Research on Reinforcement Design Based on a T-beam Bridge

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Abstract. A concrete simply supported T-beam bridge in a rural highway in a county of Yunnan, China, has been found to have a large number of cracks in the T beam when it is tested. Most of them belong to the non structural cracks. The vertical cracks in the middle part of the 1\# bent beam of the substructure were seriously damaged and the bearing capacity was low. The bridge was assessed as the IV bridge, and its cracks and other diseases were disposed after research. After the reinforcement is completed, the test shows that the bearing capacity of the bridge has been restored and improved, and the measures adopted are also effective, which can provide some reference for the reinforcement of the same type of bridge.

1. Bridge description
The bridge in this paper is located on the rural highway in a county in Yunnan, China, built in 1982. It is a concrete simply supported T-beam bridge with a span of 5 x 20m. The real picture of the bridge is shown in Figure 1. The cross-section consists of 1.25m (sidewalks and railings)+4.5m (roadways)+1.25m (sidewalks and railings). The superstructure consists of 4 reinforced concrete T-beams. The T-beams are 1.48m high and 1.6m wide. The plate thickness is 0.1m and the cross-section is shown in Figure 2.

In the process of testing the technical situation of the bridge, it is found that the T-beam of the superstructure of the bridge produces a large number of cracks, most of which belong to non-structural cracks. There are the vertical cracks in the middle part of the 1\# bent beam of the substructure.

2. Assessment of technical conditions
The bridge has been tested in detail by the inspection department, and the main diseases are summed up to the following 3 points (Note: the beam plate number principle is first span for small mileage, and the left beam is first).
Figure 1. The real photo of the bridge

Figure 2. Cross section diagram

Superstructure: (i) There are many vertical cracks in 1-1#T-beam, 2-2#T-beam and 2-3#T-beam; (ii) There are many vertical cracks in the 1-4#T beam and large area of the right web surface; (iii) The existence of multiple vertical cracks and oblique cracks in 2-1#T-beams; (iv) There are many vertical cracks and oblique cracks in the 2-4#T-beam.

Substructure: (i) The vehicle bumping at both ends of the bridge; (ii) Segregation of 4-1# pier column and 4# bent cap, the weeds grow rankly with 3# bent cap; (iii) There are vertical cracks in the middle part of the 1# bent cap, and the maximum width is 0.21mm.

Bridge deck system: (i) Longitudinal and transverse cracking of the left and right sidewalks; (ii) The left and right side guardrails appear shaking, breaking and leakage reinforcement.

According to the test results, the upper load-bearing members (main components) of the bridge is classified into class IV, so the bridge grade is finally rated as IV. The estimated cost of the reinforcement scheme is 800 thousand yuan, and the bridge can continue to be used normally after reinforcement. But the new bridge will need 4.2 million, so it is decided to reinforce the bridge.

3. Measures for maintenance and reinforcement
Because of the lack of original design data, the original design load grade standard can not be determined in this maintenance and reinforcement design. The main purpose of the reinforcement design is to ensure that the bridge can be operated safely and normally under the current permitted traffic conditions, so as to improve the durability and recovery function of the bridge.

3.1 Treatment of superstructure
The cracks produced by superstructure include two categories: structural cracks and non-structural cracks. Structural cracks refer to cracks caused by external loads, also known as stress cracks. Non-structural cracks are cracks caused by deformation, such as temperature changes, shrinkage of
concrete. In addition, due to corrosion of steel reinforcement, vehicle impact, etc., will cause cracks in concrete.

According to the regulation of “Code for Maintenance of Highway Bridges and Culverts”[5] and the status of strengthening measures and environment, surface sealing can be carried out when the width of the crack is within the limits (<0.2mm). Generally the special epoxy resin adhesive is brushed to closed. When the crack width is greater than the limit (≥0.2mm), the pressure grouting method should be used for filling epoxy resin or other sealant materials. Because there may be inaccuracy when measuring the width of the crack on site, in order to restore the crack exceeded the standard specified, and improve the overall maintenance effect of the bridge, the boundary value of the sealing and filling of the surface brush is set to 0.15mm. All the visible cracks were treated. And treatment method is shown in Table 1,

Table 1. The treatment method of dividing cracks according to the width of cracks

| crack width (mm) | Treatment       |
|------------------|-----------------|
| <0.15            | Surface brush   |
| ≥0.15            | Pressure perfusion |

The reinforcement design has taken corresponding reinforcement measures for all kinds of non structural cracks, and the reinforcement method for structural cracks is to paste carbon fiber cloth on the surface of components. The oblique cracks of web near the bearing and the vertical cracks in the middle span and the bottom of the horseshoe are treated according to the structural cracks, and the treatment method is reinforced by pasting carbon fiber cloth or steel plate reinforce-ment. The layout of carbon fiber cloth of beam span is shown in Figure 3. The profile of the carbon fiber cloth on the cross section of the beam is shown in Figure 4.

Longitudinal cracks of beams: For cracks at the bottom of the beam, two layers of carbon fiber cloth should be added on the transverse side and a layer of carbon fiber cloth should be added longitudinally. In principle, the width of the seam is greater than 0.1mm, and the cracks on the flange plate, web and transverse diaphragm should be cross bonded with two layers of fiber cloth. The length of the fiber cloth is extended from the ends of the cracks to 1m.

![Figure 3. Paste layout of carbon fiber cloth of beam span](image-url)
Vertical cracks and oblique cracks in the beam: For the vertical cracks and slanting cracks in the web of the box girder and the vertical cracks of the flange plate and extending to the web, (i) when the disease has little effect on the bridge structure, the crack width is less than or equal to 0.1mm, the sealing glue is closed and treated with pasting carbon fiber cloth. For cracks with a width greater than 0.1mm, glue was disposed and treated with carbon cloth. (ii) When the disease has great influence on the bridge structure, beam replacement or special reinforcement should be carried out.

Transverse cracks of beam: for the box girder, the transverse cracks on the roof and floor, and the cracks that width is less than or equal to 0.15mm is sealed by sealing adhesive. The cracks with a width greater than 0.15mm are treated by pressure injection and treated with carbon cloth.

3.2 Treatment plastering
Under the natural condition, the surface of concrete is easily weathered and damaged, and its damage speed is related to the quality of concrete and the external environment. Poor compactness of concrete, unevenness of inhomogeneous vibration, and long water seepage, high chloride content and many times of freezing and thawing cycle will result in accelerated destruction of concrete. In addition, the impact of vehicles and the corrosion of steel in concrete will also cause damage to concrete.

For the case of voids and pits in the test of this bridge, After partial watering of the surface, the mixture of raw concrete and stone mortar is used to smooth the surface.

In the case of leakage reinforcement, the loose concrete is chiseled out, filled with a high grade of fine stone concrete, or filled with high strength grouting material.

The bridge deck system is rebuilt to replace the side-walk panels and railings.

3.3 Treatment of substructure
In order to solve the problem of vehicle bumping at the bridge head of the substructure, the asphalt pavement on the bridge deck should be reformed after the original pavement is demolished according to the actual situation.

The vertical cracks in the middle part of the 1# bent cap are treated according to the structural cracks, and the treatment method is steel plate reinforcement. The steel plate setting is shown in Figure 5.
4. Conclusion
After the reinforcement is completed, the bridge has been tested. The results shows that the bearing capacity of the bridge has been restored and improved, and the measures taken to reinforce the bridge are also effective, which can provide some reference for the reinforcement of the same type of bridge.

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