Analysis of stress deformation characteristics of composite geomembrane Rock-fill dam with core wall

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Abstract: The Chengzigou hydropower station of composite geomembrane rockfill dam as an example of the dam body and the composite geotechnical membrane stress and deformation characteristics are used nonlinear elastic model - Duncan EB model establish three-dimensional finite element model of rockfill, by using the large finite element software—FLAC3D, which provided geogrid element to simulate flexible geomembrane shear interaction with soil. The stress and deformation of the dam and the composite geomembrane is calculated under two conditions—completion period and impoundment period. And analyze the change of the stress and strain distribution rule, which will provide the basis for the design of the geomembrane.

Introduction

Composite geomembrane core wall rockfill dam is a new type of earth and rockfill dam, which is a pile of stone as the main material and composite geomembrane as impervious body. The deformation degree has some influence on the dam body stability and security. In this paper, Combining with the Chengzigou hydropower station, the design scheme of composite geomembrane core wall rockfill dam, by using the nonlinear elastic model—Duncan E - B model, Create a composite geomembrane rockfill dam of three-dimensional finite element model by FLAC3D, Analysis of the dam and geomembrane nonlinear stress strain analysis, thus get stress and deformation result of completion period and impoundment period, and compared with them.

Project summary. Chengzigou hydropower station is located in Longnan city, Gansu province, the project is mainly composed of The first hub, water diversion tunnel, surge tank, pressure pipe, power plant and other parts. This article mainly analyze the first hub rockfill dam body and the core wall of composite geomembrane stress and deformation.

Composite geomembrane core wall rockfill dam crest elevation is 895.00m, the maximum dam height is 18.50m, crest width 6.00m, upstream dam slope 1:1.8, downstream dam slope 1:1.8. Composite geomembrane core wall structure including cushion layer and composite geomembrane. The composite geomembrane is composed of two cloth and one film, namely a layer of geotextile and two layers of geomembrane, located between the upper, lower cushion. From upstream to downstream, Composite geomembrane core wall rockfill dam is divided into upstream of the main rockfill zone, upstream of the transition zone, core wall upstream of gravel cushion layer, downstream of the transition zone, the downstream hof the main rockfill zone.

Calculation model. The lowest point of the foundation model for the origin of O, Simulate the real dam construction sequence is divided into six layers, each layer of 3 m, Dam gravel material is nonlinear material, which’s Deformation change according to the load size and Loading path. Stress-strain showed a non-linear relationship. Each partition material parameters of rock mass are shown in table 1.
Composite geomembrane is a flexible material, Geogrid shear friction with FLAC3D grid in the tangential and Attached to the grid in the normal. So let Geogrid structure unit between the filter and the geomembrane, and assigned Material properties to them to simulate. Processing of boundary constraint of the analysis model, the bottom of the bedrock is fixed constraint and its Four side is roller constraints.

Table 1  Physics parameters of Materials

| Dam partition          | Modulus of elasticity $E$ (GPa) | Poisson's ratio $\mu$ | Friction angle $\phi$ | Cohesion $c$ (MPa) |
|------------------------|---------------------------------|------------------------|-----------------------|-------------------|
| Dam gravel material    | 21                              | 0.3                    | 38                    | 24                |
| Composite geomembrane  | 12                              | 0.26                   | 22                    | /                 |
| Transition material    | 24                              | 0.22                   | 32                    | 15                |
| Cushion material       | 30                              | 0.22                   | 31                    | 17                |
| Bedrock                | 23                              | 0.3                    | 36                    | 23                |

Analysis calculations dam, and foundation mainly uses hexahedral elements, there are also a number of five-sided unit and tetrahedral elements. Composite geomembrane uses quadrilateral membrane element. Figure 1 is the Chengzigou hydropower station dam structure calculation mesh, the number of dam finite difference dividing unit is 680, foundation is 230 and composite geomembrane is divided into 32 geogrid unit.

Figure 1  Calculation mesh of Chengzigou hydropower station dam structure

**Dam and geomembrane stress deformation and results analysis.** When calculating, selecting typical sections were analyzed. By the simulation analysis of the dam and composite geomembrane obtained impoundment of large and small primary stress contour map and the vertical and horizontal displacement value distribution map in completion period and impoundment period, and compares the calculation results under two kinds of working condition.

**Stress analysis**

**Construction completion period.** See From Fig. 2.1.2.3 in construction completion period, dam body and dam foundation of the principal stress is compressive stress, most of the major principal stress is relatively small, and at the bottom of the dam body stress value maximum is 0.45Mpa, at the same time, the minor principal stress is also characterized by compressive stress is 0.148Mpa,
because composite geomembrane is a flexible material which only bear the tensile stress, and at the bottom of the geomembrane is a maximum of 2.86kN/m. The dam and foundation stress along the dam axis symmetrical distribution in this condition.

**Impoundment period.** From Fig. 2.2,2.3 can be seen that, in impoundment period, dam and foundation of the maximum stress value is 0.42Mpa, which appeared in the bottom and a compressive stress state, the minor principal stress as well as the maximum value of the stress is 0.164Mpa, the maximum tensile stress that composite geomembrane still bear at the foundation bottom is 3.65kN/m, dam subjected to water pressure in impoundment period, obviously the Outside the reservoir compressive stress is larger than the inside.

**Construction completion period.** With rockfill dam ever rising, weight increases, resulting in settlement. It can be seen from Figure 2.4 that dam maximum horizontal displacement outwards reservoir is 0.0056m, inward reservoir is 0.0056m and maximum vertical displacement is 0.029m. As composite geomembrane and dam construction simultaneously, and it is a flexible material that no resistance to bending deformation, so the deformation is mainly dependent deformation of dam deformation, the maximum displacement is 0.0056m, the maximum vertical displacement is 0.029m.

**Impoundment period.** From Figure 2.5, 2.6 dam and foundation's largest settlement Located in the composite geomembrane core wall dam about two-thirds the height, the value is 0.026m, this time maximum horizontal displacement Outside the reservoir is 0.0005m, the maximum horizontal displacement inside the reservoir is 0.0038m. Apparently, in the conditions, inside and outside the reservoir horizontal displacement is vary large, and mainly for the displacement inside the reservoir.
Figure 2.6 shows that the deformation of composite geomembrane mainly along rivers direction of the horizontal displacement and vertical settlement. Maximum horizontal displacement of the downstream is 0.018m, the maximum settlement is 0.022m.

**Conclusion.** The analysis result shows that both Construction completion period and impoundment period, The dam’s major and minor principal stresses are all compressive stress, therefore it will not appear tensile failure phenomenon of any part of the dam. Bottom of composite geomembrane become more obvious.In the construction completion period, because of the influence of Poisson effect of dam material , vertical displacement and horizontal displacement of the dam along the dam axis distribute symmetrically, and the displacement of the composite geomembrane mainly belongs to the dam displacement,and the maximum vertical displacement of the dam body appear in the composite geomembrane core wall about two-thirds the height.

To sum up, in the impoundment period, the dam is under the external load, such as Tare weight and hydrostatic pressure, uplift pressure, and so on, the major, minor principal stress and the displacement map of the dam and composite geomembrane are changed when compared with the construction completion period, especially at the bottom of the dam.

**References:**

[1] Gu Ganchen. Example of Composite geomembrane and geotextile dam [J]. Water resources and Hydropower Engineering, 2002, 33 (12): 26-32.

[2] Su Yiming, Gu Ganchen. Geotechnical film central impervious earth-rockfill dam finite element calculation [J]. Journal of Hohai university (natural science edition), 1988.16: 79-92.

[3] The Liaoning Institute of water conservancy and so on. The composite geomembrane core and earth dam with inclined core technology research report, 1992.3.

[4] Jiang Tingting, Gao Zhijun, Wang Yunxia. The research of Duncan-Zhang model and its application in engineering [J]. West China Exploration Engineering, 2009 (6): 9-11.

[5] Leng Xianlun, Sheng Qian, Zhu Zeqi. Duncan-Zhang model realization and engineering application in the FLAC3D [J]. Building science, 2009, 25 (1): 100 - 105.

[6] Zhu Xiaoling. Concrete face rockfill dam of the three dimensional finite element simulation analysis [J]. Journal of water conservancy, 2005.

[7] Liu Zude. Earth dam deformation calculation problems [J]. Journal of geotechnical engineering, 1983.