Simulation Analysis for Reinforced Concrete Face Rockfill Dam of Tuanjie Reservoir

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Abstract—**Through analyzing reinforced concrete face rockfill dam structure's mechanical characteristics in construction process and operating process, this paper adopts finite element method to carry out structural analysis for reinforced concrete face rockfill dam of Tuanjie reservoir. Deducing distribution law of the dam's stress and displacement in construction process and operating process. Analysis results show that, reinforced concrete face rockfill dam of Tuanjie reservoir is reasonable, it meets the requirements for design.**

Keywords-Reinforced concrete; Rockfill dam; Finite element program; Simulation analysis

I. PROJECT SUMMARY

Tuanjie reservoir is located Yuliang stream of the Minjiang River upstream's tributaries, which is located Pucheng county in Fujian province. Rainwater-collecting area is 13.8 km^2, total reservoir storage capacity is 2.16 million m^3. Function of the engineering is water storage irrigation for Xianyang village, the area of benefited farmland is 10500 Mu, the installed capacity is 180 kW. The engineering is make by rockfill dam, spillway and water delivery tunnel, etc. The dam is reinforced concrete face rockfill dam, the dam is make by seepage-proofing face, mortar block stone subcrust, block stone transition section and rockfill, etc. Maximum dam high is 38 m, dam crest width is 4 m, gradient of upstream face is 1:0.5, gradient of downstream face is 1:1.4. Reservoir's normal storage level is 32.3 m, design level is 35.7 m, flood level is 37.0 m.

II. CALCULATION MODEL

Model Parameters. Concrete strength grade of Tuanjie reservoir's reinforced concrete face rockfill dam is C25, elastic modulus E_1=28 GPa, Poisson ratio μ_1 =0.167[1], density γ_1=24 kN/m^3. The dam masonry's elastic modulus E_2=18 GPa, Poisson ratio μ_2=0.28, density γ_2=28 kN/m^3. The dam foundation rock is granite, rock elastic modulus E_3=17 GPa, Poisson ratio μ_3 =0.26[2].

Element Division. Finite element simulative analysis is proceeded for reinforced concrete face rockfill dam of Tuanjie reservoir. Reinforced concrete face, rockfill dam and bedrock structure model is divided by eight nodes isoparametric block element. The element is often applied to three-dimensional model of entity structure, it has plasticity, creep, expansion, stress rigidization, large deformation and large strain characteristics. it has eight nodes, each node has three translational degree of freedoms[3].

Simulation Range. Universal finite element calculation software is adopted, finite element simulative analysis for reinforced concrete face rockfill dam of Tuanjie reservoir. Calculation model simulation range is listed below, calculation model along the river is 276.2 m, transverse of the river is 95 m, vertical direction is 158 m. The simulation range of whole calculation model is 276.2 m×95 m×158 m [4]. Element division of dam and bedrock is shown in Fig.1.

Calculation Cases. Considering mechanical characteristics of dam structure in construction and operating process[5], researching four calculation cases as follows. Case 1, dam weight(construction condition); case 2, dam weight, normal storage level, tail water level and sediment pressure(operating condition); case 3, dam weight, design level, tail water level and sediment pressure(operating condition); case 4, dam weight, flood level, tail water level and sediment pressure(operating condition).

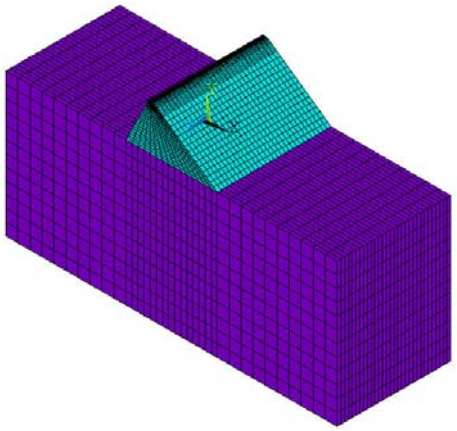

Fig.1 Element division of dam and bedrock

III. THE DAM STRUCTURE ANALYSIS

Analysis Paths. When finite element analysis is proceeded for reinforced concrete face rockfill dam of Tuanjie reservoir. two calculation paths are selected in the middle section of the dam. Path 1, choosing one calculation

point every 6.07 m from dam bottom to dam crest along reinforced concrete face rockfill dam's upstream face, there are eight calculation points totally. Path 2, choosing one calculation point every 9.34 m from dam bottom to dam crest along reinforced concrete face rockfill dam's downstream face, there are eight calculation points totally.

Stress Analysis. Calculation point's first principal stress values on the analysis path of reinforced concrete face rockfill dam's middle section under various cases are listed in the table 1.

We can see from table 1, under various cases, first principal stress on reinforced concrete face rockfill dam's calculation paths are compressive stress, but dam's upstream surface's compressive stress values gradually become smaller from dam bottom to dam crest, this is mainly because dam weight and water pressure effect together. Compressive stress values of dam's upstream face and downstream face are increase gradually along with increase of water pressure, this is mainly because the gradients of reinforced concrete face rockfill dam's upstream face and downstream face are gentle, so the first principal stress that is produced by water pressure is compressive stress on the dam's upstream face and downstream face. Compressive stress values of dam's downstream face are smaller than upstream face, this is mainly because dam's downstream face will produce tensile stress under water pressure, which offsets a part compressive stress.

Because case 3 is common condition of dam in operating process, case 4 is serious condition of dam in operating process. We obtain reinforced concrete face rockfill dam's contour maps of first and third principal stress under case 3 and case 4, contour maps of first and third principal stress are shown from Fig.2 to Fig.5.

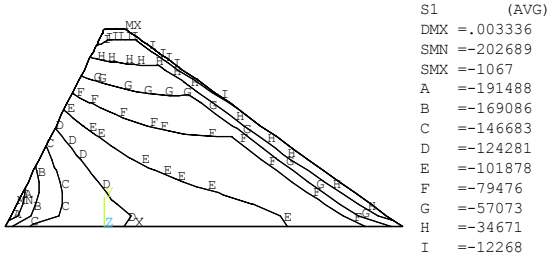

Fig.2 Contour map of first principal stress under case 3（Pa）

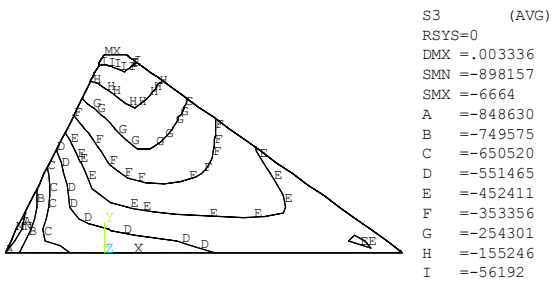

Fig.3 Contour map of third principal stress under case 3（Pa）

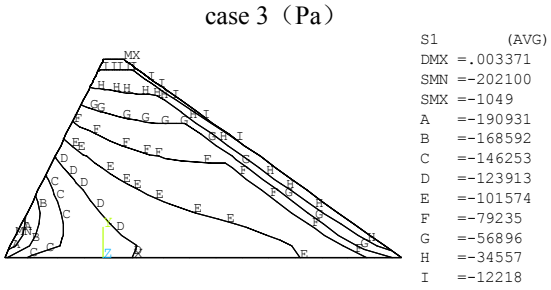

Fig.4 Contour map of first principal stress under case 4（Pa）

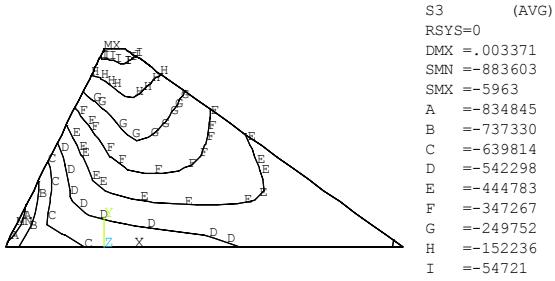

Fig.5 Contour map of third principal stress under case 4（Pa）

We can see from Fig.2 to Fig.5, under case 3 and case 4, the dam's first principal stress is entirely compressive stress, and principal stress is layered distribution along the direction of dam downstream face normal. Compressive stress values of the dam's bottom are larger, compressive stress values of the dam's crest are smaller, maximum compressive stress is -0.191 MPa, it is located junction of the dam's upstream face's bottom and bedrock under case 3. Under case 3 and case 4, the dam's third principal stress is entirely compressive stress, and principal stress is basically layered distribution along the direction of dam height. Compressive stress values of upstream face are maximum, compressive stress values decrease gradually from dam's bottom to dam's crest, maximum compressive stress is -0.849 MPa, it is located junction of the dam's upstream face's bottom and bedrock under case 3, this is mainly because dam weight and water pressure effect together.

Deformation Analysis. Through deformation analysis of reinforced concrete face rockfill dam of Tuanjie reservoir, getting the dam's contour maps of horizontal and vertical displacement in middle section. Contour maps of horizontal and vertical displacement under case 1 and case 4 are shown from Fig.6 to Fig.9.

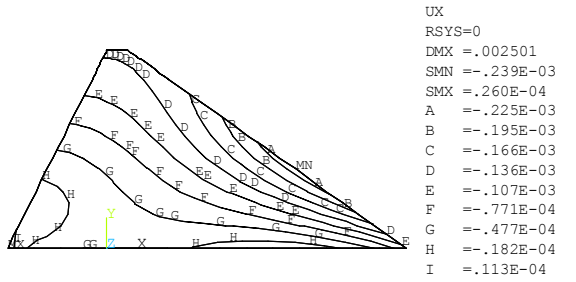

Fig.6 Contour map of horizontal displacement under case 1 （m）

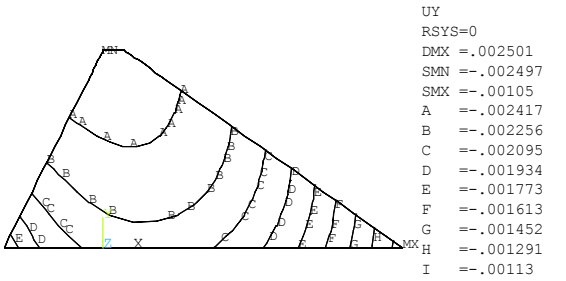

Fig.7 Contour map of vertical displacement under case 1（m）

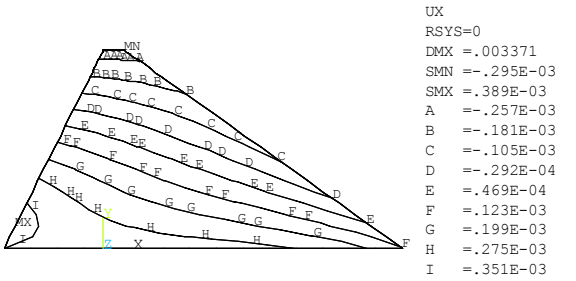

Fig.8 Contour map of horizontal displacement under case 4 （m）

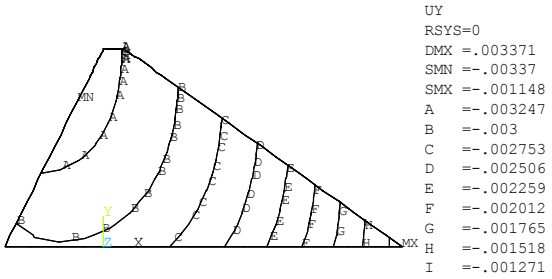

Fig.9 Contour map of vertical displacement under case 4（m）

We can see from Fig.6 to Fig.9, under case 1 and case 4, the dam's horizontal and vertical displacement is smaller, and horizontal displacement value is far less than vertical displacement value, this is mainly because the gradients of reinforced concrete face rockfill dam's upstream face and downstream face are gentle, the dam produce mainly vertical settlement displacement under weight and water pressure. Under case 1, the dam's horizontal displacement value is mainly negative, the dam's vertical displacement is mainly settlement displacement, this is mainly because the dam's weight produces regularity of distribution. Under case 4, the dam's part of horizontal displacement value is positive, and part of horizontal displacement value is negative, this is mainly because the dam's weight and water pressure produce regularity of distribution.

CONCLUSION

From the above, in construction process and operating process, reinforced concrete face rockfill dam of Tuanjie reservoir's stress is basically compressive stress, the dam won't craze, stress values can meet strength requirements. The dam's displacement value is very small, it can meet rigidity requirements. this shows, design scheme of reinforced concrete face rockfill dam is economic and reasonable, structure is safe and reliable.

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Table 1. Calculation point's first principal stress values on the dam's analysis path under various cases（kPa）

Calculation Points		①	②	③	④	⑤	⑥	⑦	⑧
Case 1	Path 1	-185.17	-31.34	-18.21	-14.10	-10.95	-7.82	-4.50	-1.28

	Path 2	-31.34	-21.81	-19.23	-16.18	-12.82	-9.20	-5.04	-1.04
Case 2	Path 1	-198.18	-197.81	-167.93	-134.82	-99.21	-56.23	-5.09	-1.32
	Path 2	-38.81	-22.21	-19.31	-16.19	-12.82	-9.21	-5.02	-1.07
Case 3	Path 1	-188.11	-198.81	-172.97	-141.11	-106.29	-69.50	-33.26	-1.30
	Path 2	-42.70	-22.34	-19.34	-16.19	-12.83	-9.24	-5.00	-1.07
Case 4	Path 1	-183.75	-198.87	-174.62	-143.22	-108.66	-72.11	-36.27	-1.20
	Path 2	-44.35	-22.39	-19.34	-16.18	-12.82	-9.25	-5.00	-1.05