Finite Element Analysis for Clay Inclined Wall Earth Dam of Baiyinhua Reservoir

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Abstract—Baiyinhua Reservoir is located in Oumulun River, Ar khorchin banner in Inner Mongolia. The irrigation area of design is 53600 mu, and it is a medium-sized reservoir which is given priority to with irrigation. This article gives the stress and deformation distribution during construction and operation which has done the three-dimensional simulation analysis for clay inclined wall earth dam of Baiyinhua Reservoir using the finite element method, providing some reference for the design and construction of clay inclined wall earth dam. The results show that clay inclined wall earth dam of Baiyinhua Reservoir satisfy the design requirements and is safe and reliable. The results show that during operations the structural stress all is stress for clay inclined wall earth dam of Baiyinhua Reservoir, and the displacement of dam is very small. This shows that the structural design is safe, reasonable and consistent with the design requirements of earth dam structures.

Keywords- Baiyinhua reservoir; Clay inclined wall earth dam; Finite element analysis; Simulation analysis; Stress distribution.

I. ENGINEERING SITUATION

Baiyinhua Reservoir is located in Oumulun River, Ar khorchin banner in Inner Mongolia. The irrigation area of design is 53600 mu, and it is a medium-sized reservoir which is given priority to with irrigation[1]. The total capacity of reservoir is 4.02 million m^3, normal water level 24m, design flood water level 28.1m, check flood level 30.3m. Hub engineering is composed of the main and auxiliary dam, spillway, and two water pipes. The main dam is clay inclined wall earth dam, which is 11m length, 740m long and 4m width. Dam was built on sand and gravel layer, using clay as the foundation seepage blanket measures, and the project is located in cold areas, the upstream of inclined wall located the protective layer of sand material[2].

II. FINITE ELEMENT MODEL

Establishing finite element model of clay inclined wall earth dam of Daiyinhua Reservoir, the tilt angle of dam upstream face and downstream face respectively is 16° and 20°, dam filling silty loam, dry bulk density of 1400 kg / m^3, the water content of 23%, the internal friction angle 14° [3-4]. The width of dam is 72.6m, and the finite element model takes 100m toward dam upstream face, 97m toward dam downstream face and 80m to the ground below [5-6]. Earth dam and bedrock FEM division are shown in Fig .1.
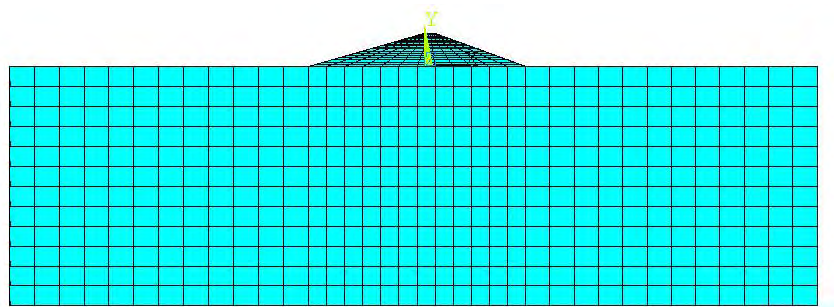

Figure 1. Earth dam and bedrock FEM division

Clay inclined wall earth dam and foundation model uses isoparametric block element which has 8-node[7]. 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[8-9] .

III. SIMULATION ANALYSIS

Considering the mechanical characteristics of dam during operation[10]，the following three cases are taken into account mainly: case 1, normal water level(5.9m depth) and structural weight; case 2, design flood level(8m depth) and structural weight; case 3, checking flood level (8.8m depth) and structural weight.

A Stress Analysis

The largest transverse compressive stress is -65.24 kPa for case 1. It appears in the middle of the bottom, and tensile stress doesn't appear in transverse direction. The largest vertical stress is -131.99 kpa. It appears in the middle of the bottom, and tensile stress doesn't appear in vertical direction.

The largest transverse compressive stress is -65.80 kPa for case 2. It appears in the middle of the bottom, and tensile stress doesn't appear in transverse direction. The largest vertical stress is -132.46 kpa. It appears in the middle of the bottom, and tensile stress doesn't appear in vertical direction.

The largest transverse compressive stress is -66.63 kPa for case 3. It appears in the middle of the bottom, and tensile stress doesn't appear in transverse direction. The largest vertical stress is -132.85 kpa. It appears in the middle of the bottom, and tensile stress doesn't appear in vertical direction.

Dam transverse, vertical stress contours are shown in Fig .2, 3, and transverse, vertical stress cloud is shown in Fig .4 and 5 for case 2.
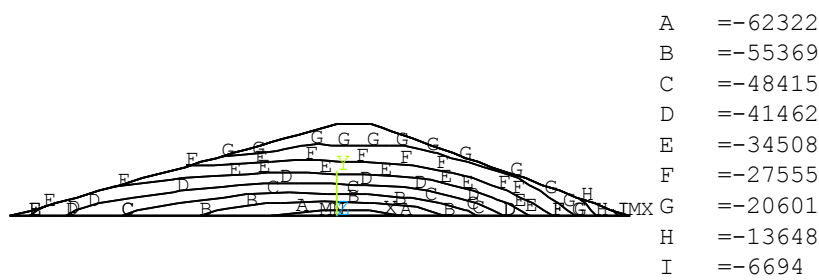

A	=-62322
B	=-55369
C	=-48415
D	=-41462
E	=-34508
F	=-27555
G	=-20601
H	=-13648
I	=-6694

Figure 2. Dam transverse stress contours for case 2 (Pa)

A	=-125185
B	=-110643
C	=-96100
D	=-81558
E	=-67016
F	=-52473
G	=-37931
H	=-23388
I	=-8846
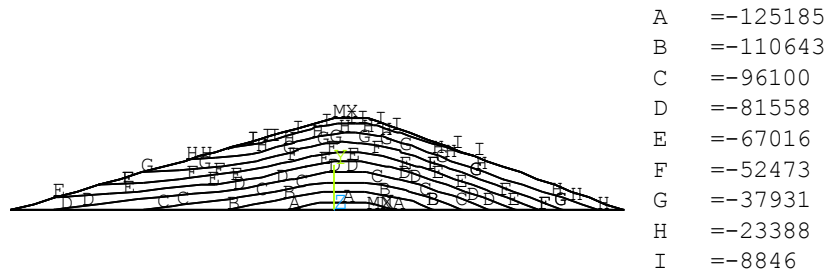
Figure 3. Dam vertical stress contours for case 2（Pa）

-65799 -58846 -51892 -44939 -37985 -31031 -24078 -17124 -10171 -3217
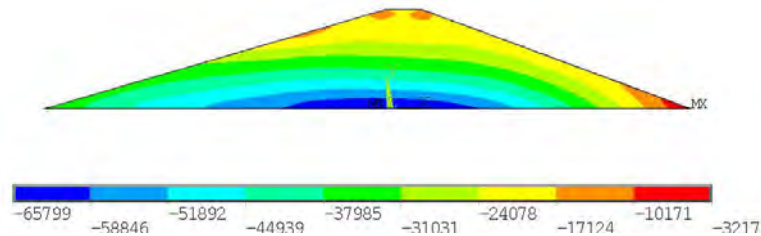
Figure 4. Dam transverse stress cloud for case 2（Pa）

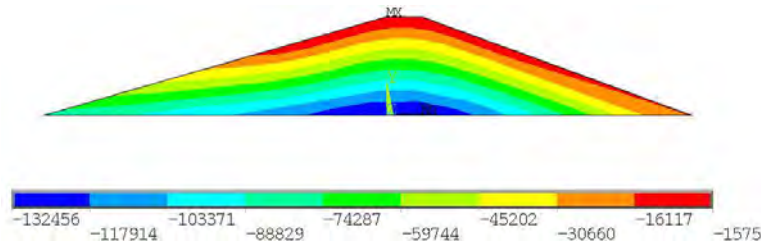-132456 -117914 -103371 -88829 -74287 -59744 -45202 -30660 -16117 -1575

Figure 5. Dam vertical stress cloud for case 2（Pa）

As can be seen from Fig .2 and Fig .4, under the action of design flood level and structural weight, all the transverse stress of dam is stress, and the stress is relatively small. The largest stress appears in the middle of the bottom, and the least stress appears at the junction of downstream face of the dam and foundation. This is resulting of the eccentric pressure which is caused by hydrostatic and structural weight. From Fig .3 and Fig .5 we can know that the vertical stress all is stress under the action of designing flood level and structural height, and the largest and least stress respectively appear in the middle of the bottom and the top of dam. This shows that the vertical stress of the dam is mainly produced by the weight of the structure.

B   Deformation Analysis

The largest transverse displacement of dam for case 1, case 2 and case 3 respectively is 0.06m, 0.09m and 0.10m. They all appear at the junction of upstream face of the dam and foundation, and the displacement direction toward the downstream side, which is produced a displacement by the action of pressure.

The largest vertical displacement of dam for case 1, case 2 and case 3 respectively is 0.54m, 0.56m and 0.57m. They all appear at the top of dam, and the displacement direction toward vertically downward, which is mainly produced a displacement by the action of structural height.

Dam transverse, vertical displacement contours are shown in Fig .6 and Fig .7, and transverse, vertical stress cloud are shown in Fig .8 and Fig .9 for case 2.
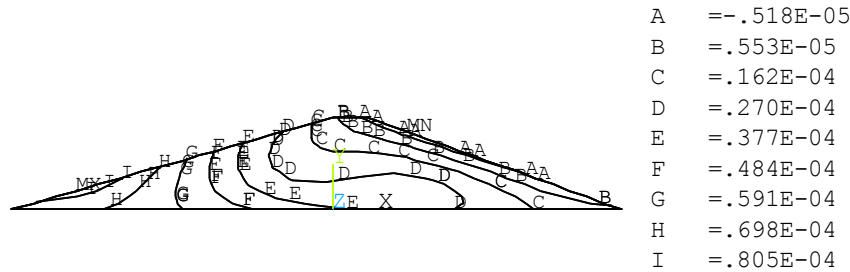
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A   =-.518E-05
B   =.553E-05
C   =.162E-04
D   =.270E-04
E   =.377E-04
F   =.484E-04
G   =.591E-04
H   =.698E-04
I   =.805E-04
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Figure 6. Dam transverse displacement contours for case 2（m）

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A   =-.531E-03
B   =-.484E-03
C   =-.437E-03
D   =-.390E-03
E   =-.343E-03
F   =-.295E-03
G   =-.248E-03
H   =-.201E-03
I   =-.154E-03
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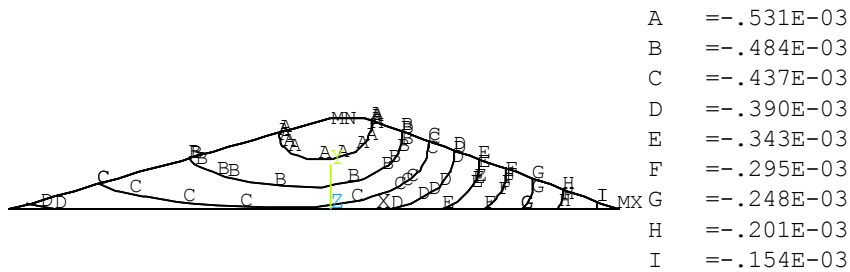
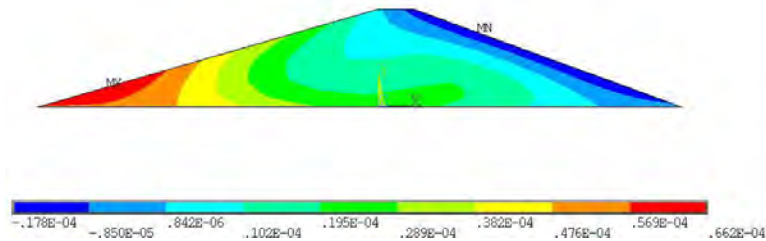Figure 7. Dam vertical displacement contours for case 2（m）

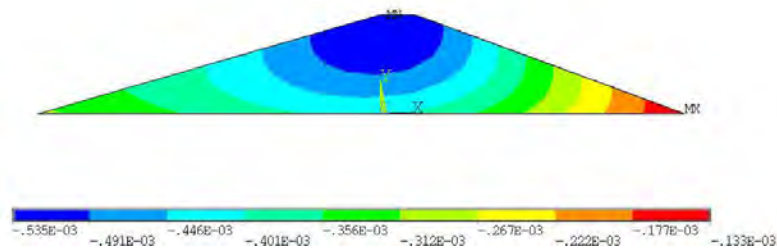Figure 8. Dam transverse displacement cloud for case 2（m）

Figure 9. Dam vertical displacement cloud for case 2（m）

IV.   CONCLUDING REMARKS

The results show that during operations the structural stress all is stress for clay inclined wall earth dam of Baiyinhua Reservoir, and the displacement of dam is very small. This shows that the structural design is safe, reasonable and consistent with the design requirements of earth dam structures.

REFERENCES

[1] B. Phansri,S. Charoenwongmit,P. Warnitchai et al. Numerical simulation of shaking table test on concrete gravity dam using plastic damage model [J]. Structural engineering and mechanics,2010,36(4):481-497.

[2] I. Karimi,N. Khaji,M.T. Ahmadi et al. System identification of concrete gravity dams using artificial neural networks based on a hybrid finite element-boundary element approach [J]. Engineering structures,2010,32(11):3583-3591.

[3] Guangxin Li. Advanced Soil Mechanics [M]. Tsinghua University Press, 2005.

[4] K. HacIefendioglu,A. Bayraktar,T. Tuerker et al.Seismic response of concrete gravity dam-ice covered reservoir-foundation interaction systems [J]. Structural engineering and mechanics, 2010, 36(4):499-511.

[5] Jiaxuan Mai. Hydraulic Structures [M]. Tsinghua University Press, 2005.

[6] Yuan Chen,Gengxin Yang,Jianhua Dong et al. Anti-sliding stability of a gravity dam on complicated foundation with multiple structural planes [J]. International Journal of Rock Mechanics and Mining Sciences,2012,55:151-156.

[7] H. Shariatmadar, A. Mirhaj. Dam-reservoir-foundatJon interaction effects on the modal characteristic of concrete gravity dams [J]. Structural engineering and mechanics, 2011, 38(1): 65-79.

[8] Xucheng Wang. Finite Element Method [M]. Tsinghua University Press, 2003.

[9] Bofang Zhu. Finite Element Method Principle and Application [M]. China Water Conservancy and Hydropower Press, 1998.

[10] Meihua Li, Feihan Wang. Earth-rockfill Dam Design and Construction [M]. China Water Conservancy and Hydropower Press, 2011.