Comparative Study on Different Slot Forms of Prestressed Anchor Blocks

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Abstract: In this paper, two models of prestressed pier, rectangular cavity anchor block and arch hollow anchor block are established. The ABAQUS software was used to calculate the stress of the surface of the neck of the pier and the cavity of the anchor block, through comparative analysis. The results show that compared with the rectangular cavity anchor block, the stress of the pier and the cavity can be effectively reduced when the arch hole is used, and the amount of prestressed anchor can be reduced, so as to obtain obvious economic benefits.

1 Introduction

With the construction of large-scale water project, the flood discharge volume of flood discharge buildings is increasing, and the size of spillway is widened, so that the thrust of the radial gate is increasing, and the prestress anchorage cable is used to balance the water thrust. The connection between the anchor block and the pier will produce a large tensile stress area and may lead to cracking of concrete [1]. In order to reduce the stress level of the pier neck and improve the stress distribution, Caichuan Li, Jiu Xu He, etc. proposed in the prestressed pier of the anchor block to open the reserved slot [2,3]; Zhu Dun, Guibi Xing suggested the use of neck slotted structure [4]; Zhaosheng He et al. studied the cavity position in the anchor block [5]; Shouyi Li et al. analyzed the size of the prestressed pier [6]; Jian-hui SI, ZHENG Zheng et al. optimized the position of the rectangular cavity of the prestressed anchor, the length of the Yokogawa and the length of the river, and the arched cavity structure is put forward, and the height of arch is studied deeply [7-9].

At present, the form of prestressed anchor block cavity is generally rectangular structure, but under the action of prestressing cable tension and arc gate thrust, the surface of the anchor block cavity will produce a large tensile stress, often to 2 ~ 3MPa, but just using the reinforcement means can not be solved. In this paper, the surface of a hydropower station surface hole for the study of the background, the prestressed anchor block were used rectangular slotted and arch slotted mode. By comparing the stress level and distribution of key parts such as the pier neck and the surface of the prestressed anchor block, the reasonable grooving form of the prestressed anchor block is obtained, which provides a
useful reference for the engineering design.

2 Calculation model

2.1 Project Overview
A hydropower station is a roller compacted concrete gravity dam. The dam body flooding system adopts the open roof overflow of the crested roof. The span of the overflow hole is 18m wide, and the hole width is 14m. The overflow weir adopts WES Practical weir, the table hole with curved working door, pier thickness of 4.0m. Prestressed main anchor laying a total of 16, 8 rows of 2 layers, the perpetual tonnage of 3200kN; The horizontal cable is arranged in three rows of five, a total of 15, the permanent tonnage of 2400kN, pull the anchor ratio of 1.4. The maximum total thrust of the arc gate 36600KN.

2.2 Calculate assumptions
1) The concrete material of the dam is calculated in terms of linearity.
2) Considering that the structural joints are provided between the sections of the table holes, the influence of adjacent dam sections is not included.
3) At the bottom of the bedrock is considered by consolidation, upstream and downstream and Yokogawa are considered in accordance with the law.

2.3 Calculation program and working conditions
In scenario 1 (case1), Prestressed main anchor from dam 0 + 034.60 to dam 0-004.00 coordinates. The length of the single main anchor is 39.4m, and the prestressed anchor block adopts the rectangular cavity structure. Anchor block size of 8.2 × 5.5 × 5m (length × height × width), reserved for the length of the river Yokogawa length of 5m, along the river to the width of 0.3 m. In scenario 2 (case2). In order to shorten the length of the main anchor cable, reduce the prestress loss, the upstream side of the tension reserved slot position to adjust to the middle position of the pier, Prestressed main anchor cable from the dam 0 + 034.60 to dam 0 + 014.00 coordinates, a single main anchor length of 20.5m, anchor neck with neck necking type, the pier neck unilateral neck depth of 0.5m, anchor The block thickness (Yokogawa) is thinned to 7.5 m. The cavity adopts the arch structure, the cavity end width is 30cm, the arch axis equation is, the arch height \( f \) is 1/10 span, the height is 0.5m. The finite element analysis of the anchor block under calculation scheme 1 and scheme 2 is shown in Fig.1 and Fig.2.

![Fig.1 Rectangular cavity structure type anchor block finite element analysis](image-url)
Two typical operating conditions were selected, namely, the normal opening of the horizontal water gate (gk1) and the unilateral opening (gk2) of the normal water inlet, respectively.

| Calculated Condition | Concrete weight | Prestressed tonnage | Equipment heavy | The arc at the end of the hole force | The oil machine supports the mast beam thrust | Unidirectional thrust of hinge hinge | Swing door hinge double hinge | Water weight and hydrostatic pressure | Uplift pressure | Wave pressure | Silt pressure |
|----------------------|-----------------|---------------------|-----------------|-------------------------------------|-------------------------------------------|---------------------------------|---------------------------------|-------------------------------------|----------------|--------------|---------------|
| gk1                  | ✓               | ✓                   | ✓               | ✓                                   | ✓                                         | ✓                               | ✓                               | ✓                                   | ✓              | ✓            | ✓             |
| gk2                  | ✓               | ✓                   | ✓               | ✓                                   | ✓                                         | ✓                               | ✓                               | ✓                                   | ✓              | ✓            | ✓             |

3. Analysis of the results

ABAQUS finite element analysis software was used to analyze different calculation schemes and load combinations. The maximum principal stress and the transverse river stress of the pier under the typical load combination of different calculation schemes are shown in Fig. 3 - Fig. 6. Respectively, cut off the prestressed pier and the anchor of the three sections, shown in Figure 7, finishing the different calculation and calculation of the operating conditions under the pier and anchor block cavity surface stress. The maximum main tensile stress of the pier is shown in Table 2, and the maximum stress on the surface of the cavity is shown in Table 3. According to the stress cloud of the pier, it can be seen that the maximum main tensile stress of the case under the case 1 is in the neck of the pier, the lower part of the anchor block and the front part of the pier. Case 2 due to change the position of the trough, shorten the length of the main anchor cable, so there is no pull stress before the door, tensile stress zone is located in the pier neck, anchor the lower part of the concrete and the middle of the middle of the pier.
It can be seen from the stress curve of the barbed river, whether in the form of rectangular cavity structure or in the form of arch-shaped cavity, the inner surface of the cavity has produced a certain tensile stress value, the use of arch-shaped cavity structure, the tensile stress area has significantly reduced, which is the main structure of the arch by the characteristics of the decision. Arched structure
in the vertical load (equivalent to the main anchor tension) has a horizontal thrust, arranged in the cavity near the secondary cable equivalent to the arch of the rod, so that the main force within the arch ring for the axial force. After the inner surface of the cavity from the arch, will reduce the Yokogawa tensile stress values and range.

Table 2, the maximum main tensile stress of the neck head (unit: Mpa)

| Program conditions | profile | Stress in the direction of the main anchor | Program Condition | profile | Stress in the direction of the main anchor |
|--------------------|---------|------------------------------------------|-------------------|---------|------------------------------------------|
| CASE1 gk1          | 4—4     | 0.2                                      | CASE2 gk1         | 4—4     | 0.1                                      |
|                    | 5—5     | /                                        |                   | 5—5     | 0.1                                      |
|                    | 6—6     | 0.2                                      |                   | 6—6     | 0.1                                      |
| CASE1 gk2          | 4—4     | 1.3                                      | CASE2 gk2         | 4—4     | 0.3                                      |
|                    | 5—5     | /                                        |                   | 5—5     | 0.1                                      |
|                    | 6—6     | 0.3                                      |                   | 6—6     | 0.1                                      |

Figure 7 schematic diagram of the pier and anchor block

Table 3 Stress Table of Anchorage Block Surface (unit: Mpa)

| Program conditions | profile | Vertical stress | Program conditions | profile | Vertical stress |
|--------------------|---------|-----------------|--------------------|---------|-----------------|
| CASE1 gk1          | 1—1     | 2.4             | CASE2 gk1          | 1—1     | 1.2             |
|                    | 2—2     | 1.4             |                    | 2—2     | 0.7             |
|                    | 3—3     | 0.0             |                    | 3—3     | 0.0             |
| CASE1 gk2          | 1—1     | 2.7             | CASE2 gk2          | 1—1     | 1.8             |
|                    | 2—2     | 1.5             |                    | 2—2     | 0.9             |
|                    | 3—3     | 0.0             |                    | 3—3     | 0.0             |
As can be seen from Table 2, the largest tensile stress of pier is 1.3 MPa under case 1, under case 2 the maximum tensile stress is 0.3 MPa, case 2 compared with the case 1 stress reduction of up to 77%, indicating that the use of arch-shaped cavity structure, the pier of the largest main tensile stress significantly reduced. On the one hand is the use of arch-shaped cavity structure, the main cable to change the tension of the transmission path to improve the prestress effect, on the other hand, as the pier has taken the necking means, the contact area between the pier and the anchor is reduced, and the prestressing force of the pier is improved. It can be seen from Table 3, case 1 under the anchor block cavity surface maximum transverse river stress of 2.7 MPa, case 2 under the maximum Yokogawa stress to 1.8 MPa, a decrease of 33.3%. Mainly by the arch-shaped cavity structure of the characteristics of the decision, more importantly, the use of arch-shaped cavity structure, not only reduces the size of the surface stress value of the cavity, but also reduce the range of tensile stress.

4 Conclusion
A three-dimensional finite element model was established for the prestressed anchor blocks of a hydropower station with a rectangular slotted form and an arch-shaped groove. ABAQUS software was used to analyze the two kinds of slotted and two kinds of load combinations. By comparing the stress level and distribution of key parts such as the pier neck and the surface of the prestressed anchor block, get the following conclusion:

1) The use of necking arched cavity structure can effectively reduce the stress level of the pier neck.
2) The use of arch-shaped cavity structure can reduce the surface of the tensile stress level and tensile stress range.
3) With the form of arch-shaped cavity, you can modify the position of the tension tank, reduce the length of the main anchor cable, reduce the prestress loss, and obtain obvious economic benefits.
4) In the form of arch-shaped cavity, it is only necessary to modify the form of the template in the form of construction, which will not increase the amount of work, but can effectively reduce the tensile stress of the surface of the pier and anchor, Has a broad application prospects and promote the value.

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