

PAPER • OPEN ACCESS

Analysis of high wind resistant stability of South Anchorage caisson of Oujiang River North Estuary Bridge in Wenzhou

To cite this article: Peishuai Chen *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **300** 022163

View the [article online](#) for updates and enhancements.

Analysis of high wind resistant stability of South Anchorage caisson of Oujiang River North Estuary Bridge in Wenzhou

Peishuai Chen^a, Zonghua Qin^b, Weisheng Rao^{*}, Dejie Li^c

CCCC Second Harbour Engineering Co., Ltd, Wuhan, 430040, China

^{*}Corresponding author e-mail: hiraoweisheng@163.com,

^achenpeishuai@foxmail.com, ^b754097512@qq.com, ^clidejieedu@163.com

Abstract. The South Anchorage caisson of Oujiang Beikou Bridge in Wenzhou adopts the scheme of "four successive heights and four subsidences", which will be attacked by typhoon during the period of caisson heightening. In order to ensure the caisson passes through typhoon season smoothly, the anti-wind stability of the caisson secondary connecting section under different wind speed and different action angle is checked. The results show that the maximum displacement of the structure increases sharply with the increase of wind speed, and the effect of load direction on the maximum displacement of the structure is less than the influence of wind speed. The relevant conclusions can provide guidance for the safe passage of the high section of Caisson in typhoon season.

1. Introduction

Wenzhou Oujiang Beikou Bridge project started in Yueqing Huanghua and ended in Lingkun Island. It is a control project of Yongtaiwen Expressway double line and Nanjin Highway across Oujiang River. The bridge is the world's first "three-tower and four-span" suspension bridge. The main bridge is a three-tower and four-span continuous double-deck steel truss beam suspension bridge. The span arrangement of the bridge is $210+800+800+275=2090\text{m}$ [1-3]. The Wenzhou area where the bridge is located is seriously affected by typhoon. Since the statistical data have been available, typhoons have landed almost every year, seriously affecting the construction of the project.

South Anchor Caisson is the first super-large caisson in the world in silt soil. The caisson adopts rectangular cross-section with a plane size of $70\times 63\text{m}$, the top elevation of the caisson is $+4.0\text{m}$ and the base elevation is -63.5m . The base is placed in the pebble layer, entering the pebble layer for 4m , and the thickness of the concrete at the bottom of the caisson is 10m . The total height of the caisson is 67.5m , the standard wall thickness is 2.0m , the partition wall thickness is 1.2m , the partition wall height is 8m , and the partition wall height is 6.1m . There are 30 rectangular wells ($10.84\times 10\text{m}$) in total. Among them, 15 wells at the back end are filled with C20 underwater concrete and 15 wells at the front end are filled with clean water.

2. Finite element calculation model and parameters

Finite element method has been widely used in caisson design. [4-6] According to the structure diagram of South Anchorage caisson, a three-dimensional integral model of caisson-foundation is established by using finite element software. As shown in Figure 1, eight-node solid elements are used in caisson and



soil. According to the measured data of sidewall frictional resistance in sinking stage, the frictional contact between sidewall and soil is established. According to field monitoring, the size of foundation model is 470*463*100m. The model consists of 133990 nodes and 105309 elements, of which 66534 nodes and 44004 elements are included in the caisson. The foundation depth is about 1.5 times of the final sinking depth of the caisson, and the distance of the foundation depth is 2 times of that of the long and short sides of the caisson.

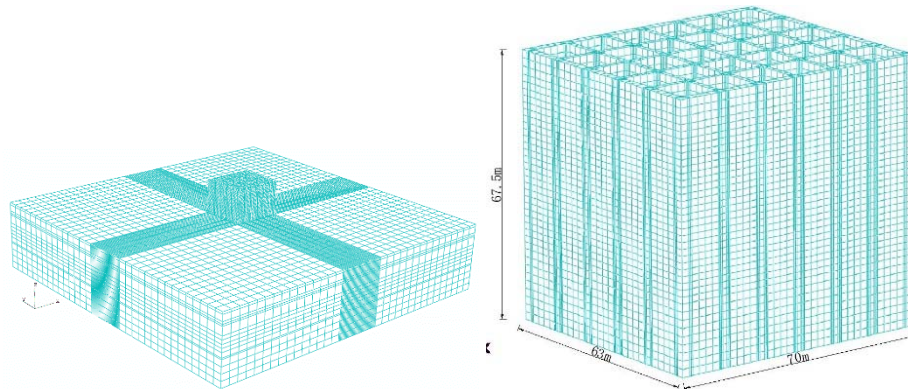


Figure 1. Three-dimensional Computing Model

Table 1. Parameters of Foundation and Soil Layer

Soil	Natural wet density $\rho/\text{g/cm}^3$	Modulus of elasticity /MPa	Cohesion C/kPa	Friction angle $\varphi/^\circ$	Suggested value of lateral friction resistance of foundation (kPa)
Silty clay	1.74	2.44	16.3	14.9	30.8
Silty clay with silt	1.72	2.22	9	15.1	30.8
Silt	1.64	1.93	12.4	14	30.8
Silty clay	1.71	2.18	13.5	16.1	30.8
Clay	1.76	2.84	23	15.8	30
Clay with silt	1.78	3.28	26.2	8.6	50
(Contain clayey soil) silt	1.83	4.46	15.1	11.5	70
Sandy silty clay	1.79	3.74	23.5	9.6	60
Silt and fine sand	1.96	9.42	9	31.7	90
Pebble	1.95	40	2	36	200

Linear elastic model is used to calculate the combined mark of caisson concrete, Mohr-Coulomb model is used to calculate the foundation soil [7], and the values of soil parameters are shown in Table 1, and Friction contact between caisson wall and soil layer is also shown in Table 1.

3. Simulated calculation and result analysis

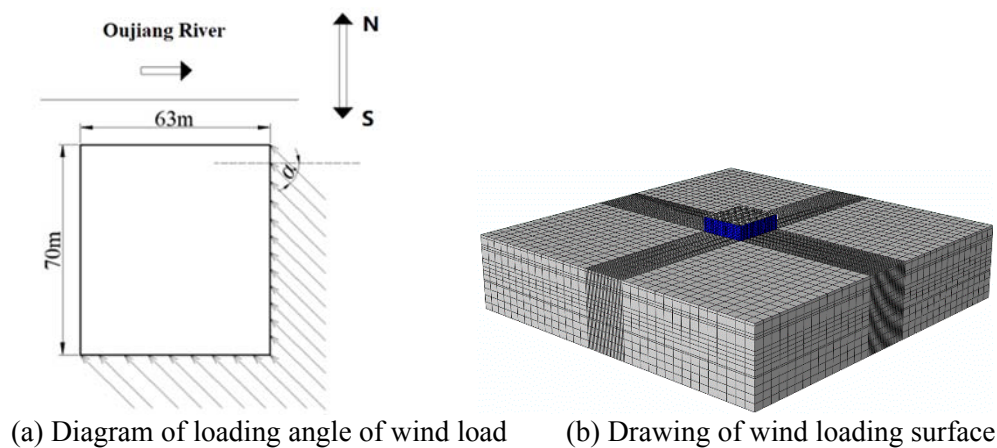
3.1. Calculation condition

Combining with the construction plan of the caisson's second heightening and subsidence, the whole calculation is divided into five construction stages for simulation calculation, and the corresponding calculation conditions are shown in Table 2.

Table 2. Calculation conditions

Stage 1	Initial Geo-stress Balance
Stage 2	Excavation of soil to - 15.638m
Stage 3	Subsidence of first to forth segments
Stage 4	successive heights of fifth to seventh segments
Stage 5	Applying wind load to successive heights

In order to fully consider the uncertainty and complexity of wind load, the basic wind speed under different typhoon grades is selected in this wind stability analysis [8, 9], and the stability of caisson structure is analysed according to different wind speed and load action angles (0° , 15° , 30° , 45° , 60° , 75° , 90°), using the conversion formula between wind speed and basic wind pressure [9, 10]. The detailed analysis is shown in Table 3. Wind load acts on both sides of the caisson to consider the most unfavourable conditions. Figure 2 is a sketch of wind load action.

**Figure 2.** Drawing of wind loading**Table 3.** Wind load calculating conditions

Calculation condition	Typhoon grade	Basic wind speed (m/s)	Basic wind pressure (kpa)
Condition 1	Storm	30	0.66
Condition 2	Typhoon	35	0.90
Condition 3	Typhoon	40	1.18
Condition 4	Violent typhoon	45	1.49
Condition 5	Violent typhoon	50	1.84
Condition 6	Super typhoon	55	2.22

3.2. Calculation results and analysis

Figure 3 show the displacement distribution of caisson-foundation at different angles of action when the basic wind speed is and 55m/s. From the figure, it can be seen that the maximum displacement is located at the top of the caisson joint section, and the soil around the caisson is deformed to a certain extent. The maximum displacement of Caisson under different wind speed and load angle is shown in Table 4. The maximum displacement results show that the maximum displacement of the caisson reaches 34.01 mm when the wind load is 55m/s along the long side of the caisson.

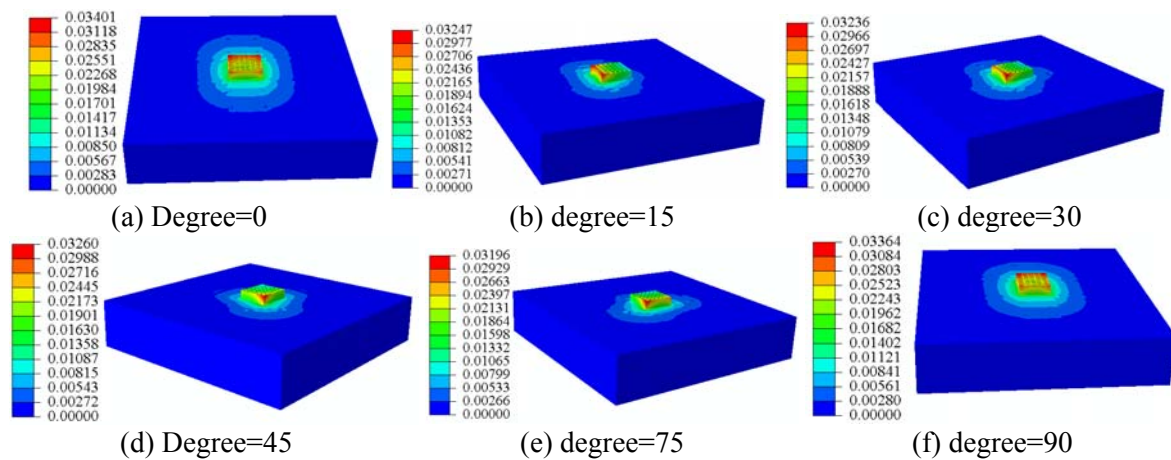


Figure 3. Displacement Distribution at Wind Speed 55m/s

Table 4. Maximum displacement of open caisson

Maximum displacement(mm)		Degree of angle						
		0	15	30	45	60	75	90
Wind speed	30	10.1	9.6	9.6	9.7	9.5	9.2	9.9
	35	13.7	13.1	13.1	13.2	12.9	12.6	13.6
	40	18.0	17.2	17.2	17.3	16.9	16.5	17.8
	45	22.8	21.7	21.7	21.8	21.4	20.9	22.5
	50	28.1	26.9	26.8	27.0	26.5	25.8	27.8
	55	34.0	32.5	32.4	32.6	32.0	31.2	33.6

Figure 4 is the curve of maximum displacement of structure changing with wind speed. It can be seen from the curve that the maximum displacement of structure increases obviously with the increase of wind speed. Figure 5 shows the variation curve of the maximum displacement of the structure with the loading angle. From the variation curve, it can be seen that the variation law of the maximum displacement of the structure with the angle is not symmetrical due to the difference of the length and the short side of the caisson. When the wind load acts positively on the windward side of the caisson, the displacement of the structure is the largest, and when the wind load acts on the long side, the displacement of the structure is larger than that of the short side. With the increase of the angle of wind load, the maximum displacement of the structure decreases first and then increases. When the angle of wind load is 75 degrees, the maximum displacement is the smallest.

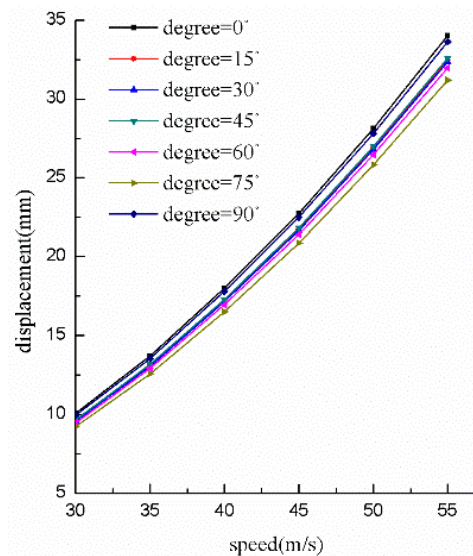


Figure 4. Maximum displacement curve with wind velocity

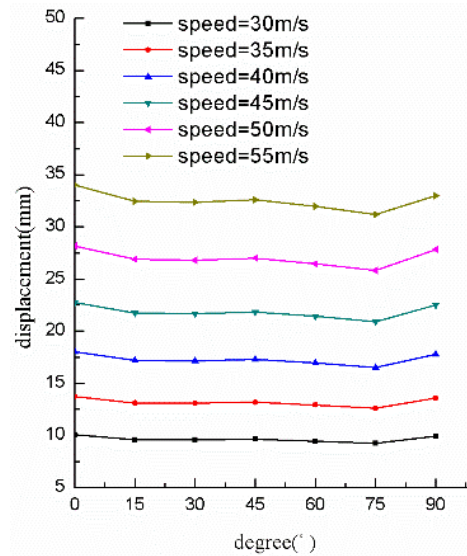


Figure 5. Curve of maximum displacement with load angle

4. Conclusion

The wind-resistant stability of the South Anchorage caisson section of Wenzhou Oujiang Beikou Bridge is analyzed by using finite element software. Relevant conclusions can provide guidance for the safe passage of the caisson section through typhoon season. The main conclusions are as follows:

(1) The results show that the influence of wind speed on the maximum displacement of the structure is far greater than that of the direction of load action, and the maximum displacement of the structure increases sharply with the increase of wind speed. When the wind load is positively acting on the windward side of the caisson, the maximum displacement of the structure is obtained.

(2) The shape of the windward surface of the structure has a great influence on the displacement distribution of the structure. For the asymmetric structure, the maximum displacement of the structure varies asymmetrically with the angle.

(3) The maximum horizontal displacement of caisson reaches 34.01mm when 55m/s wind load is applied in the long side direction of the side of the caisson height section. Measures should be taken to prevent secondary disasters.

References

- [1] ZHENG Feng-li, GU Zhi-min. Scouring Pre-Protection Techniques for Open Caisson of Middle Tower of Oujiang River North Estuary Bridge in Wenzhou [J]. Bridge Construction, 2018, 48 (1): 106 - 111.
- [2] LUO Kou, SHU Si-li, WAN Tian-bao, etc. Comparison and Selection of Structural Type for Middle Tower of Oujiang River North Estuary Bridge in Wenzhou [J]. Bridge Construction, 2018, 48 (1): 88 - 93.
- [3] GAO Zong-yu, SHI Fang-hua. Key Techniques of Design of Main Bridge of Oujiang River North Estuary Bridge in Wenzhou [J]. Bridge Construction, 2017, 47 (1): 1 - 5.
- [4] DING Zhi-quan, LIU Shu-ming. Application of Midas in Designing Caissons [J]. Construction Technology, 2010, 39 (S1): 692 - 693.
- [5] SU Jing-bo, LOU Shu-jun, HUO Rui-li. Comparisons between Standard Method and Finite Element Method for Stability of Anchorage Caisson Foundation [J]. Journal of Yancheng Institute of Technology(Natural Science Edition), 2008, 21 (4): 4 - 7.
- [6] ZHOU Jin-zhi, HE Qi. Stability Analysis of Sinking in North Anchorage of Nautilus Changjiang Bridge [J]. Science Technology and Engineering, 2017, 17 (28): 131 - 136.

- [7] TANG Wei, GE Chun-wei. Discussion on Several Problems in Open Caisson Design-Introduction to Design Regulations of Open Caisson Structure [J]. Special Structures, 2003, 20 (4): 17 - 18.
- [8] LIANG Dong, DUAN Wen-bo, ZHU Ya-zhou, etc. Study on Wind Vibration and Control of High Pier Continuous Rigid Frame Bridge in Double Cantilever State [J]. Science Technology and Engineering, 2017, 17 (6): 276 – 282.
- [9] Ministry of Communications of the People's Republic of China. Code for Wind Resistance Design of Highway Bridges: JTG/T D60-01-2004 [S]. Beijing: 2004.