Application of displacement synchronization automatic control jacking technology in upgrading and reconstruction project of super large aqueduct of South-to-North Water Diversion Project

Bo Wu[1*], Xiaolu Chen[2], Mingqin Zhao[2], Xiaomin Yang[1], Zhiyong Zhou[1,3]

1. WuDa Jucheng Structure Co., Ltd., Wuhan, Hubei 430223, China
2. Central Route Construction Management Bureau of South to North Water Transfer Project, Beijing, 100053, China
3. Engineering Research Center of Building Inspection and Reinforcement, Ministry of Education, Wuhan University, Wuhan, Hubei 430072, China

Abstract. Jack-up technology is widely used in aqueduct reconstruction projects. In this paper, a self-developed displacement synchronous automatic control jack-up technology is introduced for the upgrading and reconstruction project of super large aqueduct in South-to-North Water Diversion Project. A new large span aqueduct jack-up construction technology is proposed and studied, and the key technologies of different heights of the aqueduct are discussed. During the jack-up reconstruction of the Lihe Aqueduct from Taocha Canal Head to Shahenan Canal Project in the first phase of the middle route of the South-to-North Water Transfer Project, the overall synchronous lifting of the aqueduct body was achieved by 72 cm, and then the aqueduct body was dropped proportionally. Finally, the jack-up reconstruction of the entrance section of the Lihe Aqueduct was achieved by 50 cm, and the exit section was not jack-up, and the middle section showed a linear change. The research results have a certain reference value for the reconstruction projects of similar structures with different heights at both ends.

1 Introduction

As a remote water delivery system, the aqueduct is used to transport remote water to inadequate urban and rural areas for drinking and irrigation. In the South-to-North Water Diversion Project, the aqueduct plays a decisive role. However, due to the early construction conditions of the aqueduct, some existing aqueducts cannot satisfy the existing water demand. Therefore, in order to solve the problem of insufficient water delivery in existing aqueducts, the flow velocity should be increased by increasing the slope of the aqueduct, so as to achieve a substantial increase in the water delivery of the aqueduct. Then, it is particularly important to carry out the jack-up design of the existing aqueduct.

In the existing actual engineering research, most of the aqueduct reconstruction projects are carried out by jacking technology to reinforce or rectify the aqueduct, and there is no research on how to improve the large-span water conveyance capacity. However, the jack-up transformation technology in different projects is worthy of reference. For example, Bingyang Chen[1] and Tao Lei[2] used synchronous jack-up technology to reinforce the Shamen Aqueduct; Hua Xu[3] and Xiaomin Su[4] repaired and reinforced the cracks in the bottom plate and side of the aqueduct body under the condition of ensuring that the aqueduct is uninterruptedly watered, and then reinforced the support by cast-in-situ early strength concrete. Yunhong Zheng[5] used four jack lifting to correct the deviation of the aqueduct. Lifang Duan[6] set jacks at both ends of the beam to lift bridges and flood discharge aqueducts in batches to achieve the purpose of heightening bridge piers. The above lifting transformation technologies all adopt automatic control synchronous lifting system to control the jack upward lifting structure (the lifting speed is within 1 mm/min), and then transform it. However, the existing jacking transformation technology still has the following shortcomings: firstly, the automatic control synchronous jacking system adopts the frequency conversion speed regulation closed-loop control system or the mechanical synchronous control structure, and the frequency conversion speed regulation closed-loop control system is prone to disorder control information, while the mechanical synchronous control has the risk of structural overturning; secondly, the jacking speed is slow; thirdly, it is not suitable for large-span aqueduct lifting at both ends of different heights of the renovation project ; fourthly, when the jack is lifted by force alone, the lifting process is complex and difficult to achieve when the lifting height exceeds the maximum working distance of the jack. With the development of the times, there are about 1.4 billion people in our country at present, and the demand for water consumption is increasing, which leads to a serious shortage of existing aqueduct water. Therefore, it is necessary to design the aqueduct, so as to greatly increase the water conveyance of the reformed aqueduct.

* Corresponding author: 110841792@qq.com

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In view of the shortcomings of the existing research in the lifting technology, and in order to effectively improve the water conveyance capacity of the aqueduct, this paper takes the super large Li River aqueduct of the South-to-North Water Diversion Project as the research object, and independently develops an automatic control synchronous lifting system that synchronously controls the structural lifting according to the displacement, and uses the cushion block prepared by high strength concrete and the jack to alternately force, and puts forward a new large span aqueduct lifting construction technology, so that the lifting process of the aqueduct is faster, applicable and simple.

2 Engineering overview

The Lihe Aqueduct of Taocha Canal Head to Shahenan Main Canal Project in the Middle Route of South-to-North Water Diversion is a large-scale river crossing structure for the main canal of the Middle Route of South-to-North Water Diversion across the Lihe Aqueduct. As a super large aqueduct, the Lihe Aqueduct has a total length of 540m, a total width of 26.6m, a total of 112 supports, and a total weight of about 2000 t. Each span of the aqueduct length is 40m, width is 11.7m, each span of the aqueduct has four bearings (as shown in figure 1).

Figure 1. Lihe Aqueduct

As an important project in the middle line of South-to-North Water Transfer Project, the design flow of Lihe aqueduct is 320 m^3/s, and the increase flow is 380 m^3/s. At present, due to the increasing demand for water, it is proposed to increase the flow velocity of the Lihe aqueduct by lifting the whole entrance section of the Lihe aqueduct structure by 50 cm, not lifting the exit section and linearly changing the middle section (as shown in Figure 2), so as to achieve a substantial increase in the amount of water transported.

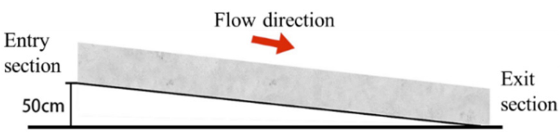


Figure 2. Schematic diagram of the aqueduct after jacking

3 Principle of the integral jacking system for large span aqueduct body in Lihe aqueduct of South-to-North Water Diversion Project

The jacking system structure used in this project is composed of self-developed automatic control synchronous jacking system, cushion block, steel cushion plate and leveling sandbag.

3.1 Brief Introduction of Displacement Automatic Control Synchronous Lifting System

The self-developed automatic control synchronous lifting system involved in this article adopts the displacement synchronous control, which is different from the mechanical synchronous control of the traditional jacking system. The main reason is that the mechanical synchronization is that an oil pump supplies multiple jacks, and the force of each jack is the same based on the principle of the connector. However, for buildings with uneven mass distribution, there will be displacement difference and serious overturning risk. Only by using the displacement synchronization can the overturning risk in the lifting of buildings be reduced. The automatic control synchronous jacking system includes ultra-high hydraulic jack, hydraulic pump station, synchronous control module and pressure and stroke measuring equipment. In order to achieve the purpose of jacking different heights at both ends of the aqueduct, the displacement synchronous control jacking system is adopted. Through its synchronous control module, the information is collected and the control valve of the hydraulic pipeline is controlled. The speed of the hydraulic pump is adjusted to make the jack synchronously (or proportionally) lift (or fall) according to the set speed and displacement. The overall synchronous lifting speed is $\leq$ 4 mm/min, the overall proportional fall speed is $\leq$ 2 mm/min, and the lifting synchronization error is $\leq$ 0.3 mm.

From the above displacement control and error parameters, it is obvious that the self-developed automatic control synchronous jacking system can effectively realize the aqueduct jacking at high speed, and avoid the risk of aqueduct overturning during the jacking process. It overcomes the shortcomings of the traditional automatic control synchronous jacking system that the lifting speed is slow and it is difficult to lift the large aqueduct with the weight of 2000 t.

3.2 Cushion block

At present, in the aqueduct jacking reconstruction project, whether in the jacking process or the jack returning process, the jack is generally used to complete the entire jacking process with a single force, which makes the jacking construction process complex and difficult to achieve when the jacking height exceeds the maximum working distance of the jack in the lifting reconstruction project; at the same time, the self-locking time of the jack is about 24h, which makes the concrete age of the late bearing recast is limited and cannot exceed the jack self-locking time. Based on the above reasons, this project uses 300mm×300mm×150mm high-strength concrete cushion blocks and jacks to alternately lift the aqueduct.

3.3 Steel plate and leveling sandbag

In the process of the aqueduct jacking or falling, by setting the steel plate and leveling sand bag, it can effectively ensure the close contact between the aqueduct body and the jacking system and the cushion block in the inclined state, so that the jack is uniformly pressed during the lifting process, and the purpose of jacking is quickly achieved. And in the process of jack oil return, the existence of leveling sand bag makes the cushion block and the aqueduct body contact closely, and increases the roughness between the contact surface, so that the aqueduct will not tilt or move under the support of the cushion block.

4 Research on jacking construction technology of large-span aqueduct body in Lihe aqueduct of South-to-North Water Diversion Project

4.1 Construction process of large-span aqueduct body jacking

The construction process design to complete the lifting of different heights at both ends of the Lihe Aqueduct is as follows. The schematic diagram of the aqueduct jacking process is shown in Figure 3.

(1) Completing the erection and enclosure of the construction platform; measuring the size and elevation of the cushion stone and support; cutting off part of the retaining walls on both sides of the cover beam; adding the production of high-strength concrete prefabricated cushion blocks.

(2) In principle, four jacks are arranged according to each support, symmetrically arranged on both sides of the support relative to the axis of the support, and two on each side. Steel plates and sand bags are set on the jack surface. A combined cushion block is arranged outside each jack, and a leveling sand bag is set at the top of the cushion block. The initial state is three layers.

(3) When the fitting load is 60 % of the weight of the structure, the jack pre-jack test is carried out, and the change of relevant data in the pre-top process is monitored.

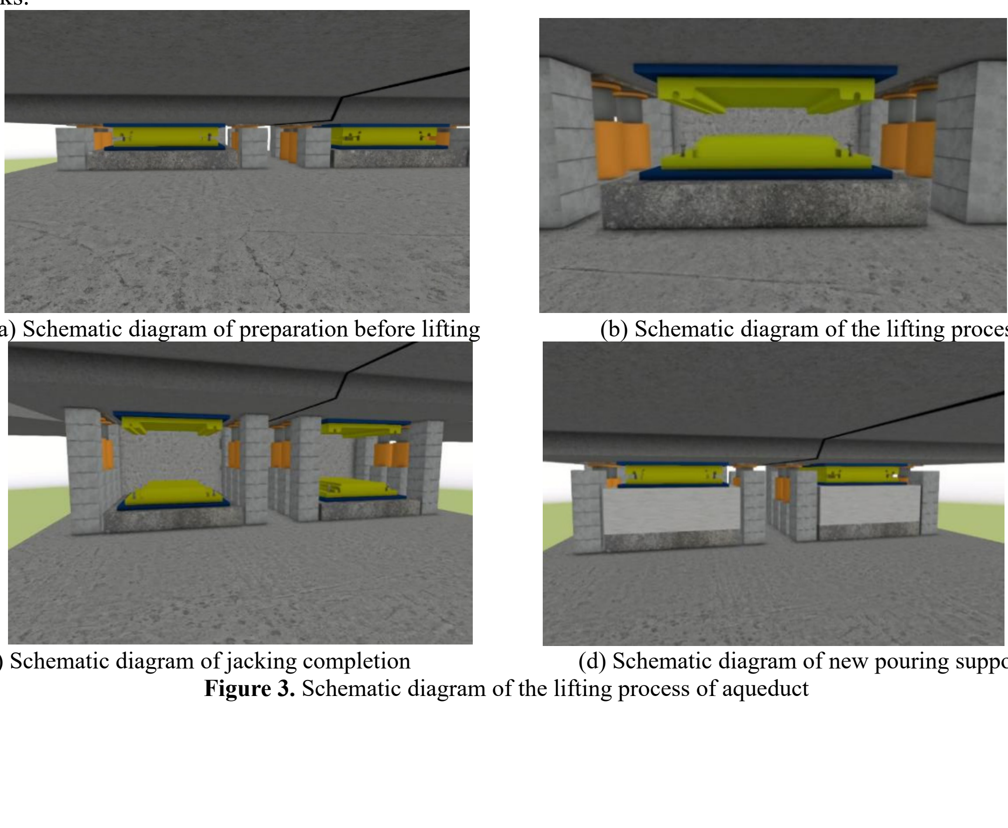
(4) When the structural load is all borne by the jack, the aqueduct body is jacked up 1 mm synchronously, and the change of relevant data during the pre-jacking process is monitored.

(5) Automatic control step by step jacking, in the aqueduct body overall jacking to12cm, between the body and the cushion block into the fourth cushion block, when the jack oil return, under the jack into the cushion block ; the jack is subjected to alternating force with the pad or steel plate ; Once again the overall jacking15cm, plug into the fifth cushion block, in turn to plug into the eighth cushion block, the overall jacking height of 72cm.

(6) The upper and lower steel plates of the support are removed to connect the anchor bolt, and the support is taken out. Then, the planting bars are drilled on the cushion stone. The layout is carried out according to the design jacking height of the aqueduct body, and the reinforcement cage and connection are added. The high-strength concrete is poured according to the layout height, and the top buried parts are reserved. Install the support on the newly cast concrete embedded parts.

(7) After the maintenance of newly-cast high-strength concrete is completed, the jack fallback control is carried out, and the aqueduct body is synchronized to the design elevation.

(8) The retaining walls on both sides of the cover beam are removed and restored, and the retaining walls are heightened and the construction is completed.



(a) Schematic diagram of preparation before lifting (b) Schematic diagram of the lifting process

c) Schematic diagram of jacking completion (d) Schematic diagram of new pouring support

Figure 3. Schematic diagram of the lifting process of aqueduct

4.2 Research on the key technology of large-span aqueduct body jacking construction technology

4.2.1 Preparation of high-strength concrete cushion block

The high-strength concrete cushion block is indispensable when the jacking height exceeds the maximum working distance of the jack, so under the self-weight of the aqueduct, the jacking construction has very high quality requirements for the high-strength concrete cushion block. The cushion block used in the construction of Lihe aqueduct body jacking is made of C60 high strength concrete, and the upper and lower cushion blocks must be guaranteed to be smooth, so as to ensure that in the process of aqueduct body jacking, when jacks and cushion blocks are alternately stressed, the cushion block will not be damaged under pressure. It also ensures that the overall jacking height error of the aqueduct body is within the controllable range during the superposition of multiple cushion blocks, which reduces the risk of cushion blocks and aqueduct overturning.

4.2.2 Pre-jacking test of large-span aqueduct body

In the construction process of the Lihe aqueduct, the pre-jacking construction of the aqueduct body is divided into two steps. Firstly, the jack is pre-jacked under the condition of 60% weight of the load structure, and then the relevant data changes in the pre-jacking process are monitored, mainly to check whether the whole jacking system has been correctly connected to ensure that the signal transmission is normal and the jacking work can be carried out normally during construction; Secondly, under the condition that the structural load is all borne by the jack, the aqueduct is jacked up 1mm synchronously, and then the relevant data changes in the pre-jacking process are monitored. The main purpose is to ensure that the jack and the steel plate are closely contacted with the bottom of the aqueduct, minimize the displacement error in the process of rapid jacking construction, and avoid the occurrence of jacking safety accidents.

4.2.3 Fallback control of large-span aqueduct body

After the overall jacking of the aqueduct body is completed by 72cm and the maintenance of the newly-cast high-strength concrete of the bearing is completed, each span of the aqueduct body is controlled by the jack to fall down to the design elevation at the speed of 2 – 4 mm / min. In the process of slot body falling, attention should be paid to the working state of jacks at both ends of each span slot body in the automatic control synchronous lifting system display, and check whether the same end is synchronous falling. After the fall of each span groove body is completed, the current elevation of the four supports should be checked to ensure that the elevation of the backward groove body is consistent with the design elevation.

5 Conclusion

Through the research on the reconstruction project of super large Lihe aqueduct in South-to-North Water Diversion Project, the following three conclusions are obtained.

(1) The self-developed automatic control synchronous jacking system not only realizes the rapid and effective lifting of the aqueduct, but also avoids the risk of the aqueduct overturning during the jacking process. It overcomes the shortcomings of the traditional automatic control synchronous jacking system that the jacking speed is slow and the weight of the large aqueduct is difficult to jack up to 2000t.

(2) High strength concrete is used to prepare cushion block and jack alternately, which improves the jacking system of traditional engineering which only depends on jack force. When the jacking height exceeds the maximum working distance of jack, the jacking construction process is simple and easy to realize. At the same time, it provides the early maintenance time for the concrete which is poured again.

(3) A new jacking construction technology for large-span aqueduct is proposed, which can quickly and effectively improve the overall entrance section of the aqueduct by 50 cm, while the outlet section of the aqueduct is not improved. It has important guiding significance for the future reconstruction projects with different heights at both ends of the aqueduct.

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