Research on the application of technology of replacing bridge Bearings without interrupting traffic

Guodong Qiao¹,*, Xin Gao², Kan Ren,¹ Jiangjiang Tao²

¹Beijing Xinqiao Technology Development Co., Ltd., Beijing, China
²Xinzhou Branch of Shanxi Highway Bureau, xinzhou, China

*Corresponding author: qiaoguodong@synqnc.com

Abstract. This article determines the bridge jacking plan and proposes a construction organization design without interruption of traffic, based on the research of bearing disease and cause analysis, bearing technical condition evaluation, jacking plan, traffic control, safety technical plan, quality acceptance and other related technologies. According to the evaluation result of the bearing technical condition, an implementation plan for replacing the support without interruption is established, whose rationality and necessity are verified by the support project.

1. The introduction
In the bridge structure, the bearing is the connection point of the upper and lower structures of the bridge. Its function is to safely transfer the load of the upper structure to the bridge piers and abutments, while ensuring that the upper structure is under the action of factors such as load, temperature changes, and concrete shrinkage and creep. Free deformation in order to make the actual force of the structure conform to the calculation diagram, and to ensure that the beam ends and pier cap beams are not damaged. Except for some special requirements, almost all newly built bridges adopt plate rubber bearings and basin rubber bearings. The processing level of my country's bearings has reached the international advanced level. With the increase in operating years, improper design and construction of some bridge bearings and the aging of the rubber bearings themselves, some bridge bearings have failed, deformed, and destroyed. At present, the damage of bridge bearings in my country has become a common phenomenon.

2. Cause of bearing disease and replacement principle

2.1. Cause analysis of bearing diseases
The most widely used rubber bearings in my country's bridges have failure modes such as voiding, excessive deformation, failure to slide normally, and cracks. The reasons for its disease and even failure include: damage to the simple support (oil felt, rubber pad, asbestos board, etc.), damage to the steel support itself, aging of the rubber support, poor quality of the rubber support, poor construction and maintenance management, The support design, type selection and layout are unreasonable.

2.2. Evaluation of bearing technical condition
According to the classification method of bridge components in the 《Standards for Technical Condition Evaluation of Highway Bridge》 (JTG/T H21-2011), and referring to the classification of
the deterioration grade of bridge bearings by the railway department, the bearing diseases are divided into five levels.

2.3. Principle of bearing replacement
If the rubber bearing reaches the failure condition, it must be replaced, and the bearing that has not reached the failure condition is mainly repaired. In order to ensure the safety and stability of the upper structure, the principle of the number of replacement supports is determined, and the uniform force and deformation of the supports after replacement are ensured.

3. Construction plan and implementation of bridge bearing replacement without interruption of traffic

3.1. Construction plan for replacing bridge bearing without interrupting traffic
The construction plan for replacing the bridge bearing without interrupting traffic mainly includes replacement plan design, jacking system selection, jack selection, jack layout principles and layout methods, traffic organization and safety technical plans.

1) Replacement scheme design
Including the principles, key points and design steps for the design of the support replacement scheme. The personnel involved in the plan, data collection and investigation, jacking equipment and methods, jacking force calculation and jacking height verification, jack selection and requirements, monitoring system design, etc.

2) Choice of jacking system
The composition, system characteristics, main technical indicators, and control principles of the synchronous jacking system.

3) Selection of jack
Select the matching jack according to the calculated jacking force and jacking displacement of each jacking point. The bridge jacking jack should be a plunger hydraulic jack. The working oil pressure range of the jack should match the working oil pressure range of the hydraulic pump. When working space permits, jacks prefer to use equipment with mechanical self-locking function to prevent accidental and sudden fall during jacking. In order to ensure reliable control of the system and clear force, it is advisable to select jack equipment with suitable capacity and avoid the use of "small and many" combinations.

4) The arrangement principle and arrangement method of the jack
The arrangement of jacking jacks should take into account the safety of the beam body and the operating space for support replacement. The resultant point of the jack layout in the longitudinal and transverse bridge directions should be coincident with the center point of the support, and placed as close to the support as possible. When installing jacking jacks, the upper and lower contact surfaces should be equipped with steel backing plates according to the results of the local pressure-bearing check calculations, and the vertical and horizontal slopes should be leveled. The upper and lower contact surfaces of the jack are ensured to be level by adjusting the wedge-shaped backing plate. In order to ensure that the leveling wedge-shaped backing plate does not appear obvious deformation under the action of large pressure, it must be dense and reliable between it and the base. In order to avoid excessive local stress from causing damage to the bridge structure, for the working top surface of the large tonnage jack, the method of installing thick steel backing plates should be adopted to redistribute the concentrated stress. Jacks should be arranged at the position of beam webs, ribs, and inner cross beams. It is strictly forbidden to arrange them in the hollows of box beams or slab beams. When the above requirements cannot be met, the distribution joist should be considered. The arrangement of jacking jacks shall be provided with lateral limit devices for bridges with large longitudinal and transverse slopes. If the jacking space of the pier is too small and the jacking jack cannot be arranged, an additional jacking support system should be designed.

5) Traffic organization and safety technology plan
The content of the traffic organization plan is to formulate the traffic organization during the replacement of plate bearings and basin bearings, as well as auxiliary measures to ensure smooth traffic. Develop a suitable traffic organization plan for the traffic control methods that need to be considered for the replacement of bearings without interrupting traffic. The construction safety technical measures stipulate the requirements of the equipment. Under the impact of live load and braking, the beam has a tendency to slip and overturn, and it is necessary to take measures to prevent the beam from falling.

3.2. Implementation of bridge support replacement without interruption of traffic

1) Construction preparation

Before the girder body is lifted, the technical status of the bridge foundation, pier abutment, main girder, bridge deck system and auxiliary engineering should be checked. Defects in the foundation, piers and upper bearing structures should be treated first. Determine the expansion joint pretreatment plan according to the bridge and jacking height. Set up temporary supports, reaction frames, and working platforms. The temporary support scheme should be specially designed, and its structural strength, rigidity and stability should be checked to ensure that the temporary support, reaction frame, and working platform have sufficient strength, rigidity and stability. The processing and installation quality of the temporary support shall meet the requirements of the design and related construction specifications. The top of the pier and abutment should be cleaned and leveled. If the top of the pier and abutment needs to be reinforced, a suitable method should be selected for reinforcement to prevent splitting and damage to the top of the pier and abutment during jacking. If there are defects or diseases in the cushion stone of the support, relevant preparations for repair or reinforcement shall be carried out.

2) Test item upgrade

The jacking equipment shall undergo periodic maintenance and testing before entering the site to ensure its normal working performance. The system sensor needs to be sent for inspection and verification and be within the validity period. The test jacking will test the linkage of the system and the sealing of the connecting pipeline. The jack needs to be loaded on the reaction frame to ensure that there is no leakage of all components. The test jacking should be carried out in stages. If abnormal operation of the system or pipeline leakage is found during the trial jacking process, the trial jacking operation should be stopped immediately, and adjustments should be made after unloading. After the trial jacking is over, provide the overall posture, structural displacement, etc., to provide a basis for the formal jacking.

3) Formal lifting

The initial condition of the original support should be recorded before the formal jacking. The formal jacking shall be carried out in stages according to the operating procedures determined in the support replacement plan, and the synchronization of the beam lifting displacement shall be the main control objective. During the lifting process of the beam body, special personnel should be sent to conduct key observations on various parts of the beam body, especially the hinge joints and the diaphragm. Confirm that no new structural cracks have occurred, and no further expansion of existing structural cracks has occurred. When an abnormality is found, the jacking should be stopped immediately and the cause should be analyzed. After the lifting height of the beam body meets the height of the support replacement, a temporary support should be selected at a suitable position around the original support, and the beam body should be returned to the temporary support to avoid long-term load on the jack. In the operable space for seat replacement, during the load conversion process, it should be ensured that the compression deformation of the temporary support should be within the set synchronization accuracy control value range.

4) Replace the bearing

When the beam is lifted into place and the temporary bearing is completed, the original damaged support is taken out. After the original support is taken out, the surface of the original structure should be cleaned. Check, repair or reinforce defective cushion stones and related auxiliary components, and the repaired or reinforced cushion stones shall meet the requirements of concrete design strength grade, size and flatness. When the original support backing plate is inclined, a wedge-shaped steel plate should be used to correct it to ensure that the support can receive the correct force. When the original support
backing plate is misaligned or out of place, it should be dealt with by the additional backing plate method to ensure the correct installation of the support and its function. The installation process of the support can refer to the relevant requirements of the new bridge construction code. Pay special attention to the need to correctly reserve the sliding space of the sliding support through structural analysis according to the temperature conditions during construction.

5) Drop beam
After the support is replaced and checked and confirmed, the beam can be dropped. The jack of the synchronous jacking system is started again to replace the load on the jack and remove the temporary support. Controlled by the synchronous jacking system, under the condition of ensuring the synchronization of the displacement, the beam body is slowly returned to the replaced support through the step-by-step beam drop method. After the beam body is reset, it is confirmed by continuous observation and inspection that each connecting surface is pressed tightly, and the position of each part is correct and working normally, remove the jacking system. Finally, remove the construction waste.

3.3. Construction quality acceptance of replacement of bridge support without interruption of traffic
The specifications, materials and production quality of the support must meet the requirements of the design and related specifications, and can be installed after passing the experience. The installation quality of the support should comply with the relevant regulations in the "Technical Specifications for Construction of Highway Bridges and Culverts" (JTG T F50-2011). After the support is replaced, it will be evaluated and accepted in accordance with the relevant standards in the "Highway Engineering Quality Inspection and Evaluation Standards" (JTG F80/1-2004). In addition to the above-mentioned relevant specifications and standards, the acceptance basis shall also refer to the original design drawings and bearing replacement design documents including bearing alteration design documents, bearing replacement construction and monitoring and other related materials.

4. Application examples
A bridge has a total length of 426.08m, and the superstructure is a 14-span prestressed reinforced concrete simple-supported T-beam with a standard span of 30m; the pier adopts reinforced concrete double-column piers, the abutment adopts reinforced concrete combined frame abutment, and the foundation is reinforced concrete Concrete bored piles; railings are provided on both sides of the bridge deck, the bridge width combination is 0.5m (guardrail) + 8.0m (carriageway) + 0.5m (guardrail), the full width of the bridge deck is 9.0m, and the net width of the bridge deck is 8.0 m. Asphalt concrete is used for bridge deck paving. The schematic diagram of the bridge layout is shown in Figure 1.
4.2. Equipment selection

1) Jack

According to the bridge height, the model is FY-RSM-100T-20mm. The 100T ultra-thin hydraulic jack has a body height of 86mm. This series of jacks are compact, flat and small in size. They are suitable for lifting and dismantling, especially for narrow spaces. For local use, this series of jacks can be directly placed between the bottom of the beam and the cover beam to complete the lifting operation.

![100T ultra-thin hydraulic jack](image)

**Figure 2.** 100T ultra-thin hydraulic jack

2) Oil pump

Adopt FY-EP-220 electric hydraulic pump (including pressure gauge), working pressure 70Mpa, flow rate 2L/min, fuel tank volume 34L.

4.3. Traffic control plan

Adopt a traffic organization plan that does not change the direction of traffic flow, closes a lane for continuous construction, and does not restrict vehicle traffic. Set a slow down sign at the bridge head to reduce the impact of the vehicle on the structure during the jacking and replacement of the support. During the lifting process, it is necessary to cover the steel plate at the location of the lifting bridge expansion joint to reduce the impact of the bridge deck elevation change on the construction process during driving.

4.4. Specific implementation methods

1) Construction preparation

Carry out construction technical disclosure and construction preparations; calculate the total weight of the bridge superstructure and deck system; record the position, number, and disease status of the replaced support on the spot, and take photos to record as the completion data; determine the jacking weight according to the superstructure and the model and number of jacks; measure the elevation of the bottom of the beam, and determine the adjustment height of the elevation of the top of the support cushion according to the measurement records.

2) Clean up the debris at the support and release excess constraints

Carefully record and check the conditions of the support, cushions, and steel plates, make records and photographs, accurately change the position and model of the support, determine the leveling height, and prepare a steel plate of the appropriate size.

3) Installation of construction equipment on site

Erection of supports and construction platforms; replacement of bridge abutments and use of platform caps as construction platforms; for replacement of bridge pier supports, use of cap beams as construction platforms.

4) Traffic control

Arrange the traffic control facilities, close the construction lanes, communicate smoothly on the bridge and under the bridge, fixed posts and personnel, and conduct comprehensive inspections.
5) Arrange jacks
The bridge has 4 T-beams for each span across the bridge, and each beam is a plate rubber bearing. The bridge is jacked up by a single-pier integral synchronous jacking method. At the same time, 8 pieces of lifting beams are required, 2 jacks are prepared for each support under each pier, and a 100T ultra-thin hydraulic jack is selected, a total of 16 sets. Dial gauges are arranged on both sides of the lifting bridge span to accurately measure the lifting height and control the lifting height of the beam body during the lifting process of the beam body. A special person is responsible for observing and recording the dial gauge readings during the lifting process; Debug the support jacking system to ensure its accuracy and synchronization.

6) Layout of monitoring points for monitoring stress and deflection
The dial indicator is placed near the root of the transverse beam to control the lifting displacement. Each beam is equipped with a dial indicator. The bridge pier is equipped with a displacement observation point to observe the displacement change of the consolidated pier. Two displacement observation meters are set at the bridge deck expansion joint. Point, observe the displacement change at the bridge deck expansion joint.

7) Trial lifting
The test jacking is carried out by system pressurization and classification. Push to about 50% of the calculated reaction force of the support, and hold the load for 5 minutes to check the safety of the jacking equipment. After there is no abnormality, the jack will fall back to its original position. Then stop when each lifting point of the beam has a displacement of 2mm, check the disengagement of all supports and the beam body, and measure the total weight of the beam body and the reaction force of each support at the same time; maintain the load state, and the load time will reach 5 minutes. Return the jack to its original position after abnormality.

8) Formal lifting
The signal commander sends out a "preparation" signal, and each is in position to prepare. After the "start" signal is sent, each oil pump will supply oil slowly and evenly at the same time, and follow the signal command. Double control is carried out with two indicators of jacking elevation (diameter) and oil pressure, and each jacking 2mm is the piston stroke step Length, 4mm is a control step, and the iron plate is placed once; each step and step stay for 1~2min, and the technician will comprehensively check and compare the working oil pressure and elevation changes of each beam for the next step of lifting. Properly adjust (the height error is not more than 2mm; the oil pressure error is not more than 0.5MPa, except for the side beams), gradually lift each beam body, and report the results to the command team immediately after reaching each level index; the safety inspector will also report The safety information in the area of responsibility is reported to the command team. Each level of operation must be performed synchronously. The height difference and oil pressure error must be strictly controlled within the error range. The error of the previous operation can be adjusted in the next operation until the beam as a whole is separated from the top surface of the support and continues to be lifted. The top surface of the support has a construction space of 5-10mm. Timely pad the support pads at the end transverse partition to ensure that each pad is stable and the pads are in place to maintain the hydraulic pressure of the jack.

9) Replace the bearings
Quickly take out the original bearings, remove the rust and dirt on the steel plate at the bottom of the original beam, apply lubricating grease, check the bearing cushion stone, polish and clean the surface of the cushion stone oil and scum. Measure whether the top surface of the cushion stone is level. If some of the cushion stone is uneven, use epoxy mortar to level it; if the top surface of some cushion stone needs to be lowered a little, use steel to chisel the part to the design elevation and use epoxy mortar Smooth out. Ensure that the allowable deviation of the top surface elevation of the support cushion stone does not exceed ±2mm, the height difference of the top four corners does not exceed 1mm, and the axis deviation does not exceed 5mm. Quickly put the new support back to the intended position accurately. After the bearings is placed and passed the inspection, the beam will be dropped.

10) Drop beam
When dropping the beam, in order to avoid collision with the support, a wooden board is inserted between the abutment or pier block on both sides of the beam body and the beam body to prevent horizontal displacement of the beam body when the beam is dropped, so as to ensure the accurate position of the support; The inverse process method also slowly lowers each beam of the same width according to the same step length and step during the lifting, which is conducive to the accurate positioning of the main beam and close contact with the support. After the beam body is in place, check the close contact between the upper and lower steel plates of the support and the cushion stone and the beam body to ensure that all the upper and lower surfaces of the support are closely adhered. After the replacement is completed, the temporary support is lifted, and the beam is placed in place sequentially. Observe changes in stress and mid-span deflection at various parts to ensure uniform jacking and no vertical and horizontal cracking of the upper structure.

4.5. Summary
Practice has proved that the construction method of continuous traffic replacement of the support is simple and convenient. It has accumulated valuable experience in dealing with bridge support diseases in the future. The construction team can be arranged to repair and replace at any time, which reduces the support in bridge operation. Maintenance costs avoid traffic jams and extend the service life of the bridge.

5. Conclusion
The bridge is an important part of the highway. As an important component, the support affects the safety of the bridge structure to a certain extent. The replacement of the damaged or failed support plays a very important position in the bridge reinforcement and reconstruction work. Compared with the traditional support replacement method, the technology of replacing the support without interrupting traffic has the advantages of non-stop traffic, shortening the construction period, saving replacement costs, and simple construction technology, and has certain popularization and application value.
Reference

[1] Code for Maintenance of Highway Bridges and Culvers (JTG H11-2004). China Communications Press, 2011.

[2] Standards for Technical Condition Evaluation of Highway Bridge (JTG/T H21-2011), China Communications Press, 2011.

[3] Fan Yehua, Chen Xiongfei. Construction Technology of Bridge Bearing Replacement without Interrupting Traffic [J]. Modern Transportation Technology, 2011.8

[4] Luo Wenlin, Chen Xiongfei, Wang Feng, Zhai Ruixing. Construction Plan of Synchronous Jacking up Technology in Bearing Replacement [J]. Modern Transportation Technology, 2010.12

[5] Yu Huinan. Application Research on Replacing Bridge Seat by Rising Whole Girder Board Synchronously [D]. Engineering Master Thesis of Jilin University, 2007