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Characteristics of environmentally friendly drains

Kim, J.H. & Cho, S.D.
Department of Geotechnical Engineering, Korea Institute of Construction Technology, Korea

Kim, S.S.
Department of Civil Engineering, Hanyang University, Korea

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ABSTRACT: The discharge capacity of eco-sound vertical drains made with natural fibers extracted from plant sources was carried out to evaluate their field application potential using triaxial type and composite discharge capacity tests employing disturbed clayey soils. The discharge capacity of the fiber and straw drain boards evaluated using a conventional triaxial type test was relatively lower than that of plastic drain board. Nevertheless, the settlement and pore pressure dissipation behaviors of the fiber, straw and plastic drain boards during the composite discharge capacity test were similar. It was found that the natural fiber drains have the potential minimum discharge capacity required for substituting conventional plastic drain boards.

1 INTRODUCTION

Over the past few decades, an increasing number of huge construction projects, promoting national key industries, such as airports and ports, have been constructed on sites underlain by thick deposits of soft cohesive soil. Sand drains and plastic drain boards (PDB) have been commonly used to accelerate consolidation of soft clay deposits in Korea. However, these technologies have serious limitations in their application, such as the high construction cost for sand drain, due to their limited supply and the long-term environmental disruption for PBD as a result of the nonperishable characteristics of plastic materials. Consequently, the needs for effective, economical and environmentally friendly drain development have lately arisen.

Eco-sound vertical and horizontal drains, made with coconut coir and jute filter, have been used for eco-sound soft ground improvement in Japan and Southeastern countries. In addition, new types of environmentally friendly vertical drain, made with straw ropes and jute filter, called straw drain board (SDB), have been recently developed in Korea. In this study, tensile strength and discharge capacity tests for these natural fiber drains have been carried out to evaluate their practical use.

2 DRAIN TYPES

In this study, conventional fiber drain board (FDB) and the new developed straw drain board (SDB), as shown in Figure 1, were tested.

(a) Fiber drain board (FDB)

(b) Straw drain board (SDB)

Figure 1. Vertical natural fiber drains.

The width and thickness of both drains were approximately 85~95 and 5~10 mm, respectively. The diameters of the four coir and straw strands were 5 to 8 mm, with each strand enveloped by two layers of jute burlap. The jute burlap was manufactured from jute fibers, which are available in many parts of Southeast Asia. Three longitudinal stitches held the coir strands in separate flow channels within the jute burlap. Figures 1(a) and 1(b) show a natural fiber drain board (FDB) made with coconut coir and jute filter and a straw drain board (SDB) made with straw strands and jute filter, respectively.

The plastic drain board (PDB), which was tested in this study to compare to natural fiber drains, was 10 cm-wide and 5 mm-thick.

3 TENSILE STRENGTH

Tensile strength tests of plastic drain board (PDB), fiber drain board (FDB) and straw drain board (SDB) were performed by following the procedures specified in ASTM D5035, Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method).

Figure 2 shows the comparisons of the tensile strengths of PDB, FDB and SDB under wet conditions. Tests on each drain board were repeated 5 times. From the results, it was found that the strain on the PDB was continuously increased after passing the point of inflection, with/without small additional strength. However, the maximum tensile strength of the FDB and SDB notably deceased after reaching a maximum value, at approximately 10% strain. Despite such differences in strength behavior, the maximum tensile strengths of the FDB and SDB were 1 to 3kN/width greater than that of the PDB, which proved to be acceptable for field installation.

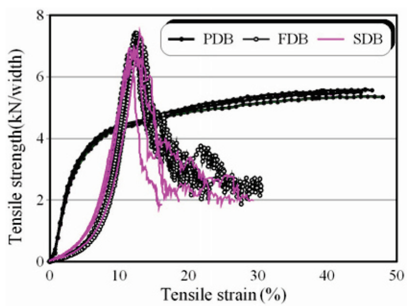


Figure 2. Tensile strengths of vertical drains.

4. DISCHARGE CAPACITY

4.1 *Test methods*

The discharge capacity of vertical fiber drains was tested using two kinds of apparatus, triaxial type and Composite discharge capacity (CDC) apparatus, which are shown in Figures 3 and 4, respectively.

The big differences between the two devices are the confining and loading conditions. With the triaxial type apparatus, a 30cm-long drain, wrapped by the rubber membrane, is confined by the water pressure. Conversely, with the CDC apparatus, a 65 cm-long drain is directly installed into the soft clay lump and confined by the surcharge load instead of the water pressure. The CDC test is more advantageous than the triaxial type apparatus in that the discharge capacity of the drain and the consolidation settlement can be monitored simultaneously.

The discharge capacity obtained using the triaxial type test is usually estimated under the confining pressures of 0.5, 1.5, 2.5 and 3.5 kg/cm^2, with hydraulic gradient (i) of 0.5. However, with the CDC test, surcharges of 0.5, 1.0, 1.5, 2.0 and 2.5 kg/cm^2 are gradually applied to the top of the composite ground, where the ground settlement and discharge capacity can be measured during the test, and the deformed shape of the drain is also investigated after the end of consolidation.

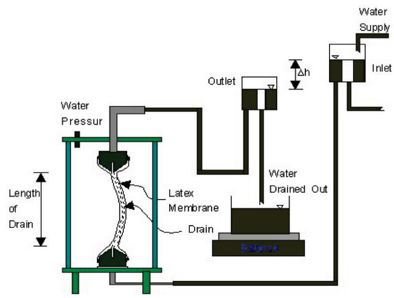


Figure 3. Schematic diagram of triaxial type discharge capacity test device.

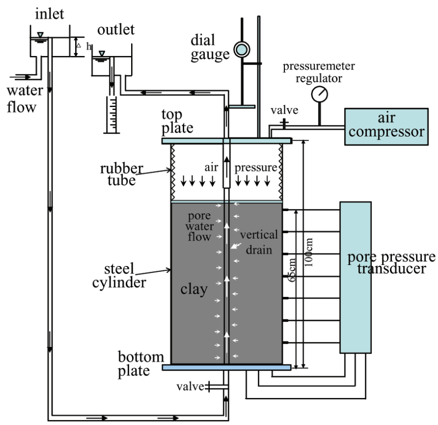


Figure 4. Schematic diagram of composite discharge capacity test apparatus.

4.2 *Triaxial type discharge capacity test results*

Figure 5 shows the triaxial type discharge capacity test results for the PDB, FDB and SDB.

The discharge capacity of the PDB by the triaxial type discharge capacity test was 80~120 cm^3/sec under straight conditions (PDB-S) and 50~115 cm^3/sec under bent conditions (PDB-B). The discharge capacity of the PDB was greater than those of the FDB and SDB. As shown in Figure 5, the FDB and SDB were relatively less free under the bent conditions than the PDB. Although the discharge capacity of the PDB under the bent conditions was greater than that of either the SDB or FDB, the difference between the straight and bent types was also significant. Actually, the PDB has greater possibility for reducing discharge capacity factors, such as kinking or bending, than either the FDB or SDB. Therefore, even though the estimate of the discharge capacity of the PDB from the triaxial type test was very high, many factors that may reduce the discharge capacity of the PDB remain once applied in the field.

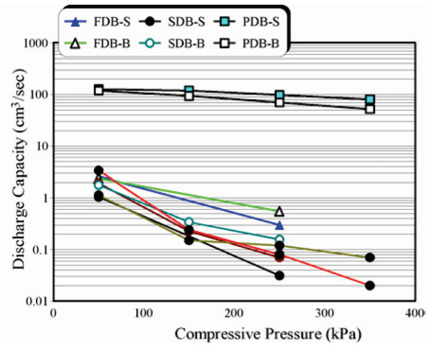


Figure 5. Triaxial type discharge capacity test results.

4.3 *Composite discharge capacity test results*

As mentioned earlier, a model test to simulate real field conditions is necessary. In this study, a composite discharge capacity (CDC) test was carried out to predict the real behaviors of the PDB, FDB and SDB in the field.

In the CDC apparatus, a 50 cm-long drain was installed into the soft ground directly, instead of applying confined water pressure, which means that the drain filter directly contacts with the clay particles. In the CDC test, surcharge to 2.5 kg/cm^2 were gradually applied to the top of the composite ground within two hours. Water-out from the sample, were measured during the test. In addition, deformation of the drains was also investigated after the test.

The soil used for the composite discharge capacity test was collected from Kwangyang area, on the southern coast of Korea. In this test, disturbed soil was used because obtaining large undisturbed sample to perform the CDC test was difficult. To remove impurities, such as shells or boulders in clay soils, the collected soils were sieved through a No. 10 sieve. At the same time, seawater was added to increase the degree of saturation of the soil particles to a value equal to twice the liquid limit of the clay soil (about 92% of water content). The specific gravity of the clayey soil used in the CDC test was 2.64, while the liquid limit and plasticity index were 47(±2%) and 21(±2%), respectively. The soil was classified as low plasticity clay (CL) via the USCS.

Figure 6 shows the discharge capacity obtained from CDC test for the PDB, FDB and SDB. The initial discharge capacities of the FDB and SDB were greater than those obtained by the triaxial type test, but that of the PDB was much lower. The final discharge capacity of the SDB by CDC test was evaluated as 0.77cm^3/sec, which was still lower than the 5.0 cm^3/sec of the PDB and 4.6 cm^3/sec of the FDB. Moreover, the trend for a decreasing discharge capacity of the SDB was also more significant than those of the PDB and FDB.

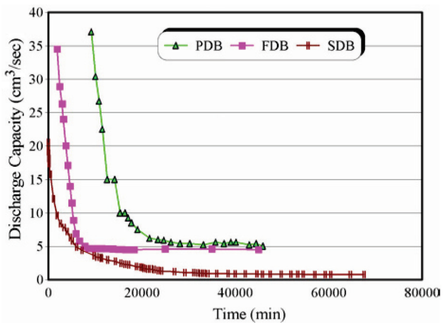


Figure 6. Discharge capacity results by CDC test.

Figure 7 shows the settlement curves for the PDB, FDB and SDB from the CDC tests. In this figure, the final settlement and settlement rate of each drain were fairly similar. Such results for the surface settlement for the instillation of the SDB is inspiring, in that

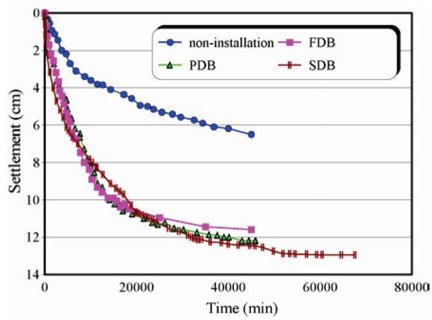
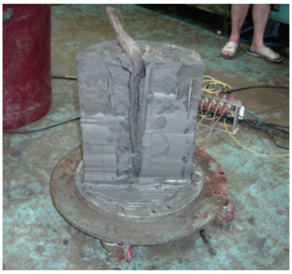


Figure 7. Settlement curves by CDC test.

(a) Deformation of the PDB



(b) Deformation of the FDB

(c) Deformation of the SDB

Figure 8. Deformed shape after model tests.

SDB has the potential requested minimum discharge capacity of a vertical drain, such as the FDB, even though the SDB has a very low discharge capacity.

Figure 8 shows the deformed shapes of the PDB, FDB and SDB after the mid-size model tests. These figures explain well why the discharge capacity of the PDB decreases drastically, but the settlement curves for the PDB, FDB and SDB are similar. As mentioned earlier, the PDB has a greater potential for reducing the discharge capacity factors, such as kinking or bending, than either the FDB or SDB. PDB was found to be relatively more bent and kinked than either the FDB or SDB. These trends are expected to be similarly in the field.

5 SUMMARY

(1) The tensile strengths of the SDB and FDB were found to be excellent compared to that of the PDB. However, the PDB resists upto very high levels of strain, while the FDB and SDB fractured at around 10% strain.

(2) The discharge capacity of the SDB obtained from the triaxial type discharge capacity test and CDC test was very low, but the settlement behavior of the SDB obtained from the CDC test was fairly similar to that of the PDB and FDB, even though the conditions of the CDC test were very limited.

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REFERENCES

ASTM D5035, "Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method)".

Korea Institute of Construction Technology (2004), "Soft Ground Improvement Method for Road Construction using Environmentally Friendly Drains (1)", Report of Construction Infra-structure Technology Research & Development Project. Ministry of Construction and Transportation, pp. 231, (Korean).

Korea Institute of Construction Technology (2005), "Soft Ground Improvement Method for Road Construction using Environmentally Friendly Drains (2)", Report of Construction Infra-structure Technology Research & Development Project. Ministry of Construction and Transportation, pp. 220 (Korean).