

Study of blasting seismic effects of underground powerhouse of pumped storage project in granite condition

Sheng Wan^{1,2,*}, Hui Li³

¹Hubei Key Laboratory of Road-bridge and Structure Engineering, Wuhan University of Technology, Hubei, Wuhan,

²Qingyuan Pumped Storage Power Generation Co., Ltd, Guangdong, Qingyuan, China

³SINOHYDRO BUREAU 14 CO., LTD. Guangdong, Guangzhou, China

*Corresponding first author e-mail: 37364674@qq.com

Abstract. Though the test of blasting vibration, the blasting seismic wave propagation laws in southern granite pumped storage power project are studied. Attenuation coefficient of seismic wave and factors coefficient are acquired by the method of least squares regression analysis according to Sadaovsky empirical formula, and the empirical formula of seismic wave is obtained. This paper mainly discusses on the test of blasting vibration and the procedure of calculation. Our practice might as well serve as a reference for similar projects to come.

1. Introduction

Pumped storage power station water diversion and power generation system consists of long tunnel and underground caverns. Guangdong has built pumped storage power station with about 500m water head difference in general, around 300 ~ 400m buried depth of underground plant^[1]. The underground powerhouse of the pumped storage power station in the area of South China power grid is largely deep buried in the granite body^[2]. During the excavation of underground powerhouse, blasting is usually used. Granite is featured with high shear strength, large compressive modulus and porosity, low water content, and among others^[3]. At the same time, granite, as a kind of rock material, has the characteristic of brittle damage^[4].

In the study of blasting seismic effect, Li Xinping^[5] and others have researched blasted damage scope and criterion of conventional hydropower station underground powerhouse with methods of on-site blasting vibration tests and data simulation, and get the speed of the blasting particles of corresponding parts. Luo Yi^[6] and others simulate cumulative damage effect of blasting and excavation of rock mass; introduce parameters of degrading with numerical simulation calculation upon excavation and explosion, considering the deterioration of rock mass parameters of different degrees of damages in calculation. With field tests and research, Zhang Wenxuan and Lu Wenbo^[7] have concluded formula for calculating of rock explosive and damage scope based on peak velocity of particle and vibration speed. Bauer A^[8] and others have achieved rock explosive damage peak vibration velocity through the test and research, and take it as the



judgment basis of rock blasting damage. Yan Changbin ^[9] and others have established corresponding relations between the rock mass damage and the sound speed change with multi blasting effects through the rock mass acoustic wave test and the regression analysis.

2. General condition

2.1. General description

The underground powerhouse of Qingyuan pumped storage power station consists of three parts-main room, auxiliary workshop and installation field. The excavation size is 169.5×25.5×55.7 m, and there are 16 openings in the tunnel. The rock wall beam is located on the upper and lower side wall of the second floor of the workshop.

2.2. Engineering geology

The underground plant is mainly distributed in coarse grained biotitic granite of Yanshan III (γ52(3)), featuring with deep, medium deep into the intrusive body, good integrity. The rock, rock strain and dikes are exposed. In the granite body, there is a small amount of kaolin alteration, chlorite alteration. Most of them are irregular mass, and they are developed along both sides of fault structure and fracture zone. The geological structure in the powerhouse area is mainly composed of faults and fissures. There are 3 main groups of fracture, nearly NE to the most joint developed, the occurrence of N25°~40°E/NW∠55° to 85°, followed by NW, NNW trend and all of them are high deep angle.

3. On-site test

3.1. Excavation design

The excavation of underground powerhouse is divided into eight floors from top to bottom, and the height of each floor is from 4.05M to 11.2m.

3.2. Blasting parameter design

In order to obtain reasonable blasting parameters during the excavation of the powerhouse, based on the analysis of blasting results, the preliminary blasting parameters are determined and adjusted continuously according to the actual conditions during excavation. The parameters of the basic blasting hole network are shown in table 1.

Table 1. Basic Parameters of Blasting Borehole Net

hole diameter(mm)	hole spacing(m)	row spacing(m)	hole spacing(m)
φ=42	2.0—2.5	0.6—0.8	4.5—5.0

3.3. Blasting vibration test

3.3.1 Instruments. It consists of three parts, a sensor, an intermediate switch (including an amplifier) and a recording device.

3.3.2 Layout of measuring points. The measuring points are arranged in the base-floor of the building, the side wall and other places, and the vibration measuring points are arranged to observe the blasting vibration. The blasting vibration measuring points are arranged according to density and distance, and each sensor is arranged in line with vertical, horizontal, radial and horizontal tangential directions.

3.4. Blasting and vibration test results

In the field of engineering blasting, Sa Rodolfo J Ki's empirical formula of blasting vibration is adopted to express the law of vibration spreading and attenuation:

$$v = K \left(\frac{\sqrt[3]{Q}}{R} \right)^{\alpha} \quad (1)$$

among which:

V: blasting particle vibration peak velocity (cm/s);

K, geological factors and blasting method of seismic wave attenuation coefficient; α is associated with geological conditions;

Q is the maximum explosive charge corresponding to the V value of the vibration velocity (Kg) ;

R is the straight-line distance between the measuring point and the center of explosion (m). The test results of vibration velocity of partial particle blasting are shown in table 2.

Table 2. Datas Of the Blasting Vibration Test

Surveying Points	(m)Blasting core distance	(cm/s)Peak velocity of particle vibration	(Hz)Vibration Frequency
1 [#]	33.24	Verticality	11.756
		longitudinal	10.376
		horizontal	10.916
2 [#]	50.82	Verticality	3.538
		longitudinal	3.397
		horizontal	2.374
3 [#]	29.45	Verticality	12.248
		longitudinal	16.639
		horizontal	8.838
4 [#]	41.54	Verticality	6.232
		longitudinal	4.455
		horizontal	4.539
5 [#]	31.52	Verticality	14.452
		longitudinal	7.196
		horizontal	5.671
6 [#]	38.90	Verticality	6.218
		longitudinal	5.845
		horizontal	5.2
7 [#]	52.74	Verticality	3.793
		longitudinal	4.606
		horizontal	3.567
8 [#]	73.74	Verticality	3.589
		longitudinal	2.467
		horizontal	2.936
9 [#]	30.12	Verticality	17.739
		longitudinal	8.342
		horizontal	6.397
10 [#]	40.95	Verticality	4.774
		longitudinal	7.106
		horizontal	4.618

4. Data analysis

4.1. Peak vibration velocity, regression analysis

Regression analysis of test data are adopted by least square method

On both sides of the same type of natural logarithm:

$$\lg v = \lg k + \alpha \lg \left(\frac{\sqrt[3]{Q}}{R} \right) \quad (2)$$

$$\text{if: } y = \lg v \quad x = \lg \left(\frac{\sqrt[3]{Q}}{R} \right) \quad k = \alpha \quad b = \lg k$$

$$\text{get } y = b + kx \quad (3)$$

Take regression analysis of measured data in Table 3, the K, α value of the main powerhouse cavern is obtained:

Verticality: $k=141.06$, $\alpha=1.322$; correlation coefficient: $r=0.96$

longitudinal : $k=133.78$, $\alpha=1.348$; correlation coefficient: $r=0.85$

horizontal : $k=146.46$, $\alpha=1.304$; correlation coefficient: $r=0.95$

4.2. Maximum charge analysis

Based on formula (1), the maximum explosive charge for ensuring the safety of buildings around the blasting area is calculated as follows:

$$Q_{\max} = R^3 \left(\frac{v}{k} \right)^{\frac{3}{\alpha}} \quad (4)$$

According to the specification of different types of safe velocity of ground particle buildings has a corresponding provisions, the most conservative $v=7$ cm/s in the standard, get the distance relations between the maximum charge and core detonation

$$\text{Verticality: } Q_{\text{verticality}} = 0.001097 R^3 \quad (5)$$

$$\text{Longitudinal: } Q_{\text{longitudinal}} = 0.001408 R^3 \quad (6)$$

$$\text{Horizontal: } Q_{\text{horizontal}} = 0.000916 R^3 \quad (7)$$

among which, Q is the maximum explosive charge (Kg); R is the maximum straight-line protective distance (m) from the explosive core.

5. Safety Control of Blasting Seismic Effect

5.1. Blasting characteristics of surrounding rock

1) Based on Table 2 and formula (3), it can be seen that in the geological conditions of granite in the underground powerhouse, the vertical vibration velocity of particles is larger than horizontal vibration velocity due to vibration caused by excavation blasting.

2) It can be seen from table 2 that the explosive stress wave caused by blasting can cause the damage of rock are waning obviously with the increase of detonation distance. When the core distance is less than 40m, the vibration velocity of the measuring point is large; when the core

distance is greater than 40m, the vibration velocity of the measuring point is rapidly attenuated.

3) Formula (4) ~ (6) attenuation coefficient α in blasting earthquake, the blasting seismic wave in horizontal vertical range, attenuation is the fastest, slowest in horizontal; overall horizontal decay rate is slightly larger than the vertical attenuation velocity.

4) The blasting damage of rock mass is anisotropic. The spreading velocity of particles in three-dimensional space is inconsistent, which leads to the formation of tensile fracture and failure form with anisotropic properties. Therefore, it is very important to protect the integrity of rock mass by adopting different sections and firing sequences.

5) the largest section of explosive dose Q , we can see that in the case of the same explosion distance, the horizontal charge is the minimum, the vertical charge is the maximum.

5.2. Blasting safety control

1) Rational controlling dose charge Q

It can be concluded from the formula (1) that the measuring point is the same as the detonation distance under the same rock mass and construction conditions, the relationship between the vibration velocity of particle blasting and V of single stage charge is Q :

$$V_2 = V_1 \left(\frac{Q_2}{Q_1} \right)^{\frac{3}{\alpha}} \quad (8)$$

According to the measured data, $\alpha=1.3$, when the single charge $Q_2=0.5 Q_1$, $V_2=0.74 V_1$, damping effect can reach about 30%.

2) Section mode and the firing sequence shall be chosen

It can be seen from the table 2 that the vibration frequency of the surrounding rock of the underground powerhouse is in the space, such as the frequency of vertical blasting, and the vibration frequency is about 400Hz. During the blasting test stage, different fragmentation modes and firing sequences can be adopted to avoid the superposition of stress waves caused by millisecond blasting delay time so as to make the vibration increase and even resonate.

3) Reasonable arrangement of blasting methods

By making comparison with blasting factor coefficient in formula (3), it can be seen that the K value of blasting seismic spreading attenuation formula in surrounding rock of underground powerhouse is large. Therefore, in underground powerhouse excavation, reasonable blasting method is adopted to increase pre-splitting blasting or increase the free surface of blasting with other means, It can play an effective role in reducing the blasting vibration caused by excavation.

6. Results

6.1. Effect of building blasting

The residual hole rate of top arch blasting:100% I-grade rock,98.5% II-grade rock, under-excavation of rock wall, 0 ~ 12 cm of over-excavation, 0 ~ 8.6 cm of uneven level, stage is generally not more than 15 cm, spacing deviation of light blasting hole is 0 ~ 5 cm.

6.2. Light blasting effect of rock face beam

The residual hole rate of top arch blasting:100% I-grade rock, 98.3% II-grade rock, under-excavation of rock wall, average over-excavation is 6.6 cm, 0 ~ 6 cm of uneven level, stage

is generally not more than 5cm, spacing deviation of light blasting hole is 0 ~ 4 cm.

6.3. Presplitting Effect of building

The residual hole rate of side-wall presplitting:97.2% I-II grade rock, under-excavation of rock wall, 0 ~ 15 cm of over-excavation, 0 ~ 8.3 cm of uneven level, stage is generally not more than 12 cm, spacing deviation of light blasting hole is 0 ~ 5 cm.

7. Conclusion

According to the parameters of the excavation and spreading rules of blasting seismic wave of Qingyuan pumped energy storage power station plant under the granite geological conditions resulted from field test, it can guide the on-site construction properly, effectively reduce country rock damage resulted from excavation. In line with later monitoring data, the research results have achieved good results and have reference value for blasting vibration control of similar projects.

References

- [1] LUO Shaoji, LIU Xueshan. Underground Power house Complex Risk Control in Pumped Storage Power Station Project [M].COLLECTED PAPERS OF PUMPED STORAGE POWER STATION CONSTRUCTION, 2013:120-124.
- [2] WANG Huiming, etc. Study On The Engineering Geologic Condition Of High-Pressure Concrete Lining Tunnel In Pumped Storage Power Station[J].GUANGDONG WATER RESOURCES AND HYDROPOWER, 2006 (11) : 8-10.
- [3] HUANG Guoliang. Construction Character and Methods of Completely Weathered Granite, 2003(1):53-55.
- [4] Chinese Society of Theoretical and Applied Mechanics. BLASTING ENGINEERING (Vol.2) [M].Pekin: Metallurgical Industry Press, 1992.
- [5] LI Xingping, etc. STUDY OF BLASTING SEISMIC EFFECTS OF UNDERGROUNDCHAMBER GROUP IN XILUODU HYDROPOWER STATION[J]. Chinese Journal of Rock Mechanics and Engineering, 2010,30 (3) : 493-501.
- [6] LUO Yi, etc. Characteristic study of surrounding rock mass deformation considering accumulative damage effect [J]. Rock and Soil Mechanics, 2014 (11) : 3041-3048.
- [7] ZHANG Wenxuan, LU Wenbo. EVALUATION OF BLAST-INDUCED DAMAGE ZONE IN EXCATION BLASTING OF LONGTAN UNDERGROUND WORKSHOP[J].ENGINEERING BLASTING, 2008,14 (2) : 1-7.
- [8] BAUER A, CALDER P N. Open Pit and Blast Seminar[J]. Kingston, Ontario, Canada: Mining Engineering Department, Queen University, 1978.
- [9] YAN Changbin, Xu Guoyuan, etc. Measurement of sound waves to study cumulative damage effect on surrounding rock under blasting load [J]. CHINESE JOURNAL OF GEOTECHNICAL ENGINEERING, 2007,29 (1) : 88-93.
- [10] SUN Mingzhi. Based on the principle of least squares regression analysis blasting vibration [J]. SHANXI ARCHITECTURE, 2008,9 (27) : 130-131.
- [11] China Society of Explosives and Explosives and Blasting, GB6722—2014 Safety Regulations for Blasting [S], Pekin: China Standards Press, 2014.