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Effect of Randomly Reinforced Soil on Increasing Resistance against Piping Phenomenon

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ABSTRACT

This paper presents an investigation on the randomly reinforced soil against piping through experimental tests. Randomly reinforced samples were prepared with two types of fiber (polyester and polyethylene terephthalate) with different diameter (0.2 and 0.3 *mm*). Experimental tests were carried out on unreinforced and reinforced samples with different percent (0.5, 0.75, 1 and 1.25%) and length (5, 25, 35 and 50 *mm*) under various hydraulic head in a special apparatus. Discharge and seepage velocity of water flow through unreinforced and reinforced samples were measured and calculated and comparison was made with unreinforced sample. The results showed that the inclusion of fiber reduces the seepage velocity and increased the hydraulic gradient and piping resistance. Furthermore, increasing of hydraulic gradient and piping resistance is function of fiber content and fiber length.

KEYWORDS:

Piping, Hydraulic Gradient, Randomly Reinforced, Seepage Velocity, Seepage Force

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1- Introduction

Hydraulic structures such as earth dams, diversion dams, flood dams, embankments, irrigation canals and drainage systems are structures that may damaged by seepage flow. When the seepage velocity increases more than a critical value, the hydraulic structure may be damaged due to piping. Piping refers to the development of channels which begins at the downstream side of the structure where the flow lines converge. Associated with this, high seepage pressure occurs. The subsequent erosion process develops backwards and due to the natural non-homogeneity in the soil the channels are irregularly shaped. If the process continues the structure may in the end collapse.

Continues the piping phenomena on hydraulic structures is caused structural damage. From 1970s investigators such as Gray and Ohashi (1983), Maher and Gary (1990), Woods (1990), Yetimoglu et al. (2003) and Yetimoglu and Salbas (2005) studied the mechanical behavior of soil reinforcement that doing the various tests on the sandy soil samples randomly reinforced and show that adding fiber on soil increasing the soil strength [1-5]. Furumoto et al. (2002) were the first researchers who proposed to increase the resistance against piping by using randomly reinforced soil [6].

A review of the literature shows that the study of application of randomly reinforced soil with fibers for improving piping resistance in hydraulic structures is very limited. Furthermore, the previous studies on the applications of fiber reinforced soil for controlling piping have mainly used fibers of small diameter (in the range of μm) which would be difficult to implement in practical applications. Therefore, it was decided in this work to examine the possibility of using two types of polyester and polyethylene fiber with two relatively large diameters for improving piping resistance and controlling the seepage velocity of a sandy silty soil.

2- Material and methodology

2- 1- Soil

The soil used in this work was a silty soil. It was composed of 70% sand and 30% silt. The physical and mechanical behavior of the soil are shown in Table 1.

Table 1. Physical and mechanical properties of used soil

Property	Value
Specific gravity (*Gs*)	2.7
Silt (%)	30
Sand (%)	70
USCS classification	SM
LL	-
PL	-
Optimum water content (%)	13.2
Maximum dry unit weight (kN/m^3)	18.1

2- 2- Fiber

Polyester and polyethylene fibers in filament form were used for reinforcing samples. Table 2 shows the physical and mechanical properties of two types of fiber.

2- 3- Apparatus

There is no standard test procedure available to measure the piping resistance of soils [1]. In the present study to investigate the piping phenomena

Table 2. Physical and mechanical properties of fibers

Fiber Properties	Polyethylene	Polyester
Fiber type	Single fiber	Single fiber
Specific gravity (*Gs*)	0.8	1.2
Diameter (*mm*)	0.2	0.3
Tensile strength (*MPa*)	624	495
Modulus of elasticity (*MPa*)	2000	3000
Melting point	255	140-167
Solubility in water	Insoluble	Insoluble
Resistance to acids and alkali	Excellent	Excellent
Water absorption	0	0

and simulation laboratory of a subsequent upward by seepage flow, an apparatus was designed and made for performing the piping tests. Fig. 1 shows the cross section of the apparatus.

2- 4- Sample preparation and test method

Preparing reinforced samples was done by mixing a specific weight of soil with desired weight of fiber. Then the moisture of this mixture was reached to optimum water content corresponding to its compaction curve. The mixture was compacted by static method in a special mould in three layers. The dry unit weight of the prepared sample was equal to the corresponding maximum dry unit weight of compaction curve. Similar procedure was used for making unreinforced samples. The diameter and length of sample were 50 and 100 *mm* respectively.

3- Results

A total of 17 tests were conducted in this work. To ensure greater accuracy each test was repeated two times.

3- 1- Critical hydraulic gradient

Figs .2-*a* and 2-*b* show the variations of seepage velocity against hydraulic gradient for natural soil and reinforced with different percentage of fiber at length of 35 *mm* for two types of fiber. As shown in Fig. 2-*a* increasing the percent of fiber (No. 1) causes increase in hydraulic gradient. Similar trend is also seen in Fig. 2-*a* for fiber No. 2.

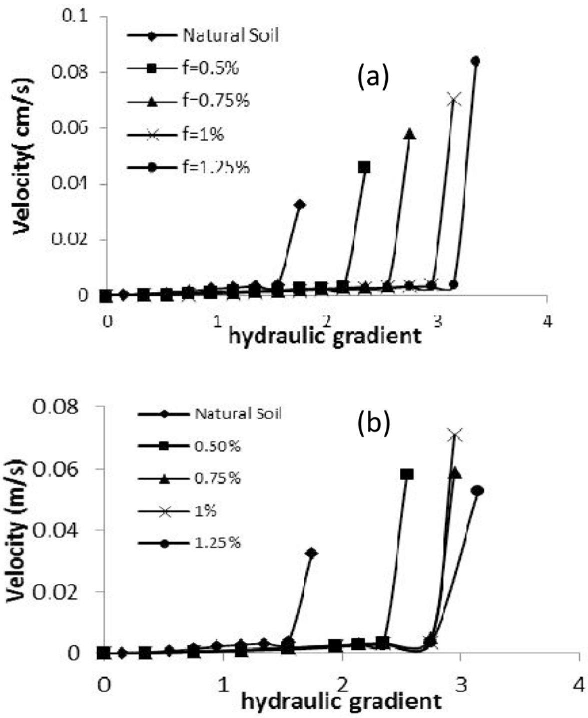

Fig. 2. Variations of seepage velocity with hydraulic gradient for different fiber content at *L*=35 *mm* (*a*): polyester and (*b*): polyethylene

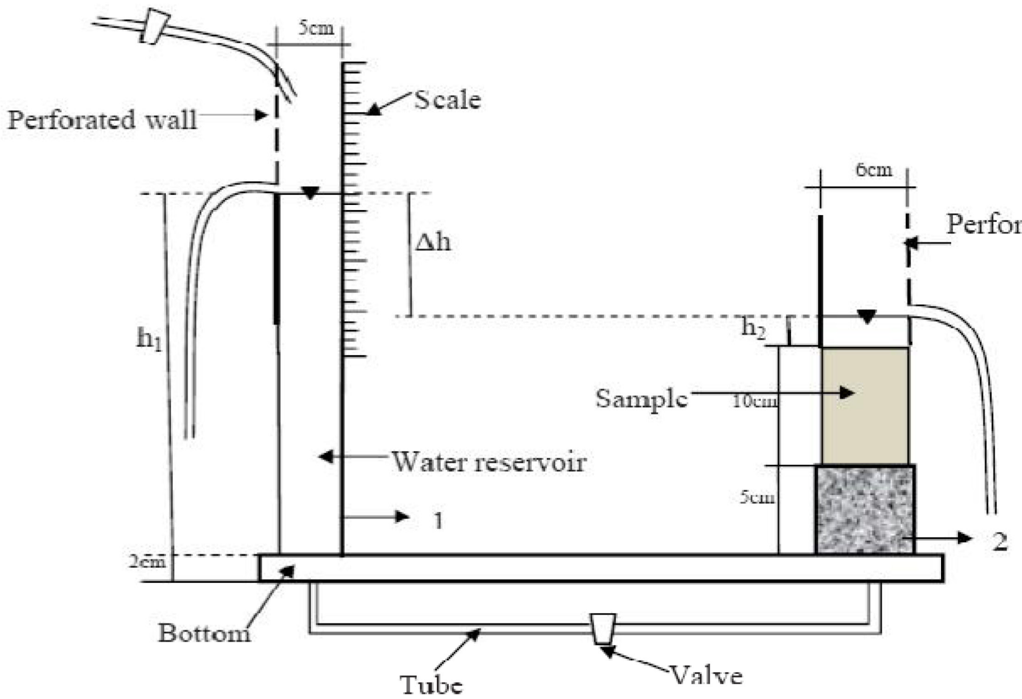

Fig. 1. Layout of apparatus

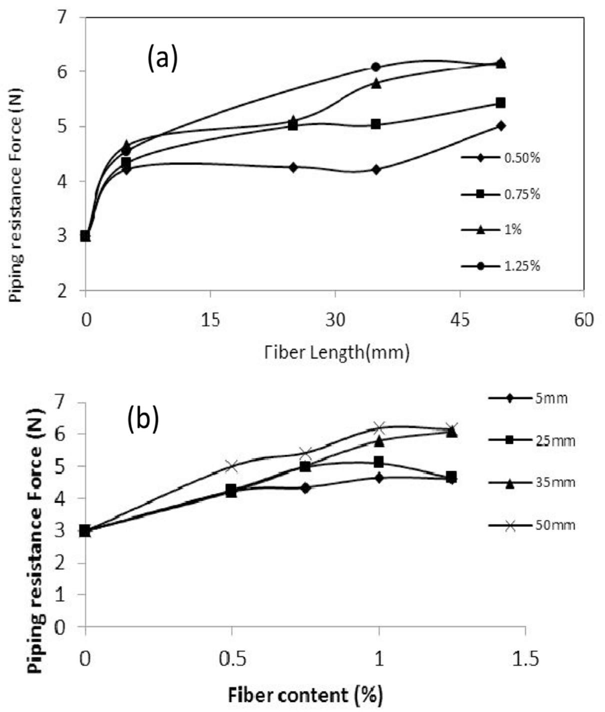

Fig. 3. Variations of piping resistant with different percent of fiber for polyester fiber (*a*): different fiber content (*b*): different length

3- 2- Piping resistance force

Variations of piping resistance versus hydraulic gradient for two types of fiber are shown in Fig. 3. Figs. 3-*a* and 3-*b* show that for both fiber the piping resistance is increased by increasing the fiber content until a specific percent then is remained nearly constant.

4- Conclusion

Effect of randomly reinforced soil on piping resistance was investigated through experimental tests. The results showed that this technique is an effective method for increasing the resistance against piping. The following conclusion can be drawn from this study.

- Critical hydraulic gradient and piping resistance are increased with increasing the length of fiber.
- At constant fiber content the fiber with less diameter and length are more effective in increasing resistance against piping.

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