Study on the Optimization of the Spacing between Chambers

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Abstract

Based on the inversion of in-situ stress, the stability of three chambers in the excavation process is simulated. In order to analyze the rationality of the distance between the Power house and the main transformer room, two distance cases of 35m and 40m were compared. At the same time, under the condition of support and no-support, the plastic zone volume and the displacement of key point around the cavern were compared. Then the better scheme was chosen.

Keywords

In-Situ Stress; Power House; Main Transformer Room; Displacement of Key Point.

1. Introduction

FLAC3D is a fast Lagrange analysis method, which uses explicit or implicit finite difference to simulate the mechanical behavior of geotechnical or other materials. FLAC3D divides the computational domain into a number of tetrahedral elements, each of which follows a given linear or nonlinear constitutive relation under given boundary conditions, The explicit or implicit finite difference scheme is used to solve the governing differential equations of the FLAC, and the mixed element discrete model is used. It can accurately simulate the yield, plastic flow, softening and deformation of the material. Especially in the field of elastic plastic analysis, large deformation analysis and Simulation of construction process, it has its unique advantages.

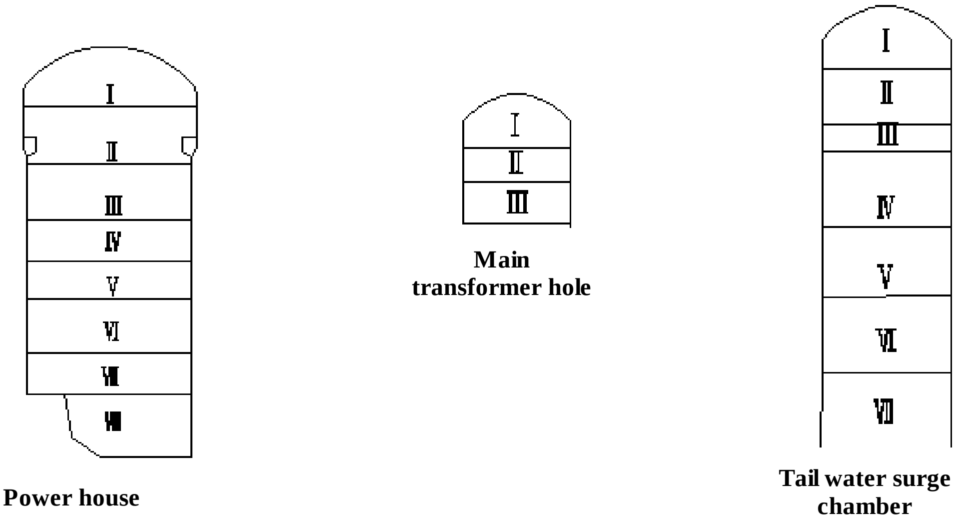


Fig. 1 Schematic diagram of layered excavation

2. Selection of excavation sequence

2.1 Selection of excavation sequence

Each cavern was excavated by using stratified method. The specific stratification is shown in Figure 1. The excavation sequence of cavern group is carried out by second schemes, as shown in table 1.

Table 1. Excavation steps of cavern group

Excavation step	Power house	Main transformer hole	Tail water surge chamber
Excavation step1	I		I
Excavation step2	II	I	II,III
Excavation step3	III	II	IV
Excavation step4	IV	III	V
Excavation step5	V		VI
Excavation step6	VI		VII
Excavation step7	VII		
Excavation step8	VIII		

In the process of considering bolt support, the method of increasing the cohesion of the surrounding rock is used to simulate the equivalent support. The equivalent supporting parameters of anchorage zone are shown as follows

$$\begin{cases} c_1 = c_0 + \eta \dfrac{\tau_s s}{a_i b} = c_0 + \Delta c \\ \varphi_1 = \varphi_0 \end{cases} \tag{1}$$

Where, $c_0, \varphi_0, c_1, \phi_1$ are Cohesive force, internal friction angle of the support and no support. τ is Shear strength of rock bolts, s is Cross section area of anchor bolt, a, b are spacing of vertical and horizontal anchor; η is dimensionless coefficient, which is related to the arrangement characteristics of anchor group.

2.2 Calculation range and calculation model

A two-dimensional model is established to calculate the stability. The boundary conditions are as follows:

Upstream and downstream boundary: from the main wall upstream to the extension of 150m, from the lower reaches of the lower reaches of the lower reaches of the extension of the 200m.

The upper and lower boundaries: on to the surface and at 1764.9m height (tail pipe bottom elevation at 1964.9m).

The computational coordinate system is defined as follows:

The X axis parallel to the axis of the plant. From the main plant to the horizontal direction of the tailrace surge chamber.

Y shaft vertical direction, vertical direction;

The Z axis parallel to the longitudinal axis of the surge chamber;

In the process of model building, the main building, the main transformer room and the tail room are simulated. At the same time, the influence of fault and alteration is considered. Rock mechanics parameters of surrounding rock are shown in table 2. The model is divided into 15083 elements and 30612 nodes. The model element is shown in Figure 2 and figure 3.

Table 2. Mechanical parameters of surrounding rock mass

Surrounding rock classification	Natural density	Tensile Strength of Rock	Poisson Ratio	Deformation Modulus	Shear strength of rock mass	
					f	c
	g/cm^3	MPa		GPa		MPa
Dwg$^{4-4}$	2.95	6.0	0.29	5.0	38	0.7
Dwg$^{4-3}$	2.81	5.0	0.28	7.0	40.0	0.8
Dwg$^{4-2}$	2.61	10.0	0.25	12.0	50.0	1.5
fault	2.40	1.5	0.36	0.8	20.0	0.05
Alteration zone	2.40	1.5	0.36	0.8	20.0	0.05

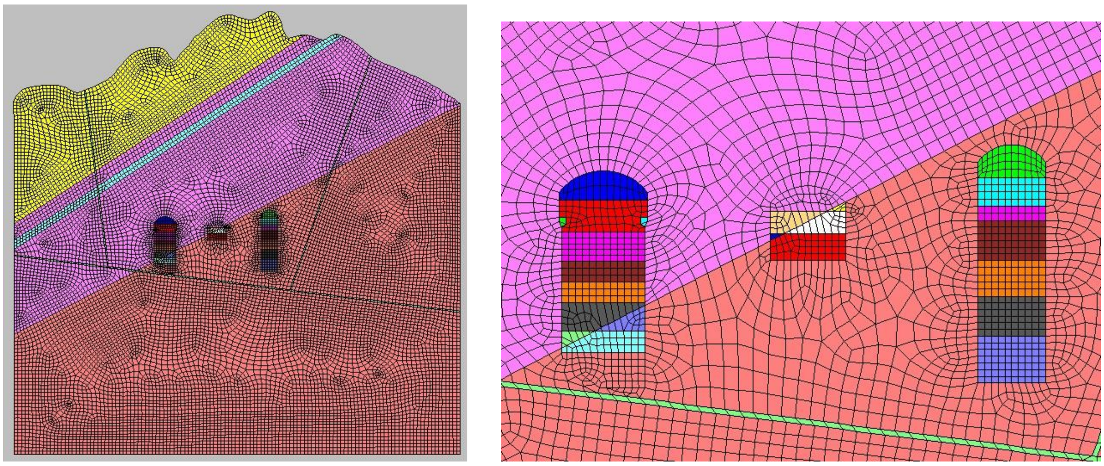


Fig. 2 The 35m distance between the main building and main transformer room

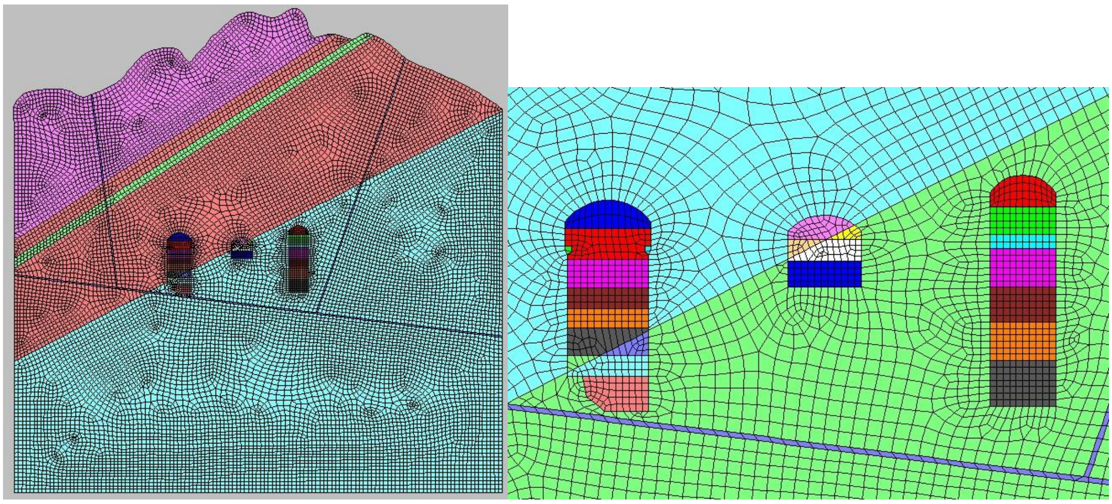
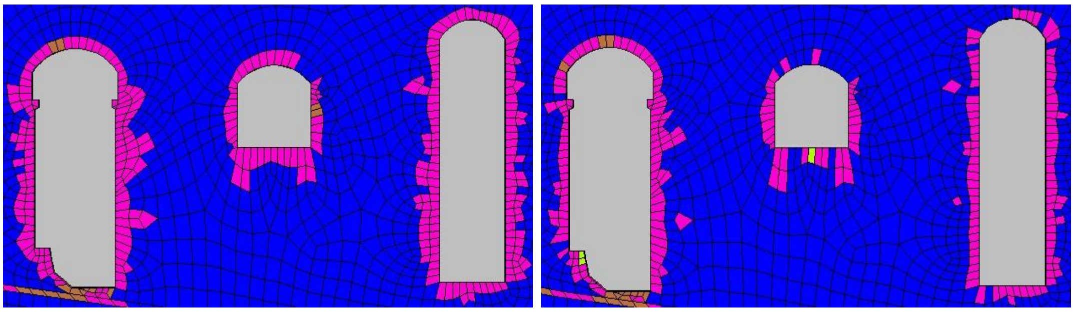


Fig. 3 The 40m distance between the main building and main transformer room

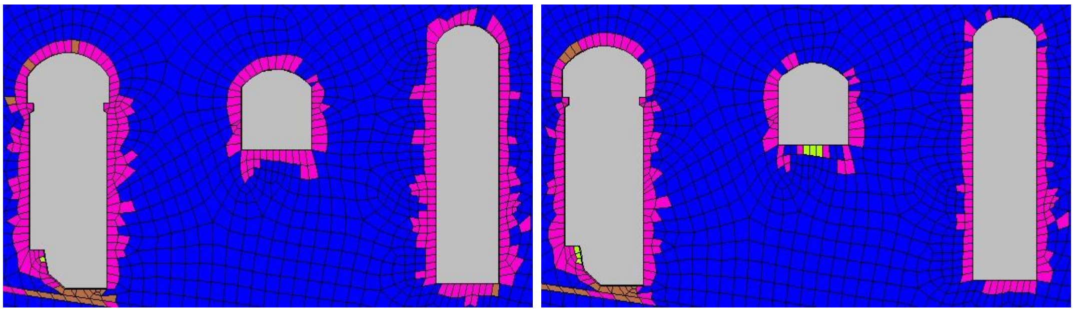
3. Comparative analysis of two kinds of cavern spacing

Figure 4 and figure 5 shows the distribution of plastic zones in the excavation of the tunnel under the condition of support and no-support in two schemes. Table 3 shows the volume contrast of the plastic zone around the cavity of the two schemes. As can be seen from the table, regardless of the working conditions of the hole or support conditions, the interaction of the tunnel interaction with 35 meters distance is relatively strong. Therefore, the plastic zone of the surrounding rock is larger. In particular, the variation of plastic zone around the main transformer room is relatively large. When the distance is 40 meters, the area of plastic zone around the hole is relatively small. Therefore, taking the distance of 40 meters is beneficial to the overall stability of cavern group.



No-support support

Fig. 4 Plastic zone of scheme 1 (35m)



No-support support

Fig. 5 Plastic zone of scheme 21 (40m)

Table 3. Two schemes' volume of plastic zone around the tunnel (m3)

Position	No-support		support	
	Scheme 1 (distance 35m)	Scheme 2 (distance 40m)	Scheme 1 (distance 35m	Scheme 2 (distance 40m)
Total plastic zone volume	11466	11069/-3.5%	9060	8884/-1.9%
Power house	3935	3786/-3.8%	3172	3176/0.1%
Main transformer hole	1707	1641/-3.9%	1268	1157/-8.8%
Tail water surge chamber	3685	3558/-3.4%	2510	2496/-0.6%

Supporting effect

Position	Scheme 1(distance 35m)		Scheme 2(distance 40m)	
	No-support	support	No-support	support
Total plastic zone volume	11466	9060/-21.0%	11069	8884/-19.7%
Power house	3935	3172/-19.4%	3786	3176/-16.1%
Main transformer hole	1707	1268/-25.7%	1641	1157/-29.5%
Tail water surge chamber	3685	2510/-31.9%	3558	2496/-29.8%

The layout of each key point was shown in figure 6.

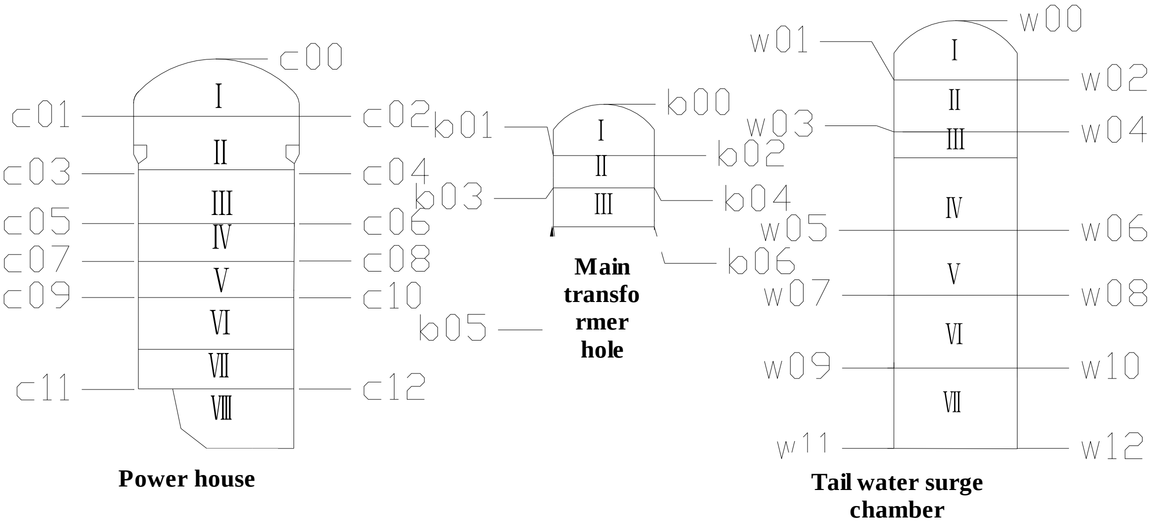


Fig. 6 Key points' layout of the surroundir

In Table 3, 4 and 5, the displacements of the key points of the main building, the main transformer room and the tail chamber are given under the two excavation schemes. As can be seen from the table, the change of the spacing has little influence on the displacement of the main building and the tail chamber, but the influence on the displacement of the main transformer chamber is relatively large. With the increase of the distance, the disturbance between the chambers is reduced relatively. Therefore, the displacement of the displacement of the interval 40m smaller, but the effect is not great. The change of displacement is less than 5%.

Table 3. The key points' displacements of the main powerhouse (mm)

Position	Key Point	Direction	Support		No-Support	
			Scheme 1	Scheme 2	Scheme 1	Scheme 2
Vault	ZC00	Combined displacement	14.445	13.989/-3.2%	14.038	13.658/-2.7%
	ZC01	Combined displacement	28.700	28.552/-0.5%	28.172	28.093/-0.3%
	ZC02	Combined displacement	16.209	16.382/1.1%	15.551	15.782/1.5%
Upstream side wall	ZC03	Combined displacement	40.680	40.619/-0.2%	39.984	39.974/0.0%
	ZC05	Combined displacement	46.114	45.994/-0.3%	45.237	45.197/-0.1%
	ZC07	Combined displacement	48.778	48.571/-0.4%	47.646	47.547/-0.2%
	ZC09	Combined displacement	49.883	49.713/-0.3%	48.546	48.401/-0.3%
	ZC11	Combined displacement	46.351	46.048/-0.7%	43.989	43.880/-0.2%
Downstream side wall	ZC04	Combined displacement	23.870	24.368/2.1%	23.103	23.692/2.6%
	ZC06	Combined displacement	27.486	28.082/2.2%	26.625	27.249/2.3%
	ZC08	Combined displacement	28.584	29.163/2.0%	27.537	28.183/2.3%

	ZC10	Combined displacement	26.964	27.193/0.9%	25.977	26.320/1.3%
	ZC12	Combined displacement	23.796	23.856/0.3%	22.301	22.636/1.5%

Table 4. The key points’ displacements of Main transformer hole

Position	Key Point	Direction	Support		No-Support	
			Scheme 1	Scheme 2		
Vault	ZC20	Combined displacement	21.299	20.838/-2.2%	20.788	20.479/-1.5%
	ZC21	Combined displacement	11.751	10.988/-6.5%	11.012	10.445/-5.1%
	ZC22	Combined displacement	10.395	10.755/3.5%	9.968	10.533/5.7%
Upstream side wall	ZC23	Combined displacement	6.676	6.527/-2.2%	6.474	6.155/-4.9%
	ZC25	Combined displacement	6.440	4.466/-30.6%	5.977	4.154/30.5%
Downstream side wall	ZC24	Combined displacement	5.162	6.243/20.9%	5.567	6.470/16.2%
	ZC26	Combined displacement	5.045	6.134/21.6%	5.486	6.545/19.3%

Table 5. The key points’ displacements of Tail water surge chamber

Position	Key Point	Direction	Support		No-Support	
			Scheme 1	Scheme 2	Scheme 1	Scheme 2
Vault	ZC00	Combined displacement	11.034	10.839/-1.8%	10.609	10.440/-1.6%
	ZC01	Combined displacement	14.756	15.042/1.9%	14.641	14.972/2.3%
	ZC02	Combined displacement	29.520	29.568/0.2%	29.281	29.361/0.3%
Upstream side wall	ZC03	Combined displacement	20.677	21.217/2.6%	20.741	21.254/2.5%
	ZC05	Combined displacement	25.490	26.455/3.8%	25.633	26.526/3.5%
	ZC07	Combined displacement	24.714	25.688/3.9%	24.862	25.826/3.9%
	ZC09	Combined displacement	20.348	21.386/5.1%	20.574	21.599/5.0%
	ZC11	Combined displacement	5.282	5.290/0.2%	4.996	5.016/0.4%
Downstream side wall	ZC04	Combined displacement	38.278	38.587/0.8%	38.046	38.364/0.8%
	ZC06	Combined displacement	46.711	48.011/2.8%	46.430	47.730/2.8%

	ZC08	Combined displacement	47.576	49.104/3.2%	47.153	48.692/3.3%
	ZC10	Combined displacement	42.666	43.514/2.0%	42.080	43.349/3.0%
	ZC12	Combined displacement	17.957	17.925/-0.2%	17.487	17.324/-0.9%

4. Conclusion

(1) From the view of the volume of plastic zone, the mutual influence of the excavation is increased due to the decrease of the distance between the two chambers. Therefore, spacing of 35 meters of the plastic zone volume significantly more than 40 meters high, unfavorable to the stability of surrounding rock mass.

(2) From the displacement of the key points in the hole, the influence of the change of space on the main building and the tail room is relatively small. However, the displacement of the main transformer chamber has a great influence on the displacement of the main chamber, and the displacement of the key point of the main transformer room is smaller than 40m. Overall, however, there is little difference in the displacement of the two schemes.

(3) Considering the plastic zone around the hole and the displacement of the key points, it is recommended to use the distance of 40 meters. Minimize the mutual influence of excavation. Guarantee the stability of surrounding rock.

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References

[1] BEAR J.Dynamics of fluids in porous media[M].New York:Elsevier, l972.

[2] Oda M.Permeability tensor for discontinuous rock masses[J].Geotechnique.1985,35(4):483-495.

[3] Oda M.An equivalent continuum model for coupled stress and fluid flow analysis in jointed rock masses[J].Water Resources Research.1986,22(13):1845-1856.

[4] Long J C S.Porous media equivalents for networks of discontinuous fractures[J].Water Resources Research, 1982, l8(3): 645-658.

[5] Peng S,Johnson A M. Crack growth and faulting in cylindrical specimens of Chelmsford granite. International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts , 1972,9(1): 37-86

[6] Y. Liu, Z. Chen, S. Li, J. Zhang, J. Gao Energy education scinence and technology PART A Volume 29 (1) April 2012. Experimental study on mechanical characteristic of weak interlayer in red-bed soft rock slope 467-474

[7] Griffith A.A. The theory of rupture [C]. Proc.1st Int. Congr. Applied Mech., Delft,1924:55-63.

[8] J. Wang, W. Tang, Y. Li, Y. Shen.Energy education scinence and technology PART A Volume 30 (1) October 2012

[9] Nolen-Hoeksema R.C. and Gordon R.B.Optical detection of crack Patterns in the opening-mode fracture of marble [J].Int. J. Rock mech. Mn. Sci. Geomech. Abdtr. 1987,24(4): 135-144.

[10] Li Xiaojing.The Study on Experiment and Theory of Splitting Failure in Great Depth Openings. Dissertation of shandong university.2007

[11] Sommer E. Formation of Fracture ‘lances’ in Glass[J]. Engineering Fracture Mechanics,1969,1: 539-546.