THE MEASUREMENT OF HIGH-SPEED RAILWAY (HSR)-PRECISION ENGINEERING

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ABSTRACT

The paper proposed the optimization of the network construction timing of the control network according to the specific conditions of the survey route. Moreover, presented here are the adjustments according to the layout requirements of the control network layout process, strengthening the control of the line level base point during the construction process. Several optimization solutions are discussed for the special design of the level control before the construction of the long tunnel. It has been explained the methodology to introduce new Continuously Operating Reference Station (CORS) technology in railway survey and design with appropriately adjustment of the position requirements of the control network according to the specification. In order to carry out the special design of the levelling route with precision, it is advisable to set a certain stable reference point in the level control of the long line. The proposed methodology can effectively solve some problems existing in the current high-speed railway construction process, and make the precision measurement control network better for survey, design, construction, supervision and operation.

KEY WORDS

High-speed railway, Precision engineering survey, Network construction timing, Levelling network

INTRODUCTION

In 2018, the Taiqing high-speed railway was completed and opened to traffic, which means that the construction of the China Railway Framework Network is about to be completed, and it entered the final stage. Since the commencement of construction in Beijing and Tianjin in 2005, China's high-speed railway technology development has steadily entered a mature stage. Under the guidance of the strategy of “introduction-evaluation-re-innovation”, the localization of high-speed rail technology has been carried out. The result is a series of independent intellectual property rights, creating a unique Chinese high-speed rail brand. On March 20, 2017, the National Development and Reform Commission officially released the “eight vertical and eight horizontal” road network plan: It is planned that by 2020, with the completion and commissioning of a number of major landmark projects, the scale of the railway network will reach 150,000 km. Out of which the high-speed railway covers 30,000 km and covers more than 80% of the big cities. Under the circumstances of China's high-speed railway's sustained and steady development, further evaluation and absorbing the previous construction experience is of great significance for improving the standardized management of technology, production and operation at all stages.

In 2009, the Ministry of Railways issued the “High-speed Railway Engineering Measurement Specification” (TB10601-2009). Through the practice of several high-speed rails such as Beijing-Shanghai, Harbin and Beijing-Shiwu, the standard system adopted has withstood the test of design, construction and operation, verifying its scientific, advanced, applicability and reliability. But in some details, there are still some areas for improvement. For example, the timing of the control network construction network is out of line with the previous design, and the design of the control network simply considers its own mesh shape without considering the actual construction conditions.

PARTICULAR TIME OF NETWORK CONSTRUCTION

The traditional railway engineering control network establishes a low-level control network at the initial stage of measurement. After the scheme is stabilized, the precision engineering measurement is carried out separately. There is a situation in which the design documents generated by the initial measurement control benchmark are inconsistent with the construction reference documents. This deviation is often huge for the earthwork volume. There are hidden dangers such as insufficient clearance in the upper cross. There are many comparison schemes for new railways, and it is uneconomical to directly establish a complete set of precision measurement and control systems when the scheme is unstable. Therefore, on the basis of referring to the traditional measurement control process, the following rules are set for the network construction timing at each stage:

1. The CP0 control network should be established by global navigation satellite system (GNSS) measurement method before the initial measurement, and the whole line should be laid at one time, unified measurement, and overall adjustment [1].
2. The CPI control network should be established in the initial test stage. When it is difficult, it should be completed before the test. The whole line should be deployed once, and the measurement should be unified, and the overall adjustment [1].
3. The CP II control network should be completed in the calibration stage and measured by GNSS measurement or traverse measurement method [1].

Selection of CP0 network construction time: In the early stage of China's high-speed railway construction, the national control network is imperfect and the accuracy is insufficient. Therefore, the specification requires the establishment of CP0 in the initial stage. After the official launch of the 2000 National Geodetic Coordinate System on July 1, 2008, the poor accuracy of the national network has ceased to exist in most areas, so the provisions of this article may not be entirely appropriate today. At this stage, China's high-speed railway and trunk railway network has begun to take shape. It is more effective and reasonable to adopt the control standard of railways at both ends and directly realize the smooth connection of road network control.

"CPI control network should be established in the initial stage of testing" is to prevent the initial survey and design data from being inconsistent with the construction network control network data. There are many options in the initial test phase. At this time, the implementation of precision measurement will result in a large cost waste. In addition, from the initial test to the opening of the trade union for a long time, the control network established at this stage often has a large segment. The control pile is destroyed, and even the local loss of the control network function may occur. With the gradual improvement of the construction of the national Continuously Operating Reference Station (CORS) base station, there are fundamental solutions to this contradiction. At present, 27 provinces and municipalities in China have built provincial-level CORS networks with an average station spacing of 40 to 70 km, and the remaining provinces have also been included in the planning. The application of CORS technology carried out by various railway design institutes in the process of multiple railway survey and design proves that the accuracy of CORS technology is sufficient to ensure the application of survey and design and the production. Moreover, efficiency will be greatly improved during the initial stage of railway survey.

Therefore, a reasonable recommendation should be that analyse the line data before the initial test, and clarify the frame control network reference adopted by the line; Establish the CP0 control network using GNSS measurement method in areas where the national control is insufficient or the CORS base station cannot cover it. And combined with national A and B GNSS control points; the initial test can be completed with CORS. After the program is basically stable, the CPI is established and the test is completed (see Table 1).

Tab. 1 - Comparison of advantages and disadvantages of different processes in precision measurement control network

Process	Pattern	Advantages and disadvantages
Traditional measurement control	Establish an initial test control network in the initial test phase, and establish a fine test network once the line is stable.	The design and construction are out of line, and it is easy to produce problems such as large deviation of earth and stone volume and insufficient clearance of upper and lower crosses.
Specification recommendation process	Initially establish CP0, CPI, establish CPII after calibration	Affected by the instability of the program, a large number of CPI supplementary network construction work is required.
Suggest further adjustments	The initial control stage determines the framework control benchmark, and the initial measurement can be completed by CORS; after the scheme is basically stable, the CPI is established for the final measurement.	Economic and operational efficiency is more reasonable and feasible under the condition of precision guarantee

With the increasing accuracy of the national surveying and mapping geographic information, the density is getting larger and larger. Especially the construction of the continuous operation reference station system CORS is more and more mature, which brings great convenience and precision guarantee for the measurement work. In the precision measurement and control of high-speed railways, the traditional process system has already had certain defects, and some adjustments should be made during the implementation process.

CONTROL NETWORK

The current specification stipulates that the CPI Control Network will deploy one GNSS control point every 4 km. After the construction period and operation period, the loss of control piles may occur, which directly affects the retest stability judgment of the line control network CPII and the track reference network CPIII. This will further affect the long-wave irregularity maintenance of the track structure. Therefore, it is recommended that the CPI be buried in the area where the construction interference is small.

With the introduction of GNSS- Real-time kinematic (RTK) technology, offline construction with low precision requirements no longer relies on total station construction stakeout. The change of operation mode makes the requirement of communication between railway control outlets in local areas no longer a hard condition (Except for mountain tunnel sections). Similarly, the requirements for control points from the center line of the line should also be changed, and should focus on point maintenance and GNSS operations. Therefore, the network requirements of the GNSS control network should be optimized and adjusted in the specification limit: The CPI basic control network recommends that 1 pair be placed every 4 km (the vertical line direction should be laid as far as possible), and the spacing should be 50 to 1 000 m.; CPII line control network is recommended to be adjusted from the current 50 ~ 200 m to 200 ~ 400 m; CPII line encryption control points should be placed within the railway construction limit. When the control network is laid, the position of the surrounding control points should be fully considered, so that the distribution and control of the entire railway control network is more reasonable [2,3,4].

LEVELING NETWORK STABILITY CONTROL

The control network plane observation uses GNSS operations with less manual intervention and strong stability, and the results are more reliable. In the process of elevation measurement, there are many problems caused by national control standards, regional settlement, crossing tunnels, crossing rivers, etc. In the precision measurement and control of high-speed railways, the quality assurance of levelling and the reasonableness of data processing methods are essential. The analysis of the operational retest data of the completed high-speed rail shows that there are serious settlements in many sections, and even led to the railway speed limit. In these areas, if there is no stable control point, the control network retest will often fail to determine the stability of the control base. In order to perform deformation monitoring in these sections, it must be taken from a reliable stable control point (national bedrock point), which is often time consuming and labour intensive [5, 6].

There are no requirements for deep burial and bedrock points in the railway elevation control network in the Interim Provisions on the Measurement of the Passenger Dedicated Railway. During the implementation of the Beijing-Tianjin Intercity and Beijing-Shanghai high-speed railways, due to the complexity of the geological conditions along the line, there are number of uneven settlement areas. In some places, the surface settlement is very critical. Therefore, the control method of deep buried level base points is adopted. Repeated retests have proved that the deep burial point has significant anti-settling properties compared to the ground control standard, which provides long-term elevation reference support for railway operation, maintenance and monitoring. Therefore, the "High-speed Railway Engineering Measurement Specification" has the following requirements for deep-buried stone: In areas with uneven surface subsidence and geological conditions, it is advisable to set a deep burial level every 10 km and set a bedrock every 50 km. The bedrock levelling point and the deep-buried levelling point should use the stable bedrock levelling point and deep-buried levelling point buried by the state or other surveying and mapping units as far as possible [1].

Therefore, in areas with uneven surface subsidence and geological conditions, the bedrock standard point should be used as a high-level control point of the line level base point, one for every 50 km. The deep burial level is the same level control point of the line level base point, but it is better than the general level point anti-sedimentation. The retesting process of the control network can be used as an important basis for judging the stability of the section. The deep buried level can be replaced by a stable old building foundation and a large abutment foundation. The bedrock and benchmarks buried by the state or other surveying and mapping units can also be selected as deep buried control piles [7,8,9].

TREATMENT OF LEVEL CONTROL NETWORK AFTER LONG TUNNEL

The high-speed railway precision measurement control network is usually established during the survey and design stage. When crossing large rivers and long tunnels, the level is measured by means of bypass observation or cross-river observation. After the construction of the bridge pavement is completed or the tunnel is penetrated, for the levelling measurement, new conditions are generated. Take the elevation control of a mountain railway tunnel as an example: the designed tunnel length is about 10km, which is affected by the ground shape and traffic conditions, and the standard bypass route reaches 100 km. According to the second-class observation method, the difference of the line closure difference before the tunnel penetration is 40. 0 mm; after the penetration is limited to 12.6 mm, the height of the fine measurement network may be broken after the tunnel is penetrated [10, 11,12 and 13]. If no additional considerations are made in the previous period, even then the precise measurement of the tunnel section before the tunnel penetration measurement will have a greater impact on the later construction. Therefore, under such special construction conditions, special design of the precision measurement of the work site must be carried out as follows [14]:

(1) According to the standard bypass design observation results, the closure difference between the elevation control points at both ends of the tunnel is calculated.

(2) Estimate the closure difference between the elevation control points of the two ends after the penetration of the inclined well, the penetration route and the level tolerance; the total error of the level measurement per km is calculated by the following formula:

$$M_w = \sqrt{\frac{1}{N}\left[\frac{WW}{L}\right]} \tag{1}$$

Where W is the correction of the level ring after various corrections/mm;

L is the level ring circumference /km;

N is thethe number of levels.

According to formula (1), take MW = 2, N = 1, L = 10, then calculate the level closure difference W = 6. 3 mm;

(3) Calculate the maximum breaking height value generated under the most unfavourable conditions:

$$H_{closure} = H_{bypass} + H_{Through} \tag{2}$$

The high-level adjustment section should be reserved for the construction of the loft and the construction of the ballastless track.

（4）After the completion measurement is conducted, the construction cut height is set according to the closed measurement level closure condition. In addition, it is coordinated with the two ends of the fine measurement net in the local range. In the as-built measurement, the entire line of precision measurement control network unified adjustment, eliminate the height, and re-measure and evaluate the line condition according to the latest fine measurement network results, and if necessary, carry out the secondary design of the vertical curve.

Similar situations include: Measurement of the construction level of large rivers and rivers across rivers; construction of ballastless (without ballast) transition sections (fine adjustment of ballast plate construction, front and rear alignment after installation of turnouts); elevation measurement of subway sections.

CONCLUSIONS

The "High-speed Railway Engineering Measurement Specification" has been promulgated and implemented for nearly 10 years. With the development of surveying and mapping science and technology and the transition of the trunk line project from the construction period to the operation period, it should be further improved to establish a complete mapping basis for system authority. It is still necessary to further study how the results of the testing and re-testing of the control network can be more effectively and safely applied to the fine adjustment of railway engineering and improvement of the level of smoothing and optimization of the line. In summary, it is necessary to carry out further systematic research on China's high-speed iron precision measurement and control technology, which helps to ensure the measurement accuracy of high-speed railway, improve measurement efficiency and quality during construction and operation. Moreover save costs, and have obvious social economy benefit.

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