

# Steel Trestle Calculation with Midas Civil

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**Abstract:** Through the construction of the water engineering of the Xiaogan-Changzhi channel project from Zhoushan Shengsi to Dinghai Highway, the construction technology of the water steel trestle is expanded, and the application of Midas Civil software in the calculation of steel trestle bridge is introduced. Through the calculation of the most unfavorable load combination for different conditions, and the accurate calculation results are obtained, which provides engineering data for the design of the offshore steel trestle.

**Key words:** Midas Civil; steel trestle; temporary structure calculation

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## 1. Project Overview

The main trestle has a total width of 8+1 meters, a span of 12m and a total length of 1410m. The trestle pile is  $\phi 800 \times 10$ mm steel pipe pile, each row of 3 steel pipe piles, each pile spacing is 3m. The rear anchor pile is installed every 24m in the bare rock zone trestle, the rear anchor pile is  $\phi 1000 \times 10$ mm steel pipe pile, and the pile diameter of the bored pile at the bottom is 1000mm. The  $\phi 430 \times 6$ mm steel pipe is used for transverse connection at 50cm above the normal water level, the lower beam is 2I40 steel, and the vertical beam is 321Bailey beam. The bridge deck is made of steel plate, and the bridge deck is made of I25, I12.6 and  $\delta=10$ mm steel plates.

## 2. Construction Process

The construction process of the trestle is shown in Figure 2-1.

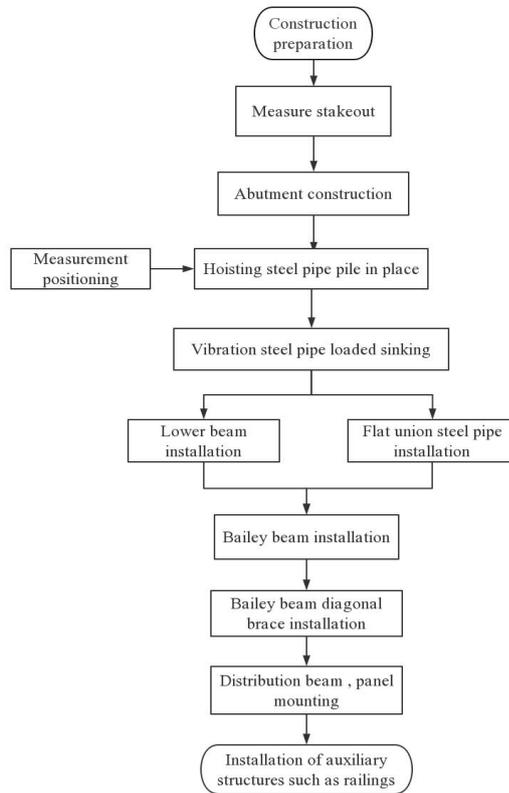


Figure 2-1. Flow chart of the construction process of the trestle

### 3. Structural Layout and Material Properties

#### 3.1 Section design

The structure is designed as a Baileybeam trestle, and the lower part adopts  $\text{Ø}800 \times 10$  steel pipe pile,  $\text{Ø}426 \times 6$  parallel connection, groove 20 diagonal support, double limb 40a beam, and the upper part is “2+3+2” combination Bailey beam, 25a@75cm and 12.6@30cm distribution beam, 10mm steel panel. The Baileybeam and the beam stop are processed by the groove 8.

The cross section design is shown in Figure 3-1.

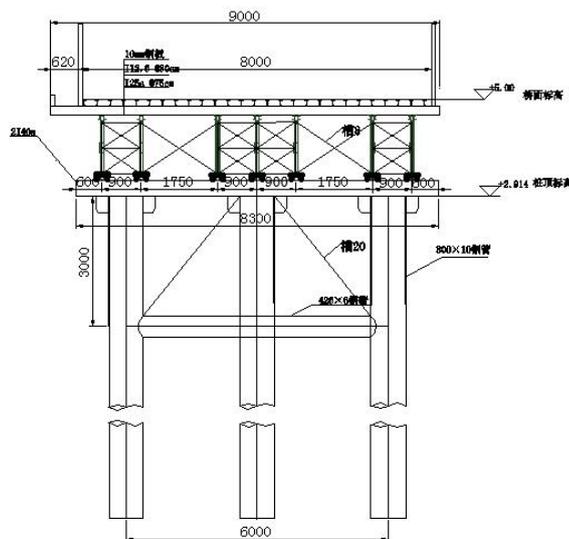


Figure 3-1. Cross section of thick overburden area and shallow overburden area

桥面标高: Deck elevation

桩顶标高: Pile top elevation

钢管: Steel Pipe

槽: Groove

#### 4. Load Analysis

##### 4.1 Superstructure load

Single Bailey truss load: 1.5KN/m, including wind bracing

All areas of steel panel deck: 1KN/m<sup>2</sup>

##### 4.2 Uniform construction load

All areas of the bridge deck: 2KN/m<sup>2</sup>, the combined load and crowd load have been considered.

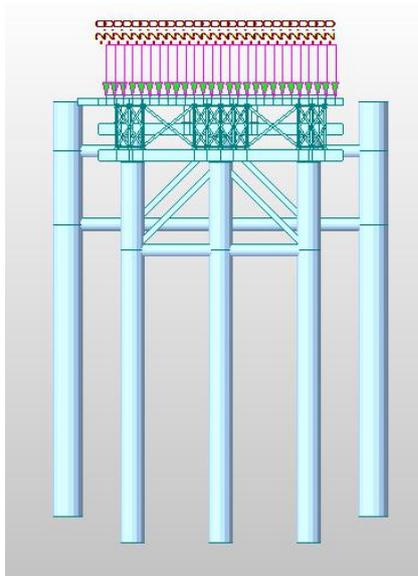


Figure 4-1. Diagram of uniform construction load

##### 4.3 Locomotive load

Crawler crane: weight 800KN, hoisting weight 200KN, track width 80cm, length 540cm, center spacing 420cm.

Tanker: full load 350KN, wheel track 1.8m, wheelbase 3.2m+1.3m, front wheel landing area 0.30m×0.20m, rear wheel landing area 0.60m×0.20m. The front axle gravity standard is 70KN, and the rear wheel gravity standard is 2×140KN.

The lateral lifting coefficient is: 1.6.

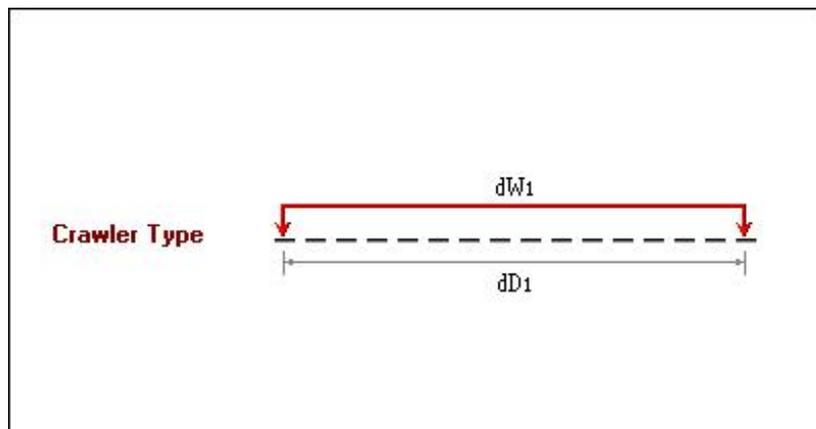


Figure 4-2. Diagram of force on crawler crane

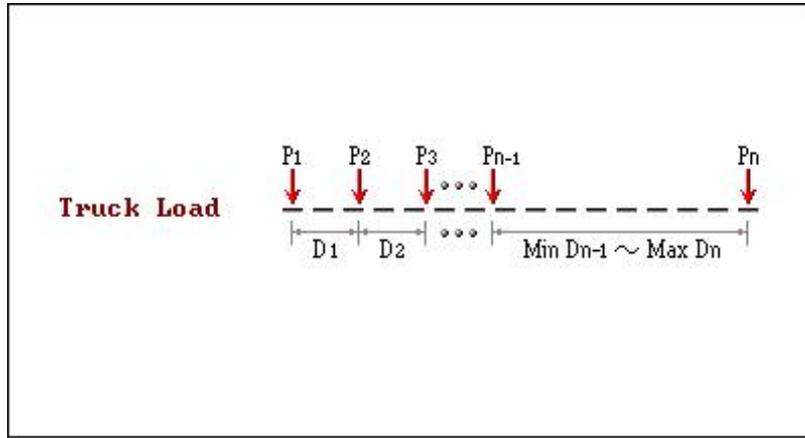


Figure 4-3. Diagram of truck load

#### 4.4 Wind load

Normal construction wind speed: 17.1m/s (seven wind);

Calculated according to the provisions of section 4.3.7 of *General Specifications for Design of Highway Bridges and Culverts* (JTG D60-2015):

$$\text{Transverse bridge wind load } F_{wh} = k_0 k_1 k_3 W_d A_{wh}$$

$$W_d = \frac{\gamma V_d^2}{2g}, \quad W_{10} = \frac{\gamma V_{10}^2}{2g}, \quad V_d = k_2 k_5 V_0$$

$$\gamma = 0.012017 e^{-0.0001Z}$$

$F_{wk}$ --transverse bridge wind load standard value (KN);

$W_{10}$ --basic wind pressure (kPa);

$W_d$ --design reference wind pressure (kPa);

$A_{wh}$ --transverse windward area ( $m^2$ );

$V_{10}$ --The basic wind speed of the design of the area where the bridge is located is based on a flat open floor and is 10m above the ground.

$V_0$ --design reference wind speed (m/s), the wind speed at the high Z from the ground;

Z --the height from the ground or the water surface (m);

$\gamma$  --air gravity density (KN/ $m^3$ );

$k_0$ --the coefficient of the design wind speed return period, which is 0.75;

$k_3$ --the coefficient of terrain geographical condition, take 1.00;

$k_5$ --the coefficient of gust wind speed, which is 1.38 in the class A area;

$k_2$ --considering the ground roughness class and the wind speed height change correction coefficient of the gradient wind, the class A area takes 1.23;

$k_1$ --wind load resistance coefficient,  $\eta K_1 = 0.74 \times 1.3 = 0.962$  (wind load coefficient of truss, including the actual area ratio of bridge deck according to 0.4);

g--gravitational acceleration ( $g=9.81m/m^2$ ).

$$\gamma = 0.012017 e^{-0.0001Z} = 0.012017 e^{-0.0001 \times 10} = 0.012$$

The benchmark of wind pressure:  $W_d = \frac{0.012 \times (1.23 \times 1.38 \times 17.1^2)}{2 \times 9.81} = 0.52 \text{ kN} / \text{m}^2$

Single Bailey beam and bridge deck windward area:  $A_{wh} = 0.4A = 0.4 \times 1.7 \times 3 = 2.04 \text{ m}^2$

The wind load is:  $F_{wh} = k_0 k_1 k_3 W_d A_{wh} = 0.75 \times 0.962 \times 1.0 \times 0.52 \times 1.68 = 0.63 \text{ KN}$

Unit I56a I-steel vertical windward area:  $A_{wh} = A = 0.56 \times 3 = 1.68 \text{ m}^2$

The wind load is:  $F_{wh} = k_0 k_1 k_3 W_d A_{wh} = 0.75 \times 0.962 \times 1.0 \times 0.52 \times 1.68 = 0.63 \text{ KN}$

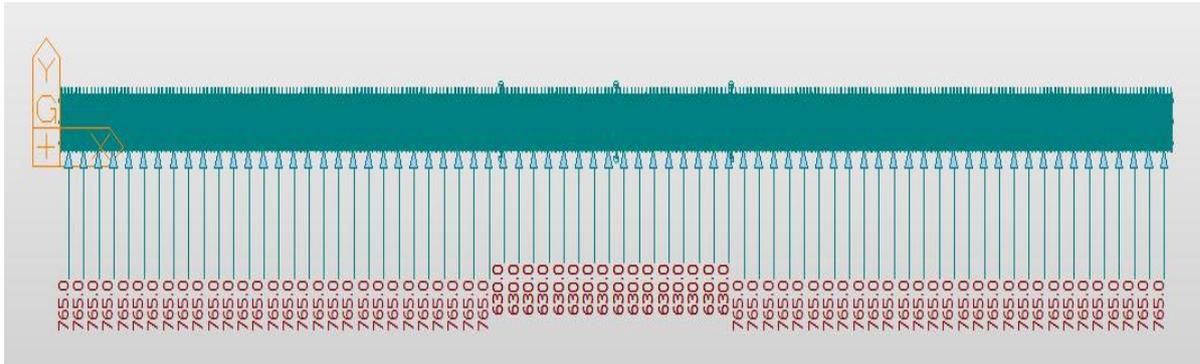


Figure 4-4. Diagram of wind load

#### 4.5 Water flow

The water flow is calculated according to *Load Code for Harbour Engineering*(JTS 144-1-2010):

$$F_w = C_w \rho v^2 A / 2$$

$$F_w = 0.73 \times 0.8 \times \frac{1}{2} \times 1.76^2 \times 0.8 \times (3.2 + 17.8) = 15 \text{ KN}$$

Point elevation  $h = 3.2 - (3.2 + 17.8) / 3 = -3.8 \text{ m}$ .

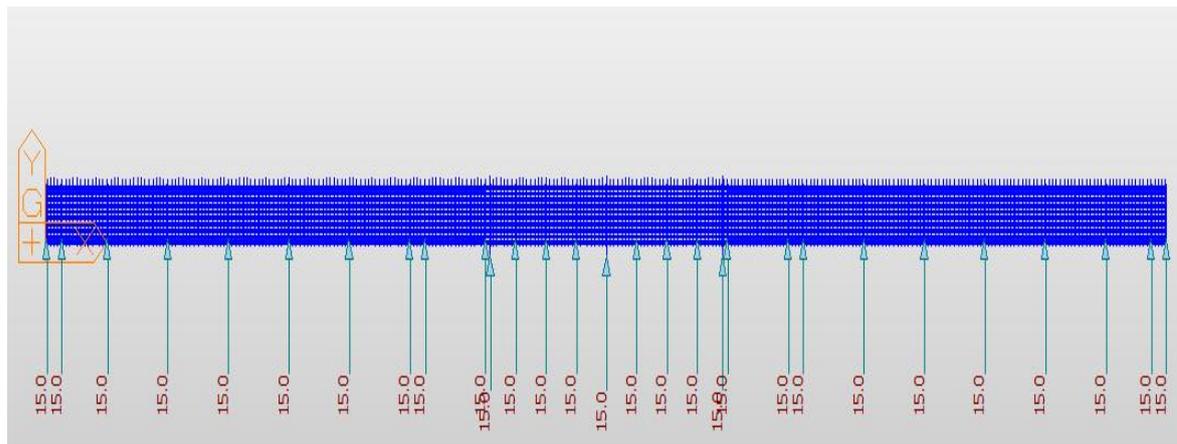


Figure 4-5. Schematic diagram of water flow load

### 5. Load Combination and Analysis Conditions

The most unfavorable construction condition is high tide, the crawler crane is not working, and the tanker is wrong.

Consider a combination of ①superstructure load, ②construction load, ③crawler crane, ④tanker, ⑤wind load, and ⑥water flow force. According to *Load Code for the design of building structures*(GB 50009-2012), the calculation combination is as follows:

Basic combination:  $1.2①+1.4 (②+③+④+0.7⑤+⑥)$

## 6. Structural Calculation

### 6.1 Main technical parameters

The working platform Bailey beam is made of 16Mn steel, and the rest is made of Q235 steel. According to *Standard for design of steel structures* (GB50017-2003) and *Design rules for cranes* (GB3811-2008), the allowable stress value of Q235 steel is 175MPa under wind load conditions; the allowable stress of 16Mn steel is 210MPa.

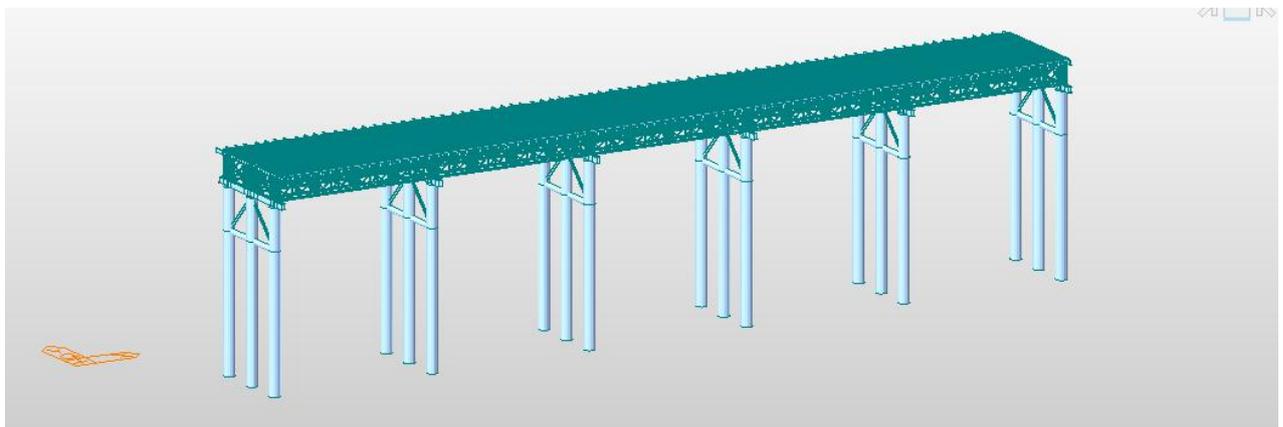
According to *Specifications for Design of Highway Steel Bridge* (JTG D64-2015), because the bridge is a temporary bridge, the allowable stress of steel is increased by 30% under the basic allowable stress, which is 273 MPa. When calculating the vertical deflection, it should be calculated with reference to *Standard for design of steel structures* (GB50017-2014). The main components of the structure are shown in the following table:

**Table 6-1.** Main component materials and allowable stresses

Serial number	Component	Material	Allowable stress [σ]MPa
1	Longitudinal distribution beam	Q235	175
2	Lateral distribution beam	Q235	175
3	Bereliang	16Mn	273
4	Steel trestle	Q235	175
5	Pile top beam	Q235	175
6	Steel pipe pile	Q235	175
7	Anchor pile	Q235	175

### 6.2 Steel trestle structure calculation

The large finite element software Midas/Civil is used to analyze the thick cover area and shallow cover area of the trestle. The model has 13156 units and 8565 nodes. The calculation model is shown in Figure 6-1.

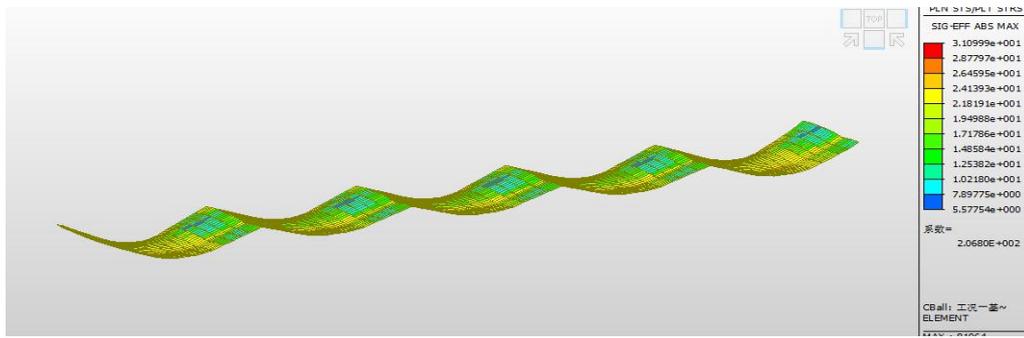


**Figure 6-1.** Model of trestle finite element

### 6.3 Check of the basic combination of the most unfavorable construction conditions of steel trestle

#### 6.3.1 Checking of bridge panel structure

The strength calculation results are shown in Figure 6-2.

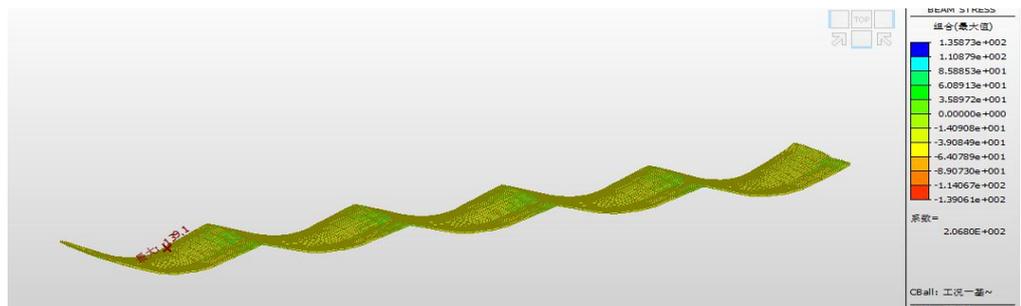


**Figure 6-2.** Strength check stress diagram of bridge panel (unit: MPa)

According to the calculation results, the maximum combined stress of the bridge deck is 31.1 MPa, which is less than the allowable stress of Q235 = 175 MPa. The strength and rigidity of the bridge deck meet the requirements of the specification.

### 6.3.2 Checking of bridge deck i-beam structure

The strength calculation results are shown in Figure 6-3.



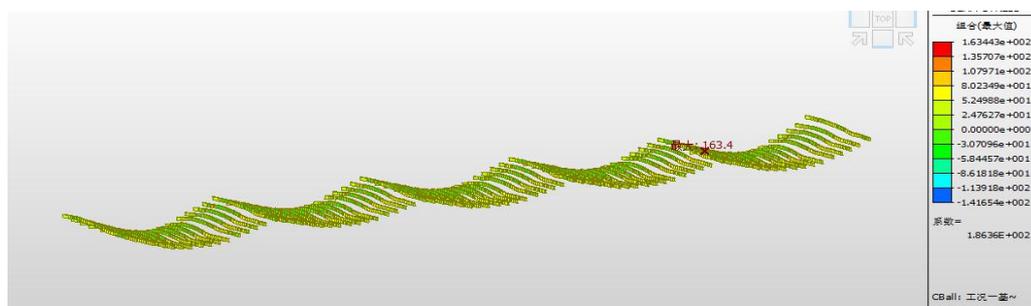
**Figure 6-3.** Strength check stress diagram of bridge deck i-beam (unit: MPa)

最大值: Max

According to the calculation results, the maximum combined stress of the bridge i-beam is 139.1 MPa, which is less than the allowable stress of Q235 = 175 MPa. The strength of the bridge deck i-beam meets the requirements of the specification.

### 6.3.3 Checking of horizontal distribution of i-beam structure

The strength calculation results are shown in Figure 6-4.



**Figure 6-4.** Strength check stress diagram of the horizontal distribution of the i-beam (unit: MPa)

最大值: Max

According to the calculation results, the maximum combined stress of the horizontally distributed i-beam is 163.4 MPa, which is less than the allowable stress of Q235 = 175 MPa. The strength of the horizontally distributed i-beam meets the specifications.

### 6.3.4 Checking of bailey beam structure

The maximum spacing of the distribution beams is 12m, and the force calculation is according to the 12m span.

6.3.4.1 The strength calculation results are shown in Figure 6-5.

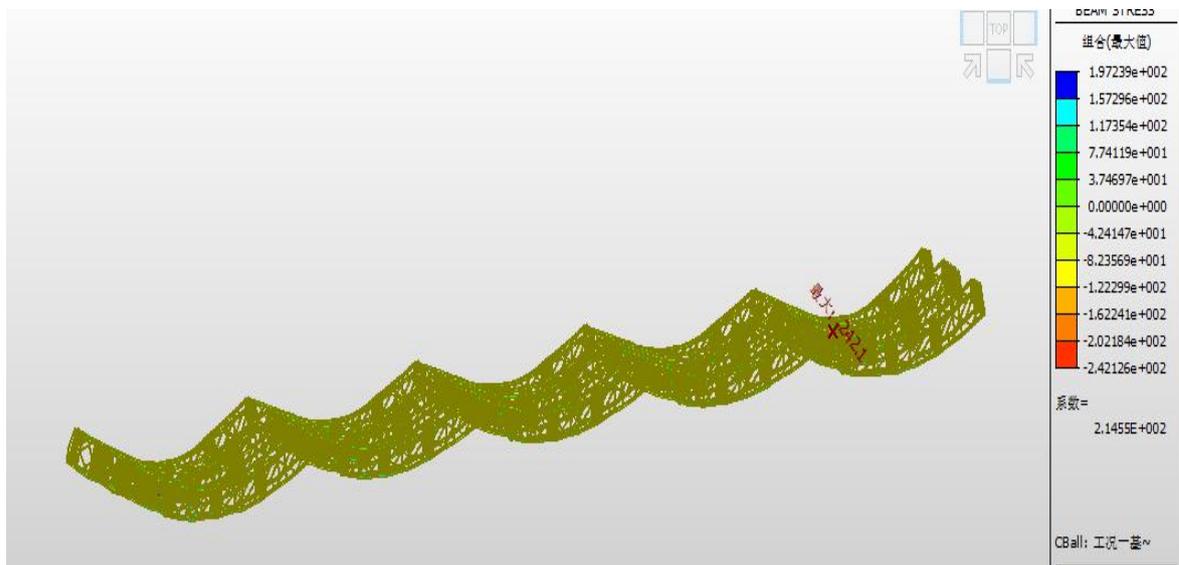


Figure 6-5. Strength check stress diagram of Bailey beam (unit: MPa)

最大值: Max

6.3.4.2 The stiffness calculation results are shown in Figure 6-6.

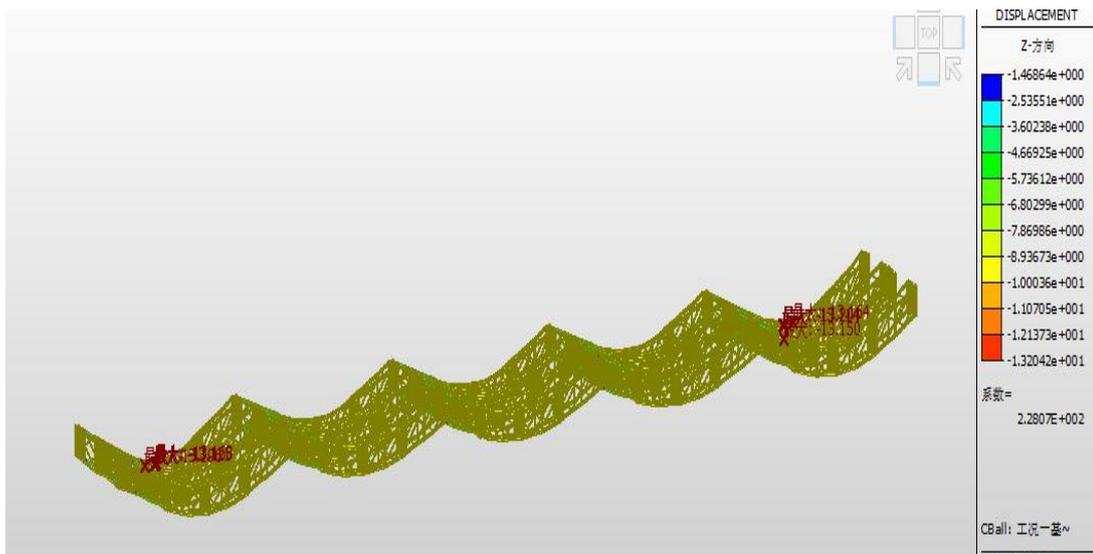


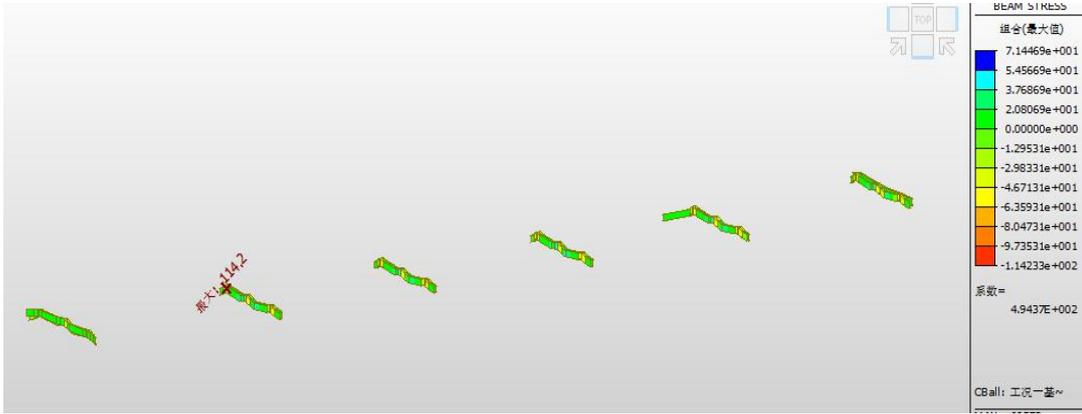
Figure 6-6. Check deflection diagram of Bailey beam (unit: mm)

According to the calculation results, the maximum combined stress of Bailey beam is 242.1MPa, which is less than the allowable stress of 16Mn  $[\sigma_w] = 273\text{MPa}$ ; the maximum deflection of Bailey beam is 13.20mm, which is less than 1/400 (12000/400=30mm) of the calculated span. The strength and stiffness of the Bailey beam meet the requirements of the specification.

### 6.3.5 Checking of pile beam i-beam structure

The maximum spacing of the distribution beams is 3m, and the force calculation is according to the 3m span.

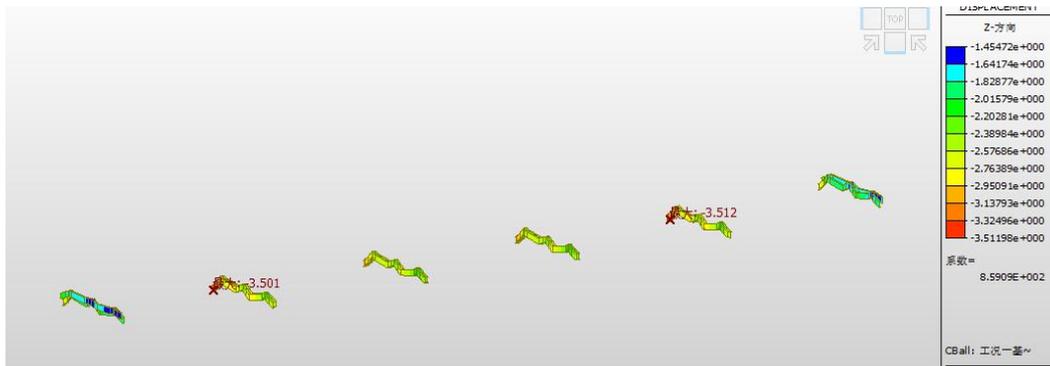
6.3.5.1 The strength calculation results are shown in Figure 6-7.



**Figure 6-7.** Strength check stress diagram of pile beam i-beam (unit: MPa)

最大值: Max

6.3.5.2 The stiffness calculation results are shown in Figure 6-8.

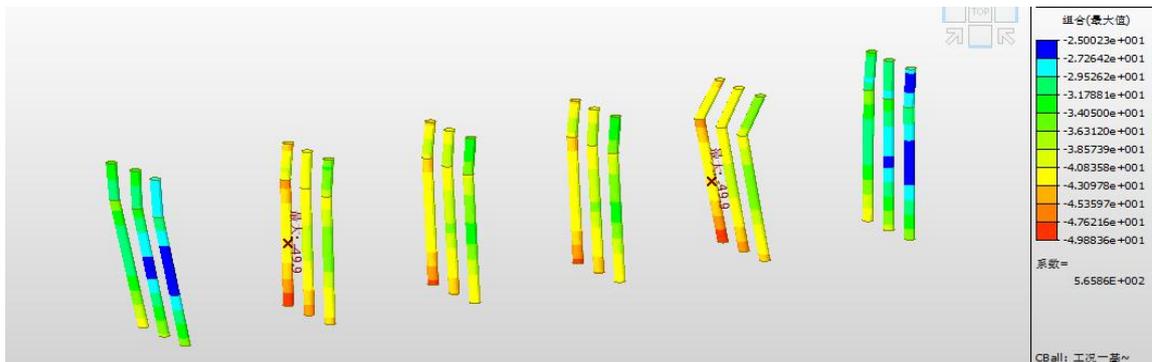


**Figure 6-8.** Check deflection diagram of pile beam i-beam (unit: mm)

According to the calculation results, the maximum combined stress of the pile beam i-beam is 114.2 MPa, which is less than the allowable stress of Q235 = 175 MPa; the maximum deflection of the pile beam i-beam is 3.51 mm, which is less than 1/400 of the calculated span ( $3000/400=7.5\text{mm}$ ). The strength and rigidity of the pile beam i-beam meet the requirements of the specification.

### 6.3.6 Checking of steel pipe pile structure

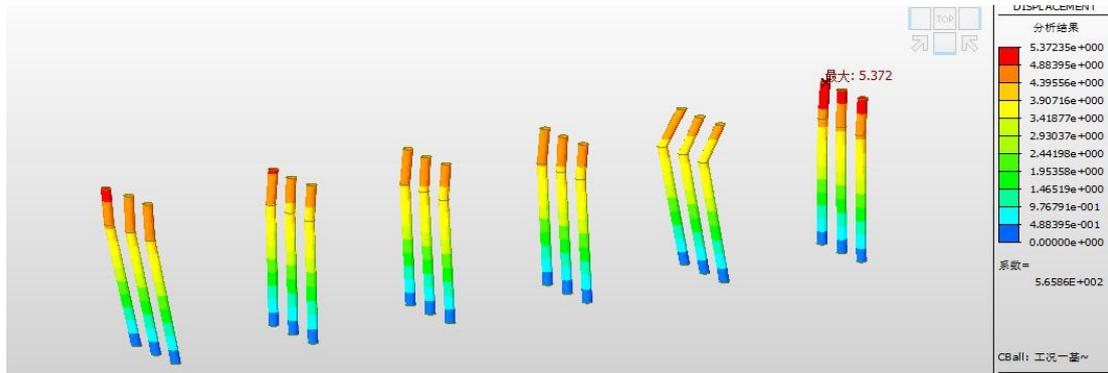
6.3.6.1 The strength calculation results are shown in Figure 6-9.



**Figure 6-9.** Stress calculation diagram of steel pipe pile (unit: MPa)

最大值: Max

6.3.6.2 The stiffness calculation results are shown in Figure 6-10.

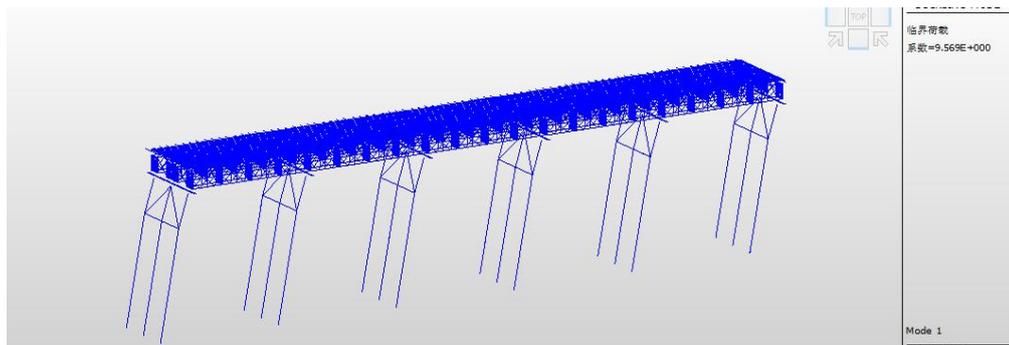


**Figure 6-10** Deformation diagram of steel pipe pile (unit: mm)

According to the calculation results, the maximum combined stress of the steel pipe pile is 49.9 MPa, which is less than the allowable stress of Q235 = 175 MPa. The maximum deformation of the steel pipe is 5.37mm, which is less than  $L/2500$  ( $20000/2500=8\text{mm}$ ). The strength and rigidity of the steel pipe pile meet the requirements of the specification.

#### 6.4 Checking of trestle stability

Through the buckling analysis, the buckling mode is observed, and the buckling analysis results are as follows:



**Figure 6-2.** Calculation results of buckling analysis

In the most unfavorable case, the overall safety factor is 9.569, which is greater than 4, which meets the requirements.

#### 6.5 Summary of calculation results of main components

Check position	Unit	Basic combination of the most adverse working conditions	Allowance	
			Allowable stress	Allowable deformation
Bridge deck stress	MPa	31.1	175	—
Deck I-beam (I12.6) stress	MPa	139.1	175	—
Horizontal distribution I-beam (I25) stress	MPa	163.4	175	—
Bailey beam stress	MPa	242.1	273	30
Bailey beam maximum deformation	mm	13.20		
Pile beam I-beam (2I40) stress	MPa	114.2	175	7.5
Pile beam I-beam (2I40) maximum deformation	mm	3.51		

Steel pipe pile ( $\phi 800 \times 10$ ) stress	MPa	49.9	175	8
Steel pipe pile ( $\phi 800 \times 10$ ) maximum deformation	mm	5.37		

## 6.6 Conclusion

Under the construction load, the stress, deflection deformation and safety factor of the trestle structure are within the scope of the specification and meet the requirements of the specification.

In the calculation of the bridge deck I25a and I12.6, some values are large. Considering the adverse factors such as rusting of materials, in order to ensure adequate safety factor, pay attention to properly adjust the laying of the I25a and I12.6 during construction.

## 7. Concluding Remarks

The steel trestle uses Midas Civil software for structural calculations, which saves computation time, improves calculation accuracy, and provides reliable engineering data for design. It provides a reference example for future design and construction, indicating Midas Civil software has considerable promotion value in construction.

## References

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