

Research on Static Characteristics of Steel-Concrete Composite Beam Cable-Stayed Bridge during Construction

Zeying Yang¹, Yongye Qu¹, Jianbo Qu², Yalei Zhang¹, Wenchao Qi¹ and Xinnan Xie¹

¹School of Civil Engineering, Shandong University, Jinan, Shandong, China

²Shandong Transportation Department, Jinan, Shandong, China

Corresponding author e-mail:253277272@qq.com.

Abstract. As the construction continues, the structural system and load of the cable-stayed bridge will change. At different construction stages, the forces and deformations of the structure will have their own characteristics. In this paper, in order to study the static characteristics of steel-concrete composite beam cable-stayed bridge during construction, the Jiqi Yellow River Highway Bridge is used as the engineering background, and the finite element modeling is carried out by midas. The main beam, cable tower and stay cable of the cable-stayed bridge are analyzed respectively. Among them, the static characteristics of steel and concrete bridge deck during construction are specially analyzed. In this way, it is ensured that all structures are in a safe state during the construction process, and then the construction

1. Introduction

The various states of the cable-stayed bridge are unstable during the actual construction process, so the simulation of the cable-stayed bridge is required. The bridge belongs to the steel-concrete composite beam structure. In particular, it is necessary to pay attention to the stress state of the bridge deck in each construction stage to prevent its damage.

2. Analysis of the Construction Phase

The deformation and stress of different parts of the cable-stayed bridge are different at each construction stage[1-5]. In this paper, the main beam, cable tower and stay cable of cable-stayed bridge are studied. Static characteristics of steel-concrete composite beam during construction were discussed.

2.1. Static Characteristics Analysis of the Main Beam

(1) Steel beam stress

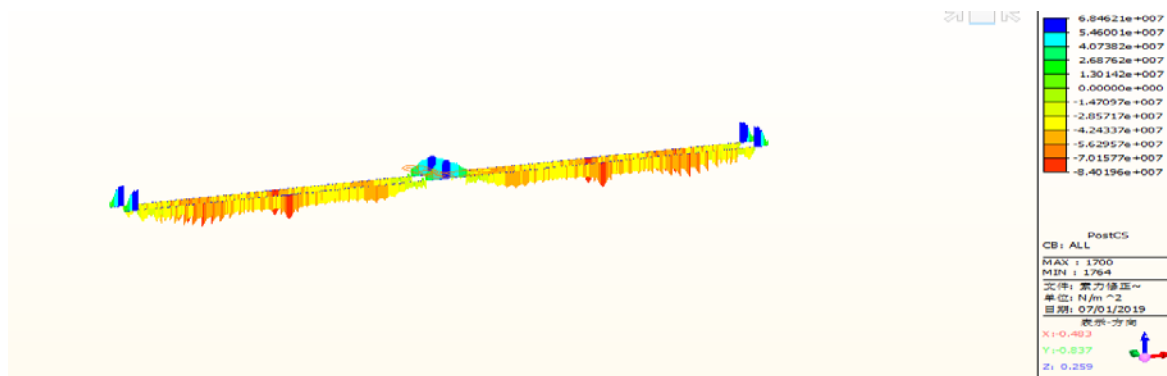
The maximum tensile stress and maximum compressive stress of the steel beam, which is part of the composite beam, at each construction stage were summarized, as shown in Table 2-1.



Table 2-1. Maximum tensile stress and maximum compressive stress of steel beam

Construction stage	maximum tensile stress(Mpa)	maximum compressive stress(Mpa)
Tower, cable, beam 1	0	1.62
Tower, cable, beam 2	1.21	8.83
Tower, cable, beam 3	15.77	12.94
Tower, cable, beam 4	36.94	15.58
Tower, cable, beam 5	54.50	19.17
Tower, cable, beam 6	71.43	26.24
Tower, cable, beam 7	78.25	36.37
Tower, cable, beam 8	81.30	48.26
Tower, cable, beam 9	79.40	43.30
Tower, cable, beam 10	92.22	57.85
Tower, cable, beam 11	102.69	75.38
Tower, cable, beam 12	113.40	84.67
Tower, cable, beam 13	123.74	110.83
Tower, cable, beam 14	128.73	130.84
Tower, cable, beam 15	128.80	147.08
Tower, cable, beam 16	125.67	165.04
Tower, cable, beam 17	125.67	165.06
Tower, cable, beam 18	125.67	165.04
Tension pressured tendons on the side-span bridge deck	125.77	175.38
Shut mid-span	124.64	176.18
Tension pressured tendons on the mid-span bridge deck	120.40	176.22
Secondary weight	120.36	172.40
Bridge deck pavement	113.58	179.79

According to Table 2-1, the maximum tensile stress of the steel beam is 128.8 MPa, which occurs in the No. 15 beam section and meets the allowable stress of the steel. Compared with the stress in the construction process and the stress in the finished bridge stage, the stress distribution is very different. The steel beam may be pulled during the construction process, but may be compressed under the finished bridge stage. This is mainly due to the fact that during the construction of the cantilever, the loading and unloading of temporary loads such as cranes will have a certain impact on the steel beam.

**Figure 2-1.** Steel beam stress on finished stage

(2) Bridge deck stress

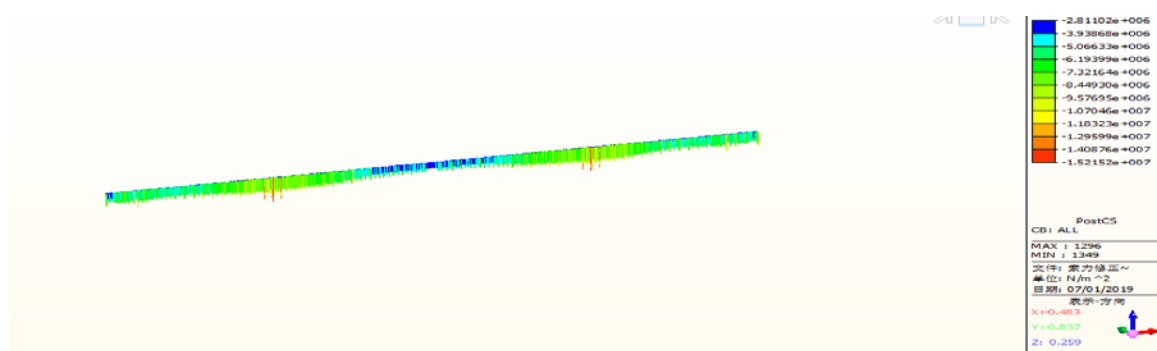
The stress of the bridge deck during the construction process and the finished bridge stage were summarized, as shown in Table 2-2.

Table 2-2. Maximum tensile stress and maximum compressive stress of bridge deck

Construction stage	maximum tensile stress(Mpa)	maximum compressive stress(Mpa)
Tower, cable, beam 1	0.65	1.52
Tower, cable, beam 2	1.15	10.54
Tower, cable, beam 3	1.07	10.68
Tower, cable, beam 4	1.10	11.22
Tower, cable, beam 5	1.14	11.91
Tower, cable, beam 6	1.46	12.82
Tower, cable, beam 7	1.44	13.65
Tower, cable, beam 8	1.27	14.33
Tower, cable, beam 9	1.31	15.08
Tower, cable, beam 10	1.43	15.69
Tower, cable, beam 11	1.5	16.28
Tower, cable, beam 12	1.72	16.97
Tower, cable, beam 13	1.89	17.61
Tower, cable, beam 14	2.21	18.22
Tower, cable, beam 15	2.39	18.80
Tower, cable, beam 16	2.77	19.37
Tower, cable, beam 17	2.77	19.37
Tower, cable, beam 18	2.77	19.37
Tension pressured tendons on the side-span bridge deck	1.7	19.37
Shut mid-span	1.67	19.39
Tension pressured tendons on the mid-span bridge deck	1.65	19.52
Secondary weight	1.72	19.53
Bridge deck pavement	1.99	20.92

During construction, almost all bridge decks have tensile stresses. If the bridge deck is more likely to be cracked during the construction process, it will have a certain impact on the overall structure of the bridge. Therefore, it is necessary to pay attention to the control of the stress of the bridge deck during the construction process.

The stress distribution of the bridge deck in each construction stage and the finished bridge stage is very different. Under the finished bridge stage, the bridge deck is all pressed, which has a great relationship with its force characteristics.

**Figure 2-2.** Bridge deck stress on finished stage

(3) Bending moment and deformation of the main beam

Since the steel beams and bridge decks are simulated separately, the bending moments in the finished bridged stage are separately analyzed and compared, as shown in Figure 2-3. In the common pier, the auxiliary pier and the mid-span, the steel beam exhibits negative bending moments, and the rests are positive bending moments. This is consistent with the deformation characteristics of the main beam in the finished bridge stage.

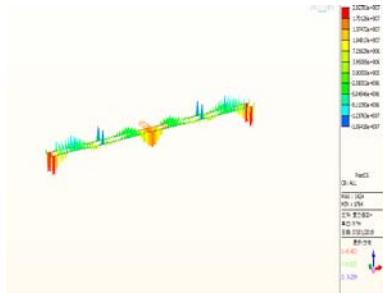


Figure 2-3. Steel beam bending moment on finished stage

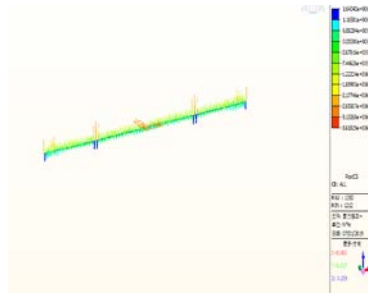


Figure 2-4. Bridge deck bending moment on finished stage

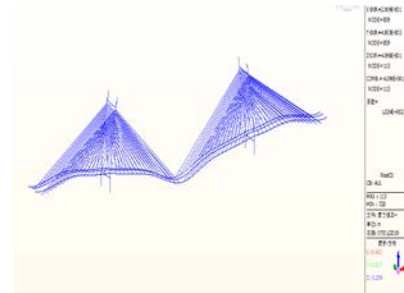


Figure 2-5. Main beam line type on finished stage

Figure 2-4 shows the bending moment of the bridge deck in the finished bridge stage. In the common pier, the auxiliary pier and the mid-span, the bridge deck exhibits a large negative bending moment and a positive bending moment, and most of the remaining bending moments are evenly distributed. The maximum positive bending moment of the bridge deck is 1643.4kN·m, and the maximum negative bending moment is 3610.3 kN·m. They all meet the requirements of the bending moment of the cable-stayed bridge design.

Figure 2-5 shows the deformation of the main beam in the finished bridged stage. Combined with the bending moment of the steel beam and the bridge deck, it can be seen that the deformation of the main beam is basically consistent with the bending moment diagram of the them. The main beam has a large deformation in the mid-span and the auxiliary pier, and the vertical maximum displacement is 41.0 cm.

2.2. Static Characteristics Analysis of the Cable Tower

By comparing the completion of the construction stage and the finished bridge stage, the axial force, bending moment and stress of the cable tower were analyzed.

(1) Axial force

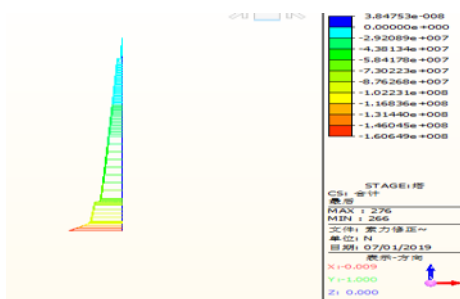


Figure 2-6. Tower axial force on completion stage

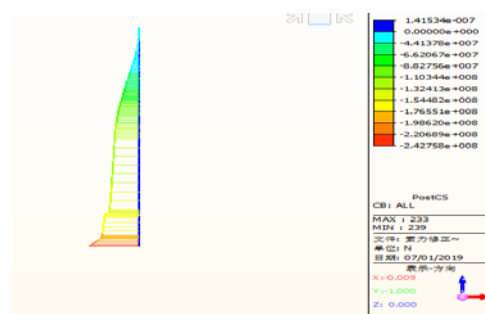


Figure 2-7. Tower axial force on finished stage

Figures 2-6 and 2-7 represent the axial forces of the tower under completion of the construction stage and finished bridge stage, respectively. At the completion of the construction, the maximum axial force of the tower occurs at the bottom of the tower, which is 160649kN. This is mainly because

at this stage, the tower is only affected by its own weight, and the closer to the top of the tower, the smaller the axial force. Comparing the two axial force diagrams, the axial force of the cable tower in the finished bridge stage is larger than that of the completion stage, especially in the upper tower of the tower. This is mainly because of the influence of the cable force, the cable is mainly anchored in the upper tower column, and the component force of the cable force in the finished stage of the bridge will have a certain influence on the axial force of the cable tower.

(2) Bending moment and deformation

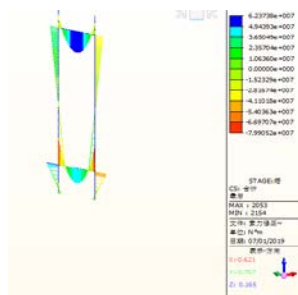


Figure 2-8. Bending moment on completion stage

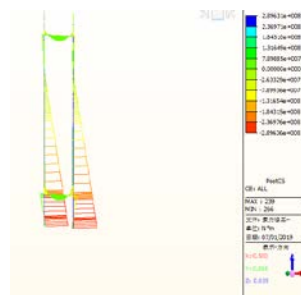


Figure 2-9. Bending moment on finished stage



Figure 2-10. Deformation on completion stage



Figure 2-11. Deformation on finished stage

Figure 2-8 to Figure 2-11 show the bending moment and deformation of the tower during the completion stage and the finished bridge stage. The deformation of the tower at the completion stage is basically consistent with the bending moment, which is much smaller in value than the bending moment in the finished bridge stage. The maximum bending moment of the tower under the bridge stage occurs in the pile cap, the value is 289636 kN·m, and the distribution characteristics of the bending moment correspond to the deformation of the tower. The bending moment is mainly concentrated in the middle and lower tower columns, which is combined with the shape of the actual tower.

(3) Stress

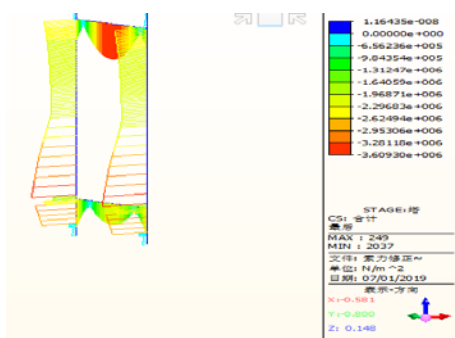


Figure 2-12. Stress on the completion stage

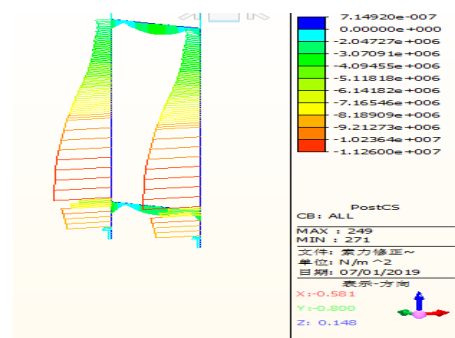


Figure 2-13. Stress on finished stage

According to the above figure, the maximum stress value of the tower is 3.6 Mpa in completion stage, which is much smaller than the maximum stress value of 11.3 MPa in the finished bridge stage. However, in two stages, the stress distribution characteristics of the tower are basically the same. In the completion stage, the stress distribution of the middle tower and the lower tower is relatively uniform, mainly due to the use of a variable cross-section design, the cross section from top to bottom is getting larger and larger. For the upper tower column, although the upper tower column received by the force component of the cable force is getting bigger and bigger from top to bottom, however, the upper column is also designed with a variable cross-section, so the stress distribution is also uniform.

2.3. Static Characteristics Analysis of Stay Cables

In addition to focusing on the static characteristics of the main beam and the tower, the static characteristics of the stay cable should also be analyzed. The stay cables are spatially fan-shaped and are arranged on both sides. Each cable surface is arranged with 16 cables in the side span and the middle span, and 7 different specifications of cables are used in the design.

Table 2-3. Stay cable force on finished stage

Stay cable	Cable tension(kN)	Stay cable	Cable tension(kN)	Stay cable	Cable tension(kN)	Stay cable	Cable tension(kN)
S16	5422.3	S8	3635.6	M16	5564.3	M8	4120.4
S15	5317.0	S7	3618.5	M15	5143.5	M7	3598.1
S14	5325.1	S6	3168.2	M14	5538.2	M6	3580.5
S13	5353.5	S5	3160.5	M13	5469.1	M5	3138.1
S12	4924.2	S4	2775.5	M12	5427.9	M4	3064.0
S11	4874.7	S3	2680.7	M11	4930.0	M3	2919.1
S10	4361.5	S2	2008.1	M10	4902.1	M2	2173.4
S9	4297.6	S1	1765.2	M9	4855.1	M1	1912.7

Table 2-3 shows the cable tension in the finished stage. It can be seen that the maximum cable tension occurs in M16 and the cable force value is 5564.3 kN. The cable tension of the cable stayed in the finished stage is gradually increased from the bridge tower to both sides, so it is necessary to use a variety of cable stays. For the same pair of stay cables, the cable tension in the mid span is greater than the cable tension in the side span, and the horizontal component of the cable force is greater than the side span in the middle span. Therefore, the tower will shift toward the mid-span, which is consistent with the deformation of the tower.

In addition to the analysis of the cable tension of the finished stage, we also analyze the cable tension during the construction stage of the No.5 and No.15 cable. The No. 5 cable is a double cantilever construction stage, and the No. 15 cable is a single cantilever construction stage. Figure 2-14 and Figure 2-15 show the cable tension of No. 5 and No. 15 in the construction phase. It can be seen that at the beginning of the construction, the cable tension has a large change, and as the construction progresses, the cable tension of the side span and the middle span tends to be stable. In the bridge decking stage, the cable tension will change considerably due to the application of the load.

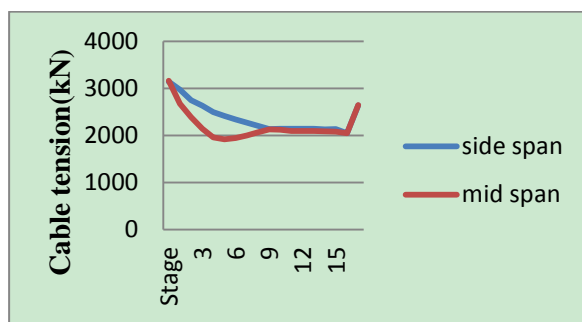


Figure 2-14. Cable tension of No. 5 stay cable on construction stage

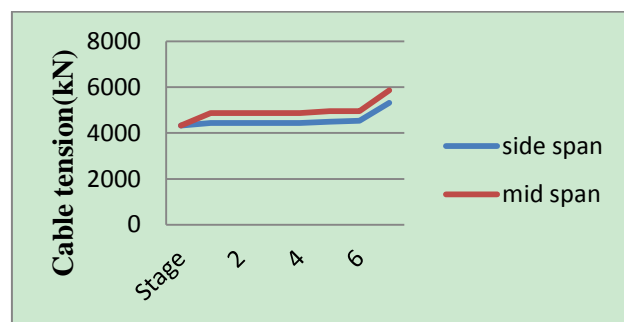


Figure 2-15. Cable tension of No. 15 stay cable on construction stage

3. Conclusion

(1) The stress distribution of the bridge deck in each construction stage and in the finished bridge stage is very different, we should pay particular attention to the stress control of the bridge deck during construction.

(2) The design of the tower with variable cross-section is conducive to the uniform distribution of the stress of the tower. The deformation of the tower is mainly concentrated on the top of the tower. In

the construction, special attention should be paid to the monitoring of the displacement of the tower top.

(3) During the construction process, it is necessary to focus on monitoring the change of cable force. If it is necessary to adjust the cable force, it is necessary to monitor the stress variation of the main beam.

4. Acknowledgments

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5. References

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