Scheme comparison and key construction technology for swivel rider cap of some super major bridge

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Abstract. In order to solve the technical problem of spherical coupling construction for bottom swivel, improve the construction quality of bearing platform and accumulate the experience of spherical coupling construction, the construction scheme and key technology were studied by taking the construction of rotary rider cap across existing Changshen Highway in the new Tongliao-Xinmin north passenger dedicated line as an example. "Two-step method" construction process of spherical coupling and the sealing method of fast and effective were proposed, and the spherical coupling compactness and construction quality were guaranteed. The results of engineering practice show that spherical coupling construction scheme about “C60 self-compacting concrete +spherical coupling ‘two-step’ construction + grouting filling” is feasible, and the application effect is good.

1. Introduction
In recent years, with the rapid development of railway infrastructure in China, the number of bridge structures across river valleys and roads and railways has increased gradually. Due to its advantages of non-interference transportation and non-interruption traffic and strong adaptability to the environment, the swivel construction method has been applied more and more widely in the construction of bridges under such complicated environments. The development and application of swivel technology also promoted the economic construction of our country to a great extent and guaranteed the railway operation. The research on technology of swivel construction has always been the focus of the research on the super major bridge. Many scholars have done a lot of research on the related technology of swivel construction of bridge [1-9]. However, there are few reports on construction scheme and technology for spherical coupling of the swivel rider cap. Based on the super major bridge across existing Changshen Highway in the new Tongliao-Xinmin north passenger dedicated line, this paper makes an in-depth study on construction scheme and key technology for spherical coupling of rotary rider cap.

2. Project profile and technical difficulties

2.1. Project profile
The bridge across existing Changshen Highway is located in tsg-1 section of the new Tongliao-Xinmin north passenger dedicated line. The whole bridge is 2.13km, and adopts prestressed concrete
continuous beam with a bridge span arrangement of (40+64+40)m to cross the Changshen Highway with the intersection angle of 90°14’. The continuous beam is designed as a single box single chamber straight web section. The main piers are solid pier with a lateral slope ratio of 50:1, and the height of the main pier no. 25 and no. 26 is 6m. The bridge firstly adopts cast-in-place continuous beam with support, then bottom swivel across the existing highway, and finally closes to complete the construction. Main pier rider cap of the bridge is combined form which is made up of an octagonal body with the geometry of 14.6×18.6×3m and a rectangular body with the geometry of 9×13.8×2m, with a spherical hinge structure of 1.7m in the middle. The plane diameter of the spherical hinge is 2.7m, and the vertical bearing capacity of the spherical hinge is 4500t.

For the construction of bottom swivel bridge with large span and larger rotating weight and greater construction risk, spherical coupling construction becomes the key to the success of rotation bridge construction after the rotation system is in place. The quality of spherical coupling is directly related to the performance of bridge structure, therefore the key to guarantee the quality of spherical coupling is to ensure the density of concrete around the key parts of the turntable and spherical hinge.

2.2. Technical difficulties

Generally, the lateral pressure generated by the ground elevation difference between bottom and edge of spherical hinge is used to fill the whole ground surface of spherical hinge to complete the construction of spherical coupling.

However, during spherical coupling construction, pouring concrete density is not easy to control, and the place is easy to appear gap in the corner between turntable and spherical hinge and the corner between top spherical hinge and turntable. The concrete at the bottom of spherical hinge is not compacted and has many bubbles, so the casting quality cannot be guaranteed. The construction difficulty of reprocessing is bigger, and the cost is higher.

3. Construction scheme and construction technology of spherical coupling in rotary cap

3.1. Selection principle of construction scheme

According to construction mechanism and requirements of bottom swivel of the bridge, after the completion of the rotary construction, the spherical coupling should be conducted before the closure construction. Therefore, the construction scheme of spherical coupling of the rotary rider cap should not only ensure the timely pouring the sealing concrete, but also be able to close the section in time to ensure the construction period of the project. That is to say, when the conditions of closing construction are reached, the construction time of spherical coupling of the rotary rider cap should be reduced as much as possible.

3.2. Scheme comparison of spherical coupling construction of rotary rider cap

3.2.1. C50 concrete of pile caps + one casting of spherical coupling. Considering the influence of existing materials and construction aging, after swivel in place and temporarily locked, the steel bar is welded and tied according to the design and specification requirements, and the spherical hinge is sealed by one casting of C50 concrete of pile caps after supporting the mold.

In order to determine the feasibility of the scheme, a 1:1 steel model of spherical hinge structure was made and analyzed through on-site simulated casting test. After the concrete is cast and vibrated, the spherical hinge model is removed after the concrete is finally set to check the concrete pouring. It was observed that there were large area of potholes and bubbles in the ground concrete of the spherical hinge model. This scheme is a traditional plugging process, and the operation technology is mature. But there are two main problems, first, the pouring concrete quality of spherical coupling of rotary rider cap is poor, second, the closing construction period is not easy to control.
3.2.2. **C60 self-compacting concrete + one casting of spherical coupling.** Based on the construction plan of section 3.2.1 for spherical coupling, replace the spherical coupling concrete with C60 self-compacting concrete, and the specific construction process remains unchanged. After the completion of pouring and vibrating, the spherical hinge model was removed after the final setting of concrete. Compared with the first scheme, there are obviously fewer pits, but there are still a few pits formed by large bubbles. There are still some problems in this scheme, such as it is difficult to control the quality of spherical coupling concrete and to control the construction period difficulty in quality control and time limit.

3.2.3. **C60 self-compacting concrete + spherical coupling ‘two-step’ construction.** Considering that the construction time of spherical coupling is not well controlled in the first two schemes and the closing construction period is difficult to be guaranteed, through analysis, it is proposed to split the concrete pouring process of spherical coupling and complete the pouring in two steps. The first step is to pour the part below the turntable, and the second step is to pour the remaining part. The C60 self-compacting concrete in the second scheme is still used for pouring concrete, and other construction conditions and technical measures remain unchanged.

After the completion of pouring and vibrating, the spherical hinge model was removed after the final setting of concrete. Compared with the second scheme, there is a significant improvement, only a few holes or gaps in the corner. Since the completion of the first step does not affect the construction of the closure section, the construction of hanger installation and sliding emplacement and binding steel bar in the closure section can be carried out synchronously, which greatly shortens the construction time of the closure section, and ensures the construction period of the project. Although this scheme can solve the problem of period control, the quality of spherical coupling concrete is still insufficient.

3.2.4. **C60 self-compacting concrete + spherical coupling ‘two-step’ construction+ grouting filling.** In order to solve the problem of corner cavity or gap defect, on the basis of the third scheme, it is proposed to introduce grouting technology for auxiliary filling. After the first step of pouring construction is completed, the gap is filled with grouting method. After the second step of pouring construction is completed, the gap is filled with grouting method again to ensure the tightness of spherical coupling concrete of the rotary rider cap.

After the completion of pouring and vibrating, the spherical hinge model was removed after the final setting of concrete. Compared with the third scheme, the effect is further improved. The concrete at the bottom of the spherical hinge model is relatively dense, with few obvious cavities or gaps. This scheme ensures the compaction of spherical coupling concrete and the period of closure construction.

3.3. **The results of scheme comparison**
According to the comprehensive comparative analysis of the construction scheme of spherical coupling, the fourth scheme is the best. Considering the quality of spherical coupling construction and the control of closing construction period, "C60 self-compacting concrete + spherical coupling ‘two-step’ construction+ grouting filling” was finally selected as the construction plan of spherical coupling of the rotary rider cap in this bridge.

3.4. **Construction process of spherical coupling**
The main construction process of the rotary rider cap is as follows: the first pouring construction of the lower cap→installation of spherical hinge locating base and lower spherical hinge and slide→the second pouring of concrete of the lower cap→reaction bearing construction→installation of slide plate and upper spherical hinge→supporting system installation of upper turntable→upper cap construction. In order to improve the construction quality of rotary rider cap and the tightness of spherical coupling concrete, combining with the construction practice of this project, the construction process of spherical coupling “two-step” construction is proposed. The specific construction process is shown in figure 1.
Figure 1. Construction process of spherical coupling

4. Key technology of spherical coupling construction and matters needing attention

4.1. Key technology of spherical coupling construction
No.1. After the end of bottom swivel, the support foot and the slide should be temporarily locked by steel wedge in time. Then the support foot and wedge and slide will be welded firmly.

No.2. The formwork with a height of 5cm was supported around the slide and the lower spherical hinge, and the contour is close to the lower spherical hinge and the outer edge of the slide. The concrete outside the slide and the spherical hinge and the concrete under the slide and the spherical hinge should procreate the elevation difference during concrete pouring, and the concrete is easier to fill the whole space after vibrating.

No.3. In the construction of upper bearing platform, vibratory holes should be reserved in the upper turntable in advance, so that vibratory rods can be inserted through reserved holes to vibrate in the construction of spherical coupling construction, so as to strengthen the casting quality of concrete. The lower spherical hinge installation is shown in figure 2.

Figure 2. Lower spherical hinge installation.
No.4. PVC grouting pipe with a diameter of 10cm shall be embedded in the construction of the upper bearing platform, which is used for grouting filling the gap left between the spherical coupling concrete and the bottom of the upper bearing platform. The construction of turntable is shown in figure 3.

![Construction of turntable](image)

**Figure 3.** Construction of turntable.

No.5. The "two-step method" used in the construction of spherical coupling is as shown in figure 4. In the first step, pouring the concrete within the reaction support, and the gap is filled with filling and grouting method. In the second step, pouring the remaining part concrete between the upper rotary table and the turntable, and the gap is also filled with filling and grouting method. Through this process, fast and effective spherical coupling is achieved.

No.6. When "the first step" pouring, the plastic pipes with a 30mm diameter tee pipe is arranged two laps underside the turntable to form annular pipe, at the same time, the grouting channel is set and extended out of the template. One circle pipe is located at the intersection of the turntable and the upper spherical hinge, and the other circle pipe is arranged on the back of the steel brace. The pipe is fixed on the turntable by using expansion bolts and snap rings, the bolts are driven into the turntable, and the underside of the annular pipe is secured by welding snap rings. A tee pipe with the nozzle up is arranged in the middle of every two support foots, which is going deep into the reserved hole of the turntable for filling with grouting. The bellows and grouting pipe layout are shown in figure 5.

![Schematic diagram of Spherical coupling construction](image)

**Figure 4.** Schematic diagram of Spherical coupling construction.
Figure 5. Bellows and grouting pipe layout.

No.7. Twelve bellows with a diameter of 70mm shall be evenly arranged between the support feet, which is fixed to the bottom of the turntable with clasp and expansion bolts. The distance between the front end of the bellows and the spherical hinge should be controlled at 6-10cm to ensure that the grouting slurry will not be blocked during grouting. The bending height of the back end should be higher than that of the concrete surface poured in the first step, to facilitate gravity grouting.

No.8. The grouting material is made of compensated shrinkage high-strength grouting material, grouting is conducted to twelve bellows mouth at the same time, and grouting is stopped until the grouting material is no longer sinking and stabilized. After the grouting material is solidified, the non-shrinking cement slurry with the same strength is pressed into the ring pipe by using the vacuum assisted grouting process.

No.9. During the grouting of ring pipe, the slurry overflows from the mouth of tee pipe and fills the gap. The valve is closed until the dissolved slurry overflows from the outlet hole, and the pressure should be sustained for a period of time to ensure the tightness of the slurry.

No.10. After "the first step" pouring, the bellows and grouting pipes are arranged at the intersection of the upper rotary table and the turntable in the same way as "the first step" method, and then "the second step" pouring is carried out after supporting mould, and the grouting is filled to complete the construction of spherical coupling.

4.2. Construction matters needing attention

No.1. The butter on the slide must be cleaned before the construction of spherical coupling of rotary rider cap, and the contact surface of concrete must be roughened before pouring.

No.2. The slump of concrete used for spherical coupling should be controlled to a large value within the allowable range.

No.3. When pouring spherical hinge concrete, it must be vibrated and compacted at the same time, without leakage vibration. Small steel bars can be inserted along the chute to assist vibration at the corner of the spherical hinge.

No.4. Considering the large volume of spherical hinge concrete, it is necessary to lay cooling pipes before pouring, and strengthen the maintenance after pouring, so as to circulate cooling through cold water and prevent cracks.

No.5. The distance between the grouting outlet and the concrete surface should be strictly controlled. Too large or too small will affect the filling quality of grouting.
No.6. Materials filled with auxiliary grouting after spherical coupling concrete pouring must be made in strict accordance with the construction proportion.

5. Conclusion

In this paper, through the comparison and selection analysis of four sealing hinge construction schemes, the spherical hinge sealing scheme of "C60 self-compacting concrete + spherical coupling ‘two-step’ construction+ grouting filling" is selected. Practice proves that construction for bottom swivel of super major bridge across existing Changshen highway goes well, construction scheme of spherical coupling is successful and feasible, which meet the requirement of closure construction time scheduling, and shorten the bridge construction period, also ensure the construction quality of spherical coupling concrete. The concrete nondestructive testing showed that spherical coupling concrete is dense and no abnormal by geological radar through the third-party testing unit. At present, the bridge has been opened to traffic, and the alignment and stress of the bridge structure meet the design and specification requirements.

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