Analysis on the Stability of Top Pushing Construction of Curved Steel Box Beam of a Cross-sea Bridge

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Abstract. The curve steel box girder has the risk of instability in the jacking construction, especially in the case of big waves on the sea surface. It is very important to analyze the stress of the structure during the jacking construction. According to the Midas Civil finite element model, a bridge span is arranged as (49+60+49) m according to various unfavorable loads. The stability of the curved steel box girder bridge during jacking construction is analyzed, and the site construction is controlled according to the calculation results.

1. Introduction

Subject to construction conditions and environmental or duration impacts, the construction method caused by pushing construction is simple, big leap, transport safety, high speed, low construction interference, more and more attention has been paid to bridge construction in China, the requirements for pushing technology are becoming more and more stringent.

Through the application of different cross-section types of bridges, it is pointed out that the non-uniform torsion in jacking construction has a great influence on the stress state of the bridge [1]. Taking Ilafalken Bridge as an example, Renaud et. point out that if appropriate attention is paid to it in the design process and strict quality control in the construction process, the jacking method can be applied to the construction of complex bridges [2]. Zuo the key design parameters of the small radius continuous curve beam on the variable curvature curve are studied, it is pointed out that the spatial finite element model should be established to analyze the force of the small radius curve beam bridge, and the horizontal bending moment of the beam caused by traction, guiding force and rectifying force should be taken into account in the process of jacking construction [3]. Due to improper construction, the thrust process often causes damage to the beam, especially, the stability of bending bridge in the process of jacking construction has always been the focus of attention. The A1 Milan-Naples Highway New Rino Bridge (572.75 m long) is introduced by Guido et. [4]. With the Liuyang River Bridge as the background, aiming at the difficulty of construction control such as vertical curve and oblique intersection, the key technology of the construction control of the inclined continuous box girder bridge, it is pointed out that the stiffness and weight of the main beam should be considered in the jacking construction, select the guide beam with reasonable stiffness, length and weight [5].

With Sanmenxia Yellow River dual-use bridge construction as the background, the transient effect and wind load on the construction of steel truss bridge under cantilever condition are studied, he results
show that when we only consider pushing and starting, the impact effect decreases with the increase of cantilever span; When considering wind loads, the transient impact effect of thrust start increases with the increase of cantilever span. Considering the low stiffness of the U steel beam during the jacking construction, Wang and so on proposed a new jacking construction method, local stress control strategy, the local yield of the bottom plate is avoided [7]. Hu studied the safety of the arch beam combination system bridge during the jacking construction, and analyzed the stress fluctuation of the structural members in the critical water stage under the action of mechanical load and wind load [8]. The results show that the temporary connection between steel arch and longitudinal beam is very important in the jacking process. Compared with linear bridge, the stress condition of curve bridge in jacking construction is more complicated. Cheng combined with the jacking construction of Shangzhi Bridge in Harbin, this paper studies the setting principles of platform, temporary pier, guide beam and other auxiliary facilities in the jacking construction of curve section and the control measures of pushing and falling beam in curve section [9]. Yang established the spatial finite element model of curved steel box girder bridge, and studied the influence of curvature radius on bearing reaction, deflection, torsion and local stress of curved steel box girder bridge [10].

2. Engineering Profile
The main line bridge of Jiaozhou Bay Bridge is the fifth upper span bridge, the superstructure is of equal height continuous steel box girder, the lower pier is column pier, the bridge type is 49m. The bridge type is arranged as follows 60 m, full length 158.0 m, curve radius R=350 The whole bridge consists of 14 beams, 12 of which are 12 m and 2 are 7 m. Steel Box girder elevation was shown as figure 1.

![Steel Box girder elevation](image1)

Figure 1. Steel Box girder elevation (unit: cm).

Temporary support column 13#,14#,15#,16# pier column with φ820×7 mm and φ630φ820×8 mm of steel pipe support, material for the steel pipe between the inclined brace using 16 channel steel, transverse brace using 16 channel steel. At the top of the steel pipe, the steel pipe is welded with the steel pipe, and the steel platform is installed with H588×300 section steel and 16 channel steel as the slide path. Elevation of brace was shown as figure 2.

![Elevation of brace](image2)
Figure 2. Elevation of brace (single span).

Table 1. Jacking construction procedure.

The first step:
1. Bridge pier construction.
2. Installation of temporary offshore support.
3. Production of steel box girder.

The second step:
1. The steel main beam section is transported to the site by trestle.
2. The steel main beam section is hoisted, assembled and pushed on the side span pushing platform.
The third step: When the main beam is pushed up to the middle of the span, the temporary matching part is used to realize the welding of the main beam.

Step 4:
1. Removal of temporary supports.
2. The concrete of bridge deck in an area is poured first (the length of B, C area is suggested 14–20 m, symmetrical arrangement along pier).
3. When the A concrete reaches 90% of the design strength, the bridge deck concrete in B, C area is poured.
4. After the concrete in the B, C area reaches the design strength, the center fulcrum falls to the design elevation.
5. Complete the subsequent process of bridge deck system.

3. Calculation parameters and load combination of support

3.1. Calculated parameter value

| Material   | Design values/MPa |
|------------|--------------------|
|            | Direct stress $\sigma$ | Shearing strength $\tau$ | Extrusion stress $\sigma_c$ |
| Q235-B     | 215                | 125                      | 215                       |
| Q345-B     | 310                | 180                      | 310                       |

3.2. Value of load
(1) Dead load: Weight of steel box girder and support structure.
(2) Wind load:

| City name  | Height above sea level (m) | Wind pressure /kN/m$^2$ |
|------------|----------------------------|--------------------------|
| Qingdao City | 76                           | R=10  | R=50  | R=100 |
|             |                             | 0.45         | 0.60  | 0.70  |
Take 0.70 kN/m² as according to the most unfavourable $R=100$.
The bridge site belongs to a kinds of ground roughness, 5m from sea level $\mu_z=1.0910$ m, $1.2815$ m, $1.42$.

(3) Push friction force: The static friction coefficient is 0.1 according to the empirical value.

### 3.3. Load combination

(1) Partial factor for permanent load, 1.2; The variable load itemized coefficient is 1.4.
(2) Load combination: 1.2; Structure weight 1.4; Wind load 1.4.

### 4. Analysis

#### 4.1. Calculation conditions
According to the construction flow of steel box girder, the working conditions are as follows:

- Working condition 1: Push 36 m steel box girder forward 6 m (cantilever 6 m);
- Working condition 2: Push 48 m steel box girder forward 9 m (cantilever 15 m);
- Working condition 3: Push 60 m steel box girder forward 9 m (cantilever 24 m);
- Working condition 4: Push 72 m steel box girder forward 3 m (cantilever 27 m, maximum cantilever state).

Due to limited space, this paper takes working condition 3 and working condition 4 as examples.

#### 4.2. Finite element analysis

Midas is used to analyze the whole support in the process of steel box girder pushing, the bottom of steel pipe column is consolidated, the steel pipe pile is rigidly connected with the top double-button I-beam, and the I-beam is rigidly connected with the top slide path. Elastic connection between slide track and steel box girder (compression only). The finite element analysis model is shown in figure 3.

![Figure 3. Finite Element Analysis Model.](image)

#### 4.3. Case Four Analysis Results
We can see from fig.4-fig.6:

(1) Considering the bending of beam and wind load, the vertical displacement of the vertical displacement of the main beam is 56.0 mm, 70.4 mm, and the vertical deformation of the main beam should be observed in time during the pushing process, and the excessive deformation should be adjusted in time;

(2) And the vertical displacement of the main beam is 44.1 under the deadweight load of each working condition mm, 59.0 mm, the pre-arch degree can be set according to the above data combined with the second phase deformation;

(3) The maximum member stress of the support structure is 78.8 MPa, less than 215 MPa, and the stability of the support meets the requirements.
5. Conclusion
By using the Midas Civil finite element software, the construction stages of the main line bridge of the fifth upper span bridge of Jiaozhou Bay Cross Sea Bridge are calculated and guided in the field construction control. The bridge has been successfully completed, displacement, stress and other indicators are within the control range.
References

[1] Granata M. F., Analysis of non-uniform torsion in curved incrementally launched bridges, Engineering Structures, 75: 374 - 378.

[2] Renaud F., Marc B., Olivier B., Pierre L., Design of a curved incrementally launched bridge, Structural Engineering International, 9 (1999), 128 - 132.

[3] Zuo J., Study and Design of Incremental Launched Continuous Bending Girder with Small Radius under Complex Condition, 36 (2019), 56 - 61.

[4] Guido F., Lucio F. T., Alessandra M., Launching of the Reno Bridge on the A1 Highway, Italy, Structural Engineering International, 20 (2021), 26 - 30.

[5] Jiang T. Y., Tian Z.C., Xu J.H., Key technologies of whole incremental launching construction control for inclined continuous box girder with steep longitudinal gradient, Progress in Industrial and Civil Engineering, 204 (2021), 2034 - 2039.

[6] H X.G., C L. J., Wang Y., Chen Z. Q., Transient dynamic effect analysis of incremental launching start-up of steel truss girder bridge under long cantilever state, Bridge Construction, 49 (4), 18 - 22.

[7] Wang J. F., Lin J. P., Xu R.Q., Incremental launching construction control of long multispan composite bridges, Journal of Bridge Engineering, 20 (2015), 1 - 9.

[8] Hu Z., Wu D., Sun L. Z., Integrated investigation of an incremental launching method for the construction of long-span bridges, Journal of Constructional Steel Research, 112 (2015), 130 - 137.

[9] C H. L., Construction Technology of Curve Bridge Push-up Railway Construction Technology, (2004), 30 - 32.

[10] Y Z., Study on mechanical properties of curved steel bridges under the incremental launching construction stage, Southeast University, 2019.