ICOLD Symposium on Sustainable Development of Dams and River Basins, 24th - 27th February, 2021, New Delhi

COMPREHENSIVE FOUNDATION TREATMENTS OF JINPING I ARCH DAM AND ITS WORKING STATE DURING INITIAL IMPOUNDMENT

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ABSTRACT

On August 24, 2014, the reservoir of Jinping I Hydropower was first impounded to the normal water level of 1880m.The dam has undergone 6 loading of high water level till now.

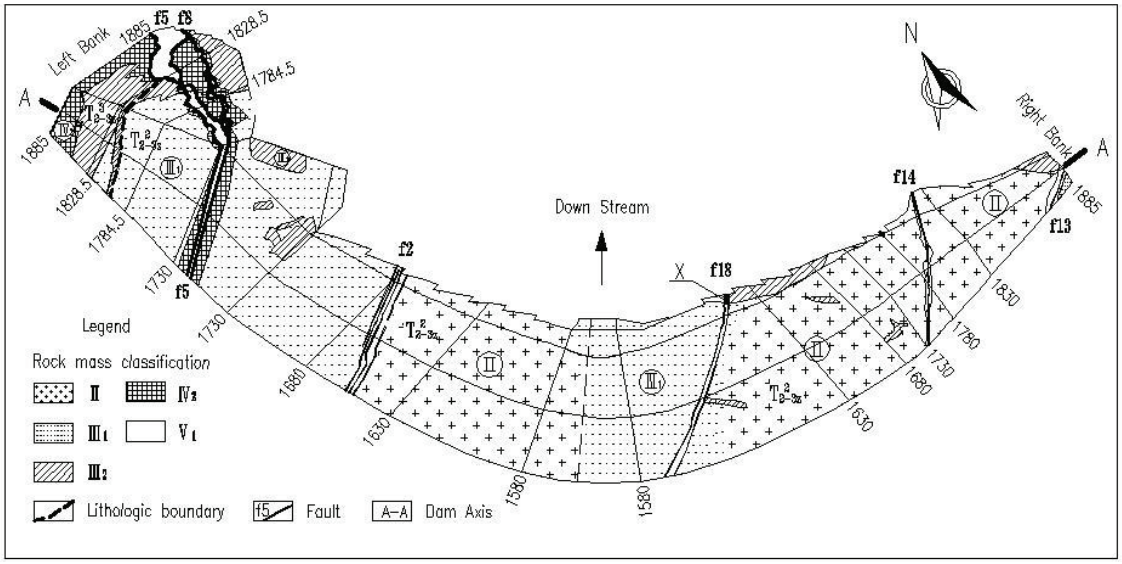
The geological conditions of Jinping I Hydropower Station are complex, especially the left bank of the dam site. For this reason, a great deal of engineering measures have been adopted. Based on the monitoring data of arch dams, foundations, etc., this paper analyzes the performance analysis of arch dams and foundation treatment measures.

1. INTRODUCTION

Jinping-I high arch dam is the highest arch dam (305 m) in the world. As located in a complex tectonic area in southwest China, the project has the most complicated geological conditions among ultra-high arch dams, characterized by deep canyon, high steep slopes, high in-situ stress, high water head and deep stress relax-ation etc. In the dam site, well-developed faults and weak rock, lamprophyre dikes, deep-buried fissures and intensively stress relaxation zones in left abutment led to 10~13 times in difference between defor-mation modulus of the two banks, giving rise to a great challenge in dam design.

Figure 1 : Jinping I Arch Dam

Jinping I arch dam bears a total water thrust of nearly 12 million tons at normal storage levels, thus require solid foundation. On the contrary, the engineering geological conditions in the left bank are extremely complicated, since there developed faults f5, f8, f2 ,lamprophyre dikes, compression displacement belts, deep cracks, and low-wave velocity tension-relaxed loose rock masses. These defects have great impacts on the dam stress, anti-sliding stability and deformation stability of dam abutment, and seepage control of the foundation. Therefore, it is necessary to carry out reasonable foundation treatment.



2. FOUNDATION TREATMENT DESIGN

(1) Principles of foundation treatment design:

According to the geological data, analyze and determine the geological defects that affect the deformation and stability of the arch dam, and then carry out targeted treatment to make the arch dam foundation meet the requirements of strength, stability of deformation and impermeability, and improve the overall stability of arch dams and slope safety. include:

- Effective engineering measures are taken on weak structural surfaces, tensile slack bands, and IV and III2 rock masses with low sound wave velocity within a certain range of dam foundation and resistance body to improve the integrity and uniformity of the base rock mass. Strength and stiffness to ensure de-formation and anti-sliding stability of the dam foundation;
- Take appropriate seepage control measures to reduce the seepage pressure, so that a favorable seepage field is formed in the hub area, which is beneficial to the stability of the arch seat;
- On the basis of calculation and analysis, the excavation slope of the arch dam and the slope of the resistance body behind the dam shall be effectively supported to ensure the stability of the slope.

For the basic treatment design of the above-mentioned unfavorable geological defects, firstly use plane finite element to carry out sensitivity calculation and analysis of various treatment schemes and processing scopes. Through comparison and selection of treatment schemes, determine reasonable treatment measures, and then use 3D finite element analysis The treatment effect is calculated to finally determine the design scheme of the dam foundation treatment. The main foundation reinforcement measures include: concrete pad, resistance body consolidation grouting, f5 (f8) faults, and replacement of the mahogany vein concrete grid, and force transfer holes.

By the trial load method linear finite element method (FEM), nonlinear and by basic load combination and /or geo-mechanical model tests, the technology of deformation stabilization control focusing on the stiffness matching between dam and foundation was proposed, the largest comprehensive foundation treat-ments project has been put forward and conducted, including a concrete cushion with height of 155m and volume of 560,000 m^3, 5 layers of grouting gallery, 720,000m long consolidation grouting, 3 layers of anti-shear gallery, and systematic concrete replacements of fault zone and lamprophyre dikes with volume of 146,000 m^3 (see Figure.2).

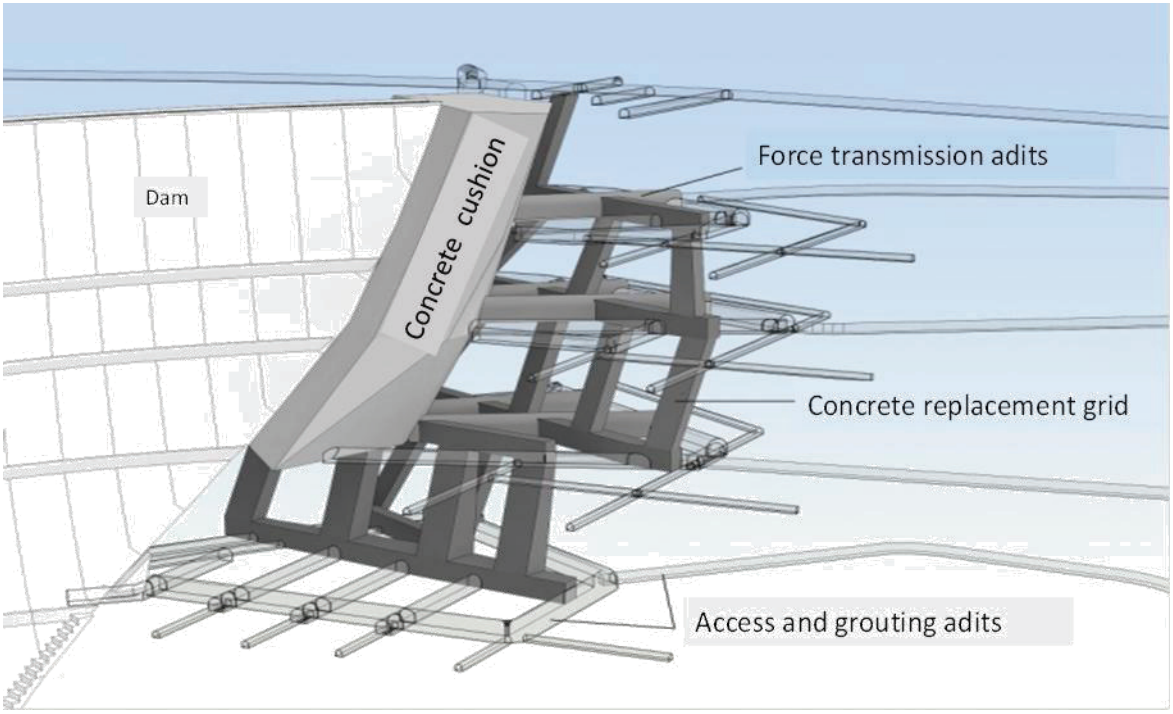


Figure 2 : Foundation treatments layout in the upper part of the Jinping I Dam left abutment.

3. MECHANICAL CHARACTERISTICS OF DAM AND FOUNDATION

(1) Arch dam

Considering the foundation treatment measures, the dam displacement and stress have the following char-acteristics:

(1) Because the right bank of Jinping first-level valley is steeper than the left bank, it has asymmetric topo-graphical characteristics. After the left and right abutment treatment, especially the left abutment pedestal, the difference in left and right abutment deformation at the same elevation is reduced.

(2) Below the height of 1700.00m, the right-arch end displacement along the river direction is generally slightly larger than the left-arch end. Among them, the maximum along-stream displacement difference occurs at an elevation of 1620.00m. The left arch end is displaced by -1.513cm along the river, with a displacement difference of 0.32cm.

(3) Above the height of 1700.00m, the displacement along the right side of the right arch is generally smaller than that on the left side. The maximum displacement along the river occurs at an elevation of 1885.00m. The arch end is displaced by 1.303cm along the river, with a displacement difference of 0.647cm. This difference is caused on the one hand by the larger arc length of the left bank dam, and by the relatively weak sand slate above the left bank of 1810.00m.

(4) Under normal water storage conditions, the large compressive stress on the upstream dam face is con-centrated toward the middle of the dam body, and the extreme value appears near the arch crown beam at an elevation of 1790.00m, and the magnitude is about 5.60MPa. There is a local compressive stress con-centration phenomenon at the left arch end at an elevation of 1580m, and the magnitude reaches 7.08MPa. The main tensile stress on the upstream dam surface is generally distributed in the contact area between the arch end of each elevation and the bedrock. The maximum main tensile stress on the dam upstream dam surface is -1.59MPa, which appears at the right half arch at an elevation of 1580.00m.

(5) The large compressive stress on the downstream dam surface is concentrated towards the left and right arch ends and the lower arch ring at an elevation of 1650.00m ~ 1580.00m. The maximum principal stress of the downstream dam is 1580.00m and the extreme value is 7.32MPa. There is a local stress concentration at the left arch end at an elevation of 1640.00m, with an extreme value of 9.30MPa.

(2) Stress and deformation characteristics of rock mass of abutment (foundation)

The main compressive stress of each plane cut surface increases as the elevation decreases. The elevation of the riverbed dam foundation is 1580.00m. Local tensile stress exists in the upstream dam, but the range is small. The displacement of the dam abutment rock mass is naturally uniform and there is no strain con-centration phenomenon, especially the displacement of the left bank pedestal is well coordinated with the displacement of the dam body and bedrock.

4. MONITORING OF DAM FOUNDATION IN INITIAL RESERVOIR IMPOUNDMENT

Table 1 : Osmotic pressure measurements in Dam foundation

Equipment	Elevation	Location	Reservoir water level 1880	
			Water head	Water head reduction factor
PDZ-1	1820.30	After curtain	1842.12	0.37
PDZ-2	1775.90	After curtain	1801.81	0.25
PDZ-3	1726.00	After curtain	1763.70	0.24
P13-3	1579.00	After drainage	1612.64	0.11
P13-4	1579.00	Dam toe	1603.77	0.08
P13-5	1545.00	1/4 depth After curtain	1645.32	0.30
P13-6	1505.00	1/2 depth After curtain	1641.90	0.37

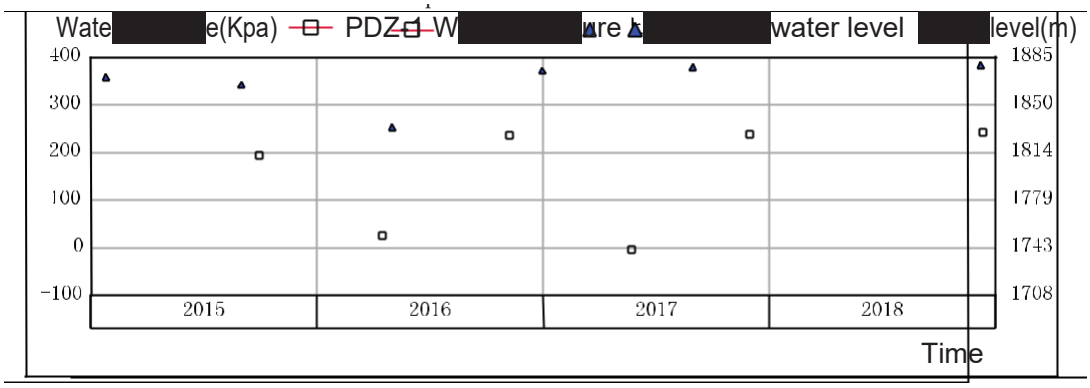


Figure 3 : Osmotic pressure measurement of PDZ-1

5. DAM SAFETY EVALUATION

After comprehensive reinforcements, the integrity and uniformity of dam foundation has been significantly improved, and the stress, deformation stability and overall safety of the dam can meet the requirements by Chinese design code.

Three-dimensional nonlinear numerical analysis and geo-mechanical test results show that the Jinping first-stage arch dam has a strong overload capacity.

The force analysis of the concrete pad and replacement hole grid was carried out, and the structural rein-forcement design was performed based on the stress results to meet the requirements of the code.

At normal water storage level, the PDZ-1 osmotic reduction factor 0.41 at the left bank 1820.3m elevation, and other osmotic reduction factors behind the foundation curtain of the dam foundation are all less than 0.25 (the maximum value appears on the concrete pad PDZ-2), which is less than the design The control value is 0.4; the reduction coefficients of osmotic pressure behind the dam foundation drainage curtain are all less than 0.11 and less than the design control value of 0.2.

From the measured values of dam foundation seepage pressure, the dam foundation seepage pressure is affected by many factors such as upstream water level, mountain groundwater level and drainage holes. Judging from the head difference ratio during loading and unloading, the measured groundwater level did not show a rapid rise or excessive rise in the measured points behind the curtain, indicating that the curtain and drainage effect of the dam foundation on both sides of the bank are good.

The seepage flow has a certain correlation with the upstream water level. At the same water level, the seepage flow shows a decreasing trend. The seepage of the 1595m horizontal hole on the left bank gradually decreased. The flow at the working point of the drainage pump at the 1595m elevation gallery of the dam is about 125L / s, which is less than the flow at the working point of the drainage pump at the 1595m collecting well, and the leakage of the dam can be controlled.

6. CONCLUSION

Jinping I Hydropower Station dam foundation treatment plan is reasonable, the effect meets the design expectations, the operation is good, the leakage is controllable, and the operation is safe.

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