Established Method of High-Speed Railway Survey Control Network

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Abstract. It is very important of high-speed railway construction surveying and mapping. Especially the establishment of construction survey control network and searching aiming at layout, measurement, data processing of adjustment calculation of the horizontal control network and the elevation control network. The most important part is the establishment of CPⅡ and CPⅢ control network. The elevation control mainly adopts second order leveling. Horizontal and elevation accuracy must to meet the requirements of high speed railway construction survey.

1 Introduction

With the progress of technology, high-speed railway has obtained a rapid growth. The new-built speed of 250~300km per hour and the old line of 200km per hour are regard as high-speed railway in Western Europe. The international railway agreement which was signed in Geneva in 1985 by the United Nations Economic Commission has stipulated that the speed of new special of passenger train high-speed railway is 300km per hour and the speed of new mixed type of passenger and freight trains high-speed railway is 250km per hour. In order to achieve the high speed condition for railway trains, the precision of high-speed railway track must be kept in the millimeter range. However, the traditional railway engineering measurement technology cannot meet the requirement of high-speed railway construction. The basis for the high-speed railway precise engineering surveying is setting up horizontal and elevation control network at all levels. Under the control of all levels of precision measurement control network, we can achieve accurate construction and the accuracy of track laying to ensure high speed and safe driving of passenger train. In this paper, the construction technology of high-speed railway construction survey control network is illustrated by a total length of 24.265km high-speed railway construction.

2 Horizontal control network

| Levels of Control Network | Methods of Measurement | Grades of Measurement | Point Spacing | Remarks |
|---------------------------|------------------------|----------------------|---------------|---------|
| CP 0                      | GPS                    | National B-Level     | 30~50km       |         |
| CPI                       | GPS                    | B-Level              | ≥1000m        | ≤4km A Pair of Point |

WGS-84 coordinate system is adopted in the horizontal coordinate system. According to the principle of grading network, we establish the horizontal control network in four grades. Along the routes, the country’s high level horizontal control points are rare and the accuracy is also poor. Therefore, we establish the first GPS framework as the benchmark of horizontal coordinate on the whole line (CP0). The second level is basic horizontal control network (CPI). The third level is line control network (CPII). The four levels is tracking laying and foundation piles control network (CP Ⅲ )[1-5].

After the exploration design units surveys CP0, CPI, CPII, and elevation control network the construction organization carry on making piles and repeating survey. The CP Ⅲ control points should be measured by construction organization [9-14].

2.1 Technical requirements of plane control network at all levels

On the basis of CPII, the construction control network adopts the method of free station intersection. During the construction phase, connecting the CPII and the CP Ⅲ control network is the main task. CP0, CPI, CPII and CP Ⅲ network requirements are shown in table 1, table2 and table3.
### Table 2. Accuracy Indices of GPS Measurement

| Levels of Control Network | Mean Error of Baseline | Relative Mean Error of the Weakest Line |
|---------------------------|------------------------|----------------------------------------|
| CP0                       | ≤0.7"                  | —                                      |
| CPI                       | ≤1.3"                  | 1/170000                               |
| CPII                      | ≤1.7"                  | 1/100000                               |

### Table 3. Technical requirements for traverse survey

| Levels of Control | Echo Length (km) | Length (m) | Mean Error of Distance Measurement (mm) | Mean Error of Angle Measurement (*) | Mean Error of Coordinate in Adjacent Points (mm) | Relative Mean Error of the Total Length of the Traverse | Misclosure Limitation of Azimuth (*) | Corresponding Traverse Grades |
|-------------------|-----------------|------------|----------------------------------------|-----------------------------------|----------------------------------|------------------------------------------------|--------------------------------|-----------------------------|
| CP II             | ≤5              | 400~800    | 3                                      | 1.8                               | 8                                | 1/55000                                             | ±3.6√n                          | Third Level                 |

Note: n is the number of angle of traverse ring

#### 2.2 The horizontal control network shape and the connection measurement methods of CP III

In order to meet the requirements of CP III measurement, we should carry on a comprehensive repetition measurement and maintenance of basic plane control network CPI, line control network CPII and elevation control network before CP III measurement. Furthermore, we also need to recover the horizontal elevation points which are lost and destroyed.

On the basis of basic plan control network CPI, line control network CPII and elevation control network, CP III measurement can be laid and measured by construction organization according to the needs of underline engineering and nail construction. As shown in figure 1, is CPI, is CPII, is CP III. The number of 1, 2, 3……14, 15, 16 in the figure are just the code in this article and not the real CP III point [6-8]. The connecting measurement method: For example, after the instrument set up, centered, and leveled over at station 2, observing CPI, CPII, using liner-angular intersection we can calculate the coordinate of the station. Then observing CP III again, we can get the coordinate of CP III, too.

![Figure 1. Connecting Measurement Methods of CP III Horizontal Control Network](image-url)
2.3 The observation instrument and limit standard of CP III horizontal network

2.3.1 Measuring Instrument

According to the estimation of the position and the relative position accuracy of the CP III horizontal network, the nominal accuracy of the total station can be used to carry out the standard network observation is mean error of horizontal direction observation in one round \( \leq 1.0'' \), mean error of distance measurement \( \leq (1\text{mm}+2\text{ppm}) \), in addition, the total station should have a motor drive, automatic collimation and data recording function. Other accuracy of the total station cannot meet the accuracy requirements of the horizontal network measurement.

2.3.2 Station Limit

The method for measuring horizontal direction of CP III plane network is full circle direction observation method which should control the main accuracy indices including the difference value return to zero in semi-observation, the difference between direction value the same direction returning zero and 2\( \epsilon \) of the mutual difference value in different value on same direction. Accuracy indices are shown in table 4.

| Control Network Name | Instrument | Set | The Difference Value Return to Zero in Semi-Observe | 2\( \epsilon \) of the Mutual Difference Value | The Difference Between Direction Value the Same Direction Returning Zero |
|----------------------|------------|-----|-----------------------------------------------------|---------------------------------------------|----------------------------------------------------------------------------|
| CP III               | 0.5''      | 2   | 6''                                                 | 9''                                         | 6''                                                                        |
| CP III               | 1''        | 3   | 6''                                                 | 9''                                         | 6''                                                                        |

2.4 The adjustment methods of CP III horizontal control network

Adjustment should not reduce the actual observation accuracy of CP III network, and ensure the smoothness of the track laying construction. Adjustment mainly has the following three calculating models: free network adjustment and correction traditional restriction network adjustment and leveling algorithm of CP III.

3 The elevation control network

1985 National Elevation datum is adopted in the elevation system. (1) The elevation control network shall be measured according to the required precision of the second-order leveling and the leveling base control network should be measured once on the whole line. When connecting to another railway, to make it easier to determine the relationship between the two railway elevation systems, we always need to carry on connecting measure with bench marks of the other railway. (2) Each bench mark should be set at 2km. Besides, according to the actual situation the key project area (such as bridges, long tunnels and special roadbed structure) shall be added. Bench marks which away from the centre line should be between 50~150m need to use a same pile with the plane control points, or be set alone. (3) Leveling method should be adopted in elevation control.

3.1 Measurement of the elevation control network

The second-order leveling is adopted in the whole line and the leveling route is laid along the line in principle. Each bench mark should be set at about 2km and each deeply buried bench mark should be set at about 20km. According to the actual situation the key project area (such as bridges, long tunnels and special roadbed structure) shall be added. Bench marks which away from the centre line should be between 50~150m can use a same pile with the plane control points, or be set alone. (3) Leveling method should be adopted in elevation control.
according to the different values of height difference between segments when the number of leveling network rings more than 20, we should calculate closure error $M_w$ according the number of rings yet. $M_\Delta$ and $M_w$ should meet the stipulate, otherwise the routes which have big closure error should be re-measured.

Calculation Formula:

$$M_\Delta = \left[ \frac{1}{4n} \left( \frac{\Delta}{L} \right) \right]^{1/2}$$ (1)

$$M_w = \left[ \frac{1}{N} \left( \frac{W}{L} \right) \right]^{1/2}$$ (2)

In the Formula: $\Delta$ —— Difference Values of Height Difference Between Segments (mm);
$L$ —— Measuring Length or Loop Length (km);
$n$ —— the Number of Segments;
$W$ —— Closing Error of Rings (mm);
$N$ —— the Number of Rings

### 3.2 Establish the foundation piles elevation control network

The points of the fourth horizontal control network (CPI) are the common points of the horizontal and the elevation control network. Elevation measurement of the CPI control point should be carried out after the completion of the CPI horizontal measurement and in accordance with the requirements of precision leveling measurement, starting and closing at second order basic bench mark. It is suggested that the elevation of the control points should be measured by the digital level and use tightly adjusted.

### 3.3 Method of Observation and Adjustment

1) As shown in figure 2 and figure 3, the observation lines can be seen that whether direct or reversed, all the bench mark of CP III can be linked in the routes.

2) Each measurement stations are set between the four points and do not have to move the instrument, so as to improve the efficiency of field observation.

3) The length of the horizontal line between the points in the leveling line is also approximately equal. In order to ensure the correctness of CP III leveling measurement, the method of independent round-trip measurement should be adopted to check the level line.

4) The method of indirect adjustment is adopted by the elevation control network adjustment. In addition, restriction adjustment is adopted by connecting to two order leveling point around survey area.

### 4 Conclusion

According to the above control measurement, after the adjustment, the precision index of high-speed railway control measurement is that the correction value of the horizontal distance should be $\leq \pm 3"$ (refer to the station to the CP III point), the mean square error of unit weight of horizontal direction should be $\leq \pm 2.5\"$, the relative error of the relative position of CP III point should $\leq \pm 1\text{mm}$ and the elevation accuracy of the whole station should meet the requirement of the second order leveling.

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