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Clogging test on filter fabric of plastic drainage board used in clay

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Abstract. Vacuum preloading technology combined with plastic drainage board has been applied more and more widely. Because the plastic drainage board is used soft-clay in most cases, it is not recommend to study the clogging of filter fabric by gradient ratio method. Therefore, we have proposed a new experimental method, i.e. axial compression clogging. This method can be used to study the clogging of geotextile in clay. Several groups of filters fabric were carried out by this method, and their performances were compared with those obtained from on-side used plastic drainage board. The results show that soil content per unit area and vertical permeability coefficient are very close to those obtained from on-side used plastic drainage board, and the values of the former are slightly smaller than those of the latter.

1. Introduction

Vacuum preloading technology combined with plastic drainage board has been applied more and more widely, especially in soft clay. Plastic drainage plate plays a triple role in draining, filtering and blocking soil.

Under the action of negative pressure, the water in the foundation seeps unidirectionally and enters the filter fabric through the soil. The soil particles gather around the filter fabric. The soil particles which are larger than the opening size of filter fabric are blocked outside the filter fabric. Because of molecular thermal motion, inertial effect, diffusion, entrapment, cohesion function and electrostatic, soil particles which are smaller than the opening size of filter fabric are partially adhered to the fabric surface, partially embedded in the pores of the filter fabric, and partially entered the filter fabric. It will clog the filter fabric, resulting in a malfunction of the drainage channel^[1].

In order to solve the problem of silting up in the application of plastic drainage board, some researchers have improved the construction technology and formed new methods such as anti-silting vacuum preloading method^[2] and controllable ventilation vacuum preloading method^[3]. From the perspective of repairing silting layer, some researchers have tried to flush silting layer through repeated vacuum pumping and suction^[4] and repeated water washing^[5], but the effect is not satisfactory. Enson C H et al. devoted to the development of filter fabric^[6], hoping to fundamentally solve the silting problem. Now the new anti-clogging plastic drainage board has been applied in vacuum preloading projects in Tianjin, Jiangsu and Guangdong^[7].



Clogging is a key problem that affects the effect of vacuum preloading reinforcement. The gradient ratio method developed by the Army Engineers Corps is an international geotextile clogging test method. The values are the pressure pipe head and seepage. Because the working environment of filter fabric is mostly silty clay, clay and other low permeability soil, when gradient ratio method is used for clogging test, the head of pressure measuring pipe changes slowly, so it is difficult to accurately judge the stability of pressure measuring pipe head. Therefore, we have proposed a new method of clogging test method, axial compression clogging test, which is more suitable to test the clogging characteristics of geotextiles in low permeability soil.

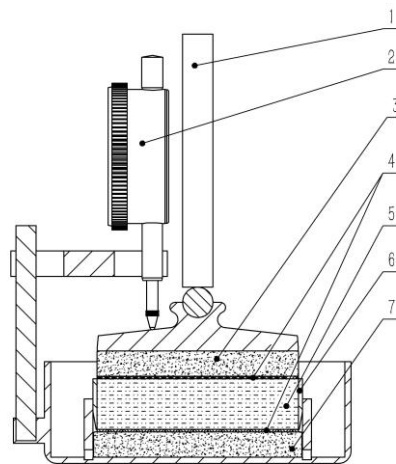
2. Test principle

Axial compression clogging test uses the axial compression device to compress the soil, so that the soil particles can move into the filter fabric with the water seepage, thus causing the siltation of geotextiles. Because the overburden pressure can change the anti-clogging performance of filter fabric, axial compression clogging test can study the clogging performance of geotextiles under specific vertical pressure, which is not possible by gradient ratio test.

3. Test plan

3.1 Test instruments and principle

The test instrument was automatic pneumatic consolidation instrument. The schematic diagram of the test device is shown in Figure 1.



1 is axial Pressure Device, 2 is Dial indicator, 3 and 7 are permeable boards, 4 is geotextile, 5 is soil sample, 6 is ring knife

Figure 1. Test instrument schematic

A ring knife with a height of 20mm and a cross-sectional area of 5000mm² was used. The cross-sectional area of the two filter fabric samples were the same as the ring knife. After cutting the soil with ring cutter or filling ring cutter with soil, filter fabric samples were placed on the top and bottom of the soil sample, and the outer side of filter fabric samples were in contact with the soil. Axial compression test was carried out to simulate the working state of plastic drainage plate filter fabric in soil.

Before the test, both filter fabric samples and permeable boards were saturated with water. After loading, the tank was filled with water. During the test, wet cotton yarn was coated around the consolidation container.

Axial load sequence is selected as required. For soils with high moisture content and low shear strength, small vertical load preloading should be applied before axial compression clogging test with automatic pneumatic consolidation instrument.

After the test was completed, the vertical permeability test and soil content of filter fabric samples were determined.

3.2 Physical properties of soil in tests

The soil was taken from the dredger fill area of Xuwei port, Lianyungang. The soil is disturbed soil with high clay content, high water content and low permeability coefficient, which belongs to typical saturated soft soil. The grain composition and physical properties of soil are shown in Tables 1 and 2.

Table 1. Grain composition of soil in tests (%)

0.5-0.25	0.25-0.075	0.075-0.05	0.05-0.01	0.01-0.005	<0.005
/mm	/mm	/mm	/mm	/mm	/mm
0.0	9.0	5.7	33.1	22.1	30.1

Table 2. Physical properties of soil in tests

w/%	G _s	w _L /%	w _P /%	I _P
77.2	2.76	53.2	30.3	2.14

3.3 Parameters of the filter fabric

5 groups of common filter fabric of synthetic filament nonwoven geotextile (sample No. 101, 105, 107, 110 and 102) were selected, as shown in Figure 2, and 1 group of anti-clogging filter fabric (sample No. 109) was selected, as shown in Figure 3. The physical and mechanical properties of the filter fabric are shown in Table 3. Compared with ordinary filter fabric, anti-clogging filter fabric has the following characteristics:

- (1) thicker, about twice as thick as the ordinary filter fabric;
- (2) larger mass per unit area;
- (3) larger effective aperture, and relatively uneven distribution;
- (4) larger permeability coefficient, up to 1×10^{-1} cm/s;
- (5) the anti-clogging filter fabric is made by mixing and rolling staple fiber, while the ordinary filter fabric is made by hot rolling long synthetic fiber.



Figure 2. The ordinary filter fabric

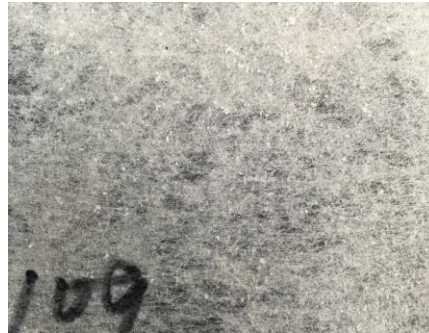


Figure 3. The anti-clogging filter fabric

Table 3. Parameters of the filter fabric

No.	thick	mass per unit area	transverse tensile strength (wet, elongation is 15%)	effective aperture (O_{95})	permeability coefficient
	/mm	/g/m ²	/N/cm	/mm	/cm/s
101	0.35	84	22	0.088	0.020
105	0.29	74	24	0.087	0.023
107	0.21	70	17	<0.075	0.006
110	0.16	84	21	<0.075	0.001
112	0.29	75	23	<0.075	0.002
109	0.67	100	18	0.140	0.106

3.4 Control parameters

The moisture content of soil was 77.2%, and its shear strength is low. In order to avoid soil extrusion caused by excessive vertical load, the pre-pressures of 1kPa, 3kPa and 5kPa were applied first, and then 12.5kPa, 25kPa, 50kPa, 100kPa, 200kPa and 400kPa were applied. The deformation stability standard was 0.001mm/h.

4. Test results

4.1 Axial compression characteristics of soil

The load displacement curves of soil samples are shown in Figure 4. With the increase of load, the vertical deformation of soil samples increased continuously. The larger the vertical permeability coefficient of the filter fabric, the larger the compressive deformation of soil. The vertical deformation of soil samples with anti-clogging filter fabric was larger than that of other soil samples.

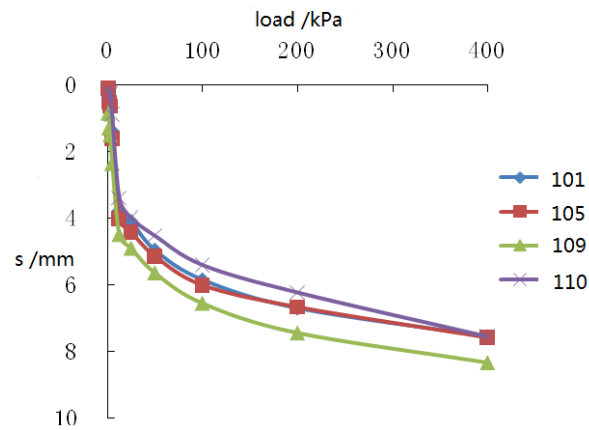


Figure 4. Load-displacement curves

During compression, the soil is consolidated. The consolidation coefficient is related to the permeability coefficient, compressibility coefficient and porosity ratio as follows:

$$C_v = \frac{k(1+e)}{a\rho_w} \quad (1)$$

If the variation of filter fabric thickness is ignored, the consolidation coefficient of soil under specific pressures can be obtained according to the load displacement curve of the sample.

Because the soil sample was saturated, the comprehensive permeability coefficient of filter fabric and the soil sample at specific vertical load could be obtained. The calculation results are shown in Table 4. Permeability coefficient is less than 10^{-8} cm/s, which cannot be obtained by conventional permeability test. Compared with the conventional filter fabric, the comprehensive permeability coefficient of the anti-clogging filter fabric and the soil was slightly larger, and the consolidation coefficient of the soil was also larger.

Table 4. Comprehensive permeability coefficient of the filter fabric and the soil

No.	comprehensive permeability coefficient of filter fabric and the soil /10 ⁻⁷ cm/s		consolidation coefficient /10 ⁻³ cm ² /s
	P=50kPa	P=100kPa	P=100kPa
101	0.039	0.032	0.29
105	0.045	0.031	0.29
110	0.039	0.029	0.27
109	0.050	0.036	0.34

After the test, the average pore ratio and moisture content of soil samples were 0.931 and 38.41% respectively, lower than the liquid limit.

4.2 Axial compression characteristics of soil

The filter fabric samples and soil samples after axial compression test are shown in Figures 5 and 6. Soil particles were embedded inside the filter fabric and adhered to the outside. The anti-clogging filter fabric adhered to more soil particles than the ordinary filter fabric.



Figure 5. The anti clogging filter fabric after the test



Figure 6. The anti clogging filter fabric after the test

When the test was finished, the filter fabric samples were removed immediately. Part of the filter fabric samples were used to measure the vertical permeability coefficient, and part of the filter fabric samples were air-dried and weighed to calculate the soil retention. The test results are shown in Table 5. The larger the filtration fabric permeability coefficient, the larger the soil retention per unit area. The soil retention per unit area of anti-clogging filter fabric was the largest. There is no significant correlation between soil retention per unit volume and other parameters, so the soil retention per unit area is more suitable to evaluate the blockage of filter fabric.

In comparison with Table 3, the permeability coefficient of all the filter fabric was reduced significantly, and the permeability coefficient of the anti-clogging filter fabric changed the most, but it was still higher than those of the ordinary filter fabric.

Table 5. Parameters of the filter fabric after the test

No.	soil retention		permeability coefficient after the test /cm/s
	per unit volume /g/cm ³	per unit area /g/cm ²	
101	0.144	0.003	0.0059
105	0.167	0.003	0.0029
107	0.053	0.002	0.0036
110	0.067	0.001	0.0003
112	0.176	0.003	0.0012
109	0.136	0.006	0.0095

4.3 Contrast with those obtained from on-side used plastic drainage board

After reinforcement, the plastic drainage board was taken from the vacuum preloading reinforcement area of Xuwei port, Lianyungang. The vacuum degree under the film was more than 80kPa for 150

days, and the sampling depth was 0m-3.5m. The corresponding new sample numbers were 101 and 109.

The soil retention per unit area of the sample no. 101 after reinforcement was 0.004g/cm^2 , and the soil retention per unit area of the sample no. 109 after reinforcement was 0.0067g/cm^2 , which were slightly larger than the results of the axial compression silting test. This is because on-side used plastic drainage board working for a long time. The clogging mechanism is more complex, and soil particles are adhering to both sides of the filter fabric. The vertical permeability coefficient of the sample no. 109 was 0.010cm/s after reinforcement, which was very close the result of the axial compression clogging test. It indicated that the evaluation of filtration fabric permeability coefficient after work by the axial compression clogging test was reliable.

5. Conclusion and advice

The clogging characteristics of plastic drainage board in soft clay were studied by axial compression clogging test. Conclusions and Suggestions are as follows:

(1) The head of gradient ratio clogging test water changes slowly and is not suitable for studying the clogging characteristics of geotextiles in soil with low permeability coefficient. The axial compression clogging test method recommended in this paper is recommended.

(2) The method of axial compression clogging test is simple and efficient. It can be used to study the clogging of geotextiles under pressure and the influence of geotextile on soil consolidation characteristics.

(3) The soil retention and vertical permeability coefficient of filter fabric in the axial compression clogging test are close to those of obtained from on-side used plastic drainage board.

(4) Vertical permeability coefficient reduction is recommended in clogging evaluation criteria, and further study is needed to determine the value.

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