Optimization Design and Effect analysis of Closure Process of cantilever continuous beam bridge

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Abstract. Closure process has a certain effect on the inner force and cumulative displacement of continuous beam bridge with cantilever construction method. Taking a 4span continuous beam bridge as an engineering example, two finite element models were established according to the tension stage of the prestressed tendons at the closure stage. Then a comparative analysis of the effect of closure order on the inner force and cumulative displacement were given according to the construction stage analysis results. It showed that the tension stage of prestressed tendon has relatively small effect on the beam’s inner force, but the tension stage of prestressed tendon has great influence on the cumulative displacement. Then the closure order of this bridge was optimized based on the analysis results. It proposed that besides the security design, an optimized closure order respect to the difficult of the lineal control should be put forward.

1. Introduction

The prestressed concrete continuous beam bridge has become the most competitive bridge type in the construction of urban bridges, highways, mountain viaducts and railway passenger dedicated lines for the advantages of smooth running, great spanning ability and mature construction technology. For the bridge structure with cantilever construction method, the final internal force of the bridge is affected by closure process, demolition sequence of temporary bearings and stage of prestressed tension [1-3]. At present, there are many researches on the structure design and construction monitoring of continuous beam bridge, but there are few studies on the influence of the closure process of Multi Span Cantilever Construction on the internal force and cumulative deformation of the finished bridge. For multi span continuous girder bridges, the design is more concerned with the final bridge internal force and the safety of the operation stage, but there are few considerations on the cumulative deformation of the completed bridge and whether the beam linear is easy to control during construction. Yang Yang [4] analyzed the influence of two closure schemes of the first span closure and first mid span closure on the linear and internal forces of the continuous girder bridge, through the comparison and demonstration of the analysis results of the deformation and internal force, the optimal closure scheme is obtained. Yi Jin [5] takes a 12 Span Rigid Frame -continuous composite beam bridge as the engineering background. The numerical simulation of the 5 closure schemes and
the conversion sequence of 3 systems is carried out to discuss the forces and deformation laws of the sequence and the transformation sequence of the system on the bridge. This paper optimizes the closure process of multi span continuous beam bridge from influence of closure process of multi span continuous girder bridge on internal force and accumulative displacement of final finished bridge and gives some rationalization suggestions.

2. Engineering background

The bridge is the main part of an oversize bridge, the bridge type is (60+2×100+60) m prestressed concrete continuous beam, a full length 321.4m (containing two sides of the beam to the side support center 0.7m); ballast bridge deck. The whole beam adopts three direction prestressing system, and the beam body is constructed by suspended casting, and the side hole unbalance section is cast in place on the bracket. Because the side pier is high, the length of the side span cannot be too large, so the cantilever construction is used in some unbalance sections. The total beam is divided into 83 beams, the length of the middle branch 0 section is 13.0m, the length of beam segment is divided into three types: 3.0m, 3.5m and 4.0m, and each closure section is 2.0m long.

![Figure 1. Layout of bridge type.](image)

3. Analysis model

Because of the high side pier of bridge, the cantilever block of the 11#pier and 13#pier is asymmetrical, the cantilever construction of the 13#block is needed after the middle span is completed. Therefore, in view of the actual situation of the bridge, it does not change the closure sequence of the bridge, but only changes the tensioning stage of the prestressed steel beam, the closure stage of the bridge is divided into the following two operating conditions:(1)Working condition one: After the construction of each closure section is completed, all roof bundles and floor bundles across the closure section will be tensioned according to the designed tension;(2)Working condition two:13#pier and 12#pier joint dragon section, the roof tension 4T14, the floor stretching 8B1, 6B2, 6B3; 12#pier and 11#pier joint dragon section, the roof tension 4T14, the floor stretching 8B1, 6B2; after the whole bridge closure, all remaining prestressed steel bundles are pulled. The calculation model is shown in Figure 2.

![Figure 2. Calculation model diagram.](image)
4. Comparative analysis results

4.1 Accumulative stress of beam body

The cumulative stress of beam and body bridge is the main design index reflecting the safety reserve of structure and ensuring the safety of structure operation. Figure 3 shows the internal forces of continuous beams under different working conditions. Figure 4 shows the stress of the beam under different working conditions.

Figure 3. Accumulative internal force diagram of beam body in a bridge forming state

(a) Working condition one: Accumulative stress in the upper and lower edge of a bridge forming state
3.8 5.5 9.7 9.2 13.1 5.1 11.9 5.2 7.6 4.0 13.9 6.8 8.2 5.4 12.2 10.9 6.2 13.7 3.2 7.6 3.5 11.9 4.4 10.1 10.6 5.3 12.0 9.9 7.5 4.3 11.9 5.2 7.5 4.1 13.1 5.2 9.7 9.2 7.4 9.2 6.3

(b) Working condition two: Accumulative stress in the upper and lower edge of a bridge forming state

Figure 4. Accumulative stress in the upper and lower edge of a bridge forming state

As shown in Figure 4, because the final system of the continuous beam bridge is an axial static structure, and only a fixed support is set, the influence of the tension on the axial force of the beam is very small at different stages of the prestressed steel bundle. The calculation results of the axial force are basically the same in the two working conditions; Due to the difference of the structural system when the tension force of partially prestressed steel bundles is tensioned at the final stage under the two working conditions, the calculation results of bending moment in the forming state of the bridge are different, the bending moment of the pivot at the pivot point is slightly larger and the other section bending moment is not very different. For the convenience of comparison, the stress of some typical sections under two working conditions is shown in Table 1.

Table 1. Stress of partial cross section in forming state bridge (MPa)

| Unit number | Unit position                   | Working condition 1 |                  | Working condition 2 |                  |
|-------------|--------------------------------|---------------------|-----------------|---------------------|-----------------|
|             |                                | Upper edge | Lower edge   | Upper edge | Lower edge   |
| 17          | 1#lock on small mileage side of 11# pier | 12.2       | 5.8          | 13.9       | 4.1           |
| 18          | 0#lock on the big mileage side of 11# pier | 7.2        | 5.8          | 7.6        | 5.2           |
| 27          | 7#block on the big mileage side of 11# pier | 8.9        | 5.8          | 9.2        | 6.3           |
| 33          | 11-12/pier span                | 4.5        | 12.6         | 5.4        | 12.2          |

It can be seen from Table 1 that there is little difference between the calculation results of cross-section stress under the two working conditions, that is, changing the tension stage of prestressed steel bundle has little effect on the internal force of the structure.

4.2 Cumulative displacement and Pre-camber degree

In the cantilever construction stage, the continuous beam bridge is static structure. In the process of closure, if no extra weight is applied, it internal force state of the bridge will not deviate from the design value. Therefore, the main goal of the construction control of the continuous beam bridge is to control the line shape of the main beam. The maximum cantilever stage displacement of the bridge is shown in Figure 5. The cumulative displacement of beams under different working conditions is shown in Figure 6.
As shown in figures 5 and 6:

(1) In the maximum cantilever stage, the maximum displacement of each Pier roof beam body is basically the same, the maximum cantilever end on both sides of 12# pier and 13# pier is the same vertical deformation. Therefore, the theoretical cumulative displacement difference between the 12# and 13# piers on both sides of closure of the two working conditions is 0.

(2) In working condition one, after the 12# pier is closed to the 13# pier, and after stretching all the prestressed steel beams across the floor and removing the temporary supports, due to more prestressed steel bundles of tensioning, the displacement of 12# pier and 13# pier span is larger, however, the small mileage side of the 12# pier and the large mileage side of the 13# pier will plummet, will produce a vertical displacement of -101mm at the end. In working condition one, after the 11# pier cantilever construction is completed, the vertical cumulative displacement of the end of 11# pier is smaller, consider installing a load such as a basket, the double cantilever structure composed of 12# pier and 13# pier is less rigid, the vertical displacement of 12# pier small mileage side caused by construction load is larger, The theoretical vertical displacement difference on the two sides of closure section between 11# pier and 12# pier before closure is 135mm.

(3) In working condition two, because only part of the steel bundles is pulled after the closure and the remaining all prestressed steel bundles are tightening after the bridge is formed, the overall stiffness of the structural system after the bridge is larger, and the displacement caused by the prestress is small. Therefore, compared with the working condition one, the total accumulative displacement of the bridge body under the condition two is smaller, and the accumulated displacement difference on the two sides of the closure section is also smaller.

(4) For bridge structure, it is necessary to set the Pre-camber degree for meet the operation requirements of the bridge line shape. Relative to the working condition two, a larger pre-camber degree should be set in the working condition one; and the cumulative displacement difference between the two sides of the working condition is larger, and the larger pre arch difference should be set at the two ends of the joint section in the construction stage. Therefore, for the working condition
one, it is difficult to control the line shape. If the working procedure is used, the focus of the line shape control is the setting of the pre-camber of the two ends of the joint and the whole line control of the whole bridge. After the analysis of the finite element model of the construction stage, there is no tensile stress in working condition two during the construction process. Each section has a certain safety factor, which can meet the safety requirements of operation. Therefore, construction process of working condition two is recommended.

5. Conclusion

The structural characteristics of multi span continuous bridges are analyzed. The influence of closure procedure on internal force, stress, displacement and camber of bridge structure is studied. The main conclusions are as follows:

(1) If the multi span continuous girder bridge first meets the middle span and then pulls out all the floor prestressed steel girders. Due to the unsymmetrical structure during the construction process, the prestress will cause the larger vertical displacement of the cantilever end of the unfinished section after the dismantling of the temporary support, which causes the greater cumulative displacement difference between the two sides of the closure segment which has not yet been closed. This causes the difficulty of alignment control in the construction process.

(2) For multi-span continuous girder bridges, if it is necessary to adopt the construction procedure of the first closure middle span bridge due to the constraints of construction conditions, it is possible to stretch some prestressed steel beams at the bottom to meet the safety requirements in the construction process and tension all remaining prestressing tendons after closure of the whole bridge. This can reduce the difficulty of line monitoring.

(3) The structure design of multi span continuous beam bridge is mainly concerned with the safety of the bridge operation, while the difficulty of the alignment control of the beam body should be considered in the construction process. It can be adjusted from adjusting the sequence of closure and prestressing tension stage.

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