Research and Development of a Fine-Tuning Information Management System for Slab Ballastless Track

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Abstract

CRTS III slab ballastless track is a new type of slab ballastless track with completely independent intellectual property rights in China. As a novel structure for on-line construction of passenger dedicated lines, a complete set of construction technologies has been established. With the advancement of high-speed railway technology, the application of CRTS III slab ballastless track will become increasingly widespread. At present, the continuous adoption of emerging technologies such as BIM, Internet of Things, and big data has led to continuous improvement in the refinement, informatization, and scientification of on-site construction management. The development of an information management system for precision adjustment of slab ballastless track, which can store data from the track slab installation and construction process in a truthful, complete, and timely manner, and subsequently analyze and apply such data to achieve genuine whole life cycle management of slab ballastless track construction, holds significant value for construction guidance and technical research.

Full Text

Research and Development of a Fine-Tuning Information Management System for Slab Ballastless Track

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Abstract CRTS III slab ballastless track is a new type of slab ballastless track for which China possesses fully independent intellectual property rights. As a new structure for on-line construction on passenger-dedicated lines, a complete set of construction techniques has already been summarized. With the development of high-speed railway technology, the application of CRTS III slab ballastless track will become increasingly widespread. At present, with the continuous application of new technologies such as BIM, the Internet of Things, and big data, the refinement, informatization, and scientific level of on-site construction management are constantly improving. The development of a fine-tuning information management system for slab ballastless track can truthfully, completely, and promptly store data from the track-slab installation and construction process, and can analyze and apply those data, thereby realizing true full-life-cycle management of slab ballastless track construction. It has great value for construction guidance and technical research.

Keywords slab ballastless track; fine-tuning; informatization; full cycle

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1 Research and Development Background

CRTS III slab ballastless track is a new type of slab ballastless track for China's railway engineering technology. It was developed through introduction, digestion, absorption, and innovation based on mature experience at home and abroad, and China has fully independent intellectual property rights for it. It has already been promoted and used on passenger-dedicated lines such as the Chengguan Line, Wuhan Intercity Circle, Chengdu–Mianyang–Leshan Passenger Dedicated Line, Panjin–Yingkou Passenger Dedicated Line, Shenyang–Dandong Passenger Dedicated Line, and Beijing–Shenyang Passenger Dedicated Line. With the development of high-speed railway technology, the application of CRTS III slab ballastless track will become even more extensive.[1]

As a new structure for on-line construction on passenger-dedicated lines, CRTS III slab ballastless track has, through test simulations and experience summarized during construction, already led to the exploration of a complete set of construction techniques.[1] However, when summarizing previous experience in slab ballastless track construction, we still found many problems urgently needing to be solved. For example, the production quality of track slabs cannot be monitored effectively in real time, resulting in a small number of nonconforming slabs entering the construction site; irregular storage of track slabs causes some track slabs to warp and deform; the data on warping deformation cannot be organically combined with track-slab fine-tuning data, increasing the difficulty of on-site fine tuning; there is no mature software for analyzing the post-grouting smoothness inspection data of track slabs, resulting in replacement of track fasteners over a relatively large range and causing certain economic losses to the construction unit; and the lack of real-time and effective data monitoring at the construction site creates hidden hazards for construction quality and construction safety.

In order to monitor more effectively the quality of track slabs produced by the track-slab plant, the laying quality and accuracy of track slabs during the construction stage, and the construction progress of each construction unit, a set of fine-tuning information management system for slab ballastless track was developed. This system enables management, design and research personnel, and technical personnel to grasp the true conditions at the construction site in real time; truthfully, completely, and promptly stores the process data of track-slab installation and construction; and analyzes and applies these data. It therefore has great value for construction guidance and technical research.

2 System Concept

To realize refined management of the fine-tuning construction process for CRTS III ballastless track slabs, the process data of "on-site detection of track-slab warping, fine tuning, post-grouting re-measurement, and smoothness inspection"

Figure 1. Data architecture of the slab ballastless track fine-tuning information system

Figure 1: Figure 1. Data architecture of the slab ballastless track fine-tuning information system

are centrally analyzed and managed, so as to make construction process control visualized, scientific, and refined. At the same time, before long-rail fine tuning, data collected from sleepers are used to predict the types of fasteners required for each sleeper, improving the accuracy of on-site fastener allocation plans and the pertinence of fastener installation, and reducing the replacement rate of fasteners during the long-rail fine-tuning stage. After completion of long-rail fine tuning, the sleeper fastener types are associated with RFID, thereby realizing full-cycle management of track-slab fine tuning and subsequent construction processes.

Based on the above concept, and according to the idea of big data, an information management system is constructed by combining technical means such as computers, BIM, and the Internet of Things. The overall concept of the system is shown in Figure 1:

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Figure 1 Data architecture of the slab ballastless track fine-tuning information system

3 Management Architecture

According to the system functional architecture, the system is oriented toward managers of slab ballastless track construction. Therefore, at the management level it is divided according to "line—owner—design, supervision, and construction units (including work areas)—administrator and supervisor." According to the different roles of managers, different functions are assigned. In terms of system functions, the system mainly displays the progress of engineering construction, the quality qualification status of the project, comparisons of data between construction processes, and Internet of Things information on fasteners. On this basis, the overall management architecture of the system is established, as shown in Figure 2.

Figure 2 Module architecture of the slab ballastless track fine-tuning information system

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4 Functional Introduction

According to the overall design of the system functional concept and management architecture, the entire information management system can be divided into five major functional modules. The specific contents are as follows.

4.1 General Functional Module–Section Management

The system manages users according to their permissions. Different permission levels correspond to different login interfaces. Administrators have the highest authority and can perform operations such as setting line information, assigning accounts, setting tolerances for each process, and configuring the management structure.

Managers of each bid section can assign several work-team accounts according to the work conditions of each bid section. Work-team accounts are managed by the team leaders, who are responsible for data inspection, uploading, and processing of over-limit information, so as to ensure that data are uploaded in a timely manner.

4.2 General Functional Module–Viewing Data in the Fine-Tuning Stage

The system can be used to view track slab inspection data, fine-tuning deviation data, inter-slab deviation data, re-measurement data, and smoothness inspection data; to compile statistics on the floating condition of track slabs and the warping condition of track slabs after grouting for each bid section and for the whole line; and to generate corresponding statistical analysis results to guide track fine-tuning.

Through smoothness inspection data, the quality status of track slab fine-tuning can be analyzed, and the track adjustment amount in the long-rail fine-tuning stage can be calculated, providing a basis for estimating the workload of subsequent track adjustment. The system can also evaluate the Track Quality Index (TQI).

4.3 Special Functional Module–Track Slab Warping Correction

Using front-end acquisition software together with precision tooling and inspection mirrors, on-site inspection of track slabs is carried out (the inspection principle is consistent with that of the slab yard' s factory inspection). The inspection results are uploaded to the information platform with one click, and the platform analyzes the warping condition of the track slabs. When the warping value does not exceed the specification requirements, the track slab warping is qualified, and the track slab fine-tuning correction value generated by the platform is zero; when the warping value exceeds the specification requirements, the platform will, according to the track–

The track-slab fine-adjustment correction values generated from the slab warping condition.

The track-slab fine-adjustment correction values generated by the platform can be transmitted in real time to the front-end track-slab fine-adjustment software. In view of the possibility of poor network connectivity on site, the front-end acquisition software is also synchronously configured with a warping-analysis function; the generated warping correction values are automatically added to the track-slab fine-adjustment parameters to guide track-slab fine-adjustment operations.

Fig. 3 Visualization interface for track-slab warping detection

Track-slab warping detection should generally be carried out after the slab has been manufactured. In view of the influence of warping in CRTS III slab-line track slabs on track-slab fine adjustment, the system incorporates track-slab warping detection operations after rough track-slab placement and before fine adjustment. Based on the measured coordinate data of the center of the track-slab bearing platform, the optimal plane is fitted, and track-slab warping correction parameters are obtained. These are then used to guide track-slab fine adjustment, thereby accelerating the speed and improving the accuracy of track-slab fine adjustment, as shown in Fig. 3.

4.4 Special Function Module–Comparative Analysis of Data after Fine Adjustment and Grouting

During self-compacting concrete grouting, factors such as insufficient clamping pressure, over-grouting, and loosening of the fine-adjustment devices may cause the displacement of the track slab to exceed the specification requirements; therefore, remeasurement is necessary. By comparing the remeasured data with the fine-adjustment data, the upward floating amount of the track slab can be directly reflected, and the relationship curve between the clamping pressure of the compression tooling and the upward floating amount can be analyzed.

Through analysis of large quantities of data, the relationship curve between clamping pressure and upward floating amount can be used to eliminate errors in the construction tooling system during the fine-adjustment stage and improve the overall construction quality of the track slab, as shown in Fig. 4.

Fig. 4 Comparative analysis interface for fine-adjustment and remeasurement data

Fig. 5 System material-planning table

4.5 Featured Function Module–Pre-configuration of Fasteners In previous CRTS III slab ballastless track construction processes, the analysis of fastener configuration was generally carried out during the long-rail fine-adjustment stage using a track-inspection trolley. The main focus was the track quality index (TQI). That is, when laying the rails, factors such as production errors of the track slab and construction deviations were not considered, and the fasteners all adopted the standard design model. In the long-rail fine-adjustment stage, the track geometry was adjusted by replacing base plates and limit blocks. This process easily resulted in substantial waste of fasteners and base plates, and also caused certain omissions in the conventional fine-adjustment stage.

The information management system moves this operation to after grouting and before long-rail laying. Using fine-adjustment frames, total stations, and precision levels, it collects sleeper-by-sleeper data on the coordinates of the rail-seat center, taking into account geometric parameters such as gauge, level/superelevation, alignment, profile, alignment/profile short-wave irregularity (checked with a 30 m chord and 5 m chord), alignment/profile long-wave irregularity (checked with a 300 m chord and 150 m chord), twist, gauge variation, level/superelevation rate of change, and alignment/profile rate of change. It analyzes and predicts in advance the types of fasteners required sleeper by sleeper, provides a fastener pre-configuration plan, minimizes fastener replacement during the long-rail fine-adjustment stage, and improves the accuracy and pertinence of the fastener procurement plan.[2]

The fastener pre-configuration plan is calculated so that all output data are consistent with the dynamic inspection trolley; the generated fastener configuration table can directly guide on-site construction.

5 Conclusion

At present, the system has completed testing on some sections of the Beijing–Shenyang Passenger Dedicated Line, the Nanchang–Ganzhou Railway, and the Guangqing Intercity Project. All system functions have basically been implemented, and the data acquisition and analysis functions operate normally.

The slab ballastless track fine-adjustment information management system displays, manages, and analyzes track-slab inspection, fine adjustment, remeasurement, smoothness inspection, sleeper-by-sleeper fastener types, and related RFID information sets during the on-site installation process of slab ballastless track. While improving the refinement and informatization level of construction management, the big data generated during construction can also be connected with the railway engineering management platform and serve the line operation and maintenance stage, thereby realizing, in the true sense, full informatization and whole-life-cycle management of slab ballastless track construction.

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Development of Delicate Adjusting Information Management System for the Slab Ballastless Railway Track

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Abstract: CRTS III slab ballastless railway track is an innovative slab ballastless track with completely independent intellectual property rights of China. As a new structure type of line construction for passenger special line, a complete set of construction techniques has been summed up. With the development of CRH (China Railway High-speed) Technology, the application of CRTS III slab ballastless railway track will be increasingly more extensive. Currently, with the continuous application of new technologies such as BIM (Building Information Modeling), IoT (Internet of things), big data, and etc., the construction site management is also improving in refinement, information, scientific degree. The development of delicate adjusting information management system for the slab ballastless railway track enables the storage of the construction data in track plate installation process in a true, complete and timely manner, which is later used for analysis and application to realize the full life cycle management of slab ballastless track construction in real sense. The system is of great construction guidance value and technical research value.

Key Words: Ballastless Track; Delicate Adjusting; Informatization; Lifecycle