Research on the Mechanical Characteristics of Long Span Cantilever Casting Deck Arch Bridge

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Abstract. In order to study the mechanical characteristics of long span cantilever casting deck arch bridge, taking Jiashi super-large bridge with 225m main span as an example, and the finite element software Midas civil is used to analyze the mechanical characteristics of the completion state of the bridge and the changes of the internal force in each construction stage. The results show that the internal force at each segment of the arch ring is small and uniform when the closing segment of long span cantilever casting deck arch bridge is constructed, which can make the closing operation of the main arch ring safely and smoothly. What’s more, the internal force at the arch feet and vault of the main arch ring is large when the bridge is completed, while the internal force at the two construction segments adjacent to the vault is larger than that at the vault which needs to be paid more attention.

1. Introduction

The reinforced concrete arch bridges occupy a considerable proportion in long span arch bridges which not only have many construction methods, but also cost less money in the later maintenance[1] [2]. And the cantilever casting construction method has a good development prospect in the construction technology of long span reinforced concrete arch bridges with the unique advantages of better spanning ability, less lifting procedure and higher degree of mechanization[3] [4]. In recent years, the cantilever casting method has been rapidly developed in the construction of long span reinforced concrete arch bridges at home and abroad[5] [6]. The research on the mechanical characteristics of the long span cantilever cast deck arch bridge can provide an important reference for the construction and monitoring of similar bridges.

2. Project Overview

The whole length of Jiashi Bridge is 406m. The span of the bridge is arranged as 4×30m prefabricated T-beam+225m main arch (with 15×16m short T-beam on the arch) +1×30m prefabricated T-beam. The plane of the bridge is on a straight line. The main bridge is a reinforced concrete box arch bridge with a net span of 225m, a net height of 37.5m, a net span ratio of \( f_0/L_0=1/6 \), and an arch axis coefficient of \( m=1.74m \). The arch axis is catenary and the height of the cross-section of the arch is equal. The elevation of the two arch feet of the main arch is equal, too. What’s more, the superstructure of Jiashi Bridge is composed of five parts: main arch ring, cushion beam, arch columns, cap beam and simply supported short T-beam. The arch box is a single box and double chamber structure with the height of 4.1m and the width of 10m.
The main arch is constructed by cable-stayed buckling method belonging to cantilever casting method. There are 17 construction stages. The main work of each construction stage is briefly summarized in Table 1 below.

Table 1. Cantilever casting construction stage table of Jiashi arch bridge

| Stage | Work                                           |
|-------|------------------------------------------------|
| 1     | Excavate the foundations; pour the skewbacks; cast the junction piers and cap beams in place; construct the anchors. |
| 2     | Erect the brackets of arch feet; cast the segments of arch feet in place; assemble towers on the junction piers. |
| 3     | When the concrete strength of No.1 segments reaches 90% or more, tension the No.1 buckles and the anchor cables; remove the brackets; assemble the hanging basket in the No.1 segments. |
| 4     | Pour No.2 segments; tension No.2 buckles and anchor cables; move the hanging baskets. |
| 5     | Pour No.3 segments; tension No.3 buckles and anchor cables; move the hanging baskets. |
| 6     | Repeat step 5 to complete the construction of the No.4 to 6 arch ring segments. |
| 7     | Pour No.7 segments; tension No.7 buckles and anchor cables; move the hanging baskets. |
| 8     | Repeat step 7 to complete the construction of the No.8 to 21 arch ring segments. |
| 9     | Cast the closed segment in place. |
| 10    | Remove buckles and anchor cables symmetrically by grade when the concrete strength of the closed segment reaches 100%. |
| 11    | Remove the tower; pour the symmetrical No. 1 and 14 arch columns. |
| 12    | Pour the symmetrical No.7 and 8 arch columns. |
| 13    | Pour the symmetrical No.6 and 9 arch columns. |
| 14    | Pour the symmetrical No.3 and 12 arch columns. |
| 15    | Pour the symmetrical No.4,5,10 and 11 arch columns. |
| 16    | Pour the symmetrical No.2 and 13 arch columns. |
| 17    | Erect the short T-beam on the arch ring; complete the bridge deck pavement; complete the engineering. |

Figure 2 shows the general arrangement of the construction buckles and anchor cables. The buckles and anchor cables on the left towers are 21 pairs as same as the right towers. The force of each pair of buckles and anchor cables is equal, and the materials of them are Φs15.2 steel strands.

3. Finite element model

The main bridge model was established by Midas Civil. There are 2067 nodes and 1711 units. A total of 17 construction stages are divided and the corresponding construction stage loads are applied, including structural self-weight, tensile force of buckles and anchor cables, secondary loads, etc. The construction stage model including the boundary conditions is shown in Figure 3. The load combination in completion stage of the model has considered the loads including the primary stress of steel strands, the secondary stress of steel strands, the concrete shrinkage and creep, and the moving load conditions...
according to the specification besides the loads already considered in construction stage. The bridge model in completion stage is shown in Figure 4.

4. Analysis of mechanical characteristics

4.1. Mechanical characteristics in completion stage

The internal force in completion stage is shown in Figure 5 to 7. The axial force in Figure 5 shows the main arch ring in completion stage is in pressure and the pressure has little difference which is between $1.3 \times 10^5$ kN and $1.8 \times 10^5$ kN. The shearing force in Figure 6 shows the shearing force at arch segments connected to the arch columns is larger because of the load transfer by the columns. The shearing force at the arch feet is larger than it at the vault and the shearing force at other parts is small. The bending moment in Figure 7 shows the negative bending moment at arch feet is the largest. The positive bending moment at the vault is large but it is smaller than it at two construction segments adjacent to the vault. In Figure 8 deformation in completion stage, the maximum deformation is at the two arch segments adjacent to the closed segment which is up to 23 cm. Therefore, much attention must be paid to the bending moment and deformation at the two segments adjacent to the closed segment besides the internal force at arch feet and vault for long span cantilever casting deck arch bridge when constructing or designing.
4.2. Mechanical characteristics in construction stage

There are only axial force and bending moment characteristics of the main arch ring being analyzed in the following studies because the shearing force of the arch bridge is small. Figure 9 shows that the axial force of the main arch ring is almost all pressure in the construction stage. The pressure at the arch feet, the L/4 arch ring, and the vault is increasing with the construction proceeding. The pressure of the arch is sharply increased in construction stage 10 because the buckles and anchor cables are removed which can no longer provide tensile force for the arch. The pressure of the arch is also sharply increased in construction stage 17 because of the applying of the bridge deck pavement load.

In Figure 10, it shows that the L/4 arch segments are always bearing the negative bending moment and the top part of them is in tension while the vault is always bearing the positive bending moment.
during the construction. The arch feet are bearing negative bending moment in most of the construction stages and the value of the bending moment is small when the arch feet are bearing positive bending moment in other stages. The bending moment of the vault and the arch feet is basically the same and the value of it is small in construction stage 9 (casting the closed segment).

Figure 10. Bending moment of the arch in each construction stages (the bending moment is positive at the segments whose bottom is in tension and is negative at the segments whose top is in tension)

It shows from the above two figures that when casting the closed segment (construction stage 9) by using the cantilever casting construction method, the internal force of each part of the arch is small and uniform, and the mechanical state is almost at the best time during the whole construction stage, which can make the closing operation of the main arch ring safely and smoothly.

5. Conclusions

According to the analysis of the mechanical characteristics of long span cantilever casting deck arch bridge, the following conclusions can be drawn:

The main arch ring is compressed in axial in completion stage. The shearing force at arch segments connected to the arch columns is larger because of the load transfer by the columns. The negative bending moment at arch feet is the largest and the positive bending moment at the vault and some adjacent segments is large.

The deformation and the positive bending moment of the two segments adjacent to the closed segment is larger than the closed segment. Therefore, it is necessary to pay more attention to the tow segments during the design and construction.

During the cantilever casting construction, the axial force changes of the key sections of the main arch are that almost all the key sections of the arch is in compression and the pressure at the arch feet, the L/4 arch ring, and the vault is increasing with the construction proceeding. The bending moment changes of the key sections of the main arch are that the L/4 arch segments are always bearing the negative bending moment while the vault is always bearing the positive bending moment during the construction. The arch feet are bearing negative bending moment in most of the construction stages and bearing positive bending moment in other stages.

The internal force at each segment of the arch ring is small and uniform when the closing segment of the arch is constructed by cantilever casting method, which is very beneficial to the closing operation of the arch.

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