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Determination of Design Parameters by Seepage Pressure Induced Hanging Bag Test

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ABSTRACT

Geotextile tubes has been successfully implemented around the world as alternatives to concrete mound or rubble built structures for shoreline protection, slope protection and sludge dewatering. However, the lack of design rules and methods for geotextile tube technology instigates limitations to its vast applications. This is probably why engineers, designers and contractors are rather hesitant to use geotextile tube technology. In this paper, a pressure induced hanging bag test was conducted have been conducted on a model tube filled with dredged fill material. Design parameters such as geotextile permeability with respect to various filling pressures are derived. The test procedures and both the benefits and limitations of the test are discussed.

1. INTRODUCTION

Geotextile tubes are made from strong and flexible textile materials that are capable of retaining fine-grained materials though permeable enough to allow the excess water from the hydraulically filled slurry to dissipate. In recent years geotextile tubes were used as groins and breakwaters to protect or mitigate shoreline/coastline erosions (Cantré, 2002; Gibeaut et al., 2003; Alvarez et al., 2007; Pilarczyk, 2008; Parab et al., 2011), as containment dikes for land reclamation and man-made islands (Fowler et al., 2002a; 2002b), and as revetments acting as mass-gravity barrier-type structures and protection dikes to prevent damage to valuable structures caused by natural calamities (Restall et al., 2002; Lawson, 2008).

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Geotextile tubes has been of interest in various studies due to its wide applications in civil engineering. Laboratory evaluation results on the permeability and retention characteristics of geotextiles can be found in the studies of Moo-Young et al. (2002), Koerner & Koerner (2006), Weggel et al. (2011) and Vashi et al. (2013). Model tests and large-scale experiments on geotextile tubes can be found in the literature (Recio & Oumeraci, 2009; Kriel, 2012; Kim et al., 2013b, 2014a, 2014b). Numerical (Kim et al., 2013a, 2014b) & analytical methods (Plaut & Klusman, 1999) were also conducted to study the stability of stacked geotextile tubes. In general the studies available in the literature focuses on the investigation of the hydraulic stability of stacked geotextile tubes and the geotextile performance in strength, durability and permeability. However, very little is presently understood about the consolidation behavior of the fill materials and the stress and strain behavior of the confining geotextile.

This paper presents the methods and results for a proposed pressure induced hanging bag test, an improved hanging bag test. As a result of the pressure induced hanging bag test, design parameters such as the seepage quantity and coefficient of permeability were derived.

2. MATERIALS, LABORATORY SETUP AND METHODS

2.1. Fill Material and Geotextile Properties

The model test was carried out at the geotechnical engineering laboratory at Kunsan National University. The fill material was obtained from a local dredging site in the Saemangeum river estuary near Gunsan City. The physical properties of the dredged fill are shown in Table 1.

Table 1. Dredged Fill Properties

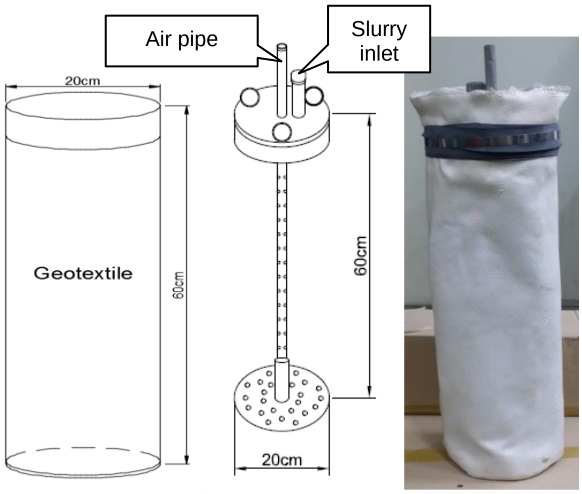
Item	Unit	Quantity
Specific gravity of soil solids, G_s	N/A	2.63
Percent passing #200 sieve	%	29.5
D_{10}	N/A	0.028
D_{30}	N/A	0.075
D_{60}	N/A	0.160
C_U	N/A	5.71
C_C	N/A	1.26
Soil classification (USCS)	N/A	SM (Silty-Sand)

The geobag used in the test is made of a made of a woven P.P. (polypropylene) geotextile material. Two types of geobag were used, woven and composite. Both geobags are 60 cm in height and has a theoretical diameter of 20 cm. The idealized cross-section of the geobag is shown in Fig. 1(a). The physical properties of the geotextile tube are shown in Table 2.

Table 2. Geotextile Properties

Description		Composite	Woven
Tensile Strength (kN/m)	Weft	177.51	162.48
	Warp	185.48	184.55
Elongation (%)	Weft	12.93	13.01
	Warp	13.78	12.90
Apparent opening size, AOS (ASTM 4751: μm)		145	472
Permeability (ASTM 4491: cm/s)		5.8×10^{-2}	1.1×10^{-1}

2.2. Seepage Quantity Test



(a) (b) (c)

Fig. 1 Geobag details: (a) Geobag dimensions; (b) geobag contraption; and (c) actual setup of the geobag contraption

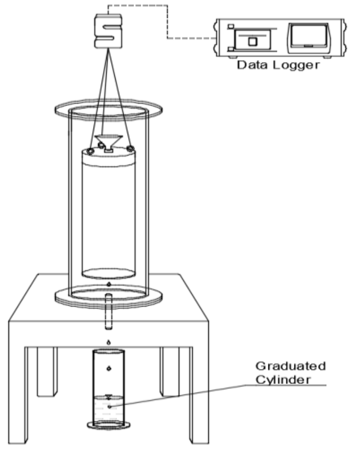


Fig. 2 Geobag filling setup

The seepage quantity test was conducted first. In this test, the geobag in Fig. 1(a) is inserted into geobag contraption shown in Fig. 1(b). The contraption held the geobag (Fig. 1c) and keep it in place throughout the entire test. The slurry inlet is located at the topmost portion of the geobag contraption. The idealized experiment setup for the seepage quantity test is shown in Fig. 2. Prior to the filling process, the geobag contraption is positioned inside an acrylic cylinder. This is to insure that the water discharge from within the geobag can be measured. The acrylic cylinder has a diameter of 28 cm and is 100m high. The geobag is suspended and supported by an electronic load cell. The load cell is connected into a data logger which records and transmits the recorded data into a computer. The water discharge is collected and measured with respect to elapsed time. The geobag is filled with slurry of 150% moisture content. The slurry filling of the woven and composite PP geobags lasted for 25 min and 42 min, respectively.

2.3. Coefficient of Permeability Test

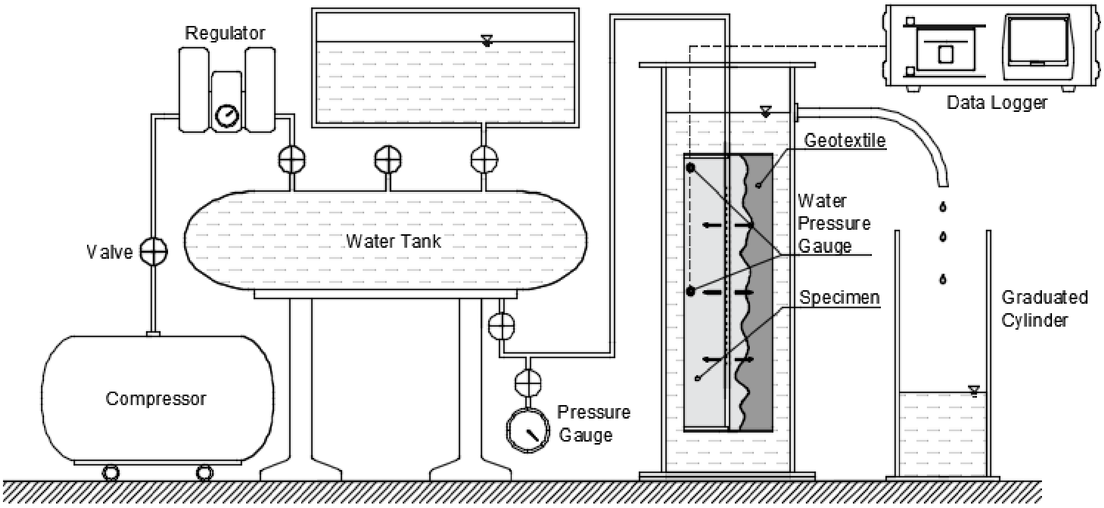


Fig. 3. Experiment setup for the coefficient of permeability test

After the each filling of the geobags in the seepage quantity test, the air pipe at the top of the geobag contraption is connected into the pressure pipe as shown in Fig 3. This is done in order to induce pressure inside the geobag during the dewatering process. Prior to the filling process, pressure gauges were installed inside the geobag in the manner as shown in Fig. 3. These gauges were connected into a data logger which transmits the data readings into a desktop PC. During the test, the depth of the external water was kept at the same level in order to maintain the value of the external water pressure. The water discharge was measured with respect to the dissipation time. The pressures applied increasingly at 20 kPa, 39 kPa, 59 kPa and 78 kPa correspondingly. The coefficient of permeability of the combined soil and geotextile membrane is determined using Darcy's equation:

$$k = \frac{Q \cdot L}{A \cdot \Delta h \cdot t} \tag{1}$$

where k is the permeability of the soil-geotextile composition; Q collected volume of water; L is the length in which the water will travel normal to the surface of the permeable geotextile (in this test, it is equivalent to 0.5 of the geobag theoretical diameter, D_T); A is the cross-sectional area of the contained soil in the geobag ($\pi D_T^2/4$); Δh is the pressure head reading at the pressure gauge shown in Fig. 3; and t is the elapsed time.

3. RESULTS AND DISCUSSIONS

3.1. Seepage Characteristics

The concentration of slurry fill during the filling process is shown in Fig. 4. Concentration is defined as the ratio between the mass (kg) of soil quantity in the slurry mixture, W_{soil}, to the total mass of the slurry ($W_T = W_{soil} + W_{water}$). Due to the dissipation of water, the slurry concentration decreases as time passes. Similarly, due to dissipation of water particles, the solid particles are condensed and forming as filter cakes along opening of the geotextile membrane, thereby, clogging the path of water dissipation and decreasing the flow rate of water as shown in Fig. 5. The recorded geobag weight during the test is shown in Fig. 6. This implies that during the filling phases, the geobag gains mass. Conversely, the mass of the geobag is decreased to a certain degree during the dewatering phase.

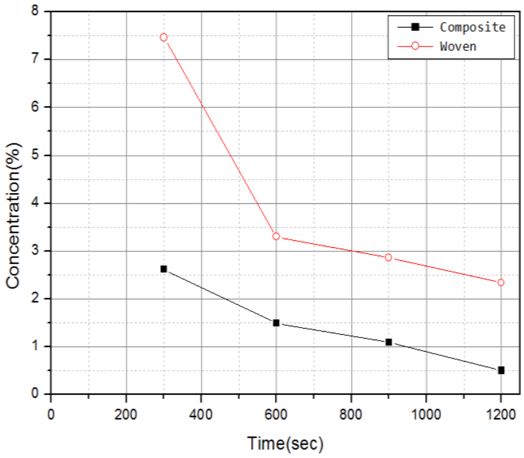


Fig. 4 Concentration of liquid vs. elapsed time

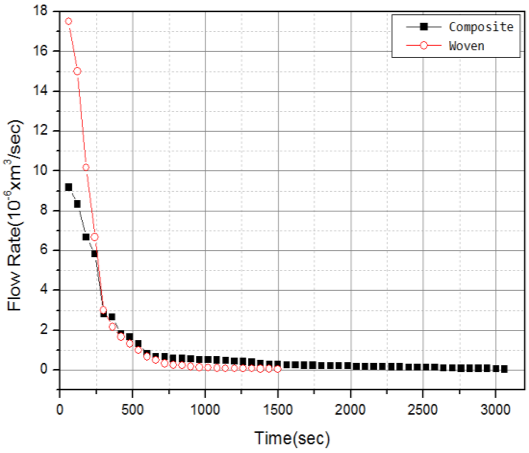


Fig. 5 Flow rate vs. time

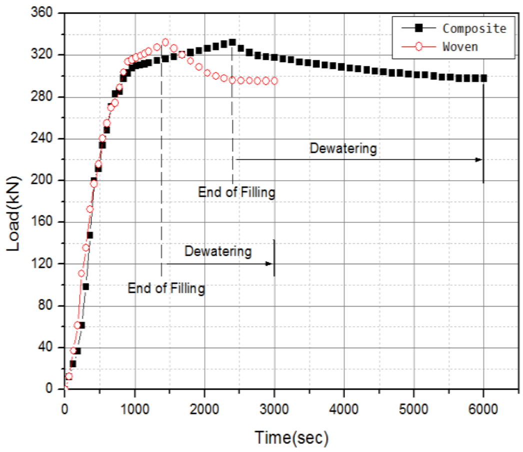


Fig. 6 Geobag weight

3.2. Geotextile Permeability

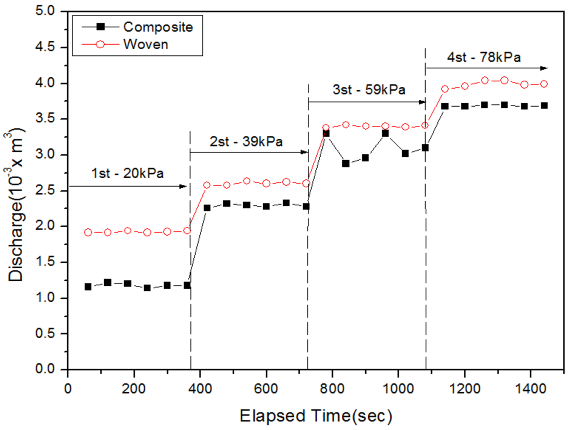


Fig. 7 Water discharge

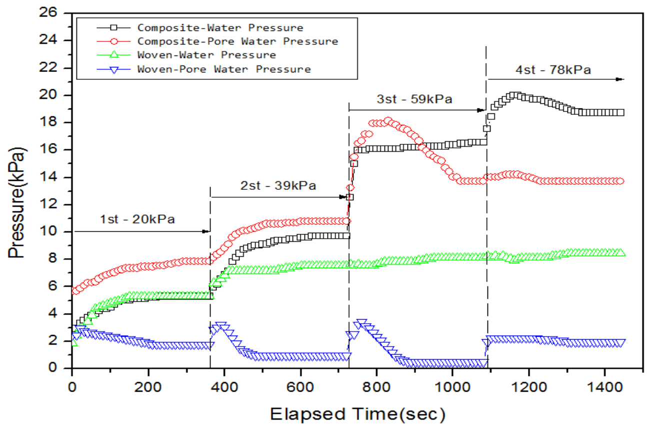


Fig. 8 Pressure development inside geobag

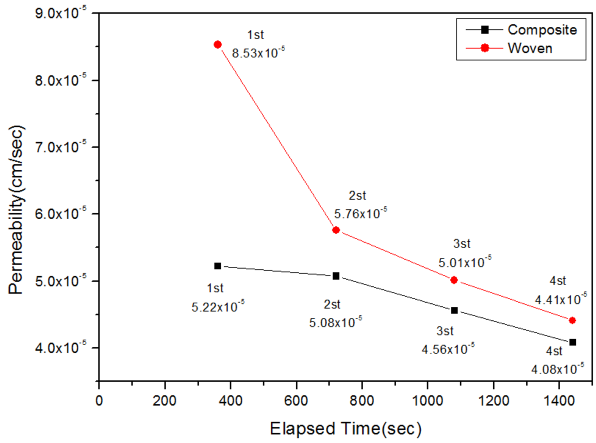


Fig. 9 Soil-geotextile permeability

The results for the pressure induced seepage test are shown in Figs. 7 – 8 and the deduced design characteristics of the woven and composite geobag are summarized in Table 3. The introduction of seepage pressure in the geobag increases the amount of water dissipation as shown in Fig. 7. Likewise, the pressure inside the geobag increases with the seepage pressure (Fig. 8). Therefore, in designing geotextile tubes, the seepage pressure should be carefully monitored as it will have a direct effect on the confining geotextile membrane. The soil-geotextile permeability decreases as time passes, mainly due to the dissipation of water and condensation of the solid particles. Regardless of the increasing seepage pressure, the soil-geotextile permeability gradually decreases as the fill material densifies. This can be attributed to the formation of filter cakes on the apparent opening of the geotextile membrane.

Table 3. Summary of Results

Injection Pressure		20 kPa	39 kPa	59 kPa	78 kPa
Coefficient of Permeability (cm/sec)	Composite P.P.	$8.53\text{x}10^{-5}$	$5.76\ \text{x}10^{-5}$	$5.01\ \text{x}10^{-5}$	$4.41\ \text{x}10^{-5}$
	Woven P.P.	$5.22\ \text{x}10^{-5}$	$5.08\ \text{x}10^{-5}$	$4.56\ \text{x}10^{-5}$	$4.08\ \text{x}10^{-5}$
Discharged Volume (m^3)	Composite P.P.	$1.18\ \text{x}10^{-3}$	$2.30\ \text{x}10^{-3}$	$3.09\ \text{x}10^{-3}$	$3.69\ \text{x}10^{-3}$
	Woven P.P.	$1.93\ \text{x}10^{-3}$	$2.60\ \text{x}10^{-3}$	$3.40\ \text{x}10^{-3}$	$3.99\ \text{x}10^{-3}$

4. CONCLUSIONS

Based on the laboratory tests conducted, the following conclusions are drawn:

- Due to the dissipation of water, the slurry concentration decreases as time passes. Similarly, due to dissipation of water particles, the solid particles are condensed and the finer particles formed as filter cakes long the openings of the geotextile membrane, thereby, clogging the path of water dissipation and decreasing the flow rate of water.
- The recorded geobag weight during the test which implies that during the filling phases, the geobag gains mass. Conversely, the mass of the geobag is decreased to a certain degree during the dewatering phase.
- The introduction of seepage pressure in the geobag increases the amount of water dissipation. Likewise, the pressure inside the geobag increases with the seepage pressure. Therefore, in designing geotextile tubes, the seepage pressure should be carefully monitored as it will have a direct effect on the confining geotextile membrane.
- The soil-geotextile permeability decreases as time passes, mainly due to the dissipation of water and condensation of the solid particles. Regardless of the increasing seepage pressure, the soil-geotextile permeability gradually decreases as the fill material densifies. This can be attributed to the formation of filter cakes on the apparent opening of the geotextile membrane.

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