Level Surveying Method and Accuracy Analysis on Passenger Dedicated Line CP-Network

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Key words: passenger dedicated line, trigonometric leveling,CPIII network points

SUMMARY

Ballastless track is directly on a solid substrate pouring of concrete layer foundation under a rail, it has an overall strong, longitudinal, lateral stability, and is easy to keep track of the geometric shape and position, so it is conducive to high-speed driving. As the high speed and smoothness of the line is high demand, and the high demand for leveling survey. Thus, CPIII control network must be constructed for laying of the Ballastless Track. Free station side-angle resection is used to build CPIII plane control network, while the elevation control is build by precise leveling. According to the new passenger rail lines code for engineering survey, CPIII points must joint to the ground known level point lessen distance 2km. Because the bridge height is usually 10 meters higher than the ground. it is very difficult to transmit the elevation of the bench mark on the ground to the bridge by geometric leveling. In this paper, A method with trigonometric leveling is introduced, which with no measurement of instrument and target height, and a Z-shaped observing-routine was proposed to measure the elevation of CPIII network points. Beijing-Tianjin inter-city project survey results indicate that the program measurement method is reasonable.

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1. INTRODUCTION

Ballastless track is directly on a solid substrate pouring of concrete layer foundation under a rail, it has an overall strong, longitudinal, lateral stability, and is easy to keep track of the geometric shape and position, so it is conducive to high-speed driving. As the high speed and smoothness of the line is high demand, and the high demand for leveling survey. Thus, CPIII control network must be constructed for laying of the Ballastless Track. Free station side-angle resection is used to build CPIII plane control network, while the elevation control is build by precise leveling. According to the new passenger rail lines code for engineering survey, CPIII points must joint to the ground known level point lessen distance 2km. Because the bridge height is usually 10 meters higher than the ground. it is very difficult to transmit the elevation of the bench mark on the ground to the bridge by geometric leveling. In this paper, A method with trigonometric leveling is introduced, which with no measurement of instrument and target height, and a Z-shaped observing-routine was proposed to measure the elevation of CPIII network points. Beijing-Tianjin inter-city project survey results indicate that the program measurement method is reasonable.

2. ELEVATION MEASUREMENT FOR CPIII NETWORK

2.1 CPIII Control Network

Compared with traditional measurement of railway lines, the passenger dedicated line control network consists of GPS-based control network CPI, line control network CPII, and CPIII control network. CPI is B-class GPS network laid along the line, measured by GPS. CPII line control network is the basic control network measured by traverse Surveying or GPS. CPIII is high precision fix point network for construction, documentation, acceptance and maintenance the ballastless track. CP III network points are located in both **lateral crash wall as** shown in Figure 2.1. the point distance is 65 meters or so.

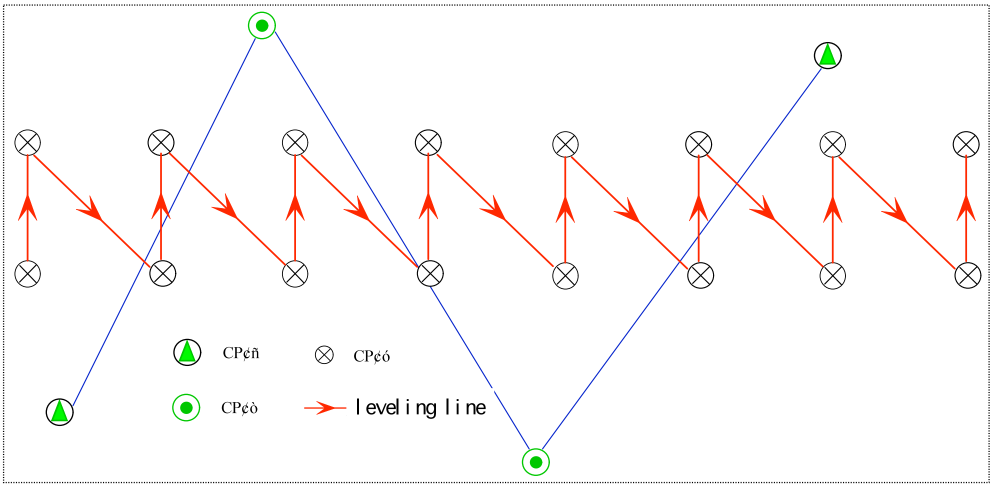

Fig2.1 CPIII network

2.2 The technique requirement of CPIII points height survey

In the roadbed section, CPIII network points measured after completion of subgrade; in the bridge section, when the overhead beam erection and the two borders concrete barrier walls are completed, two borders points will be laid upon the two borders concrete barrier. In order to avoid the interaction, elevation and plane is to be measured separately. Table 2.1 shows the technical requirements of CPIII network measurement.

Table 2.1 Technique Requirement of leveling for **CPIII** points

leveling	occasional errors of per km(mm)	permissible errors（mm）			
		difference of to and from measurement	anneded misclosure	Loop misclosure	right line and left line misclosure
Second code leveling	1.0	$4\sqrt{L}$	$4\sqrt{E}$	$4\sqrt{L}$	$4\sqrt{L}$

Where L length of anneded in km, E length of loop in km

3. THE IMPLEMENT OF CPIII POINTS ELEVATION SURVEYING

3.1 Height transmit

CPIII control points must be measured in conjunction with the ground known elevation points every 2km, according to the passenger dedicated line measurement specification. Due to the bridge surface generally 10 meters above the ground, it is not possible to **transmit** height above bridge by differential leveling, so the trigonometric leveling is considered using high-precision total station such as Leica TCA2003, Sokkia net06 etc. It's the key to minimize the influence of targets high error and instrumental height error in trigonometric leveling, In this paper, the effects of both effectively has been deleted by the methods without measuring instruments high, and targets high. The method is showed as follows as figure 3.1

In order to measure the elevation difference between point A and point B, it should be measured the distance S_1 and vertical angle α_1 between point O and point A that are set Total Station in point O and set prism in point A. Then it should be measured the distance S_2 and vertical angle α_2 between point O and point B which the prism height is equal to that of point A. It is assumed that the elevation of the Total Station center is H_0. The elevation of point A and point B can be calculated as follows:

$$H_A = H_0 + \Delta h_1 - v$$
$$H_B = H_0 + \Delta h_2 - v$$

The elevation difference H_{AB} between point A and point B can be calculated as follows:

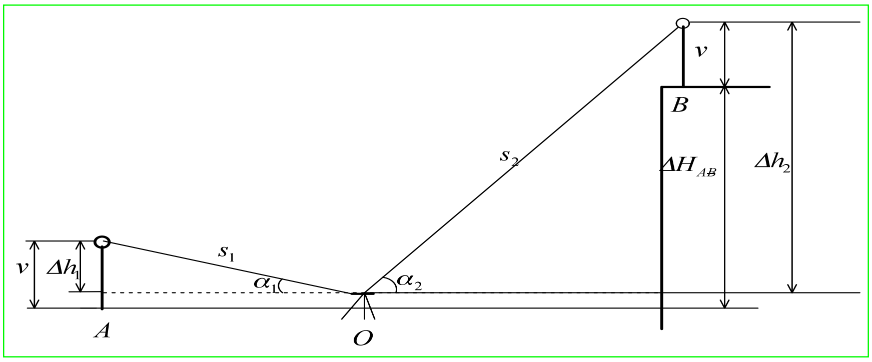

Figure 3.1 elevation transfer

$$\Delta H_{AB} = H_B - H_A = \Delta h_2 - \Delta h_1$$

The height difference between point A and point B has eliminated the instrument height error and prism high error, It's no need to take amount of these error. According to the trigonometric leveling principle, here is the height difference calculation formula as follows:

$$\Delta h = s_2 \sin\alpha_2 - s_1 \sin\alpha_1 + (1-k)\frac{s_2^2\cos^2\alpha_2 - s_1^2\cos^2\alpha_1}{2R}$$

In the formula, R represents the earth radius which is 6370 km, k means refraction coefficient which is 0.14. In the actual measurement, we should restrict the length and size of vertical angle of observation, which the maximal distance is less than 50 meters, the maximal angle is less than 25 degree. We adopt Leica TCA 2003 total station to measurement the angle and distance, whose accuracy of measurement angle is 0.5 seconds and measurement distance is ±(1 mm + 1 ×10 - 6 D), Table 3.1 gives the technical requirements of Vertical angle observations and distance measurement.

Table 3.1 the technical requirement for trigonometric leveling

Vertical angle observations	measurement number	4
	difference between two readings	≤±1.0"
	difference of index among different measurement	≤±5.0"
	difference among different measurement	≤±2.0"
distance measurement	measurement number	4
	reading number	4
	difference among four reading value	≤±2.mm
	difference between different measurement	≤±2.mm

3.2 Differential Leveling of CPIII Network

As shown in Figure 2.1, CPIII network points are high dense located along the crash wall, so a Z-shaped observing-routine is proposed to measure the elevation as shows in Figure 3.1

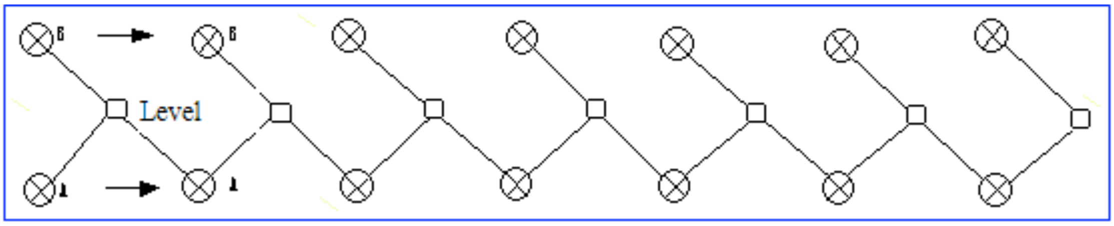

Fig 3.1 leveling line

The measurement model is FB BF and Trimble Dini12 electronic level is used in the actual measurement. Suppose in the first station backsight looking rod A, foresight looking rod B, the first measurement of the height difference between two points along the left and right, and then moving the rod A to the next point at the same side, we measured diagonally line height difference between two points to complete the first leg of measurement. And then the level and rod A moved the next station at the same time, and so on. For every section, the operating group included the regular observation staff and regular staff holding the level ruler, and checked station tolerance according to the second-code differential leveling standards and specifications.

4. ACCURACY ANALYSIS AND CONCLUSION

Take Beijing–Tianjin passenger line height measurement, for example, selection of routes 8 km of data for analysis. In this section, seven known benchmark are used and six times trigonometric leveling are carried out in six positions, twice observation each station. Table 4.1 shows the trigonometric leveling accuracy.

Table 4.1 Elevation accuracy of trigonometric leveling

ground known points	points on the bridge	height difference observation (m)	difference between the two observations (mm)	average value (m)
BM31995	D0376	-12.13155 -12.13169	0.14	-12.13162
BM31947	D0371	-10.70085 -10.70079	-0.05	-10.70079
BM31897	D0365	-9.84653 -9.84614	-0.39	-9.84639
BM31841	D0358	-10.05095 -10.05123	0.27	-10.05108
BM31789	D0351	-9.19149 -9.19131	-0.17	-9.19142
BM31739	D0345	-8.94354 -8.94327	-0.27	-8.94341

As can be seen from the table, after transform of instrument high, height differences in a station are ≤ 1mm, trigonometric leveling accuracy of compliance with the technical design requirements. Figure 4.1 shows this paragraph 70 CPIII points to and from the difference of height difference.

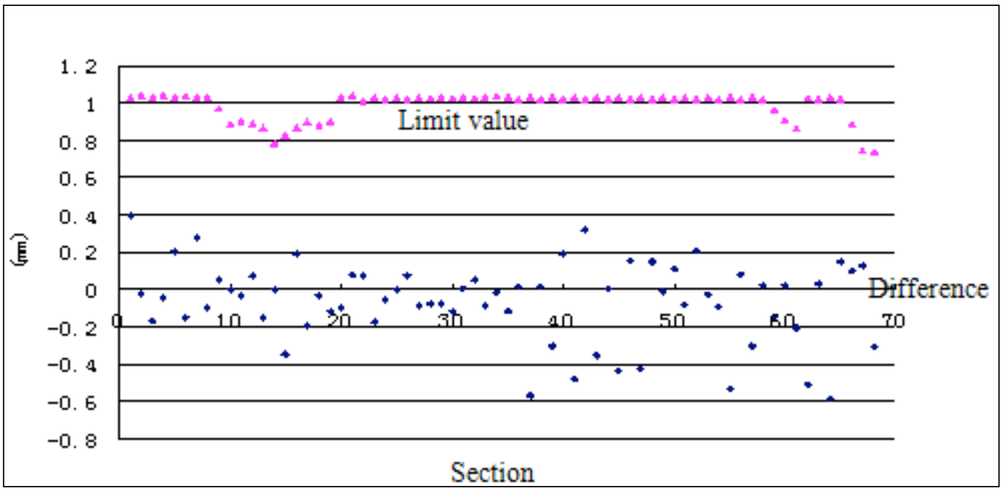

Fig4.1 to and from the difference of height difference and tolerance

It can be seen from the figure, CPIII point from height difference limits in -0.4~0.6mm, the majority are within in ±0.2 mm, much less than the limit value. The accuracy of CPIII control points reached the second-order leveling of precision requirements. It should be meet the requirement in construction of high speed railway ballastless track. In the whole, the methods and schemes designed in this project are scientific and feasible.

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