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Uplift pressure removal system in underground structure utilizing geocomposite system

Shin, E.C.
Civil and Environmental System Engineering, University of Incheon, Incheon, Korea

Das, B.M.
College of Engineering and Computer Science, California State University, Sacramento, California, USA

Kim, J.I. & Park, J.J.
Civil and Environmental System Engineering, University of Incheon, Incheon, Korea

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ABSTRACT: Recently the large scale civil engineering projects are being implemented by reclaiming the sea or utilizing seashore and river areas. Ground water level in the reclaimed land is relatively high. This high ground water level causes the destruction and crack of building foundation by uplift pressure and ground water leakage. Laboratory model tests were conducted by utilizing geocomposite drainage system for drain the water out to release the uplift pressure. Based on the laboratory test results, measured pore water pressures are varied with the applied water pressure from the top of soil specimen and it converges about 50%~57% of the initial pore water pressures. This is indicated that the uplift water pressure is eliminated 43%~50% by the installation of geocomposite drainage system at the bottom of soil specimen. Quantity of drainage is increased linearly with the applied water pressure. Numerical analysis results are indicated that the pore water pressure is increased lineally with the water pressure. At each water pressure step, decreasing patterns of pore water pressures are almost identical to each other. The result of numerical analysis shows that quantity of drainage is lineally increased with the applied water pressure. Laboratory model test results are compared well with the results of the numerical analysis. It can be concluded that the geocomposite drainage systems in the lower part of the underground structures are great advantages to reduce the uplift pressure in the high ground water table area.

1 INTRODUCTION

Civil Engineering construction projects are being used to reclaiming the sea area or utilizing seashore and riverside for the cost price of site. This reclaimed area is mostly soft ground consisted of clayey and silty soil. In this area, safety problems such as heaving for excavation, leakage, uplift pressure, failure and crack of foundation of structure, and settlement of these are caused by the high ground water level of reclaimed area and seashore. Many of underground structures such as subway, underpass, parking lot, and LNG storage facilities are being construced in the area of high ground water level. For removing the ground water leakage and uplift pressure that can be occur, considering method is required after construction of these structures. The drainage system used geosynthetics is widely used in embankment, sub-base of road, reinforced retaining wall. In this paper, uplift pressure removal system that utilized geocomposite consisted of non-woven geotextile and geonet is studied by the laboratory model test and numerical analysis.

2 GROUND PHASE AND CONSIDERING METHOD FOR UPLIFT PRESSURE

If the structure is constructed below under ground water level, water pressure acts on the structure face from a right angle. Specially, uplift pressure is called that acts upward pressure on bottom of structure.

Uplift pressure is caused of ground phase of boiling, piping, and heaving. These are caused of inducing strength falling, consolidation, and compression, and hence the settlement of ground, cracking of structure, and what is worse structure failure occur (Chang et. al., 1996). Dead weight, preloading method, holding down anchor method, external drainage system, and permanent under drainage system are usually used for engineered considering countermeasure method (G. Rumann, 1982, Holts, R.D. et. al., 1995, Korner, R.M. et al., 1990).

3 GEOSYNTHETIC AND HYDRAULIC TEST

3.1 *Geocomposite*

Geocomposite consists of 4 layers of geosynthetics that used in this test. The bottom layer is black non-

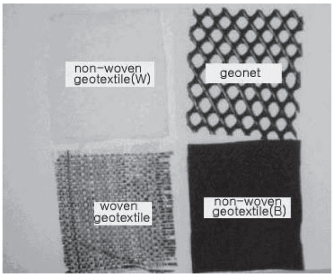

Figure 1. Components of geocomposite.

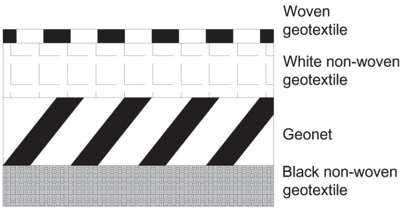

Figure 2. Cross section of geocomposite.

woven geotextile, the second layer is geonet, the third layer is white non-woven geotextile, and the top layer is woven geotextile (Figure 1).

The thickness of bottom layer geotextile is 3 mm and needle punched, the thickness of geonet is 5 mm, and the thickness of third layer's non-woven geotextile is 4 mm and needle punched. Figure 2 shows a cross-sectional view of geocomposite.

3.2 *Permeability test*

This test was conducted to evaluate permeability of geocomposite according to ASTM method (ASTM, 1987). The geocomposite specimen was saturated in the water tank for more over 24 hours.

The cross-plane permeability (permittivity) test apparatus is consisted of hydraulic loading system, steel cylinder, and high level water tank (Figure 3).

The in-plane permeability (transmissivity) test apparatus has the same loading system however, the specimen bed is rectangular. In the cross-plane and in-plane permeability tests, compression stress was applied total 7 loading steps from 0.0~3.0 kg/cm^2 and checked the permeability at each step.

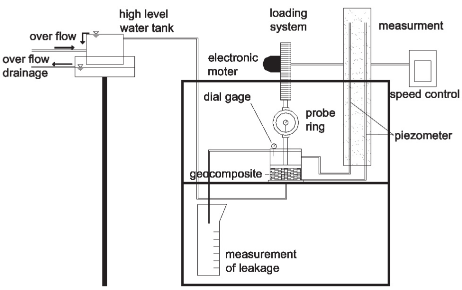

Figure 3. Diagram of cross-plane permeability test.

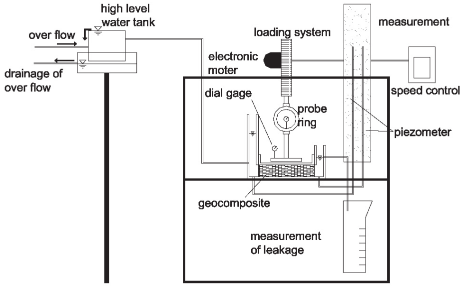

Figure 4. Diagram of in-plane permeability test.

The cross-plane permeability test results are represented in the left axis in Figure 5 and permeability was decreased as compression stress was increased. The ranges of permeability was 0.040~0.018 cm/sec.

The in-plane permeability test results are represented in the right axis in Figure 5, and the result are similar to those of cross-plane test. The test result is ranges from 10.09 to 0.64 cm/sec.

The cross-plane and in-plane permeabilities of geocomposite decrease about 55% and 94% by increasing the compression stress, and rate of decreasing tends to become smaller. The ratio of cross-plane and in-plane permeabilities is from 250 to 35, it decreases with increasing the compression stress.

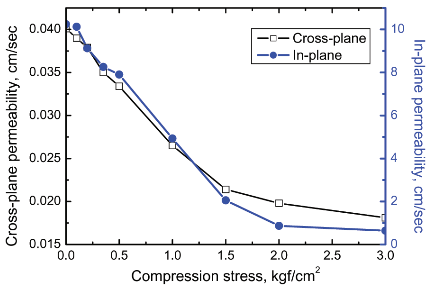

Figure 5. Permeability test results with compression stress

4 LABORATORY DRAINAGE TEST

4.1 *Soil property*

In this test, silty soil was used that obtained from the west sea of Korea. The physical soil properties are shown in Table 1.

The specific gravity of soil specimen is 2.66, the maximum dry density is 1.65 tf/m^3. The optimum water content is 16.23%, and Aterberg limit test is N.P. The permeability of this soil is 7.83×10^{-7} cm/sec. In Unified Soil Classification System, the soil is classified as silty sand, SM.

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Table 1. Physical property of soil specimen.

Specific gravity	Maximum dry Density (tf/m^3)	Passing % of # 200%	Optimum water content (%)	Perme-ability (cm/sec)	Aterberg limit	USCS
2.66	1.65	17.79	16.23	7.83 $\times 10^{-7}$	N.P	SM

4.2 *Test apparatus*

Test apparatus has a water pressure cylinder that connected with air compressor, pore water pressure measurement and data logger. Figure 6 shows the test apparatus and the schematic diagram of laboratory drainage system is shown in Figure 7.

The apparatus consisted of two steel cylinders, and upper cover. The diameters of inner and outer cylinders are 674 mm and 800 mm, respectively. The water pressure cylinder was made of acryl for observing quantity of water, bottom and top covers are made of steel. This cylinder contains water and compressed by air compression. It makes to supply the pressured water to the apparatus and soil specimen. Pore water pressure can be measured with the plastic tubes which are installed in the soil specimen, and at the bottom of soil specimen.

Figure 6. Test apparatus of laboratory drainage system.

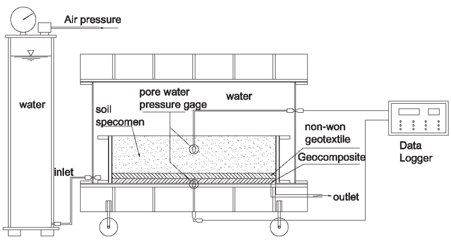

Figure 7. Schematic diagram of laboratory drainage system.

4.3 *Test process*

Geocomposite that has 650 mm diameter was installed in inner cylinder and sand was filled at the edge of cylinder. After then, non-woven geotextile filter was installed over the geotextile and bentonite was filled at the edge of geotextile for preventing of leakage against side surface. Sufficient pressured water was supplied for de-airing from the geosynthetics specimen.

Reclaimed soil was compacted by layers after installing drainage and filter layers. The relative compaction of soil specimen was approximately 90%.

After compacting of soil, water was supplied to the outer cylinder and the soil was saturated with water for over 24 hours.

4.4 *Test result*

The test results were shown in Figures 8 and 9. Pore water pressure at the top of filter was slowly decreased with the elapsed time. However, the pore water pressure at the bottom layer was quickly decreased.

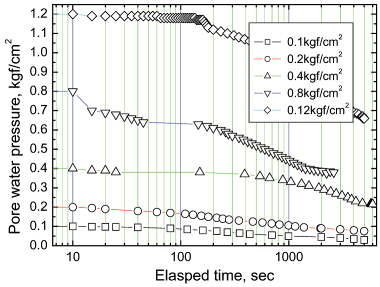

Figure 8. Pore water pressure at the top of filter.

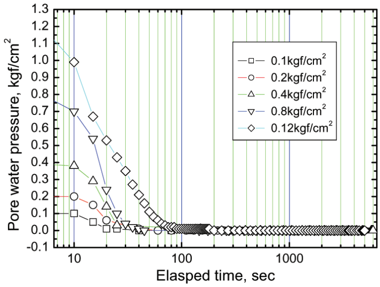

Figure 9. Pore water pressure at bottom layer.

For evaluation of the theoretical drainage quantity, the equation of permeability was modified as

$$q = \frac{60A \times 102\,p \times k}{L}$$

Where, A is cross-sectional area (356787.5 mm^2), k is permeability (7.89×10^{-7} cm/sec), p is inlet water pressure(10 kPa), and L is the length of soil specimen (169 mm).

Figure 10 is the result of comparison with experimental and theoretical values.

The quantity of drainage increases linearly with the supplied water pressure as shown in Figure 10. Experimental value was 3~20% larger than that of theoretical value. However, the trend of drainage quantities is very similar to each other.

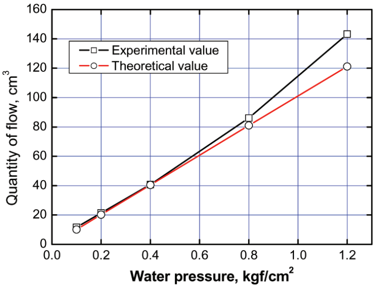

Figure 10. Comparison of drainage quantity.

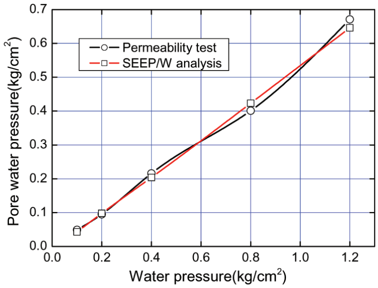

Figure 13. Compared pore water pressure.

5 NUMERICAL MODELING

Seep/W was used for numerical seepage analysis.

Figure 11 is illustrated the mesh for numerical analysis. In this analysisl, 2d axisymmetric model was used. Total head of seepage analysis is shown in Figure 12. The results of experimental data and numerical analysis for pore water pressure in soil specimen are compared in Figure 13. The difference in drainage quantity is about 4~13%.

6 CONCLUSION

In this paper, the feasibility of utilizing geosynthetics for uplift pressure removal drainage system was investigated. The cross-plane permeability is 35~250 times against in-plane permeability and it is decreased with increasing pressure.

Uplift water pressure is eliminated 43%~50% by the installation of geocomposite drainage system at the bottom of soil specimen. When the structure is constructed at high water level area such as reclaimed land from the sea, geocomposite system is very effective for removal of uplift pressure, and in result construction is economically benefit.

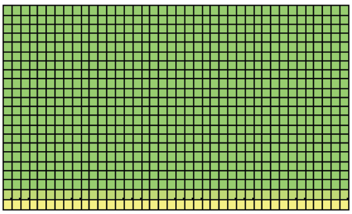

Figure 11. Mesh for numerical analysis in soil specimen.

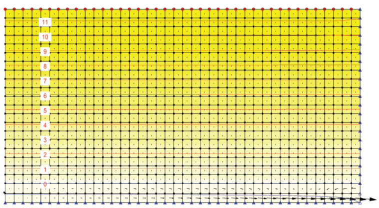

Figure 12. Total head for numerical analysis.

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