Review of Research on Elevation Positioning of Concrete Filling Surface of Bored Piles

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Abstract. The main research contents and methods of concrete perfusion elevation of bored piles at home and abroad are summarized. The shortcomings in the study of concrete pouring height of bored piles are expounded, and some views are put forward on future research.

1. Introduction
Bored piles have the advantages of “significantly improving the bearing capacity of single piles, reducing the number of piles and costs; using flexibility, clear force, and simple calculation”. The bored piles have been widely used in the foundation of structures such as cross-sea bridges and offshore wind power stations, and the pile diameter and length are getting larger.

When injecting underwater concrete, it is difficult to judge the exact position of the concrete pouring surface due to the presence of a floating layer between the concrete and the mud layer. In order to ensure the quality of the pile top concrete, it is often necessary to super-irrigate over 0.5m in the design of the pile top. For example, if the pile diameter is 3m and the super-irrigation is 0.5m, the amount of super-filled concrete is about 3.5m³. For a large and medium-sized project, hundreds of squares of concrete will be wasted, resulting in economic losses of hundreds of thousands. The over-irrigation part needs to be removed and landfilled after the excavation of the foundation pit, occupying the land and destroying the environment[1]. Therefore, the depth measurement of the concrete surface of the bored pile is an important task.

In order to solve the problem of over-filling of concrete, a series of related researches have been carried out at home and abroad. This paper will analyze the status of this research.

2. Research status of concrete perfusion elevation

2.1. Temperature method
Zhang Guoqiang and Cao Huibin[2] selected temperature and resistivity as physical parameters, and designed and processed temperature and resistivity measurement probes, several field tests were conducted and the results showed that: There is no significant change in resistivity measurements at the interface between the mud and the mud; there is a significant change in the temperature measurement, but the change is not obvious. Therefore, the author believes that temperature cannot be used as a precise positioning method, and can be used as an auxiliary means for initial judgment.
2.2. Pressure method
Zhang Guoqiang and Cao Huibin[2] selected pressure as a physical parameter, and designed and processed the pressure measuring probe. Then several field tests were conducted and the results showed that the measured values of top pressure and side pressure have obvious changes at the interface between mud and concrete, and the mutation is obvious. The JTG-1A type concrete perfusion elevation locator was developed to fill the gap in the domestic test field.

Li Liangliang, Lu Shitao etc.[3] designed and processed the pressure sensor probe, and by several field tests they found that the measured compressive stress changes significantly during the concrete infusion process. As the concrete surface is higher than the pressure probe, the pressure is basically proportional to a straight upward trend. Based on this, a concrete super-irrigation height control device for bored piles was developed. Through the engineering example excavation verification, the control over-irrigation height error is less than 0.2m.

From the above research results, it can be found that using pressure as a physical parameter is feasible to determine the perfusion elevation of concrete by pressure change during the perfusion process. However, the detection device is not portable, and the construction is cumbersome and the cost is high, so it is difficult to be promoted.

2.3. Hammer method
Now the elevation control of bored pile heads in China basically uses the method of measuring hammer + rope to determine the underwater concrete interface. The principle and equipment of the method are very simple, so it gets widely used and popularized.

Yang Gang[4] produced a special set of hammers that can be adjusted in quality by mass. The hammer is made of a circular steel pipe with a wall thickness of 3 to 4 mm, 133mm in diameter and 200mm in height. The bottom is sealed with 3~4mm steel plate and sand is filled internally to adjust the weight to the desired specific gravity.

Zhang Lei, Cui Jianjun, etc.[5] also developed a hammer measuring device to adjust the density by changing the volume. The hammer consists of a measuring rope, a hollow and a solid cone hammer. The hollow hammer is on the top and the solid hammer is on the bottom. They are connected by a thread and form a cavity. The size of the cavity can be adjusted by the depth of the thread to change the volume of the measuring hammer.

When the hammer method is used to determine the elevation of the concrete surface, the human factors interfere greatly, and it is easy to see the inaccurate control of the height of the pile top. So it is recommended to use a digital force measuring device to reduce the error caused by experience and human factors.

2.4. Ultrasonic method
Ultrasonic working principle is using the transducer to emit ultrasonic waves in the water when the ultrasonic waves encounter obstacles and reflect back to the transducer. According to the ultrasonic round trip time and the wave propagation speed in the water, the distance between the obstacle and the transducer \( s=\frac{ct}{2} \) can be found.

Lan Kai[6] proposed a method for measuring the elevation of concrete infusion surface by ultrasonic wave. The three key technologies of the propagation characteristics of ultrasonic waves in the mud, the influence of the floating layer on the ultrasonic wave propagation, and the numerical simulation of the ultrasonic wave in the liquid filled pile are studied, and then developed a prototype of the elevation instrument. It has accumulated experience and provides some reference value for the latecomer further improve the design.

Shao Chun, Yan Taining, etc.[7] found that there is a part of the reflection when the ultrasonic wave penetrates the floating layer, and there is a part of the transmission when it encounters the concrete interface. Then they developed a set of ultrasonic concrete pouring surface elevation. According to the results of indoor and outdoor tests, it can be found that when the specific gravity of the mud is not high, the ultrasonic measurement has a certain precision. However, as the specific
gravity of the mud increases, the wave velocity changes with it and the error of the measurement results also increases. It is recommended to establish a more accurate wave velocity model in the future to improve the measurement accuracy in high specific gravity mud.

Ultrasonic method for determining the elevation of concrete infusion surface is a new technology, and the interference of the floating layer on ultrasonic waves is still not well solved. However, due to its advantages of convenient carrying, simple operation, real-time monitoring, and reduction of labor, construction companies and scientific research units are carrying out vigorous research, and it is the future development trend.

2.5. sampler
Due to factors such as construction, equipment and technology, it is still difficult to accurately determine the elevation of concrete infusion surface. Therefore, some domestic scholars have carried out research on underwater samplers. Through the preliminary judgment method, the components are sampled at the perfusion elevation position to achieve the purpose of accurate judgment, and errors are completely avoided.

Zhang Lei, Cui Jianjun etc.[5] developed a hydraulic control underwater sampler. The sampler consists of a hydraulic tube, a hollow and a solid cone hammer. The hollow cone hammer is on the top and the solid cone hammer is on the bottom. They are connected by a boom and form a cavity. By adjusting the hydraulic pressure value, the hollow cone hammer is separated from the solid cone hammer, and the mixture flows into the cavity. After the sampling is completed, the hydraulic pressure value is continuously adjusted to close the hollow and the solid cone hammer. The sampler is proposed to identify the material in the cavity.

Jin Xuxing[8] developed an underwater concrete sampler for judging the position of the top of the bored pile. The storage cylinder at both ends is open, and the guide rod is fixed to the upper storage cylinder. Two split movable panels are respectively hinged at the fixing plate of the storage cylinder. The limiting rod is disposed on the side wall of the storage barrel to limit the rotation amplitude of the movable plate. The device has a simple structure and low cost, but it is inconvenient to carry and operate when the measurement depth is large.

At present, most of the construction sites use simple samplers in the form of steel bars and funnels because of its convenient material selection, simple production and principle, low cost and easy operation. They are obtained certain applications. However, the sampling position is not accurate, and human factors have a great influence. Therefore, the simple sampler still needs further research.

2.6. Others
In addition to the above research methods, the author believes that some new methods can be tried. For example, the infrared photographing underwater visual method uses the underwater camera to monitor the elevation of the concrete pouring surface. Due to the different consistency of the mud, the floating slurry and the concrete during the filling process, the torque generated by the rotation is different, then the consistency meter can be developed.

3. Conclusion
In the construction of pile foundation engineering, it is difficult to solve the problem of “too much overfilling concrete”. Domestic scholars and companies carry out relevant theoretical and experimental research, and current research methods include temperature, pressure, hammer, ultrasonic and sampler, has achieved certain research results. But due to factors such as technology, equipment and construction, the corresponding detection and sampling devices have not been promoted. However, I believe that with the development of science and technology, the concrete pouring surface elevation meters will be introduced to the market in the near future.
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