Landmarks in Earth Reinforcement, Ochiai et al. (eds),
© 2001 Swets & Zeitlinger, ISBN 90 2651 863 3

Construction and monitoring of geotubes

E.C. Shin & Y.I. Oh
University of Inchon, South Korea

B.M. Das
California State University, Sacramento, USA

E.S. Lee
E & S Engineering Company, Seoul, South Korea

ABSTRACT: Pilot scale field tests were conducted to evaluate the performance of a geotube. The geotube was made of a woven geotextile which conformed to the minimum specifications provided by the U.S. Army Corps of Engineers. The results of a number of laboratory tests are presented: direct shear tests to determine the geotextile-sand interface friction angle, cyclic fluctuation tests to estimate the soil particle loss from the geotube, and long- and short-term environmental tests to evaluate the environmental effects of dissipated water from the geotube. Based on the present study it appears that the geotube is a fast, efficient, and environmentally sound dredging fill technique.

1 INTRODUCTION

Geotubes are made of permeable, soil-tight geotextile. They are hydraulically filled with dredged soil. Attempts are now being made to use geotubes in coastal engineering projects such as shore protection and breakwaters. Geotubes also help store and isolate contaminated materials obtained from dredging. The diameter and length of the geotubes vary, depending on the field conditions. The typical length and width are 150-180 m and 4-5 m, respectively.

Initial studies regarding geotextile containers are found in the work of Koerner and Welsh (1980). Botzan et al. (1982) and Harris (1987, 1989, 1994) reported the use of geotextile containers in erosion control. Bogossian et al. (1982) and deBruin and Loos (1995) evaluated the effectiveness of geotubes for erosion control. Environmental dredging and backfill technology using geotubes was reported by Fowler et al. (1994) and Pilarczyk (1996).

In most cases, a single layer of woven geotextile is used to construct the geotube. According to the U.S. Army Corps of Engineers, the minimum physical properties of woven geotextile to be used for constructing geotubes should be as follows:

Tensile strength: 175 kN/m
Elongation: 10%
Trapezoidal tearing strength: 140-160 kN/m
Seaming strength: 105 kN

This paper summarizes the performance of a pilot scale field test using a geotube in Inchon, South Korea.

2 PROPERTIES OF SOIL AND GEOTEXTILE

The soils used for this study were Jumoon Jin sand, dredged sand, and dredged organic soil. Jumoon Jin sand is a standard poorly graded silica sand used in Korea. The dredged sand was obtained from the Songdo Land Reclamation area in South Korea. The dredged organic soil was collected from the detention basin located on the west coast of Inchon, South Korea. The detention basin is used for temporarily holding the water before discharging it to the sea. The physical properties of these soils are given in Tables 1 and 2, and the grain-size distributions for the three soils are given in Figure 1.

Table 1. Physical properties of the sand.

Item	Quantity	
	Jumoon Jin sand	Dredged sand
Effective size, D_{10} (mm)	0.37	0.09
Uniformity coefficient, C_c	1.53	4.67
Coefficient of gradation, C_u	1.10	1.06
Maximum dry unit weight, $\gamma_{d(max)}$ (kN/m^3)	16.09	15.3
Optimum moisture content, w_{opt} (%)	15.2	16.2
Specific gravity, G_s	2.65	2.65
Unified soil classification	SP	SP

Table 2. Physical properties of the organic soil.

Item	Quantity
Specific gravity, G_s	2.29
Liquid limit, LL (%)	39.00
Plastic limit, PL (%)	30.25
Plasticity index, PI	8.75
Passing 0.075 mm sieve (%)	21.94
Organic content (%)	15.33
Unified soil classification system	OL

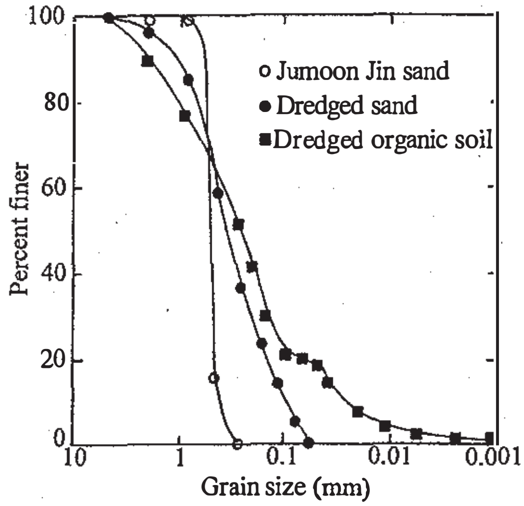

Figure 1. Grain-size distribution of soil used for the present study.

The geotextile generally used to construct geotubes are either woven geotextile or composite geotextile (i.e., an external layer of woven geotextile and an internal layer of non-woven geotextile). For the present study two woven geotextile, designated in this paper as K-1 and K-2, were used. The physical properties of these two geotextile are given in Table 3.

3 LABORATORY TESTS

Before carrying out the pilot test in the field, several laboratory tests were conducted to determine the compactibility of the soils and geotextile. These tests are briefly described in the following sections.

3.1 *Large scale direct shear tests*

Large scale direct shear tests were conducted to determine the interface friction angle between the geotextile and the two types of sand described in Table 1. The interface friction angle is an important param-eter in determining the stability of geotubes when they are placed on sloping ground for shore protection and projects such as the construction of breakwaters. Figure 2 is a schematic diagram of the direct shear test box used for the tests. The size of the geotextile used for the tests was 0.3 m × 0.3 m.

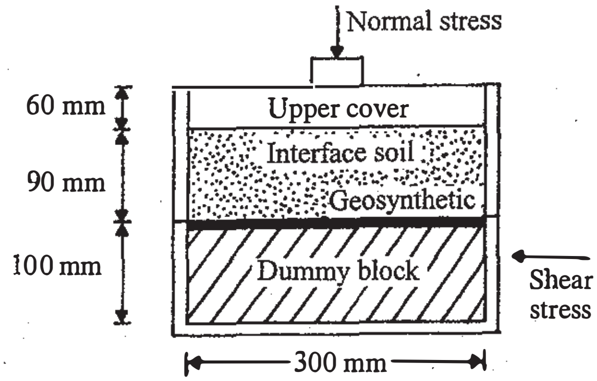

Figure 2. Schematic diagram of direct shear test.

Tests were conducted with normal stress varying up to 700 kN/m^2 (ASTM D-5321 test method). The sands were compacted to 90% of maximum dry unit weight [$\gamma_{d(max)}$] as given in Table 1. The interface friction angles thus determined are summarized in Table 4. It should be noted that the tests showed apparent cohesion (c_a) in the range of 36-38 kN/m^2. The interface friction angles reported in Table 4 are fairly large and are workable in the stability analysis of geotubes in the field.

3.2 *Cyclic fluctuation tests*

One important function of a geotube is its capability to hold the backfill soil inside the tube with minimum loss. A quantitative evaluation of this factor can be done using a cyclic fluctuation device. The device used for the present test had a water basin measuring 1.3 m (length) × 1.3 m (width) × 1.7 m (height). The geobag holding box inside the water-basin was made of steel wire and fixed to a vertical pole which moved up and down at a desired rate. To conduct the tests, dredged sand (see Table 1) was placed in the geobags up to 80% of its total volume. The geobags were subjected to 10,000 cycles of vertical fluctuation in water at the rate of 70 cycles/min. At the end of the test, the loss of soil particles was determined by measuring the grain-size distribution. The total loss of soil for the two geotextiles under consideration is shown in Table 5. The soil particle loss rate for various grain sizes is shown in Fig. 3, which shows that silt size particles have the highest loss rate.

Table 3. Properties of geotextile used for the present study.

Property	Test Method (ASTM)	Unit	Geotextile	
			K-1	K-2
Mass per unit area	D-5261	g/m^2	600	700
Tensile strength	D-4632, D-4595	kN/m	196	245
Elongation	D-4632, D-4595	%	10-50	10-50
Coefficient of permeability	D-4991	cm/sec	$10^{-2} \sim 10^{-4}$	$10^{-2} \sim 10^{-4}$
Material	—	—	Polyester (PET)	Polyester (PET)

Table 4. Direct shear test results.

Geotextile	Interface friction angle (deg)	
	Dredged sand	Jumoon Jin sand
K-1	33.6	37.2
K-2	34.8	38.3

Table 5. Cyclic fluctuation test with dredged sand.

Geotextile	Soil lost (%)
K-1	5.05
K-2	6.09

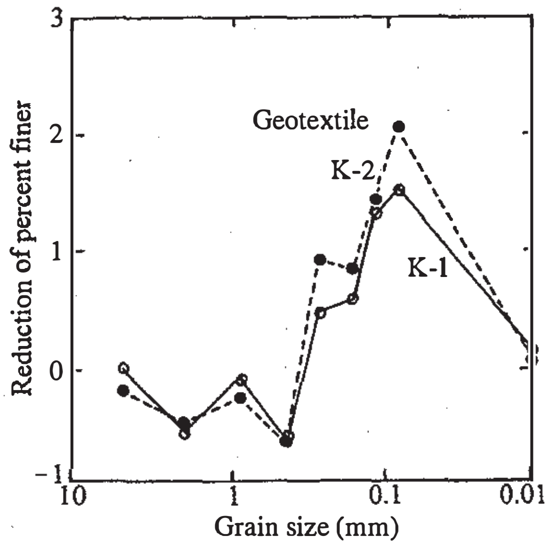

Figure 3. Cyclic fluctuation test results.

3.3 *Environmental tests*

Two types of environmental tests were conducted—short-term self-weight filtration tests and long-term diffusion tests. The short-term self-weight filtration test was performed in the field at the water detention basin in Inchon. Since the K-1 and K-2 geotextile essentially gave similar results, it was decided to conduct further tests only with the K-1 geotextile. Thus for the environmental tests the geo-textile tube was made from the K-1 geotextile. The geotube was 2 m long and 1 m wide, and it was filled with 3.5 m^3 of dredged organic soil. Dissipated water samples of 1000 ml each were collected from the geotube at time intervals of 0, 0.33, 0.5, 1, 2, and 3 hours. These water samples were used to determine the suspended solids (SS) and the chemical oxygen demand (COD). The variations of SS and COD with time are shown in Fig. 4. From this figure it may be seen that the magnitudes of SS and COD rapidly decreased within 20 minutes after filling the dredged organic soil in the geotextile tube. After the first 20 minutes, the rate of decrease of SS and COD with time dropped rapidly. The results of SS= 110 ppm and COD = 45 ppm at time = 20 minutes after the beginning of the tests are below the Korean EPA standards of SS = 120 ppm and COD= 130 ppm.

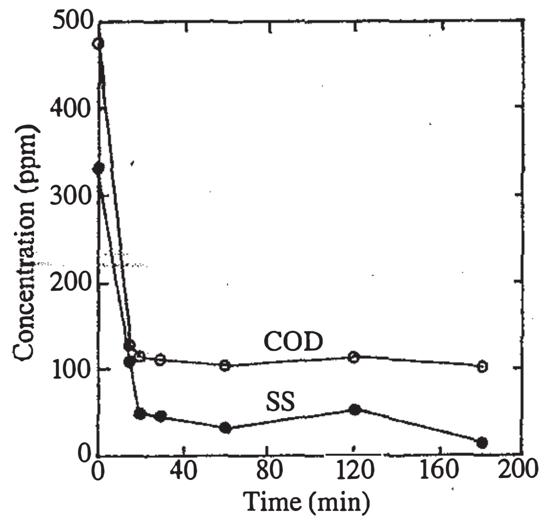

Figure 4. Variation of SS and COD.

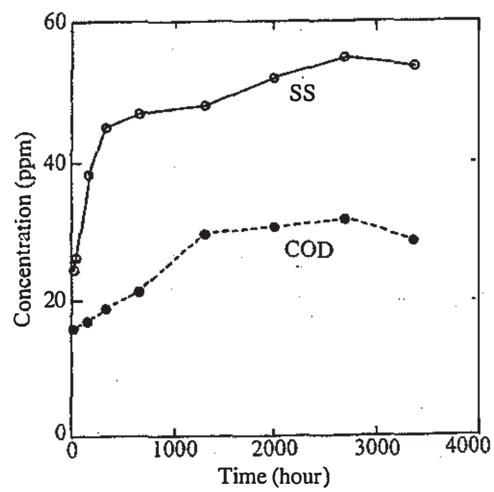

Figure 5. Variation of SS and COD with time — diffusion test.

A long-term diffusion test, which lasted for six months, was also performed on a geotube filled with dredged organic soil obtained from the detention basin. The geotube had a circumference of 250 mm and a length of 500 mm. The variations of SS and COD with time obtained from this test are shown in Fig. 5. The magnitudes of SS and COD increased with time and reached maximum values in about 100 days. These maximum values of SS and COD are substantially lower than those specified by the Korean EPA.

4 FIELD PILOT TEST

A field pilot test was conducted in the dike construction work of the Songdo land reclamation project in the Bay of Inchon. A single layer of K-1 geotextile (Table 3) was used for fabricating the geotube. The geotube had a circumference of 8 m and a length

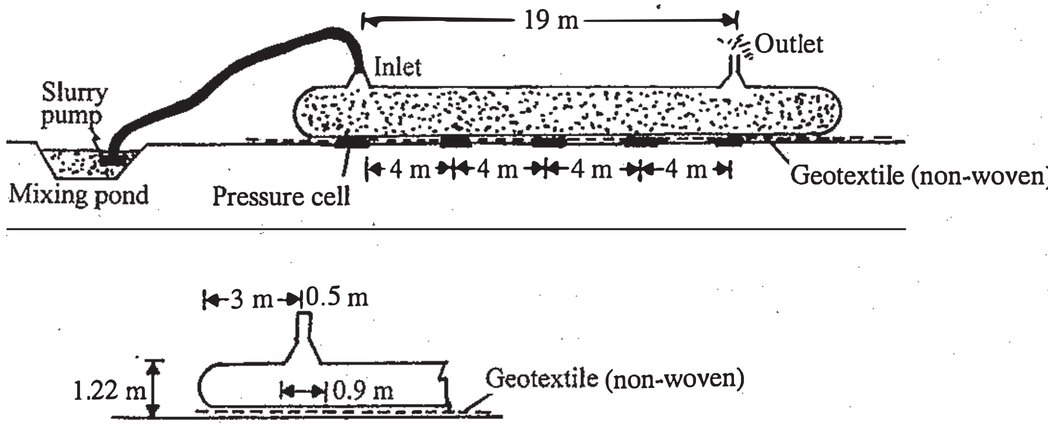

Figure 6. Schematic diagram of the field pilot test.

of 25 m and it was filled by pumping in dredged sand from the site. The soil-water mixing ratio, pumping pressure, and pumping speed were varied to determine their optimum values. For this case, a soil-water mixing ratio of 4:6 was found to be more workable. The unit weight of the filled soil, elongation of geotextile, and vertical pressure were measured for about 3 months. The schematic diagram of the geotube field pilot test is shown in Fig. 6 along with the placement of the pressure cells. The pressure cells were installed at 4-m intervals right below the non-woven geotextile layer. The non-woven geotex-ile was used to prevent the erosion of soil around the geotube due to dissipation of water from the geotube. The distance between the inlet of the dredged soil and the outlet of overflow was about 19 m.

The construction sequence of the geotube was as follows: (1) preparation of subgrade (foundation soil), (2) installation of pressure cell, (3) covering the area of subgrade with non-woven geotextile, (4) placing the geotube over the geotextile, (5) mixing and pumping the slurry into the geotube; and (6) completing the slurry injection into the geotube.

Starting with the beginning of slurry pumping, the effective height, the unit weight of soil, and vertical pressure were monitored by the pressure cells at various time intervals up to 3 months. The variation of the vertical pressure with time is shown in Fig. 7. This figure indicates that the vertical pressure increased up to 100 minutes and then decreased. The pressure stabilized after about 2 days. The observation of pressure with the pressure cells showed that the magnitude of vertical pressure is greater near the inlet compared to that near the outlet. The effective height of the geotube and the unit weight of soil that was monitored with time are plotted in Fig. 8. The effective height of the geotube reached 1.2 m at a time of 100 minutes and stabilized at 0.7 m. This trend is similar to that observed from the pressure cells; however, the unit weight of the pumped soil in the geotube increased continuously with time due to

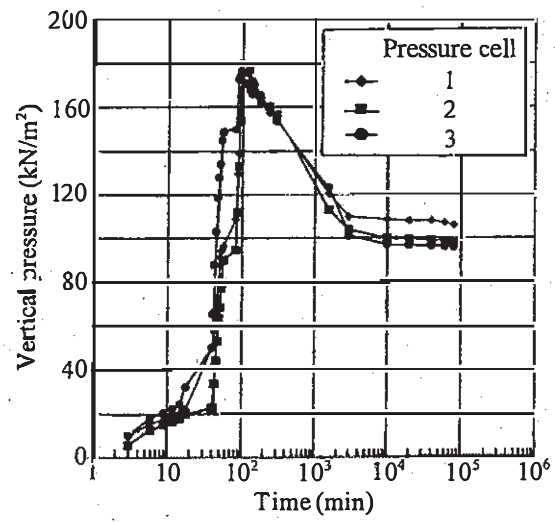

Figure 7. Variation of vertical pressure with time.

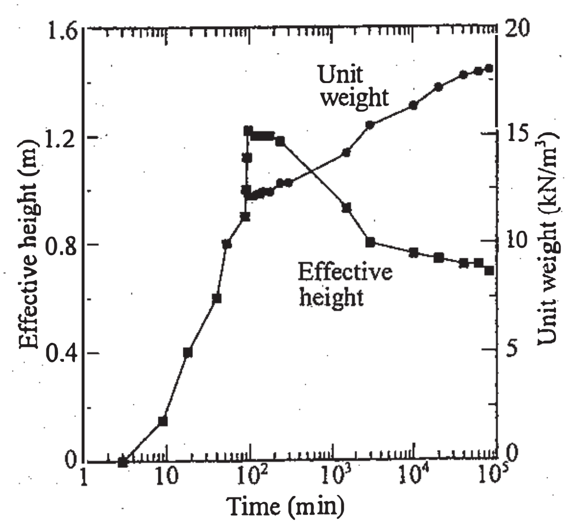

Figure 8. Variation of effective height of geotube and weight of soil with time.

the dissipation of water from the tube. The effective height of 1.2 m reached during pumping is about 80% of the maximum possible height of the geotube. During the test it appeared that any further increase in effective height might cause failure by rupture.

5 CONCLUSIONS

The results of a pilot scale field test to determine the functionality and performance of a geotube are presented. A number of laboratory tests were conducted, such as direct shear test to determine the geotextile sand interface friction angle, cyclic fluctuation tests to estimate the soil particle loss from the geotube, and long- and short-term environmental tests to evalu-ate the environmental effects of dissipated water from the geotube, and their results are presented herein. Based on the various laboratory tests and the field pilot test reported, the following conclusions can be drawn:

1. A geotextile for fabricating geotubes should have a minimum permeability of 10^4 cm/sec. This will keep the particle loss ratio to less than 10%, which is desirable.
2. For the short-term self-weight filtration test, the magnitudes of SS and COD rapidly decreased within the first 20 minutes, after which the rate of decrease of SS and COD dropped.
3. The environmental test results indicate that the quality of dissipated water from the geotube are far below the minimum Korean EPA standards.
4. The optimum ratio of the water-soil mixture to be pumped into the geotube is about 6:4.
5. To avoid rupture, the soil-water slurry pumped into a geotube should not exceed that required to reach 80% of its effective height.

REFERENCES

Bogossian, F., R.T. Smith, J. C. Vertimatti & O. Yazbek 1982. Continuous retaining dikes by means of geotextile. *Proc. II Int.Conf. Geotextiles, Las Vegas:*211-216.

Botzan, D., L. Kellner & C. Moisa 1982. Construction elements for river bank defense structures using woven geotextiles. *Proc. II Int.Conf. Geotextiles, Las Vegas:*223-227.

deBruin, P. & C. Loos 1995. The use of geotubes as an essential part of an 8.8-m-high North Sea dike and embankment. *Geosynthetics world*,April/May:7-10.

Fowler, J., C. J. Sprague & D. Toups 1994. *Dredged material-filled geotextile containers*, U.S. Army Corps of Engineers, Environmental Effects of Dredging Technical Note, EEDP-05-01.

Harris, L.E. 1987. Evaluation of sand-filled containers for beach erosion control, an update of the technology. *Proc., Coastal Zone '87*, ASCE:2479-2487.

Harris, L.E. 1989. Developments in sand-filled container systems for coastal erosion in Florida. *Proc., Coastal Zone '89*, ASCE:2225-2233.

Harris, L.E. 1994. Dredged material used in sand-filled containers for scour and erosion control. *Proc, Dredging '94*, ASCE:537-546.

Koerner, R.M. & J.P. Welch 1980. *Construction and Geotechnical Engineering Using Synthetic Fabrics*, Wiley, New York:160-229.

Pilarczyk, K. W. 1995. Geosystems in hydraulic and coastal engineering–an overview. *Proc, 1st European Geosynthetics Conf. (EuroGeo1)*, Maastricht, The Netherlands.