Stability analysis of steel platforms based on Midas Fea Nx

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ABSTRACT. Taking the water drilling construction platform of a bridge anti-collision pier project as the background, Midas fea nx software is used to establish a three-dimensional finite element model of the construction platform, simulate and analyze the load conditions imposed on the steel platform, as well as carry out linear buckling analysis, bearing capacity calculation and stability calculation of the steel pipe piles, and the following conclusions are drawn: The overall deformation and stress of the construction platform are in accordance with the specification, and the deflection and equivalent stress of each member are in accordance with the specification; the bearing capacity and stability of the steel pipe piles meet the construction requirements.

Keywords: finite element analysis; steel platform; stability analysis; linear buckling analysis

1 Introduction

With the continuous development of bridge construction in China, water-based construction platforms have been widely used in the construction of bridges across rivers, seas and rivers. At present, domestic and foreign for the rigid platform checking is mainly hand calculation, anlys, and midas civil. Shen Bo et al. used midas civil to carry out structural calculations on the steel trestle bridge, which provided reliable data for engineering design and certain reference experience for future similar projects[1]; Yongsheng Wu and Yun Xie used Midascivil to calculate the force on the steel platform under the most unfavorable working conditions, which resulted in improved efficiency and a significant reduction in repeated calculations[2]; Li Yi through a number of calculations to optimize the final use of shallow cover layer area platform using concrete anchor piles to solve the platform stability problems of the steel sheath and steel pipe pile combination of independent steel platform structure form[3]; Yang Liu proposed design ideas, precautions and construction methods for the construction platform design, through the design study of the main pier construction platform for the drilled piles of the main channel bridge of the Yangtze River[4]; Through the analysis and research on the force situation of deep-water pile foundation construction platform for large bridges, Zhu Jiajun proposes to adopt the spatial structure calculation method,

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which can better adapt to the design requirements of optimized structural system for large and complex construction platforms while considering the role of spac[5];Guo Ting studied the influence of the different positions of the drilling rig on the stability of the structure, and put forward the matters that should be paid attention to during the construction, which provided a reliable basis for the construction[6].

In this paper, we will use Midas fea nx software to simulate and analyze the steel platform to provide some experience for the subsequent similar projects.

2 Project overview

A bridge is to be reinforced with crash piers and guards installed, and the construction of the crash piers requires the erection of a steel platform for construction. Among them The foundation of the steel platform consists of steel pipe pile and steel pipe protector, the diameter of the steel pipe pile is 1.2m, the wall thickness is 8mm, the diameter of the steel pipe protector is 3.6m, the wall thickness is 22mm, the steel pipe pile and the steel pipe protector are connected with a flat link, which is a round steel pipe with a diameter of 0.63m and a thickness of 6mm; The diagonal support is made of round steel pipe with a diameter of 0.63m and a thickness of 6mm, and the load-bearing beam on the steel pipe pile is a double 24A I-beam; The main longitudinal beam of the steel platform uses the 321-type beret beam, and the main beam is welded on the distributing beam with I20a I-beams at a spacing of 0.5m, and the distributing beams are covered with 8mm later grooved surface steel plates.

3 Structural design of steel platforms

The plane size of the construction platform is 36m×35m, the maximum span of the platform is 12m, the top elevation is +6m, and the design water level is +3.32m. The structure arrangement is as follows: panel, distribution beam, main longitudinal beam, cross beam, pile foundation. The specific structural arrangement is shown in the following figure1:

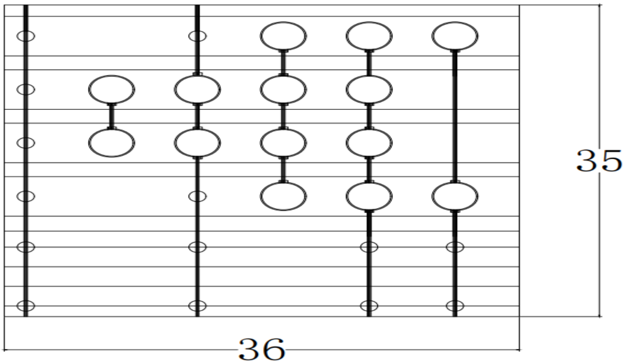

Fig. 1. Top view of structure

The material of the Bailey's Beam rods in this project is 16Mn. According to the "Steel Structure Design Standard" GB50017-2017[7], under the action of basic combination, the design value of its tensile, compressive and bending strength is 305 MPa, and the design value of shear strength is 175 MPa. Referring to its tensile, compressive and bending stress tolerance value of 273 MPa and shear stress tolerance value of 208 MPa[8]; The design value of tensile, compressive and bending strength is 215 MPa (thickness of plate is less than 16 mm) and the design value of shear strength is 125 MPa, except for the beribboned beams, which are made of Q235 steel[9].

4 FEA model

In the finite element model, the plate unit is used to simulate the bridge deck slab, and the rest of the bars are simulated by the beam unit, and a total of 55,033 units are established. When calculating the platform, the distribution beam and panel, distribution beam and longitudinal beam, crossbeam and steel pipe pile are connected in the form of common node, the longitudinal beam and crossbeam are connected in the form of node coupling, and the position of steel pipe pile foundation and steel protection tube at the embedded point is considered according to the solidification. The model is shown in the figure2 below:

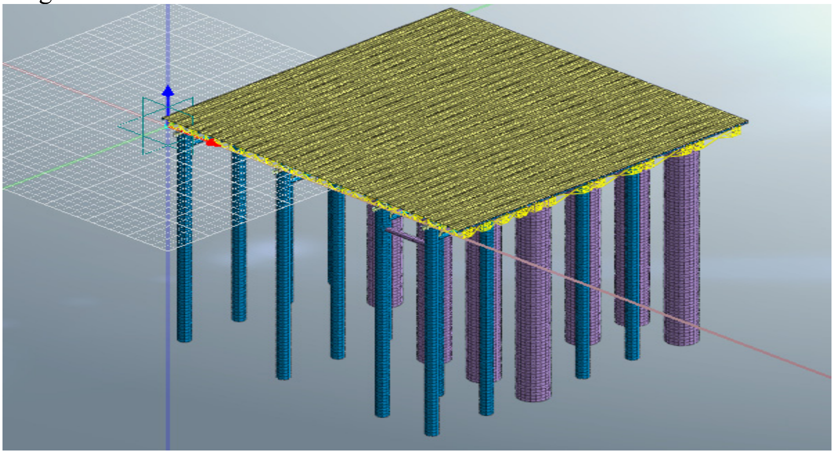

Fig. 2. MIDAS FEA NX model

5 Calculation and analysis of steel platforms

5.1 Working condition analysis

Three working conditions were analyzed for the model. Condition 1 is when the platform is not under construction and the construction unit is stationary on the platform; Condition 2 is normal construction of the platform，Under this condition, one crawler crane is hoisting on the trestle roadway, four JKL-15T impact drills are drilling on the platform, and the maximum stacking load is adopted in the material stacking area, in which the crawler crane is located between two steel piles of the steel trestle, which is the most unfavorable condition of the construction platform; Working condition 3 is the normal construction of the platform, under this working condition, 1 set of crawler crane is hoisting on the trestle roadway, 4 sets of JKL-15T type percussion drills are drilling on the platform, and the maximum stacking load is adopted in the material stacking area, in which the crawler crane is located on the top of the steel pipe piles, which is the most unfavorable working condition for the load bearing of the steel pipe piles.

5.2 Load Scheme

1. Component self-weight
2. Track lifting load Track lifting weight is 130t, the lifting weight is considered as 20t, the total weight is G=150t. Track size is 5600mm*900mm, track center spacing is 5.6m, considering the partial load is 3:1 distribution, one side of the track 112.5t, one side of the track 37.5t.
3. The model of the drill on the rig loading platform is expected to be JKL-15T hammer drill. The base of the hammer drill is 8.5m long, 2.3m wide, 13.5t dead weight and 14.6t hammer weight, so the total weight of the hammer drill is G=28.1t, and the impact coefficient of 1.3 is considered in the calculation.
4. Stacking load: The design load of the material loading area on the platform is 15KPa.

5.3 Load combination:

Working condition 1:1.0 dead load +1.0 live load

Working condition 2: 1.2 dead load +1.4 live load (overall most unfavorable working condition)

Working condition 3: 1.2 dead load +1.4 live load (the most unfavorable working condition of single pile)

5.4 Analysis of simulation results

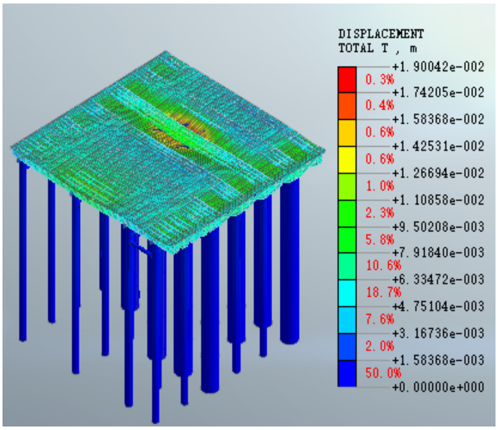

Fig. 3. Deformation nephogram

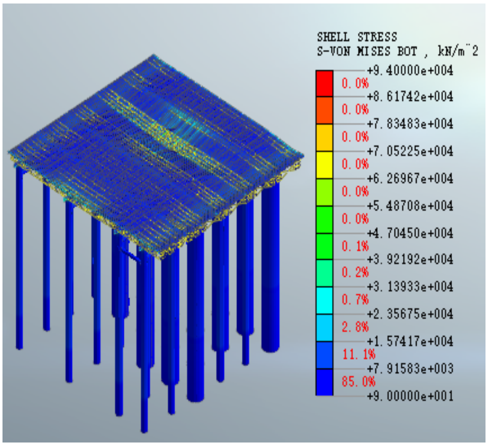

Fig. 4. equivalent stress nephogram

Calculations by Midas Fea NX showed that, as shown in Figs. 3 and 4, the maximum deformation location occurred at the panel constructed by the drilling rig, with a maximum deformation of 19 mm; and the maximum stress was 94.8 MPa, which occurred at the web of the distributor beam under the load of the crawler crane; The maximum stress of 94.8 MPa occurred at the web of the distributor beam under crawler crane loading; I25a I-beam distribution beam combined stress"$\sigma max = 83\, MPa < f = 215\, MPa.$" I25a I-beam distribution beam shear stress"$\tau max = 46.4\, MPa < fv = 125\, MPa$" ; beribboned beam shear stress "$\tau max = 58.6\, MPa < fv = 175\, MPa$" , the maximum axial force appearing on the beribboned beam is 65.9KN<175KN,beribboned beam displacement maximum deflection " $\omega max = 10.5\, mm < [\omega] = 6000/400 = 15\, mm$" he combined stress "$\sigma max = 85.5\, MPa < f = 215\, MPa$" in the load-bearing beam I-beam crossbeam. The shear stress "$\tau max = 43.7\, MPa <$

$fv = 125\ MPa"$. The maximum deflection $"\omega max = 2.7\ mm < [\omega] = 3{,}150/400 = 7.875\ mm"$ for the double spliced I40b I-beam beam; The axial compressive stress $"\sigma max = 31MPa < f = 215\ MPa"$ of Φ1200×8 mm steel pipe pile is a compression member, only the axial compressive strength and axial compressive stability of steel pipe pile should be calculated here. Φ1200×8 mm steel pipe pile axial compressive stress σmax=31MPa<f=215 MPa. The use of the member is in accordance with the specification.

5.5 Comparison of Working Conditions

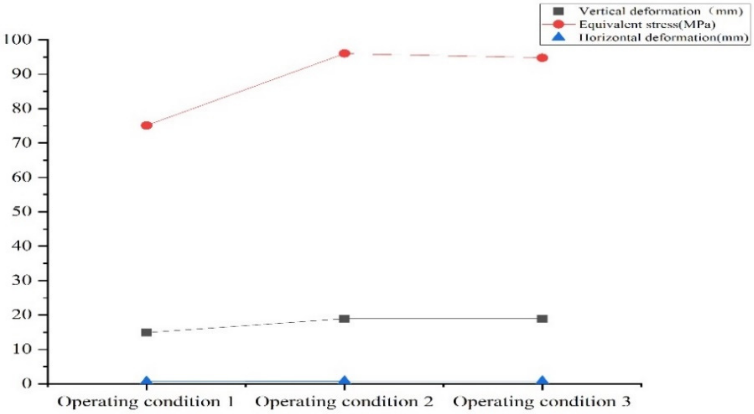

Fig. 5. Comparison of overall structural data for numerical analysis

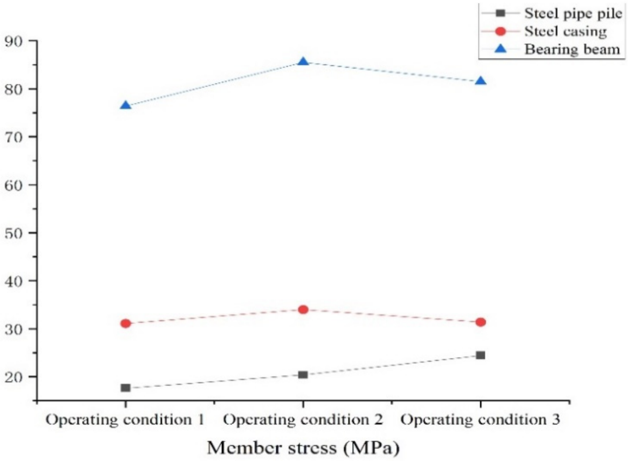

Fig. 6. Comparison of maximum equivalent stress of steel pipe piles

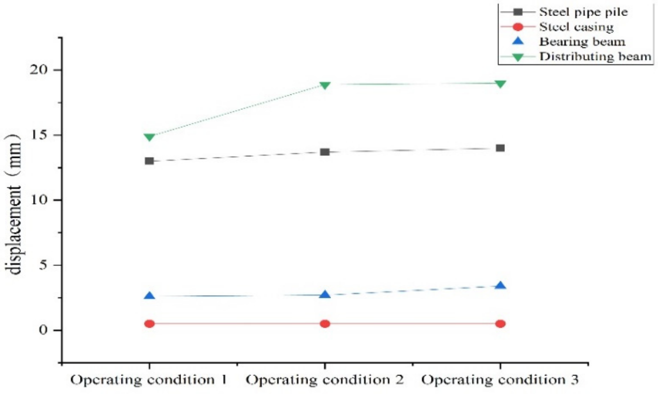

Fig. 7. Maximum displacement change of member

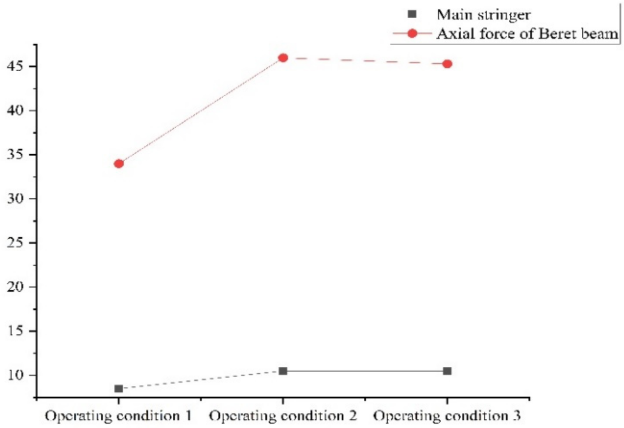

Fig. 8. Deformation and axial force change of the main longitudinal beam

By comparing the data of the overall structure of the results of the analysis, we get Figures 5 to 8, from which we can see that the working and stopping of the construction equipment as well as the position of the crawler crane have different effects on the rigidity and stability of the construction platform. The most significant impacts were the construction of the construction platform and the shutdown, which resulted in an increase of 26.8% and 27.8% in the overall structural displacement and equivalent stresses, respectively; the axial force of the main longitudinal beams of the structure increased by 35.3%, which is a large change. The change between Case 2 and Case 3 is not obvious in the overall structure, the larger change is the maximum equivalent stress of the steel pipe pile, the tracked crane is placed directly above the steel pipe pile, the maximum stress on the steel pipe pile increases by 20%, the change is more obvious, and the rest of the components have less change.

6 Stability analysis of steel pipe piles

6.1 Analysis of overall stability of steel pipe pile system

For the drilling construction platform, its steel pipe positioning piles form an integral steel pipe positioning pile system through the horizontal connection system, which assumes the role of supporting the upper truss of the drilling construction platform. It is usually adopted to establish the overall finite element model of the structure, and then carry out the overall elastic stability buckling analysis to obtain the overall elastic instability safety coefficient of the structure and the instability modes. In this paper, Midas Fea Nx was used to establish a spatial finite element model, and according to the careful modeling analysis of the force state of the drilling construction platform under each working condition, the maximum load of a single pile obtained from the calculation and analysis of working conditions 1 and 2 was applied to the steel pipe locating pile system as a variable static load at the same time. Linear buckling analysis of Midas Fea Nx was used to calculate the 1st to 6th order buckling safety factors and the 1st order instability modes of the steel pipe locating pile system under different load combinations. The results of the calculations are shown below:

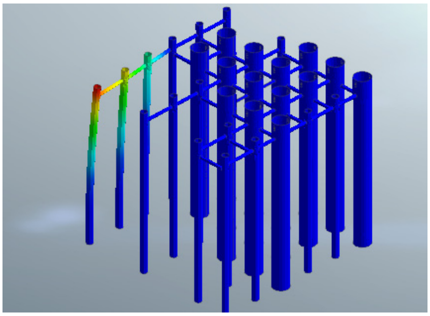

Fig. 9. first-order instability mode (working condition 1)

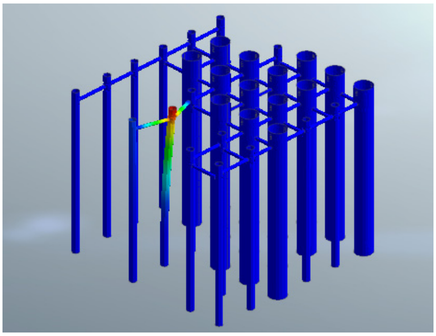

Fig. 10. first-order instability mode (working condition 2)

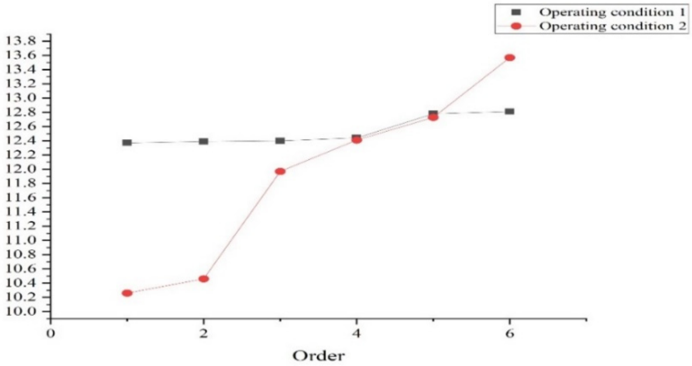

Fig. 11. Comparison of buckling safety factors

From Figures 9 and 10, it can be seen that the destabilization location of the steel pipe pile group system is different between Case 1 and Case 2 loading, the destabilization under Case 1 loading is on the steel pipe piles directly loaded by the crawler crane, and the destabilization under Case 2 loading is on the lower-left corner of the platform, therefore, the first-order destabilization modes of the steel pipe pile system are different in the different construction conditions; It can be obtained from Fig11 that the buckling safety factor of the steel pipe pile system under the stoppage condition (Condition 1) is 12.37, which indicates that it can withstand 12.37 times the load applied to a single pile, and the buckling safety factor of the steel pipe pile system under the loading of the overall most unfavorable condition (Condition 2) is 10.26, which can withstand 10.26 times of the load load applied with the steel pipe piles, and the stability of the drilling platform is good[10] .

6.2 Checking calculation of bearing capacity of steel pipe pile foundation

According to the simulation results, the maximum value of the single pile bearing capacity of the platform is 764 KN. The stratigraphic information of the holes with shallow sand layer and thick silt layer is selected as an example for the calculation of the bearing capacity of the pile foundation, and the corresponding stratigraphic information is shown in Table1:

Table 1. Soil information

serial number	Soil layer name	Thick-ness (m)	Standard value of side friction resistance	End resistance standard value
1	medium-hard sand	0.5	90	4000
2	Fully weathered granite	7.7	130	5000

The bearing capacity of steel pipe pile is calculated with reference to the relevant design requirements in the Code for Design of Building Pile Foundation (JTJ4-2008) as follows:

$$Q_{uk}=Q_{sk}+Q_{pk}=u\Sigma q_{stk}l_i+\lambda_p q_{pk}A_p=1.13\times0.8\times(7.7\times130+0.5\times90)=946KN>764KN$$

The calculated bearing capacity of the steel pipe piles of the platform meets the design requirements.

6.3 Stability checking of steel pipe pile

The size of the steel pipe pile is Φ1200*8mm round steel pipe, which is considered as a compression bending member. According to the calculation results, the maximum axial force and bending moment under the most unfavorable working condition and the most unfavorable bending moment are 1,220KNN and 27.57KN. M, respectively. The calculated length L of the steel pipe pile is taken as 23.18. The strength calculation of Φ1200*8mm steel pipe pile is as follows:

$$\frac{N}{A}+\frac{M}{\gamma W}=\frac{1220\times10^3}{29958.2}+\frac{27.57\times10^6}{1.15\times8.87\times10^6}=43.43MPa<215MPa$$

Meet design specification requirements [11].

The stability calculation of Φ1200*8mm steel pipe pile is as follows:

Its length to slenderness ratio is calculated as follows:

$$\lambda=\frac{ul_0}{i}=\frac{0.7\times23180}{421.4}=38.5$$

Checking the table gives its stabilization factor $\varphi = 0.903$.

The stability calculation of steel pipe piles is considered as compression bending member, which is calculated as follows:

$$\frac{N}{\varphi Af}+\frac{\beta_{mx}M}{\gamma W(1-0.8\frac{N}{N'_{Ex}})}=\frac{1220\times10^3}{0.903\times29958\times215}+\frac{1.0\times27.57\times10^6}{1.2\times8.87\times10^6\times(1-\frac{1220\times10^3}{3.73\times10^7})\times215}=02<1.0$$

According to the calculation results, the strength and stability of the member meet the relevant design requirements.

7 Conclusions

By taking an offshore drilling platform as the engineering background and using Midas fea nx to establish an overall finite element model, the following conclusions were obtained by analyzing only the loading conditions generated by the construction equipment on the platform without considering the role of wind, waves and other complex factors and the influence of pile-soil effect on the drilling platform.

1) The overall structural equivalent force of the water drilling construction platform is much lower than the strength design value of Q235B, and the structural stability of the water drilling construction platform meets the requirements for use.

2) The maximum deflection of the platform occurs at the position of the grooved steel plate at the loading position of the crawler crane and at the position of the connection between the distributor beam and the grooved steel plate, the maximum bending moment occurs at the top of the steel drum near the loading position of the rotating crawler crane, the maximum shear force occurs at the main beam at the loading position of the crawler crane, and the maximum axial force occurs at the steel drum near the loading position of the rotating crawler crane. The maximum equivalent force of the platform occurs in the distribution beam where the drilling platform is connected to the steel plate of the groove surface.

3) The buckling coefficients of steel pipe pile groups are all above 10, the structure is stable; the bearing capacity and stability of single piles meet the specification requirements.

4) From the analysis of the simulation data, it is recommended to strengthen the rig construction platform as well as the steel trestle bridge, for example, by increasing the thickness of the main girder and the distribution girder, and at the same time, to optimize the structural dimensions appropriately in the rest of the locations other than the loading locations, i.e., where the stresses are smaller.

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