

Development of Under-anchorage Effective Prestress Detecting Instrument and Engineering Application

ZOU Zheng-qi¹ and GAO Hua-rui^{2,*}

¹CCCC First Highway Consultants Co., Ltd. , Xi'an, Shaanxi, China

²Geotechnical and Structural Engineering Research Center of Shandong University, Jinan, Shandong, China

*421334170@qq.com

Abstract. For detecting under-anchorage effective prestress of steel strand by lift-off test convenient. Revealing the testing principle of lift-off text and developing the testing instrument. The instrument consists of data acquisition card, oil pressure sensor, high precision displacement sensor and electric oil pump. Based on the graphical software platform LabVIEW, the test program is compiled by using G language. And further gives the program source code. Integrating the texting instrument (LTF 1.0) of under-anchorage effective prestress based on the software and hardware. So the engineering application is carried out. The research results show that the instrument can detect the under-anchorage effective prestress effectively by the load-displacement curve. Meanwhile it has the advantages of high precision, good safety and convenient operation. Through field application, the effective prestress of prestressed steel strand anchor was increased from 54.4% to 94.7%, and same strand dispersion was reduced from 10.2% to 1.7%.

1. Introduction

Prestressed anchoring technology is widely used in slope engineering, bridge engineering and geotechnical reinforcement projects. The tension quality of prestressed steel strands is closely related to the engineering quality [1] [2]. For the bridge project, if the prestressed anchor is too large, it will lead to deformation of the beam body. If the prestressing force of the anchor is insufficient, it will cause the cracking of the beam bottom and the deflection of the beam body, which will affect the safety of the project [3] [4]. Therefore, it is very necessary to carry out effective prestressed anchoring test.

Anchor prestressed test is divided into damage detection and non-destructive testing. Nondestructive testing is mainly through the ultrasonic [5], vibration and other techniques to measure the tension, but environmental factors will greatly affect the non-destructive testing, and thus the measurement accuracy is low. Although the damage detection has high accuracy, it will cause permanent damage to the structure and strand, and is not easy to operate. In contrast, the lift-off test, as a kind of micro-damage detection method [6], can not only accurately measure the effective prestressing force of steel strand under anchor [7], but also lessens the damage to steel strand and can be used in actual engineering [8] [9].

At this stage, there is fewer research results on the lift-off test, less specialized manufacturers can produce equipment used in lift-off test, and the corresponding criteria in the software are not rigorous enough. In order to obtain the tensile value of strand more accurately and apply this technique to



engineering better, this paper presents an instrument based on LabVIEW software to detect the effective prestress of strand by using the lift-off test.

2. LIFT-OFF PRINCIPLE

Lift-off test, also known as the anti-pull method, tension the prestressed steel strand located in the un-grouting corrugated pipe, resulting in the prestressed strand work load. In the actual testing process, the relationship between the tensile test value and the displacement (tensile-elongation curve) is analyzed, and the effective prestress value under the anchor can be obtained.

In the testing process, the prestressing strand is affected by three forces: F_0 , the effective prestress under the anchor; F_1 , the reverse tension applied during the inspection; F_2 , the reaction force of the anchor on the clamping piece. The relationships among the three are as follows:

$$F_1 + F_2 = F_0 \quad (1)$$

Under the ideal condition, the curve of the anchor effective prestressing force measured by the lift-off test is shown in Fig.1.

The first stage: When jacking the prestressing strand with tension, it can be regarded as an elastic body, and its equivalent stiffness k is expressed as follows.

$$k = F_1 / \Delta l = EA / L \quad (2)$$

In the formula, E is the strand elastic modulus; A is the strand cross-sectional area; Δl is the strand elongation of the exposed section.

The tension is applied on the exposed strand, then the elongation changes linearly with the increase of F_1 , as shown in Fig. 1 OA. At the same time, F_2 gradually decreases.

The second stage: when the jacking force F_1 increases to the same as the effective pre-stressing anchor F_0 , the clip between the exposed section and the anchoring section is disengaged, and the two parts of the strand are simultaneously stressed. In equation (2), L increases, the equivalent stiffness of the strand decreases, and the slope of the tension-extension curve decreases, as shown in Figure 1, section AB. At this point, the tension at point A is the effective working stress under the anchor.

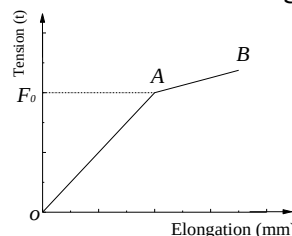


Figure 1. The tensile-elongation curve

3. ANCHOR EFFECTIVE PRESTRESS DETECTION SYSTEM RESEARCH AND DEVELOPMENT

3.1. System hardware and software environment

1) National Instruments (USA) develops LabVIEW software. LabVIEW is a program development environment that is significantly different from other computer languages in that LabVIEW uses a graphical editing language G to write programs that create charts and graphs instead of text lines. And LabVIEW uses data flow programming, and the data flow between nodes in the block diagram determines the order in which VIs and functions execute.

LabVIEW offers many controls similar in appearance to traditional instruments such as oscilloscopes and multimeters that can be used to easily create user interfaces. The user interface is called the front panel in LabVIEW. With icons and wires, you can programmatically control the objects on the front panel. The graphical source code for LabVIEW is somewhat similar to a flowchart, so it's called block diagram code.

LabVIEW has powerful data processing capabilities that give full play to your computer's capabilities, allowing users to define and assemble their own instruments to create more powerful instruments.

2) The chassis uses the NI cDAQ 9181 Ethernet chassis from NI, which accommodates four general-purpose 32-bit counters for use with the capture card.

System uses National Instruments NI 9215 acquisition card, the acquisition card has a sampling rate of 100kS / s, 16-bit resolution, can be 4 simultaneous sampling analog input.

Acquisition system also includes displacement sensor, electric oil pump and hydraulic pressure sensor. Acquisition hardware is shown in Figure 2. Among them, the hydraulic pressure sensor and the tubing are connected by using high-pressure thread tee.

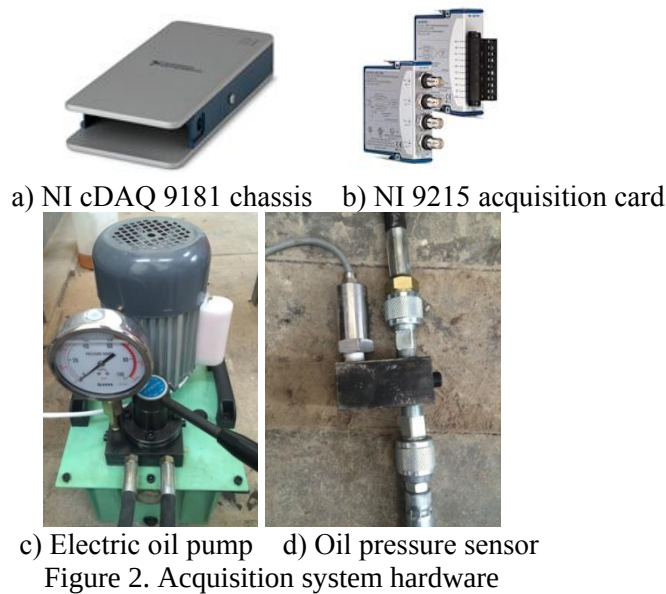


Figure 2. Acquisition system hardware

3.2. Detection process

The system uses an electric oil pump to load the strand, the hydraulic pressure sensor fixed on the electric oil pump measures the oil pressure, and the displacement sensor fixed on the jack extends the measures elongation. The data is sent to the data acquisition card as an electrical signal, the acquisition card will be converted to a signal based on LabVIEW prepared by the data analysis program, the last tensile - extension curve through the LabVIEW front panel display.

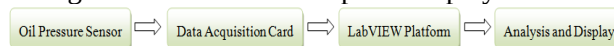


Figure 3. Data acquisition process

3.3. Data acquisition procedures

For hydraulic and displacement sensors, pressure and displacement changes are linear with the voltage. In order to ensure the accuracy of the actual test, the sensor can be calibrated through multiple measurements. The results are shown in Table 1 and Table 2.

Table 1. Hydraulic sensor calibration

Voltage (V)	0.68	1.36	2.04	2.66	3.35
Tension (t)	2	4	6	8	10

Table 2. Displacement sensor calibration

Voltage (V)	0.97	1.96	2.99	3.92	4.91
Elongation (mm)	10	20	30	40	50

After linear fitting the two sets of data, the voltage tension coefficient is 0.34 (V/t) and the voltage extension coefficient is 0.098 (V/mm). After the output voltage is input into the computer, the voltage needs to be analyzed and processed by LabVIEW.

We use hydraulic sensors and displacement sensors for signal acquisition. The LabVIEW program is shown in Figure 4.

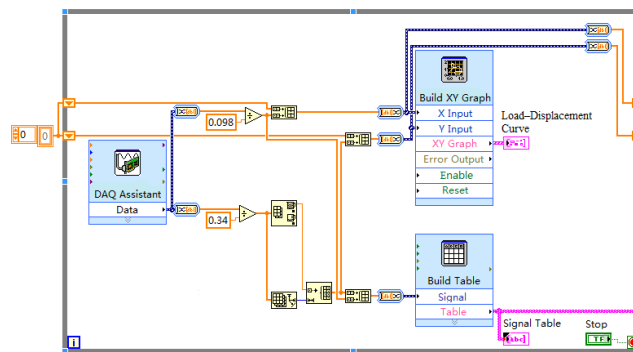


Figure. 4 Test program block diagram

The procedures for testing the following steps:

- 1) Configure the capture card. After the sensor is connected, then the data acquisition card should be configured. If the configuration is not reasonable, the work will be repeated and the acquisition process will be affected. To choose the correct measurement method, and the channel and related parameters are set to ensure the accuracy of the test.
- 2) Run LabVIEW virtual program. The sensor is connected to the acquisition card, and then run the program for data acquisition, the collected data is transmitted as an electrical signal to the computer through the DAQ Assistant. Enter the LabVIEW program for processing, the final output to be detected images. In the front panel, we can intuitively observe real-time detection of data.
- 3) The analysis and extraction of the data. When the detection image reaches the inflection point, click the "stop" button to complete the acquisition, and save the data for subsequent analysis and application.

4. PROJECT PROMOTION AND APPLICATION

4.1. Control passing rate

Based on the research software and test hardware, the anchor effective prestressing instrumentation (LTF 1.0) with lift-off test is integrated. Based on test equipment, we have carried out the application of engineering promotion. Choose to extract a 14th of the main bridge to explain. As shown in Fig. 5, three strands (19 root / bunch) of prestressed steel strands were randomly taken from this section and tested by using the instrument (LTF 1.0).

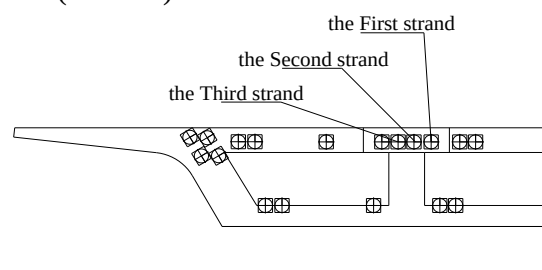


Figure 5. Test bridge cross-sectional view

The actual site test is shown in Figure 6. Three strands (randomly selected)'s single pass rate are only 54.4%, and the test results are shown in Figure 7. It can be seen that due to the quality of construction and other reasons, the tension of multiple strands can't meet the standard requirements, affecting the quality of the project.

This instrument can detect the problems in the actual on-site testing process and guide the on-site construction. In the subsequent construction, the bridge was tested again, the test results were shown in Figure 8.



Figure. 6 the actual test

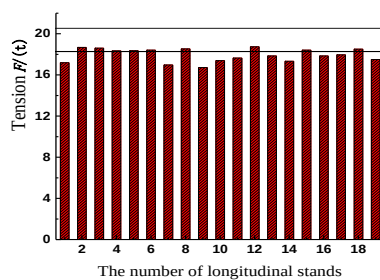


Figure 7. Strand tension (1)

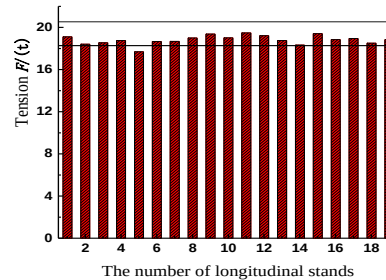


Figure 8. Strand tension (2)

By comparing the two tests can be seen, the first test strand average tension is 17.95t, did not meet the testing standards. The average tensile force of the second test strand is 18.68t, which reached the test standard, and the passing rate of single strand increases from 54.4% to 94.7%. The results show that the detection of tension control can make the strand average tension significantly improved.

4.2. Control the same strand dispersion

The same strand dispersion reflects the uniform distribution of tensile force. When the same strand dispersion is too large, the strand stress is not uniform, which will make a single strand break off, resulting in construction accidents. Therefore, it is necessary to control the same strand dispersion. Select the two sets of strand data before the tension control and after the tension control are compared. Before controlling the tension, the same strand dispersion of prestressing strand reaches 10.2%, in which the maximum tension of single strands in the strand reaches 21.94t, while the minimum is only 16.65t. The difference between the two reaches 5.29 t. This will seriously affect the mode of stress on the strand, or even cause wire breakage, causing serious engineering accidents. The distribution of tension in the test is shown in Figure 9.

In the subsequent construction, the steel strand was tested again. After guidance, the same strand dispersion significantly decreased, and the uniformity of the strand was guaranteed. Test tension distribution is shown in Figure 10.

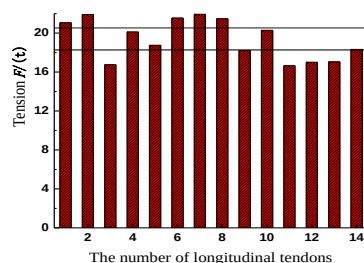


Figure 9. Strand tension (3)

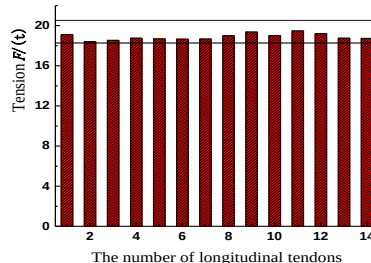


Figure 10. Strand tension (4)

It can be seen from the comparison that for the first time, the same strand dispersion is as high as 10.2% and does not reach the test control standard. Through the control of the tensioning process, the same strand dispersion has been reduced to 1.7% in the second test, which guarantees the construction quality. At the same time, it is shown that the same strand dispersion be effectively controlled by controlling the tension.

5. CONCLUSION

- 1) The principle of lift-off test is explained. We can tension the prestressed steel strand located in the un-grouting corrugated pipe, and analysis the tension - elongation curve to obtain the anchor effective prestress by using the lift-off test.
- 2) In this study, we developed the lift-off test equipment, which has the characteristics of high frequency, real-time, friendly software interface, easy to use and safe. After analyzing the tension - elongation curve, the anchor effective prestress can be detected accurately.
- 3) The testing instruments can be applied to the effective prestress test of prestressed anchorage structure in geotechnical engineering and bridge engineering. Comparing the results of before and after the tension control, the passing rate of effective tension increases from 54.4% to 94.7%, and the same strand dispersion decreases from 10.2% to 1.7%. Tension control can significantly improve the quality of the project, and has a wide range of promotional value.

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