Stabilization of Black Cotton Soil by Using Glass Fibres

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Abstract— Soil stabilization is the process which enhances the properties of soil by mixing of different admixtures in various proportions. Stabilization increases the load bearing capacity of soil by mixing of glass and plastic fibre in different percentage in expansive soils. In this paper, effect of mixed plastic and glass fibre in varying proportion on Mass Dry Density (MDD), Optimum Moisture Content (OMC), specific gravity and California Bearing Ratio (CBR) on Black Cotton Soil has been discussed. The percentage of 6 mm glass fibre by dry weight of soil was taken as 1%, 1.5%, 2% and 2.5% and the percentage of 12 mm glass fibre by dry weight of soil was taken as 1%, 1.5%, and 2% constantly. By using the above test on the black cotton soil the compressive strength and and its property is increased by using glass fibre as an admixture.
Keywords: Black Cotton Soil, Glass Fibres

I. INTRODUCTION

Most buildings and other civil engineering construction projects are started as raw land. The first step to be performed is site investigation in order to know the situation of the site. It is difficult to find location that has perfect soil properties. Possible alternative solutions to solve this reality are:
Avoid that site. Relocate the planned construction project to another site. Replace unsuitable soils. After obtaining the soil properties, it can be determined the soils are unsuitable, then remove with the better soils. Try to modify the existing soil. This is called as ground modification.

A. Mechanical Modification

External mechanical forces are used to increase soil density, including soil compaction by using many methods, such as static compaction, dynamic compaction, or deep compaction by heavy tamping.

B. Hydraulic Modification

Pore-water is forced out of the ground through drains or wells. Lowering the groundwater level by pumping from trenches or boreholes can be applied for coarse-grained or cohesion less soil and for fine-grained or cohesive soil, application of the long-term of external pressure (preloading) or electrical loads (electro kinetic stabilization) is needed. Another technique can be applied such as hydraulic modification is by using geo-synthetics.

C. Physical and Chemical Modification

One example of this method is soil stabilization by physically mixing/blending additives with top layers at depth. Additives can be natural soils, industrial by-products or waste materials, and other chemical materials that can react with the ground. Other applications are ground modification by grouting and 2 thermal modifications which are already discussed before.

D. Modification by Inclusions and Confinement

This group is considered as strengthening soil by materials, such as meshes, bars, strips, fibers, and fabrics correspond to the tensile strength. Confining site with concrete, steel, or fabric elements can also form stable-earth retaining structures. Conventional pile foundations are not considered in this group, although sometimes they are called as "compressive reinforcement".

E. Fibre

A fibre is a unit of matter characterized by flexibility, fineness and a high ratio of length to thickness (or diameter) as shown in Fig.1. The fibre has been considered a general term that refers to all filaments, yarns, staples, bristles/hairs, buffings, chips, crumbs and other similar highly flexible entities. A filament is an untwisted individual fibre and can be crimped or uncrimped. A yarn refers to a bundle or series of filaments twisted to produce a single fibre in which the foundation soil reinforced randomly with natural root fibres visible in an excavated trench closer to the tree as shown in Fig.2 supporting a tree. Basic Description of Fibre-Reinforced Soil individual filaments cannot be separated. Crimping of filaments helps prevent filament separation when the yarn is made. A staple is a cut length of fibre, measured and expressed in millimetres.

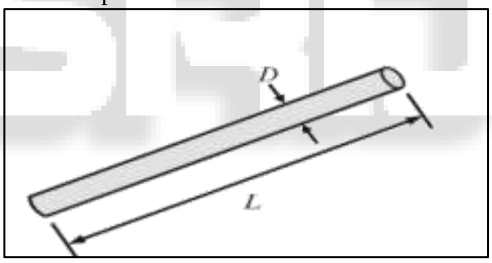

Fig. 1: Glass Fibre

Fig. 2: Foundation soil reinforced randomly with natural root fibers

Fibres are obtained from natural, synthetic and waste (nonhazardous type) materials, and therefore, they may be categorized into the following three types:

- Natural fibres
- Synthetic fibres
- Waste fibres

In addition to coir and jute fibres, as shown in Fig.3, there are several other natural fibres, such as wood chips, bamboo fibres, sisal fibres, palm leaves, grasses, banana fibres, corn stalks, oat and flax straws, manila fibres, cotton fibres, etc. They are available locally in different places worldwide, and can be used as the geofibres. Human and animal hairs are also available as natural fibres.

Most natural fibres originate from plant and vegetation, animal and mineral sources. Bamboo grids and mats are also used as soil reinforcement to create systematically reinforced soils as the geosynthetic reinforcements are used. Of most natural fibres, coir has the greatest tensile strength and retains this property even in wet conditions. It is a biodegradable organic fibre material containing 40% lignin and 54% cellulose. The high content of lignin, which is a complex hydrocarbon polymer, makes the coir fibres degrading slowly, and so they are useful in different applications. The coir fibres may play their roles for a long period (1–2 years) when included within the soil mass, even in saline environment. Bamboo fibres are very strong in tension but have low modulus of elasticity and high water absorption. The best quality of bamboo fibres is that they are seldom eaten by pests or infected by pathogens. Certain fibres, such as sisal fibres, have very high initial tensile strength and are strong as the equivalent polyester fibres.

There are some common natural fibers discussed by Hejazi:

1) Coconut (coir) Fiber:

It is from matured coconut, or coconut husk, normally 50-350 mm long and contains mainly cellulose, pectin, tannin, lignin and other water soluble substances. Due to high lignin content, it will be degraded slowly than other natural fibers. Because of that, the coconut fiber can be long-lasting, around 4-10 years of service life. Typically, it has much tensile strength when wet. This fiber is produced mostly in South Asian countries, like Indonesia, Philippines and India.Fig.3.(a) shows the example for coir fiber. Reinforcing soil by coir fibers can increase tensile strength.

2) Palm Fibers:

This fiber, which has low elasticity modulus and tensile strength,is extracted from decomposed palm trees. Soil reinforced with palm fibers has greater unconfined compressive strength, CBR and shear strength parameters.

3) Jute:

Jute is one of natural fibers grown in India, China, Pakistan, Bangladesh and Thailand. Singh and Bagra conducted study about effect of jute fiber inclusion on CBR improvements. The contents of Jute fiber were determined by dry weight of soil, which are 0.25% to 1% (interval of 0.25%). Other variation used is dimension of the fiber (the length and diameter). The lengths were 30 mm up to 90 mm with the interval of 30 mm, while two diameters were considered: 1 mm and 2 mm. Tests results indicate that the CBR value of soil was increased as the inclusion of jute fiber (0%-1%). Maximum increase is 200% at 1% jute fiber inclusion with the diameter of 2 mm and 90 mm length. Fig.3.(b) shows the example for jute fiber.

Some synthetic (man-made) fibers are also discussed by Hejazi:

1) Polypropylene (PP) Fibers:

Polypropylene fiber is the most common synthetic fiber used as a reinforcement material for the soil improvement and concrete (Song et al., 2005). This fiber has properties of hydrophobic, non-corrosive resistance over chemicals, alkalis and chlorides. Reinforcing soil with polypropylene fiber can increase UCS and shear strength.

Fig.4.(a) shows the example for Polypropylene (PP) fibers fiber.

2) Polyester:

One of polymer category contains the ester functional group in their main chain. Although many types of this polymer, it is commonly referred to as polyethylene terephthalate (PET). Maheshwari et al. (2011) studied clayey soil reinforced with randomly distributed polyester fiber. Amount of polyester fibers (diameter of 12 mm) mixed with clayey soil (highly compressible) varies from 0 to 1%. The result of this study show that significant increase in bearing capacity with the inclusion of polyester fibers up to 0.50%, then it will be decreased with further inclusion of fibers.

3) Glass Fibers:

Glass fibers inclusion in silty sand increases the triaxial peak strength, because fiber inclusion is more effective for uncemented soil. The friction angle of glass fiber reinforced sandy soil is also increased from 35° to 46°. Significant improvement in soil strength parameters of glass fiber reinforced-soil into various soil media happened. This is shown clearly by the increasing in cohesion values and internal friction angles. The lightweight, ready availability and non-biodegradable characteristics of this fiber is advantage proof that this fiber can be used for long term soil improvement.

In recent years the uses of fibers in various fields have gained much importance. Several researches on soil reinforced fibers have been reported some amongst are shown below. The research on fiber-reinforced soils demonstrated that this material might be a practical and cost In comparison with systematically reinforced soils, randomly distributed fiber reinforced soils exhibit some advantages. Randomly distributed fibers offer strength isotropy and limited potential plane of weakness that can develop parallel to oriented reinforcement fibers are used to evaluate a methodology for preventing crack developments in clays due to desiccation.

It is suggested that the reinforcing fiber concept might be improved if longer fibers are used. Glass fiber is formed when thin strands of silica-based or other formulation glass are extruded into many fibers with small diameters suitable for textile processing. The technique of heating and drawing glass into fine fibers has been known for millennia; however, the use of these fibers for textile applications is more recent. Until this time, all glass fiber had been manufactured as staple. Fig.4.(b) shows the example for glass fibers fiber. And Fig.5. shows example of Waste fibres: (a) old/used tyre fibres, (b) waste/used plastic fibres.

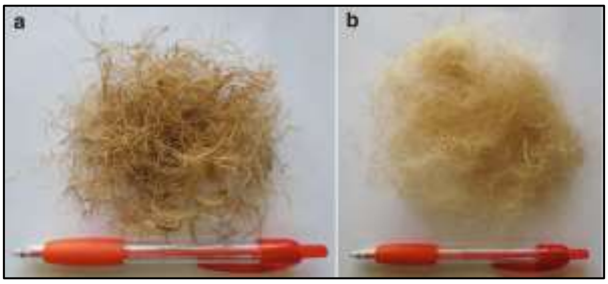

Fig. 3: Natural fibres: (a) coir fibres, (b) jute fibres

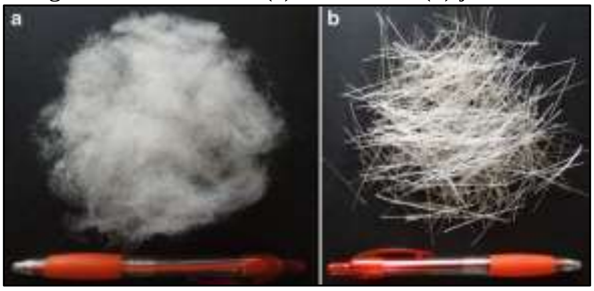

Fig. 4: Synthetic fibres: (a) polypropylene (PP) fibres, (b) glass fibres

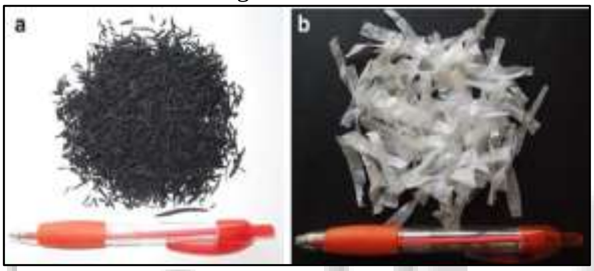

Fig. 5: Waste fibres: (a) old/used tyre fibres, (b) waste/used plastic fibres

F. *Fiber-Reinforced Soil*

Another solution to reinforce soil is by using fiber. It has been a solution to stabilize thin soil and localized repair of failed slopes. Unlikely geosynthetics, another reinforcement method using fibers is applied by distributing the fibers randomly. Fibers which can be used either natural fibers or synthetic fibers. Hejazi made a simple study by reviewing more than 100 researches of soil reinforcement by using natural and synthetic fibers.

To prepare sample or specimens of fiber-reinforced soils to be tested in the laboratory, it can be mixed either manually or mechanically by using mixing machine. Whatever the mixing method used, many researches implicitly assume that the fibers will be randomly distributed in the soil mass. That orientation distribution would give the soil strength isotropy. Effects of fiber-reinforced soil are relatively similar to geosynthetics-reinforced soil for both coarse-grained and fine-grained soils, such as increasing bearing capacity and soil strength.

G. *Advantages and Disadvantages of Soil Reinforcement Using Fiber*

1) Advantages:

1) Cheap, locally and widely available, ecofriendly.
2) It can enhance the soil strength.
3) It is not significantly affected by weather conditions, compared to cement, lime and other chemical stabilization techniques.
4) Reinforcing soil with fiber can inhibit the tensile crack propagation and change the failure mechanism after initial formation.
5) The lightweight, ready availability characteristics of glass fiber is a proof that glass fiber can be used for long term soil improvement.

2) Disadvantages:

1) Despite the fact that many researches have been conducted to determine the effects of using fibers to improve the soil, there are still no scientific procedures or standard, especially for field project.

II. METHODOLOGY

The experimental work consists of the following steps:

- Specific gravity of soil
- Determination of soil index properties
  - Liquid limit by Casagrande's apparatus
  - Plastic limit
- Particle size distribution by sieve analysis
- Determination of the maximum dry density (MDD) and the corresponding content (OMC) of the soil by Proctor compaction test.
- Preparation of reinforced soil samples.
- Testing of prepared samples.

III. MATERIALS USED FOR CONDUCTION OF EXPERIMENTS

A. *Black Cotton Soil*

Black cotton soil is used for the conduction of experiments which brought from nearby place from Bidar as shown in Fig.6. And the physical properties of Black cotton soil is Listed as shown in Table 1.

Fig. 6: Sample black cotton soil used for testing

Sl.No	Properties	Values
1	Colour	Black
2	Specific gravity(G)	2.45
3	Grain size distribution	
	Fine sand(%)	2.2
	Silt(%)	22.3
	Clay(%)	75.3
4	Atterberg Limits	
	Liquid limit(w_L)(%)	58
	Plastic limit(w_P)(%)	28
	Plasticity index(PI)	30
5	IS Classification	MI

6	Compaction Optimum moisture content(OMC)(%) Maximum dry density(MDD)(g/cc)	12 1.53

Table 1: Physical Properties of Soil

B. Glass Fibre

Glass fibre is a material consisting of numerous extremely fine fibres of glass. Size of glass fibres used are of 6mm and 12mm.

IV. Objectives of the Study

1) The main objective of this study is to investigate the use of glass fiber in geotechnical applications.
2) To check out the strength of soil by varying the percentages of glass fibres by carrying out tests on soil samples such as consistency limit test, compaction test, CBR test, specific gravity, etc.

V. Results and Discussion

A. Specific Gravity of the Soil

The specific gravity of soil is the ratio between the weight of the soil solids and weight of equal volume of water. It is measured by the help of a volumetric flask in a very simple experimental setup where the volume of the soil is found out and its weight is divided by the weight of equal volume of water. This test is carried out for two times as shown in Table 2 and the value was 2.45

Sample Number	1	2
Mass of empty bottle (M1) in gms.	112.45	115.27
Mass of bottle+ dry soil (M2) in gms.	163.83	165.27
Mass of bottle + dry soil + water (M3) in gms.	390.088	398.16
Mass of bottle + water (M4) in gms.	359.448	367.87
specific gravity	2.4	2.5
Avg. specific gravity	2.45	

Table 2: Specific Gravity Calculations

B. Liquid Limit

The Casagrande's Apparatus is used with tool cuts a groove of size 2mm wide at the bottom and 11 mm wide at the top and 8 mm high. The number of blows used for the two soil samples to come in contact is noted down as shown in Table 3 and Graph is plotted taking number of blows on a logarithmic scale on the abscissa and water content on the ordinate shown in Fig.7 Liquid limit corresponding to 25 blows only.

No Of Blows	Water Content (%)
28	53.80
33	51
34	59.88

Table 3: Liquid Limit

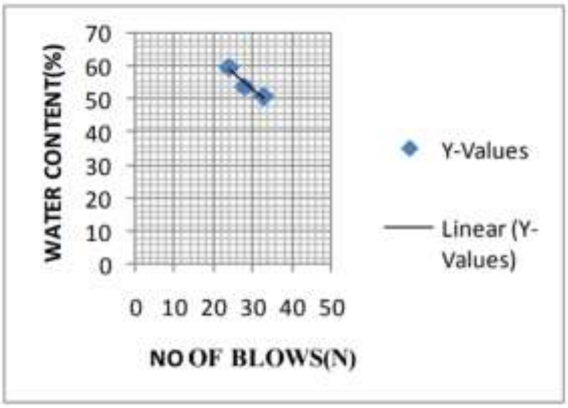

Fig. 7: Graph for Liquid limit for 25 blows

From the graph we obtained the liquid limit corresponding to 25 blows. Liquid limit is = 58%

C. Plastic Limit

This is determined by rolling out soil till its diameter reaches approximately 3 mm and measuring water content for the soil, which crumbles on reaching this diameter.The detail of the test shown in Table.4. Plasticity index (Ip) was also calculated with the help of liquid limit and plastic limit;

$$Ip = wL - wP$$

Where, WL-Liquid limit WP- Plastic limit.

Mould	1	2	3
Wt. of container , W1 (gm)	8.8	8.5	8.2
Wt. of container+ wet soil sample,W2(gm)	15.3	14.4	15.5
Wt. of container+ dry soil sample,W3(gm)	13.5	12.7	13.1
Water content (%)={(W2-W3)/(W3-W1)}*100	28.2	23.61	32
PLASTIC LIMIT (MEAN VALUE, %) = 28%			

Table 4: Plastic Limit

$$IP = WL - WP = 58 - 28 = 30$$

So soil is high plasticity clay. It is also determine from the IS plasticity chart

As per the plasticity chart we obtained that the soil is above A- line and CH or OH group. So soil is highly clay or high plasticity

Liquid limit is = 58%
PLASTIC LIMIT = 28%
Plasticity index= 30

D. Modified Proctor Test

The soil sample is taken without fibres and the standard proctor test is conducted. The details of the readings shown in Table 5 and graph is shown in Fig.8

Soil sample taken: 6KG
Volume of mould used: 2650.71cu.cm

Description	Trial 1	Trial 2	Trial 3	Trial 4
% of water added	6	10	14	18
Moisture content	6.66	12	25	36
Dry density	1.39	1.53	1.48	1.30

Table 5: Standard Proctor Test Results

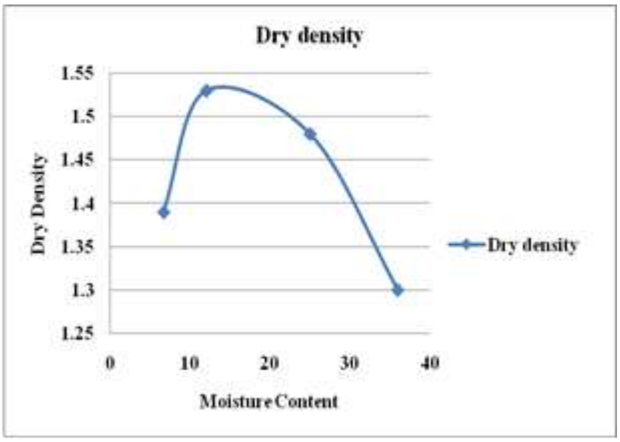

Fig. 8: Graph for Maximum dry density

Description	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
% of water added	6	10	14	18	22
Moisture content	6.25	12.5	17.2	21.4	30.7
Dry density	1.4	1.46	1.48	1.51	1.35

Table 6: 1% Fibre of 6mm Size

Description	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
% of water added	6	10	14	18	22
Moisture content	7.14	10.34	16.12	21.42	30.76
Dry density	1.42	1.46	1.5	1.48	1.34

Table 7: 1.5% Fibre of 6mm Size

Description	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
% of water added	6	10	14	18	22	26
Moisture content	7.69	11.11	12.50	21.42	30.76	45.54
Dry density	1.36	1.45	1.46	1.44	1.34	1.16

Table 8: 2% Fibre of 6mm Size

Description	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
% of water added	6	10	14	18	22
Moisture content	7.69	11.11	16.12	33.33	38.46
Dry density	1.35	1.39	1.44	1.32	1.22

Table 9: 2.5% Fibre of 6mm Size

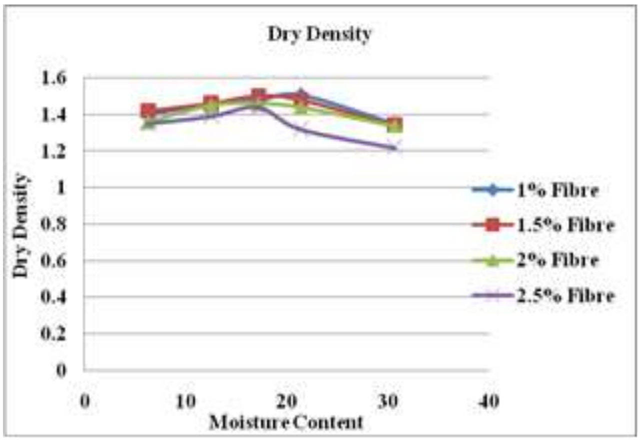

Fig. 9: Dry density for 6mm glass fibre

Description	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
% of water added	6	10	14	18	22
Moisture content	6.6	12.5	16.1	30.4	33.33
Dry Density	1.4	1.43	1.45	1.33	1.26

Table 10: 1% Fibre of 12mm Size

Description	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
% of water added	6	10	14	18	22	26
Moisture content	8.3	16.6	21	23	36	45
Dry density	1.36	1.39	1.4	1.41	1.3	1.19

Table 11: 1.5% Fibre of 12mm Size

Description	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
% of water added	6	10	14	18	22
Moisture content	8.3	16	23	33	50
Dry density	1.34	1.39	1.34	1.3	1.1

Table 12: 2% Fibre of 12mm Size

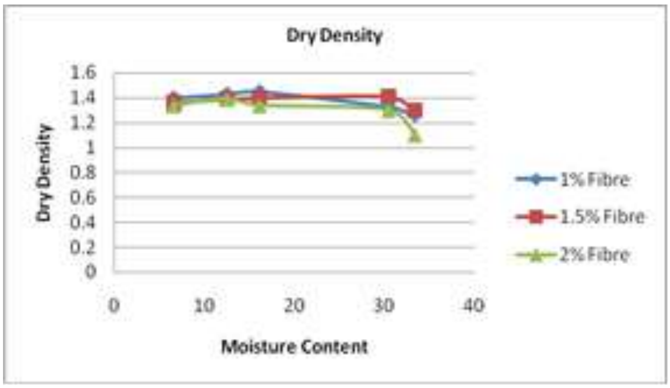

Fig. 9: Dry density for 12mm glass fibre

E. *CBR Test*

CBR values of 6mm glass fibre		CBR values of 12mm glass fibre	
2.5 mm penetration	5 mm penetration	2.5 mm penetration	5 mm penetration
6.42	6.7	6.42	6.62

6.48	6.8	6.68	6.86
6.59	7	6.88	7.25
6.5	6.68	7	6.89

Table 13: Cbr Values of 6mm And 12 Mm Glass Fibre

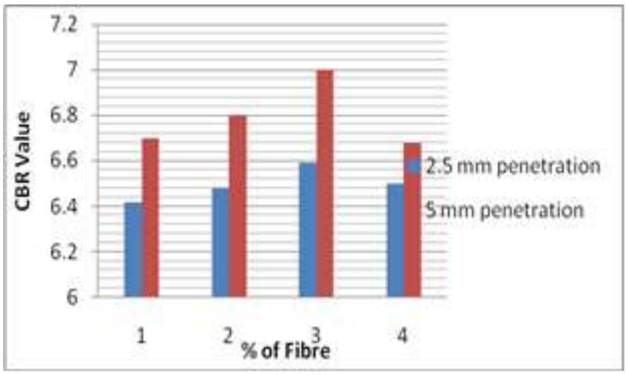

Fig. 10: CBR values of 6mm glass fibre

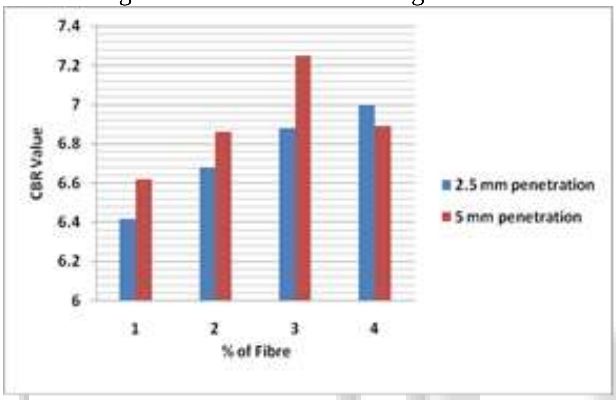

Fig. 10: CBR values of 6mm glass fibre

VI. CONCLUSION

1) Mixing of soil with varying percentage of glass fibre lead to decrease in swelling behavior of soil and CBR value increases for soaked condition.
2) Mixing of soil with varying percentage of 6mm lead to an increase in MDD and CBR value increases for soaked condition.
3) Mixing of soil with varying percentage of 12mm lead to an increase in MDD and CBR value increases for soaked condition.
4) Mixing of soil with 12mm fibre with soil had been better performance as compared to 6mm fibre.
5) It has been observed that there is not so significant increase in the strength of soil in the proctor test.
6) The CBR value increases with increase in length of fibre.

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