Study on mechanical properties of rear fulcrum hanging basket of cable-stayed bridge

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Abstract. In order to study the mechanical properties of diamond hanging basket in the construction process, this paper takes the diamond hanging basket used in the construction of Jialing River Bridge in Baiyanba as the engineering background, and uses Midas / Civil finite element software to establish the hanging basket model to analyze the influence of structural stress, deformation and temperature load of hanging basket in the construction process. The results show that the stress and deformation of the hanging basket meet the requirements during the construction process; under the action of heating, the vertical deformation of the hanging basket is large, and the influence of temperature should be considered when the hanging basket is erected, and the stress meets the requirements. The effect of cooling on the structure can be ignored.

Keywords: Cable-stayed bridge; Rhombic hanging basket; Back pivot; Mechanical property; Temperature load.

1   Introduction

As the core of cantilever casting construction methods, controlling deformation and stress is challenging during construction [1-3]. The diamond-shaped hanging basket, as a type of truss-type hanging basket, features a simple structure and clear load distribution. Wu et al. [4] conducted a stress analysis of a continuous box girder diamond-shaped hanging basket on a certain bridge. Zhao [5] analyzed the deformation, internal force and overall anti-overturning calculation of the key parts of the diamond hanging basket; Cao et al. [6] obtained the internal force, stress and deformation of the bridge in the maximum cantilever state and the completed bridge state by finite element calculation. Wang et al. [7] analyzed the strength and stiffness of the main components of the hanging basket suspension system. Xie et al. [8] verified the feasibility of the finite element calculation results through comparison.

The above studies are mostly aimed at the influence of the load on the hanging basket in the no-load state, and there are few related studies in the construction process. Stress and deformation are the main control indexes in the construction process. Therefore, the finite element model of diamond hanging basket is established in this paper to

analyze the stress, deformation and temperature effect of hanging basket in the process of construction and pouring, which can provide reference for similar hanging basket construction.

2   Project profile

Baiyanba Jialing River Bridge is a prestressed concrete cable-stayed bridge with double cable planes. The bridge span is 149m + 133m. The center height of the standard beam section of the box girder is 3.3m, the top width of the box girder is 33.2m, the bottom width of the box girder is 5.5m, and the net spacing between the box girders is 13.90m. The standard beam segment of the box girder has a height of 3.3m, a top width of 33.2m, a bottom width of 5.5m, and a clear spacing between box girders of 13.90m. Cantilever casting of the box girder is carried out using rear support diamond-shaped hanging baskets. The length of the 0# segment of the box girder is 6m, meeting the requirements for the starting length of hanging basket assembly. In cantilever casting of the box girder, the maximum segment control weight is 450 tons.

3   Finite element module method

The hanging basket model was established using the finite element software Midas/Civil, as shown in Figure 1. The model consists of 648 nodes and 774 elements. It includes all load-bearing systems such as the main truss, transverse connection system between columns, front upper crossbeam, and bottom basket. The hanging basket suspension straps are simulated using truss elements subjected to tension only, while the remaining components are simulated using beam elements.
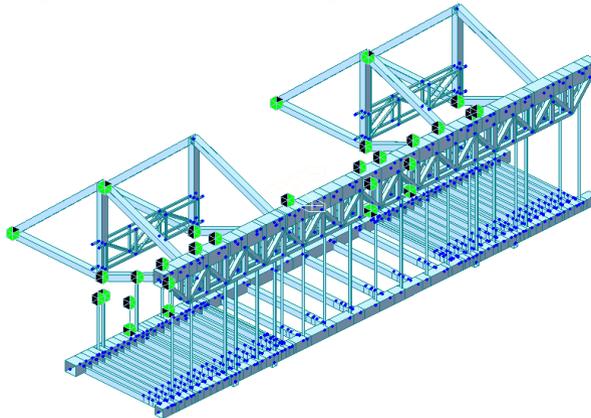

Fig. 1. Hanging basket calculation model Load calculation

3.1   Load calculation

According to the design of the hanging basket, the weight of newly poured concrete is borne by the bottom longitudinal beams for top and bottom plate loads (B/C zone), by the inner cavity lower longitudinal beams for top plate loads (D zone), and by the lower longitudinal beams of the wing plate for flange plate loads (A zone). The load distribution is converted into line loads using the strip method. The load strip division areas are shown in Figure 2:

Fig. 2. Transverse load distribution diagram of bridge

During concrete pouring, the load primarily acts on the longitudinal beams, with a concrete density γ of 26 kN/m³. The load distribution for the box girder segments is shown in Table 1.

Table 1. Load values on different regions

Area	A	B	C	D
Concrete load(kN)	767.68	471.74	97.81	1163.24
Model hard loading(kN)	120.00	3.96	1.25	410.00
Machine load(kN)	69.75	9.00	2.85	193.50
Vibration load(kN)	111.60	14.40	4.56	309.60

3.2   Load combination

The load combinations and coefficients for the hanging basket are as shown in Table 2.

Table 2. Load combination table

Number	Load combination	Remark
1	（① ×1.05+②+③)×1.2+(④+⑤)×1.4	Strength; Stability
2	① +②+③+④	Rigidity
3	① ×1.2+⑥×1.4	Overall warming
4	① ×1.2+⑦×1.4	Overall cooling

Note: In the table above, ①represents the weight of poured concrete; ②represents the self-weight of the hanging basket; ③represents the self-weight of the formwork; ④represents the load from construction equipment and personnel; ⑤represents the load generated from pouring and vibrating concrete; ⑥represents overall temperature rise; ⑦represents overall temperature decrease.

4   Main component checking

Under the most unfavorable working conditions in the construction stage, the stress analysis of each component part of the hanging basket and the whole diamond hanging basket is carried out respectively.

4.1   Structural strength and rigidity

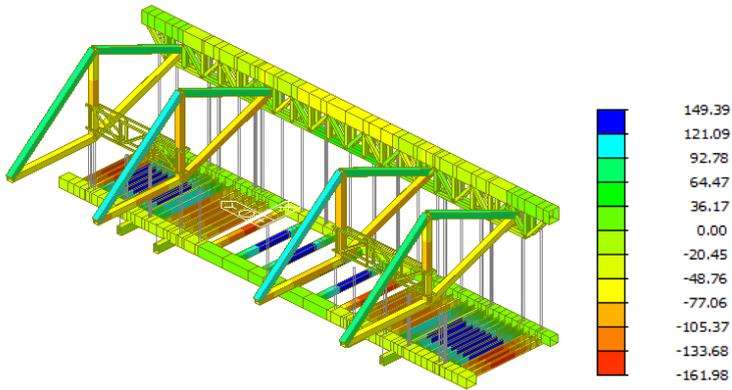The strength and stiffness of the hanging basket structural calculation are illustrated in Figures 3 to 4.

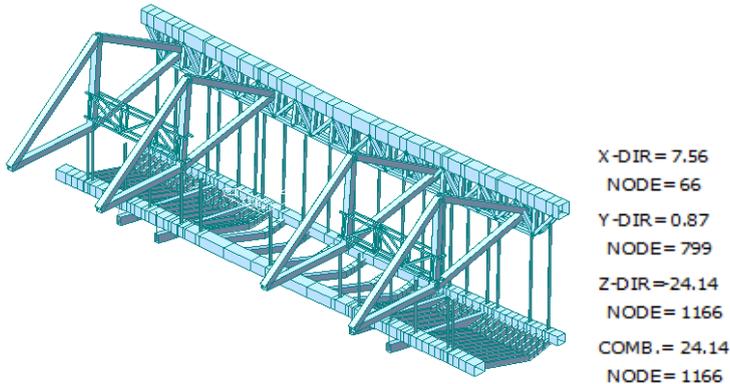**Fig. 3.** Hanging basket structure stress diagram (MPa)

Fig. 4. Hanging basket structure displacement diagram (mm)

From Figure 3-4, it can be observed that during the construction process, the maximum stress in the hanging basket occurs at the longitudinal beam of the bottom basket, with a maximum stress value of 161.98 MPa; the maximum deformation of the hanging

basket occurs at the front lower crossbeam, with a maximum deformation value of 20.30 mm, meeting the requirements for stress and deformation.

4.2   Thermal effect analysis

Existing studies indicate that the highest and lowest effective temperatures for steel bridge decks in hot regions are 46°C and -9°C respectively. According to the temperature conversion formula, the temperature range is determined to be -11°C to 46°C. Therefore, this study assumes a temperature variation range of 11°C to 60°C for the overall structure.

4.2.1 Overall heating calculation

Using load combination 4 for calculation, the strength and deformation of the hanging basket are illustrated in Figures 5 to 6.

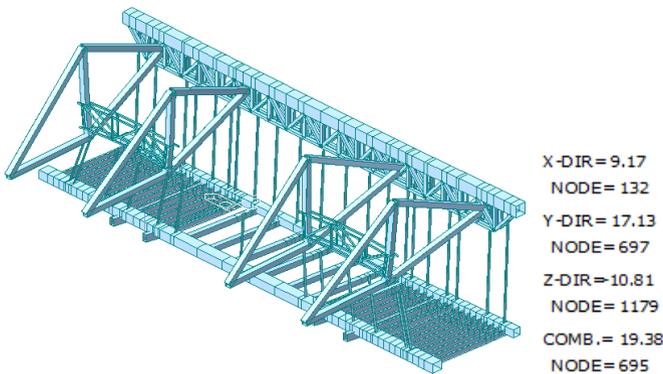**Fig. 5.** Stress diagram under the action of hanging basket heating (MPa)

Fig. 6. Displacement diagram under the action of hanging basket heating (mm)

According to empirical calculation, it can be observed from figures 5-6 that under the overall temperature rise effect, the maximum stress on the hanging basket occurs at the main truss, with a stress value of -154.9MPa, which does not exceed the allowable stress value. The maximum deformation of the hanging basket occurs at the front lower beam, with a maximum vertical deformation value of 10.81mm. Therefore, attention should be paid to the selection of template elevation during formwork construction.

4.2.2 Overall cooling calculation

Using load combination 5 for calculation, the strength and deformation of the hanging basket are illustrated in Figures 7 to 8.
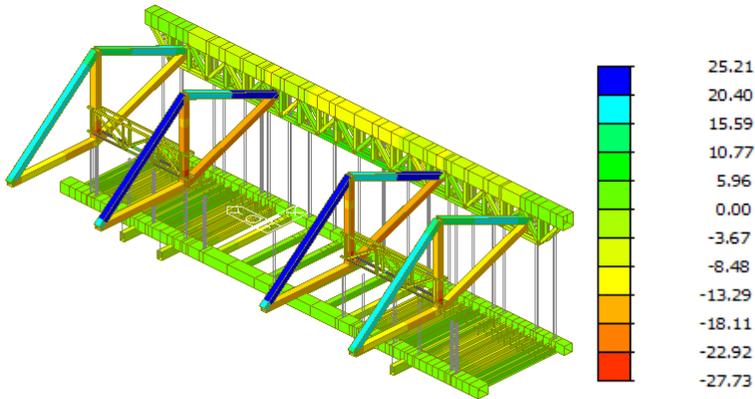

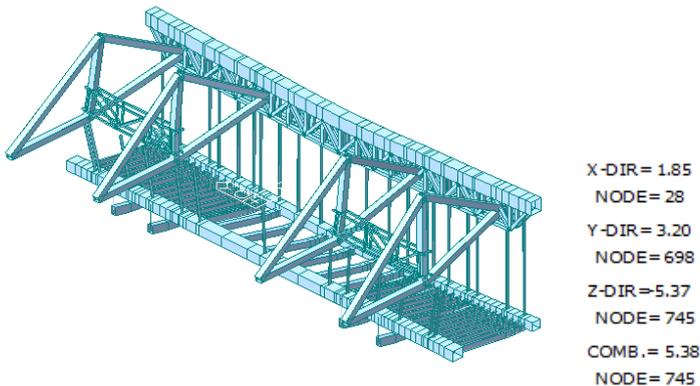**Fig. 7.** Stress diagram under the cooling effect of hanging basket (MPa)

Fig. 8. Displacement diagram under the cooling effect of hanging basket (mm)

Based on empirical calculation, it can be inferred from figures 7-8 that under the overall cooling effect, the maximum stress in the hanging basket occurs at the main truss, with a maximum stress value of -27.7MPa, which is less than the allowable stress

value, meeting the requirements. The maximum vertical deformation of the hanging basket occurs at the front upper beam, with a deformation value of -5.4mm, which is less than 1cm. Therefore, the influence of temperature reduction on the stress and deformation of the hanging basket can be neglected.

5   Conclusion

Through analyzing the structural stress, deformation, and considering the effects of temperature load during the construction phase of the diamond-shaped hanging basket on a certain cable-stayed bridge under construction, the following conclusions are drawn.

(1) In this paper, the finite element model is established to calculate the stress and deformation results of each component of the hanging basket during the construction process. It is found that the diamond hanging basket meets the stress and deformation requirements during the construction process.

(2) The impact of overall temperature changes on the stress and deformation of the hanging basket structure was analyzed. The results indicate that under overall temperature rise conditions, the vertical displacements of the lower front beam and longitudinal beam of the hanging basket are relatively large, suggesting the consideration of setting the formwork elevation to account for the effects of temperature rise during actual construction. The impact of overall temperature drop on the hanging basket structure is negligible and can be disregarded. In the construction process, we should focus on the impact of temperature rise.

(3) This paper mainly studies the stress, deformation and temperature effect of diamond hanging basket in the construction stage, which can provide guidance for the design and calculation of finite element software of similar hanging basket system and cantilever pouring construction.

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