Analysis of Linear Influence of Long-span PC Continuous Rigid Frame Bridge during The Winter Break

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Abstract. In the construction of large-span PC continuous rigid frame bridges, linear changes occur during the winter. In order to study the influence of the girder linear change on the monitoring line shape of the bridge, the actual bridge under construction was selected as the research object. Based on the finite element analysis software combined with the measured deformation data of bridges, the main influencing factors of the main beam linear deformation during the winter break are analyzed. When the latest construction section of the cantilevered beam is untensioned and retains the beam-end hanging basket to enter the cantilever wintering stage, the final analysis results show that the linear deformation of the main beam during the period of the winter break is as follows. When the length of cantilevered beam is less than 13L/32, the linear deformation of the cantilevered main beam during the winter break period has a little influence on bridge alignment; when the length of the cantilevered main beam exceeds 13L/32, the girder will gradually produce the downward deflection during the winter break. In order to avoid the continuous downward deflection of the main beam during the winter, the prestressed reinforcement of the latest construction section need to be tensioned to reduce the amount of deflection of the main beam during the winter break.

1. Introduction
Because the continuous rigid frame bridge has many characteristics such as deep depth span, large span, no need for large support, convenient construction and good economy, the high-rise and long-span prestressed concrete continuous rigid frame bridge is often the preferred bridge type for bridge designers when crossing the deep valley of mountainous area [1]. The prestressed concrete continuous rigid frame bridge is usually constructed with balanced cantilever cast-in-place construction. The construction period of long-span PC continuous rigid frame bridge constructed by this method is usually more than one year. However, due to the long winter time and low temperature in the northern region, there will be a winter break period of 3 to 5 months in duration, that is, during the construction of the balanced cantilever of the long-span PC continuous rigid frame bridge, a long period of cantilever winter will occur, and the linear change of the cantilever main beam during the winter break will directly affect the monitoring line shape of the bridge. Liu Zhixiong and others compared the different cantilever lengths of the Inner Mongolia Yellow River Bridge at different winter load, and determined the optimal cantilever length of the cantilever over the winter[2]. Zhao Xiaolong and others analyzed the stability of the Songhua River Bridge under the wind load and the eccentric load and proposed safety measures for large cantilever winter[3]. Wei Xin focused on the Weiji River, and analyzed the deflection and stress changes of the main girder of the long-span prestressed concrete continuous rigid frame bridge on construction during the winter break period to evaluate the safety of the bridge during the winter break[4]. Li Xiangwang and others conducted a linear analysis of a
continuous rigid frame bridge and compared the monitoring results, and concluded that the long
cantilever overwintering effect on the linear shape of the continuous rigid frame bridge is
small[5]. The above research and analysis are all carried out for the pre-stress of the suspended section
of the suspended girder after the construction of the pre-stress is completed. In the actual construction,
due to the influence of various factors, it is often impossible to reach the cantilever winter stage after
the completion of the construction target block. Even after the concrete pouring of a block is
completed, the concrete pulp cannot be pressed into the prestressed pipe and prestressing cannot be
stretched and enter the cantilever winter stage due to sudden temperature changes. Therefore, it is
necessary to study the influence of long cantilever overwintering on the line shape of bridges in
various cantilever states during the construction of balanced cantilever construction of high-rise and
long-span PC continuous rigid frame bridges. Based on a large-span PC continuous rigid frame bridge
in the northwestern region, the author analyzed the linear deformation of the bridge during the winter
break in different cantilever states, and combined the monitoring results of the main beam shape
during the winter break. The detailed analysis of the linear deformation of the cantilever over the
winter during the construction of the long-span PC continuous rigid frame bridge was carried out. The
results of this study have practical reference significance for guiding the construction control of the
same type of bridges in northern China.

2. Engineering situation
A continuous rigid frame bridge in northwestern China, and the main bridge span is arranged at
(95+3×180+95) m, and adopts a framing prestressed concrete variable section continuous rigid frame
form. The main beam section adopts a single box single-chamber box section, the box girder top width
is 12.5m, the bottom plate width is 6.5m, the flange plate cantilever length is 3m, the box girder root
beam height is 11m, the middle of the span beam height is 4m, and the box girder height is 1.8
parabolic changes. The main pier adopts hollow thin-walled pier, and these piers are numbered from
6# pier, 7# pier, 8# pier and 9# pier from small mileage to large mileage. The highest pier body is 7#
pier 163m, and the shortest pier body is 9# pier 90m. The bridge belongs to the ultra-high pier and long
span PC continuous rigid frame bridge. The foundation adopts a pile group foundation of bored
piles. The overall layout of the main bridge is shown in figure 1.

The bridge adopted balanced cantilever cast-in-place construction and was divided into four
suspended casting "T" structures of 6#, 7#, 8# and 9#. Each "T" structure was divided into 22 cast-in-
place segments. According to the actual construction progress and climatic conditions at the site, at the
end of the year, 6# "T" structure was poured to 14# block, 7# "T" structure was poured to 11# block,
8# "T" structure was poured to 12# block, 9# "T" structure was poured to 12# block, because the
minimum temperature suddenly dropped to around 0 °C, which seriously affected the quality of
prestressed pipe grouting. After analysing and calculating, combining with relevant specifications,
ultimately it was decided that the latest construction sections would not be tensioned and entered into
the cantilever winter stage. At the beginning of November of that year, the bridge stopped the
construction of each "T" structure. Due to the untensioned prestressing of the latest construction
section, the beam end basket and formwork were retained and resumed in march next year. The "T"
structure had a winter break that lasted four months. During the winter break, the average temperature
in the area was 8 °C to -13 °C, and the average relative humidity was 64% to 71%. In order to grasp
the linear change of the main cantilever girder during the winter break, the bridge deck elevation of the
already constructed section was surveyed during the stopping operation and the resumption of
construction, so as to grasp the linear change of the cantilever section.

3. Linear theory analysis and measured results of long cantilever winter stage
The linear change of each "T" structure during the winter break is mainly due to the shrinkage and
creep effect of concrete [6-7]. In order to accurately calculate the linear deformation of the "T"
structure entering the winter break during various cantilever states, this study used the MIDAS
program to make the finite element numerical simulation results by reasonable setting of the actual
environmental parameters of the structure, which can closer to the true value. The finite element model of each suspended casting "T" structure in the winter is shown in figure 2.

![Figure 1. Main bridge general layout](image1)

![Figure 2. Cantilever stage finite element model](image2)

3.1. Analysis of influence of prestressed tension on linear deformation of cantilever girder in winter

When the cantilever construction of continuous rigid frame bridge enters into the winter break period, there are prestressing tension and no-tensioning in the latest construction section. In order to explore the influence of the latest construction segment prestressing tension on the line deformation of cantilever main girder during the winter break, MIDAS program was used to simulate the line deformation of cantilever main girder under the following two conditions of overwintering. First, the cantilever wintering stage is entered after the tension prestressing of the latest construction section without moving cradle. Second, the latest construction section will enter the cantilever winter stage without tensioning prestressing force. The 6#, 7#, 8#, 9# "T" structure are respectively poured into the 14# block, 11# block, 12# block, 11# block. Through the finite element numerical simulation, in the latest construction section tension prestress and untensioned prestress, under the joint action of beam weight, prestressed load, hanging basket load and construction temporary load, the results of the theoretical linear change of "T" structure during the whole winter break period are shown in figures 3 to 6.

![Figure 3. The theoretical linear deformation of 6# "T" structure pouring to 14# segments during the winter break](image3)

![Figure 4. The theoretical linear deformation of 7# "T" structure pouring to 11# segments during the winter break](image4)

![Figure 5. The theoretical linear deformation of 8# "T" structure pouring to 12# segments during the winter break](image5)

![Figure 6. The theoretical linear deformation of 9# "T" structure pouring to 12# segments during the winter break](image6)

From figure 3 to 6 above, the calculation results of theoretical line shape change of cantilever overwintering of each cantilever "T" structure can be seen as follows:

- The linear variation values of the cantilever "T" structures during the winter are between -4.5mm and 7.5mm. According to the requirements of relevant codes, the allowable error of linear construction in balanced cantilever construction of continuous rigid frame bridges is ±10 mm[8-9], and the theoretical variation of the above-mentioned cantilever "T" structures during the winter period is less than the construction allowable error. Therefore, the linear variation of the main cantilever beams during the winter break period has little influence on the monitoring alignment of bridges.
The upper deflection of the two ends of the cantilever main beam increases obviously when the tensioned prestressing force enters the cantilever wintering stage, and increases gradually with the increase of the cantilever length in a certain length range of the main beam when it enters the cantilever wintering stage. For the same cantilever girder, the influence of tension prestressing on the change of line shape of each section decreases with the decrease of the distance between each section and 0# block.

3.2. Verification of cantilever winter alignment in bridge construction

According to the actual construction situation, under the condition that the latest construction sections of the cantilevered main girder were not tensioned and the hanging basket at the end of the girder was retained, the cantilevered "T" structures entered the four-month cantilevered wintering stage when they were poured to 14# block, 11# block, 12# block, 12# block respectively. In order to accurately grasp the linear change of each cantilever "T" structure during the winter, elevation measuring points were set at the end of each cantilever casting block of different cantilever "T" structure. High-precision total station and level were used to measure the measuring points of the whole bridge before and after the winter break, so that the linear changes of the cantilever "T" structure occurring can be obtained during winter. The measured line deformation values of each cantilever "T" structure are compared with the corresponding theoretical analysis values. The results are shown in figure 7 to 10.

Comparing the theoretical and measured values of the line deformation of the "T" structures from figure 7 to 11 above, it can be seen that the measured line deformation of the main girder during the winter break basically coincides with the theoretical line deformation. When the latest construction section at the cantilever end was not tensioned and the hanging basket at the beam end was retained, the linear change of the main beam during the winter was small, and the actual field measurement environment had not reached the perfect state. Therefore, compared with the theoretical value, the measured value of the main girder line deformation will show a small fluctuation phenomenon, and can not be fully combined with the theoretical value to form a smooth curve of change. However, the overall change pattern and trend of the main girder's line shape reflected by the measured change values during the overwintering period are consistent with the theoretical calculation results, and the change values are roughly consistent. It can be seen from the measured results that the maximum vertical upward deformation value of each cantilevered "T" structure is 3 mm and the maximum vertical downward deformation value is 5.5 mm, which are less than the construction allowable error ±10 mm required by the code. Moreover, the overall alignment of the main girder is characterized by the upper deflection at both ends. That is to say, the cantilever overwintering has little influence on the
alignment of the long-span PC continuous rigid frame bridge in the construction process when the latest construction section is not tensioned and the hanging basket at the end of the girder is retained.

3.3. Analysis of the length of untensioned cantilever over winter

In order to explore the relationship between the cantilever length of the main girder and the linear deformation of the main girder during the winter break period, the linear variation of the main girder during the winter period was analyzed when the cantilever length is L/8, L/4, 3L/8, 13L/32 and 7L/16, respectively. L is the calculation span of the bridge. The MIDAS program was used to carry out the finite element numerical simulation of the structure, and the linear deformation of each cantilever "T" structure during the winter break period was calculated under different cantilever lengths. The calculation results are shown in figure 11 to 14.

As can be seen from figure 11 to figure 14 above, the maximum vertical upward and downward deformations of the cantilever "T" structures are 5 mm and 7.5 mm respectively, which are less than the construction allowable errors ±10 mm required by the code. That is to say, the cantilever overwintering of continuous rigid frame bridge has less influence on the bridge alignment under the condition that the cantilever length mentioned above is not tensioned in the latest construction section and the hanging basket at the end of the beam is retained. However, when the cantilever length reaches 13L/32 and enters the cantilever wintering stage, the linear deformation of the main girder during the wintering period will change from the upper deflection at both ends to the lower deflection at both ends, which will have a relatively negative impact on the bridge alignment control. In order to avoid the continuous deflection of the main girder during the cantilever construction, the cantilever length of the main girder of PC continuous rigid frame bridge with high piers and long spans should be less than 13L/32 during the winter break if the cantilever overwintering stage is necessary.

4. Conclusion

In this paper, a PC continuous rigid frame bridge with high pier and long span in Northwest China was taken as an object of study. Through theoretical analysis of the line deformation of the bridge entering the winter break without tensioning prestressing at the latest construction section and retaining the hanging basket at the end of the beam, and comparison with the measured line deformation of the main girder, the following conclusions are drawn.

- In the process of balanced cantilever construction of long-span PC continuous rigid frame bridge, the cantilever wintering stage is entered when the latest construction section is not tensioned and the hanging basket at the beam end is retained. When the cantilever length of the main girder is less than 13L/32 and the safety of the main girder during the winter break is guaranteed, the influence
of the cantilever overwintering on the bridge alignment is small, and the normal construction can be continued after the winter break.

- In the process of balanced cantilever construction of long span PC continuous rigid frame bridge, when the length of cantilever main girder exceeds 13L/32 in winter, the latest construction segment prestressing at the end of tensioned girder should be considered to avoid excessive downward deflection of main girder during the winter break. Therefore, when the suspension casting is approaching the winter break period, the risk of no tensioning prestressing and grouting of the final beam end construction section should be considered in advance. If necessary, it can enter the winter break period ahead of time after the tension of the latest construction section and grouting of the tunnel, so as to avoid the cantilever main beam entering the winter break period when the tension of the latest construction section cannot be carried out.

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