Static Calculation and Analysis of Certain Gravity Dam

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Abstract. At present, the main work of gravity dam research tends to adopt modern design theory and analysis methods to solve engineering problems. The most commonly used method is finite element method numerical simulation technology. This method discretizes the elastic continuum into a combination of a finite number of elements, and considers the continuous conditions of displacement between the elements. It can comprehensively consider the effects of various influencing factors. It has obtained good application results in the structural analysis of the dam. In this paper, a concrete gravity dam is taken as an engineering example. Based on the force of the dam, ANSYS finite element software is used to perform static analysis on the hydrostatic pressure, lifting pressure, dead weight and other loads.

1. Introduction
Gravity dams are built with materials such as concrete or stone. Under the effect of water pressure and other loads on a gravity dam, the dam body mainly depends on the anti-sliding force generated by the dam body's own weight to meet the stability requirements. The compressive stress generated by the dam body's own weight is also used to offset the tensile stress caused by water pressure to meet the strength requirements. The main static forces that gravity dams bear are their own weight, hydrostatic pressure, and lift pressure. The hydrostatic pressure depends on the upstream and downstream water levels, and the hydrostatic pressure \( P = \gamma h \). Lifting pressure includes upward buoyancy and seepage pressure. The buoyancy is the buoyant force generated by the water depth downstream of the dam. The seepage pressure is the upward hydrostatic pressure generated by the bedrock joints and cracks under the action of the difference between the upstream and downstream water levels. The static analysis of the gravity dam provides a reliable theoretical basis for the safety and reliability of the dam.
2. Project overview
This paper takes a hydropower station dam as an example for analysis. The foundation of the gravity dam is embedded in bedrock and the foundation is rigid. The material density of the dam is 2400kg/m³, the elastic modulus is 35GPa, and the Poisson's ratio is 0.2. The calculation and analysis water level is 120m. The key lateral dimensions of the gravity dam are shown in Figure 1.

3. Establishment of computing model
The dam modeling adopts the method of point-line-area-body-complex from low-level to high-level. The calculation model is established from simple to complex, and it is gradually realized. The pre-processing is mainly to build the model. The main work is to define the file name, define the type of the real constant element, define the material properties, and then create the model and mesh it. Because the basic section of gravity is a triangle, the model is relatively simple to set up. You only need to determine each key point in the coordinate system, then connect the points into a line, and finally the surface is formed by the line to complete the model.

4. Constraints and loads on the dam
First, apply displacement constraints to the bottom of the dam body model: Open the function dialog box for applying displacement constraints on nodes, and select all nodes at the bottom of the dam body model to run and apply the displacement constraints. Second, the application of gravity acceleration: open the corresponding function dialog box and enter the gravity acceleration 9.8 operation is complete. Third, applying hydraulic pressure load: Set the upstream of the dam with water, and the downstream without water, and then apply the hydraulic pressure load to the upstream dam surface through the corresponding function of ANSYS software. The resulting mesh model with displacement constraints and loads applied is shown in Figure 2.

5. Post-processing and results analysis
5.1. Post-processing
The static analysis of the dam is carried out. Through the static finite element analysis of the gravity dam, the displacement field and stress field of the dam under the static load can be known, so as to understand the safety performance of the dam.

The deformation map of the dam is shown in Figure 3. From the figure, we can see that the deformation of the dam is mainly caused by the deformation of the upstream dam surface, while the downstream dam surface is basically unaffected. The deformation of the upstream dam surface is gradually decreasing from the dam top to the dam bottom. The results of software analysis show that the largest deformation at the dam top has generated a displacement deformation along the X direction of 1.78 cm.

The displacement cloud map of the dam body in the X direction is shown in Figure 4. From the figure, we can see that when the dam body is subject to the displacement of the dam bottom and the hydraulic pressure load, the part with a large displacement in the X direction is the dam top, which is almost 1.78 cm. The displacement variation decreases from top to bottom. There is almost no displacement.

The displacement cloud map of the dam body in the Y direction is shown in Figure 5. From this figure, we can see that when the dam body is subject to dam bottom displacement constraints, hydraulic pressure loads, and the dam body's own weight, the parts that produce large displacements in the Y direction are the middle part of the upstream dam surface and the middle part of the downstream dam surface, 0.103 cm and -0.282 cm, there is almost no displacement at the bottom of the dam and inside the dam body.
Figure 8. Stress cloud diagram in the first principal direction of the dam

Figure 9. Stress cloud diagram in the third principal direction of the dam

The stress cloud diagram of the dam body in the X direction is shown in Figure 6. From the figure, we can see that when the dam body is subject to dam bottom displacement constraints, hydraulic pressure loads, and the dam body’s own weight, the parts that are subjected to greater stress in the X direction are the dam top and dam, where the situation at the dam is more complicated. The ground along the upstream dam face bears the stress in the negative X direction, and the long-term stress along the dam bottom is in the positive X direction.

The stress cloud diagram of the dam body in the Y direction is shown in Fig. 7. From this figure, we can see that when the dam body is subject to dam bottom displacement constraints, hydraulic pressure loads, and the dam body’s own weight, there are two places where the stress is greater in the Y direction are the dam ridge and the dam toe. The stress in the positive Y direction, while at the dam toe, is the stress in the larger negative Y direction.

The stress contours of the dam body in the first and third principal directions are shown in Figs. 8 and 9, respectively. From the figure, we can see that when the dam body is subject to the displacement of the dam bottom, the hydraulic pressure load, and the dam body’s own weight, the first principal direction stress of the dam body is concentrated at the dam site, and the force is more concentrated compared to other parts of the structure. The connection between the concrete and the bedrock surface is the most obvious. Therefore, it can be seen that the stress on the bend of the dam structure and the hydraulic interface and the interface with the foundation is the largest, which is also an important reason for easy slippage.

5.2. Results analysis

After analyzing the above post-processing results, the following conclusions can be drawn. The maximum tensile strain and tensile stress appear at the top of the dam and at the connection between the dam and the rock, which may cause cracking of the concrete. The maximum tensile stress is 1.78 MPa, although it is less than the tensile strength of the concrete 1.96 MPa, but cracks still occur here because the plain concrete cannot transmit the tensile force. In addition, there is a tensile stress of 0.713 MPa at the dam site and stress concentration at the dam site. These locations are areas that need special attention when designing gravity dams. Because the dam top and upstream dam surface need to bear a large upstream water pressure load, cracks are likely to occur. After the reservoir is impounded, the cracks on the dam surface may further expand due to the pressure of the meltwater on the fracture surface until it penetrates the drainage pipe or corridor, which will cause the concrete of the dam body to be dissolved and damage the durability of the dam.

6. Conclusion

This paper uses the finite element method and ANSYS software to perform static calculation and analysis on a concrete gravity dam. The specific content is as follows:

The conclusion is drawn from the analysis of the gravity dam by using the finite element method. When the gravity dam discussed in this article is under normal water level and full reservoir conditions, it is subject to the effects of upstream hydrostatic pressure, dam bottom displacement constraints, and
The dam body produces the maximum horizontal positive displacement at the dam top, and the dam heel is subject to greater pressure. These effects may cause cracks in the dam dam top, upstream dam face, and dam heel, which have certain effects on dam safety influences.

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