Construction and Monitoring Technology of the Rotation of the National Highway 108 Bridge Crossing the Railway

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Abstract. Bridge rotation construction significantly reduces high-altitude work, lowers construction difficulty, and minimizes disruption to traffic below. At the same time, it enhances construction efficiency and improves overall safety. This paper takes the national highway 108 overpass of the Nantongtu Railway (K633+114.3) as an example, and carries out rotary construction of the bridge while monitoring and controlling the main stages of the construction process to ensure that the rotary structure is in a safe state during the construction process. During the preparation and construction process, real-time data was obtained through testing and monitoring, and the data was tracked and analysed in real time. Feedback data on elevation and internal force for subsequent stages was provided, which was used to guide and control the bridge rotation process to ensure that the bridge line and internal force met the design requirements and the bridge rotation construction was completed successfully.

Keywords: Cross-line bridges; Rotary construction; Rotary monitoring; Foundation pit monitoring; Engineering applications.

1 Introduction

With the rapid development of urban transportation in China, road interchanges have become an inevitable trend [1]. Particularly, when constructing new bridges above existing highways and railways, the construction process is not only constrained by the operation of existing traffic lines but also poses significant safety risks to these lines[2,3]. The primary safety risk is the hazards associated with high-altitude operations. Construction workers need to carry out hoisting and assembly at elevated heights, posing a risk of falling, while the lifting and installation of large components, as well as the erection of support structures, are susceptible to wind loads and vibrations, potentially compromising structural stability. Additionally, the construction process inevitably disrupts the traffic below, as falling materials or equipment may endanger passing vehicles and pedestrians, increasing traffic safety risks. To ensure construction safety and efficiency, partial road or railway closures are often necessary, which not only causes traffic congestion but may also affect nearby residents and economic activities. Moreover, limited construction space presents another major challenge. Performing construction above existing roads and railways requires precise control over the

G. Zhao et al. (eds.), *Proceedings of the 2025 8th International Conference on Traffic Transportation and Civil Architecture (ICTTCA 2025)*, Atlantis Highlights in Engineering 39,
https://doi.org/10.2991/978-94-6463-793-9_19

transportation, lifting, and installation of equipment and materials. The restricted workspace increases construction difficulty and imposes higher demands on construction techniques and equipment. Furthermore, vibrations, noise, and dust pollution generated during construction may impact the surrounding environment and railway operations, necessitating additional safety and protective measures, thereby further increasing construction costs and management complexity. Consequently, the rotational bridge construction technique has emerged and has rapidly developed in recent years, with its core technologies becoming key factors in ensuring engineering quality and construction safety [4-6].

2 Project Overview

The rerouting project of National Highway 108 from Xiangfen to Quwo to Houma crosses the South Tongpu Railway at Pier 11# to Pier 13#, with a total bridge length of 140 meters. The bridge alignment follows an easement curve, with the vertical curve arranged on the bridge. It has a radius of 10,000 meters and longitudinal slopes of 1.6% and -3.4%. The bridge is located in the Zhangli to Xiangfen section, with the railway mileage at the crossing point being K633+114.3.

The bridge span design consists of a 70m+70m rotational T-beam structure. The top segments of the rotational piers have span lengths of 67m+67m, with 3m cast-in-place closure segments on both sides. The bridge is connected by rotating counterclockwise by 54°. The main pier of the rotational bridge, Pier 12#, has a rectangular cross-section, with a pier height of 5m and a pier-girder integral structure. The pier body dimensions are 8.0m × 8.0m (longitudinal × transverse). Pier 11# is a transition pier with a frame-type structure, having a pier cross-section of 2m × 2m and a height of 7m. A reinforced concrete cap beam is installed on top. Pier 13# is a semi-ribbed abutment with four rib plates and a reinforced concrete cap beam.

The girder structure is a single-box, three-chamber design with variable height, variable cross-section, and straight web design. At the middle support, the girder height is 7.5m (along the girder centerline), while at the end supports, the height is 3.0m. The bottom plate adopts a circular curve transition with an R=32,625.0cm radius. The box girder has a top width of 25.7m, a bottom width of 20m, and cantilever slabs extending 2.85m. The site construction layout of the rotational bridge is shown in Figure 1.

Fig. 1. Rotational bridge construction site diagram.

3 Excavation Pit Monitoring

3.1 Foundation Pit Monitoring Point Layout

This project is adjacent to a railway, and during the excavation of the foundation pit, uneven displacement of the surrounding strata may occur, posing a potential threat to the structural safety of nearby buildings [7,8]. Such excavation activities may cause adverse effects such as soil displacement and deformation. During the excavation process, a large amount of soil is unloaded, leading to the redistribution of soil and water pressures, which disrupts the original balance system [9]. As a key factor in maintaining the new balance system, the retaining structure must withstand the redistributed soil and water pressures, resulting in displacement [10]. These displacement effects may lead to horizontal and vertical displacement changes in buildings and structures surrounding the foundation pit, thereby affecting their stability and safety [11,12]. Therefore, it is necessary to implement strict monitoring measures during the excavation process to track the displacement changes of the surrounding strata and structures in real time, provide early warnings, and take corresponding reinforcement measures to ensure structural safety and stability during construction [13]. The layout of the foundation pit and surrounding monitoring points for this project is shown in Figure 2.

The red-marked points represent the surface settlement observation points around the foundation pit, adjacent to the railway line, mainly monitoring any settlement changes in the surface soil on the railway side during excavation. The blue-marked points represent the observation points at the top of the foundation pit, primarily monitoring the horizontal and vertical displacement of the crown beam at the top of the pit. A high-precision total station (1s) is used for three-dimensional coordinate observation during monitoring of the foundation pit top, while a Trimble electronic leveling instrument (0.5mm) is used for settlement observation of the surface soil near the railway.

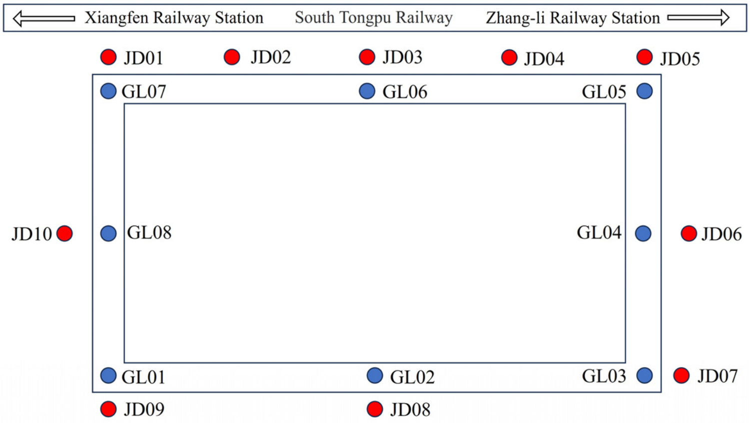

Fig. 2. Schematic diagram of the foundation pit and surrounding monitoring point layout.

3.2 Key Data Analysis of Foundation Pit Monitoring

The key data analysis of foundation pit monitoring is an essential step in ensuring construction safety [14,15]. During displacement monitoring, the collected data needs to be processed and analyzed to extract critical information, assess the stability and safety of the foundation pit.The changes in horizontal and vertical displacement at the top of the foundation pit during the monitoring process are shown in Figure 3, while the changes in surface settlement around the foundation pit are shown in Figure 4. The theoretical control values for each monitoring item are listed in Table 1. Through a comprehensive analysis of the monitoring data from the foundation pit of the main pier (12#) of the overpass crossing the South Tongpu Railway (633+114.3), as well as the comparison between the measured data and theoretical values, it is evident that all control indicators are within normal limits, and the foundation pit at the main pier is in a stable condition.

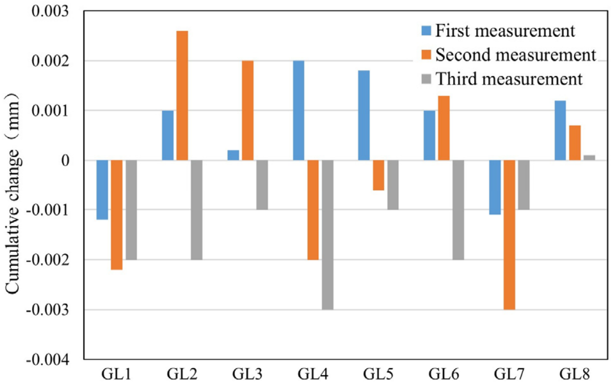

Fig. 3. Cumulative changes in horizontal and vertical displacement at the top of the foundation pit crown beam.

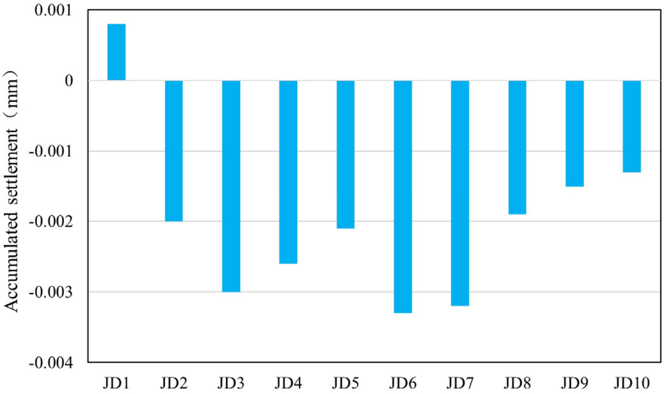

Fig. 4. Cumulative changes in surface settlement around the foundation pit

Table 1. Foundation pit monitoring data index control value.

Content	Prewarning value (mm)	alarm value (mm)	controlling value (mm)
Horizontal displacement of foundation pit top	±10	±15	±20
Vertical displacement of foundation pit top	10	15	20
Ground subsidence around foundation pit	15	20	25

4 Monitoring of Scaffold Deformation

The box girder is constructed using the cast-in-place method with scaffolding. Under the influence of self-weight and other construction loads, the scaffolding undergoes deformation, which includes both elastic and inelastic deformation [16]. The exact deformation of the scaffolding can only be determined through preloading tests [17,18].

4.1 Layout of Scaffold Monitoring Points

During construction, deformation monitoring of the scaffolding should be conducted. Monitoring sections are primarily arranged at the 1/4-span and 1/2-span positions of the bridge. Each monitoring section is equipped with six strain monitoring points and six settlement observation points to track strain and settlement changes in the scaffolding. Each span contains six monitoring sections, with each section comprising six measurement points. In total, the scaffolding for both the left and right spans of the bridge includes 72 strain monitoring points and 72 settlement observation points. The strain monitoring points and settlement observation points are positioned at the top and bottom of the scaffold columns, respectively, as illustrated in Figure 5.

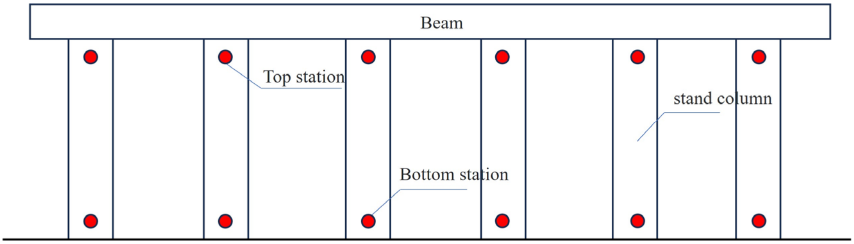

Fig. 5. Support deformation monitoring section measuring point layout diagram

4.2 Purpose and Data Analysis of Scaffold Preloading

The primary objective of scaffold preloading is to eliminate the inelastic deformation of the scaffolding and foundation by applying an initial load, thereby enhancing the load-bearing capacity and stability of the structure. This process not only effectively reduces internal stress concentration and minimizes potential failure risks but also ensures tighter connections between components, reducing the likelihood of leakage. Additionally, As shown in Table 2, preloading provides real-time measured data that can be used to verify the rationality of the design and optimize the construction plan [19,20].

Table 2. Precompression deformation data of A1 and A2 block support of main pier

AI			A2		
Measure point	Elastic deformation (mm)	Non-elastic deformation (mm)	Measure point	Elastic deformation (mm)	Non-elastic deformation (mm)
1# (Xiangfen direction)	9.8	2.9	1# (Xiangfen direction)	8.9	3.6
2# (Xiangfen direction)	9.5	2.7	2# (Xiangfen direction)	9.9	2.9
3# (Xiangfen direction)	9.6	3.3	3# (Xiangfen direction)	9.1	3.7
1# (Houma direction)	9.1	2.8	4# (Xiangfen direction)	10.1	2.6
2# (Houma direction)	10.2	2.7	1# (Houma direction)	9.3	3.4
3# (Houma direction)	10.4	2.5	2# (Houma direction)	9.7	2.8
			3# (Houma direction)	9.5	3.9
			4# (Houma direction)	8.7	2.6

4.3 Calculation of Formwork Elevation

The rationality and accuracy of the main girder's formwork elevation directly impact the linear smoothness of the girder and its consistency with design requirements [21,22]. When determining the formwork elevation, if the considered factors align well with actual conditions and are effectively controlled, the final bridge deck alignment will be in good condition. Conversely, if there is a deviation between the considered factors and actual conditions, and the control measures are inadequate, significant discrepancies may arise between the bridge deck alignment and the design alignment.

To ensure construction accuracy and that the bridge structure meets design performance requirements in its final state, it is essential to precisely calculate the camber of the main girder at various construction stages before formwork installation. It is important to note that the formwork elevation of the main girder is not identical to the final designed bridge elevation. Instead, a reasonable camber must be set to counteract deformations (such as deflection) occurring during construction. The calculation formula for the formwork elevation is shown in Equation (1):

$$\Delta_k = \Delta_s + f_y + f_z \tag{1}$$

$$f_y = f_d + \frac{f_1}{2} \tag{2}$$

In the equation: $\Delta_k$is the theoretical control value for the girder alignment during construction (the bottom formwork elevation); $\Delta_s$is the design elevation; f_y is the designed camber; f_d is the deflection caused by dead loads, including prestress, self-weight, secondary dead loads, shrinkage, and creep; f_1 is the deflection due to live loads; f_z is the camber of the support system, which is the negative value of the scaffold deformation, determined by combining theoretical values with measured data from preloading tests.

5 Linearity Detection

Considering the safety requirements of the main bridge spanning a railway, a construction scheme of "support first, then rotation into place" was adopted. Consequently, the stability of the entire structure during the rotation process is of paramount importance. In addition to the reasonable configuration of counterweights and the implementation of stable rotation construction measures as per design requirements, monitoring structural deformation enables early warnings of unfavorable deformations, thereby ensuring construction safety. Therefore, displacement monitoring of the main pier and critical sections of the main girder (such as beam ends and key nodes) is particularly important to maintain the overall stability and safety of the structure during construction.

5.1 Monitoring Point Layout

5.1.1 Benchmark Point Layout

At the junction between the main girder and the main pier, three benchmark points are established on the top surface of the girder, with one point designated for verification. During observation, a high-precision total station and a leveling instrument are used to transfer the coordinates and elevations of third-order or higher leveling network points to the benchmark points to ensure elevation measurement accuracy. Once the benchmark points are installed, they should be clearly marked and protected. During construction, these benchmark points serve as reference points for measuring the top elevation of the girder. Before each test, the benchmark points must be cross-checked, and periodic re-measurements should be conducted to maintain accuracy.

Since the bridge rotation process may impact the benchmark points, two additional benchmark points are set on the bearing platform. These additional points facilitate measurements during and after the rotation process, ensuring the accuracy and stability of elevation measurements throughout construction. This approach effectively guarantees the overall quality and safety of the bridge construction.

5.1.2 Alignment Monitoring Point Layout

For main girder alignment measurements, monitoring sections are set at each span support, mid-span, and the 1/4 span positions. Given the relatively wide bridge deck, the elevation measurements are controlled at six points along the transverse section of each girder segment, as illustrated in Figure 6. To minimize the influence of external factors, the monitoring points are positioned along the centerline of the section and near the inner side of the guardrail. A total of nine monitoring sections are arranged along the entire bridge, with six measurement points per section, resulting in a total of 54 main girder coordinate monitoring points. The layout of the main girder alignment monitoring sections is shown in Figure 7.

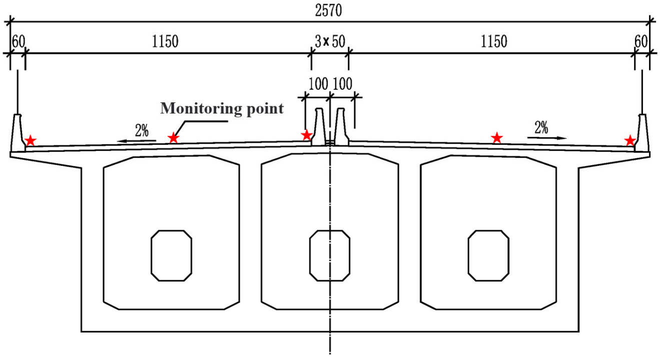

Fig. 6. Schematic diagram of linear measuring point arrangement of main beam

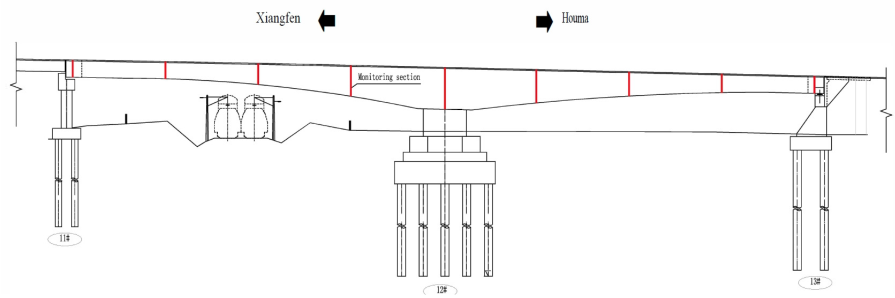

Fig. 7. Schematic diagram of linear monitoring section of main beam

5.2 Monitoring Key Points

The linear measurement of the main girder adopts a method combining linear through measurement and local block elevation measurement. After each construction cycle of a girder segment is completed, a comprehensive measurement of the elevation of the completed girder segment should be conducted. During key construction stages, through measurement should be carried out. This elevation measurement can effectively reflect the deflection changes of the main girder during the actual construction process, and the data obtained is an important basis for construction monitoring and analysis.

During the second-stage constant load construction stage, as the load is applied and adjusted, the frequency of observations should be increased to ensure timely grasp of the deformation situation.

The bridge deck elevations and other deformation values provided in the design for each stage are usually based on design parameters under a certain standard temperature. However, as construction often spans seasons and day and night, the separation process of structural deformation caused by temperature changes from the measured deformation values is rather complex. Therefore, when measuring, it is advisable to choose periods with smaller temperature variations to reduce the influence of temperature and sunlight on construction control. Generally, it is recommended to conduct measurements in the early morning or before sunrise, when the temperature is relatively stable, which helps improve measurement accuracy. Figure 8 shows the cumulative deformation of each monitoring point calculated from eight measurements at different times for this project. It can be seen from the figure that the cumulative deformation has reached a stable state in the last two days.

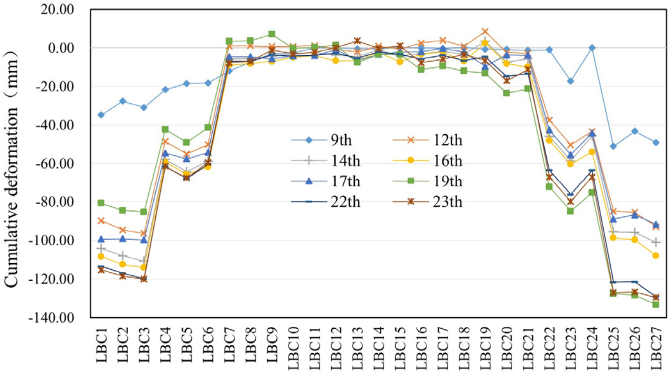

Fig. 8. Linear monitoring data curve diagram

6 Stress Monitoring

During construction, obtaining real-time and accurate information about the stress conditions at key sections of the main girder and main pier is crucial. This not only provides early warnings regarding the stress safety of the main girder but also allows for the verification of theoretical parameters, thereby providing a strong basis for construction control. Since the physical, mechanical, and time-related parameters used in design calculations cannot be entirely consistent with actual engineering conditions, the actual stress in the structure may not match the expected design results. Therefore, stress monitoring at the control sections of the main girder during the construction phase is particularly important. It provides reference data for both design and construction control, helping to ensure the safety and structural performance of the bridge.

6.1 Stress Monitoring Point Layout and Objectives

During the construction of the main girder, the girder body is subjected to a combination of axial pressure and varying bending moments [23]. Therefore, it is essential to install stress sensors at key control sections to monitor stress variations. Observations should be conducted before and after each construction stage, with timely monitoring during critical construction phases. Considering the structural stress characteristics, the construction features of the entire bridge, and the construction schedule, stress monitoring is performed at the pier tops and the 1/4-span sections of each main girder span.

The layout of the stress monitoring points for the main girder is shown in Figure 9. These sections primarily monitor the stress changes in the concrete bottom slab of the main girder during the construction process, system transformation, bridge deck paving, and subsequent operational phases. Implementing stress monitoring serves two main purposes: first, ensuring that the stress conditions at each section remain normal throughout the construction process and that the stress state stays within a safe and controllable range; second, providing a basis for adjusting construction parameters by comparing the monitored values with theoretical values.

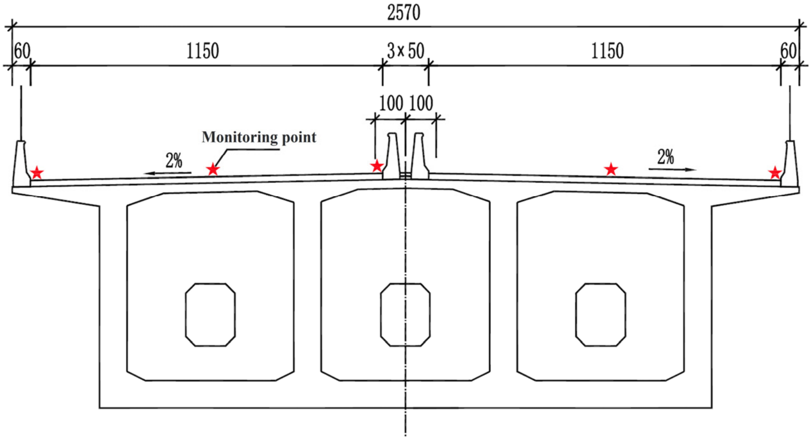

Fig. 9. Layout of Stress Monitoring Points for the Main Girder

6.2 Stress Monitoring Process and Data Analysis

The measurement points within the concrete bottom slab of the box girder are horizontally arranged along the longitudinal bridge direction. After being embedded in the structure, the installed sensors first record the initial values, and subsequent tracking observations are conducted based on construction progress. During each reading, both temperature and stress measurements must be recorded simultaneously. The monitoring results are promptly compiled to facilitate the analysis of the current stress conditions.

The stress monitoring data obtained through the embedded sensors are shown in Figure 10. The stress control value for this project is set at ±20 MPa. As observed in Figure 10, the stress variations during the construction process remain within the normal range.

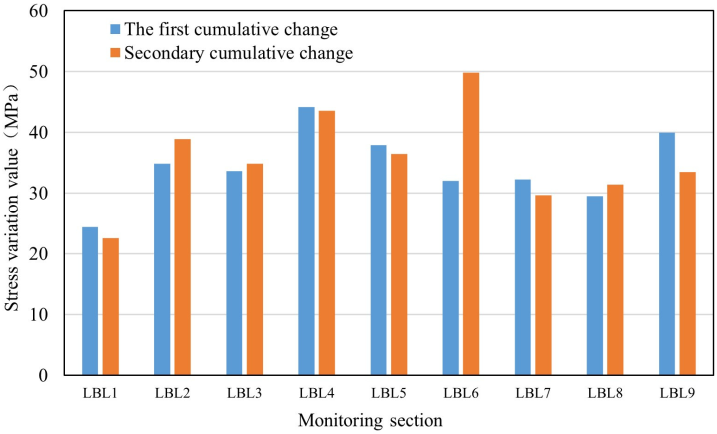

Fig. 10. Stress Monitoring Data

7 Rotation Monitoring

A trial rotation must be conducted before the official rotation, with a trial rotation angle set at 5°. During the trial rotation, a comprehensive inspection of the traction power system, rotation system, position control system, and anti-tilt safety system must be carried out to ensure the safety and reliability of the entire system. Meanwhile, monitoring personnel should collect initial data on the rotation system to establish the relationship between the rotation speed of the main bridge pier and the tangential velocity at the girder end. This preparation is essential for tracking the entire rotation process and ensuring that the rotation speed remains within the required range.

During the official rotation, it is crucial to ensure the structural safety of the bridge and the normal operation of the existing railway lines. This requires real-time monitoring of key parameters, including the starting torque, rotational torque, vertical displacement of the front end of the main girder, support displacement, rotational speed, transverse acceleration at the front end of the main girder, vertical vibration at the front end of the main girder, and stress changes in the controlled sections before and after rotation. Continuous monitoring of these key control parameters is essential to guarantee the safety and reliability of the construction process.

7.1 Rotation Monitoring Control Precision and Allowable Deviations

The control accuracy for various parameters during the rotation process is shown in Table 3.

Table 3. Rotation Control Index Error Table

Number	Program	Permissible variation

1	eight of cantilever end of main beam (mm)	±20
2	The main beam axis transverse bridge deflection (mm)	±10
3	Pier axis space deviation (mm)	±10
4	The relative displacement between the support foot and the guide rail (mm)	±1
5	Horizontal rotation axis inclination (%)	±3
6	Concrete stress (%)	±20
7	Rotational traction moment (%)	±3
8	Rotational angular velocity (rad/min)	0.02
9	Linear rotation speed of the cantilever end of the main beam (m/s)	2
10	Vertical acceleration of cantilever end of main beam (m/s)	2
11	Bridge site wind speed (m/s)	0.5

7.2 Main Girder Elevation and Axis Monitoring

A total of six monitoring points are arranged at the cantilever end, with four surrounding points used for elevation monitoring and two central points serving both elevation and axis monitoring. The arrangement of monitoring points is shown in Figure 11. A 360° prism is installed at the cantilever end of the main girder at both large and small mileage positions, as illustrated in Figure 12. One total station is placed on each side of the cap beam to conduct timed observations at 5-minute intervals, calculating the planar position and height changes of the front end of the main girder. By conversion, the rotation speed of the front end, as well as changes in elevation and axis position, can be obtained.

During the rotation process, if the vertical displacement at the cantilever end of the main girder exceeds ±50 mm, the cause of the displacement should be identified, and corrective measures should be taken promptly.

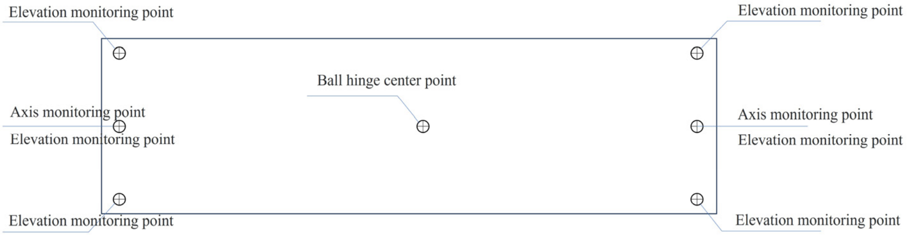

Fig. 11. Schematic Diagram of Main Girder Elevation and Axis Monitoring Points

Fig. 12. Installation Diagram of the 360° Prism at the Cantilever End of the Main Girder

7.3 Rotation Speed and Amplitude Monitoring

7.3.1 Rotation Speed Monitoring

Time measurement is conducted using a timer, while angle measurement is controlled by an arc length and angle observation scale set on the observation platform, As shown in Fig. 13. During the rotation process, the scale on the millimeter paper tape is observed to calculate the rotation speed, with the dial plate illustrated in Figure 14. The rotation speed during the process is crucial to ensuring the smooth movement of the structure, with the angular velocity controlled at 1°/min. When the structure is 100 cm away from the closure position, the rotation speed is reduced, and at 50 cm, continuous rotation is stopped. A step-by-step (jogging) approach is then used to precisely position the main girder.

Fig. 13. Dial Plate

7.3.2 Rotation Amplitude Monitoring

At the cantilever ends of the main girder at both large and small mileage positions, vertical and transverse acceleration sensors and vertical and transverse amplitude sensors are installed. The sensors used are 981B-type vibration pickups, as shown in Figure 14. During the rotation process, if the transverse acceleration at the cantilever end of the main girder exceeds 4.6 m/s^2, rotation must be immediately stopped, and the specific cause should be identified and adjusted accordingly.

Fig. 14. Main Girder Amplitude Sensor

7.4 Support Foot and Pier Inclination Monitoring

By monitoring the dynamic displacement and stress of the support feet, potential longitudinal and transverse overturning during the rotation process can be effectively prevented. Real-time monitoring of the gap variations between the support feet and the sliding track helps maintain structural balance, preventing sudden contact or detachment between the support feet and the sliding track. In practice, one displacement sensor is installed at each pair of support feet, working in conjunction with a dynamic strain gauge and data acquisition instrument to continuously track vertical displacement changes during both test rotations and actual rotation.

For stress monitoring, string strain gauges are embedded in each support foot, with eight measurement points set up. By monitoring stress changes, the internal concrete stress state of the support feet under rotation loads can be analyzed. When the support feet contact the sliding track, their stress varies, reflecting the eccentricity of the rotating structure. This provides a theoretical basis for center-of-mass adjustments and rotation balance control. Additionally, two inclinometers are installed on the turntable to monitor tilt angle variations, which reflect pier verticality changes. Monitoring covers multiple critical stages, including before and after the removal of temporary ball hinge fixation, load testing process, counterweight process, rotation initiation, posture adjustments, and before and after closure segment construction. During the rotation process, data is recorded every 5° to capture any critical parameter changes in real time.

7.5 Rotation Positioning and Locking

During the rotation process, angle scale markings are placed on the turntable to monitor the rotation position and prevent under-rotation or over-rotation. Additionally, inclinometers on the turntable provide real-time monitoring of the pier inclination changes. To ensure precise alignment with the bridge axis, total stations are set up on both side-span straight sections to verify the axis position. Once the centerline of the girder reaches the predetermined design position, a leveling instrument is used to measure the elevation of the cantilever end, and jacks are employed for posture adjustments, ensuring precise positioning.

The adjustment process includes the following key steps: slowing down the rotation 1 meter before the center axis closure, monitoring personnel reporting measurement data to the control station every 10 cm, stopping continuous rotation and switching to a step-by-step (jogging) approach when the remaining rotation distance reaches 50 cm, and after each jogging movement, measurement personnel recording the axis alignment status. Within the final 20-30 cm, to prevent over-rotation, adjustments are made to pier verticality and elevation. Pier verticality is adjusted using inclinometers, while elevation is monitored with a leveling instrument. The micro-adjustment system of the rotation structure fine-tunes elevation, ensuring elevation consistency between mid-span and side spans, with a tolerance within 5 mm. After positioning the axis and completing step-by-step adjustments, data is rechecked. If errors exceed tolerance, secondary adjustments are performed. Finally, permanent support feet and limit devices are installed to restrict structural rotation, ensuring construction safety and precision.

8 Conclusion

Based on the results and discussions presented above, this study provides a comprehensive analysis of the monitoring and control measures implemented in the bridge rotation process to ensure precision, stability, and safety. The findings highlight the effectiveness of real-time data acquisition, strict rotational speed control, and structural safety mechanisms in minimizing errors and preventing misalignment. The conclusions are as below:

(1) The rotation process involves a detailed monitoring system covering elevation, axis alignment, rotation speed, amplitude, support foot displacement, and pier inclination to ensure precise control and structural stability.

(2) Various sensors, total stations, inclinometers, and leveling instruments provide real-time data, allowing for immediate corrections to prevent excessive displacement, improper alignment, or structural imbalance.

(3) The rotation speed is strictly controlled at 1°/min, with gradual deceleration and step-by-step fine-tuning near closure to ensure accurate alignment and minimize errors within a 5 mm tolerance.

(4) Stress monitoring of support feet, pier inclination tracking, and the installation of permanent supports and locking mechanisms help maintain structural safety and prevent overturning or misalignment.

Future research could explore the integration of intelligent automation and AI-based predictive modeling to further enhance rotation precision and real-time decision-making. Additionally, the long-term performance of the bridge after rotation, including structural durability and maintenance requirements, warrants further investigation.

Acknowledgments

Thanks to all the authors for their contributions to the completion of this paper.

References

1. Ma Xingchuan. Current Development and Prospects of Skew Bridge Rotation Technology [J]. Railway Standard Design, 2020, 64(6): 92-97.
2. Xu Chao, Wang Changfeng, Dou Guokun, et al. Design and Anti-Tipping Stability Analysis of Temporary Bearings for Bridge Rotation Construction [J]. Railway Construction, 2018, 58(11): 50-52, 62.
3. Ba Huaiqiang. Application Research on Construction Safety Management of Large Rotating Bridges Based on BIM Technology [J]. Highway, 2023, 68(11): 86-92.
4. Bao Longsheng, Liu Xinran, Feng Xinran, et al. Mechanical Performance Simulation Study of Temporary Rotation Pier System for Large-Span Bridges [J]. Journal of Shenyang Jianzhu University (Natural Science Edition), 2024, 40(4): 690-696.
5. Chen Hongtao. Design of Asymmetrical Rotating Bridges Over Railways in Expressway Reconstruction and Expansion [J]. World Bridge, 2022, 50(2): 20-25.
6. Jian Fangliang, Xu Shengqiao, Gao Jingqing, et al. Key Technologies for Ultra-Heavy Rotating Bridges [J]. Railway Standard Design, 2021, 65(11): 179-184.
7. Gao Luheng, Zhang Taiyue, Zhou Feng, et al. Key Technologies for Post-Tensioned Prestressed Cross-Continuous Beam-Column Nodes in Prefabricated T-Beam Wing Slabs [J]. Building Structures, 2024, 54(16): 126-131.
8. Li Chunsheng, Zhu Deqing, Lu Jiufei, et al. Design of Health Monitoring Plans for Reinforced Small and Medium Span Bridges [J]. Building Structures, 2022, 52(S2): 1917-1923.
9. Yang Yongqing, Gao Yufeng, Huang Shengqian, et al. Research Progress in Bridge Construction Monitoring in 2020 [J]. Journal of Civil and Environmental Engineering (Chinese and English), 2021, 43(S1): 70-78.
10. Zhu Zhibao. Construction Monitoring Technology for the West Anchor Pit of the Nizhou Waterway Bridge on the Humen Second Bridge [J]. Bridge Construction, 2016, 46(5): 6-11.
11. Li Zelu, Li Xinwei, Li Huapeng, et al. Intelligent Monitoring Technology and Application of Rotating Bridges Over Railways Based on Cloud Monitoring Platform [J]. World Bridge, 2024, 52(4): 69-76.
12. Luo Jinbiao, Zhang Huanjing, Zhong Changyu. Construction Monitoring and Safety Analysis of Temporary Support Systems for Thin-Walled Pier Bridges—A Case Study of Gaozeng Bridge [J]. Science, Technology and Engineering, 2022, 22(34): 15284-15290.
13. Hao Changshun, Liu Baodong, Sun Wupeng, et al. Review on Research and Application of Health Monitoring Technology for Large-Span Railway Bridges [J]. Journal of Railway Science and Engineering, 2024: 1-25.
14. Wang Ningbo, He Zheng, Zhang Shengzhong, et al. Research on High-Precision Real-Time Prediction Method for Spatial Position of Rotating Bridges [J]. Bridge Construction, 2022, 52(5): 36-43.
15. Mao Liwei, Chen Yinwei, Yang Qizhi, et al. Experimental Study on Rotational Stability of Large Cantilevered Central Cable-Stayed Bridges [J]. Bridge Construction, 2023, 53(S2): 88-96.
16. Chen Feng, Li Xinwei, Li Zelu, et al. Key Technologies for Construction Control of the Xinyang Marshalling Yard Bridge Over the Beijing-Guangzhou Railway [J]. World Bridge, 2023, 51(4): 50-56.

17. Chen Shuli, Du Mingkang, Cui Chunkai. Study on the Influence of Uneven Sliders on the Dynamic Performance of Large-Span Rotating Bridges [J]. Railway Standard Design, 2024, 68(5): 89-96.
18. Duan Haisong, Liu Xu, Yao Lijun, et al. Research Status and Prospects of Anti-Tipping Technology for Skew Rotating Bridge Construction [J]. Railway Standard Design, 2024, 68(5): 97-105.
19. Huang Shengxiang, Yang Baocen, You Xinpeng. Application Research on GPS Dynamic Geometric Monitoring System in Bridge Construction [J]. Journal of Wuhan University (Information Science Edition), 2009, 34(9): 1072-1075.
20. Li Qianming, Ma Xingchuan, Zhang Peihui. Analysis of Reasonable Values for Rotational Angular Velocity and Angular Acceleration in Flat Rotation Bridge Construction [J]. Railway Construction, 2024, 64(2): 86-90.
21. Shang Haitao. Application Research on Flat Rotation Method in Railway Bridge Construction [J]. Journal of Railway Engineering, 2013, 30(1): 29-34, 84.
22. Li Tianping, Li Wenzhou. Stress Calculation of Spherical Hinge Contact Surface in Large-Span Bridge Rotation Systems [J]. Journal of Lanzhou University of Technology, 2023, 49(4): 122-128.
23. Sheng Guangzu, Qin Jiangang, Li Xin, et al. Causes and Analysis of Upper and Lower Spherical Hinge Misalignment Induced by Asymmetrical Rotation Construction [J]. Journal of Guilin University of Technology, 2021, 41(3): 560-566.