Research on Innovation of Experimental System Based on Vacuum Preloading Method

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Abstract. Aiming at the problems of traditional vacuum pre-compression technology, which is difficult to visually observe the material curing effect and low sampling accuracy, this paper independently developed a set of new modular transparent model barrels and controllable vacuum pressure manifolds. Based on traditional experimental methods, improve the model barrels and vacuum dividers in the experimental system. Experimental research shows that the improved experimental system not only solves the shortcomings of the traditional experimental system, but also can be assembled on site, which is beneficial to the areas with abundant water resources. The project of reclaiming land from the sea provides support, which has certain production and economic benefits.

1. Introduction

With the rapid economic development of Zhoushan in recent years, the 20,800 square kilometers of sea area in Zhoushan accounts for about 50% of the sea area of the whole province, and the land area is in short supply. At present, in engineering, vacuum preloading method is generally adopted for foundation reinforcement of fill soil. Because of its low cost, relatively mature working method and simple construction, this method has become an important means to develop land resources in coastal cities. Through the research of domestic and foreign engineering practice and indoor model experiment, the vacuum preloading method still has some problems, such as; The consolidation time of vacuum preloading method is longer, and the efficiency of drainage system decreases with the passage of time, so it is difficult to maintain the vacuum degree under the membrane to reach the initial standard. Engineering practice and indoor experiment, there is the wastage of the vertical drainage system problems, now engineering and experiment, the drainage plate is often adopted to drainage, drainage plate with the passage of time, there will be a drainage plate bending, the bending phenomenon of the influence on the engineering practice is resulting in a loss of efficiency of drainage, the dissipation of pore water pressure slows down. For indoor experimental study, due to the boundary effect, the soil will produce deflection¹. This situation will cause a great error for indoor experimental study, and the overall settlement deformation can not be well predicted and better applied to engineering practice.

At present, due to the opaque material of the traditional model bucket, the stratification effect of Marine soil is not easy to observe after vacuum preloading, and the demoulding of soil samples is difficult. In the process of demoulding, the torque in the horizontal direction often causes the deformation of the inner wall of the model bucket, making the demoulding of soil difficult². Therefore, this paper aims to solve the problems existing in the current method, design a new modular transparent
model bucket by itself, and improve the overall experimental system. In solving a problem, on the basis of the traditional better apply vacuum preloading method to Zhoushan, in a number of engineering research of Zhoushan Marine silt under vacuum preloading settlement deformation, in order to better cope with engineering foundation settlement, has important significance for predicting the development of engineering foundation settlement, the improved modular barrels transparent model also has a certain production and economic benefits.

2. Materials and Methods

The traditional vacuum preloading experiment system includes jet pump, manifold rack, suction filter bottle, model barrel, etc., through the connection of equipment, the model barrel is sealed and preloaded. On the basis of improving the traditional model barrel, the vacuum of the experiment is also tested. The manifold rack has been improved to some extent [3]. At present, most of the vacuum pressure control is to directly connect the drain pipe to the vacuum pump for one-time pressurization. Some experiments on the staged pressurization are through a manifold pipe directly connected to the vacuum pump, and the design is very rough and cannot be effective. Regulating the vacuum pressure cannot be very stable either. In order to solve the current experimental needs, a controllable vacuum pressure manifold is designed. A threaded hole that can place a pressure gauge is designed at the nozzle of the vacuum pump, and between the nozzle of the pump and the threaded hole. Design a threaded hole for the ball valve. In order to facilitate the experiment and facilitate the placement, the branch pipes without a support and all the nozzles on one side were improved for some experiments, and 3 nozzles were placed symmetrically, and there were bases at both ends. In addition, the three symmetrically placed nozzles are all threaded holes, and ball valves can be installed to adjust the output of vacuum pressure.

The experiment mainly consolidates the soil samples through the drainage system and the air extraction system, and tests the pore water pressure, vacuum degree, and settlement through the measurement system. In order to save water resources, a cooling circulating water tank is independently designed. The drainage system is composed of a new type of drainage plate, steel wire hose and suction filter bottle [4]. The suction system is mainly a vacuum pump and a vacuum manifold. The entire experimental system is pumped by a vacuum pump, and the pressure control valve on the manifold is controlled by the pressure control valve on the manifold to regulate the pressure of the vacuum gauge on the manifold, the vacuum gauge on the suction bottle, and the vacuum gauge in the model barrel, which is more convenient. With pressure control, it can also be measured whether there is more loss in vacuum pressure during the transfer process, so as to understand the vacuum preload test system's consolidation efficiency and the degree of influence of the vacuum pressure on it. The steel wire hose is connected with the drainage plate set in the model barrel, and the water in the soil sample is drawn out and discharged into the suction filter bottle connected with the steel wire hose through the vacuum pressure.

![Figure1. New model barrel experiment system connection.](image1)

![Figure2. Vacuum divider.](image2)
3. Results & Discussion

The physical properties of the marine soil taken from the waters near the Changzhi Island Xincheng Bridge in Zhoushan are shown in Table 1. The test carried out a statistical test on the moisture content of the 5 barrels of soil samples taken, and a total of 40 groups were sampled. From the table, it can be seen that the moisture content of the marine soil taken is close to 90%, and the liquid limit content is also greater than 40%, indicating that the soil samples taken have the characteristics of high water content and high liquid limit. According to the test of chemical properties, the soil sample is organic soil. According to the soil particle composition table, it can be seen that the overall particles of the soil sample are relatively fine. According to the representative value of the physical indicators in the table, the liquid-plastic limit content and the liquid-plasticity index can be seen. The sex index IL=4.5, and the soil sample is flow-plastic.

Table 1. Typical property programs of marine soil.

| Moisture content (ω%) | Proportion (Gₛ) | Plastic limit (Wₛ (%) | Liquid limit (W₅ (%) | Natural density (g/cm³) | Liquidity Index (I₇) | Plasticity Index (Iₚ) |
|-----------------------|-----------------|-----------------------|----------------------|--------------------------|----------------------|------------------------|
| 89.24                 | 2.72            | 32.3                  | 44.9                 | 1.8                      | 4.5                  | 12.6                   |

Table 2. Grading composition of marine soil.

| Particle size (mm) | Percentage content (%) |
|--------------------|------------------------|
| >0.075             | 4.62                   |
| 0.075-0.05         | 3.1                    |
| 0.05-0.01          | 40.1                   |
| 0.01-0.005         | 12.7                   |
| <0.005             | 34                     |

In order to more accurately determine the organic content and chemical element content of the soil samples, the research team took a total of 2 kg samples, took 1 kg each into 2 sample bags, and sent them to two testing institutions in Shanghai and Qingdao for testing. All operations in the testing are carried out in strict accordance with the marine soil testing and testing procedures.
The chemical properties of soil mainly include the test of the content of soluble salt, cation exchange capacity, organic matter and PH value. Through the inspection of the testing unit, it was found that the content of soluble salts in the soil samples taken from the area was mainly chloride, calcium and sodium, and the content of other elements was relatively small, and the content of organic matter was relatively high. The content and composition of the soluble salts in the silt soil have a greater impact on the particle surface of the marine silt soil[5]. The cations attached to the surface of the soil particles will be replaced with cations, which will cause changes in physical and mechanical properties. Through the analysis of the test data results of the test report, the marine soil in the sea area has a humic acid content of 0.75% and a pH value of between 7.35 and 8.36, which is alkaline soil.

In this paper, three experiments were carried out using traditional model buckets and modular transparent model buckets to measure the vacuum degree of Zhoushan silt, pore water pressure and other indicators. In the first experiment, the traditional model barrel was used to directly load 80KPa, but the traditional model barrel was difficult to demold in the later stage. During the vacuuming process, radial contraction occurred, and the barrel body was easily crushed, which affected the reinforcement effect of preloading[6]. In order to better improve the experiment efficiency, the second experiment adopts the secondary plate test plan, the model barrel is replaced with a segmented plexiglass barrel, and the loading method is directly loaded with 80kPa, and the secondary plate is started after the pre-compression is 14d. The period is 25d in total. During the experiment, a pore pressure meter was placed 80 cm from the bottom of the barrel, 60 cm from the bottom of the barrel, and 10 cm from the bottom of the barrel to measure the pore water pressure. Place 3 vacuum gauges on the soil surface, 50cm from the bottom of the barrel and 10cm from the bottom of the barrel to monitor the changes in vacuum at 3 different depths.

The third experiment adopted the direct loading 80kPa scheme, and the model barrel was a segmented plexiglass barrel with a period of 23 days. During the test, place a pore pressure gauge at 80 cm from the bottom of the barrel, 60 cm from the bottom of the barrel, and 10 cm from the bottom of the barrel. 3 vacuum gauges are placed on the soil surface, 50cm from the bottom of the barrel, and 10cm from the bottom of the barrel. Monitor the change of vacuum degree at 3 different depths.
4. Conclusions
Modular transparent model barrels are used in the improvement of this experiment. The self-developed new modular transparent model barrels not only reduce the impact of soil compression and deformation, but also improve the accurate sampling of consolidations. After pre-compression, the amount of soil settlement is greater, and it can also be assembled on site, easily demolded as a whole, and fully transparent 360-degree observations. It provides support for sea-land reclamation projects in areas with rich water resources and has certain production and economic benefits.

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