Comparative study of single and two way observation in precision leveling

Yiteng Xu
Tianjin Port Engineering Institute Co., Ltd. of CCCC First Harbor Engineering Co., Ltd., Key Laboratory of Geotechnical Engineering, Ministry of Communications, Key Laboratory of Geotechnical Engineering of Tianjin, Tianjin 300222, China;
Corresponding author’s e-mail: xuyiteng@tpei.com.cn

Abstract. Precise leveling is an important part of engineering construction project. With the increasing requirements of engineering construction projects, the demand for smart leveling is also increasing, but in the actual survey operation, there are many shortcomings in precision leveling, which has a certain impact on engineering project construction and scientific research. Through the comparative analysis of one-way leveling and two-way round-trip leveling, it is found that there is still uncertainty in the replacement of two-way round-trip leveling by one-way leveling.

1. Introduction
In water conservancy and hydropower projects, precision leveling has become an important means to ensure the quality and monitor the external deformation. With the progress of Surveying and mapping technology, digital level gradually replaces optical level. The digital level has the characteristics of objective reading and high accuracy, and it has no error, Miscellany and other problems, and avoids the error of final position estimation [1]. In engineering survey, deformation monitoring and high precision leveling network observation, the application of digital level greatly reduces the influence of human error on the survey results. However, the current operation cycle of leveling is relatively long, especially the precision leveling mainly adopts round-trip observation according to the requirements of "National Leveling Standards of First and Second Class" to eliminate or weaken the errors in leveling [2]. In this paper, a water resources and hydropower engineering of deformation monitoring control network in the period of five periods one-way data (to test, reverse measurement) and numerical distribution pattern of two-way data back and forth, poor closed elements through the contrast analysis of one-way observation precision leveling is discussed in water conservancy and hydropower reviews the feasibility of the application of deformation monitoring control network [3].

2. Information
The data of this study are the second-class leveling data of each recheck and inspection in deformation monitoring control network. The measured data are observed by Trimble Dini 03 digital level (accuracy 0.03mm/km), which avoids the reading error caused by human factors, and the results are highly reliable. The two-way observation and one-way observation are carried out at the same time, and the instruments used are unified, the lines are unified, and the operators are unified. The data were divided into 5 periods, namely, 5 periods for double trip and 10 periods s for one-way trip (including 5 periods for forward test and 5 periods for back test).
3. Data processing flow
Precise leveling is mainly refer to a national second-class leveling specification requirements, using observation, back and forth will first five cycle data in the data for each one-way observation data extraction respectively, namely to the test data and return to the test data, and adjustment of calculated respectively, and compared by statistics and data distribution form, analysis the feasibility of single observation results of alternative return measurement. The method flow is shown in Figure 1.

![Data processing flow diagram](image)

Figure 1 Data processing flow

4. The experimental contrast

4.1. Comparison of route adjustment
In leveling net adjustment, the algebraic and theoretical values of the height difference of each loop should be equal to zero. If it is not equal to zero, then the closure difference $\sum h$ is generated. The total length of the closed loop is expressed as $L_{total}$, and the length of the route is expressed as $L$. The result after adjustment should be expressed as $(\sum h / L_{total}) * L$. This method is used to adjust the leveling network. The leveling results are evaluated according to the code for first and second class leveling of China (GB/T 12897-2006). $\sum h \leq 4\sqrt{L_{total}}$. In leveling, adjustment weight can be divided into two types: the number of measuring stations and the length of measuring section [4]. The adjustment is carried out according to the length of the measuring section.

Suppose a leveling route is laid between leveling points A and B as shown in Fig. 2. The elevations of leveling points A and B are known, and they are set as $H_A$, $H_B$, $n_1$, $n_2$, .... C is the midpoint. Observe the elevation of all points, calculated the most or value of the elevation $H_C$ at point C.

$H_C$ can be calculated from the height difference $H_{AC}$ and $H_{BC}$ observed by leveling route $A \rightarrow C$ and $B \rightarrow C$ respectively, from which the observed elevations are $H_{C1}$ and $H_{C2}$ respectively. The values are as follows:

$$H_{c1} = H_A + h_{AC} ; H_{c2} = H_B + h_{BC}$$

When $H_{C1}$ and $H_{C2}$ are observed with different accuracy, their "weights" are also different. They are set as $P_{C1}$ and $P_{C2}$ respectively, In this way, the most or value of elevation $H_C$ at point C is:
According to the elevation $H_A$ of point A, the elevation difference $H_{AC}$ observed on leveling route $A \rightarrow C$ and the elevation difference $h_{BC}$ observed on leveling route $B \rightarrow C$, the observed elevation $H_B$ of point B can be deduced as:

$$H_B = H_A + h_{AC} - h_{BC}$$

The height closure error of leveling line $A \rightarrow B$ is:

$$f_h = \Delta H_B = H_{C1} - H_{C2}$$

The following can be obtained from formula (2):

$$H_{C2} = H_{C1} - f_h$$

The distance of leveling route $A \rightarrow C$ is $S_{AC}$, the distance of leveling route $B \rightarrow C$ is $S_{BC}$, and the distance of $A \rightarrow B$ is $S_{AB}$ ($S_{AB} = S_{AC} + S_{BC}$) to determine the "weight" value of the altitude observation value, which is obtained by substituting into Equation (1) [5]:

$$H_C = H_{C1} - \frac{S_{AC}}{S_{AB}} \cdot f_h$$

Figure 2 Leveling diagram

This paper studies the leveling line results in five periods, and compares the height difference of each route after one-way and round-trip observation results adjustment. The adjustment results are shown in Table 1.

| Date       | Detail          | 2019.12.01 | 2020.03.15 | 2020.06.28 | 2020.10.11 | 2021.01.24 |
|------------|-----------------|------------|------------|------------|------------|------------|
|            | Double          | 0.36       | -1.08      | -0.08      | -1.09      | 0.00       |
|            | One Way (To)    | 0.26       | -1.15      | -0.30      | -1.41      | -1.30      |
|            | One way (return)| 0.44       | -1.07      | 0.24       | -0.74      | 1.24       |

Among the leveling lines in five periods, the closure error of two-way round-trip survey fluctuates in [-1.08, 0.36]. There are two lines whose closure error is more than 1 mm, and the closure errors of other lines are less than 1 mm. The results of the round-trip measurement are basically stable. In one-way measurement, the closure error fluctuates in [-1.97, 1.24]. There are two lines with closure error more than 1 mm, and the two-way measurement closure errors of other lines are less than 1 mm. Comparison curves of one-way measurement and round-trip measurement data changes are shown in Fig. 3.
From the data results of adjustment, although there are differences between one-way measurement and round-trip measurement, the data can meet the requirements of National Leveling Standards (GB/T 12897-2006), and the difference between one-way measurement and round-trip measurement in 80% of the data is less than 1mm, as shown in Fig. 4. Therefore, it is considered that the results of one-way survey data after adjustment of most leveling lines are more reliable, but although all the data meet the requirements of the specification, there is still a large difference in one leveling line, so it is not appropriate to use one-way survey results in the process of precision survey of important projects.

4.2. Closure error evaluation comparison

It can be seen from Figure 3 that the broken line trend of the closure error values of one-way measurement and round-trip measurement is basically similar, and there is no obvious big fluctuation. However, there are some differences in the numerical results of single and two-way measurement adjustment, and the discrete distribution is not obvious and scattered.

The important index to evaluate the quality of leveling results is the closure error. \( W \) represents the closure error and \( W_1 \) represents the allowable value of the closure error. The \( W/W_1 \) is smaller, the result is the better. The result quality of closed ring is evaluated by leveling method. The \( W/W_1 \leq 1/3 \) is excellent, \( 1/3 < W/W_1 \leq 3/4 \) is good, \( 3/4 < W/W_1 \leq 1 \) is acceptable, and \( 1 < W/W_1 \) is overrun [6]. Through the data collation and induction in five periods, it is found that the quality of data results is above good. From the whole statistical results, it is found that the quality of two-way round-trip measurement results is significantly better than that of one-way measurement results, and the overrun of one-way measurement results is significantly more serious than that of round-trip measurement results.
5. Conclusion
(1) There is a certain correlation between the one-way measurement results and the two-way round-trip measurement results. Most of the one-way measurement results can replace the two-way round-trip measurement data results for specific work. However, the value of individual line height difference and closure error caused by accidental factors is too large, and the reason can not be determined by the way of one-way and two-way measurement.

(2) In precision leveling, even the use of digital level is still inevitably affected by the environmental factors and the system error caused by the equipment itself. The one-way measurement results if there is no round-trip measurement inspection process, it is easy to cause data errors and greater error impact. Therefore, it is not suitable to use one-way leveling results instead of round-trip survey results in the survey of major engineering projects.

References
[1] Geng Xiaomin, Yan Xiaoping. Error analysis of precise leveling in earthquake monitoring [J]. Surveying and spatial geographic information, 2010, 33 (03): 234-235 + 239.
[2] General Administration of quality supervision, inspection and Quarantine of the people's Republic of China. GB / T 12897-2006, national first and second class leveling specifications [S]. Beijing: China Standards Press, 2006:1-10.
[3] Su Guangli, Chang Liu, Deng Dongjian. Comparative analysis of single and two-way observation in seismic leveling [J]. Geospatial information, 2018, 16 (04): 100-104 + 11.
[4] Wang Lei, Guo Jiming, Yu Yongping, Shen Lili. Influence of weighting method of leveling network on accuracy evaluation [J]. Surveying and mapping bulletin, 2011 (05): 26-28 + 88.
[5] Kong Xiangyuan, Guo Jiming. Control surveying [M]. Wuhan: Wuhan University Press, 2006.
[6] Cui Xizhang, Yu zongtao, Tao Benbao, et al. Generalized surveying adjustment [M]. Wuhan: Wuhan University Press, 2009.