Study on performance of plastic drainage board for soft foundation reinforcement in Lianyungang Port

ZHENG Ai-rong*, WANG Shi-ning
CCCD Tianjin Port Engineering Institute Ltd., Key Laboratory of Geotechnical Engineering, Ministry of Communications, PRC, Key Laboratory of Geotechnical Engineering of Tianjin, Tianjin, 300222, China, CCCC First Harbor Engineering Company Ltd., Tianjin, 300461, China

*Corresponding author’s e-mail: airong717@163.com

Abstract. The performance of the plastic drainage board has a significant influence on the soft foundation reinforcement effect by plastic drainage board combined with the vacuum preloading reinforcement method. The physical and mechanical properties of a large number of plastic drainage boards used in Lianyungang Port were compared. Studies have shown that there are correlations between their physical and mechanical indexes; the physical and mechanical properties of plastic drainage boards of different manufacturers vary greatly; the anti-clogging filter membrane has better penetration and anti-clogging performance than ordinary filtration membranes. After reinforcement, the mechanical properties of the plastic drainage board change little, the physical properties and the hydraulic properties change greatly, and the permeability coefficient of the filter film decreases obviously.

1. Introduction
In order to develop into a regional central port, Lianyungang Port has carried out a large-scale land reclamation epeirogenic project. In order to save costs, the materials used for land reclamation are taken from the dredged soil in the nearby sea area to form an ultra-soft foundation with high water content and high clay content. If the conventional preloading soft foundation reinforcement method is used, long-term drying is required. The appearance of plastic drainage board is very important for soft foundation reinforcement. It has the characteristics of industrialization, high drainage efficiency, low cost, convenient and efficient installation and less disturbance to soft soil layer, and quickly replaces the sand well, becoming the most commonly used drainage channel in soft foundation reinforcement engineering, forming a plastic drainage board combined with vacuum preloading soft foundation reinforcement method. This method can be used to strengthen the plate immediately after the completion of the filling, which greatly improves the efficiency of the foundation reinforcement [1-4].

2. Sampling
The test samples were taken from multiple soft foundation reinforcement projects in Lianyungang Port, including 13 sets of plastic drainage boards and 2 sets of post-construction plastic drainage boards.

3. Performance of composite and core
The good plastic drainage board core board has good raw materials, no bubbles, large thickness of the rib and the bottom plate, and large mass per unit length. The test results of the composite and core board are shown in Table 1. The performance difference of plastic drainage boards of different
manufacturers is very large. The performance of some plastic drainage boards is far lower than the specification requirements and has not been applied in engineering. Therefore, it is necessary to strengthen the test of plastic drainage boards.

Table 1. Test results of plastic drain board

| No. | type      | width | thickness | unit length mass | tensile strength (dry, when E.L is 10%) | E.L | vertical water (side pressure 350 kPa) | buckling strength |
|-----|-----------|-------|-----------|------------------|----------------------------------------|-----|--------------------------------------|------------------|
|     |           | mm    | mm        | g/m              | kN/10cm                                | %   | cm³/s                                | kPa              |
| 01  | integral  | 98    | 4.1       | 88               | 3.0                                    | 12  | 44                                   | 1084             |
| 02  | integral  | 98    | 4.1       | 86               | 2.7                                    | 13  | 48                                   | 1138             |
| 03  | integral  | 98    | 4.1       | 86               | 2.6                                    | 14  | 25                                   | 1098             |
| 04  | integral  | 49    | 4.5       | 53               | 3.4                                    | 13  | 75                                   | -                |
| 05  | integral  | 50    | 4.6       | 58               | 3.3                                    | 11  | 53                                   | -                |
| 06  | integral  | 51    | 4.5       | 57               | 3.1                                    | 14  | 23                                   | -                |
| 07  | integral  | 98    | 3.8       | 81               | 2.4                                    | 12  | 42                                   | 1640             |
| 08  | integral  | 99    | 3.7       | 96               | 2.3                                    | 19  | 19                                   | -                |
| 09  | integral, anti-clogging | 99 | 4.3 | 94 | 2.3 | 15 | 24 | 734 |
| 10  | separate  | 99    | 3.7       | 98               | 1.5                                    | 14  | 17                                   | 566              |
| 11  | integral  | 100   | 3.8       | 88               | 1.9                                    | 15  | 4                                    | 349              |
| 12  | separate  | 101   | 4.3       | 91               | 2.5                                    | 20  | 39                                   | -                |
| 13  | integral  | 99    | 3.8       | 98               | 2.8                                    | 13  | 114                                  | 1668             |

Longitudinal water flow is a comprehensive indicator with many influencing factors and a large range of numerical values. The width and thickness have a great influence on the longitudinal water flow. The larger the width and thickness of the plastic drainage board, the larger the drainage space, and the larger the longitudinal water flow of the plastic drainage board. In general, the drainage plate with a larger water flow value has a shorter stabilization time. There are many reasons for the small amount of water passing. Taking sample No.10 as an example, the amount of water passing through is small, which is related to the thinness of the filter membrane, the wet elongation of the membrane, the small thickness of the core plate and the small buckling strength of the core plate.

The buckling strength of plastic drainage boards varies greatly, and there are few testing requirements for soft foundation reinforcement projects. If the buckling strength is too low, the ribs will fall under the vacuum suction and the lateral pressure of the soil, and the drainage space will be drastically reduced, which will greatly affect the drainage efficiency of the plastic drainage board, such as the water discharge and pressure of the No. 11 plastic drainage board in Table 1. The buckling strength test of the core plate adopts the strain method, and the sample after buckling is shown in Figure 1. The ribs are bent and deformed, and the individual positions of the bottom plate also have irreversible creases. In the early stage of buckling deformation, the growth rate of stress is very slow. When the yield strength, that is, the buckling strength, reaches a slight decrease, the stress continues to increase. The buckling strength of most integral plastic drainage boards is significantly higher than that of conventional plastic drainage boards, indicating that the presence of the filtration membranes has a certain effect on improving the buckling performance.
4. Membrane performance
The filter test results are shown in Table 2. The permeability coefficients vary greatly and are positively correlated with the equivalent pore size. The permeability coefficient of the anti-clogging filter membrane is 0.106 cm/s, far exceeding the general geotextile. The equivalent pore size test adopts the dry sieve method. The equivalent pore size of the anti-clogging filter membrane is the largest, up to 0.14mm, that is, the soil particles with the particle size less than 0.14mm when not clogging may pass through the filter membrane. The tensile strength of the filter membrane is not much different. The transverse wet tensile strength of all the membranes is smaller than the longitudinal dry tensile strength, and the elongation corresponding to the stress peak is quite different.

Table 2. Test results of membranes

| No. | thickness (mm) | mass per unit area (g/m2) | effective aperture (O95, mm) | vertical permeability coefficient (cm/s) | longitudinal tension (E.L is 10%, N/cm) | transverse tension (E.L is 15%, N/cm) |
|-----|----------------|--------------------------|------------------------------|----------------------------------------|-----------------------------------------|----------------------------------------|
| 01  | 0.35           | 84                       | 0.088                        | 0.020                                  | 31                                       | 8                                       |
| 05  | 0.29           | 74                       | 0.087                        | 0.023                                  | 36                                       | 12                                      |
| 07  | 0.21           | 70                       | ≤0.075                       | 0.006                                  | 22                                       | 14                                      |
| 09  | 0.67           | 100                      | 0.14                         | 0.106                                  | 30                                       | 14                                      |
| 10  | 0.16           | 84                       | ≤0.075                       | 0.001                                  | 26                                       | 14                                      |
| 12  | 0.29           | 75                       | ≤0.075                       | 0.002                                  | 30                                       | 22                                      |

5. Performance of plastic drain board after reinforcement
The test results of the plastic drainage board after reinforcement are shown in Table 3. The width, thickness and tensile properties have not changed significantly. The mass per unit length has increased significantly, and the results are discrete. This is due to the adhesion of a large amount of soil particles to the filter membrane and the core plate of the plastic drainage board after the work, as shown in Figure 2. The soft foundation reinforcement process has a certain influence on the water passing performance of the plastic drainage board [5]. The water discharge capacity of the plastic drainage board after the work is reduced, but the decrease is not large.
Table 3. Test results of plastic drain board

| type          | width | thickness | unit length mass | tensile strength (dry, when E.L is 10%) | E.L. | vertical water (side pressure 350kPa) |
|---------------|-------|-----------|-----------------|------------------------------------------|------|--------------------------------------|
|               | mm    | mm        | g/m             | kN/10cm                                  | %    | cm³/s                                |
| narrow        |       |           |                 |                                          |      |                                      |
| initial       | 50    | 4.6       | 58              | 3.3                                      | 11   | 53                                   |
| after reinforce| 51    | 4.6       | 80              | -                                        | -    | 45                                   |
| ordinary      |       |           |                 |                                          |      |                                      |
| initial       | 99    | 4.3       | 94              | 2.3                                      | 15   | 24                                   |
| after reinforce| 99   | 4.2       | 138             | 2.4                                      | 15   | 22                                   |

Figure 2. Filter membrane and core after reinforcement

6. Conclusion
(1) The performance of plastic drainage boards of different manufacturers of the same model varies greatly, and detailed test and inspection must be carried out before engineering application.
(2) The physical and mechanical indexes of plastic drainage boards do not exist independently and have certain correlation.
(3) The anti-clogging filter membrane has better anti-clogging performance than the ordinary filter membrane, and the permeation performance is higher;
(4) The mechanical properties of the plastic drainage board after the work change little, the obvious clogging, the physical properties and hydraulic properties change greatly, and the vertical water flow and the vertical permeability coefficient of the filter are reduced.

References
[1] Zhang Z., Li Y., et al. (2002) The effect of plastic drain board in atmospheric pressure soft-base reinforcement. Journal of Guangzhou university, 1(2):68-71.
[2] Xia Y., Chen J., Chen Y.. (2011) Effect and economic analysis of direct vacuum preloading method for consolidation of soft ground. Port & Waterway Engineering, (9):224-229.
[3] Dong Z., Li W., Zhang G.. (2006) Experimental study on treatment of soft soil inintertidal zone with vacuum preloading. Chinese Journal of RockMechanics and Engineering, (2):3390-3494.
[4] Sun Z., Niu N.. (2005) Effect and monitoring of vacuum preloading for soft foundation treatment of storage yard in Huanghua port. Port & Waterway Engineering, (4):27-30.
[5] Chen G., Hong X., Wang B., et al. (2016) Laboratory test of plastic drain filter clogging under vacuum preloading. China Harbour Engineering, (1): 23–27.