RESEARCH ARTICLE OPEN ACCESS

The hanging basket stress calculation and stability analysis during cantilever construction

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ABSTRACT
The bearing capacity and stability of the Hanging Basket is a key point in the process of cantilever construction. It is important to set up finite element analytical model accord with the actual stress state of structure. According to the Laotuanpo NO.2 bridge as an engineering example, the strength, stiffness and stability of the Hanging Basket is analyzed using the space truss model. The analytical calculation shows that the design for Hanging Basket in cast-in-cantilever construction plan completely conforms to the specifications and design requirements. It is provide a solid theoretical foundation for the reliability of Hanging Basket during cast-in-cantilever construction.
Keywords-Triangle Hanging Basket, strength, stiffness, stability

I. FOREWORD

Hanging Basket suspended pouring construction is the longitudinal beam is divided into some little sections, with a Hanging Basket as construction equipment to Symmetrical cantilever construction. Hanging Basket is structure that able to move along the top of the box girder, anchored on the already completed pouring sections, make all the construction work of the next element in the Hanging Basket, and the cycle until the job is completed cantilever pouring [1]. Construction of Hanging Basket is safe, reliable, high efficiency of construction, during construction of a small amount of deformation characteristics, are widely used in the Continuous Rigid Frame bridge construction.

This paper refer to do analysis of a building continuous rigid frame bridge in Yunnan province. The bridge is 90 m + 160 m + 90 m variable cross-section single box single chamber structure, The Box girder with vertical web , the width of top palate is 12 m, the width of bottom palate is 6.5m,the length of flange plate is 2.75 m, The height of NO.0 section is 10 m, The height of the box grider in middle span is 3.5 m, The web with a variable thickness from 100cm to 50cm, The bottom palate is from 140cm to 32cm. The length of NO.0 section is 12m, The length of closure section in middle span is 2m, The super large bridge box girder cantilever pouring using Triangle Hanging Basket construction,In this paper ,the finite element analysis software Midas civil 2012 for the Triangle Hanging Basket in the cantilever construction process of stress calculation and stability analysis.

II. THE STRUCTURE OF THE HANGING BASKET

This Triangle Hanging Basket usually have five parts,they are main truss system，anchorage system，working system， formwork system， suspension system. The main truss system is consisted of vertical rod, Front beam,back coss beam, Oblique rod, Bottom chord rod,Bottom longitudinal beam,Bottom cross beam, Bottom end beam, The anchoring system is consisted of several fine rolled twisted bars, they are 32 mm in diameter, They put the Hanging Basket anchor on the already pouring beams; Running system is rolling running system, Through the Hanging Basket of main girder supporting steel pillow it forward on the wheel, Formwork system is composed of bottom formword, side formwork and internal formwork[2], Suspension system is consisted of several 32mm diameter fine rolled twisted bars, which are connected to the bottom of the hanging baske to the upper together to ensure the overall force. This Triangle Hanging Basket weighing about 750KN, the Triangle Hanging Basket structure shown in Figure 1.

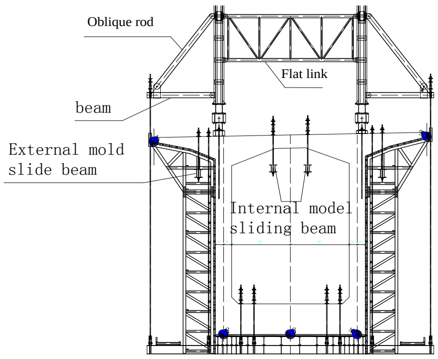

Fig1.Hanging Basket structure diagram.

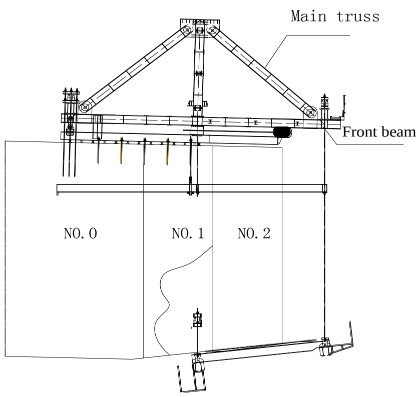

Fig2.Hanging Basket structure diagram

In accordance with the relevant specifications[3][4], Hanging baske weight and the weight of the concrete to be poured ratio should be controlled at between 0.3-0.5, under special circumstances and should not be more than 0.7, The maximum allowable amount of deformation of the main truss for 25mm, Bottom longitudinal beams deflection allowable amount of L / 400, This Triangle Hanging Baske of steel using Q 235, Elastic Modulus is 2.1×105MPa, Allowable Stress[σ]=205MPa, Tensile strength of the standard value 32mm diameter fine rolled twisted bars fpk=930MPa, Design value of tensile strength fpd=770 MPa, When the hanging baske Construction and walking safety factor against overturning K=2.

III. HANGING BASKET LOAD PARAMETER CALCULATION

3.1 Load Factor.

Overload factor of 1.2 when pouring concrete box girder, Pouring concrete power factor is 1.2Hanging Basket Shock load factor was 1.3 when walking.

3.2 Load Combinations

In order to verify the strength of the Hanging Basket structure, stability, and stability when walking. Take load combinations I: concrete weight + additional power load + dead weight + people and equipment loads; load combinations II: dead weigh + additional impact load.

Load combinations I for the main truss bearing checking calculation system strength and stability,Load combinations II for Hanging Basket walking for checking.

3.3 Hanging Basket Design Load Calculation

(1) The No. 0 and NO.1 Long span bridge in the element using bracket cast construction, the rest of the element using the Traveler Symmetrical Cantilever pouring Construction, No. 2 element maximum weight, so take the load box girder No. 2 element calculation, the length of this element is 3.0m, No. 2 element pouring concrete weight is 1930KN, Hanging Basket of quality and quality ratio is 0.389 concrete beams meet regulatory requirements [3], considering overload load factor is 1930 × 1.2 = 2316KN, concreting power coefficient of 0.2, So this element of the additional power load is 1930 × 0.2 = 386KN.

(2) The weight load of Hanging Basket is 750KN, It includes the weight of the main truss, the internal formwork, formwork and the bottom side of the formwork, etc.

(3) Crowd and construction machinery loading is 2.5KN / m2.

(4) Shock additional load: Hanging Basket Shock factor of 0.3 when walking, the Shock the additional load 0.3 × 750 = 225KN.

IV. HANGING BASKET STRENGTH AND RIGIDITY CALCULATION

When pouring concrete box girder weight is shared by side forwork and bottom forwork, assuming Hanging Basket force when the force transmission route follows[5].

(1) The weight of the concrete box girder flange plate and side formwork of, put on external guiding beam and external removable beam, and then passed to a finished construction of the element of the wing and the Hanging Basket of the former main truss beams respectively.

(2)The weight of the concrete box girder roof of the next segment, in-mold, and its weight within the stent by sliding beams were applied in the previous sections has finished construction of the main beam ceiling and Hanging Basket on the front beam.

(3) The weight of the front of the box girder beams concrete floor, concrete weight and the weight of the web platform Hanging Basket bottom section has been applied to the segment finished pouring the girders and stringers Hanging Basket bottom front, and then spread to the main truss.

Therefore, it is necessary to carry out their assigned weight, weight distribution concrete box girder shown in Figure 3,This Triangle Hanging Basket made using Midas Civil 2012 space truss system modeling analysis, Beam element simulation with the main truss, truss elements to simulate the suspender, it's the model shown in Figure 4.

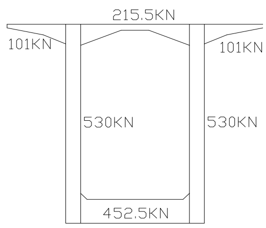

Fig3. Box girder weight distribution

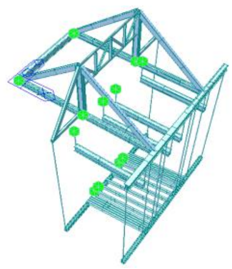

Fig4. Hanging Basket calculation model

4.1 Hanging Basket strength checking

4.1.1 Main truss strength checking

Main truss bottom stringers and vertical rod is constituted by a square cross-section rod composed 2I40b ordinary hot-rolled steel channel, Oblique rod produced by the 2 [40b ordinary hot-rolled steel channel, Front beam by 2I50c ordinary joist steel composition. Bottom stringers by I40b ordinary joist steel composition, With the load combination I for checking the strength of the main truss, after computing model to get this Hanging Basket of internal forces and the main truss girder stresses in Table 1.

Table 1 Main truss internal forces Table

Main truss rods	Oblique rod	vertical rod	Bottom chord rods	Front beam	Flat link rods
stress（Mpa）	119.43	-175.10	-164.80	-172.4	37.73
F（KN）	1724.47	-2226.1	-1314.71	0.06	-5.08
My（KN.m）	-35.16	107.50	-216.33	438.99	-4.14

From Table 1, the maximum tension of main truss is 1724.47KN, maximum pressure of main truss is -2226.11KN. Main truss maximum tensile stress is 119.43 Mpa <[σ] = 205Mpa. Its location on the Oblique rod, the maximum compressive stress is the main truss 175.10Mpa <[σ] = 205Mpa, its position on the vertical rods[6].

4.1.2 The main girder stiffness calculation[7]

Hanging Basket of the main truss deformation shown in Figure 5:

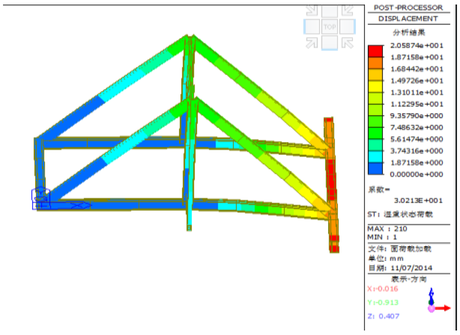

Fig5.Hanging Basket of main truss deformation figure

Maximum deformation occurs as shown in Figure 4 on the front Hanging Basket of beams, The maximum deformation of 20.6mm <[ξ] = 25mm, Hanging Basket of the main truss stiffness to meet the requirements. Hanging Basket by the model calculation shows the maximum anchor reaction force for 1074KN. Middle fulcrum supporting force for 2283.3KN.

4.2 Bottom die structure calculation

4.2.1 The calculation of longitudinal beam under the web

(1)The calculation of load

Take NO.2 block box girder load calculation The length is 3.0m The concrete weight of the web is about 530 KN. Box girder web plate width is 0.7 m，Set up four I40b joist steel, the spacing of 200 mm.Template by weight 2.5KN / m^2 meter; crowd equipment load by 2.5KN / m2 meter; pour concrete load by 2KN / m2 meter; So the local load of the bottom of the web plate girder is q=1.2×（530/3+2.5×0.7）+1.4×（2.5×0.7+2×0.7）=218.51KN；Then each longitudinal beam line load is: q / 4 = 54.63 KN/m.

2）Force calculation

Midas civil 2012 is adopted to establish the model calculating the longitudinal beam, It is concluded that the beam stress diagram, as shown in Figure 6.

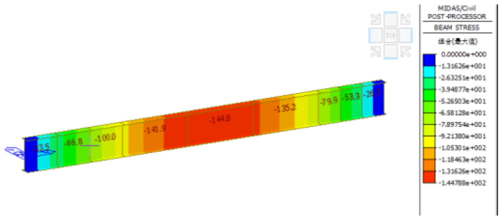

Fig6. Web of girder stress diagram

4.2.2 The calculation of longitudinal beam under the baseplate

(1) The calculation of load

Take NO.2 section box girder load calculation The length is 3.0m, Baseplate concrete weight of about 452.5 KN, Set up eight I40b joist steel, The baseplate width of box girder (excluding web) is 5.1 m, Template by weight 2.5KN / m2 meter; crowd equipment load by 2.5KN / m2 meter; pour concrete load by 2KN / m2 meter; So the local load of the bottom of the baseplate girder is q=1.2×(452.5/3+2.5×5.1) + 1.4 ×（2.0× 5.1+2×5.1）=224.86KN；Then each longitudinal beam line load is: q/8=28.11 KN/m.

(2) Force calculation

Midas civil 2012 is adopted to establish the model calculati

Midas civil 2012 is adopted to establish the model calculatingthe longitudinal beam, It is concluded that the beam stress diagram, as shown in Figure 7.

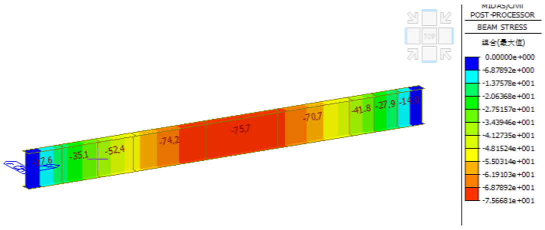

Fig7. Floor bottom longitudinal beam stress diagram

The model calculation, as shown in figure 6 can be concluded that the plate bottom longitudinal beam under the maximum stress of 75.7 Mpa < [united] = 205 Mpa, maximum deflection is 5.7 mm < L / 400 = 13 mm, former fulcrum reaction of 48 KN, protection after a counterforce 40.3 KN, meet the specification requirements.

4.2.3 The calculation of the cross rods behine the Bottom die structure

The cross rods behine the Bottom die structure adopts two I40b hot rolled joist steel, Those cross rods s under load is mainly by the longitudinal beam passed. The bottom longitudinal beam calculation shows that the bottom of the web in longitudinal beam counterforce 75.6 KN, after floor place after the bottom longitudinal beam counterforce 40.3 KN, using Midas civil 2012 model, the beam deformation diagram and the beam stress calculated.

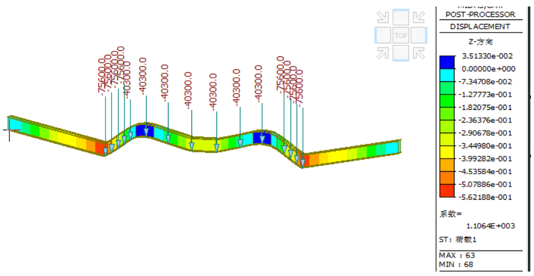

Fig8. The back bottom formwork beam deformation figure

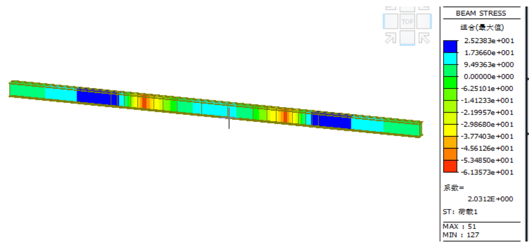

Fig9. The back bottom formwork beam stress diagram

Figure 9 illustrates the bottom die beam maximum stress is 61.36 Mpa, each joist steel maximum stress is 30.68 Mpa < [σ] = 205 Mpa, from Figure 8 shows the maximum deformation of 0.56 mm to meet specification requirements.

4.2.4 The Calculation ofcross rods before the Bottom die structure

The cross rods before the Bottom die structure adopts two I40b hot rolled joist steel, Those cross rods under load is mainly by the longitudinal beam passed. The bottom longitudinal beam calculation shows that the bottom of the web in longitudinal beam counterforce 91.4 KN, after floor place after the bottom longitudinal beam counterforce 48KN, using Midas civil 2012 model, the beam deformation diagram and the beam stress calculated. As shown in Figure 10 and shown in Figure 11.

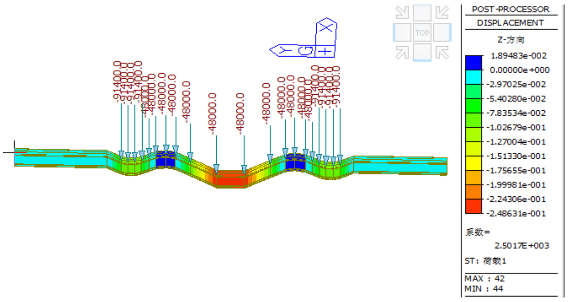

Fig10.The front bottom formwork beam deformation figure

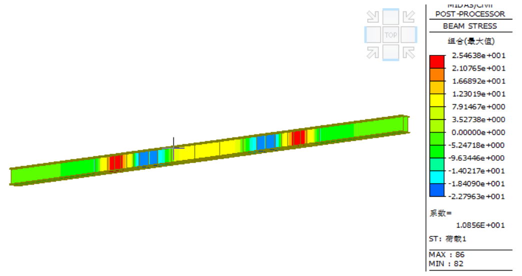

Fig11. The front bottom formwork beam stress diagram

Figure 11 illustrates the bottom die beam maximum stress is 25.46 Mpa, each joist steel maximum stress is 12.73 Mpa < [σ] = 205 Mpa, from Figure 10 shows the maximum deformation of 0.24 mm to meet specification requirements.

4.3 Force calculation of the suspender

By the model data shows: in the pourng state suspender axial maximum tension is 385.1 kN;Hanging Basket to walk, that the maximum axial tensile force of suspender is 53.77 KN. The suspender is 32 mm diameter Finish Rolled Threaded Reinforcing Bar, its tensile strength standard values is 770 mpa.

A=804.25mm2 ,

$$\sigma=\frac{N}{A}=\frac{385.1KN}{804.25mm^2}=478.83Mpa<770Mpa$$

The results show that the strength of suspender satisfies the requirement of technical specification for construction of Bridges.

V. STABILITY CALCULATION OF THE HANGING BASKET

Based on literature [8] and in combination with the practical situation of Hanging Basket. For the rigidity calculation of Hanging Basket pouring condition and the walking state resistive overturning of the calculation, the following calculation for the calculation of a triangle truss [8].

5.1 Hanging Basket rigidity calculation of pouring condition

Hanging Basket pouring conditions of the back anchor point of the each main truss reaction is 1074 KN, According to the Hanging Basket design drawings, The back fulcrum is made of four root diameter is 32 mm Finish Rolled Threaded Reinforcing Bar anchorage on the already finished pouring box girder. The Finish Rolled Threaded Reinforcing Bar tensile strength design value of fpd=770 MPa, The calculation every Finish Rolled Threaded design of Reinforcing Bar tension of 619.3 KN, So the back anchor point allowable force [F] = 4 x 619.3 KN = 2477.2 KN，Calculate the Hanging Basket pouring state safety factor K = 2.3 > 2，The results show that the stability of the Hanging Basket in the pouring state meet the requirements of technical specification for construction of Bridges.

5.2 Hanging Basket rigidity calculation of walking condition

The Hanging Basket triangle truss and bearing when installed firmly welded into a whole. Use a jack walked in the orbit, When walking Hanging Basket, anchor beam reinforcement need to be removed, Hanging Basket backend relies on the vertical prestressed anchorage box girder, and when walking Hanging Basket, the back anchor point hanging wheel fixed on the box girder, this make the Hanging Basket not capsize, so the load combination II is adopted for checking, Hanging Basket load for the weight of 750 KN, bearing impact load of 225 KN, After model calculation shows the anchor point with single main truss reaction force of 233.8 KN. According to the Hanging Basket design drawings, the walking condition the back anchor point allowable force [F] = 686 KN. Calculation of Hanging Basket state safety factor K = 2.93 > 2, the results show that the state of walking stability of the Hanging Basket satisfies the requirement of technical specification for construction of Bridges.

5.3 Calculate the stability of vertical rod

The vertical rod use 2I40b section form, the section form is shown in Figure 12.The height of vertical rod is 4500mm, Calculated by the model in the condition of concrete pouring, The vertical rod the maximum axial force is 2226.11 KN.

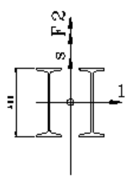

Fig12. the uprightsectional view

Calculate the features section I=4.5563×108 mm^4 ;

A=1.88×104 mm^2 ; $i=\sqrt{\frac{455630000}{18800}}=155.7$;

$$\lambda=\frac{l}{i}=\frac{4500}{155.7}=28.9$$

$$N=\varphi\sigma A=0.969\times215\times18813.777=3919KN>2226.1KN$$

The results show that the vertical rod stability meet the requirements of technical specification for construction of Bridges.

VI. CONCLUSION

In this paper according to the Hanging Basket structure form and mechanical characteristics, spatial truss finite element model is established, the analysis model of the whole stress and the stability of Hanging Basket, can draw the following conclusions:

(1)This Triangle Hanging Basket of main truss strength checking each bar in the case of load combination I stress are less than the allowable stress, meet the specification requirements. vertical rod and oblique rod stress is the largest, they are the largest stress in the process of Hanging Basket construction rod, so to them the highest strength, stiffness and stability requirements.

(2) The stability of the Hanging Basket rod checking and integrity checking: The Hanging Basket of main truss rods can satisfy the requirements of rod stability, In the front and back beam with triangle main truss junction, should be in strict accordance with the design of welding steel plate to improve, Channel steel, i-steel and H section steel compound of stiffening rib box section should be enough, The integrity stability of the Hanging Basket experience is also meet the requirements of specification.

(3) Hanging Basket construction scheme of the main truss stressing definite and rational design. Specific operation should not only guarantee the Hanging Basket in the uniform synchronous walk slow, prevent reverse Hanging Basket, and strictly to strengthen the control of Hanging Basket deformation observation.

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