A STUDY ON THE BLASTING VIBRATION CONTROL OF CREEP MASS HIGH SLOPE

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ABSTRACT :
The borehole blasting vibration of the creep mass high slope of a hydropower station is observed, analyzed and processed. The decay experience formula of the blasting earthquake wave is obtained, with which elevation effect is considered. Based on features of the creep mass high slope of the hydropower station, several damage standards for the borehole blasting vibration are given. On the basis of the decay experience formula and damage standards, the blasting safety control parameters of new cast-in-situ concrete of the creep mass high slope are derived. At last, in the light of construction characteristics of the creep mass high slope, the control measures of the blasting vibration are proposed. The construction effects of the project prove that the research achievements of this paper are applicable in the project, and the blasting of the project is satisfactorily finished.

KEYWORDS:
high slope; blasting vibration; elevation effect; control

According to the engineering geological conditions of the hydropower station slope, its slope includes two rock area, i.e., creep mass rock area and downstream and integrity rock area. Creep mass of the power station is close to the left abutment of imports and its upstream section's， with a distribution of approximately 750m along the river, and an elevation of 230-650m, a vertical depth of 30-76 m. The total volume is 1288 × 104m3. The course of the strata is nearly parallel to the shore rock slope, inclining to the mountains with a slope angle of 28~37. Soft and hard rock phases run alternatively. There is dislocation development between the rock phases. Also there exists structure in the same direction with that of the slope. As to foot Luolou (siliceous rocks, mainly limestone siliceous mudstone, with a small number of siltstone interbedding fabric), clay gouged intercalation develops in the strata; modulus of deformation is low. F63, F69 and F147 Fault and the gulch cutting further undermine the continuity of the layered rock. During the geological period, due to the long-term weathering, rock breaks into loose shape, and jointed fracture develops, filled with secondary mud. Under the influence of general agency including self weight, the strata bend, break and fall slowly toward the direction of the slope until partial collapse and landslides take place. Therefore, blasting is the key of the high slope engineering. In order to ensure the safety and stability of the creep mass, monitoring and control of its deep hole blasting vibration level is applied.

1. BLASTING AND TESTING

Blasting technology applied in the construction includes deep presplit blasting technology and shallow slope plastic blasting technology. Deep borehole blasting is the main method with hole depth of 10 to 20 m, diameter of 140 mm. The distance between holes is (4~5) × (5~6) m, the line of resistance is 3 to 4 m, and the explosives consumption is 0.35 ~ 0.45Kg/m3. Generally, two holes form a section. Elementary error outside the hole is used. A total of 15 non-conductive squibs are adopted. Two ways of charging are used, namely, mixed bag charging and two-way charging. The charging structure is continuous charging. The maximum amount of explosive for one time is 150 to 300 Kg.
More than 60 numbers of 8 groups are collected. Part of the data is presented in Table 1, and the vibration waveform measured is as shown in Figure 1.

Table 1 Test Data

Measuring point	Elevation gap from the blasting center *H*/*m*	Horizontal distance from the blasting center *D*/*m*	Straight distance from the blasting center *R*/*m*	Maximum charge *Q*/*Kg*	Vibration velocity $V/cm.s^{-1}$
1	16	66	69	180	3.346
2	23	99	101	220	2.175
3	36	110	115	180	1.289
4	46	186	190	220	0.656
5	54	92	108	110	1.08
6	66	211	220	95	0.286
7	86	182	201	95	0.392
8	95	146	175	96	0.535
9	115	117	212	96	0.718
10	135	220	259	96	0.265

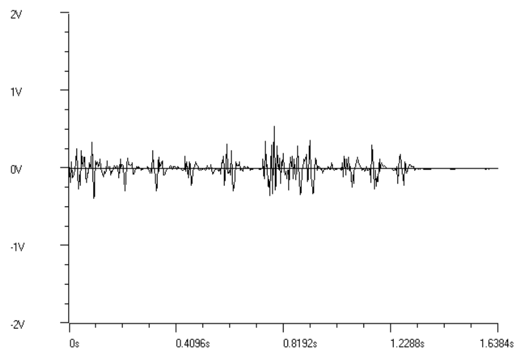

Fig.1 Typical vibration waveform of blasting

2. REGRESSION ANALYSIS

Blasting in accordance with national safety regulations and research achievements at home and abroad, the following experience formula is usually adopted for the dissemination and attenuation of the blasting vibration

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

Where: V for blasting vibration speed, cm / s; K for coefficient related with such factors as the geology environment and blasting method; α for seismic wave attenuation coefficient related with geological conditions; Q for the maximum priming dose one time corresponding to the velocity V, Kg; R for the straight distance between the measuring points and the explosive center, m; $\rho = \sqrt[3]{Q}/R$ for the proportion of charge.

The formula above applies to flat terrain. While for site with larger elevation difference, the altitude effect of the blasting seismic wave propagation should also be considered. Therefore, the formula should be revised as

$$V = K\left(\frac{\sqrt[3]{Q}}{D}\right)^{\alpha}\left(\frac{\sqrt[3]{Q}}{H}\right)^{\beta} \tag{2}$$

Where: D for the horizontal distance between the explosive center and the measuring points, m; H for the difference of elevation between explosive center and unexploded measuring point, m; β for the elevation influence coefficient, and the other symbols mean the same to the aforesaid.

Linear regression[4-6] based on data measured is performed. Without considering leveling effect, r=0.862, and the regression accuracy requirements are met. After several point farther away from the regression line, r=0.928, which is a more desirable result, and further obtain the following results: k=218.7762, α=1.8418. Therefore, without considering the evaluation effect of blasting vibration velocity, the empirical formula should be as follows:

$$V = 218.7762\left(\frac{\sqrt[3]{Q}}{R}\right)^{1.8418} \tag{3}$$

When considering the elevation effects, after the regression, ∣ F ∣ = 27.66 ≥ F0.01 (2, 43) = 5.15, thus a significant linear relationship is observed and the accuracy requirements of the regression is met. It can be further obtained that k=205.2262, α=1.4986 and β=0.2855. Therefore, considering the altitude effect, the empirical formula for blasting vibration speed should be

$$V = 205.2262\left(\frac{\sqrt[3]{Q}}{D}\right)^{1.4986} \cdot \left(\frac{\sqrt[3]{Q}}{H}\right)^{0.2855} \tag{4}$$

After comparing the data measured with the calculation results of the experience regression formula, it can be proved that the deviation of empirical formula from the data measured is greater when the elevation effects is not considered. This is due to the big elevation difference of the creep mass slope (the height of the entire slope is about 300 m with each grade level 20 m). With the increase in elevation of the slope from the explosion source, the elevation amplification effect of vibration gets more obvious. Thus, for blasting vibration control of the creep mass of high slope, it is recommended to adopt empirical formula with consideration of the elevation effect.

3. CRITERIA AND SECURITY CONTROL PARAMETER

3.1 destruction standards of blasting vibration

Physical data that measure blasting earthquake strength include particle velocity, acceleration and displacement caused by blasting vibrations. Currently particle velocity is adopted as a criterion in most cases at home and abroad. Since destruction that cause by blasting vibrations to buildings, structures, and rock are under the influence of many complex factors such as the complexity of the destruction process and geotechnical media variability, there is no uniform requirement as to the permissible criteria for destruction of blasting vibration. Generally it is determined based on the current research results and the specific engineering facts.

During construction, the main object for protection is the creep mass high slope designed and the freshly-placed concrete support structures. According to the national Safety Regulations for Blasting (GB6722-2003), Construction Technical Specification for Rock Foundation Excavation Engineering of Hydraulic Buildings (SL-94), as well as domestic and foreign research results and engineering experience, especially the specific geological conditions of the creep mass high slope, the following criteria is proposed: for creep mass high slope the security particle velocity is [v] = 6cm/s; the particle velocity security of the fresh concrete retaining structure is as Table 2.

Table 2 The safety vibration velocity of the particle of new cast-in-situ concrete

Concrete age /d	0~3	3~7	7~28	>28
Safety vibration velocity /$cm.s^{-1}$	≤2.0	≤3.0	≤5.0	≤8.0

3.2 security parameters control

According to criterion and the empirical formula, vibration control security parameters of various parts of blasting creep mass high slope can be derived. According to the construction characteristics of creep mass slope, under normal circumstances, during the whole construction process of creep mass high slope, it is impossible to wait until all the fresh-placing concrete within the support district arrive its age (28 d) to perform blasting construction, and it is also impossible to give support after the completion of the blasting of the entire project. Blasting and supporting are alternatively performed throughout the entire construction process. Therefore, during the whole period of engineering, the first object demanding protection is the fresh concrete support. It is because the fresh concrete support does not reach age (28 d). At this time, its permissible security velocity is still lower than the safe velocity for the high slope in question. In this way, as long as the permissible safety velocity of the fresh concrete support is met, the permissible safety velocity safety velocity of the slope designed is met. The safety vibration control parameters (the maximum amount of charges used for a section in blasting, Qmax) is analyzed in the following paragraph.

Based on the permissible safety vibration velocity of the fresh concrete support and the empirical formula for the regression of creep mass, the corresponding relationship between allowable maximum charge Qmax (Kg) of the blasting of new cast-in-situ concrete at the creep mass slope with the horizontal distance D (m) and the elevation H (m) can be derived, as shown in table 3.

Table 3 The relation of Qmax（Kg） with D（m）and H（m）

Concrete age 0-3*d*						[*v*]≤2.0*cm/s*			
H/D	20	30	40	50	60	70	80	90	100
20	Q_{max}	10	19	33	50	78	109	147	192
40			Q_{max}	46	73	108	152	205	267
60					Q_{max}	132	185	249	325
80							Q_{max}	292	381
Concrete age 3-7 *d*						[*v*]≤3.0*cm/s*			
H/D	20	30	40	50	60	70	80	90	100
20	Q_{max}	18	38	66	105	155	216	291	379
40			Q_{max}	92	146	215	301	405	529
60					Q_{max}	261	366	493	643
80							Q_{max}	579	755
Concrete age 7-28 *d*						[*v*]≤5.0*cm/s*			
H/D	20	30	40	50	60	70	80	90	100
20	Q_{max}	43	89	156	247	364	510	687	896
40			Q_{max}	217	345	508	712	958	1249
60					Q_{max}	618	865	1164	1518
80							Q_{max}	1366	1782

4. BLASTING EARTHQUAKE CONTROL METHODS

4.1 Reduce the amount of the charge Q

To reduce the amount of the charge is the most direct and effective measure to control blasting earthquake. From (1) it can be seen that when the distance R, lithologic character and blasting conditions are the same, the relationship between the sound particle velocity V1 and V2 and amount of the charge Q1 and Q2 is: $V_2 = V_1[Q_2/Q_2]^{\frac{\alpha}{3}}$ .When α=1.3~1.9, when the amount for a section is reduced from double hole (often 2~4 holes in the same segment for conventional blasting) to single hole for one segment, if the amount of the charge Q2= 0.5Q1, then V2 = (0.74~0.64) V1, VR is about 30％.

4.2 Change the direction of the line of least-resistance W

According to the mechanical principles, theoretically, in similar geological and terrain conditions and lithologic environment and when the blasting parameters are the same, the direction where earthquake effect is the strongest is in the least resistance W's rear, while at its side the effect is weaker. Therefore, a slash or V-shaped initiation scheme is recommended.

4.3 A reasonable choice of the time interval of initiation Δt

A complete single-blasting seismic wave should include the early phase, the main shock and aftershocks of the phase. The cycle of main shock is generally 20~50 ms. In order to avoid that a vibration wave overlap with the wave of the next segment, the time interval Δt for the next segment should be identified to ensure that the initiation occurs after the completion of the aftershocks, i.e., Δt≥50 ms. But in practice, because the hole is in relatively great number while the non-conductive detonators (or electric detonators) is in relatively small number, it is recommended to increase the number of non-conductive detonators (or electric detonators).

4.4 Presplit blasting

Practice proves that the presplit blasting VR rate is above 30％ in most cases. In some cases, this rate achieves over 50％. Presplit blasting has become an effective VR measure that is commonly used.

4.5 Elementary errors

In case of great hole depth, single-hole charge exceeds the maximum quantity of charge, the methods of elementary error inside-hole and outside-hole can be used together. Of course, the "half-step" blasting method can also be used. That means, the step height is reduced by half, and the hole depth, single-hole charge and the maximum seismic velocity decrease.

4.6 Multi-segment high-precision millisecond blast pipe

According to the requirements of Δt control, generally the blast pipe should not be used in neighboring segments. In addition, in most cases, there are two holes or single hole in one segment. Thus a great number of blast pipe is required for blasting each time and the total time interval is great. Therefore, high precision millisecond blast pipe with a number of 1~30 should be adopted, which satisfying the needs of VR blasting. Furthermore, the higher the precision degree is, the more accurate the control of Δt, and the better the VR effect.

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