Research on Construction Elevation Control of Wide-with Cable-Stayed Bridge with Low Pylon

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Abstract, Elevation monitoring is an important step in the construction process of wide low tower cable-stayed bridge. In this process, it mainly controls the difference between the actual elevation and the design elevation in the cantilever construction process of beam section, and controls the formwork elevation value of each section of beam section construction. In the study of cantilever construction elevation monitoring method, this paper analyzes the engineering background and elevation detection process error analysis, elevation control value selection and elevation linear control analysis, and takes a wide low tower cable-stayed bridge as an example, combined with the actual test results to verify the method. It is concluded that the elevation correction error is controllable and the construction alignment is consistent with the design alignment. The vertical alignment error meets the specification requirements, which can provide reference for the elevation control of similar projects.

1. Introduction
There are many factors that affect the elevation of low tower cable-stayed bridge in the construction process, especially the cantilever pouring construction[1]. In this process, the elevation of each cut-off is affected by many aspects and changes with the construction process. At this time, it is necessary to measure and control each cut-off in the construction process, and analyze the measured elevation data and design data by comparing them[2]. Analyze the influence of linear control, elevation monitoring can well control the elevation of each cut in the construction process. In this paper, a two tower three span low tower cable-stayed bridge is taken as an example. The main bridge is a three span continuous structure with two spans of 77 + 135 + 77m. The structure system of tower beam consolidation and tower pier separation is adopted. The finite element model of the whole bridge is shown below. This paper analyzes the error analysis of elevation detection process, the selection of elevation control value and elevation linear control analysis, so as to ensure the safety and smooth closure of the bridge[3].

Figure 1 Full bridge finite element model
2. Error analysis of elevation detection

2.1. Main girder cross section
The cross section of the main girder adopts the form of single box three chamber inclined web. The width of the single bridge deck is 30m, the cantilever length on both sides is 5.5m, the thickness of the middle chamber roof is 39m, and the thickness of the side and middle chamber floor is 30m.

![Figure 2 Cross section of middle pivot](image)

2.2. Error analysis of elevation monitoring
In the process of field monitoring, according to repeated experiments and result analysis, the error of elevation monitoring mainly includes the error of level itself, the error of observation and the error under the influence of external conditions.

| Error               | Matters needing attention                                                                 |
|---------------------|-------------------------------------------------------------------------------------------|
| Level error         | The error caused by the collimation axis not parallel to the leveling tube axis, ruler length error, marking error and zero point difference[4]. |
| Observation         | The bubble of the level pipe should be in the middle, the level ruler should be placed upright and standardized, and the reading should be measured many times to reduce the line of sight error[5]. |
| External condition error | Pay attention to the light and the sinking of the level.                                       |

3. Selection of elevation control value

3.1. Construction pre-arch degree
In determining the construction pre-arching degree, the structural pre-arching degree stipulated in the design document, the elastic deformation caused by the support and the arch bearing all the construction loads, the inelastic deformation caused by the extrusion of the rod joints and the compression of the unloading equipment after loading, and the settlement of the support and the arch foundation after loading should be considered first.

The calculation of construction pre-arching degree should be determined by combining the five stages of the site.

| phase    | step                                                                 |
|----------|----------------------------------------------------------------------|
| phase one| Accurately measure the vertical elevation H1 of the roof construction. |
| Phase two| Measure the elevation H2 of the vertical form after the concrete is cast and hardened. |
| Phase three| Measure the vertical die elevation H3 before the longitudinal prestressed beam is tensioned. |
| Phase four| After the tensioning and grouting of the prestressed bundle is completed, the elevation of the vertical form is measured, H4. |
Phase five

Compare the difference between the first four stages to see if it meets the design requirements.

3.2. Pre-arch degree of the bridge
The pre-camber and the reverse deflection are generated to offset the transverse deflection, and the values are the vertical deflection of the total transverse load and half of the static and live load\[6\].

At present, due to the calculation of concrete creep, whether it is a theory of aging, and the calculation method of correction theory of aging or rules are difficult to estimate the influence of concrete creep, right in the construction of this effect does not directly identification, correction, is usually built in previous similar downwarping quantity to span length of analogy, and elevation of reserved by the model\[7\].

3.3. Basket adjustment value
The calculation of the adjustment value of the hanging basket is mainly calculated by the counterweight of the hanging basket itself. After the completion of the construction of the 0 block, the counterweight of the hanging basket is started when the 1 block is carried out. From this, we can know how much the deformation of the hanging basket is, and then determine its value\[8\].

4. Linear control analysis of main girder

4.1. Arrangement of measuring points in construction stage
Starting from Block 0, 5 monitoring datum points are buried at the top and 3 at the bottom of the beam. Therefore, the deformation of the bridge deck and the deformation of a reference point of the cable tower are not affected by each other. See Figure 3 for the layout of main girder elevation control points.

![Figure 3 Single box three chamber measuring point diagram](image)

4.2. Elevation test results and analysis
According to the top 5 points of No. 1 block on site, the data before and after pouring of No. 1 block can be measured according to Table 3. According to the elevation data before and after casting. Table 4 can be obtained.

| Elevation/m | Big side | 1     | 2     | 3     | 4     | 5     |
|-------------|----------|-------|-------|-------|-------|-------|
| The measured elevation |          | 23.898 | 23.691 | 23.923 | 23.615 | 23.476 |
| The stationing height |          | 0.190  | 0.125  | 0.095  | 0.180  | 0.134  |
| Calculate the actual elevation |          | 23.708 | 23.566 | 23.828 | 23.435 | 23.342 |
| Design elevation |          | 23.680 | 23.537 | 23.858 | 23.462 | 23.325 |
| Deviation     |          | 0.028  | 0.029  | -0.030 | -0.027 | 0.017  |
| Elevation/m | Big side |
|------------|----------|
|            | 6        | 7        | 8        |
| The measured elevation | 19.504 | 19.496 | 19.512 |
| Vertical elevation of bottom point | 0.089 | 0.08 | 0.095 |
| Calculate the actual elevation | 19.415 | 19.416 | 19.417 |
| Design elevation | 19.405 | 19.405 | 19.405 |
| Deviation value | 0.010 | 0.011 | 0.012 |

In Table 3, the deviation of 5 points at the top of the beam is within 3 cm, and in Table 4, the deviation of 3 points at the bottom of the beam is within 2 cm. The elevation of the five points on the top of the beam is all within the controllable range.

In figure 4, EBFB stands for elevation of bottom of formwork beam. DBBE stands for design beam bottom elevation. SSB stands for small side block. BSB stands for big side block. On the main girder line, mainly according to the actual construction situation on the site, through the comparison and analysis with the theoretical calculation, constantly adjust the elevation of the vertical form, so that the bridge linear meet the design requirements. When the stiffness of the main girder is relatively small, the adjustment of cable force has a great impact on the linearity of the main girder. Attention should be paid to the adjustment of the height of the main girder during construction, and the measurement should be carried out in accordance with the first four stages of adjusting the construction pre-arching degree [8]. Note that the last measurement should be conducted after the cable force adjustment is completed and the tension is completed [9]. The hanging cable of this project is carried out in Block 3, so attention should be paid to the relevant data after the hanging of the cable is completed from Block 4. The figure below is a linear control discount chart.

It can be seen from the figure 4 that the elevation of the bottom plate mould erection of the mid span is consistent with the elevation of the bottom of the mould erection beam, and there is a deviation at block 12, but the deviation value is within the scope of the specification, and finally the mid span is closed smoothly. The main girder alignment meets the requirements.

5. Conclusion
On the basis of the analysis of the measurement of elevation points in the cantilever casting construction of the wide low-pylon cable-stayed bridge, the source of the measurement error and the linear control principle of the bridge formation are emphatically analyzed in this paper, and the method of eliminating the measurement error and the calculation process are given. It can be summarized in the following four points.
1. The elevation monitoring error analysis mentioned in the article plays a key role in the accuracy of the measured data, and this method can be applied to similar engineering projects.

2. Selection of elevation control values. Taking 8 points as an example, there are 5 points at the top of the beam and 3 points at the bottom of the beam. Systematic data analysis is made for each truncated position.

The data of each truncation position is analyzed systematically. The difference between the measured elevation and the design elevation of the 8 points is within the standard range, and the measurement method is feasible.

3. According to the comparison of elevation data before and after casting, it is found that the deviation value can be controlled and is within the standard range.

4. Elevation linear control analysis is made. In the process of analyzing the measured elevation, the elevation data of the bottom of the vertical beam is obtained through calculation, and the overall results are in good agreement with the design beam bottom elevation data, and the vertical linear error is within the standard range.

Thus, this engineering project is taken as an example to verify the principle of elevation linear control mentioned in this paper. According to the broken line chart obtained from the data, the results show that the overall agreement with the design is good, within the standard range. This paper method can provide reference for elevation monitoring of similar projects.

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