

Study on Monitoring Methods in Cavern Engineering Construction

Ge Tao^{1,a}, Zhang Zhigang^{1,b}

¹Aeronautics Engineering College, Air Force Engineering University of PLA, Xi'an, Shanxi, China

^agetaoge@163.com, ^b57931087@qq.com

Abstract. This paper has discussed the collection of monitoring in one national defense cavern. Based on the peculiarities of the cavern, many monitoring methods for crustal stress and displacement were compared and analyzed. Stress relief methods have perfect effect in crustal stress monitoring. Total station monitoring methods are used in multi-places in displacement monitoring which give accurate feedback to the cavern displacement and reverse-analysis. All of these ensured proper construction.

1. Introduction

The national defense project is a large cavern group engineering, located in the southern part of China. This project has the characteristics of large scale storage, complex geological conditions, construction operation, difficult construction, especially the main depot for large span and high side wall structure, and a multi junction tunnel, complex spatial relationships, a number of construction work long-term influence each other. These characteristics require that monitoring work should lay stress on key points, rational layout, scientific and timely information about displacement and stress change of surrounding rock supporting system in construction, so as to provide basis for designing and adjusting supporting parameters in order to ensure safety and progress of construction. The No. 1 cavern of the main cave consists of the main pit, the pit and the subsidiary caverns as is shown in Tab.1. The three sections of the main tunnel are located in the micro and weak weathered granite. The supporting measures include the combination of anchor and anchor cable, shot Crete support and concrete lining. The three main parts of the main pit are rock anchors and crane girders. The spatial relationship is very complicated. Safety, flat layered vaults of A2 layer in the excavation process of the tunnel excavation stability on both sides of the high side wall and the adjacent auxiliary excavation effect on main hole should not be ignored, the surrounding rock stress and displacement of the size and stability of cavern directly determines the safety, the engineering monitoring and construction must pay attention to the problem.

2. Layout of monitoring scheme

The main contents of site monitoring for monitoring program layout are as follows: (1) The determination of monitoring items, the selection of monitoring means and instruments and tools; (2) The determination of location and location of measurement points; (3) The formulation of implementation plans.



2.1 Determination of monitoring project

The principle of monitoring the project and determining the monitoring items is simple monitoring, reliable results and low cost, which is convenient for the construction units to use. The monitoring elements should be placed near the working face as far as possible. The concept of the measured physical quantity is clear, the value is significant, the data is easy to analyze, and the feedback is easy to be realized.

But the actual monitoring project should be based on the specific engineering characteristics to determine, mainly depends on: (1) The scale of the project, the degree of importance; (2) The shape and the size of the project structure, and support characteristic; (3) The size and orientation of stress; (4) The engineering geological conditions and construction process; (5) Methods; (6) To minimize interference construction under the condition of displacement to the main parts of monitoring the whole project, including a variety of different geological units and the complex parts of the tunnel structure. For shallow tunnels, surface settlement and vault settlement monitoring are important.

2.2 Determination of means and instruments

The instruments and instruments are determined with high precision total station and rod displacement meter, inductance displacement meter system and so on.

2.3 Layout of measuring points

The arrangement of measuring points of stress measurement accuracy is affected by the instrument itself and the use of the measurement method of impact, restricted by the engineering geological environment, rock conditions and other factors to a great extent, so the actual choice of measuring points mainly consider the following points:

- (1) In the original stress zone.
- (2) The mass of the rock mass.
- (3) Avoid the influence of the fault on the measurement results.
- (4) Avoid the stress distortion zone, the unstable region and the interference source, and consider the test conditions at the same time.

The cavern displacement deformation, deformation monitoring of surrounding rock on poor quality and local unstable block; feedback from the design and evaluation of rationality of supporting parameters should be set in the monitoring section, the representative area in engineering, special areas (such as hole and bifurcation) should also set up monitoring section. The measuring point of displacement and deformation should ensure the continuity of the measuring wire. The circumference convergence monitoring, the vault settlement, the multi point displacement meter and the surface settlement should be arranged on the same section as far as possible. The displacement meter is usually arranged in the vault, side wall and arch of the cavern.

In view of the current situation of the project, select the key section No. 1 main chamber II monitoring, adopt advanced instruments and means, and use the more complex cross triangle monitoring network in convergence monitoring.

2.4 Setting of measuring points

The setting of measuring points should be evaluated before the excavation of the tunnel. The selection of measuring points can select the location of boreholes according to the characteristics of the in-situ stress measurement.

Based on the information construction monitoring, considering the technology, economy and construction conditions, tables 1 and 2 show the main monitoring items, instruments and actual measurement points. The rod type displacement meter is used in the arch, vault and arch foot of the project.

Table 1 Instruments and equipments

Serial number	item	Model	Technical indicators			Number		
			range	Resolution ratio	Uncertainty	actual	Spare	Total
1	Total station	TC2002		0.1(mm) 0.1"	1(mm)+1(ppm) 0.5"	1		1
2	Level gauge	Ni005A		0.1(mm)	0.5(mm/km)	1		1
3	Inductance displacement tester	DGW-3				1		1
4	Sinking point					50	5	55
5	Displacement meter	SGJ-V	5points	0.01(mm)		24		24
6	Reflection point					16		16

Table 2 Stat. for monitoring items and points

Serial number	item		Position and quantity of measuring point			
	Monitor content	Use components	Number of sections	Number of each sections	Element quantity	Wire length
1	Pressure of surrounding rock	Ground stress measuring the surrounding rock of arch	1	5		
2	Vault settlement	Leveling point, Settling instrument	10	5	50	
3	Internal convergence	Convergence gauge, Displacement meter	4	6	24	
4	Space displacement	Total station	4	4		
5	Ground displacement	Multipoint Displacement Meter	4	6	24	4×38(m) 4×30(m) 4×20(m)

The actual monitoring instrument, the internal displacement convergence of the main tunnel cavern vault settlement, cavern and dimensional displacement monitoring in the side wall and the arrangement of measuring points:

(1) Convergence displacement monitoring

The method of convergence displacement monitoring convergence displacement monitoring mainly adopts convergence gauge and displacement meter prototype monitoring instrument combination, can also be carried out using 3D displacement monitoring total station, by contrast the monitoring results of different times, the relative convergence indirectly reflect the cavern. In the convergence gauge and displacement meter by monitoring, using the above complex cross triangle monitoring network, measuring points along the wall layout, can accurately reflect the displacement of wall, bar type displacement meter with the wall, at the same time with the convergence of the displacement meter.

(2) Vault settlement

The settlement of the vault settlement in the vault settlement is arranged and monitored during the excavation of the A2 layer of the flat arch. A total of 10 sections were arranged and the distance was 20m. 5 sinking points are embedded in each section, and the distance is 5m. A total of 50 measuring points are needed and 5 additional reserves are added, with a total configuration of 55. The sinking point should be located near the excavation surface (within 3M). The settlement monitoring of the vault can be fitted with the convergence meter. According to the principle of convergence measurement, the settlement of the vault can be measured through the derivation and calculation, and the settlement monitoring of the vault can be directly arranged by the settlement instrument. In this project, the vault sinking point is

buried on the top of the tunnel by the expansion screw, and the settlement of the vault is measured by a settling instrument or a high precision horizontal instrument.

(3) Monitoring of three-dimensional displacement of the cavern

The construction site with the total station reflector measurement points, the layout of 4 transects, the micro weathering section and the weak weathering section are arranged 2 sections (the same section as the electric anchor). 4 measuring points are embedded in each section, the upper and middle two layers are buried, and each layer is two points. A total of 16 reflection points are needed. The time for reflection measurement is as follows: during the B1 layer excavation, the upper measurement points are placed and observed. After the excavation of B1, C1 and A1 layers, the middle level measurement points are placed, and the upper and middle measurement points are observed. The monitoring sections are all determined according to the actual situation.

(4) Middle displacement of the surrounding wall of the hole

The middle displacement inductance bar type borehole displacement meter in the surrounding wall of the cave is arranged and buried during the excavation of the A2 layer and begins to be monitored. A total of 4 sections were arranged, both in the breeze and weak weathering sections. 6 inductor type displacement meters are embedded in each section, and 3 on the left and right walls. 24 inductance type drilled displacement meters must be buried in all. The displacement meter is long 10m and has 5 displacement points. The distance between the measured points is 1, 1, 1, 2, and 5m. The 5 points displacement meter are embedded in the hole of the side wall, and the depth of the hole is 10.5m.

3. Applicability analysis of monitoring methods

This paper mainly studies and analyzes from two aspects: the in-situ stress and displacement deformation. The in-situ stress measurement is based on the engineering geological conditions and adopts different monitoring methods. The caverns are mainly located in the third section of surrounding rock belt, for rock, length 90m, and weakly weathered granite weathered hard rock - and more complete, the whole structure, the fissure is developed, more pressure, there is a group of high angle joints, affect the integrity of rock mass. According to the drilling revealed in the elevation of 22.4~24.7m and -6~8m, existence of fracture zone, broken rock. The test ground stress is mainly concentrated in this area. But the granite in the left side is weak weathering, the rock mass is basically block structure, there is a fault, the rock mass on both sides of the fault is broken, and the integrity is destroyed. Therefore, the influence of the left fault should be considered when monitoring the ground stress. At the same time, due to the ups and downs of the mountain, the space stress is concentrated and the stress is complex. It is necessary to monitor the ground stress in time before and during the construction process.

According to the actual construction of this project, the practicability of various monitoring methods in this project is discussed in turn.

Direct measurement of ground stress, flat jack method, rigid inclusion gauge method, hydraulic fracturing method, due to the existence of fracture zone on the left side, and belongs to the fault, rock pressure, change greatly, and considering the actual operation problems, does not recommend the use of these methods.

In the main cavern, rock hard, however, due to the fault and the middle layer of the main hole for crushing, and other important cavern, acoustic emission method can be used as an auxiliary means of measurement, around the hole in the ground stress measurement by acoustic emission method.

There are many kinds of stress relief methods in indirect measurement of crustal stress. Surface stress relief method can be used to measure rock mass stress on both sides of the fault, such as rock mass intact hard area, A1 small hole upper surface stress. The technology of bore hole stress relief is very mature, and has standardized measurement procedures. As long as the reasonable placement of measuring points can be used to monitor the crustal stress in every cavern of the project. The partial stress relieving method is a part of the stress relief of the measuring point, but it is not suitable to use this method in the measurement of three dimensional geostress. In addition, borehole holographic interferometry, parallel drilling and central drilling, borehole delay survey and local wall stress relief are all considered.

Considering the complexity of the engineering rock mass or the immaturity of monitoring methods, it is not suitable for the project.

Therefore, The stress monitoring method should be determined based on the engineering geological conditions, , the excavation before drilling in the roof and will be extended to the deep hole drilling than 20m, the number of holes should not be too much, too much will affect the integrity of rock mass, the fault, also should carry out stress measurements. In the course of construction, stress monitoring should be carried out at the top of the cavern with the construction.

Displacement deformation monitoring method, traditional instrument monitoring method because of its convenient operation and flexible, with its broad applicability for monitoring the detailed structure, such as the measurement of small range of cavern, at the junction of the main hole and the hole line positioning and excavation leveling level, determine the precise location of monitoring points, bolt the distance. The traditional monitoring method is a necessary monitoring method, which is also applied in the project.

There are many kinds of prototype monitoring instruments used in prototype monitoring instrument measurement. They can be applied to this project in terms of their performance, but their results are all affected by instrument accuracy.

The total station monitoring method can change with the engineering practice and is very flexible, and it is also widely used in this project. In the project, the free station method and the fixed station method can be used to monitor the tunnel, and the remote monitoring can be realized by the rear intersection method. The total displacement of the cavern can be measured at any place in the middle of the whole cavern. It can be measured with other instruments.

Near view photogrammetry, which is mainly influenced by the visual condition, requires high conditions, so this method is rarely used in this project.

4. Conclusions

The application of borehole overcoring technique the measurement technology is the most mature method for in-situ stress measurement, stress measurement in the cavern, and can obtain very good results. The displacement of the cavern engineering deformation monitoring in many parts of the total station monitoring, accurately grasp the spatial displacement of the whole main tunnel, laid the foundation for the back analysis of displacement of cavern, ensure the smooth progress of the construction. The measurement method of this project can be popularized.

References

- [1] B. Amadei, O. Stephansson. Rock stress and its measurement [M]. London:Chapman & Hall, (1997).
- [2] Gao Wei, Zheng Yingren. Discussion of some displacement prediction methods in geotechnical engineering[A]. Chinese Society for Rock Mechanics and Engineering. Proceedings of the Chinese Society for Rock Mechanics and Engineering Sixth Academic Conference[C]. Beijing: Science and Technology of China press, Vol.25(6) (2000), p.90-p.93.
- [3] C.L.Smith, D.R.Schmitt, T.J.Ahrens. Analysis and Modelling of Holographic Measurements of In Situ Stress[J]. International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts, Vol.25(6) (1988), p.353-p.362.
- [4] Feng Zhongren, Zhang Xingcai, Zhang Shixiong, et al. Monitoring study on drift deformation of daye iron mine[J]. Chinese Journal of Rock Mechanics and Engineering, Vol.23(3) (2004), p.483-p.487.