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# Application of new pumping technology in dewatering in deep soft soil pit

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**Abstract.** The soft soil stratum has low carrying capacity, poor permeability and is hard to be drained, which affects the excavation speed of foundation pit. This paper introduces the application of a new type of dewatering technology in deep soft soil foundation pit dewatering. This technology adopts air compressor and vacuum pump to improve the water collection efficiency and pumping efficiency effectively and gains good economic and environmental benefits.

## 1. Introduction

Thick layers of soft soil are widely distributed in the deltas of coastal rivers such as the Yangtze River and the Pearl River. The thickness of soft soil is generally about 20m, and the thickest area can reach nearly 40m. With the increasingly prosperous economy, the demand for underground space development and utilization has become increasingly urgent, and foundation pit projects in soft soil areas have become deeper and larger. The soil layer in soft soil area has the characteristics of large natural water content, high compressibility, low carrying capacity, and high groundwater level. If effective dewatering measures are not taken to increase the carrying capacity of the soil layer, it will be extremely difficult to excavate the foundation pit, which makes construction speed of the project severely restricted. Due to the long excavation and construction time, the support of pit is difficult to form in a short time, resulting in excessive deformation of the foundation pit enclosure and causing serious damage to the surrounding environment. Although the soft soil has a large natural water content, its capillary water binding capacity is large, and the permeability is quite low ($k<10^{-5}$cm/s), which makes it difficult to be drained by the traditional pipe well pumping method. Light-weight well points, electroosmosis and jet well points have the advantages of effectively reducing and discharging capillary water, but their applicable depth is limited (generally less than 6 meters), therefore these methods cannot be used in deep foundation pit projects in soft soil areas [1]. Therefore, the vacuum tube well dewatering technology, which can reduce the vacuum degree of the soil and accelerate the collection of groundwater, is widely used in the drainage of soft soil.

Pan Xiuming[2] discussed the working principle, performance characteristics, application scope and construction effect of vacuum deep well dewatering technology based on the engineering example of vacuum dewatering test section of Beijing Metro Line 10, and found that the single well water output capacity of vacuum tube well is higher than ordinary tube well. Cong Shuyu[3] studied the drainage effect of vacuum tube wells in Nanjing silty clay layer and found that vacuum tube wells can effectively drain the silty soil layer. Zhao Yunfeng[4] used vacuum tube wells to solve the problem of draining cohesive soil, saturated silt soil effectively.

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However, the equipment of vacuum tube well used above includes vacuum pumps, submersible pumps, and deep well filter tubes. Each well needs to be wired with cables, water outlet pipes, and vacuum pipes. The pipeline layout is complicated, which causes great safety hazards. During the operation of vacuum tube well, the labour cost is very high no matter when it is installed, inspected or maintained. Due to the poor permeability of soft soil layer, the submersible pump runs under anhydrous conditions for a long time, making its service life is short. Due to the existence of water pumps and cables, the vacuum degree of vacuum tube wells can hardly reach the requirements, hence the pumping efficiency is not ideal.

In order to conquer this difficulty, Shanghai Changkai Geotechnical Engineering Co., Ltd. has developed a new set of pressure-suction combined pumping technology [5], which effectively improves the efficiency of pumping, and greatly saves the cost of electricity. The application of this technology can effectively reduce the impact of dewatering on the surrounding environment settlement and gains good economic and environmental benefits.

## 2. Introduction of pressure suction combined pumping technology

Pressure-suction combined pumping equipment is composed of six parts: water vapor mixing system, control system, power system, air supply system, vacuum system and pipeline system. The working principle is as follows:

a) The compressed air produced by the air compressor 1 enters the pipe through the flue pipe 2 and forms a water-air mixture in the pipe. The specific gravity of the water in the outlet pipe is reduced because it is full of bubbles. The pressure of the water column in the outlet pipe 3 is lower than the pressure of the water column outside the pipe, so a pressure difference occurs. Under the action of the pressure difference between the water column inside and outside the pipe, the water mixed with air gradually rises in the outlet pipe, and finally is sucked out by the vacuum pump 7 and discharged to the water outlet 4.

b) When the water level is below the outlet pipe 3, the air compressor 1 stops supplying air, the vacuum pump 7 sucks the air in the well through the vacuum pipe 6, negative pressure is formed in the well. The water in the layer flows into the well through the sidewell 5 under the action of the pressure, so as to ensure that the water-gas mixture in the well is continuously discharged.

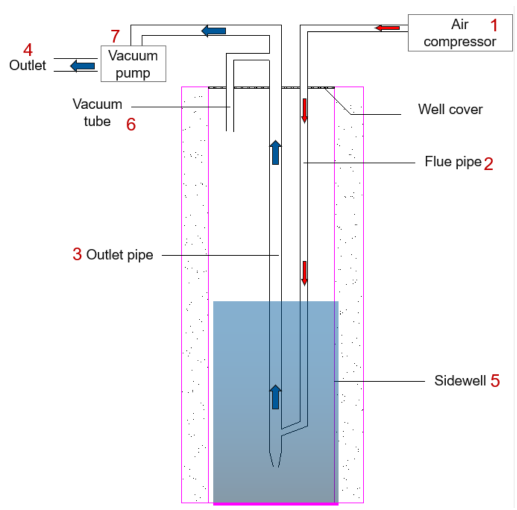


Figure 1. Schematic diagram of pressure-suction combined pumping technology

The pressure-suction combined pumping technology uses the time-sharing air supply intelligent control cabinet to control the air supply time and interval time of each well and the air supply pressure of each well. The time-sharing air supply intelligent control cabinet can independently set the corresponding parameters according to the water output capacity and dynamic water level of each pumping well, so that the pumping efficiency of each well is improved to achieve the best dewatering effect.

The characteristics of pressure-suction combined pumping technology are as follows:

1. The equipment has a simple structure without the need for submersible pumps and auxiliary pipelines, requires less one-time investment, and reduces human influence factors during the pumping process.

2. The compressed air generated by the air compressor enters the pipe in time sharing, forming a water-vapor mixture in the pipe, and the pressure difference between the inside and outside of the outlet pipe can promote the water absorption efficiency of the vacuum pump and overcome the impact of the well being filled with water after an accidental power outage on site.

3. The entire piping system is airtight, and the well pipe is in a relatively vacuum state, and the water output effect is greatly improved.

4. This equipment is suitable for a wide range of applications. It can be suitable for deep wells of various diameters and materials, for the wells whose depth is inferior to 30m.

## 3. Field comparison test

### *3.1Test setup*

In order to compare the dewatering effect of traditional pumping technology and pressure-suction combined pumping technology, a foundation pit in Shanghai was selected for comparison test. The area of the foundation pit is about 10,524 $m^2$, the corresponding excavation depth of the foundation pit is 14.65~15.10m; the underground diaphragm wall separates the phreatic water inside and outside the pit, and the main stratum is ①$_3$ layer of clayey silt,④ layer of silty clay, layer ⑤$_{1-1}$ of clay and layer ⑤$_{1-2}$ of silty clay.

Each technology has 3 test wells, all of which are φ273 mm tube wells. The test started on April 1$^{st}$, 2020 and ended on May 30, lasting for two months. The test is divided into three stages:

The first stage is from April 1st to April 10th until the second layer of soil is completely excavated. The second stage of pumping test lasts from April 13$^{th}$ to May 6$^{th}$ when the excavation of the third layer of soil was finished. The third phase of pumping test began on May 8$^{th}$, until the end of the excavation of the fourth layer of soil on May 30.

In the process of soil excavation, a representative soil sample is selected for soil water content test. Each process is connected to the electricity meter box separately. At the end of the test, the electricity degree of the two processes are counted. The practicability of the two different pumping processes is compared through the water output, soil water content during excavation, and power consumption.

### *3.2 Comparison of single well water output*

Here we take the average of the daily water output of each of the three wells of each pumping process to compare the average daily water output of a single well for the two pumping processes. The comparison of the single well pumping volume of the two pumping processes in the three stages is shown in the following figures.

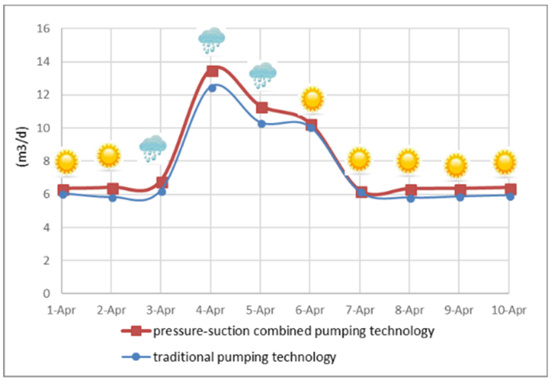


Figure 2. Curve of single well water output in the first stage

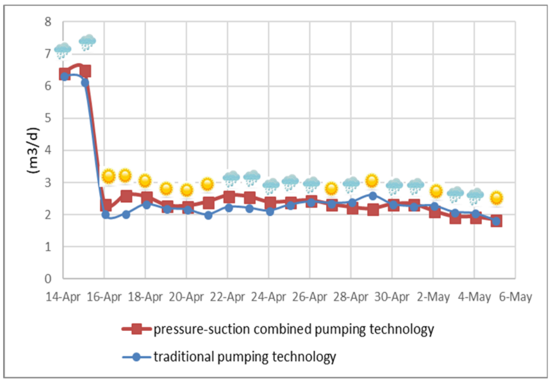


Figure 3. Curve of single well water output in the second stage

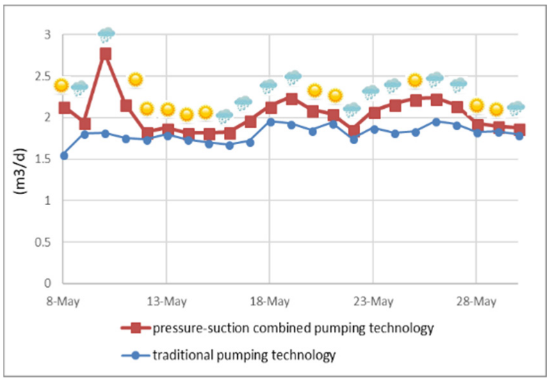


Figure 4. Curve of single well water output in the third stage

As shown in the figure, in each stage of the pumping test, the water output of the wells using super-pressure-suction combined pumping technology is greater than that of the wells using traditional pumping technology, and the water output of a single well is increased by about 10%.

At the same time, during the comparison period, the influence of the weather cannot be ignored. During the comparison operation period, continuous rainfall will reduce the vacuum pumping time. Under fine weather conditions, the advantage of the pressure-suction combined dewatering process will be more obvious.

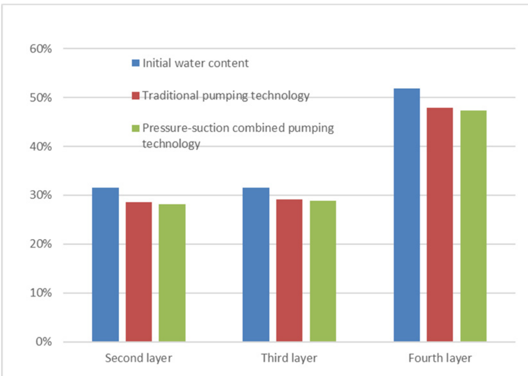


Figure.5 Histogram of soil water content using traditional technology and pressure-suction combined pumping technology

*3.3 Comparison of soil water content*

During the excavation of the soil layer, soil samples are taken, and soil samples that are not completely disturbed (above class III soil) are selected for water content test. Six boxes of soil samples for each process of each sampling are taken to test the water content of the soil samples. The test results are averaged. The second and third layers of soil are ①$_3$ layers of clayey silt, and the fourth layer of soil is ④ layers of gray silt clay. The result shows in Fig.5.

*3.4 Power consumption comparison*

At the end of the test, the total power consumption of traditional pumping technology was 17479.8 degrees, and the power consumption of pressure-suction combined pumping technology was 14899.1 degrees. The pressure-suction combined pumping technology saved about 14.8% of electricity compared with traditional pumping technology. In fact, the energy-saving effect of pressure-suction combined pumping technology is better than that measured in the test, because the three wells cannot maximize the efficiency of vacuum pumps and air compressors of pressure-suction combined pumping technology. Usually the power of a vacuum pump is about 7.5 KW, which can be used for 4-6 wells, and the power of an air compressor is 5 KW, which can be used for 8-12 wells. According to the calculation that the vacuum pump drives 4 wells and the air compressor drives 8 wells, the power required for a single well is 2.5KW. In addition to the vacuum pump in the traditional water pumping process, each well requires a submersible pump with a power of 1.5KW, which translates into a power required for a single well of 3.375KW. According to this calculation, under ideal circumstances, the super-pressure-suction combined pumping technology saves about 25.9% of electricity compared to the traditional pumping technology.

## 4. Conclusions

In soft soil areas, the depth of phreatic water is relatively shallow. The water in the soft soil layer is affected by capillary force and is difficult to be discharged freely by gravity. It is necessary to reduce the vacuum degree of the soil so that the groundwater can be collected to the vacuum tube well for discharge. Deep vacuum well dewatering technology is widely used in foundation pit dewatering projects in soft soil areas, but it has disadvantages such as lax vacuum sealing, low dewatering efficiency, and short equipment service life. Based on the vacuum deep well dewatering technology, Shanghai Changkai Geotechnical Engineering Co., Ltd. has developed pressure-suction combined pumping technology.

Compared with the traditional pumping technology, the pressure-suction combined pumping technology has obvious cost advantages. Using pressure-suction combined pumping technology to form holes, the cost of forming wells is reduced by more than 30% compared with traditional pumping technology, the cost of pumping system equipment is reduced by more than 50%, the amount of mud removal is reduced by 30%, the amount of filter backfilling is reduced by 27%, and the cost of operating equipment is reduced by 50%. In addition, after using this technology, workers can simultaneously manage 50% more pressure-suction combined pumping wells than traditional pumping wells, which improves labour productivity and saves labour costs.

The pressure-suction combined pumping technology adopts a time-sharing air supply system, and intelligent control realizes the optimization of air supply. That achieves efficiency optimization, green energy saving effect and reduces carbon dioxide emissions. In addition, this technology can not only solve the problem of dewatering in engineering construction, but also provide corresponding services for the treatment of groundwater pollution in environmental geotechnical engineering, with good ecological benefits.

The use of pressure-suction combined pumping technology can save dewatering time about 5-10 days, effectively solve the problem of dewatering in hundreds of deep foundation pits in the Yangtze River Delta and the Pearl River Delta. It ensures the safety of the surrounding environment of the project and achieves great social benefits.

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