Research on Bridge Construction Control Technology Based on Mobile Formwork

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Abstract: After years of development and exploration of bridge construction technology, new construction methods have emerged. Relevant researchers continue to deepen the research and exploration of mobile formwork. The application of this method to bridge construction has only been developed in recent years. Because of this bridge construction method has many advantages, it is selected in modern bridge construction. The scope of application is more and more extensive. The construction method of the movable formwork construction method is procedural, which can greatly reduce the construction period, it has a relatively small impact on normal traffic, does not require a large amount of basic treatment work before the construction and can make the construction period to a large extent. shorten. These advantages make the construction method of mobile formwork developed and applied relatively quickly, especially in the construction of medium and small span bridges, the advantages of its application are more obvious. In the construction of large-scale bridges, large-scale movable formworks are needed. There are still many problems that need to be solved in the construction of large-scale movable formworks for construction bridges, such as crack control, faulty stage control, and construction safety guarantee. In the study of this paper, the application technology of mobile formwork in bridge construction was discussed from aspects of construction design, construction control, etc., through the moving formwork structure. In terms of force analysis, load, etc., the key technologies for control of construction box girders are studied. From the aspects of abutment structure processing, pre-compression of movable formwork and intermediate-outside formwork adjustment, the key construction technology of "one-mold double beam" movable formwork was studied. The passage provides practical reference for relevant technical personnel of bridge construction and provide method cases for researchers in the field of mobile formwork construction control technology.

1. Introduction
In recent years, in the construction of roads and bridges, the construction method of movable formwork has been gradually applied. The main structural composition and construction process of the movable formwork are briefly discussed as follows: The outriggers are installed on the pier or the platform of the bridge and the main beam of the steel structure is supported above the outrigger; in the structural composition of the movable formwork, the main load-bearing components is the main beam of the steel structure; the construction machinery, the formwork part and the own weight of the concrete beam section, all of which require the main beam of the steel structure to provide support [1]. After the single concrete construction pouring work is completed, the horizontal separation of the template of the movable formwork needs to be achieved. This work is mainly accomplished through the transverse hydraulic system [2].

When the main beam of the steel structure is in the upper part of the concrete formwork beam, it
is called an upward moving formwork and vice versa. When the main beam located in the lower part of the concrete box girder, it is called a downward-moving movable formwork. There are major differences between the two types of movable formwork, which are mainly reflected in the aspects of the main beam of the steel structure, the mode of movement of the formwork, the overall rigidity of the formwork structure and the support method of the support leg. The construction method of the movable formwork construction method is procedural, can greatly reduce the construction period, has a relatively small impact on normal traffic, does not require a large amount of basic treatment work before the construction and can make the construction period to a large extent [3]. These advantages make the construction method of mobile formwork develop and apply relatively quickly, especially in the construction of medium and small span bridges, the advantages of its application are more obvious [4].

There are many construction methods for concrete bridges, including on-site pouring method, prefabricated installation method, cantilever construction method and jacking construction method. Compared with these common construction methods, the mobile formwork construction method has many advantages: The construction method of the stand presents a standardized construction process and the beam body has a good integrity to ensure that it can provide high-quality bridge construction projects [5]. At the same time, effective safety control can be performed during the construction process; The construction equipment can be reuse and resources can be saved. The method is reasonable and economical and practical. This method has a wide range of application. When the bridge construction site is in the following situations, the method of selecting the movable formwork is appropriate. These include: overhead bridge construction, scaffolding or scaffolding foundation handling difficulties, bridge spans exceeding 10 holes, crossing deep valleys, beaches, railways, etc. The construction of mobile formwork occupies less land, less influences and pollutes the environment, it is conducive to civilized construction. External factors have less impact on construction, conditions such as rivers, roads and other underpasses have little effect on this method [6]. The mobile formwork construction method is applicable to continuous or simply supported girder bridges with a span of 25 to 65m. Through the addition of roof enclosure measures, the effect of weather on the construction period can be avoided.

2. The Overall Design of The Movable Formwork of Wu Sihu Bridge

According to the relative position of the steel girder, the movable formwork can be divided into two types: an upward-moving formwork and a downward-moving formwork. Upward movable formwork: The main beam of the movable formwork is located above the concrete main beam, otherwise it is called the downward type movable formwork. In the typical bridge construction case, this text relies on Wuzhou Lake Bridge Project in Hubei Province, Hubei Province. The middle bridge pier is relatively low and the minimum pier is 3.5m. Because the down-moving movable formwork requires 7m clearance, the bridge does not meet this requirement. As a result, this bridge selects an upward-moving movable formwork [7].

![Figure 1 Overall condition of the bridge and its section structure](image)

During the construction of the Wu Si Lake Bridge, an on-site movable formwork was used for in-situ pouring. Each joint has the same construction process, its single-span construction process is shown in Figure 2 below:
Figure 2 Single-span construction process for movable formwork

Follow the workflow in Figure 3 until all spans have been completed. Figure 5 shows the status of the movable formwork of Wu Sihu Bridge under different construction conditions.

Figure 3 Mobile formwork construction status

(a) Pouring state                    (b) Open walking state

Figure 3 Mobile formwork construction status

3. Mobile form bridge construction control technology

Simulating the whole process of bridge construction, adjusting the state variables of various design parameters to obtain good operating results is an important part of bridge construction control technology. Firstly, we must determine the internal force of the bridge in the bridge forming state and determine the linear expectation; Through the simulation calculation of the construction process, according to the various construction conditions, get the theoretical values of stress and deformation and other related control parameters. The structural deformation and internal forces of each construction stage shall be determined by means of inverse calculation backwards starting from the completion state. During the construction process, the whole process needs to monitor the actual response of the structure's stress and deformation and to obtain the actual operation trajectory, compare the difference between the actual trajectory and the theoretical trajectory. If there is a big difference between the two, it is necessary to analyze the causes of the differences and make adjustment during the construction of the follow-up phase, to ensure that the actual and design trajectories basically conform to each other and provide guarantee for the overall state of the final bridge [8].

Bridge construction control is mainly aimed at the whole construction process of the bridge. The actual structure of the operating conditions to determine, when the deviation of the actual trajectory and the theoretical reference value exceeds the limit, adjust the structure of the control parameters, so that the actual operation of the bridge track and the theoretical reference track height in line with.

3.1. Wu Sihu Bridge was taken as the research object to analyze the control technology during the construction of the bridge.

The method for the construction of the movable formwork of the bridge adopts an upward type and the full bridge is divided into eight joints. Each joint has the same construction process, the specific construction process is divided into the following steps:

Step1: Use the middle leg and back support to pour the first span;

Step2: Complete pouring, tensioning and maintenance, while unloading hydraulic jacks, so that moving molds die, mold, ready to move the whole machine;

Step3: Implementation of vertical movement across;

Step4: After the vertical movement is completed, the rear branch and the middle leg are lifted with the jack, the front leg is moved forward one by one and the mold is closed;

Step5: After the transport of the middle leg;
Step 6: After the middle leg in place;

Step 7: Enter the next construction cycle.

The upward moving modular method construction process is shown in Figure 4 below. It includes seven sub-processes on the way and describes a working cycle of the movable formwork.

3.2. Control the elevation.

(1) Correct the elastic deformation value. In the implementation of the pouring process, the reinforcing steel skeleton will affect the stiffness of the moving formwork, it is necessary to correct the value of the elastic deformation of each span. In this study, the modified elastic deformation value is based on the empirical formula, based on the finite element calculation of preloading, the measured results and the finite element calculation of the first span casting and the elastic deformation value of the first span is corrected.

(2) Correct the elastic deformation value of the standard span. According to the contribution factors of the stiffness of the moving formwork, the proportion of the first span reinforcement frame can predict the elastic deformation value under standard spanning conditions. According to the impact factors of the stiffness of the movable formwork, the proportion of the standard cross-reinforced steel frame is used to modify the elastic deformation value of the final span concrete.

3.3. Control Strategy of Staggered Benches for Concrete Box Girders.

More effective control measures for the wrong stage: Apply a reverse-compressed concrete bridge to the cantilever section, apply the main beam to the top formwork. Based on the above control concept, the use of cantilever-side error-proof platform technology is more effective. Pier top fixed formwork proofing station. In the first span, the elastic deformation of the movable formwork template is the correction value of the pre-compression elastic deformation, and the elastic deformation value of the fixed template is measured after the pre-compression; in the standard span, the displacement deformation of the first template is measured during the first span. Value, as the elastic deformation of the standard span, the value of the elastic deformation of the fixed template is the measured deformation of the first span fixed template; In the final span, the elastic deformation of the span movable formwork template is the measured deformation correction value of the standard span movable formwork template, set the pre-camber separately.

3.4. Controls the lateral elevation.

The control section selects the position of the hanging beam, distributes multiple elevation monitoring points evenly over each cross-sectional position and controls the lateral bridge elevation. In the construction of the movable formwork, the elevation of the main beam can be made more accurate.

4. Key construction technology of "one mold double beam" movable formwork

The "one mold and two beam" type movable formwork is used to construct two transverse box girders simultaneously through a movable formwork. The main problems in the construction process include:

Two pieces of box girder concrete pouring box girder tension, template adjustment, etc., will affect each other, requiring a high degree of synchronization and coordination; Two pieces of box girder
spacing and angle change, template adjustment, boom position, the support points for the traveling car and the legs of the movable formwork are set; The assembly of the movable formwork starts from the position of the abutment, and the abutment back wall is constructed first.

In the construction process, take the following technical measures to improve the problem.

4.1. Abutment structure processing.
The movable formwork is assembled from the abutment position. Generally, due to the problem of stretching the box girder, it is necessary to wait for the construction of the abutment back wall after the box girder is stretched. Before the construction of the box girder, the abutment back wall shall be poured first; The temporary leg at the rear end of the movable formwork shall be removed or the subgrade shall be constructed first.

4.2. Middle outside template adjustment.
The vertical height is adjusted by the spiral top at the bottom of the formwork support, the lateral position of the intermediate outer formwork is adjusted by traversing the hanging beam and the telescopic top screw.

4.3. Moving mold preload.
120% of the maximum loading load is used to preload the moving formwork. The internal model weight is 3.5 tons. The normal construction-related population and the mechanical tool load are 2.5 KN/m². Sandbags and water are used as preloading materials. In-order-to approximate the actual load, the sandbags are placed on the end of the box girder and in the position of the web, the water pressure is pre-pressed on the wing plate, floor cavity and top position. The preloaded total load of the monolithic box girder is 5103 KN. In the preloading and unloading process, it is necessary to maintain the deflection observation and monitor the locations where the stress is greater.

4.4. Change the adjustment line spacing and hanging beams.
The distance between the juxtaposed box girders will gradually change. For the bridge section on the flat curve, each time the moving formwork is used to construct one span beam, the position adjustment of the hanging and the formwork is required.

The overall construction control process for the "one mold, two beams" type movable mold frame is shown in Figure 5.

![Figure 5 Overall Construction Control of a One-Piece Double-Beam Type Mobile Formwork](image)

5. Conclusion
There are many tasks in the construction of long-span bridges. In highway construction planning, the
construction of bridges in coastal areas is arduous and large number of cross-river bridges construction are required. In area of the bridge construction, the application of large-span mobile formwork construction technology has become increasingly widespread and has been favored by the bridge engineering community. By studying the bridge construction technology of mobile formwork, the work quality of survey, design and safety control of bridge construction can be further improved.

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