A Layered Settlement Monitoring Device for Foundation and Application of its Assembly Method

Bin Qian1*, Changqi Guo2, Bingyi Li3, Xinjie Zhan1, and Mingqiao Fan1

1 Geotechnical Engineering Department, Nanjing Hydraulic Research Institute, Nanjing, Jiangsu, 210024, China
2 China Eastern Route Corporation of South-to-North Water Diversion, Beijing, 100038, China
3 Suzhou University of Science and Technology, Suzhou, Jiangsu, 215009, China
*E-mail: bqian@nhri.cn

Abstract. For the vacuum preloading foundation treatment project, water covering construction is often carried out during vacuum pumping. It is very inconvenient for the monitoring personnel to measure the readings in the water with layered settlement instruments and equipment. This paper introduces an assembly method of foundation layered settlement monitoring device, including the assembly process of the monitoring device itself and the assembly process of embedding the monitoring device in the foundation. It has the advantages of simple structure, simple installation and stable data. It can realize the in-situ monitoring of different foundations, save manpower and material resources, and greatly improve the monitoring efficiency and accuracy.

1. Introduction
At present, the deep (layered) settlement of the foundation is mainly observed by embedding settlement markers (deep markers and layered magnetic rings) in the foundation soil. For the embedding of deep settlement markers, it is required to be buried at the required depth of the foundation soil design. The settlement of settlement markers at different depths is measured by leveling and elevation measurement method, which is similar to the surface settlement observation method [1,2]. Its disadvantage is that it is necessary to bury the deep settlement markers at different depths for many times. One hole can only bury the deep settlement markers at one depth. It is necessary to bury the deep settlement markers in multiple holes, which has a large workload; The layered standard can be buried through one hole, and the layered magnetic ring can be fixed on the PVC layered settlement pipe. The settlement pipe can penetrate the whole soft soil layer, and the soil settlement at different depths of the foundation can be measured by the layered settlement instrument on the same layered settlement pipe.

Many domestic engineers have carried out different transformation and promotion of layered settlement, which has been applied in different engineering practices, and greatly improved the monitoring accuracy of layered settlement of foundation soil. Zhu Keliang [3] and others have developed a layered settlement magnetic ring that can adapt to various site environments and the total density can be adjusted as needed, which greatly eliminates the impact of the inconsistency between the gravity of the settlement magnetic ring and the surrounding soil on settlement monitoring and improves the monitoring accuracy of layered settlement. Xu Hao [4] and others improved the traditional magnetic layered settlement instrument and invented a new automatic electric layered
settlement instrument which can realize automatic unmanned monitoring, simple installation, simple use, strong anti-interference and stable data. Yang taipeng [5] and others studied how to fix the proposed position of the settlement ring, and proposed a layered settlement instrument that can simply fix the settlement ring, which greatly improves the accuracy and quality of monitoring data. Shao Xianfeng [6] and others provided a new device for layered settlement monitoring of high fill soil that can maintain the vertical characteristics of each sleeve and ensure that each settlement pipe and settlement plate only settle along the vertical direction.

However, for the vacuum preloading foundation treatment project, the membrane is often covered with water of about 1.0m during vacuum pumping, and the monitoring personnel often have to carry the layered settlement instruments and equipment into the water to take readings. The site area is large and covered with water of 1.0m, which brings great inconvenience to the monitoring personnel. Therefore, in order to facilitate the on-site environmental conditions and improve the work efficiency of monitoring personnel, this paper provides a rod settlement instrument applied to the automatic monitoring of foundation layered settlement after vacuum preloading foundation treatment, and introduces its device and assembly method.

2. Test Principle
The test principle of the rod settlement instrument for automatic monitoring of foundation layered settlement is as follows: the settlement pipe is vertically buried in the foundation of the borehole, and multiple telescopic hydraulic anchor heads are set at different positions of the settlement pipe. When the settlement pipe is embedded, the telescopic anchor head is retracted into the anchor head base, and after the settlement pipe is embedded, the telescopic anchor recovered into the anchor head base is pulled out through the anchor head driving source. The telescopic anchor head is supported in the foundation. After the assembly of the foundation layered settlement monitoring device is completed, the transmission line of the displacement sensor is led out from the top of the settlement pipe and connected to the wireless data transmission equipment; Carry out settlement treatment on the foundation. The foundation settlement drives the telescopic anchor head at different positions to move. The telescopic anchor head drives the telescopic rod in the displacement sensor to move, monitors the movement amount of the telescopic rod, and transmits the signal through the transmission line, so as to realize the settlement of the soil layer where each telescopic compression anchor head is located on the site.

3. Device and Embodiment
As shown in figure 1, the rod settlement instrument for automatic monitoring of foundation layered settlement. The serial numbers in figure 1 are: 1 settlement pipe, 2 displacement sensor, 3 corrugated hose, 4 anchor head monitoring device and 5 base.

Figure 1. Schematic diagram of the overall structure of the foundation settlement monitoring device.
3.1. Anchor Head Monitoring Device
The anchor head monitoring device is shown in Figure 2. The serial number in the figure indicates: 1 settlement pipe, 2 displacement sensor, 3 corrugated hose, 401 anchor head base, 402 is the telescopic anchor head arranged in the anchor head base, and 403 is the anchor head driving source driving the telescopic anchor head.

Three telescopic anchor heads are set, and the included angle between any two adjacent telescopic anchor heads is 120 °. The side wall of the settlement pipe is provided with a strip hole for the telescopic anchor head to pass through. Taking the settlement pipe as the axis, the monitoring area is further increased to the outside. The anchor head driving source drives the telescopic anchor head to insert into the foundation through the strip hole. The telescopic anchor head can move up and down in the strip hole with the foundation. In the process of settlement monitoring, after the foundation settles, the telescopic anchor head can settle in the strip hole with the foundation.

Figure 2. Schematic diagram of overlooking structure for monitoring and monitoring device for anchor head.

3.2. Settlement Monitoring Unit
The settlement monitoring unit comprises a displacement sensor arranged in the settlement pipe and an anchor head monitoring device connected with the displacement sensor. The anchor head monitoring device comprises an anchor head base, a telescopic anchor head arranged in the anchor head base and an anchor head driving source driving the telescopic anchor head. The side wall of the settlement pipe is provided with a strip hole for the telescopic anchor head to pass through, the anchor head driving source drives the telescopic anchor head to insert into the foundation through the strip hole, and the telescopic anchor head can move up and down in the strip hole with the foundation. The settlement monitoring unit is shown in Figure 3. The serial number in the figure is: 2 displacement sensor, 201 cylinder, 202 telescopic rod, 203 transmission line, 204 waterproof plug, 3 corrugated hose, 4 anchor head monitoring device, 201 anchor head base, 202 the telescopic anchor head arranged in the anchor head base, 203 the anchor head driving source driving the telescopic anchor head.

Figure 3. Structural diagram of connection between displacement sensor and anchor head monitoring device.
head monitoring device, 401 anchor head base, 402 telescopic anchor head and 403 anchor head driving source.

The displacement sensor is a magnetostrictive telescopic displacement sensor, including a cylinder, a telescopic rod, a monitoring head and a transmission line. The cylinder is installed on the inner wall of the settlement pipe and is fixedly connected with the settlement pipe. The telescopic rod slides freely along the cylinder, the telescopic rod is connected with the anchor head monitoring device, the monitoring head is arranged at the front end of the telescopic rod, and the monitoring head is used to monitor the displacement of the telescopic rod. The transmission line is led out from the top of the settling pipe.

After the settlement pipe is buried in the foundation of the borehole, part of the soil enters into the settlement pipe from the strip hole, affecting the normal operation of the internal settlement monitoring unit. In order to ensure the normal operation of the settlement monitoring unit, the internal structure of the settlement pipe is further optimized. Specifically, a corrugated hose is also arranged in the settlement pipe. The corrugated hose is pasted on the inner wall of the settlement pipe, the corrugated hose is wrapped outside the anchor head monitoring device, and the corrugated hose is provided with a through hole matched with the gap of the telescopic anchor head. After the telescopic anchor head passes through the through hole, the corrugated hose is wrapped around the outer circumference of the telescopic anchor head. In the process of settlement monitoring, the telescopic anchor head settles in the strip hole with the foundation. Due to the flexibility of the corrugated hose itself, during the lowering of the telescopic anchor head, the corrugated hose is above the telescopic anchor head extends downward, and the corrugated hose below the telescopic anchor head compresses downward. By setting the telescopic corrugated hose, the foundation soil does not enter the settlement pipe.

After the settlement treatment of the foundation, the telescopic anchor head settles with the foundation, so as to drive the telescopic rod in the displacement sensor to move. The monitoring head monitors the movement of the telescopic rod and transmits the signal through the transmission line.

3.3. Assembly Mode

Stainless steel pipe is selected, and stainless steel metal corrugated hose is embedded in the stainless steel pipe. Install the displacement sensor on the inner wall of the stainless steel pipe, retract the telescopic anchor head in the anchor head monitoring device into the anchor head base, and connect the anchor head monitoring device to the displacement sensor. On the side wall of the stainless steel pipe, the position corresponding to the telescopic anchor head is provided with a strip hole for the telescopic anchor head to pass through, and the telescopic anchor head can slide in the strip hole. On the side wall of the stainless steel metal corrugated hose, the position corresponding to the telescopic anchor head is provided with a through hole for the telescopic anchor head to pass through, and the through hole is clearance matched with the telescopic anchor head. A plurality of stainless steel pipe extension rods are arranged under the stainless steel pipe at the bottom, and a base anchored in the foundation is arranged to form a settlement pipe buried in the foundation. Locate the target monitoring point, drill holes at the target monitoring point, and bury the settlement pipe vertically in the hole. The anchor head driving source in the anchor head monitoring device will be recovered to the top of the telescopic anchor in the anchor head base to support the telescopic anchor head in the foundation and complete the assembly of the foundation layered settlement monitoring device.

Multiple settlement monitoring units are set at the subbase at different heights to summarize and sort out the layered settlement data of the foundation at different depths, sort out the layered settlement monitoring results, obtain the settlement of each measuring point, the settlement rate of each measuring point, the soil compressibility between two adjacent measuring points, and draw the cumulative layered settlement time curve, load time curve Settlement rate time curve of each measuring point, etc.
4. Figures
The rod settlement instrument for automatic monitoring of foundation layered settlement provided in this paper has the following advantages:

1) Firstly, based on the two monitoring methods commonly used in Engineering (settlement standard and layered standard), the layered settlement is not limited to the field environment such as vacuum preloading and water covering conditions, which greatly improves the work efficiency. At the same time, the monitoring personnel do not need to carry instruments to measure the water, which ensures the safety and saves a lot of manpower and material resources.

2) The hydraulic anchor head device is used to replace the layered magnetic ring to ensure that the anchor head settlement ring can be accurately positioned at the established position of the settlement pipe.

3) Magnetostrictive high-precision displacement sensor is arranged in the settlement pipe, and then transmitted in real time through wireless. The measurement results are stable and have strong anti-interference, which improves the measurement accuracy and greatly improves the timeliness and accuracy of data.

Through the research and introduction of this paper, the rod settlement instrument for layered settlement automatic monitoring in vacuum preloading foundation treatment monitoring will have a broader application background.

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