Construction technology of spherical keyway formwork with cantilever for high arch dam

Zhou Mei-rong, Zhang Xue-mei*

Institute of Civil Engineering, Nantong Institute of Technology, Nantong, jiangsu, 226300, China

The first author: Mei-rong zhou(1983-),Female, Lecturer, The research direction: Development and management of new construction technology

*Corresponding author’s e-mail: Jntbochuang@126.com

Abstract: High arch dam is a special and complex structure, which requires high quality of concrete pouring surface. This paper puts forward the structure system of the special cantilever spherical keyway formwork for high arch dam, through the reasonable setting and construction control of keyway panel system, support system, connecting parts and anchorage parts, the research results show that the construction quality of the special cantilever spherical keyway formwork system for high arch dam can be effectively controlled.

1. Introduction
A large formwork is a large-sized tool formwork. The large formwork has the characteristics of fast construction speed, good construction quality, strong structural integrity and smooth and smooth concrete surface[1-2]. The arch dam construction environment is complex and the construction quality requirements are strict[3-4]. Therefore, the large formwork is widely used in arch dam engineering. In this paper, the application of large formwork in arch dam engineering, combined with engineering practice, proposes a special arch joint structure system and related control points for high arch dam.

2. Design of cantilever spherical keyway joint structure
The special transverse joint steel key formwork structure of the high arch dam is mainly composed of keyway plate system, support system, joints, anchors and grouting systems.

   Keyway panel system: The keyway panel consists of a 3mm steel plate formwork with ribs of 50*5 angle steel and 9 spherical keyways per panel. Each panel is provided with a connection hole on four sides according to the same hole modulus, and a connection hole connected to the vertical turns is also provided on the intermediate rib. At the same time, the panel surface and the casting height are provided with anchor holes; the support system: mainly composed of a working platform bracket, a vertical cymbal, a shaft, a connector and the like. Connector: The connector mainly includes a U-shaped card, a hook bolt, an S-shaped adjustment member, and an L-shaped adjustment member. U-shaped cards are used for inter-template connections. Hook bolts: There are two kinds of hook bolts for the keyway template. The small hook bolts are used for the connection between the keyway panel and the secondary cofferdam. The hook bolts are used for the connection between the secondary cofferdam and the vertical support. S-shaped adjustment members and L-shaped adjustment member is used for up and down adjustment of the panel, wherein the S-shaped member is for a planar formwork system and the L-shaped adjustment member is for a keyway formwork system. The anchor is mainly
composed of a bolt, a B7 bolt and an anchor rib, and a plastic cup sleeve, and is subjected to the concrete side pressure of the formwork. The grouting system is mainly composed of a grouting tank, a slurry baffle and a riser.

The front view of keyway template is shown in figure 1.

![Figure 1: Elevation of keyway formwork](image1.png)

The side view of keyway template is shown in figure 2.

![Figure 2: Side view of keyway template](image2.png)

3. Construction sequence
Preparation before construction → Assembly of transverse joint formwork → Embedding of anchoring system → Installation of transverse joint formwork → Correction reinforcement and formwork acceptance concrete pouring → Formwork removal and climbing cone hole repair → Next formwork construction

4. Construction technology and implementation

4.1. Horizontal seam keyway template assembly
The assembly site is selected as the assembly platform, the site requirements are flat, and the square wood can be placed on the horizontal floor to form a simple working platform. On the assembly platform, according to the template structure diagram, the template panel, the backing, the bracket, and the working platform, protective railings, etc. are combined and installed, and the keyway is installed after the template is installed in place.

The main installation procedure for the template is as follows: On the assembly platform, multiple panels are bolted together to form a unit. According to the assembly drawing, two vertical cymbals are placed on the back of the panel according to the size, and the hooks are fixed to the panel by hook bolts. Mount the connection module on the bracket and assemble the bracket to the cofferdam. The
shaft should be fitted with a good shaft guard and note that the lengths of the extended threads at both ends of the shaft are equal. Reinforce the vertical sills and brackets with scaffolding steel tubes, taking care to adjust the entire stencil system. Assemble the main work platform. Assemble the suspension rods, screw into the frame, work up and down the work platform and guardrails. The assembled template number will be assigned to the location and equipment number for shipment to the poured concrete location. After the template is installed in place, install the keyway on the panel.

4.2. Anchoring system
According to the warehouse face template layout diagram and the anchor structure diagram, before the concrete of the warehouse layer is poured, the required positioning cone of the next warehouse layer is installed to the predetermined position of the template. After the inspection is completed, the concrete is poured, and the pre-inserted bolt of the positioning cone is injected into the concrete. Prepare for the suspension of the template. The transverse joint cantilever keyway template anchoring system is shown in figure 3.

4.3. Install the transverse seam template
According to the warehouse panel template layout diagram and the anchor layout diagram, after the concrete strength meets the design requirements, the template anchoring system of the previous warehouse concrete transverse plane has been embedded to install the warehouse layer cantilever keyway template. Before the installation of the cantilever formwork, the control line and control coordinates of the arch dam face should be released as the cantilever keyway formwork to improve the installation and construction baseline and base point to ensure the accuracy of the template installation. When constructing a single transverse joint surface, the cantilever keyway template is sequentially installed on the concrete surface from one end of the transverse joint to the other according to the layout template of the warehouse surface. When hanging and lifting the cantilever keyway formwork, the car crane is generally used for construction.

After the template is hung, pull the line along the entire position and adjust the inclination of the template and the shaft. Use the height adjustment member for vertical adjustment, and hit the wedge with a hammer to make the template close to the concrete surface. Horizontal lines and plumb lines are used to correct the straightening of the template to ensure that the template is horizontal and vertical. Use a U-shaped card connection between the horizontal cantilever keyway templates. In order to prevent slurry leakage and misalignment during concrete pouring, the joints between the two cantilever keyway templates are filled with special materials to ensure that the template surface is flat. To ensure that the concrete is poured, the template can be easily removed, and the horizontal surface is smooth and clean. After the horizontal joint cantilever keyway template is installed, the surface of the template should be cleaned and the release agent should be used. When using a release agent, only
apply a small amount of paint to avoid contamination of the environment with the release agent.

When the grouting system needs to be installed in the storehouse of arch dam, the bottom row of keyways of the cantilever keyway template steel panel can be removed, and then the joint grouting system, including the plug, the grouting tank, the riser, etc., is installed on the surface of the panel.

The operation of the paddle part can be fixed with the steel bar on the surface of the keyway template 500mm above the concrete surface, besides, the spacing is determined according to the specific engineering design requirements.

Grouting tank and venting tank operation. The M12 nut is welded to the rib of the venting groove or the grouting trough template. The M12 screw is connected to the M12 nut through the Ø12 hole on the panel during installation, and the screw is fixed on the panel behind the panel with the nut.

The installation of the blade, the exhaust groove and the feed slot of the horizontal seam keyway template is shown in figure 4.

Lift pipe arrangement. The lift pipe is a semi-circular steel pipe, which is closely attached to the cantilever keyway template, and is spot-welded with the formwork panel, and is arranged vertically between the keyways, which rises with the template.

When the height difference between adjacent blocks of the arch dam is small, the transverse joint cantilever template triangle bracket can be removed and used. When the adjacent block of the arch dam is reversed, the cantilever keyway template can also be used upside down. When the template is used upside down, adjust the back of the panel so that the height of the back is not higher than the height of the panel. The first-layer and second-layer channels of the keyway template needs to be removed before it is inverted, and the removed parts are kept in a safe place to facilitate the recovery of the later template.

The removal of the transverse keyway template triangle bracket is shown in figure 5.
In addition to the installation and adjustment of its own structure, the transverse cantilever keyway template can also add auxiliary facilities that are beneficial to the construction of the warehouse surface, including the following aspects: The steel mesh platform is installed at the top of the formwork as a construction platform and passageway, to ensure construction safety, the outer side needs to hang the safety net. According to the construction needs and the template structure, the top of the formwork panel can be provided with a cantilever platform, and the tool room, the frequency machine room, the spray machine and the like can be placed on the platform. It does not affect the construction and structural safety, but also facilitates the construction of the warehouse surface, and the cantilever platform can rise with the template. In winter construction, the transverse sulcus of the arch dam should be fully insulated, and the triangular legs of the cantilever keyway template should be laid with thermal insulation material in time. The frame structure made of steel pipe can be used to fill the insulation material and fix it in the cantilever template triangle. The part of the leg has a coverage similar to that of the template leg, which can ensure the insulation effect of the transverse surface. The thermal insulation structure can be raised with the template, which is convenient and effective. The upper and lower water stop parts of the arch dam are constructed with water stop formwork. The water stop form is made according to the actual water stop structure. It is a cantilever structure formwork and can be installed as a whole. It is more convenient and safer to construct than the previous project using loose steel formwork.

4.4. Correction, reinforcement and acceptance
When the lateral cantilever keyway template is used for the first time, the upper opening of the panel is 10 mm longer than the design line of the position. In the future, when a vertical mold is set, the panel will be received within 6 mm (can be adjusted according to the actual situation of the project). After the transverse joint cantilever keyway template is installed in position, the measurement and acceptance are performed according to the arch dam body shape using the total station, and correction and reinforcement are performed. After correcting the template and completing the hardening, accept the template and perform the next step after accepting the examination.

4.5. Pouring concrete
In the concrete pouring process, the concrete pouring speed is strictly controlled according to the template design standard to prevent the concrete from exerting a large side pressure on the cantilever template due to the excessive speed\(^5\). In the concrete pouring process, the person in charge is responsible for the care of the template, mainly to check the template connection bolts and the reinforcement support, and to tighten the treatment to ensure the stability of the template\(^6\). In order to
ensure the quality of concrete pouring, the placement of the cantilever formwork of the transverse joints, especially the placement of the joint grouting system, the concrete gradation should be adjusted correspondingly when pouring the storehouse with the joint grouting system, and strengthen the vibration of the concrete at the place of the stop grouting piece and the place of the grouting pipe, so as to prevent quality accidents caused by leakage vibration.

4.6. Demoulding and climbing cone hole repairing

After casting the concrete, the template can be removed after the strength reaches the release strength\(^7\). Loosen the vertical U-shaped card connection between the panel positioning cone and the B7 bolt on the panel. Remove the connecting module triangular wedge, insert it into the other hole of the connecting module, and then tap with a hammer to move the bottom of the template away from the concrete surface. Loosen the safety pin and lift the entire template unit. The staff stood on the lower working platform, took out the first layer of hanging positioning cone and B7 bolts, and repaired the climbing cone hole with the same pre-shrinking mortar to make the repaired concrete color consistent.

5. Conclusion

According to the main components of the formwork system of high arch dam, the reasonable setting and construction control of keyway panel system, support system, connecting parts and anchorage parts should be adopted, so that the concrete pouring quality of arch dam can be ensure.

Acknowledgments

Project funding: Scientific research and development project of the ministry of housing and urban-rural development in 2018, Intelligent detection method and new technology of secondary treatment for cracking of concrete structure(K52018094)

References

[1] Xu, B.Q., Wang, Y.W., Wu, W.K.(2017) Study on the Construction Method for Space Polygonal Fair-faced Concrete Structure Using Wood Template.J.The Construction Technology,7:54-57.
[2] Deng, L.W., Jin, W.Y. (2017) Formwork Supporting Technology for Construction of Large Section Column Frame Fair-faced Concrete.J.The Construction Technology,7: 25-27.
[3] Liu, R.B. (2017) Design and Field Measurement Analysis of High Formwork Support System in a Workshop.J.The Construction Technology,11:85-88.
[4] Liu, J., Wang, L.B. (2018) Formwork Construction Technology for Arch Structure of Large Span Box Arch Bridge.J.The Construction Technology,1:54-56.
[5] Chen, L., Wang, D.H. (2016) Formwork Support System Monitoring Testing During Mass Special-shaped Concrete Pouring.J.The Construction Technology,11:52-54.
[6] Zhou, H.L. (2018) Research on Bridge Construction Control Technology Based on Mobile Formwork.J. Earth and Environmental Science, 189:34-36.
[7] Spottiswoode, A.J.(2012) Investigation of Paperboard Tubes as Formwork for Concrete Bridge Decks.J. Construction and Building Materials,30:767-775.