E3S Web of Conferences **38**, 03025 (2018) https://doi.org/10.1051/e3sconf/20183803025
ICEMEE 2018

Monitoring calculation of closure change of Extradosed Cable-stayed Bridge

Jing Xian SHI[1], Zhi Hong RAN[2]

[1]Oxbridge College, Kunming University of Science and Technology,KunMing 650106 Yunnan, China；
[2]School of Architecture and Urban Planning. Yunnan University, Kunming 650091, Yunnan, China

Abstract: During the construction of extradosed cable-stayed bridge in Yunnan province, China, the construction unit has made certain changes in the construction process of the closure section due to environmental restrictions: remove the hanging basket after the closure, the sling shall not be provided in closure section, the function of the sling is realized by the hanging basket on the 16th beam. In case of this change, the bridge has been constructed to section 15th. In order to ensure the smooth and orderly progress of each stage in the closure phase, this article is arranged according to the construction plan, appropriate adjustment of related procedures, checking the bridge safety at all stages of construction, the stress and force of the main girder are compared to ensure the safety of the construction after closure changes. Adjust the height of the beam of the 16th and 17th to adapt the new construction plan, and the bridge closure smoothly.

1 Engineering Overview

The bridge analyzed in this paper is located in Yunnan province in China, main spans of extradosed cable-stayed bridge is 2*85m, bridge width is 27m; the grade of Urban trunk road is Ⅲ, the motor vehicle is two-way and four-lane; the design speed is 30km/h; design load for highway is levelII, the throng is 3.5kN/m^2; design useful life of 100 years. The design elevation of the bridge is 454.589-451.389m.

The facade layout of the main bridge is shown in figure1, and the structure of the cable-stayed bridge is adopted. The main beam adopts single box three-compartment large cantilever variable cross-section PC continuous box beam (shown in figure2), the main pier is thin wall type pier, high 28m, and the deck thickness is 5m. The pier beam adopts the consolidation form. The bridge model material is summarized in table 1.

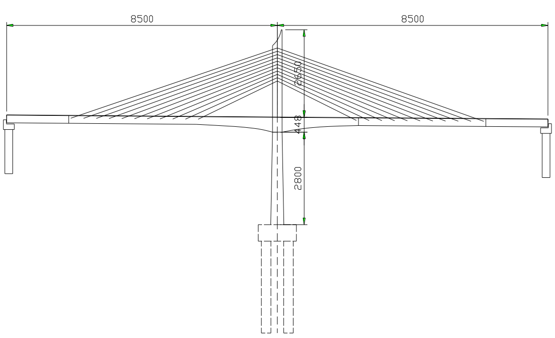


Figure 1 Main Bridge Elevation Layout/ cm

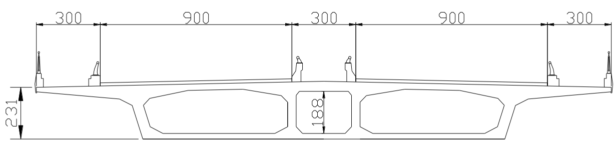


Figure 2 Main Bridge PC Continuous Box Girder Layout /cm

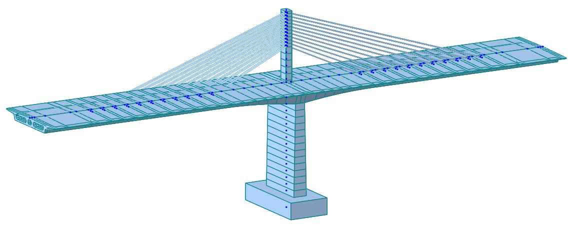


Figure 3 The overall calculation model of structure

Table 1 Material parameters Summary of calculation model

Material code	Unit type	Material type	Elastic Modulus (MPa)	Volumetric weight (kN/m3)	Coefficient of thermal expansion (1/℃)

* Corresponding author: sara_shivip@163.com；1973941@qq.com

1	Bridge pier, main beam, main tower	Concrete50	3.45E+04	26	1.00E-05
2	Stay Cables	High strength steel wire	1.95E+05	78.5	1.20E-05
3	Prestressed	High strength steel wire	1.95E+05	78.5	1.20E-05

This monitoring calculation adopts the MIDAS Civil8.32 analysis program. The structure of the structure is analyzed by the structure of the space bar system. The structure consists of bridge pier, main beam, main tower and lasso. The structural analysis model is shown in figure 3. The total bridge has 146 units and 172 nodes. The boundary conditions in the analysis are: the bottom end consolidation of the cable tower, the transition pier and the auxiliary pier are simulated by the movable hinge support, and the lower end of the cast-in-place bracket is fixed hinge support.

2 Construction change requirement

According to the requirements of construction sequence diagram in the original bridge design document, the cantilever of closure strap and its formwork system are 32tons heavy, remove the hanging basket before closure stage, at the end of the closure, the weight is 58tons. But the construction unit proposed: remove the hanging basket after the closure, the sling shall not be provided in closure section, the function of the sling is realized by the hanging basket on the 16th beam, that meansthe former lifting point is located on the 17th beam segment and is 58cm from the starting point, to realize the function of the dragon sling (number of beam segment is shown in Figure 4). The concrete wet weight of all the hedrons is borne by the cantilever end, so the closure weight is increased from 58 to 105tons.

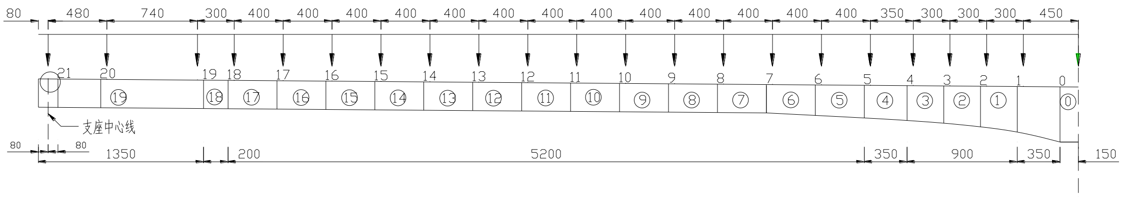


Figure 4 Diagram of the main beam section numbers

When this change is proposed, the bridge has been constructed to 15th beam segment, in order to ensure the successful completion of the sub stages in the closure section, the relevant procedures are adjusted properly in accordance with the construction plan. The hanging basket shall not be removed until it is closed and only moved forward; the weight of the cantilever end is 105tons; after repeated trial calculation, in order to make the bridge state as consistent as possible with the original design, it is necessary to adjust the single tension of 11th cable to 415tons, and make two adjustments after the completion of the bridge, reduce the single tension of 11th cable to 395tons. The closure conditions of the two models are shown in table 2.

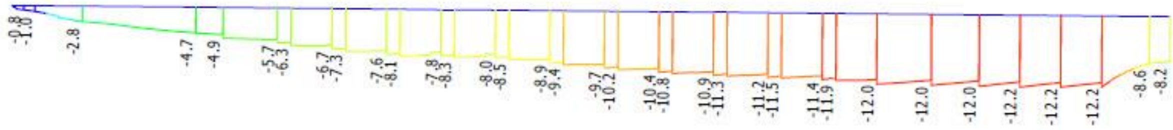
Table 2 Comparison table of condition adjustment

Name of construction component	Description of the original model	Described conditions of the adjustment model
16th section of Beam	Tension cable-stayed	Cable Tension of 11th adjustment to 415t
17th section of Beam	Move forward Hanging basket、Pouring concrete、Tensioning prestress	
Side-span	With full framing construction	
Closure Section	Tear down hanging basket、Put 32t in final closure at both ends of the closure	Move forward Hanging basket (The front hanging point is located on the 17th beam section and from the starting point of 0.58m)
	Pressure 58t in the end of the closure	Pressure105t in the end of the closure
	Installation of closure and steel skeleton、Unloading and pouring concrete、Waiting for age then tensioning prestress	
	Tear down Hanger	Tear down hanging basket
Side-span	Tear down full framing	
	Stage II load	Stage II load, The second adjustment of 11th cable tension to 385t
	Into the bridge conditions	

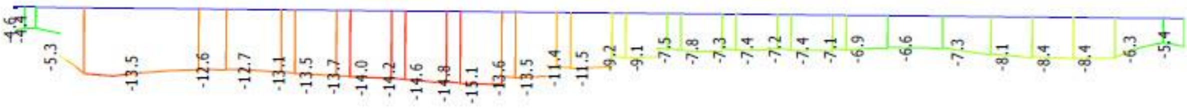
3 Safety checking calculation in construction stage

The stress calculation results of the main girder in each construction stage are shown in figure5 and 6.It can be seen from the picture, the stress change is small compared with the original model and the adjusted model, but they are all within safe limits. The results of pier strength calculation are shown in table 3. As you can see from the table, the capacity of the maximum cantilever stage (cast concrete in the concrete) meets the requirements.

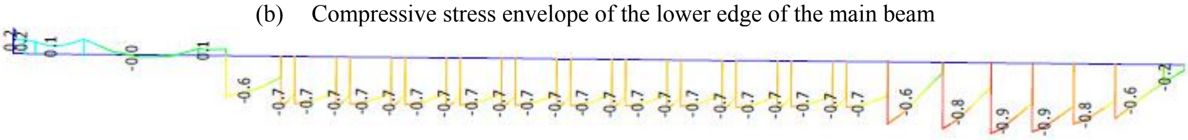
《Guidelines for Design of Highway Cable-Stayed Bridge》(JTG/T D65-1-2007) Specification 3.4.2 stipulate: Under construction the safety factor of the cable-stayed cable should greater than 2.0. The calculations results of the force of the bridge are shown in table 4, it can be seen from the table that all the forces of the cable meet the standard requirements.



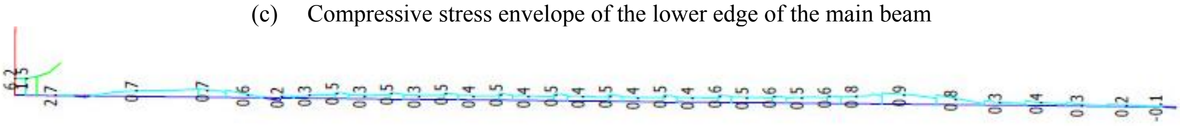
(a) Compressive stress envelope of the upper edge of the main beam



(b) Compressive stress envelope of the lower edge of the main beam

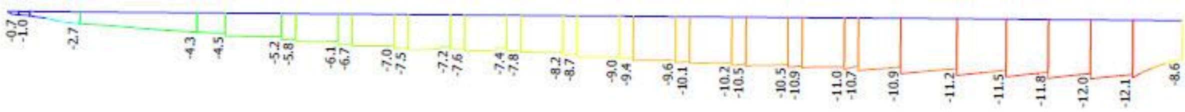


(c) Compressive stress envelope of the lower edge of the main beam

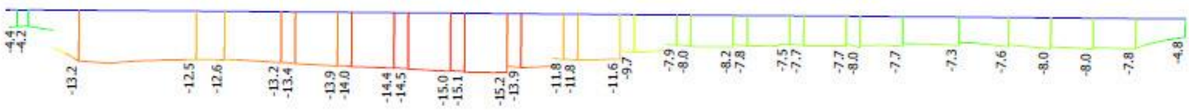


(d) Tensile stress envelope of the lower edge of the main beam

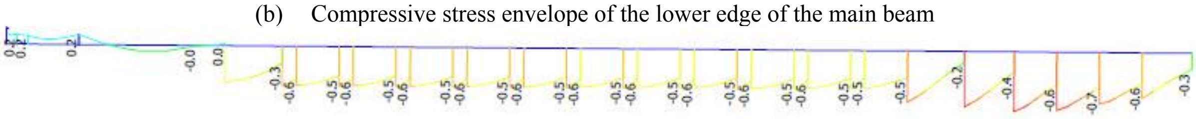
Figure 5 Calculation results of main beam stress in construction stage the original model / MPa



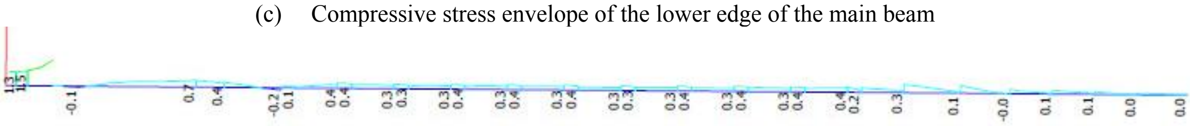
(a) Compressive stress envelope of the upper edge of the main beam



(b) Compressive stress envelope of the lower edge of the main beam



(c) Compressive stress envelope of the lower edge of the main beam



(d) Tensile stress envelope of the lower edge of the main beam

Figure 6 Calculation results of main beam stress in construction stage the adjusted model / MPa

Table 3 Calculation Results of Bridge pier and tower Strength in Construction Stage

	Load Conditions	Largest Cantilever Stage (Original model)	Largest Cantilever Stage (Adjusted model)
Pounding Bottom Section	Axial Force/kN	-130460	-132177
	Forward Bending Moment/kN.m	522	536
	Section Resistance/kN	1480000	1450000
	Safety coefficient	11.65	10.97

 https://doi.org/10.1051/e3sconf/20183803025

The Tower Bottom Section	Axial Force/kN	-55713	-57407
	Forward Bending Moment/kN.m	421	434
	Section Resistance/kN	143000	141000
	Safety coefficient	2.6	2.45

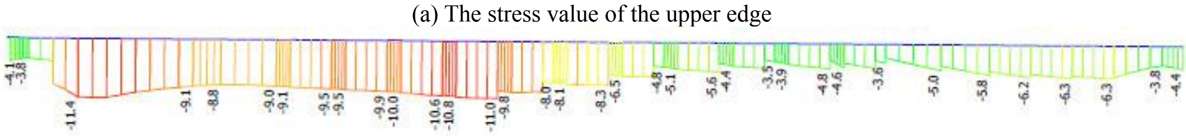
Table 4 The maximum cable force calculation results in the construction stage

Serial number	The original model/kN			The adjusted model/kN			Safe coefficient	
	Main beam side	Bridge tower side	Average value	Main beam side	Bridge tower side	Average value	The original model	The adjusted model
1	3266	3270	3268	3266	3270	3268	2.47	2.47
2	3283	3287	3285	3283	3287	3285	2.46	2.46
3	3317	3321	3319	3317	3321	3319	2.43	2.43
4	3614	3620	3617	3614	3620	3617	2.45	2.45
5	3648	3654	3651	3648	3654	3651	2.43	2.43
6	3680	3686	3683	3680	3686	3683	2.4	2.4
7	3980	3987	3984	3980	3987	3984	2.42	2.42
8	4006	4013	4010	4006	4013	4010	2.4	2.4
9	4028	4036	4032	4028	4036	4032	2.39	2.39
10	4047	4055	4051	4047	4055	4051	2.38	2.38
11	4062	4071	4067	4720	4729	4724	2.37	2.04

4 The comparison of stress of the main beam and the cable force

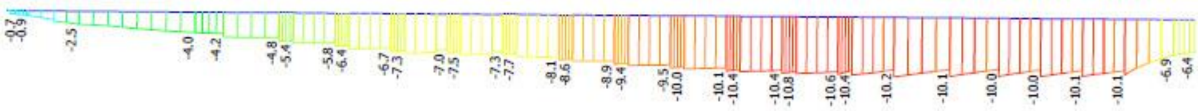
The upper margin and lower edge stress of the original model and the adjusted model are shown in figure 7 and 8. It can be seen from the picture, the maximum value of upper margin compressive stress is 0.3 MPa, the lower margin stress difference is 0.8 MPa. The lower edge of the bridge produces tensile stress due to the automobile live load, therefore; the 0.8 MPa compressive stress of the modified model is beneficial to the structure. Table5 is a comparison of the calculation results for the bridge stage. The maximum difference was 2.4% after adjustment of cable force. Table 8.10.4-1in Terms 8.10.4 of 《Standard for quality inspection and assessment of highway engineering》(JTG F80/1-2004) stipulate: The measured force and the design of the force extreme error are 10%, therefore, the original model and adjusted model of the force difference of 2.4% can not affect the load-carrying capacity of the bridge.

(a) The stress value of the upper edge



(b) The stress value of the lower edge

Figure 7 The stress map of the original model when end of construction /MPa



(a) The stress value of the upper edge

(b) The stress value of the lower edge

Figure 8 The stress map of the adjusted model when end of construction /MPa

Table 5 The calculation results of cable force in the end of the construction stage

Serial	Main	Bridge	Average	Main	Bridge	Average	The difference of cable	Relative

number	beam side	tower side	value	beam side	tower side	value	force between original and adjustment model/kN	difference (%)
1	2624	2628	2626	2637	2642	2640	14	0.5
2	2658	2663	2660	2677	2682	2680	19	0.7
3	2699	2704	2702	2725	2729	2727	25	0.9
4	2965	2971	2968	3000	3005	3003	35	1.2
5	3028	3034	3031	3070	3076	3073	42	1.4
6	3092	3099	3095	3142	3148	3145	49	1.6
7	3415	3422	3418	3477	3484	3481	62	1.8
8	3522	3530	3526	3593	3601	3597	71	2
9	3631	3639	3635	3710	3718	3714	80	2.2
10	3735	3743	3739	3823	3831	3827	88	2.4
11	3834	3843	3838	3915	3924	3920	81	2.1

5 Adjustments Calculate of shuttering elevation

Due to the change of construction sequence and plan, the height of the bridge cannot reach the design value under the completed shuttering elevation. Detailed calculations revealed that the maximum difference between the predicted primary bridge and the original design is 17.5mm. Therefore, the beam 16th and 17th sections should be adjusted, and found by the adjusted model, the folding angle of the 17.5mm is generated on the beam 15th-16th section. To mitigate this situation, the following are dealt with:

1) In order to closure, the 17th beam is not changed;

2) Raise the shuttering elevation of the 16th beam segment to 8mm.

At the time of closure,altitude difference is 15mm between west of final closure and side span,altitude difference is 16mm in East side. However, based on 0.78% design data, the theoretical height difference should be 15.6mm,then successfully complete the bridge construction.The table 6 can be show that the calculation of completed bridge after the adjustment of elevation of the formwork.

Table 6 Calculation result of completed bridge Linetype

Beam section number	Shuttering elevation/m	Deflection at the stage of pouring		Difference analysis with design				
		Placing concrete to make the front of the casting beam downwarping/mm	The hanging basket produces a downwarping/mm	Finished bridge elevation/m	Design elevation/m	Altitude difference between Design elevation and bottom of beam	The difference between the predicted primary bridge and the design elevation	Elevation at closure/m
West 17th	451.893	-103	-30	451.735	454.425	2.69	0	451.715
West 16th	451.824	-93	-30	451.709	454.399	2.69	0	451.688
East 16th	450.802	-93	-30	450.687	453.377	2.69	0	450.666
East 17th	450.809	-103	-30	450.651	453.341	2.69	0	450.631

Note：The design elevation is the elevation value of the construction drawing + aftershrinkage creep+ Live load displacement /2

6 Conclusion

Through the calculation of the stress of the main girder and the cable force at each stage of construction and the calculation results of the elevation of the vertical mold, it can be seen that the bridge is in a safe state after the adjustment of the formwork.

1) The stress of the adjusted formwork is within the safe range, and the bearing capacity meets the requirement during the maximum cantilever stage, and the bridge is in a safe state.

2) The calculation result of cable force satisfies the requirement that the safety factor of stay cable is more than 2.

3) After adjustment, there is a small gap between the cable forces, and the maximum gap is 88ton in cable 10th. Compared with the original model, the difference of 2.4% does not affect the carrying capacity of the bridge.

4) After adjusting the elevation of the formwork of the beam section, the finished bridge shall conform to the design line according to the changed working procedure.

References

1. JTG/T D65-1-2007.Guidelines for Design of Highway Cable-Stayed Bridge [S].
2. JTG F80/1-2004.Standard for quality inspection and assessment of highway engineering[S].
3. Shi Jun,Zhao Yue. Closure Technology of Huiqing Yellow River Bridge[J]. Construction Technology.2011(05):44-48.
4. WEI Zuo-ming,MENG Fang-cheng,CHEN Wen. Linear Sensitivity Analysis at Construction Phase of Extradossed Cab1e-stayed Bridge[J]. Western China communication Science and Technology.Bridge and Tunnel engineering.2014(06):65-68.
5. ZHAO Fu-xing. The analysis and research on construction control of low-pylon cable-stayed bridge[J]. HeiLongJiang jiaotong keji.2016(02):80-81.
6. Sun Fuyang. Construction Monitoring of Asymmetric Extradosed Railway Cable-stayed Bridge Tower Beam [J].Railway Construction Technology 2016 (04):15-19.
7. Ming Yuan,Dong Huang Yan. Optimization on Closure Scheme of Multi-Span Prestressed Concrete Box-Girder Bridge[J]. Advanced Materials Research,2011,1067(163).
8. Zhan Yong Yao,Xiao Meng Zhang,Shuai Li,Lian Fu Li,Xiang Hong Pan,Kai Yao. Influence of Closure Sequences on the Rigid Frame-Continuous Girder Bridge Closure[J]. Applied Mechanics and Materials,2013,2547(361).
9. Jun Dong,Tian Liang,Jiang Xiao Feng. Investigation on Optimization of Cable Tension for Extradosed Cable-Stayed Bridge under the Rational Completion Stage[J]. Advanced Materials Research,2014,3456(1020).
10. Shao-min Jia. Geometric Closure Control of the Main Channel Girder of Jiaxing-Shaoxing Bridge[J]. Journal of Highway and Transportation Research and Development (English Edition),2015,9(1).