

Force Analysis for Concrete Arch Dam Structure of Banjiang Reservoir

Ji Dongyu

Hunan Urban Construction College
Xiangtan, China
hnjdy@126.com

Abstract—Concrete arch dam is the main structure of water conservancy projects, which have the advantages of a artistic shape of structure and good mechanical properties, and it has been widely used in water conservancy projects. Banjiang Reservoir is located in Zijiang River two tributaries of Dongkou County, Hunan Province, which is a reservoir to generate electricity, combined with irrigation water resources and hydropower engineering. This article gives the stress and deformation distribution during construction and operation which has done the simulation analysis for concrete arch dam structure of Banjiang Reservoir using the finite element method. The results show that Concrete Arch Dam Structure of Banjiang Reservoir satisfy the design requirements. Using concrete arch dam scheme of Banjiang Reservoir River is reasonable. Basically, circumferential stress of arch dam upstream face is compressive stress. Furthermore, the arch's first principal stress which is small can meet the strength requirements, so the structure is safe and reliable.

Keywords—Banjiang reservoir; Concrete arch dam; Finite element method; Stress distribution; Simulation analysis.

I. ENGINEERING SITUATION

Banjiang Reservoir is located in Zijiang River two tributaries of Dongkou County, Hunan Province, which is a reservoir to generate electricity, combined with irrigation water resources and hydropower engineering[1]. The distance is 12km from the site of dam to country and the controllable area of upstream of dam site is 36.4 m². Normally, the reservoir is 39 m. The flood level of design is 42.5 m. and corresponding downstream water level is 15.9 m. Check flood level is 43.1 m, and corresponding downstream water level is 16.4 m. Hub engineering is composed of dams, factories, irrigation and power diversion canal, flood discharge pipe and other

buildings[2]. The dam is concrete singles arch dam which is scheduled circle and fixed outer radius[3]. The maximum height is 44.7 m, and the dam bottom thickness is 15 m. Arch section ratio of thickness to height is 0.37, the maximum central angle 119°43', the minimum central angle 21°. The concrete strength of arch class is C20.

II. CALCULATION MODEL

A Model Parameters

Concrete arch dam structure of banjiang reservoir uses concrete strength grade of C20, elastic modulus $E_1 = 25.5$ GPa, poisson ratio $\mu_1 = 0.167$ [4], bulk density $\gamma_1 = 24$ kN/m³. The rock of dam is quartz sandstone, and dam's riverbed hasn't tomographic. The elastic modulus of rock is $E_2 = 20$ GPa[5], poisson ratio $\mu_2 = 0.28$.

B Model Element

Concrete arch dam and bedrock structure model uses isoparametric block element which has 8-node[6]. The element is applied to three-dimensional model of the entity structure, have properties of plasticity, creep, swelling, stress stiffening, large deformation and large strain. The element has eight nodes and each node has three translational degrees of freedom[7-8].

C Model Size

The size of the entire calculation model is that it takes 65m along the direction of the river, 55m the direction of across the river, 33.6m the vertical direction. The simulation range of model is 65m × 55m × 33.6m (along the river × across the river × the vertical direction). The element division of arch and rock is shown in Fig .1.

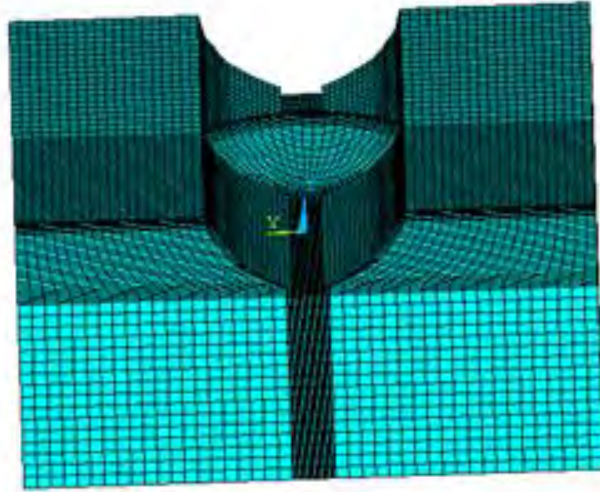


Figure 1. Arch and bedrock FEM division

D Calculation Condition

Considering the mechanical characteristics of arch structure during operation[9], the following five cases are taken into account mainly: case1(structural weight),case2(structural weight and normal water level),case3(structural weight, design flood level and tail water level),case4(structural weight, checking flood level

and tail water level),case5(structural weight, design flood level, tail water level and earthquake).

III. ARCH STRUCTURE ANALYSIS

A Stress Analysis

The first principal stress and vertical stress of arch various case contour map see Fig .2 to Fig .11.

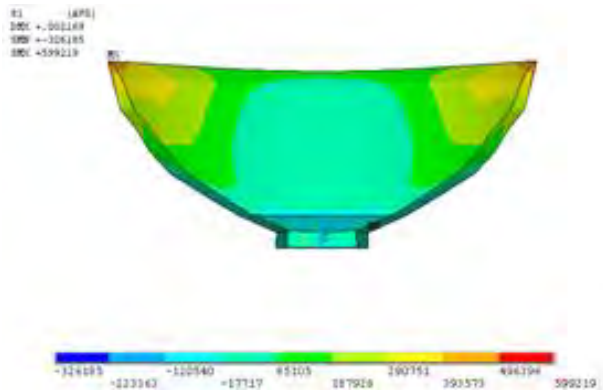


Figure 2. Cloud map of arch's first principal stress under case 1 (Pa)

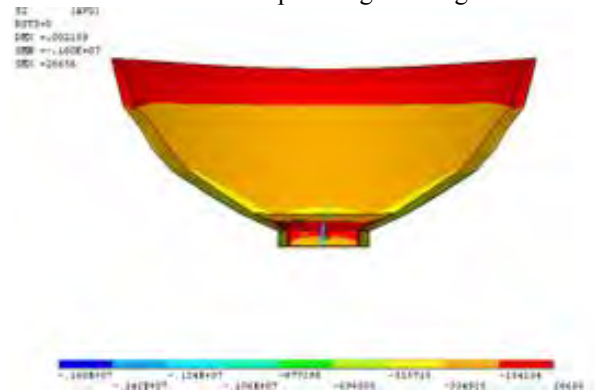


Figure 3. Cloud map of arch's vertical stress under case 1 (Pa)

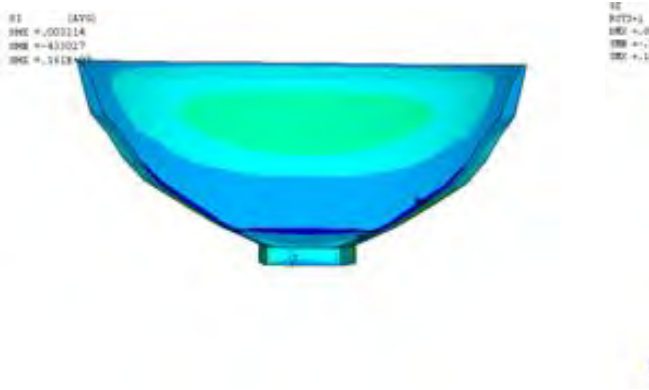


Figure 4. Cloud map of arch's first principal stress under case 2 (Pa)

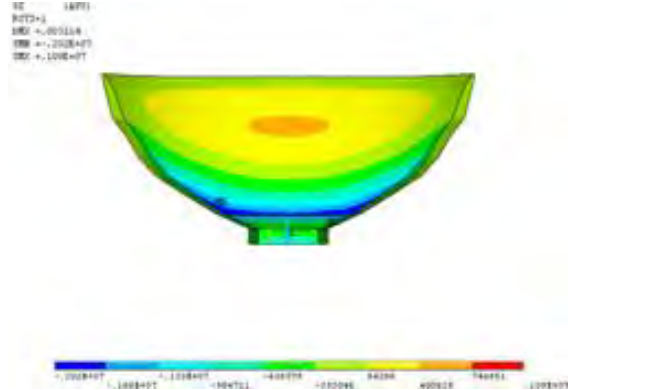


Figure 5. Cloud map of arch's vertical stress under case 2 (Pa)

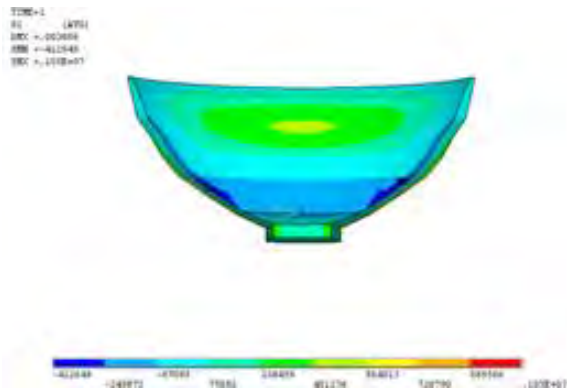


Figure 6. Cloud map of arch's first principal stress under case 3 (Pa)

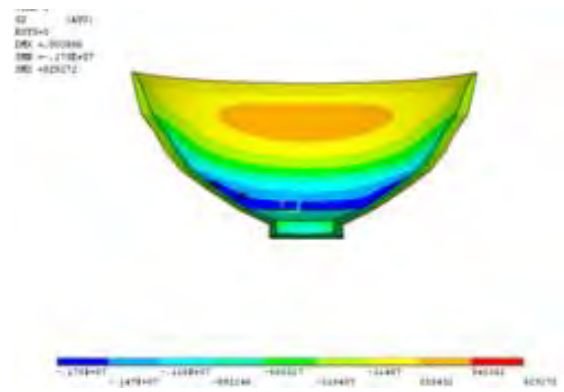


Figure 7. Cloud map of arch's vertical stress under case 3 (Pa)

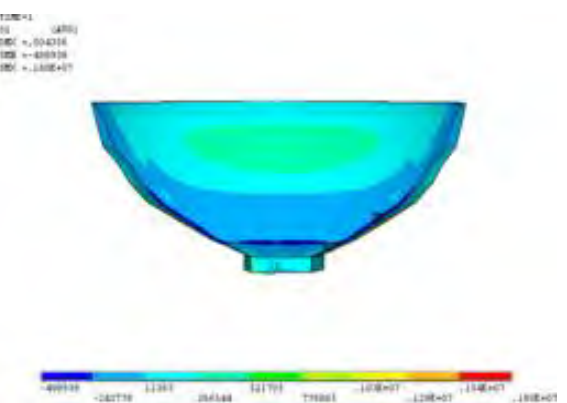


Figure 8. Cloud map of arch's first principal stress under case 4 (Pa)

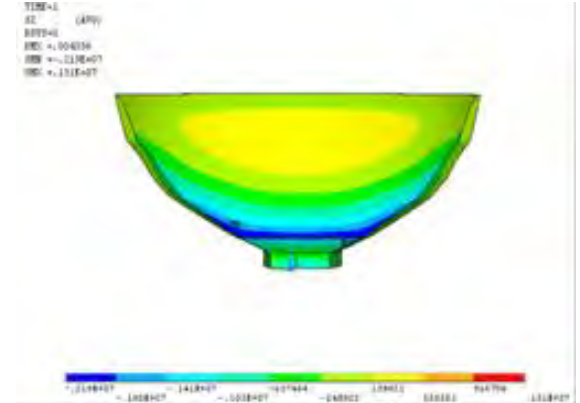


Figure 9. Cloud map of arch's vertical stress under case 4 (Pa)

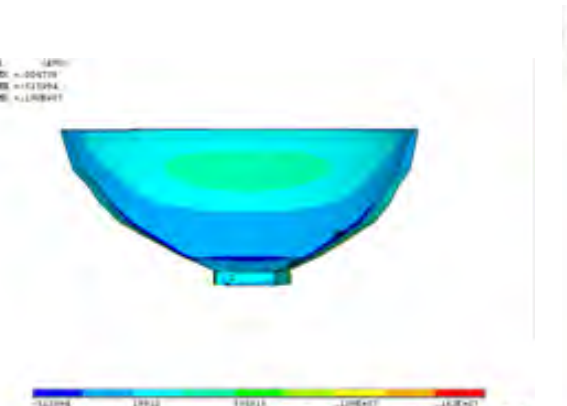


Figure 10. Cloud map of arch's first principal stress under case 5 (Pa)

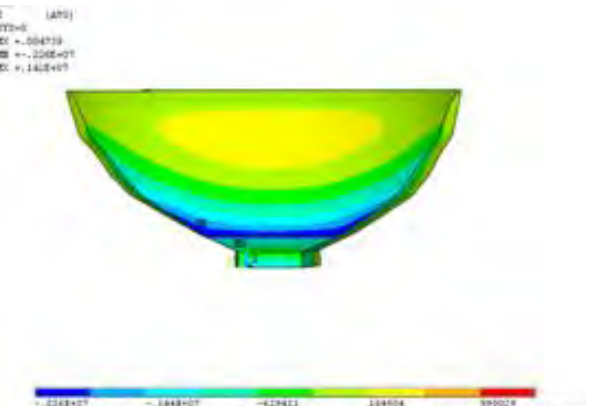


Figure 11. Cloud map of arch's vertical stress under case 5 (Pa)

As can be seen from Fig .2 to Fig .11, the first maximum principal stress of arch dam occurred mainly at the junction of abutment and bedrock, and the stress distribution is very complicated at the junction of bedrock and arch dam bottom. Because of water pressure and structure weight, these parts occurs the stress concentration[10]. The first principal stress of arch dam is gradually reduced from the bottom to the top of the dam, and its first principal stress increases with increasing water pressure. Vertical stress of arch emerges basically layered

distribution, and vertical stress distribution is more complicated at the junction of bedrock and dam bottom.

B Deformation Analysis

By deformation analysis of concrete arch dam structure of Banjiang Reservoir, we calculated vertical displacement and radial displacement distribution maps of various case. Arch's vertical displacement and radial displacement contours for case3 are shown in Fig .12 and Fig .13.

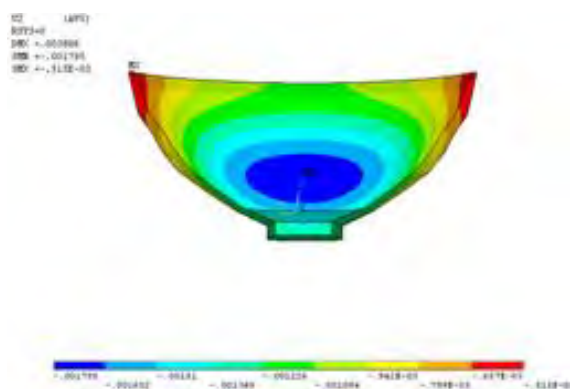


Figure 12. Cloud map of arch's vertical displacement under case 3 (Pa)

As we can see from Fig .12 and Fig .13, with the increase of the water level, the radial displacement significantly increased on the key points of arch dam crown's section, but the maximum radial displacement occurs in the middle of the arch crown, while radial displacement is smaller in the top and bottom of the arch crown. Arch radial displacement is greater than the vertical displacement, and the maximum vertical displacement occurs at the top of the arch crown.

IV. CONCLUDING REMARKS

In summary, using concrete arch dam scheme of Banjiang Reservoir River is reasonable. Basically, circumferential stress of arch dam upstream face is compressive stress. Furthermore, the arch's first principal stress which is small can meet the strength requirements, so the structure is safe and reliable.

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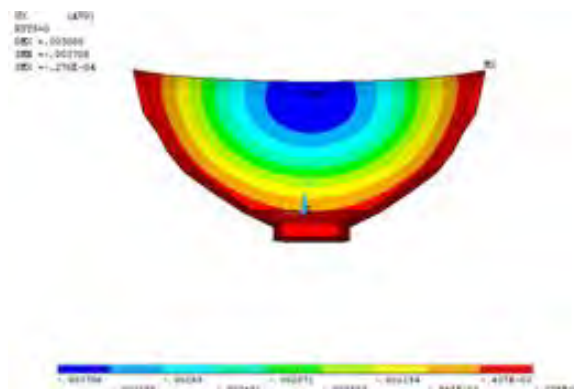


Figure 13. Cloud map of arch's radial displacement under case 3 (Pa)

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