Study on Influence of Suspension Interval Length on Construction and Closure of Main Girder of Continuous Rigid Frame Bridge

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Abstract. Cantilever pouring construction is a commonly used construction method for continuous rigid frame bridges, but during the construction process, the occurrence of overcasting intervals sometimes occurs. Based on the construction monitoring project of the Bahe Bridge, the finite element software was used to simulate the actual construction process. The measured values of the deflection of the overcast interval were compared with the theoretical values, and the concrete shrinkage and prestressed steel bundles were analyzed. Under the influence of influences on the deflection and stress of different sections of continuous rigid frame bridges with different durations of overcasting. The results show that the variation of the stress of the main beam is small and can be neglected under different conditions of different casting intervals. Different overcasting intervals and different section stoppages have a greater impact on the deflection of the main beam section. In the actual construction, preventive measures should be taken in advance, and the design elevation of the suspended girder section should be adjusted in time to facilitate the construction of the closed section.

1. Introduction
The continuous rigid frame bridge is widely used in the construction of bridges in China due to its beautiful appearance, large clearance under the bridge and reasonable force. The continuous rigid frame bridge adopts the construction method of symmetric cantilever casting. The long-span prestressed concrete continuous girder bridge with cantilever construction has a long construction period and complicated external environment, so that the actual stress and deformation state of the bridge structure is difficult to match the design state. In order to ensure that the line shape and internal force of the bridge structure meet the design requirements, reasonable adjustment measures must be taken for the case of overcasting interval, the deformation and stress state of the beam body should be analyzed, and the concrete shrinkage and creep should be analyzed in detail to ensure the subsequent Close the construction accuracy.

During the cantilever construction process, the time difference of the overcasting interval between different pier constructions may occur due to various reasons. At present, many scholars have made fruitful achievements in the research of the cantilever construction of rigid frame bridges. For example, He Mingxuan has studied the height and stress difference of each control section after the completion of the bridge with winter shutdown stage and normal continuous construction. Yuan Guangxuan has studied the influence of the suspension on the section deflection of continuous rigid frame bridges. However, most studies tend to affect the structure during construction phase simulation, ambient...
temperature, concrete shrinkage and creep, etc. [6]. In the presence of the overcast interval, the linear shape and deflection of the main beam are also affected. At present, there are relatively few studies on the influence of the suspension time interval on the structural performance. Based on the field monitoring data, this paper discusses the effects of the duration of the overcasting on the construction and closing of the main girder of the continuous rigid frame bridge for different working conditions of different overcasting intervals and different stopping positions. Monitoring provides a reference.

2. Engineering background and finite element analysis

According to the Bahe Bridge project, the design speed is 30km/h, and the design load is highway-I grade. It is divided into nine joints and the total length is 1500m. Among them, (70+120+70)m is the main bridge, which is a continuous rigid frame with variable cross-section of prestressed concrete. The single-chamber single-chamber section has a height of 3m across the middle beam; the top of the box girder is 11m wide and the bottom plate is 6.3m wide; the box girder outside the 0th block changes by a quadratic parabola. Each single T box girder is divided into 15 pairs of blocks except for block No. 0, and the mid-span and side-span closed sections are 2.0 m. The bridge has a total of 92 units and 99 nodes, which are divided into 21 construction stages.

The finite element software MIDAS/Civil was used to establish the real bridge model, and the three stages of hanging basket placement, pouring concrete and prestressed tension were simulated to simulate the construction process of each section. By setting the suspension interval between the construction stages and setting the duration of each construction phase, the front and rear conditions of the main beam subjected to the suspension time interval are studied. The finite element model is shown in Figure 1.

![Finite element model](image)

3. Influence of the duration of the overcasting on the main beam

In this project, due to construction technology reasons, the interval between the No. 7 pier and the No. 8 pier is one month. When the No. 7 pier No. 3 block was poured and tensioned, the No. 8 pier No. 0 block was poured. Construction monitoring continued until the construction of the mid-span.

3.1 Section deflection value of the pier before the occurrence of the overcast interval

By arranging the measured actual data, it can be concluded that the elevation of each block section in the suspended pouring interval changes regularly, and the variation also increases from the top to the end. The theoretical values are similar to the measured values, as shown in Figure 2.

![Actual measured value and theoretical value of each block of Pier No. 7](image)
It can be seen from the figure that the measured values of the deflection of each block of the No. 7 pier are basically consistent with the theoretical values. Except for the sudden change, the minimum difference is 0.298 mm and the maximum difference is 4.364 mm. Among them, there is a sudden change at the No. 4 node and the No. 8 node. After careful analysis, it is caused by the measurement error of the construction monitoring personnel and is ignored. In general, from Blocks 1-15, the deflection value of the overhanging end portion continues to increase as the cantilever end grows.

In the previous section of Block No. 14 in Figure 2, the beam body showed a downward deflection trend, and the beam body of the No. 15 block section was uplifted. This is because the construction stage is in the construction of the No. 15 block, and the prestressed steel bundle is pulled.

3.2 Sectional deflection value of Pier No. 7 at one month of overcasting interval

Figure 3. Deflection of the No. 7 pier with a suspension interval of one month

Comparing the theoretical value of the suspended pouring interval with the measured value for one month, it is found that, except for the mutation of the No. 6 block, the measured values of the other segments are consistent with the theoretical values. The error is only between 0-7mm. The theoretical value of this model is more reliable.

It can be seen that when the overcasting interval is one month, the deflection value of Block No. 1-15 of No. 7 Pier has obvious changes with the completion of the pouring. As the block number increases, the amount of deflection changes gradually. The maximum value is the end of block 15 with a difference of 36.278 mm (lower deflection). The minimum value is in block 1 with a difference of 2.162 mm (lower deflection). Among them, the No. 15 block developed from the state of the upper arch to the state of the lower deflection. After analysis, the concrete shrinkage and the prestressed steel bundle were almost completed, and the concrete creep was still occurring. At the same time, the effects of concrete shrinkage, creep and prestress loss on the deflection of the main beam are different under different suspension intervals. The model renderings are as follows:

Figure 4. Deflection change before suspension of one month

When constructing the closed section, it is necessary to ensure that the deflection of the two ends of the beam is within a certain error range. The design requires that the difference between the two sides of the deflection should not exceed 12 mm. Therefore, the deflection changes of the No. 7 and No. 8 piers in Helong are compared, as shown in Figures 5 and 6.
It can be seen from Fig. 5 and Fig. 6 that the newly poured No. 8 pier, due to the combined effect of prestressed steel bundle and concrete shrinkage and creep, as the cantilever end continues to grow, the deflection change first becomes larger and then becomes smaller. When the suspension interval is one month, there is a significant difference between the previously constructed No. 7 pier and the newly poured No. 8 pier. And the difference gradually increases as the cantilever end grows. The difference between the 13th block is 11.782mm, the 14th block is 14.727mm, and the 15th block is 17.162mm. The error allowed by the construction of the closed section has exceeded 12 mm, and corresponding adjustment measures are required during the construction of the closed section.

3.3 Influence of different overhanging time intervals on the main beam
In Fig. 6, the difference between blocks 1-13 is within 12 mm, and the 14-15 segments exceed the allowable error value. These values are only obtained if the overcast interval is one month. In order to further study the influence of the duration of the overcast interval on the section deflection, the suspension spacing is set to 0, 1, 2, 4, 6, 8, 10, 12 (months), etc., respectively, to simulate the No. 15 block of No. 7 and No. 8 piers. Different working conditions of suspension spacing. As shown in Figure 7.
It can be seen from Fig. 7 that since the No. 8 pier is just poured, the deflection of Pier No. 8 changes smoothly and stabilizes at -36 mm, while the deflection of Pier No. 7 changes from fast to slow, with the increase of the duration of the overcasting interval. Large, and finally exceeded the deflection value of Pier 8.

Careful analysis shows that when the time between suspensions is less than 10 months, the lower deflection of the end of Pier No. 7 is less than Pier No. 8, with an interval of 11 months and beyond. The curve is gradually gradual, and as the time interval increases, the value of deflection changes more and more slowly. The prestressed concrete continuous rigid frame bridge of this paper is constructed by cantilever casting method. In order to ensure the accuracy of the closing, the difference between the two ends can not exceed 12mm, that is, the interval length is 4-24 months. This interval is in accordance with the conditions for the construction of the closed section. When the overcast interval is 1-3 months or more than 24 months, certain measures must be taken to ensure the normal construction of the closed section.

### 3.4 Influence of different position of suspended casting section on deflection of main beam

It is known that different suspension spacing times cause different changes to the main beam line shape under the same section. In order to more accurately construct the section, the influence of different section positions on the deflection of the main beam is studied. An analysis of the case where the overcast interval is one month has been made. The difference between the 13th block is 11.782mm, the 14th block is 14.727mm, and the 15th block is 17.162mm. It is indicated that the deflection value of the 14th and 15th block segments does not meet the design requirements when the interval is one month. Therefore, a more detailed study was made on 8-15 blocks. As shown in table 1.

| Section number | Interval between deflections greater than 12mm |
|----------------|---------------------------------------------|
| 15             | 1-3, t≥24mon                                |
| 14             | 1-2, t≥24mon                                |
| 13             | t≥24mon                                     |
| 12             | t≥36mon                                     |
| 11             | t≥36mon                                     |
| 10             | t≥36mon                                     |
| 9              | t≥36mon                                     |
| 8              | t≥5years                                    |

By analyzing the data in Table 1, it can be seen that the deflection value of different overcast sections becomes larger as the overhanging time increases. Among them, the difference of the deflection change of the block No. 6-13 after the suspension casting interval is 2a reaches 12mm. However, under normal
circumstances, there will be no downtime for two years, and no further analysis is required. The difference between the 14th block and the interval of 1-2 months and $t>2a$ is greater than 12mm; the 15th block is when the interval is 1-3 months and $t>2a$, the difference exceeds the allowable value.

4. Analysis of specific gravity and stress change of deflection factors under suspended casting interval

4.1 The proportion of factors that cause deflection changes

The main factors causing concrete deflection include: concrete shrinkage, creep and prestress loss; under the combined action of the three, concrete produces different degrees of arching or lower deflection. In Figure 2, the block 15 is the phenomenon that the prestressed steel bundle is stretched, and the shrinkage and creep of the concrete just started to occur. It can be analyzed that the proportion of the three main factors changes with time.

**Figure 8. The proportion of the downward factors**

It can be seen from Fig. 8 that with the increase of the time of suspension casting, the shrinkage effect of concrete has no obvious change; the creep of concrete shows a slow growth trend; the influence of prestress loss on the deflection of main beam is gradually reduced. When the prestressed steel bundle is stretched, the prestress loss effect accounts for the largest proportion. At this time, the concrete shrinkage and creep effect just occurred. As shown in Figure 2, the cantilever end will be deflected. It can be seen that the effects of concrete shrinkage and creep stress on the deflection of the main beam are different under different suspension intervals.

4.2 Large-scale main beam stress of Pier No. 7

**Table 2. Effect of suspending time interval on main beam stress**

|    | 0month | 1month | 1year |
|----|--------|--------|-------|
| No.7 | -1.69  | -1.71  | -1.72 |
| No.8 | -1.58  | -1.59  | -1.6  |
| No.9 | -1.47  | -1.49  | -1.5  |
| No.10| -1.4   | -1.41  | -1.42 |
| No.11| -1.31  | -1.32  | -1.33 |
| No.12| -1.19  | -1.19  | -1.2  |
| No.13| -0.92  | -0.994 | -0.995|
| No.14| -0.517 | -0.517 | -0.517|
| No.15| 0.0148 | 0.0144 | 0.0143|
By analyzing the data in Table 2, the suspension time interval is selected as 1 month, 1a, 2a, and the main beam stress of block 7-15 is studied. The data shows that the stress of each block is slightly reduced, and the maximum value is 0.04 MPa, which is negligible.

The results show that the influence of the duration of the overcasting on the stress of the main beam is small and can be ignored.

4.3 Construction proposal for Pier No. 8 with suspended casting interval

For the continuous rigid frame bridge type shown in this paper, specific construction suggestions are proposed. Adjust the design elevation of the cantilever end before the deflection changes beyond 12 mm. If there is a time between suspensions during the construction process, when the overcasting time is 1-2 months, the construction needs to adjust the main beam linearly before the block No. 14; when the overcast interval is 3 months, the cantilever casting needs to be The adjustment is made before the block No. 15; when the interval length is ≥ 2a, the design elevation should be adjusted before the block No. 13. And as time goes on, the block segments that need to be adjusted in advance are getting closer to block 0. At the same time, self-flowing concrete grouting is a new type of special material to deal with construction elevation error [8]. As shown in Table 3.

Table 3. Construction block number to be adjusted

| Suspension interval | Section number |
|---------------------|----------------|
| 1 month             | No. 13         |
| 2 months            | No. 13         |
| 3 months            | No. 14         |
| 4~36 months         | N/A            |
| 2 years             | No. 12         |
| 3 years             | No. 8          |
| 5 years             | No. 7          |
| 10 years            | No. 6          |

5. Conclusion

When the work is stopped for one month, the theoretical value of the deflection of each section of the first pier No. 7 is consistent with the variation of the measured value. The variation law of the deflection caused by the overcasting interval is the result of the combined action of prestress and concrete shrinkage and creep. The three main factors also have different proportions in different suspension intervals.

1. For the same overcast interval, the lower deflection value of blocks 1-15 gradually increases; for the same overcast section, the change of deflection value also increases with the growth of the overhang interval.

2. If the suspension time interval is only within 3 months, the main beam of the post-casting pier shall be linearly adjusted before the No. 14 block pouring construction. If the time interval is 4-23 months, it can be strictly monitored according to the actual situation of the monitoring point. If the time interval is greater than or equal to 24 months, it should be adjusted in the pouring of the No. 13 block or even the earlier block to offset The effect of the deformation of the pier first poured.

In this paper, the influence of the overcast interval on the deflection of the main girder of the rigid frame bridge is analyzed in detail. In fact, the variation of the deflection of the main beam caused by the duration of the overcasting interval is a result of the superposition of multiple factor effects, and further research is needed, such as: concrete water-cement ratio, ambient temperature, humidity, and curing age of concrete. During the construction, according to the construction characteristics and the actual situation of the construction monitoring, the design elevation of the main beam should be adjusted in time to avoid the phenomenon that the elevation difference is too large.
References:
[1] Sun Li. Case Analysis of Continuous Rigid Frame Bridge Construction Monitoring Technology[J]. Journal of Highway and Transportation Research and Development, 7,(2016).
[2] Liang Yao. Bridge Construction Monitoring Technology[J]. Construction Technology, (S1): 338-340,(2014).
[3] Zhao Xinze. Influence of Concrete Shrinkage and Creep on Construction Control of Continuous Rigid Frame Bridge[J]. Architectural Engineering Technology and Design, 19,(2016).
[4] He Mingxuan. Study on the influence of winter shutdown stage on structural performance of long-span prestressed continuous rigid frame bridge[D]. Jilin University, (2014).
[5] Yuan Guangxue, Sun Yanfei, Qin Bingbing. Study on the Influence of Shutdown on Sectional Deflection in Cantilever Casting Construction of Continuous Rigid Frame Bridge[J]. Highway, 139, (2018).
[6] Liu Chenglong, Chen Qiang, Li Zhenwei. Influence of Temperature on the Elevation of Long Cantilever Box Girder Bridges by Suspension Method and Its Countermeasures[J]. Bridge Construction, (1): 39-42,(2003).
[7] CHEN Shouhui. Analysis of Shrinkage and Creep Effects of Long Span Prestressed Concrete Continuous Box Girder Bridge[J]. Railway Construction, (8):15-17,(2009).
[8] JIANG Chong-hu, ZHAO Jian, HE Sheng-jun. Treatment of Elevation Error of a Suspended Box Girder Construction[J]. China Foreign Highway, 31(6), (2011).