Innovation and Practice of Engineering Quality Management in Comprehensive Test Section of Datong-Xi'an High-speed Railway

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Abstract: The main line of the comprehensive test section of Datong-Xi'an High-speed Railway is 86.666 km long and has 3 stations including Yuanping West Station, Xinzhou West Station, and Yangqu West Station. To sustain both operational testing at the speed of 350 km/h and scientific tests of new technologies, adaptive reconstructions such as the application of communications, signals, and electrification have been completed, and technical reconstructions such as Polyurethane Reinforced Ballasted Track and CRTS I Vibration-damping Double-block Ballastless Track have been carried out. Therefore, the test section provides an important experimental environment and favorable testing conditions for the comprehensive test of high-speed railway. The engineering of the section, featuring complex organization and management, wide-range quality management, considerable quality-influencing factors, difficult and high-risk construction, has innovated the concept of quality management and proposed measures such as total quality management and Refined Quality management based on three major theories of Zero Defects, Total Quality Management, and Refined Quality Management. The engineering has achieved remarkable results in quality management: no accident due to negligence or poor quality occurred in construction, the organization is efficient, the test data is accurate and reliable, and the engineering is 100% qualified for the final acceptance.

Keywords: high-speed railway; Datong-Xi'an Railway Passenger Dedicated Line; quality management; engineering management

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To enhance China's innovation capability in high-speed railway technology, improve railway technical standards and advance the progress of independently-developed key technologies and equipment for high-speed railways, the former China Railway Corporation has decided to build a comprehensive test section between Yuanping West Station and Taiyuan North Station of the Datong-Xi'an Passenger Dedicated Line, thus delivering an experimental environment for China's self-developed materials, technologies, equipment, and processes. Among comprehensive railway tests conducted over the years, the one conducted in Datong-Xi'an Passenger Dedicated Line emerges as the largest in scale, longest in duration, most comprehensive in specialties, and most difficult one [1]. It has achieved a series of technological innovations, which are of great significance to China's Going Global strategy for its high-speed railway. The engineering of the test section is different from conventional railway construction[2], for it has realized the integration of scientific experiments and engineering construction, involves the development, testing, application, and promotion of new materials, technologies, equipment, and processes, and faces great challenges in engineering quality management. Given this, a variety of management measures have been adopted in line with the quality management system, which provides a strong guarantee for engineering quality and helps promote the completion of testing tasks.

1 Engineering Overview

The comprehensive test section of Datong-Xi'an High-speed Railway has three stations, Yuanping West Station, Xinzhou West Station, and Yangqu West Station. It starts from Yuanping West Station K164 + 800 (DK166+800) and ends at the abutment tail of Xiezi Village Bridge K251+466 (DK253+436). The mainline is 86.666 km long, the minimum curve radius is 4 000 m, and the maximum slope is 30%. Besides, there are 7 tunnels in the comprehensive test section with a cumulative length of 20.827 km, as well as 12 grand bridges and 21 large and medium bridges on the mainline. The entire route is paved with CRTS I Vibration-damping Double-block Ballastless Track.

To sustain both operational testing at the speed of 350 km/h and scientific tests of new technologies, 23 renovation projects have been carried out, including adaptive reconstructions (communications, signals, and electrification) and technical reconstructions (Polyurethane Reinforced Ballasted Track and CRTS I Vibration-damping Double-block Ballastless Track). After more than one year of adaptive reconstructions, relevant construction tasks have been completed, which provides an important platform for the comprehensive tests of high-speed railway.

2 Features of engineering quality management

Although there is not much construction in the comprehensive test section, the engineering still faces great uncertainty in scientific experiments, difficulty in engineering quality control, and complexity in tasks of comprehensive test, so it is necessary to overcome construction difficulties and comprehensively strengthen quality management [3-4] to ensure quality and safety of the engineering and complete test tasks. The engineering has the following features:

(1) Complex engineering organization and management. Participation units of survey, design, construction, supervision, supply, test initiating, test supporting, measurement and consulting, third-party inspection, and other specialties are involved. Therefore, the engineering organization and management encounter great challenges when facing blending specialties, cross-functional coordination, and parallel tasks of scientific experiment and engineering construction.

(2) Wide-range engineering quality management. Engineering quality management involves quality control of survey, design, construction, scientific experiment, analysis of test data, acceptance of works, operation management, and other aspects. The quality control of each link determines the accuracy and reliability of test data.

(3) Considerable quality-influencing factors. The quality of railway engineering is directly or indirectly influenced by survey, design, materials, machinery, physical environment, operation methods, test methods, technical measures, management systems, quality of constructors, and other factors. In particular, there are lots of uncertainties in scientific experiments. Once the test items and methods are adjusted, factors of engineering quality control will also change accordingly.

(4) Difficult and high-risk construction. Engineering reconstruction in the comprehensive test section entails innovations and faces considerable difficulties such as the lack of on-site construction experience involving Four New Techniques (new technique, materials, process, and method), immature quality control methods, and unstable construction quality. Besides, comprehensive tests of the earthquake early-warning system remain insufficient and the first proposed set of testing methods of earthquake early-warning system for high-speed railway still needs continuous improvements. Therefore, quality management of the engineering encounters risks.

3 Engineering Quality Management Theory

Based on the three major quality management theories of Zero Defects, Total Quality Management, and Refined Quality Management, innovative measures have been proposed and objectives for quality management have been updated.

Zero Defects, first introduced by Philip Crosby in 1970s, defines Quality as a state of assurance to requirements, emphasizes Doing Things Right the First Time, highlights the prevention and control of quality problems, and seeks to eliminate unproductive work through cultivating the staff's quality awareness and improving process and techniques.

Total Quality Management is a

quality-focused process developed by the General Electric Company. It aims to ensure all associated employees work toward the common goals, involves the entire process of development, design, production, sales, and service, and forms a quality management system where each management level or department of the enterprise is assigned with respective responsibilities for product quality.

Refined Quality Management is to transform extensive management into a sequenced, normalized, standardized and refined one, and turn traditional empirical management into a scientific one. It allows managers to follow systematic and quantitative planning schemes instead of relying on management experience and enables managers to deal with problems accurately and normatively according to schemes, which help achieve precise positioning, careful planning, standardized construction, and persistent improvement.

4 Engineering Quality Management System

In the practice of quality management, the guiding ideas need to be updated and management be comprehensively strengthened; in the positioning of engineering quality responsibility, the concept of responsibility for the whole life cycle should be established and the awareness of long-term responsibility for engineering quality be enhanced; regarding the engineering quality management objectives, Zero Defects is taken as the standard, that is, the standard is evolved from Basic Conformity into Zero Defects; in terms of management methods, extensive administrative management should be transformed and the priority of management be shifted from ex-post evaluation to strict control of process standards and prevention of common engineering quality problems; in terms of work, with Total Quality Management as the management method, a proper balance is to be struck between the construction period and quality, quantity and quality, cost and quality, main engineering and protection engineering, key processes and general processes. Besides, under the guidance of engineering quality concepts, comprehensive quality management that involves all staff and the whole process is to be implemented and practices of engineering quality management be carried out.

4.1 Building a quality assurance system

A responsibility system that takes the project undertaker as the core of quality control and participation units as the main body of quality responsibility has been established, thus forming a work pattern where each unit carries out its duties and cooperates closely with others. According to the division of quality responsibilities, the project undertaker, design unit, test-initiating unit, supervision unit, and construction unit shall respectively establish corresponding quality assurance systems in the early stage of engineering construction, construction preparation period, engineering implementation period, project final acceptance, test period, project recovery period and quality warranty period to implement quality responsibility of relevant units.

Datong-Xi'an Railway Passenger Dedicated Line Co., Ltd. (DaXi PDL for short), as the project undertaker, shall complete the construction of the test section on schedule and ensure construction quality. During the test, it needs to provide support and guarantee work.

China Railway Taiyuan Group Co., Ltd. (Taiyuan Group for short) is responsible for the specific organization and implementation of comprehensive tests as well as safety management. During the test period, it should strictly implement rules and regulations, carefully organize various tests, and ensure that no driving or personal accidents occur.

China Academy of Railway Science Corporation Limited takes the lead in the test. Before the formal test starts, it should ensure that the sensors are pre-embedded, test points are installed, and the test system works normally; during the test, it is responsible for the collection and analysis of test data; while ensuring all tests are completed, it should strengthen the comparative analysis of measured data and theoretical results and promptly submit test reports.

The equipment manufacturers shall ensure that the test equipment is safe, reliable, and in good condition, and timely install and debug the equipment according to the test plan to meet test requirements. During the test, the participants must obey the unified command of the Taiyuan Railway Bureau and strictly implement relevant rules and regulations to ensure driving and personal safety.

4.2 Strengthening quality awareness

Taking Zero Defects as the operating standard, no defects are allowed, and a perfunctory attitude is even more undesirable[5]. The participant units have put forward their own quality goals from the beginning, and have adopted various measures to strengthen quality awareness and assurance.

After the quality objectives are clarified before the engineering starts, the project department further decomposes the quality objective responsibilities and quality assurance measures into the operation team and on-site constructors, with particular attention to the role of constructors in controlling the engineering quality. Through participating in various forms of learning activities such as pre-construction post training, detailed technical disclosure, and improvement of safety awareness, on-site commanders at all levels have got to know how to manage the site and what effect to be achieved.

4.3 Refining systems and methods of quality management

Quality assurance entails the establishment and improvement of effective systems and methods. In conjunction with the Datong-Xi'an Passenger Dedicated Line and on the basis of national mandatory standards and relevant specifications of the former CHINA RAILWAY, a set of quality management systems and measures were formulated, including *Interim Measures for Routine Quality Assessment and Processing*, *Interim Measures for Closed Management of Rectifying Quality Problems*, *Measures for Investigating Quality Responsibility*, *Administrative Measures for Cadres Overseeing Key Processes*, *Administrative Measures for the Real-name System of Major Process Operations (Provisional)*, *Management Measures for Engineering Quality Commitment*, *Implementation Rules for Construction Quality Risk Management*, *Notice on Organizing the Acceptance of the Initial Workpiece (Pre-Station Engineering)*, *Implementation Rules for the First Engineering Evaluation of Post-Station Engineering (Provisional)*, *Interim Measures for Completion Test of Unit Engineering*, *Decision to Strengthen Quality Management of Engineering Entities*, *Implementation Rules for Inspection and Evaluation of Material Quality Management*, *Administrative Measures for One to Three Job Responsibility on Construction Site (Provisional)*, *Administrative Measures for Operation Guide on Construction Site, Weekly Meeting on Quality and Monthly Meeting on Scheduling*. Refined Quality management systems and methods provide strong support for the construction of the comprehensive test section.

4.4 Implementing comprehensive quality management

To ensure that the quality objectives are achieved, all participant units must implement comprehensive quality management across the entire process of construction and testing[6]. To ensure that the engineering quality is always in control, all construction and testing personnel must be fully involved. Besides, quality work must be strictly implemented with a high starting point, in line with high standards and in pursuit of high quality. A quality assurance system, where the commander is in charge, the division of labor is clear, the responsibility is assigned to each unit, should be established. Quality assurance measures should be formulated and dynamic monitoring of the entire process be implemented[7]. To achieve smooth communication of information, the centralized office should be implemented. To improve the organization of engineering quality management at all levels, a comprehensive quality management group needs to be established. To ensure orderly production and keep all the quality indicators under control, the participation units must strictly follow the operation instructions during construction, strengthen the process control, and adopt comprehensive quality management that involves all staff and the whole process.

4.5 Refined Quality management of engineering quality

As a kind of systematic management, Refined Quality management aims to continuously improve every process of management and give full consideration to the coordination among departments to achieve the optimal allocation of resources. Refined Quality engineering management is to grasp every construction link, assign responsibilities to every worker, and carry out every aspect of design, con-

struction, and later service in a fastidious manner [8-9].

(1) To formulate and implement the system of acceptance of the initial workpiece. Through the acceptance of the initial workpiece, construction technology, methods, and procedures are defined. Through on-site tests and demonstrations, unified comprehensive analysis of the various technical parameters, construction technology, methods, and procedures obtained is made, standards are determined based on a unified consensus, and operation instructions of the individual project are formulated for subsequent construction.

(2) To disclose technics before construction. It is to extend technical disclosure to every part and every procedure of engineering so that all the personnel involved in the construction can master the quality standards and key points. In the key process, to meet the test and acceptance standards, the system of supervision by engineers should be implemented, the quality of engineering be evaluated, and existing problems be rectified by on-site testers [10].

(3) To keep regular assessments and credit evaluation. To further strengthen engineering quality management and implement quality responsibility, the construction unit, in line with relevant regulations, should regularly evaluate the construction drawings of the design unit, conduct a credit evaluation of the engineering quality of construction and supervision units, and urge the participation units to implement contractual commitments.

(4) To keep regular quality inspection and evaluation. To mobilize the participation units to strengthen construction management and engineering quality, the project undertaker should implement monthly inspection, quarterly evaluation, and year-end comprehensive evaluation of engineering quality management. According to the relevant regulations and evaluation methods, the project undertaker is to organize the quality inspection and comprehensive evaluation of each participation unit and report the results to the departments of design, construction, supervision, and relevant departments of DaXi PDL in time. If necessary, the evaluation results shall be copied to their respective competent departments, and the awards and penalties shall be applied in accordance with the company's rules and regulations.

5 Conclusion

Strict quality control has been implemented throughout the engineering and remarkable results has been achieved: no accident due to negligence or poor quality occurred in the construction of the comprehensive test section of Datong-Xi'an High-speed Railway, the organization of testing is efficient, the test data is accurate and reliable, and the engineering is 100% qualified for the final acceptance. Through Refined Quality management, various participation units have formed scientific, mature, and highly-operable quality standards and construction process. The construction of the section has provided a test environment for China's independently-developed technologies, equipment, and processes, has accumulated experience for China's subsequent construction of high-speed railways, and has laid an important foundation for China's Going Global strategy.

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