Study on the Engineering Properties of Fibre-Reinforced Low Plastic Clay

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Abstract -*Soil has been used as a construction material for a long period of time. Being poor in mechanical properties, it has been putting challenges to civil engineers to improve its properties depending upon the requirement which varies from site to site. Soil reinforcement by randomly distributed discrete fibres is similar to the stabilization of soils by admixtures. Synthetic fibres are widely used in soil improvement in the recent years. Soil improved by randomly distributed fibres is approximately a homogeneous media in contrary to the other methods of mechanically stabilizing systems that is the main advantage of using this method. Since the orientation and location of fibres between soil particles are completely random parameters, extensive laboratory tests are required to estimate the behaviour of these soils. In this paper, some geotechnical characteristics of low plasticity clay (LPC) treated with glass fibre is determined. The chosen percentages of additives are 0, 0.25, 0.5, 0.75, 1 and 1.25% for the stabilization of LPC. The optimum moisture content (OMC) increased slightly and maximum dry density (MDD) decreased by fibre reinforcement. The unconfined compressive strength of LPC was also increased. It was found that glass fibre reinforcement is effective method of stabilization of low plastic clay.*

Keywords: *Synthetic fibres; stabilization; orientation; unconfined compressive strength; reinforcement*

1. INTRODUCTION

Soil has been used as a construction material for a long period of time. Because of low shear strength and high compressibility, soft clayey soils cause substantial distress and excessive settlement to overlying structures and infrastructure if appropriate measures are not taken. Soil reinforcement by randomly distributed discrete fibres is similar to the stabilization of soils by admixtures. Fibre reinforced soil has been used in many countries in the recent past and further research is in progress for many hidden aspects of it. Fibre reinforced soil is effective in all types of soils (i.e. sand, silt and clay).

For effective utilization of locally available soils in civil engineering projects, development of technically viable and economically feasible methods to improve the mechanical properties of soil to suit the requirements of engineering structures is a pre-requisite. Fibre reinforcement causes significant improvement in tensile strength, shear strength, and other engineering properties of the soil. This study may also encourage the use in soil reinforcement of recycled glass fibres derived from industrial glass wastes. Glass fibre has the unique property of retaining its elastic modulus and tensile strength at 70–75% of that of original fibres even under 450 ℃ temperature. Its ready availability, high tensile strength, lightweight and non-biodegradable characteristics make it more beneficial for long-term ground improvement remediation.

The main aim of this research is to study the effect of glass-fibre reinforcement on the strength of soil. A series of proctor compaction and unconfined compressive strength tests were carried out to evaluate the influence of glass-fibres on the soil behaviour.

1.1 LITERATURE REVIEW

Mali et al., (2014) conducted study on 'Strength Behaviour of Cohesive Soils Reinforced with Fibers'. Soft silty or clayey soils are extensively distributed worldwide and they can be improved with reinforcement in the form of randomly distributed fibers of natural and synthetic types. Among the natural fibers, coir and jute are produced in large quantities in South Asian countries. Polypropylene, polyester, polyethylene and glass fibers are widely available synthetic fibers. It is necessary to determine the optimum fiber content and fiber length for any fiber type in the laboratory prior to field applications. This paper reviews the strength behavior of cohesive soils reinforced with coir fibers, polypropylene fibers and scrap tire rubber fibers as reported from experimental investigation, that includes triaxial, direct shear and unconfined compression tests.

Baruah et al., (2015) conducted study on effect of glass fibers on red soil. A series of tests were performed with red loam soil with glass fibre as reinforcement at various percentage content to find out its effects on the soil and to find whether the particular soil – reinforcement combination is useful.

Patel et al., (2016) conducted 'Experimental Investigation on Strength Aspects of Glass Fiber Reinforced Fine Grained Soil'. A series of consolidated undrained (CU) triaxial tests was carried out on glass fiber-reinforced fine grained soil to investigate the influence of fiber reinforcement on the strength, stiffness and energy absorption capacity of soil compacted at different dry unit weights. Soil with varying compacted dry unit weight (γd = 14.3 to 16.8 kN/m^3) was reinforced with 20 mm long fiber of varying fiber content (fc = 0.25 to 1%). Test results have shown that the addition of fibers has significantly improved the stress-strain, stiffness and EAC response of soil. The strength improvement is more pronounced with increasing compacted dry unit weight and fiber content up to an optimum value of 0.75% fiber content. Both cohesion and friction components of shear strength parameters have increased with fiber content and they further improve with compacted dry unit weight. Contribution of fiber in strength improvement is higher at low confining pressure and decreases with increase in confining pressure. Fiber inclusions have restrained the soil dilatancy which decreases with increasing dry unit weight of soil. Fiber reinforcement improves the stiffness modulus and energy absorption capacity of soil which increases with fiber content, confining pressure and compacted dry unit weight. Glass fiber can be used as reinforcement material to strengthen the soil for different geotechnical applications.

Patel et al., (2018) conducted the study on to investigate the effects of glass fibre reinforcement on the shear strength and deformation behaviour of a cohesive soil under different compaction states. The fibre diameter was 0.15 mm, varying in length from 10 to 30 mm, and in content from 0 to 4% by weight of the dry soil. The separate and joint effects of fibre content,fibre length, confining pressure and dry unit weight on the deviator stress response, pore water
pressure response, deformation mode, stiffness and shear strength of the specimens were evaluated. The shear strength of the reinforced soil increases with the moulding dry unit weight, though the optimum fibre content and fibre length remain the same for all dry unit weights. Multiple-regression statistical analysis was carried out to develop an expression for predicting the major principal stress at failure of the glass fibre-reinforced cohesive soil.

Shekar et al., (2018)conducted the study on the effect of glass fibre reinforcement on the shear strength properties of the sand clay mixture. The soil samples were prepared by mixing 50% of locally available Barak river sand with 50% of local clay soil. Triaxial tests were conducted on the soil samples containing five different percentage of fiber to know the effect of fiber content on the shear strength of the soil. Unconsolidated Undrained (UU) Triaxial tests were conducted under three different confining pressures for each sample. Samples were prepared with five different values of moisture content considering 2% less than OMC (Optimum Moisture Content), 1% less than OMC, OMC, 1% more than OMC, and 2% more than OMC to study the effect of water content (w) on behavior of fiber reinforced soil. A parametric study has been carried out in this paper to know the effect of different influencing parameters on the cohesion value and angle of internal friction. The results show that the failure stress and angle of internal friction increase with increase in fiber content up to an optimum value then decrease. On the other hand, the cohesion value increases consistently with increase in fiber content. The study also indicates that the peak deviator stress, angle of internal friction and cohesion values increase with increase in water content up to an optimum value which is less than OMC then decrease with further increase in water content.

1.2 MATERIALS

Soil used in this study is collected from Thonnakal region, Thiruvananthapuram, Kerala, India. It is collected at a depth of 65m from the ground level. The soil collected from the site is dried and powdered. Then the initial properties of soil are determined using standard procedures and the results are tabulated in table 1 and figure 1 shows the plasticity chart. From the test results, the soil can be classified as poorly graded sand according to Indian Standard Classification system.

Glass fibre is purchased from local suppliers. It is a material consisting of numerous extremely fine fibres of glass. It is an ideal product for construction and stone industry, easy to handle and use. It does not emit toxic and harmful substances. It has roughly comparable mechanical properties to other fibres such as polymers and carbon fibre. Although not as rigid as carbon fibre, it is much cheaper and significantly less brittle when used in composites. Glass fibres are therefore used as reinforcing agent for many polymer products. This material contains little or no air or gas, is denser. It can also be used as a reinforcement material with high tensile strength, resistant to alkalis, fire resistant, good chemical properties, and excellent durability, anti-leakage performance, lower price, does not decompose and will not rust over time.

Table 1. Properties of Thonnakal clay

Properties	Result
Specific Gravity	2.63
Clay (%)	71
Silt (%)	20
Sand (%)	9
Liquid limit (%)	34.2
Plastic limit (%)	14.52
Shrinkage limit (%)	12.36
Plasticity index (%)	19.68
IS Classification	CL
OMC (%)	26.58
MDD (g/cc)	0.970
UCC Strength (KN/m^2)	95.12

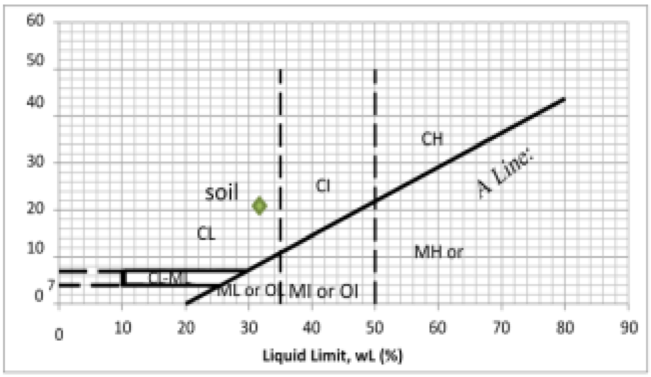

Chart 1 . Plasticity chart

Table 2. Properties of glass fibre

Properties	Value
Colour	Whitish
Length (mm)	12
Diameter (mm)	0.15
Aspect ratio	80
Specific gravity	2.57
Number of fibre (million/kg)	235
Composition	SiO_2, Al_2O_3,CaO

2. RESULTS AND DISCUSSIONS

2.1 Compaction characteristics

The strength of weak soil can be altered by the addition of glass fibres in varying percentages. In the present investigation a series of compaction tests were carried out by varying fibre content. The effect of fibre on OMC and MDD are shown in Fig.1 and 2.The data from the test indicates that the optimum moisture content of stabilized clay are more than that of raw soil. Glass fibre is added to the raw sample in different proportions such as 0%, 0.25%, 0.5%, 0.75%, 1% and 1.25%. Addition of glass fibre leads to the increase in the optimum moisture content. Increased optimum moisture content may be due to the trapping of water at the soil-fibre interfaces, as fibre content increases and also fibre does not absorb moisture. Figure 2 shows the variation of maximum dry density of clay with different percentage fibre content. Maximum dry density decreased very slightly on addition of glass fibre. The decrease in density is most likely a result of the fibre having less specific weight in comparison to that of clay. At higher fibre content, formation of soil-fibre lumps was observed, which might have caused some extra void within soil matrix resulting in drop of MDD.

Table 3. Variation on OMC and MDD

Percentage fibre	OMC	MDD
0	26.58	0.97
0.25	26.59	0.96
0.5	26.6	0.95
0.75	26.6	0.95
1	26.62	0.94
1.25	26.63	0.92

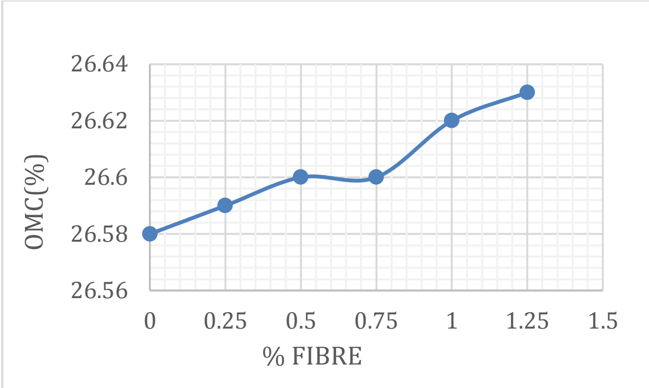

Chart 2. Variation on OMC with percentage of glass fibres

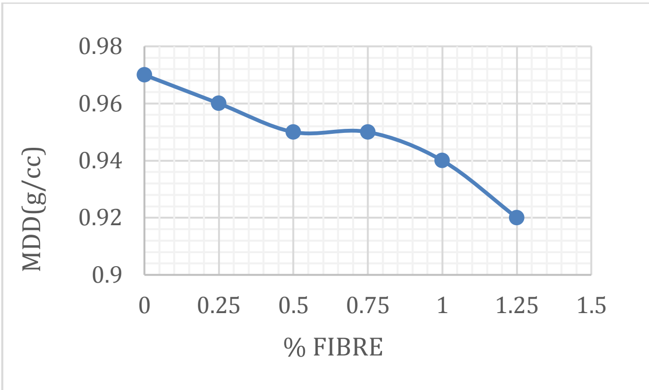

Chart 3.Variation on MDD with percentage glass fibre

2.2. Unconfined compressive strength

It is seen that the UCS values of fiber-reinforced samples are greater than those of unreinforced samples. With an increase in fiber content, the UCS experiences an initial increase followed by a decrease and the maximum value of the strength is found at the fiber content of 0.75%.

Table 4. Variation of unconfined compressive strength

% Fibre	UCS (KN/m²)	% increase in UCS
0	95.12	0
0.25	99.13	4.211
0.5	116.01	21.953
0.75	280.44	194.831
1	212.77	123.691
1.25	209.73	120.489

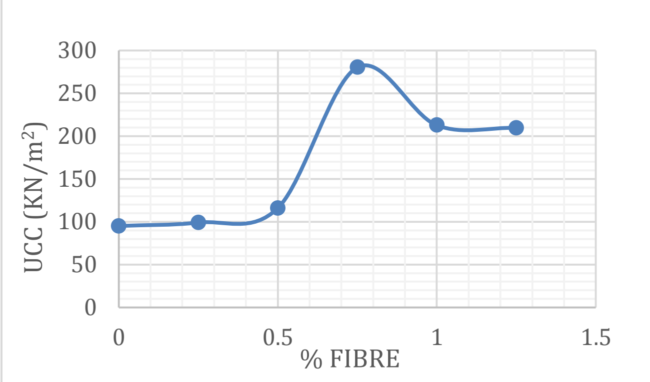

Chart 4 . Variation of UCS with glass fibre content

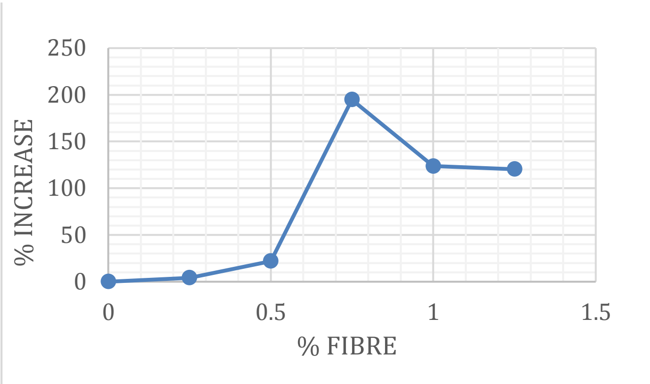

Chart 5. Percentage increase in UCC glass fibre content

3. CONCLUSIONS

The following conclusions are drawn from the study:

- Addition of glass fibre leads to slight increase in OMC and decrease in MDD. This might be due to the reason that water absorption capacity of glass fiber is zero.

- Fibers within soil oppose the proper densification of soil during compaction,resulting in some increase in void ratio which accommodates extra moisture within specimen. At higher fibre content, formation of soil-fibre lumps was observed, which might have caused some extra void within soil matrix resulting in drop of MDD.

- Though the MDD decreased with the increase in fiber content, the UCC value increased gradually up to 0.75% of fiber content and then decreased. The fibers being strong in tension enhance the bond strength between its surface and the soil particles.

- Randomly distributed discrete fibers form a coherent matrix with the soil grains and restrict displacement.

- Glass fibre addition to low plastic clay showed significant increase from 95.12 KPa to 280.44 KPa, an increase of 194 % in overall unconfined compressive strength of the soil. Optimum UCC value obtained at 0.75% fiber content.

- The inclusion of fibres increases the contact surface between soil particles withfibres.

REFERENCES

[1] Shivanand Mali and Baleshwar Singh., (2014). “Strength Behaviour of Cohesive Soils Reinforced with Fibers” International Journal of Civil Engineering Research. Vol 5 (353-360)

[2] Himadri Baruah., (2015) “Effect of glass fibers on red soil” International journal of advanced technology in engineering and science vol 3(1) pp 217-223.

[3] Suchit Kumar Patel and Baleshwar Singh., (2016). “Experimental Investigation on Strength Aspects of Glass Fiber Reinforced Fine Grained Soil” International journal of earth sciences and engineering. Vol 9, Pp 32-39

[4] HimadriShekharSaha, DebjitBhowmik., (2018) “Effect of Glass Fibre on Shear Strength of Soil” Trans Tech Publications, Switzerland ,Vol. 775, pp 603-609

[5] Suchit Kumar Patel and Baleshwar Singh., (2017). “Shear strength response of glass fibre-reinforced sand with varying compacted relative density” International Journal of Geotechnical Engineering