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Analysis of Deformation Velocity and Stress Field of Rock Mass During Construction of Power System Engineering

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Abstract. Based on the comprehensive analysis of the basic parameters of the reservoir dam, the engineering hydrogeological conditions and the internal relationship between the time and space deformation of the valley and the reservoir dam after impoundment, a three-dimensional model of about 500 m on the left and right banks of transverse river direction is established for dynamic simulation. The deformation and stress evolution of the high slopes of rock and soil on both sides of the dam area of a large power project are simulated by using finite element method and finite difference method, and the development law of deformation, stress distribution and the change characteristics of internal unbalanced force are analyzed, as well as the deformation speed of the high slopes on both sides of the river in the direction of facing the airport and the speed of valley deformation. The research results can provide reference for the stress distribution, valley deformation law and safety monitoring of rock mass on both banks in design and research of dam engineering.

Keywords. Deformation, stress, speed, three-dimensional simulation

1. Introduction

The deformation of two bank slopes of large power stations can be regarded as the result of long-term interaction of external conditions and internal characteristics of materials, which has strong time-effect characteristics. The aging deformation is mainly caused by the rheological characteristics of rock and soil itself. The rheology of slope refers to the slow and continuous deformation of natural and artificial slopes composed of soil, rock and other materials under the action of gravity and external load [1]. The rheological characteristics of rock mass determine the continuous deformation of rock mass in the long course, and its rheology is mainly composed of creep, which presents the characteristics of nonlinear change, and whether the accelerated creep occurs or not directly determines whether the rock mass will be destroyed [2]. Therefore, the

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instability of slope engineering is mainly manifested in the aging deformation process that develops continuously with time. When the deformation accumulates to a certain extent, the slope will enter the stage of rapid development or accelerated creep. In addition to the time-dependent deformation characteristics of rock and soil, the deformation of slope is also affected by excavation disturbance, reservoir water and rainfall during construction. G. W. Rathod and K. S. Rao [3] discussed the stability of rock slope of India Subansiri Lower hydropower station based on limit equilibrium and finite element analysis. H. J. Park et al. [4] used the point estimation method to analyze the stability of the rock slope of Gunwi-gun dam in South Korea. H. Shen and S. M. Abbas [5] studied the stability of a rock slope in Zagunao Town, Sichuan Province by using the random set discrete element method (RS-DEM). N. Vatanpour et al. [6] analyzed the stability probability and sensitivity of a rock slope in an urban area of northeast Iran. X. S. Tang et al. [7] used the improved cognitive clustering zoning method to analyze the stability of the left bank abutment slope of Jinping I. In this paper, finite element combined with finite difference method are used to simulate and analyze the deformation of large hydropower projects.

2. Transverse Velocity Analysis

The calculation result of x velocity is shown in figure 1, and the velocity unit is the international standard unit "m/s". From the velocity nephogram near the dam area, it can be seen that the right bank velocity is positive, and the left bank velocity is negative, and it is deformed towards the river valley. There is an x velocity isosurface on the right bank and no velocity isosurface on the left bank. The deformation velocity of both banks are very small, and they all have the velocity towards the valley, and the velocity of the left bank towards the valley is slightly higher than that of the right bank towards the valley, and the velocity change is not closely related to the upstream and downstream.

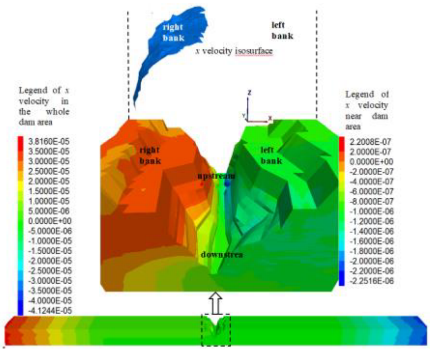


Figure 1. Velocity nephogram of transverse river.

By superposing the cross-river velocity values of the parallel and opposite points on both banks towards the river valley, and corresponding to the actual time, we can get the changes of the valley deformation velocity at different elevations (988 m in the upper part, 900 m in the middle and upper part, 830 m in the middle and lower part, and 730 m in the lower part) in the plunge pool behind the dam (figure 2). At different elevations, the speed law of the valley deformation changes is similar, and the magnitude is very small, which is closely related to the elevation. The positions corresponding to the valley deformation velocity from large to small are upper, middle upper, middle lower and lower respectively, and the valley deformation velocity of the position with high elevation is slightly higher than that of the position with low elevation.

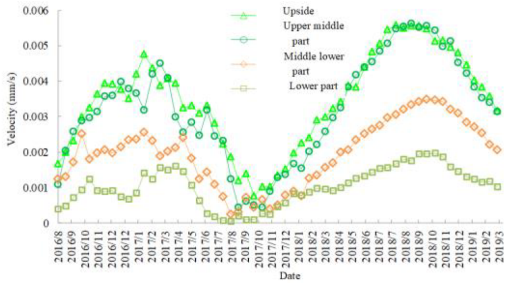


Figure 2. Velocity comparison of valley deformation at different elevations.

3. Stress Field Analysis

After long-term geological tectonic movement, rocks and soils will form in-situ stress field, accompanied by surface modification, internal rock mass deformation and even destruction, resulting in stress release and transfer. In-situ stress, as the basic occurrence condition of rock mass, is an essential initial condition in the analysis of large-scale hydropower projects. In-situ stress has an important influence on the deformation development, development trend, failure mode and mechanism of rock mass medium, and has a great influence on the safety of the project.

The large-scale geostress field in this project area is analyzed below. The spatial distribution of the maximum principal tensile stress in the large-scale field and near the dam area in the whole region is shown in figure 3. The tensile stress in the near dam area is greater than that in the far dam area, and the rock mass is almost in compression state, with only local tension. Near the direction of the river, the maximum tensile stress in the rock mass is about 1 MPa, which mainly appears in the upper superficial part, while the lower rock mass is in compression, and the tensile stress states on the left and right banks are basically symmetrical.

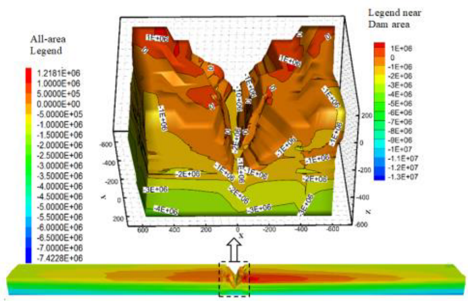
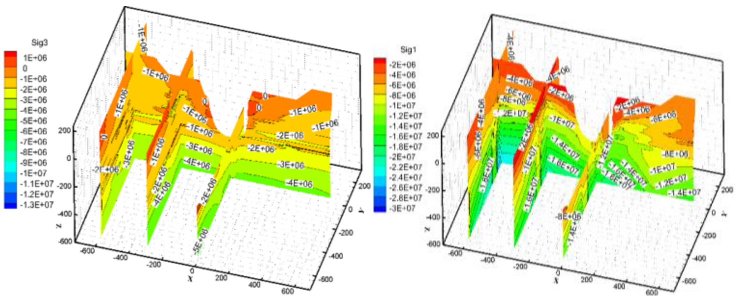


Figure 3. Nephogram of maximum principal tensile stress.

The nephogram results are imported into the Tecplot software through the interface program, and the cloud images are sliced at the positions near the dam area of *x*=-600 m, *x*=-300 m, *x*=0 m, *y*=0 m, respectively, to generate a two-dimensional section at the corresponding position. The cloud image of the internal structure section of the maximum tensile stress isoline is shown in figure 4(a). From the internal isoline, it can be seen that whether in the direction of transverse river or longitudinal river, the tensile stress is evenly distributed along the elevation, and the deep layer is generally a compression area, and the tensile area only appears in the upper shallow layer.

Slice the nephogram at *x*=-600 m, *x*=-300 m, *x*=0 m, *y*=0 m near the dam area, respectively, to generate two-dimensional sections at corresponding positions, the internal structure profile nephogram of the maximum compressive stress isoline is shown in figure 4(b). From the distribution of internal isoline structure, it can be seen that whether in the direction of transverse river or longitudinal river, the distribution of compressive stress along the elevation is more uniform than the spatial distribution of tensile stress, and the gradient along the elevation is obvious. The maximum compression of rock mass near the dam area can reach 30 MPa, which appears in the deep part of the rock.



(a) Maximum principal stress (b) Minimum principal stress

Figure 4. Isograms of principal stress in different sections near the dam area.

The spatial distribution of the maximum principal compressive stress in the large-scale field and near the dam area in the whole region is shown in figure 5, which is similar to the maximum tensile stress nephogram. The maximum compressive stress is uniform and regular in a large area, increasing from high to low, and the maximum compressive stress of rock mass is 27 MPa. Near the dam area, the maximum compressive stress on the left and right banks are evenly distributed along the elevation with good symmetry.

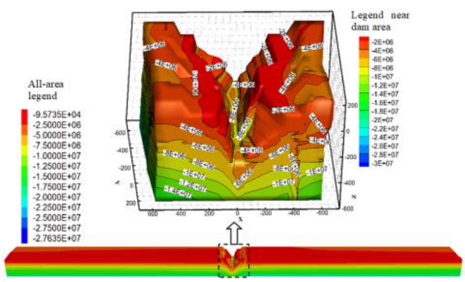
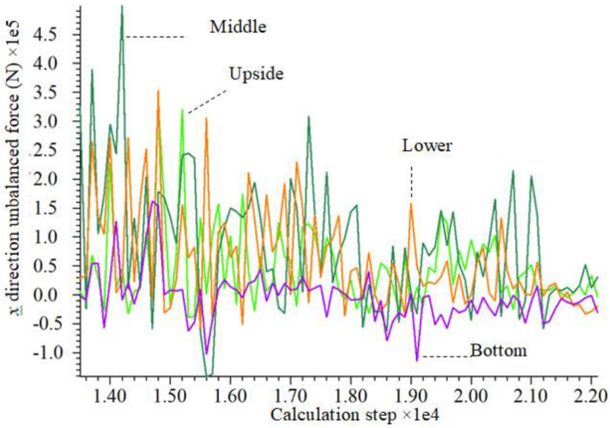
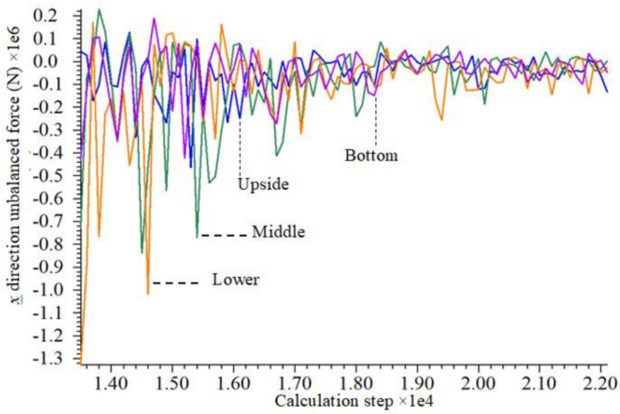


Figure 5. Nephogram of maximum principal compressive stress.

As shown in figures 6(a) and 6(b), the evolution process of the unbalanced force in the transverse direction of the characteristic points on the left and right banks of the plunge pool behind the dam at different elevations (988 m in the upper part, 900 m in the middle part, 830 m in the lower part and 730 m in the bottom) show that the unbalanced force in the *x* direction on the left and right banks gradually decreases from large to small, indicating that it tends to be stable gradually and has no obvious correlation with the elevation.



(a) Variation process of unbalanced force in the cross-river direction of characteristic points at different elevation of the plunge pool on the right bank



(b) Variation process of unbalanced force in the cross-river direction of characteristic points at different elevation of the plunge pool on the left bank

Figure 6. Variation process of unbalanced force in the cross-river direction of characteristic points at different elevation

4. Conclusions

The deformation analysis in the cross-river direction shows that the maximum total displacement of unilateral rock mass towards the river valley can reach nearly 20 mm, and the transverse displacement at the river channel is relatively minimum. Due to the relatively strong vector field on the right bank, the center of the reservoir disk tends to develop towards the left bank.

The velocity analysis shows that both banks have the deformation velocity towards the river valley, which is positively correlated with the elevation. The velocity of the valley deformation is slightly higher at the high elevation, and the law of velocity of the valley deformation at different elevations is basically similar, and overall, it is very small. The velocity of the left bank towards the valley is slightly higher than that of the right bank towards the valley, and it is not closely related to the upstream and downstream.

Acknowledgments

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