Static analysis of PC slab stiffened beam suspension bridge under temperature

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Abstract. In view of the influence of temperature on the construction of PC slab stiffened beam suspension bridge, combined with the Moon Bay Bridge, the finite element software Midas Civil is used to conduct a static analysis of the Moon Bay Bridge under temperature. The calculation results can be similar to the bridge construction Provide reference, there is a certain reference significance.

1. Introduction
Suspension bridges are widely used on highway bridges due to their large spanning ability. Suspension bridges are flexible structures. Stiffening beams are the main components of suspension bridges. Research on them will help us improve our understanding of them and further improve them. Design theory is of great significance. Xu Gongyi [1] combined the design of the real bridge and applied the research results to the engineering design of prestressed slab stiffened beam suspension bridges and steel plate stiffened beam suspension bridges, and conducted in-depth theoretical analysis and wind tunnels for their wind stability issues and design engineering measures. Model tests, so as to draw conclusions about the suitable span range and application conditions of different types of beam structures. Fan Shenghui [2] based on the finite element analysis platform, using its secondary development tools, chose the APDL+UIDL development mode, and developed a special menu and supporting parameterized programs for modeling stable suspension bridges. The mechanical properties of reinforced concrete slab stiffening beams in stable suspension bridges are studied. The secondary development program is used to quickly generate bridge models with different stiffening beam segment lengths and different plate thicknesses. The non-linear finite element static analysis is carried out under four sets of standard load conditions, and the most suitable stiffening beam segment length and bridge slab thickness are selected after analyzing and comparing the calculation results. Wang Wenqing [3] According to the structural force characteristics of the concrete slab stiffening beam self-anchored suspension bridge, considering the influence of various non-linear factors, the advantages and disadvantages and applicable conditions of various finite element discrete models are analyzed and compared. Finite element modeling method of anchored suspension bridge. The mechanical properties and scope of application of the concrete slab stiffening beam self-anchored suspension bridge are studied and discussed. Xia Chang [4] conducted wind tunnel forced vibration tests and numerical simulations based on the slab stiffened beams of Wujiang Bridge, and identified flutter derivatives at multiple angles of attack. The research results show that, based on reasonable
mesh division, the method of numerical simulation can correctly identify the flutter derivative at the angle of attack. Wang Da, Xie Wei, Yang Qin, Liu Yang [5] proposed a local segment model correction method based on the finite element model correction technology. Sections were taken near the 1/4 span of the stiffening beam, a local model was established, and 5 stress conditions were drawn up. Taking the axial force of the stiffening beam chord as the objective function, the equivalent boundary elastic constraint was corrected and the research was verified. Effectiveness of the method. Pu Yu, Tao Qingdong [6] used numerical integration method and established model through Abaqus finite element software to analyze the natural vibration characteristics of long-span slab stiffened beam suspension bridge. By changing the ratio of rise to span, ratio of side span to mid-span, and deck System parameters such as quality, suspender tensile rigidity, number and position of beams, etc., are discussed, and their influence on natural vibration characteristics is discussed. The temperature effect has a certain influence on the concrete stiffening girder. In this paper, the Moon Bay Bridge is taken as the research object, and the static analysis of the PC slab stiffening girder suspension bridge under temperature is carried out.

2. Project Overview
The Moon Bay Bridge crosses the Jinsha River and connects Daxing Town, Yongshan County, Yunnan Province, and Dexi Township, Jinyang County, Sichuan Province. The main bridge of the Moon Bay Bridge adopts a single-span 465m prestressed concrete slab stiffening beam suspension bridge design. The span is 130m, and the main cable side of the Yunnan shore is 140m. Considering the hoisting and erection of the main beam, the sling spacing is 6m, and the main bridge has a total of 78 prestressed concrete slab stiffening beams (Figure 1).

The prestressed concrete slab stiffening beam standard beam section is dumbbell type, the beam width is 1300cm, the axis beam height is 70cm, and the center spacing of the two main cables (suspensions) is 1150cm. The prestressed concrete stiffening beam has a total of 37 bundles of longitudinal prestressing beams. The N1 long beam is made of 15 pre-stressed steel beams with a diameter of 15.2mm and a length of 461.58m, a total of 21 bundles. The short bundle uses 12 pre-stressed steel bundles of 15.2mm, a total of 16 bundles, of which N2 has 8 bundles, and the length is 443.5m, N3 has 2 bundles, length is 335.5m, N4 has 2 bundles, length is 251.5m, N5 has 2 bundles, length is 167.5m, N6 has 2 bundles, length is 71.5m, (stiffened beam section figure 2). The length of the longitudinal prestressed steel beam of the bridge is up to 461.58m, which is the longest prestressed beam at home and abroad.

![Figure 1. Diagram of Moon Bay Bridge (unit:m)](image-url)
3. Suspension bridge unit simulation

(1) Since the bending stiffness of the main cables and slings is relatively small, they mainly bear tension and basically do not bear pressure. Therefore, the spatial cable element with initial tension is used for modeling and analysis.

(2) The simulation of the main saddle adopts rigid beam elements.

(3) Due to the shear deformation of the main tower, the spatial beam element is used to simulate the finite element analysis.

(4) The simulation of prestressed concrete slab stiffening beam adopts spatial beam elements, and each element has six degrees of freedom. According to the drawing size, first draw the section shape of the prestressed concrete slab stiffener in Auto CAD, and then use the section characteristic value calculator function of the finite element software MIDAS/CIVIL for analysis and calculation.

4. Boundary condition processing

The selection of boundary conditions is a key part of finite element software modeling and analysis. When using the finite element software MIDAS/CIVIL to simulate analysis and calculation, in order to make the calculated results close to the actual situation, the boundary conditions must be handled well.

(1) The bottom of the pylon limits all the degrees of freedom of the corresponding nodes, and adopts the consolidation method.

(2) The main cable restricts all degrees of freedom of the corresponding node, and its 4 anchor points are all fixed.

(3) The relative displacement of the saddle and the top of the tower is considered by adopting the method of releasing the rigid connection in the X direction of the main cable at the top of the tower;

(4) The rigid connection of the prestressed concrete slab stiffening beam and the lower node of the boom is used in the forward installation analysis, and the rigid connection in the elastic connection is used in the upside-down analysis.

The structural unit parameters of the Moon Bay Bridge are shown in Table 1, and the finite element model of the Moon Bay Bridge is shown in Figure 3.

| Component name | Material                  | Elastic Modulus (MPa) | density (Kg/m³) | Poisson's ratio | Thermal expansion coefficient |
|----------------|---------------------------|-----------------------|-----------------|----------------|------------------------------|
| Main cable     | High-strength galvanized steel wire | 195e9                 | 12000           | 0.2            | 1.2e-5                       |
| Boom           | High-strength galvanized steel wire | 195e9                 | 12000           | 0.2            | 1.2e-5                       |
| Main tower     | C50 concrete              | 3.45e9                | 2549.3          | 0.3            | 1.0e-5                       |
| Main beam      | C55 concrete              | 3.55e9                | 2549.3          | 0.3            | 1.0e-5                       |
5. Static analysis under temperature

The Moon Bay Bridge adopts prestressed concrete stiffening beams, and its main cable suspension rods also have a certain effect on temperature deformation, and the effect of temperature needs to be considered. This article only considers the overall temperature increase or decrease.

The Moon Bay Bridge is located in Yongshan County, Zhaotong City, Yunnan Province. According to the data of Yongshan County Meteorological Bureau, the annual average temperature is 16.4°C, the lowest monthly average temperature is 6.7°C, the highest monthly average temperature is 25.2°C, the extreme highest temperature over the years is 38.8°C, and the extreme lowest temperature -3.6°C. The reference temperature is 20°C, and the overall temperature rise is 18.8°C and the overall temperature drop is -23.6°C. The displacement envelope diagram of the main cable under temperature is shown in Figure 4, and the internal force diagrams of the main cable and the boom are shown in Figure 5 and Figure 6.

![Figure 4. The displacement diagram of main cable under temperature of Moon Bay Bridge](image-url)
6. Conclusion

It can be seen from the above chart that under the effect of temperature, the overall temperature rises and the main cable slack. The main cable at the mid-span position shifted downwards, and the main tower gradually elongated as the temperature increased. Near the main tower, the main cable and the stiffening beam produce upward deflection, and the internal force under the effect of the overall temperature increase is opposite to the internal force under the effect of the overall temperature decrease. The displacement axial force under live load has a greater influence than the displacement axial force under temperature.
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