Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 03, March-2020

Evaluation of Shear Strength Parameters for Design of Dam for a Drinking Water Project-A Case Study

D.V. Sarwade[1], Senthil. P.[2] and Hari Dev[3]
[1]Scientist-D, [2]Scientist-B, [3]Scientist-E
Central Soil and Materials Research Station
Olof Palme Marg, Hauz Khas, New Delhi-110016

***Abstract* - Determination of shear strength parameters of a rock mass is an important aspect in the design of structures such as rock slopes, dam foundations, tunnels, shafts, waste repositories, caverns for storage and other purposes. Shearing failure along weak horizontal planes either through the foundation rock or interface of concrete to rock or within the dam body may result in water retaining structures. In-situ direct shear test are conducted to evaluate the shear strength parameters viz. cohesion and friction angle. These tests should be conducted near the dam foundations. Tests can be conducted easily in the drifts whereas complicated loading arrangements are required for testing in open. It requires a trench, steel I sections, sand bags or concrete blocks providing the normal load and a reaction frame or thicjk concrete pad for applying shear force. Determination of concrete-rock (CR) interface shear strength parameters of biotite rich phyllite by direct shear tests in open trench have been discussed in the present paper. Foliation joints of parent rock are striking parallel to dam axis and dipping sub-vertically towards upstream direction. Failure interface in almost all the blocks indicate that shearing has taken place through rock mass at a plane below the probable/anticipated failure plane.**

Keywords - In-situ shear tests; open trench; phyllites; isarda drinking water project, rajasthan

I. INTRODUCTION

In-situ shear strength parameters of rock mass are required for design of structures founded on or constructed in rock mass [1]. Geological features play a very crucial role in affecting engineering behaviour of rock mass. Same rock type may have significantly different shear strength parameters depending upon site-specific geological characteristics [2]. Hence, it is important to conduct in-situ shear tests to determine the shear strength parameters viz; cohesion and frication angle of the rock mass. The kind of arrangements for testing in drifts and open trenches has been discussed by some researchers [3]. (Fig. 1)

In-situ shear tests are used to determine the peak and residual shear strength of rock mass as a function of stress normal to the sheared plane. The shear strength parameters, cohesion 'c' & angle of friction 'ϕ' are evaluated by drawing a trend line using linear regression on the normal stress versus shear stress plot. Results are usually employed in stability analysis of dam foundations, limit equilibrium analysis of slope stability problems and numerical analysis of dam-foundations [4]. The range of normal stress to be adopted for conducting tests should be in coherence with the range of normal stress to be expected due to the proposed structure.

Fig. 1: Testing methods in drift and open trenches

In the present paper, a case study of determining in-situ shear strength parameters of biotite rich phyllites in an open trench at Isarda drinking water project, Rajasthan has been discussed. The tests were conducted on concrete to rock (CR) blocks and the dead load was provided by means of concrete blocks on the MS plates supported by graders across the trench. Because of loose rock, the walls of trench were supported by MS plates for application of shear forces. Six tests at different normal stress were conducted.

II. DETAILS OF CASE STUDY

The Isarda drinking water project in Tonk district of Rajasthan, envisages construction of a 20.50 m high (from river bed level) and 4983.50 m long, earth cum masonry dam across Banas River, a tributary of Chambal River, near village Banetha, Uniyara Tehsil, Tonk District, Rajasthan. On completion, the dam would impound 365.62 Mcum of water for drinking purpose with a gross catchment of 37820 Sq Km at FRL 262 m. The project has been designed for the maximum flood inflow of 40462 Cumes (14.29 lac Cusecs) and gross live capacity of 296.89 Mcum. A 592.50 m long spillway, with 38 number of radial gates (12 m x 11.80 m) is designed for a flood discharge of 38740 Cumes (13.69 lac Cusecs) of water. The L-section of the project is shown in Fig. 2.

Mica-schist, phyllite and quartzite belonging to the Hindoli Group of the Bhilwara Supergroup are exposed in the project area. In the river portion, there are no exposures and river channel area is covered by thick alluvial deposits and river sand. A small linear patch is observed along the left bank of the river exposing steeply dipping phyllites, schist and quartzites. On the right bank of the river, a narrow low-lying strike ridge consisting of quartzites, phyllites and schist are exposed and surrounded by alluvial and aeolian deposits. The general trend of phyllite rock varies from N20^{0}E-S20^0 W to N40^0 E-S40^0 W with dip from 75^0 to 85^0 north-westerly (towards upstream direction). The dam axis aligns in

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 03, March-2020

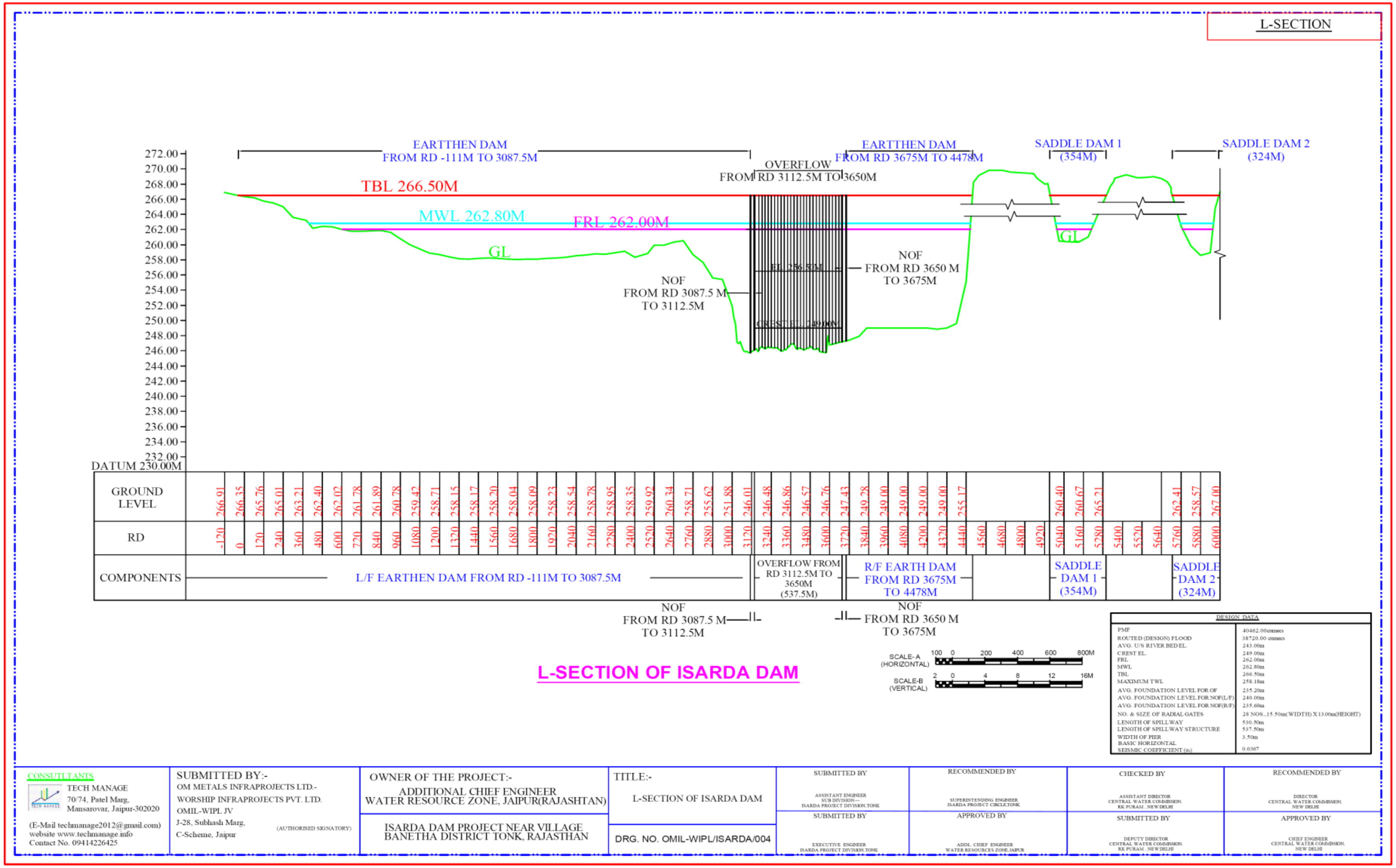

Fig. 2: L-Section of Isarda Drinking Water Project, Rajasthan

N25^{0}E-S25^{0}W direction. The strike of the foliation is almost parallel to the dam axis.

III. TESTS AND INTERPRETATION

Six numbers of shear tests were conducted on concrete-rock interface. Blocks were prepared using M20 grade concrete on chiselled smooth surface of rock mass in accordance with provisions contained in [5] and [6] in the open trench at dam spillway section at different RD's on fine grained, dark grey coloured, vertical to sub-vertical, dipping upstream side phyllite rock mass. These tests were conducted at normal loads of 10T, 15T, 20T, 25T, 30T and 35T. The range of normal loads has been chosen based on proposed height of the dam. Some of the photographs of the in-situ shear test are given in Fig. 3 [7].

Loading Arrangements

Concrete test blocks

Testing on concrete to rock interface

Fig. 3: Glimpse of testing in an open trench

Normal and shear stresses were obtained from normal and shear loads recorded during the test using following equations:

Shear Stress, $$\tau = \frac{P_s}{A} = \frac{P_{sa}\cos\alpha}{A} \qquad (1)$$

Normal stress, $$\sigma_n = \frac{P_n}{A} = \frac{P_{na} + P_{sa}\sin\alpha}{A} \qquad (2)$$

where, P_{sa}= applied shear load, P_s= Total shear load, P_n= Total normal load, A = Actual sheared area measured by upturning the failed test block, P_{na}= Applied normal load, α= Inclination of applied shear force (15^0).

Applied normal load is reduced after each increment in shear force by an amount P_{sa} sin α in order to maintain the normal stress constant. At failure and after failure (residual), the shear stress is plotted against the normal stress and the curve fitting is drawn using linear regression analysis. Intercept of trend line on Y-axis gives cohesion 'c' and slope of the line gives friction angle 'ϕ' of rock mass. The test results are given in Table 1. Shear stress - shear displacement data at different normal loading are plotted in Fig. 4.

Theoretically, as the value of normal stress increases shear stress should also increase. This is not possible in real conditions due to progressive failure, complex pattern of joints and formation of key etc. while shearing the blocks at different locations. Pattern and properties of rock mass discontinuities is the main reason for scattered data. From Fig. 4, it could be seen that test results at 15T normal load is nearly matching with that of blocks tests at normal loads of 25T and 35T. Further, on overturning the blocks, formation of rock key in the direction of shear was observed in DST-2 tested at 15T normal load, thus providing additional resistance to shearing. The formation of such key could not be observed in other tests. Therefore, test results of block tested at 15T normal load have been omitted for linear fitting of data for determining shear strength parameters.

TABLE 1: Results of In-situ Shear Tests on Concrete-Rock Interface

Test No	RD (m)	Area of Shear Surface, cm^2	Normal Load, T	Shear Load (T)		Normal Stress, MPa	Shear Stress (MPa)	
				Peak	Residual		Peak	Residual
DST-1	3200.988	5475	10	34	11	0.18	0.59	0.20
DST-2	3199.557	6123	15	60	45	0.24	0.92	0.70
DST-3	3195.923	5439	20	65	31	0.36	1.14	0.54
DST-4	3194.572	5365	35	54	31	0.64	0.95	0.55
DST-5	3193.213	5414	30	68	34	0.54	1.19	0.60
DST-6	3191.132	5612	25	57	17	0.44	0.96	0.29

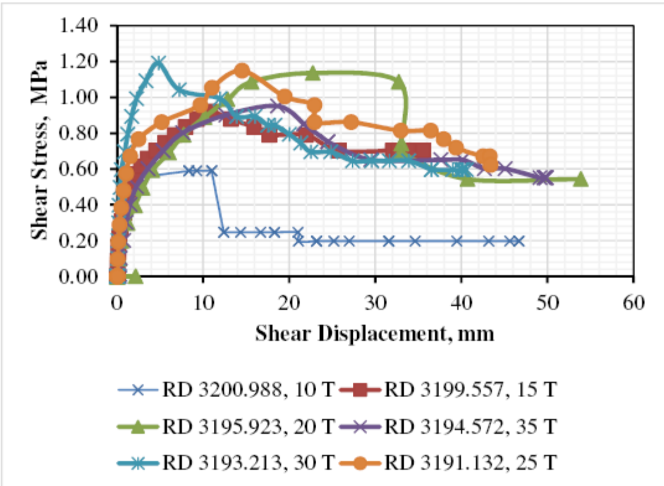

Fig. 4: Plot of Shear Stress and Shear Displacements

Shear stress-normal stress plots for deriving shear strength parameters viz. cohesion (c) and friction angle (ϕ) at peak and residual states are shown in Fig. 5. The friction angle (ϕ) at peak and residual states were found to be 40^o and 37^o, respectively and cohesion (c) value for peak and residual states are 0.60 MPa and 0.11 MPa, respectively. The blocks were overturned after the shear tests and actual area under shear was recorded and used for computation of stresses from loads. The photos of overturned blocks for CR interface are shown in Fig. 6. From these photographs, it is clear that failure interface in almost all the blocks, indicate that the shearing has taken place through rock mass at a plane below the concrete-rock interface.

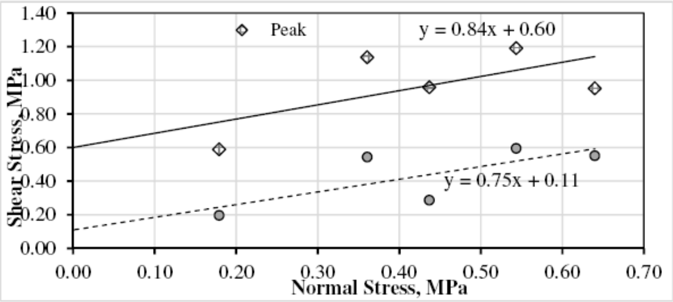

Fig. 5: Plot of Shear Stress and Normal Stress

IV. CONCLUSIONS

In-situ tests are important as it is impossible to simulate the actual field conditions in the laboratory. Six direct shear tests (DST) were conducted on concrete-rock (CR) interface at dam spillway section of Isarda drinking water Project, Rajasthan for obtaining shear strength parameters.

The friction angle (ϕ) at peak and residual states were found to be 40^{o} and 37^{o}, respectively and cohesion (c) value for peak and residual states are 0.60 MPa and 0.11 MPa, respectively.

Failure interface in almost all the blocks indicate that shearing has taken place through rock mass at a plane below the probable/anticipated failure plane. Thus, it can be termed as failure through rock-rock interface. Therefore, it can be concluded that the shear strength of concrete-rock interface is higher than rock-rock interface and evaluated parameters are critical shear strength parameters.

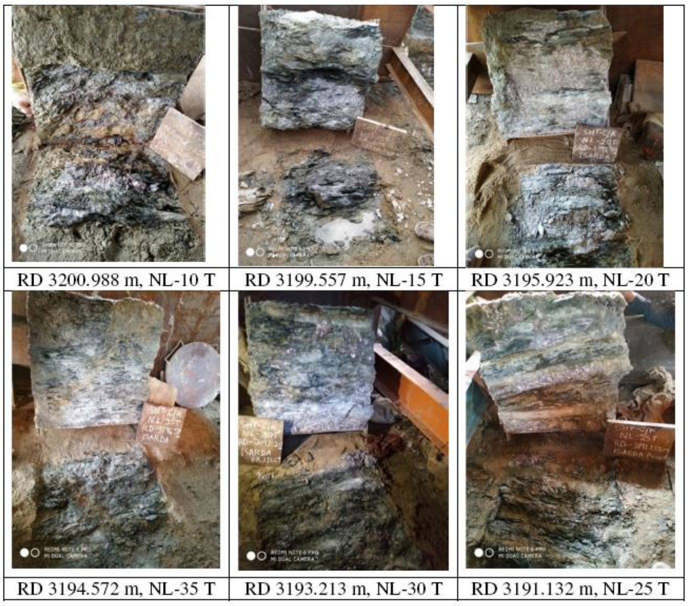

Fig. 6: Photographs of overturned Concrete blocks

ACKNOWLEDGEMENTS

The authors wish to acknowledge the guidance and support of Shri. S. L. Gupta, Director, CSMRS during the preparation of manuscript.

REFERENCES

[1] Rajbal Singh and D.V. Sarwade (2009): “Interpretation of Shear Strength Parameters of Rock Mass”, Proceedings of Indian Geotechnical Conference on Geotechnics in Infrastructure Development (GEOTIDE), Guntur, 17-19, December, 2009

[2] Hari Dev (2017): Shear Strength of Rock Mass - Interpretation and Analysis, Proceedings of International Conference on Engineering Geological Solutions for Sustainable Development (EGCON 2017), IIT Delhi, 5-6 October, 2017.

[3] G.V. Ramana, Shashank Pathak, Hari Dev, Rajbal Singh and V.K. Gupta (2014): Shear Strength of Deccan Granite Rock Mass in Open Trench, Proceedings of INDOROCK 2014: Fifth Indian Rock Conference, 12 –14 November, 2014.

[4] Ehsan Bakhtiyari, Ali Almasi, Akbar Cheshomi, Jafar Hassanpour (2017): Determination of Shear Strength Parameters of Rock Mass using Back Analysis Methods and Comparison of results with Empirical Methods, European Journal of Engineering Research and Science, Vol. 2, No. 11, November 2017.

[5] IS 7746 (1991): Indian Standard of code of practice for In-situ Shear test on rock, Bureau of Indian Standards, New Delhi.

[6] ISRM (1981): International society for Rock Mechanics and Rock Engineering, suggested methods for In-situ Determination of Direct Shear Strength

[7] CSMRS Report (2019): Report on in-situ shear strength parameters of rock mass at dam spillway section of Isarda drinking water project, Rajasthan, Central Soil and Materials Research Station, New Delhi, July, 2019.