Checking Calculation Analysis for Construction of Long-span Steel Box Girder Bridges

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Abstract: With the rapid development of China's society and the implementation of the Belt and Road policy in recent years, many large-scale complex steel structure bridges are constructed, typically represented by the Hangzhou Bay Sea-Crossing Bridge and the Hong Kong-Zhuhai-Macao Bridge. In this paper, the checking calculation for the overall force of the steel box girder during construction is studied. The analysis shows that the steel box girder concerned has good stiffness and ductility.

1 Introduction
With the acceleration of China's modernization development process and the construction of the Belt and Road, many large-scale complex steel structure bridges are required and their construction process is complicated. Therefore, it is necessary to carry out corresponding calculation and analysis based on the specific construction conditions, to ensure the construction safety.

The project studied in this paper is located in the Wuding-Xundian Expressway section of Yunnan. The Zhangjiu River No. 5 Bridge is set to span the Zhangjiu River, local roads and ditches. It is designed with a single-box four-cell continuous 65m steel box girder. The girder has the diameter of 55m+65m+55m, the height of 2.7m (the height of the contour inside the box girder), the total weight of 1441.15 tons and maximum installation height of 55m, made of Q345D (material).

2 Calculation of Model
There are three side-by-side boxes in the project, and they have not formed a whole before the pouring of concrete panel. The boxes have little influence on each other. In addition, the computer capacity is limited, and the number of simulation units for the three boxes is large, so it is necessary to simplify the overall structure. The single span and boundary conditions of the bridge are basically consistent, and so are the load conditions. Therefore, a single span is selected for the bridge for analysis. The geometric model is shown in Fig. 1. The model coordinate system takes the XZ plane as the bridge cross section and the Y direction as the axial direction.

The computational grid is a four-node tetrahedral element, and the entire computational domain is divided into 212,515 units and 70,718 nodes. The overall grid and local computational grid are shown in Fig. 2.
3 Calculation of Loads and Boundary Conditions

3.1 Introduction of Load Forms

Two working conditions are considered in this calculation. Working Condition 1: dead load; Working Condition 2: dead load + concrete panel; Working Condition 3: dead load + concrete panel + construction load, of which, the load applied to the concrete panel is 2KN/m². The load distribution for calculation is shown in Fig. 3.
panel is: wood template → steel pipe support → bottom plate for the steel pipe support → stiffening rib. As seen from the above transmission path, the construction load and the concrete dead load are finally transmitted to the steel box, and the steel box structure bears the total load.

3.2 Introduction of Material Properties and Boundary Conditions

The calculated material is considered based on the linear elasticity. The calculation parameters of the concrete include: elastic modulus $E_s=2.8E10$ Pa, Poisson's ratio $\mu=0.167$, density $=2500$Kg/m$^3$. The metal material is Q35, elastic modulus $E_s=2.06E11$ Pa, Poisson Ratio $\mu = 0.3$, density $= 7850$ Kg / m$^3$. During the calculation, the boundary condition is imposing hinge constraint onto the gasket at the bottom of the bridge.

4 Analysis of Calculation Results

4.1 Stress Analysis

The stress magnitude and distribution of the bridge under different working conditions are shown in Table 3.1. The stress distribution laws of the bridge under each working condition are basically consistent. Working condition 3, namely the one with the dead load of concrete panel and construction load considered, is the control working condition $[1]$. The analysis in this report mainly focuses on Working Condition 3.

Fig.5 shows the overall Mise stress distribution of the box. Figs 6 and 7 show the stress distribution of each section inside the box. As seen from Figs 3.1 to 3.3, the main tensile stress area of the box is mainly distributed in the upper and middle areas of the box, and the stress gradually increases from both ends toward the middle, and the maximum is about 110 MPa, which is much smaller than the yield value of the steel, i.e. $[\sigma]=295MPa$ and the overall stress gradient of the box is large, and the stress-bearing area exceeding 50 MPa is small.

In addition, there is also a large tensile stress area at the bottom of both ends of the box. The analysis considers that a certain stress concentration phenomenon occurs during the calculation mainly due to the full constraint on both ends $[2]$.

The shear stress distribution of the box is shown in Fig. 7. It can be seen from the figures that the main control direction is XZ direction, i.e. the box cross section. The overall shear stress distribution increases gradually along the middle to both ends, and the maximum shear stress is 30.4MPa, which is less than the specified value, i.e. $[\tau]=170MPa$.

| Stress and Displacement Load | Mise Stress | Displacement |
|-----------------------------|-------------|--------------|
|                            | Maximum     | Distribution Area | Maximum | Distribution Area |
| Dead load                   | 23.3 MPa    | The main tensile stress is mainly distributed in the upper and middle areas of the box. | 1.76     | The maximum value of the displacement occurs at the mid-span of the bottom of the box and gradually decreases along both ends. |
| Dead load+ Concrete panel   | 95.3 MPa    | The main tensile stress is mainly distributed as above, and there are also large tensile stress areas on both ends. | 8.5      | The maximum value of the displacement appears at the mid-span of the bottom of the box and decreases along the ends. |
| Dead load+ Concrete panel +construction load | 110.9MPa | The main tensile stress is mainly distributed as above, and there are also large tensile stress areas on both ends. | 9.57     | The maximum value of the displacement occurs at the mid-span of the bottom of the box and gradually decreases along both ends. |
4.2 Deformation Analysis

The deformation magnitudes and distribution of the box under different working conditions are

\[ \sigma \geq 20 MPa \]

\[ \sigma \geq 50 MPa \]
shown in Table 1. The deformation distribution laws of the box under each working condition are basically consistent. Working condition 3, namely the one with the dead load of concrete panel and construction load considered, is the control working condition [1].

The overall deformation distribution of the box is shown in Fig. 8. Fig. 9 is the deformation diagram. It can be seen from the figures that the maximum deformation of the box is mainly distributed in the middle part of the bottom of the box, which gradually decreases along both ends, and its maximum value is about 9.6mm.

Since the single span of the bridge is 20m long, and the ratio of deflection to span is about 1/2000, which is less than 1/600, meeting the requirements of the specification [4].

5 Conclusion
Through the above finite element analysis results, the following brief conclusions can be drawn:

a) The calculated bridge stress, deformation distribution law and numerical value are within a reasonable range, and the calculation results can provide reference for engineering design.

b) Through the analysis of the calculation results, the deflection-to-span ratio of bridge is about 1/2000, which meets the requirements of the specification.

References
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