New Horizons in Earth Reinforcement – Otani, Miyata & Mukunoki (eds)

Effects of palm fibers on CBR strength of fine sand

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ABSTRACT: Soil often lacks the tensile strength but this defect may be resolved with the incorporation of reinforcing elements with proper tensile strength. Elements made of metal, synthetic or natural materials have been used for this purpose. Many research studies have been reported in the literature about the soils reinforced with natural fibers such as coir, jute, sisal, flax, reed and wood fiber. However, less attention has been given to palm fibers and their influences on the soil strength behavior. This paper discusses the influence of palm fibers on CBR strength of fine sand. Samples were prepared with the fiber dry weight ratios of 0.5% and 1.0%, with the lengths of 20 mm and 40 mm. CBR tests were conducted under dry and submerged conditions. The results show that the addition of palm fibers increases the CBR strength of the sand specimens considerably.

1 INTRODUCTION

According to history findings in ancient times, natural fibers such as hey, wood, and bamboo were used for the improvement of construction materials [5]. The use of appropriate elements in soil improves its engineering properties such as strength, hardness and deformability. Materials used for the reinforcement are usually made of metal, geosynthetics or natural materials like plant roots and stems.

Nowadays, natural fibers as Kenaf, Coir, Banana, Jute, Flax, Sisal, Palm, Reed, Bamboo and Wood Fibers are used for soil reinforcement and stabilization [1, 2, 6, 8-11]. The most advantages of using natural materials are due to environmental and economical considerations.

Many research studies have been reported on soil reinforced with natural fibers [1, 2] and [3-8]. Ghavami et al., (1999) observed that the addition of 4% coconut and sisal fibers to soil causes its deformability to increase significantly. Besides, the crack creation in dry seasons was highly lessened. A study by Prabakar and Sridhar (2002) on soil specimens reinforced with sisal fibers showed that both fiber content and aspect ratio have important influences in shear strength parameters (c, ϕ). They observed that an optimum value for the fiber content exists such that the shear strength decreases with increasing the fiber content over this value. Mesbah et al., (2004) performed tensile tests on soil specimens reinforced with sisal fibers and concluded that the fiber length and the tensile strength of fibers are the most important factors affecting the tensile strength of the soil composite. Bouhicha et al., (2005) working on reinforced soil composites made of barely fibers observed that the presence of the fibers causes shrinkage and curing time to decrease. In addition, they reported that the shear, bending, and compression strengths of specimens increase for specific fiber contents.

2 EXPERIMENTAL STUDY

2.1 *Materials*

The utilized soil is fine sand (SP) supplied from Kerman city. Palm fibers were obtained from Bam city in Kerman province. The properties of these materials are given in Tables 1 and 2 respectively.

2.2 *Preparation of samples*

CBR specimens were prepared and tested according to ASTM D-698B procedure. Compression tests were performed under both moist and submerged conditions.

Table 1. Properties of the sand.

Property	Value
Sand (%)	95.0
Silt and Clay (%)	5.0
Unified Classification	SP
AASHTO Classification	A-3
G_s	2.66
C_u	2.85
C_c	1.2
Plasticity	NP
w_{op} (%)	16.0
γ_d (kN/m^3)	15.86
ϕ	43°

Table 2. Physical and mechanical properties of palm fibers.

Property	Palm fiber		
	Lower	Upper	Mean
Diameter (mm)	0.11	1.4	0.42
Length (mm)	115	900	295
Density (kN/m^3)	8.4	9.76	9.06
Natural moisture content (%)	3.8	7.8	5.9
Water absorption upon saturation (%)	139	159	149
Tensile strength (MPa)	77.15	151.39	123.23
Modulus of elasticity (GPa)	1.75	3.26	2.47
Strain at failure (%)	3.7	6.3	5.1

To evaluate the effects of the fiber length, two sizes of 20 mm and 40 mm, for fiber percentage of 0.5, 1, and 2 were examined. Optimum water content was obtained from the standard Proctor test as about 16% for plain and reinforced specimens. The required water was added in two stages in order to prepare more homogenous specimens [3]. In the first stage, the half of the water was added to the mixture of the soil and fibers, and followed by 15 min continuously mixing with hand. Then, the second portion of the water was added, followed by 5 min hand mixing. Submerged specimens were placed in water for 48 hours, then taken out and allowed to drain before being loaded.

3 RESULTS AND DISCUSSION

3.1 *Moist specimens*

Figures 1 and 2 presents the results of CBR tests for moist specimens reinforced with 20 mm or 40 mm fibers, and fiber contents of 0.5, 1 or 2%. It is seen that adding 0.5 to 1% fibers enhances the CBR strength significantly up to 56% increase in the strength with respect to plain specimens. However, this effect gradually diminishes at higher fiber contents such that the strength at 2% fiber content decreases slightly. Obviously, the presence of fibers in the soil, more than what required for optimum reinforcement, can substitute soil particles with weaker materials; therefore, reducing the bearing strength of the soil. In addition, it appears that longer fibers contribute further to the strength. This can likely be attributed to the more mobilized frictional resistance around the fibers, and consequently, higher tensile stresses developed in the fibers. Another words, the failure mode of fibers seems to be more pullout rather than breakage, as observed also during the experiments. This trend is expected to lessen for longer fibers such that an optimum length is obtained for any fiber content. Previous studies show that the optimum fiber length becomes larger as the fiber content decreases (Prabakar and Sridhar, 2002).

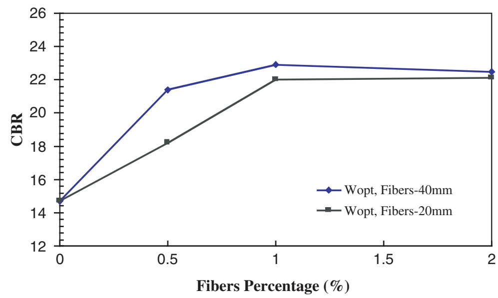

Figure 1. Effect of Palm fiber content on CBR strength (moist condition).

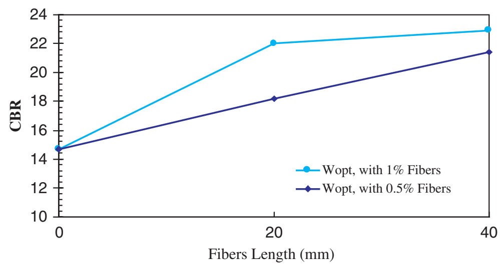

Figure 2. Effect of Palm fiber length on CBR strength (moist condition).

3.2 *Submerged specimens*

Figures 3 and 4 present the CBR results for the fiber-reinforced specimens under submerged condition. Similar to the results for moist specimens, the CBR values show some improvement due to the reinforcement with the maximum of 41% increase for the specimen with 1% of 40 mm fibers. Longer fibers also have resulted in higher CBR values. However, these increases are not as pronounced as those for the moist specimens where 56% increase was observed for the specimen with 1% of 40 mm fibers (Fig. 1 or 2). Besides, the effect of fiber length has evidently diminished for submerged specimens particularly for those with 0.5% fiber content. Saturation has obviously important influences on the soil behavior that can be explained in view of three aspects. First, the strength and modulus of soil itself decrease because of the water interaction with fine, cohesive particles. Second, the loss of capillarity because of saturation reduces the effective stress, and consequently, the soil bearing capacity. Third, the frictional resistance between fibers and soil particles reduces as water lubricates the surfaces of soil particles and fibers, and thus reduces the pullout capacity of the fibers. This aspect is more important if it is realized that the CBR strength of the specimens are greatly controlled by the pullout, rather than the breakage, behavior of the fibers as explained for the moist specimens. A comparison between the

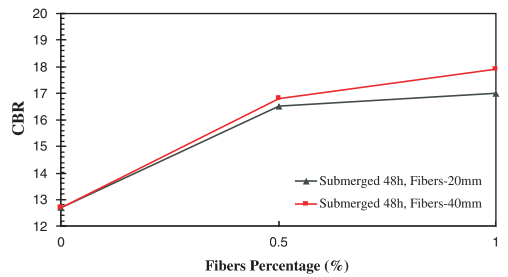

Figure 3. Effect of Palm fiber content on CBR strength (submerged condition).

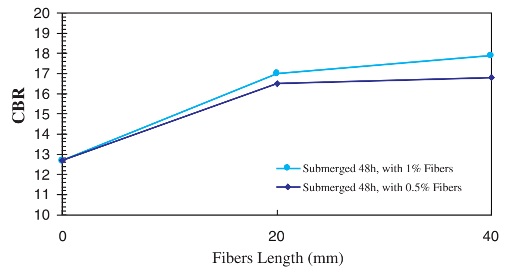

Figure 4. Effect of Palm fiber length on CBR strength (submerged condition).

results of moist and submerged specimens can be seen in Fig. 5 in which the major roles of water in the reduction of CBR values due to both soil and fiber interactions with water are apparent.

Similar to the results in figures 1 and 2, it can also be seen in figures 3 and 4 that there appear to be some optimum fiber contents or fiber lengths for which maximum bearing strength values for the specimens can be achieved.

4 CONCLUSIONS

1. Fibrous palm waste can be converted into a value-added product for soil reinforcement.
2. Sand specimens reinforced with palm fibers show some increase in CBR strength.
3. Submergence of plain and reinforced specimens causes the CBR bearing strength to decrease considerably. This can be attributed to the water interaction with soil particles, and the reduced frictional resistance of fibers caused by water.
4. There appear to be some optimum fiber contents or fiber lengths for which maximum bearing strength values can be obtained for a given soil condition.
5. The failure mode of fibers appears to be more pullout than breakage.
6. Further research is under way to evaluate the durability of these fibers when mixed with soil.

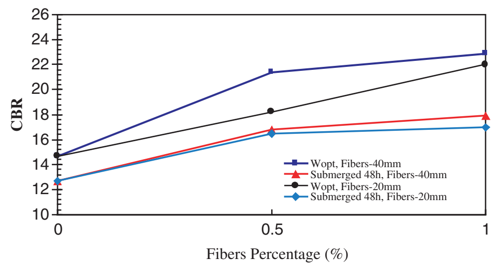

Figure 5. Comparison between the results of moist and submerged specimens.

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