Research on the Method of Measuring the Elevation of Bored Pile Head by Pressure

Xiaoling Liu1*, Peng DU1, Shuai Peng1, Lianhong Fu2, Qiang Chang1
1Haikou college of economics, Haikou Hainan, 571127, China
2Ningbo Yitong Construction Co. Ltd., Ningbo Zhejiang, 315800, China
*Corresponding author’s e-mail: liuxiaoling1042@163.com

Abstract. The detection of pile top elevation is a key link of pile quality control. Based on the jacking principle, this paper analyzes the shortcomings of the existing measurement methods, innovatively introduces the pore pressure to consider the influence of the change of slurry level, effectively proposes an improved pressure detection method, and designs a pressure detection device. The device is simple and easy to operate, which can provide reference for the field research on the elevation of the top of bored pile.

1. Introduction
When bored pile is filled with concrete under water, the concrete strength of pile head must reach the design grade after cutting out the laitance. According to article 6.3.30.5 in technical code for construction pile foundation[1] JGJ94-2008, the last perfusion should be controlled and the height of overfilling should be 0.8 ~ 1.0m. Taking the conventional construction pile diameter of 1.5m as an example, the average overfill is 1m, and the concrete waste generated by over filling will reach about 1700m3 per thousand piles, not including the cost of cutting pile head and waste treatment. Therefore, it is of great economic value and social significance to carry out the research on detecting the elevation of pile head of bored pile.

At home and abroad it is more to carry out the research achievements of bored piles testing pile head elevation, its detection methods have hammer method[2], sampling method[3], inductive measurement method[4], conductive measurement method[5], etc, mainly in the research of inductive measurement method and engineering application, but the head of bored pile in pressure method, there is little research. Zhang guoqiang and cao huibin[6] selected pressure and temperature as physical parameters and conducted many field tests. The results showed that the pressure and temperature at the interface between slurry and concrete had obvious changes, and the pressure mutation was obvious. Finally, based on the pressure and temperature, the first concrete perfusion elevation locator was developed in China. Li liangliang, lu shitao et al[7] found after many field tests that the pressure in the slurry remained basically stable, and the pressure changed significantly during the concrete pouring. With the increase of the concrete surface above the pressure probe, the pressure basically increased in a straight line. According to the principle of pressure difference under certain depth due to the different weight of slurry and concrete, a kind of control device for overfilling height of bored pile was developed. In this method, the weight of slurry and concrete should be measured before concrete pouring, and the initial data should be collected by the pressure probe. Based on this, the alarm value of the overfill height can be obtained. This paper will analyze the shortcomings of the existing measurement methods and carry out the research on the detection of the elevation of bored pile head based on the improved pressure method.
2. Existing Problems
For bored pile to fill underwater concrete, it is usually used by the method of helicopter catheter. In the process of perfusion, a mixing layer is formed between the slurry and concrete mixture due to the sinking of coarse aggregate, the floating of fine aggregate and the falling clay of hole wall, which is called the laitance layer. In other words, there are three layers of material in the hole from top to bottom, namely, the slurry layer, the laitance layer and the concrete mixture layer.

According to theoretical analysis and field construction, the difficulty of concrete perfusion is not only related to the properties of concrete itself, but also related to the pressure difference \( p \) between the concrete surface and the slurry surface in the pile hole, which can be approximately described in the following formula.

\[
p = \rho_c g(H_2 - \Delta h) - \rho_m g(H_1 - \Delta h)
\]

In the formula: \( \rho_c \) and \( \rho_m \) are the density of concrete mixture and slurry, and \( \Delta h \) is the depth of concrete mixture embedded in the pipe.

![Schematic diagram of the perfusion process](image)

FIG. 1 Schematic diagram of the perfusion process

In the process of concrete perfusion, under the condition that the hole wall does not collapse, the construction personnel often pump water and try to reduce the slurry height \( H_1 \), so as to increase the pressure difference between concrete mixture and slurry in the pipe, so that the concrete is easy to be poured. When the concrete is poured to the last pump truck, especially near the end of the pouring, the pressure difference will become smaller and smaller. Only by pumping water to reduce the water head to increase the pressure difference, its effect is limited, and the concrete needs to be slowly poured by vibrating the catheter up and down. Therefore, it is necessary to consider the influence of slurry level change and catheter vibration in the research of detecting the elevation of bored pile head by the pressure. However, no relevant literature has been consulted at home and abroad.

3. Method Improvement
Considering the change of slurry level during the perfusion process, the author innovatively designed a set of device for detecting the elevation of concrete pile top based on the improved pressure method [8]. Its basic components include: horizontal support, hard push rod, total pressure sensor and pore pressure sensor, as shown in FIG. 2 and FIG. 3.
In the process of concrete pouring, the hard push rod will successively contact and immerse in three layers of materials. Among them, the push rod in the slurry layer is affected by hydraulic pressure. In the sticky laitance layer, the main force will gradually change from the hydraulic pressure to the jacking force, while in the concrete mixture layer, the main force is the jacking force. At the design elevation of bored pile head and at the bottom of the push rod, the total pressure sensor and the pore pressure sensor are provided at the same time. The total pressure sensor uses the earth pressure cell to detect the jacking force and the hydraulic pressure. The pore pressure sensor can only detect the hydraulic pressure, and the jacking force is the difference between the total pressure and the pore pressure. If the total pressure and pore pressure sensors are connected to the acquisition system and the calculation program is set, the relationship curve between the jacking force and the perfusion time can be obtained immediately. According to the mechanical analysis, the basic law of the curve can be predicted as follows: When the bottom of the hard push rod is immersed in slurry, the jacking force is zero. When the bottom of the push rod is immersed in the laitance, the jacking force will rise slowly with the increase of the embedding depth. While the concrete mixture touches the push rod, the jacking force will rise rapidly and greatly. There is an inflection point between small and slow rise and large and rapid rise, which is the early warning judgment point of the boundary between concrete mixture and laitance. Therefore, once the inflection point is captured, it can be determined that the concrete mixture surface has reached the bottom of the push rod.

Considering the site construction environment, the detection device needs to be integrated as far as possible for the convenience of operation. The author further simplifies and transforms the device, as shown in FIG. 4 and FIG. 5. FIG. 4 with the conventional dynamometer, holes are arranged at a certain distance on the hard push rod. During the perfusion process, slurry can freely enter and exit the rod to balance the hydraulic pressure on and off the hard board, so as to effectively avoid the influence of the slurry level change. FIG. 5 is based on FIG. 4, the hard push rod with holes is replaced by a slender and solid rod. The above methods do not require wiring and pressure sensors, so it can effectively reduce the interference caused by the wire and the sensitivity of the sensor, the operation is more simple, more accurate detection, more extensive.
4. Conclusion
This paper analyzes the deficiency of the existing measurement technique, based on the jacking principle, on the basis of the traditional pressure detection method, the pore pressure sensor was innovatively introduced in the design elevation position, which can effectively capture inflection point between concrete mixture and laitance. Therefore, an improved pressure detection method for the elevation of bored pile head is proposed, and the method has high extensibility.

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