Analysis and Test of The boom Tension in a Tied arch bridge

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Abstract. The boom tension of the tied arch bridge has a great influence on the state of the bridge, which is the key monitoring project in the construction stage. In this paper, a concrete-filled steel tube arch bridge with a span 60m is taken as an example. Based on the theoretical analysis of boom tension of tied arch bridge and the test of construction process, the following results are drawn: in the construction stage, the suspender tension is reasonably controlled to achieve the expected goal of the construction period. The cable force in the finished stage basically coincides with the design expectation. When the bridge is completed, the error precision control of boom tension is better, which ensures the safety of the bridge in the operation stage.

1 Theoretical Calculation

In this paper, a concrete filled steel tube arch bridge with a span 60m is taken as an example, The facade arrangement of this tied arch bridge is shown in Figure 1, calculation vector height is 12m, ratio of rise to span is 1/5, and vertical and horizontal beam system is adopted for bridge deck structure. 10 sets of booms are set in each of the arch ribs, one-end tension, tension at the top of arch rib, the fixed end is arranged at the bottom of the tie beam.

Boom: The whole bundle extrusion cable system of OVM.GJ15-12 steel strand is used. The supporting anchorage is A (fixed end) and B (tension side) set of anchorage for the whole beam of OVM.GJ steel strand, the standard strength of the hanger is f_{pk}=1860MPa, and the breaking tensile force is 3125kN. The steel strand is a high strength and low relaxation galvanized steel strand. The outer HDPE jacket of the boom is orange in color.

The theoretical calculation adopts the MIDAS/Civil analysis program and the boom adopts the space truss element (as shown in Figure 2). The boundary conditions are as follows: the bottom hinges of the full framing, hinges at both ends of the arch, the cast-in-place bridge deck unit is consolidated with the tie beam and crossbeam. The material characteristics of the boom in the model are shown in Table 1.

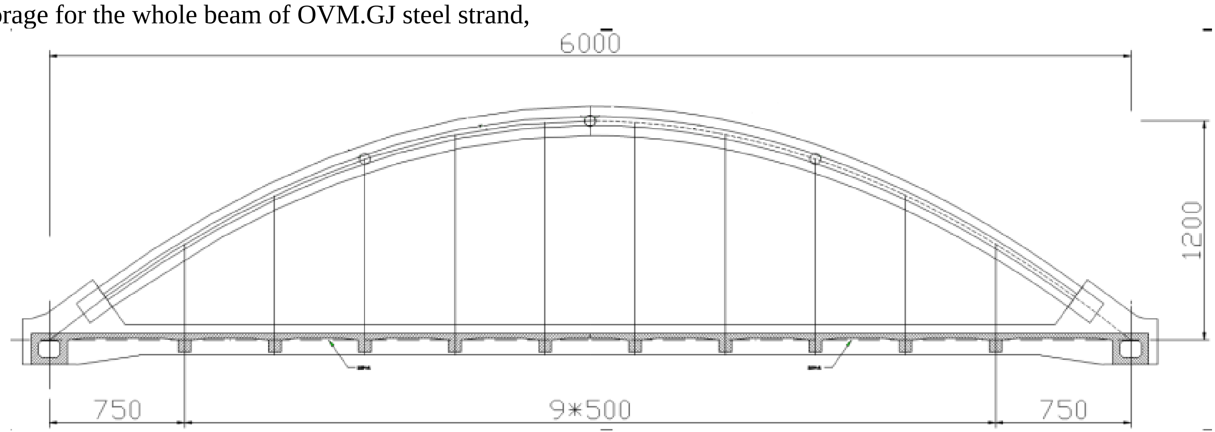

Figure 1 The layout of the main bridge(Unit：cm)

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Figure 2 Simplified calculation model of the whole structure

Table 1 The cross section of the boom and the properties of the material

Cross section Area/m^2	Asy /m^2	Asz /m^2	Czm /m	Material type	Modulus of elasticity/MPa	Bulk density /kN/m^3	thermal expansion coefficient
0.0059	0.0054	0.0054	0.0435	Steel	1.95E+05	7.85E+01	1.20E-05

Note：**Asz**-Unit local coordinate system ,Effective Shear Area of Z axis (m2)；**Czm**-The distance between the section of the -z axis and the edge to the edge fiber along the local coordinate system of the unit(m).

According to the monitoring and calculation results, the maximum cable force in each stage of the whole construction process is shown in Table 2. It can be seen from the table that the safety factor is greater than 4, which meets the safety requirement of the cable in the construction condition specified by the <Guidelines for Design of Highway Cable-stayed Bridge> (JTG/T D65-1-2007)3.4.2

Table 2 The calculation result of the boom tension

Boom number	Boom quantity	Sectional are/mm^2	Beam end cable force/kN	Arch end cable force /kN	Safety factor
101	2	1680	572.2	572.4	5.46
102	2	1680	572.2	572.4	5.46
201	2	1680	661	661.3	4.73
202	2	1680	661	661.3	4.73
301	2	1680	649.8	650.2	4.81
302	2	1680	649.8	650.2	4.81
401	2	1680	650.8	651.2	4.80
402	2	1680	650.8	651.2	4.80
501	2	1680	666.3	666.7	4.69
502	2	1680	666.3	666.7	4.69

2 Testing Methods and Instruments

Select the main two construction stages: test the tensioning stage of the boom and the bridge completion stage. The tension stress of suspender is tested by frequency method, that is indirectly testing the transverse vibration frequency of booms, and using the inherent relationship between frequency and tension force to convert the actual cable force. Detailed technical details are based on the following papers:

- <Singular Perturbation Method for Solving Non-linear Vibration of Inclined Cables> (Journal of Southwest Jiaotong University,2006);
- <A New Method to Enhance the Estimation Accuracy of Stay Cable Tension> (Journal of Highway and Technology Research and Development,2007);
- <Singular Perturbation Method for Solving Non-linear Vibration of Stay Cable(I) — Theory Expressions> (CEBM,2011);
- <Singular Perturbation Method for Solving Non-linear Vibration of Stay Cable(II)— Engineering Application> (CEBM,2011).

The test instrument using JMM-2681 Cable force measuring instrument, as shown in figure 3.

Figure 3. Cable force measuring instrument

3 Test Result

The test should meet the following requirements:the accelerometer adopts full seal design, high reliability, super stability, waterproof and moisture proof. The measurement error of cable force is less than 2%. The data acquisition requires an analytical instrument with high sensitivity, which can detect the weak vibration signal of the cable, the built-in charge amplifier, the data acquisition circuit, the automatic shift and zero adjustment, and the 1024 point FFT spectrum analysis. Rely on the measuring instrument to ensure the test accuracy.

When there is a large deviation in the test process, the parameters of the boom need to be identified by the measured data, such as line density, boundary condition correction coefficient, nonlinear correction coefficient and other parameters. The tension test results for the end of the boom and the bridge completion stage are shown in Table 3 and 4.

Table 3 Test result of cable force at completion stage of tensioning boom Unit：kN

Point number	Upper reaches	Down stream	average value	The difference between the upper and lower reaches	Theoretical calculation value	The difference between the mean and the theoretical value
West 05	514	521	518	-7	497	20
West 04	503	511	507	-8	496	11
West 03	478	479	478	-1	496	-17
West 02	524	504	514	20	495	19
West 01	505	516	511	-11	495	15
East 01	518	511	515	7	495	19
East 02	511	518	515	-7	495	19
East 03	485	480	482	5	496	-13
East 04	483	489	486	-6	496	-10
East 05	514	504	509	10	497	12

Table 4 Test result unit of cable force at completed bridge state Unit：kN

Point number	Upper reaches	down stream	average value	The difference between the upper and lower reaches	Theoretical calculation value	The difference between the mean and the theoretical value
West 05	537	547	542	-10	559	-17
West 04	638	645	642	-7	637	4

West 03	602	612	607	-10	609	-2
West 02	624	637	631	-13	615	15
West 01	641	658	650	-17	647	2
East 01	649	638	644	11	647	-4
East 02	619	638	629	-19	615	13
East 03	621	624	623	-3	609	13
East 04	626	617	622	9	637	-16
East 05	563	572	568	-9	559	8

4 Conclusion

Through the theoretical analysis and construction process test of the boom tension of the tied arch bridge, the following conclusions are drawn:

1)During the construction stage, the control of the boom tension is reasonable and the expected target of the construction period is reached. The boom tension at the completion stage is basically consistent with the design expectation.

2)The error of the boom tension is controlled within 20kN and the precision is well controlled when the bridge is completed. Such construction control results can ensure the safety of the operation stage of the bridge.

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