Rock Testing at Diamer Basha Dam Project

Essias Roche Au Project De Barrage Diamer Basha

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ABSTRACT

Rock testing for a dam project on rock foundation and for deign of underground facilities is very much essential for determination of strength and other index properties of the rock. It helps in getting basic knowledge of the stress state for engineering e.g in what direction and with what magnitude is the major principal stress acting and to have a specific and formal knowledge of the boundary conditions for stress analysis conducted in the design phase of large dam. Water and Power Development Authority (WAPDA) Pakistan has planned to build Diamer Basha Dam, a 272 m high RCC dam on river Indus for which the construction work is going to start soon. The dam would have two underground cavern type powerhouses on both sides of the dam. Laboratory as well as field tests have been carried out at the site for determination of the rock mass characteristics and strength. Rigid Plate Load and Flatjack tests were conducted at the site as a part of the geotechnical investigations. The paper summarizes the Geotechnical Investigations carried out so far at Diamer Basha Dam site and gives the details of rock mechanics tests.

RÉSUMÉ

L' essais roche pour un projet de barrage sur le fond rocheux et pour la conception d'une installation souterraine est très essentiel a fin de determiner la force et les autres propriétés indice de la roche. Il aide à obtenir des connaissance de base d'état de contrainte pour l'ingenerie, par example dan la quelle direction et avec quelle étendue le contrainte majeur principal agit et avoir une connaissance spécifique et de forme des conditions qui marque la limite pour les analyses de contrainte sur le fond rocheux accomplies dans la phase de conception d'un grand barrage. L'autorité de Dévéloppement de l'Eau et de l'Energie (WAPDA) Pakistan a projeté de construire le barrage Diamir Basha, un barrage RCC 272 m de hauteur sur le riviere Indus pour lequel la construction va commencer bientôt. Le barrage aurait deux usine électriques de type Caverne enterré. Les essais au laboratoire aussi bien que les épreuves sur terrain avaient été réalisé au site a fin de determiner les caracteristiques et la force de masse de roche. Les essais Rigid Plate Load et Flatjack avaient été faites au site comme une partie des enquete geotechnical. L'article résume les énquetes géotechnical réalisées pour l'instant au site du barrage Diamir Basha et le détail des essais mécaniques de roche.

Keywords: In situ stresses, rock foundation, large dams, modulus of deformation

1 INTRODUCTION

Diamer Basha dam is proposed to be constructed on Indus River. about 315 km upstream of Tarbela Dam and 40 km downstream of Chilas town. The dam would be an RCC (Roller Compacted Concrete) dam having maximum height of 272 m which would make it the world's tallest RCC dam. The dam will create storage of 10.0 BCM or 8.14 MAF and generate 4500 MW hydropower capacity through two underground (cavern type) powerhouses, one on each bank. Two diversion tunnels and one diversion channel will divert the river flows during construction.

The proposed project site is located in the northern mountainous area of the Kohistan region. The Kohistan terrain was formed in the course of the tectonic collision of the Indian and the Eurasian plates, accumulating a 40 km thick sequence of mafic, ultramafic, plutonic, volcanic, metamorphic and sedimentary rocks. This Kohistan Island Arc is bounded by the Main Karakoram Thrust (MKT) in the north and west and by the Main Mantle Thrust (MMT) to the south and east.

Figure 1. Panoramic view of river Indus at Diamer Basha Dam site

The morphology of the project area is rugged and characterized by mountainous terrain with a high relief, with elevations exceeding 8,500 m a.s.l. (Figure 1). The Indus River is the major drainage artery. At the proposed damsite, the river level is at about 950 m elevation, about 100 m below the Karakoram Highway aligned along the left river bank. In the river bed sand, gravel and boulders cover the bedrock to a thickness of 50 m.

Diamer Basha dam site is underlain by bedrock of the Chilas Complex. comprising gabronorite and ultramafic rock intersected by doleritic dikes and pegmatite veins. Overburden consists of nullah deposits in forms of terraces and alluvial fans, locally extensive moraine deposits. and slope debris from rock toppling and sliding. The high RCC dam requires in-situ rock mechanics tests to investigate the deformation of these zones

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under the expected loads of the dam and loads acting on it. In situ stresses are also being determined at the level of powerhouse cavern.

2 GEOTECHNICAL INVESTIGATIONS

A comprehensive program of geotechnical investigations has been implemented for determining the rock properties at the project area. More than 16.500 m drilling has been done in 140 boreholes at the site in different phases. Adits and trenches have been excavated for detailed exploration. Rock mechanics laboratory tests have been carried out. Field rock mechanics tests were conducted to assess the in situ rock stress and rock modulus of deformation. Details of the investigations are as under:

Table 1. Details of the Drilling Works

Sr. No.	Outfit	No. of Boreholes	Total Length (m)	Period
1	MONENCO	37	3753	1981-84
2	WAPDA	15	1073	2001-02
3	NEAC	23	1830	2002-04
4	DBC	65	9918	2005-08
	TOTAL	140	16574	

Table 2. Details of the Adits

Adit No.	Preparing Outfit	Location	Length (m)	Remarks
1	NEAC	Right Bank	216	At the dam Axis D
2	NEAC	Left Bank	400	
3	DBC	Left Bank	256	Including Main (129.7 m) and side heading (126.1 m)
4	DBC	Left Bank	532	Including Main (422 m) and side heading / branch of 110 m
5	DBC	Right Bank	650	Including Main (450 m) and two perpendicular branches of 100 m each
		TOTAL	2054	

3 LABORATORY TESTING

For assessment of the engineering geological properties of the rock and to obtain parameters for the geotechnical design. a number of rock mechanics tests have been carried out. Three major campaigns of laboratory tests have been performed 1981-84, 2002-2004 and 2005-2008. In addition to this. some core samples were selected and tested in the field both involving Hock shear tests and point load strength index testing.

Testing of the two main hard rock types had been done by carrying out thousand of index tests. Average values have been used for defining rock properties. They are presented in table 3 and 4.

Table 3. Summary of Index Tests results on Gabronorite

	Spec Gravity	Unit Weight	Water absorption	Porosity
Average	2.94	2.92	0.22	0.65
Standard Deviation	0.03	0.03	0.10	0.29
Min	2.87	2.86	0.05	0.14
Max	3.01	2.98	0.43	1.27

Table 4. Summary of Index Tests results on Ultramafic

	Spec Gravity	Unit Weight	Water absorption	Porosity
Average	3.29	3.23	0.7	2.22
Standard Deviation	0.17	0.17	0.64	1.88
Min	2.84	2.83	0.11	0.35
Max	3.54	3.48	3.51	10.00

Following figure compiles the compressive strength on both types of rocks data tested in the Central Material Testing Laboratories, Lahore.

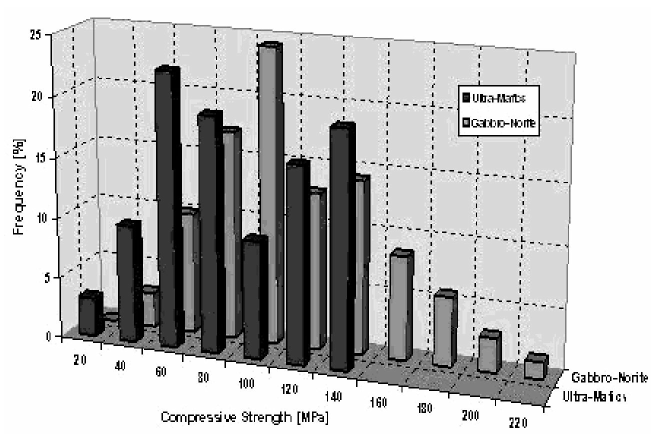

Figure 2. Frequency Distribution of UCS on UMA and GN

The standard values of intact rock material as derived from Laboratory tests are as under;

Table 5. Standard values of intact rock material

	Unconfined Compressive Strength UCS (MPa)	Young's' Modulus of Deformation (GPa)	Poisson Ratio	Tensile Strength (Mpa)
Gabronorite	100 MPa	50 GPa	0.25	14 Mpa
UMA	80 Mpa	100 GPa	0.26	-

4 FIELD TESTING

WAPDA conducted Rigid Plate Load tests to determine modulus of deformation and Flatjack tests for the in situ stress measurement. The details are as under:

4.1 *Rigid Plate Load Tests*

Four (4) tests, two (2) vertical and two (2) horizontal were conducted in Adit No.1. The rock in Adit No.1 is

Norite/Hornblendite. The tests were conducted in accordance with ASTM D4394-08. The surface of the rock was prepared as per standard at all the selected locations. The diameter of the rigid plate was 1 ft. Three strain gauges were fixed at each of the plates to measure the surface deformations.

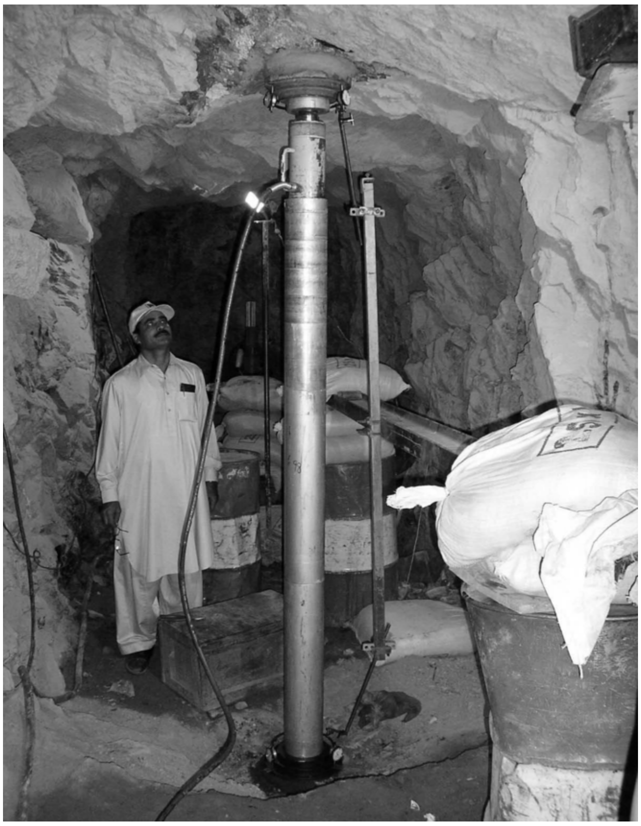

Figure 3. Vertical Rigid Plate Load Test in Adit No.1

The test was performed in five cycles of loading and unloading each in ten increments at 1 minute per increment. .Following table shows the obtained results;

Table 6. Summary of Rigid Plate Load Tests

Chamber No.	Orientation	Modulus of Deformation (E)	
		Top/Left (GPa)	Bottom/Right (GPa)
1	Vertical	1.54	7.34
	Horizontal	265.54	171.64
2	Vertical	15.38	8.8
	Horizontal	47.48	31.00

A typical graph of one of the test is shown below;

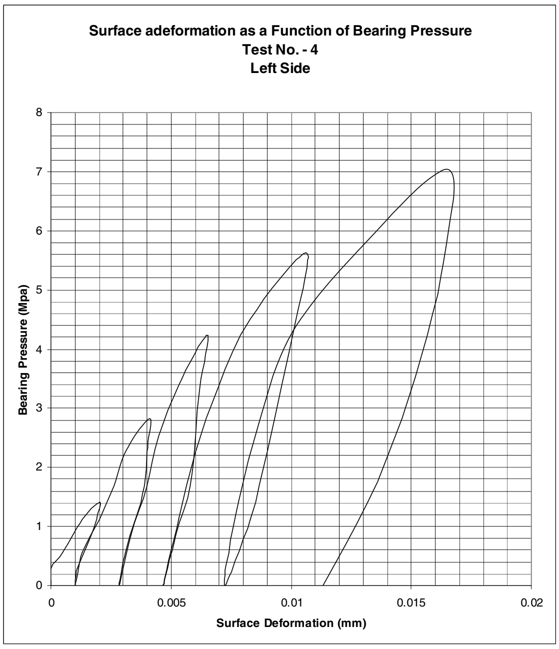

Figure 4. Test result plotted to determine Modulus of Deformation

4.2 *Flatjack Tests*

The tests were conducted in the floor of Adit No.1. The tests were conducted according to ASTM D4729-87. For the test a vertical slot of size 1.25 x 1.25 x 0.076m was made at the base of Adit in which flatjack was inserted. The slot was made using drill machine. A number of vertical concentric holes close to and overlapping each other were drilled until the slot of required dimension was made.

Figure 5. Measurements before inserting the Flatjack into the slot

The flatjack was then carefully inserted and grouted with cement mortar. The mortar was given sufficient time to get the significant compressive strength. The flatjack was pressurized in increments of 100 Psi until the cancellation of pressure at all the measuring points. Deformation was recorded after each pressure and the peak pressure (6000 KPa) was maintained for 15 minutes. Following figure shows the typical curve for one of the tests.

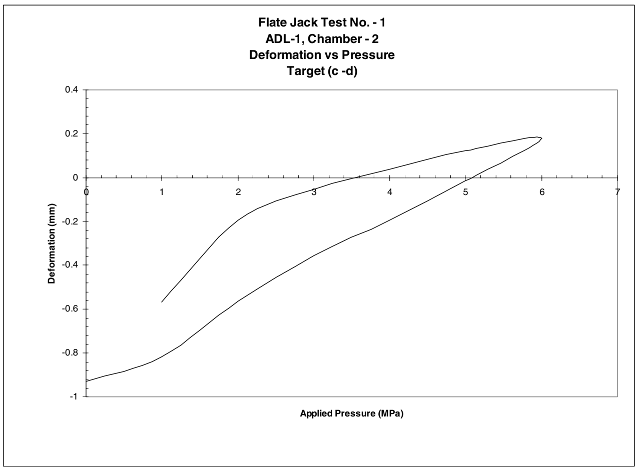

Figure 4. Typical deformation curve obtained from the test

4.3 *Tests planned in near future*

WAPDA has arranged the services of an internationally renowned company for accurately measuring the state of in-situ rock stress and modulus of deformation. Following tests will be conducted in exploratory Adits No. 4 and 5.

- Over Coring Tests
- Rigid Plate Load Tests

A total No. of 32 Overcoring tests shall be performed in both the adits in 8 holes each of 90 m deep i.e approximately upto the invert level of proposed power house cavern. A total No. of 16 Rigid Plate Load Tests (Horizontal and Vertical) will be performed in both the adits. The modulus of deformation will be measured by a multiple point extensometer to be installed through a 6 m deep hole in the center of the two opposing load plates. Local Contractors have been assigned the work to construct the chambers and drilling in the adits. While Overcoring tests are to be performed by an international testing lab.

For these tests, excavation of 4 chambers each of 6m x 8m x 8m have been completed in the adits. The holes for conducting the Overcoring tests are nearing completion. Drilling for the installation of borehole extensometer to record the deep deformation is also undergone. Some details of these tests are as under:

4.3.1 *Overcoring Test*

The tests will be carried out with CSIRO or compatible testing probe which provides complete 3-D stress tensor i.e. principal in situ values and their direction with vertical observations only. Ground water is present for test locations at deeper depths and will be accounted for in selecting the testing probe. The test will require the drilling of borehole with two different diameters, approximately 35-39 mm outside diameter for the installation of the triaxial cell (stress tensor gauge and approximately 40-146 mm for overcoring). The smaller diameter hole has to be centered in the large diameter hole. During the overcoring process and core extraction the deformation of the rock surrounding the triaxial cell shall be recorded, which are related to the occurring stress relief. The Modulus of deformation and Poison ratio will be obtained by testing the overcored samples in a biaxial pressure chamber.

In order to avoid the interference in the work, it is recommended to have about 5 m distance in tunnel chainage between Overcoring and Rigid Plate loading tests.

4.3.2 Rigid Plate Load Test

The location of these tests are within the Adit 4 and 5 and their branches. The loading plates need to be seated on even surfaces covered by a thin mortar bed. The preparation for the even surfaces is under progress at the moment. The plates of larger diameter, 1.1 m will be used. The maximum load would be around 6 MPa and at this load a creep test shall also be performed. The rock mass deformation shall be measured with a multiple point extensometers to be installed through the hole in the center of the two opposing plates.

4 CONCLUSIONS

Extensive investigations have been carried out at Diamer Basha Dam site to delineate the geology and geotechnical properties of the area including the rock mechanics tests.

The rocks at Diamer Basha Dam Project; Gabronorite and Ultramafic have high strength:

Compressive strength is of the order of 80-100 MPa
Modulus of deformation is of the order of 50-100 MPa

In situ stress measured is prerequisite for the orientation and design of an underground power house (Cavern) especially when it is located under high mountains next to a deep cut valley.

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