Post construction stage geotechnical investigation on Adavinainarkoil reservoir, Tirunelveli district, Tamil Naidu

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Abstract

Under the *Dam Safety Assurance and Rehabilitation Project* (DSARP) of Tamil Nadu State, many projects constructed about 3 - 5 decades ago and essentially few century old, have been referred to GSI for assessment of the present health status and longevity of the structures and for proper documentation of geological and geotechnical data. Geological data's are not available for many of the dams in Tamil Nadu, even if available, it is scattered and sketchy. The present paper deals with post construction stage geotechnical investigation on Adavainarkoil Reservoir, Tirunelveli district, Tamil Nadu, and contain details on *Regional geological milieu, site characterization, structural details, seepage analyses and seismic status of the dam site.*

The Adavinainarkoil reservoir envisages the construction of 74.20 m high and 670 m long Masonry dam with uncontrolled central spillway of 100 m length, built across the River Hanuman Nadhi, a tributary of Chittar River in Tamiraparani basin, with storage capacity of 174 m c ft.

Charnockite and migmatite with linear strings of pyroxene granulite are the prominent rock types, traversed by granite, pegmatite and quartz veins. The pyroxene granulite exhibits spheroidal weathering, at places. The area had under gone poly phase of deformation. The general trend of foliation is N 65°-70°W S 65°- 70° E with steep to moderate dip (50°-65°) due S20°-25°W, where as the dam axis is oriented along N62°W S62°E direction. There are four prominent joint sets observed, of which, foliation joints are prominent. The foliation joints are pronounced in the riverbed and are sympathetic to the shears guided by the river lineament. Achan koil lineament is located 2.5 km south of the dam site. Shearing affects in the pyroxene granulites and the biotite gneiss, in the downstream of the reservoir may be the causative factures of this major geological structure. However, no distress was observed on either side of the abutment structures.

The dam has been provided with drainage galleries at three different levels. There are 26 blocks of different length and size, each block joint had been provided with "V" notch to measure the seepages. Transverse drainage galleries were provided with pressure gauge meter. In the lowest gallery at El 210.6m, at vertical drain shaft hole No 60, 61 & 63

heavy seepage with high pressure was observed requiring immediate attention. The drainage galleries are chocked due to heavy calcination. At places, along with calcinations iron stains and red/yellow precipitation was also distinct. At the exit No 3 from the left end abnormal seepage with respect to the reservoir level 115.25m was also distinct. Particles like sand and gravel are also noticed in the drainage chute near the "V" notch (exit No 3) warranting immediate rectification.

No perceptible seismic risk is evident for the project. However, recent events of earthquakes of low to moderate magnitude in the peninsular part of India warrant installation of seismograms at the project site for information and mitigation of impending danger if any to the existing dams of this region for retrofitting as well as for the design of new ones.

1. Introduction:

The World Bank aided Dam Safety Assurance and Rehabilitation Project (DSARP), intends to examine all the dams/Reservoir in Tamil Nadu, to assess the present health status and to take up the rehabilitation work. Because, geological and geo technical data's are not available for many of the dams in Tamil Nadu. Even if available, they are scattered and sketchy. Hence, documentation of geological information of large dams in Tamil Nadu has been taken up under DSARP.

The Adavinainarkoil reservoir envisages the construction of 74.20 m high and 670 m long masonry dam with uncontrolled central spillway of 100 m length (Picture 1), built across the River Hanuman Nadhi, a tributary of Chittar River in Tamiraparani basin, with storage capacity of 174 m c ft. The dam site is located on the foothills of the eastern hill flank of the Western Ghats, at Mekkarai village, Sengottai taluk, Tirunelveli district, Tamil Nadu. The present paper dealt with post construction stage geotechnical investigation on Adavainarkoil Reservoir, Tirunelveli district, Tamil Nadu, contains details on ***Regional geological milieu, site characterization, structural details, seepage analyses and seismic status of the dam site***.

Picture 1 A panoramic view of the Adavinainar reservoir (upstream)

2. Regional Geological Milieu:

The Adavainarkoil Reservoir is located in the high-grade metamorphic terrain of Pre Cambrian age. Charnockite and migmatite are the predominant rock types of the region (Abdullah et. al.1983). The khondalite group of rocks consist mainly garnet sillimanite gneiss, garnetiferous quartzo feldspathic gneiss, crystalline lime stone, calc granulite etc. Large linear masses of charnockite are exposed in the hilly region. The migmatised derivatives are chiefly consisting of granite gneiss and biotite gneiss ± garnet, intruded by granite, pegmatite and quartz veins. The contact between the Khondalite and Charnockite group of rocks is marked by the conspicuous Achankoil lineament trending NW-SE (Gopalakrishnan et al 1990).

3. Site Characterization:

3.1 Salient Features:

1	Name of the project	Adavinainarkoil Reservoir	
2	Location	Mekkarai village	
3	Nearest Town	Sengottai, Tirunelveli district, Tamil Nadu	
4	Type of Dam	Masonry dam with centrally located uncontrolled surplus spill way	
5	River	Hanuman Nadhi (River)	
6	Purpose	Mainly for irrigation	
7	Height	47.20 m	
8	Total length	670.0 m	
9	Surplus spill way	100.0 m	
10	Top width of dam	5.0 m	
11	MWL	248.50 m	
12	FRL	247.00 m	
13	Capacity at FRL	174 mcft	
14	Annual storage	348.0 m	
15	Water spread area	87.16 Ac	
16	Free catchments area	15.54 sq km	
17	Dam axis trend	N 62°W S 62° E	
Surplus Arrangements			
1	Length of the spill way	100.0 m	
2	Average bed level	+201.00 m	
3	Crest level	247.00 m	
4	Depth of over flow crest	1.5 m	
5	Maximum flood discharge	12,600 cusecs	
Irrigation sluice			
		Mettukkal	Karisalkal
1	Location	LS 260 m – 266 m	314m – 320 m
2	Sill level	+216.80 m	+206.80 m
3	Size of vent	0.90 m x1.50 m	1.52 m x 1.83 m
4	Discharge	22.95 cusecs	140.40 cusecs
	Pre construction stage investigation	1982-83	
	Year of Construction	1991-2001	

(Source: Project Authority)

3.2 Geomorphology:

The drainage pattern is sub-trellis to sub-dendritic, indicating a structural control and the drainage density is poor to moderate. Landforms present are dissected plateaus, colluvial fans and pediment slopes. Major ongoing Geo-dynamic process is one of erosion rather than of deposition (Balachandran et al 1996). The average elevation of the hills in the region is 1500 m to 1700 m above m.s.l. The elevation of valleys of Hanuman Nadhi varies from 150 m to 250 m above m.s.l. The hillocks present in the area are structural and/or denudation hills.

3.3 Geology:

Charnockite / migmatite with linear stringers of pyroxene granulite are the prominent rock type present in the dam site (Balasubramanian-1999 et al). Mafic rocks occur as enclave, traversed by granite, pink pegmatite and quartz veins. The pyroxene granulite exhibits spheroidal weathering, at places (Picture 2). The migmatised derivative of biotite gneiss/granite gneiss shows more intensity of weathering.

Picture 2 Pyroxene granulite exhibiting spheroidal weathering (downstream)

3.4 Structure:

The study area had under gone poly phase of deformation. General trend of foliation shows N 65°-70°W S 65°- 70° E with steep to moderate dip (50°-65°) due S 20°-25° W, where as the dam axis orientation is N 62°W S 62° E direction. There are four prominent joint sets in the investigated areas, viz:

i. Strike joint N 65°-70°W S 65°- 70° E with dip 50°-65° due SW direction (prominent)
ii. N 50°-60°E S 650°- 60° W with 40° dip due NW
iii. N 10°W S 10° E with sub vertical dip
iv. N 30°-40°E S 30°- 40° W with 45° dip due SE

The Achan koil lineament is passing 2.5 km south of the dam site (Ramalingam et al 2004). Shearing in the pyroxene granulites and biotite gneiss are found in the downstream of the reservoir may the resultant of this major geological structure.

4. Significant Observations:

4.1 Abutments:

The right abutment of the dam abutted against the massive charnockite/migmatite rocks. At the left abutment, weathered charnockite gneiss with linear stringers of pyroxene granulite intruded by pink pegmatite followed by lateritic soil observed. The pyroxene granulite exhibits spheroidal weathering. Due to high intensity of weathering in the left abutment, it was excavated for considerable depth for abutting into fresh rock. Comparatively the left hill flank is lower than the right abutment hill flank. In vicinity, no sign of distress was observed on both the abutments.

4.2 Drainage Galleries:

The dam has been provided with drainage gallery of standard size and shape at three different elevation levels. There are 26 blocks of different length and size, each block joint had been provided with "V" notches to measure the seepages. Transverse drainage galleries provided with pressure gauge meter. In the lowest gallery at El 210.6, the vertical drain shaft hole No 60, 61 & 63 water jet was observed. The flow may be in order of >1000 lpm, requiring immediate attention. Besides, examined the present status of the drain shafts located in the drainage galleries, most of them are chocked due to heavy calcinations (picture 3). At places, along with calcinations iron stains and red/yellow precipitations were also observed. At the exit No 3 from the left end, seepage water flows above the "V" notches (>17cm) (Picture 4), depicts that the seepages are abnormal with the corresponding reservoir level of 115.25 m. If the reservoir is full, than the amount of seepage will be multi fold. Particles like sand and gravel are also noticed in the drainage chute near the "V" notch (exit No 3) warranting immediate rectification (Jayabalan et al 2009).

Picture 3 Drains choked with calcinations

Picture 4 Seepage water flows above V-notch

The "V" notches and piezometers provided in the galleries are not functioning. The drains in the drainage galleries are filled with heavy calcinations (block 7, 8, 9 & 18). Ingress of the water into the drainage gallery by piping is observed d/s face of block No.22. (Picture 5)

5. Seepage analysis:

Seepage analytical data for the drainage galleries are collected, synthesized and available in the form of progress report (Jayabalan et al 2009).

Discharge through the "V" notch Standard formula

1.42 H 5/2 m^3/sec

Where, 1.42 is constant, H= Height of water in v notch
Conversion of units = 1m3 = 1000 lits

Picture 5 Ingress of the water into the drainage gallery by piping

6. Seismic Status:

The dam site is located near the Achankovil Shear zones aligned in NW-SE direction. This lineament is being considered as the major tectonic feature of this region.

Seismically the dam site is located in Zone II of the Seismic Zonation Map of India published by the Bureau of Indian Standards – I.S. 1893-Part-I: 2002.

Though no perceptible seismic risk is evident for the project, recent events of more and more virgin areas experienced earthquakes of low to moderate magnitude in Peninsular part of India which was once considered as a stable shield area can not be ignored. Hence, installing seismograms at the project site will certainly provide invaluable information for mitigation of impending danger if any to the existing dams of this region for retrofitting as well as for the design of new ones.

7. Conclusion:

670 m long, 74.20 m high Masonry dam with uncontrolled centrally located spill way of 100 m length abutted against the massive charnockite in the right and weathered charnockite/ gneisses in the left abutment. *No visible sign of distress was observed on either side of the abutment structures.*
The dam has been provided with drainage galleries at three levels, each drainage gallery being provided with pressure gauge meter and V notches. However, none of them are in working condition. Heavy seepages observed in the blocks between 7 and 9 (500 to 700 LPM) with the corresponding reservoir level of 116.25m. *If the reservoir is full, than the amount of seepage will be multi fold.*

In the lowest gallery at El 210.600, the vertical drainage shaft hole No 60,61 & 63 water flows/gushed out from the drain shaft with heavy noise depicts that the *seepages may be >1000 lpm and are more alarming, warranting immediate attention*.

Most of the vertical drainage shafts are chocked due to heavy calcinations. Along with calcinations Iron stains and red/yellow precipitations are also observed at place, recommended for reaming to release pore pressure. The toe drains provided with the drainage galleries got silted up with heavy calcinations (calcinations observed in the d/s phase of block No.7, 8, 9 & 18). Water seepage with heavy pressure observed in the d/s phase of block No.22.

At the outset, *the present investigation revealed that the seepages are from the Dam structure and not from the foundation level*.

Installing seismograms at the project site will certainly provide valuable information for mitigation of impending danger if any to the existing dams of this region for retrofitting as well as for the design of new ones.

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