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Simulation Calculation and Monitoring of *Deformation of Concrete-Filled Steel Tube Arch Bridge*

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Abstract. Concrete-filled steel tubular arch bridge is a relatively new structure system, because of its unique mechanical properties, it has a good advantage in the construction of modern Bridges. In the course of construction, the arch rib axis and the system beam will have the upper and lower deformation. If improper linear control, the compression performance of the material cannot be fully played after the arch rib is formed, which has a great influence on the state of the bridge. In order to make the arch axis of the bridge more reasonable, this paper takes a concrete-filled steel tube arch bridge with a span 60m as an example. Through theoretical analysis and monitoring， it is found that the line shape control of the bridge is reasonable in the construction stage; the line shape of the bridge stage is basically consistent with the design expectation, and the line type is smooth, the multiple cable adjustment is eliminated and the expected target of the construction period is reduced.

1. Computer simulation calculation

The object of this article is a city road bridge in Yunnan, China，and the speed of the design is 20km/h; the design load is highway - II. The main bridge is a through concrete-filled steel tube arch with a span of 60m. The calculated height is 12m, the rise span ratio is 1/5, and both ends are all prestressed concrete hollow slabs with span 20m. Due to the novel structure of the bridge, deformation monitoring must be carried out in the construction process. There are 2 concrete filled steel tube arches in the whole bridge. The section of the arch rib is dumbbell type, 160cm height, the outer diameter of the pipe is 65cm, the wall thickness is 14mm, and the transverse distance between the arch ribs is 5.0m.

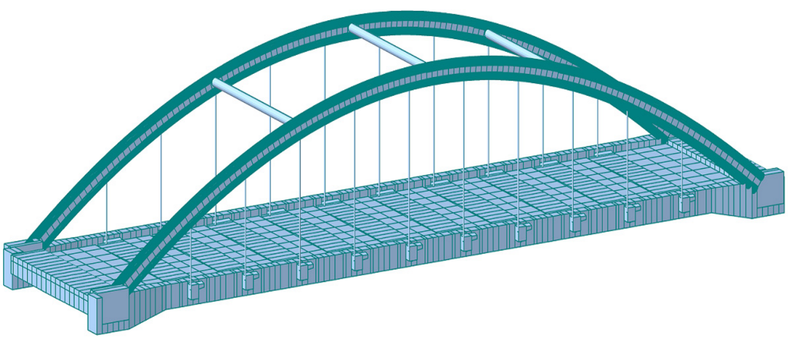


Figure1. Integral structure calculation model

The MIDAS/Civil analysis program is used in the theoretical calculation，the main arch, the wind bracing, the tie beam and the cross beam are the spatial beam elements；the hanger is the spatial truss element and the deck plate is the space plate element (the calculation model is shown in Figure1). The boundary conditions are as follows: the bottom hinges of the full framing (only compression, stiffness 100kN/mm), the two ends of the arch foot are hinged (longitudinal movable); and the cast-in-place bridge deck unit is consolidated with the tie beams and crossbeams.

Table 1. The calculated material parameters

Material number	Unit type	Material type	Modulus of Elasticity /MPa	Bulk Density kN/m^3	Thermal Expansion Coefficient 1/℃
1	Plate, Concrete in steel tube arch	Concrete	3.45E+04	2.50E+01	1.00E-05
2	Arch ribs and wind braces	Steel	2.10E+05	7.85E+01	1.20E+05
3	Prestress and hanger	Steel	1.95E+05	7.85E+01	1.20E-05
4	Beam concrete	Concrete	3.45E+04	2.60E+01	1.00E+05

The main contents of theoretical calculation are as follows: according to the design drawings, the design height of beams and arches is calculated. On this basis, according to the calculation results of the monitoring and calculating model, the camber and the linear of the bridge are calculated according to the following formula:

Bridge camber =(Maximum displacement of vehicle live load+Maximum load displacement of pedestrian load)/2-Later creep displacement(30 years);

Bridge linear=Design elevation+Bridge camber;

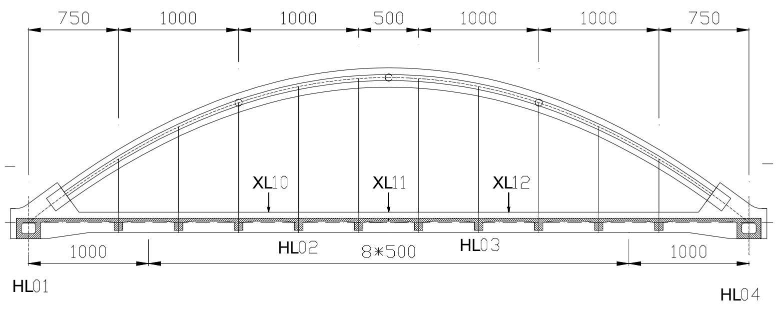
Construction camber=The cumulative displacement of each node before the bridge is completed；

Design elevation of concrete after pouring=Bridge linear+Bridge linear；

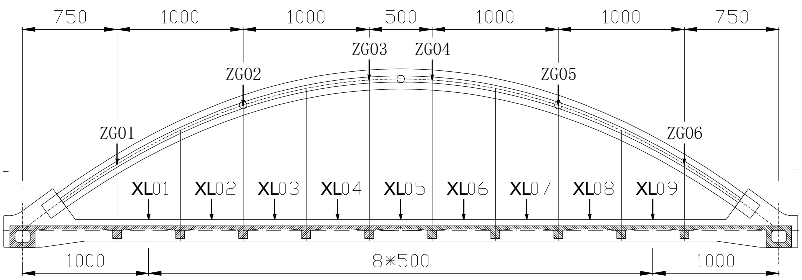
Elevation mode=Design elevation of concrete after pouring=deformation of support.

The bridge camber is calculated according to the above formula, the long-term deflection is positive, and the reverse arch is not required according to the standard. Therefore, the design elevation of the tie beam and arch is the bridge line of the tie beam and arch. In the cumulative displacement of the bridge, the arch rib is down 3mm, the tie beam is up 5mm, and the crossbeam is up 12mm. There is no need to set up the camber of construction. The elevation of the model is the sum of the design elevation and the deformation of the support.

2. Layout of geometric monitoring points



A) Upstream side



B) Downstream side

Figure2. Vertical view of displacement measuring point /cm

Geometric monitoring mainly includes deformation monitoring of tie beam and main arch. Through monitoring, each construction theoretical elevation is provided, and the height of the tie beam and main arch is monitored in real time.The Level instrument and Total Station are mainly used 2DL700 and NTS-352R.

The map of the deformed point measurement is shown in figure 2. 8 measuring points are arranged for each arch rib. 9 elevation measuring points are arranged for each tie beam, at each measuring point, the 5cm of the Φ28 steel outcrop and the embedded 10cm shall be placed in the beam segment. There are 36 height monitoring points for the main beam of the whole bridge (also taking into account the axis monitoring,see figures 2 and 3). 1 main point is placed on the main arch vault.

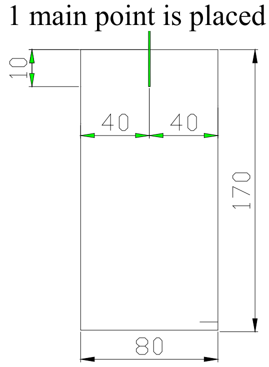


Figure3. Layout of the elevation and axis monitoring points of tie beam /cm

Deformation monitoring of tie beam: The height control is carried out at each measuring point in the process of pouring, prestressing and tensioning suspenders. Deformation monitoring of main arch：the total station is used to carry out height control at each measuring point during the process of hoisting main arch, hoisting, pouring concrete and tensioning suspenders. The precision level is used to monitor the height and foundation settlement of the tie beam and the measurement error of the round-trip is not greater than 1mm.

3. Formwork elevation calculation

The test should meet the following requirements: the acceleration pickup is designed with full sealing, 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.

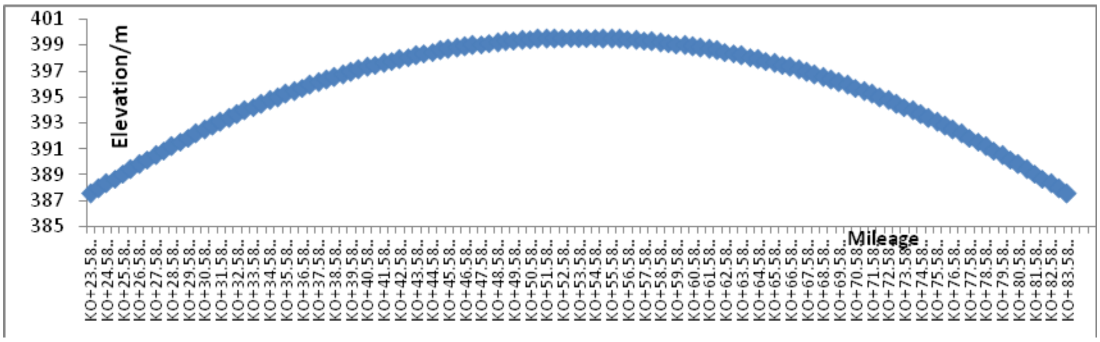


Figure 4. The elevation of the main arch

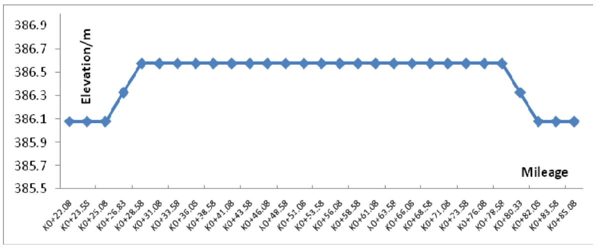


Figure 5. The elevation of tie beam

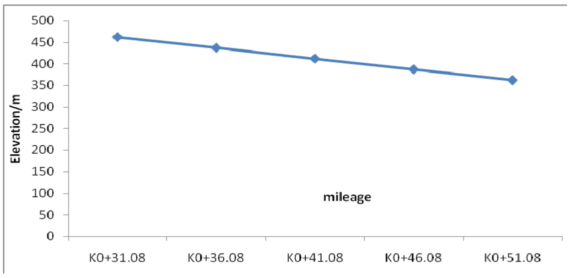


Figure 6. The elevation of crossbeam

4. Monitoring results

The results of four construction processes are mainly analyzed:

Stage1-tie beams and crossbeams are poured and completed for the first prestressing tensioning stage (see Table 2);

Stage2-main arch closure and completion of concrete perfusion stage (see Table 3);

Stage3-the completion stage of the tensioning hanger (see Table 4);

Stage4- completion stage (including pavement and two phase dead load) (see Table 5)

Table 2. Linear measurement report of tie beam and crossbeam in stage1 (11.2℃/71%)

Survey spot Number	Mileage	Upstream/m	Downstream/m	①Average Value/m	②Theoretical calculation Value/m	①-② /mm
XL01	K0+33.58	---	388.267	388.267	388.274	-7
XL02	K0+38.58	---	388.268	388.268	388.273	-5
XL03	K0+43.58	---	388.265	388.265	388.273	-8
XL04	K0+48.58	---	388.266	388.266	388.273	-7
XL05	K0+53.58	---	388.269	388.269	388.273	-4
XL06	K0+58.58	---	388.268	388.268	388.273	-5
XL07	K0+63.58	---	388.283	388.283	388.273	9
XL08	K0+68.58	---	388.281	388.281	388.273	8
XL09	K0+73.58	---	388.281	388.281	388.274	7

XL10	K0+43.58	388.265	---	388.265	388.273	-8
XL11	K0+53.58	388.268	---	388.268	388.273	-5
XL12	K0+63.58	388.273	---	388.273	388.273	-1
HL01	K0+23.58	387.858		387.858	387.867	-9
HL02	K0+46.08	387.978		387.978	387.987	-9
HL03	K0+61.08	387.979		387.979	387.987	-8
HL04	K0+83.58	387.859		387.859	387.867	-8

Table 3. Linear measurement report of tie beam and crossbeam in stage2 (17.8℃/76%)

Survey spot Number	Mileage	Upstream/ m	Downstream /m	①Average Value/m	②Theoretical calculation Value/m	①-② /mm
XL01	K0+33.58	---	388.265	388.265	388.271	-6
XL02	K0+38.58	---	388.265	388.265	388.270	-5
XL03	K0+43.58	---	388.263	388.263	388.270	-7
XL04	K0+48.58	---	388.262	388.262	388.270	-7
XL05	K0+53.58	---	388.267	388.267	388.270	-3
XL06	K0+58.58	---	388.264	388.264	388.270	-5
XL07	K0+63.58	---	388.279	388.279	388.270	9
XL08	K0+68.58	---	388.276	388.276	388.270	6
XL09	K0+73.58	---	388.275	388.275	388.271	4
XL10	K0+43.58	388.263	---	388.263	388.270	-7
XL11	K0+53.58	388.266	---	388.266	388.270	-4
XL12	K0+63.58	388.269	---	388.269	388.270	-1
HL01	K0+23.58	387.870		387.870	387.868	2
HL02	K0+46.08	387.978		387.978	387.984	-6
HL03	K0+61.08	387.976		387.976	387.984	-8
HL04	K0+83.58	387.859		387.859	387.868	-9

Table 4. Report on linear measurement of main arch in stage3 (17.8℃/76%)

Survey spot Number	Mileage	① Upstream /m	② Downstream /m	③ Average Value/m	①-② /mm	④Theoretical calculation Value/m	③-④/mm
ZG01	KO+31.08	392.766	392.767	392.766	-1	392.773	-6
ZG02	KO+41.08	397.432	397.430	397.431	2	397.438	-7

ZG03	KO+51.08	399.444	399.443	399.443	1	399.439	5
ZG04	KO+56.08	399.442	399.445	399.443	-3	399.439	5
ZG05	KO+66.08	397.433	397.430	397.432	3	397.438	-7
ZG06	KO+76.08	392.764	392.768	392.766	-4	392.773	-7

Table 5. Linear measurement report of tie beam and crossbeam in stage3 (27.6℃/58%)

Survey spot Number	Mileage	Upstream /m	Downstream/ m	①Average Value/m	②Theoretical calculation Value/m	①-② /mm
XL01	K0+33.58	---	388.274	388.274	388.281	-7
XL02	K0+38.58	---	388.276	388.276	388.284	-8
XL03	K0+43.58	---	388.278	388.278	388.286	-8
XL04	K0+48.58	---	388.282	388.282	388.287	-5
XL05	K0+53.58	---	388.286	388.286	388.287	-1
XL06	K0+58.58	---	388.289	388.289	388.287	2
XL07	K0+63.58	---	388.295	388.295	388.286	9
XL08	K0+68.58	---	388.291	388.291	388.283	8
XL09	K0+73.58	---	388.283	388.283	388.281	2
XL10	K0+43.58	388.279	---	388.279	388.286	-7
XL11	K0+53.58	388.285	---	388.285	388.287	-2
XL12	K0+63.58	388.287	---	388.287	388.286	1

Table 6. Report on linear measurement of main arch in stage4 (27.6℃/58%)

Survey spot Number	Mileage	① Upstream /m	② Downstream /m	③ Average Value/m	①-② /mm	④Theoretical calculation Value/m	③-④ /mm
ZG01	KO+31.08	392.766	392.768	392.767	-2	392.775	-8
ZG02	KO+41.08	397.424	397.426	397.425	-2	397.432	-7
ZG03	KO+51.08	399.429	399.432	399.431	-3	399.425	5
ZG04	KO+56.08	399.433	399.428	399.431	5	399.425	5
ZG05	KO+66.08	397.424	397.428	397.426	-4	397.432	-6
ZG06	KO+76.08	392.766	392.767	392.767	-1	392.775	-8

5. Conclusions

Through the theoretical analysis of the main arch, tie beam and crossbeam of the concrete filled steel tube arch bridge in this paper, the concrete engineering practice of the whole process monitoring of the construction process can be carried out, and the following conclusions can be drawn:

1) Aiming at the concrete-filled steel tubular arch bridge in this paper, the construction control theory and the stress warning mechanism are applied to establish a reasonable index system for construction error tolerance. It achieves the expected goal of achieving smooth alignment, eliminating multiple cable adjustment and reducing construction cycle. The internal force and linear of the structure at the completion stage are basically consistent with the design expectation.

2) The elevation error of the tie beam and the main arch is controlled within the range of 5-10mm; the elevation error of the main arch installation elevation after simple adjustment is basically eliminated; these construction control results can ensure the operation safety of the bridge at operation stage, and the control accuracy is better than that of the completed similar bridges.

Acknowledgment

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