Permeability Test on Reinforced Clayey Sand

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***Abstract*—**Composite soils have been widely used in civil engineering applications, especially in slopes, embankment dam and landfills. This paper aims to investigate effect of fiber inclusion on permeability of composite soil (i.e. sand composite). A series of laboratory permeability tests carried out to evaluate fiber effect on hydraulic conductivity behavior of composite sand. Clayey sand was selected as soil part of the composite and natural fiber was used as reinforcement. The fiber parameters differed from one test to another, as fiber length were changed from 10 mm to 25 mm and fiber content were varied from 0.1% and 0.3%. For each test, permeability coefficients derived and the results were compared. The results proved that inclusion of fiber affected hydraulic conductivity of sand composite so that increasing in fiber content and length caused increasing in permeability coefficients.

***Keywords*—**Permeability, Reinforced, Fiber, Sand

I. Introduction

THE permeability test is one of the oldest tests for soils. In this study, permeability device will be used to determine the hydraulic conductivity of a fibre reinforced soil. Different aspect of reinforced soil has been investigated in literature. Fletcher and Humphries (1991) investigated influence of fibre inclusion on compaction of silty clay soil. Unlike the case of sandy gravel reported by Hoare (1977), the test results indicated that increasing the fibre content causes a modest decrease in the maximum dry unit weight. The optimum water content was found to increase by increasing fibre content. Other researchers (Nataraj and McManis, 1997; Al Wahab and El-Kedrah, 1995; Puppala et al., 2006; Miller and Rifai, 2004; Ozkul et al., 2007; Kumar Tabor, 2003) also reported similar results. In contrast, some researchers such as Ozkul et al, 2007 reported not significant changes on compaction parameter by fibre inclusion. Applications of soil strengthening or stabilization range from the mitigation of complex slope hazards to enhancing the subgrade stability. The mixing of short randomly distributed fibres to a soil specimen may be considered same as other admixtures used to stabilize soil. Material used to make fibres for reinforcement may be obtained from paper, metal, nylon, polyester and other materials having widely varied physical properties. There have been numerous past papers published on the topic of fibre strengthening of soils. Examples include Lee et al., 1973, Hoare, 1979, Andersland and Khattac, 1979, Freitag, 1986, Gray and Ohashi, 1983, Gray and Rafeai, 1986, Maher and Gray 1990, [12] and Ho, 1994, [13], Ranjan et al. 1996, [1], Consoli et al. 2009.All of the papers listed above have generally shown that; strength of the soil was improved by fibre reinforcement. The investigation on permeability characteristic of clayey sand composite is very limited. The purpose of this survey is to evaluate clayey sand behaviour induced by fibre inclusion.

II. Material

Composite soils consist of two parts. The first part is soil part which can be dealt as normal soil. The second part is reinforcement part which can be made up of any material which helps soil to have better performance.

A. Soil Type

The soil type in this study was Western Australian sand. The properties of clay are presented in table 1. The sand distribution curve is presented in Fig 1. The soil part was reconstituted in lab by using sand with 20% of kaolin clay.

TABLE I
CLAY PROPERTIES

No.	Type	
1	Soil type	Clay
2	Liquid Limit	49
3	Plastic Limit	23
4	Pl. Index	26

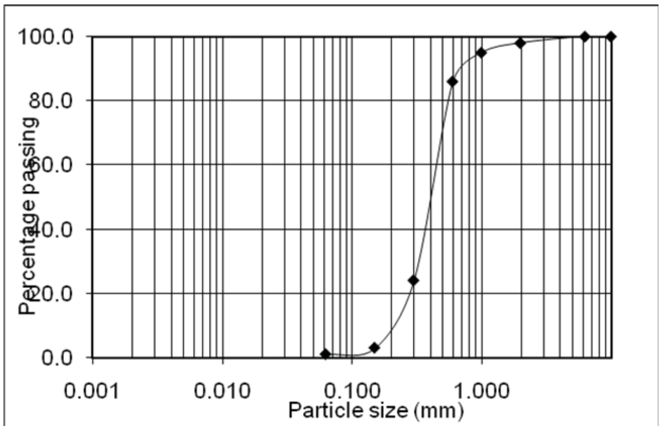

Fig. 1 Sand Particle Distribution

B. Fiber Type

The natural fiber has been used for this investigation. Figure2 shows the used fiber. The used fiber has good potential to absorb energy and good adhesion with soil particle.

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Fig. 2 Natural fiber

III. TEST PROGRAM

A series of constant head permeability tests have been conducted on reinforced sand composite.

C. Permeability Test

Permeability is a measure of the ease in which water can flow through a soil volume. It is one of the most important geotechnical parameters. However, it is probably the most difficult parameter to determine. In large part, it controls the strength and deformation behavior of soils. It directly affects the following:

- Quantity of water that will flow toward an excavation
- Design of cutoffs beneath dams on permeable foundations
- Design of the clay layer for a landfill liner.

For fine grained soil Falling head permeability test is done, whereas constant head permeability test is done for the coarse grained soil. As this study is focused on clayey sand, the constant head permeability test was applied.

D. Main Equipments

- Constant head apparatus
- Specimen preparation equipment
- fiber
- Balance

Figure 3 shows the chamber which was used to run permeability test. Figure 4 shows the apparatus of running the constant head permeability test.

Fig. 3 Sample chamber

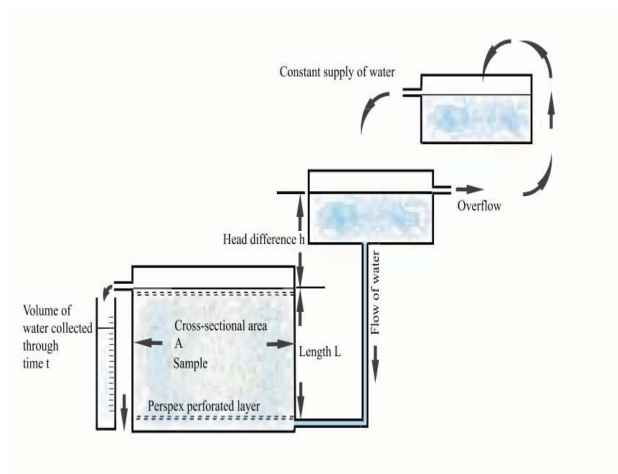

Fig. 4 constant head apparatus

IV. TEST METHODOLOGY AND PROCEDURE

- Sufficient water mixed into the sample to prevent segregation of particle sizes during placement into the permeameter. Enough water should be added to allow the mixture to flow freely, forming layers.
- One porous stone on the inner support ring in the base of the chamber positioned.
- A scoop used, the prepared specimen poured into the lower chamber, using a circular motion to fill the lower chamber to a depth of 1.5 cm. Special care was taken until a uniform layer formed.

- An appropriate tamping device used to compact the layer of soil to the desired density. The compacting repeated procedure until the sample is within 2 cm of the top of the lower chamber section.
- The sample length recorded
- The constant head funnel, rod and meter stick assembled.
- The level of the funnel was adjusted to allow the constant water level in it to remain a few inches above the top of the specimen.
- The vertical distance between the funnel overflow level and the chamber outflow level measured accurately.
- Adequate time allowed for the flow pattern and/or specimen to stabilize.
- After equilibrium flow was established, the time taken to have specified volume of water flowing out recorded. Use a measuring cylinder and a stop watch.
- Test repeated for three or more times, the average time were calculated.

a. Equation to be used

$$K=VL/Aht \quad (1)$$

Where,

K = Coefficient of permeability
V = Collected volume of water
L = Length of soil column
A = Area of the soil column
h = Head difference
t = Time required to get V volume

V. Results and Discussions

The permeability tests were performed in order to determine effect of fibre inclusion on hydraulic conductivity of reinforced clayey sand composite. Table II shows the effect of fibre on hydraulic conductivity of the samples.

TABLE II
HYDRAULIC CONDUCTIVITY OF THE SAMPLES

Sample type	Coefficient of permeability (Cm/S)
Unreinforced sample	1.2 E- 5
Reinforced with 0.1 % of fibre at 15mm	2.5 E -5
Reinforced with 0.2% of fibre at 15mm	2.7 E -5
Reinforced with 0.3 % of fibre at 15mm	3.45 E -5
Reinforced with 10mm of fibre at 0.1% content	2.07E -5
Reinforced with 25mm of fibre at 0.1% content	2.76 E -5

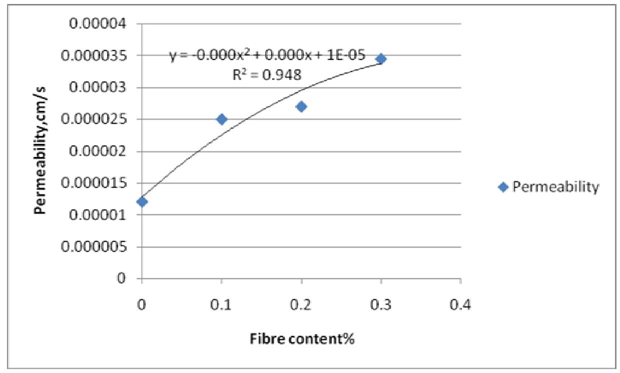

Fig. 5 Results of permeability test in different fiber content (at 15mm)

Figure 5 and figure 6 visualize the results of the tests. The results proved with increasing in fibre content and length the hydraulic conductivity increased. The best line which could represent the laboratory data was derived and regression of that was determined.

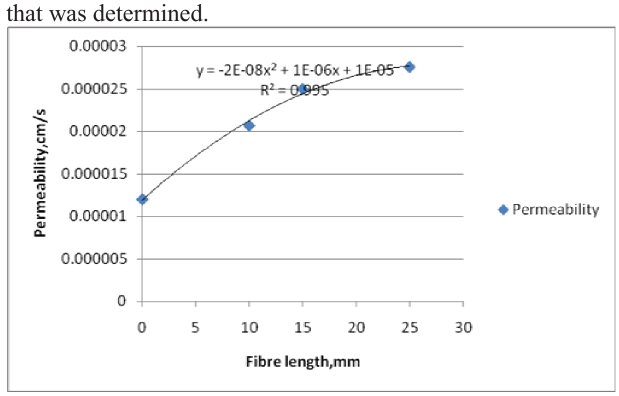

Fig. 6 Results of permeability test in different fiber length (at 0.1% fiber content)

VI. Conclusion

A series of permeability test performed. The methodology which applied to the test was constant head method. The clayey sand was reinforced by short plastic fibre .The results from the tests presented in this paper which showed effect of each fibre parameters on permeability characteristics of composite samples. It was proved that increase in fibre content and length caused increase in hydraulic conductivity. The value of coefficient of permeability jumped from 1.2 E- 5 (cm/s) to 3.45E -5 (cm/s) with increasing in fibre content from zero to 0.3% and also with increasing in fibre length from 10mm to 15 mm the value of coefficient of permeability increased from 2.07 E -5 (cm/s) to 2.5 E -5 (cm/s). The behaviour of composite soil in terms of hydraulic conductivity was not linear due to change in fibre content and fibre length. Interaction of fibre and soil could be reason of increasing hydraulic conductivity as may cause creating some paths for water to escape in soil matrix.

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