens to ascertain the strength related properties such as Specific gravity of the soil, Liquid limit, Plastic limit, Standard Procter Test and Unconfined Compression Strength Test of various mixes. The soil specimens are tested, and the average is reported for each soil mix for each test. All the tests are conducted as per Indian standards.

Specific gravity of the soil

The specific gravity of soil under investigation was determined as per standard density bottle method and with usual test method prescribed in I.S. 2720 (Part 3) 1980.
The pycnometer was dried thoroughly and weighted with cap tightly screwed on. The cap and pycnometer was made with a vertical line parallel to the axis of the pycnometer so that each time the cap was screwed the same amount. The cap was unscrewed and about 200gm of oven dried soil passing 4.75mm I.S. Sieve was put in and weighted again. Sufficient water was add to cover the soil about half full and cap was screwed on. It was then shaken well and connected to vacuum pump to remove entrapped air. Air was allowed to evacuate for at least 20 minutes. Pycnometer was shaken occasionally to assist in the air evacuation. After the entrapped air had been largely removed, the pump was disconnected and pycnometer was filled with water about three fourth full. Vacuum was reapplied for at least 5 minutes. Evacuation was continued until very few bubbles appear on the top of the water. After the air had been eliminated, pycnometer was filled with water completely up to the mark. The pycnometer was dried from the outside and weighted. Then pycnometer was filled with water up to its top and screwed. The pycnometer was weighted after drying it on the outside thoroughly. The test was repeated twice more.

$$\text{Specific Gravity} = \frac{(w_2 - w_1)}{(w_4 - w_1) - (w_3 - w_2)}$$

W_1 = Weight of bottle in gram.
W_2 = Weight of bottle + Dry soil in gram
W_3 = Weight of bottle +Soil + water
W_4 + Weight of bottle + Water

The value of specific gravity helps up to save extent in identification and classification of soils. It gives an idea about the suitability of the soil as a construction material. Higher value of specific gravity gives more strength for roads and foundations. Table 3 shows the specific gravity result.

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Table3 Specific Gravity Result

S.No	Observation and calculations	Determination No.			
		1	2	3	4
1	Mass of empty pycnometer (M_1)	624g	624g	624g	624g
2	Mass of pycnometer and dry soil (M_2)	833g	830g	825g	818g
3	Mass of pycnometer soil, filled with water (M_3)	1598g	1595g	1590g	1583g
4	Mass of pycnometer filled with water only (M_4)	1466g	1464g	1461g	1456g
	Calculations				
5	(M_2-M_1) gm.	209g	206g	202g	197g
6	(M_3-M_4) gm.	132g	131g	129g	126g
7	$G = \frac{(5)}{(5)-(6)}$	2.71	2.74	2.78	2.83

Liquid limit

The Liquid limit of the soil under analysis was determined according to the standard procedure prescribed in I.S.270 (Part V) 1970.

About 120 gm. of oven dry soil was sieved through 425-micron I.S. sieve after that soil mixed with known quantity of water in a dish for obtain uniform past. After required time of maturing of soil to ensure that water will penetrate into the pores of soil, a small amount of soil of this paste is placed in the cup of the liquid limit device, and the surface is smoothened and levelled with a spatula to a maximum depth of 1 cm. By using casagrande tool width 2mm at bottom, 11 mm at top and 8mm deep a groove is cut through the sample along the symmetrical axis of the cup in one stoke.

After cut by groveling tool, the handle of casagrande tool is turned until the two parts of the soil sample come in to contact the bottom of the groove along a distance of 12mm at a rate of 2 revolutions per second and number of blows were recorded ranging between 25 and 40 at incensing percentage of water. Moisture content at recorded number of bows as per the standard procedure and flow curve is prepared.

The percentage moisture content at which a soil changes with decreasing wetness from the liquid to the plastic consistency or with increasing wetness from the plastic to the liquid consistency The values obtained indicates that the material is non critical (LL between 20 – 35) as per IS 1498 – 1970. Table 4 shows the liquid limit result for Mix-1.

Table 4 Liquid Limit Result

S.No	Observation and calculations	Determination No.			
		1	2	3	4
1	No. Blows (N)	40	33	30	20
2	Moisture Content Container No.	1	2	3	4

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3	Mass of empty container (M_1)gm.	31	32	32	31
4	Mass of container + wet soil (M_2)gm.	46	47	46	45
5	Mass of container + dry soil (M_3)gm.	42	42.8	41.7	40.3
	Calculations				
6	Mass of water = (M_2-M_3) gm.	4	4.2	4.3	4.7
7	Mass of dry soil = (M_3-M_1)gm.	11	10.8	9.7	9.3
8	Water content, w = $\frac{(6)}{(7)} \times 100$ %	45%	42.2%	40.6%	36.5%

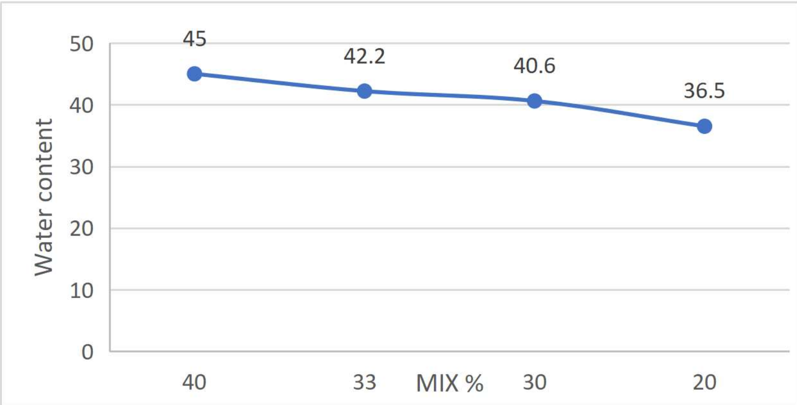

Fig 3 Liquid Limit Graph for Mix-1
Liquid limit as obtained from graph = 45
(Corresponding to 25 blows)

Table 5 Liquid limit Result for various %

Mix	LL%
Mix-1	45
Mix-2	42.2
Mix-3	40.6
Mix-4	36.5

Plastic limit

For determination of the plastic limit of a soil I.S. 2720 (Part 5)-1970 was followed. Soil is air-dried and sieved through a 425µ IS sieve. About 30gm of soil is taken in evaporating dish. It is mixed thoroughly with distilled water till it becomes plastic and can be easily molded with fingers. About 10gm of the plastic soil mass is taken in one hand and ball is formed. The ball is rolled on a glass plate to form a soil thread of uniform diameter. The rate of rolling is kept about 80 to 90 strokes per minute. The process is repeated till the thread crumbles. The water content at which the soil starts crumble just about 3mm diameter is determine by standard procedure.

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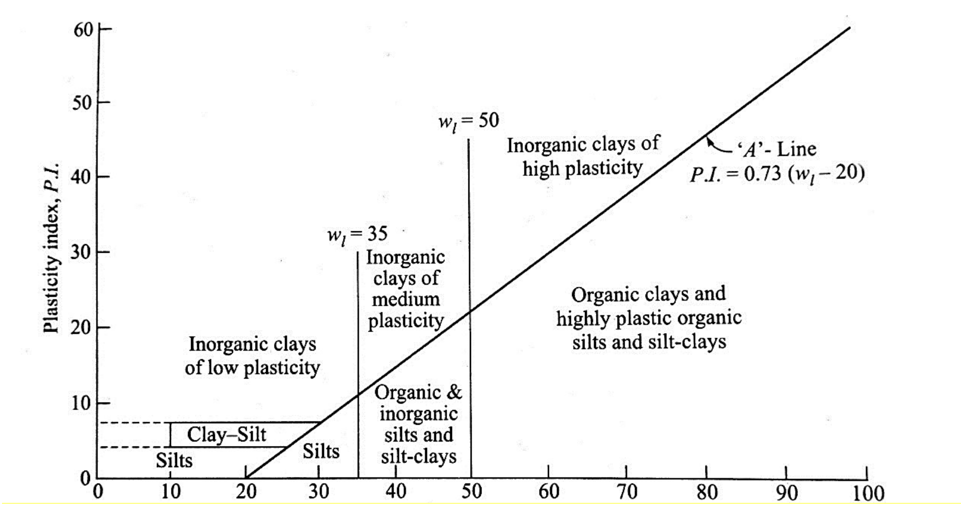
Fig 4 Plastic limit test of the soil

$$I_p = W_L - W_P$$

W_L- Liquid limit

W_P- Plastic limit



Liquid Limit, w_L

Fig 5: Plastic Index Chart

The percentage moisture content at which a soil changes with decreasing wetness from the plastic to the semi- solid consistency or with increasing wetness from the semi-solid to the plastic consistency. Table 6 shows the plastic limit result for Mix-1.

Table 6 Plastic Limit Result

S.No	Observation and calculations	Determination No.			
		1	2	3	4
1	Moisture Content Container No.	1	2	3	4
2	Mass of empty container (M_1) gm.	32gm	32gm	32gm	32gm
3	Mass of container + wet soil (M_2)) gm.	38.16gm	38.50gm	38.86gm	39.18gm
4	Mass of container + dry soil (M_3)) gm.	36.96gm	37.23gm	37.61gm	37.87gm

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	Calculations				
5	Mass of water = (M_2-M_3) gm.	1.2gm	1.27gm	1.38gm	1.49gm
6	Mass of dry soil = (M_3-M_1) gm.	4.96	5.23gm	5.58gm	5.87gm
7	Water content, w = $\frac{(5)}{(6)} \times 100$ %	24.33%	23.72%	22.68%	21%

Table 7 Plastic limit results for various %

MIX	PL%
Mix-1	24.33
Mix-2	23.72
Mix-3	22.68
Mix-4	21

Plasticity Index = Liquid Limit – Plastic Limit
= 45-24.33 = 20.67
From Liquid Limit chart soil was CI type
By similar method liquid limit, plastic limit and plasticity index is determined at various percentage of fiber and hair and results of experiment shown in Table 8

Influence on various mix of fibre and hair on Atterberg's limits

Table 8 Influence on various mix of fiber and hair on Atterberg's limits

Mix	L.L %	P.L %	P.I %
Mix-1	45	24.33	20.67
Mix-2	42.2	23.72	18.48
Mix-3	40.6	22.68	17.52
Mix-4	36.5	21	15.5

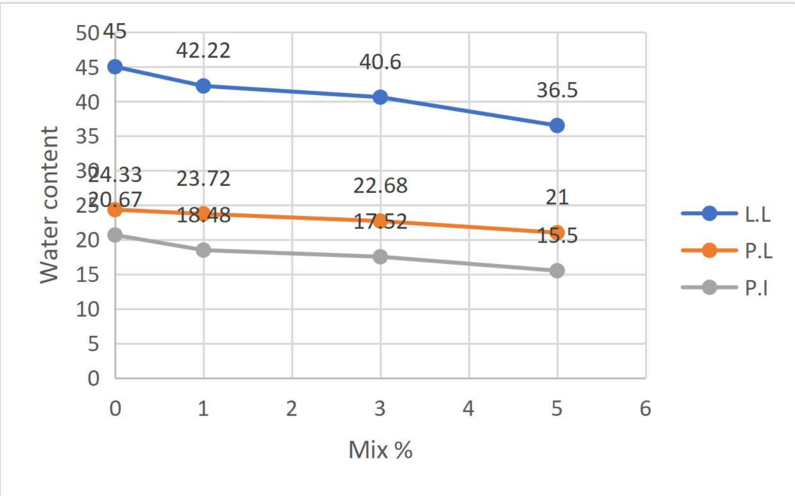

Fig 6 Influence on various mix of fibre and hair on Atterberg's limits

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Fig 6 show that up to 15 of fibre and hair is added, there is a considerable decrease in PI, and after that value seems to be almost constant.

Standard Procter Test

This test was performed as per standard procedure laid down in I.S. 2720 (Part 7) 1965. It consists of mound 1000 ml capacity with an internal diameter of 100 mm and internal effective height is 127.3 mm. The hammer has a mass of 2.6 kg and the free fall of hammer is 310mm.

About 2.5 Kg of oven dry and cooled soil was taken. The soil was sieved through I.S sieve of 4.75mm. This soil was mixed thoroughly by adding 10% of water by weight. The sample was covered with wet cloth and allowed to mature. The mould was cleaned, dried and greased lightly. The empty mould attached to base plate was weighted without collar. The collar was then attached to the mould. The mixed soil sample then placed in mould to about one-third of its height and each layer was compacted by 25 free falls of standard hammer. The soil surface of compacted soil was screeched with spatula before the second layer was placed. Utmost care was taken that blows were equally distributed over the surface of each layer. After three layers were laid, collar was removed and excess of the soil was trimmed of to make it level with mould. Mould and soil together was weighed. Its dry density was determined as per the standard procedure.

Fig 7 Standard Procter Test

$$\text{Wet density} = \frac{\text{weight of soil in mould(gms)}}{\text{volume of mould (cc)}}$$

$$\text{Moisture content \%} = \frac{\text{Weight of water (gms)}}{\text{Weight of dry soil (gms)}} \times 100$$

$$\text{Dry density (gm. /cc)} = \frac{\text{Wet density}}{1+\frac{\text{moisture content}}{100}}$$

Standard Proctor tests (ASTM D698-07) have been carried out to determine the maximum dry density and optimum moisture content for all the nineteen number of the samples. Fig.3 &Table 7,8 shown all the curves of soil samples.

Diameter of mould = 100mm
Height of mould = 127.3
Volume of mould, V = $\pi/4 \times (10)2 \times 127.3$ = 1000 ml
Specific Gravity of Solids, G = 2.72

Table 9 Standard Proctor Test for normal soil

S.No	Observation and calculations	Determination No.			
		1	2	3	4
1	Mass of empty mould + base plate	5400g	5400g	5400g	5400g
2	Mass of mould + base plate + compacted soil	6873g	7100g	7048g	7042g

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	Calculations				
3	Mass of compacted soil, M= (2-1)	1468g	1695g	1648g	1642g
4	Bulk density, $\rho = \frac{M}{V}$	1.46g/ml	1.69g/ml	1.648g/ml	1.642g/ml
5	Water content, w	9%	16%	19.6%	21%
6	Dry density, $\rho d = \frac{\rho}{1+w}$	1.34	1.45	1.38	1.35
7	Void ratio, $e = \frac{G\,\rho_w}{\rho d} - 1$	1	0.84	0.93	0.97
8	Dry Density at 100 % saturation (ρd) theomax $= \frac{G\,\rho_w}{1+wG}$	2.15g/ml	1.87g/ml	1.77g/ml	1.71g/ml
9	Degree of Saturation, $S = \frac{w\,G}{e} \times 100$	24 %	50 %	54 %	57%

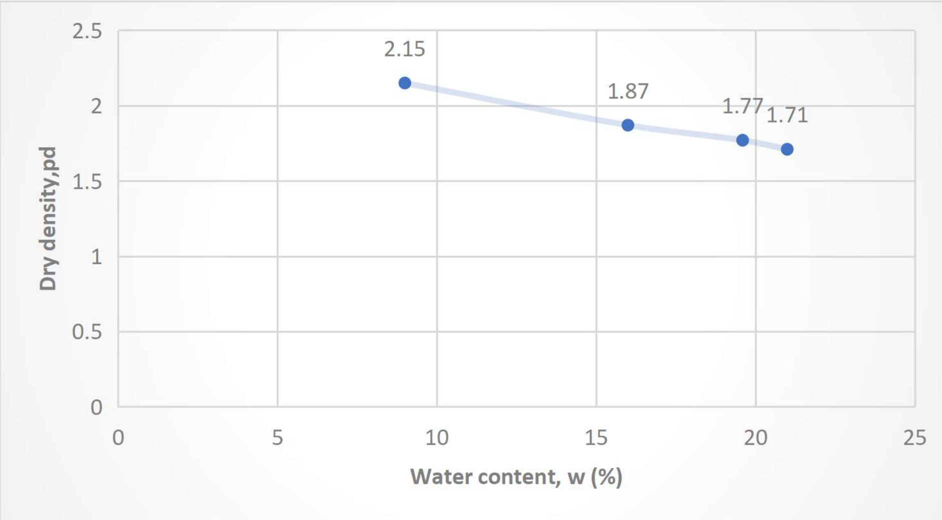

Fig 8 Standard Proctor Test graph

Influence of Fibre And Hair on OMC and Dry Density

Table 10 Standard Proctor Test result for various percentage

% Fibre And Hair	OMC (%)	MDD(g/cc)
Mix-1	16.2	1.45
Mix-2	16.3	1.42
Mix-3	17	1.40
Mix-4	17.85	1.395

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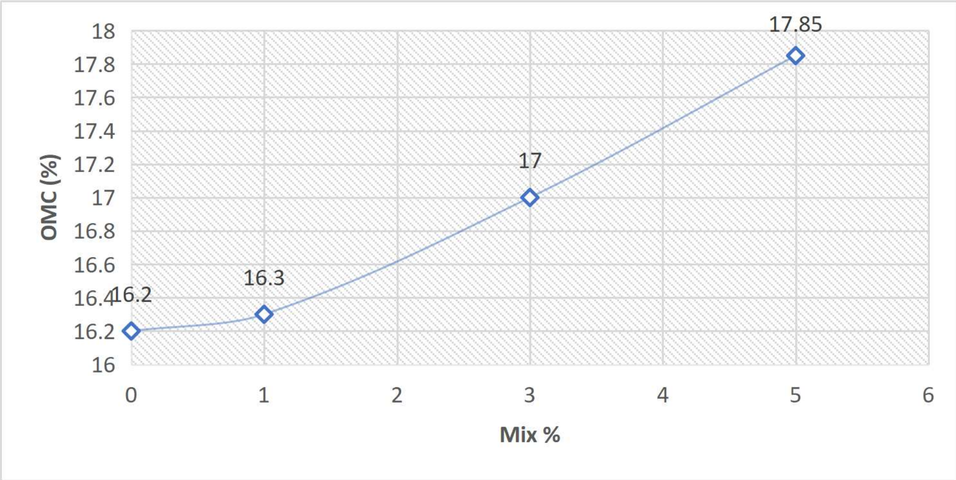

Fig 9 Standard Proctor Test graph various mix

It can be inferred from Figure 5, 6 that there is increase in OMC with increase Fibre and hair. The increase is due to the addition of Fiber and Hair, which decreases the quantity of free silt and clay fraction and coarser materials with larger surface areas were formed. This implies also that more water is needed in order to compact the soil- Fiber and Hair mixture.

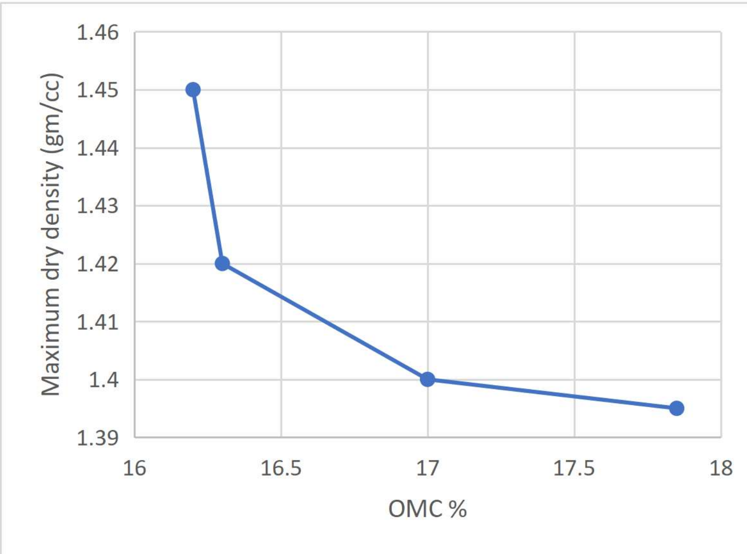

Fig 10 Standard Proctor Test graph

The MDD decreases by increase the content of Fiber and Hair. The MDD decreases in MDD can be attributed to replacement of soil by the Fiber and Hair which has relatively low specific gravity.

Unconfined Compression Strength Test

This test was conducted as per I.S 2720 (Part 10) – 1973.

a) Preparation of Sample

Required quantity of oven dried soil was sieved through I.S sieve 475μ and then soil sample was prepared by taking into consideration of weight of the soil calculated from the volume of mould and maximum dry density. Tap water was used and mixed at O.M.C. A homogeneous sample was prepared by mixing thoroughly the soil and water in an open bowl. Mould used was split type and it was properly greased with oil from inside and soil mixture prepared was put in layers and compacted. The sample was removed by splitting the mould into two parts.

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Fig 11 Preparation of Sample

b)Testing of soil sample

The specimen was placed on the bottom plate of the unconfined compression machine (proving ring type) then raised gradually to make its contact with the upper plate. The dial gauge and proving ring were set to zero. The compression load was applied to the specimen by turning the handle to produce an axial strain of $1/2$ to 2% per minute. The shearing was continued till the specimen failed. The compression force was determined from the proving ring reading and axial strain was counted from the dial gauge reading. Three samples were tested in this way and the average reading was considered by taking least count of proving ring as 0.5kg/ division and by dividing it with the X-sectional area at the center of bulge.

Fig 12:Testing of soil sample

$$qut = \text{Load} / \text{corrected area}(A')$$

qu = Compressive stress

A'= Cross- sectional area / (1-ε)

The unconfined compressive strength of the cylindrical shaped specimens (50 mm diameter and 100 mm length) were determined according to BS 1377 (1990). The cylindrical specimen was placed on the base plate and the load frame has been fixed without any stress application upon the specimen. The geotechnical properties of these sodium chloride stabilized soil samples were evaluated and compared with that of soil before stabilization.

Table 11 Unconfined Compression Test for Mix-1

Dial gauge reading	Strain(ϵ)	Proving ring reading	corrected area	load (kg)	Axial Stress (kg/cm^2)

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50	0.00641	15	19.75	7.5	.37
100	0.012	35	19.86	17.5	.88
150	.0192	62	20.01	31	1.54
200	.0256	77	20.14	38.5	1.91
250	.0320	90	20.27	45	2.22
300	.030	98	20.40	49	2.40
350	.044	93	20.53	46.5	2.26
400	.0312	85	20.68	42.5	2.05

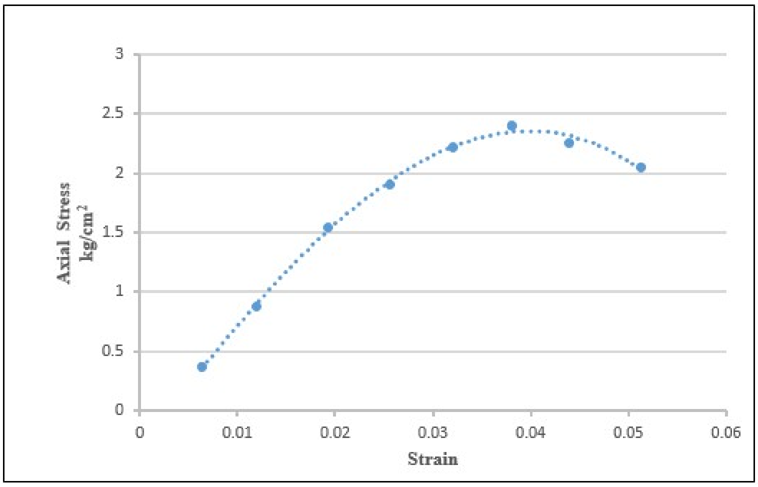

Fig 13 Unconfined Compression Test graph

As obtained from graph,
USC = 2.37 kg/cm^2

Table 12 Unconfined Compression Test for various Mix

Mix	Axial Stress (kg/cm^2)
Mix-1	2.37
Mix-2	3.58
Mix-3	4.85
Mix-4	5.42

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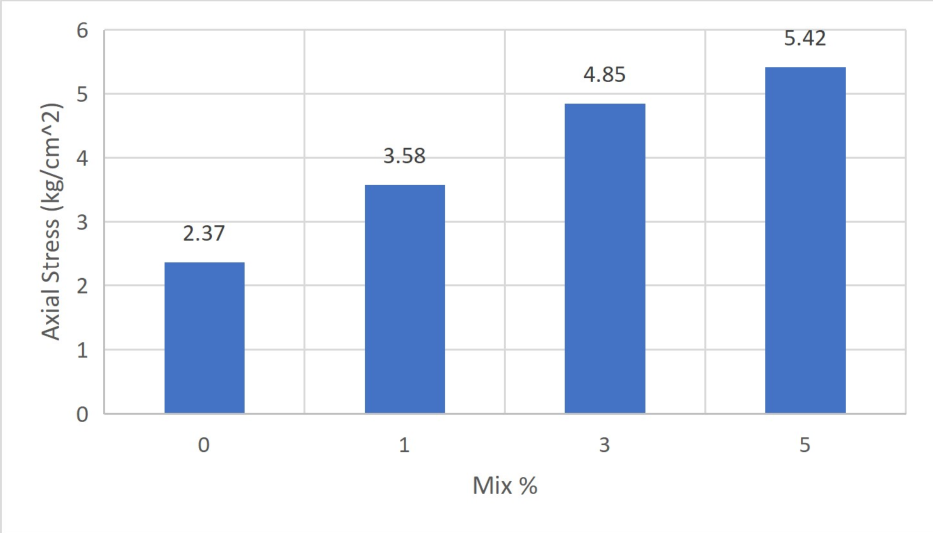

Fig 14 Unconfined Compression Test Results for various mix

Figs.13 &Table 14 shown the Unconfined Compression Test Results for various mix. The maximum axial stress obtained from mix-5%.then the axial stress is reduced.

CONCLUSION

In the light of the preceding results and discussion, the following can be concluded: -

a) The usage of Recron Fiber and Hair material in the stabilization of soil gives better option to increase the soil strength.

b) It is observed that liquidity and plasticity of the soil decreases with addition of Hair and recron fibers this happens because of non plastic nature of soil.

c) There will be appreciable improvements in the optimum moisture content from 16.2% to 17.85% and maximum dry density when treated with Recron Fiber and Hair.

d) The addition of stabilisers increases the unconfined compression strength value from 2.37% to 5.42% which is more than the ordinary method.

e) It can reduce ground improvement costs by adopting this method of stabilization.

f) We have successfully experimented up to the mix of 5% recron fiber and 2.5% human hair into black cotton soil and it is observed that the more we add the mixture more the result we get.

g) Overall it can be concluded that fiber reinforced soil can be considered to be good ground improvement technique specially in engineering projects on weak soils where it can act as a substitute to deep/raft foundations, reducing the cost as well as energy.

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