Proceedings of the 2023 International Conference on Functional Materials and Civil Engineering
DOI: 10.54254/2755-2721/24/20230720

Common diseases and maintenance measures of concrete beam bridges

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Abstract. Bridges are important infrastructure, and their safety, durability, and applicability are of significant importance to human life and property safety. This paper analyzes the common diseases and maintenance measures of concrete beam bridges, using the specific example of the Heihe No. 3 Bridge. The testing process, inspection content, and measuring point layout of reinforced concrete beam bridges are introduced. Furthermore, the detection methods of different types of reinforced concrete beam bridges are compared and analyzed for steel corrosion state detection, steel protection layer thickness detection, and carbonization depth detection. Finally, the paper briefly discusses the application of BIM in concrete beam bridges.

Keywords: concrete beam bridge, disease, maintenance measures, detection, BIM.

1. Introduction

In the process of transportation development in China, bridges, as important transportation infrastructure, have been widely used around the world, and concrete bridges account for a considerable proportion. Under the influence of various factors such as performance, environment, and load, a large number of concrete beam bridges have developed different degrees of diseases during their operation period, which poses a threat to the normal use of bridges. Therefore, research on the diseases and maintenance measures of concrete beam bridges is urgent. At the same time, a comprehensive and reasonable testing program is of great significance for the maintenance and management of bridges.

This paper focuses on concrete beam bridges, analyzes their common diseases and maintenance strategies, and analyzes the testing program for reinforced concrete beam bridges using a specific example. Additionally, the paper provides an outlook for the application of other technical means in concrete beam bridges.

2. Common diseases and maintenance strategies

This chapter analyzes the common diseases of concrete beam bridges and discusses their protective strategies.

2.1. Diseases and causes of concrete beam bridges

According to the location of the diseases, the diseases of concrete beam bridges can be divided into diseases of the bridge deck system, upper structure, and lower structure [1].

2.1.1. Diseases and causes of simply supported beam bridge deck system. The diseases of the simply supported beam bridge deck system are mainly divided into three parts: bridge deck pavement, expansion joints, and guardrails. The diseases of the bridge deck pavement mainly include cracks, bumps, and jumping; the diseases of the expansion joints include blockage, deformation, and damage; and the diseases of the guardrails mainly include fracture, spalling, and exposed reinforcement.

Most of the diseases that occur in the bridge deck system are the result of the accumulation of damage during the bridge's service life, and some are due to construction problems and environmental factors [1].

2.1.2. Diseases and causes of hinge joint. The hinge joint in a hollow slab beam bridge is a typical weak link. If early-stage diseases occur, problems such as single-slab stress will occur, shortening the service life of the structure.

The causes of hinge joint damage include repeated loads causing fatigue damage, insufficient hinge joint structural dimensions, natural disasters, unreasonable selection of hinge joint forms, untreated joint surfaces between the hinge joint and the hollow slab, and the damage rate of the hinge joint accelerated by multiple actions of overloaded and overweight vehicles.

2.1.3. Diseases of bearings. The main diseases of simple bearings include aging, damage, and failure. The main diseases of plate rubber bearings include aging, dirt, cracking, bulging, and deformation; the main diseases of pot rubber bearings include rust, bolt fracture, welding detachment, and damage; the main diseases of polytetrafluoroethylene plate bearings include aging, dirt, and damage; the main diseases of roller bearings include large displacement creeping and tilting; and the main diseases of pendulum-type bearings include concrete spalling and exposed reinforcement, loose nuts, warped and twisted pads, and fracture.

2.1.4. Cracks on the bottom plate and their causes. Under the condition of overloading, the increased tensile stress in the transversely distributed bottom plate can cause longitudinal cracks to form. The main reasons for crack formation are inadequate thickness of the bottom plate and insufficient strict control over the construction quality of prestressed reinforcement and bottom plate.

2.1.5. Cracks on the web plate and their causes. Due to the excessive actual reinforcement at the bottom of the slab-beam, concrete shrinkage causes an increase in crack width, which then appears as vertical cracks on the web plate of the hollow slab-beam bridge. Due to its low shear strength, cracks occur at the junction, and diagonal cracks appear on the end web plate.

2.1.6. Reinforcement or steel strand disease and their causes. The key factors causing rust on the reinforcement are insufficiently dense concrete and inadequate thickness of the protective layer. The probability of steel reinforcement corrosion in concrete members exposed to humid or corrosive media environments for a long time will be greatly increased. If the concrete member has already experienced diseases such as cracks or spalling, the corrosion rate of the reinforcement will be significantly accelerated.

2.1.7. Waterlogging alkali on the cap and its causes. the inability of the beam body to discharge accumulated water normally is the main reason for the occurrence of waterlogging alkali. Waterlogging alkali can cause the external concrete to lose its bearing capacity or the protective layer to peel off, exposing the reinforcement [1, 2, 3].

2.2. Maintenance measures

Treatment of crack in the box girder: The thickness of the bottom plate should be appropriately increased; transverse rib plates should be installed at the junction of the beam end; necessary upper and lower steel bars should be added on the bottom plate; the diameter of longitudinal steel bars in the bottom plate

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should be appropriately increased; cement consumption should be strictly controlled, and maintenance should be carried out immediately after the concrete reaches the initial setting state; effective measures, such as water sprinkling, should be taken to reduce the temperature of the concrete inside the box.

Preventive maintenance of expansion joints: Firstly, asphalt mastic should be filled in the top of the expansion joint; secondly, epoxy concrete should be filled in the upper half of the expansion joint, and epoxy resin should be filled in the lower half, and the RPC expansion joint should be replaced; finally, fly ash and steel fiber should be added in appropriate amount to the concrete of the expansion joint. For damaged expansion joints, the commonly used reinforcement methods include the following: setting a reinforcement layer on the bridge deck; adopting the planting method for reinforcement; using steel plate bonding for reinforcement; and using the external prestressing method for reinforcement.

Treatment of alkali immersion: Drainage holes should be checked for blockage, and water accumulation in the beam plate should be checked. Clogged drainage pipes should be cleared in a timely manner during daily maintenance, and damaged components should be replaced in a timely manner.

To ensure the good condition of the bridge throughout the predetermined service life and extend the service life of the bridge, preventive maintenance should be strengthened. At the same time, attention should be paid to the selection of maintenance timing. According to the relationship between the technical condition of the bridge and time, the degradation model of the bridge should be used as the basis to predict the laws followed during the continuous degradation process of the technical condition of the bridge and preventive maintenance work should be carried out immediately before the bridge degrades to the third-class bridge [1, 2, 3].

3. Inspection of reinforced concrete beam bridges - a case study of Heihe bridge No. 3

This paper will use Heihe Bridge No. 3 as an example and combine it with other beam bridges to provide a detailed description of the inspection scheme for reinforced concrete beam bridges through comparative analysis.

3.1. Introduction to Heihe bridge No. 3

Heihe Bridge No. 3 has a total length of 178.98 m, with a straight-line slope on the bridge line, and the bridge span structure is composed of 10 holes of 16m ordinary reinforced concrete beams. The foundation of the lower structure is a caisson, and the soil composition at the bottom of the foundation is a sandy cemented layer. The pier body is a reinforced concrete round-end structure, and in order to prevent the impact of floating ice, there is an ice-breaking structure made of mortar-blocked stones on the upstream side of the bridge pier. The bridge abutment construction follows the "abutment - large - 106" standard drawing, and the design load level of the bridge is medium-22 [4].

3.2. Bridge inspection plan

Inspection objective: Through inspection and evaluation of the Heihe No.3 Bridge, the overall bearing capacity and health status of the bridge can be assessed and the engineering bearing capacity of the bridge can be identified. This inspection aims to provide a basis for the safe operation, maintenance and repair of the bridge and railway line [4].

Test process: The main testing includes strain gauges, accelerometers, dial gauges and other bridge structures, and the following test process diagram is obtained [4].

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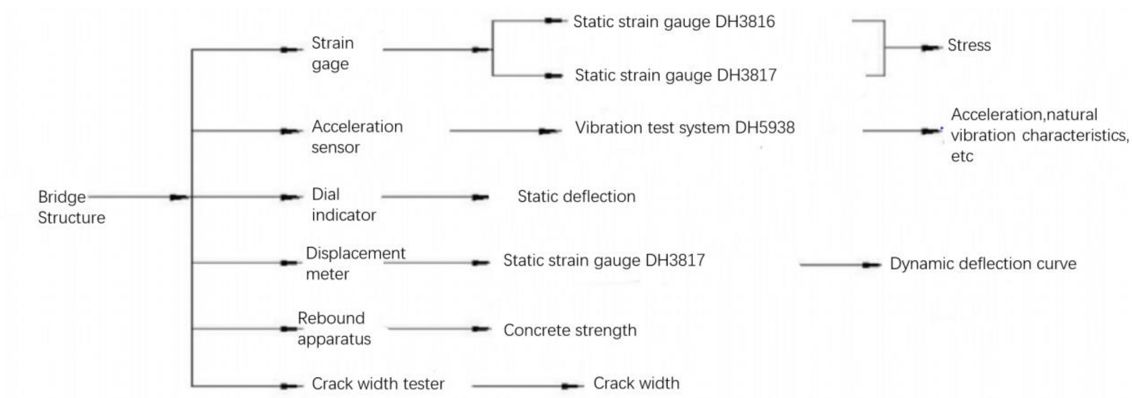

Figure 1. Block diagram of the test flow.

Inspection content and project introduction: In order to comprehensively and completely evaluate the working condition of the entire bridge, projects including upper bridge cross structure, lower pier and abutment concrete strength testing, bridge appearance inspection, and static and dynamic load tests are conducted [4].

Pier and abutment concrete strength testing: The actual strength of concrete is a key parameter for determining the bearing level. The rebound method is used to determine the compressive strength of the upper bridge cross structure and lower pier and abutment concrete, and then the concrete strength conversion value of the measured component is calculated [4].

Comprehensive inspection of bridge appearance quality: Key inspections are carried out on the development of cracks or cracks on the surface of the beam and pier and abutment concrete, the depth and width of cracks, the position of the bearing, the condition of the road nails, the condition of the bridge pillows and the bridge deck [4].

Static load test: The static load test of the bridge can directly determine the working condition and bearing capacity of the structure as a whole. The test content includes the deflection and strain of the cross-section at the mid-span position and the strain of the cross-section at the bearing position [4].

Dynamic load test: The dynamic load test of the bridge can reflect the dynamic characteristics and dynamic response of the bridge cross structure under dynamic loads. The main test contents include the dynamic deflection and dynamic strain of the cross-section at the mid-span position, as well as the natural frequency and damping ratio of the structure [4].

Two Dongfeng 4 locomotives with axle loads as shown in Figure 2 are used for loading. The loading is carried out in an increasing manner from low to high speed, from 10km/h to 60km/h, and the test is assisted by passing through the train load [4].

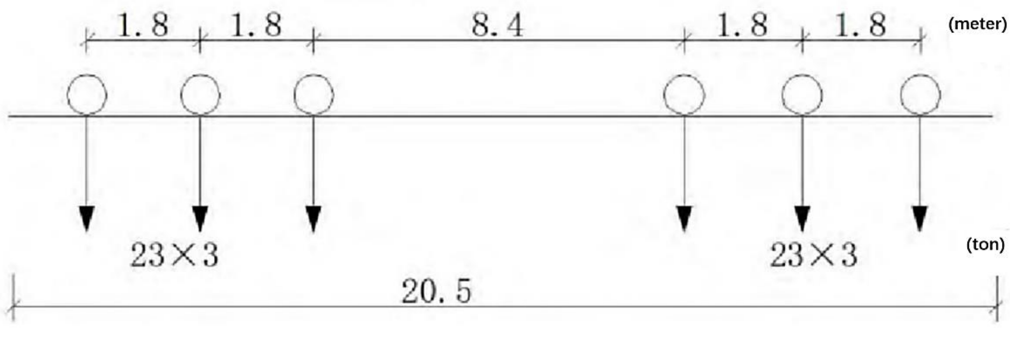

Figure 2. Layout of axle base and axle weight of Dongfeng 4 diesel locomotive.

Sensor layout: Considering that the bridge body has been externally prestressed with reinforcing bars (as shown in Figure 3), after careful analysis, the following sensor layout diagram is obtained. Among them, in order to measure the deflection, two displacement meters are placed at the bottom of the mid-span beam. In order to facilitate the analysis of the dynamic characteristics of the beam, square transverse and vertical pickup sensors are respectively placed at the mid-span position of the bridge deck to pick up the dynamic signals in the horizontal and vertical directions, as shown in Figures 4-5 [4].

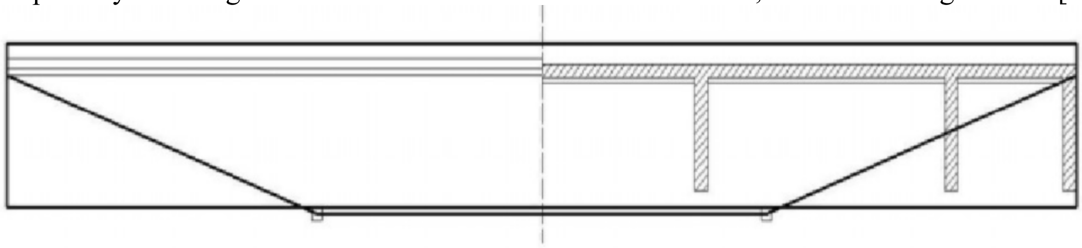

Figure 3. Schematic diagram of external prestressed reinforcement.

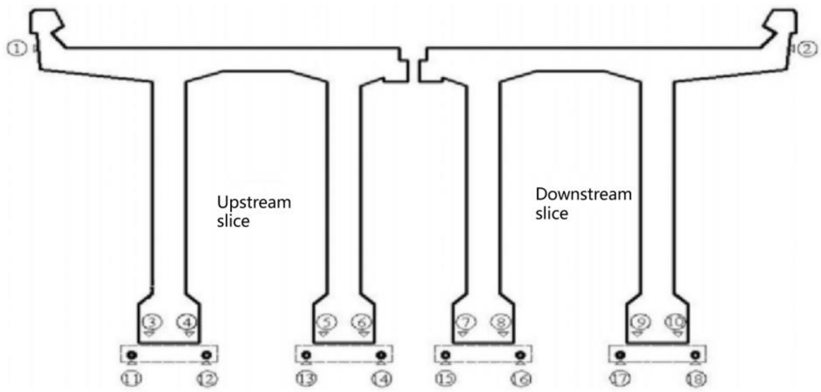

Figure 4. Arrangement of strain gauge at mid-span section.

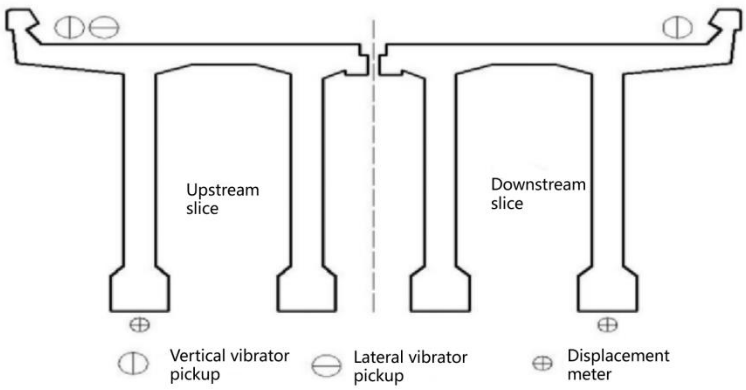

Figure 5. Layout of mid-span displacement meter and vibrator.

3.3. Partial differences between different beam bridges and Heihe bridge No. 3

The steel reinforcement corrosion detection of the reinforced concrete simply supported beam bridge: A steel reinforcement corrosion detector was used to detect the corrosion status of the steel reinforcement in the components of the bridge. One component was selected from the T-beam and hollow slab-beam, with a total of 200 measuring points for steel reinforcement corrosion detection. The potential of steel reinforcement corrosion in the components is shown in Figures 6-7.

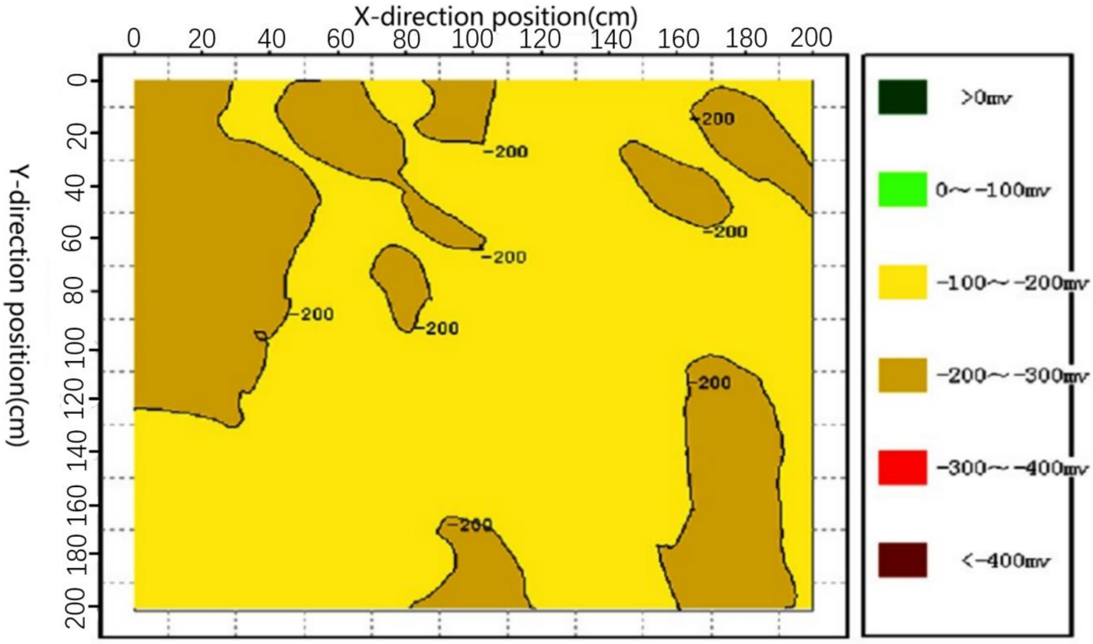

Figure 6. Steel corrosion potential diagram of hollow slab beam.

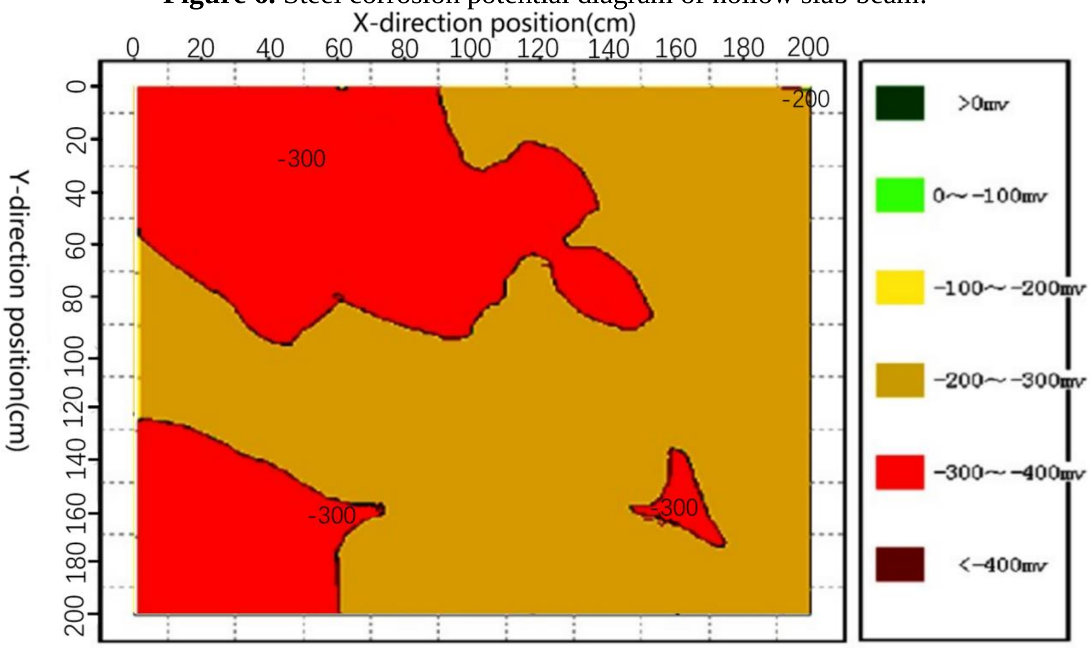

Figure 7. Corrosion potential diagram of beam reinforcement.

The steel reinforcement protection layer thickness detection of the reinforced concrete simply supported beam bridge: A steel reinforcement detector was used to measure the thickness of the concrete protection layer for a total of 200 measuring points in 13 components of the bridge.

The concrete carbonation depth detection of the reinforced concrete simply supported beam bridge: The carbonation depth detection of concrete was carried out in 10 main stress components with a total of 30 measuring areas for carbonation depth detection [5].

4. Application of BIM in concrete beam bridges

OSIS-BIM, a C# language-based software developed by secondary development of Revit, provides a simple, efficient, and fast way for BIM design of small and medium span concrete beam bridges. Data is the core of this software, and it adopts a model object-oriented design concept. Dynamic relationships between various bridge components are established through data, and the model is expressed in 3D. Existing drawings are analyzed and effective descriptive information is extracted to construct a universal graphic database for the enterprise. This helps bridge engineers quickly match the required bridge parameter information during the design process, and achieve drawing reuse by referencing or modifying the drawing contents.

Based on the study of a large number of concrete beam bridge structures and drawing classifications, and referring to the existing general graphic design of concrete beam bridges in the Ministry of Transportation, a parameterized component modeling classification system is formed according to section form, span, and other parameter information. Through secondary development of BIM software, digital design of concrete beam bridges is realized.

The specific technical route is shown in Figure 8 [6].

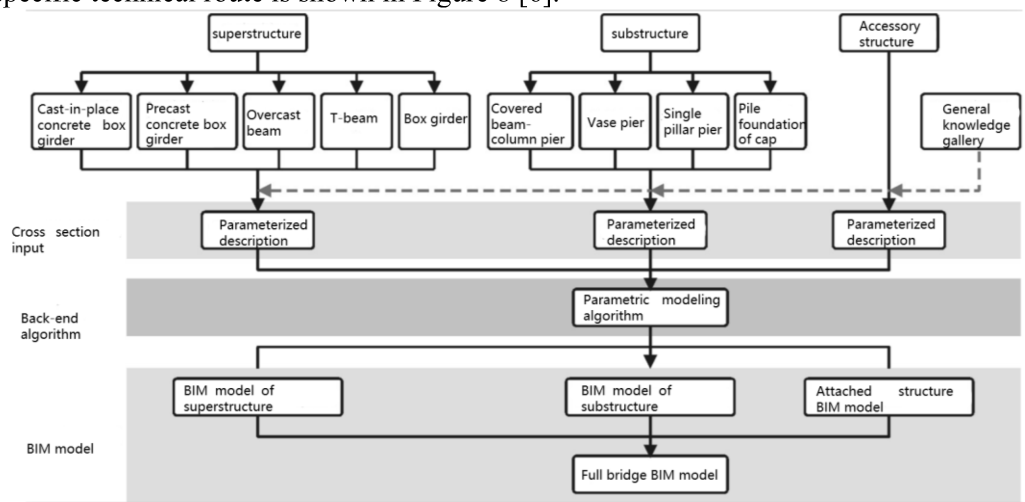

Figure 8. Technical route.

5. Conclusion and outlook

By analyzing the common diseases and maintenance measures of concrete beam bridges and combining with specific examples to analyze the testing scheme of reinforced concrete beam bridges, the following conclusions are drawn:

(1) The diseases of concrete beam bridges are divided into bridge deck system diseases, upper structure diseases, and lower structure diseases.

(2) The testing scheme of reinforced concrete beam bridges includes clarifying the testing objectives, combing the testing process, conducting upper bridge span structure and lower pier and abutment concrete strength testing, bridge appearance inspection, and static and dynamic load tests, with four parts of layout points. Different beam bridges have slightly different testing contents, but most of the principles are similar.

(3) The application of BIM technology in concrete beam bridges has broad development prospects, providing new ideas for bridge design, construction, and monitoring.

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DOI: 10.54254/2755-2721/24/20230720

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