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Experiment Study on the Whole Deformation Process of Arch Dam Bedrock

Wang Li

College of civil engineering, Baicheng Normal University, Baicheng, 137000, China

Email: 55860477@qq.com

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Abstract. Through the data variation characteristics of multi-point displacement meter and sliding micrometer on the abutment in the excavation process, analyze the deformation development law of dam foundation unloading. Monitored the whole process of dam foundation deformation before the dam abutment excavation, spring back during unloading after the excavation, compression deformation after the dam concrete pouring. The results provide a scientific basis for evaluating the rock mass quality, adjusting the rock mass mechanics design parameter, the design and construction of dam foundation excavation. Meanwhile, the conclusion has reference meaning for excavation project for the future.

Introduction

The max height of concrete hyperbolic arc dam is 294.5m. The direction of the river at dam site is near the N-S. The concrete arch dam foundation rock is mainly dark clouds granite gneiss and amphibole plagiogneiss. The rock formations of dam site area present monoclonal structure and the occurrence is N75°~85°W, NE∠75°~90°.

The foundation surface only has one level III fault named F11 in the right bank between 1245m ~1207m. The dam site influenced by geological structure, the stress of dam foundation rock is height. The stress σ1 of bank slope ground inclines along the slope basic parallel to the surface of the Earth. The maximum stress σ1 of bank slope ground achieves 8MPa~17MPa and the stress σ1 of valley horizontally ground achieves 22MPa~35MPa. The larger excavation depth of dam which achieve 112m, easy cause the rock mass unloading relaxation and lead to decrease of rock mass mechanics parameters. The characteristics mainly display as: "Onion skin" phenomenon, unloading "rebound", crack open along existing joint phenomenon. It is need to monitor the rock mass deformation to understand the changing rule of rock mass unloading relaxation of the dam foundation and its effect on the stability of the engineering safety.

It is closely related that relaxation degree of rock, depth and original rock stress state, features of rock structure, differences in lithology, excavation size, overhead conditions and differences in support. Rock mass stress redistribution of dam foundation will further relax along with time after excavation [2]. The weight of dam concrete pouring back over increase and the rock stress partially restore. With the re-consolidation grouting open fracture is compact and the loose rock also makes a corresponding increase [3]. The dam rock mass quality undergoes the process of the good(nature), deterioration (excavate), better (pouring and handling). The following study of this paper makes a discussion about the dam monitoring, acoustic and experimental results, the rules of rock foundation unloading and relaxation.

Monitoring Test Methods

Dam deformation takes the sliding micrometer and multi-point displacement meter to monitor, and the monitoring arrangements is shown in Table 1. Deformation modulus tests and acoustic tests was carried out to understand the mechanics parameter of rock mass after the change of relaxation. The deformation modulus tests take rigid bearing plate method and the acoustic tests take drilling test method [4].

Table 1: The parameters table of the installation of the monitoring equipment which has been laid under the abutment foundation

Instrument Number	Project site	Bottom elevation of dam (m)	Hole depth (m)	Drilling position /dip	The shallowest position of monitoring points (m)		Remarks
					Elevation (m)	The distance from the excavation face(m)	
C2A-HV-01	left bank EL1130m monitoring hole	1162.0	31.5	SE115°/ upward 57°	1159	5	left abutment advanced monitoring, laying prior to excavation
C2A-M-04			30		1161	2.5	
C2B-HV-03	right bank EL1060m monitoring hole	1087.0	28.0	NW54°/ upward 56°	1086.5	0.5	right abutment advanced monitoring, laying prior to excavation
C2B-M-07			26		1085	2.9	
A20-HV-01	20# dam foundation	960.7	15.5	vertical down			excavation prior to laying
A21-HV-01	21# dam foundation	953.0	15.5	vertical down			
A22-HV-01	22# dam foundation	953.0	15.5	vertical down			
A22-HV-02	22# dam foundation	953.0	15.5	vertical down			
A26-HV-01	26# dam foundation	961.0	15.5	vertical down			

Note: In the code HV denotes the sliding micrometer, M denotes multi displacement meter.

Whole Process Deformation of Rock Foundation

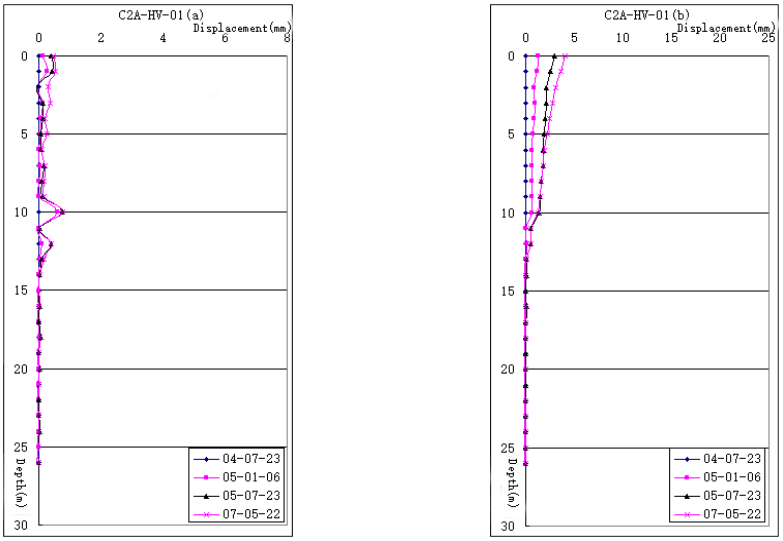
The Abutment Deformation of Unloading Excavated Rock Mass. In order monitor the deformation of abutment excavation, set the monitoring hole to monitor the precocious deformation in the left and right banks. The monitoring number in left abutment is C2A-HV-01 and in right abutment is C2B-HV-03. The variation curve of monitoring deformation of sliding micrometer in advance along with hole depth shown in Fig.1 and Fig.2. Where, the curve in (a) figure is displacement variation with hole depth and in (b) figure is total displacement variation with hole depth. It is same in both figure, coordinate system of relative deformation refers to two adjacent displacement between the measuring points along the borehole axis and coordinate system of total deformation refers to the bottom of the hole which also is the sum of the relative displacement from the bottom of the hole to the orifice.

It is can be seen from the monitoring results of sliding micrometer, the unloaded and relaxed rock deformation exist in the dam shoulder of both banks, which include as following. According the results of the sliding micrometer monitoring, unloading looseness existing in the rock mass of the left and right bank abutment.

The depth of side micrometer hole C2A-HV-01 is 31.5m in left bank 1130m elevation. The shallow measuring point elevation of dam abutment is 1159.0m, and which is 5m distance from the dam foundation surface. The range of deformation of measured rock mass unloaded looseness is 0~17m. The unloading gap opens exists in the location of 6m, 15m, 17m deep from the surface of dam abutment. The open width is 0.46~0.78mm and the total unloading deformation is 4.08mm on the location deep in 5.

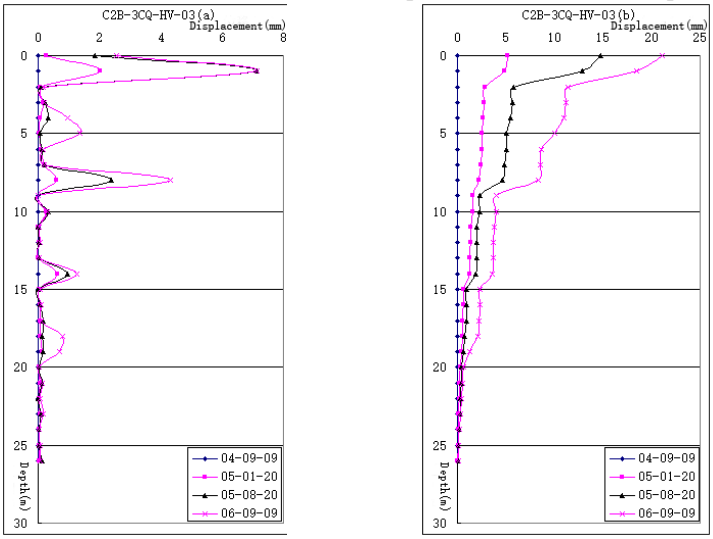
The depth of side micrometer hole C2B-HV-01 is 28m in right bank 1060m elevation. The shallow measuring point elevation of dam abutment is 1086.5m, and which is 0.5m distance from the dam foundation surface. the range of deformation of measured rock mass unloaded looseness is

0~19m.The unloading gap opens exists in the location of 1m, 8m, 14m, 19m deep from the surface of dam abutment. Where, the gap in deep 1m and 8m is wide open and the width is 7.2mm and 4.1mm. The total unloading deformation is 21.05mm, and the most obvious unloading looseness in the dam abutment is in range of deep 2m in which range the deformation is about 50% of the total deformation.



(a) Displacement with hole depth (b) Total displacement with hole depth

Fig. 1 Curve of left bank C2A-HV-01 displacement with hole depth



(a) displacement with hole depth (b) total displacement with hole depth

Fig. 2 Curve of right bank C2B-HV-03 displace with hole depth

Along with the excavation elevation, the variation curve of displacement change of sliding micrometer and multipoint displacement meter located in the left and right dam abutment are shown in Fig.3 and Fig.4. The depth of left bank sliding micrometer is 5m and that of multipoint displacement meter is 2.5m. From the changing graphics, it can conclude that the process of deformation of dam is basically uniform and the deformation of dam is leveling off as the excavation if finished. The depth of sliding micrometer measured located on the left bank is 0.5m and depth of multipoint displacement meter is 2.9m. it can see from figure 4, the relaxation deformation is larger in the deep 0.5m of dam abutment and the maximum relaxation deformation is 21mm. the relaxation deformation is 11.4mm deep in the 2.5m which is sliding micrometer located. the relaxation deformation is 8.7mm deep in the 2.9m which is multipoint displacement meter located. The deformation of sliding micrometer basically the same as that of multipoint displacement meter in the depth of 2.5m. the deformation of dam foundation gradually leveled off with the end of excavation.

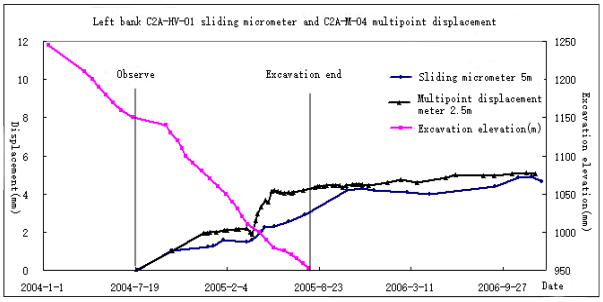


Fig.3 Curve of excavation deformation in left bank abutment

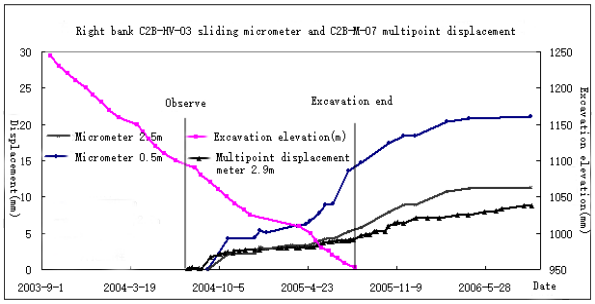


Fig. 4 Curve of excavation deformation in right bank abutment

It can conclude from the monitoring results of rock mass unloading deformation of dam abutment located above 1060m elevation, the range of unloading deformation of dam abutment between 17m~19m. but the unloading of shallow surface (within 2m range) is obvious, and the unloading deformation is about 50% of total unloading deformation. In addition, the unloading of the rock mass gradually decrease and the rate of deformation gradually decrease along with the increase of excavation distance and the extension of time [5].

Excavation Unloading Deformation of Dam Foundation Rock Mass in Riverbed Dam Section. The serious unloading rebound deformation emerged in the dam foundation rock mass after dam foundation excavation to design elevation 953m. for monitoring the deformation range, installed the sliding micrometer on the surface dam foundation. The depth of hole is 15.5m and the observation time is only one month or so. The relationship of hole depth with sliding micrometer deformation of A21-HV-01 and A22-HV-01 in the riverbed dam section shown in Fig.5 and Fig.6. The unloading deformation rate of dam foundation in 21, 22, 23 riverbed dam section are shown in table 2.

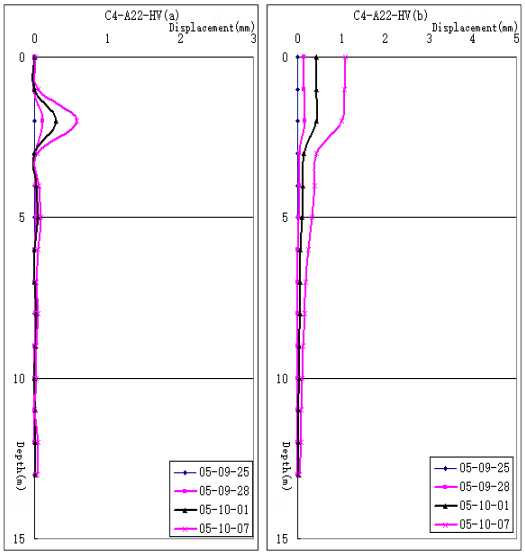


Fig. 5 Relationship curve of dam foundation A21-HV-01deformation with hole depth

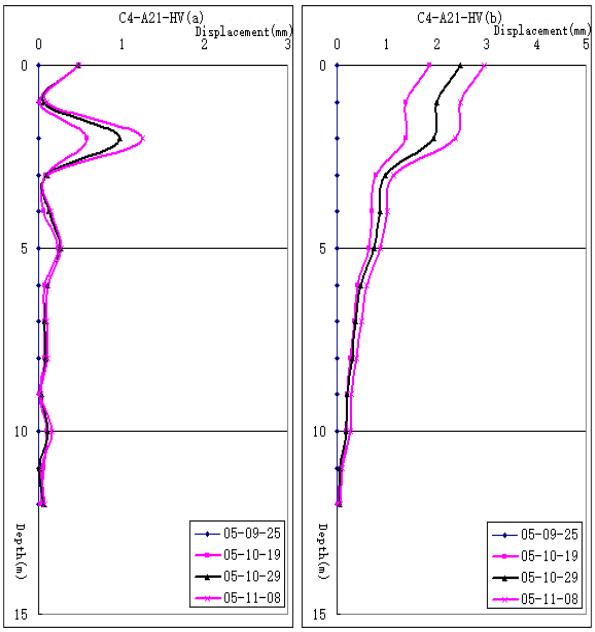


Fig. 6 Relationship curve of dam foundation A22-HV-01deformation with hole depth

Table 2 The unloading excavation deformation of river dam foundation rock mass

dam section	measuring point number	deformation range(m)	the deformation rate after excavation(mm/d)
21#	A21-HV-01	0.0~3.0	0.067
22#	A22-HV-01	0.0~3.0	0.083
23#	A23-HV-01	0.0~3.0	0.075

Conclusion

The monitoring unloading deformation of dam abutment rock mass shows that, the unloading deformation range of abutment rock mass between 17m~19m. But overall, about 50% of the deformation concentrate in the range of 2m depth. In addition, the unloading deformation rate of rock mass decrease with the excavation distance increase and the time prolonged.

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