

Geotechnical Appraisal of Dam Foundation of Adavinainarkoil Reservoir Project, Tirunelveli District, Tamil Nadu

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Abstract

The Adavinainarkoil Reservoir Project has been constructed with a 47.20 m high and 670 m long masonry dam across Hanuman Nadhi a tributary of Chittar River in the Tambaraparani Basin. The dam is located near Mekkarai Village in Sengottai Taluk of Tirunelveli District, Tamil Nadu. The main objective of this scheme is to store a part of seasonal flood water, which goes to the sea unutilised for irrigation. From the reservoir, the flows can be regulated to stabilize the existing ayacut areas downstream through already existing tanks and to irrigate new areas.

Detailed, construction stage geotechnical investigation for the Adavinainarkoil Project has been carried out for assessing the foundation medium of both the abutments of the dam and stilling basin. Charnockite gneiss with associated linear bands and stringers of pyroxene granulite and granite gneiss are the prominent rock types present in the foundation. Extensive shearing along the pyroxene granulite bands and along the prominent joint sets in the left abutment and stilling basin area was observed. These shears are sympathetic to Achankoil Lineament, which is passing 3 km south of the dam site. They were tackled by adopting suitable remedial measures. The depth of excavation has been increased to reach the acceptable foundation media, resulting in increase in height and base width of the dam. Major shears are extending for indefinite depths and are weathered. It was not possible to remove the soft material in these zones up to the fresh rock hence, it was recommended to excavate up to a depth, double the width and fill the zones with rich mortar to surmount the foundation problem. In addition, rock-bolting, modification in the direction of consolidation grout holes to intercept the maximum number of joints and closely-spaced grout holes in some select reaches were recommended.

Introduction

Adavinainarkoil Reservoir Project located near Mekkarai village in Sengottai taluk of Tirunelveli district, Tamil Nadu (Fig. 1), consists of a 47.20 m high and 670 m long masonry dam constructed across Hanuman Nadhi, a tributary of Chittar River in Tambaraparani Basin. The reservoir with a storage capacity of 174 mcf is located at the foot hills of Western Ghats. By constructing this dam the seasonal flood water is stored and the flows are regulated to stabilize the irrigation of existing ayacut areas downstream through already existing tanks. The paper highlights the geotechnical problems encountered in the dam foundation and the remedial measures adopted.



Fig. 1. Location Map

Layout

The dam axis is aligned N62° W – S62° E and is almost parallel to regional foliation trend. The left abutment extends between Ch. 0 m and 320 m with a moderate slope whereas the uncontrolled overflow spillway has a span between Ch. 320 and 420 m. The right abutment stretches between the Ch. 420 m and 670 m.

Geology and structure

Regionally the Project area is occupied by Khondalite, Charnockite and Migmatite Group of rocks, which are intruded by younger granite and pegmatite. The foundation area is occupied mainly by charnockite gneiss with thin bands, enclaves and lenses of pyroxene granulite, granite gneiss and biotite gneiss.

These are traversed by pegmatite veins, intruding both across and along the foliation. The biotite gneiss and sheared pyroxene granulite bands exposed in the foundation show deep weathering. The shear zones are regarded as sympathetic to the Achankoil Lineament which is passing 3 km south of dam site. The general foliation trend in the foundation is N50° to 70° W – S50° to 70° E with 50° to 65° dips towards S40° to 20° W.

Geotechnical evaluation left abutment

Dam Blocks 1 to 11

These blocks cover an area of about 10,500 sq m of the foundation. Massive and hard charnockite gneiss, sheared and highly weathered bands of pyroxene granulite,

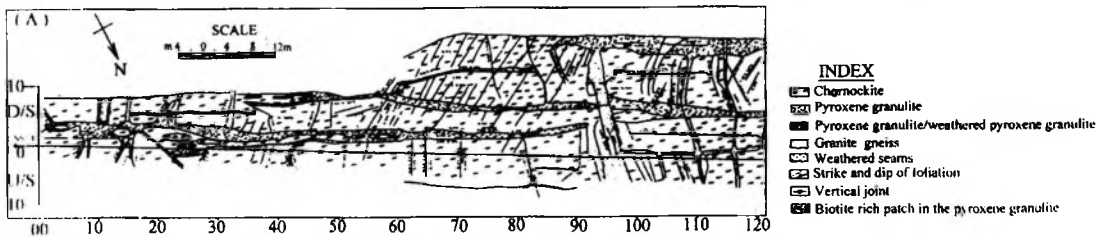


Fig.2. Foundation geological map of adavinainarkoil reservoir project (A) Part of Left Abutment

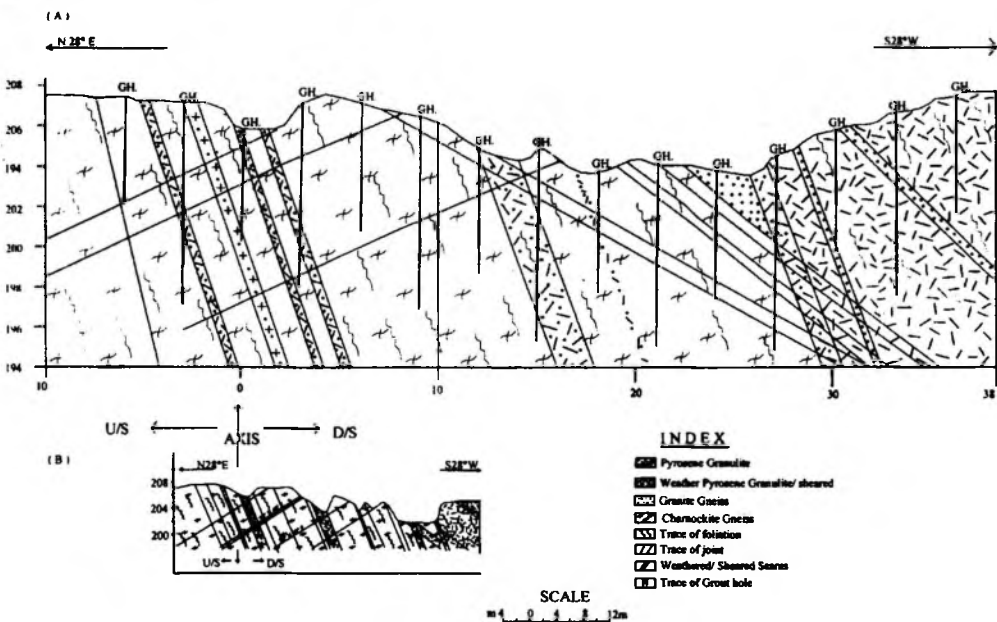


Fig.3. Geological section across the dam axis at (A) CH. 294m, (B) CH 304m

Table 1: Joints observed in the dam foundation.

| Set No. | Strike | Dip amount/ Direction | Spacing in m | Remarks |
|---------|------------------------------|-----------------------------------|--------------------------|--------------------------------|
| 1. | N60° to 65°W S60° to 65°E | – 60° to 75° towards 30°W | S25°- Spaced 15 to 30 cm | Foliation joints |
| 2. | N25° to 50°E to 50°W | -S25° 70° to 85° towards 65°W | N40° to 0.5 to 2 m | Weathered and rough |
| 3. | N55° to 60°E S55° to 60°W | – 70° to vertical S35° to 30°E | towards 1 to 2 m | Smooth and partially weathered |
| 4. | N10° to 40°E S10° to 40°W | – 50° to 70° towards 80°W | N50° to 0.50 m to 1 m | Rough and weathered |
| 5. | N70° to 80°W S70° to 80°E | – 10° to 15° towards 20°E | N10° to Random | Filled with pegmatite veins, |

biotite gneiss and granite gneiss were exposed in the foundation. They are intruded by pegmatite veins, which are highly weathered and altered. The five sets of joints observed in the foundation media are given in table-2. The pre-construction stage geotechnical exploration of the foundation by drilling has revealed that the pyroxene granulite bands are highly weathered causing poor core recovery. Therefore, it would involve enormous amount of excavation in the foundation media to reach fresh rock level. Hence, an alternative proposal of constructing an earth dam on the left abutment between Ch. 0 m and 240.00 m with a kink of 5° at Ch. 230 m towards upstream where sound rock is expected at a shallow depth was proposed. It was not considered by the project authorities instead, a masonry structure along the old alignment was finalized.

In the left abutment (Fig.-2 & 3) deep weathering is persistent along the shear zone which is parallel to foliation/ foliation joints. The shears cut-across other sets of prominent joints in the foundation area. In total, seven such shears have been observed in the foundation media, with their width varying from 0.20 m to 2 m and the length from 25 m to 175 m. These shear zones run parallel or sub-parallel to the dam axis with moderate to steep dip towards downstream.

In addition, a number of minor weathered seams disposed perpendicular to the dam axis merge with main shear zones. There are seventeen such zones observed in the foundation media with width varying from 0.50 m to 2 m and length from 2.00 m to 19.00 m. Besides these shear zones, minor seams were also observed and recorded.

Remedial measures

- i. In general, along these shear zones, excavation has been done up to fresh rock level to the maximum possible extent or else up to double the width of the weak zone and back filled with concrete.
- ii. A number of weathered seams and joints run normal to the dam axis from Ch. 0 m to 60 m. They are likely to transmit the reservoir water from upstream to downstream. Hence, the curtain grout holes were recommended to be extended up to Ch. 30 m and also the drainage gallery/drainage duct extended up to Ch. 30 m with the provision of drainage holes. Consolidation grouting of the foundation was suggested from Ch. 60 m to 224 m with the holes inclined at 60° and directed towards right abutment.
- ii. In other reaches, consolidation and curtain grout holes of the foundation were

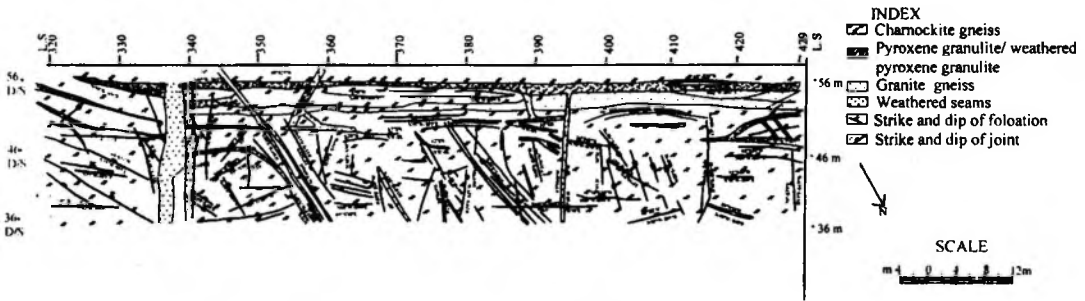


Fig. 4. Foundation geological map of Adavinainarkoil Reservoir Project (C) Stilling Basin Area

suggested vertically and in some reaches the interval is very close say 3m x 3m.

- iii. In some reaches, weathering was found extending to a depth of 3 m and beyond. At such locations, in addition to dental treatment, mat concreting has been suggested to transmit the load uniformly.
- iv. Wherever the dam block terminates at or close to the prominent weathered seams (trending parallel to the axis) the block width has to be extended beyond the weathered seams into the fresh rock.

Dam Blocks 12-19 (Over Flow Section)

The overflow section extends from L.S. 320 m to L.S. 420 m excluding the guide walls. The dam block extends up to the Ch. 36 m d/s, beyond which the stilling basin continues up to Ch.56 m. This area is mainly occupied by charnockite gneiss, pyroxene granulite and granite gneiss. The gneiss is massive and blocky where the granulite bands are highly weathered and show deep depression in an en-echelon pattern perhaps due to intense weathering. Foliation trends N60° to 65°W – S60° to 65°E with dip amount varying from 60° to 70° towards S25° to 30° towards west, i.e. towards downstream side. In addition to foliation, five prominent sets of joints were present in the foundation which is mostly weathered / stained at places and some of them have shown the reversal of dip.

A linear body of granite gneiss with 1 to 1.5 m width occurs 10 m downstream of the dam body. The prominent weathered pyroxene

granulite bands present in these reaches vary in thickness from 1 to 2 m with 1.5 to 2 m depth of weathering. Likewise, five such bands were observed in these reaches. The prominent open joints / seams filled with weathered material and also of transported material in the river course vary in width from 1.5 m to 2.5 m. The length varies from 1 m to 42 m. Five such seams were located in the dam foundation.

Stilling basin area

It is occupied by massive, hard and compact charnockite and granite gneiss. The granite gneiss occurs as a linear band with a width of about 1 to 3 m. The pyroxene granulite found in the foundation is deeply weathered due to foliation shear. Such type of bands with width varying from 0.5 to 2 m and length from 0.8 m to 103 m are found at eleven locations. Prominent open joints were observed at fifteen locations, with width varying from 0.4 to 4 m, length from 1 m to 15 m and depth up to 3 m. In addition, some incipient tight joints were also mapped in the foundation. For these deeply weathered zones and open joints (Fig -4), dental treatment was suggested.

The stilling basin baffle wall was proposed to be terminated at Ch. 56 m d/s from the dam axis. A prominent weathered zone was intercepted from Ch.55 m to Ch. 57 m d/s. It is disposed vertically to an indefinite depth, the removal of which down to fresh rock level was not possible. Termination of the baffle wall in the middle of prominent weathered seam might result in retrogression / scouring

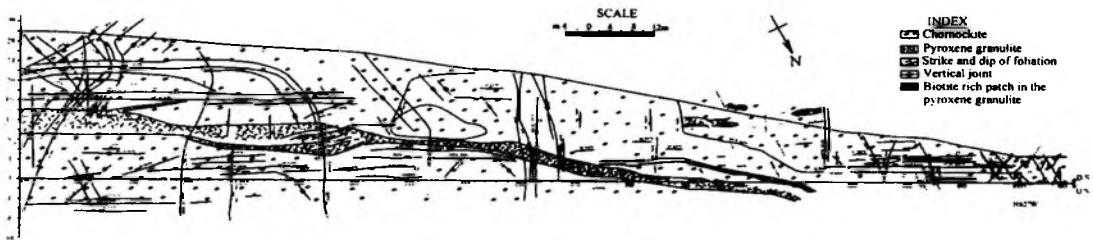


Fig. 5. Foundation geological map of Adavinainarkoil Reservoir Project (B) Part of Right Abutment

of the weathered and sheared pyroxene granulite towards u/s leading to destabilization of the baffle wall. Hence, the foundation concrete was suggested to be extended up to Ch. 57 m d/s. Wherever fresh rock was available beyond the weathered zone, excavation down to fresh rock level or a shear key and anchoring the wall to fresh bed rock by pile, if the excavation is too deep were recommended. This was to be evaluated keeping in view of the techno-economic considerations. Further, additional grout holes in areas of weathered/ shear zones and joints and seams were recommended in addition to foundation grouting of the entire area.

Right abutment

Dam Blocks 20– 26

The non-overflow right abutment dam blocks fall between L.S. 475 m and 663 m. It covers an area of 5,368 sq m and is occupied by charnockite gneiss and pyroxene granulite. At places, biotite rich patches occur in the pyroxene granulite bands. Occasionally coarse grained pegmatoidal charnockite was found running parallel to gneissosity. The general foliation direction is $N60^{\circ}W - S60^{\circ}E$ with a dip of 70° to vertical towards $S30^{\circ}W$. Five prominent sets of joints have been recorded. They are curvilinear, smooth and some of them are almost parallel to dam axis. (Fig. 5). Generally the rocks covering this abutment are massive because they are in rain shadow region of Western Ghats. The weathering effect is very less when compared to left abutment. The charnockite gneiss exposed in the foundation is generally hard,

fresh and compact and the discontinuities / joints present in the foundation are slightly open to tight in nature.

Remedial Measures

- i. Wherever weathered and stained surfaces were found in the foundation they were recommended to be removed by chipping before concreting.
- ii. Between Ch. 542 m and Ch. 559 m, 9 m and 14 m d/s, a huge charnockite block rested on weathered pyroxene granulite. This was to be anchored to the fresh rock available below the weathered rock.
- ii. Additional consolidation and curtain grout holes were suggested from Ch. 535 m to 565 m; 8 m to 26 m d/s at a spacing in the order of 3 m x 3 m square pattern. It was recommended to consolidate the rock with foliation and N – S trending joints, which are open and highly weathered.

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