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INVESTIGATION OF SHEARING RATE EFFECTS ON SAND-REINFORCED WITH WASTE POLYAMIDE FIBERS

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ABSTRACT

This paper presents the experimental results of influence of shearing rates on shear strength parameters of sand mixed with waste polyamide fibers. Direct shear test apparatus has been used for experiments. The sand was SP in the Unified classification system. Polyamide fibers with length of 8 mm have been used and mixed with sand such that uniform mixtures have been obtained. The fiber contents in sand-fiber mixtures have been 0.1%, 0.2%, and 0.3%. Various sand-fiber uniform mixtures have been prepared with 4%, 7%, and 12% moisture contents. Each mixture has been poured in the direct shear test mold and normal stress has been applied. Three normal stresses of about 15.7, 31.4, and 62.8 kPa have been used. Data such as variations of shear stress versus shear displacement and friction angles of each mixture has been recorded. The shear stress has been applied with rates of 1, 2, 3, and 4 mm/min. The results have shown that with increasing fiber contents the mixture friction angle generally increases. For a given fiber content in the mixture, with increasing the shear rate the friction angle increases. It has also been found that the moisture content has insignificant effect on friction angle changes.

Keywords: Direct shear test, soil reinforcement, shear rate, moisture content.

INTRODUCTION

The stress-strain behavior of saturated soils can be affected by the applied rate of loading. This is important when earthquake or other dynamic loading is applied to soils. The loading rate effect has been studied extensively since pioneering work of Taylor (1943) and Casagrande and Wilson (1951). The effect of loading rate on the soil response has been experimentally studied by a number of researchers (Taylor, 1943; Casagrande and Wilson, 1951; Richardson and Whitman, 1963; Lefebvre and Lebueuf, 1987; Lefebvre and Pfendler, 1966; Sheahan et al., 1996; David and Campanella, 1997; Dinesh et al., 2003). The results from these experiments show that the strength of the soils increases with increase in the rate of loading.

Design engineers may face two key points. Due to limiting appropriate land for construction, low strength soil may be encountered in practice. Thus soil improvement and soil reinforcement may be called for. On the other hand, as a result of the increase in the amount of solid waste all over the globe, engineers and researchers carry out investigations to find applications for such wastes. According to the data published by EPA, the solid waste stream in the United States in 1988 included 14.4 million metric tons of plastics occupying 20% by volume of the available landfill spaces. There is good news that these two are looked at the same time. Several studies have been carried out to find feasibility of

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using shredded scrape tires for soil reinforcement (Foose et al., 1996; Ghazavi; 2004; Ghazavi and Amel Sakhi, 2005; Ghazavi and Amel Sakhi, 2005b). The interest of reducing waste material has allowed the use of such unconventional materials in civil engineering practice and their use is becoming more widespread.

There are also other options to reinforce inappropriate soil using steel or geosynthetic inclusions such as fibers (Gray and Ohashi, 1983; Gray and Al-Refeai, 1986; Maher and Gray, 1990; Showbridge and Sitar, 1990; Lowton et al., 1993; Kumar et al., 1999; Santoni et al., 2001; 2002; Yetimoglu and Salbas, 2003).

Most of the above research was carried out experimentally under controlled strained and under normal shearing rates. However, to the best knowledge of the authors, the effect of loading rate on the strength of waste material reinforced soils has not been studied yet. In this study, direct shear test has been used to determine the effect of strain rate on the strength parameters of sand-polyamide fiber mixture. The results will be presented for un-reinforced and reinforced specimens.

MATERIALS AND METHODOLOGY

Soil

Sandy soil with a grain size distribution shown in Fig. 1 has been used in the present experiments. The coefficient of uniformity, C_U and the coefficient of curvature, Cc, for the soil are 3.15 and 0.68, respectively. The soil is SP in the Unified classification system.

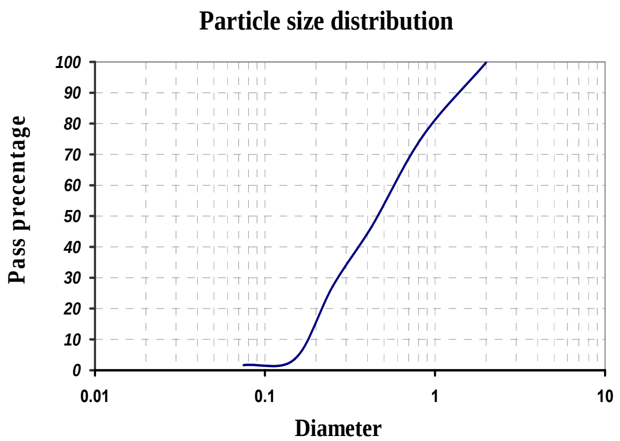

Figure 1. Particle size distribution of sand

Polyamide Fibers

The fibers were cut with lengths of about 8 mm due to the limiting size the shear test box apparatus. Therefore, the so called size effect is not present. The physical and mechanical properties of polyamide fibers are given in Table1.

Table1. Mechanical and physical properties of polyamide fibers

Fiber	Stability of Fiber	Stiffness CN/Tex	Stiffness gm/d	Fracture Resistance	Tensile Strength
Polyamide	Tex 1880	85	8	161	22%

EXPERIMENTAL PROGRAM AND SPECIMEN PREPARATION

The experimental program consisted of 3 phases. Each moisture contents of 4%, 7%, and 12% correspond to each phase of experiments. A dry density of 1.644 gr/cm^3 was kept the same for all specimens in the three all phases.

The weight of the dry sand is calculated initially by considering the target dry density of 1.644 gr/cm^3, the given moisture content used in each phase, and the volume of the specimen in the shear test box. In each phase, three polyamide fiber contents of 0.1%, 0.2%, 0.3% by weight, with respect to the dry sand, were used to reinforce the sand. In all specimens, fibers were randomly distributed, but the length of polyamide fibers were 8mm in all of them. In each phase the tests were conducted on none reinforced soil as well.
Waste polyamide fibers were mixed with and randomly distributed in the sand such that a uniform mixture was achieved. Water was then added to the fiber-sand mixture and mixed thoroughly to reach again a uniform mixture. The uniformity of all mixtures was always controlled by eye observation. Mixtures were subsequently poured into the shear test box and compacted to reach the target dry density.

Direct shear tests were carried out according to the procedure described by ASTM D3080-90 in order to determine the shear strength characteristics of reinforced sand. The dimensions of the shear test apparatus were 5×5×2.5 cm. In performing shear tests, a controlled strain rate was adopted. At each phase, three normal stresses of 15.7, 31.4, and 62.8 KPa were applied. At each phase, direct shear tests were conducted with different strain rates. Shear stresses were then applied to each mixture to reach the failure stage.

For a given water content (of 4%, 7% and 12%) and a given fiber content (of 0.1%, 0.2% and 0.3%), direct shear tests were conducted at four strain rates of 1,2,3,4 mm/min to determine their effects on shear strength parameters of the reinforced sand. The results of these experiments will be shown in subsequent section.

TEST RESULTS AND DISCUSSION

Effect of polyamide fibers on sand friction angle

The effects of polyamide fiber contents friction angle of reinforced sand for different water content and shearing rate are shown in Figs. 2-5. As illustrated, it is clear that the friction angle of the soil-polyamide fiber mixtures increases with increasing fiber content.

When sand is subjected to shear strain, the friction between particles resists against shearing strain. The resultant shear force is caused by relative movement of sand particles. Due to the presence of polyamide fibers between sand particles, the shear stress between fibers and sand grains are transferred to fibers, producing tension stress in fibers. As seen in Figs. 2-5, in some cases, polyamide fibers cause an increase of more than about 8° in the sand friction angle.

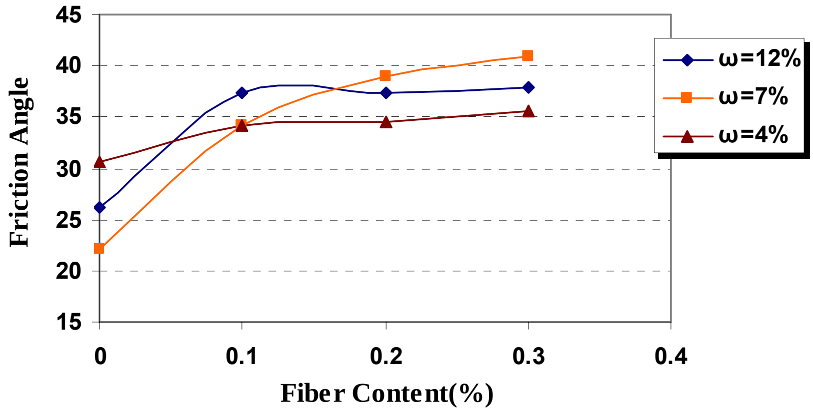

Figure 2. Variation of friction angle versus fiber content for different water content for the strain rate of 1mm/min

Adding 0.1% fiber to the sand has a significant effect on the friction angle of the sand. Moreover, by increasing fiber content more than 0.1%, the increase rate of the friction angle decreases.

The results show that the amount of water content has insignificant affect on the increase of the friction angle.

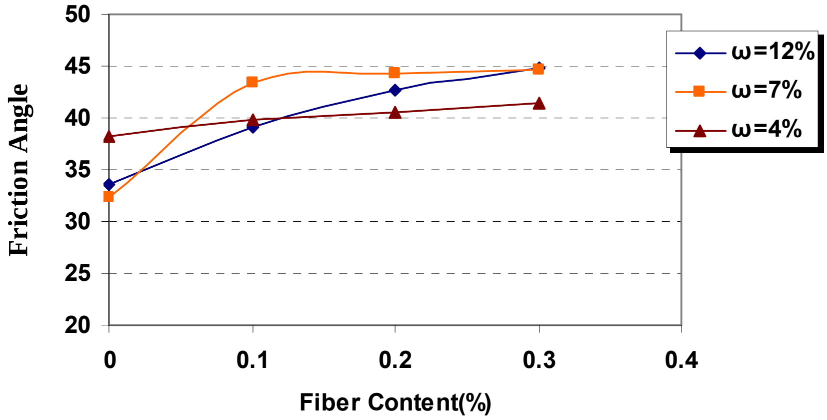

Figure 3. Variation of friction angle versus fiber content for different water content for the strain rate of 2mm/min

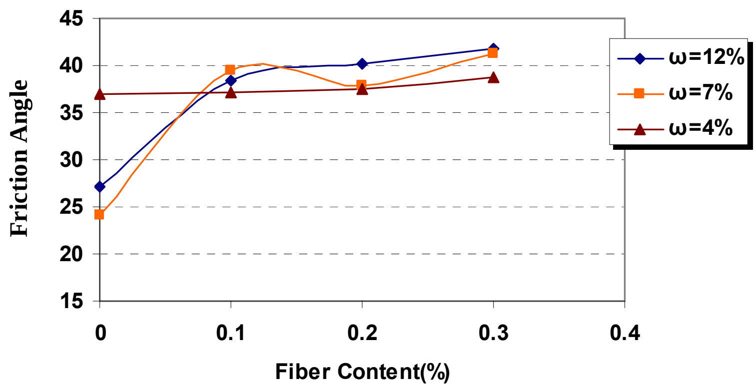

Figure 4. Variation of friction angle versus fiber content for different water content for the strain rate of 3mm/min

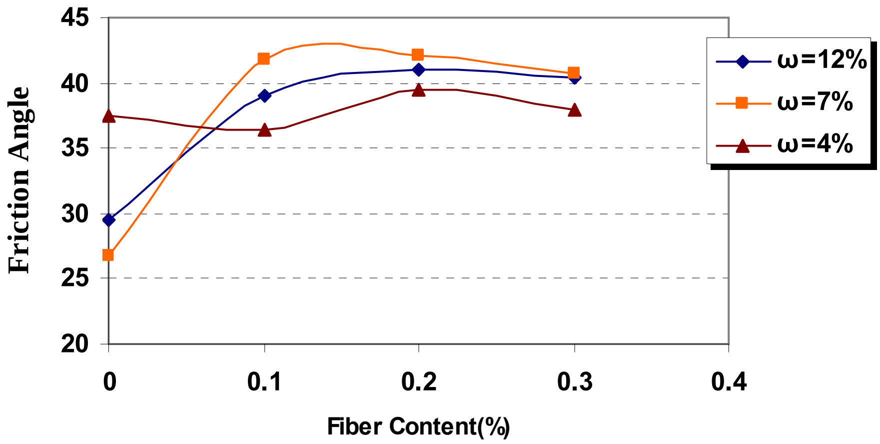

Figure 5. Variation of friction angle versus fiber content for different water content for the strain rate of 4mm/min

Effect of strain rate on the friction angle of mixtures

As mentioned before, four different shearing rates were used for each test. As a sample, the variation of shear stress versus horizontal displacement is plotted in Fig.6. In this figure, a typical stress-displacement response of samples under 62.8 kPa normal stress with 0.2% fiber content and 7% water content at various shearing rates is shown. It is clear that the peak shear strength of the sand-polyamide mixtures increases with increasing shear rate.

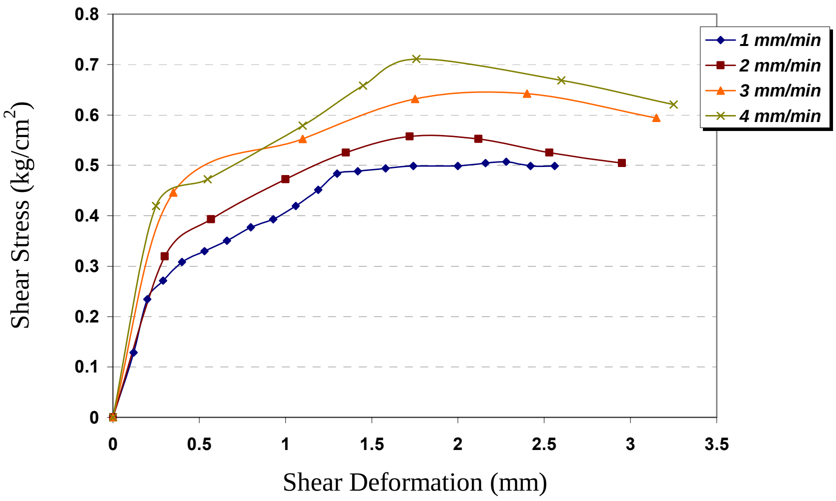

Figure 6. A typical stress-deformation response of sand-polyamide mixture with 0.2% fiber content and 7% water content

The effect shearing rate on the friction angle of soil-polyamide fibers is shown in Figs. 7-10. It is evident from these figures that there is an increase in the friction angle of soil-fiber mixtures with an increase in shearing rate. To consider the effect of water content on the strain rate effect, specimens were prepared with three different water contents. Test results show that water content does not affect the friction angle due to increasing shearing rate.

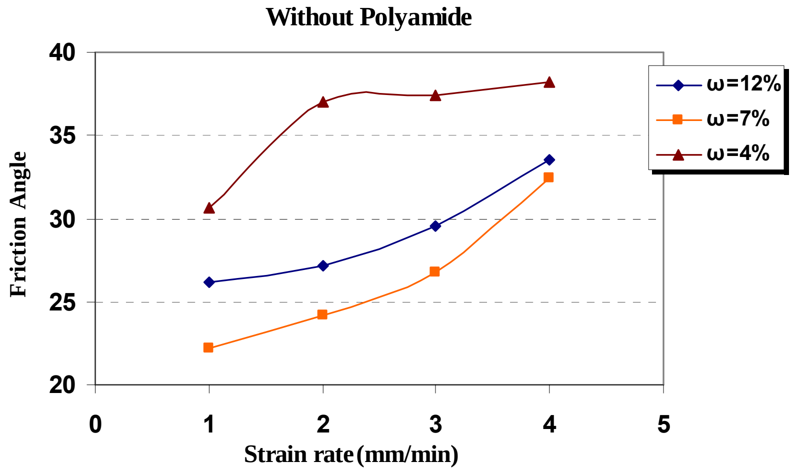

Figure 7. Variation of friction angle versus strain rate in different water content for specimens without polyamide

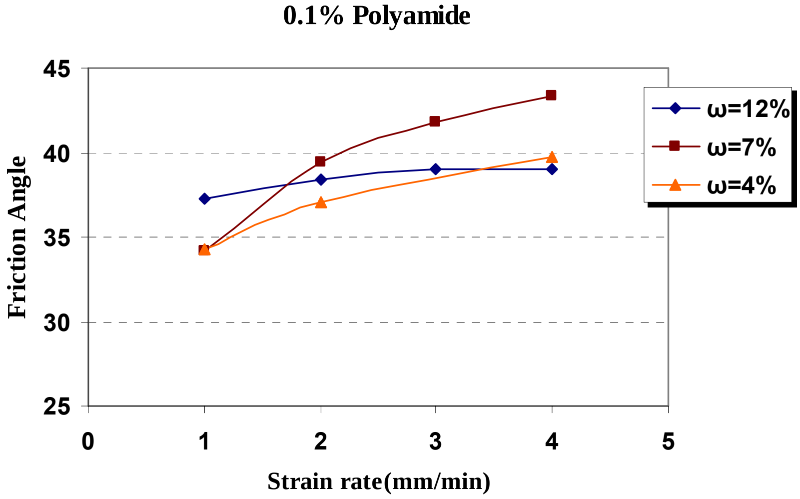

Figure 8. Variation of friction angle versus strain rate in different water content for specimens with 0.1% polyamide

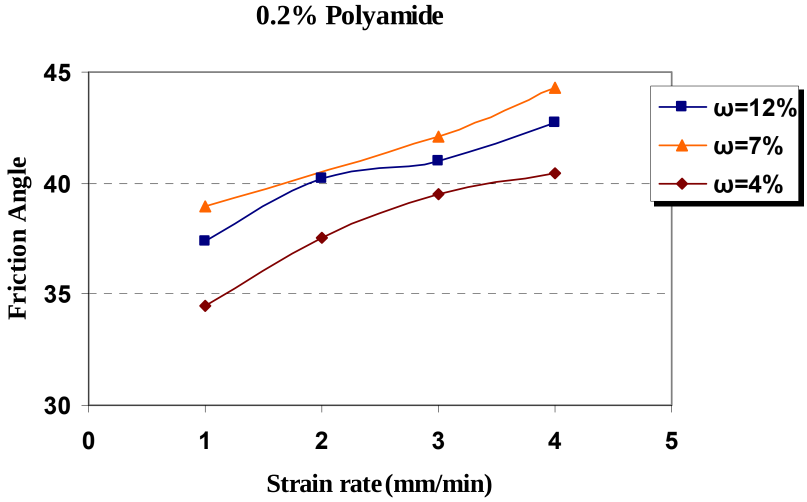

Figure 9. Variation of friction angle versus strain rate in different water content for specimens with 0.2% polyamide

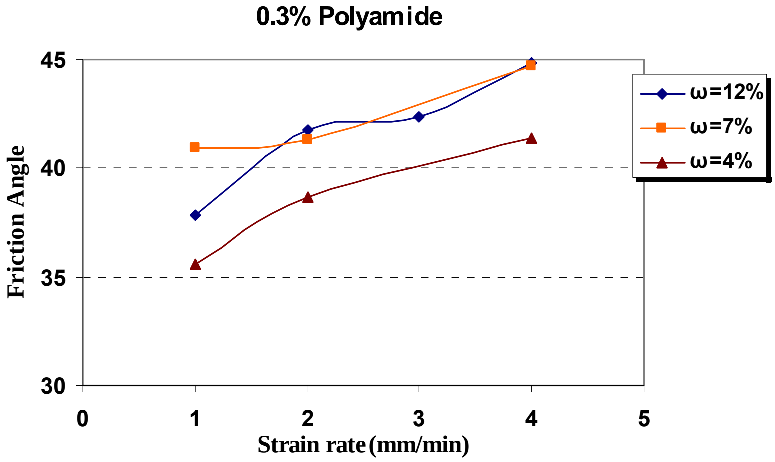

Figure 10 . Variation of friction angle versus strain rate in different water content for specimens with 0.3% polyamide

CONCLUSION

An experimental investigation has been carried out to show the effect of amount of polyamide fibers and the shearing rate on the friction angle of soil-polyamide mixtures. Within the testing materials and procedure adopted in this paper, some conclusions have been derived from these experiments. These are:

1. An increase in polyamide fiber content results in increasing the friction angle of polyamide-sand mixture.
2. By adding polyamide fibers in excess of 0.1% or 0.2% by weight to the sand, the rate of increasing the friction angle decreases.
3. Shearing rate can cause significant effect on the friction angle of sand- reinforced with-polyamide fibers.
4. The variation of water content can not affect the value of friction angle of sand-polyamide fiber mixtures compacted at a constant dry density and subjected to various shearing rate.

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