Effect analysis of vacuum prepressing reinforcement of soft soil foundation

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Abstract. The supercharged vacuum pre-pressure method is to increase the supercharge system on the basis of the direct vacuum pre-pressure, and to increase the pressure in the middle of the vacuum process, thus achieving the goal of saving efficiency and increasing construction costs. Based on the reinforcement project of a blowout foundation in Lianyungang, this paper analyses the process of soil surface subsidence, pore water pressure, stratified subsidence and groundwater level when the soft foundation is reinforced by supercharged vacuum prepressing method by field test method. The paper will provide data support for future actual projects.

1. Introduction
The development of cities depends on the adequate land supply, especially for the coastal cities. The reclamation project is an important to resolve this problem. Due to the economic and environmental concerns, the mud from channel dredging was widely used in reclamation projects. It reduces great demand of the sand source shortage used in reclamation projects and solves the dispose of channel dredge spoils.

The vacuum preloading method was first proposed by Kjellman in 1952 [1-5], and be applied in some cases in America and Japan. But due to the restriction of seal technology, vacuum load producers and installation technology of setting vertical drainage channels, the effect of vacuum preloading method was not as well as accepted. In 1984, Tianjin Port Engineering Institute Co., Ltd led a success in-site test of vacuum combined with surcharge preloading method in Tianjin, and the equivalent load in this test reached 70 to 92 kPa, meeting the using requirement of most storage yard, road and general industrial and civil buildings.

Based on the reinforcement project of a blowout foundation in Lianyungang, this paper analyses the process of soil surface subsidence, pore water pressure, stratified subsidence and groundwater level when the soft foundation is reinforced by supercharged vacuum prepressing method by field test method. Provide data support for future actual projects.

2. Profiles of the engineering case
The engineering case using conventional vacuum preloading method to treat dredger fill foundation locates at Lianyungang area. The dredger fill foundation is consisting of high water content (about 120 \% to 130 \%), low-permeability (lower than $10^{-7}$ cm/s) and low bearing (near 0 kPa) mud. The foundation needs to be treated before using. The conventional vacuum preloading method was therefore used in testing zone.
The total area of the test area is 39141 m². The soft soil base is reinforced by the supercharged vacuum pre-pressure (OVPS) technology. The surface of the blown soil is first artificially inserted in the field area, with a depth of 5 meters, a spacing of 1 m, and a pre-pressure of 50 days. After the surface forms a hard shell, the mechanical plate is made. Depth 18m, spacing 1m, insert board to complete the construction of supercharged tube, the total length is 5m, the depth of burial is greater than 2m, and the length of the drain board with its corresponding position is not less than 3.0 m, and the drain board head is bent back into silt. Not less than 1.5 m, after the laying is completed, vacuum is started. The design vacuum requires 80 kPa, and the total vacuum time is 130 days. The distribution of soil layer and basic parameters of each layer in testing zone are listed in Table 1.

| Layer               | Thickness (m) | Weight (kN/m³) | Sub-weight (kN/m³) | Shearing strength | Cohesion (kPa) | Internal friction angle (°) |
|---------------------|---------------|----------------|-------------------|-------------------|----------------|-----------------------------|
| Dredger fill mud    | 6.1           | 15.9           | 5.9               | 14.1              | 7.92           |                             |
| Mud                 | 2.2           | 16.2           | 6.2               | 14.57             | 7.67           |                             |
| Silty clay          | 2.7           | 18.5           | 8.5               | 18.93             | 12.13          |                             |
| Silty               | 7.8           | 19.3           | 9.3               | 5.23              | 28.97          |                             |
| Clay                | 6.2           | 18.8           | 8.8               | 20.71             | 10.42          |                             |

3. Test results

3.1. Surface settlement
The variation of surface settlement is shown in Fig.1.
Fig. 1 shows that the consolidation degree in testing zone reached over 85% after 150 days treatment, and the velocity of surface settlement is less than 2.5 mm/day. The total settlement during the foundation treatment is 1.811 m.

3.2. Pore pressure
The pore pressure in the centre of testing zone was recorded during foundation treatment. 6 pore pressure monitors were installed in different depths with 3 m intervals, and the banishment of pore pressure during the treating process and strength enhancing of soil in different depths can be traced. The variation of pore pressure is shown in Fig. 2.

![Figure 2. The variation of pore pressure in different depths](image)

The pore pressure in different depths reduced. Pore pressure of shallow soil reduced rapidly, and deep soil had a smaller reduction velocity.

3.3. Layered settlement
The settlements of each layer were also recorded in the test. 5 settlement monitors were installed in different depths with 3 m intervals. The development of layered settlement is shown in Fig. 3.
The soil in different depths has different settlement velocities. Shallow and weak surface layer has larger velocity and deep layer has much less velocity of settlement.

4. Conclusions
This paper analyzed the effect of conventional vacuum preloading method based on an engineering case, settlement and pore pressure were tested to show the reinforce effect. The main conclusions are as followed.

- The consolidation degree in testing zone reached over 85% after 150 days treatment, and the velocity of surface settlement is less than 2.5 mm/day. The total settlement during the foundation treatment is 1.811 m.
- The pore vanished with different velocities in different depths. Pore pressure of shallow soil vanished more rapidly than deep soil.
- The settlement velocities of soil in different depths are different. The surface weak dredger fill settles with a much larger ratio than other layers.

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