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Reinforcing Liquefied Weak Soils Using Eco-Friendly Synthetic Polymers

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ABSTRACT

With increased construction and reduced amount of suitable ground, humankind has considered the stabilization of weak soils to use them. In this investigation, the effect of synthetic fibers and resins on soil stabilization during recent years has been studies which indicates the closeness of textiles science with soil engineers; and the suitable effect of fibers in soil stabilization.Improving weak soils unsuitable for application in attics, foundations, road beds, dams, and … in order to create soil configuration with desired engineering properties is referred to as "soil stabilization and reinforcement". The phenomenon of using fibers to improve behavioral characteristics of various materials is an old idea. As shown by Hongu and Philips in their New Fibers, 4000 years ago, human beings used fibers as a strengthening component in soil. Also, the use of fibers in the Great Wall of China supports the argument that the knowledge of textile engineers, since ancient times, along with civil engineers, has been their assistant in improving the useful life of various structures. To prevent such subsidence and/or other weak mechanical properties, specific techniques need to be applied to improve such properties. Designers have always used mechanical processes such as compaction, drainage by sandy wells, and consolidation, and chemical processes such as modification and stabilization or the use of reinforcing components in order to increase soil strength. Natural soil at project sites is not always suitable for use and it is possible that due to load application, considerable subsidence occurs in low quality soils.

Keywords: *Soil Stabilization, Weak Soils, Fibers*

INTRODUCTION

So far, various components such as glass fibers, galvanized steel, and polymers made of geo-textiles, geo-grids, and cut fibers made of polyethylene, polyester, polypropylene, have been used for soil reinforcement. Gray and Ohashi have developed a model for soil and fiber behavior at the cutting areas [1-8].

Experimenting many samples of sands reinforced with plastic and plant fibers and copper wires in direct cut machine and analyzing the results, they determined the amount of necessary fibers for optimal conditions of shear strength [9-17]. During recent years, there has been an increase in the use of soils reinforced by various reinforcement components, especially geo-synthetic materials, with many applications in geo-techniques. Fibers produced either synthetically or naturally, mixed with soil, lead to increased shear and tension strengths and modified engineering properties of soil. One type of such synthetic fibers is fibrous carpet waste and geotextile whose disposal and correct use have a special importance from an environmental point of view. Improving weak soils unsuitable for application in attics, foundations, road beds, dams, and … in order to create soil configuration with desired engineering properties is referred to as "soil stabilization and reinforcement". Soil fiber reinforcement, on the one hand, involves the direct use of fibers randomly into a matrix such as soil; and on the other, the use of fibers with a specific array such as geo-synthetics family. In fact, reinforced soil is a mixed matter made by the combination and optimization of the properties of each ingredient [18-33].

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Physical methods such as adding discrete elements with a random distribution such as the use of natural and synthetic fibers form a relatively successful approach in soil performance improvement. Moreover, studies indicate that tension-strain strength properties of randomly-distributed fiber-reinforced soils is a function of fibers amounts, length to width ratio, and fraction level of fibers in the soil direction and fibers and resistance associated with considerable improvements in resistance, bearing capacity, deformation, and volume changes of matrix (soil). Weidel was the first to introduce the concept of fiber-reinforced soil in 1996. He stated that the use of reinforcement element in soil would increase its shear strength [47-59].

Experimental studies on soils mixed with various fibers indicate interesting results. In most cases, adding fibers to the soil is associated with a considerable increase in soil stability against various conditions. Previous research indicated that adding fibers would increase the CBR levels of polypropylene-reinforced sand and clay considerably, without a sign of post-experiment failure [60-74]; and would decrease the sudden subsidence of expanding soils [75-76]. Waste rubber tires enhance the bearing capacity of weak sand; while a combination of rubber tire strings and rubber walls would lead to higher increase in bearing capacity [77-84]. Adding geotextiles from woven coconut fibers, too, has a good effect on CBR [85-91]. Increased unrestricted pressure resistance has been another issue discussed by experimental studies [92-103]. Tension strength is the most apparent feature of the fibers which leads to increased tension resistance of soil mixtures [104-105]. Increased amount of fibers would increase the share of fibers in the increased tension strength; and increased length of such fibers would reduce that share [106].

By increasing the fibers' length-to-width ratio, peak resistance and overall volume changes would increase [107]; and critical restricting stress would occur in a lower value [108]. At smaller length-to-width ratios, inflation is reduced . If the length-to-width ratio and fibers concentration remain fixed, the higher length of the fibers will reduce the mixture's resistance compared to shorter fibers. If the fiber length is higher than grain size, it will be more effective and this value should be at least equal to the grain size (regardless of the length to width ratio). When the fiber length becomes equal to the grain size and pore size, the effect of fibers will be removed [109]. Increased fiber length would not create a clear change in internal fraction angle while tenacity and final shear strength would increase linearly [110-111]. Increased length would lead to maximum increase of UCS [117], as well as increased CBR and deformation. Reduced hardness [122] and optimal humidity levels [123] too, would occur following the length increase. Increased shear strength is another important role of fibers in soil mixtures [124-126]. Although the use of rubber powder in weak sand is associated with reduced shear strength [127], under drained and non-drained experimental conditions in axial share experiments, resistance is increased [123]. Changes in shear strength, too, have been studied examining the shear strength parameters. Tenacity is influenced by the addition of fibers [7, 8] while the use of polypropylene fibers would not change the tenacity [124]. Increased internal fraction angle of mixtures [120] and it non-linear growth is apparent in some samples [128]. Tenacity and effective internal fraction angle are increased markedly in the three-axial pressure experiment. Internal fraction angle is a little higher under drained loading compare to non-drained loading. Marked drop in the initial hardness of materials occur when fibers increase the rupture stress of sand. However, some experiments have not indicated a considerable effect on sand's initial hardness. On the other hand, passing through the twentieth century and exhaustion of non-renewable resources, the need for environment-friendly materials is felt more. Many investigations have been conducted in various countries based on mechanical properties and physical performances of natural fiber-reinforced materials. Natural fibers, such as palm, cotton, sisal, hemp, bamboo, and coconut, in addition to these advantages, have other benefits such as lower cost, abundant resources, and dissolubility. Therefore, pioneer research explores such parameters as different percentages of hemp and barley straw fibers, different lengths, and moisture percentage, on the improved shear properties of sandy soil. Nataraja and McManis examined the behavior of clay and sand reinforced with synthetic fibers through density, direct shear, single-axial, and CBR experiments and reported increased shear strength, single-axial pressure strength, and especially, increased CBR. Studies performed on soil reinforcement using polypropylene fibers by Abtahi et al. (2009) increased bearing capacity between 800 and 1000% by UCS test; and stabilized the soil using polymer resins [126-165]. Tang et al. (2006) found the importance of fibers in soil reinforcement; and were able to change pressure strength and behavior of soil using polypropylene fibers. Considering 12 sample groups, relative to changes in fiber percentiles of 0.25, 0.15, and 0.05 soil weight and using pressure strength and three-axial tests, they achieved a maximum pressure of 229.8 KPa. However, the resistance of the samples without fibers had a pressure strength of about 152.1 KPa. The images from SEM microscope indicate that fibers have brought together soil grains through their interconnected webs which delay grain rupture during loading [166-182].

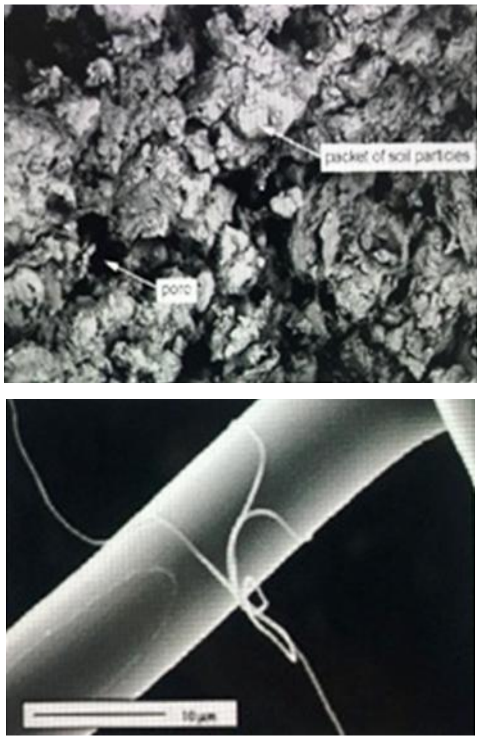

Figure1. *Electronic microscope image of polypropylene fibers and soil reinforced with it [127]*

Marandi et al. (2008) reinforced silt sand soil by palm fibers which is an example of environment-friendly materials. They examined soil pressure strength and CBR. One of major purposes could be soil reinforcement of highly seismic regions in northern Iran.

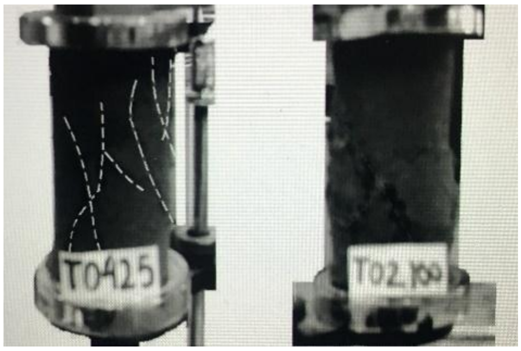

Figure2. *The effect of fibers in the rupture types of fibers*

Figure3. *Natural Palm Fibers*

In recent years, combinations of fibers and previous stabilizers such as cement has been very popular such that in Australia, soil engineers were able to stabilize a runway matrix.

Figure4. *Phases of airport matrix soil stabilization by polypropylene fibers and cement*

Result and Discussion

Considering the research during recent years on the effect of fibers, it could be said that:

- Evidence from SEM microscopic images demonstrate that fibers would increase the affinity of particles and prevents their liquefaction in weak soils.
- Soil fiber reinforcement would cause the soil to act in an integrated manner in load bearing which leads to increased load bearing.
- Fibers have a long life in soil, especially natural ones.
- Fibers perform very well in saturated state.
- Increased soil internal fraction angle and tenacity. Increased fraction angle indicates increased resistance mainly due to fibers slipping in the environment –and not their flowing.
- Fibers could be combined with older stabilizers and be a good supplement for them.
- Cost-effectiveness of fibers compared to other stabilizers is an indication that they are suitable in soil stabilization.
- Fibers are easily used in soil stabilization applications.
- The most important advantage of fibers, compared to other chemical stabilizers (many of which are toxic) is lack of environmental hazards.

Based on above results, very strong performance, ease of use and cost –effectiveness, in addition to eco-friendliness, are the main parameters of using this combination as some suitable stabilizers for any soil even those in very bad saturation conditions.

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