Proc. of the Intl. Conf. on Advances In Engineering And Technology - ICAET-2014

ISBN: 978-1-63248-028-6 doi: 10.15224/ 978-1-63248-028-6-03-75

Effect of Fiber Properties on the strength of Fiber Reinforced Soil: A Review

[Akash Priyadarshee, Anil Kumar Chotu, Vikas Kumar]

***Abstract*—Fiber reinforcement is one of the new emerging soil reinforcement technique. Absence of weak plane is major advantage of fiber reinforcement. It is similar to the reinforcement provided by the plant of roots. Randomly distributed fibers provide interlocking and friction resistance to resist the movement of soil particles, which significantly increase the load carrying capacity. Now a days fiber reinforcement is used in the embankment, slope stabilization, pavement application. For efficient application of fiber reinforcement, proper understanding of effect of different parameters like fiber parameters and soil parameters on the behavior of fiber reinforced soil is required. In this paper brief review of the research and development for fiber reinforced soil to understand the effect of different fiber parameters based upon the experiments is presented.**

***Keywords*—Peak stress, load carrying capacity, triaxial test, direct shear test.**

I. Introduction

Soil reinforcement is one of the fast growing ground improvement techniques. Ease of construction, overall economy and availability of different options are major advantages of soil reinforcement. With development in the soil reinforcement area materials and methods both are changing. Initially metals were used for reinforcement purpose, but now materials prepared from the polymers have accelerate the utilization of soil reinforcement. Major advantages of polymer based materials are less degradation rate and overall cost. Similarly use of sheets, bars etc. are traditional form of reinforcement. But now different other forms like Geocell, fiber etc. are also available. Fiber reinforcement is one of the new techniques. Fiber reinforced soil is also known as 'Ply soil' [1].

Akash Priyadarshee
Civil Engineering Department, NIT Jalandhar
Punjab, India

Anil Kumar Chhotu
Civil Engineering Department, NIT Jalandhar
Punjab, India

Vikas Kumar
Civil Engineering Department, NIT Jalandhar
Punjab, India

Fiber has been used from a long time, but utilization as construction material is not frequent because of less understanding of potential benefit of fiber reinforcement. In this technique fibers are randomly mixed in the soil. Absence of clear cut potential plane of weakness is major advantage of fiber reinforced soil, which is generally exist parallel to the soil and reinforcement interface in other form of reinforcement [2]. Properties of fiber reinforced soil depend upon the properties of fiber as well as soil properties. In this study effect of fiber properties like; fiber content, length of fiber, surface properties of fiber and fiber type on the strength of fiber reinforced soil is presented.

II. Mechanism of Fiber Reinforcement

In fiber reinforcement technique, fibers which are randomly mixed in soil may be natural or synthetics type. Jute, coir etc. are example for natural fiber and polypropylene, glass fibers are example of synthetic fiber. The reinforcing mechanism fiber reinforcement is similar to the roots of plants. Plant roots bind soil particles and resist its movement [3]. Similar to that when stress applied on fiber reinforced soil, deformation in the surface of fiber takes place because of soil particles. This deformation increases the interlock resistance between the soil particles and fiber. Normal force acting at the soil fiber interface, also mobilizes frictional resistance at soil-fiber interface. So, the interlock force, friction force and bond strength are primarily responsible for resistance of movement of soil particles, which enhances the load carrying capacity of fiber reinforced soils [4]. Since fibers are randomly distributed in the soil, so stress isotropy is achieved.

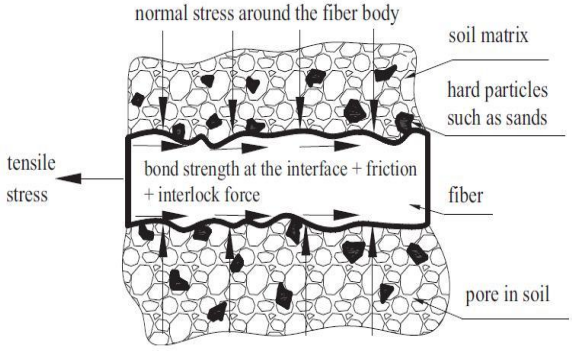

Fig. 1.7 Interaction between soil particle and fiber [4]

Proc. of the Intl. Conf. on Advances In Engineering And Technology - ICAET-2014

ISBN: 978-1-63248-028-6 doi: 10.15224/ 978-1-63248-028-6-03-75

III. Parametric Effect

To understand the behaviour of fiber reinforced soil different studies based upon model tests, case study and triaxial tests have done. Case studies on roads by Lindh and Erriksson [5], on embankment by Gregory [6], Santoni et al [7], on landfill liners by Refai, [8] have shown the beneficial utilization of fiber reinforcement in different applications. Through model test on strip footing supported by fiber reinforced soil, improvement in the bearing capacity and stiffness have reported by Al-refai [9], and Wasti and Butun [10]. Gray and Al-refai [11], Maher and Gray [2], Al-refai [12], Michalowski and Zhao [13], Ranjan et al. [14], Michalowski and cermak [15] through triaxial test have shown that performance of fiber reinforcement depends upon the fiber properties like length of the fiber, fiber content, stiffness of fiber and surface properties of soil and soil properties like soil type, size of particles etc. To develop the understanding of behaviour of fiber reinforcement influence of each parameter were considered. In the following section the influence of fiber parameters on fiber reinforced soil obtained by different researchers are presented.

A. *Fiber Content*

Fiber content is defined by the amount of fiber present in unit mass or unit volume of soil-fiber mixture or solid soil. With increase in fiber content, strength of soil increases. It is observed from the test results of triaxial test [14] that peak stress increases with increase in the fiber content (Fig. 1). Model test results on the strip footing supported by fiber reinforced soil [12] have also shown improved load carrying capacity due to fiber reinforcement (Fig. 2) and it increases with increase in fiber content. This happened because with increase in fiber content, there will be more fiber to resist the soil movement. This increase in resistance, enhance the load carrying capacity of soil. But after certain limit the improvement in the load carrying capacity of soil doesn't improve significantly (Fig. 1). Improvement in the strength due to fiber inclusion is because of interaction between fiber and soil, but with further increment of fiber in the soil-fiber matrix fiber-fiber interaction increases and soil-fiber interaction decreases. The fiber content after which further improvement in the strength of soil is not significant is known as optimum fiber content.

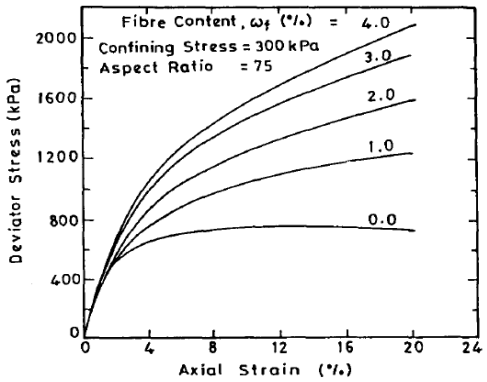

Fig. 1 Stress strain behaviour of fiber reinforced sand for different fiber content [14]

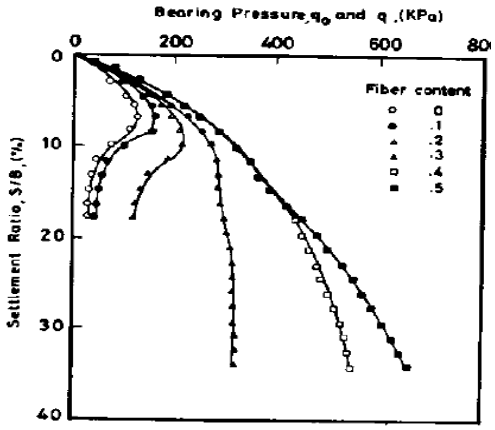

Fig. 2 Load-settlement characteristics of fiber reinforced soil under strip footing [12]

B. *Size of Fiber*

Through experimental investigation it is observed that the performance of fiber reinforcement depends upon the parameters effect the dimension of the fiber like; length of the fiber, diameter of fiber and aspect ratio of the fiber [16,17,12]. Load carrying capacity of soil increases with increase in the length of fiber (Fig. 3). Since strength improvement due to fiber takes place due to interaction between surface of the fiber and soil particles. So, interaction of fiber and soil is proportional to the surface area of the fiber. When length of fiber increases, surface area of fiber also increases, so more friction mobilize. Due to increase in frictional resistance more tensile stress in fiber mobilizes, because of that confining pressure for soil present in the matrix of the fibers increases. These increased frictional resistance and increased confinement pressure are major component of strength improvement of fiber reinforced soil. Increased friction resistance directly resist the movement of soil particles and increased confinement increases the shear resistance of soil. Small fibers have inadequate friction resistance due to small surface area, so during shearing pull out phenomena takes place. For longer fiber if tensile strength of fiber is not adequate then breakage in the fiber may take place. It is also observed by researchers that after an optimum length of fiber further improvement in the strength of the soil is marginal. Longer fiber doesn't remain straight in soil-fiber matrix, folding of such fibers takes place. Due to this full length of the fiber doesn't contribute significantly in the strength improvement. Longer fiber have also tendency of breakage and it is more at higher confinement pressure.

Diameter of fiber has also impact on the performance of fiber reinforcement [17]. Stress-strain responses obtained from triaxial tests have shown that deviator stress increases with increase in the diameter, due to increased pull out resistance (Fig. 4). Fig. 5 shows the failure envelope obtained from the triaxial test on fiber reinforced soil with different aspect ratio i.e. ratio of length of the fiber to the diameter of fiber [2].

Proc. of the Intl. Conf. on Advances In Engineering And Technology - ICAET-2014

ISBN: 978-1-63248-028-6 doi: 10.15224/ 978-1-63248-028-6-03-75

Major Principal Stress at failure is found increasing with increase in the aspect ratio.

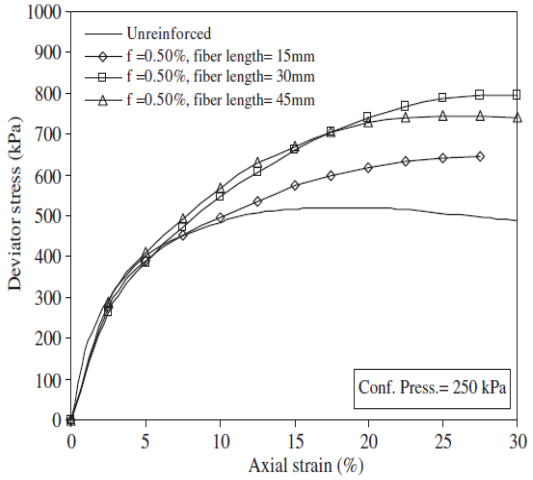

Fig.3 Effect of length of fiber on the stress-strain behaviour of fiber reinforced soil [16]

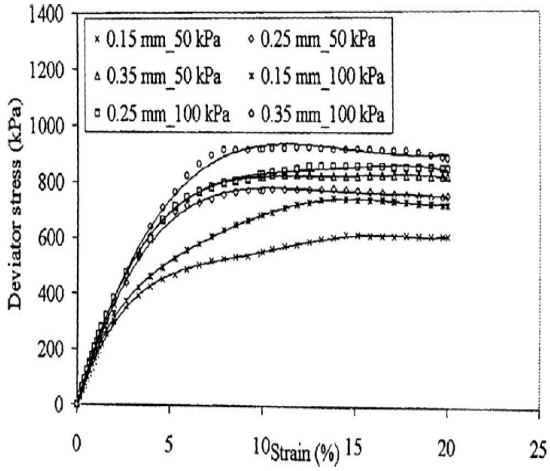

Fig. 4 Effect of diameter on the Stress-strain behaviour of fiber reinforced soil [17]

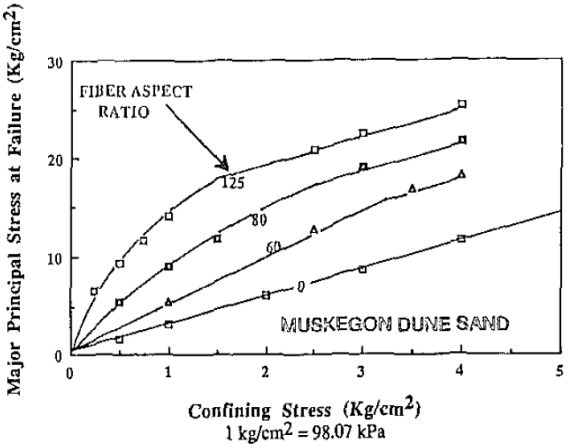

Fig. 5 Effect of aspect ratio of fiber on the properties of fiber reinforced soil [2]

C. *Effect of Surface Properties of Fiber*

To understand the effect of the surface properties of fibers on the load carrying capacity of fiber-soil mixture, different fibers with different roughness of the fibers were used. It was observed that fiber with more surface roughness have greater potential to improve the strength of the soil [16,18]. The surface interaction for better shear strength parameters of soil can be obtained through coating of surface of the fiber (Fig. 6). Since strength improvement of fiber reinforcement takes place due to the friction resistance and interlock resistance between fiber surface and soil particle. Hence this friction resistance and interlock resistance increases with increase in the roughness of the fiber. The interaction of the fiber and soil also depends upon the soil particles. Soil having angular particles has greater friction and interlock resistance than the soil having rounded particles [18]. Fibers with smooth surface have greater tendency of pullout during shearing. The interaction of fiber to fiber is lesser than the fiber to soil. Therefore amount of fiber in the soil-fiber mixture should be at optimum so that maximum interaction between soil to fiber can be achieved.

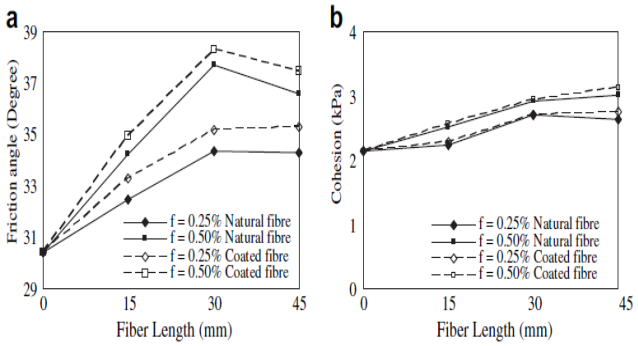

Fig. 6 Effect of coating of fiber on the shear strength parameters of fiber reinforced soil [16]

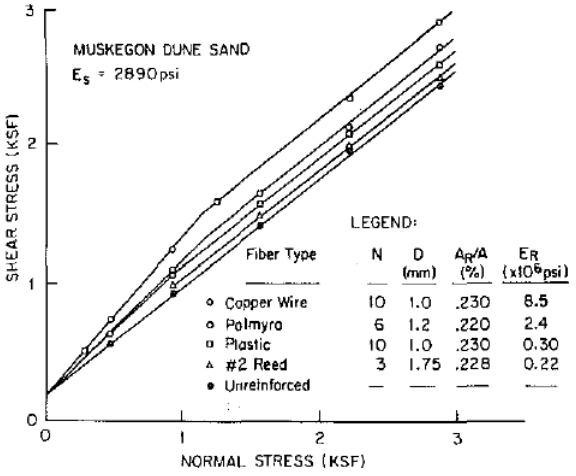

Fig. 7 Effect of fiber type on the failure envelope of fiber reinforced soil [20]

Proc. of the Intl. Conf. on Advances In Engineering And Technology - ICAET-2014

ISBN: 978-1-63248-028-6 doi: 10.15224/ 978-1-63248-028-6-03-75

D. *Fiber Type*

Different types of fibers are available as an option for reinforcement, like natural fibers and synthetic fibers. Natural fibers can be obtained from the plants. Advantages of the natural fibers for geotechnical purposes are local availability and since these are natural product so, it is environment friendly and helpful in sustainable development. Major disadvantage for the natural fiber is biodegradation with time and their properties can be changed with moisture content [19]. Synthetic fibers are produced from the petroleum products. They have high resistance against the environment. There properties doesn't change much even in sever condition. Among synthetic fibers, polypropylene and glass fibers are mostly used for the construction process. Different fibers have different stiffness and strength so there contribution for the improvement in the strength is different. Fibers having greater stiffness have more strength improvement capacity (Fig. 7).

Different fibers have different roughness i.e. surface properties so; there contribution in the higher shear strength parameters will be higher, because of greater friction resistance.

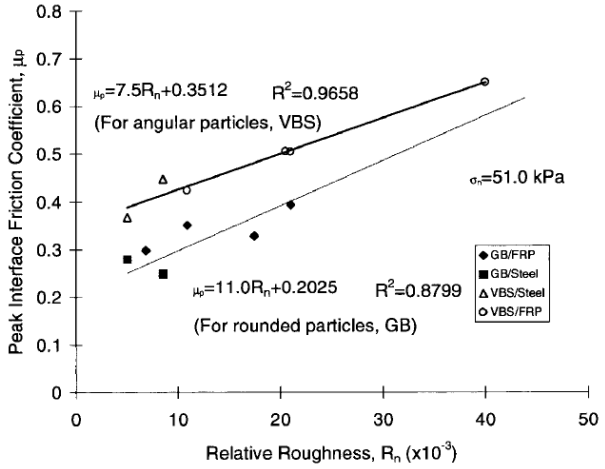

Fig. 8 Effect of toughness of fiber on the strength parameter of fiber reinforced soil [18]

IV. Conclusion

This paper have shown the beneficial contribution of fiber reinforcement in the strength improvement of soil. Iinfluence of fiber properties on behaviour of fiber reinforced soil are also discussed in the brief. To get the maximum benefit from the performance of fiber-reinforced soil, one must consider all the influencing parameters and their working mechanism. Yet further research is required to understand the behaviour and for proper design of fiber reinforced soil structure.

References

[1] A. Mcgown, K.Z. Andrawes, and M.M.Al-Hasani, "Effect of inclusion properties on the behavior of sand." Geotechnique, 28(3), 327-346, 1978.

[2] M.H Maher, and D.H. Gray, "Static response of sand reinforced with randomly distributed fibers." Journal of Geotechnical Engineering, ASCE, 116(11), 1661-1677, 1990.

[3] L.J., Waldron, "Shear resistance of root-permeated homogeneous and stratified soil," Soil science society of America Proceedings, vol. 41, 1977, 843-849, 1977.

[4] C. Tang, B. Shi, W. Gao, F. Chen, and Y. Cai, "Strength and mechanical behavior of short polypylene fiber reinforced and cement stabilized clayey soil." Geotextiles and Geomembranes, 25, 194-202, 2007.

[5] E. Lindh, L. Eriksson, "Sand reinforced with fibers: a field experiment." Proceedings of the International reinforced soil Conference on Performance of Reinforced Soil Structure, Glasgow, UK, 471-474, 1990.

[6] G.H. Gregory, D.S. Chill, "Stabilization of earth slopes with fiber reinforcement. Proceedings of the sixth International Conference on Geosynthetics, Atlanta, Georgia, 1073-1078, 1998.

[7] R.L. Santoni, J.S. Tingle, S.L. Webster, "Engineering properties of sand-fiber mixture for road construction." Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 127 (3), 258-268, 2001.

[8] S.M. Refai, "Impact of polypropylene fibers on desiccation cracking and hydraulic conductivity of compact clay liners." Dissertation submitted in partial fulfillment for requirements of Doctoral Degree, Wayne State University, Detroit, Michigan, 2000.

[9] T.O., Al-Refai, "Model tests on strip footing on reinforced sand." Journal King Saud University, 4, 155-169, 1992.

[10] Y. Wasti, and M.D. Butun, M.D, "Behavior of model footing on sand reinforced with discrete inclusion." Geotextiles and Geomembranes, 14, 575-584, 1996.

[11] D.H. Gray, T.O. and Al-Refai, "Behavior of fabric-versus fiber reinforced sand." Journal of Geotechnical Engineering, ASCE, 112(8), 808-820, 1986.

[12] T.O. Al-Refai, "Behavior of granular soils reinforced with discrete randomly oriented inclusion." Geotextiles and Geomembranes, 10, 319-333, 1991.

[13] R.L. Michalowski, and A. Zhao, "Failure of fiber-reinforced granular soils." Journal of Geotechnical Engineering, ASCE, 122(3), 226-234, 1996.

[14] G. Ranjan, R.M. Vasan, and H.D. Charan, "Probablistic analysis of randomly distributed fiber reinforced soil." Journal of Geotechnical Engineering, ASCE, 122(6), 419-426, 1994.

[15] R.L. Michalowski, and J. Cermak, "Triaxial compression of sand reinforced with fibers." Journals of Geotechnical and Geoe+nvironmental Engineering, ASCE, 129(2), 125-136, 2003.

[16] Ahmad, F., Bateni, F., and Azmi, M. (2010). "Performance evaluation of silty sand reinforced with fibers." Geotextiles and Geomembranes, 28, 93-99.

[17] G.L.S. Babu, and A.K. Vasudevan, "Strength and stiffness response of coir fiber reinforced tropical soil." Journal of Materials in Civil Engineering, ASCE, 20(9), 571-577, 2008.

[18] J.D. Frost, and J. Han, "Behavior of interfaces between fiber-reinforced polymers and sands." Journals of Geotechnical and Geoenvironmetal Engineering, ASCE, 125(8), 633-640, 1999.

[19] J. Prabakar, and R.S. Sridhar, "Effect of random inclusion of sisal fiber on strength behavior of soil." Construction and Building Materials, 16, 121-131, 2002.

[20] Gray, D.H., and Ohashi, H. (1983). "Mechanics of fiber reinforcement in sand." Journal of Geotechnical engineering, ASCE, 109(3), 335-353.