Static loading test and analysis of prestressed concrete bridge

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Abstract. In order to test the structural performance for the bridge of Linxi 9th road project, the static test of precast prestressed concrete bridge hollow slab was carried out by four stage static loading method. Under the condition of elastic working, the flexural bearing capacity, crack propagation and relative residual displacement of the main control sections of the hollow slab are mainly investigated. The results of static loading test show that, when the efficiency of static loading test is 97%, the structural calibration coefficient, residual displacement of main measuring points and crack propagation meet the requirements.

1. Introduction
The bridge loading test is mainly to determine the actual working state by measuring the stress and deformation of the bridge structure under the static or dynamic test load. It is the most direct and effective method to test the actual performance of bridge structure, such as the strength and rigidity of the structure. Tang Weidong\textsuperscript{[1]}, Li Junyu\textsuperscript{[2]} and Mo Haihua\textsuperscript{[3]} have detected and analyzed the existing bridge structure by static load test, dynamic load test, and dynamic-static load test respectively, which provided reference and basis for the detection, identification and further maintenance and reinforcement of the existing bridge structure. Shi Zhou\textsuperscript{[4]} and others analyzed the deflection and stress of the reinforced concrete arch bridge through static and dynamic load test, and verified the reinforcement effect.

Before installation, we can know the actual working state of the structure under the test load, so as to judge the safety bearing capacity and evaluate the operation quality of the bridge, which is helpful to discover the hidden disease of the bridge structure and inspect the design and construction quality of the bridge structure. In this paper, according to Specification for inspection and evaluation of bearing capacity of highway bridges\textsuperscript{[5]}, General Specifications for design of highway bridges and culverts \textsuperscript{[6]}, and Specifications for design of highway reinforced concrete and prestressed concrete bridges and culverts \textsuperscript{[7]}, carry out static load test to measure deflection and crack of beam and slab, and compare test value with calculated analysis value to evaluate safety performance of bridge.

2. Loading test design
2.1. Project overview
The length of precast prestressed concrete bridge hollow slab is 9.96m, the calculated span is 9.6m, and the height is 0.5m. The mid-span section of bridge slab is shown in Figure 1. The concrete strength is 30MPa and the design parameters of precast bridge slab are given as follows.

(1) The bending moments of mid-span under the self weight, the second stage dead load and urban-A load are 111.97kN\textperiodcentered;m, 92.39kN\textperiodcentered;m and 120.96kN\textperiodcentered;m respectively.

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(2) The geometric characteristics of mid-span section, including the moment of inertia of full section and the moment of inertia of cracking section, are 0.00981 m$^4$ and 0.00521 m$^4$, respectively.

![Figure 1. Cross section of bridge slab (unit: mm)](image)

2.2. Loading detection method technology

In the test, there are two kinds of counterweights used for loading. The counterweights sizes are 2.58 m × 1.00 m × 0.18 m and 1.58 m × 1.00 m × 0.18 m, weighing 11.5 kN and 6.7 kN respectively. In order to carry out the load test of the precast slab under the serviceability limit state, the equivalent moment in mid-span reaches 314.53 kN·m with 12 counterweights under full load according to the principle of moment equivalence in mid-span. The equivalent moment is equivalent to 97% of the design moment. In order to load conveniently, the counterweights are placed vertically on the long side of the beam as shown in Figure 2.

![Figure 2. Test loading method](image)

In this test, the method of symmetrical loading of line load on both sides of the mid-span is adopted to ensure a certain range of pure bending moment area in the mid-span. The loading test is under four stage loading conditions, four counterweights are added for each stage of the first two stages, and two counterweights are added for each stage of the last two stages. The detailed loading is shown in Figure 3. The static test load can be determined according to the principle of equivalent control of internal force, strain or displacement. The efficiency of static test load can be calculated according to Formula 1, which should be between 0.95 and 1.05.

$$\eta_s = \frac{S_s'}{S (1 + \mu)}$$  \hspace{1cm} (1)

Where, $S_s'$ is the maximum calculated effect value of the internal force, stress or displacement of the loading control section corresponding to a certain loading test item; $S_s$ is the calculation value of the most unfavorable effect of the internal force, stress or displacement of the same load control section.
generated by the checking load; $\mu$ is the impact coefficient value taken according to the specification; $\eta_\text{q}$ is efficiency of static test load.

\[ \text{Figure 3. Arrangement of loading counterweights (unit: cm)} \]
(a) First stage loading (b) Second stage loading (c) Third stage loading (d) Fourth stage loading

3. Test results and analysis

The static load test is carried out in the precast site, which is a concrete loading platform. In order to deduct the influence of bearing deformation, a digital dial indicator is used to measure the bearing at both ends. A total of 5 dial indicators (see Figure 3) are arranged at the beam support, mid-span and quarter point to measure the deflection of the beam, and the crack width is observed by the crack width observation instrument.

3.1 Crack behavior

Before loading, there are a few concrete shrinkage cracks in the precast slab. After the second stage loading, the vertical cracks appear at the corresponding positions of the two sides of the precast slab span. With the increase of the load, the vertical cracks appear symmetrically from the middle of the span to both sides. There are 7 cracks at full load, the maximum crack width is 0.12mm, which appears at the side of mid span slab. Some cracks extend to the beam bottom, but they are not penetrated at the beam bottom. The crack interval is about 0.4~0.7mm, and the interval near the mid span is small. After unloading, the residual crack width is 0.02mm. Tracking observation of the largest crack in the mid span. The change of crack width with the increase of load is provided in Table 1.

\[ \text{Table 1. Maximum vertical crack width in mid-span} \]

| Loading stage | Initial value | stage 1 | stage 2 | stage 3 | stage 4 |
|---------------|---------------|---------|---------|---------|---------|
| Mid-span moment (kN·m) | 0.00 | 185.57 | 259.17 | 289.07 | 314.53 |
| Crack width (mm) | 0.00 | 0.00 | 0.02 | 0.08 | 0.12 |
When fully loaded, the maximum crack width of mid-span section is 0.12mm, which is less than the design allowable value of 0.2mm, and the crack closure width after unloading is 0.10mm, which is more than \(2/3\) of the growth width. This meets the specification requirements.

### 3.2 Deflection behavior

The deflection value of each measuring point under test load at all stages is shown in Table 2 and Figure 4. The deflection value is the value after removing the influence of settlement of fulcrum. The measured value of mid-span deflection = mid-span deflection - (bearing 1 deformation + bearing 2 deformation) / 2. The curve between the measured value and the analysis value of the mid-span deflection of the bridge slab is shown in Figure 5.

| Measured deflection (mm) | 0.00 | 0.43 | 1.22 | 1.60 | 1.87 |
|--------------------------|------|------|------|------|------|
| Measuring point 1        | 0.00 | 0.43 | 1.22 | 1.60 | 1.87 |
| Measuring point 2        | 0.00 | 1.68 | 5.61 | 7.16 | 9.26 |
| Measuring point 3        | 0.00 | 2.36 | 8.46 | 11.64| 13.85|
| Measuring point 4        | 0.00 | 1.67 | 5.63 | 7.86 | 9.37 |
| Measuring point 5        | 0.00 | 0.41 | 1.26 | 1.71 | 2.01 |

The maximum value of deflection calibration coefficient of mid-span section in this test is 91%, which is less than 1, meeting the specification requirements. According to the analysis in Figure 4, under the action of service load, the measured deflection values are all smaller than the cracking section analysis values. The relative residual displacement of the main measuring points is less than 20%, which meets the specification requirements.

![Figure 4. Deflection curve under all loading stages](image)

![Figure 5. Deflection curve in mid-span](image)

### 4. Conclusions

Based on the four-stage loading test of precast reinforced concrete bridge hollow slab, when the equivalent bending moment in the span was equivalent to 97% of the design load, the structure was close to the elastic working stage. Crack, deflection and other data indicators met the requirements of the specifications, which showed that the design and construction quality achieved the expected effect.

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